Rice-Fish Research and Development in Asia

Edited by

C.R. dela Cruz
C. Lightfoot
B.A. Costa-Pierce
V.R. Carangal
M.P. Bimbao

ICLARM

International Center for Living Aquatic Resources Management

Rice-Fish Research and Development in Asia

Edited by

Catalino R. dela Cruz
Clive Lightfoot
Barry A. Costa-Pierce
Virgilio R. Carangal
Mary Ann P. Bimbao

1992

ICLARM

International Center for Living Aquatic Resources Management

Rice-Fish Research and Development in Asia

Proceedings of the Rice-Fish Farming Research and Development Workshop, 21-25 March 1988, Ubon, Thailand; and the Rice-Fish Farming Systems Research and Development Workshop, 23-27 October 1989, Central Luzon State University, Muñoz, Nueva Ecija, Philippines.

Edited by

CATALINO R. DELA CRUZ
CLIVE LIGHTFOOT
BARRY A. COSTA-PIERCE
VIRGILIO R. CARANGAL
MARY ANN P. BIMBAO

1992

Published by the International Center for Living Aquatic Resources Management, MCPO Box 2631, 0718 Makati, Metro Manila, Philippines

Printed in Manila, Philippines

Dela Cruz, C.R., C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao. 1992. Rice-Fish Research and Development in Asia. ICLARM Conf. Proc. 24, 457 p.

ISSN 0115-4435
ISBN 971-1022-88-5

ICLARM Contribution 555

Contents

FOREWORD

The Asian Rice Farming Systems Network (ARFSN) was established to: (i) promote and coordinate collaborative research between national and international research institutions in farming systems with major emphasis on problems common in Asia; (ii) provide a mechanism for sharing information, technology and methodology generated by national research systems, the International Rice Research Institute (IRRI) and other international institutions; and (iii) provide a feedback mechanism to national research systems for field-identified problems.

The ARFSN operates through a Working Group composed of national farming systems program leaders who act as country coordinators for the Network's projects, project leaders and selected scientists in the region who are invited depending on the topic for discussion. IRRI provides coordination through a Network Coordinator for the various projects.

The ARFSN's project on rice-fish, a collaborative effort involving many institutions throughout Asia, is led by the International Center for Living Aquatic Resources Management (ICLARM) in Manila, Philippines. The objectives of the project are to: (i) develop and refine rice-fish research methodologies; (ii) evaluate options for integration of rice and fish production which will increase the productivity and income of Asian rice farmers; (iii) establish collaborative research on rice-fish farming among national, international and regional research institutions; and (iv) exchange and distribute research information on rice-fish farming among rice and aquaculture scientists in Asia.

ICLARM coordinates and links with national programs in the participating countries (Bangladesh, India, Indonesia, China, Vietnam, Malaysia, Korea, Thailand and Philippines). Research on rice-fish farming is being pursued in each country by interdisciplinary teams of agronomists, aquaculturists and social scientists to develop appropriate technologies through on-farm trials.

The first workshop, Rice-Fish Farming Research and Development Workshop, was held in Ubon, Thailand on 21-25 March 1988. There were 52 participants from 11 countries: Thailand (21); Philippines (8); Bangladesh (6); Canada, Indonesia (4); India (3); China (2); and Malaysia, Bhutan, Singapore, Laos (1). An additional 53 Thai observers attended. The objectives were to: (i) discuss plans for the on-farm and on-station experiments and formulate common methodologies; (ii) determine strategies for rice-fish farming systems research and development; and (iii) review the state-of-the-art in rice-fish farming.

R. Syamanonda, Director General, Department of Agriculture, Thailand, opened the workshop by noting that farmers have accepted rice-fish farming because it has increased their income and family protein consumption. Little financial investment is needed. Farmers must plant rice and rice needs water; for fish, dikes must be raised and a refuge must be dug. Fish feeds include natural production and noxious weeds affecting dike, leading to weed control. Fish excrement is a useful fertilizer for rice. Fish culture in ricefields also controls some rice pests. In addition to fish, rice yields increase by about 15%.

The Director General of the Department of Fisheries, Thailand, Mr. Vanich Varikul, went on to emphasize that in Thailand and other Asian countries, rice and fish have always been the two most important staple food. Inscribed on a stone tablet from the Sukhothai Period – a Thai early kingdom that flourished 700 years ago – are words that appropriately describe the prominence that the country has placed on these two commodities. The inscription read simply: "There were rice in the fields, fish in the water". It was the king's description of the significance of rice and fish in the lives of his people. In the last 25 years, Thailand has increased its total fishery production ten fold from 220,000 t in 1960, to 2.2 million t in 1985. But of the 2.0 million t from marine catch, almost 800,000 t are trash fish which are being processed into fishmeal. The remaining supply does not reach inland markets and is an unaffordable luxury to many of the people in the villages. Policies aimed at improving the nutritional status of the people and emphasizing on cheap sources of good quality protein. Thus, there is a need to promote and develop inland aquaculture and this includes rice and fish culture. In addition to improving people's nutritional status, the incomes of rice farmers must be increased, land use intensified and farm activities must be diversified. In Thailand, farmers fall back on other commodities when the main crop is not doing well. Too much focus has been on irrigated ricelands with little attention to rainfed ricelands. There is also a need to coordinate the numerous programs and activities of different agencies concerned with rice-fish culture.

Prayut Siripanit, Deputy Minister, Ministry of Agriculture and Cooperatives, Thailand, closed the ceremonies with the observation that research on rice-fish culture involving the Departments of Fisheries and Agriculture has had results that can help farmers. Thus, their concerted efforts will accelerate the development for the farmers in the future.

The second workshop, Rice-Fish Farming Systems Research and Development, was held at the Central Luzon State University, Muñoz, Nueva Ecija, Philippines, on 23-27 October 1989. Thirteen countries were represented by 72 participants: Philippines (33); Thailand (20); Indonesia (4); China (3); Korea, India, USA (2); and Bangladesh, Madagascar, Malaysia, Nepal, Singapore, Vietnam (1). The objectives were to: (i) discuss the progress made in rice-fish farming systems and component technology research; (ii) determine a common methodology for rice-fish on-station research and extension; and (iii) conceptualize bankable projects and credit schemes for rice-fish farming.

Mr. Carlos G. Dominguez, Secretary of Agriculture, Philippines, opened the second workshop observing that the potential of rice-fish farming in Asia is great. Consider a resource of approximately 116 million ha of ricefields, of which 46.6 million ha are irrigated. Even if only 20% of these irrigated fields would produce fish at a conservative rate of 150 kg/ha, there would be an incremental supply of fish to 1.39 million t. On a broader perspective, rice-fish farming as a system can contribute to sustained rural development, socioeconomic upliftment and increased incomes of rural families. Because of farm diversification, it can result in maximum utilization of farm labor, particularly during off-season periods. The system can also provide opportunities for rural investment and profitability to private investors without necessarily converting mangrove areas into aquaculture ponds. And yet, despite these potentials and foreseeable advantages that can be derived from rice-fish farming, we had noted in the past a decline in fish cultivation in ricefields which was most pronounced in technologically advanced countries. The decline was attributed to several factors, most significant of which were technical factors associated with rice intensification programs which used pesticides and high-yielding rice varieties that could not accommodate fish rearing. Other constraints identified were limited information on appropriate techniques, the attitude of the farmers, their reluctance to change work habits and to modify their ricefields to accommodate fish culture. There are indications, however, that rice-fish farming is regaining popularity in Asian countries, for example, in Indonesia and Thailand. In Indonesia, rice-fish farming area was 49,000 ha in 1977 and then more than doubled to 114,000 ha in 1984. In Thailand, there were 4,497 farms in 1972 rising to 5,634 farms in 1983. While rice-fish culture has developed erratically in the Philippines, at its height in 1983, high average yields over 5 t/ha of rice and 208 kg of fish were demonstrated.

The papers presented in the two workshops covered the whole range of rice-fish systems environments: irrigated, rainfed, deepwater and coastal. For the first time, extensive information on these very important farming systems, which was ignored in the past, has been brought together into one publication.

Kenneth T. MacKay
Director General,
ICLARM

ACKNOWLEDGEMENT

Generating and collating the materials for this book involved many people from both national and international research centers, funding agencies and non-government organizations. We would like to first acknowledge the research and extension work of the national scientists in Bangladesh, China, India, Indonesia, Republic of Korea, Malaysia, the Philippines, People's Republic of China, Thailand and Vietnam. Secondly we would like to thank our partners in the international arena, particularly the International Rice Research Institute, the Asian Institute of Technology, the International Institute of Rural Reconstruction, and the Network of Aquaculture Centres in Asia/Food and Agriculture Organization of the United Nations. Research was made possible by funds from the International Development Research Centre of Canada, Asian Development Bank, the United Kingdom Overseas Development Administration, Canadian International Development Agency, International Funds for Agricultural Development, Ford Foundation, International Foundation for Science and Care International.

Special thanks are due to Dr. Roger S.V. Pullin and Mr. Jay L. Maclean for their guidance in the preparation and critical review of this book. We also acknowledge the efforts of the staff from ICLARM's Information Division, particularly: Leticia B. Dizon and Casilda I. Guevara in the additional editing and production processes; Christopher M. Bunao, Ovidio F. Espiritu and Albert B. Contemprate for the layout and artwork; and Ma. Graciela R. Balleras and Virgilio Martin J. Castrillo for typesetting the manuscripts.

Introduction to Rice-Fish Research and Development in Asia*

C. LIGHTFOOT
B.A. COSTA-PIERCE**
M.P. BIMBAO
C.R. DELA CRUZ
International Center for Living Aquatic Resources Management
MCPO Box 2631
0718 Makati, Metro Manila
Philippines

LIGHTFOOT, C., B.A. COSTA-PIERCE, M.P. BIMBAO and C.R. DELA CRUZ. 1992. Introduction to rice-fish research and development in Asia, p. 1-10. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

An overall perspective of rice-fish research and development in Asia is given through a country analysis and highlights of research. Existing and potential rice-fish areas, and rice-fish system characteristics and their performance in Bangladesh, China, India, Indonesia, Korea, Malaysia, Philippines, Thailand and Vietnam are presented. Similarly, highlighted are research findings on production systems, indigenous knowledge, effects on rice yield and pesticide management. Country analysis shows that rice-fish systems presently occupy only a very small percentage of the potential area. The wide array of systems that exist can be broadly characterized by field design, growing period and fish species. Three types of field design are common: trench within the ricefield, pond or sump within or adjacent to the ricefield, and deepwater ricefield. Two types of growing periods, concurrent with the rice and rotational after the rice, are found. Carp, tilapia, silver barb, snakeskin gourami and prawns are grown. Research on productions systems revealed that while most systems are for growout operations, ricefields are also suitable for nursery operations. In many cases, especially where traditional systems exist, researchers have found that farmers have more knowledge about rice-fish culture than researchers. Research has also found that modest increases of 10 to 20% are to be expected in rice yields when fish are cultured in ricefields. While overuse of pesticides has limited fish culture in ricefields, research findings indicate that proper application, selection of chemicals and integrated pest management (IPM) strategies can overcome this constraint.

This introduction provides an overall perspective on rice-fish culture across the nine Asian countries (Bangladesh, China, India, Indonesia, Korea, Malaysia, the Philippines, Thailand and Vietnam) participating in the Asian Rice Farming Systems Network (ARFSN) rice-fish project, and highlights important findings of the two workshops. The analysis cross references the papers so that readers are guided to relevant areas.

Country analysis compares the extent of existing and potential areas of rice-fish culture in irrigated, rainfed, deepwater and coastal brackishwater environments. For each of the countries reported, the types of systems used, the rice varieties, fish species, rice and fish yields and incomes are compared.

---

*ICLARM Contribution No. 919.
**Present address: Hale Ohia Road, P.O. Box 1050, Volcano, Hawaii 96785, USA.

Important research findings bring to the readers' attention the fact that: i) most production systems are growout operations but ricefields can also be used for nursery operations; ii) indigenous knowledge of rice-fish often exceeds that of researchers; iii) rice yields usually increase when fish are present in the ricefields; and iv) with special exceptions, pesticides do not necessarily restrict the adoption of rice-fish culture.

Country Analysis of Existing and Potential Areas

Rice-fish systems presently occupy a very small percentage of the area judged to be suitable for them. The data shown in Table 1 of potential and existing areas for rice-fish farming in the reporting countries indicate that only China and Indonesia have significant areas. The paucity of data in the table suggests that fish are cultivated in so few ricelands that national statistics rarely bother to record them. Conversely, areas where there is potential

Table 1. Potential and existing areas for rice-fish farming in Asia.

Country		Ricefield area[a] ('000 ha)	Potential/Suitable area ('000 ha)	Existing area ('000 ha)	Author in this volume
Bangladesh	Total	10,229	615	Not known	Dewan, see p. 11
	Irrigated	1,227			
	Rainfed	9,002			
China	Total	32,798	5,000	985.5 (1986)	Xu and Guo, see p. 315
					Li, see p. 17
	Irrigated	30,902			Wang, see p. 325
	Rainfed	2,296			Xu and Guo, see p. 315
India	Total	40,991	2,000	Not known	Ghosh, see p. 27
	Irrigated	14,349			
	Rainfed	26,644			
Indonesia	Total	9,889	1,570	94.3 (1985)	Koesoemadinata and
	Irrigated	6,230			Costa-Pierce, see p., 45
	Rainfed	3,659			Syamsiah et al., see p. 287
Korea	Total	1,229	127	0.1 (1989)	Kim et al., see p. 63
	Irrigated	1,118			
	Rainfed	111			
Malaysia	Total	647	120	Not known	Ali, see p. 69
	Irrigated	427			
	Rainfed	220			
Philippines	Total	3,426	181	1.4 (1982)	Sevilleja, see p. 77
	Irrigated	1,473		0.2 (1986)	
	Rainfed	1,953			
Thailand	Total	9,378	254		Fedoruk and
	Irrigated	1,313			Leelapatra, see p. 91
	Rainfed	8,065			
Vietnam	Total	5,691	326	Not known	Mai et al., see p. 105
	Irrigated	2,276			
	Rainfed	3,415			

[a]Source for 1985-87 data: IRRI. 1989. Implementing the strategy work plan for 1990-1994: IRRI toward 2000 and beyond. International Rice Research Institute, Manila.

for rice-fish culture are significant in all countries reporting.

Among the countries listed, Indonesia is second to China in rice area being used for rice-fish farming. Fish culture is concentrated in irrigated and coastal ricelands. Although it is much smaller in area, Thailand is next to Indonesia in the extent of rice-fish culture. Fish are grown in many different ways in both irrigated and rainfed environments. Rice-fish farming has been successful in parts of India's brackishwater and irrigated areas where water level can be controlled. Interest in deepwater rice-fish farming is growing partly because India has more than 4 million ha of deepwater rice areas, the largest in South and Southeast Asia. Similarly, Bangladesh has more than 2 million ha of deepwater areas planted to rice. The potential of this resource for stocking and feeding fish has not been tapped yet. The area devoted to rice-fish farming in the Philippines is still limited. Rice-fish culture techniques for irrigated rice using tilapia and carp have not yet diffused to many farmers.

Country Analysis of System Characteristics and Performance

The data presented in Table 2 compare rice-fish systems, fish species, rice varieties and their yields and income across the countries of concern.

A variety of systems exists, with many variations in field engineering, species used, fish stocking rates and sizes, crop rotations, etc. In general though, three types of field design predominate: shallow trench within the ricefield in the Philippines, Indonesia and China; pond refuge adjacent to the ricefield in Indonesia, India, Thailand and China; and deepwater ricefields in India and Bangladesh. Trenches or ditches constructed in varying sizes and layouts are reported by Fagi et al., Li, Sevilleja and Wang which act as fish refuges. Li also reports ridge-ditch field designs with rice-azolla fish systems. Li and Wang report some cases in China where ponds or sumps constructed adjacent or connected by a canal to the ricefield are used. Similar methods are used in Indonesia as presented in Koesoemadinata and Costa-Pierce, in Malaysia by Ali, in the Philippines by Sevilleja, and in Thailand by Chapman, Fedoruk and Leelapatra, and Thongpan et al. The ridge-ditch design is similar to the Indonesian *surjan* design reported by Koesoemadinata and Costa-Pierce, although the latter has much wider ridge and ditch.

Concurrent culture of fish and rice as well as rotational systems where fish are grown after rice are common throughout Asia. Combinations of rotational and concurrent rice-fish systems arranged in one-year sequential cropping pattern are best developed in Indonesia. Koesoemadinata and Costa-Pierce and Syamsiah et al. describe the Indonesian concurrent rice-fish *minapadi*; fish culture in between two rice crops *penyelang*; and fish culture during long fallow periods after the second rice crop *palawija* systems. Examples of one-year cropping patterns are *minapadi-minapadi-palawija*; and *minapadi-penyelang-minapadi-palawija*. When practised in combination, these systems can produce annual fish yields of over 1,000 kg/ha.

The most important fish species found in ricefield systems are carps (Indonesia, India, China), tilapias (Philippines, China, Thailand), *Puntius gonionotus* (Thailand), and *Trichogaster pectoralis* (Thailand). Both mono- and polyculture of these species are practised. Many other species of fish and other animal (e.g., shrimps and frogs) are found in ricefields. In deepwater and coastal areas of Bangladesh, India and Vietnam, Haroon et al.; Ghosh; and Mai et al., respectively, report that shrimps are

Table 2. Selected data on rice-fish by environment and system.

Environment/system	Rice variety	Rice yield (t/ha)	Fish species	Fish yield (kg/ha)	Income (US$/ha)	Author in this volume
Bangladesh						
Freshwater/capture			*Channa*, catfishes, minnows, *Colisa*, spiny eels, shrimps			Dewan, see p. 11
Freshwater/culture						
concurrent/on-station			Indian major carps, *Hypophthalmicthys molitrix*, *Cyprinus carpio*, *Puntius gonionotus*, *Cirrhinus reba*	43-147	30-134	Dewan, see p. 11; Haroon et al., see p. 165
	aman	0.5-1.4	Indian major carps, *Heteropneustes fossilis*	198-225		Haroon et al., see p. 165
	boro	3.2-7.7	*H. fossilis*	98-213		Haroon et al., see p. 165
		4.2-4.5	*P. gonionotus*, *Oreochromis niloticus*	213-508		Haroon et al., see p. 165
with feeding	BR 11	3.8-4.1	*O. niloticus*	317-488	825	Haroon et al., see p. 165
concurrent/on-farm	*aman*		*Macrobrachium rosenbergii*	40-50		Dewan, see p. 11
	aman		*M. rosenbergii*	162-390		Haroon et al., see p. 165;
rotational/on-farm			Indian major carps, *C. reba*, *Hypophthalmichthys molitrix*, *Ctenopharyngodon idella*, *P. gonionotus*, *C. carpio*	223-856	688	Dewan, see p. 11; Haroon et al., see p. 165
Brackishwater/capture			*Penaeus monodon*	210		Dewan, see p. 11;
			Mugil corsula, *Mystus* sp., *Lates calcarifer*, *Labeo bata*	80		Haroon et al., see p. 165
Brackishwater/culture/rotational						
traditional			*Penaeus* spp., *Metapenaeus* spp.	210-300		Haroon et al., see p. 165
			Polydactylus sexfilis, *L. calcarifer*	80-400		
improved			*Penaeus* spp.	280-450		Haroon et al., see p. 165
Brackishwater-freshwater						
rotational	*boro*		*P. monodon*, *M. rosenbergii*	200-250		Haroon et al., see p. 165
			L. calcarifer, Indian major carps, *Mugil* sp.	150-175		
concurrent	*aman*		*P. monodon*, *M. rosenbergii*, *H. molitrix*, Indian major carps	83-130		Haroon et al., see p. 165
China						
Freshwater/culture						
field-pond/double rice		9.5		1,119	583	Xu and Guo, see p. 315
ridged/single rice		7.8		1,572	732	Xu and Guo, see p. 315
rice-azolla-fish						
non-ridged/double rice		11.4		760	528	Xu and Guo, see p. 315
non-ridged/single rice		8.0		731	507	Xu and Guo, see p. 315
rice-fish rotation in						
swampland/single rice		4.3		1,312	529	Xu and Guo, see p. 315
concurrent/ridge ditch						
on-farm/experimental		4.8-5.0		117-200	1,039-1,269	Xu and Guo, see p. 315
on station/species compositin		8.3-9.0	*C. idella*, crucian carp, *C. carpio*	1,582-1,896	1,404-1,582	Xu and Guo, see p. 315
concurrent/growout			*C. idella*, *C. carpio*, crucian carp, tilapia		750-1,500	Li and Pan, see p. 151
concurrent/hatchery	early	3.3	*C. idella*		198 (gross)	Nie et al., see p. 173
	median	5.6	*C. idella*		332 (gross)	
	late	8.6	*C. idella*		471 (gross)	

continued...

Table 2 (continued).

Environment/system	Rice variety	Rice yield (t/ha)	Fish species	Fish yield (kg/ha)	Net income (US$/ha)	Author in this volume
India						
Freshwater						
irrigated/wetland	modern	2.7	murrels, catfish, carps	500-700		Dehadrai, see p. 367
deepwater	deepwater rice	2.0-2.5	Indian major and Chinese carps, catfish	1,100		Dehadrai, see p. 367
valley fields	deepwater rice	1.0-2.0	Indian major carps	500-800		Dehadrai, see p. 367
beels	modern	1.0-3.0	mussels, catfish, carps	20-80		Dehadrai, see p. 367
concurrent/rainfed						
capture/deepwater (river basin)		1.0-1.5	natural stocks	3 (1 year)		Ghosh, see p. 27
capture/inland		2.0-3.0	wild stocks	300 (1 year)		Ghosh, see p. 27
mountain valley/waterlogged		1.0-1.5	*C. carpio*	highly variable		Ghosh, see p. 27
terrace						
shallow/wild feeding	traditional	0.3-0.8	*C. carpio*	28-186		Ghosh, see p. 27; Dehadrai, see p. 367
pest control/low stocking rate		1.5-2.3	*C. striata*	28-112		Ghosh, see p. 27
irrigated		3.0-5.0	*O. mossambicus*, *C. carpio*, *Cirrhinus mrigala*, *L. rohita*	77		Ghosh, see p. 27
shallow						
hatchling to fingerlings		1.5-3.7		112-153		Ghosh, see p. 27
growout		5.2	carp, *M. rosenbergii*	630-930 (1 year)		Ghosh, see p. 27
no feeding		1.8-1.9	*H. fossilis*, *Clarias batrachus*	199		Ghosh, see p. 27
with feeding	*Ratna*, *Pankaj*, *Jaya*	1.9-6.4	*H. fossilis*, *C. batrachus*	360-490		Ghosh, see p. 27
Brackishwater						
traditional						
pokkali			*Metapenaeus* spp., *Penaeus* spp., *M. rude*, *Palaemon stylifera*, *Caridina gracilirostris*, *Acetes* sp. *M. dussumieri*, *Etroplus maculatus*	500-600		Ghosh, see p. 27
kharan	salt-resistant, local	0.5-1.5	*E. suratensis*, *Mugil* spp., *Penaeus* spp., perches	500-2,000		Ghosh, see p. 27 Dehadrai, see p. 367
bhasabadha (wild cropping)			*Liza* spp., *Mugil cephalus*, *Lates calcarifer* *Mystus gulio*, *Macrobrachium* spp., *Metapenaeus* spp., *Penaeus* spp., *P. stylifera*, *Rhinomugil corsula*, *Parapenaeopsis sculptilis*			Ghosh, see p. 27
modified						
pokkali	salt-resistant, local	0.7-2.7	brackishwater shrimp, tilapia, natural stocks	785-2,135 (1 year)		Ghosh, see p. 27 Dehadrai, see p. 367
bhasabadha	salt resistant, modern, CRS 1, CSR 3, SR 26B	2.5-3.0	*P. monodon*, *L. parsia*, carps, mullets, natural stocks	600-1,200 (1 year)		Ghosh, see p. 27 Dehadrai, see p. 367
shallow/rotational	SR 26B	1.5-3.0	carp, *M. rosenbergii*, *P. monodon*, *L. parsia*, tilapia, natural fry	870-1,000 (1 year)		Ghosh, see p. 27
deepwater/growout on-farm	CR 1014, *Jaladhi*	2.0-4.2	*C. carpio*, *H. molitrix*, Indian major carps	76 (119 days)-1,100 (1 year)		Ghosh, see p. 27

continued...

Table 2 (continued).

Environment/system	Rice variety	Rice yield (t/ha)	Fish species	Fish yield (kg/ha)	Income (US$/ha)	Author in this volume
on-farm/experimental						
no feeding	NC 492 *Sabita*	1.7-2.1	*C. carpio*, *H. molitrix*, Indian major carps, *O. niloticus*, *P. gonionotus*, local species	267-813		Mukhopadhyay et al., see p. 255
with feeding	NC 492 *Sabita*	1.6-3.2	*C. carpio*, *H. molitrix*, Indian major carps, *O. niloticus*, *P. gonionotus*, local species	692-922		Mukhopadhyay et al., see p. 255
Indonesia						
Freshwater/irrigated/concurrent						
on-station		3.2-6.0	*C. carpio*	224-320	328-680	Syamsiah et al., see p. 287
(rice+fish+duck)-(rice+fish+duck)-duck	IR 64	11.7	*C. carpio*	185	2,060	Syamsiah et al., see p. 287
fertilizer levels						
zero TSP		6.7	*C. carpio*	1,400		Pagi et al., see p. 273
25-150 kg/ha		6.6-7.4	*C. carpio*	1,300-1,600		Pagi et al., see p. 273
densities and irrigation methods						
1,600-4,160 fish/ha (WS)		7.5-8.4	*C. carpio*	10-119		Pagi et al., see p. 273
2,000-5,000 fish/ha (DS)		5.5-5.8	*C. carpio*	80-192		Pagi et al., see p. 273
on-farm						
minapadi-penyelang-minapadi		13		250-780	1,599-2,130	Koesoemadinata and Costa-Pierce, see p. 45 Yunus et al, see p. 131
rice-*palawija*				256-1,000	140-230	Koesoemadinata and Costa-Pierce, see p. 45
minapadi-penyelang-palawija				255	1,280	Koesoemadinata and Costa-Pierce, see p. 45
minapadi-penyelang-vegetable-*penyelang*				302	450	Koesoemadinata and Costa-Pierce, see p. 45
ricefield pond (*payaman*)					360-970	Koesoemadinata and Costa-Pierce, see p. 45
rice-rice-fish	IR 64		*C. carpio*	80-367	474-1,236	Pagi et al., see p. 273; Yunus et al, see p. 131
(rice+fish)-(rice+fish)-fish	IR 64		*C. carpio*	320-850	932-1,400	Pagi et al., see p. 273; Yunus et al, see p. 131
(rice+fish)-fish-(rice+fish)-fish	IR 64		*C. carpio*		1,414-1,430	Pagi et al., see p. 273
(rice+fish+duck)-(fish+duck)-(rice+fish+duck)-(fish+duck)	IR 64		*C. carpio*		1,498	Pagi et al., see p. 273
Coastal freshwater (*sawah tambak*/rotational			milkfish, Java carp and tilapia, *C. carpio* *M. rosenbergii*, marine shrimp		2,000-3,500	Koesoemadinata and Costa-Pierce, see p. 45
Korea						
Freshwater/concurrent/ with feeding			*Misgurnus anguillicaudatus* *Parasilurus asotus*, *O. niloticus*	1,210-1,260 2,720	23,238 (gross)	Kim et al., see p. 63

continued...

Table 2 (continued).

Environment/system	Rice variety	Rice yield (t/ha)	Fish species	Fish yield (kg/ha)	Net income (US$/ha)	Author in this volume
Malaysia						
Freshwater/capture/sump						
single rice crop			*Trichogaster pectoralis*, *T. trichopterus*, *C. macrocephalus*, *C. striata*, *Anabas testudineus*	302-470		Ali, see p. 69
			T. trichopterus, *C. macrocephalus*, *C. striatas* *T. pectoralis*	88-175		Ali, see p. 69
Philippines						
Freshwater						
capture	traditional mountain	2.5-3.0	*M. anguillicaudatus*	1-10 kg/180-700 m²		Sevilleja, see p. 77
culture						
on-farm						
concurrent	traditional mountain		*C. carpio*, *O. niloticus*	129		Sevilleja, see p. 77
pond	IRRI varieties	6.1	*O. niloticus*	53.3		Torres et al., see p. 295
with inorganic fertilizer	IRRI varieties	5.9-6.0	*O. niloticus*	148-169		Torres et al., see p. 295
with animal manure	IRRI varieties	5.4-6.0	*O. niloticus*	180-200		Torres et al., see p. 295
trench	IRRI varieties	6.3	*O. niloticus*	73.3		Torres et al., see p. 295
with inorganic fertilizer	IRRI varieties	6.5-6.8	*O. niloticus*	44-130		Torres et al., see p. 295
with animal manure	IRRI varieties	5.8-6.1	*O. niloticus*	46-133		Torres et al., see p. 295
on-station						
concurrent	IRRI varieties	3.3-6.3	*C. carpio*, *O. niloticus*	78-303		Sevilleja, see p. 77
rotational	IRRI varieties	3.3-6.3	*C. carpio*, *O. niloticus*	390-629		Sevilleja, see p. 77
border planting pattern	IR 66	2.5-5.1	*O. niloticus*	105-195		Sevilleja et al., see p. 373
trench or pond refuge	IR 64	1.6-2.3	*O. niloticus*	27-396		Sevilleja et al., see p. 373
animal manure	IR 64	1.5-2.1	*O. niloticus*	58-152		Sevilleja et al., see p. 373
Thailand						
Freshwater/rainfed						
concurrent						
trap sump	rainfed rice		wild species	30-60		Fedoruk and Leelapatra, see p. 91
terraced field				400		Fedoruk and Leelapatra, see p. 91
open dike	rainfed rice		*C. carpio*, *P. gonionotus*, tilapia	125-413		Fedoruk and Leelapatra, see p. 91
Khoo Khad		1.2-2.1	*P. gonionotus*, *Aristichthys nobilis*	38-214		Thongpan et al., see p. 301
Amnart Charoen	RD 6, RD 8, SPT, KDML 105, native	2.1-3.0		79-146	61-104	Thongpan et al., see p. 301
Kheuang Nai	RD 6, SPT, KDML 105	1.8-3.0		264-363	206-235	Thongpan et al., see p. 301
Det Udom	RD 6, KDML 105, native	2.3-2.9		182-220	113-128	Thongpan et al., see p. 301

continued...

Table 2 (continued).

Environment/system	Rice variety	Rice yield (t/ha)	Fish species	Fish yield (kg/ha)	Net income (US$/ha)	Author in this volume
Freshwater/closed dike						
rainfed/concurrent	rainfed rice			180-300		Fedoruk and Leelapatra, see p. 91
irrigated/concurrent	high yielding			180-900		Fedoruk and Leelapatra, see p. 91
irrigated/rotational	high yielding			750-900		Fedoruk and Leelapatra, see p. 91
deepwater			*Trichogaster* sp., *P. gonionotus*	940-1,875		Fedoruk and Leelapatra, see p. 91
Dom Noi (irrigated and rainfed)		1.3-2.7	*C. carpio*, *O. niloticus*	8-238		Thongpan et al., see p. 301
Vietnam						
Freshwater/concurrent						
(rice+shrimp)-(rice+shrimp)	dry season	5.7				Mai et al., see p. 105
(rice+fish/shrimp)-(rice+fish/shrimp)	wet season	5.2	*M. rosenbergii*, *P. gonionotus*	187 shrimp; 214 fish		Mai et al., see p. 105
(rice+shrimp)-(rice+shrimp)	traditional, wet and dry seasons	3.5-5.7		64		Mai et al., see p. 105
Brackishwater-freshwater/rotational						
rice-shrimp (no feeding)	traditional	3.0		50	74	Mai et al., see p. 105
rice-shrimp (with feeding)	traditional	3.5		80	134	Mai et al., see p. 105
Brackishwater/rotational						
(fish/shrimp)-(rice+fish/shrimp)	*Khmer do*, IR 42	2.4	*Metapenaeus lysianassa*, *M. tenuipes*, *M. ensis*, *Penaeus indicus*	2-3 kg shrimp/day		Mai et al., see p. 105
			Pseudapocryptes lanceolatus	15 kg fish/day		Mai et al., see p. 105

added to the rice-fish systems. Giant freshwater prawns (*Macrobrachium rosenbergii*) and finfishes are stocked during wet or monsoon months, while marine shrimps and fishes are cultured during summer or saline water months.

Thailand, Bangladesh and India have seasonally important ricefield capture fisheries system. In India, Ghosh reports significant contributions to the protein nutrition of poor people in the densely populated rice-growing districts made by such systems.

Research Findings on Production Systems

While most rice-fish production systems are growout operations, the ricefields can also be used for nursery operations.

Ricefields are being used both as fish nurseries and growout for table fish in China as reported in Li and Pan; in Indonesia by Yunus et al., Syamsiah et al. and Costa-Pierce; and in Thailand by Chapman. Interestingly, raising fingerlings in ricefields was shown by Costa-Pierce to be more profitable than growout in Indonesia. Furthermore, Costa-Pierce pointed out that in Indonesia, shallow ricefields may be better suited to nursery systems. Indonesia and China have rice-fish culture systems well integrated with inland aquaculture production networks as reported by Koesoemadinata and Costa-Pierce, Sastradiwirja, Costa-Pierce, Li and Xu, and Guo. Many rice farmers in Java produce common carp (*Cyprinus carpio*) fingerlings for sale to fish farmers who grow the fingerlings to table-size. Furthermore, Syamsiah et al. report that Indonesian farmers integrate ducks and home gardens into their rice-fish culture systems.

Research Findings on Indigenous Knowledge

The stock of indigenous rice-fish knowledge often exceeds that of the researchers. This was certainly found to be the case where traditional rice-fish farming systems has existed for many years as they have in freshwater environments of China, Indonesia, Malaysia and Thailand and in coastal brackishwater environments of Bangladesh, India and Vietnam.

However, in irrigated and deepwater environments, culturing fish is not traditional. In the recent past, rice-fish systems for irrigated (China, Indonesia) and rainfed (Thailand) environments have been pioneered generally by farmers themselves. Today, researchers are involved in developing improved systems for these environments. This is particularly true for irrigated rice-fish farming in the Philippines and Korea where technologies are being developed with much reliance on research results. Similarly, researchers in Bangladesh and India are providing farmers with new systems for culturing fish in deepwater ricefields.

Research Findings on Effects on Rice Yield

Over the years, it has almost become a conventional wisdom among farmers that rice yields are increased when fish are present in the ricefields. Indeed, with few exceptions, scientists report modest increases in rice yield. Lightfoot et al. summarized published data on rice yields from China, India, Indonesia, Philippines and Thailand to find that average per cent increases in rice yields ranged from +4.6 to +28.6. However, these averages hide a wide variation in reported effects.

Some researchers, as in the case of Bangladesh, Korea and Indonesia, reported modest increases. Haroon et al. reported up to 14% increases in Bangladesh rice yields and Kim et al. reported Korean farmers obtaining comparable or better yields of rice in the presence of fish. In Indonesia, 6.6% increases were reported by Syamsiah et al. For others, the picture was less certain. Nie Dashu et al.

reported yield increases ranging from 11 to 35% in China. In India, while Mukhopadhyay et al. reported 1-11% range of rice yield increases, Ghosh reported an increases between 9 and 23%. Similarly, the Philippine picture is uncertain. The report of Torres et al. that rice yields were neither positively nor negatively affected by the presence of fish contrasts starkly with the 47-50% increases reported by Fermin.

Few instances of decreased rice yields were reported. Thongpan et al. observed that nine out of 25 of their cooperating farmers experienced yield losses from -29 to -1%. Two per cent decreases were reported in India by Mukhopadhyay et al. Neither group offered any mechanisms by which the reported reductions might have occurred.

Research Findings on Pesticide Management

With special exceptions, pesticides do not necessarily restrict the adoption of rice-fish culture.

Dewan, Ghosh, Kim et al. and Xiao all report that rice-fish farming declined due to the use of pesticides in rice production. Irrigated systems being more polluted than rainfed and deepwater ricefield which experience lower levels of chemical inputs were the most affected. That the adverse effects of pesticides on fish were aggravated by farmers' tendencies to apply more pesticide than was needed was pointed out by Sevilleja, and Fedoruk and Leelapatra. Proper application methods and selection of chemicals with low toxicity as discussed in Kim et al., Koesoemadinata and Costa-Pierce, Sevilleja and Xiao can alleviate toxicity problems somewhat. Cagauan and Arce suggest how pesticides can be applied and still preserve or enhance yields of both rice and fish. There are other trends in rice production that favor fish. Insecticide use is decreasing in some countries as more pest-resistant varieties are being used and the Integrated Pest Management (IPM) is proving successful. These decreases may support Waibel's finding that the economic benefits from insecticide use under farmers' conditions are much less than claimed.

Conclusions

Findings as highlighted here suggest several measures and directions for future research and development in rice-fish culture. Conclusions emerging from the papers and discussions presented here direct us towards finding new roles for rice-fish in the wider context of aquaculture and agriculture sector development. Not only are we directed towards roles in the hatchery-fry-fingerling-growout continuum, but also in the supportive role for the expansion of IPM. Indeed, IPM could act as a vanguard for expansion in rice-fish culture.

In seeking to develop new roles, two measures will be important. The first measure to be taken is the participation of farmers and fishers in the generation of new systems. In these new systems measures must be taken to insure that rice yields are, at worst, not sacrificed and at best increased. Such directions and measures can only assist in the realization of the reported potential for fish production in Asian ricefields.

Chapter 1
Country Overviews

Rice-Fish Farming Systems in Bangladesh: Past, Present and Future

SOMEN DEWAN
Department of Aquaculture Management
Bangladesh Agricultural University
Mymensingh, Bangladesh

DEWAN, S. 1992. Rice-fish farming systems in Bangladesh: past, present and future, p. 11-16. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Bangladesh has approximately 2.83 million ha of ricefields where 0.2 million t of wild fish are caught annually. Fish production can be increased considerably in these ricefields if fish culture is practised. Capture and culture rice-fish systems exist in very limited scale. In capture systems, wild fish stock enters the flooded ricefields and gets trapped after rice harvest. In culture systems, concurrent and rotational rice-fish systems are practised by stocking fish and shrimps in inland freshwater or coastal ricefields.

Little research has been done on rice-fish farming systems in Bangladesh. On-station and on-farm experiments focused on evaluating different stocking densities and combination of species such as Indian major carps and Chinese carps, common carp (*Cyprinus carpio*), silver barb (*Puntius gonionotus*) and tilapia (*Oreochromis mossambicus*). Gross yields from different combinations of these species vary widely with stocking densities and survival. Incomes ranged from US$30 to 134/ha in concurrent and US$688/ha in rotational systems. Rice-fish culture also provides opportunity for reducing unemployment.

Some constraints must be resolved and more research must be done if rice-fish farming has to succeed in Bangladesh. Strong political will is needed to resolve social issues on land ownership and rights on water use. Technical, production inputs and credit support are also necessary.

Introduction

Agriculture forms the basis of Bangladesh economy. Fish is the cheapest source of animal protein and contributes about 80% of the total protein intake in Bangladesh (Karim 1978). The abundant water sources of Bangladesh provide scope for increased fish production. Vast areas of ricefields can be utilized for rice-fish culture. Recently, rice-fish culture has gained attention because of observations that certain pesticides can control rice pests without affecting fish (Arce 1985). Moreover, fish culture in ricefields not only increases fish production but may also increase rice production. Hora and Pillay (1962) report that rice-fish culture can increase rice yield by about 15%. Expansion of rice-fish culture in the inundated areas will not only increase animal protein supplies, but will also increase the income of rural people.

Past and Present Status of Rice-Fish Systems

Prevailing Rice-Fish Systems

Farmers have been harvesting fish from ricefields for a long time in Bangladesh. Both capture and culture systems exist.

In capture systems, farmers do not stock fish but depend on wild stocks entering the inundated ricefields. Farmers do little to prepare their ricefields for retaining fish. Fields are normally surrounded by dikes of variable heights. Some make sumps of variable size and depth in the lowest portion of the ricefield. Some make brush shelters in the sumps to provide shelter for the fish and prevent stealing. After harvesting the rice crop, few kilograms of wild fishes such as *Channa, Anabas, Clarias, Heteropneustes, Colisa,* minnows, spiny eels and small shrimps are caught. Fertilizers and artificial feeds are rarely applied in the ricefields.

In culture systems, the farmers construct ponds of different sizes in low-lying areas of the field. During monsoon, when ponds and ricefields are full with rainwater, farmers release carp fry. Specific stocking densities are not followed. Brush shelters are built in miniponds. Normally, farmers do not apply fertilizers or give supplementary feed. After harvesting rice in November to December, fish harvest continues until March.

In coastal areas, farmers culture marine shrimps (such as *Penaeus monodon, P. indicus, P. semisulcatus* and *Metapenaeus monoceros*) in ricefields using traditional *bheri* system. Here, ricefields are enclosed by small embankments with inlet channels and sluice gates. Fields may vary from 3 to 50 ha. Shrimp is produced both by rotational and concurrent systems. After harvesting rice in December to January, tidal water full of shrimp and fish fry is allowed to enter the ricefields. Some of the species found are *Labeo bata, Mugil corsula, Mystus* sp., *Lates calcarifer* and *P. monodon.* Bamboo screens (locally known as *bana*) are then placed over the sluice gate to prevent fish and shrimps from escaping. Neither fertilizers nor supplementary feed are provided. Shrimp harvests start at the end of April and continue up to July. Fish now in the water-supply channel are harvested during September. About 210 kg of shrimp and 80 kg of fish are harvested (MPO 1985).

Occasionally, farmers produce freshwater shrimp (*Macrobrachium rosenbergii*) along with transplanted *aman* rice. Monsoon rains wash out the salinity of the ricefields. After transplanting in August, farmers release 7,000–8,000 shrimp fry collected from nearby rivers. Shrimps are harvested after rice in November to February. Without fertilizer or supplemental feed, yields vary from 40 to 50 kg/ha (Haque 1987).

Rice-Fish Research and Development

Relatively little research has been done on rice-fish farming systems in Bangladesh. At present, only the Farming System Research and Development Program of Bangladesh Agricultural University (BAU) and the Fisheries Research Institute (FRI) have been conducting research on rice-fish farming.

Das and Dewan (1982) conducted fish growth experiments in rice-fish concurrent systems. *Labeo rohita, Cirrhinus mrigala, Cyprinus carpio* and *Oreochromis mossambicus* were stocked both in monoculture and polyculture at 2,000/ha for *L. rohita* and *C. mrigala*, and 7,000/ha for *C. carpio* and *O. mossambicus.* The plots were fertilized with 180 kg/ha urea, 160 kg/ha triple superphosphate and 40 kg muriate of potash. Fish were harvested 75 days after rice. All species showed better growth in monoculture than in polyculture. *O. mossambicus* showed highest average growth, closely followed by *C. carpio. C. mrigala* had the lowest growth rate.

BAU's Farming System Research team conducted rice-fish culture experiments on farmers' fields at Kazirshimla, Mymensingh in 1985, 1986 and 1987, and at the Agronomy Field Laboratory in 1987. All experiments used concurrent systems of *L. rohita, Catla catla, C. mrigala, Hypophthalmichthys molitrix, C. carpio* and *Puntius gonionotus* with rice. In each experiment, fish of different densities and species combinations were released after 10–15 days of transplanting *aman* rice in August. All experimental plots received 178 kg/ha urea, 125 kg/ha triple superphosphate and 67 kg/ha muriate of potash. Fish were harvested in November just after the rice. Among the three species studied at the Agronomy Field Laboratory in 1987, *C. carpio* gave the highest average growth (Table 1). In the farmers' fields at Kazirshimla, *P. gonionotus* showed the highest average growth followed by *C. catla* and *C. carpio. C. carpio* and *P. gonionotus* were not used in the 1985 and 1986 experiments. Among the fish released in those years, *C. catla* showed the highest average growth. Better fish yields and higher net returns of fish were obtained in the experiments conducted at the Agronomy Field Laboratory and in farmers' fields at Kazirshimla in 1987. The lowest yields and net returns in 1986 might be associated with the prolonged drought during that season.

Rotational systems were tested on farms in 1987 at Randia Village, Mymensingh, by BAU's Farming System Research team. This system has one single crop, i.e., *boro* rice is cultivated from mid-December to April, after which the fields are left fallow due to excessive water during monsoon. To investigate the productive use of the ricefield, an experiment was conducted in a 2.5-ha ricefield surrounded by high land with only one outlet. Seven species of fish (*C. catla, L. rohita, P. gonionotus, C. carpio, C. mrigala, Ctenopharyngodon idella* and *H. molitrix*) were released in July and harvested during the early December. Only 80 kg urea, 60 kg triple superphosphate and 20 kg muriate of potash were applied. Unfortunately, a considerable number of fish were lost to monsoon floods. *C. catla, C. carpio* and *C. idella* grew better than the other species. Total yield was 856 kg/ha and net return was US$688/ha.

Economic Significance and Profitability

Rice-fish culture could improve the economic condition of rural people. Eighty per cent of Bangladesh's people live in rural areas and most of them are dependent on agriculture. The promise of increased rice and fish production not only provides cash but also improves nutrition. Additional incomes from fish in ricefields achieved in experiments ranged from US$30 to 134/ha in concurrent systems and US$688/ha in rotational systems. Moreover, if monocrop rice areas in central and coastal regions can be leased to unemployed persons for rice-fish farming, then unemployment may be reduced.

Future Prospects and Constraints

Potential Resources and Prospects

Bangladesh has about 2.83 million ha of ricefields where water stands for about four to six months. At present, about 0.2

Table 1. Performance of fishes in rice-fish polyculture.

System/ Location/Year/ Fish species	Stocking density (fish/ha)	Average initial weight (g)	Average final weight (g)	Mortality (%)	Yield (kg/ha)	Gross income (US$/ha)	Net returns (US$/ha)
Concurrent, on-station							
Agronomy Field Laboratory, 1987	2,220				147	168	134
P. gonionotus	555	10.0	95	7	51		
C. carpio var. *specularis*	1,110	7.0	189	63	77		
L. rohita	555	5.5	62	47	19		
Concurrent, on-station							
Kazirshimla, 1987	1,678				79	110	38
P. gonionotus	357	10.0	135	32	33		
C. mrigala	607	6.0	69	69	13		
C. catla	250	7.0	115	43	16		
C. carpio var. *specularis*	464	6.5	113	34	34		
Kazirshimla, 1986	1,800				43	48	30
L. rohita	790	2.3	55	73	12		
C. mrigala	683	11.9	85	55	26		
C. catla	63	16.0	112	22	5		
C. reba	264	3.6	0	100	0		
Kazirshimla, 1985	1,521				94	92	49
L. rohita	739	6.0	100	15	63		
C. catla	109	26.0	117	36	8		
C. mrigala	13	10.0	62	31	1		
H. molitrix	660	30.0	55	36	23		
Rotational, on-farm							
Randia Village, 1987	5,000				856	840	688
C. catla	500	8.0	1,200	63	241		
L. rohita	1,000	6.0	300	71	87		
P. gonionotus	400	9.0	300	52	52		
C. carpio	600	7.5	1,000	64	216		
C. mrigala	800	6.0	300	57	103		
C. idella	100	7.0	1,300	54	60		
H. molitrix	600	7.5	600	73	97		

million t of wild fish are caught every year (MPO 1985). Culturing fish in these inundated ricefields would increase fish production considerably. Fish can also be cultured in irrigated, coastal and deepwater *aman* areas. In coastal areas, shrimp and fish can be cultured using concurrent and rotational techniques. Traditional production systems can be improved.

Constraints to Development

Major biological, technical and socioeconomic constraints to raising fish in ricefields are listed below:

1. In order to harvest market-size fish within three to four months, farmers have to stock large fingerlings which are not available in sufficient quantities at the right time.

2. Indiscriminate use of insecticides in rice causes heavy mortalities in the fish population.
3. Pests, especially crabs and rats, make holes in the dike which make it difficult to retain water at the desired depth.
4. Rice-fish farming is risky because of excessive rainfall causing flooding or prolonged drought.
5. Preventing fish escape is very difficult in fragmented holdings demarcated by low dikes that permit water from one field to flow into another. Moreover, farmers are reluctant to raise bunds or make trenches in small ricefields.
6. Theft of fish.
7. Farmers do not want to culture fish in their fields because they lack knowledge about improved methods of rice-fish farming and its benefits.
8. Lack of qualified and experienced extension workers to teach and motivate farmers.
9. Lack of proper and relevant research on how to improve farming systems.

Future Research Thrusts

Since rice-fish research has only been going for a few years in Bangladesh, there is still plenty of work to be done. To maximize fish production in ricefields, the following research should be investigated:

1. Selection of hardy, fast-growing species with high tolerance to pesticides, high temperature, low water levels and salinity in coastal areas.
2. Determine suitable stocking rates and combinations of different species.
3. Determine suitable doses of fertilizer and low-cost supplementary feed for fish.
4. Effects of various insecticides on fish as well as on the environment as a whole to identify suitable insecticides and proper doses.
5. Field designs that satisfy water requirements for both fish and rice which are economical and acceptable to rice farmers.
6. Descriptions and cost-benefit analyses of existing systems to improve and restructure research and development thrusts.

Development Strategies

Strategies for developing rice-fish farming systems should contribute to the generation of rural employment, provision of better nutrition and increase of foreign exchange earnings.

Success of rice-fish farming requires a strong political will because success is dependent on land ownership patterns, rights over using water bodies, and timely supply of inputs and credit.

Adaptive research programs should be cognizant of research results obtained in other Asian countries. The FRI, universities and other interested institutes should undertake research programs in different agroecological zones. Research results should be tested in farmers' fields through pilot projects in different regions. Technologies developed should be made available to farmers through government and nongovernment organizations.

Training is an important element in human resource development. To this end, research and training institutes should undertake appropriate training programs for extension workers and farmers.

Availability of fingerlings is vital to the adoption of rice-fish. Government seed multiplication farms should take effective steps to ensure adequate supplies of quality fingerlings.

Necessary arrangements should be made that ensure credit facilities for rice-fish farming on easy terms to all categories of farmers especially to poor farmer cooperatives.

References

Arce, R.G. 1985. Rice-fish farming systems. Report of the 16th Asian Rice Farming Systems Working Group Meeting, 9-13 November 1985. Dhaka, Bangladesh.

Das, N.C. and S. Dewan. 1982. Paddy-cum-fish culture. Department of Aquaculture and Management, Bangladesh Agricultural University, Mymensingh. 64 p. M.S. thesis.

Haque, M.F. 1987. Improved methods of fish culture. Government Quarters. Rayer Bazaar, Dhaka, Bangladesh.

Hora, S.L. and T.V.R. Pillay. 1962. Handbook on fish culture in the Indo-Pacific region. Fish. Biol. Tech. Pap. 14. 204 p. FAO, Rome.

Karim, M. 1978. Status and potential of Bangladesh fisheries. Ministry of Fisheries and Livestock, Dhaka, Bangladesh.

MPO. 1985. Economic analysis of fisheries, modes of development. Master Plan Organization, Ministry of Irrigation, Water Development and Flood Control Technical Report No. 28:1-10. Dhaka, Bangladesh.

Rice-Fish Farming Systems in China: Past, Present and Future

LI KANGMIN
Asian Pacific Regional Research and Training Centre for Integrated Fish Farming
Freshwater Fisheries Research Center
Chinese Academy of Fisheries Sciences
Wuxi, China

LI, K. 1992. Rice-fish farming systems in China: past, present and future, p. 17–26. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Rice-fish culture has a long history in China. However, rice-fish farming system was just a sporadic and spontaneous production practice before the founding of the People's Republic of China. In the recent four decades, rice-fish culture went through the process of normal development, severe fluctuations and rapid development. The success of induced spawning of cultured fishes in 1958 and improved rice-fish culture techniques favored the development of various rice-fish farming systems. Although large expansion of rice-fish area was experienced in the past years, the potential for development is still great. Rice-fish culture is a type of integrated fish farming that combines rice cultivation with aquaculture to promote a balanced ecosystem. It has been recognized as an important approach to help poor peasants out of poverty.

Introduction

The rapid increase in world population has also become a challenge to China. There is an urgent need to raise per unit yields of land and waterbodies as well as expand the area of arable land.

Experience has shown that rice-fish culture can increase rice production by 10% and produce fish at 300 kg/ha on the average, or provide 4,500–7,500 large fingerlings/ha for growout ponds or pens in lakes.

Historical Background of Rice-Fish Culture in China

Rice-fish culture is an age-old practice in China but there are no accurate records when it actually started. Related historical information is very scanty.

In 1978, a tomb of the mid-Eastern Han Dynasty (25-220 AD) was excavated at Lao Tao Si, Mian County, Shanxi Province. One of the unearthed relics was an intact ricefield model made of red pottery. The unearthed tomb contained 18 pieces of miniature pottery of aquatic plants and animals including lotus flowers, lotus leaves, lotus seeds, water chestnuts, duckweeds, soft-shelled turtles *(Trionyx sinensis)*, grass carp *(Ctenopharyngodon idella)* and *Carassius auratus* (Guo 1985). Before this excavation it was believed that rice-fish culture began in the period of the Three Kingdoms (220-280 AD). The unearthed cultural relics of Mian County not only indicate that rice-fish culture in China dates further back in the historical record, but also fills an important gap in kind in the history of rice-fish culture in China. Mian County is located in the Hanzhong basin south of Qinlin mountain, near the border of Sichuan and Shanxi Provinces. Its climate permits only a single-crop rice cultivation. The unearthed ancient model indicates that aquatic plants such as lotus, water chestnuts and duckweeds, as well as aquatic animals such as fish and turtles can grow in ricefields.

Although pond fish culture began at the end of the Shang Dynasty (1401–1154 BC), the only cultured species was common carp *(Cyprinus carpio)* until the Tang Dynasty. It is likely that other species may not have been deliberately stocked in ricefields in the mid-Eastern Han Dynasty. When ricefields were irrigated, wild fish and naturally-occurring turtles would have been likely introduced into the fields and grew naturally. However, people already noticed the coexistence of rice and fish in ricefields at this ancient date. Nevertheless, if fish were purposely stocked, rice-fish culture was just in its embryonic stages.

Rice-fish culture was mentioned in Weiwu's "Recipes of Four Seasons", that is, "a species of small fish produced in the ricefields in Pi County has yellow scales and red tail, and can be used for making fish sauce". The dynastic title Weiwu refers to the first emperor of the Wei Dynasty, Caocao, a warlord who lived at the end of the Eastern Han Dynasty and the Three Kingdoms. Pi County is on the northwest of Chendu, where King Duyu of Shu once built his capital. The small fish with yellow scales and a red tail is likely the *C. carpio*. Although this record did not clarify if *C. carpio* was cultured in ricefields, it should be noted that it was during that time when *C. carpio* culture began to develop from small ponds to vast expanses of waterbodies. Fish culture might have started in ricefields.

Moreover in Sichuan, a mountainous region, ricefields are flooded year-round. In the winter when fields are fallow, the water stored in the fields provides favorable conditions for fish culture. In view of its locality, rice-fish culture techniques might have been extended from the well developed Hanzhong basin to the western region. This expansion may have happened after Zhuge Lian, a great statesman and strategist in the period of the Three Kingdoms, entered Sichuan.

Rice-fish culture as recorded in the "Wonders in Southern China" written by Liu Xun in 889–904 of the Tang Dynasty (618–907 AD) quotes: "In the districts of Xin Long, etc., there are hillside plots and deserted buildings here and there. The flat areas are hoed to be open spaces near the houses. When spring rains come, water is stored in the plots around the houses. *C. idella* fingerlings, which were purchased in advance, are then released into the flooded fields. One or two years later, the fish grow up and the grass roots in the plots are all eaten. This method not only fertilizes the fields but also produces fish. Then, rice can be planted without barnyard grass. This is a superior method of benefitting the people" (CFFCEB 1982). The culture of *C. idella*, black carp *(Mylopharyngodon piceus)*, silver carp *(Hypophthalmichthys molitrix)* and bighead carp *(Aristichthys nobilis)* began at the beginning of the Tang Dynasty. From then on to when Liu Xun's book was written, more than 200 years had passed. The people were familiar with the feeding habits of *C. idella* and could distinguish its fry from other species. They made use of *C. idella* to condition ricefields. This was the earliest record of rotational rice-fish culture in China, and was a great step towards advanced rice-fish culture techniques.

In the Ming Dynasty (1368–1644) the chronicle (1392) of Qing Tian County, now in Zhejiang Province, mentioned several *C. carpio* species of black, red or mottled colors, which are cultured in ricefields and ponds. Qing Tian and Yong Jia Counties are known for salted *C. carpio* at home and abroad. Through hundred years of domestication, a good stock had been bred which was adaptable to the ricefield environment. Also, a fish processing method had been developed. However, rice-fish culture was limited to the hilly areas along the Oujiang River before the founding of the People's Republic of China.

Status of Rice-Fish Culture in China

State-of-the-Art

In modern China, rice-fish culture is common in the southeastern and southwestern provinces, especially in mountainous areas. In nearly 40 years from 1949, rice-fish culture went through the process of normal development, severe fluctuations, then to rapid development. For example, taking Sichuan Province to represent the status of the rice-growing areas because of its similar situation with the other provinces (Fig. 1), the development of rice-fish culture can be divided into three stages: from 1949 to 1956, stable developmental stage; from 1957 to 1978, fluctuating developmental stage; and from 1979 to 1984, rapid developmental stage (Feng 1984).

In the past, most fry stocked in ricefields came from eggs collected from the Yangtse and Pearl Rivers in provinces adjacent to these rivers. In hilly regions, either *C. carpio* broodstock were released in ricefields for natural spawning or fish nests with sticky fertilized eggs were put into ricefields for hatching. Under these conditions, it was impossible to immediately promote and implement rice-fish culture techniques. In 1958, induced spawning of cultivated fish in China was successful. This development ended the dependence on the great rivers for fry, and had greatly contributed to the rapid development of fish culture in ricefields.

In the 1950s, rice technologies were developed. Irrigation systems transformed arid lands into arable fields. Traditional rice cultivars (*Oryza indica*) were changed to *O. japonica* or hybrid strains. The practice of broadcast sowing was changed to seedling transplanting. These measures

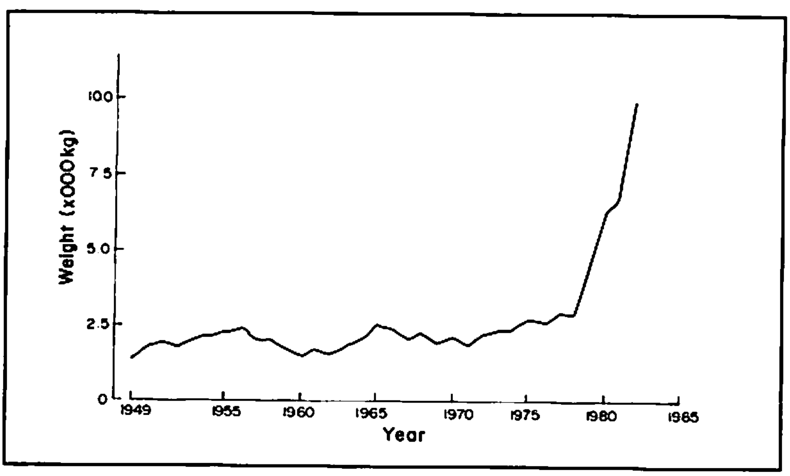


Fig. 1. Fish production from rice-fish culture in Sichuan Province. (Sources: Feng 1984; Jiang 1987).

increased rice production. However, these innovations created new constraints to rice-fish culture: close planting; consecutive croppings; sundrying of the field; and the application of chemical insecticides and fertilizers.

Nie and Wang (1981) studied the relationship between rice and fish and found that both benefit from each other. He called this mutualistic association and this has provided the theoretical basis for rice-fish culture in China. Since then, rice-fish culture techniques have been improved, and the problems caused by the changes in rice agronomy and the destructive applications of chemicals and fertilizers, have been partially solved.

In the 1980s, especially after the First National Rice-Fish Culture Seminar in 1983, a production movement called "Hundred jin Fish, Thousand jin Rice Grains" (one jin = 0.5 kg) has spread rapidly to all rice-fish areas.

Techniques and Methods

The techniques and methods of rice-fish culture depend on the local agroclimate, water supply, soil fertility and availability of fry. Many system types have emerged since 1979. There are three types of culture systems: 1) rotational rice-fish farming or fish culture in ricefields during the winter fallow, summer fallow, or during both seasons; 2) mixed rice-fish farming, i.e., fish culture intercropping in one or two consecutive rice crops; and 3) rice-fish culture in rotational and concurrent rice farming. Generally, fingerlings are raised in mixed farming systems, while food fish are raised in rotational farming systems (Li 1988).

There are two methods of tilling rice: bedding and ridging. It has been shown that the ridging field tillage method is more suitable to rice-fish culture. Ridging tillage is also called a semiarid, free-plowing type of rice farming system. In China, it has now been transformed into a ridge rice planting-ditch fish farming system (Fig. 2). The guiding principle of this method is soil fertility biothermodynamics theory proposed by Professor Hou Guangjiong. One ditch and one ridge alternate every 60 or 84 or 100 cm where two, three and four rows of rice seedlings, respectively, can be planted on top of the ridge. The space for fish can be made larger while keeping the rice population or number of seedlings the same by reducing the planting space to 10 cm. The ditch is 30 cm deep with 26 cm of water at rice transplanting time, after which water levels are raised to the top of ridges. Rice plant roots absorb nutrients and moisture continuously because the water, oxygen and heat contained in the soil are stable. This is also conducive to good fish growth because of the increased rate of organic matter decomposition and more natural foods are produced compared to the bedding field tillage method (Deng and Xu 1984; Zhong et al. 1987). This method also improves the ecological environment for the growth of rice and fish by deepening the tilled soil layer and increasing the water column. Also, the economic returns are higher. Fish yields reach 1,500–3,750 kg/ha and rice yields 5,250–7,500 kg/ha.

Fish ditches and sumps are dug in ricefields to overcome the constraints posed by sundrying and the application of chemicals and fertilizers. Either shallow ditches and small sumps or wide ditches and large sumps can be constructed. The shallow ditch is usually 33 cm in width and depth, with the small sump usually 1–2 m^2 wide and 80 cm deep. Ditches and sumps cover 5–8% of the ricefield area. The wide ditches are 45 cm in width and depth; while the large sump is 2.5–4.0 m wide and 1.5–1.8 m deep. Ditches and sumps might be dug on one side of a plot. They account for 10% of a plot. The small waste pool, ditch and ash pond can be utilized and renovated to widen ditches or sumps. This flexibility offers many advantages. Ditches and sumps enlarge the water area of the rice plot. Broad ditches or sumps can be used as spawning ponds for

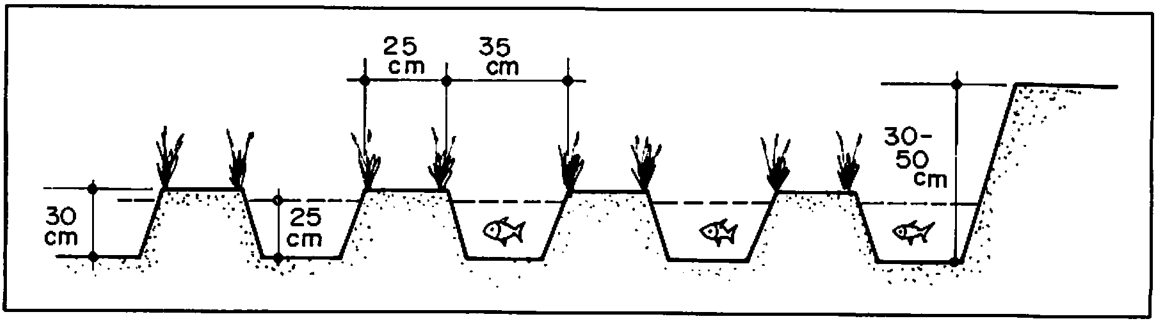


Fig. 2. Ridge rice planting-ditch fish farming system.

C. carpio and *C. auratus*, or as fry nurseries. However, the depth of the sump should not be greater than 66 cm, otherwise, *C. carpio* would not swim into the ricefields to search for food, especially when feeds are given. Stocking fish can be done early and harvesting can be postponed, thus, the growth period can be extended and fish production is increased. Earthworks can be done in winter to alleviate labor constraints in summer.

Fish Species Cultured in Ricefields

Several fish species can be cultured in ricefields. Below are some recommended species.

Common carp. C. carpio which has black, red, white or a mottled color, grows quickly and is sluggish. It does not jump, is reluctant to escape, and is very adaptable to the ricefield environment. It has been domesticated, can survive 40°C water or in shallow waters even with its dorsal fin above the water surface.

Tilapia. Tilapias are very resistant to low dissolved oxygen (DO) levels. *Oreochromis mossambicus* and *O. niloticus* can tolerate DOs as low as 0.1 ppm. Moreover, tilapia can withstand very high levels of CO_2, with maximum tolerance levels of 72.6 ppm for *O. macrochir* and 50 ppm for *Sarotherodon esculentus.* It can also tolerate high levels of other gases (NH_3, H_2S) coming from the decomposition of organic matter. *O. aureus* can tolerate 2.4 ppm of un-ionized NH_3 (48-hour LC_{50}) (Pullin and Lowe-McConnell 1980).

Grass carp. C. idella are herbivorous fish and can control wild aquatic weeds in ricefields. Grass carp fingerlings (total length above 6.6 cm) feed on macrophytes. The size of fingerlings stocked in ricefields should be within the range of 3.3 to 5.0 cm as this would prevent the fish from eating rice seedlings (Luo 1985).

Catfish. These are omnivorous fish which are resistant to diseases and are very adaptable to the environment of small waterbodies with low DOs. Prolonged exposure to extreme of turbidities as in the ricefields favors the growth of olfactory feeders, such as *Clarias* species *(C. fuscus, C. batrachus, C. macrocephalus, C. leather)* over visual feeders (Khoo and Tan 1980).

Loach. In China, loach *(Misgurnus anguillicaudatus)* is also cultured with rice. After rice seedlings are transplanted, *M. anguillicaudatus* brooders are stocked at 150 kg/ha. About 1,125 kg/ha of these fish can be collected after rice harvest. They subsist only on natural food. The methods for harvesting the fish must be adapted to their biological behavior in different seasons. For example, during winter, pig manure or cowdung is heaped in ricefields to lure the fish, and these fish can be harvested several times. In spring, a bamboo trap is put before the outlet and the fish swim into it and are collected. In autumn, the water in the plot is drained and the field is completely sundried. Afterwards, the area is refilled with a small amount of water which induces the loach to emerge from the soil. The fish then can be collected by a dip net (Wang 1985).

Other species. As rice-fish culture techniques develop, the species stocked in ricefields have diversified from fish to prawn (*Macrobrachium* sp.) and American snail; and from local fish to some exported species.

Other Integrated Systems

Several three-tier agriculture-aquaculture systems are being tested such as a rice-watervelvet-fish, rice-chicken-fish, rice-fish-fruit (grape, banana or sugar cane) and rice-fish-frog systems. The latter is a pesticide-free integrated system where the fish and frogs control rice pests and diseases. The final products from this system consist of grains, oil, meat, fish and frogs – all of which are quality food for human consumption (Ying 1986).

Economic Significance

Culturing fish in ricefields results in the eradication of weeds and harmful insects, loosening of soils, increasing DO levels and improving the fertility of ricefields, thus, rice production may be increased to between 8.0 and 47.3% (Nie et al. 1985). Nie (Outlook Weekly 1987) estimated in 1981 that if the rice-fish area is expanded to 6.6 million ha in three years, with the average rice yield of 3 t/ha, the national rice production could be increased by 2 million t and 30–50 billion fingerlings (10–13 cm) can be harvested annually for restocking in ponds and lakes. Expansion of rice-fish culture could play an active role in the fulfillment of the national aqua-product objectives (Outlook Weekly 1987).

Prospects and Constraints of Rice-Fish Culture

Prospects

In future, rice-fish culture in China will develop rapidly along with other agricultural enterprises. There are 24.6 million ha of rice lands in China, 25% of which are suitable for fish culture. In 1982, some 344,520 ha were used for rice-fish culture; 441,000 ha in 1983 and 557,720 ha in 1984. This represents a 62% increase in rice-fish area in China (Jiang 1987). In Sichuan province, rice-fish area doubled in four years from 67,333 ha in 1979 to 156,666 in 1982 (Jiang 1983). There is great potential for further development of rice-fish culture if the trends of large expansion in rice-fish area continues. Fish yields in general, has reached 225–750 kg/ha and even 750–2,250 kg/ha have been reported. In Qujiang County, Guangdong Province, a woman cultured *C. leather* in a 0.06-ha rice plot. After 86 days, 422 kg fish and 515 kg rice were harvested – a production record in rice-fish culture.

Constraints

Some constraints associated with modern rice technologies have hindered rice-fish culture from 1957 to 1978. However, since then, the problems associated with sundrying and application of chemicals and fertilizers have been partially solved. Fertilization techniques have also improved. The principle is to maximize the use of organic manure and minimize chemical fertilizers. If chemical fertilizers are used with manure, the bulk of manure should be applied basally for the whole growth period. Topdressing of chemical fertilizer is applied in small amounts and in stages.

Although the fish in ricefields act as a biological control of weeds and diseases, they cannot totally replace chemicals. The principles of application are to choose chemicals which are of low toxicity, have low residual effects, are highly effective and eury-spectrum. Among rice pests and bacterial diseases, the most damaging are the yellow rice borer *(Tryporyza incertulas)*, armyworm *(Pseudoletia oryzae)*, sheath and culm blight of rice *(Hypochnus sasakii)*, bacterial leaf blight *(Xanthomonas oryzae)* and instant rice blight. The LC_{50}s of chemicals to fish in ricefields are presented in Table 1.

This practice of sundrying the field is proven to be not necessary if fish are cultured in ricefields. The bottom-dwelling omnivorous fish functions better than sundrying (Xu et al. 1986).

China's rice-fish culture is spreading from the hilly regions to the plains. Although the economic benefits of rice-fish culture are better than those of monocropping, its revenues are much lower compared to other rural industries. As a result, labor shortage is a main problem affecting further development in these countrysides on the plains. If rice-fish culture develops from the south to the north in Beijing, Liaoning and Jilin Provinces, water will be the main constraint due to soil porosity. If extensive systems become semi-intensive, insufficient supply of fry of desirable species and palatable fish feeds will be the major constraints.

To achieve high and stable yields, different culture systems should be adopted in line with the different socioeconomic and natural conditions in the regions. Good quality strains and stock should also be made available. However, this job will not be easy. In areas with long experience in rice-fish culture, farmers adhere to traditional techniques. On the other hand, in the newly developed areas, farmers lack the technical know-how and there is also lack of technicians to promote rice-fish culture. Thus, extension programs on rice-fish culture techniques should be organized.

Development Strategy

China has a population of more than one billion, 80% of which live in rural areas. Grain production is largely performed by manual labor. Considering the country's socioeconomic conditions, China must develop agricultural infrastructure. Agricultural modernization should proceed from adaptable agriculture to ecological agriculture to mixed agriculture-aquaculture and finally to industrialized agriculture. This process outlines the evolutionary approach to modernize China's agriculture.

Mixed agriculture refers to an integrated system of various agricultural enterprises in a unit area, space or waterbody, with multistrata structure and multigrade utilization matrix. Rice-fish is an important component which combines crops with aquaculture to promote a balanced ecosystem. It increases rice production and decreases labor; it popularizes fish culture techniques, thus, fish production is greatly enhanced. Fish cultured in ricefields serves as a biological control on rice pests, which is beneficial to both the rice crops and people's health. Rice-fish culture is a low-cost production system, has quick returns on investment and generates higher incomes. Thus, it has been recognized as an important approach to help poor peasants get out of poverty.

Research Thrusts and Methodologies

Research on rice-fish culture should be intensified. Various models of rice-fish systems have evolved in line with local agroclimate and socioeconomic conditions. Benefits from the different rice-fish culture systems should be quantified in an input-output analysis or costs and returns analysis. The positive economic returns should be highlighted to facilitate extension work when promoting rice-fish culture.

Table 1. The LC_{50} of chemicals to fish in ricefields.

Type and names	Test species	LC_{50} (ppm) 48-hour	LC_{50} (ppm) 96-hour	Toxicity[a]	Kinds	Normal dosage (ppm) g/ha	Normal dosage (ppm) 100%	Normal dosage (ppm) 30%	Safety[b]
Insecticides									
Dipterex	*C. carpio*	6.2		M	90% crystals	1,125	1.52	0.46	3
DDV	*C. carpio*	4.0		M	80% emulsion	1,125	1.04	0.31	3
Fenitrothion	*C. carpio*	4.4		M	50% emulsion	750	0.51	0.15	3
Malathion	*C. carpio*	9.0		M	50% emulsion	750	0.53	0.16	3
Roxion	*C. carpio*	40.0		L	40% emulsion	750	0.43	0.13	2
Parathion	*C. carpio*	5.0		M	50% emulsion	750	0.51	0.15	3
Methamidophos	salmonid		51.0	L	50% emulsion	750	0.49	0.14	2
Metacrate	*C. carpio*	15.3		L	20% wettable powder	1,500	0.56	0.17	2
Isoprocarb	*C. carpio*	4.2		M	10% wettable powder	3,000	0.45	0.14	3
Chlordimeform	*C. carpio*	15.2		L	25% wettable powder	750	0.25	0.08	2
Germicides									
Kitazine	*C. carpio*	5.0		M	40% emulsion	1,500	0.45	0.14	3
Kitazine-P	*C. carpio*	5.1		M	40% emulsion	1,500	0.92	0.28	3
Hinosan	*C. carpio*	1.3		M	40% emulsion	750	0.43	0.13	3
Isoprothiolane	*C. carpio*	6.7		M	40% emulsion	1,125	0.63	0.19	3
EL-291	*C. carpio*	14.6		L	20% wettable powder	750	0.23	0.07	2
Sanmate	*C. carpio*		96.6	L	50% wettable powder	750	0.56	0.17	1
Jingangmycin	*C. carpio*	100.0		L	5% wettable powder	1,125	0.08	0.02	1
Imidan	*C. carpio*	5.3		M					
Erasan		2.0		M					
Lebaycid		2.0		M					
Landrin		38.1		L					
Baygon			1.03	M					
Furadan carbofuran	trout		0.23	H					
Bassa	*C. carpio*	12.6		L					
Rotenone	*C. carpio*	0.032		E					
Topsin	*C. carpio*	11.0		L					
Blasticidin S	*C. carpio*	40.0		L					
Thiram, TMTD	*C. carpio*	4.0		M					
Seedvax	fish	0.4-1.8		E					
Herbicides									
2,4D	*C. carpio*	40		L					
Agritox	*C. carpio*	14.0		L					
DCPA, propanil		0.42		H					
Nitrofen		2.1		M					
Benthiocarb		3.6		M					
Prometryne		23.5		L					
Pentachlorophenol		0.35		H					

[a]L(low) for common carp in 48 hours, LC_{50} = 10; M (moderate), LC_{50} = 1–10 ppm; H (high), $LC_{50} < 1$ ppm.
[b]1 = Safe if applied; 2 = safe if applied when water depth is 10 cm; 3 = safe if 30% of chemicals drops in the water and when fish grows larger.
[c]Especially to grass carp.

The relationships among aquatic plants, animals and their environments is a complex one. Ecological studies should emphasize the need to fully utilize natural resources (water, soil, sunlight, temperature and air). The methodology of ecological systems theory may be very useful for this.

It is generally believed that chemicals of low toxicity will not cause mass fish mortalities in ricefields, but opinions regarding the standard safe dosages differ. For example, carbofuran is safe for use in rice-fish culture because it does not accumulate in the fatty tissues of fish (Estores et al. 1980). However, carbofuran is extremely toxic to *C. idella* (Mao et al. 1985). Probably, the latter refers to acute toxicity, while the former refers to chronic toxicity and absence of residual effects. Experiments on the standard dosages of chemicals to different fish species should be done. Research is also necessary to develop alternative pest control techniques that will not harm fish.

The average farm size in China are becoming larger but their numbers lessen as a result of the ongoing economic reforms in rural areas. Much has been written about the decline of the family farm. Yet experience in the United States, western Europe and Japan indicates that family farming is not incompatible with modern techniques. In the United States, family farms are responsible for about two-thirds of all farm sales. The average size of a family farm in the United States is more than 120 ha. In Japan, where family farm size averages 1 ha, agriculture is nevertheless highly complex and mechanized (Schultz et al. 1964). Rice-fish culture has been and originally was a side occupation of family farms. However, it should not necessarily be connected with smallholders or small-scale self-sufficient farming systems. In fact, a modern large-scale family farm can adopt rice-fish combinations. The individual size of rice-fish fields could reach 10 ha according to the experiments of JPFRI (1983). The key point is to improve the techniques and to invent new agricultural and aquaculture machines.

In deepwater and waterlogged areas, as well as reclaimed lands from lakes and the sea, the combination of agriculture and aquaculture can protect the environment, increase rice production and improve people's diet by increasing animal protein production. China is now investigating the feasibility of deepwater rice-fish culture.

Conclusions

In developing agricultural countries, one characteristic of undeveloped peasant agriculture is its low level of self-sufficiency. The productivity per worker and yield per unit of land are both low. Agriculture and aquaculture combinations are the best ways to raise per unit yields. Rice-fish culture should be recognized as part of the larger agricultural system. Let rice-fish farming be a true "New Alchemist" farm.

Acknowledgements

I would like to thank Guo Yixian of the Institute of Crop Breeding and Cultivation, Chinese Academy of Agricultural Sciences, for his guidance; Hu Baotong, for reviewing this paper; Li Peizhen for consultation; Qin Dongzhu for advice and Don Peiya for providing information during the preparation of this paper.

References

CFFCEB. 1982. Science on the culture of freshwater fish species in China. Chinese Freshwater Fish Culture Editorial Board. International Development Research Centre-TS 16 E.

Deng, Q. and N. Xu. 1984. The preliminary test on semi-dryland rice-fish farming. Sichuan Aquatic Products (1):24.

Estores, R.A., F.M. Laigo and C.I. Adordionisio. 1980. Carbofuran in rice-fish culture, p. 53–57. *In* R.S.V. Pullin and Z.A. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Feng, E. 1984. Rice-fish culture: a proper breakthrough in opening up a new phase of fishery production in Sichuan. Sichuan Aquatic Products (1):1.

Guo, Q. 1985. Lao Dao Si Han Dynasty Tomb in Mian County, Shanxi Province. Agricultural Archaeology (5):429–450.

Jiang, C. 1983. Taking advantage of winter fallows to develop fish culture, p. 11–15. *In* Proceedings of the First National Ricefield Fish Culture Seminar, 11–15 August 1983, Wenjiang, Sichuan Province, China.

Jiang, Ci-mao. 1987. Studies on the economic problems related to rice-fish culture, p. 180. *In* Chinese Academy of Fisheries Science (ed.) The economic problems of utilization and development of aquatic resources in China. Oceanic Publishers, Wuxi, China.

JPFRI. 1983. Pamphlet on technical know-how of rice-fish culture. Jiangxi Provincial Fisheries Research Institute. Jiangxi, China.

Khoo, K.H. and E.S.P. Tan. 1980. Review of rice-fish culture in Southeast Asia, p. 1–14. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Li, K. 1988. Rice-fish culture in China: a review. Aquaculture 71:173–186.

Luo, Y. 1985. The significance and economic benefit of rice-fish culture. Aquatic Products Conf. Proc. 4. Science and Technology (1).

Mao Z., W. Wu, S. Yu, J. Xu, L. Huang, D. Chen, J. Yang and Z. He. 1985. Rice-fish culture techniques. Zhejiang Science and Technology, Zhejiang, China.

Nie D. and J. Wang. 1981. Studies on rice and fish mutualism. Fishery Techniques and Information (6):1–3.

Nie D., Y. Chen and J. Wang. 1985. Recent development of fish culture in the rice paddy in China. Proceedings of Asian symposium on freshwater fish culture. Beijing, China.

Outlook Weekly. 1987. Introduction to Nie Dashu with a quotation of the letter Nie sent to the Central Commission of Chinese Communist Party in August 1981. Outlook Weekly (26), 29 June 1987.

Pullin, R.S.V. and R.H. Lowe-McConnell, editors. 1980. The biology and culture of tilapias. ICLARM Conf. Proc. 7, 432 p.

Schultz, T.W. 1964, reprinted 1976. Transforming traditional agriculture. *In* H.M. Southworth and B.F. Johnston (eds.). 1967. Agricultural development and economic growth.

Wang, Y. 1985. The main technical measures of rice loach culture. Hunan Aquatic Products (2): 20.

Xu X., Z. Yu, D. Zhang, X. Zuo, P. Yang, J. Wang, M. Peng and Y. Zhu. 1986. High yielding experiment of rice-fish culture in stretches of paddies about 20 ha. Jiangxi Aquatic Product Science and Technology (1):1.

Ying, P. 1986. Rice pest and disease control by fish and frogs-probing a pesticide-free stereo agricultural system. Selected paper on fishery economics (3, 4):40–42.

Zhong, L., G. Wu and B. Wu. 1987. Scientific freshwater fish farming. Science Popularization, Canton, China.

Rice-Fish Farming Development in India: Past, Present and Future

APURBA GHOSH
Central Inland Capture Fisheries Research Institute
Barrackpore - 743, West Bengal, India

GHOSH, A. 1992. Rice-fish farming development in India: past, present and future, p. 27–43. *In* C.R. de la Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Rice-fish culture is an age-old practice in India. The country has a resource of 2.3 million ha of deepwater rice plots in the freshwater sector, drawing attention for immediate exploitation through rice-fish culture. In addition, monocropped ricefields under high monsoon precipitation in some coastal belts of the country are also used for fish culture during the summer fallow period, particularly for raising prawns. Based on these two traditional techniques of rice-fish culture, diverse techniques are being evolved by the farmers in different parts of the country with the sole objective of deriving higher returns from ricefields. Transformation of the techniques from capture-culture to culture system with necessary inputs has been projected with economics. Research thrusts needed for better management of the fish agroecosystem to develop complementary interrelationships between the two commodities is also discussed.

Introduction

The Indo-Pacific Region is well known for its vast rice area, with fish considered as the main protein food for the people. India is no exception. Presently, the country utilizes 39 million ha for rice cultivation which is the highest in the world. This includes 2.3 million-ha deepwater plots (Dutta 1981).

More than two decades ago, rice-fish integration was prevalent in 135 million ha of ricefields involving 107 countries of the world. But by 1975, with the advent of high-yielding varieties (HYV) of rice, rice-fish culture was restricted to 44 countries. Although several countries discontinued integrating fish in ricefields, the total rice-fish area remained almost the same due to an increase in area in some countries including India (SEAFDEC/AIA 1980).

Production of fish from ricefields is an age-old practice in India. Apart from the inland ricefields, rainfed areas along the coast are also used for monsoon monocropped rice cultivation. During the rest of the year, these areas usually remain fallow due to the high salt content of the soil and scarcity of irrigation water. Rice-fish culture in coastal saline areas aims at utilizing the summer fallow period for brackishwater aquaculture without affecting the subsequent rice crop during the monsoon season.

This paper briefly discusses some traditional techniques of rice-fish culture along with the new innovations to increase the productive potential of arable land.

Past and Present Status of Rice-Fish Farming

In India, rice-fish farming is a growing venture. Already, the country has nearly 2 million ha of rice plots for the production of fish. These fish-yielding rice plots show great systems diversity in the past and present. The classification of rice-fish systems are:

a. freshwater rice plots
- perennial deepwater
- flooded river basin
- seasonal and perennial waterlogged wetlands
- defunct riverbeds and shallow oxbow lake
- impounded rainfed with and without improvisation
- mountain valley
- running water terrace

b. coastal rice plots
- plots for monsoon rice and summer fish farming
- plots for monsoon rice and fish besides summer fish farming.

The foregoing types of rice agroecosystems can further be extended to include irrigated rice plots under integrated farming.

Rice-Fish Farming in the Past

The age-old system of rice-fish farming mainly belongs to West Bengal and Kerala. On the other hand, the Ganges and Brahmaputra Plains used to provide a capture fishery resource in the ricefields. These primitive ricefield plots are summarized in Table 1.

Present Rice-Fish Farming Systems

Some rice-fish production systems have been developed aside from the modification of the shrimp filtration and wild cropping systems. These are integrated farming in mountain valley plots, running water terrace type plots and impounded rainfed plots (without improvisation) in the freshwater sector. Rice-fish culture in terrace systems was also practised in the North Hill states in the past.

CAPTURE FISHERIES RICE PLOTS

Presently in the eastern part of India, indigenous species are usually found in flooded ricefields and farmers usually collect them when the water level subsides and rice is harvested. In the East Godavari District, such inundated rice plots are the source of naturally occurring spawn and fingerlings. India is yet to explore and develop such a promising source of ricefield capture fisheries.

MODIFIED SHRIMP FILTRATION SYSTEM

The traditional system of shrimp filtration in rice plots of Kerala and Goa has been modified in the current practices. Major changes in the management include the desalinization in *pokkali* plots through various devices, namely, field trenching in a crisscross manner for quick removal of runoff water carrying surface salt deposits that have accumulated during brackishwater prawn culture. In addition, farmers now scrape out the topsoil from ricefields and heap the soil in places for better salt removal. After these heaps are washed by rainwater, the soil is again spread over the field to obtain better rice yields. Production from such

Table 1. Species cultured in different rice-fish systems in India.

System type	Species cultured	Source
Rice-fish integration system in freshwater (in flooded river basins deepwater rice plots, perennial waterlogged wetlands, oxbow type lakes, low-lying rice plots, etc. in Uttar Pradesh, Bihar, West Bengal, Orissa, Assam; production 3 kg/ha/year)	*C. carpio, C. catla, L. rohita, Cirrhinus mrigala, Puntius pulchelus, Rasbora daniconius, C. batrachus, H. fossilis, C. striata, C. gachua, Rhinomugil corsula, Chromis caeruleus, C. dimidiatus, C. ternatensis, Macrognathus aculeatus, Mastacembelus armatus, M. pancalus, Aplocheilus panchax, Nandus nandus, Notopterus notopterus, Puntius ticto, P. sophore, Amblypharyngodon mola, Ambassis nama, A. ranga, O. mossambicus, Glossogobius giuris*	Hora 1951; Chakrabarti and Ghosh 1981; Jhingran 1983
Prawn filtration system (in *pokkali* plots, Kerala; production 500–600 kg/ha/year)	*Metapenaeus dobsonii, Metapenaeus monoceros, Penaeus indicus, P. semisulcatus, Macrobrachium. rude Palaemon stylifera, Caridina gracilirostris, Acetes* sp., *Mugil dussumieri, Etroplus maculatus*	Panikkar 1937; Gopinath 1955; Panikkar and Menon 1956; Menon 1954; George et al. 1968; Natarajan and Ghosh 1980
Khazan system (in Goa)	*M. dobsoni, M. dussumieri, P. merguiensis, E. suratensis, P. monodon* and *P. indicus*	
Wild aquacropping in *bhasabadha* system (in West Bengal)	*L. parsia, L. tade, Mugil cephalus, Lates calcarifer, Mystus gulio, M. rosenbergii, Metapenaeus brevicornis, M. monoceros, P. monodon, P. indicus, P. semisulcatus, P. stylifera, M. rude, Rhinomugul corsula, Parapenaeopsis sculptilis*	Pillay and Bose 1957

rice-fish plots has been raised to 785–2,135 kg/ha/year by selective stocking of prawns which accounts for 80% of production.

MODIFIED *BHASABADHA* SYSTEM OF WEST BENGAL

By selective stocking of *Penaeus monodon* and mullets and occasionally *Oreochromis mossambicus*, the traditional system of culture in ricefields of Hasnabad, Basirhat, Malancha, Gopalpur, Haroa, Sandeshkhali and Nzat could be modified to increase fish and prawn production to 600–1,000 kg/ha/year (Jhingran and Ghosh 1987). Juvenile mortality has been reduced considerably by recent introduction of the built-in nursery system and supplementary feeding. In such a modified method of culture, entry of predator species is avoided by filtration of incoming water using bamboo mats and velon nets. The introduction of salt-resistant varieties of rice (e.g., CSR 1, CSR 3, SR 26B) in these fields has increased rice yields from 2.5 to 3.0 t/ha.

MOUNTAIN VALLEY PLOTS

In northeastern India, many ricefields are located in valleys where water accumulates from the adjoining hills and flows down the valley by gravity. Dwarf varieties of rice are generally cultivated in such plots integrated mainly with *Cyprinus carpio*. Fish production from such plots range from 200 to 1,000 kg/ha during the monsoon. Recently, such integrated farming is gaining popularity in these areas.

RUNNING WATER TERRACE SYSTEM

In the hilly terrain of Meghalaya and Sikkim, ricefields are in the form of steps on mountain slopes. As in Japan, terraces provide opportunities to have a form of running water fish culture system in ricefields. Water from stream-irrigated and rainfed plots trickles down from a higher to lower altitude creating a flow-through system within the plots. These terrace-type rice plots are stocked with *C. carpio* at 6,000/ha and fed with either mustard oilcake mixed with rice bran (1:1 ratio) at 1 kg/ha/day or simply provided with domestic kitchen wastes to get an average production of 186 kg/ha in two months (Anon. 1979).

IMPOUNDED RAINFED PLOTS WITHOUT ANY IMPROVISATION

In recent years, in the low lying areas of West Bengal, rice plots with earthen dikes are often increased in height to impound more water and entrap naturally occurring species such as *Puntius* sp., *O. mossambicus, Channa punctatus, C. gachua, C. striata, Clarias batrachus, Heteropneustes fossilis, Mastacembelus pancalus, Ambassis* sp., *Macrobrachium lamarrei, M. rude, M. mirabile* and *M. dayanum*. These are then grown and propagated within the rice plots from July to November. Yields are poor as the field gets exposed in winter allowing predation by birds, snakes and otters and destruction through parasitic infection damage due to the indiscriminate use of pesticides.

There are other farmers who, instead of depending on nature, stock their plots with carp and tilapia and prevent the escape of fish. However, they maintain neither a specific stocking density nor species ratio. Little feed is provided. A low yield of 300 kg/ha is generally obtained from such rice plots.

Status of Rice-Fish Research and Development

During the last three decades, experiments have been conducted in several states of the country to improve the production potential of fish/prawn in ricefields. Presently, most research activities in rice-fish culture are confined to deepwater ricefields in freshwater and coastal ricefields in brackishwater habitats. The main objective is to evaluate the performance of different species of fish and prawn reared for short duration in ricefield ecosystem.

Research and Development in Inland Rice-Fish Culture

The State Fisheries Department, Government of West Bengal, undertook nursery rearing of carps in a 279-ha ricefield (Hora 1951). Carp fry (19–64 mm) were stocked at 1,457/ha and raised to 127–135 mm size in three to four months. The total yield was estimated to be 112 kg/ha with an overall survival of 34%.

Iyenger (1953) carried out some experiments in plots at the Hasserghatta and Visweswarya Farms in Karnataka to control insect pests in the ricefields through stocking of *Channa striata*. The average fish yield in four months was 112 kg/ha, showing a growth of 7–13%. Iyenger (1962) also improved the yield of rice in terrace-type plots through integration of fish. Twelve 25.5-m^2 plots were manured with compost at 272 kg and a mixture of ammonium sulfate with superphosphate at 103 kg in the ratio of 1:1 applied. Of the three treatments, for each terrace with four plots, *C. striata* were stocked at 400, 300 and 200/plot. The lowest density gave the best result. The average yield of fish was 28 kg/ha, and an increased production of rice at 277 kg/ha was achieved.

O. mossambicus and *C. carpio* were stocked at 2,500 kg/ha in the rice plots at the Central Rice Research Institute (CRRI), Cuttack. The average size of *O. mossambicus* at stocking and harvesting was 13 and 35 g, respectively, while for *C. carpio*, 4.0 and 200 g. The yield was 77 kg/ha in three months comprising 40% tilapia. A Mahsuri ricefield (0.16 ha) was stocked with carps at 6,000/ha at a 5:3:2 ratio of *C. carpio, C. mrigala* and *L. rohita*. The overall recovery after two months was 34%. Two plots of CR 1014 (tall variety) rice gave an average yield of 76.2 kg/ha of *C. carpio* when stocked at 7,250/ha and reared for 119 days. The rice yield was 2,719 kg/ha (Dutta et al. 1979).

Muddana and others using rice plots at Hebbal in Karnataka as carp nursery, raised 17.5-kg carp fry to 152.5-kg fingerlings/ha in 71 days (Jhingran 1983).

In West Bengal, *H. fossilis* and *C. batrachus* were stocked at 1:2 ratio at 10,000 fingerlings/ha in Randhunipagal ricefields. With no supplementary feeding, catfish yield was 199.4 kg/ha and 18.4 t/ha for rice yields. However, with supplementary feeding (fish meal and rice bran at 1:2 ratio and given 5% of the fish biomass), yields were increased to 375 kg/ha for catfish and 1.88 t/ha for rice. The yield of rice was low (1.79 t/ha) in the control plot without fish. Similarly, *H. fossilis* and *C. batrachus* yields in other rice plots trials were 410 kg/ha (*Ratna*), 360 (*Pankaj*) and 490 (*Jaya*) with rice yields of 3.8, 3.7 and 6.4 t/ha, respectively, against 3.2, 3.0 and 5.9 t/ha of rice in the control plots during March-June, July-November and November-April. Thus, in the integrated system, total annual yields were 1,260 kg/ha of fish, 13.4 t/ha of rice and 23.7 t/ha of straw. In these plots, fewer incidences of stemborer were recorded (Dutta et al. 1986).

For extending the rearing period of fish, part of the rice plot is usually converted into a perimeter canal, central pond or lateral trench (Figs. 1a, 1b and 1c). Besides renovations, the ricefield is fertilized with farmyard manure or compost at 30 t/ha, N at 120 kg/ha, P_2O_5 at 60 kg/ha and K_20 at 20 kg/ha in three phases during planting, tillering and

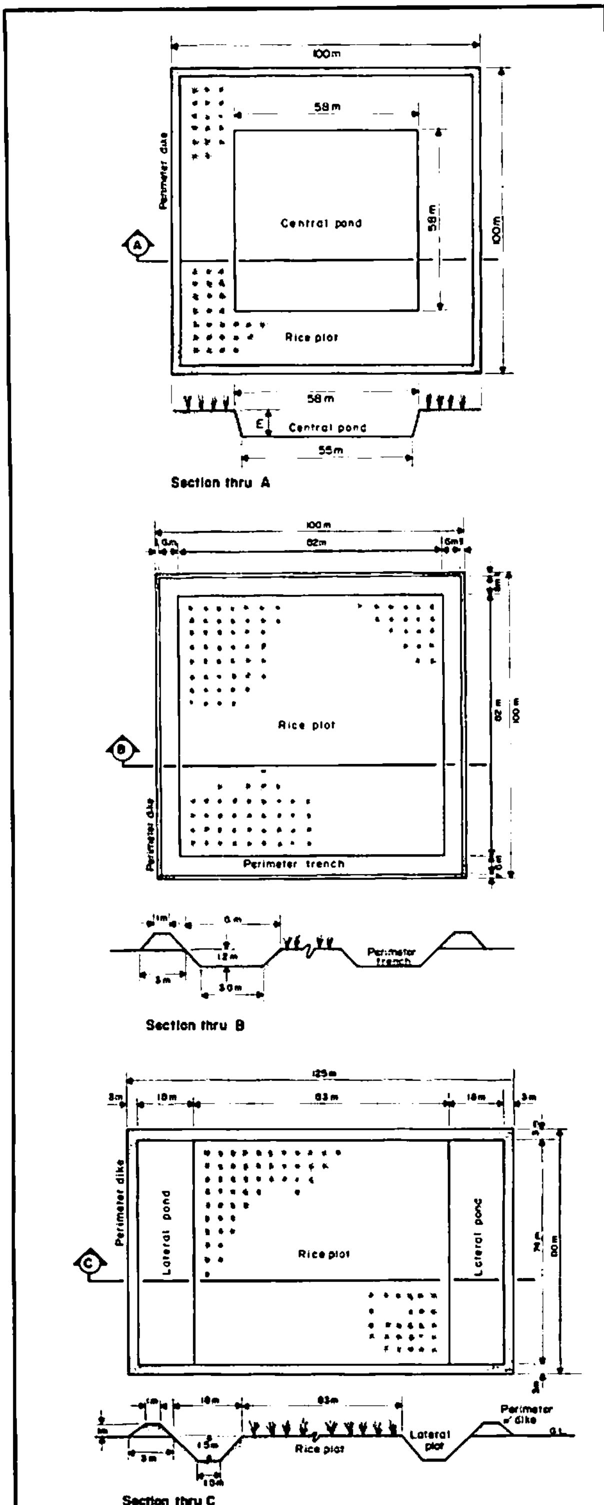


Fig. 1. Designs of renovated rice plots for rice-fish culture.

flowering. Experiments were conducted in a renovated 1.02-ha rice plot with a perimeter canal of 0.27 ha at the Rahara Farm of the Central Inland Fisheries Research Institute (CIFRI). The canal was trapezoidal in shape with a top width of 6 m, a base width of 3.6 m and a full canal water depth of 1.2 m. During the monsoon season, a deepwater variety of rice (*Jaladhi* 2), capable of growing rapidly like a hydrophyte in deepwater, was sown directly in a 0.75-ha plot in June. One month after sowing rice, fingerlings of Indian major carps (*L. rohita, C. catla, C. mrigala*) were stocked at 6,000/ha at a ratio of 3:4:3. Fish were fed 2–5% of body weight with mixed rice bran and mustard oil cake at 1:1 ratio. The plot was gradually allowed to dry in December, and fish moved to the perimeter canal. During summer, an HYV rice (such as *Ratna*, *Jaya* or *Pusa*) was cultivated in the same plot using canal water for irrigation (Table 2). Pesticides (Dimecron and BHC) were also applied to control rice pests. To prevent pesticide washing from the perimeter canal harboring the fish, a low dike along the periphery of the rice plot was erected. The monsoon harvest produced 1,200 kg/ha of rice, while the summer crop produced 4,300 kg/ha. During these seasons, *C. catla*, *L. rohita* and *C. mrigala* were stocked in the perimeter canal at sizes ranging from 52.3 to 64.6 mm (11.7–15.2 g). In 10 months of fish rearing (six and four months for the monsoon and summer rice crops, respectively), a production of 700 kg/ha with mean size ranging from 160 to 268 mm (72.6–200.6 g) was achieved (Ghosh and Saha 1980).

Research and Development in Coastal Rice-Fish Culture

Due to limited and uncertain income from monsoon-dependent agriculture, efforts are being made to culture

Table 2. Average values of physico-chemical conditions in a rice plot renovated for fish culture for different seasons.

Parameters	Monsoon (Jul-Oct)	Winter (Nov-Feb)	Summer (Mar-Jun)
Water temperature (°C)	27.2–29.0	17.3–25.2	25.5–29.8
pH	7.1–8.0	7.2–8.3	7.6–8.0
DO (ppm)	3.2–4.5	3.0–4.4	2.2–2.9
Total alkalinity (ppm)	89.5–121.0	124.0–162.0	137.0–157.0
COD (ppm)	2.0–15.8	2.1–11.4	4.4–11.4
Specific conductivity (μmhos/cm)	229.0–489.0	0.96–2.85	464.0
NH_3 - N (ppm)	0.02–2.6	0.003–0.06	0.08–0.3
PO_4 (ppm)	0.03–0.09	0.84–0.26	0.04–0.09

brackishwater fish and prawn in the coastal ricefields during summer season in West Bengal, Kerala and in Karnataka. High rainfall in these areas reduces the salinity of the soil to a considerably low level during the monsoon season when rice is cultivated on the same plots (Gopinath 1955). A survey by the Indian Institute of Management revealed that rice-fish culture in coastal areas covers around 2,520 ha in Karnataka and 7,100 ha in Kerala (Srivastava 1985). A report of the Marine Products Export Development Authority estimated that there are 30,000 ha under rice-fish culture in coastal West Bengal (Anon. 1987). Since integration of brackishwater aquaculture with rice involves the possibility of gradual accumulation of salt in the soil which may affect the subsequent rice crop in the long run, the CIFRI carried out investigations to assess the suitability of this culture system for the coastal soils of India.

Initially, a study was conducted on the salinity cycle and seasonal changes in biological and chemical properties of different low lying intertidal wetlands of coastal West Bengal. Based on the maximum water salinity, the coastal area is categorized into highly saline (electrical conductivity [EC] > 30 μmhos/cm), moderately saline (20 < EC > 30 μmhos/cm) and low saline (< 20 μmhos/cm). Salinity levels of the soils remain at 8.5–13.5 μmhos/cm during summer when estuarine water inundates the plots. With the onset of the monsoon, the reduction in salinities are not the same for all the three categories. In the low and moderately saline regions, the salt content of the soils were reduced to practically safe levels for the subsequent rice cultivation; while for the highly saline zone, reduction in salinity was not as dramatic (Table 3).

The second phase of the study investigated the extent of residual soil salinity during the rice-growing period. Soil samples were collected from different rice-fish plots during the monsoon season and their nearby traditional rice plots in the coastal West Bengal. Soils under the rice-fish culture system showed slightly higher ECs (2.6–9.3 μmhos/cm) compared to plots under rice cultivation (0.7–3.6 μmhos/cm) (Table 4). The former soils remained submerged under saline water during summer months. Although all farms had a history of summer brackishwater aquaculture for several years, it was interesting to observe that salt accumulation in the soil was not as pronounced to affect the subsequent rice crop. Such lowering of soil salinity can be ascribed to the high monsoon precipitation in the region (Chattopadhyay et al. 1983).

Table 3. Some important properties of the coastal rice plots.

Parameter	Highly saline (EC* > 30)	Medium saline (EC 20-30)	Low saline (EC < 20)
Water			
DO (ppm)	6.4–12.8	7.2–20.4	4.0–18.4
Alkalinity (ppm)	80.0–232.0	106.0–414.0	130.0–244.0
pH	7.4–8.4	7.5–8.5	7.2–8.4
N (ppm)	0.06–0.16	0.09–0.31	0.65–1.37
P (ppm)	tr**-0.12	0.1–0.22	0.01–0.28
Plankton (individual/m^3)	75×10^1–82×10^3	75×10^1–12×10^3	37×10^1–71×10^2
Soil			
pH	7.0–8.3	7.9–8.3	7.5–7.9
Organic C (%)	0.3–0.5	0.7–0.9	0.8–1.3
Average N (ppm)	100.8–168.0	165.2–201.6	145.6–257.0
Average P (ppm)	5.0–8.0	9.0–15.0	10.0–17.0
Benthos (individual/m^2)	16×10^2–30×10^5	36×10^3–18×10^7	52×10^3–24×10^3

*EC = electrical conductivity in µmhos/cm.
**tr = trace.

Table 4. Electrical conductivity (EC in µmhos/cm) of coastal soils under different culture systems.

	Rice-fish (brackishwater)	Rice monoculture
No. of samples	14	14
Range	2.6–9.3	0.7–3.6
Average EC	4.3	2.0

During the third phase of the study, short-term brackishwater aquaculture was carried out in two 0.015-ha rice plots with saline tidal water (EC 7.0–40.0 µmhos/cm) at the Regional Research Center of the Central Soil Salinity Research Institute (CSSRI), Canning, West Bengal, during April to June in 1982–86. Average fish and prawn production of 0.43 t/ha in three months was obtained during the summer fallow season. High salinity buildup in the soils (maximum EC 24.0 µmhos/cm) due to brackishwater aquaculture was decreased to safe levels during subsequent *kharif* rice cultivation by the high monsoon precipitation of the region (average annual rainfall is 1,750 mm, of which about 80% occurs in June to September), and frequent runoff and leaching. The average monsoon rice production was 3.3 t/ha which was highly comparable with the production of conventional rice cultivation in the region. Variations in EC values during the post-brackishwater aquaculture period during the monsoon season are shown in Table 5. Results indicated that if the monsoon precipitation is around normal, there would be little danger of residual salt accumulation in the soil of rice-fish plots during the monsoonal rice cultivation period. A concurrent system of freshwater aquaculture also produced, on an average, 440 kg/ha of fish and prawn during the rice cultivation period.

Technologies developed through applied research on rice-fish culture were taken to the farmers' plots. Developments took place both in freshwater inland and coastal saline plots.

A 1.09-ha rice plot in Bandipur, West Bengal, which was producing only one crop of rice (2.7 t/ha/year) in a traditional system, was renovated, keeping 65% of the area in rice, 33% perimeter canal and

Table 5. Average variations in electrical conductivity (EC in µmhos/cm) during different cropping periods.

Year	Brackishwater fish culture (summer)			Freshwater rice culture (monsoon)		
	Initial soil	Irrigation water	End of experiment soil	Initial soil	During growth	End of experiment soil
1982	13.1	23.3	24.0	7.8	5.2	7.2
1983	9.2	32.2	22.6	4.6	3.6	6.3
1984	11.4	34.2	24.8	3.5	2.9	5.8
1985	9.0	24.4	18.6	4.8	4.2	6.9
1986	10.3	30.5	20.8	6.2	3.8	6.6

the rest for dikes. Two crops of rice, *Ratna* in summer and *Jaya* in the monsoon, and one annual crop of carp were raised. Yields were 4.2 (*Ratna*) and 3.2 (*Jaya*) t/ha of rice and 237 kg/ha/year of carp in the initial phase. In subsequent years, fish yields increased to 630 kg/ha/year. Similarly, in freshwater rice plots with excavation of deeper pools at Minakhan, fish yields ranged from 650 to 930 kg/ha/year and rice yields, 5.1 to 6.4 t/ha/year.

In coastal saline areas of West Bengal, plots belonging to 35 farmers were developed. In recent years, fish yield in these plots average was 826 kg/ha/year and rice yield, 2.7 t/ha during the monsoon season. In low salinity plots near Basirhat in West Bengal, management practices were further developed and yields improved: 50 kg/ha of *P. monodon;* 250 kg/ha of mullet; 3,000 kg/ha of tilapia and 2.4 t/ha of rice (Table 6).

Economic Significance and Profitability

Besides better land use, rice-fish culture is lucrative and economizes investment costs for the crops. In *pokkali* system where dikes and other earthwork already exist, the capital cost for the integration is quite low (US$5,333 per 16 ha) and an annual investment of US$7,500 gives a net margin of US$2,175 for a payback period of one year to fixed capital (Table 7).

From Table 8, it is clear that higher margins occur in the *bhasabadha* type of farming system with selective stocking compared to the *pokkali* system, with return over capital investment at 56% and 29%, respectively. For the *bhasabadha* system, the annual net margin is US$1,209 against an annual investment of US$2,137, and the payback period is one year for the capital cost of US$917.

In renovated freshwater ricefields, although the return on investments is moderate (39%), the payback period spans to 13 years for a capital cost of US$2,833 (Table 9). But if the farmer owns the land, the capital cost drops to only US$611/ha, lowering the payback period to two years. With an annual investment of US$1,064/ha in two rice crops and one aquatic crop, an annual net margin of US$415/ha is realized.

Prospects and Constraints

Rice-fish culture has great prospects in India if the agronomic aspects of growing rice and rearing problems for better fish growth are properly understood and their techniques become complementary. Rice-fish culture offers opportunities for farmers to supplement their income and

Table 6. Rice-fish farming in India.

Location	Type of rice plot	Fish stocked	Fish production (kg/ha)	Rice production (t/ha)
Present trends				
East Godavari (wild crop)	Deepwater (river basin)	Natural stocks	3 (1 year)	1.0–1.5
Kerala (modified *pokkali* system)	Shallow (brackishwater)	*P. monodon*, *P. indicus* and natural stocks	785–2,135 (1 year)	1.5–2.5
NE Hill Complex (mountain valley)	Waterlogged	*C. carpio*	Highly variable	1.0–1.5
Meghalaya (terrace system)	Shallow (hilly)	*C. carpio*	186 (2 months)	0.5–0.8
West Bengal (modified *bha-sabadha* system)	Shallow (2 aquatic crops)	*P. monodon*, *L. parsia* and natural stocks	600–1,000 (1 year)	2.5–3.0
West Bengal (ordinary plot)	Rainfed (inland)	Wild stock (tilapia, *Channa* sp., catfish, prawns, etc.)	300 (1 year)	2.0–3.0
West Bengal (sewage enriched)	Shallow (low salinity)	*P. monodon*, *L. parsia*, tilapia and natural fry	1,000 (1 year)	1.5–3.0
Trends in research and development				
State Fisheries plot, W.B.	Shallow (nursery)	Carp (1,457/ha)	112 (3–4 months)	2.5–3.7
Karnataka plot	Shallow (nursery)	Carp fry to fingerlings	153 (71 days)	1.5–2.0
Karnataka farms	Terrace type (pest control)	*C. striata*	112	1.5–2.0
Karnataka plot	Terrace type	*C. striata* (200-400/plot)	28	1.8-2.3
CRRI, Cuttack	Irrigated (extension)	*O. mossambicus* and *C. carpio* (2,500/ha)	77 (3 months)	3.0–4.0
CRRI, Cuttack (Mahsuri plot)	Irrigated (extension)	*C. carpio*, *C. mrigala* and *L. rohita* (6,000/ha)	34% recovery (2 months)	3.0–5.0
State Agri. Dept., West Bengal (CR 1014 plot)	Deepwater (production)	*C. carpio* (7,250/ha)	76 (119 days)	2.0–2.7
Pandua, W.B. (*Jaladhi* 1)	Deepwater (production)	*H. molitrix*, *C. mrigala*, *C. catla* and *L. rohita* (9,000/ha)	1,100 (1 year)	2.1 4.2
Pandua, W.B. (Randhunipagal)	Shallow (production)	*H. fossilis* and *C. batrachus* (10,000/ha)	199 (no feed) 375 (with feed) Control (no fish)	1.8 1.9 1.8
Hooghly, W.B. (*Ratna/Pankaj/Jaya* crops in succession)	Shallow (production)	*H. fossilis* and *C. batrachus*	410 360 490	3.8 3.7 6.4
CSSRI, W.B. (SR 26 B)	Shallow (brackishwater)	Carp and *M. rosenbergii* (in monsoon), *P. monodon* and *L. parsia* (in summer)	870 (1 year)	3.0
24 Parganas, W.B. (Developing)	Shallow (freshwater)	Carp with *M. rosenbergii*	630–930 (1 year)	5.2
24 Parganas, W.B. (Developing)	Shallow (coastal)	Brackishwater shrimp and fish with tilapia	826 (1 year)	2.7

Table 7. Economics of traditional shrimp filtration (*pokkali*) system in a 16-ha ricefield in Kerala (modified from George et al. 1968).[a]

Item	Economic life (year)	Annual depreciation (US$)	Costs/Value (US$)
Capital costs[b]			
Fixing sluice gate (6 nos.) @ US$33.33 each	10	20	200.00
Bamboo and arecanut screen (6 nos.) @ US$5.56 each	5	6.67	33.33
Shed for store, watch and ward, etc.	10	19.44	194.44
Net for fishing (3 nos.)	5	16.67	83.33
Net for water filtration (3 nos.)	5	6.67	33.33
Annual costs			
Services			
Lease @ US$333.33/ha			5,333.33
Dike maintenance			133.33
Maintenance of sluice gates			16.67
Rent of canoes @ US$0.22/day/canoe for 3 canoes for 5 months			100.00
Wages for laborers (4) @ US$25.00/ month for 5 months			500.00
Wages for supervising staff (1) @ US$41.67/month for 5 months			208.33
Miscellaneous			111.11
Annual investments			
Annual depreciation on fixed capital			69.44
Interest @ 12% on capital			65.33
Annual costs			6,402.78
Interest @ 15% on annual costs			960.44
Annual sales			
P. indicus - 4,100 kg @ US$1.67/kg			6,833.33
P. monodon - 67 kg @ US$3.33/kg			223.33
M. dobsoni - 7,194 kg @ US$0.33/kg			2,398.00
M. monoceros - 393 kg @ US$0.56/kg			218.33
Income and returns			
Capital costs (US$)		544.44	
Annual investment costs (US$)		7,498.00	
Annual sales (US$)			9,673.00
Annual net margin (US$)			2,175.00
Return to fixed capital (%)			399.50
Return to investment (%)			29.00
Net margin to sales (%)			22.48
Net present value (NPV) for annual net margin (US$)			1,977.28
Payback period (year)			1
Internal rate of return (IRR in %)			363

[a]Original values in Indian Rupee were converted to US$ at the rate of US$1 = Rp18.00, as of 1987.
[b]Cost outlays for construction of dikes and other earthworks have not been considered as they are already in existence.

Table 8. Economics of a 1-ha modified *bhasabadha* type of rice-fish culture system in Gopalpur-Basirhat, West Bengal (modified from Ghosh 1981).[a]

Item	Economic life (year)	Annual depreciation (US$)	Cost/Value (US$)
Capital costs[b]			
Dike construction	10	44.44	444.44
Construction of sluice gates	10	13.89	138.89
Nets, gears, crafts, boats, etc.	6	55.56	333.33
Annual costs			
Services			
Labor charges for seed bed preparation, transplant, weeding, reaping, etc.			88.89
Labor charges for fish culture operations @ 2 laborers/ha/day			666.67
Lease of rice-field/ha/year			250.00
Maintenance costs			111.11
Material inputs			
Seed (100,000 *Penaeus monodon*) @ US$4.44/thousand including transport cost			444.44
Miscellaneous expenses			111.11
Annual investment			
Annual depreciation on fixed capital costs			113.89
Interest @ 12% on fixed capital costs			110.00
Annual costs			1,672.22
Interest @ 15% on recurring costs			250.83
Annual sales			
Sale of *P. monodon* - 250 kg @ US$3.89			972.22
Sale of other prawns and mullets - 250 kg @ US$0.83			208.33
Sale of tilapia - 3,000 kg @ US$0.56			1,666.67
Sale of carp and freshwater shrimp - 250 kg @ US$0.83			208.33
Sale of paddy - 2,400 kg @ US$0.12			300.00
Income and returns			
Capital costs (US$)			916.67
Annual investment costs (US$)			2,136.94
Annual sales (US$)			3,355.56
Annual net margin (US$)			1,208.61
Return to fixed capital (%)			131.80
Return to investment (%)			56.30
Net margin to sales (%)			36.00
Net present value (NPV) for annual net margin (US$)			1,065.39
Payback period (year)			1
Internal rate of return (IRR in %)			120

[a]Original values in Indian Rupee were converted to US$ at the rate of US$1 = Rp18.00, as of 1987.
[b]Cost outlays for construction of dikes and other earthworks have not been considered as they are already in existence.

Table 9. Economics of 1-ha renovated rice-fish culture plot having horticulture on the dike crest.[a]

Item	Economic life (year)	Annual depreciation (US$)	Cost/Value (US$)
Capital costs[b]			
Cost of land			2,222.22
Earthworks	20	30.56	611.11
Variable costs			
For monsoon rice in 0.67 ha			
Rice seed - 60 kg @ US$0.22/kg			13.33
Labor - 20 man-days at US$0.89/man-day			17.78
For summer rice in 0.67 ha			
Rice seed - 50 kg @ US$0.28/kg			13.89
Single superphosphate 400 kg @ US$0.06/kg			25.78
Muriate of potash 66.6 kg @ US$0.08/kg			5.33
Urea - 220 kg @ US$0.14/kg			30.56
Pesticide			4.44
Laborer - 30 man-days @ US$0.89/man-day			26.67
For fish culture			
Fish seed 6,000 @ US$1.11/100 nos.			66.67
Cowdung 5,000 kg @ US$1.11/t			5.56
Ammonium sulfate 70 kg @ US$0.07/kg			4.67
Single superphosphate 50 kg @ US$0.06/kg			3.22
Mustard oilcake for feed 360 kg @ US$0.17/kg			60.00
Rice bran for feed 360 kg @ US$0.06/kg			20.00
Laborer 300 man-days @ US$0.89/man-day			266.67
For horticulture on 0.04 ha of dike crest area			
Seed			0.83
Inorganic fertilizer			0.56
Laborer 20 man-days @ US$0.89/man-day			17.78
Hire for power tiller @ 3 hours/year			2.50
For farm equipment and implements			
Hire for fishing gears and tools			5.56
Hire of equipment for plowing, soil dressing, mowing, etc. (for 2 rice crops)			5.56
Hire for reaping, threshing, winnowing (implements for 2 rice crops)			2.78
Hire for tools			2.78
Annual investments			
Annual depreciation on fixed capital			30.56
Interest @ 12% on fixed capital			340.00
Annual variable costs			602.89
Interest @ 15% on variable costs			90.44
Annual sales			
Sale of 550 kg paddy (from 2 crops) @ US$0.14/kg			763.89
Sale of 5,610 kg of hay @ US$0.06 per 3 kg			103.89
Sale of 700 kg carp @ US$0.83/kg			583.33
Sale of vegetables, fruits, etc.			27.78
Income and returns			
Capital costs (US$)			2,833.33
Annual investment costs (US$)			1,063.89
Annual sales (US$)			1,478.89
Annual net margin (US$)			415.00
Return to fixed capital (%)			14.65
Return to investment (%)			39.01
Net margin to sales (%)			28.06
Net present value (NPV) for annual net margin (US$)			377.28
Payback period (years)			13
Internal rate of return (IRR in %)			8

[a]Original values in Indian Rupee were converted to US$ at the rate of US$1 = 18.00 Rupee, as of 1987.
[b]Cost outlays for construction of dikes and other earthworks have not been considered as they are already in existence.

to obtain better returns from a unit area of land, but the system has also some constraints.

Potential Resources and Prospects for Rice-Fish Farming

States with heavy monsoon precipitation, particularly West Bengal, Assam, Iripura, Manipur, Orissa, parts of Bihar in the eastern part of the country, and some areas of the Andhra Pradesh, Karnataka and Kerala in the south have good potential for further development of rice-fish farming. The deepwater ricefields, retaining around 50 cm of water or above during monsoon months, are ideal for fish integration. Low-lying ricefields bounded by high irrigation dikes, railway tracks and highways on at least two sides of the field, are especially suitable for rice-fish farming. Already some work in this direction has been initiated under an International Rice Research Institute (IRRI) program on rice-fish culture in Midnapur, Parganas and Murshidabad Districts of West Bengal. In Assam, many of the old fortresses constructed by tribal chiefs of the states are considered most suitable for rice-fish farming. The 37-ha Jangal Balahu Garh fortress in Nawgong District offers a ready-made site for rice-fish farming. It has high perimeter dikes, horizontal deep trenches and wooden sluices present in one corner of the plot for draining excess rainwater. There are other nonflood prone areas in Goalpara and Dhubri Districts of the state which could also be developed for rice-fish culture. In the maritime states of the country, except in West Bengal and Kerala, monocropped ricefields are not adequately utilized for culturing fish and prawn in a sequential system. Impoundment of saline mudflats under tidal inundation is primarily undertaken for reclamation of saline swamps for agricultural purposes in the long run. Due to the presence of tidal brackishwater in the vicinity of coastal ricefields, fish and prawn culture can be easily integrated following sequential system.

Although there exist immense scope and potential for the development of rice-fish farming in the country both in inland and coastal rice plots, the technology for undertaking such integrated farming has not yet been implemented due to various constraints. In some rice-growing areas of the country, farmers have adopted and modified the technology to suit their requirements for raising a secondary fish crop in ricefields with or after rice crop. In most rice-producing states in India, however, rice-fish farming technology has not yet diffused to the farmers.

Constraints to Development

The major constraint in rice-fish farming is the application of pesticides. This problem has been discussed by Khoo and Tan (1980). Many pesticides used on rice such as Endrin, Dieldrin, Thiodan, DDT, BHC, etc., are toxic to fish (Grist 1965). Regular use of these pesticides is likely to result in mortality of fish and other beneficial organisms useful for biological control of rice pests. In coastal rice-fish culture, however, pesticides cause fewer problems, because these are generally not used for monsoon rice cultivation. But in years of high pest infestation, application of pesticides becomes necessary to save the crop. In such cases, fish stocked under concurrent rice-fish culture are likely to be adversely affected.

Flooding of plots is also a common problem which results to considerable escape of stocked animals and the coming in of undesirable carnivorous fish.

Nonjudicious stocking of fish which are less suitable in the rice-fish culture system, often results in poor yields. In India, *C. carpio, Labeo rohita, L. bata, C. mrigala, Puntius javanicus, O. mossambicus, Clarias batrachus,* *Macrobrachium rosenbergii* and *M. malcolmsonii* vary in different environments of the ricefields. The species mix also depends upon the characteristics of the rice plots. In case of coastal ricefields, *P. monodon, Liza parsia, L. tade* and *O. mossambicus* are preferred by the farmers in the brackishwater phase of the sequential system.

In some cases where ricefields are shared by more than one owner, conflicts among shareholders often restrict proper utilization of the land. Insecurity of land tenure exists when ownership of a particular piece of land is uncertain, in dispute or under short-term lease. The investment outlays and the stream of benefits stretching over a long period of time, make it necessary that land tenure is secure.

There are some constraints to coastal rice-fish farming. Brackishwater aquaculture is becoming so lucrative for commercial production of exportable prawn that farmers are tempted to extend the brackishwater aquaculture phase even during rainy season, thereby foregoing the monsoon-dependent rice crop. Salinization of the soil is another problem encountered in coastal rice-fish culture, particularly in the years of low monsoon precipitation (Chattopadhyay et al. 1987). During brackishwater aquaculture, the seepage of saline water to the adjoining rice plots used exclusively for agriculture, is also a problem. This may increase the soil salinity of rice plots and which will affect the general agricultural activities of the area.

Research Thrusts and Methodologies Preferred

In Southeast Asia, irrigated ricefields with dwarf rice varieties are stocked mainly with tilapia and common carp. Pest problems can be solved to some extent by the application of integrated pest management (IPM) techniques. In India, irrigated rice plots are usually not stocked with fish due to their shallowness and the application of pesticides is essential to increase rice yields. The IPM techniques, successfully applied in rice-fish plots in Southeast Asia, may also be tried in India. If necessary, rice plots may be renovated so that stocked fish will be removed from the rice plots before pesticide applications. Experiments should be initiated in irrigated areas of West Bengal, Orissa and Andhra Pradesh to test the efficacy of IPM techniques under Indian conditions, and for widescale adoption in other rice-producing states of the country.

Suitable rice varieties for different types of rice-fish culture are lacking. For example, most of the deepwater rice varieties exhibit poor yields. The development of better rice varieties which give higher yields and have greater pest resistance, is one of the basic requirements for successful concurrent rice-fish farming. In coastal rice-fish culture there is also a great need for suitable rice varieties. Although the CSSRI in India has screened some salt-tolerant varieties (Table 10), there is still a need to develop more varieties which exhibit equally good performance under a comparatively wider salinity range.

The selection of fish species and its stocking density are factors which differ under varying ecological conditions and water depths of rice plots. So far, very little research has been done. Furthermore, species which normally breed in confinement should find place as stocking components for higher yield.

As fertilizer requirements of rice and fish are different, a compromise should be made when grown together. Practically no work has been done to develop a suitable fertilizer management schedule for this farming system.

In coastal rice-fish farming, salinization of the soil during the monsoon rice cultivation period may create problems, especially during the years of low precipitation. Further research

Table 10. Rice varieties suited to different water depths and soil salinities. (Source: Yadav et al. 1979).

Water depth (cm)	Soil salinity (EC in µmhos/cm)	Rice varieties
15–25	<5	*Jaya*, *Mahsuri*, *Pankaj*, IR 8
15–25	5–8	CSR 1, CSR 2, CSR 3, SR 26-B, *Nona-Sail* (S), *Nona-Bokra*
15–25	8–10	CSR 1, CSR 2, CSR 3, SR 26-B, *Nona-Sail* (S) *Hamilton*, *Matla*, *Nona-Bokra*
25–50	<5	SR 26-B, NC 1281, *Kalomota* (Sel)
25-50	5–8	SR 26-B, NC 1281, *Nona Sail* (S), *Nona-Bokra*, *Hamilton*, *Matla*, *Kalomota* (Sel)

should be carried out to develop suitable desalinization techniques.

Due to poor fish productivity in ricefields, research on suitable formulated supplemental feeds convenient for application in ricefields should be done. There should be a feeding zone located in the deeper areas of the rice-fish plot which is free from rice plants or other floating or submerged weeds, where the fish could be trained to feed.

Rice-Fish Farming Development Strategy

Apart from the ricefield capture fishery resources of the Ganga, Brahmaputra and Godavari river basins which are subjected to floods during the monsoon season, deepwater ricefields can be also exploited by integrating fish culture. About 2.3 million-ha deepwater ricefields are available in the country, but no macrolevel survey has been undertaken to demarcate areas suitable for rice-fish farming. It is essential that each state government, particularly the eastern states, form a joint committee to compose of officials from the Agriculture and Fisheries Departments to undertake macrolevel surveys for locating potential deepwater ricefields for fish culture, keeping in mind the physical and biological requirements of fish culture.

Conclusions

The current rice-fish farming systems in India are diverse in nature, depending on the local agroclimatic conditions and topographical features of the land. Considering the resources of the country, it can be said that deepwater ricefields are suitable for fish culture due to the abundance of water and the use of rice varieties that are generally pest resistant. Even if 30% of the existing deepwater ricefields in the country are used for rice-fish farming, production from inland waters could reach 2.2 million t.

Acknowledgement

The author is thankful to Dr. A.G. Jhingran, CIFRI Director, Barrackpore, for his guidance in the preparation of this country paper.

References

Anon. 1979. ICAR Leaflet. Indian Council for Agricultural Research Complex, Shillong Meghalaya, India.

Anon. 1987. Report of the task force on the best land use options for the saline soil areas in coastal districts of West Bengal. The Marine Products Export Development Authority, Ministry of Commerce, Cochin, India. 19 p.

Chakrabarti, P. K. and A. Ghosh. 1981. Role of insectivorous, mollusc-eating and weed-eating fishes in paddy-cum-fish culture. Paper presented at the Summer Institute on Farming System Integrating Agriculture, Livestock and Fish Culture, 6 July-8 August 1981, Central Inland Fisheries Research Institute, Barrackpore, India.

Chattopadhyay, G. N., A. Ghosh and P.K. Saha. 1983. A note on the possibility of salinization of soils under paddy-cum-brackishwater aquaculture in some coastal saline soils. J. Indian Soc. Coast. Agric. Res. 1(1):7-12.

Chattopadhyay, G.N., A. Ghosh, C.R. Biswas P.K. Chakrabarti and A.K. Banddopadhyay. 1987. Rice-fish culture in high coastal saline soils - a case study. Paper presented at The First Indian Fisheries Forum, 4–8 December 1987, Mangalore, India. (Abstract).

Dutta, S.K. 1981. Cultural practices of deepwater paddy in relation to fish culture. Paper presented at the Summer Institute on Farming System Integrating Agriculture, Livestock and Fish Culture, 6 July-8 August 1981, Central Inland Fisheries Research Institute, Barrackpore, India.

Dutta, S.K., D. Konar, P.K. Banerjee, S.K. De, P.K. Mukhopadhyay and P.K. Pandit. 1986. Prospects of increasing food production in India through different systems of paddy-cum-fish culture in freshwater areas: a case study. Int. Rice Comm. Newsl. 35(1):11-39.

Dutta, S.N., S.L. Kar and S. Jena. 1979. Observations on paddy-cum-fish culture. Paper presented at the Symposium on Inland Aquaculture, 12-14 February 1979, Central Inland Fisheries Research Institute, Barrackpore, India.

George, M.J., K.H. Mohammed and N.N. Pillai. 1968. Observations on the paddy field prawn filtration of Kerala, India. FAO Fish. Rep. 57(2):427–442.

Ghosh, A. 1981. Techno-economic aspects of the paddy-cum-fish culture and brackishwater fish culture. Lecture Note, Bank Official Training Organized by the College of Agricultural Finance, August 1981, Puna, India.

Ghosh, A. and S.K. Saha. 1980. Scope of paddy-cum-fish culture in India, p. 1009-1015. *In* J.I. Furtado (ed.) Tropical ecology and development, part 2 (Proc. V Internat. Symp. Trop. Ecol., 16-21 April 1979, Kuala Lumpur, Malaysia.) International Society of Tropical Ecology, Kuala Lumpur.

Gopinath, K. 1955. Prawn culture in the ricefields of Travancore Cochin, India. Proc. Indo-Pac. Fish. Counc. 6:419–425.

Grist, D.H. 1965. Rice. Longman, London.

Hora, S.L. 1951. Fish culture in ricefields. Curr. Sci. 20(7):171-173.

Iyenger, H.D.R. 1953. Paddy-cum-fish culture: pilot studies conducted at Hesserghatta and Visweswaraya Canal Farms in Mysore State. Indian J. Vet. Sci. and Anim. Husbandry 23(4):289–297.

Iyenger, H.D.R. 1962. Further studies on paddy-cum-fish culture at Hesserghatta fish farm, Mysore State. J. Bombay Nat. Hist. Soc., 59(1):301-305.

Jhingran, A.G. and A. Ghosh. 1987. Aquafarming in coastal India. J. Indian Soc. Coast. Agric. Res. 5(1):1-9.

Jhingran, V.G. 1983. Fish and fisheries in India. Second revised and enlarged edition (1st reprint). Hindustan Publishing Corporation, Delhi.

Khoo, K.M. and E.S.P. Tan. 1980. Review of rice-fish culture in southeast Asia, p. 1-14. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Menon, M.K. 1954. On the paddy field prawn fishery of Trivancore Cochin and an experiment in prawn culture. *In* Proceedings of the 5th Meeting of the Indo-Pacific Fisheries Council (IPFC), Section II & III, 22 January-5 February, Bangkok, Thailand.

Natarajan, A.V. and A. Ghosh. 1980. The study of paddy-cum-fish culture in India. Bull. Cent. Inl. Fish. Res. Inst. 32:11.

Panikkar, N.K. 1937. The prawn industry of Malabar coast. J. Bombay Nat. Hist. Soc. 39(2):343–353.

Panikkar, N.K. and M.K. Menon. 1956. Prawn fisheries of India. Proc. Indo-Pac. Fish. Counc. 6(3):328–344.

Pillay, T.V.R. and B. Bose. 1957. Observations on the culture of brackishwater fishes in paddy fields in West Bengal (India). Proc. Indo-Pac. Fish. Counc. 7:187–192.

SEAFDEC/AIA. 1980. Rice-fish culture research in Asia. Asian Aquaculture 3(10):4.

Srivastava, U.K. 1985. Inland fish marketing in India. Vol. 1. Indian Institute of Management, Ahmedabad, India.

Yadav, J.S.P., A.K. Bandyopadhyay, K.V.G.K. Rao, T.S. Sinha and C.R. Biswai. 1979. Coastal saline soils of India. Bull. Cent. Soil Salinity Res. Inst. (5):1-34. Canning, West Bengal, India.

Development of Rice-Fish Farming in Indonesia: Past, Present and Future*

SANTOSA KOESOEMADINATA
Research Institute for Freshwater Fisheries
Agency for Agriculture Research and Development
1 Jalan Sempur
Bogor, Indonesia

BARRY A. COSTA-PIERCE**
International Center for Living Aquatic Resources Management
MCPO Box 2631
0718 Makati, Metro Manila
Philippines

KOESOEMADINATA, S. and B.A. COSTA-PIERCE. 1992. Development of rice-fish farming in Indonesia: past, present and future, p. 45-62. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Rice-fish farming has been practised in Indonesia for more than a century. It is widely recognized as having great potential in rural development and in the management of natural resources in the rice agroecosystem. Rice-fish farming in 1985 in Indonesia employed over 302,000 people who worked on 94,309 ha of ricefields and produced 63,218 t of fish.

The growth of rice-fish culture in Indonesia since 1980 indicates that current systems are profitable and adaptable to many areas of the country where large fish markets exist for the wide variety of fish sizes produced. Growth in the area and intensification of yields in rice-fish culture has been centered in Java. Annual average fish production from ricefields in Java reached 805 kg/ha in 1985. The most popular species used are common carp (*Cyprinus carpio*) and Java carp (*Puntius javanicus*) with a cropping pattern of *minapadi-penyelang-minapadi-penyelang*. While increased pesticide use and planting of high-yielding rice varieties have occurred, Indonesian rice-fish culture systems have been able to adapt and flourish.

Introduction

The first trials of growing fish in ricefields in Indonesia date from 1860 (Ardiwinata 1957; Vincke 1979). In modern times, rice-fish farming systems have been widely adopted by rural rice farmers, especially in Java, and are now regarded as a traditional form of management of natural resources in rice agriculture. Rice-fish culture is based on the use of available ecological niches and thus represents one of the most rational, effective and beneficial ways of optimizing the

*ICLARM Contribution No. 748.
**Present address: 6 Hale Ohia Road, P.O. Box 1050, Volcano, Hawaii 96785, USA.

use of rice lands in Indonesian rural areas.

Irrigated land in rural areas has become alarmingly scarce in recent years due to the high demand by urban industries and of housing an expanding population. The scarcity of agricultural land is especially apparent on the heavily-populated island of Java (population over 100 million) where average land ownership per family has fallen to 0.59 ha (Soemarwoto 1985). In Central Java, Hart (1976) estimated that a typical household of five persons had to control 0.5 ha of ricefields for an adequate income; 0.15 ha was the minimum size required for subsistence.

Rural poverty and underemployment still characterize the Indonesian situation while great economic strides in national agricultural outputs have been made. The gross domestic product of Indonesia averaged 7.7% per year during 1970–82 but per capita income remained relatively unchanged during this period (World Bank 1983, 1984). Over half of all households in Java fall below the absolute poverty line. In 1983, per capita income in Indonesia averaged US$550/year.

Fish culture in ricefields can provide an adequate means of income and food for the rural poor since the production of a nutritious grain and a high-quality, valuable protein can be accomplished from one system on the same piece of land (Schuster 1955; Coche 1967). Rice is the staple food for the people of Indonesia and throughout Southeast Asia (Grist 1985). However, it is common knowledge among scientists and rural development workers that a rice diet is not a complete one, especially for infants, growing children, and pregnant and lactating women. A rice diet must be supplemented with animal protein. Protein-energy malnutrition is one of the major causes of child mortality in Southeast Asia and is widespread, affecting 33% of the preschool children in Indonesia in 1980 (CBS 1981).

Fish is the traditional and most preferred source of animal protein in Indonesia and will remain so in the foreseeable future. In 1986, fish consumption per capita in Indonesia was 14.7 kg/year, which increased to 15.1 kg/capita/year in 1987. However, the growth in fish consumption rates per capita in Indonesia, is still far below those of other Asian countries such as Malaysia, the Philippines, Thailand, Singapore and Brunei (FAO 1984). Based on the 1980–82 data for these countries, fish consumption rates were 47.6, 33.4, 20.2, 32.6 and 33.6 kg/capita/year, respectively. The main reasons for the low fish consumption rate in Indonesia are the scarcity of fish and poor economic conditions prevailing in rural areas which make fish protein an expensive commodity requiring expenditure of scarce cash resources. Expansion of low-cost aquaculture development in ricefields could help increase fish supplies in rural areas, providing nutritional benefits as well as additional employment opportunities for the rural population.

Expansion of employment opportunities in the rice farming agroecosystem in Indonesia is essential. Recent population growth has created a skewed population size structure where a huge number of youth are trying to find work or are underemployed. The national economy and traditional agricultural sectors, while growing at an impressive pace, have failed to absorb these youth. There has been an alarming long-term decline in labor use in rice farming in Indonesia, particularly in Java. Collier et al. (1982) reported a decline from 1,523 hours per rice cropping season in 1924–30 to 1,152 hours in 1977–80. This report also concluded that the ability of the Javanese rice sector to absorb more and more landless laborers has declined and probably come to a full stop.

In many parts of Indonesia, rice-fish culture is well integrated into the local rice economy and plays a major role in increasing the incomes of rural farmers. Fish culture in ricefields requires relatively small capital inputs, has a very short payback period, and uses little advanced technology. In isolated villages far from the sea, fish culture in ricefields in Indonesia assumes tremendous nutritional and economic importance. Family incomes and nutritional standards can be closely related to the success or failure of fish crops raised in ricefields. Rice-fish culture yields an average increase in revenue of 28% above rice revenue and contributes significantly to overall family income from small landholdings (Djajadiredja et al. 1980; Schmidt 1980). Rice-fish culture also reduces household expenditures for costly purchases of animal protein.

Fish culture in ricefields in Indonesia plays an important role in the supply and distribution of seed fish for growout. Rice-fish systems are an essential part of the aquaculture production network in Indonesian rural areas (Costa-Pierce, this vol.). The role of rice-fish farming in this respect has been recently augmented in West Java due to the widespread adoption of intensive aquaculture systems such as running water systems (RWS) and reservoir cage culture. Expanded seed markets and higher prices due to increasing market demand for seed fish have brought increased opportunities and financial benefits for Indonesian rice farmers since the mid-1970s.

This paper reviews the past and present status of rice-fish farming in Indonesia. A synthesis of the existing information on the subject was obtained from the literature, published as well as unpublished, and in reports in the Indonesian language. In addition, recent data from short-term surveys in West Java which focused on existing production systems and their economics are included.

Current Status of Rice-Fish Farming

Rice-fish farming in Indonesia began in the mid-19th century during the Preanger residency in West Java (Ardiwinata 1957). According to Satari (1962), traditional rice-fish culture began during the last 10 years of the 19th century. Ardiwinata (1957) stated it is likely the practice was known before 1860 in the Ciamis area of West Java. In other parts of the Preanger residency, small-scale farming of fish in ricefields certainly occurred before 1872.

Extension to Central and East Java, North and Central Sumatra, North Sulawesi, Bali and Lombok Islands of rice-fish farming outside its origin (West Java) was made by students of religious schools (*santris*), merchants and government officials. Further expansion of rice-fish culture was made possible by the development of ricefield irrigation systems and government extension efforts. By 1934, officials of the Agricultural Extension Service were actively spreading rice-fish culture practices to areas outside Java. By the 1950s, rice-fish farming systems were scattered on the islands throughout the country. During this time, it was recorded that rice-fish culture was practised in approximately 50,000 ha of ricefields, and average fish production levels were 100 kg/ha/year (Ardiwinata 1957).

Today, rice-fish farming is reported in 17 of the 27 provinces in Indonesia. Rice-fish farming is practised in all provinces in Java and the northern provinces of Sumatra, except in Riau and Jambi. There are no records of rice-fish farming in any of the provinces of the islands of Kalimantan, Maluku or Irian Jaya. However, as Ruddle (1980) has pointed out, rice-fish farming is probably more widespread than recorded by current data. Recent large-scale migration of farmers from Java to the outer islands of Indonesia may have contributed to the spread of rice-fish farming systems. However, few data exist on the extent of rice-fish culture in the outer islands.

Statistics reveal that the average area of rice-fish farms increased steadily from 1960 to 1969 but declined from 1974 to 1979 (Table 1). This decline coincided with a government rice intensification program

Table 1. Area, production and yield of rice-fish farms by island, Indonesia, 1975–85. (Source: DGF 1985).

Year	Java	Sumatra	Sulawesi	Bali-Nusa Tenggara Islands	Indonesia
1975					
Area (ha)	28,502	10,798	19,169	14,187	72,656
Production (t)	25,238	1,373	2,639	738	29,988
Yield (kg/ha)	886	127	138	52	413
1976					
Area (ha)	26,840	7,635	15,680	10,451	60,607
Production (t)	16,520	1,238	2,908	717	21,383
Yield (kg/ha)	616	162	186	69	353
1977					
Area (ha)	22,371	10,351	6,255	9,934	48,911
Production (t)	11,139	3,609	2,365	588	17,701
Yield (kg/ha)	498	349	378	59	362
1978					
Area (ha)	39,220	11,499	5,947	11,255	67,588
Production (t)	18,222	2,881	3,279	685	25,067
Yield (kg/ha)	465	258	551	61	370
1979					
Area (ha)	52,295	12,247	6,353	8,524	79,419
Production (t)	21,216	4,459	2,697	748	29,120
Yield (kg/ha)	406	364	425	88	367
1980					
Area (ha)	54,923	14,208	7,158	12,653	88,942
Production (t)	24,682	6,704	3,338	771	35,495
Yield (kg/ha)	449	472	466	61	399
1981					
Area (ha)	66,538	13,965	7,395	9,057	96,955
Production (t)	37,930	ND	184	566	49,529
Yield (kg/ha)	511	ND	20	63	511
1982					
Area (ha)	108,359	12,256	6,850	9,919	137,384
Production (t)	32,923	5,304	3,256	577	40,060
Yield (kg/ha)	304	433	476	58	306
1983					
Area (ha)	83,659	11,491	6,910	6,843	108,903
Production (t)	40,280	8,937	2,250	698	52,165
Yield (kg/ha)	482	778	326	102	479
1984					
Area (ha)	87,785	12,810	5,952	7,185	113,732
Production (t)	47,951	7,765	2,192	972	58,880
Yield (kg/ha)	546	606	368	135	518
1985					
Area (ha)	64,855	14,387	5,706	9,361	94,309
Production (t)	52,181	8,056	2,071	910	63,218
Yield (kg/ha)	805	560	363	97	670

ND = No data.

known as the "Five Points Efforts" (*panca usaha*) included in the Mass Guidance Project (BIMAS) and promoted by the Ministry of Agriculture. From 1980 to 1984, however, the area of rice-fish farming increased dramatically, reaching a maximum of 137,384 ha in 1982. Nearly all of the increased area of rice-fish farming was located in Java. By 1985, Java accounted for nearly 69% and Sumatra 15% of Indonesia's rice-fish farming area. It is noteworthy that since 1975 rice-fish in South Sulawesi and Bali has declined sharply. The reasons for this are unclear.

Fish production from rice-fish farming from 1975 to 1985 increased as much as 200%. Increases were noted from year to year since 1980 in most parts of the country, except in Aceh, North Sumatra, North and South Sulawesi. Increased fish production from rice-fish farms was due not only to expansion in the area, but also due to a significant increase in intensity of the practice. By 1985, average annual fish yields obtained from rice-fish farming in Indonesia increased to 670 kg/ha. Significant progress in the intensification of rice-fish culture occurred in Java where annual average fish production levels increased to 805 kg/ha compared with 481 kg/ha in 1983 and 546 kg/ha in 1984.

Rice-Fish Farming Systems

The classic Indonesian rice-fish farming systems of *minapadi, penyelang* and *palawija* have been reviewed by numerous authors (Ardiwinata 1957; Djajadiredja et al. 1980; Khoo and Tan 1980; Ruddle 1980). All of these systems require physical modifications to the ricefield to accommodate fish and ensure their proper growth and survival.

According to Ardiwinata (1957), the various systems of rice-fish culture developed in 100 years in West Java in the following sequence. Fish were first grown as a secondary or fallow season crop (*palawija*), aiming to furnish food for the farmer's family. Excess fish produced were sold to local markets within the rice-growing districts. As fish markets grew with population, fish were included into other parts of the yearly rice-growing cycle. Fish production was undertaken between rice crops (*penyelang* or intermediate cropping) to produce fish not only for consumption but also as seed for resale to pond owners. In addition, the *minapadi* system (concurrent cropping) was initiated between the planting of rice seedlings and the time of first weeding.

As markets for seed fish grew, rice-fish farming practices and systems responded to market demands. *Minapadi* fish production was extended to include a second cultivation period after the first rice weeding until the second rice weeding, and a third period following the second rice weeding until the flowering of the rice plant. *Penyelang* was modified for raising fry to fingerling size instead of producing fish for consumption.

Palawija or rotational cropping is the oldest type of rice-fish culture practised in Indonesia. Instead of the usual fallow or dry season cropping period after rice harvest, the dikes of the ricefield are raised and a single crop of fish is stocked in ricefields after a single annual crop of rice has been harvested. In its traditional form, the practice was carried out by farmers to provide fish for the immediate and extended family. In more recent times, however, as the market permeated rural areas and since additional income was needed, *palawija* became a means for producing fish and fingerlings for sale. Growing fish during *palawija* is often preferred to other crops such as soybeans, mungbeans, maize or vegetables. This is because the risks in growing terrestrial crops are often greater, such as rat infestation which is a chronic problem in agricultural areas during the dry season.

In the modern *palawija* system, 5–8 cm fingerlings are stocked and grown for a 3- to 6-month period. The system is adopted in agricultural areas where good sources of irrigation water can be obtained throughout the year. If adequate land preparation is performed – e.g., by applying fertilizers or introducing ducks to fertilize the soil by their excretion, and by reducing pests such as snakes, eels, aquatic insects, etc. – fish production from *palawija* can be higher than any of the other rice-fish systems practised in Indonesia. In Subang Regency, West Java, fish yields from 75-day *palawija* are higher than those obtained from 50-day *minapadi* or 30-day *penyelang* systems, i.e., 300, 150, and 100 kg/ha, respectively (Taslim and Syamsiah 1987). Thus, *palawija* is very popular with rice farmers and fish breeders. Since ricefield dikes are raised, *palawija* offers the farmer a large surface area of relatively deep water to be stocked with fish for three to six months.

However, the advantages of *palawija* must be balanced with its reported disadvantages. The system is hampered by fish mortalities due to predators such as snakes, birds and water insects. In some areas, poaching can also be problem. For these reasons, some farmers have shortened the rearing period of fish in *palawija* to sequential 1- or 2-month rearing periods, producing two to three crops of seed fish for further resale to fish growout operations.

Many farmers have developed *palawija* in Subang Regency, West Java (UPP 1985, 1986; Yunus et al., this vol.). This choice of one type of system has created seasonal shortages in the supply of seed fish since most farmers' requirements fall nearly the same time of year, i.e., at the end of rice harvest. Seasonal shortages of seed at the end of each rice harvest increase the price of seed fish. To deal with this, farmers must try to obtain seed fish before rice harvest and store the fish in small backyard ponds.

Multicropping of high-yielding varieties (HYV) of rice which mature in 105–125 days compared with traditional rice varieties (160 days) poses another problem to rice farmers who incorporate fish into their cropping pattern. The needs of the rice always takes precedence over the needs of fish. On top of this, rice-fish systems face competition from agricultural extension agents promoting terrestrial crops during *palawija*, specifically soybeans and maize. However, notwithstanding the current constraints for incorporating *palawija* fish cultivation into the existing rice farming systems, *palawija* has been widely adopted recently in certain parts of the country (especially in the lowland areas of West Java) where excellent technical irrigation systems exist.

The *penyelang* or intermediate system of rice-fish farming cultivates fish between two rice crops for 1–1.5 months. Rice farmers often practise *penyelang* system while waiting for rice seedlings to grow in seed beds and to be transplanted to ricefields (28–30 days), or while waiting for rice seedlings from elsewhere. Because of the widespread use of HYV and thus multiple cropping of rice, i.e., four to five crops in two years, many farmers with irrigated rice have abandoned *palawija* and adopted *penyelang* with its relatively shorter periods of fish rearing. As a consequence, in the upland areas of West Java (Cianjur, Sukabumi, Bandung, Garut and Tasikmalaya Regencies), called the "cradle of rice farming" in Indonesia, the sequence of rice-fish cropping is now *penyelang-minapadi-penyelang-minapadi*, rather than *palawija-penyelang-minapadi-penyelang-minapadi*.

Penyelang has been observed to produce lower fish yields compared with *palawija* or *minapadi* (Taslim and Syamsiah 1987). However, since rice will always be the principal crop in Indonesia, *penyelang* may have the greatest potential for future development. The seasonal timing of modern rice farming does not conflict with *penyelang*. *Penyelang* is thereby less restrained by agronomic advances in rice farming, such as the application of agrochemicals and introduction of HYV and can produce a variety of fish sizes. In addition, ricefields during *penyelang* are sought by fish breeders to reproduce fish (mainly common carp [*Cyprinus carpio*]).

The *minapadi* rice-fish system is the most popular and widely used presently in Indonesia (Fig. 1). Rearing of fish in this system is carefully synchronized with rice cultivation in order not to adversely affect rice yields. In *minapadi*, fish are cultured simultaneously with rice for 20–45 days. An initial fish rearing period is conducted between rice transplanting and the first rice weeding (21–28 days). A second fish rearing period is between the first and second weeding periods (40–45 days). A third fish rearing period of 50 days can be performed during second weeding until the flowering of the rice plant.

Physical preparation of the ricefield for *minapadi* varies from one place to another, particularly in the design and construction of fish trenches (Fig. 2). There are at least three considerations involved in the construction of trenches. The first is that these should be wide and deep enough to safely accommodate all fish during drying and weeding of the ricefields. Secondly, trenches should not be too large to remove too many rice seedlings from the ricefield. The third consideration is the safety of fish from predation, poaching and other mishaps such as damage to the dikes.

Usually, two rows of rice seedlings have to be removed for the construction of 40–50-cm-wide trenches. It is often thought that with rice being the most important crop, utmost care must be taken not to remove too many rice plants for trench construction. However, in many areas of Indonesia, income from fish crops grown in ricefields is higher than income from rice. For this reason, many farmers have increased the size of trenches to give

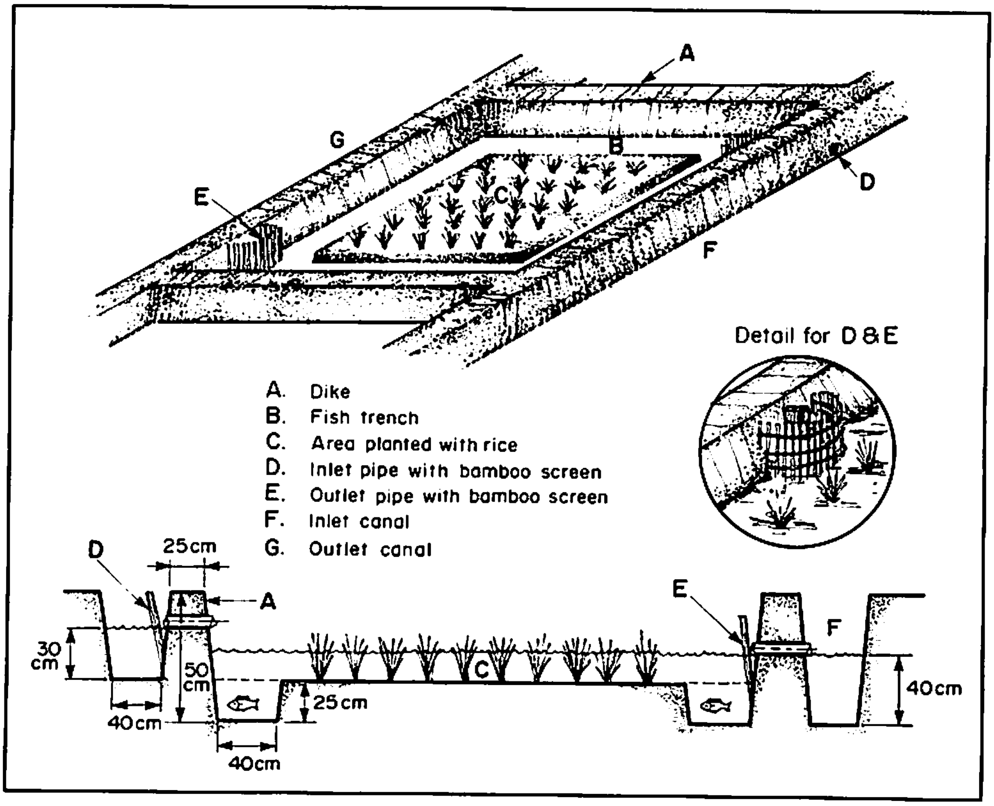


Fig. 1. Ricefield construction for *minapadi*.

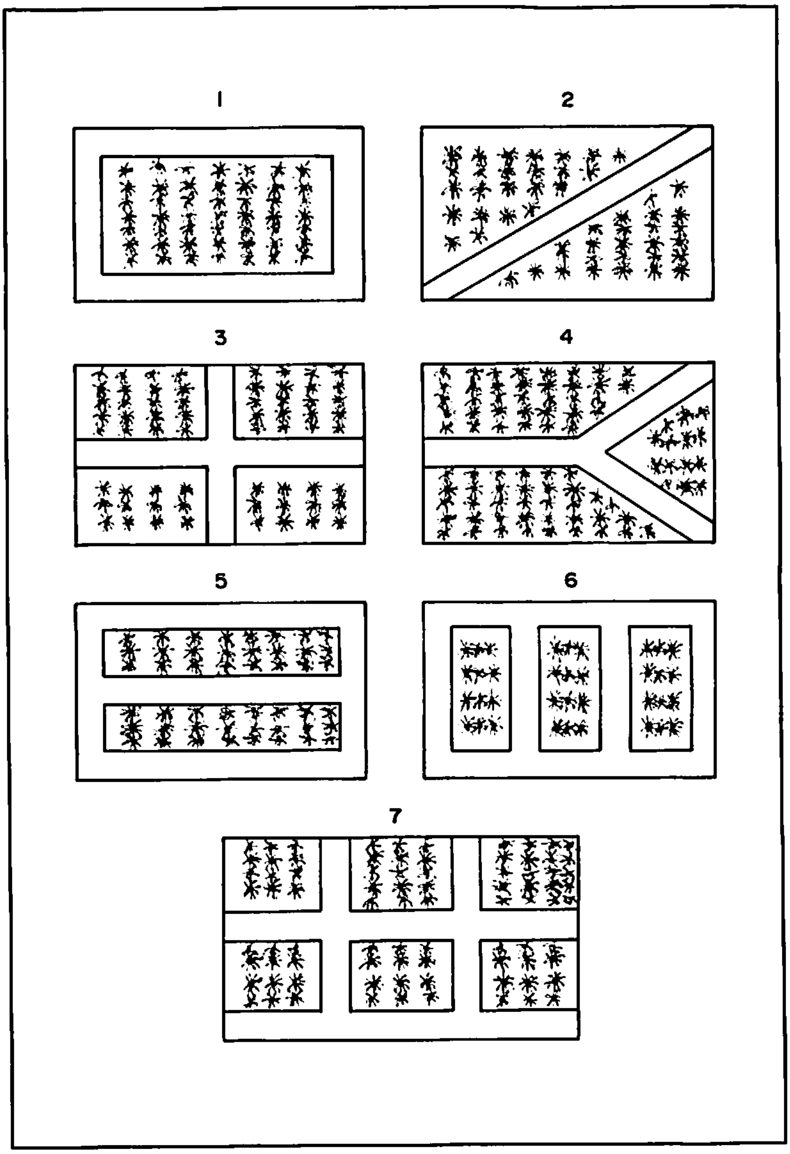


Fig. 2. Design and construction of fish trenches in *minapadi*.

more growing space for fish. This can be seen in rice-fish farming centers in West Java, particularly the Garut and Tasikmalaya Regencies. Rice-fish farmers in the Cianjur Regency prevent any decrease in rice yields by planting the rice seedlings from the area of the trenches to adjacent rows, thereby doubling the planting density of rice in the rows alongside trenches (*endong* planting). By planting rice seedlings in this way, farmers report no decrease in rice yields.

Another important type of rice-fish culture system is the *sawah tambak*, which is found only in the coastal lowlands of the province of East Java, specifically in the regencies of Lamongan and Gresik. Fish yields from *sawah tambak* are the highest of the rice-fish culture systems in Indonesia. In 1986, this system was practised on 16,566 ha of land and yielded 34,840 t of fish for an annual average yield of 2,103 kg/ha (DPPJT 1986). Tribawono (1980) reported that in Lamongan, fish yields from *sawah tambak* ranged from 2,000 to 3,500 kg/ha/year. Recently the *sawah tambak* systems have expanded to other areas of East Java, notably the basins of the Brantas and Solo Rivers.

The area where *sawah tambak* occurs in East Java is only 1–2 m above sea level and has a strong seasonality: annually flooded throughout the wet season and completely dry during the dry season. This makes traditional wet rice cultivation difficult or impossible. Soils are poor for crop farming, being marine clay. In 1950, farmers built 1.4–2.0-m dikes and trenches around their fields to prevent floods from damaging their rice crops and to grow fish year-round (Fig. 3). Because of the high dikes, this unique system acquired the name of *sawah tambak* since coastal brackishwater ponds in the area look similar. However, *sawah tambak* systems are nearly all freshwater.

Sawah tambak systems are principally polyculture, with milkfish (*Chanos chanos*) and Java carp (*Puntius javanicus*) as main species. Java tilapia (*Oreochromis mossambicus*), *Cyprinus carpio* and freshwater prawn (*Macrobrachium rosenbergii*) are usually grown together with them. Since 1986, marine shrimp (*Penaeus monodon*) have also been cultured in some freshwater and seasonally brackishwater *sawah tambak* systems after a 10-day acclimation period to freshwater.

The principal production systems in *sawah tambak* are: 1) fish and wet season rice concurrently for four to six months; 2) fish and wet season rice concurrently for four months, then dry season rice; 3) fish in trenches and dry season rice for six to seven months; 4) continuous aquaculture in former ricefields, harvesting three crops of fish, each with 4-month growout periods (Tribawono 1980).

Payaman and *surjan* are two other types of rice-fish farming systems currently used in Yogyakarta and West Java, respectively. *Payaman* systems are constructed near a village and river to make

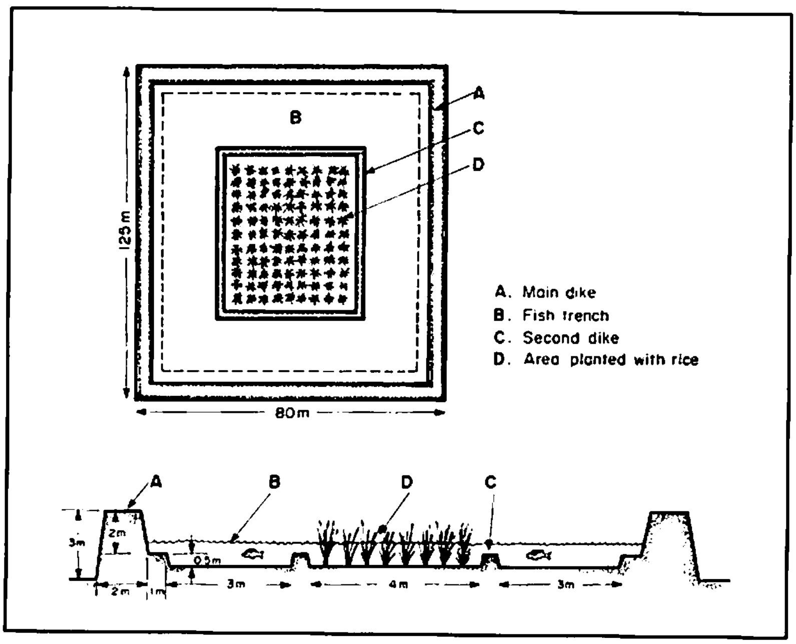


Fig. 3. Design and construction of a one-ha *sawah tambak* ricefield.

better use of an unproductive part of a ricefield (Fig. 4). Fish are stocked in a pond constructed next to the ricefield and forage into it. The pond becomes a refuge for fish when ricefields are drained. *Surjan* systems are used in coastal areas of West Java where soils are poor due to drainage problems. Farmers construct a series of raised and sunken soil beds to maximize the production of rice, land crops and fish in one system (Fig. 5). Ruddle (1980) has described a *surjan* system in the Karawang Regency in West Java.

Cropping Patterns in Rice-Fish Culture

Application of the various rice-fish systems described above can be done in various cropping patterns or production systems. Cropping patterns can be manipulated to obtain higher fish and rice yields and thereby increase income. Administering certain cropping patterns may conserve the fertility of agricultural soils or improve the productivity of marginal lands in rural areas. Farmers employ various cropping patterns suitable to their individual climatological, agronomic and sociological conditions.

Studies conducted by the Research Institute for Freshwater Fisheries (RIFF) in 1985 in the Subang Regency of West Java found three cropping patterns which produced two crops of rice and several fish crops a year. Cultivation of fish in ricefields in Subang involved the production of fingerlings of 50–100 g size for further ongrowing in intensive aquaculture systems such as cages or running water systems. The cropping patterns found were rice-rice-*palawija*; *minapadi-penyelang-minapadi-palawija*; and *minapadi-minapadi-palawija*. *Palawija* was the most popular, followed by *minapadi* and *penyelang*. *Minapadi* was practised for 20- to 60-day periods and

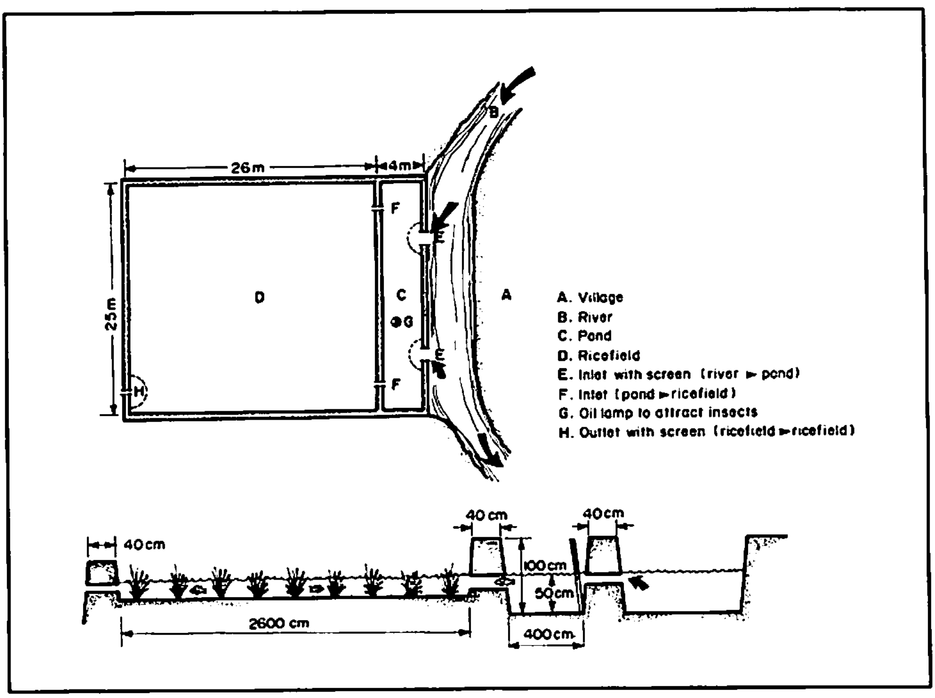


Fig. 4. Design and construction of *payaman* ricefield.

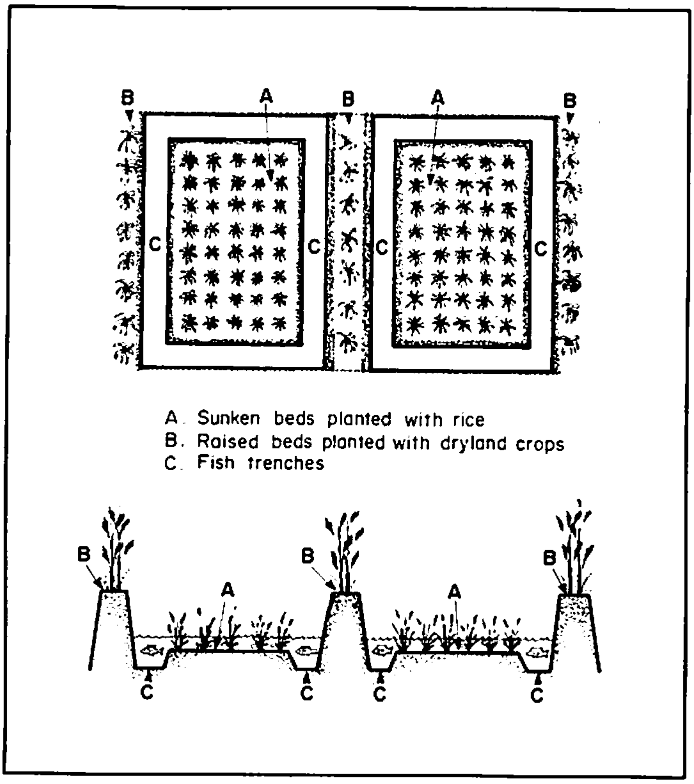


Fig. 5. Design and construction of *surjan* ricefield.

penyelang for 30 days. Because of the longer growing period, *palawija* in Subang produced the highest fish yield (354 kg/ha) compared with *minapadi* (143 kg/ha) and *penyelang* (114 kg/ha). RIFF data coincide with observations of Taslim and Syamsiah (1987) in the district of Binong, Subang. According to their data, *palawija* was the most widely used type of rice-fish culture (1,194 ha), compared to *minapadi* (260 ha) and *penyelang* (15 ha), and fish yields from *palawija* were significantly higher when compared with *minapadi* and *penyelang* (e.g., 300, 150 and 100 kg/ha, respectively). It was also found that 8,475 ha of the ricefield area (88%) was left fallow after rice harvest in Subang and that a large potential for expansion of rice-fish culture existed.

Unfortunately at present, there is not enough data from other parts of Indonesia to further analyze existing cropping patterns. However, it can be assumed that various cropping systems have been developed by farmers to suit their local conditions. For example, based on results of surveys in the upland areas of West Java, (Bogor, Cianjur and Sukabumi Regencies), it was found that *minapadi* and *penyelang* were the most popular, using a cropping pattern of *minapadi-penyelang-minapadi-penyelang*. Surveys suggest that farmers optimize rice yields, notwithstanding the low price and sometimes lower income from rice.

Knowledge of cropping patterns in rice-fish farming in Indonesia is still very limited. More studies are needed to reveal the advantages and disadvantages of various cropping patterns in economic terms as well as effects on soil fertility and long-term productivity of agricultural lands.

Species of Fish Used in Rice-Fish Culture

Eight main fish species are raised in Indonesian ricefields. Production levels of these species and their importance in the main islands of the country are presented in Table 2.

Common carp is the main fish cultivated in ricefields. It is also the main cultivated fish in ricefields in Aceh (2.8% of the national level), North Sumatra (6.1%), West Java (38.5%), North Sulawesi (1.6%), South Sulawesi (0.7%), Bengkulu (0.7%) and Bali (0.6%). In Java, common carp production amounted to 40.7% of the total production of fish from rice-fish farming. Statistical data also show that the production of "other" fish species from ricefields has increased remarkably, from 2.5% of the national total in 1975 to 29.8% by 1985. In Java, this production of "other" fish species reared in ricefields comprised 34.6% of the total production in 1985.

Java carp is the second most important fish cultured in ricefields especially in Java (Table 2). Java carp is produced mainly in East Java from *sawah tambak*. It is also important in the special administrative region of Yogyakarta in Java, accounting for 24.2% of the production from rice-fish farming.

Java tilapia is an important cultured fish in ricefields in East Java (3.2% of the national level), West Java (1.3%), West Sumatra (0.2%), North Sulawesi (0.2%) and Central Java (0.2%).

Nilem carp (*Osteochilus hasselti*) is a minor species in ricefields in West Java (1.7%), Central Java (0.1%), North Sulawesi (0.1%) and West Sumatra (0.1%).

A preliminary survey conducted by RIFF in the district of Ciampea, Bogor, West Java, revealed that rice farmers in 14 villages were engaged in the culture of ornamental fish in ricefields. At least 16 species of freshwater ornamental fish were recorded during the survey. Breeding of fish is carried out six to seven times a year and new breeder fish are introduced after two to three breeding cycles. Main species cultivated in ricefields are *Barbus*, *Costy*, *Ambassis* and *Asmania*. The majority of these farmers cultivate ornamental fish for a 6-month period during *palawija*. Fish were being marketed in Jakarta.

Table 2. Fish production (t) by species in ricefields and their relative importance (% in brackets) at the national level, by island, Indonesia, 1975–85. (Source: DGF 1985).

Island	Total	Common carp	Java carp	Java tilapia	Nilem carp	Nile tilapia	Giant gourami	Sepat siam	Kissing gourami	Others
Indonesia	63,218	29,933	8,046	3,559	1,277	564	65	101	733	18,940
	(100)	(47.3)	(12.7)	(5.6)	(2.0)	(0.9)	(0.1)	(0.2)	(1.2)	(30.0)
Java	52,181	21,232	7,839	3,019	1,138	117	64	29	702	18,041
	(100)	(40.7)	(15.0)	(5.8)	(2.2)	(0.2)	(0.1)	(0.1)	(1.3)	(34.6)
Sumatra	8,056	6,503	183	258	67	356	0	2	27	660
	(100)	(80.7)	(2.3)	(3.2)	(0.8)	(4.4)	-	(0.0)	(0.0)	(8.2)
Sulawesi	2,071	1,468	7	198	72	37	0	70	4	215
	(100)	(70.9)	(0.3)	(9.6)	(3.5)	(1.8)	-	(3.4)	(0.2)	(10.4)
Bali-Nusa Tenggara Islands	910	730	17	84	0	54	1	0	0	24
	(100)	(80.2)	(1.9)	(9.2)	-	(5.9)	(0.1)	-	-	(2.6)

Socioeconomics of Rice-Fish Culture

General descriptions of the economic feasibility of the rice-fish farming in Indonesia are given by Ardiwinata (1957); Djajadiredja et al. (1980); and Schmidt (1980). In general, these authors claim that the profit obtained from fish cultivation can cover operational costs for rice cultivation. Djajadiredja et al. (1980) reported that the major costs for rice-fish culture were: construction (35%); labor (34%); seed fish (18%); and others such as fertilizers, pesticides and taxes (less than 6%). They also reported a rate of return of rice-fish farming that ranged from 68 to 107% of total costs. Schmidt (1980) estimated that the total rate of return from a rice-fish farm in Indonesia was 83.7% per 100 m^2, and that the ratio of family labor to wage labor was 0.3. He concluded that rice-fish culture could provide substantial amounts of income and employment in Indonesian rural areas.

Rice-fish farming is a very significant employer of rural people in Indonesia. Rice-fish farming employed a total of 302,486 persons (Table 3).

Recent surveys from West Java have shown that various cropping patterns yield a wide range of net returns, as shown by farms surveyed in Sukabumi, Cianjur and Bogor Regencies (Table 4). Net returns reported are within the range of those reported by Djajadiredja et al. (1980). Farmers in the Cianjur Regency reported even higher fish production and net returns in the *penyelang* and *minapadi* using supplemental feeds (Table 4).

Rates of return in cultivating ornamental fish in Ciampea District of Bogor are reported to be 80–96% (Table 4). These rates of return were lower than those observed for all other rice-fish systems employing food fish.

Prospects for Rice-Fish Culture

By 1984, Indonesia had a recorded 4.9 million ha of irrigated ricefields (Tarrant et al. 1987). Of these, an estimated 1.57 million ha were suitable for rice-fish culture (DGF 1987). At present, only 94,309 ha or 6% of these fields are being used for fish culture. A large expansion in rice-fish culture can be accommodated. Expansion of rice-fish culture is warranted not only due to the protein, economic and employment needs of the rural population but also for producing seed fish for grow-out in an expanding inland aquaculture industry. If just 10% of the suitable irrigated ricefields were used for rice-fish culture at an average fish production of 500 kg/ha/year, an additional 78,500 t of freshwater fish would be available annually. This additional fish production would more than double the fish production from ricefields achieved in 1985.

Table 3. Number of rice farmers engaged in rice-fish farming by island, Indonesia, 1976–85. (Source: DGF 1985).

Province	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Indonesia	157,546	118,893	139,329	130,875	211,041	236,248	204,436	248,331	262,192	302,486
Java	65,093	52,303	71,492	67,343	123,526	145,411	135,871	161,266	164,878	211,157
Sumatra	27,841	32,233	24,756	29,335	45,265	50,058	35,863	41,487	44,302	41,833
Sulawesi	28,963	15,062	16,772	11,747	17,779	22,203	22,417	22,724	10,545	23,447
Bali-Nusa Tenggara Islands	43,647	19,295	26,309	22,450	24,471	18,576	10,285	22,854	30,467	26,049

Table 4. Fish production and net returns per hectare per year for different cropping patterns practised by farmers in selected regencies, Indonesia.

Location/Cropping pattern	Fish production (kg)	Net returns (US$)[a]	Rate of return (%)
Sukabumi Regency			
Minapadi-penyelang-palawija	255	1,280	183
Minapadi-penyelang-minapadi	400	2,050	202
Minapadi-penyelang-minapadi	250	1,200	219
Cianjur Regency			
Minapadi-penyelang-vegetables-*penyelang*	302	450	
Minapadi-penyelang-minapadi	385	1,550	242
Minapadi-penyelang-minapadi	780	1,560	201
Bogor Regency			
Minapadi-penyelang-minapadi	380	2,130	
Rice-*palawija*	256	140	110
Ciampea, Bogor Regency[b]			
Ricefield pond, farm 1	80,000[c]	360	96
Ricefield pond, farm 2	24,000[c]	970	80
Palawija (6 months)-rice	1,000	230	93

[a]Original values in Indonesian Rupiah were converted to US$ at the rate of US$1 = Rp 1,647 as of 1987.
[b]Pertains to ornamental fish.
[c]In number of fish.

Total land use for aquaculture in Indonesia was 377,958 ha with 238,868 ha in brackishwater ponds, 94,309 ha in rice-fish culture, and 44,778 ha in freshwater ponds (Table 5). The use of potential land area available for aquaculture was 28%. Rice-fish culture has utilized only 6% of its potential. During Indonesia's fourth five-year development program (PELITA IV), rice-fish culture by 1988 was targeted to reach 82,500 ha (DGF 1985). By 1985, the area of rice-fish culture in Indonesia reached 94,309 ha. This rapid expansion indicates that the acceptance of rice-fish culture is very high, and that the systems are profitable for small-scale farmers where adequate knowledge and seed supply exist.

Table 5. Utilization of potential aquaculture resources in Indonesia, 1985. (Source: DGF 1987).

Aquaculture resource system	Potential area (ha)	Area utilized (ha)	Per cent utilization
Brackishwater ponds	840,000	238,868	28
Freshwater ponds	180,000	44,778	25
Rice-fish culture	1,570,000	94,309	6
Cage culture	135,000	3	<1
Mariculture cages	18,715	0	0

Constraints to Development of Rice-Fish Culture

Fish cultivation in ricefields uses the same resource base as rice cultivation. Rice is still considered the principal crop. A major constraint to the expansion of rice-fish culture is, therefore, the sometimes conflicting agronomic needs of both crops. There is a growing concern about the environmental effects of modern, intensive methods of rice agriculture on rice-fish culture. Increased pesticide and fertilizer use and the adoption of HYV rice have threatened the viability of rice-fish culture throughout Asia (Khoo and Tan 1980; Koesoemadinata 1980).

Pesticides are detrimental to fish and the aquatic food web which supports the fish (Koesoemadinata 1980; Takamura and Yasuno 1986). The adverse effects of pesticides on fish are their lethal and chronic toxicity, persistency and accumulation in biological systems. Koesoemadinata (1982) measured the toxicity to common carp and Java carp of 24 insecticides commonly used in irrigated ricefields. It was found that 8% were extremely toxic, 62% were highly toxic, 17% were moderately toxic and 12% had low toxicity (Table 6). There may be no single answer to the problem of pesticide use in rice-fish culture, but a rational approach is to use selective pesticides which have little or no impact on fish or the aquatic food web (Koesoemadinata 1980).

In Indonesia, the use of pesticides is controlled by a government pesticide committee. Extremely toxic and persistent chemicals such as Endrin, DDT, BHC and other organochlorines are prohibited from the aquatic environment. In 1986, the government issued Presidental Decree No. 3 to help with the problem of pest resistance and resurgence of brown plant leafhoppers. The decree declared that pest control in ricefields could only be accomplished with pesticide formulations containing buprofezin, BPMC, MIPC and carbofuran as active ingredients. Koesoemadinata (1982) found that pesticides containing these active ingredients were not directly harmful to fish if applied at recommended rates.

There is an urgent need to formulate ecological guidelines for fish cultivation in ricefields. This lack of guidelines is a major constraint to the development of rice-fish culture systems. The carrying capacities of fish in ricefields, and how agronomic practices of fertilization, feeding, different cropping systems and soil types, affect the aquatic food web are almost totally unknown.

Farmers in Indonesia have mentioned the following constraints that affect the success of rice-fish culture: lack of reliable sources of quality seed fish; lack of high quality, reasonably-priced supplemental feeds; control of predators and pests; lack of sufficient water during the seasons of *palawija* and *penyelang*; and lack of technology on how to best store fish on the rice farm when fish prices are low.

Conclusions

Within the framework of rural development, rice-fish culture has great potential in Indonesia. In addition, from an environmental point of view, rice-fish culture can play a large role in the management of natural resources in the rice agroecosystem. Rice-fish culture requires small cash outlays and could provide significant increases in rural employment and family incomes. Rice-fish systems could also improve the nutritional status of rural people directly by additional consumption of fish, or indirectly by improving incomes.

Rice-fish farming should be given sufficient attention in its role in fostering the development of a vibrant rural aquaculture production network. In Indonesia, rice-fish culture is the central fish nursery system, and is essential for the survival and expansion of inland aquaculture, especially cage and running water systems.

Table 6. Lethal toxicity of rice insecticides to common carp (*Cyprinus carpio*) and Java carp (*Puntius gonionotus*). (Source: Koesoemadinata 1982).

Insecticide	Active ingredient concentration (g/l)	Common carp		Java carp	
		96-hour LC_{50} (ppm)	95% confidence limits	96-hour LC_{50} (ppm)	95% confidence limits
BPMC	500	4.00	2.84–5.64	24.00	20.34–28.32
Carbaryl	85[a]	8.20	7.19–9.34	6.40	5.92–6.91
Cartap hydrochloride	50[a]	1.15	1.01–1.31	0.22	0.20–0.24
Chlorpyriphos ethyl	200	0.31	0.21–0.47	2.40	2.88–4.01
Chlorpyriphos methyl	240	5.50	5.30–5.70	3.80	3.60–3.90
Cyanophemphos	250	2.75	2.25–3.36	3.80	3.30–4.37
Diazinon	600	3.60	2.02–4.28	6.60	5.74–7.59
Dicrotophos	500	360.00	290.30–446.40	310.00	264.90–362.70
Dichlorvos	500	2.30	2.04–2.59	3.70	2.50–3.90
Etrimphos	500	7.50	6.58–8.55	7.40	6.32–8.66
Fenthion	550	3.60	3.39–3.82	3.90	3.50–4.30
Fenitrothion	500	4.70	4.08–5.41	7.00	6.36–7.70
Isoxanthion	550	1.40	1.27–1.54	1.80	1.55–2.09
Malathion	600	4.50	3.44–5.89	13.00	11.50–14.69
MIPC	50	10.09	8.70–11.70	26.60	20.94–33.78
Monocrotophos	200	310.00	269.60–356.50	320.00	262.50–390.40
Metamidophos	208	70.00	55.12–88.90	130.00	17.10–144.30
MTMC	300	11.50	9.35–14.14	13.50	11.44–15.93
Methomyl	200	4.80	4.17–5.52	7.50	6.70–8.40
Methoate	500	230.00	198.30–266.80	105.00	92.10–119.70
Phentoate	608	0.94	0.81–1.09	3.30	3.00–3.60
Propoxur	50	66.00	58.41–74.58	45.00	40.91–49.50
Quinalphos	250	5.80	4.96–6.79	5.40	4.35–6.70
Triazophos	400	8.10	5.06–12.98	3.10	2.76–3.47

[a]In per cent.

Rice-fish culture is not successful everywhere in Indonesia. Constraints inherent to intensive methods used in modern rice agriculture can be a threat to the widespread adoption of rice-fish culture. The uneven distribution of rice-fish culture in Indonesia suggests that its advantages are still unknown to most farmers in the country. Therefore a continuing extension program focused first on the spread of the existing best available technologies, then upon improved technologies, is needed. Longer-term basic research is also needed. Increased fish production could be accomplished by understanding and effectively using the available ecological niches in the ricefield agroecosystem.

The impressive growth of rice-fish culture in Indonesia since 1980 indicates, however, that current development and extension efforts have been effective, and that previous constraints posed by pesticide use or adoption of HYV have not had long-term consequences. Rice-fish farming is profitable nearly everywhere in the country. This bodes well for the future of the systems in Indonesia.

References

Ardiwinata, P.O. 1957. Fish culture on paddy fields in Indonesia. Proc. Indo-Pac. Fish. Counc. 7: 119–162.

CBS. 1981. Statistical profile of children and mothers. 1980-1981. Central Bureau of Statistics, Jakarta.

Coche, A.G. 1967. Fish culture in ricefields: a world-wide synthesis. Hydrobiologia 30:1–44.

Collier, W.L., H. Hadikoesworo and S. Saropie. 1982. Labor absorption in rice-based agriculture. International Labor Organization, Geneva.

DGF. 1985 Prospects for the development of aquaculture in Indonesia. Directorate General of Fisheries, Jakarta. (In Indonesian).

DGF. 1987. Prospects for the development of aquaculture in Indonesia. Directorate General of Fisheries, Jakarta. (In Indonesian).

Djajadiredja, R., Z. Jangkaru and M. Yunus. 1980. Freshwater aquaculture in Indonesia, with special reference to small-scale integrated farming systems in West Java, p. 143–165. *In* R.S.V. Pullin and Z. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4. 258 p.

DPPJT. 1986. (East Java figures for 1986). Dinas Perikanan Propinsi Jawa Timur, Surabaya. (In Indonesian).

FAO. 1984. A study of methodologies for forecasting aquaculture development. FAO Fish. Tech. Pap. 248. 47 p.

Grist, D.H. 1985. Rice. Longman, London.

Hart, G. 1976. The survival strategy of labor allocation. Paper presented at the "Workshop on Household Duties", 3–7 April 1976, Singapore.

Khoo, H. and E.S.P. Tan. 1980. Review of rice-fish culture in Southeast Asia, p. 1–14. *In* R.S.V. Pullin and Z. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4. 258 p.

Koesoemadinata, S. 1980. Pesticides as major constraints to integrated agriculture-aquaculture farming systems, p. 45–51. *In* R.S.V. Pullin and Z. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4. 258 p.

Koesoemadinata, S. 1982. Lethal toxicity of 24 insecticide formulations commonly used for rice pest control in irrigated ricefield to two Indonesian freshwater fish species *Cyprinus carpio* and *Puntius gonionotus*. Bull. Penelitian Perikanan (Fish. Res. Bull.) 2: 67-82.

Ruddle, K. 1980. A preliminary survey on fish cultivation in ricefields, with special reference to West Java. Bull. Natl. Mus. Ethnol. 3:801-822.

Satari, G. 1962. Wet rice cultivation with fish culture: a study of some agronomical aspects. Bogor Agricultural University, Bogor. Ph.D. thesis. (In Indonesian).

Schmidt, U.W. 1980. Integrated aquaculture in West Java. DCP/MR/PO/11. FAO, Rome. 19 p.

Schuster, W.H. 1955. Fish culture in conjunction with rice cultivation. World Crops (UK) 1:11-14, 67-70.

Soemarwoto, O. 1985. A quantitative model of population pressure and its potential use in development planning. Indon. J. Demogr. 24:1-15.

Takamura, K. and M. Yasuno. 1986. Effects of pesticide application on chironomid larvae and ostracods in ricefields. Appl. Entomol. Zool. 21:370-376.

Tarrant, J., E. Barbier, R.J. Greenberg, M.L. Higgins, S.F. Linter, C. Mackie, J. Murphy and V. Veldhuizen. 1987. Natural resources and environmental management in Indonesia: an overview. United States Agency for International Development, Jakarta.

Taslim, H. and I. Syamsiah. 1987. Rice-fish farming systems at Binong, Subang, West Java, Indonesia. Paper presented at the IRRI and ARC 8th Meeting of the Asian Rice Farming Systems Working Group, 30 Aug-9 Sep 1987, Islamabad, Pakistan. 22 p.

Tribawono, D. 1980. Fish culture in *sawah tambak*. National workshop to increase efficiency in the development of freshwater fish culture, 28-31 January 1980, Cisarua, Bogor. 21 p. (In Indonesian).

UPP. 1985. Pilot project management unit. Annual report for 1984/1985 of the pilot project management unit to develop freshwater fish culture in Subang, West Java. West Java Provincial Fisheries Agency, Bandung. (In Indonesian).

UPP. 1986. Pilot project management unit. Annual report for 1985/1986 of the pilot project management unit to develop freshwater fish culture in Subang, West Java, Indonesia. West Java Provincial Fisheries Agency, Bandung. (In Indonesian).

Vincke, M.M.J. 1979. Aquaculture en riziere: situation et role futur, p. 208-223. *In* T.V.R. Pillay and W.A. Dill (eds.) Advances in aquaculture. Fishing News Books, Surrey, England.

World Bank. 1983. Wages and employment in Indonesia. Washington, DC.

World Bank. 1984. Indonesia: selected aspects of spatial development. Washington, DC.

Rice-Fish Farming Systems and Future Prospects in Korea

BYEONG HYEON KIM
Research Bureau
Rural Development Administration
Suwon, Korea

HEE DONG KIM
YOUNG HO KIM
Research Bureau
Kyonggi Provincial Rural Development Administration
Hwasong, Korea

KIM, B.H., H.D. KIM and Y.H. KIM. 1992. Rice-fish farming systems and future prospects in Korea, p. 63–67. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Korea has considerable potential for fish production in its ricefields. Of the 980,000-ha irrigated ricefields, about 13% are suitable for rice-fish farming. While rice-fish farming has been practised for about 30 years, it has not become popular. Short rice cultivation periods, use of agricultural chemicals and competition from inshore and pelagic fisheries explain this. Demand for freshwater fish has increased recently due to socioeconomic factors at the farm level and exhaustion of inshore fishery by environmental pollution.

Loach (*Misgurnus anguillicaudatus*) is already a popular species for commercial rice-fish farming. Other species such as catfish (*Parasilurus asotus*), Nile tilapia (*Oreochromis niloticus*) and common carp (*Cyprinus carpio*) also appear to be suited for rice-fish farming. Rice yield in rice-fish culture is almost the same as rice monoculture even though 14% of the rice-fish area is devoted to canals or ponds.

Current technology on rice-fish farming is still insufficient to make sound practical recommendations. More research is needed on the safe use of pesticides for fish growth and human consumption, improvement of fish culture, suitability of species and design of rice-fish facilities.

Introduction

Rice-fish farming has been practised in Korea since the 1950s. Fish are stocked after the rice is transplanted in May and grown over the warm humid summer for 90–135 days, depending on the latitude and the rice variety. However, this practice did not spread at that time because fish supplies from inland waters met demand. Today, inland resources are limited by pollution of waterways and ponds, and increased use of agricultural chemicals. National fish production in 1987 was 3.33 million t, most of which came from marine fishing. Inland fish production only accounts for 1.7% (Fig. 1). The dominant species, commercially reared in artificial ponds or reservoirs, are mirror carp (*Cyprinus carpio* var. *specularis*), eel *(Fluta alba)*, common carp *(Cyprinus carpio)* and trout *(Salmo gairdneri)* (Table 1). A combination of declining fish supplies, economic development favoring urban centers and decreasing farm incomes has recently spurred interest in rice-fish farming.

There exists considerable potential for expanding rice-fish areas. Korean farmers cultivate 22% of the total land area which is just over 21 million ha. Ricefields occupy 1.35 million ha while the rest of the cultivated land supports upland crops (Fig. 2). Seventy-two per cent of the ricefields (about 980,000 ha), have irrigation systems. Crops grown are shown in Fig. 3.

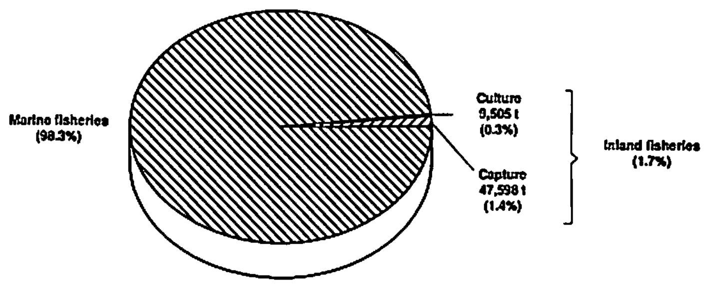


Fig. 1. Fish production (t) from marine and inland fisheries, Korea, 1987. (Source: MAFF 1988)

Rice-Fish Farming

Rice-fish farming was practised during the 1960s in the southern provinces of Sunchon-Gun and Kyongsan-Gun. *C. carpio* and loach (*Misgurnus anguillicaudatus*) were the species farmed.

Rice-fish farming declined in the 1970s because of the introduction of high-yielding varieties, use of toxic agricultural chemicals, and increased catch from inshore and pelagic fisheries. Interest has increased recently because farmers need to use their fields more efficiently.

In 1989, 487 farmers were culturing fish in 95 ha of ricefields. *M.*

Table 1. Production (t) and value (US$)[a] of fishery products from inland fisheries, 1987. (Source: MAFF 1988).

Fish and aquatic products	Production (t)	Value (US$)
Capture	47,598	75.92
Culture	9,501	64.75
C. carpio var. *specularis*	3,592	15.39
F. alba	2,441	36.97
C. carpio	936	3.69
S. gairdneri	704	4.69
Snakehead (*Ophiocephalus argus*)	287	1.58
Silver carp (*Hypophthalmichthys molitrix*)	70	0.44
O. niloticus	56	29.17
Goldfish (*Carassius auratus* var.)	51	0.18
M. anguillicaudatus	15	0.08
Parasilurus asotus	12	0.07
White fish (*Hypomesus olidus*)	8	0.01
Sea shiner (*Tribolodon keta* W.)	4	0.01
Salmon (*Oncorhynchus keta* W.)	2	0.002
Blue gill (*Lepomis machrochirus R.*)	1	0.0005
Mullet (*Mugil cephalus* L.)	1	0.002
Other finfish	80	0.10
Mollusc	1,228	1.15
Algae	13	0.06

[a]Original values in Korean Won were converted to US$ at the rate of US$1 = Won792 as of 1987.

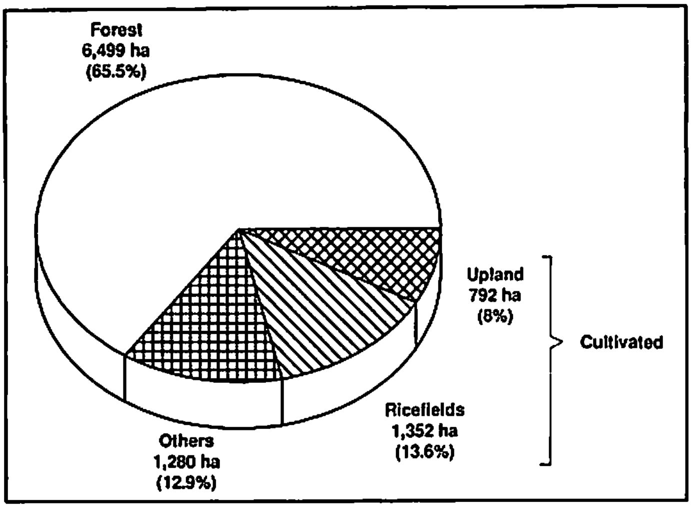


Fig. 2. Area ('000/ha) of land use, Korea, 1987. (Source: MAFF 1988)

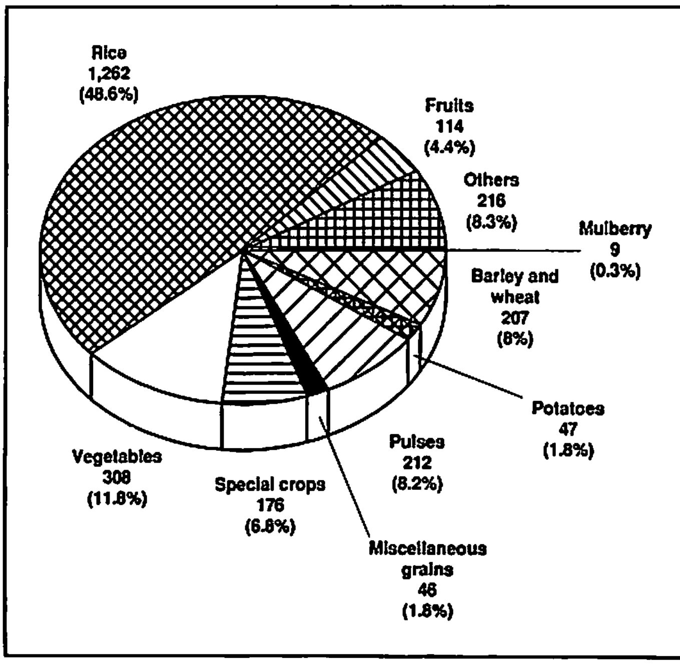


Fig. 3. Area ('000/ha) of cultivated land by crop*, Korea, 1987. (Source: MAFF 1988)
*Crop area exceeds cultivated area because of multiple cropping in irrigated fields.

anguillicaudatus was the only species reported to be farmed. For rice-*M. anguillicaudatus* farming, field borders were reinforced with 130-cm steel sheets buried to 30 cm to prevent *M. anguillicaudatus* escape. In addition, a coarse net was placed over the field to prevent bird predation. Rice planting densities were reduced by 50%. Water depth was maintained at more than 10 cm throughout the season. Fingerlings were released about a week after transplanting at 614,000/ha. Commercial feeds were supplied daily. No chemicals were used for weed or pest control. The average cost for fishfarm construction (Fig. 4) was US$9,348 in 1989 and gross income was US$23,238/ha.

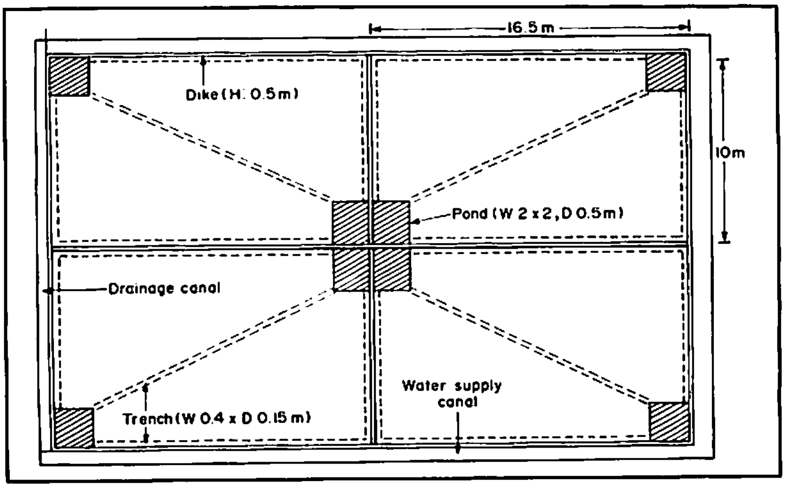


Fig. 4. Plane figure of rice-fish farming field.

Research on Rice-Fish Farming

Research on *C. carpio* carried out between 1963 and 1967 in Jinhae Aquaculture Research Center recommended stocking densities of 3,000–5,000/ha without feeding and 15,000/ha with feeding. Fish yields were about 250 kg/ha without feeding and about 1,000 kg/ha with feeding.

Successful results in rice-fish experiments at Kyonggi Provincial Rural Development Administration during 1988 and 1989 with catfish (*Parasilurus asotus*) encouraged other research institutes to investigate other fish species such as *M. anguillicaudatus*, *C. carpio* var. *specularis*, Nile tilapia (*Oreochromis niloticus*) and *C. carpio*.

Rice yield in association with catfish or tilapia was comparable or better than rice monoculture (Table 2), even when 14% of the ricefield area was devoted to canals or ponds. Improved rice growth is believed to be due to increased soil fertility caused by uneaten fish feeds and fish feces. However, rice yields were significantly reduced by 44% without weed control.

After four months in the ricefields, fish yields were 1,260 kg/ha for *P. asotus* and 2,720 kg/ha for *O. niloticus* (Table 3). *P. asotus* fingerlings (2.5 g and 5.9 cm) grew to 84.5 g and 23.4 cm; while *O. niloticus* (76.7 g and 15.9 cm) grew to 198.1 g and 21.9 cm. The survival rates were 50% and 92%, respectively.

Not all herbicides affected fish survival (Table 4). *C. carpio* var. *specularis*

Table 2. Effect of herbicides on the growth and yields of rice in rice monoculture and rice-fish culture experiments at Kyonggi Provincial Rural Development Administration, Korea, 1989.

Treatment[a]	Heading date	Culm length (cm)	No. of panicles per hill	No. of grains per m²	Polished rice yield (kg/100 hill)	Percentage of nonplanting area	Polished rice yield (kg/ha)	Index (%)	Weight of weeds (dry matter in g/m²)
Rice monoculture, herbicide	10 Aug	68	19.3	35,300	2.38	0	4,950	100	3.6
Rice-*P. asotus*, herbicide	12 Aug	74	20.5	40,900	2.71	14	4,850	98	1.8
Rice-*P. asotus*, no herbicide	9 Aug	72	14.9	26,300	1.50	14	2,680	54	93.0
Rice-*O. niloticus*, herbicide	1 Aug	78	21.4	49,000	2.90	14	5,170	104	1.1

[a]Sechaibyeo was transplanted 15 May at planting density of 30 x 16 cm. Chlometoxyfen was applied 2 days after transplanting at 30 kg/ha, fish were released 20 days after herbicide application.

Table 3. Effect of herbicides on survival rates, growth and yields of fish in four months in rice-fish culture experiments at Kyonggi Provincial Rural Development Administration, Korea, 1989.

Treatments[a]	No. of fingerlings (no./ha)	Survival rate (%)	Fish length (cm) 6 Jun	Fish length (cm) 5 Oct	Fish weight (g) 6 Jun	Fish weight (g) 6 Oct	Fish yield (kg/ha)
Rice-*P. asotus*, herbicide	30,000	49.8	5.9	23.4	2.5	84.5	1,260
Rice-*P. asotus*, no herbicide	30,000	51.6	5.9	22.8	2.5	78.4	1,210
Rice-*O. niloticus*, herbicide	15,000	91.6	15.9	21.9	76.7	198.1	2,720

[a]Sechaibyeo was transplanted 15 May at planting density of 30 x 16 cm. Chlometoxyfen was applied 2 days after transplanting at 30 kg/ha, fish were released 20 days after herbicide application.

Table 4. Survival rates of *C. carpio* var. *specularis* at different stocking dates after herbicide application in rice-fish experiments at the Kyonggi Provincial Rural Development Administration, 1989.

Herbicides	Fish stocking day(s) after herbicide application (DAH)[a] 1 DAH (%)	2 DAH (%)	3 DAH (%)	4 DAH (%)	15 DAH (%)
Butachlor + Pyrazolate	32	92	100	100	100
Chlometoxyfen	-	-	-	-	100
Pretilachlor	-	-	-	-	100
Mefenacet + Bensulfuron methyl	-	-	-	-	100

[a]Dashes (-) mean no experiment was done.

fingerlings were affected by Butachlor + Pyrazolate only if stocked one to two days after herbicide application. Chlometoxyfen, Pretilachlor and Mefenacet + Bensulfuron methyl did not affect the survival rate of *C. carpio* var. *specularis* if stocked 15 days after herbicide application. Herbicide residues in fish tissues and their safety for human consumption are still to be evaluated.

Conclusions

Short duration rice varieties and heavy use of chemicals have been the limiting factors for rice-fish farming in Korea. However, successful commercial rice-*M. anguillicaudatus* farming and research findings with other fish species suggest more opportunities for rice-fish farming.

Current research information still falls far short of providing practical recommendations. Research by rice and fish scientists on rice-fish culture facilities; raising mixed species; minimal use of chemicals on rice; residual effects of chemicals in fish for safety in human consumption; time, density and size for stocking fish; fish feeding regimes; and adaptability of fish species to rice-fish conditions will contribute to the expansion of rice-fish farming in Korea.

Reference

MAFF. 1988. Statistical yearbook of agriculture, forestry and fisheries. Ministry of Agriculture, Forestry and Fisheries, Republic of Korea.

Rice-Fish Farming Development in Malaysia: Past, Present and Future

AHYAUDIN BIN ALI
School of Biological Sciences
Universiti Sains Malaysia
11800, Minden, Penang
Malaysia

ALI, B.A. 1992. Rice-fish farming development in Malaysia: past, present and future, p. 69–76. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish farming research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Fish is an important protein source in Malaysia. Most of the freshwater fish are obtained from ricefields, especially from the Kerian Irrigation Area of northwest Perak. The most important ricefield species are the herbivorous gourami *(Trichogaster pectoralis* and *T. trichopterus)*, the carnivorous snakehead *(Channa striata)*, the omnivorous catfish *(Clarias macrocephalus)*, and the insectivorous climbing perch *(Anabas testudineus)*. In Malaysia, the capture method of rice-fish culture is practised where no field preparation, fish stocking or feeding is done. Here, the fish depend on the natural productivity of the ricefields for food. A sump or pond, dug at the lowest section of the fields, provides shelter during low water levels and double as a harvesting basin. With the introduction of rice double-cropping and the subsequent heavy uses of herbicides and pesticides, fish yields have declined substantially from 461.4 and 301.6 to 367.0 kg/ha in the 1930s and 1940s, to 88.3, 128.0 and 174.6 kg/ha in 1985, 1986 and 1987, respectively. A short growing season has also resulted in the dominance of subharvestable fish. Rice-fish farming is still important economically, where it can contribute up to 6.79% and 8.98% to the seasonal incomes of owner and tenant farmers, respectively. However, to increase the income and the efficiency of the system, improvements to the current system are needed and are discussed further in the paper.

Introduction

Rice-fish culture has been known in Asia for several centuries (Coche 1967). The system was introduced to Southeast Asia from India about 1,500 years ago (Tamura 1961). According to Coche (1967) only 0.65% or 136,000 ha out of about 21 million ha of ricefields in Southeast Asia are utilized in rice-fish farming.

In Malaysia where annual per capita fish consumption varies from 20 to 25 kg (Khoo and Tan 1980), the importance of rice-fish culture has long been recognized (Heath 1934; Soong 1947, 1948, 1949, 1950, 1951, 1955). Fish provide additional income (Hickling 1961) especially important to tenant farmers, who form 60% of the rice farmers in Peninsular Malaysia (Tan et al. 1973). There are approximately

352,000 ha of ricefields under cultivation in Peninsular Malaysia, of which only 34.10% or 120,000 ha have sufficient water depths (15–16 cm) for rice-fish cultivation (Tan et al. 1973). These areas are situated primarily in the "rice bowl" states of Perlis, Kedah and northern Perak in the northwest region of Peninsular Malaysia (Fig. 1). Thus in Malaysia, ricefields are available for rice-fish farming to produce cheap animal protein.

Past and Present Status of Rice-Fish Farming Systems

In Malaysia, as in other Southeast Asian countries, fish supplement rice in the local diet, and are the most important and cheapest animal protein source (Hora and Pillay 1962; Khoo and Tan 1980). Most of the fish sold in the country are caught from the surrounding seas. For freshwater fish, the most important source is the ricefield.

The numerically most important species obtained from ricefields are the snakeskin gourami *(Trichogaster pectoralis)*, a species introduced from Thailand in the early 1920s (Soong 1948). This herbivorous species is now preferred over the two-spot gourami *(T. trichopterus)* in the ricefield ecosystem of Krian. The catfish *(Clarias macrocephalus)* is the third most abundant species in the ricefield, but is the most important species economically. It is essentially nocturnal and omnivorous in nature, feeding on benthic worms, insects, etc. The snakehead *(Channa striata)* is also economically important. It is a top level predator in the ricefield ecosystem,

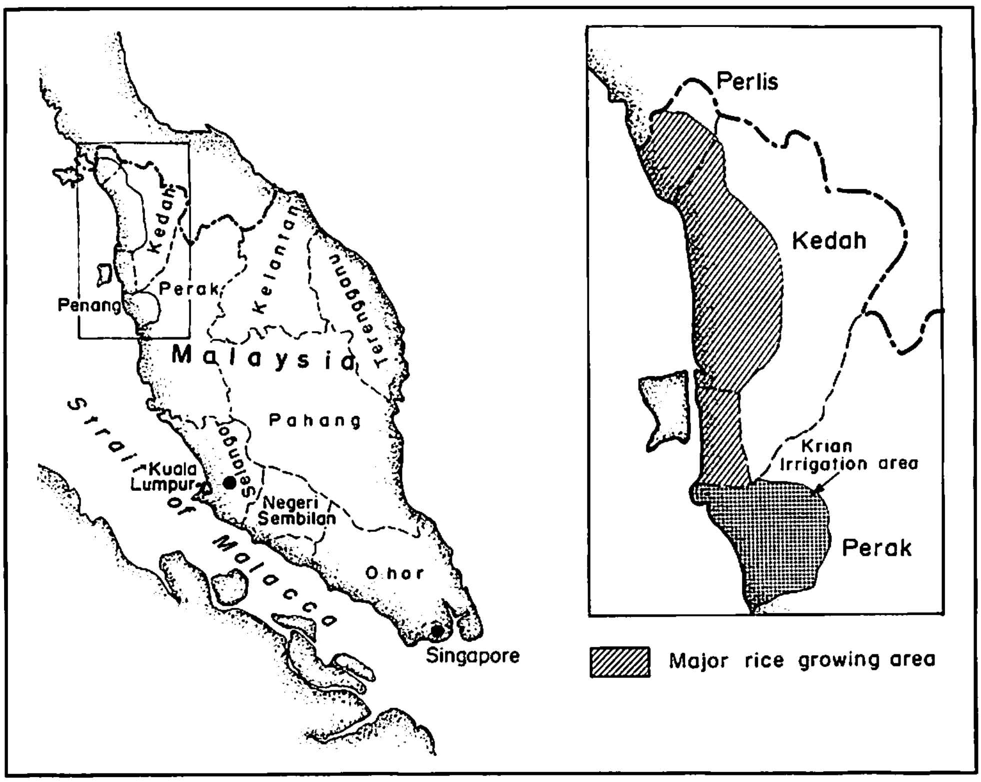


Fig. 1. Map showing the major rice-growing areas of Peninsular Malaysia.

feeding mainly on other fish, frogs, tadpoles, etc.

Snakeskin gourami are salted and sundried before being sold in the market, while catfish and snakehead are sold alive since dead ones have no market value (Tan et al. 1973). Climbing perch *(Anabas testudineus)* are relatively unimportant economically, but important nutritionally, being consumed by farming families or processed into fermented fish locally known as *pekasam*.

The single most important rice-fish farming area in the Peninsular is the Krian Irrigation Area of northwest Perak (Fig. 1) which covers an area of 25,000 ha (Tan et al. 1973). The area is the oldest irrigation scheme in the country, completed in 1906. It has been successfully converted to double cropping of rice in the early 1970s and relies primarily on two main water sources, the Bukit Merah Reservoir and the Krian River. The Krian area is noted for its fish from ricefields. Fish harvested from its ricefields have been exported to Singapore, Indonesia and southern Thailand (Soong 1948; Tan et al. 1973). Currently, the area is still the most important source of freshwater fish in the country although catches have declined significantly following the introduction of double cropping of rice. The rice-fish farming systems described in this paper are based essentially on methods practised in this area.

Rice-Fish Production Methods

Rice-fish culture in the Krian area is essentially capture fishery with very little management inputs. Wild fish from irrigation canals and sump ponds enter the flooded ricefields early in the season, are trapped and grown together with rice until they are harvested from sump ponds at the end of the rice growing season (Soong 1948). Field preparations such as digging perimeter trenches, repairing the dikes for the retention of fish (Khoo and Tan 1980), and applying organic fertilizers to promote zooplankton growth are not done. Fish stocking or restocking is not also practised. No supplemental feed is given, fish obtain their food solely from natural food organisms in the ricefields (Tan et al. 1973). The fertility of the ecosystem depends primarily on fertilizers applied twice during the rice-growing season. The chemical fertilizers used are urea (46% N) and NPK (17.5–15.5–10.0) at the rate of 56 and 112 kg/ha per application, respectively.

The sizes of the fields used in the rice-fish system vary from 0.81 to 1.42 ha (Ali 1987a). A sump pond with a diameter ranging from 6.5 to 8.0 m and 2.0 m deep is dug at the lowest elevation to function as shelter during periods of low water levels and high water temperatures in ricefields, and as a catch basin during fish harvests (Fig. 2). The sump pond, shaded by trees with its surface covered with water hyacinth *(Eichhornia crassipes)*, is generally cooler and has higher dissolved oxygen concentrations compared to the shallower ricefields (Ali 1987b).

Ricefields are prepared for planting by spraying emergent aquatic macrophytes such as *Cyperus* sp., *Monochoria* sp. and *Limnocharis* sp. with herbicides such as Gramoxone (paraquat-based), then manually cutting and removing the dead weeds with scythe (Ali 1987a). The extremely soft and boggy bottoms preclude the use of heavy machinery.

The rice planting schedule for the Krian area is shown in Table 1. After four months from the transplanting when the rice is ripe and the fields are dry, the sump ponds are drained and the fish harvested. Fish are sold to dealers who also provide a water pump, nets and other accessories needed for fish harvest. The sump ponds, however, are not completely harvested. Small fish are left behind to provide stock for the next season.

Besides using sump ponds to harvest fish, farmers also use gourami nets to trap the fish in ricefields, and cast and lift nets to catch fish from irrigation

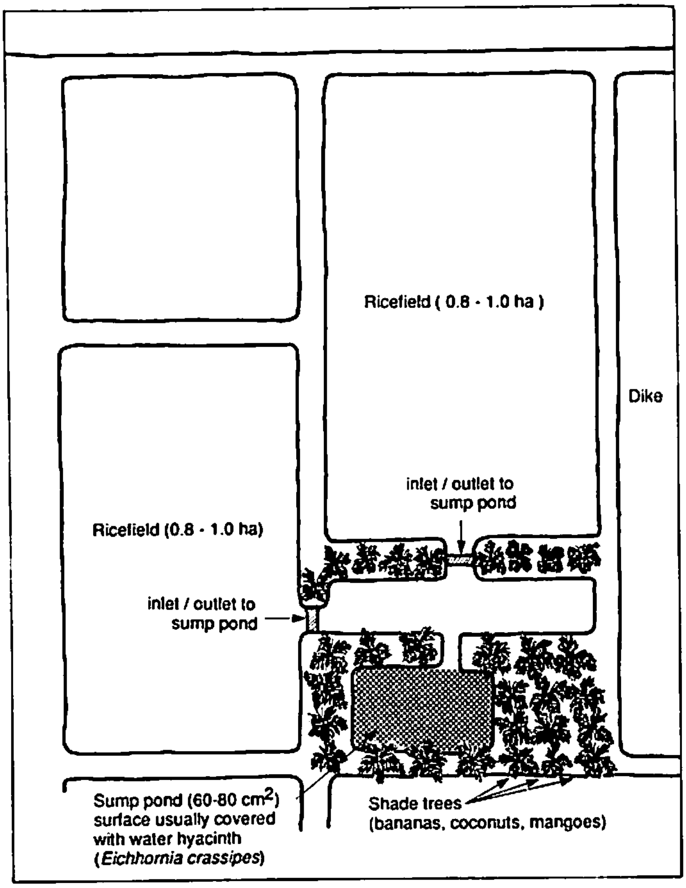


Fig. 2. A typical layout of a rice-fish farming system of the Krian Irrigation Area.

canals. However, these harvesting techniques contribute only a small portion to the total fish harvest.

Yields obtained from Krian ricefields have been steadily declining. Heath (1934) and Soong (1948) reported average yields of 532 kg/sump pond and 302–423 kg/sump pond, respectively. Since the average size of ricefields connected to the sump pond is 1.15 ha, the yields per hectare of ricefield reported by the two researchers would be 461.4 and 301.6–367 kg/ha, respectively. These yields were obtained when single cropping of rice was still practised and the growing season was 6–10 months. Tan (1973) reported a yield of 470.3 kg/ha. The reported fish yield seems to indicate single cropping. In contrast, Tan et al. (1973) reported a fish yield of only 93.2 kg/ha in areas practising double cropping of rice; and over a three-year interval, a 57.2% decline in harvest was observed. Ali (1987a) monitored fish yields in farmers' fields for three consecutive four-month growing seasons in late 1985 to early 1987 (Table 2). These fish yields were similar from those obtained by Tan et al. (1973).

The most abundant and dominant species observed by Ali (1987a) was the snakeskin gourami. However, catfish and snakehead were the more economically important species (Table 2).

The short rice growing season (four months) prevented fish from reaching harvest size by the end of the rice growing period. This resulted in the dominance of subharvestable size fish, which could reach as high as 45.7% of the total biomass harvest (Table 3). Single rice crops would allow fish to grow for as long as eight months before harvest. However, according to Tan et al. (1973), there were probably two generations of fish in the sumps or ponds due to the long rice growing season.

Table 1. A typical planting schedule of Krian Irrigation Area.

Days	Activity
0	Field preparation - spraying of herbicides (Paraquat - 1.2 to 2.5l/ha of commercially prepared concentration), cutting, raking and removing dead weeds
	Seeding
20	Transplanting
40	
	First fertilization - 5.6 kg/ha of Furadan (Carbofuran) mixed with urea (56 kg/ha) and NPK (112 kg/ha) fertilizers
60	Second fertilization - same as in first application
80	
150	Harvesting of rice - fields dry or beginning to dry fish in sump ponds are harvested

Farm net income per hectare per season obtained during the study ranged from US$26.05 to 40.86 (1987) (Table 2). In this case, the annual income from fish which was US$75.32, was significantly lower compared to the net income of US$281.65/ha observed by Tan et al. (1973).

Economic Significance

Income from fish sales provides an important supplementary contribution to the total annual income of farmers. In Tan et al. 1973, fish sales contribution to total income was 6.09 and 11.80% for owner and tenant farmers, respectively, in double rice cropping areas. The current corresponding values are 6.79 and 8.98%. It can be appreciated that no matter how low the contribution of fish makes to total income, the profit obtained from the sale of fish from ricefields is essentially a net profit since little costs are involved. Thus, this makes fish culture important to farmers. However, there is a need to do more on the relative contribution of rice-fish farming to the economy of the rural rice farmers, which at present is lacking. The

Table 2. Fish yields obtained from the harvest of sump ponds monitored for three consecutive growing seasons from 1985 to 1987 (modified from Ali 1987a).

		1985 Sept-Dec		1986 Feb-May		1987 Sept 86-Jan 87	
Species	Fish price (US$/kg)[a]	Yield (kg/ha)	Income (US$/ha)[a]	Yield (kg/ha)	Income (US$/ha)[a]	Yield (kg/ha)	Income (US$/ha)[a]
T. pectoralis	0.14	18.1	2.53	15.4	2.16	64.6	9.04
C. macrocephalus	1.01	9.5	9.60	13.1	13.23	16.6	16.77
C. striata	0.51	27.3	13.92	37.4	19.07	29.5	15.05
Marketable yields		54.9	26.05	65.9	34.46	110.7	40.86
Total yields		88.3		128.0		174.6	

[a]Original values in Malaysian dollars were converted to US$ at the rate of US$1 = M$2.57 as of 1987.

Table 3. Harvestable and subharvestable components of fish yields obtained from three consecutive harvests in 1985 to 1987 (modified from Ali 1987a, 1990).

Seasons	Total fish yield (kg/ha)	Harvested fish: Subharvestable (kg/ha)	(%)	Harvestable[a] (kg/ha)	(%)
1985 (Sep-Dec)	88.3	24.0	27.2	54.9	62.2
1986 (Feb-May)	128.0	53.5	45.7	65.9	51.5
1987 (Sep 86-Jan 87))	174.6	43.4	24.9	110.7	63.4

[a]*T. pectoralis* ≥ 14.0 cm; *C. striata* ≥ 25.0 cm; *C. macrocephalus* ≥ 20.0 cm.

only exhaustive survey was conducted in the early 1970s (Tan et al. 1973).

Current Rice-Fish Farming Research and Development

Although rice-fish farming has a very high potential in Malaysia, no research is currently being conducted on improving the prevailing culture and management techniques. Most studies were carried out in the 1940s and 1950s by Soong (1947, 1948, 1949, 1950, 1951, 1955) and by several researchers later in the early 1970s during the transition period from single to double rice cropping (Tan 1971; Yunus and Lim 1971; Moulton 1973; Tan 1973; Tan et al. 1973). Currently, research on the basic ecology of rice-fish farming is being conducted primarily by Ali (1987a, 1987b, 1988, 1990) in order to formulate and design more effective culture techniques and management strategies that will counteract the declining fish harvests.

Prospects and Constraints

With over 350,000 ha of ricefields available for potential rice-fish farming, the prospect for increased fish production using this system remains very good. In spite of the intensive use of herbicides and pesticides, rice-fish farming is still the most important source of freshwater fish in the country. Currently, there are no real or apparent social constraints to hold back the development of rice-fish farming systems. Manpower is not a major problem since in the rural areas, farming has always been an activity involving everyone in the family.

A preliminary survey conducted in the Krian area indicated that all the ricefield-sump pond systems are still producing fish, albeit at a lower level. The major factors affecting production are the short growing season for fish due to double cropping of rice and intensive use of herbicides and pesticides in the ricefields. Pesticides such as Thiodan, Malathion, Furadan and paraquat-based herbicides are commonly used (Tan et al. 1973). There is, however, a growing awareness among farmers on the adverse effects of pesticides on both fish populations and the ecological balance of the ricefields (Khoo and Tan 1980). Thus, the emphasis now is towards using less amount of harmful pesticides in the ricefields.

The other constraint on the expansion of rice-fish farming in Malaysia is the lack of research and development on improving the culture and management techniques currently being used. Techniques employed in the early 1930s and 1940s have remained unchanged. Thus, more research in the area of culture techniques and management strategies is needed in order to increase future production. The ecological studies currently being conducted by Ali (1987a, 1987b, 1988, 1990) indicated that changes to the prevailing techniques need to be done to improve fish production. Constructing perimeter trenches as is done in Thailand (Boonsom 1984) to increase living space, restocking to replenish natural populations, giving supplementary feed, and more restraint in the use of pesticides to minimize damages on zooplankton populations in the ricefields (Lim et al. 1984; Ali 1988), will result in better fish yields.

A potential development strategy would be having a research-cum-demonstration prototype farm established in the target area in order to demonstrate to the farmers first hand new culture methods and management techniques. This approach should also be supplemented with a network of extension officers helping to quickly disseminate new information obtained.

Conclusions

If the existing rice-fish farming system in Malaysia is continued, the prognosis for the future remains bleak. New culture methods and management techniques are needed to invigorate the system. Efforts to increase yields should involve upgrading and modifying existing systems rather than introducing new and untested techniques, since rice-fish culture is essentially a symbiotic form of relationship that has taken hundreds of years to evolve (Ruddle 1982). In Malaysia, especially the rice-fish farming system of Krian, it is still important not only to produce freshwater fish, but also to act as a generic reservoir for important aquaculture species such as the catfish and snakehead. With an increasing demand for catfish (especially from Thailand) that is currently not being met, the economic outlook for rice-fish culture remains positive.

Acknowledgements

The author wishes to thank International Development Research Centre (IDRC) of Canada for providing the travel grant to attend the workshop, the International Foundation for Science (IFS) for providing the research grant, and Universiti Sains Malaysia for the ancillary facilities used during the study.

References

Ali, A.B. 1987a. Yields obtained from the Krian method of ricefield fish culture monitored for three consecutive growing seasons. Paper presented at the Asian Biology - International Foundation for Science Day Symposium, 14–17 October 1987, Kuala Lumpur, Malaysia.

Ali, A.B. 1987b. The ecology of fish culture in ricefields: some ecological aspects of fish culture system of North Krian. Paper presented at the Asian Biology - International Foundation for Science Day Symposium, 14-17 October 1987, Kuala Lumpur, Malaysia.

Ali, A.B. 1988. Some ecological aspects of snakeskin gourami *(Trichogaster pectoralis)* populations harvested from ricefield-fish culture system. Indo-Malayan Zool. 5: 101–110.

Ali, A.B. 1990. Some ecological aspects of fish populations in tropical ricefields. Hydrobiologia 190:215–222.

Boonsom, J. 1984. Zooplankton feeding in the fish *Trichogaster pectoralis* Regan. Hydrobiologia 113:217–221.

Coche, A.G. 1967. Fish culture in ricefields. A worldwide synthesis. Hydrobiologia 30:1–44.

Heath, R.G. 1934. Fish production in the Krian irrigation area. Malays. Agric. J. 22:186–189.

Hickling, C.F. 1961. Tropical inland fisheries. Longman, London. 295 p.

Hora, S.L. and T.V.R. Pillay. 1962. Handbook on fish culture in the Indo-Pacific region. Fish. Biol. Tech. Pap. No. 14, FAO, Rome. 204 p.

Khoo, K.H. and E.S.P. Tan. 1980. Review of rice-fish culture in Southeast Asia, p. 1–14. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Lim, R.P., M. Abdullah and C.H. Fernando. 1984. Ecological studies of Cladocera in ricefields of Tanjung Karang, Malaysia, subjected to pesticides treatment. Hydrobiologia 113:99–103.

Moulton, T.P. 1973. The effects of various insecticides (especially Thiodan and BHC) on fish in the paddy fields of West Malaysia. Malays. Agric. J. 49:224–253.

Ruddle, K. 1982. Traditional integrated farming systems and rural development: the example of ricefield fisheries in Southeast Asia. Agric. Admin. 10:1–11.

Soong, M.K. 1947. Preliminary report on sepat siam investigations in Krian. Offprint Special Communication Southeast Asia, Fish. Conf. Pap. No. 9. Singapore.

Soong, M.K. 1948. Fishes of the Malayan paddy fields I: sepat siam [*Trichogaster pectoralis* (Regan)]. Malay. Nat. J. 3:87–89.

Soong, M.K. 1949. Fishes of the Malayan paddy fields II: Aruan; serpenthead fishes. Malay. Nat. J. 4:29–31.

Soong, M.K. 1950. Fishes of the Malayan paddy fields III: Keli; catfishes. Malay. Nat. J. 5: 88–91.

Soong, M.K. 1951. The fitness of ecological niches into which fish are introduced at various ages and the survival of the transplanted fish. Proc. Indo-Pac. Fish. Counc. 3:218–227.

Soong, M.K. 1955. Fish culture in paddy fields in the Federation of Malaya. FAO International Rice Commission Fourth Session, Tokyo, Japan, 1954 (mimeo) Indo-Pac. Fish. Counc. 6th. Sess., IPFC/CSS/CP 26 5 p.

Tamura, T. 1961. Carp cultivation in Japan, p. 103–112. *In* G. Borgstrom (ed.) Fish as food. Academic Press, New York.

Tan, S.P. 1971. The use of "pukat sepat" in the harvesting of "ikan sepat siam", [*Trichogaster pectoralis* (Regan)] in the paddy-fields of northern Krian, Perak. Malay. Agric. J. 48:69–72.

Tan, S.P. 1973. The significance of sump-ponds in harvesting paddy-field fishes in northern Krian, Perak. Malay. Nat. J. 26:26–31.

Tan, C.E., B.J. Chong, H.K. Sier and T. Moulton. 1973. A report on paddy and paddy-fish production in Krian, Perak. Min. Agric. Fish. Bull. No. 128. Kuala Lumpur, Malaysia. 57 p.

Yunus, A. and G.S. Lim. 1971. A problem in the use of insecticides in paddy fields in West Malaysia - a case study. Malay. Agric. J. 48:167-178.

Rice-Fish Farming Development in the Philippines: Past, Present and Future

RUBEN C. SEVILLEJA
Freshwater Aquaculture Center
Central Luzon State University
Muñoz, 3120 Nueva Ecija
Philippines

SEVILLEJA, R.C. 1992. Rice-fish farming development in the Philippines: past, present and future, p. 77-89. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Rice-fish culture in the Philippines was adopted as a national program for pilot implementation starting 1979. The maximum total area covered under the program was 1,397 ha achieved in 1982 with an approximate total fish production of 243 t. The concurrent system in ricefields with a center or peripheral trench was commonly practised by farmers with tilapia *(Oreochromis niloticus)* and common carp *(Cyprinus carpio)* as the preferred species. The intensive use of pesticides and the small fish at harvest due to the short duration of fish culture period were identified as some of the technical constraints which hamper the development of rice-fish farming in the country. Other factors were socioeconomic and management-related in nature.

There is a bright future for rice-fish farming development in the Philippines due to the vast area of potential resources which can be exploited using the available production systems. There is also a renewal of interest and increased awareness of the benefits that can be derived out of this system. Research is likewise underway, with the involvement of several government and non-government research institutions, for the development of alternative and modified systems which are expected to solve most of the problems associated with concurrent rice-fish culture.

Introduction

In the Philippines, fish culture in ricefields is not a unique practice. However, the scientific integration of agriculture and aquaculture farming systems has a short history since the cultivation of rice with other crops and livestock has always taken precedence over the production of aquatic products (dela Cruz 1980a).

Rice-fish culture has not been given much attention in the past because of lack of a workable technology that farmers could easily adopt. On the other hand, rice-fish culture itself might have been regarded as a poor investment for possible research (Campos 1985). For instance, Manacop (1960) proposed a research and development program to the International Rice Research Institute (IRRI) in 1960, but this was not implemented. It was only in 1974 that the concept of rice-fish culture technology began to be transformed into an operational reality when researchers at the newly established Freshwater Aquaculture Center (FAC) of the Central Luzon State University (CLSU) conducted an exploratory trial in culturing fish with rice (Anon. 1974). Having discovered its potentials, FAC undertook an extensive research and development program on rice-fish culture directed at developing an appropriate low-cost technology for fish production in rice farms. The ultimate objective was to increase the availability of animal protein supply and thereby improve the nutrition of the people in inland areas (Arce and dela Cruz 1978). Henceforth, successive trials and experiments have resulted in the generation of a rice-fish culture technology package.

Past and Present Status of Rice-Fish Farming Systems

Description of Prevailing Rice-Fish Production Systems

Recognizing the potentials of the technology in the socioeconomic upliftment of rural farmers, the Department of Agriculture (DA) launched in May 1979 the National Rice-Fish Culture Program locally known as *Palay-Isdaan*, covering 931 ha in 41 selected provinces in the 12 regions of the country. The program aimed to increase the income of rice farmers and to improve their nutritional status providing protein through the fish produced in their ricefields (Arevalo 1987).

Farmers participating in the program adopted the technology for concurrent rice-fish culture as recommended by the FAC. The ricefield was modified by constructing a center trench running lengthwise with the dikes made slightly higher and wider than in rice monoculture (Figs. 1a and b). A screened gate was provided on the dike to prevent entry of wild fish and escape of stocked fish. The fish species used were the Nile tilapia *(Oreochromis niloticus)* or common carp *(Cyprinus carpio)*. Their stocking rates in monoculture and polyculture systems in rice-fish culture and other details of the technology are shown in Tables 1 and 2, respectively.

Data from the DA revealed a general downward trend in total area and productivity of rice-fish culture from 1982. Its area during the initial six months of implementation was 193 ha, only about 19% of the original target area, hitting a peak in 1982 at 1,397 ha (Table 3). Very limited data and information are available on the extent of rice-fish culture practices outside of the national pilot implementation program. In a survey of 53 farms in Central and Southern Luzon conducted by Tagarino (1985), the average area of rice-fish fields was 0.59 ha, representing about 21% of the total farm area of an average farmer. Concurrent rice-fish culture was adopted, although the majority of the farmers did not follow the recommended practices. About 60% of the farmers adopted the peripheral trench design. The aquatic plant *Colocasia* sp. was grown on the sides of the dikes, while other vegetables or crops were planted on the top (Fig. 2).

The Nile tilapia and common carp were grown either singly or in combination at stocking densities of 5,500–9,500/ha. Although farmers used the high-yielding IRRI rice varieties, they did not apply the required kind and amount of fertilizers. Occasionally, supplemental feeds, mainly rice bran, were given. Fish harvest was generally done prior to the rice harvest. The average rice and fish production were 4,825 kg/ha and 232 kg/ha, respectively.

While the trench-type of ricefield facility is generally adopted by rice-fish farmers in most parts of the country, a unique system is being practised in the rice terraces of the Cordillera mountain ranges in Northern Luzon. These terraced rice lands which are spread over the provinces of Ifugao, Kalinga-Apayao, Mt. Province and Benguet involve 120,000 farm

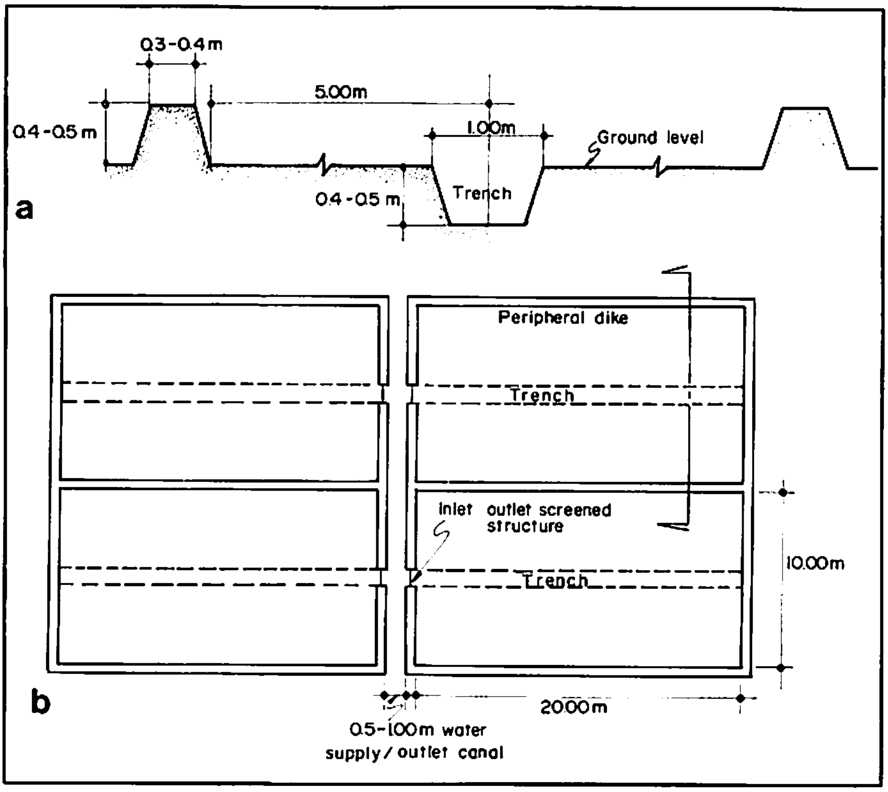


Fig. 1a. Cross-section of a ricefield, dike and trench. (Source: dela Cruz 1980a).
b. Location of trench for a ricefield measuring 10 x 20 m. Scale 1:280. (Source: dela Cruz 1980a).

Table 1. Recommended fish species and stocking densities in rice-fish culture. (Sources: dela Cruz and Lopez 1980; FAC 1985).

Fish culture system	Species	Rice-fish culture system	Stocking rate (fish/ha)	Stocking size (g)
Monoculture	*O. niloticus*	concurrent	5,000	15–25
		rotational	10,000	
	C. carpio	concurrent	3,000	5–10
Polyculture	*O. niloticus* +		3,000	15-25
	C. carpio	concurrent	2,000	5–10
	O. niloticus +		10,000	15-25
	C. carpio	rotational	5,000	5–10

Table 2. Recommended technical package for concurrent rice-fish culture. (Source: FAC 1985).

I. Technical inputs		II. Schedule of production activities[a]	
Kind	Recommended quality, quantity and procedure of application	Culture day	Activity
Rice seeds	IRRI HYV to be transplanted at a distance of 20 x 20 cm between hills on seedbed	0	seedbed preparation
		1	soak rice seeds
		3	broadcast germinated seeds
		5	treat growing seedlings with recommended insecticides
Fish species	Monoculture: *O. niloticus* - 5,000; *C. carpio* - 3,000	10–4	land preparation - plowing, harrowing, clearing, improving dikes, trenching
	Polyculture: *C. niloticus* + 3,000; *C. carpio* - 2,000		basal fertilization and pesticide application
Inorganic fertilizer	Urea (46–0–0): 75 kg/ha	24	pull rice seedlings
	Ammonium phosphate (16–20–0): 150 kg/ha basal and top dressing applications	25	transplanting
		28–29	irrigate ricefields, 3–5 cm deep
		29	apply recommended herbicide
		32	fish stocking, raise water level to 7–10 cm deep
Pesticides and herbicides	Furadan (1–3 bags/ha)		
	2-4-D IPE	75	reduce water depth to 5 cm, apply fertilizer top dressing
	Broadcast prior to transplanting		
	Other insecticides (0.01% conc.)	76–95	increase water depth to 10–15 cm deep
	Drain ricefield until fish are collected in the trench before spraying	96–124	increase water depth to 20 cm deep
		125–130	drain ricefields and harvest fish
		131–135	harvest rice crop

[a]May vary depending on the rice variety.

Table 3. Total area and production levels of the National Rice-Fish Culture Program, 1979-86. (Source: Arevalo 1987).

Year	Total area (ha)	No. of farms	Average area per farm (ha)	Production/ha Rice (kg)	Fish (kg)
1979 (May-Oct)	193	428	0.45	4,965	115
1980	249	446	0.56	5,150	208
1981	497	1,141	0.44	5,015	155
1982	1,397	2,284	0.61	5,010	174
1983	759	1,237	0.61	4,450	164
1984	424	932	0.45	3,900	152
1985	607	1,177	0.52	4,300	119
1986	185	550	0.34	3,850	140

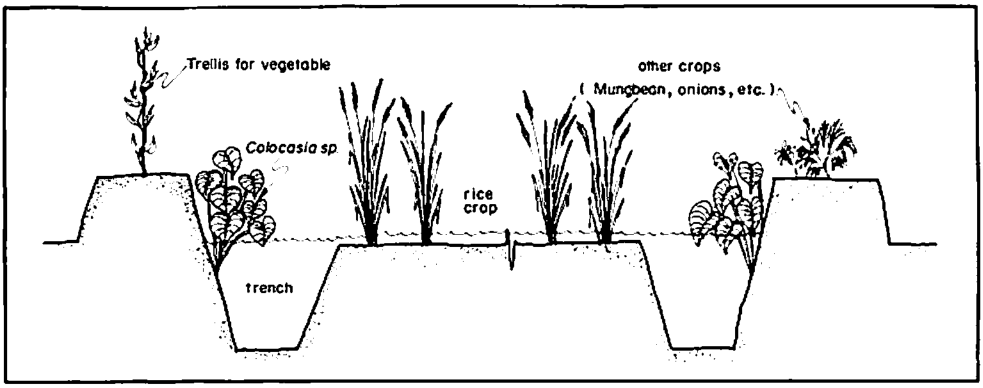


Fig. 2. Cross-section of a typical rice-fish field with peripheral trench showing areas planted to various crops.

households with average landholdings ranging from 0.15 to 0.25 ha (NFAC 1984). Most farmers have a single traditional late-maturing (about five to six months) mountain rice variety which does not require pesticides. However, rice production is low with average yields of only 2.5–3.0 t/ha (NFAC 1984).

The most popular fish grown is a cold water fish known as cyprinid loach or Oriental weather fish *(Misgurnus anguillicaudatus)*, locally known as *dojo, panispis, yoyo* or *u-u* believed to have been introduced by the Japanese in World War II (Bocek 1982). There is no deliberate stocking of the fish. They enter into the ricefields through irrigation water supplied by streams or surface runoff. To facilitate harvesting, pits *(pukungan)* measuring 1–2 m wide and 1–2 m deep are constructed at the center of the ricefield. Farmers also catch the fish with the use of bottle-shaped traps known as *bubo*. A traditional catch ranges from 1 to 10 kg in ricefields with areas ranging from 180 to 700 m^2 (Cagauan 1987).

The culture of other species was introduced in the rice terraces, notably common carp and Nile tilapia. Bocek (1982) reported that stocking the ricefields with carp at 200/ha with a mean culture period of 147 days and no supplemental feeding, produced 129 kg/ha/year; while stocking with Nile tilapia at 8 fry/m^2 or 80,000/ha yielded fish averaging 250 g each.

Status of Rice-Fish Research and Development

Research on rice-fish farming system is mainly undertaken at the FAC (Table 4). Established in 1973 as the lead national agency for freshwater aquaculture research, one of its major functions is to develop low-cost technologies appropriate for rural development.

Among the initial experiments was an exploratory trial on rice-fish culture conducted about 14 years ago. Between 1974 and 1987, a total of 74 experiments were completed covering various research areas (FAC 1974–1984; CLARC 1985–1987). In these studies which mainly used high-yielding IR varieties, Nile tilapia and common carp were found to be the most suitable for culture in ricefields, either in monoculture or in polyculture. Under the concurrent system, stocking densities of 3,000/ha for common carp and 5,000/ha for Nile tilapia were found appropriate for monoculture without supplemental feeding. Polyculture of common carp and Nile tilapia at a stocking rate of 2,000 and 4,000/ha, respectively, gave the highest yields. Fish production ranged from 78 to 303 kg/ha.

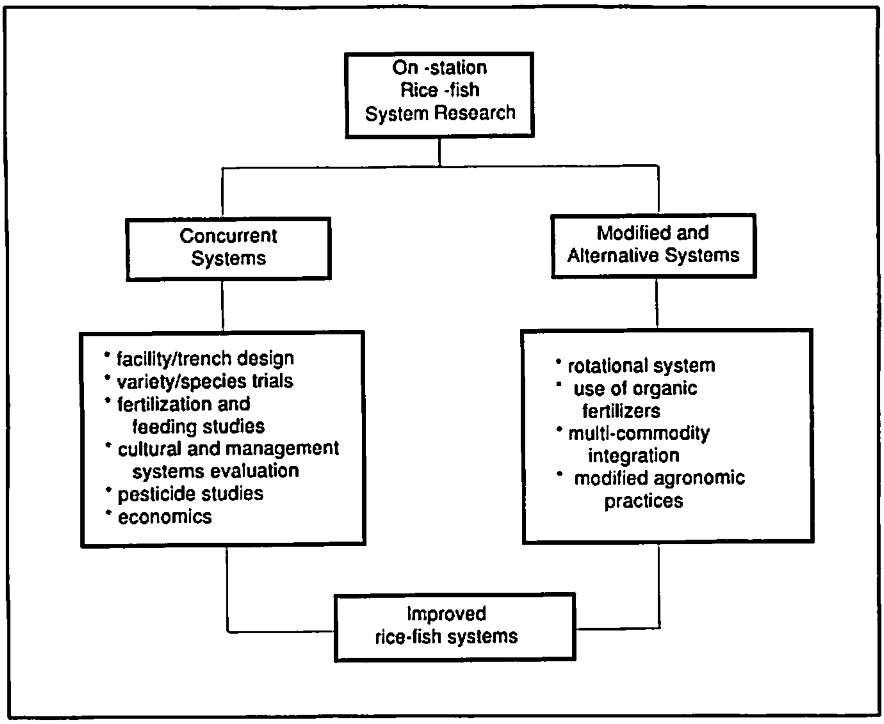


Fig. 3. Research areas for the development of improved rice-fish systems.

Table 4. Completed research on rice-fish culture at the Freshwater Aquaculture Center. (Sources: FAC 1974–1984; CLARC 1985–1987).

Research area	Number
Trench design and evaluation	4
Variety/Species trials	
Rice	10
Fish	6
Paddy field carrying capacity	6
Fertilization and feeding studies	10
Cultural/Management systems evaluation	
Rice	4
Fish	6
Studies on pesticides	10
Alternative and modified systems	
Rotational system	8
Organic and azolla fertilization	2
Rice-pig-fish combination	4
Economic analysis	4
Total	74

In a rotational system, a stocking rate of 10,000/ha for tilapia under monoculture system was found most suitable; while for polyculture, a combination of 5,000/ha *C. carpio* and 10,000/ha tilapia appeared most promising. Fish yields ranged from 390 to 629 kg/ha.

In both concurrent and rotational systems, yields of IR rice varieties ranged from 3.3 to 6.3 t/ha. Case studies of some of these systems and reviews of the rice-fish culture technology development were prepared by dela Cruz (1980a).

Current research efforts on rice-fish farming systems are geared mainly towards the development of modified, improved or alternative management systems for the traditional and more established concurrent rice-fish culture. Fig. 3 presents the different research areas for the development of improved techniques and systems under the rice-fish culture systems research program of FAC.

Modified Agronomic and Alternative Practices for Rice-Fish Culture

Substantial research is being done on alternative cultural and management practices for rice as they affect fish in a concurrent rice-fish culture.

USE OF ORGANIC FERTILIZERS

Cagauan and Nerona (1986) evaluated azolla as a biofertilizer in rice-fish culture system using Nile tilapia. Results showed that fresh azolla incorporated in the soil at the rate of 2–5 t/ha during land preparation (about seven days before transplanting), is comparable to 50 kg/ha urea (46–0–0) and 100 kg/ha ammonium phosphate (16–20–0) of inorganic fertilizers. Greater fish and rice yields were obtained applying azolla at the same rate plus half the fertilization rates of inorganic fertilizers. This implies that fertilizer expenses can be reduced by partial substitution of inorganic fertilizers since the farmer can grow his own azolla.

Mang-umphan (1987) compared organic fertilizer applied basally at the rate of 350 kg/ha with inorganic fertilizers applied at 60.9 kg/ha urea, 200 kg/ha ammonium phosphate and 75 kg/ha muriate of potash (0–0–60). Results showed that fish production in ricefields with 100% organic fertilizer were higher by about 25% compared to yields from ricefields with only inorganic fertilizers. However, there was a slight reduction in rice production.

A rice-fish-pig integration was evaluated to test the substitutability of pig manure to inorganic fertilization (Sevilleja et al. 1985). Pig pens were constructed alongside the rice-fish fields so that pig manure is gathered in a settling or collecting pond underneath the pigpens where irrigation water passed. Results showed that pig manure can be a substitute for inorganic fertilizer. Fish in manured ricefields grew at 0.68 g/day which was higher than in chemically fertilized ricefields at 0.22 g/day. Rice yields were also comparable with those using inorganic fertilizer.

Although research is still preliminary in nature, the results appear promising. More trials are being undertaken which also include the use of cattle manure and the testing of various rice planting distances and patterns.

APPROPRIATE CROPPING PATTERN FOR ROTATIONAL RICE-FISH SYSTEM

This system is alternative to the concurrent rice-fish culture system which reduces the pesticide hazard. The scheme involves the culture of rice and fish in the same ricefield alternately or at different times. Several advantages of this system have been reported by dela Cruz and Lopez (1980).

In a study comparing different rotational patterns, tilapia production in fish fields (ricefields utilized as fishponds) previously planted to rice ranged from 406 to 527 kg/ha in four months at 10,000/ha stocking density (Sevilleja and Lopez 1986). Fish production in a concurrent system stocked at 5,000/ha ranged from 98 to 112 kg/ha. Results also indicated that the cropping rotation must include at least one rice crop to be economically attractive.

Research Programs and Projects

Research on rice-fish culture received a big boost with technical assistance provided by the Asian Development Bank (ADB). The 2.5-year project which commenced late 1987 is being implemented by the International Center for Living Aquatic Resources Management (ICLARM) with CLSU and IRRI as cooperating institutions. In the Philippines, the FAC is designated to carry out the on-station experiments of the project.

The increasing involvement in rice-fish culture research by other agencies, notably the DA, is indeed a welcome development. The DA's Regional Integrated Agricultural Research System (RIARS) in Central Luzon has started on-farm research in rice-fish culture, focusing on variety trials and fertilizer studies. The DA-IRRI Prosperity Through Rice Project is looking into rice-fish culture as a means of increasing farm incomes.

Likewise, the DA through its defunct National Food and Agricultural Council (NFAC), also launched the Save Our Terraces Program (STP) which included a rice-fish farming system component (NFAC 1984). The Banaue Area Development Center (BADC) was established in Banaue, Ifugao Province, as the seat of on-farm experimentation on technology verification. The general objectives of the STP are to increase the farm productivity and incomes of rice terrace farmers and to improve the nutritional conditions and status of the population. Trials are currently underway at the BADC following lowland rice-fish culture recommendations (Cagauan 1987; Arce 1988).

Economic Significance

Rice-fish culture is considered as an ideal method of land use since the land is utilized for the production of both rice and fish (Coche 1967). Viewed from a broader perspective, the system allows farmers to diversify their production and enables them to fully utilize farm labor, especially during the periods of low labor demand and off-season. Thus, the system results in the maximum utilization of farm resources.

Information on the economics of rice-fish culture is scarce. Perhaps this is largely because fish culture in ricefields is still largely a small-scale, backyard type of operation where the produce, especially fish, is mainly consumed by the farm household. About 80% of the total fish production in ricefields is consumed by the farm family (Tagarino 1985).

However, the available information shows that rice-fish culture is a profitable enterprise. Table 5 shows that the net returns from rice-fish culture is higher by about 27%, compared to rice monoculture (Arevalo 1987). Although expenses are higher in rice-fish culture resulting from more labor expenses and fingerling costs, this is more than compensated by the income from fish. Tagarino (1985) also showed that concurrent rice-fish culture is profitable.

Case studies have shown that profits are higher on concurrent and rotational rice-fish systems than rice monoculture (dela Cruz 1980a; Sevilleja and Lopez 1986). In Torres and Sevilleja (1983), among four freshwater fish production systems, rice-fish culture obtained the highest rate of return (2.55) and capital productivity (3.55).

Prospects and Constraints

Resource Potentials and Prospects for Rice-Fish Farming

The Philippines is basically a rice-producing country where majority of the farmers depend on rice production for their livelihood. Likewise, Filipinos are generally rice- and fish-eating people.

In 1985, the national total rice area was around 3.24 million ha, about 558,943 ha were irrigated under the direct supervision of the National Irrigation Administration (NIA). Outside these areas, about 650,000 of ricefields are irrigated by farmer-managed communal irrigation systems and are under pump irrigation (NEDA 1985; NIA 1985).

Table 5. Comparative costs and returns per hectare per crop of rice monoculture and concurrent rice-fish culture under the 1986 National Rice-Fish Culture Program (modified after Arevalo 1987).

Item	Price per unit (US$)	Value/Cost (US$/ha)[a]	
		Rice monoculture	Rice-fish
Gross returns		700	799.75
Rice	0.18/kg	700	673.75
Fish	0.90/kg	-	126.00
Costs		469.35	505.6
Variable		389.85	426.10
Labor[b]		244.25	248.30
Seeds	0.30/kg	15.00	13.50
Fertilizer		57.50	57.50
Chemicals		73.10	66.20
Fingerlings	0.01/pc	-	37.50
Screens, plastic bags		-	3.10
Fixed		79.50	79.50
Interest on loan		11.25	11.25
Land amortization		29.00	29.00
Irrigation fee		21.85	21.85
Others[c]		17.40	17.40
Net returns		230.65	294.15

[a]Original values in Philippine Pesos were converted to US$ at the rate of US$1 = Pesos 20.00 as of 1987.
[b]Includes in kind payment for harvesting and threshing.
[c]Includes *Samahang Nayon* (Farmers' Association) contributions, land tax and crop insurance.

Rice production in the country is concentrated in Regions II, III and VI which accounts for more than 50% of the country's production. These regions have the most extensive irrigated areas. The largest irrigation systems are found in Regions II (Magat River) and III (Upper Pampanga River Integrated Irrigation System). Cagayan Valley (Region II) is largely a landlocked area, while a great portion of Central Luzon (Region III) is inland. If fish supply in these areas is to be increased, then substantial increases in fish production from inland resources should be made. Irrigated ricefields provide great potentials for fish culture. For example, if 10% of the total irrigated ricefields of about 1.2 million ha is devoted for rice-fish culture, an additional fish production of 24,000 t would be available at an estimated average yield of 200 kg/ha. This would mean an increase of about 4.3% over the 1987 fish production from the aquaculture of 560,970 t. This increase would be much more significant in landlocked rice-producing but fish-deficient areas where the technology is envisioned to be adopted.

The rice terraces, also in Region II, cover an area of approximately 30,000 ha. No one knows the extent of rice-fish culture in these areas. In 1987, only 25.5 ha were documented as devoted to rice-fish culture in the province of Ifugao (BADC 1987). A sizeable portion of the rice terraces maintains their natural grandeur with continuous irrigation by rivers and streams. In general, however, the terraces are faced with the problem of possible destruction due to underutilization and abandonment (NFAC 1984). Rice-fish culture is a potentially beneficial technology for the rice terraces. However, farmers should first be liberated from their bondage of traditional rice culture practices.

Constraints to Development

Several authors have presented excellent reviews on the subject of rice-fish culture (Hora and Pillay 1962; Khoo and Tan 1980; Temprosa and Shehadeh 1980). All demonstrate the bright economic potentials of rice-fish culture. However, in spite of its technical and economic feasibility, the technology has not been widely adopted. The constraints that hamper the development of rice-fish culture are technical, socioeconomic and management-related in nature. Moreover, there are other reasons for the decline and for the failure of expansion programs which are complex and difficult to define (Pullin 1985).

Farmer acceptance of the technology has been hampered by some built-in technical constraints within the system itself. The combined culture of rice and fish faces the problem of intensive use of pesticides, generally recognized as necessary, especially with the use of high-yielding rice varieties. Although some advances had been achieved on selecting the kind of chemicals that are safe for use in rice-fish culture and their proper application methods and dosages (Arce and dela Cruz 1978; Heinrichs et al. 1988), still some farmers indiscriminately use pesticides resulting in irreversible damage to fish and humans as well.

One general criticism of the system is the relatively small fish at harvest especially in concurrent rice-fish culture because of the short fish culture period. This problem is further aggravated by the concept of multiple cropping in rice cultivation, which leaves little time for fish culture because of the shorter duration of water in ricefields. Water use is critical, especially in the concurrent system. Adopting the system may complicate rice culture management practices.

Another reason is the lack of understanding of the technology by farmers who have not fully appreciated its economic benefits. Farmers generally consider that raising fish in ricefields requires additional expenses for fingerlings and the construction of bigger dikes and trenches. Moreover, expenditures on supplemental feeds can be considerable if farmers aim for higher fish production. These additional cash outlays may compound their financial problems.

Many farmers also lack motivation or find it difficult to change work and social habits in order to grow fish with the more important rice crop. Marketing can also be a problem. Freshwater fish must be sold live or fresh to command a high price. In coastal areas, the market price of freshwater fish can be discouragingly low because consumers prefer marine fish.

Farmers complain of the lack of fingerling supply. Although there have been considerable development and improvement in the tilapia hatchery industry because of the high rates of return (Yater and Smith 1985), the problem may not be availability, but the timing and accessibility to seed sources.

Expansion of rice-fish culture should be a logical eventuality considering the farmers' very limited farm size and low production levels. The limited adoption of rice-fish culture in the rice terraces of the Cordilleras is attributed to the lack of proven technology packages highlighting the farming systems production approach to intensify and maximize land utilization; inadequate adaptable rice production technology; shortage of trained extensionists; limited accessibility into many areas; and limited availability of desired fish species (Ramsey 1983; NFAC 1984).

Research Thrusts/Needs and Methodologies Preferred

Rice-fish farming systems remain a wide open field for multidisciplinary research in the Philippines involving agronomists, agricultural economists and other social scientists. Although substantial research have been underway, numerous constraints need to be resolved to accelerate the diffusion of the technology to farmers. Several authors have identified general research needs in rice-fish farming (dela Cruz 1980b; Furtado 1980), which to date remain basically the same. However, in the light of the increasing recognition of aquaculture as an integral part of a farming systems approach to agricultural development, there is a need to reorient research thrusts to focus on both the agronomic and fish culture aspects of rice-fish culture.

Improvement and refinement of the techniques for rice-fish culture, for both the concurrent and rotational systems, remain a major research thrust for the future. Specifically, more information should be generated in the role played by the rice agronomy in relation to fish culture in ricefields. Consequently, understanding the agronomic and aquaculture interactions may result in the development of modified, improved or alternative rice-fish farming systems. Some relevant research areas include the use of appropriate fish species as biological control of weeds and insect pests and the use of organic manures and pesticides and their attendant biological and economic implications.

In the Philippines, tilapia is the primary species grown in ricefields. Genetic improvement of the fish is ongoing as a national top priority research program. Evaluation should include testing tilapia in ricefields. A range of other fish species should also be developed.

More research on the socioeconomics of rice-fish farming systems are needed. Research areas are on impact assessment, optimum resource allocation, substitution and complementarity among commodities, full employment and labor resources and social desirability of the technology.

Technologies must be verified both under different environmental conditions and in farmers' fields. Together with technology packaging, costs and returns should be documented and disseminated.

Rice-Fish Farming Development Strategy

More institutional support is necessary to accelerate the adoption of the technology. Better liaison between researchers and farmers can be established with more appropriate extension approaches and systems validation. The government should consider policies and programs in support of rice-fish culture such as subsidies, incentives, access to credit and infrastructural support. These points have long been the recommendations of the National Rice-Fish Coordinating Committee, but have not been fully implemented.

The farmers, who are the ultimate beneficiaries, should be educated more on the nature and significance of the technology. There is therefore a need for a more vigorous information dissemination campaign.

Conclusions

The future outlook of rice-fish farming systems in the Philippines is definitely bright. Despite some setbacks in the past which have hampered the development of the technology, very recent and current developments show a renewal of interest and increasing awareness of the benefits from rice-fish culture.

Farmers are slowly laying aside some of their indifferences towards the technology. There is sufficient justification to be optimistic that in due time, rice-fish culture will play a major role in the social and economic upliftment of a majority of Filipino rice farmers.

Acknowledgements

The author wishes to thank the ADB for its technical assistance grant for the ICLARM-IRRI-CLSU Rice-Fish Farming Systems Project. Thanks also are due to Prof. A.G. Cagauan for providing substantial information about rice-fish culture in rice terraces; to Mr. E.M. Vera Cruz and Mr. N.O. dela Cruz for preparing the figures and illustrations; and to Ms. N.T. Andres for typing the manuscript.

References

Anon. 1974. Exploratory trial on rice-fish culture. Progress Report of the Freshwater Aquaculture Center. NSDB-Assisted Project No. 7103. Central Luzon State University, Nueva Ecija, Philippines.

Arce, R.G. 1988. Rice-fish culture trials at the Banaue Agricultural Development Center (BADC), Banaue, Ifugao. Paper presented at the Planning Workshop on Rice-Based Research and Development Program for the Cordilleras, 11-12 February 1988, Nueva Vizcaya Institute of Technology, Nueva Vizcaya, Philippines.

Arce, R.G. and C.R. dela Cruz. 1978. Improved rice-fish culture in the Philippines, p. 136-145. *In* Proceedings of the Second International Commission on Irrigation and Drainage (ICID) Regional Afro-Asian Conference, 4-9 December 1977, Manila, Philippines.

Arevalo, T.Z. 1987. The rice-fish culture program. Paper presented at the Fisheries Forum on "The Developments in Integrated Agri-Aquaculture Farming Systems", 27 March 1987. Bureau of Fisheries and Aquatic Resources, Quezon City, Philippines. 12 p.

BADC. 1987. Status report, 1987. Banaue Agricultural Development Center, Department of Agriculture (District Office, Ifugao Province), Ifugao, Philippines.

Boeck, A. 1982. Rice terraces and fish: integrated farming in the Philippines. ICLARM Newsl. 5(3):24.

Cagauan, A.G. 1987. Biology and culture of potential fishes in the rice terraces region. Central Luzon Agricultural Research Consortium Review, Central Luzon State University, Nueva Ecija, Philippines.

Cagauan, A.G. and V.C. Nerona. 1986. Tilapia integrated rice-fish culture with *Azolla* as biofertilizer. Fish. Res. J. Philipp. 11(1 and 2):29-34.

Campos, A.C. 1985. Rice-fish culture in the Philippines, p. 315-323. *In* Trin Ton That (ed.) Rice: progress assessment and orientation in the 1980s. Proceedings of the 16th session of the International Rice Commission, 10-14 June 1985, Los Baños, Laguna, Philippines. Int. Rice Comm. Newsl. 34(2). Food and Agriculture Organization, Rome.

CLARC. 1985-1987. Integrated review and evaluation of completed and ongoing researches. Central Luzon Agricultural Research Consortium Review. Central Luzon State University, Nueva Ecija, Philippines.

Coche, A.G. 1967. Fish culture in ricefields. A world-wide synthesis. Hydrobiologia 30:1-44.

dela Cruz, C.R. 1980a. Integrated agriculture-aquaculture farming systems in the Philippines with two case studies on simultaneous and rotational rice-fish culture, p. 209-224. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

dela Cruz, C.R. 1980b. Integrated farming with fish as a major enterprise, p. 22-23. *In* M.H. Tetangco (ed.) Proceedings of the Symposium/Workshop on Agribusiness Systems for Integrated Crop-Livestock. Fish Farming FFTC Book Series No. 16. Los Baños, Laguna, Philippines.

dela Cruz, C.R. and E.A. Lopez. 1980. Rotational farming of rice and fish. Fish. Res. J. Philipp. 5(1):39-52.

FAC. 1974-1984. Freshwater Aquaculture Center Technical Report No. 2-23. Central Luzon State University, Nueva Ecija, Philippines.

FAC. 1985. Fish culture in rice paddies Technical Brochure. Freshwater Aquaculture Center, Central Luzon State University, Muñoz, Nueva Ecija, Philippines.

Furtado, J.I. 1980. Research and information requirements for integrated agriculture-aquaculture farming systems, p. 251-256. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Heinrichs, E.A., G.B. Aquino, J.A. McMennamy, J. Arboleda, N.N. Navasero and R.G. Arce. 1977. Increasing insecticide efficiency in lowland rice, p. 41-47. *In* Agricultural mechanization in Asia. Farm Machinery Industrial Research Corp., Tokyo, Japan.

Hora, S.L. and T.V.R. Pillay. 1962. Handbook on fish culture in the Indo-Pacific Region. Fish. Biol. Tech. Pap. 14. Food and Agriculture Organization, Rome. 264 p.

Khoo, K.H. and E.S.P. Tan. 1980. Review of rice-fish culture in Southeast Asia, p. 1–16. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Manacop, P. 1960. A proposal: program of research on rice-paddy-fish culture for the International Rice Research Institute, IRRI, Los Baños, Laguna, Philippines. 16 p.

Mang-umphan, K. 1987. Culture of Nile tilapia (*Oreochromis niloticus* Linneaus) in rice-fish culture using chemical and commercial organic fertilizers. Central Luzon State University, Nueva Ecija, Philippines. M.S. thesis.

NEDA. 1985. Philippine yearbook 1985. National Economic and Development Authority. Manila, Philippines.

NFAC. 1984. Save our Terraces Program: phase one. National Food and Agriculture Council. Ministry of Agriculture and Food. Manila, Philippines.

NIA. 1985. Annual Report 1985. National Irrigation Administration. Manila, Philippines.

Pullin, R.S.V. 1985. Time to reappraise rice-fish culture. ICLARM Newsl. 8(4):3–4.

Ramsey, P. 1983. Rice-fish practices in Ifugao Province, Philippines. ICLARM Newsl. 6(3):8.

Sevilleja, R.C., A.V. Circa and R.L. Encarnacion. 1985. Preliminary trial on integrated rice-pig-fish farming system. Central Luzon Agricultural Research Consortium Review. Central Luzon State University, Nueva Ecija, Philippines.

Sevilleja, R.C. and E.A. Lopez. 1986. Rotational fish-crop system. Central Luzon Agricultural Research Consortium Review. Central Luzon State University, Nueva Ecija, Philippines.

Tagarino, R.N. 1985. Economics of rice-fish culture systems, p. 122–150. *In* I.R. Smith, E.B. Torres and E.O. Tan (eds.) Philippine tilapia economics. ICLARM Conf. Proc. 12, 261 p.

Torres, M.C. and R.C. Sevilleja. 1983. Preliminary economic analysis of freshwater fish production under various management systems. Freshwater Aquaculture Center Tech. Rep. 23, Central Luzon State University, Nueva Ecija, Philippines.

Temprosa, R.M. and Z.H. Shehadeh. 1980. Preliminary bibliography of rice-fish culture. ICLARM Bibliogr. 1, 20 p.

Yater, L. and I.R. Smith. 1985. Economics of private tilapia hatcheries in Laguna and Rizal provinces, Philippines, p. 15–23. *In* I.R. Smith, E.B. Torres and E.O. Tan (eds.) Philippine tilapia economics. ICLARM Conf. Proc. 12, 261 p.

Ricefield Fisheries in Thailand

ALEX FEDORUK
WATTANA LEELAPATRA
Department of Fisheries
NIFI Building, Kasetsart University
Bangkhen, 10900
Bangkok, Thailand

FEDORUK, A. and W. LEELAPATRA. 1992. Ricefield fisheries in Thailand, 91–104. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Fish are produced in ricefield capture and culture fisheries in Thailand. Annual production from ricefield capture fisheries is about 75,000 t valued at US$75 million. These fisheries may be in jeopardy due to agriculture pollution and large-scale water management developments which reduce the entry of wild fish to ricefields.

Ricefield culture fisheries account for less than 0.05% of the country's 8.9 million-ha rice lands. The integration of rice and fish is increasing despite setbacks related to the introduction of high-yielding varieties of rice and use of pesticides. About 3,000 farms are engaged in rice-fish farming. Annual rice production is 3,000 t, while fish production ranges from 30 to 900 kg/ha and in some cases, 1,875 kg/ha. The potential is vast for the expansion of rice-fish farming through improved production techniques and new production systems.

The cultivation of rice and fish makes good use of agricultural lands, produces fish for home consumption, increases rice yields and generates additional income from fish sales. Increasing the benefits of rice-fish farming within the context of integrated rural development is proposed. This could be done by instituting a Department of Fisheries program on rice-fish farming involving coordination with other agencies and the development of appropriate technical services.

Introduction

Ricefield capture fisheries relies on natural fish seeding. Its contribution to rural welfare is ensured so long as the integrity of wild fish populations is maintained. Current concerns in this regard include the decimation of stocks by agricultural and industrial pollutants and the prevention of fish migration to spawning grounds by water projects. Mitigating such losses in the interest of supporting rural development could be achieved through improving management techniques in ricefield fisheries.

Integrated rice-fish farming has been practised in Thailand for perhaps more than 200 years (Pongsuwana 1962). Early applications, largely localized in the Northeast, were apparently simple and dependent upon capturing wild fish for stocking into ricefields. During and after the World War II, the Department of Fisheries (DOF) promoted rice-fish farming by providing seed fish and extending technologies. Ricefield fisheries proliferated in the Central Plains (Fig. 1). In the 1950s, fish yields ranged from 137 to 304 kg/ha/crop, while rice yields were increased by 25 to 30% in rice-fish fields in the Central Plains (Pongsuwana 1962).

However, in the 1970s, the consequences of introducing to Thailand high-yielding varieties (HYV) of rice resulted to

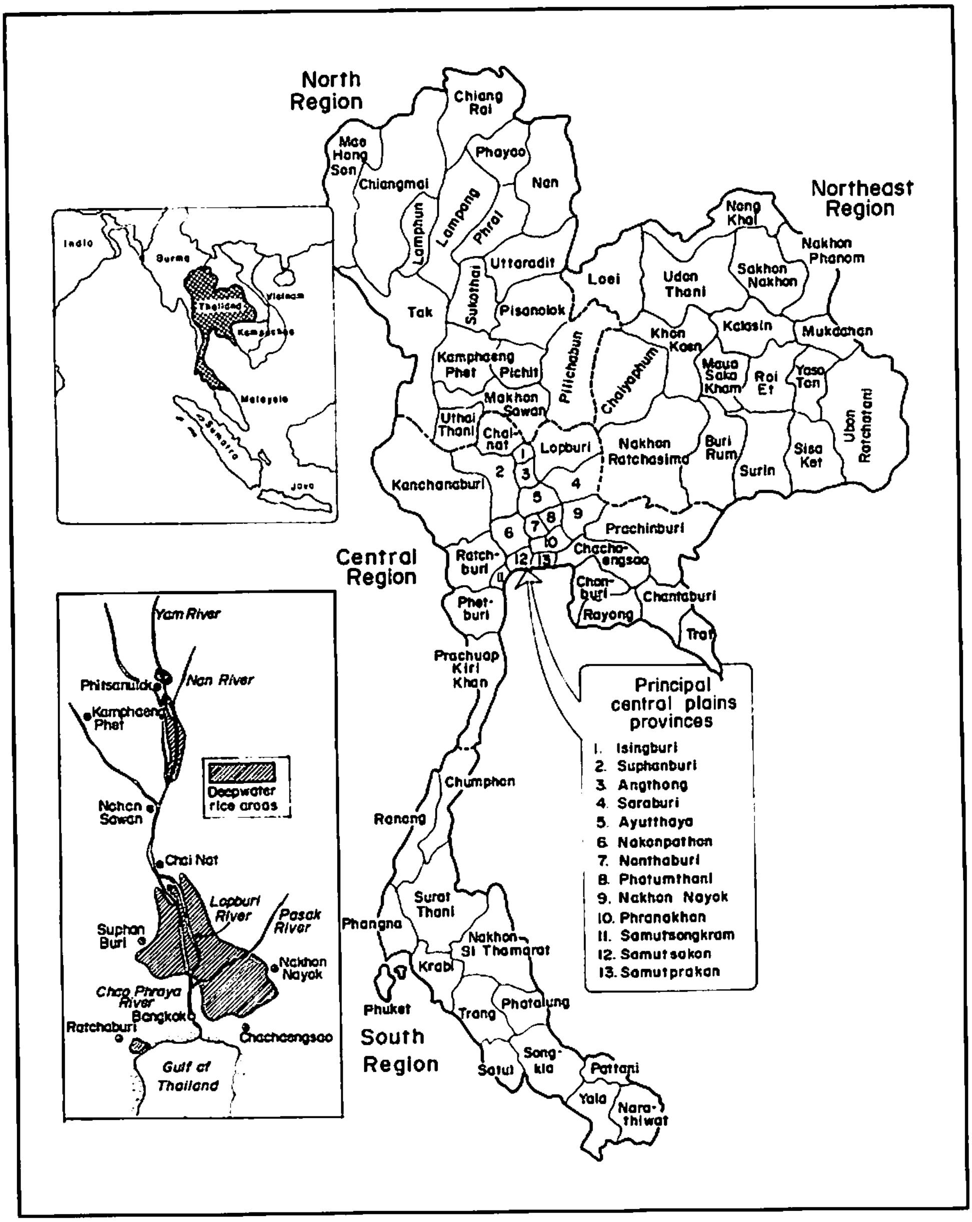


Fig. 1. Regions and provinces of Thailand. Insert: Principal deepwater rice areas of Thailand.

a near collapse of rice-fish farming in the Central Plains. Relying on heavy pesticide applications to achieve the target production, the use of HYV resulted in environments toxic to fish. Farmers either separated their rice and fish operations or stopped growing fish. Moreover, the DOF's Center for Rice-Fish Farming Research in Chainat established in 1968 to develop appropriate technologies, was closed in 1974.

Despite these setbacks, rice-fish farming was not discontinued. In recent years, it has recovered especially in the Central Plains, North and Northeast Regions. This revitalization was due to the: 1) more discriminate use of HYV; 2) emergence of rice pesticides which, if properly applied, were not toxic to fish; 3) increased capability of the DOF to deliver supporting technical services; 4) verification of the economic viability of some rice-fish farming practices; 5) growing perception of the economic benefits of rice-fish farming; and 6) promotion of rice-fish in special projects assisting disadvantaged farmers.

This paper examines the potential of ricefield fisheries in Thailand with a particular focus on rice-fish farming within the context of rural development.

Status of Rice Production and Rice-Fish Farming

Resource Base

The resource base for rice-fish farming in Thailand are the ricefields and the rice varieties grown. About 8.9 million ha is under rice cultivation, approximately 19% is potentially irrigated. About 5.6% of the rice land is double cropped, one crop is grown in the wet season and the other, in the dry season with irrigation. The distribution by provinces and fisheries zones is shown in Table 1.

The type and variety of rice grown determines the culture period, water regime in the field and the quality of water as influenced by fertilizers and pesticides. Ricefield capture fisheries operate in the environment predicated by rice. Rice-fish farming, however, involves measures for improving fish production by modifying the environment without affecting rice productivity.

Table 1. Rice area, production and yield by Fisheries Command Zone (FCZ) and Region, 1982–83. (Source: Department of Agricultural Extension, Bangkok, Thailand).

Region	Total			Double cropped		
	Area ('000 ha)	Production ('000 t)	Yield (kg/ha)	Area ('000 ha)	Production ('000 t)	Yield (kg/ha)
Central	1,964	4,090	2,082	506	1,756	3,468
FCZ 1	865	1,822	2,107	264	891	3,367
FCZ 2	477	1,060	2,222	185	695	3,752
FCZ 3	622	1,207	1,940	57	171	3,010
North	2,112	4,578	2,167	66	201	3,019
FCZ 4	1,430	2,634	1,842	32	118	3,678
FCZ 5	682	1,944	2,849	34	83	2,409
Northeast	4,258	4,942	1,161	35	79	2,270
FCZ 6	1,965	2,002	1,018	10	22	2,294
FCZ 7	1,355	1,777	1,311	17	41	2,372
FCZ 8	938	1,163	1,240	8	16	2,025
South	654	1,135	1,735	26	66	2,568
FCZ 9	538	946	1,760	25	60	2,557
FCZ 10	116	189	1,625	0.2	0.8	4,000
Thailand	8,987	14,744	1,640	633	2,101	6,318

[1]Totals may not tally due to rounding off.

Rice Cultivation

GENERAL AGRONOMY

Thailand grows three types of rice: lowland, deepwater and upland, with lowland rice accounting for more than 95%. Rice varieties, including glutinous and non-glutinous, have been developed for different soil types and climates of the country. Some are hybrids of native varieties which are photoperiod sensitive and have a definite harvesting date. Others, referred to as RD varieties in Thailand, are crosses between native and HYV developed by the International Rice Research Institute (IRRI). They are mostly photoperiod insensitive and can be grown any time provided water is available (Table 2).

Table 2. Agronomic characteristics of common rice varieties in Thailand. (Source: Department of Agricultural Extension, Bangkok, Thailand.

Rice varieties	Kind[a]	Optimum water depth (m)	Culture period (days)	Harvest time
Photo insensitive				
RD 1, 2, 3, 21, 23	NG	0.1–0.15	120–130	
RD 4, 10	G	0.2–0.3	127–130	
RD 5, 11	NG	0.1–0.15	135–140	
RD 7	NG	0.5	120–130	
RD 9	NG	0.1–0.15	115–125	
RD 25	NG	0.1–0.15	100	
RD 17 (Floating)	NG	1.0	140	
Photo sensitive				
Central Region				
88, S-4	NG	0.1–0.15	130–150	21–26 Nov
148, RD 27	NG	0.1–0.15	130–150	3–10 Dec
123, 17	NG	0.1–0.15	130–150	19–20 Dec
North Region				
62M, RD 6, NS	G	0.2–0.3	130–150	20–26 Nov
105, 148	NG	0.2–0.3	130–150	25 Nov
Northeast Region				
HY-71, RD 6, RD 8, ND	G	0.2–0.4	130–150	Nov
NSG-19, RD 15, KDM-105	NG	0.2–0.4	130–150	Nov
KPM-148, KTH-17	G	0.2–0.4	130–150	Nov
South Region				
PR-2, NP-132, RD 13	NG	0.2–0.3	130–150	Feb
Floating Rice				
NC	G	1.0	200–240	30 Nov
T-161, PG-56, RD-19	NG	0.5–1.0	200–240	Dec
Upland Rice				
SM	G	0.15–0.20	130–150	15 Oct
GML	NG	0.15–0.20	130–150	Nov/Dec

[a]NG = nonglutinous; G = glutinous.

The RD varieties are shorter and require less growing time and water depth than native varieties. Moreover, they are dependent upon relatively heavy applications of fertilizers and pesticides, and are seriously affected by water depths exceeding 30 cm which often occur during rainy season. The RD varieties perform best in the dry season with irrigation. Although the productivity of RD varieties is higher (50% or more) than native varieties, grain quality is poorer.

In growing rainfed lowland rice, farmers tend to hold as much water in the fields as possible to ensure water against insufficient rainfall. Consequently, bund heights are often 30 cm or more. Crop duration of the first rice crop ranges from 130 to 150 days. The growing period of rainfed rice and fish is shown in Fig. 2.

If a second crop of RD varieties is grown under irrigation, growing time may range from 100 to 140 days; February through July in the Central, North and Northeast Regions; and April through September in the South.

Deepwater rice, including floating and tall varieties, are grown in extensively

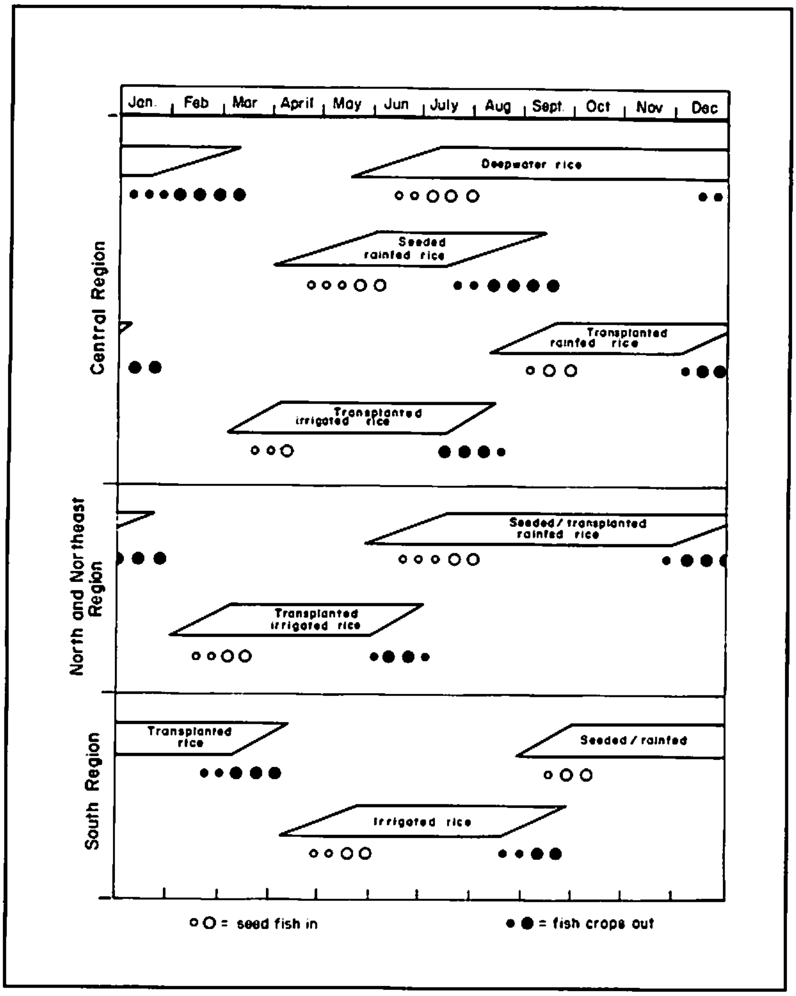


Fig. 2. Growth duration of rice and associated fish crops by type of rice and regions.

flooded swampy terrain. There are about 700,000 ha of deepwater rice in Thailand, mostly around the Chao Phraya River between Bangkok and Chainat and some further North around the Yom River (Fig. 1). Floating rice varieties are grown in areas where water depths is greater than 1.0 m, while tall varieties with limited elongation ability are grown where water depths range from 0.5 to 1.0 m. With few exceptions, individual fields are not bunded and territory is designated by simple fences or reference markers. The growing period is about eight months and applications of fertilizers and pesticides are generally low. Crops are adversely affected by drought every two to three years. Average yield is 1–2 t/ha, but is lower in some southern parts of the Central Plains where acid sulfate soils occur.

Rice is also grown in mountainous areas of the North, Northeast and South. Production, while relatively small, is of significance locally. Fields are often terraced and individually bunded to allow water depths of 15–30 cm. Most rainfed crops are planted by direct seeding and irrigated crops by transplanting. About seven tillers per plant is usually reached 30 days after seeding or 10 days after transplanting.

WATER MANAGEMENT

Rice requires varying amounts of water at different growing stages, so that water levels need to be managed by farmers (Fig. 3). The first rice growth stage which is the nursery period, lasts 10 days when seeds are transplanted and 30 days when directly seeded. Water depths at this stage increase gradually from nearly zero to about 5 cm. For the next 50 days, water depth is increased as the rice plant grows. Maximum water depths are maintained until the crop matures. Water is drained to zero about one month before harvesting.

FERTILIZATION

Some farmers apply organic fertilizers before starting the crop. Few apply fertilizers to rainfed varieties during the growing period, since most believe that whatever they apply is lost when flooding occurs and that local varieties are unresponsive to fertilizers. Inorganic fertilizers are always applied to HYV. The

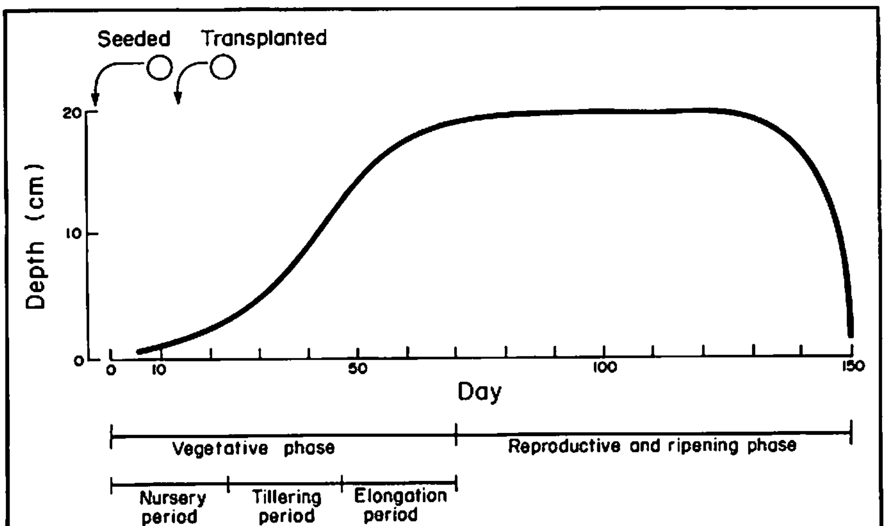


Fig. 3. Representative water regime in rice cultivation.

recommended rate ranges from 60 to 100 kg/ha spread over three applications: first in the nursery period; the second about 40 days after the crop has started; and the last, about 20 days later.

PEST CONTROL

Principal pests in rice farming include weeds and insects. Weed control involves timely flooding of fields, use of mechanical weeders, hand weeding and use of chemical herbicides. Use of insecticides for insect pest control is increasing not only with HYV but also with traditional rice (Table 3). Its effectiveness and environmental impact varies with kind and application technique. Pesticides are applied as foliar sprays and by broadcasting granules. Most farmers tend to use more than the recommended rates.

HARVESTING

Water is drained about one or two weeks before harvest to facilitate the movement of machinery and workers. Generally, rice are harvested manually, but mechanical harvesters are sometimes used. During the dry season, fields are left fallow. A second crop of rice or other crops is grown in irrigated areas but in rainfed areas, second crop is rarely grown.

Table 3. Common insecticides used in rice culture in Thailand. (Source: Koesoemadinata 1980).

Insecticide	Toxicity to fish (96-hour LC_{50} in ppm)
Common in the 1970s	
Gamma-BHC	0.13
BPMC	5.4
Dieldrin	0.0113
Endosulfan	0.0028
Endrin	0.00063
Malathion	1.3
Parathion	1.269
Recent introductions	
Carbaryl	5.5
Carbofuran	1.27

Ricefield Capture Fisheries

Ricefield capture fisheries of Thailand rely on wild fish entering ricefields with no fish management inputs. Predominant species are usually predators such as snakehead (*Channa striata*) and walking catfish (*Clarias batrachus*) and other air breathers (e.g., climbing perch [*Anabas testudineus*]). Some carps and barbs frequently become prey to predators or die for other reasons. Fish are captured manually or by traps during rice harvest.

Production from this capture fishery is generally unrecorded. Unsubstantiated claims, however, indicate that past yields were higher than current ones. The reason may be due to decline in wild stocks which is associated with agricultural pollution and to water projects which have impeded natural fish migration. Spiller (1985) postulates that ricefield capture production in Thailand may be around 25 kg/ha, while those in other Asian countries range from 1.5 to 84 kg/ha. Assuming 1/3 of the rice lands produce fish at 25 kg/ha, the annual yield of the ricefield capture fishery will be about 75,000 t. With US$1/kg wholesale value at the landing place, total value is $75 million.

Ricefield Culture Fisheries

PRODUCTION

Yearly fish production in rice-fish farming by region from 1975 to 1982 is shown in Fig. 4. There is no data in the southern region where it is presumed negligible. Production in the three regions increased from 600 t in 1975 to 3,000 t in 1982. The accelerated increase from 1980 to 1982 may be a reflection of the

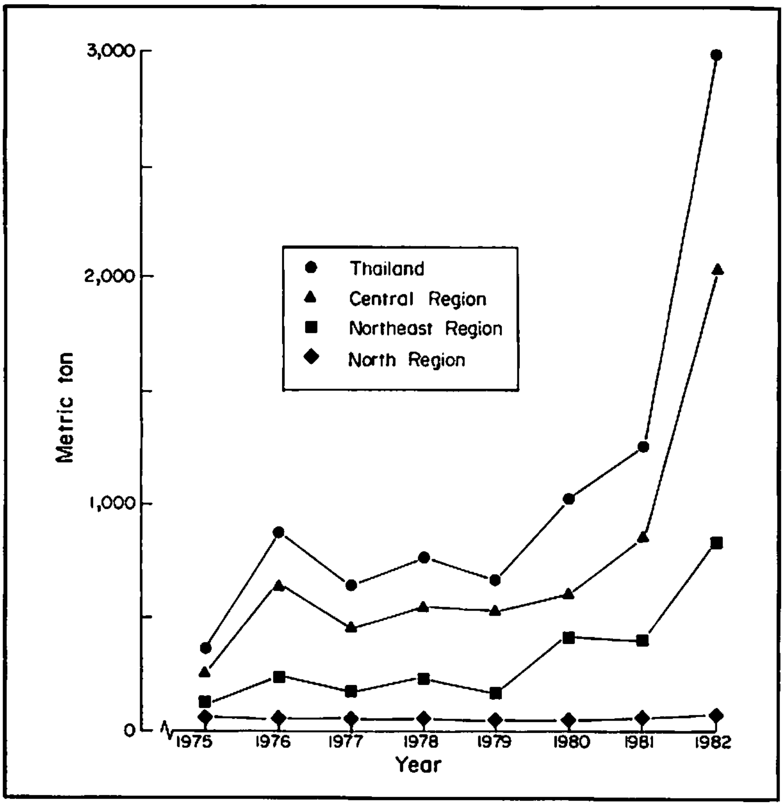


Fig. 4. Fish production in rice-fish farming in Thailand. (Source: DOF 1983)

development and technological factors identified earlier.

There were 2,620 rice-fish farms covering 2,820 ha of ricefields, or 0.03% of Thailand's total rice area (Table 4). Eighty per cent of the farms were in the Northeast, 18% in the Central Region and 2% in the North. Fish production in ricefields from the Central Region which accounts for 71%, may be an overestimate, since there is no adequate distinction between harvests from rice-fish culture in ricefields and intensive fish culture in ponds.

With more hatchery seed fish available, introduced species accounted for 93% of the fish yields in ricefields compared to 77% in 1975 (Table 5). However, some case studies showed that farmers continuously crop wild fish, which are not accounted in the production data (Fedoruk and Leelapatra 1985). Among the cultured species, common carp (*Cyprinus carpio*) and silver barb (*Puntius gonionotus*) are becoming more popular.

MANAGEMENT PRACTICES

In irrigated areas, concurrent and rotational systems are practised. The three types of rice-fish farming are the trap sump, open dike and closed dike. Trap sump and open dike are usually found in rainfed areas. Closed dike type is found in rainfed, irrigated and deepwater environments.

For the trap sump, a 50-100-m² area, 1.0–1.5-m deep sump is dug at the lowest part of the field. No bunding is involved. The sump provides refuge for fish while concentrating them for harvest. Some

Table 4. Fish production in rice-fish culture fisheries, Thailand. (Source: DOF 1983).

	Region			
	Central	North	Northeast	Thailand
No. of rice-fish farms	474	68	2,086	2,628
Total area (ha)	1,420	79	1,321	2,820
Average/farm size (ha)	3.0	1.2	0.6	1.1
Production (t)	2,090	37	818	2,945
Yield (kg/ha)	1,472	468	619	1,044
Value at farmgate price (US$/ha)	1,472	468	619	1,044
Total value (US$ million)	2.08	0.03	0.82	2.93

Table 5. Comparison of 1975 and 1981 rice-fish culture fisheries, Northeast Thailand. (Source: DOF 1983).

	1975		1981	
No. of farms		675		1,741
Total area (ha)		402		1,068
Average farm size (ha)		0.6		0.6
Total fish yield (t)		107		393
Yield composition in tons (%)				
Introduced species	77	(72)	365	(93)
O. niloticus	28	(26)	45	(12)
P. gonionotus	0		91	(23)
C. carpio	49	(46)	229	(58)
Wild species	30	(28)	28	(7)
C. batrachus	8	(7)	9	(2)
C. striata	15	(14)	15	(4)
Others	7	(7)	4	(1)
Production (kg/ha)	266		362	
Introduced species	192		336	
Wild species	75		26	

farmers stock fish, but they escape when fields become flooded. Thus, the reported fish production from wild fish is about 30–60 kg/ha/crop. The trap sump, a transition from rice-fish capture to culture fisheries, demonstrates that simple management can increase fish production from 25 to 30–60 kg/ha. Trap sumps are widespread in Thailand, but since few introduced fish are involved, its area and production are not usually represented in the DOF's statistics.

The open and closed dikes are bunds converted to dikes built to 1 m. Management practices involve stocking of seed fish and applying inputs at varying levels. The water inlets and outlets are screened by nets or bamboo fences to control the entry and exit of fish. There are spillways or buried conduits in dikes for automatically controlling water levels, for directing discharge through fish traps, or for secondary uses. Trap sumps are also used. In some cases, fish refuge trenches 1–2 m wide and 0.5–1.0 m deep of various lengths are constructed. A mix of *C. carpio*, *P. gonionotus* and Nile tilapia (*Oreochromis niloticus*) are stocked to exploit the niches in ricefields. Fertilizers, mainly organic, are provided to promote the production of fish food organisms in ricefields. Supplemental feeds, largely indigenous materials such as rice bran and boiled rice, are fed to the fish.

Open dikes, applied on sloping or hilly terrain, are characterized by a two- to three-sided dikes in the lower part of the ricefield. Fish are free to forage beyond the ricefield as water conditions allow. Spiller (1985) estimated that fish yields range from 125 to 188 kg/ha/crop. In a case study where management was sophisticated, fish yield was 413 kg/ha/crop with a B:C of 1.6:1 (Fedoruk and Leelapatra 1985).

Closed dikes completely enclose the ricefield. Fish yields from this type range from 180 to 300 kg/ha/crop in concurrent systems under rainfed conditions, from 180 to 900 kg/ha/crop when grown with HYV, and from 750 to 900 kg/ha/crop when produced in rotational systems with irrigation water depending on the density, the initial size of fish at stocking and duration of culture period (Spiller 1985). Growing fish with rainfed rice in closed dikes is most common and is geared to the production of table fish only. Few farmers practise rice-fish farming using irrigation water.

In two separate surveys of 4 and 14 farms in Northeast Thailand, increases in rice yields ranged from 3 to 22% (Spiller 1985). Only one farmer who produced a second irrigated crop and used HYV reported a 58% decrease in rice yields.

Some innovative isolated cases have been observed by Spiller (1985). These methods illustrate adaptations to circumstances and the evolutionary direction of management. Noticeable examples are:

1) A closed-dike rainfed operation in Maha Sarakham pump water from an adjoining pond that is enriched with dung from chickens raised above the pond.
2) A rotational rice-fish system in Kalasin incorporated separate adjoining brood and nursery ponds fed with irrigation water which allowed self-reliance in seed fish. Some brooders were produced in the ricefield.
3) Trials by the Chiang Mai Fisheries Station involved the use of double dikes to check flooding problems in concurrent rice-fish culture. The higher outer dike controls the flood waters, while the lower inner dike controls water levels in the field.
4) Instead of placing the trapping sump within the ricefield, a few farmers in Sakhon Nakhon concentrate fish in sumps outside the field. The sump may be connected to the field by a trench or a buried conduit.
5) Few farmers in the Central Plains grow fish and deepwater rice together in closed-dike fields. Enclosing dikes have been built to 1 m or more, but dike breakdown is common due to the pressure of holding deep water. Adult fish (gourami [*Trichogaster* sp.] and *P. gonionotus*) are stocked rather than fingerlings. The time available (8-month culture period) allows spawning within the fields. Even with fish escape due to flooding and dike collapse, yields are still reported to range from 940 to 1,875 kg/ha/crop.
6) One farmer in Sakhon Nakhon practised rotational culture without modifications for fish. After rice harvest, the field was merely flooded and stocked with fingerlings, which reputedly grew well. Since the fish were grown during the dry season, irrigation was available and water levels were controlled.
7) Integration of rainfed rice and fish is practised in terraced fields on hilly terrain around Ubolratana Reservoir. Fedoruk and Leelapatra (1985) reported fish yield of 400 kg/ha/crop, with the fish culture extended in refuge trenches after the rice harvest.

Fisheries projects with rice-fish components are all in Northeast Thailand. Results are limited to field experiences and observations which serve as the basis for techniques being extended. Below are observations and recommendations summarized from Anon. (1983), Thongpan et al. (1984), and Lysack (1985).

OBSERVATIONS

1) Rice-fish farming is most productive in fertile soils with a good waterholding capacity. Water

losses through seepage in sandy soils limit production.

2) Rice production in rice-fish farming is generally higher than in rice monoculture.
3) Flooding and dike breaching, which allow fish to escape, are common.
4) Fish eat young rice plants.
5) The supply and quality of seed fish are inadequate. Those provided by the DOF are often too small – many die during transport, while many more die soon after stocking.
6) Water from irrigation networks is often too muddy and fish do not grow adequately in such water.
7) *C. striata* eat introduced fish.
8) Fish from ricefields are easy to sell provided *O. niloticus* are 400–600 g and *P. gonionotus*, at least 100–200 g.
9) *O. niloticus* often reproduce in the ricefields which results in stunted growth.
10) Chinese carps grow to 1 kg in four months in ricefields.
11) Brackishwater constrains adequate rice and fish yields.
12) Retting kenaf in ricefields reduces water muddiness while stimulating the growth of organisms for fish food.

RECOMMENDATIONS

1) Construct sturdy dikes high enough (1–2 m) to prevent flooding. Grow plants on dikes to help stabilize slopes.
2) Screen ricefield water inlets and outlets.
3) Install refuge trenches around the ricefield to ensure water for fish and allow extended growth period for fish after rice harvest.
4) Use strong-stemmed rice varieties when fish are grown.
5) Stock fish only after rice plants have five to seven tillers.
6) A mixture of fish species is the best. The recommended stocking rates for polyculture are 2,500 *C. carpio*, 1,250 *P. gonionotus* and 1,250 *O. niloticus*, or a total of 5,000/ha.
7) Use large (7–10 cm) fish for stocking.
8) Add fertilizer (composted farm straw, weeds and manure) regularly.
9) Incorporate nursery ponds adjacent to ricefields as part of a fenced trench refuge. Proposed dimensions are 100–500 m^2 and 0.5–1.0 m deep. A suitable management regime involves: drying a pond until the mud cracks; liming and fertilizing; water refilling, fish stocking and applying supplemental feeds (such as boiled rice).

Seed Fish

Seed fish for rice-fish farming are obtained from the DOF, private hatcheries, wild capture and farmers.

The DOF's freshwater seed fish production is about 150 million/year, but is expected to increase due to the development of 10 new field stations. Out of the 15 species produced, 68% (102 million) consist of *P. gonionotus*, *O. niloticus* and *C. carpio* which predominate rice-fish culture. Fifty-seven per cent is produced in the Northeast, 26% in the Central, 13% in the North and 4% in the South. The overall distribution indicates that 70% are stocked in public waters, 20% in fishponds and 10% (15 million) in ricefield fisheries (Table 6).

DOF stations in the Central, North and Northeast Regions distribute about 80% of their seed fish in March to October, with a peak (60% of the total) in June to August. The balance is released in small amounts from November to April. Fish are generally less than 5 cm, mostly about 3 cm.

Studies by the DOF are underway to determine the status of seed fish production by the private sector. Preliminary information indicates there are up to 100 operations in the Northeast with an output of about 130 million seed fish per year. Some operations occur in the North, estimated at 15 million. Although outputs from operations in the Central Region may well exceed 200 million/year; only 5% of these goes to rice-fish farming. In contrast, about 35% of the privately-produced seed fish in the Northeast is sold to rice-fish farmers; and a similar distribution from the Northern Region is assumed. It is also assumed that there are no significant seed fish operations for rice-fish farming in the Southern Region.

The species available from private hatcheries include Chinese carps, Indian major carp *Labeo rohita*, *P. gonionotus*, *O. niloticus* and *C. carpio*. Chinese carps are most available in the Central Region; *L. rohita* are mostly produced in the Northeast (Table 6).

Optimizing fish production in rice-fish farming requires that seed fish are stocked during the early stages of rice crops to allow the longest period of growth. The timing by type of rice and region is shown in Fig. 2. The figure also indicates that the current availability of seed fish for hatcheries more or less coincide with the needs for fish culture in ricefields.

Most private sector seed fish production in the North and Northeast is for rainfed ricefields. Stocks are available from June to August. Some operations in the Central Region are also rainfed; but a few use irrigation water and can supply seed fish throughout the year.

Seed fish prices of DOF and the private sector are presented in Table 7. In both cases, seed fish are usually sold at the production facility. Some private producers, however, may transport supplies to a district center convenient to customers and charges a premium for transport costs.

Table 6. Estimated distribution of seed fish (in millions) for rice-fish farming from the Department of Fisheries (DOF) and private hatcheries, by species and region, Thailand. (Source: Fedoruk and Leelapatra 1981).

	Region				
	Central	North	Northeast	South	Thailand
DOF hatcheries	3.8	2.1	8.5	0.6	15.0
P. gonionotus	1.8	1.0	4.1	0.3	7.2
O. niloticus	1.1	0.6	2.5	0.2	4.4
C. carpio	0.9	0.5	1.9	0.1	3.4
Private hatcheries	10.0	5.2	45.5	-	60.7
P. gonionotus	4.0	2.6	23.0	-	29.6
O. niloticus	0.3	0.2	1.7	-	2.2
C. carpio	2.1	1.3	11.4	-	14.8
L. rohita	1.6	1.0	9.0	-	11.6
Chinese carps	2.0	0.1	0.4	-	2.5
Total	13.8	7.3	54.0	0.6	75.7
P. gonionotus	5.8	3.6	27.1	0.3	36.8
O. niloticus	1.4	0.8	4.2	0.2	6.6
C. carpio	3.0	1.8	13.3	0.1	18.2
L. rohita	1.6	1.0	9.0	-	11.6
Chinese carps	2.0	0.1	0.4	-	2.5

Table 7. Seed fish prices (US$/100 pieces). (Source: Fedoruk and Leelapatra 1981).

Source	Sizes/Species	Price
Department of Fisheries (DOF)[a]	2–3 cm	0.40
	3–5 cm	0.80
	5–7 cm	1.20
Private sector	Small	
	P. gonionotus	0.24–0.60
	O. niloticus	0.40–0.80
	C. carpio	0.40–0.80
	L. rohita	0.80–2.00
	Chinese carps	1.20–2.00
	Large	
	P. gonionotus	0.80–1.20
	O. niloticus	0.80–1.20
	C. carpio	0.80–1.20
	L. rohita	2.00–4.00
	Chinese carps	2.00–2.80

[a]Prices are standardized by size regardless of species or location.

Conclusions and Recommendations

Rice-fish farming is an established agricultural production system in Thailand. It promotes rational use of limited agricultural lands while providing important contributions to the rural economy through fish production and increases in rice yields. Other benefits include income generation through commercial production of table fish and seed fish. Achieving these benefits is highly consistent with policies of Thailand's current social and economic development plans.

Two principal developments are required by the government to support rice-fish farming. One concerns the integrity of ricefield environments and of wild fish stocks which are basic to existing fisheries as well as their expansion. The other concerns the technical services involved in promoting expansion. Both could be addressed through a DOF-initiated national program on rice-fish farming. The program could include placement of infrastructure for guiding land uses consistent with the interest of ricefield fisheries and for servicing ricefield fisheries in accordance with developmental objectives. The concept involves a centralized plan providing structure for: 1) DOF activities; and 2) coordination of roles by other government agencies and some nongovernment organizations such as the National Energy Board, the National Economics and Social Development Board and the Department of Agriculture (in formulating an appropriate agricultural land policy); the Accelerated Rural Development, the US Peace Corps, the Canadian University Services Overseas, etc., (in research and extension on rice-fish farming); and the Bank of Agriculture and Agricultural Cooperatives (in accessing credit to rice-fish farmers and external assistance).

DOF activities would focus on: 1) the development and verification of appropriate technologies including new applications such as producing seed fish; 2) the development of the seed fish resources required for expansion from within the DOF and through promoting self-reliant supplies by the farmers and commercial supplies by the private sector; and 3) the maintenance of the national plan including liaison in developing external assistance.

References

Anon. 1983. Report on the Rice-Fish Farming Workshop, 9-10 November 1983, Surin Technology College, Surin, Thailand.

DOF. 1983. Freshwater fish farm production, 1982. Department of Fisheries, Bangkok, Thailand. 70 p.

Fedoruk, A. and W. Leelapatra. 1981. Field survey, 3–20 December 1981. (Unpublished).

Fedoruk, A. and W. Leelapatra. 1985. Synopses of rice-fish culture research in Thailand. FAP/ WP-29. Department of Fisheries, Bangkok, Thailand.

Koesoemadinata, S. 1980. Pesticides as a major constraint to integrated agriculture-aquaculture farming systems, p. 45-51. *In* R.S.V. Pullin and Z. H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Lysack, C. 1985. Proceedings of the First Volunteers Fisheries Conference, 20-21 April 1983, Sakorn Nakorn Rice Experimental Station, Sakorn Nakorn, Thailand.

Pongsuwana, V. 1962. Progress of rice field fish culture in Thailand. Proceedings of the 10th Indo-Pacific Fisheries Council (IPFC) Session, II:157-163.

Spiller. 1985. Rice cum fish culture: environmental aspects of rice and fish production in Asia. Report FAP/WP-15. 48 p. FAO Office for Asia and the Pacific. Bangkok, Thailand.

Thongpan, W., K. Kanpruk, C. Saisong, R. Kongsri, J. Sollows, D. Chandrapanya and P. Jiamvijit. 1984. Rice-fish integrated farming system research and development, Ubon, Thailand. Farming Systems Research Institute, Department of Agriculture, Bangkok, Thailand. 27 p.

Ricefield Aquaculture Systems in the Mekong Delta, Vietnam: Potential and Reality

MAI VAN QUYEN
Southern Institute for Agricultural Sciences
Ho Chi Minh City
Vietnam

LE THANH DUONG
Farming Systems Research and Development Center
Can Tho University
Vietnam

DANG KIM SON
Cui Long Delta Rice Research Institute
Omon, Hau Giang
Vietnam

PHAM NGOC MINH
NGUYEN DANG NGHIA
Southern Institute for Agricultural Sciences
Ho Chi Minh City
Vietnam

MAI, V.Q., T.D. LE, K.S. DANG, N.M. PHAM and N.D. NGUYEN. 1992. Ricefield aquaculture systems in the Mekong Delta, Vietnam: potential and reality, p. 105–115. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Rice is one of the main agricultural products of Vietnam. But its yield is low because input levels are low. A way of increasing ricefield productivity is to integrate aquaculture into rice production. This would also bring into productive use the excess farm labor in Vietnam.

Ricefield aquaculture in Mekong Delta has great potential. Surveys in three districts of Hau Giang Province showed that rice-shrimp systems are dominant in both fresh- and brackishwater environments. Initial investigation in freshwater environment involving one case each in Long Phu and Phung Hiep Districts of Hau Giang

indicated that the net returns from rice cropping patterns with shrimp was much higher than the patterns involving dry and wet season rice with early *mua* rice or soybean. In brackishwater environment such as in Nha Be District, Ho Chi Minh City, rice-patterns (with and without feeding) gave higher net returns by 53 and 176%, respectively, than a sole rice crop.

Introduction

Vietnam is predominantly an agricultural economy. Food grains, particularly rice, are the main products of Vietnamese agriculture. Food grain production amounted to 19 t in 1988 of which rice was 16.4 t.

The agriculture sector (including crop cultivation, animal husbandry and aquaculture) accounts for 38% of the country's total output value and 49% of national income. It also employs about 62% of the national labor force (SPC/UNDP/FAO/WB 1989) or about 70% if aquaculture and capture fisheries are included.

Agriculture absorbs a greater proportion of labor force than necessary (i.e., farm sizes are too small to provide full employment even at peak season). For example, it is estimated that in the Red River Delta, there is an absolute labor surplus of 45–50% (SPC/UNDP/FAO/WB 1989).

Low crop yields combined with small landholdings cause poverty in Vietnam. Low yields in rice is attributed to low input levels.

Thus, the integration of aquaculture in rice farming would provide additional work for tapping some of the excess farm labor. Productivity of ricefields would also be enhanced.

The Mekong Delta occupies 4 million ha of natural land. About 2,487,000–2,650,000 ha are devoted to agricultural activities (Nguyen 1989). Rice is being grown on 2 million ha (Mai et al. 1988). Since Mekong Delta is flat, the river and canal systems are widespread and reticulate like a web throughout the Delta. Therefore, fishes and shrimps can swim from the far north of Sea-Lake Tonle-sap, Kampuchea, to the Delta or from the sea by tide, to lay their eggs and develop. Fishes, shrimps and other aquatic creatures were abundant before the advent of pesticides in Vietnam's ricefields (Duong 1989; Dang 1986). Nowadays, they are scarce due to environmental degradation. Thus, the ecosystems and aquatic productivity need to be restored. With a resource of 800-km seashore, 4 million ha of natural land and canal systems, the central government has recently released a new economic policy that encourages the people to work hard on their fields to gain more benefits (MAFI 1988). Therefore, integrating aquaculture to rice farming in the Mekong Delta is very promising.

Potential of Ricefield Aquaculture in the Mekong Delta

Occupying one-eighth of the Vietnam territory, the Mekong Delta plays a very important role in the export of aquatic products (Table 1). The export value of shrimps caught from the sea and river mouths is 71% of the national value. While the export value of shrimps coming from brackishwater is as much as 80%, the Mekong Delta supplies 100% of the exported shrimps raised in freshwater areas. Shrimps caught from brackish- and freshwater areas come from ricefield aquaculture systems. Mekong Delta has 41% of the total ricefield area in the country (Table 2). This comprises the summer-autumn or wet season rice crop. The transition crop within the year in the Mekong Delta is as much as 70% that of the whole country. Besides shrimp culture in ponds, ditches or mangrove forests,

Table 1. Estimated shrimp catch (t) and value of exports (million US$), Vietnam, 1990. (Source: Duong 1989).

Aquatic products	North Vietnam		Coastal Part		South Vietnam Mekong Delta		Total	
	Catch	Value	Catch	Value	Catch	Value	Catch	Value
Shrimp								
Sea and river mouth	3,000	9	2,000	6	25,000	38	30,000	53
Brackishwater	4,400	9	3,000	6	33,500	60	40,900	75
Freshwater	0	0	0	0	10,000	20	10,000	20
Total	7,400	18	5,000	12	68,500	118	81,000	148
Squid and other sea products		10		20		22		52
Total export of aquatic products		28		32		140		200

Table 2. Percentage of rice area in the Mekong Delta and Red River Plain to total rice area, Vietnam, 1988. (Source: MAFI 1988).

Season crop	Vietnam ('000 ha)	Mekong Delta ('000 ha)	Mekong Delta %	Red River ('000 ha)	Red River %
Winter-spring crop	1,822	576	51	941	50
Summer-autumn	989	699	71	0	0
Mua	2,847	1,048	87	544	19
Total	5,719	2,321	41	1,030	18

farmers in Hau Giang Province (Phung Hiep, Long Phu, Thot Not, My Xuyen Districts), Cuu Long (Binh Minh), Tien Giang (Cai Be), Long An (Go Cong) and Tp Ho Chi Minh (Nha Be) also raise shrimps in ricefields (Fig. 1). This way, farmers provide more shrimps for home consumption, and also contribute to the export earnings of the country.

Survey on Ricefield Aquaculture Systems

EXISTING RICE-FISH SYSTEMS

Quick surveys (Nguyen et al. 1988; Le and Duong 1990; Le et al. 1990) in three districts of Hau Giang Province have shown the dominant rice-shrimp/fish systems being practised by farmers and their production levels (Table 3).

The dominant systems are: 1) rice-freshwater shrimp/fish system year-round (such as in Thanh Loc 1 hamlet in Thot Not District and Cai Con and Mang Ca hamlets in Phung Hiep District); 2) rice-brackishwater shrimp/fish system year-round (such as in Giong Co hamlet in My Xuyen District; and 3) rice-shrimp/fish system alternatively every six months (such as in Long Thoi commune, Nha Be District, Ho Chi Minh City). In the third system, rice is grown in freshwater months and shrimp/fish is cultured in brackishwater months. The fish species and rice varieties used are shown in Table 4.

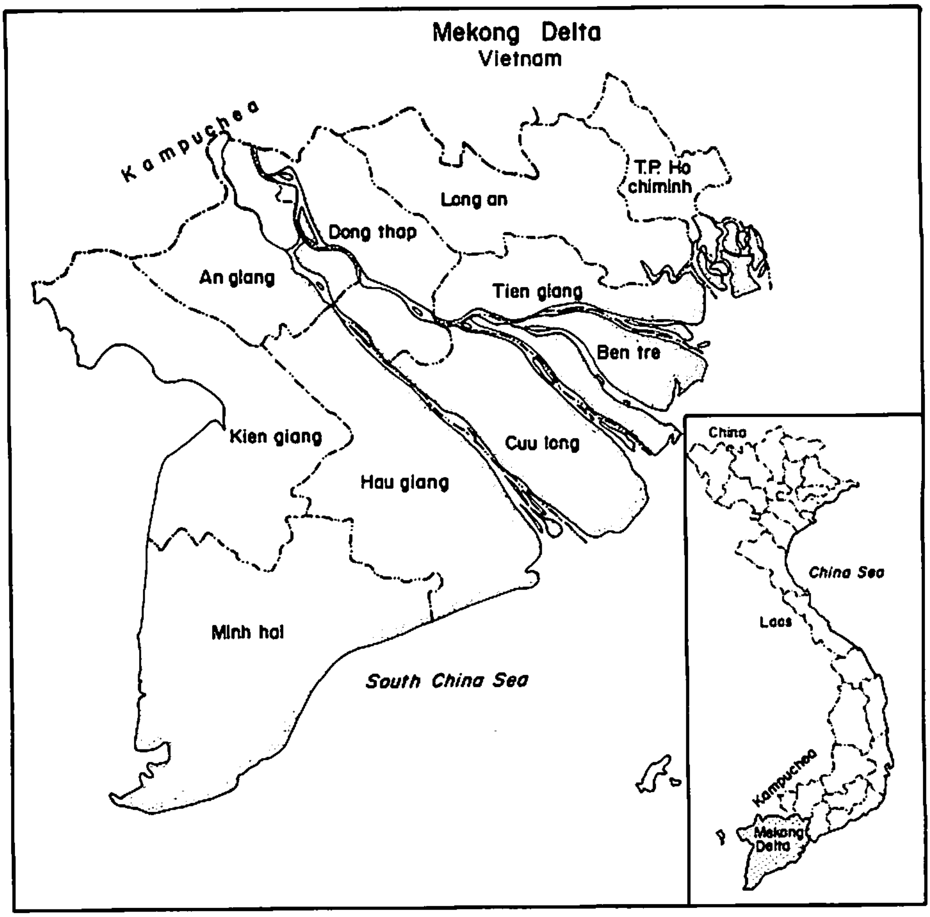


Fig. 1. Map of Vietnam and location of Mekong Delta.

Table 3. Rice-shrimp/fish cropping patterns and production in Mekong Delta, Vietnam. (Sources: Nguyen et al. 1988; Le and Duong 1990; Le et al. 1990).

Location	Farmers interviewed (no.)	Cropping pattern[a]	Rice yield (t/ha)		Shrimp/fish yields	
			Wet season	Dry season	Wet season	Dry season
Giong Co Hamlet[b]		WSR-Fallow	2.4			
	42	(WSR+F+S)-(F+S)	2.4		2-2.5 kg shrimp/day; 15 kg fish/day	2.5-3 kg shrimp/day, for 4 months
Thanh Loc 1 hamlet[c]		WSR-DSR	5.2	5.7		
	43	(WSR+S)-(DSR+S)	5.2	5.7	187 kg shrimp/ha	
		(WSR+F+S)-(DSR+F+S)	5.2	5.7	214 kg fish/ha	
Mang Ca Hamlet and Cai Con Hamlet[d]	100	WSR-DSR	3.9	4.0		
		WSR-TR	3.9	3.5 (TR)		
		(WSR+S)-(TR+S)	3.9	3.5 (TR)	79 kg shrimp/ha	
		(WSR+S)-(DSR+S)	3.9	4.0	48 kg shrimp/ha	

[a]DSR = dry season rice; WSR = wet season rice; F = fish; S = shrimp; TR = traditional rice.
[b]Located in Tham Don Village in My Xuyen District, Hau Giang Province.
[c]Located in Trung An Village, Thot Not District, Hau Giang Province.
[d]Both located in Dai Thanh Village, Phung Hiep District, Hau Giang Province.

Table 4. Rice varieties and shrimp/fish species in rice-shrimp/fish farming.

Location (hamlet)	Rice varieties: Dry season	Rice varieties: Wet season	Shrimp/Fish species Both seasons
Thanh Loc 1	Dry season rice	Wet season rice	*M. rosenbergii* *Puntius gonionotus*
Cai Con and Mang Ca	Dry season rice Traditional rice	Wet season rice	*M. rosenbergii*
Giong Co	*Khmer do* IR 42	*Khmer do* IR 42	*Metapenaeus lysianassa* *M. tenuipes,* *M. ensis* *Penaeus indicus*[a] *Pseudapocryptes lanceolatus*

[a]*P. indicus* is rare in the wet season.

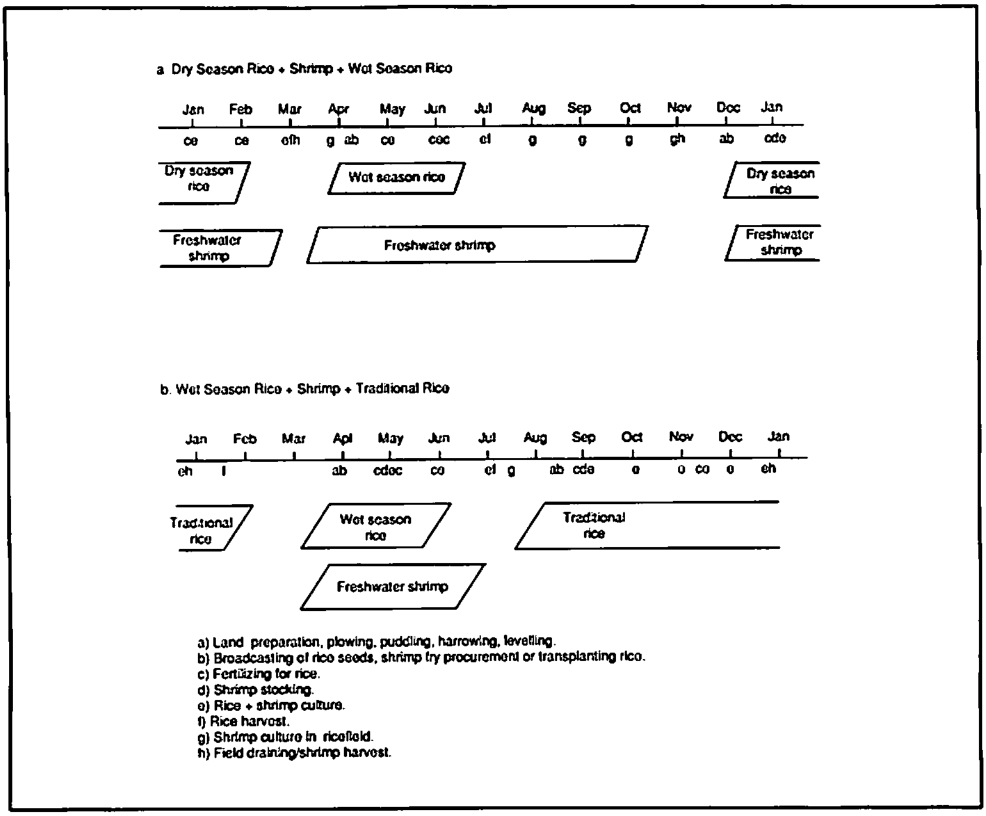
RICE-FISH SYSTEMS CROPPING CALENDAR

The cropping calendars in the four hamlets surveyed are shown in Figs. 2 to 4. Two crops of rice are produced per year, except in Giong Co hamlet. Rice are usually directly seeded at the rate of 100–300 kg/ha per crop. However, transplanting rice is most common in Giong Co hamlet. The high seeding rate is necessary for compensating any damage from weeds and fish. Particularly, for the traditional rice variety, farmers either broadcast the rice seed at the rate of 75 kg/ha per crop or transplant seedlings at 40 kg/ha per crop. More than 50% of the farmer-respondents practising direct seeding apply herbicides. Chemical fertilizers are applied at the rate of 38–350 kg/ha per crop in Giong Co hamlet and 368–376 kg/ha per crop in Thanh Loc 1 hamlet; while in Cai Con and Mang Ca hamlets, application rates are 40–80 kg N and 20–35 kg P_2O_5 per ha.

Freshwater shrimp (*Macrobrachium rosenbergii*) fry are bought from fishermen and stocked in growout ponds adjacent to ricefields. One month after rice seeding or transplanting, the young shrimp are moved into the ricefields at average stocking rates varying from 0.5/m² (in Cai Con and Mang Ca hamlets) to 2/m² (in Thanh Loc 1). Fish stocking rate is 2.6/m². The shrimps and fish are fed alternately with rice bran, broken rice, rough rice, coconut meal, dried cassava, crabs, snails and dead animals.

In Giong Co hamlet, stocking rate for marine shrimps is not known. Feeding is not done. Rice are harvested about a week ahead of the shrimp/fish. However, shrimp/fish harvest may further be delayed depending on market prices.

Ricefields have surrounding dikes high enough to prevent the shrimps from escaping during floods. A peripheral canal along the inner side of dikes is provided. The layouts of a rice-shrimp field by a farmer and that proposed by extension workers are shown in Fig. 5. Flopgate culverts (Figs. 6a, b, c) are installed to regulate the flow of water and insure good water quality of the rice-shrimp/fish area.



Figs. 2a and b. Cropping calendar for rice-shrimp farming in Caicon and Mang Ca Hamlets, Dai Thanh Village, Phung Hiep District, Hau Giang Province, Vietnam.

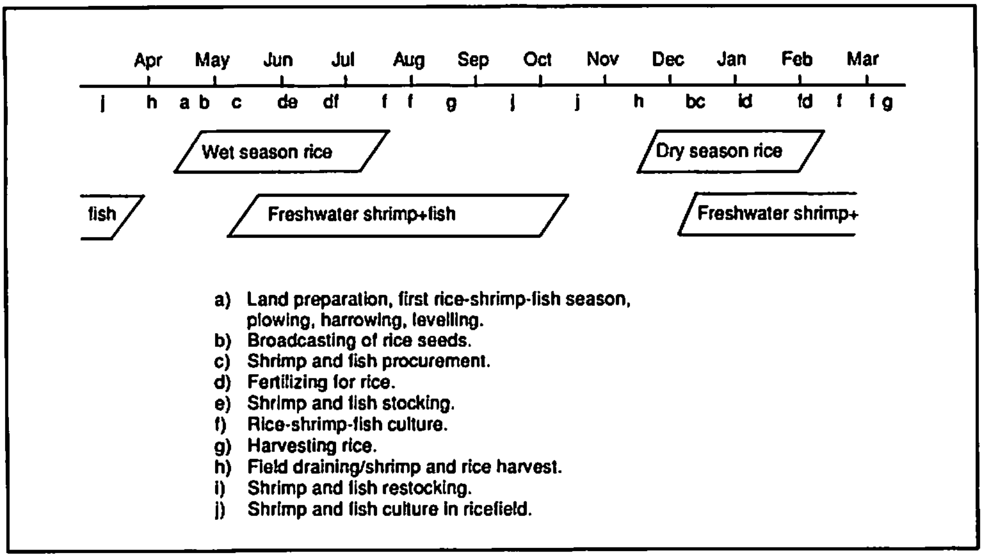


Fig. 3. Cropping calendar for rice-shrimp farming in Than Loc 1 Hamlet, Trung An Village, Thot Not District Hau Giang Province, Vietnam.

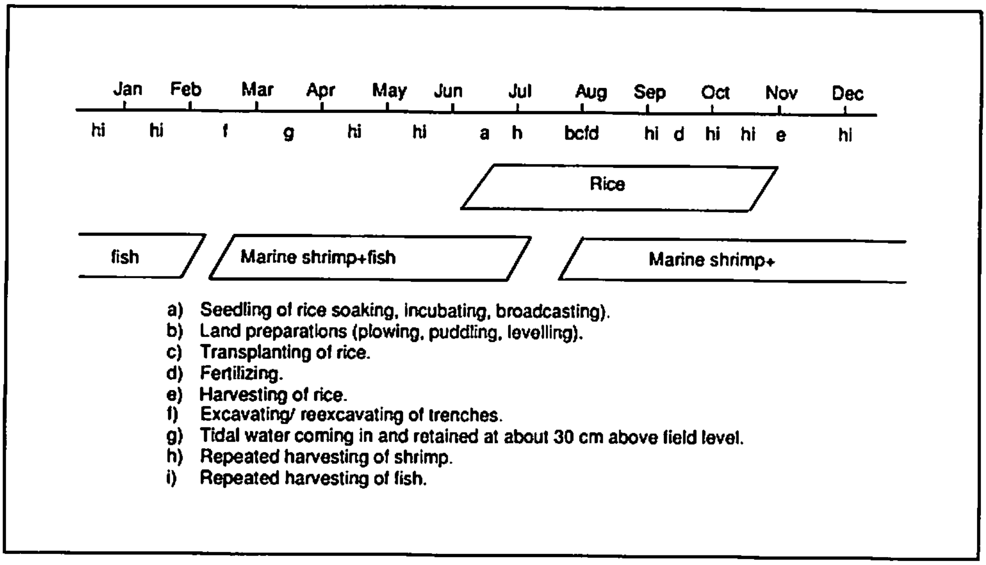


Fig. 4. Cropping calendar for rice-shrimp/fish farming in Giong Co Hamlet, Tham Don Village, My Xuyen District, Hau Giang Province, Vietnam.

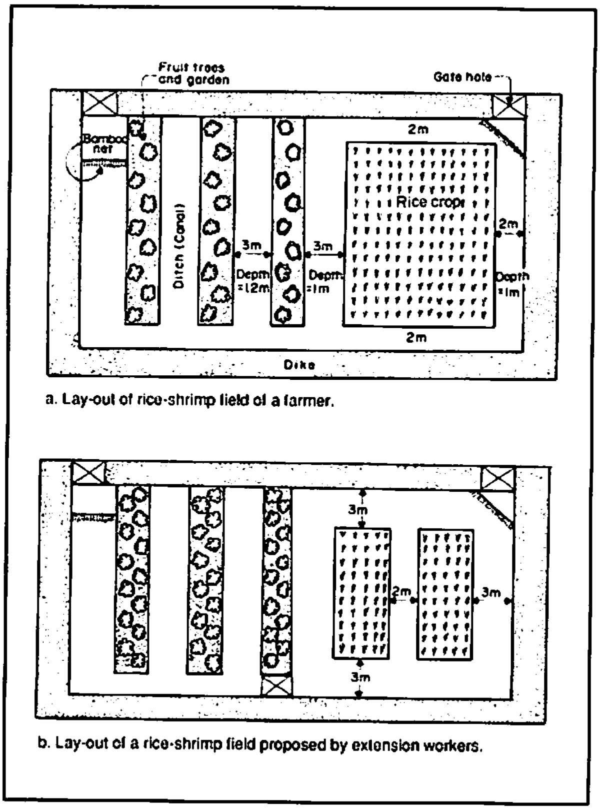


Fig. 5. Layouts (a and b) of a rice-shrimp field.

LABOR INPUTS FOR RICE-FISH SYSTEMS

More labor is required in rice-shrimp/ fish farming than in rice or shrimp/fish monoculture (Table 5). Thus, this integration would create jobs and exploit excess farm labor.

Initial Investigation of Ricefield Aquaculture in the Mekong Delta

CASE OF ISLAND DUNG,
LONG PHU, HAU GIANG

An investigation on rice-shrimp system in freshwater environment was done during the 1984 wet season. Three patterns had been compared: 1) summer-autumn or wet season rice followed by early *mua* rice; 2) wet season rice followed by freshwater shrimp; and 3) wet season rice, followed by winter-spring or dry season rice followed by soybean. Giant prawn (*M. rosenbergii*) has been raised after the summer-autumn or wet season rice harvest. This pattern gave the

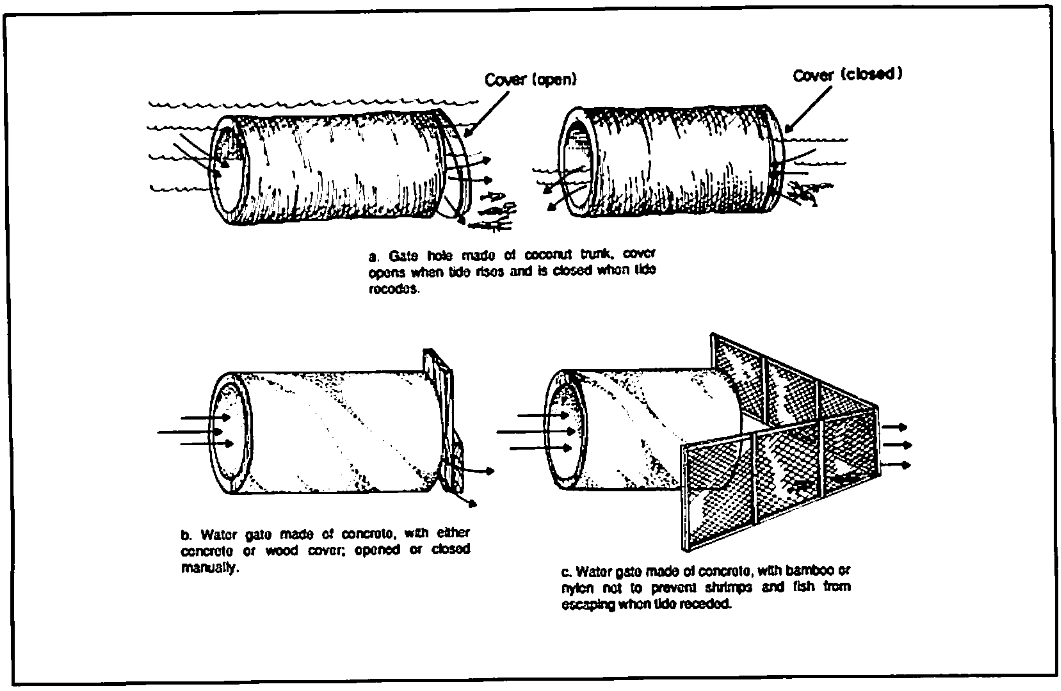


Fig. 6. Some types of water gate setting in rice-shrimp fields to get shrimp fingerlings from the river by tide.

Table 5. Labor (man-days/ha/year) in rice monoculture and rice-shrimp/fish farming systems. (Sources: Nguyen et al. 1988; Le and Duong 1990; Le et al. 1990).

Location (hamlet)	Rice monoculture		Shrimp/Fish		Rice-Shrimp/Fish	
	range	average	range	average	range	average
Than Loc 1	91–360	196	27–267	155	134–489	333
Cai Con and Mang Ca	25–230	144	32–125	95	88–432	239
Giong Co	29–115	74	10–210	78	36–325	148

highest net return and man-day value (Table 6).

CASE OF DAI THANH COMMUNE, PHUNG HIEP DISTRICT, HAU GIANG (FRESHWATER ENVIRONMENT YEAR ROUND)

A survey using different cropping patterns was carried out on 27 farmers' fields where the soil is high in organic matter and nitrogen. The winter-spring (dry season) followed by summer-autumn (wet season) rice pattern served as a control. Nine farmers who raised shrimps in winter-spring followed by summer-autumn rice crops gained an average net return of 10,503 kg rice/ha/year (291% higher than the control). Nine others who raised shrimps in summer-autumn followed by early *mua* rice crop gained net returns of 8,883 kg rice/ha/year (247% higher than the control). Results also showed that the returns to materials from rice-shrimp pattern is highest (Table 7).

Table 6. Efficiency of rice-shrimp pattern in freshwater island Dung, Long Phu, Hau Giang, 1984 wet season. (Source: Dang 1986).

Cropping pattern	Gross returns[a] converted in rice (t)	Net returns[a] rice (t)	Man-day (kg rice/day)
Summer-autumn rice-early mua rice	8.0	2.2	19.0
Summer-autumn rice-shrimp	8.5	6.7	59.0
Rice-rice-soybean (Intensive farming)	17.8	4.0	17.0

Table 7. Net returns of different cropping patterns of farmers in Long Phu, Hau Giang Province. (Source: Vo et al. 1989).

Respondents	Winter-Spring 1988-89 (kg rough rice)	Summer-Autumn 1988 (kg rough rice)	Shrimp 1988 (kg rough rice)	Total 1988 Net returns (kg rough rice)	Returns to materials	Returns to labor
Average of 9 farmers	2,847	2,466	4,963	10,503 (291.3%)	14.2	5.0
Average of 9 farmers	*Mua* 88 2,641	2,274	5,011	8,883 (247%)	28.0	4.7
Average of 9 farmers	Winter-Spring 88-89 2,077	1,522	-	3,600 (100%)	3.2	2.8

CASE OF NHA BE DISTRICT, HO CHI MINH CITY (SIX MONTH FRESHWATER, SIX MONTH BRACKISHWATER)

Nha Be District has 6,000 ha which grows only one traditional tall rice crop because of the hydrologic situation of this area. In the upstream, the field is intruded by four months of brackishwater; in the middle part, six months; and in the downstream part, seven months of brackishwater – with different salt concentrations that prevent farmers from doubling their rice croppings. The soil is poor in structure, rich in organic matter and exchangeable iron; therefore, dike is very weak and can be easily destroyed by tide and heavy rain. Thus, shrimp culture in the district used to be a minor undertaking, although the natural resource of shrimp is abundant. The farmers could not harvest more than 50 kg shrimp/ha because of extensive shrimp culture without feeding.

Results from the survey with three models performed by farmers in Long Thoi commune, Nha Be District, showed that traditional tall rice monoculture gave net returns of US$38 (Table 8). The second farmer who improved his dikes got 50 kg of shrimp. His net returns was 53% higher than that obtained from rice

Table 8. Returns from rice-shrimp pattern using traditional tall rice crop in brackishwater environment, Nha Be, Ho Chi Minh City, 1989. (Source: Nguyen and Nguyen 1989).

Pattern	Rice yield (kg/ha)	Shrimp (kg)	Gross returns (US$)[a]	Total costs (US$)[a]	Net returns (US$)[a]	% increase from rice monoculture
Rice monoculture	2,800	-	125.17	87.17	38.00	-
Rice-shrimp (no feeding)	3,000	50	178.81	120.70	58.11	53
Rice-shrimp (with feeding)	3,500	80	263.75	158.69	105.05	176

[a]Original values in Vietnam Dong were converted to US$ at the rate of US$1 = 4,474 Dong as of 1988.

monoculture. The third farmer who applied 3,000 kg compost and fed the shrimp with rice bran, broken rice and rotten animals and secured the dikes to prevent leaking, harvested 80 kg shrimp. His net returns was 176% higher than rice monoculture.

Conclusion

The Mekong Delta is endowed with abundant natural resources. It has revealed enormous potential in ricefield aquaculture systems, particularly rice-shrimp systems. The extensive rice-shrimp fish systems operated by farmers in Long Phu, Phung Hiep, Thot Not and My Xuyen Districts of Hau Giang Province and Nha Be, Ho Chi Minh City, showed that the potential is being realized. However, in order to fully harness the potential, a strong research program is needed. It also requires reasonable market price support and strong initial support from the government.

Acknowledgements

The senior author acknowledges the leadership of IRRI, ICLARM and CLSU, especially Drs. V.R. Carangal and C.R. dela Cruz, enabling him to attend the workshop. We also thank C.R. dela Cruz for expanding this paper and Lita Katimbang for typing the manuscript.

References

Dang, K.S. 1986. Farming systems in the Mekong Delta. Publish House, Ho Chi Minh City, Vietnam. 380 p. (In Vietnamese).

Duong, H.H. 1989. Agriculture in the Mekong Delta. Publish House, Ho Chi Minh City, Vietnam. (In Vietnamese).

Le, T.D. and N.T. Duong. 1990. Survey on rice-brackishwater shrimp-fish farming. Farming Systems Research and Development Center, Can Tho University, Can Tho City, Vietnam.

Le T.D., N.T. Duong and Q.T. Nguyen. 1990. Case study on rice-shrimp-fish polyculture farming. Farming Systems Research and Development Center, Can Tho University, Can Tho City, Vietnam.

MAFI. 1988. Annual Report. Ministry of Agriculture and Food Industry. Ho Chi Minh City, Vietnam. (In Vietnamese) (Unpublished)

Mai, van Q., D.P. Garrity, M.K. Hong, N.D. Nguyen. 1988. Rice production in the Mekong Delta and its role in food production in Vietnam. A report of an IRTP late flowering-rainfed lowland monitoring tour to Cambodia, Vietnam and Thailand, 8-18 December 1988. 15 p.

Nguyen, N.M. and D.N. Nguyen. 1989. Survey on rice-fish culture in Nha Be, Ho Chi Minh City. Southern Institute of Agricultural Sciences, Ho Chi Minh City, Vietnam.

Nguyen N.T. 1989. Dong Bang Song Cuu Long Fai nguyen-MOI truong-Phat trien: (Special report (1984-86) by 60-02 project). Hanoi-TP, Ho Chi Minh City, Vietnam. 403 p.

Nguyen, Q.T., V.S. Nguyen and V.S. Tran. 1988. Case study on rice and shrimp farming. Mekong Delta Farming Systems Research Center, University of Can Tho, Can Tho City, Vietnam. (Unpublished).

SPC/UNDP/FAO/WB. 1989. Vietnam: Agricultural and food production sector review (VIE/88/033). Draft Mission Report. State Planning Committee, Socialist Republic of Vietnam; United Nations Development Program; Food and Agriculture Organization of the United Nations, Rome, Italy; and the World Bank, Washington, D.C.

Vo, T.X., D.T. Nguyen and C.T. Nguyen. 1989. Report of a survey on rice-fish culture in Phung Hiep district, Hau Giang province. Mekong Delta Farming Systems Research Center, University of Can Tho, Can Tho City, Vietnam. (Unpublished).

Chapter 2
Production Systems

Rice-Fish Systems as Intensive Nurseries*

BARRY A. COSTA-PIERCE**
International Center for Living Aquatic Resources Management
MCPO Box 2631
0718 Makati, Metro Manila
Philippines

COSTA-PIERCE, B.A. 1992. Rice-fish systems as intensive nurseries, p. 117–130. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Rice-fish culture systems are an intricate part of the inland aquaculture production network in West Java, Indonesia. Expansion of inland aquaculture in West Java has fueled a concomitant expansion in fish production from ricefields. Fish production from ricefields jumped from 17,701 to 58,880 t from 1977 to 1984. Due to increased market demand, the majority of increased fish production has been of seed fish for further restocking. Growing emphasis is being placed upon extension and intensification of ricefields as nurseries for expanding inland aquaculture.

Intensive rice-fish nursery systems were studied in the Cianjur and Subang Regencies, West Java, in 1986–87. In Cianjur, a combined *minapadi-penyelang* nursery system produced four crops of fish and one crop of rice with total yields of 370 kg/ha and 5,667 kg/ha, respectively, in six months. Economic surveys of existing rice-fish and pond nurseries in Cianjur showed that net returns from semi-intensive, 30–50-cm deep nursery ponds, converted from ricefields, averaged US$500/ha in 30 days. Net returns were lower, from US$53 to 186, and culture periods longer (40 days), for all other types of rice-fish nursery systems. In Subang, an intensive rice-fish nursery system was studied for one year. The system produced 11.7 t of rice in two crops and 791 kg fish from five crops (3 *minapadi*, 1 *penyelang*, 1 *palawija*). Net return was US$1,697/ha/year, with fish comprising 31% of the total.

The importance of small fish cultured in ricefields in supplying protein for the densely populated rice-growing districts of West Java, has not been fully appreciated. Increased market demand and high prices for seed fish make intensive rice-fish nursery systems attractive investments for farmers in the Cianjur and Subang Regencies. However, an important protein source, small fish, once produced in traditional rice-fish growout systems and sold directly as human food within the rice-growing regions, is now being diverted into the more lucrative markets for seed fish. Local fish markets and people dependent upon them could experience diminished fish protein supplies if current market forces continue.

Introduction

Indonesian rice-fish culture is localized in East Java, West Java, North Sumatra and North Sulawesi (Koesoemadinata and Costa-Pierce, this vol.). Even within these four provincial centers, rice-fish culture is practised widely only within a few, contiguous, restricted group of districts (*kecamatan*), and is not widespread. In

*ICLARM Contribution No. 474.
**Present address: 6 Hale Ohia Road, P.O. Box 1050, Volcano, Hawaii 96785, USA.

these districts, rice-fish culture plays a central role in supplying seed fish for further ongrowing in an expanding inland aquaculture production network. Large market demand for seed fish has fueled a concomitant expansion in rice-fish nursery systems in these areas. In contrast, development of rice-fish nurseries in areas of Indonesia outside Java, as well as in neighboring Asian countries, is not as well developed, or is unknown.

Constraints posed by modern rice farming technology have limited the expansion of rice-fish culture. This could possibly be partially relieved by developing rice-fish nurseries rather than focusing wholly upon the traditional use of ricefields as fish growout systems.

Rice-Fish Systems in the Aquaculture Production Network of West Java

West Java is the most densely populated region of Indonesia and contains the rapidly expanding urban complexes of Jakarta and Bandung. West Java is also an important center of inland aquaculture and rice-fish culture (Djajadiredja et al. 1980). The province has the highest inland fish production in Indonesia (120,411 t in 1985) (DPPJB 1986). Nearly 21% of West Java's total inland fish production comes from rice-fish culture, with 1985 production estimated at 24,807 t. An estimated 93% of all ricefields in West Java are irrigated year-round, and the most productive rice-growing centers are the Cianjur and Subang Regencies (*Kabupaten*). These two regencies account for 33% (8,261 t) of the total fish production from ricefields in the province (DPPJB 1986).

Common carp (*Cyprinus carpio*) is the most preferred fish in West Java. In a survey of 477 people surrounding two new reservoirs in West Java, 78% preferred common carp in the Saguling Reservoir Region, and 94% in the Cirata Reservoir Region (Table 1). Average fish consumption rate for the Saguling Region was 12.4 kg/capita/year, and for Cirata, 11.8 kg/capita/year (Table 2). These rates are lower than the national rate reported in 1986 of 15.05 kg/capita/year (Soeprapto 1987).

Table 1. Species preferred by residents of Saguling and Cirata Reservoir Regions, West Java, Indonesia. (Source: IOE/ICLARM 1987).

	Saguling					Cirata		
	Fresh (n=465)			Salted[a] (n=292)			Fresh Cirata (n=175)	
Fish species	No.	%	Fish species	No.	%	Fish species	No.	%
C. carpio	228	49	Sardines (*Rasbora argyrotaenia*)	258	88	*C. carpio*	165	94
O. mossambicus	70	15	Sepat siam (*Trichogaster pectoralis*)	155	53	Other fish[c]		6
Milkfish (*Chanos chanos*)	41	9	*Puntius javanicus*	112	38			
O. niloticus	29	6	Others[b]		<10			
Other fish[b]		21						

[a]Responses can be multiple.
[b]Includes *P. javanicus*, Nilem carp (*Osteochilus hasselti*), Puntius (*P. binotatus*, *P. bramoides*), river prawn (*Macrobrachium rosenbergii*), hampal (*Hampala macrolepidota*), snakehead (*Ophiocephalus striatus* or *Channa striata*), walking catfish (*Clarias batrachus*), kissing gourami (*Helostoma temmincki*), *bawal* and *rembang* (miscellaneous ocean fish).
[c]Includes *P. javanicus*, Java tilapia (*Oreochromis mossambicus*), *O. niloticus*, *C. batrachus*, and *H. temmincki*.

Table 2. Per capita fish consumption rates in the Saguling and Cirata Reservoir Regions, West Java, Indonesia. (Source: IOE/ICLARM 1987).

Reservoir	Villages/Respondents (no.)	(no.)	Eat fish: Fresh	Eat fish: Salted	Fish consumption rate (kg/capita/year): Fresh Range	Fresh Mean	Salted Range	Salted Mean	Total average consumption
Saguling	23	308	272 (88%)	292 (95%)	2.9-10.2	5.8	0.4-10.2	6.6	12.4
Cirata	16	56	175 (99%)	173 (98%)	4.8-10.6	8.0	1.4-8.1	3.8	11.8

Rice-fish culture systems are an essential part of the aquaculture production network in West Java. Recently, these systems have had to respond to rapidly changing market demands and prices for their products, namely, small common carp of 3–5, 5–8, 8–12-cm lengths and 80–100-g sizes. Since the economic viability of rice-fish culture in West Java is inextricably connected to the inland aquaculture and rice production systems of West Java, it is important to review recent developments in these areas.

Until 1976, the majority of rice-fish culture systems and methods in West Java were traditional ones oriented towards producing small common carp as food fish for direct local consumption, or for producing seed fish for further ongrowing in ponds located within the rice-growing region (Fig. 1). Traditional, low-yielding rice varieties depend on seasonal rains. The availability and price of fish from ricefields were largely influenced by the weather. Abundant rain meant abundant, low-cost fish in the rainy season and diametrically opposite market conditions during the dry season.

Rapid changes swept the traditional rice farming and rice-fish agroecosystem from 1970 to 1984 in Indonesia. The area of irrigated ricefields increased from 3.7 to 4.9 million ha, area planted to high-yielding varieties (HYV) of rice increased from 0.8 to 6.8 million ha, distribution of government-subsidized inorganic fertilizers increased from 0.2 to 4.1 million t, and distribution of government-subsidized pesticides increased from 1,080 to 14,210 t (Tarrant et al. 1987). Ricefields planted to HYV rice increased from 18.5% in 1974, to 73.4% by 1985. Rice yields in Java jumped from an average of 2.80 t/ha in 1974 to 4.46 t/ha in 1985, and from 2.45 t/ha to 3.79 t/ha in Indonesia during this period (Rosegrant et al. 1987).

From 1976 to 1985, rice production showed an impressive growth of 6.8%/year due to the following factors: 1) government rice intensification program (in 1969 only 35.7% of Indonesia's ricefields were under this program, by 1985 this increased to 72.3%; 2) irrigation development; 3) development and dissemination of modern rice varieties; 4) interventions in marketing and price supports; and 5) fertilizer and pesticide subsidies. Fish production in ricefields also increased impressively, over 33%/year from 17,701 t in 1977 to 58,880 t in 1984 (DGF 1979, 1986). Much of this increase in fish production was due to large increases in production in West Java.

By 1976, intensive running water systems (RWS) (Suprayitno 1986) moved from a demonstration scale into the mainstream of the inland aquaculture production network in West Java. In 1985, over 5,000 units of 10–100-m^2-concrete raceways were present in West Java. A growing market demand for 80–100 g (average size) common carp for stocking in RWS was created which reverberated throughout the aquaculture production network, fueling increased production of seed fish from rice-fish systems (Fig. 1).

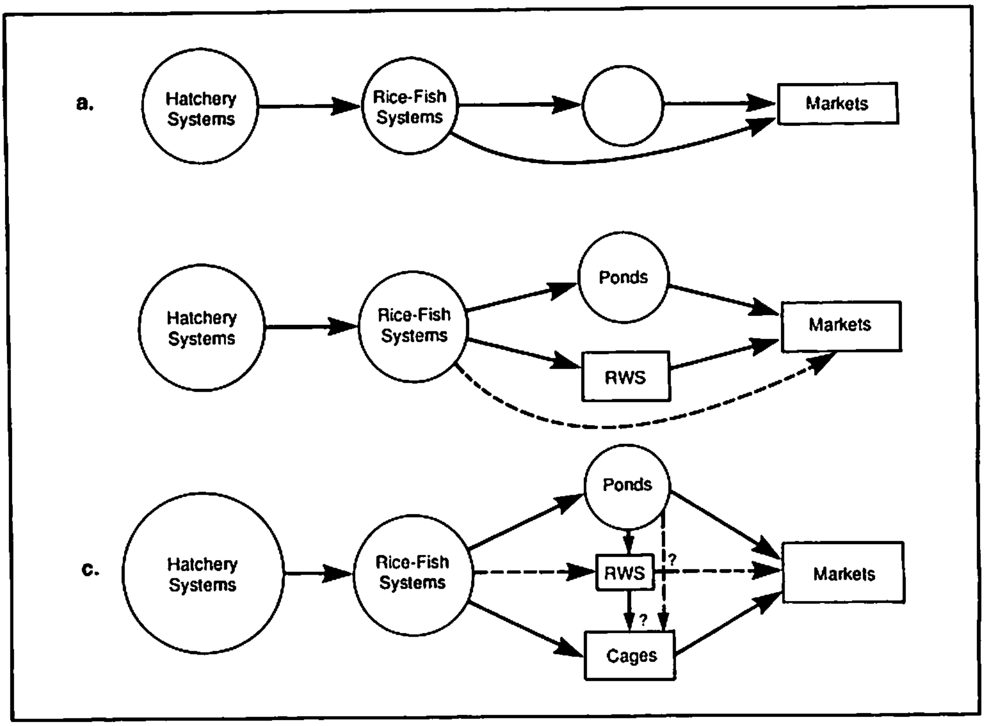


Fig. 1. Historical development trends of the aquaculture production network for *C. carpio* in West Java from 1910 to present. Traditional network (a) developed from 1910 to 1976. Rice-fish systems supplied seed fish for further ongrowing in family ponds and fish for direct consumption by people living within the rice-growing districts. Network from 1976 to 1985, (b) where fish markets increased in size due to tremendous population pressure in West Java. The number of ponds and rice-fish systems also increased. Running water systems (RWS) moved from the laboratory to commercial-scale, increasing the demand for seed fish and contributing to the expansion of rice-fish and pond nurseries. The dashed line indicates the decrease in production of small fish, once used as direct human food, from rice-fish culture to fish markets in West Java. Changing network (c) from 1986 to present. Demands for freshwater fish continue to expand, but the number of traditional fish ponds remain relatively constant due to urbanization and a sharp drop in numbers of RWS occurs. Rapid development of reservoir cage culture creates increased demand for seed fish for stocking, causing increased development of rice-fish nursery systems. Rice-fish culture plays a relatively minor role in supplying local fish to people within the rice-growing districts. Question marks indicate possible future routes of the changing aquaculture production network, while dashed lines represent new connections between rice-fish, RWS and cage systems observed in January 1988.

However, from 1985 to 1987, the number of RWS fell dramatically due to the following factors: 1) poor quality of seed fish coming from the Bandung Region, combined with poor handling and transportation techniques; 2) increase in the price of seed fish from Rp1,200–1,300/kg in 1984 to Rp1,700-1,800/kg in 1987; 3) increase in price of fish feeds from Rp300/kg in 1984 to Rp450/kg in 1987; 4) decrease in fresh fish prices from Rp1,800–2,000/kg in 1984 to Rp1,500-1,700/kg in 1987; and 5) business management failures (DPKC 1987). In addition, by 1986, the higher profitability and lower operating costs of reservoir floating net cage culture had been demonstrated (IOE 1986; LPPU 1986; RIIF 1983). Operators of the reservoir floating net cages were able to sell fish at consistently lower prices than owners of RWS, further exacerbating the financial problems of RWS.

Expansion of reservoir (and lake) floating net cage culture has a much greater potential to create more permanent changes in the rice-fish culture system and to fuel a much larger expansion in West Java (Fig. 1). Rapid expansion of reservoir aquaculture has occurred in a very short period of time (1985–88). Its operating costs are lower and fish productivities of cages are higher. Reservoir floating net cages in the Saguling Reservoir, developed from 1985 (zero fish production), produced 2,554 t of common carp in 1988, more than 20% of the total inland fisheries production for the entire Bandung Regency in 1985 (DPPJB 1987). Nearly all of the seed fish used in reservoir cages originated from rice-fish culture in the Bandung, Cianjur and Subang Regencies. The impact on rice-fish systems in West Java at current levels of reservoir cage production is causing rapid expansion in area, changes in management practices, system types and economics of rice-fish systems (DPKC 1987).

Larger increases in fish production from ricefields in West Java are also anticipated, for two reasons. First, it has been estimated that irrigated rice area must increase to 10.3 million ha by the year 2000 (Tarrant et al. 1987), if Indonesia is to maintain its rice self-sufficiency defined at 320 kg/capita/year (Sayogyo 1978). Expansion of irrigated rice lands will correspondingly increase the available areas for rice-fish culture. Second, according to the government reservoir aquaculture development programs, floating net cage aquaculture will expand from its current center in the Saguling Reservoir into another (Cirata Reservoir) in 1988. Total fish production from the two reservoirs by 1992 will reach a minimum of 12,928 t, or 11% of the total inland fish production (culture and capture) from the entire province of West Java for 1985 (DPPJB 1987). If this occurs, floating net cages in both reservoirs will require approximately 2,585 t of seed fish of an 80–100 g average size (Effendi, pers. comm.). Nearly all of this seed, barring any major development efforts in the expansion and intensification of pond nurseries, will need to originate from rice-fish culture.

While increased demand for seed fish could fuel a significant expansion of rice-fish culture in West Java, and possibly Indonesia, complete conversion of the rice-fish culture systems into seed production could also imperil fish supplies in local markets. A large proportion of small fish production harvested from ricefields, sold to small local markets and consumed locally, would, due to market forces, be shifted into the more profitable resale market as seed fish for floating net cages or other growout systems. Until very recently, the majority of rice-fish culture systems in West Java produced small common carp in very short fish production cycles for direct sale to small local markets (Fig. 1).

The importance and magnitude of this production of small fish to human nutrition has heretofore been unrecognized. Few aquaculturists or rural development experts have considered that many Asian cultures prefer, for household economic as well as cultural reasons, to purchase and eat small (50–200 g) rather than large fish ($\geq$0.5) kg. In a survey conducted in 16 villages in West Java, 71% of the respondents preferred common carp of an average size of 67–200 g; and 85% of the respondents preferred tilapia (*Oreochromis* spp.) of an even smaller size, 25–50 g (Table 3). If the great demand for seed fish for floating net cages develop as planned, local fish markets within the densely-populated rice-growing districts could experience fish shortages.

Technology and Economics of Rice-Fish Nurseries

Radical changes are occurring and will continue to occur in the rice-fish culture system in West Java (Fig. 1). To document current technological and economic changes in rice-fish culture

Table 3. Fish sizes preferred from a survey of 16 villages in West Java, Indonesia. (Source: IOE/ICLARM 1987).

Average fish size (g)	No. of respondents consuming fish			
	Oreochromis spp.	%	*C. carpio*	%
25–33	69	57	0	0
33–50	34	28	0	0
50–67	10	8	0	0
67–100	2	2	44	26
100–200	6	5	78	45
200–333	0	0	20	12
333–500	0	0	4	2
500–1,000	0	0	26	15

occurring as a result of the expansion of inland aquaculture in West Java, scientists at the Institute of Ecology (IOE), Padjadjaran University (Bandung, Indonesia) in cooperation with the International Center for Living Aquatic Resources Management (ICLARM, Manila, Philippines), surveyed rice-fish culture systems in inland fisheries centers in West Java in 1986–87. Fisheries centers within a 100-km radius of the Saguling and Cirata Reservoirs were identified from the 1986 reports of the West Java Provincial Fisheries Service and the DGF. Survey areas included portions of Bandung, Cianjur, Sukabumi, Subang and Tasikmalaya Regencies. After a few months of survey, it was found that the great majority of seed fish for stocking reservoir aquaculture systems were originating from rice-fish nursery systems in the Cianjur and Subang Regencies. It was thereby decided to focus all further surveys on rice-fish culture in those regencies. Surveys on fish seed marketing routes, rice-fish cropping patterns, fish and rice yields, and economic data were monitored. In addition, two candidate systems for the best available existing technology of rice-fish nursery systems were documented.

The Cianjur and Subang Regencies of West Java have recently undergone rapid expansion in rice-fish culture. It is estimated that 61% of all irrigated ricefields in Cianjur (DPKC 1987), and 32% in Subang (UPP 1985, 1986), are used for rice-fish culture. Production of fish from rice-fish systems in the Cianjur Regency in 1987 was 4,872 t, the highest in West Java (DPKC 1987). The Cianjur Fisheries Service plans to increase rice-fish area to 10,000 ha by 1989. To meet the estimated 1988–89 demand for seed fish in expanded freshwater aquaculture, the Cianjur Regency must produce an additional, approximately 580 t of 80–100-g common carp (DPKC 1987).

In the Cianjur Regency in 1987, IOE/ICLARM scientists documented a rice-fish nursery system that used very short (one month) *minapadi* cycles (Fig. 2). The system incorporated *minapadi-penyelang* rice-fish systems, and produced four crops of seed fish from three *minapadi* and one *penyelang* cycles, along with 5,677 kg of rice in six months. Total fish yield was 370 kg/ha in six months, ranging from 41 to 58 kg/ha/month for the *minapadi* systems. Total fish yields for all three *minapadi* cycles were 144 kg/ha/rice crop and 226 kg/ha for the *penyelang* cycle (Fig. 2). Total *minapadi* fish yield reported here was higher than the average of 75–100 kg/ha in three to four months reported by Coche (1967); fish yield from *penyelang* (Fig. 2) was also higher than the 150 kg/ha in four to six months reported by the same author.

Unfortunately, economic data were not available for this intensive nursery system. However, in farmer interviews in 1986–87, it was learned that numerous

Fig. 2. Aquaculture management of different rice and fish cropping patterns in an intensive rice-fish nursery system over a six-month period in Cianjur Regency, West Java, Indonesia, 1987.

Month	1 1.5	2	2.5 3	3.5 4	4.5 5	5.5 6
System		*Minapadi 1*	*Minapadi 2*	*Minapadi 3*		*Penyelang*
Terrestrial	Rice planted	Rice weeded	Rice weeded	Paddy dried	Rice harvested	
Aquatic	Fish seeded	Fish harvested Fish restocked	Fish harvested Fish restocked	Fish harvested	Fish seeded	Fish harvested
Fish stocked into	pond hatchery	ricefield	ricefield		ricefield	
Fish size	1–3 cm	10–20% 5–10 cm 80–90% 3–5 cm	10–20% 8–12 cm 80–90% 5–10 cm	5–10% > 16 cm 90–95% 10–15 cm	5–10 cm	10–20% > 16 cm 80–90% 10–15 cm
Fish number	50,000-60,000	20,000-40,000	500-1,000		1,000–3,000	
Mortality (%)		40–60	20–40	10–40		10–40
Market		5–10 cm sale 3–5 cm restocking	8–12 cm sale 5–10 cm restocking	sale		sale
Fish yield (kg/ha/year)		41	58	45		226

operators of rice-fish systems in Cianjur shifted to intensive fish nursery systems with very short *minapadi* cycles due to more favorable returns. A separate financial survey was conducted using five examples of each of the four existing types of fish nursery systems in the Cianjur Region. Results showed that net returns were highest for the semi-intensive, deepwater (30–50 cm) nursery ponds (that had been converted from ricefields) (Table 4).

Factors other than finances will need to be considered before any large-scale conversion of ricefields to pond nurseries will occur in West Java. For example, current government policies to preserve ricefields and maintain national rice self-sufficiency would prevent any large-scale conversion (dela Cruz, pers. comm.).

The Subang Regency has thousands of hectares of ricefields of rich volcanic soils that are technically irrigated by the Jatiluhur Reservoir. Subang's rice-fish cropping pattern is no longer influenced by seasonal rains due to the widespread development of irrigation networks (Table 5). In Subang, a special inland fisheries development project (pilot project management unit, or UPP in Indonesian) was created in 1982 by the West Java Provincial Fisheries Service to document and improve existing practices and expand rice-fish areas. Major routes of seed distribution from Subang rice-fish systems to inland aquaculture in West Java were documented (Fig. 3) (UPP 1985). UPP (1985) also documented the different cropping patterns of rice-fish culture existing in 11 villages in Subang (Table 6).

Table 4. Net returns from rice-fish culture in the Cianjur Regency, Indonesia. (Source: DPKC 1987).

System type	Culture period (days)	Net returns (US$/ha)*
Penyelang	40	185
Palawija	40	52
Minapadi	40	150
Semi-intensive pond	30	498

*Original values in Rupiah were converted to US$ at the rate of US$1 = Rp1,647 as of 1987.

Table 5. Yearly rainfall and cropping pattern of rice-fish culture in the Subang Regency, Indonesia, 1984. (Source: UPP 1985).

Month	Rainfall (mm)	Area (ha)	Farmers (no.)	Fish production (kg)
January	225	41	40	4,214
February	155	10	38	3,017
March	107	3	3	210
April	198	8	11	1,520
May	161	17	24	1,798
June	0	25	30	3,125
July	44	191	215	50,410
August	0	120	150	40,320
September	0	370	400	101,000
October	105	616	400	163,157
November	122	666	420	192,655
December	148	29	72	3,435

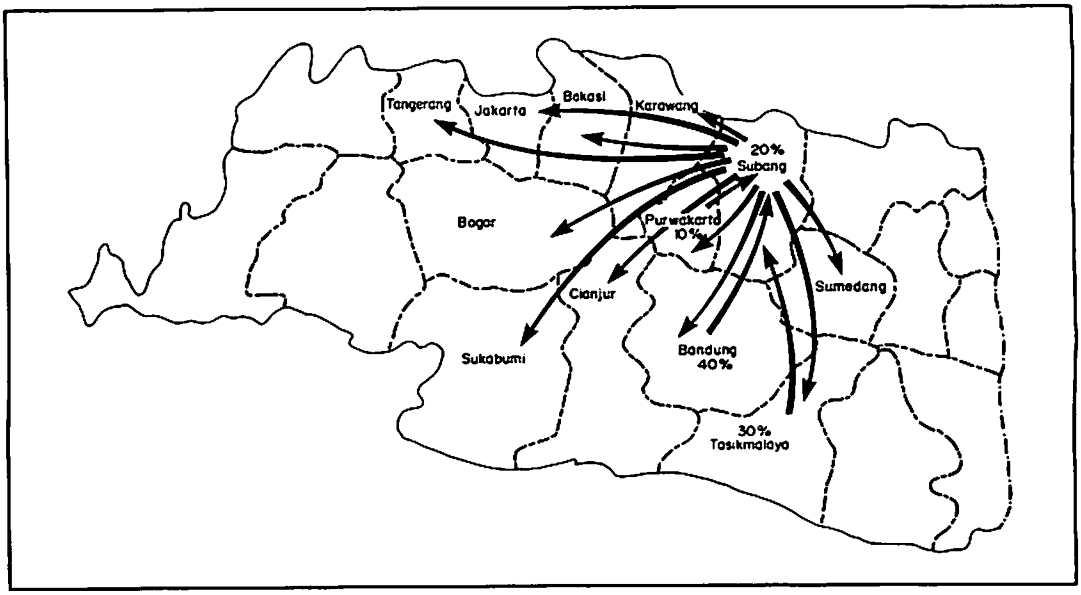


Fig. 3. Routes of *C. carpio* seed from rice-fish nurseries in the Subang Regency to aquaculture growout systems in West Java. Also shown are the major supply routes of fry *C. carpio* (1-3 cm average size) from pond hatcheries in the regencies of Bandung (40%), Tasikmalaya (30%), Subang (20%) and Purwakarta (10%) into rice-fish nursery systems in Subang. (Modified from UPP 1985).

Seven villages were chosen by the UPP for a rice-fish development project. These villages had a population of 52,550. Ricefields comprised 82% (5,763 ha) of the villages' total land area (UPP 1985, 1986). Rice-fish culture in the seven villages has recently expanded (Table 7). In particular, *palawija* systems showed dramatic increases in terms of number of farmers involved, rice-fish culture area and fish yields.

It is known that *palawija* fish production is the most productive of the three methods of rice-fish culture in Indonesia. Fish yields in traditional Indonesian *palawija* in three months produce 600 kg/ha

Table 6. Cropping patterns of rice-fish culture systems in the Subang Regency, West Java, Indonesia. (Source: UPP 1985).

Village	Jan	Feb	Mar	Apr	May	Jun	
Cieadas		*minapadi*			*penyelang*	*minapadi*	
Nanggerang		*minapadi*			*penyelang*	*minapadi*	
Binong		*minapadi*			*penyelang*	*minapadi*	
Karangwangi		*minapadi*			*penyelang*	*minapadi*	
Kihiyang	*minapadi*			*penyelang*	*minapadi*		
Tanjungsari	*minapadi*			*penyelang*	*minapadi*		
Citrajaya	*minapadi*			*penyelang*	*minapadi*		
Mulyasari			*penyelang*		*minapadi*		
Mekarwangi			*penyelang*		*minapadi*		
Sumbersari			*penyelang*		*minapadi*		
Gambarsari		*minapadi*			*penyelang*	*minapadi*	

Village	Jul	Aug	Sep	Oct	Nov	Dec	
Cieadas				*palawija*			*minapadi*
Nanggerang				*palawija*			*minapadi*
Binong				*palawija*			*minapadi*
Karangwangi				*palawija*			*minapadi*
Kihiyang			*palawija*			*minapadi*	
Tanjungsari			*palawija*			*minapadi*	
Citrajaya			*palawija*			*minapadi*	
Mulyasari			*palawija*			*minapadi*	
Mekarwangi			*palawija*			*minapadi*	
Sumbersari			*palawija*			*minapadi*	
Gambarsari				*palawija*			*minapadi*

Table 7. Growth of rice-fish culture in Subang Regency, West Java, Indonesia. (Source: UPP 1986).

System type	Area (ha)	Farmers (no.)	Culture period (days)	Average rice production (kg)	Average fish yields (kg/ha)
Minapadi					
1982	5.0	40	60	750	150
1985	278.2	670	60	32,930	118
Penyelang					
1982	94.8	?	30	7,016	74
1985	20.5	146	30	1,694	83
Palawija					
1982	632.3	1,100	60	126,460	200
1985	1,570.1	2,503	60	471,154	300

in fertile areas, 300 kg/ha in moderately fertile areas, and 100–200 kg/ha in unfertile areas (Ardiwinata 1967). Similar findings in Southeast Asia have been reported by others. Middendrop (1985) found that fish yields from *palawija* are higher than yields from *minapadi* systems in northern Thailand. Coche (1967) mentioned that fish yields from *palawija* were greater than *minapadi* in Indonesia, Japan, Thailand and Vietnam.

Traditional *palawija* in Indonesia were, however, oriented towards producing 125–200-g (average size) common carp for local food. While a wide diversity of different stocking and harvesting patterns in *palawija* continues to exist in Subang (Tables 8 and 9), surveys have shown

Table 8. Approximate culture period (days) to reach various sizes of fish in *palawija*, West Java, Indonesia. (Source: Modified from UPP 1985).

Harvest size	Stocking size 3–5 cm	5–8 cm	8–12 cm	100 g
Seed fish (100 g) for cages and running water systems	60–80	40–60	30–40	-
Rice-fish growout (125-200 g) for local food	90–120	75–90	60–75	30–40
Consumption size (>200 g)	60–80	40–60	30–40	20–30

Table 9. Stocking densities and sizes of *C. carpio* in *palawija* systems. (Source: UPP 1986).

Stocking				
Size (cm)	Density (fish/ha)	Culture period (days)	Harvest size (cm)	Mortality (%)
1–3	70,000–100,000	30	3–8	40–60
3–5	10,000–15,000	50	5–8	30–50
5–8	6,000–10,000	50	8–11	20–40
5–8	1,500–3,000	50–90	12–18	10–40
8–11	1,000–2,000	30	12–18	10–40

that an increasing number of *palawija* systems in the regency produced 80–100-g seed fish for further restocking in reservoir floating net cages and in RWS.

An owner-operated 1-ha rice-fish nursery in Subang was studied for one year, and costs and net returns recorded. The system produced 11.7 t of rice and 791 kg/ha of fish over the one-year period (Table 10). Fish production came from three *minapadi*, one *penyelang* and one *palawija*. Net returns were calculated using the scheme of Herdt (1978) and are presented in Table 10. Net return was US$1,690 ha/year, with fish comprising 31%. Cost of fry was 28% of the value of the fish produced. The net return from fish was 73% of fish gross receipts. Rice-fish culture studies in Southeast Asia estimates cost of fry as 30–50% of the value of the fish produced, and net returns from fish as 30–65% of fish gross receipts (Khoo and Tan 1980).

The attractiveness of rice-fish nurseries can be evaluated in terms of the amount of cash returned to small-scale farmers for the quantity of family labor invested. Small farmers in Indonesia are very short of cash, using family labor in all possible circumstances. Small cash outlays are made when virtually no risk is involved, e.g., during rice harvest, when hiring part-time labor can maximize income. Thus, an index of income earned per unit of labor invested may be more relevant than any straightforward economic analysis of rice-fish farming systems, especially in a labor-rich and capital-poor situation like rural Indonesia (Smith, pers. comm.).

For the rice-fish nursery system studied in West Java (Table 11), the opportunity cost of family labor, equivalent to working in a 1-ha rice-fish nursery system for one year, is US$342. This labor gave a net return of US$1,690. Thus, for every US$0.61 (agricultural wage rate per day in West Java 1988) of labor invested by the farming family, a return of US$3.00 is realized. This indicates that

Table 10. Aquaculture management of different rice and fish cropping patterns in an intensive rice-fish nursery system over a one-year period in Subang Regency, West Java, Indonesia, 1987.

Month	System	Terrestrial	Aquatic	Fish stocked into	Fish size (cm)	Number of fish	Mortality (%)	Market	Fish yield (kg/ha/year)
1		Rice planted	Fish seeded	Pond hatchery	1-3	50,000-60,000			
1.5									
2	*Minapadi* 1	Rice weeded							
2.5									
3		Rice weeded	Fish harvested,	Ricefield	8-12 (20-30%)		20-50	8-12 cm sale	110
			Fish restocked		5-10 (70-80%)	500-1,000		5-10 cm restocking	
3.5	*Minapadi* 2				>16 (5-10%)		10-40	sale	45
4		Paddy dried	Fish harvested		10-15 (90-95%)				
4.5	*Penyelang*		Fish seeded	Ricefield	5-10	1,000-3,000			
5		Rice harvested							
5.5									
6		Rice planted	Fish harvested	Ricefield			10-40	sale	226
			Fish restocked		1-3	50,000-60,000			
7	*Minapadi* 3	Rice weeded							
8		Rice weeded							
9		Paddy dried	Fish harvested		8-12 (20-30%)		20-50	8-12 cm sale 5-10 cm sale, restocking	110
9.5		Rice harvested							
10			Fish stocked		5-10 (70-80%)	1,500-3,000			
11	*Palawija*	Field fallow							
12			Fish harvested		> 18 (5-10%) 12-16 (90-95%)		10-40	sale	300

Table 11. Costs and returns (US$) for a one-hectare intensive rice-fish nursery system in Subang, West Java, Indonesia, 1987.

	Fish	Rice	Rice-fish
Total costs	188.83	427.63	616.46
Cash cost for labor	12.14	36.43	48.57
Transportation of laborers	12.14		
10 harvest days x 2 crops x 3 people x Rp1,000/ person/day		36.43	
Non-cash costs for family labor	30.97	310.81	341.78
Supervising, harvesting, level field, making channels	30.97		
Fixing ditches		45.17	
Breaking ground		54.65	
Plow fields		54.65	
Fix main dike		23.98	
Fertilize, planting		18.21	
Weeding 1		14.57	
Weeding 2		10.93	
Clean dikes		15.18	
Destroy pests		6.07	
Harvest		45.54	
Sun-dry rice		21.86	
Non-cash cost for labor in kind		10.93	10.93
Meals 10 days x 2 crops x 3 people x Rp300/person/day		10.93	
Cash costs for material inputs	145.72	69.46	215.18
Minapadi 40 kg seed fish @ Rp1,500/kg			
Penyelang 50 kg seed fish @ Rp1,500/kg			
Palawija 50 seed fish @ Rp1,500/kg			
60 kg rice seed @ Rp200/kg			
Fertilizer, pesticide		69.46	
Gross returns	707.65	1,598.36	2,306.01
Minapadi 1 110 kg fish @ Rp1,350/kg	90.16		
Minapadi 2 45 kg fish @ Rp1,400/kg	38.25		
Minapadi 3 110 kg fish @ Rp1,500/kg	100.18		
Penyelang 226 kg fish @ Rp1,500/kg	205.83		
Palawija 300 kg fish @ Rp1,500/kg	273.22		
11,700 kg rice @ Rp225/kg		1,598.36	
Net returns	518.82	1,170.73	1,689.55

*Original values in Rupiah were converted to US$ at the rate of US$1 = Rp1,647 as of 1987.

small farmers in West Java greatly benefit from their rice-fish nursery operations.

Conclusions

Inland aquaculture in West Java has significantly expanded from 1976 to the present. This growth has provided the driving force for concomitant expansion of rice-fish culture due to the larger market demand for seed fish.

Intensive rice-fish nursery systems are at the forefront of development in the aquaculture production network of West Java due to their critical role in supplying seed fish for expanding running water and reservoir cage aquaculture systems.

Family labor is productively used in intensive rice-fish nursery systems especially in labor-rich, cash-poor societies if market demand for seed fish are great.

In contrast to the forecasts of Pantulu (1979), it appears that, in West Java, intensive rice-fish nurseries with short fish production cycles can be very compatible with the intensive methods used in modern rice agricultural technology.

Intensive nursery ponds converted from ricefields that hold 30–50 cm water are more profitable than any of the rice-fish nursery systems. This finding, while deserving of further study, may not be practical in West Java due to current national regulations that disallows large-scale conversion of ricefields to fishponds.

Fish produced from ricefields are an essential protein source especially in the heavily-populated regions in West Java. The use of ricefields to supply the increasing demand for seed fish has caused, and will continue to cause, conversion of traditional rice-fish growout systems into intensive nurseries. Thus, a complete conversion to intensive fish nursery systems will diminish fish/protein supplies for immediate human consumption in West Java.

Acknowledgements

Many people and institutions have seen the value of Indonesian rice-fish culture and have tirelessly worked to research, extend, promote and develop it. In this light, I would like to express my warm thanks to all my close institutional collaborators and scientific colleagues in IOE, Padjadjaran University, Perusahaan Umum Listrik Negara, DGF, DPPJB, DPKC and Subang, unit Pelaksanaan Teknis - Saguling and Cirata, Pilot Proyek Management Unit (UPP) Budidaya Air Tawar Subang, Prof. Dr. Otto Soemarwoto, Ir. Gelar Wira Atmadja, Pepen Effendi, Ir. Sutandar Zainal, H. Sutisna, Ir. Tatang Gandawiria and Edi Sudira.

Special thanks to Drs. Ian R. Smith and Joseph Gartner for their comments on the economic analysis.

References

Ardiwinata, R.O. 1967. Fish culture on paddy fields in Indonesia. Proc. IPFC 7:119–154.

Coche, A.G. 1967. Fish culture in ricefields, A world-wide synthesis. Hydrobiologia 30:1-44.

DFKC. 1987. Work program. Dinas Perikanan Kabupaten Daerah Tingkat II Cianjur Thn 1988/1989. Dinas Perikanan Kabupaten Cianjur. Dinas Perikanan Cianjur, West Java, Indonesia. 23 p. (In Indonesian).

DGF. 1979. Fisheries statistics of Indonesia, 1977. Directorate General of Fisheries. Department of Agriculture, Jakarta, Indonesia.

DGF. 1986. Fisheries statistics of Indonesia, 1984. Directorate General of Fisheries. Department of Agriculture, Jakarta, Indonesia.

Djajadiredja, R., Z. Jangkaru and M. Junus. 1980. Freshwater aquaculture in Indonesia with special reference to small-scale agriculture-aquaculture farming systems in West Java, p. 143-165. *In* R.S.V. Pullin and Z.A. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

DPPJB. 1987. Annual report, 1986. Dinas Perikanan Propinsi Jawa Barat, Bandung, Indonesia. (In Indonesian).

DPPJB. 1986. Annual report, 1985. Dinas Perikanan Propinsi Jawa Barat. Bandung, Indonesia. (In Indonesian).

Herdt, R.W. 1978. Costs and returns for rice production, p. 63–80. *In* Economic consequences of the new rice technology. International Rice Research Institute, Manila.

IOE. 1986. Environmental impact analysis of the Saguling dam: studies for implementation of mitigation of impact and monitoring. Report to Perusahaan Umum Listrik Negara, Jakarta, Indonesia. Institute of Ecology, Padjadjaran University, Bandung, Indonesia.

IOE/ICLARM. 1987. Quarterly report II for project activities development. Consulting services development of aquaculture and fisheries activities for resettlement of families from the Saguling and Cirata Reservoirs. Report to Perusahaan Umum Listrik Negara, Jakarta, Indonesia.

Khoo K.H. and Tan 1980. Review of rice-fish culture in Southeast Asia, p. 1-4. *In* R.S.V. Pullin and Z.A. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

LPPU. 1986. Training in aquaculture skills to support the scheme of the resettlement project of PLTA Cirata. Lembaga Penelitian Padjadjaran University. Report to Perusahaan Umum Listrik Negara, Jakarta, Indonesia. (In Indonesian).

Middendorp, A.J. 1985. Integrated rice/fish culture: practices and prospects. Working Group on Small Scale Integrated Aquaculture, International Agricultural Center, Wageningen, The Netherlands. 40 p.

Pantulu, L.R. 1979. Role of aquaculture in water resource development: case study of the lower Mekong basin project, p. 53–58. *In* T.V.R. Pillay and W.A. Dill (eds.). Advances in aquaculture. Fishing News Books, Surrey, U.K.

RIIF. 1983. Floating net fish culture and breeding in Juanda Lake, an experiment in supporting the resettlement program of PLTA Saguling project. Research Institute for Inland Fisheries. Report to Perusahaan Umum Listrik Negara, Jakarta, Indonesia.

Rosegrant, M.W., F. Kasryno, L.A. Gonzales, C. Rasahan and Y. Saefudin. 1987. Price and investment policies in the Indonesian food crop sector. Final report submitted to the Asian Development Bank (ADB) for the project, "Study of food demand/supply prospects and related strategies for developing member countries of ADB, Phase II." Asian Development Bank, Manila.

Sayogyo. 1978. The lowest social stratum in rural Java. Prisma 3: 3–14. (In Indonesia).

Soeprapto, R. 1987. Exports of fishery products expected to earn US$620 million. The Indonesia Times. 4 December 1987:5.

Suprayitno, S.H. 1986. Manual of running water fish culture. ASEAN/SF/86/Manual No. 1, ASEAN/UNDP/FAO Regional Small-Scale Coastal Fisheries Development Project, Manila. 34 p.

Tarrant, J., E. Barbier, R.J. Greenberg, M.L. Higgins, S.F. Lintner, C. Mackie, J. Murphy and V. Veldhuizen. 1987. Natural resources and environmental management in Indonesia: an overview. Unites States Agency for International Development, Jakarta, Indonesia.

UPP. 1985. Annual report of the pilot project management unit for developing freshwater fish culture in Subang, West Java, 1984/1985. Pilot Project Management Unit. Dinas Perikanan Propinsi Daerah TK. I Jawa Barat. West Java, Indonesia. (In Indonesian).

UPP. 1986. Annual report of activities of the pilot project management unit (UPP) for the development of fish culture in Subang, West Java. Pilot Project Management Unit. Dinas Perikanan Propinsi DT I Jawa Barat, Bandung, Indonesia. 48 p. (In Indonesian).

Evaluation of Rice-Fish Production Systems in Indonesia

MOCHAMAD YUNUS
ATMADJA HARDJAMULIA
Research Institute for Freshwater Fisheries
Bogor, Indonesia

IIS SYAMSIAH
SADELI SURIAPERMANA
Research Institute for Food Crops
Sukamandi, Indonesia

YUNUS M., A. HARDJAMULIA, I. SYAMSIAH AND S. SURIAPERMANA. 1992. Evaluation of rice-fish production systems in Indonesia, p. 131–137. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Rice-fish farming systems in Indonesia, known as *minapadi* (concurrent), *penyelang* (intermediate) and *palawija* (rotational), together with rice production patterns are practised widely in Indonesia, especially in Java. Results from the 32 rice-fish farmers surveyed in West Java in 1987 and 1988 showed that the introduction of fish into the ricefield increased rice productivity. The rate of return on inputs per year averaged 127% for the rice-rice-fish and 173% for the (rice+fish)-(rice+fish)-fish cropping patterns. Constraints identified were the need for more quality seed fish to support the expansion of rice-fish farming, the use of pesticides and optimizing production of rice and fish through better design of fish refuges.

Introduction

Rice and fish are the staple foods for the majority of people in Asia. Rice-fish farming is an ideal method of land use, since it produces high quality grain and animal protein simultaneously (Satari 1962). Fish culture in ricefields requires relatively small capital inputs and has a short payback period (Ruddle 1982). In Indonesia, fish culture in ricefields has been practised for more than a century, and is still widely practised (Djajadiredja et al. 1980; Koesoemadinata and Costa-Pierce, this vol.). It assumes a tremendous household economic importance as well as being an essential part of the nation's inland aquaculture production system (Costa-Pierce, this vol.).

There are many advantages of rice-fish culture. Khoo and Tan (1980) revealed that with the introduction of fish into the ricefields, the yield of rice is increased by 4 to 15%. This probably results from the increased soil fertility due to fish feces, the additional fertilizers used and remnants of supplemental food, better aeration of the water and greater tillering. Thus, ricefields are rich (oftentimes richer than many fish culture ponds) in natural aquatic fish foods due to constant fertilization, besides plowing and drainage of the ricefield (Costa-Pierce, this vol.). Satari (1962) revealed that by introducing fish into ricefields, rice grow better, branch higher, the effective tillering rate and grains per tiller are higher, and the rate of empty grains is lower. Fish also reduce the need for fertilizer on rice (Li 1986) and may decrease weed growth in ricefields by 30% between transplanting and first weeding periods (Satari 1962). Fish also consume many destructive insects and insect larvae which damage rice plants as well as consume many human disease vectors (Khoo and Tan 1980). Thus, fish culture in ricefields can be a valuable addition to management of natural resources in the rice agroecosystem (Costa-Pierce, this vol.).

Some Economic Analyses

A survey was conducted in West Java (Cianjur, Sukabumi and Bogor Districts) in 1987 by the Research Institute for Freshwater Fisheries (RIFF). Data collection was done by interviewing rice-fish farmers using a questionnaire and visiting their ricefield area. The results obtained from 14 respondents showed that *minapadi-penyelang-minapadi* was the cropping pattern adopted most by the farmers. The system produced an average of 500-800 kg of fish (700 kg/ha) and 12-16 t of rice (13 t/ha) in one year. Rate of return on inputs ranged from 86 to 126% (Table 1). Fish accounted for 22-48% of total net returns.

The ratio of net returns from fish to rice production costs for a single crop of *minapadi* and *minapadi-penyelang-minapadi* ranged from 41 to 54% and 56 to 115%, respectively (Table 2). The latter was able to pay more for the rice production costs because the system produced more fish.

Another baseline survey was conducted in 1988 by the Sukamandi Research Institute for Food Crops (SURIF)

Table 1. Input-output analyses of *minapadi-penyelang-minapadi* cropping pattern per year from farm surveys conducted by RIFF in Sukabumi, Cianjur and Bogor, 1987.[a]

Location	Area (ha)	Total input costs[b] (US$)	Total net returns (US$)	Net returns of fish to total net returns (%)	Rate of return on inputs (%)
Sukabumi	1	1,492.78	1,657.21	22	111
Cianjur	1	1,080.36	1,302.88	48	120
Cianjur	0.95	1,020.81	1,232.31	22	121
Sukabumi	0.50	813.50	983.37	26	121
Bogor	1	1,361.84	1,712.53	22	126
Subang	1	696.72	599.39	27	86

[a]Original values in Indonesian Rupiah were converted to US$ at the rate of US$1=Rp1,600, as of 1987.
[b]Includes land rent and ricefield construction.

Table 2. Ratio of net return of fish on rice input costs in *minapadi* and *minapadi-penyelang-minapadi* cropping pattern from farm surveys conducted by RIFF in Sukabumi, Cianjur and Bogor, 1987.[a]

Area (ha)	Rice input costs (US$)	*Minapadi* Net returns of fish (US$)	*Minapadi* Rate of fish returns on rice inputs (%)	*Minapadi-penyelang-minapadi* Net returns of fish (US$)	*Minapadi-penyelang-minapadi* Rate of fish returns on rice inputs (%)
1	541.65	291.56	54	625.93	115
0.95	486.43	218.75	45	268.75	56
0.50	276.00	123.12	45	259.37	93
1	569.65	234.21	41	369.68	65
1	499.65	246.87	49	356.87	71
1	194.06	96.87	50	132.01	68

[a]Original values in Indonesian Rupiah were converted to US$ at the rate of US$1=Rp1,600, as of 1987.

and the RIFF in Binong Village, Subang District, where about 15% of the 10,234-ha irrigated ricefields were used for fish *palawija* and 2% for concurrent rice-fish culture. Details on the methodology is discussed in Syamsiah et al. (this vol.). Sixty farmers were interviewed but only 18 responses were analyzed. The cropping patterns adopted by farmers were: rice-rice-fallow; rice-rice-fish; (rice+fish)-rice-fish; (rice+fish)-(rice+fish)-fish; and (rice+fish)-fish-(rice+fish)-fish.

Rice yields from rice monoculture and rice-fish culture averaged 10.8 and 10.9 t/ha/year, respectively. Rice monoculture yields ranged from 8.0 to 14.0 t/ha/year; while in rice-fish culture, 9.0 to 13.0 t/ha/year.

Fish production from rice-rice-fish ranged from 80 to 367 kg with an average of 241 kg/ha/year; while in (rice+fish)-(rice+fish)-fish, 320 to 850 kg with an average of 550 kg/ha/year.

The ratio of net returns on inputs per year in the rice-rice-fallow, rice-rice-fish and (rice+fish)-(rice+fish)-fish patterns, averaged 115, 125 and 173%, respectively (Tables 3-5). On the average, the income from fish was able to cover 20 and 59% of rice production costs in the rice-rice-fish and (rice+fish)-(rice+fish)-fish patterns. By introducing fish into the cropping patterns, the productivity of ricefields and the farm incomes have increased.

Labor, a major cost in all cropping patterns, accounted for 68% of total costs, followed by fertilizers and tax (12% each), chemicals (5%) and seed/fingerlings (3%).

Prospects and Constraints

Prospects

About 94,309 ha of ricefields throughout the country are being used to culture fish. This area is only 8% of the total potential irrigated ricefields or 1% of the total ricefield area in Indonesia which is about 7,195,946 ha.

West Java has 542,821 ha of potential irrigated ricefields, but only 8% are currently used to culture fish (Ahmad and Darmawiredja 1989). A larger expansion of rice-fish culture in this region has a great possibility, since seed fish demands from reservoir floating net cages and running water systems are increasing (Costa-Pierce and Hadikusumah 1990).

Table 3. Input-output analyses of rice-rice-fallow cropping pattern per year from farm surveys conducted by SURIF and RIFF, Binong, Subang District, 1988.[a]

Items	Area (ha)						Average
	0.35	1.0	0.5	0.25	0.7	0.7	
Input costs	300.66	688.06	379.70	204.55	502.73	544.85	436.73
Seed	5.45	13.64	12.12	4.55	13.64	10.00	
Fertilizers	31.52	78.79	37.88	24.06	75.76	64.55	
Chemicals	19.39	75.03	18.18	9.45	29.09	33.94	
Labor							
land preparation	29.09	60.61	41.21	28.79	64.24	77.58	
seedling	4.85	7.27	4.85	1.82	3.64	9.70	
planting	11.52	49.09	12.12	18.18	21.82	24.24	
fertilizing	2.42	4.85	4.85	3.64	9.09	12.73	
pest eradication	10.30	18.48	7.27	7.27	9.09	12.12	
weeding	5.82	16.67	9.39	3.64	10.91	21.21	
harvesting	143.94	290.91	185.45	82.55	212.12	223.03	
Tax	36.36	72.73	46.36	20.61	53.33	55.76	
Value of output	663.03	1,454.55	927.27	412.73	1,069.70	1,116.96	940.73
Net returns	362.36	766.48	547.58	208.18	566.97	572.12	504.00
Rate of return on inputs (%)	120	111	144	102	113	105	115

[a]Original values in Indonesian Rupiah were converted to US$ at the rate of US$1 = Rp1,650, as of 1988.

Table 4. Input-output analyses of rice-rice-fish cropping pattern per year from farm surveys conducted by SURIF and RIFF, Binong, Subang District, 1988.[a]

Items	Area (ha)						Average
	0.70	1.15	0.70	0.40	0.28	0.21	
Input costs	517.88	684.55	417.01	237.03	244.06	181.64	380.30
Rice	486.06	647.27	360.95	208.30	204.48	153.45	343.39
Seed	10.91	10.91	9.09	5.45	3.88	3.03	
Fertilizers	64.24	65.45	53.03	15.15	25.76	10.61	
Chemicals	73.64	38.79	23.94	8.48	6.67	7.27	
Labor							
land preparation	40.61	63.33	30.04	20.00	20.00	25.45	
seedling	5.45	7.58	3.64	3.64	2.73	3.64	
planting	20.61	36.36	30.30	12.12	8.48	10.00	
fertilizing	9.70	9.70	5.45	6.06	4.85	2.73	
pest eradication	7.88	26.67	5.45	6.67	3.64	3.64	
weeding	16.97	29.09	15.15	5.15	6.06	3.64	
harvesting	212.73	287.88	147.88	100.73	98.18	67.09	
Tax	53.33	71.52	36.97	24.85	24.24	16.36	
Fish	31.82	37.27	56.06	28.73	39.58	28.18	36.91
Fingerlings	9.09	13.64	30.30	10.24	24.24	6.06	
Feed	2.73	0.91	1.82	1.21	1.09	1.21	
Labor							
land preparation	7.58	7.58	7.88	7.27	7.27	13.94	
stocking	0.91	0.91	0.91	0.91	0.91	0.91	
maintenance	9.09	10.00	9.09	3.64	3.64	3.64	
harvesting	2.42	4.24	6.06	5.45	2.42	2.42	
Value of output	1,111.52	1,517.27	925.76	636.36	541.82	394.85	854.55
Rice	1,060.61	1,440.00	739.39	509.09	490.91	335.45	762.55
Fish	50.91	77.27	183.36	127.27	50.91	59.39	92.00
Total net returns	593.64	823.73	508.75	399.33	297.76	213.21	474.24
Rate of return on inputs (%)	115	122	122	168	122	117	127
Net returns of fish on rice inputs (%)	4	6	36	47	5.5	20	19.7

[a]Original values in Indonesian Rupiah were converted to US$ at the rate of US$1 = Rp1,650, as of 1988.

Table 5. Input-output analyses of (rice+fish)-(rice+fish)-fish cropping pattern per year from farm surveys conducted by SURIF and RIFF, Binong, Subang District, 1988.[a]

Items	Area (ha)						Average
	0.50	0.45	0.70	0.70	1.50	0.50	
Input costs	394.55	375.52	447.27	473.64	1,160.73	374.12	537.58
Rice	315.76	300.67	397.27	410.00	960.61	317.76	450.30
Seed	7.76	6.97	16.67	17.27	27.27	7.45	
Fertilizers	55.09	35.21	59.39	64.24	117.27	32.73	
Chemicals	15.09	20.61	9.09	15.15	60.61	6.06	
Labor							
land preparation	21.15	21.82	25.45	29.09	60.61	26.06	
seedling	3.64	3.64	3.64	5.15	10.30	3.64	
planting	20.55	16.97	20.61	19.39	34.24	16.36	
fertilizing	3.64	2.73	3.64	3.64	5.45	3.64	
pest eradication	4.85	12.12	5.45	4.55	5.45	3.64	
weeding	6.06	9.09	4.85	9.09	12.12	8.48	
harvesting	142.24	136.97	198.79	193.94	501.82	167.88	
Tax	35.70	34.55	49.70	48.48	125.45	41.82	
Fish	78.79	74.85	50.00	63.64	200.12	56.36	87.27
Fingerlings	50.00	45.45	27.27	37.88	165.15	33.33	
Feed	7.27	5.76	0.61	5.45	5.58	2.73	
Fertilizers	-	1.21	5.45	-	-	-	
Labor							
land preparation	9.09	7.58	3.64	6.06	6.06	5.45	
stocking	0.91	0.91	0.91	0.91	0.91	0.91	
maintenance	9.09	9.70	9.09	9.09	15.15	10.91	
harvesting	2.42	4.24	3.03	4.24	7.27	3.03	
Value of output	1,134.55	908.48	1,183.03	1,371.52	3,243.64	975.09	1,469.33
Rice	712.12	687.27	993.94	969.70	2,509.09	840.00	1,118.67
Fish	422.42	221.21	189.09	401.82	734.55	135.09	350.67
Total net returns	740.00	532.97	735.76	897.88	2,082.91	600.97	931.76
Rate of return on inputs (%)	187	142	164	189	179	161	173
Net returns of fish on rice inputs (%)	109	49	35	82	56	25	59

[a]Original values in Indonesian Rupiah were converted to US$ at the rate of US$1 = Rp1,650, as of 1988.

Rapid expansion of reservoir fish culture has occurred in the Saguling Reservoir (West Java) which has a total area of 5,340 ha during 1985–88. Fish culture in floating net cages in this reservoir started in 1985 with 57 units of cages operated, producing 17.4 t of common carp. By 1988, the floating net cages increased to 1,236 units which produced 2,554 t of fish (Sutandar et al. 1990). The system has expanded to the Cirata Reservoir (West Java) in 1988 and already has 100 units of floating net cages, producing 31.9 t of fish by the end of 1988. The seed fish used in these reservoirs' floating net cages mostly originated from rice-fish culture in the Subang, Bandung and Cianjur Regencies (Effendi 1988; Costa-Pierce, this vol.).

The government's rice-fish production program included the expansion of rice-fish culture to other regions and a rice intensification program. In West Java, around 20,000 ha are to be included in this intensification program, starting 1989.

Constraints

An expansion of rice-fish farming will increase the need of seed fish. Moreover, improved seed fish production techniques should also be considered to prevent the poor quality of fish seed which has been observed by the Fisheries Service in Cianjur since 1987.

The use of pesticides in rice-fish culture needs proper attention. Using integrated pest management has been successful for brown planthoppers. Use of insecticides against fish parasites have to be in accordance with Presidential Decree No. 3, 1986 (Ahmad and Darmawiredja 1989). Only nine out of the 30 kinds of insecticides (Bassa, Baycarb, Hopcin, Kiltop, Mipcin, Folithion, Mikrab, Tsumacide and Unden) are recommended by the government. The decree also specified the active ingredients in the pesticides (see Koesoemadinata and Costa-Pierce, this vol.).

Farmers are concerned that rice production is lower due to the reduction of area used for rice cultivation due to construction of trenches as fish refuges. Better techniques to optimize production of rice and fish should be found.

Research Activities

In the effort to get better fish yields, different strains of common carp from isolated areas in Indonesia have been collected by the RIFF in collaboration with Dalhousie University, sponsored by the International Development Research Centre of Canada (IDRC). Experiments on the crossing of different strains are on-going. But the research activities are still limited to pond fish, and are lacking for rice-fish culture purposes.

On the use of pesticides in rice-fish farming system, Koesoemadinata (1982) found that 8.3% of the rice pesticides were extremely toxic to fish, 62.5% were highly toxic, 16.7% were moderately toxic and 12.5% were of low toxicity. The Pesticide Committee stated that extremely toxic and persistent chemicals categorized as water contaminants, such as endrin, DDT, BHC and other organochlorines, are not allowed to be used in aquatic environments.

An experiment on evaluating the effects of fish stocking densities was conducted by the RIFF at Sukamandi. Results showed that although there is no significant effect of different stocking densities of fish on rice production, a trend of higher rice production for higher fish stocking densities exists. Moreover, an initial stocking density of fish between 2,000 and 4,000/ha gives better fish production. In this experiment, 4% of the ricefield area was used for the trench.

Conclusions

Rice-fish farming systems are practised widely in Indonesia and have a great potential for expansion. The area of ricefields used for fish cultivation has increased steadily since 1979, 75% of which are located in Java. The increased fish production in Java Island until 1986 has indicated significant progress in the intensification of rice-fish culture.

The minapadi-penyelang-minapadi pattern is adopted by most farmers in West Java, while in Binong Subdistrict, the *palawija* system or *minapadi-minapadi*-fish pattern is widely practised. The rate of return on inputs per year in the *minapadi-penyelang-minapadi* averaged 114%, and net returns from fish covered 73% of rice production costs. In Binong Subdistrict, the rate of return on inputs per year in *minapadi-minapadi*-fish pattern averaged 173%; net returns from fish covered 59% of rice production costs. In the same area, using the rice-rice-fish pattern, net returns from fish paid only 20% of rice productions costs.

In this Regency, a larger expansion of rice-fish culture has a great possibility, since rapid expansion of reservoir fish culture has occurred in a short period of time, increasing dramatically the demand for seed fish from rice-fish culture. Efforts to increase hatchery production of seed fish of high quality should be considered. Other research areas are focused on use of pesticides in rice-fish culture and on fish stocking densities.

References

Ahmad, S.S. and M.R. Darmawiredja. 1989. Prospects and problems of rice-fish in West Java. Paper presented in Rice-Fish Workshop, Sukamandi, Subang, West Java, Indonesia, 4 February 1989. 25 p. (In Indonesian).

Costa-Pierce, B.A. and H.Y. Hadikusumah. 1990. Research on cage aquaculture systems in the Saguling Reservoir, West Java, Indonesia, p. 112–217. *In* B.A. Costa-Pierce and O. Soemarwoto (eds.) Reservoir Fisheries and aquaculture development for resettlement in Indonesia. ICLARM Tech. Rep. 23, 378 p.

Djajadiredja, R., Z. Jangkaru and M. Yunus. 1980. Freshwater aquaculture in Indonesia with special reference to small-scale agriculture-aquaculture farming systems in West Java, p. 143–165. *In* R.S.V. Pullin and Z. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Effendi, P. 1988. Evaluation of fisheries development in Saguling and Cirata Reservoirs during PELITA IV and the work plan of UPTD Saguling-Cirata fisheries in PELITA V. Dinas Perikanan UPTD Saguling-Cirata, West Java, Indonesia. (In Indonesian).

Khoo, K.H. and E.S.P. Tan. 1980. Review of rice-fish culture in Southeast Asia, p. 1–14. *In* R.S.V. Pullin and Z. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Koesoemadinata, S. 1982. Lethal toxicity of 24 insecticide formulations commonly used for rice pest control on irrigated ricefield to two Indonesian freshwater fish species *Cyprinus carpio* and *Puntius gonionotus*. Bull, Penelitian Perikanan (Fish. Res. Bull.) 2:67–82.

Li K. 1986. A review of rice-fish culture in China. Network of Aquaculture Centers in Asia (NACA)/WP/86/30, Bangkok, Thailand. 13 p.

Ruddle, K.A. 1982. Traditional integrated farming systems and rural development, the example of ricefield fisheries in Southeast Asia. Agriculture Administration 10:1–11.

Satari, G. 1962. Wet rice cultivation with fish culture: a study of some agronomical aspects. Bogor Agricultural University, Bogor, Indonesia. 126 p. Ph.D. Thesis.

Sutandar, Z., B.A. Costa-Pierce, Iskandar, Rusydi and H. Hadikusumah, 1990. Aquaculture resettlement option in the Saguling Reservoir, Indonesia: its contribution to an environmentally-oriented hydropower project, p. 253–258. *In* R. Hirano and I. Hanyu (eds.) The Second Asian Fisheries Forum. 991 p. Asian Fisheries Society, Manila, Philippines.

Fry Nursery Techniques in the Rice-Fish Systems of Northeast Thailand

GREG CHAPMAN
Sakon Nakhon Rice Experiment Station
A. Muang, Sakon Nakhon 47000
Thailand

CHAPMAN, G. 1992. Fry nursery techniques in the rice-fish systems of Northeast Thailand, p. 139–143. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Observations from an on-farm research and extension project conducted from 1984 to 1989 in Northeast Thailand have revealed great diversity in fry nursery facilities and management. Many management procedures fall short of what is needed. Instruction in basic nursery management would greatly improve fry production without the need for new technologies. Suggested fry nursery techniques can increase fish production and lower operating costs. Furthermore, the more efficient use of fry can partially redress the current seed fish supply problem.

Introduction

Mortality in rice-fish systems largely depends on fish growth rates during the fry-nursing stage because the fish growth rate determines the size of fingerlings stocked. It is generally accepted by farmers and researchers that heavy mortalities occur when undersized fingerlings are stocked. Successful fry to fingerling rearing is achieved by a relatively modest number of rice-fish farmers.

Apart from a brief description by Surintaraseree (1988), research specifically examining nursery facilities and management in Thailand has not been undertaken. The information on fry-rearing facilities and management used in rice-fish farms described here comes primarily from observations made between 1984 and 1989 in an on-farm research and extension project. After this examination, several improvements are suggested.

Description of Fry Nursery Systems

The following descriptions of nursery layouts and management strategies in both rainfed and irrigated areas serve only to show the variety of systems in

*Present address: P.O. Box 26, A. Muang, Nong Khai 43000, Thailand.

use. Surintaresee (1988) found that most farmers realize the importance of fry-nursing but only those raising fish for sale utilized adequate levels of nursery management.

All species raised *(Cyprinus carpio, Oreochromis niloticus, Puntius gonionotus, Aristichthys nobilis* and *Hypophthalmichthys molitrix*) are stocked together in the nurseries. Supplementary feeding is common because plankton productivity is inadequate. The amount of feed provided depends on the financial resources and/or availability of materials. Feeding, however, is rarely done on a fish biomass basis.

Farmers stock fry as early as possible to maximize the rearing period. Usually, fish are stocked when nurseries have accumulated about 0.5 m of water. Nursery periods usually last between three and five weeks. One to two weeks after transplanting rice, 2–5 cm total length fingerlings are released into the ricefields. Stocking densities are highly variable and often not even considered in nursery systems.

One of the simplest facilities used is a plastic screened cage set in the pond. Cages are stocked early in May, water permitting, when fry of all species are still available from government and private hatcheries. Early stocking gives fry approximately four weeks to attain the 5–7 cm total length desired for stocking into ricefields. Cages also provide protection from aquatic predators. There are a number of disadvantages associated with this method, however. As is true of any enclosed system, there is a danger of fry escape should the enclosure become punctured, and theft is easy. Frequent inspection and guarding are necessary. Transport from cages to field increases stress on the fish and adds labor. Another expense associated with this type of nursery is that of fertilizing the water to encourage adequate plankton production. Farms in the Northeast produce insufficient organic inputs so supplemental feeding with rice bran, termites, and occasionally with pelleted feed, is necessary.

A simple nursery of fine mesh plastic or bamboo fencing placed in natural low areas within a ricefield have been designed (Fig. 1). Although plastic netting must be purchased and has a shorter life, its convenience over the stronger bamboo explains its prevalence. These areas are generally small, between 10 to 50 m².

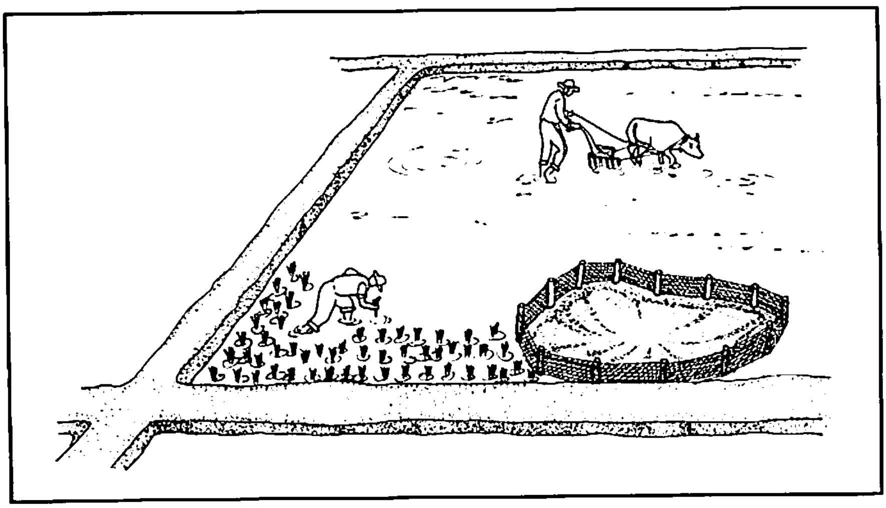


Fig. 1. A natural low area used as a nursery facility during ricefield preparation. (Reproduced with permission from US Peace Corps 1986).

These enclosed depressions are stocked following the first rains when water depth reaches 30–50 cm. This extremely turbid water is of poor quality, therefore some type of supplemental feed is provided. Farmers reduce this problem by surrounding the low areas with earth bunds. Fencing embedded in bunds provides added protection from predators.

Occasionally, nursery areas of 400–800 m^2 are especially prepared from irrigated ricefields. These nurseries are used to spawn *O. niloticus* and *C. carpio*. Nursery fields are flooded from January until March when *C. carpio* spawn. Fry, spawned in enclosures within nursery fields, are released by opening the spawning enclosures. The fry feed on decomposed rice stubble and other plant matter, and hence supplemental feeds are not supplied (Surintaraseree 1988). Predator control is difficult in this open system, but because nursing occurs during the dry season, aquatic predators are less numerous than during the rainy season. Semi-aquatic and terrestrial predators still pose a threat. As stocking occurs only in June or July, fish reared in nursery fields are large and suffer fewer poststocking mortalities. High flow rates and 20 cm-deep water avert mortalities due to high water temperature.

Although these systems require additional labor, cash costs are negligible partly because no feed is needed.

A frequently observed fry-rearing system utilizes a trench refuge (Fig. 2). Trenches on one or two sides of the field are located at the low end so that they collect water first. Fry are stocked before field preparation when the water depth in the trenches has reached about 0.5 m. Cages or fencing in the trench contain the fry. Bunds around the trench prevent turbid water from the ricefield entering the nursery. Before the rains, the trench is limed and manured at approximately 1 kg per 20 m^2 and 3 kg per 16 m^2, respectively. More developed facilities have outlets for releasing fish into the field and draining during floods. If water level should drop and water temperature approach lethal levels, farmers shade a section of the nursery.

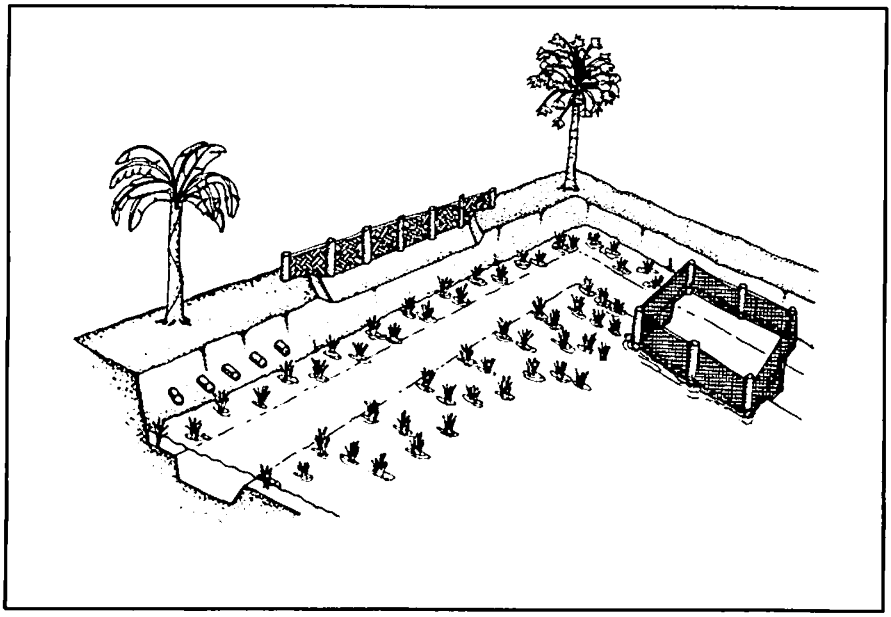


Fig. 2. A trench refuge with outlets and a spillway used for fry-nursing. (Source: US Peace Corps 1986).

A similar fry-rearing system has its refuge pond within the ricefield (Fig. 3). These nurseries are managed in the same manner as the trench nurseries. Low bunds are constructed around the 0.5-m x 1.5-m ponds to maintain water quality during field preparation and prevent aquatic predators from entering the nursery. Composts of rice straw and household wastes are sometimes used to promote plankton growth.

Fry have been successfully reared in all of the aforementioned nursery layouts. Productive fry-nursing can be achieved almost regardless of the facility. What distinguishes the productive systems is their management.

Constraints to Better Nursery Management

Basic fry management in rice-fish systems includes: the installation of a fence around the nursery; liming and manuring using compost; supplemental feeding with rice bran, broken rice, termites, pelleted feeds or other suitable feeds; stocking the nursery as early as possible; and stocking fingerlings of at least 5 cm total length, no more than one week after transplanting.

Probably the greatest constraint to better fry-rearing in Northeast Thailand is the lack of familiarity with basic nursery management practices. When rice-fish culture was initially promoted, one of its advantages was its simple management. This is not the case during the fry nursing stage, however. This should be stressed to potential adopters so that they may have a full understanding of what is required.

Labor can be a constraint as fry-nursing coincides with ricefield preparation. Feeding and feed acquisition are particularly labor-intensive activities. Natural food production reduces the amounts of time required to collect or prepare supplemental feeds. Therefore, time invested in liming and manuring eventually reduces labor for feeding.

Fry availability is another constraint faced by farmers, especially for those experiencing late rains. Seed fish must be made available at later dates in such circumstances. Associated with late rains is the reduced duration of nursing and hence stocking of undersized fingerlings.

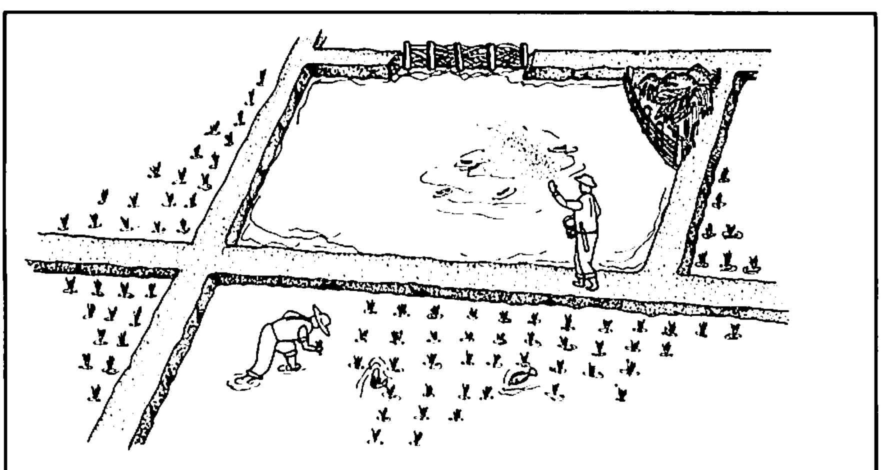


Fig. 3. A nursery pond refuge contiguous with the ricefield. (Source: US Peace Corps 1986).

Again, education in basic nursery management can partially resolve this constraint.

Other deficiencies have been noted in otherwise well-managed nurseries. Fertile nursery water is lost when water from ricefields overflows the refuge following heavy rains. Similarly, water is lost when the field is drained through the refuge. Ideally, the nursery should be completely closed from the field, and provided with a separate water outlet.

Generally, the most popular species in rice-fish systems (*C. carpio, O. niloticus* and *P. gonionotus*) are reared together, but there is evidence from highly fertile nurseries that Chinese carp impede tilapia growth. Some consideration might be given to raising the two species in isolation.

Benefits of Optimal Nursery Management

The primary benefit from good management is that large fingerlings will be stocked into ricefields, thereby increasing survival. Secondly, benefits from increased fingerling survival involve the reduction in stocking rates as the current practice of farmers is to stock two or three times the recommended rate. Likewise, protection from predation in the nursery ensures that a greater number of fingerlings will be available for stocking. Moreover, the number of fry conserved reduce the seed fish supply problem.

Finally, an indirect but consequential derivative of good fry-nursing may be higher adoption rice-fish culture by farmers. Inadequate fry-nursing virtually assures poor production; improvements insure some measures of success.

Conclusions

Notwithstanding the lack of research dedicated to fry-rearing in rice-fish systems, many different nursery facilities and management regimes have developed.

Facilities range from simple enclosures in ponds and trenches to specialized ponds incorporated into the rice-fish field. There is no preferred or acceptable nursery model. Nurseries are constructed in accordance with the local environment and available resources. Management practices vary substantially, with only few farmers adhering to the principles of proper fry management. Observations suggest that management, not the physical characteristics of the systems, determines their success. It must be stressed that fry-rearing, unlike other phases of rice-fish integration, is management intensive.

Nursery management is a critical phase in rice-fish culture because it strongly affects production. Its benefits are reduced production costs and mitigating the seed fish supply problem.

Acknowledgements

The author is most grateful to the International Development Research Centre of Canada (IDRC) for providing the travel grant to attend the workshop; and to the Farming Systems Research Institute (FSRI) for its always generous assistance.

References

Surintaraseree. 1988. Rice-fish culture systems: a survey in northeast Thailand. Asian Institute of Technology, Bangkok. 117 p. M.Sc. Thesis.

US Peace Corps. 1986. Handbook for aquaculture in Thailand, second edition. The United States Peace Corps Volunteer Program, Thailand. 159 p.

Status of Ricefields as Hatcheries/Nurseries for Tilapia in the Philippines

LOUREEDA C. DARVIN
Philippine Council for Aquatic and Marine Research and Development
Los Baños, Laguna
Philippines

DARVIN, L.C. 1992. Status of ricefields as hatcheries/nurseries for tilapia in the Philippines, p. 145–150. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

The future of an integrated aquaculture program including rice-fish depends on the expansion of decentralized hatcheries. However, ricefields as nurseries are not yet used in the Philippines as extensively as in other countries. Rearing fry and fingerlings of Nile tilapia (*Oreochromis niloticus*) is practised in excavated ricefields in small- and medium-scale hatcheries/nurseries in Laguna and Rizal Provinces. This paper details the prevailing management practices for ricefields as breeding and nursery ponds for tilapia production in the Philippines, and how rapid urban development, industrialization, escalating land costs and prospects for other economic uses of agricultural lands will determine the future of ricefield hatcheries in the Philippines.

Introduction

Much has been written about the Philippine experience in the commercial production of tilapia (*Oreochromis* spp.) (Smith et al. 1985; Guererro 1987; Bimbao and Smith 1988). Success was spurred by the emergence of hatchery operations as a specialized function of the industry and as a subsidiary economic activity in certain rural areas of the country.

More than 300 million fingerlings are estimated to be produced annually by over a thousand small- and medium-scale tilapia hatcheries in the Philippines (Yater and Smith 1985). The Nile tilapia (*Oreochromis niloticus*) is grown economically in net enclosures, cages, earthen ponds and ricefields (Guerrero 1981; The Technical Committee for Tilapia 1983; Guerrero 1985).

The use of ricefields for tilapia fingerling production is a particularly important development in the Philippine government's new agenda for developing rice-fish culture which previously failed to attract the private sector (Lastimosa 1982; Pullin 1985; Tagarino 1985; Bimbao and Smith 1988). Less than 100 ha of rice-fish farms in Central Luzon, Southern Luzon and Panay Island are on recent record (Corre 1985; Tagarino 1985). However, no hard figures are available for hatchery production from ricefields throughout the Philippines.

The more than 400 private tilapia hatcheries in the province of Laguna in Southern Luzon, however, draw considerable attention. Most of these hatcheries operate amidst lowland ricefields and along the periphery of the 90,000-ha freshwater lake, Laguna de Bay.

Yater and Smith (1985) estimated an aggregate annual production of 225 million fingerlings from the hatcheries in Rizal and Laguna Provinces. These hatcheries supply the bulk of fingerling requirements in the major tilapia-producing areas in the Philippines. In other areas, land-based hatcheries and freshwater demonstration farms of the Department of Agriculture and lake-based hatcheries supply the bulk of fingerling requirements for growout operations (Guerrero 1985).

This paper details the prevailing management practices of ricefields as hatcheries and nurseries for tilapia. In most cases, ricefields were already excavated to hold deep water and are being used exclusively for fish production purposes.

Ricefields as Tilapia Hatcheries and Nurseries

Laguna has 13,000 ha of ricelands; less than 5.0 ha are used for concurrent rice-fish farming as it is traditionally conceived (Tagarino 1985). This figure has probably declined; concurrent rice-fish systems appear to be a rare feature of ricefields in the area. Where fish production is practised, it is common for portions of the rice farm to be allocated exclusively for fish breeding, nursery and growout.

Privately operated hatcheries in the Philippines tend to be small, even for backyard operations. Hatcheries are often located in the corners of ricefields near residences where they can be monitored by members of the household (Yater and Smith 1985).

Small-Scale Hatchery/Nursery Systems: the Sto. Domingo Experience

The hatcheries of Sto. Domingo in Bay, Laguna, provide a classic study of tilapia farming as an economic base for community development (Gaite et al. 1985). The technology in the breeding of *O. niloticus* introduced by the Freshwater Demonstration Fishfarm (FDFF) of the Bureau of Fisheries and Aquatic Resources (BFAR) caught on from one enterprising farmer to residents who immediately saw signs of new economic opportunity.

At least 42.5 ha of hatcheries operate in the municipality of Bay, 80% of which are in Sto. Domingo (Darvin 1989). In spite of cut-throat competition within the community (Banasihan, pers. comm.), the industry has survived. Market accessibility has been a major advantage; the area's proximity to cage culture operations in Laguna de Bay and minor lakes in nearby San Pablo City, assures the operators of buyers. The hatcheries are also well known among tilapia growers in Central Luzon and Bicol Region (Gaite et al. 1985).

The number of households engaged in the breeding and nursery of tilapia has increased from 126 in 1982 to more than 260 in 1987 (Costa-Pierce et al. 1989). Monthly production of tilapia fingerlings probably exceeds 1,000,000 (Comia, pers. comm.); roughly equivalent to the production of the three DA freshwater farms in the province (at FDFF, Los Baños Freshwater Fishfarm and Sta. Cruz Fishfarm).

LAND PREPARATION AND MANAGEMENT

As standard practices, ricefields are developed for fish breeding and nursery by excavation of a fish refuge, increasing the height of dikes, installing wire screens in water gates and fencing materials to keep predators out and prevent fish stock from going astray (dela Cruz 1980; Tagarino 1985).

Ricefield plots with areas ranging from 100 to 400 m² are manually excavated to 1.0–1.5 m to store water. Nurseries lie adjacent to the breeding pond but no specific pond designs or layouts are applied. Poor siting, irregularly shaped ponds, narrow and inadequate dikes make some of the ponds prone to flooding. Similar land preparation and water management practices are applied for both breeding and nursery ponds.

Water is supplied through irrigation canals to screened bamboo inlets. One week before stocking, ponds are fertilized with chicken manure at the rate of 1,000 kg/ha.

Inorganic fertilizers are applied rarely. Some operators believe that chicken manure stimulates reproduction. Because pond refuges are small, pests and predators like tadpoles, mudfish (*Ophiocephalus striatus*) and birds are generally removed manually or scared away.

Ponds are thoroughly drained, levelled and refilled with water at monthly intervals after each breeding and nursery cycle.

BROODSTOCK AND FRY MANAGEMENT

Breeders of *O. niloticus* (Philippine and Israel strains) weighing 50–100 g are stocked at 4–5/m² (Costa-Pierce et al. 1989). Sex ratios vary from 1:4 to 1:7 male to female (Guerrero 1981). Breeders are replaced after seven months to one year.

The majority of operators procure breeders from cage-reared stocks from Laguna de Bay and from Aquatic Biosystems, a private firm in the locality. The FDFF has *O. niloticus* breeders of various strains but stocks for dispersal purposes are limited (Comia, pers. comm.).

The availability of relatively cheap supplemental feeds such as rice bran and copra meal gives room for flexibility in feeding practices among hatchery operators. The use of chicken starter mash and broiler pellets or crumbles are also common (Yater and Smith 1985). Feeding usually depends on the visual food demands of the stocks. In spite of the availability of various feed formulations for tilapia fingerlings, rice bran remains the most common feed.

Schooling fry are scooped daily from the breeding ponds with dipnets and transferred directly into adjacent nursery ponds. Nets of different sizes and designs are used for sorting fry. Sorting is done only when there are purchase orders.

The majority of fingerlings are sold at size 22 (11–15 days old), size 17 (16–32 days old) and size 14 (30–40 days old) (Yater and Smith 1985). These are bought in bulk purchases up to 500,000 fingerlings by middlemen from Central Luzon for further nursery rearing and resale at higher prices (Comia, pers. comm.).

Fry are also collected with a beach seine during total draining of breeding and nursery ponds. A series of net enclosures or *hapas* are temporarily installed to hold graded fingerlings. Techniques for counting, packing and transporting tilapia fry and fingerlings are described by Yater and Smith (1985) and the Technical Committee for Tilapia (1983). Breeding ponds generally produce 16,000–20,000 fry or 80 fry/m² per month.

PROFITABILITY

Most operators manage six to seven ponds of 200 m² each. With 1,000 breeders, farmers may harvest up to 30,000 fingerlings per pond per month. Capital costs for pond construction and nets range from US$43 to US$48 in 1989 (Costa-Pierce et al. 1989). Monthly earnings average US$95–143 but can reach US$952. Fingerlings are sold from US$0.0038–0.01 a piece. Some operators have themselves become middlemen, selling fingerlings with a mark up of US$0.001 per piece.

At least four operators have gone into production of common carp (*Cyprinus* *carpio*) fingerlings and one into experimental trials with Japanese carp. With technical assistance from the FDFF, diversification may occur in the future. However, production of cut-flowers, e.g., aster and gladiolus, is beginning to encroach on the ricefields of Sto. Domingo.

Medium-Scale Hatchery/Nursery Systems

Tilapia fingerling production remains a secondary occupation to medium-scale hatchery/nursery operators. Mr. Victorino Barundia as related by Rebong (1987) successfully produces tilapia fingerlings with rice, vegetable, garlic, watermelon and pigs in his 2.6-ha farm in Cabuyao, Laguna. Rice bran from the farm is used as a feed. Papaya, banana and pole beans are also planted along the fishpond dikes.

A total of 9,000 m^2 is allotted to three breeding and three nursery ponds. Manure from the piggery is drawn through a pipe directly into one of the breeding ponds, while fresh manure is hauled daily to the rest of the ponds. The fry feed on thick algal mats that form in the 40–50 cm deep nurseries. Chicken manure is applied basally at 1,000 kg/ha with side dressing of urea (46-0-0) at weekly intervals.

Six to eight times a day, a hired laborer walks around the pond edges to collect schooling fry. The fish are given one gallon of commercial feed crumbles and pellets (26% crude protein) three times a day and are fed to satiation with rice bran. Occasionally, the feeds are formed into balls coated with rice bran and fed to the fish in feeding trays.

Mr. Barundia shortened his draining cycle from 45 to 30 days and claims to have subsequently increased his production from 300,000 to 500,000 fingerlings per month. His farm record for 1987 showed a net income of US$1,000–1,190 in 45 days.

In the 3-ha hatchery of Mr. Cristeto Villarin in Pila, Laguna, lime, chicken manure and rice hull ash, are applied to stimulate production of zooplankton in nursery ponds. Water from an irrigation canal is checked for toxicity by placing a few fingerlings in the supply canal overnight before the water is drained into the ponds. The fry are collected with a fry sweeper in the morning only to prevent stress. Fry and fingerlings are hauled through a steel cart running along the concrete water supply canal.

The conversion of ricefields for nursery and growout of freshwater aquarium fishes is a recent development in Pila, Laguna. Traditional pond methods are applied except for the use of nets for roofing and fencing of individual ponds. It is unlikely, however, that the technology will stimulate a gold rush syndrome which marked the beginning of the tilapia industry, since operators have inadequate knowledge of management practices and markets are uncertain.

Production of Sex-Reversed Fingerlings

Sex-reversed fingerlings are produced in *hapas* installed in earthen ponds at the Aquatic Biosystems' farm in Bay, Laguna. The fry are collected from breeding ponds and graded with a series of hand nets of different mesh sizes. The smallest fish from 8 to 11 mm are kept for sex reversal in 1 x 3 x 1 m *hapas* at 100/m^2. The fry are fed with SRT-99, a commercial hormone-laced feed formulation of 30 µg methyltestosterone/g feed at 20–30% of the fry body weight for 21 days. The 2.7-ha farm can produce from 40,000 to 200,000 sex-reversed fingerlings at US$0.01/fish (Costa-Pierce et al. 1989; PCAMRD-DOST 1989).

At present, the transfer of this technology to small-scale producers seem to be constrained by the lack of experience of fish farmers and the perceived sophistication of the technology. But the use of *hapas* may scale down the sex-reversal technology to the level of fish producers in ricefields. Sex-reversed fingerlings may reach market size after four months and may prove promising for stocking in rice-fish systems to be able to harvest table-sized tilapia.

Concurrent Rice-Fish Culture

The technology for rice-fish culture is well documented for growout of Nile tilapia (dela Cruz 1980; Tagarino 1985). However, the production of table-sized tilapia from the technology is affected by its early reproduction. A ricefield system for tilapia fingerling production is still wanting. Although tilapia breeds well in shallow waters as is the case in ricefields, systematic techniques for collecting fry and fingerlings in a ricefield system is yet to evolve.

Problems and Constraints

The future of an integrated rice-fish program is partly anchored on the expansion of decentralized hatcheries with fingerling production as specialized function. Ricefields provide a large resource base for this purpose. With the new interest and anticipated improvements in rice-fish systems, farmers with small landholdings may soon find attractive the production of fry and fingerlings concurrent with rice, in order to diversify their crops and augment their income. As hatcheries concentrate in Laguna, the potential for small-scale fingerling production from ricefields in other areas is still untapped. An example of an area with such potential is the Magat Reservoir in Northern Luzon (Region 2). Its tilapia cage culture industry has more than 2,000 operators and is in great need for fingerlings. At present, more than 50% of the tilapia seeds come from Nueva Ecija (Region 3) and Laguna (Region 4) Provinces. Tilapia fingerlings produced from rice-fish systems that could be introduced to this landlocked area could, analogous to the situation in West Java, Indonesia, supply the seeds for the cages in the reservoir (dela Cruz, pers. comm.).

Large, corporate hatchery producers have a competitive advantage as reliable sources of seed supply. The decentralized nature of small-scale hatcheries, however, provides some leverage. In Laguna de Bay, cage culture and land-based hatcheries give semblance to mutually dependent production systems. In areas where expansion of cage culture is possible, whether in freshwater lakes or in the coastal zones, these systems will evolve together.

The future of ricefield hatcheries will depend to a large extent on the opportunity costs of agricultural lands. Rapid urban development, industrialization, escalating land costs and agricultural diversification, slow down the adoption of rice-fish farming.

Hatchery operations and practices, as in the case of Sto. Domingo, have taken the path of traditional agriculture where the trade is passed on to the children. This should be of interest as tradition is likely to sustain and expand the endeavor in the community. However, tradition may be overruled, since in many areas, farmers do not own the land they till.

It is clear from the experiences discussed that management practices vary from one fish farmer to another. Where the fundamental aspects of the technology are known, farmers tend to be guided by economy and convenience, factors that contribute to the Filipino farmer's innovativeness and ability to go beyond the present technological dimensions of a rice-fish system.

Providing motivation for farmers to adopt rice-fish farming remains a challenge in many regions of the Philippines. But as in the rest of Southeast Asia, rice-fish farming lives as a tradition and fertile area for research. New perspectives, more research and a resurge of efforts are needed to create a new wave of optimism for rice-fish farming in the Philippines.

References

Bimbao, M.P. and I.R. Smith. 1988. Philippine tilapia economics: industry growth and potential, p. 539–551. *In* R.S.V. Pullin, T. Bhukaswan, K. Tonguthai and J.L. Maclean (eds.) The second international symposium on tilapia in aquaculture. ICLARM Conf. Proc. 15, 623 p.

Corre, V.L. 1985. Status, potential and needs of tilapia culture in Panay Island, Philippines, p. 165–173. *In* I.R. Smith, E.B. Torres and E.O. Tan (eds.) Philippine tilapia economics. ICLARM Conf. Proc. 12, 261 p.

Costa-Pierce, B.A., M.P. Bimbao, S.P. Zainal and P. Effendi. 1989. ICLARM South-South technology transfer: Philippine aquaculture technology and Indonesia, Part II. Naga, the ICLARM Quarterly, 12(1):14–16.

dela Cruz, C.R. 1980. Integrated agriculture-aquaculture farming systems in the Philippines: with two case studies on simultaneous and rotational rice-fish culture, p. 209–223. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Darvin, A. 1989. In-house report on fish rehabilitation program in Bay, Laguna, 5 p.

Gaite, M.C., J.N. Morales, O.C. Orilla and B.B. Pili. 1985. The adoption of tilapia farming and its impact on the community of Sto. Domingo, Bay, Laguna, Philippines, p. 44-49. *In* I.R. Smith, E.B. Torres and E.O. Tan (eds.) Philippine tilapia economics. ICLARM Conf. Proc. 12, 261 p.

Guerrero, R.D. III. 1981. Introduction to fish culture in the Philippines. Philippine Education Company, Quezon City, Philippines.

Guerrero, R.D. III. 1985. Tilapia farming in the Philippines: practices, problems and prospects, p. 3–14. *In* I.R. Smith, E.B. Torres and E.O. Tan (eds.) Philippine tilapia economics. ICLARM Conf. Proc. 12, 261 p.

Guerrero, R.D. III. 1987. Commercial production of tilapia in freshwater ponds and cages in the Philippines, p. 14–20. *In* R.D. Guerrero III, D.L. de Guzman and C.M. Lantican (eds.) Tilapia farming. PCARRD Book Series No. 48, 68 p.

Lastimosa, P.L. 1982. Spreading the word about rice-fish culture. Monitor 4(5):2–3.

PCAMRD-DOST. 1989. The commercial production of sex-reversed tilapia. PCAMRD-DOST Primer No. 1/89, 2 p.

Pullin, R.S.V. 1985. Time to reappraise rice-fish culture. ICLARM Newsl. 8(4):3–4.

Rebong, L.D. 1987. Brief success story of Mr. Victorino Barundia. Search for Outstanding Fishfarmer. In-house report, Department of Agriculture, Sta. Cruz, Laguna.

Smith, I.R., E.B. Torres and E.O. Tan (eds.) 1985. Philippine tilapia economics. ICLARM Conf. Proc. 12, 261 p.

Tagarino, R.N. 1985. Economics of rice-fish culture systems, Luzon, Philippines, p. 127–150. *In* I.R. Smith, E.B. Torres and E.O. Tan (eds.) Philippine tilapia economics. ICLARM Conf. Proc. 12, 261 p.

The Technical Committee for Tilapia. 1983. The Philippines recommends for tilapia. PCARRD Tech. Bull. Ser. No. 15-A.

Yater, L.R. and I.R. Smith. 1985. Economics of private tilapia hatcheries in Laguna and Rizal provinces, Philippines, p. 15–32. *In* I.R. Smith, E.B. Torres and E.O. Tan (eds.) Philippine tilapia economics. ICLARM Conf. Proc. 12, 261 p.

Ricefields as Fish Nurseries and Growout Systems in China

LI KANGMIN
PAN YINHE
Freshwater Fisheries Research Centre
Chinese Academy of Fisheries Science
Wuxi 214081, China

LI, K. and Y. PAN. 1992. Ricefields as fish nurseries and growout systems in China, p. 151–164. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc 24, 457 p.

Abstract

This paper describes the present status of Chinese rice-fish farming systems. Rice-fish culture in China is in the process of development from extensive to semi-intensive culture; from monoculture to polyculture; and from a self-sufficient natural economy to a commercial economy. As the country's cultivated land area has shrunk at an annual rate of about 500,000 ha over the past three decades, fish production from rice-fish farming must increase. Preliminary analysis of natural foods and trophic levels showed that potential fish production in ricefields could be 160–390 kg/ha.

In 1988, the area of rice-fish farms in China reached one million ha, accounting for 5% of the total area suitable for rice-fish farming. Ricefields can produce 4,500/ha large-sized fingerlings. One million ha of rice-fish fields could produce 14% of the fingerlings needed for pond culture.

Rice-fish growout systems, which produce fingerlings to market size food fish, can be mixed rice-fish farming, rotational or both mixed and rotational farming. Fish culture techniques and intensity of rice cropping in these farming systems vary. More than 50% of rice-fish farming systems are for growout.

Introduction

Fish culture in ricefields depends on physical, technological and socioeconomic conditions. China covers temperate, subtropical and tropical zones. Sixty per cent of inland waters (not including Tibet) are within the area from the warm temperate to tropical zones, so that a seven- to eight-month growing period for warmwater fish exists. Owing to the seasonal winds from the southeast and southwest, plus the topographic effects, precipitation in China decreases from south to north and from the southeast to northwest. The annual precipitation in east China is about 400 mm with rainfall concentrated between July and September. Heavy rains occur with high ambient temperatures so that the climate in the rice region is suitable for fish production.

Photosynthesis in water bodies in the north during summer is higher because of sufficient solar radiation. Primary production is also high due to abundant natural food resources, making fisheries production in water bodies also high, and on annual basis becomes similar to production from waters in the south.

From economic and geographical viewpoints, most inland waters are concentrated in east and south China, where densely populated cities are situated. With a large market demand, inland fisheries are well developed and rice-fish farming has great potential.

Based on the climatic conditions and historical background, areas suitable for rice-fish culture can be divided into three main regions. These are:

1) *Yangtze River, Middle and Lower Reaches*. This area includes Hubei, Hunan, Jiangxi, Anhui, Jiangsu, Zhejiang Provinces and Shanghai. The ricefields in this region accounts for more than 50% of the area under rice cultivation in China. In this region, the climate is moderate; water resources are abundant; irrigation facilities are setup; and people are experienced in rice-fish farming. There is a considerable amount of winter fallow fields in mountainous districts in the western part of Hunan and the southern part of Hunan and Jiangxi. They are suitable for developing rice-fish farming.
2) *South China*. The area includes Guangdong, Guangxi, Fujian, Hainan Provinces and Taiwan. The ricefields in this region accounts for 20% of the nation's total area under rice. This region is situated in the subtropical-tropical zones. With higher temperatures and abundant rainfall year-round, it is a promising area for rice-fish farming.
3) *Southwest China*. It includes Yunnan, Guizhou and Sichuan Provinces. The ricefields in this region accounts for 20% of the rice area in China. In this region, rice-fish farming has a long history. Minority peoples in the south and southwestern parts of Guizhou and southern Yunnan culture fish in ricefields, as well as farmers in rural Sichuan Province where 0.8 million ha of fallow winter fields are not fully utilized (Li 1985).

There are some rice-fish farming in Shannxi, Shanxi, Beijing, Heilongjiang, Jilin, Liaoning and Hebei Provinces.

For a long time, many have asked if rice-azolla, rice-fish or rice-azolla-fish farming systems could be undertaken in northern China. Azolla and warmwater fishes are grown in subtropic and tropic zones, whereas water temperatures in ricefields in the north are low. The growth period for azolla and fish is short, and it is also difficult for them to overwinter. Besides, water resources are limited. However, 10 years of studies on rice-azolla-fish farming in Huanan County, Heilongjiang Province (46.07°N, 130°E), proved that rice in association with azolla and fish can give numerous ecological, economic and social benefits (Wang et al. 1988).

In 1988, China set a new record for aquatic production of 10 million t (She 1989). Production from freshwater aquaculture in 1988 reached 3.9 million t, which accounted for 86% of the total inland aquatic production (Ding 1989). It is difficult to get the exact fish production figures from ricefields. China has more than 20 million ha of ricefields. In 1986, rice-fish area was 985,517 ha (Nie and Wang 1988), which accounted for 5% of the total ricefields. In 1988, this area reached one million ha (Ding 1989), Chinese practices have proven that rice-fish farming can increase rice production by 10% and produce 225-750 kg/ha fish on average (Li 1988). With just 150 kg/ha, one million ha could produce 150,000 t fish, which is equal to 4% of freshwater aquatic products in 1988. In 1981, fish production from ricefields was 14,047 t, only 1.4% of the production from freshwater aquaculture of 1,014,060 t (Cai 1985). These figures indicate that rice-fish farming will play a more important role in freshwater aquaculture. Rice-fish farming in China is in the process of development from extensive to semi-intensive culture; from monoculture to polyculture; and from a self-sufficient natural economy to a commercial one.

The Ricefield Environment

Almost 97% of ricefields in China are irrigated. Thus, only rice-fish farming in irrigated areas is discussed here.

A rice-fish field is just like a small open ecosystem. In the abiotic part, the environmental factors are water, heat, light, air, nutrients and soil. As compared to fishponds, a rice plot is a shallow water body. There is a great diurnal change of water temperature within the range of 10°C (Zheng et al. 1962; Ding 1978). The fertility of ricefields fluctuates. The soil contains a high organic matter content. The dissolved oxygen level is, on the average, normal: 1.8-6.9 mg/l (Zheng et al. 1962); 1.5-8.2 mg/l (Ding 1978). If rice-fish farming is practised, the respiration of fish will produce a large amount of CO_2, which could be beneficial to rice. In the biotic part, rice are autotrophs. Fish are heterotrophs. One has to know what their feeds are and how many trophic levels are involved in feeding fish.

Huang (1984) studied three trophic levels in winter fields in Sichuan Province. The primary trophic levels included aquatic weeds (Table 1), algae and rice wastes. These trophic levels also included phytoplankton; five phyla and 30 genera. Diatoms, which are easily digested by fish, accounted for 54% (Table 2). The second trophic level included 75 zooplankton species: six kinds of protozoa; 38 rotifers; 17 cladocera; and 14 copepods. Rotifers accounted for 45% (Table 3). During the early growing stage, all cultivated fish fry feed on zooplankton, especially rotifers (FPEB 1982). The third trophic level included 12 kinds of benthos; two oligochaete worms; three mollusca; six aquatic insects; and one leech (Table 3). The predominant species were *Branchiura* and *Limnodrilus*.

The potential production for herbivorous fish can be estimated according to the formula:

$$F = B \times U/K$$ (FPEB 1982)

where:
- F = potential fish production (kg/ha);
- B = the maximum biomass (wet weight)(kg/ha);
- U = the utilization rate (%); and
- K = the food conversion factor (FCF) (wet weight).

The biomass of aquatic weeds are about 15 t/ha during rice-growing season and 15–38 t/ha during the fallow season – 80% of which can be eaten by grass carp (*Ctenopharyngodon idella*). Suppose 65% is eaten by the fish in order to sustain the reproduction of weeds. The FCF for *C. idella* is 100 (fresh weight) or 120 (wet weight). *C. idella* potential production is 78 kg/ha and the maximum would be 195 kg/ha. The potential fish production for plankton-feeders and benthic feeders can be estimated according to the formula:

$$F = B \times P/B \times U/K$$ (Huang 1984)

where:
- P/B = coefficient of production to average biomass.

Table 1. Dominant aquatic weeds in ricefields.

Common name	Scientific name	Diameter
Emergent plants		
	Marsilea quadrifolia	
	Monochoria vaginalis	
Alligator weed	*Alternanthera philoxeroides*	
	Rotala indica	
Arrowhead	*Sagittaria pygmea*	
Barnyard grass	*Echinochloa crus-galli*	
	Monochoria korsakowii	
	Scirpus yagara	
	Fimbristylis	
Pickerelweed	*Pontederia*	
Sweetflag	*Acorus*	
Spikerush	*Eleocharis*	
Cattail	*Typha*	
Floating plants		
	Zemra paucicostata	
Water fern	*Salvinia*	2 cm
Giant duckweed	*Spirodela polyrhiza*	8 mm
Water meal	*Wolffia arrhiza*	1–1.5 mm
Lesser duckweed	*Lemna minor*	5 mm
Water velvet	*Azolla filiculoides*	1 cm
	A. imbricata	
	Hydrocharis asiaticus	
Submerged plants		
	Hydrilla verticillata	
	Myriophyllum spicatum	
Pondweed	*Potamogeton crispus*	30–60 cm
	P. malaianus	
	P. maackianus	
Waterweed	*Elodea*	15 cm
Coontail	*Ceratophyllum*	30 cm
Water milfoil	*Myriophyllum*	30 cm
Naiad	*Najas*	60 cm
Eelgrass	*Vallisneria*	45 cm
	Uticularia	
	Heleocharis yokoscensis	

Table 2. Phytoplankton in ricefields.

Common name	Dominant genera	Phylum/Class	Number of genera
Diatoms	Synedra Fragilaria Navicula Stauroneis	Bacillariophyta	10
Green algae		Chlorophyceae	7
Blue-green algae		Cyanophyceae	7
Euglenoids	Euglena	Euglenophyceae	4
Dinoflagellates		Pyrochophyceae	2

Table 3. Zooplankton and benthos in ricefields.

Kind	Dominant organism	Number of species
Zooplankton		
Protozoa		6
Rotifer		38
Cladoceran	*Ceriodaphnia rigaud*	17
	Moina micrura	
Copepod	*Mesocyclops leuckarti*	14
	Eucyclops seerulatus	
Benthos		
Oligochaete worms	*Branchiura sowerbyi*	
	Limnodrilus hoffmeisteri	2
Mollusca	*Viviparus chinensis*	
	Corbicula spp.	
	Segmentina nitidella	3
Aquatic insects	*Chironomus*	
	Diptera	
	Cybister larvae	6
Leech		

Phytoplankton in ricefields averages about 1,060,942 ind/l, the biomass, 3.107 mg/l. The highest is 2,155,120 ind/l, with a biomass of 6 mg/l, among which diatoms account for 54%. The average phytoplankton biomass in terms of area is 9.3 kg/ha or a maximum of 18 kg/ha. The phytoplankton P/B is 187 according to FPEB (1982). The FCF for silver carp (*Hypophthalmichthys molitrix*) is 40 (He and Li 1975) and the utilization rate is 70%. F is equal to 30 kg/ha. The maximum potential production for *H. molitrix* will be 59 kg/ha.

On zooplankton in ricefields, rotifer accounts for 45%. The average biomass is 213 ind/l, 5.027 mg/l. The highest biomass 582 ind/l, 10.818 mg/l in which copepods account for 74%. The biomass of zooplankton is 15 kg/ha. Zooplankton P/B coefficient is 20 (He and Li 1975). The FCF for bighead carp (*Aristichthys nobilis*) is 10 and the utilization rate of zooplankton 25%. Therefore, the potential production for *A. nobilis* is 7.5 kg/ha. At maximum zooplankton biomass of 32.4 kg/ha the potential production for *A. nobilis* will be 16 kg/ha. The average biomass of benthos in ricefields is 560 ind/m^2 or 10.458 g/m^2; and the maximum biomass is 1,836 ind/m^2 or 29.099 g/m^2. The P/B coefficient of microdrili and chironomids ranges from 5.4 to 6.5 (Winberg 1972 in Huang 1984). The FCF for *C. carpio* yearling to benthos is 4.4 (Kapzuhkuh 1952, in Huang 1984). Supposing the FCF for *C. carpio* is 4 and the utilization rate is 25%, the potential fish production of omnivorous fish is 45 kg/ha; the maximum being 118.2 kg/ha. In addition, the detritus and bacteria are not calculated. If added, the total fish production could be increased by 30% (He and Li 1983; Schroeder 1978). To sum up, the total fish production could be 208.7–504.2 kg/ha only from the natural food in ricefields (Table 4).

By the same method, analysis of data from Sanming, Fujian Province, shows the carrying capacity is 152 kg/ha. Analysis on incomplete data from Jiangxi Province shows benthos in ricefields can be converted into 39-71 kg benthos feeders per hectar (Yin 1985). Analysis on incomplete data by Ding (1978) showed that the biomass of aquatic vascular plants could

Table 4. Estimates of fish production from natural food in ricefields. (Source: He and Li 1983; Schroeder 1978)

Carp species	Food	Biomass (B) kg/ha	Utilization rate (U)	Food conversion factor (K)	Potential fish production (F) Ave.	Max.
Grass	Aquatic weeds	30,000–53,000	65	120	78	195
Silver	Phytoplankton	9.3	70	40	30	59
Bighead	Zooplankton	15	25	10	7.5	16
Common	Benthos		4	25	45	118.2
Total					160.5	388.2
Add: Detritus and bacteria[a]					48.2	117.2
Grand total for F					208.7	504.2

[a]Approximately 30% of total fish production.

be converted into 21–38 kg herbivorous fish per hectare. The potential fish production in ricefields is between 98 to 390 kg/ha (Ding 1978; Yin 1985; Yin 1986). If manure and feeds are applied, and if rice pests and rice wastes are included as feedstuffs, the production would be higher.

Interaction between rice and fish is a mutual symbiosis. Rice and fish benefit and help each other not only in brief durations such as in mixed farming, but also in longer periods such as in rotational rice-fish farming. Rice-fish farming is considered as an ecosystem that fully utilizes natural resources, saves energy and recycles wastes.

Ricefields as Fish Nurseries

Significance

Rearing fry and fingerlings in ricefields meet the demands of pond culture, reservoir and lake fisheries and aquaculture in both the south and north. For example, in Heilongjiang Province, common carp seed (5–6 cm) can be supplied by farmers, but *H. molitrix*, *A. nobilis* and *C. idella* fingerlings all come from Yangtze River and Pearl River deltas (APPRS 1989). There are 1,246 hatcheries in China. The area of state-owned fish nurseries is 23,733 ha; while the area of collective and private fish nurseries is 94,493 ha. The total nursery area is 118,226 ha which accounts for 3% of the aquaculture area (3,894,973 ha) (Anon. 1986). In general, ricefields can produce 4,500 large-sized fingerlings/ha (Nie and Wang 1988), so one million ha of rice-fish fields will produce 4,500 million large-sized fingerlings, which will account for 14% of fingerling production. However, this does not mean all ricefields could or will produce fingerlings.

Utilization Forms

Ricefields are used for fish culture for hatching, rearing postlarvae to fingerlings, rearing small to large fingerlings, rearing large-sized fingerlings to table fish, and rearing fry to table fish. Usually, ricefields are used as fish nurseries in the lowland areas, with fish growout systems in the mountainous districts. Hatching fish in ricefields is the least successful because of low survival rate.

Selection of Fish Species

The selection of fish species to be stocked in ricefields depends on their characteristics. First, the fish should be able to live in shallow waters and feed on natural foods present in ricefields. Second, they should be beneficial to rice growth and should increase rice production and should thrive in lowlands or waterlogged areas. Third, the availability of seed fish should be considered. Farmers near the Yangtze and Pearl Rivers collect fry from rivers and stock them in ricefields. This help in improving the broodstock of cultivated fish. Fourth, as far as nurturing fry and fingerlings is concerned, medium- to large-sized fingerlings should meet the market demand. Fifth, it is better to choose fish species feeding on the first or second trophic levels. According to the biological behavior of Chinese carps, rearing periods in ricefields in the Yangtze River drainage basin are two years for *C. carpio* and *Carassius auratus* and tilapia (*O. niloticus*); two years for *H. molitrix* and *A. nobilis*; and three years for *C. idella* and black carp (*Mylopharyngodon piceus*).

Rearing Techniques for Fry and Fingerlings

Rearing fry and fingerlings in ricefields can be divided into two parts: nurturing three- or four-day old postlarvae, which have begun to eat food, to fingerlings (about 3 cm long) in 18-25 days; and rearing summerlings to fingerlings with a body length of 8-20 cm in three to five months. Fish at the fry stage are delicate and small; with little power of movement and ability to feed. Their diet is restricted. They have a low environmental adaptability and are vulnerable to predators. In addition, they have high metabolic rates. Therefore, rearing should be managed carefully to maximize survival rates.

PREPARATION OF FISH NURSERIES

Fish trenches and sumps need to be provided for transferring fish and for harvesting. Bunds should be compacted and raised to 50-60 cm high to prevent fish escape during heavy rains and through holes made by swamp eels (*Fluta alba*), water snakes and moles. Water inlet and outlets with convex bamboo screens are positioned on bunds at opposite corners. The screen size is 1 m wide, 80 cm high, and 2 mm between bamboo slats. The convex of the screens should face inward. The lower part of a screen should be buried deep into the field, the sides into the bunds.

NURTURING FRY TO FIRST FINGERLINGS (SUMMERLINGS)

In Yangtze River drainage basin, rice nurseries and fallow fields before transplanting of early rice are used to rear postlarvae to summerlings. Monoculture is adopted due to the different rice and fish production cycles. Propagation of *C. carpio* is coincident with sowing of early rice, so *C. carpio* postlarvae are nurtured in rice nurseries. In general, the ratio of rice nurseries to ricefields is 1 to 10; the same area ratio used for fish nurseries to ricefish fields. Propagation of *C. idella* needs higher temperature, so that it is 25-30 days later than *O. niloticus* and half a month later than *C. carpio*. *C. idella* postlarvae may be stocked directly with early rice. In Yangtze River Middle Reach areas, early rice is transplanted in late April, whereas the earliest transferring of *C. idella* summerlings comes in late May. There is a time gap between transplanting and stocking. If winter fingerlings are stocked, early rice and fish can match well, but it is costly and time-consuming.

A method of nurturing fish was experimented by stocking *C. idella* fry (8 mm) directly into early ricefields in Taoyuan County, Hunan Province. This method has some advantages: fingerlings are uniformly sized and healthier, they grow fast and need no feeding. The rearing techniques are:

1) Fifteen days before sowing and stocking, rice nurseries are treated with quicklime at a rate of 375–750 kg/ha. A hot quicklime emulsion is evenly spread to eradicate leech and predators. Lime application adjusts the pH of the soil which is conducive to fish growth and can help release N, P, K and other nutrients held by the soil. To clear ricefields, other chemicals such as rotenone, teacake, croton and bleaching powder are also used.
2) There is no need to apply manure to rice nurseries because manure for rice has already been applied before sowing. However, fermented manure should be applied to fallow fields to propagate plankton (rotifers, nauplii, microzooplankton, etc.) three to five days before stocking at a rate of 750 kg/ha. Zooplankton establish quickly after manure applications. Peak populations occur in the following order: protozoans, rotifers, nauplii, microcladocerans, macrocladocerans, copepods. The peak time depends on the type of manure. Fry stocking should be timed to ensure a sufficient supply of palatable natural food at each growing stage of the fry. After stocking, additional manure should be applied to stabilize the abundance of natural food.
3) Stocking densities depend on local conditions, but in general, are 750,000-900,000 fish/ha. A few fry are tried first to observe the effects of temperature differences. Filling of rice nurseries with water in steps is important to achieve the maximum growth and survival of the fry.
4) The water color and the behavior of fry should be observed twice daily to determine the amount of manure and feed to be administered and to remove predators (*Cybister* spp., loach [*Misgurnus anguillicaudatus*], *F. alba*, water snake, duck, etc.). If green algae (*Spirogyra, Zygnema* and *Mongeotia*) grow, plant ashes can be put on the algae or they can be killed by applications of 0.7 ppm copper sulfate.
5) Summerlings can be transferred to ricefields when they grow to 3–5 cm.

NURTURING SUMMERLINGS TO FINGERLINGS

Due to the low survival rate in rearing postlarvae to summerlings in ricefields, farmers often stock summerlings instead of fry into ricefields. Summerlings can be stocked with double-cropped early rice or single-crop late rice, or first with early rice and then consecutively cultured with late rice for three to five months until they become fingerlings or marketable food fish. Usually, polyculture and stepwise stocking are adopted. In some places, e.g., in Fujian Province, winter fingerlings are stocked into winter fallow fields to be reared to spring fingerlings from November to March for about 127 days, with the supply of feeds dependent on the weather and feeding activity of fishes. The rearing techniques are:

1) Disinfection should be conducted by submerging summerlings in 2% saline water for five minutes before stocking. This is to prevent fish diseases.
2) Summerlings are stocked 5-10 days after transplanting rice seedlings.
3) Stocking densities depend on local conditions. In general, *C. idella* summerlings are stocked 1-2 months later than *C. carpio* and half-month later than *O. niloticus* In Sichuan Province, if *C. carpio* is the predominant species, 7,500–12,000 *C. carpio* summerlings (3 cm), 3,000–4,500 *C. carassius* summerlings (3 cm) can be stocked in mid-April; 3,000–4,500 *C. idella* summerlings (5 cm) in late May for a total stocking of 13,500–21,000. In Zhejiang Province, the total stocking number is about 3,000/ha in extensive culture; and 4,400/ha in semi-intensive culture. The different stocking densities of *C. carpio, C. auratus, C. idella* and *O. niloticus* in fish nurseries and growout systems in ricefields are presented in Table 5 (Chen et al. 1985; Yin 1986; JPAPB 1986).
4) When fish are stocked in ricefields, manure and duckweeds are applied to peripheral trenches at a rate of 375 and 750 kg/ha, respectively, every two weeks. Feeds such as rice bran and rapeseed meal are applied to the sumps at a rate of 15-37 kg/ha every week. Water depth is increased to a maximum.
5) It is appropriate to harvest fish several days before rice irrespective of whether it is early, middle or late rice. The water should be drained slowly to allow fish to go to the trenches and sumps, where they are caught by dip nets.

Ricefields as Fish Growout Systems

Significance

Rice-fish culture is a traditional practice in mountainous districts where people's fish protein source comes mainly from ricefields. Although 75% of freshwater aquatic products in 1988 came from pond culture (Ding 1989), it is impossible to convert more fertile farmland into fishponds in the present circumstances. China's cultivated land area has decreased at about 500,000 ha/year over the past three decades (Gu 1989). Therefore, fish production from rice-fish culture has increased every year, e.g., in Sanming, Fujian Province and Chengdu, Sichuan Province (Table 5).

Table 5. Fish production from ricefields, 1981–85. (Sources: Pan 1986; Yin 1986).

	Production (t)				
City	1981	1982	1983	1984	1985
Sanming					
ricefields	159.90	445.00	699.50	1,103.50	2,246.20
ponds	784.30	2,009.40	2,431.70	3,211.00	5,663.70
ricefields, %	20.39	22.15	28.74	34.36	39.67
Chengdu					
ricefields	266.05	402.95	1,162.45	2663.30	4,589.05
ponds	2,879.80	3,624.65	4,621.10	7,224.85	11,661.05
ricefields, %	9.3	11.12	25.16	36.86	39.35

Utilization Forms

Rice-fish systems that culture fingerlings to adult or market size food fish are growout systems. Rice-fish growout systems can be mixed rice-fish farming, rotational farming, or both mixed and rotational farming. Fish growout systems account for more than 50% of rice-fish farming systems, e.g., in Jiangxi Province, ricefields as fish nurseries account for 25%; as fish growout systems (in association with fish nurseries), 40%; as fish growout systems, 10% in mixed farming; and as fish growout systems and nurseries, 20% in rotational farming systems. Rice nurseries as fish nurseries account for 5% of intercropped farming (JPAPB 1986).

Selection of Fish Species

In 1983, a study on culturing growout over one year showed that *H. molitrix*, *A. nobilis* and *C. idella* summerlings reached 150, 200 and 125 g, respectively, all smaller than the market size (500 g). *C. carpio* and its hybrids could reach market size (150–250 g). Fish species which could be reared from summerlings or large-sized fingerlings to adult fish are *C. carpio*, *C. carassius* and *O. niloticus*. In general, fish stocked should be winter or spring fingerlings. From the growth rate viewpoint, it is catfish (*Clarias leather*) that grows fastest in monoculture. Its body weight gain is 168 times in a four-month growing period in ricefields. Its individual average weight at harvest is four times that of *O. niloticus* and 10 times *C. carpio* (Chen 1988).

Rearing Techniques

Fish growout systems in rice-fish farming include double-crop ricefields-fallow fields, fallow-fields double cropped ricefields, winter fallow fields, crop-late ricefields, early ricefields-fallow fields and waterlogged areas.

STOCKING DENSITY

Stocking density varies with local conditions. As mentioned earlier, there is a time gap between the stocking of *C. carpio* and *C. idella*. In Sichuan, if *C. carpio* is the predominant species, 1,500–2,250/ha *C. carpio* winter fingerlings (50 g or 10 cm) are stocked in April; 750–1,200/ha *C. auratus* (6.6 cm) in June, with 300–450/ha *C. idella* winter fingerlings (50 g) added. If *C. idella* is the predominant species, 300–600/ha *C. carpio* winter fingerlings (10–13 cm) and 300–600/ha *C. auratus* winter fingerlings (6.6 cm) are stocked in late April. Stocking of 1,500–3,000/ha *C. idella* winter fingerlings (50 g) to be reared to large-sized fingerlings is done in mid-June. If *O. niloticus* is the predominant species, 6,000–9,000/ha *O. niloticus* winter fingerlings (6.6–10 cm) or 12,000–18,000/ha *O. niloticus* summerlings (3 cm); 300–600/ha *C. carpio* winter fingerlings; and 150–300/ha *C. idella* winter fingerlings are stocked in May. In all cases, 750–1,500 kg/ha fish can be achieved under normal semi-intensive management. Chen et al. (1985) recommended that if *O. niloticus* is the predominant species, the optimal stocking density is 3,750–4,500/ha *O. niloticus* winter fingerlings (10 cm) and 750–900/ha *C. carpio* winter fingerlings (Table 6). In Jiangxi Province, if *O. niloticus* winter fingerlings (10 cm) are stocked, they can grow to 250 g each during a four- to five-month growing period. When harvested in late September or early October, a fish yield of 450–900 kg/ha can be achieved, of which 70% would reach market size (100–250 g), and the 30% below 100 g could be restocked as winter fingerlings for the next year (Yin et al. 1983). It is better to stock fish early in the year. *C. idella* winter fingerlings should be stocked after

Table 6. Stocking densities in fish nurseries and growout systems in ricefields. (Sources: Chen et al. 1985; JPAPB 1986; Yin 1986).

Dominant species	*Cyprinus carpio* Stocking density (fish/ha)	Size (cm)	*C. auratus* Stocking density (fish/ha)	Size (cm)	*C. idella* Stocking density (fish/ha)	Size (cm)	*Oreochromis niloticus* Stocking density (fish/ha)	Size (cm)
C. carpio								
nurseries	7,500–12,000	3.3	3,000–4,500	3.3	3,000–4,500	5		
growout	1,500–2,250	10	750–1,200	6.6	300–450	50 g*		
	4,500	6.6					3,000	11–13
C. idella								
nurseries	1,500–3,000	3.3	1,500–3,000	3.3	7,500–12,000	5		
growout	300–600	10–13	300–600	6.6	1,500–3,000	50 g*		
O. niloticus								
nurseries	1,500–2,250	3.3			1,500–2,250	5	12,000–18,000	3.3
growout	300–600	10			150–300	10	6,000–9,000	6.6–10
	300–600	10			150–300	10	12,000–18,000	3.3
	750–900	10					3,750–4,500	10
	2,250–4,500	10					1,800–3,000	11.5–13.2 g

*Interstocked to be reared to large-sized fingerlings.

the beginning of the rice reproductive stage.

MANURE AND FEED APPLICATION

Manure usually accounts for 70% of basal fertilizer applications and the rest, chemical fertilizers. In semi-intensive culture, fertilizers and feeds should be applied and good water quality kept. When *C. carpio* or *O. niloticus* is the dominant species, 750 kg/ha fermented manure and 375 kg/ha *Wolffia* should be applied to trenches every two weeks and 15–30 kg/ha rice bran and rapeseed meal to sumps every week. Likewise, 750 kg of fermented manure and 375 kg tender grass or duckweeds are applied to fallow fields every week if fish rearing follows rice harvesting. Added are 15–30 kg/ha of fine feeds every two to three days in sumps. When *C. idella* is the predominant species, 750 kg/ha *Wolffia* are applied at the beginning every two weeks, and grass afterwards. The water in fallow fields should be as deep as possible.

THINNING AND INTERSTOCKING

If *O. niloticus* winter fingerlings are stocked, they will reproduce heavily in ricefields. It is important to thin the postlarvae out by using a net with mesh size of 1 x 0.5 cm. By this method, an experiment yielded market size *O. niloticus* (100-200 g) which accounted for 81% and market size *C. carpio* (300 g), 71% (Chen et al. 1985). In May or June, some summer fingerlings are interstocked in ricefields to be reared to large-sized winter fingerlings for the next year.

DISEASE, PREDATION AND ESCAPE PREVENTION

Based on experiences in pond culture, every 10 days after July, supplemental feeds soaked in a 3% saline or 3% garlic solution should be applied for three or four consecutive days. Every 15 days, bleaching powder should be used to sterilize the feeding platforms at a rate of 0.37 mg/l. Every 20 days, a quicklime emulsion should be spread over fish trenches and sumps or 90% dipterox applied at 12 mg/l during periods of high incidence of fish diseases (such as enteritis). Routine management is very important to eliminate predators such as *F. alba*, kingfishers, egrets, etc., and to fill holes on bunds made by water snakes, etc.

Problems and Consequences

In previous years, the concept of "rice first, fish second" was followed. When a contradiction occurred between rice and fish production, farmers often abandoned fish to secure rice production. Now, it is time for us to propose the concept of "rice and fish, fifty-fifty". This does not mean that fish should occupy half of the ricefield, rather it is to ensure proper growth conditions for fish in ricefields. When good growth conditions for fish are provided, fish production generally reaches 750 kg/ha while rice production increases by 10% due to mutual benefits (Zhang 1986).

A new freshwater aquaculture production system should be evolved that integrates a broodstock fishfarm, rice-fish farming system and pond, reservoir and lake culture systems into a unified production system. The functions of broodstock fishfarm should be hatching and first stage nurturing. The functions of rice-fish farming systems should be to rear summerlings to large-sized fingerlings or to rear large-sized fingerlings to food fish. The functions of pond culture, reservoir and lake culture systems should mainly be due to culture large-sized fingerlings to market size fish. This will contribute significantly to national aquaculture production (Zhang 1985).

Owing to the expanded area of rice-fish farming systems, the demand of fry, summerlings and especially winter fingerlings, is increasing. Moreover, China has only four original broodstock fishfarms and 42 improved broodstock fishfarms. Their annual production can only provide 2.5% and 0.9% of fry and fingerlings needs, respectively (APPRS 1989). If every household cultures fish in ricefields, supply of fry cannot meet the demand. Hatcheries should be rationally distributed in rice-producing regions to ensure fry supply.

The main problems of fry and fingerlings nurtured in ricefields in China are poor varieties, early maturing, poor quality, low production and serious degradation of the economic characteristics of cultured fish. We recommend that a hybrid of common carp, *C. carpio* var. *jian*, be stocked in ricefields. The hybridization was undertaken at the Freshwater Fisheries Research Centre (FFRC) in recent years. The merits of this hybrid are high back, thick body, better resistance to fish diseases, fast growth, capability of reaching market size in one growing season and stable economic characteristics. Another recommended hybrid for rice-fish culture tried at FFRC is the cross of male *O. aureus* and *O. niloticus*. Its monosex rate reached 95% and tolerated a temperature 2.5–3°C lower than its female parent and its catching rate was 2.7 times higher than *O. niloticus* (Wang et al. 1989). In a rice-fish experiment in 1989, hybrid summerlings (3 cm) of this fish reached 15-17 cm, or an average weight of 100 g in 90 days, while *O. aureus* reached only 10 cm. If *C. carpio* is stocked with *O. niloticus* in polyculture, *C. carpio* gains more weight because they can utilize different ecological niches although both fish are omnivorous. Thus, *C. idella*, *O. niloticus* and *C. carpio* are the best combination in ricefields.

In order to increase economic returns, farmers are trying to culture in ricefields new aquatic products, such as *F. alba*, the soft-shelled turtle (*Trionys sinensis*), *C. leather* and snakehead (*Ophiocephalus argus*). In the south, wooly-handed crab (*Eriocheir sinensis*) [cultured only in China], young pearl clams (*Hyriopsis cumingii* and *Cristaria plicata*) and freshwater prawns (*Macrobrachium rosenbergii* and *M. nipponensis*) have been tested, and in the north, rainbow trout (*Salmo gairdneri*). The biological basis for their integration and specific culture techniques should be studied.

There are many lowland, shallow lakes and uncultivated waterlogged areas in Central China, which are dry in winter and flooded in summer (Zhang and Guo 1988). Deep and broad peripheral fish trenches could be dug to form a new design of rice-fish fields. The earthwork can be used to build peripheral dams with the height dependent on the maximum water level as determined from historical records. Then, fish can be cultured in trenches while rice or deepwater rice can be cultivated on the central table land. When floods come, there is no problem for rice if a deepwater variety is planted and fish can swim up to the table land. After harvesting rice, the whole field can be refilled with water for fish culture.

Acknowledgements

The authors express their thanks to Messrs. Guo Xianzhen and Cai Renkui, the Director and the Deputy Director of the FRCC, respectively, for granting permission to present and publish this paper; and to IRRI, ICLARM and CLSU for sponsoring them to attend the Second Asian Regional Workshop on Rice-Fish Research and Development. Thanks are also due Prof. Yin Pizhen for allowing them to cite his manuscript, and to Li Peizhen whom the authors consulted in the preparation of this manuscript.

References

Anon. 1986. Source of fish seed in Heilongjiang. News report. China Fisheries 86(6).

APPRS. 1989. The status of fish seed production and the developmental strategy in China. Aquatic Products Policy Research Society. China Fisheries 89(5).

Cai, R. 1985. Selected teaching materials. Nanjing Agriculture University, Nanjing, China.

Chen, H. 1988. A preliminary study on rice-fish culture with *Clarias leather* without tillage in Yunnan plateau. Paper presented at the Symposium on Rice-Fish Culture in China, 10–13 October 1988, Wuxi, China.

Chen, J., P. Chen and X. Jin. 1985. Experimental report on nurturing fingerlings in winter fallows. Fujian Fisheries 85(3).

Ding, R. 1978. Rice-fish culture experiment and the preliminary study on the principle of rice increment. Freshwater Fisheries 78(5).

Ding, X. 1989. The 40 years' achievements of Chinese freshwater aquaculture. China Fisheries 89(6).

FPEB. 1982. Freshwater fisheries enhancement techniques and fishery planning. Freshwater Fisheries Enhancement Techniques and Fishery Planning Editorial Board. Institute of Hydrobiology, Wuhan, China.

Gu, C. 1989. Industries eating up the nation's best land. China Daily, 11 March 1989.

He, Z. and Y. Li. 1975: Discussion on the food of silver carp. Acta Hydrobiol. Sin. 5(4):541–548.

He, Z. and Y. Li. 1983. Studies on the water quality of the high yielding fishpond in He Lie Commune, Wuxi (II). Plankton. J. Fish. China 7(4) (1983).

Huang, M. 1984. Aquatic resources in winter fallows in Sichuan Province and the estimate of fish production. Sichuan Fisheries 84(1).

JPAPB. 1986. Economics on rice-fish culture in Jiangxi Province. *In* selected papers on rice-fish culture cooperation workshop in East China, Fuyang, Zhejiang Province. Jiangxi Provincial Aquatic Products Bureau, China.

Li, K. 1988. Rice-fish culture in China: a review. Aquaculture 71:173–186.

Li, R. 1985. Chinese aquatic produce geography. Agriculture Press, Beijing, China. 123 p.

Nie D. and J. Wang. 1988. Recent development of fish culture in ricefields in China. Acta Hydrobiol. Sin. 12(4), (Dec. 1986).

Pan, S. 1986. Study on the strategic position and orientation of rice-fish culture in Sanming, Fujian Province. Fujian Fisheries 86(4).

Schroeder, G.L. 1978. Autotrophic and heterotrophic production of microorganisms in intensively manured fishponds and related fish yields. Aquaculture 14:303–325.

She, D. 1989. Ten years' reform of fisheries: a review. China Fisheries 89(1).

Wang, C., D. Xia, M. Hu and H. Wang. 1989. A study on the utilization of the hybrid vigor of *O. nilotica* female x *O. aurea* male. Freshwater Fisheries (6) 1989.

Wang, Z., P. Wang and Z. Jie. 1988. Studies on steroscopic agriculture of rice-*Azolla*-fish symbiosis. Paper presented at the 1988 Symposium on Rice-Fish Culture in China. 10–13 October 1988, Wuxi, China.

Yin, P., X. Xu, X. Qian, K. Gano and J. Nei. 1983. Experiment report on culturing *O. niloticus* in ricefields. Freshwater Fisheries 83(3).

Yin, P. 1985. Fish and frog culture techniques in paddies. Jiangxi Provincial Fisheries Research Institute, Jiangxi, China. (manuscript)

Yin, R. 1986. The status and prospect of rice-fish culture in Chengdu. *In* selected papers on rice-fish culture. National Aquatic Products Bureau, Beijing, China.

Zhang, J. 1986. The effect of drought on rice-fish culture and its countermeasures in Chongqing. *In* selected papers on rice-fish culture. National Aquatic Products Bureau. Beijing,

Zhang, S. 1985. Several problems concerning the development strategy of fisheries sciences. Fujian Fisheries 85(3).

Zhang, Y. and D. Guo. 1988. Eco-environment of lake and bog wetlands in Hannan flooding region of Hubei Province. Journal of Ecology 7(5):30–34.

Zheng, G., R. Zhang and G. Zhang. 1962. Preliminary report on culturing tilapias in ricefields. An offprint in Fujian Province.

Rice-Fish Production Systems in Bangladesh

A.K. YOUSUF HAROON
Fisheries Research Institute, Riverine Station
Chandpur, Bangladesh

S. DEWAN
Faculty of Fisheries
Bangladesh Agricultural University
Mymensingh, Bangladesh

S.M.R. KARIM
Bangladesh Rice Research Institute
Gazipur, Dhaka
Bangladesh

YOUSUF HAROON, A.K., S. DEWAN and S.M.R. KARIM. 1992. Rice-fish production systems in Bangladesh, p. 165–171. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Descriptions of prevailing freshwater and brackishwater rice-fish farming systems practised in Bangladesh are presented. Freshwater production systems of concurrent rice-fish (growout and hatcheries/nurseries) and rice-shrimps are still in experimental stages. Yields obtained from experiments are low. *Puntius gonionotus* and tilapia (*Oreochromis niloticus*) seem to be the better species for rice-fish system rather than Indian major carps (*Catla catla, Labeo rohita, Cirrhinus mrigala*). Freshwater giant prawn (*Macrobrachium rosenbergii*) appears to be suitable. In brackishwater or coastal areas, traditional and improved rotational or concurrent rice-fish/shrimp production systems are practised. From December to March, shrimp and fish are either carried by tidal water inflow or stocked to produce one crop of fish/shrimp by April. With the onset of monsoon in July, the same riceland is transplanted to *aman* rice, and stocked or seeded naturally by tidal inflow. In areas with low tidal amplitude and low salinity, *boro* rice may be produced from November to April, followed by fish/shrimp culture beginning in July until October or November. With the improved system of shrimp/fish culture, combined yields of shrimp and fish vary from 280 to 450 kg/ha. Some may even produce as high as 700 kg/ha of shrimp alone.

Introduction

The practice of harvesting fish and prawn from inundated ricefields is probably as old as rice farming itself. It is a very common scene in rural Bangladesh during the monsoon. Increasing demand for rice by both farming communities and government has encouraged farming that depends on biocides that are toxic to fish. As a result, rice farming has developed, while fish habitats have gradually degraded (Ahmad 1988).

Declining fish catches from inland waterbodies and increasing population has reduced the intake of fish in Bangladesh households. At present, 0.78 million t of fish per year are produced, of which inland fisheries contributes about 80%. By the year 2005, about 1.2–1.5 million t of fish would be needed but production will only be around 0.81 million t (MPO 1985a). More fish must come from inland waters. This has led to renewed interests in utilizing ricefields in freshwater and brackishwater habitats for fish production.

Bangladesh has more than 2.83 million ha of seasonal floodplains planted to rice where water remains from four to six months (Karim 1978). Current capture fishery harvest in these areas is around 37 kg/ha (MPO 1985a). The south-west and south-east coastal areas of Bangladesh subject to inflow of seawater contain more than 150,000 ha of shrimp farms. Aside from shrimp farms, low-lying areas producing one crop of wet season rice can be used for integrated aquaculture.

Rice-Fish Research in Freshwater Habitats

While capture fisheries in ricefields is well established, formal culture systems are still largely experimental. Fish yields from capture, estimated to be 37 kg/ha, could be drastically increased by culture techniques (MPO 1985b).

Research on rice-fish culture is being carried out by the Fisheries Research Institute, Farming System Research and Development Program of the Bangladesh Agricultural University, Bangladesh Rice Research Institute and non-government organizations.

FRI Activities

Experiments on rice-fish (with Indian major carps (e.g., *Catla catla, Labeo rohita, Cirrhinus mrigala*) and rice-shrimp (with giant freshwater prawn *Macrobrachium rosenbergii*) production systems have been completed at the FRI's Riverine Station, Chandpur in 1988 and 1989 (Haroon et al. 1989). In 1988, two experiments determined the optimum stocking density of shrimp and fish. The first rice-shrimp experiment used three densities of shrimp; the second, used two densities of fish with two combinations of fish species at each density. Both experiments received the recommended 200 kg/ha urea, 130 kg/ha triple superphosphate (TSP) and 250 kg/ha cowdung. No supplemental feeding was provided. In the second year, the best stocking density of shrimp/fish from the first year, was tried at various levels of inorganic fertilizers. In both years, two crops of rice were grown one after the another. Fish and shrimp were stocked 20 days after transplanting the first rice crop. Fish and shrimp were kept in the refuge trenches during transplanting of the second rice crop and were harvested prior to harvesting of the second rice crop.

Yields of the first transplanted *aman* rice crop (July-December) and the second *boro* crop (January-May) for the two-year period of the experiment are shown in Table 1. Additional fertilizer applied in the second *aman* crop doubled its yield but did not have significant effect on the *boro* rice crop.

Shrimp yields followed stocking densities but the best sizes were achieved at the lowest density (Table 2). Size and yield at 7,500/ha stocking density improved with additional 50% individuals. Yields at this stocking density increased by 39% with more 50% juveniles.

Fish yields for both years at stocking densities of 8,000 and 16,000/ha are shown in Tables 3 and 4. Highest yields were obtained with 8,000/ha stocking density. However, both densities may have been too high as all fish grew poorly. Available food during the 180-day culture period may not have been sufficient. Increasing the amount of fertilizer did not improve yields. Stocking density should be lower than 8,000/ha in future experiments.

The two-year experiment on rice-shrimp indicated that *M. rosenbergii* could be one of the best species for such integration. With regard to rice-fish, using Indian major carps seem to be unsuitable for concurrent culture with rice.

On-farm trials where *Puntius gonionotus* was stocked at 1,875–3,750/ha in the ricefields of 11 farmers for four months resulted in fish yields ranging from 140 to 450 kg/ha and zero production on five farms because of flooding.

FSRDP Activities

Fish yields from experiments conducted by FSRDP between 1985 and 1987 using concurrent rice-fish systems with different combinations of *L. rohita, C. catla, Cirrhinus reba, Cyprinus carpio* var. *specularis* and *P. gonionotus* ranged from 43.2 to 146.3 kg/ha/crop (Hossain et al. 1987). Fourteen per cent more rice was obtained in fields with fish than in rice monoculture. Rotational system of rice followed by fish have yielded 856 kg/ha (Dewan, this vol.). Here, *C. catla, L. rohita, C. mrigala, P. gonionotus, C. carpio* var. *specularis, Ctenopharyngodon idella* and *Hypophthalmichthys molitrix* were cultured for six months. An on-station experiment in 1988 examined the effects of *P. gonionotus* and *Oreochromis niloticus* polyculture versus monoculture. Stocking rates were held constant at 7,000/ha. The highest fish yields were obtained from *P. gonionotus* monoculture (Table 5). Yields from *P. gonionotus* and *O. niloticus* polyculture and *O. niloticus* monoculture did not differ much. Fish did not appear to reduce rice yield. Indeed, yields may have been slightly increased.

BRRI Activities

A rice-fish culture experiment in Kismat at Mymensingh was conducted with six farmers in 1988. Rice (BR 11) seedlings were transplanted in August and 6,250 *O. niloticus* fingerlings were released at the rate of 60 kg/ha one month later. Water levels were maintained at 25–30 cm. Fertilizer was applied at 60–40–40 kg of NPK/ha with the first and second top dresses at 15 and 30 days after transplanting. Low-cost supplemental feed and insecticides were used during the culture period. Average rice yields in sole plots were 4.01 t/ha while those in rice-fish were 3.97 t/ha (Table 6). Fish culture did not significantly affect rice yield. On the other hand, rice-fish culture produced 400 kg/ha of fish with a net return of US$825 compared to rice monoculture at US$505. This included the additional income of US$36 for fish fingerlings.

NGO Activities

The Noakhali Rural Development Program (NRDP) has stocked 50 ricefields in 1989. Species stocked were *H. molitrix, C. idella, C. catla, L. rohita, C. mrigala* and *C. carpio*. Moreover, farmers have leased out monocropped *boro* ricefields for six

Table 1. Rice yield from rice-fish/shrimp farming experiments, FRI Riverine Station, Chandpur, 1987–89.

Year	Ricefield area (m^2)	Yield of *aman* 1st crop (t/ha)		Yield of *boro* 2nd crop (t/ha)	
		Range	Average ± s.d.[a]	Range	Average ± s.d.[a]
1987–88	52–129	0.54–0.70	0.60 ± 0.15	3.36-7.70	4.50 ± 1.69
1988–89	63–141	1.13–1.40	1.30 ± 0.17	3.20-4.80	3.96 ± 0.70

[a]s.d. = standard deviation.

Table 2. Growth and yield of shrimp from rice-shrimp farming experiments, FRI Riverine Station, Chandpur, 1987–89.

Year	Treatment	No. released	Average weight (g)		Culture period (days)	Survival (%)	Above 30 g size (%)	Yield (kg/ha)
			Initial	Final ± s.d.[a]				
1987-88	Normal fertilization[b]							
	7,500/ha	230	8.66	18.17 ± 9.90	180	82	22	162
	15,000/ha	540	9.25	13.13 ± 6.01	180	80	2	230
	22,000/ha	1,048	9.20	14.76 ± 7.65	180	71	3	390
1988-89	Normal fertilization[b]							
	7,500/ha + additional 50% individuals	241	8.18	57.50 ± 27.01	240	34[c]	88	222
	100% increase of urea, TSP							
	7,500/ha + additional 50% individuals	275	7.25	46.50 ± 22.90	240	50[c]	81	262
	7,500/ha	225	7.90	39.43 ± 19.56	240	76	79	225

[a]s.d. = standard deviation.
[b]Urea at 200 kg/ha; TSP, 130 kg/ha; cowdung, 250 kg/ha.
[c]Affected by flood.

Table 3. Growth and yield of fish from rice-fish farming experiments, FRI Riverine Station, Chandpur, 1987–88.

Stock density (fish/ha)	Combination[a]	Average weight at stocking (g)				Culture (days)	Average weight at harvest (g)				Yield (kg/ha)
		C. catla	*L. rohita*	*C. mrigala*	*H. fossilis*		*C. catla*	*L. rohita*	*C. mrigala*	*H. fossilis*	
8,000	A	13.2	9.5	11.0	10.0	180	45.0	51.0	35.0	41.0	225
8,000	A	9.5	6.3	10.9	10.9	180	27.0	49.0	43.0	31.0	222
16,000	B	7.1	39.3	10.3	10.0	180	28.0	29.0	44.0	19.0	213
16,000	B	24.4	10.0	5.8	10.0	180	31.0	54.0	73.0	30.0	198

[a]A = *C. catla* 40%; *L. rohita* 15%; *C. mrigala* 40%; *Heteropneustes fossilis* 5%; B = *C. catla* 40%; *L. rohita* 25%; *C. mrigala* 25%; *H. fossilis* 10%.

Table 4. Growth and yield of fish from rice-fish farming experiment, FRI Riverine Station, Chandpur 1988–89.

Stocking density (fish/ha) and fertilizer treatments[a]	Average weight at stocking (g)				Culture period (days)	Average weight at harvest (g)				Yield (kg/ha)
	C. catla	*L. rohita*	*C. mrigala*	*H. fossilis*		*C. catla*	*L. rohita*	*C. mrigala*	*H. fossilis*	
8,000 ha with 50% increase in urea, TSP	1.55	1.90	1.16	11.96	240	40.0	60.0	50.0	b	98
8,000/ha with 100% increase in urea, TSP	1.17	2.71	1.19	12.38	240	23.0	50.0	40.0	b	213
8,000 ha with 150% increase in urea, TSP	1.22	4.60	1.47	13.45	240	13.0	60.0	13.0	20.0	115

[a]Recommended dose: urea at 200 kg/ha; TSP, 130 kg/ha; cowdung, 250 kg/ha; b = no retrieval.

Table 5. Performance of fish in rice-fish culture in Agronomy Field Laboratory of BAU, 1988.

Treatment	Species	Stocking density (fish/ha)	Average weight (g)		Survival (%)	Yield (kg/ha)	Rice yield (t/ha)	
			Initial	Final			with fish	without fish
T_1	*P. gonionotus*	3,500	1.80	79.52	67	179		
	O. niloticus	3,500	1.62	67.80	50	119		
	Total	7,000				299	4.39	3.85
T_2	*P. gonionotus*	7,000	1.82	102.53	71	508	4.50	3.85
T_3	*O. niloticus*	7,000	1.61	76.70	42	213	4.22	3.85

Table 6. Productivity of rice-fish integrated system (six 500-m^2 farms) during *T. aman* season, Kismat, Mymensingh, BRRI, 1988.

Farm	Length (cm)	Weight (g)	Fish population at harvest (fish/ha)	Survival (%)	Average fish weight (kg/ha)		Rice yields (t/ha)	
					At harvest	Net gain	Rice-fish	Rice alone
1	12.0	100.0	4,875	78	487.5	427.5	4.00	4.10
2	12.0	100.0	4,500	72	450.0	390.0	4.05	4.00
3	11.5	95.8	3,750	60	359.0	315.0	3.87	4.00
4	10.5	87.5	3,625	58	317.0	302.5	3.78	3.87
5	12.0	100.0	3,875	62	387.5	327.5	4.07	4.00
6	12.0	100.0	4,375	70	437.5	377.5	4.10	4.10
Mean			4,167	66	416.7	356.7	3.97	4.01

months to farmers interested in rice-fish culture. Farmers use rotational system of rice followed by fish. Stocking densities range between 3,075 to 6,246/ha. Fish yields vary from 223 to 700 kg/ha.

Rice-Fish Systems in Brackishwater Habitats

Traditional Systems

Today's brackishwater rice-fish/shrimp farming has its roots in the traditional *bheri/gher* system of Satkhira-Khulna regions. In *bheri/gher* culture systems, ricefields are enclosed by small embankments with inlet and outlet channels controlled by sluice gates. The enclosed area, the *gher*, may vary from 3.50 ha to more than 50 ha. Tidal water carrying postlarvae shrimp and fish juveniles are trapped in the lowlying depressions or *ghers*. Among the shrimps, *Penaeus monodon, P. indicus, P. semisulcatus* and *Metapenaeus monoceros* are the target species; while *Polydactylus sexfilis* and *Lates calcarifer* are the desired fish. Yields of shrimp and fish are about 210 and 80 kg/ha, respectively (MPO 1985b). In the late 1950s, more than 100 such farms were reported in Satkhira alone (MPO 1985b). Present land use is one crop of local transplanted *aman* rice (*Patnai*). In some regions of the southwest, brackishwater shrimp is either rotated with rice or grown concurrently. In high saline areas of the south-east, farmers grow shrimp/fish between April and December and produce salt in the remaining time. Yields of shrimp are around 300 kg/ha and fish, 400 kg/ha (FAO and SIDA 1985; MPO 1985b).

Improved Systems

Farmers are gradually improving their systems by stocking fish and shrimps, applying fertilizers, providing supplemental feeds and producing fish and shrimp seed in nurseries.

SHRIMP/FISH CULTURE FOLLOWED BY RICE

In shrimp/fish system followed by rice, postlarvae of *P. monodon* and *P. indicus* are stocked at a rate of 15,000–20,000/ha. Screens on the water inlet and outlet sluices keep out wild stocks and predators. Lime and fertilizers are added during land preparation. Rice bran, wheat bran and mustard oil cake provide supplementary feed. Stocking occurs between November and January with harvesting between April and July. Yields of shrimp and fish vary from 280 to 450 kg/ha depending on the volume of water exchanged and level of inputs (FAO and SIDA 1985).

In July, farmers begin transplanting their aman rice following traditional lines. Selective stocking of *M. rosenbergii, P. monodon,* Indian major carps and *H. molitrix* are sometimes done instead of stocking wild species. Stocking rates vary from 12,000 to 15,000/ha and produce around 83–130 kg/ha of fish and shrimps (Haroon 1987).

BORO RICE FOLLOWED BY SHRIMP/FISH

Where tidal water does not flood farms in October or November, *boro* rice can be grown. Transplanting is done between November and December, and harvesting in April. The following July, *M. rosenbergii* and *P. monodon* are stocked at a rate of 15,000–20,000/ha in the fallow fields. Some farmers also stock *Mugil* sp., *L. calcarifer* and Indian major carps with shrimp. Harvesting is done between October and November. Shrimps are harvested by cast nets or bamboo traps placed infront of the sluice gates. Fish are harvested after shrimps by draining the water from the *gher*. Shrimp yields vary between 200 and 250 kg/ha and fish between 150 and 175 kg/ha.

Conclusions

Considering irrigated and rainfed deepwater ricefields and shrimp saline areas all over Bangladesh, one can only conclude that the potential for rice-fish and shrimp farming is great. In many of these areas, short season rice varieties and pesticides do not limit fish production. There is no doubt that fish farming could play a key role not only in increasing protein supplies to all but also in economic development of farmers and low income rural people (Gupta 1987; Haroon 1987). Perhaps the time has come to reconcile rice production with other crops (Ahmad 1988).

References

Ahmad, K.U. 1988. "Should rice production in Bangladesh be reconciled with other crops?" Association of the Development Agencies in Bangladesh News, November-December issue. Dhaka, Bangladesh.

FAO and SIDA. 1985. Marine small-scale fisheries of Bangladesh: a general description. Food and Agriculture Organization, Rome and Swedish International Development Authority, Stockholm.

Gupta, M.V. 1987. Prospects of integrated fish farming in Bangladesh. *In* FRI (eds.) Training Manual No. 1. Directorate of Fisheries, Fisheries Research Institute, Mymensingh, Bangladesh.

Haroon, A.K.Y. 1987. Integrated paddy-cum-fish/shrimp farming. *In* FRI (eds.) Training Manual no. 1, Directorate of Fisheries, Fisheries Research Institute, Mymensingh, Bangladesh.

Haroon, A.K.Y., M. Alam and M. A. Mazid. 1989. An experimental study on integrated paddy-cum-fish/shrimp farming practice in Bangladesh. I. Effects of stocking densities on growth and yield. Bangladesh Jour. Fish. 12(1):100–108.

Hossain, S.M.A., S. Dewan, M.S. Islam, M.S. Hossain and M.M. Ali. 1987. Rice-fish culture: an adaptable technology for Bangladesh. Bangladesh Agricultural University J. Ext. Educ., Mymensingh, Bangladesh.

Karim, M. 1978. Status and potential of Bangladesh fisheries. Ministry of Fisheries and Livestock, Government of Bangladesh, Dhaka. 125 p.

MPO. 1985a. Final report, Chapter 4: Fisheries. Master Plan Organization. National Water Plan Project, Ministry of Irrigation, Water Development and Flood Control. Government of Bangladesh, Dhaka.

MPO. 1985b. Coastal shrimp aquaculture resources. Master Plan Organization. National Water Plan Project Tech. Rep. 18, Ministry of Irrigation, Water Development and Flood Control, Government of Bangladesh, Dhaka.

Chapter 3
Economic and Biological Interactions

Mutualism of Rice and Fish in Ricefields

NIE DASHU
CHEN YINGHONG
WANG JIANGUO
Institute of Hydrobiology
Academia Sinica
Wuhan, China

NIE D., Y. CHEN, and J. WANG. 1992. Mutualism of rice and fish in ricefields, p. 173–175. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Experiments were conducted with grass carp *(Ctenopharyngodon idella)* in a rice-fish system. The objectives were to increase rice production with negligible extra cost and to reduce farmers' labor for weeding. *C. idella* of 3.5–4.0 cm were stocked in a ricefield at 2/m² and allowed to grow throughout summer. Results showed that they increased rice yields generally by 10% or more; however, the experimental data gave increases of 11–35%. *C. idella* controlled weeds and harmful insects. By eating grass, they reduced the need for farmers' labor for weeding. *C. idella* feces also helped fertilize the ricefields. *C. idella* also ate mosquito larvae – an added benefit to public health. The concurrent rice-*C. idella* system proved highly suitable for raising advanced fingerlings, which grew from 3.5–4.0 to 11–16 cm during the summer crop. Ricefields stocked with fish gave 38 to 62% more revenue than fields without fish. The whole system was very much appreciated by the farmers.

Introduction

In China, fish culture in ricefields is an old practice but the conventional methods used have produced small benefits and been of little interest to agronomists. Rice-fish culture declined during the early sixties, when changes in agricultural production systems made the contradictions between rice and fish culture severe. Increased pesticide use was a major problem. Rice-fish culture was almost abandoned.

In the early seventies, we used grass carp fry or fingerlings in rice-fish culture in attempts to increase rice productivity, assuming that the fish would eat the weeds that compete with rice for light, space and nutrients, at the same time help farmers save on labor used for weeding. This relationship between rice and fish is called mutualism, because the two crops benefit from each other and render the ricefield ecosystem more profitable.

Materials and Methods

From 1980 to 1983, rice-fish experiments were made in Hunan Province during the early, median and late rice crops in fields which were well drained and not affected by drought. Increasing rice production was the primary objective. Concurrent culture systems, where fish are reared with the rice crop, were studied. This system is more widely used than rotational systems in China and is suitable for culturing fingerlings.

The new concurrent rice-fish culture method differs from the traditional methods as follows:

- A trench is dug along the dike of the ricefield after transplanting the rice seedlings. The seedlings are then densely retransplanted along the inner edge of the dike. They act as a hedge fence that prevents fish escapes during heavy storms. They also compensate for the lost space occupied by the trench.
- *C. idella*, a weed control species, is stocked at two 3.5–4.0-cm fingerlings/m² without feeding.

Results

Weed Control

C. idella adapt well to life in ricefields and control weeds thoroughly than hand weeding and more efficiently than herbicides. Ricefields usually need weeding two or three times per crop, if no fish are stocked. Among the many species of weeds in ricefields, there are some which *C. idella* like to eat (such as *Hydrilla verticillata* and *Eleocharis yokoscensis*) and some which *C. idella* do not usually eat (such as *Callitricha stagnalia* and *Sagittaria pygmea*). However, *C. idella* that lack plentiful of food will still eat the latter. *C. idella* have enough space and food when stocked at 2/m² in ricefields; weed control is optimal at this rate.

In two experiments, the quantities of weeds present after fish harvest were as follows: with fish, 33 kg/ha in experiment I and 450 kg/ha in experiment II; without fish, 435 kg/ha in experiment I and 6,525 kg/ha in experiment II. Therefore, the areas started with fish had 14 to 15 times less weeds than areas without fish.

Mosquito control

C. idella help to control mosquitos. A 4.6-cm *C. idella* fingerling can eat 272 mosquito larvae in 24 hours. Stocking ricefields with two *C. idella*/m² can almost eliminate mosquito larvae: a big benefit to public health.

Rice and fish production

Ricefields stocked with *C. idella* always produced 10% or more rice than those without fish. In a series of trials (one during the early crop and three during the median crop, with plot sizes ranging from 0.08 to 1.47 ha), the increased rice production from stocking fish ranged from 537 to 1,574 kg/ha, or 11 to 35% above the production from fields without fish. The increases are due not only to weed control but also to the manuring effect of *C. idella* feces. Tests showed that *C. idella* fingerlings excrete about 1.5 g feces/day. For the 60-day early rice crop, stocked fish produced about 537 kg/ha of feces. Thus, stocking *C. idella* can save on fertilizer.

C. idella fingerlings stocked during the summer rice crop grew from 3.5–4.0 cm initial length to 11–16 cm (Table 1). The advanced fingerlings produced were very healthy. They were also produced very economically as there was no need for nursery ponds, feeds or fertilizer, and very little extra labor was required to take care of the fish, which solely depended on eating weeds, plankton and

Table 1. Harvests of advanced *C. idella* fingerlings, stocked with summer rice.

Plot No.	Area (ha)	No. of fish stocked	No. of fish harvested	No. of fish harvested/ha	Survival (%)
1	2.94	41,500	18,430	6,269	44
2	1.47	29,500	8,250	5,612	28
3	1.29	19,600	10,090	7,822	51

Table 2. Comparison of revenues from ricefields with and without stocked *C. idella* fingerlings.[a]

Type of crop	Product	Net yields (kg/ha)	Value (US$)	Total value (US$)	Increase in revenue (%)
Early crop					
With fish	Rice	3,272	153	198	54
	Fingerling	5,172	45		
Without fish	Rice	2,734	128	128	
Median					
With fish	Rice	5,596	262	332	38
	Fingerling	6,084	70		
Without fish	Rice	5,138	241	241	
Late					
With fish	Rice	8,595	403	471	62
	Fingerling	7,845	68		
Without fish	Rice	6,218	291	291	

[a]Original values in Yuan were converted to US$ at the rate of US$1 = Yuan 3.70 as of 1983.

insect larvae. The plankton density in ricefields without fish is normally about 43 kg/ha, compared to 19 kg/ha for those stocked with *C. idella* fingerlings.

The ricefields stocked with *C. idella* gave 38 to 62% more revenue than those without (Table 2). This was much appreciated by the farmers.

Discussion

This new system of rice-fish culture not only utilizes water space to rear fish for food, but also uses the fish as a tool to reduce weeds and insects and to increase rice yields. The key to this is the choice of fish species and its feeding habits. Through repeated experiments, we are convinced that *C. idella* is the best weed eliminator among freshwater fish and ricefields are an excellent habitat for it. *C. idella* is recommended as a tool for weed control in the rice growing areas of the world.

What's Happening to the Rice Yields in Rice-Fish Systems?*

CLIVE LIGHTFOOT
ANNE VAN DAM**
BARRY COSTA-PIERCE***
International Center for Living Aquatic Resources Management
MCPO Box 2631, 0718 Makati, Metro Manila
Philippines

LIGHTFOOT, C., A. VAN DAM and B.A. COSTA-PIERCE. 1992. What's happening to the rice yields in rice-fish systems?, p. 177–183. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Even though rice-fish farming has been practised in Asia for many years, little quantitative data on yield effects exist. Indeed, the study of fish effects on rice is replete with hearsay and confounding, inconclusive experiments. An analysis of the data culled from eighteen studies was undertaken to answer the question of what happens to the rice yields in rice-fish systems. This analysis was done not to know if rice yields were higher, but to build new management practices to stabilize rice yields on similar or higher levels. Incomplete data sets and confounding experiments permit us only to report that despite increases and decreases in rice yield on average, observations show a 15% increase in rice yields. Unfortunately, few authors offered adequate explanations for yield differences. Mechanisms that might explain how fish increase rice yield were also poorly reported. A handful of studies have reported that fish feed on rice pests including weeds, and various pathways have been traced for fish to contribute to soil fertility. These experiences tell us that fish feed, fertilizer input, fish stocking rates, water depth, soil nutrient status and rice variety will be among the important management variables determining rice yield.

Introduction

Rice yields deserve careful study because Asia's resource poor farmers are so utterly dependent on rice. Households must grow enough rice to survive. Predicting rice production and matching input levels is a vital calculus for farmers.

Rice-fish farming has been practised for many years, but what happens to rice yields when fish are stocked in ricefields is still unclear. More often than not, farmers tell of rice yield increases, but data gathered from farms as well as research stations are not always conclusive. Nevertheless, many authors have

*ICLARM Contribution No. 725.
**Present address: Thorbechestraat 60, 6702 B5 Wageningen, The Netherlands.
***Present address: 6 Hale Ohia Road, P.O. Box 1050, Volcano, Hawaii 46785, USA.

quoted farmers (or quoted other authors who quoted farmers) to elevate to the status of conventional wisdom the increase in rice yield when fish are stocked. Ruddle's 15% figure is often quoted although he merely stated that "it is well established" that rice yields go up by 15% when fish are grown in the rice field (Ruddle 1982). What little data is cited in the literature suggests that outcomes are not uniform or predictable.

A similar situation exists when authors explain mechanisms for yield increases. There is a plethora of can, might and maybe but little experimental evidence. Often, today's authors must go back to experiments conducted in the 1950s and the 1960s to get their evidence. Coche's oft quoted weeds' effect is based on the experiments in the 1950s in Africa (Coche 1967). Indeed, many of the still unquantified mechanisms were put forward by Ardiwinata (1958). We do not make these points to criticize but to highlight a situation that needs to be rectified.

If fish are going to increase or decrease rice yields, farmers must know about it. We need to know what is happening to rice yields in rice-fish systems so that management strategies can be set by farmers to ensure not only favorable but also predictable outcomes.

Effect of Fish on Rice Yields

Evidence to date from research stations and farms from several countries indicates that rice grown with fish can yield more or less than rice grown alone (Table 1). Regardless of rice yield level, we find that differences can be negative or positive. Differences however, do strongly favor positive outcomes on the average (range = +4.6 to +28.6). The range of differences was found to be very wide, from -58% to +183%! Moreover, Spiller (1985) indicates that rice yield increases as fish production increases.

Unfortunately, it is difficult to interpret the information from the various reports and compare yields among environments/climates. Authors are not very clear about the conditions under which yields were reached: soil types and fertility, input levels, rice variety, etc. are either difficult to extract or not reported at all. The yield increase figures in Table 1 were calculated on the basis of rice area using the size of the fish refuge given by the authors, but often it is hard to find how much of the rice area was devoted to the fish refuge. It was therefore not possible to perform a more rigorous statistical analysis of the data in search for some key factors affecting rice yields and possible mechanisms for yield increases. In none of the work do we find adequate explanations of why yields were high or low except in cases where crops were severely damaged. Notwithstanding the uncertainty of outcomes, it seems that growth and production of the individual rice plants are increased. Strongest evidence is from Thailand and the Philippines where rice yields from rice-fish and rice alone were compared on the same farm. Also, various reports speak of better tillering and higher grain weight (China Freshwater Fish Committee 1973; Li 1988). From these data it is not unreasonable to assume a 10-15% increase when fish are present. The much greater variability in the data from Thailand may be caused by the environment: rainfed, low-input traditional varieties against irrigated modern varieties in the Philippines. Rice yield increases are large and frequent enough to warrant a search for mechanisms.

Mechanisms for Rice Yields

Many mechanisms have been put forward to explain the yield increases observed in rice crops when grown with fish. Some of these are clearly indirect rather than direct effects. The precise water control necessary for good fish production will, through better weed and nu-

Table 1. Effect of fish on rice yields in various rice-fish systems.

Country	Year	Approximate yield level t/ha	Yield change % Average	Yield change % Range	n	System: Refuge type	System: Water management	System: Location	System: Rice variety	System: Fish species	System: Fish density /m²	System: Fish size (g)	Source	Data quality
Thailand	1985	1.8	+ 11.5	-28.9 - +99.0	12	pond	irrigated	farm		CC/ON/PG	ng	ng	Thongpan et al. this vol.	paired fields on 12 farms
	1985	1.5	+ 10.2	-21.4 - +39.1	13	pond	rainfed	farm		CC/ON/PG	ng	ng	Thongpan et al. this vol.	paired fields on 13 farms
	1983	2.3	+ 6.3	-58.3 - +22.2	8		most rainfed	farm		ng	ng	ng	Spiller 1985	paired fields on 8 farms
	1984	2-2.3	+ 15.8	ng	23		irrigated	farm	glutinous	CC/PG/ON/AN	avg 0.32	ng	Middendorp and Verreth 1986	5 mono vs. 15 rice-fish farms
	1987	2-2.6	+ 26.4	0 - +183.3	11	pond	rainfed	farm		CC/ON/PG	ng	ng	Thongpan et al. this vol.	paired fields on 11 farms
China	1973	4	+ 28.6	+ 6.2 - +103.6	6	ng	ng	ng	various	ng	ng	ng	China Freshwater Fish Commission 1973	"controlled experiment"
			ng	+ 8 - +47.3	ng	ng	ng	ng	ng	ng	ng	ng	Nie et al. 1985	no information
	1980-83	5.5	+ 21.4	+11.2 - +35.1	4	trench	irrigated	station	ng	CI	2	3.5-6 cm	Nie Dashu et al. this vol.	data from four crops
Indonesia	1985	5.5-6.5	+ 6.6	ng	ng	trench	irrigated	station	ng	CC	ng	ng	Syamsiah et al. 1988	data from six collaborators
India	1987	2-2.5	+ 4.6	- 2.2 - +10.9	8		deepwater	farm	NC-492, Sabita	IMC poly	1	275	Mukhopadhyay et al. this vol.	controlled experiment
	1987	2-2.5	+ 11.1	- 4.5 - +43.1	4		deepwater	farm	NC-492, Sabita	IMC poly	1	490	Mukhopadhyay et al. this vol.	controlled experiment
	1980-83	4-4.5	+ 16.9	+ 8.5 - +23.3	3	trench	irrigated			HF/CB	0.5/0.5	ng	Datta et al. 1985	controlled experiment
	1982	1.8	+ 6.2	+ 5.1 - + 7.4	2	trench	irrigated			HF/CB	0.5/0.5	ng	Datta et al. 1985	controlled experiment
Philippines	1977-78	6	+ 9.3	- 0.4 - +41.3	19	trench	irrigated	farm	IRRI	most ON	0.5	app. 20	Arce and dela Cruz 1978	paired fields
	1989	6	+ 13.4	ng	5	trench	irrigated	farm	IR 64	ON	0.5	2.2	Torres et al. this vol.	paired fields on five farms
	1989	6	+ 10.2	ng	5	pond	irrigated	farm	IR 64	ON	0.5	2.6	Torres et al. this vol.	paired fields on five farms
	1988	6	+ 8.6	ng	3	trench	irrigated	farm	IR 66	ON	0.5	5.3	Dela Cruz and van Dam 1988	paired fields on three farms
	1988	6	+ 15.6	ng	3	trench	irrigated	farm	IR 66	CC	0.5	0.6	Dela Cruz and van Dam 1988	paired fields on three farms
	1988	6	+ 12.4	ng	3	trench	irrigated	farm	IR 66	ON/CC poly	0.33/0.17	5.3/0.7	Dela Cruz and van Dam 1988	paired fields on three farms

Table notes:

1. avg = average; ng = not given; poly = polyculture.
2. All rice yields were calculated on the basis of area planted to rice, excluding the fish refuge area. Yield increases were calculated as: 100*(yield from RF - yield monoculture)/(yield monoculture).
3. Fish species: CC = *Cyprinus carpio*; ON = *Oreochromis niloticus*; PG = *Puntius gonionotus*; AN = *Aristhichtys nobilis*; CI = *Ctenopharyngodon idella*; IMC = Indian major carps; HF = *Heteropneustes fossilis*; CB = *Clarias batrachus*.

trient management, definitely improve rice yields, whether there are fish present in the water or not. The additional tillage given to ricefields for fish will improve rice yields whether there are fish present or none.

Weed control, pest and disease control, and soil nutrient management typify the areas where direct beneficial effects have been found. "Katengese experimental ricefields stocked at the rate of three adult fish (*Tilapia melanopleura*[1]) per acre three weeks after the transplanting of one-month-old rice seedlings have proved successful in keeping the ricefields completely free of weeds and algae", reports Coche of work done in the Congo during the 1960s (Coche 1967). Another study done in the 1960s in Indonesia found that ricefield weed biomass was significantly reduced by the grazing of carp and tilapia (Satari 1962 in Moody, this vol.). Similar results were obtained in China where fish reduced the number of weeds and their fresh weight (Xu and Guo, this vol.).

"After three years of observation, it has been concluded that the majority of snails normally present in the ricefield could be controlled by the joint action of these fish". Here Coche is reporting on *T. melanopleura* and *Haplochromis mellandi* eating snail food and snails in an African experiment in the 1960s (Coche 1967). Fish have also been seen to eat other rice pests and pathogens. Fedoruk and Leelapatra cite that "consumption by fish of rice pests is shown in a research in China (Liao 1980) where insect predators in rice were reduced by 12-75% with the introduction of fish into ricefields" (Fedoruk and Leelapatra, this vol). Also in China, Xu Yuchang and Guo Yixan observed reductions in rice leafhoppers and rice striped disease incidence in comparative experiments of rice monocropping and rice-fish culture. Unfortunately, their report does not say anything about the statistical validity of the results (Xu and Guo, this vol.). Interestingly, their fish seemed not to predate on spiders; in fact they observed an increase in spider populations in the rice-fish plots. Other work in China has found fish to predate on rice stemborers, rice leaf folders and rice planthoppers (China Freshwater Fish Committee 1973, in Spiller 1985). Stemborer eggmasses are reduced, number of leaves rolled by leaf folders are reduced, and number of planthoppers are reduced despite confounding effects wrought by differential applications of insecticide. Over a period of three months, rice planthopper populations were found to be lower in ricefields with fish compared to fields without fish (Xiao, this vol.).

Various pathways have been traced for fish to contribute to soil fertility (Pierce 1968; Khoo and Tan 1980; Lipton 1983; Middendorp 1985). Roger's scheme helps explain these pathways (Fig. 1).

Firstly, fish grazing on the aquatic biomass contribute through their feces to nitrogen accumulation at the soil surface. Secondly, grazing reduces algal biomass; this helps keep the pH near neutral which in turn reduces ammonia losses via volatilization. Water pH is a major factor in determining nitrogen losses (up to pH 9, the un-ionized ammonia concentration increases by a factor 10 per unit increase in pH [Roger 1988]). This mechanism would only be important in the earlier stages of the crop though, as algae are shaded out quickly after the rice canopy closes.

Lastly, through increasing the aerobic layer at the soil-water interface by their feeding actions, fish slow the denitrification process that leads to volatilization of nitrogen. Nitrogen losses from volatilization range from 2 to 60% (Fillery et al. 1984).

Differences in soil nutrient status are being detected. Organic matter, nitrogen, available phosphate and potassium levels were all higher in fields where rice had

---

[1]See Philippart and Ruwet (1982), p. 25. This name was used for various species, e.g., *Tilapia rendalli* and *T. zillii*.

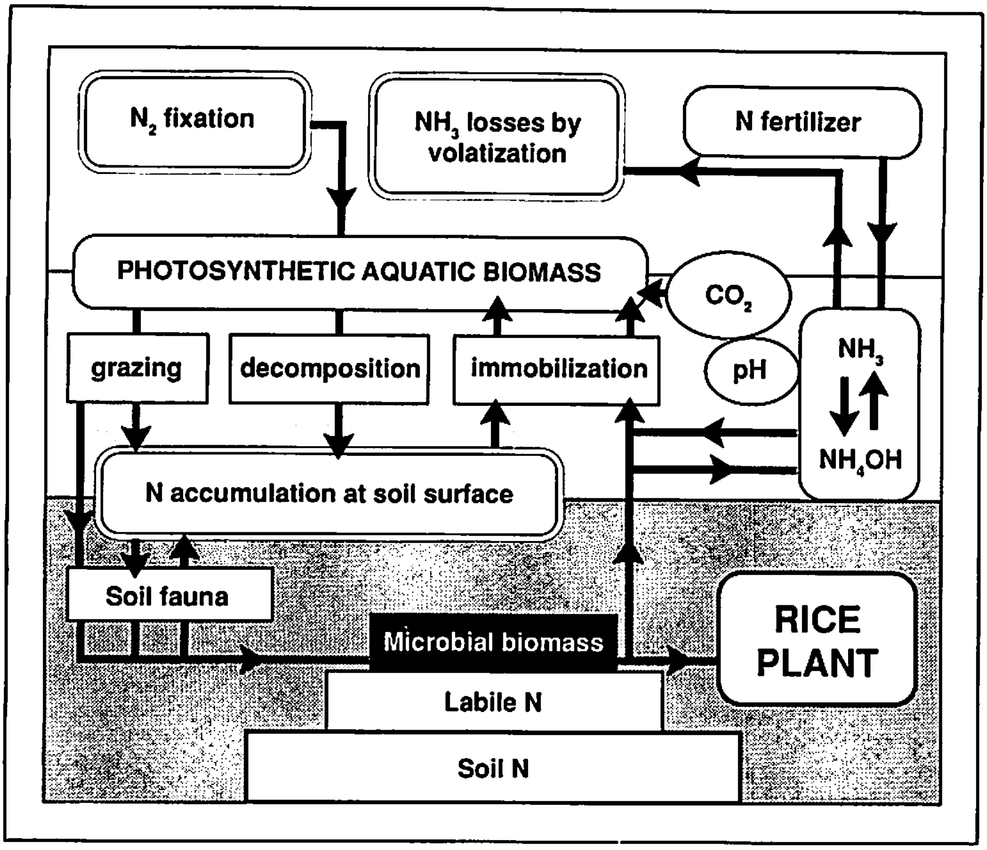


Fig. 1. The role of the photosynthetic aquatic biomass in nitrogen recycling in wetland ricefields (Source: Roger 1988).

been grown with fish compared to fields of rice alone (Xu and Guo, this vol.). As one might expect, differences were most marked in the soils of the sumps and trenches (Li 1988). Again, little statistical strength in these reports exist.

Discussion

Not all interactions between rice and fish are positive. There have been reports of carp uprooting rice seedlings if stocked too early (Khoo and Tan 1980). Stocking Nile tilapia (*Oreochromis niloticus*) negatively affected rice yields in experiments in the Philippines (van Dam 1990). Growing fish in ricefields demands greater water depth and higher bunds. Optimal water depths for fish are between 15 to 25 cm which is deeper than the 10 cm optimum for many modern rice varieties. Strengthened and higher bunds demand more labor. Moreover, farmers and governments worry about loss of ricefield area to fish trenches. The presence of fish also curtails some rice crop protection techniques - some chemicals reduce fish growth, ricefields cannot be drained to kill rice viral stem rots, etc.

Farmers and governments need to be able to predict more accurately what will happen when fish are stocked in ricefields. Research aims not just to know if yields are higher or not, but to build new management practices that stabilize rice yields at similar if not higher levels. The major constraints to reaching this aim are the manifold opportunities for confounding in rice-fish experiments. In the literature reviewed here, effects of fertilizer use, fish feeding, and carry-over effects in rotational systems were confounded in the comparative data. Not enough details were reported to thoroughly analyze and compare the accumulated data.

With the available information, we did not succeed in reaching a more definite conclusion about why fish increase rice yields. However, the "average of average" rice yield increases as reported from the 18 studies assembled in Table 1 is remarkably close to the 15% increase reported by Ruddle (1982). Experiences documented here suggest that fish feed and rice fertilizer input, fish stocking rates, water depth and fluctuations, soil nutrient status and rice variety will be among the most important variables determining yield differences. Well-designed and controlled experiments comparing rice-fish with rice monoculture could of course clarify things instantly. Such experiments would, however, be very site- and climate-specific. It would help a great deal if some consensus about reporting on rice-fish trials existed, so that all reports would contain information on at least a minimum array of variables about both rice and fish. Multivariate statistical techniques could then be used to do across-site and -season analyses and extract the most important variables. Perhaps managing these "principle components" will help farmers and researchers predict more accurately what is happening with rice yields in rice-fish systems.

References

Arce, R.G. and C.R. dela Cruz. 1978. Improved rice-fish culture in the Philippines. Proceedings, International Commission on Irrigation and Drainage Second Regional Afro-Asian Conference., ICID Tech. Pap. 10:136-145.

Ardiwinata, R.O. 1958. Fish culture on paddy fields in Indonesia. Indo-Pac. Fish. Coun. 7(II-III): 119-1154.

China Freshwater Fish Committee. 1973. Freshwater fish culture in China. Science Publishers, Peking, China. 1,688 p. (in Chinese).

Coche, A.G. 1967. Fish culture in rice fields: a world-wide synthesis. Hydrobiologia 30(1): 1-44.

Datta, S.K., D. Konar, P.K. Banerjee, S.K. De, P.K. Mukhopadhyay and P.K. Pandit. 1985. Prospects of increasing food production in India through different systems of paddy-cum-fish culture in freshwater areas: a case study. Paper presented at the Sixteenth Session of the Food and Agriculture Organization and International Rice Commission, 10-14 June 1985, Los Baños, Laguna, Philippines.

dela Cruz, C.R. and A.A. van Dam. 1988. Semi-annual Report, Rice-Fish Farming Systems Research Project, 1 January-30 June 1988. International Center for Living Aquatic Resources Management, Manila, Philippines.

Fillery, I.R.P., J.R. Simpson and S.K. De Datta. 1984. Influence of field environment and fertilizer management on ammonia loss from flooded rice. Soil Sci. Soc. Am. J. 48:914-920.

Khoo, H.K. and E.S.P. Tan. 1980. Review of rice-fish culture in Southeast Asia, p. 1-14. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Li Kangmin. 1988. Rice-fish culture in China: a review. Aquaculture 71:173-186.

Liao, K.T. 1980. Rice paddy fish culture. Pearl River Fisheries Institute. Bureau of Aquatic Products, Guandong Science and Technology Publishing Co., Guandong.

Lipton, A.P. 1983. Prospects of paddy-cum-fish culture in the northeastern region of India. Seafood Export J. 15(1):25-30.

Middendorp, A.J. 1985. Integrated rice-fish culture: practices and prospects. Working group report on small scale integrated aquaculture. International Agriculture Centre, Wageningen, The Netherlands.

Middendorp, A.J. and J.A.J. Verreth. 1986. The potential of and constraints to fish culture in integrated farming systems in the Lam Pao Irrigation Project, Northeast Thailand. Aquaculture 56:63-78.

Nie Dashu, Chen Yinghong and Wang Jianguo. 1985. Recent development of fish culture in the rice paddy in China. Proceedings of Asian Symposium on Freshwater Fish Culture in Beijing.

Philippart, J-Cl. and J-Cl. Ruwet. 1982. Ecology and distribution of tilapias, p. 15-59. *In* R.S.V. Pullin and R.H. Lowe-McConnell (eds.) The biology and culture of tilapias. ICLARM Conf. Proc. 7, 432 p.

Pierce, P.C. 1968. Fish production possibilities for Ghana's proposed irrigated paddy rice scheme p. 114-132. *In* Proceedings of the 9th Annual United States Agency for International Development/Ghana Agriculture Conference.

Roger, P.A. 1988. Biology and management of the floodwater ecosystem in tropical wetland rice fields. Handout for the 1989 Training Course of the International Network on Soil Fertility and Sustainable Rice Farming (INSURF).

Ruddle, K. 1982. Traditional integrated farming systems and rural development: the example of ricefield fisheries in southeast Asia. Agricultural Administration 10:1-11.

Satari, G. 1962. Wet rice cultivation with fish culture. A study on some agronomical aspects. University of Indonesia, Bogor, Indonesia. 126 p. Ph.D. thesis.

Spiller, G. 1985. Rice cum fish culture - environmental aspects of rice and fish production in Asia. Consultancy report, Food and Agriculture Organization, Bangkok, Thailand.

van Dam, A.A. 1990. Multiple regression analysis of accumulated data from aquaculture experiments: a rice-fish culture example. Aquacult. Fish. Manage. 21:1-15.

Fish-Crustacean-Weed Interactions

KEITH MOODY
Department of Agronomy
International Rice Research Institute
Los Baños, Laguna, Philippines

MOODY, K. 1992. Fish-crustacean-weed interactions, p. 185–192. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Increased water depth as a result of increasing bund height to permit fish culture in ricefields causes a reduction in weed growth. Further decrease in weed growth occurs when fish are introduced into ricefields resulting in reduced weeding costs. Tadpole shrimp (*Triopus* sp.) which are used to control weeds in transplanted ricefields in Japan also reduce weeding costs, but they cause severe damage to rice seeded directly. Weeds, not controlled indirectly by increasing water depth or directly by introducing fish, must be controlled either manually, mechanically or chemically. Hand weeding and mechanical weeding should, in most circumstances, have little effect on fish. However, the negative effects of herbicides on fish and microcrustaceans that serve as important food sources for fish cannot be overlooked. Additional research is needed to further quantify positive and negative interactions among weeds, fish and crustaceans.

Introduction

The only universal pests in rice are weeds exceeding tolerable levels in nearly all seasons (Moody and Cordova 1985). As they are found in all crops in all fields, it is necessary to invest in weed control practices to reduce yield losses caused by weed competition. Many techniques can be used to reduce either directly or indirectly the weed problem in rice. No matter what technology is used, the aim is to maintain weed populations at levels which do not cause economic losses.

Water Depth

Certain physical modifications must be made to ricefields for fish culture. The height of the bunds surrounding the field must be raised to give an adequate depth of water. The depth of water required depends on the size and type of fish cultured, but it must be at least 10 cm for part of the culture period (Khoo and Tan 1980).

Many weeds cannot germinate in flooded fields (Wrigley 1969). Weed populations decrease as the depth of water increases. Emergence and growth of *Echinochloa crus-galli* (L.) P. Beauv. become increasingly poor with increased depth of submergence (Arai et al. 1954, cited in Arai 1963). When water depth reaches 15 cm, *E. crus-galli* stops growing and most of the plants die. Hernandez (1923, cited in Garcia 1931) reported that 15-20 cm water was effective in controlling a number of common weed species.

Manna et al. (1969) reported that the incidence of grass weeds and sedges was negatively related to the depth of standing water which was positively related to the prevalence of algal weeds. Therefore, the reduction of weed growth in ricefields where fish are cultured may be merely due to the increased water depth, rather than the effect of the fish themselves.

Biological Control

Fish in Rice Culture

CONCURRENT RICE-FISH

Stocking fish in ricefields could be an inexpensive biological method of weed control (Satari and Trimarini 1974). Tubb (1961) reported that during early rice growth, fields containing milkfish (*Chanos chanos*) required much less weeding than fields without fish. This could have been partly due to the depth of water in the field - initially, the water level was maintained at 20 cm and then increased to 30 cm as the seedlings grew. Also, the rice tillers were clean and free from algae.

The introduction of herbivorous fish into ricefields controls weeds and reduces weeding labor and costs (Khoo and Tan 1980; Chen 1984, cited in Mochida 1983). Among the most useful species are *Puntius gonionotus*, *Oreochromis mossambicus*, *Trichogaster pectoralis* Regan and *Cyprinus carpio* L. (Liu 1987a, 1987b) reported that weeds almost completely disappeared in rice-azolla-fish (Table 1) and rice-fish systems, and that intensive labor for weeding was minimized. The almost total lack of weeds was attributed to fish activity.

Table 1. The effect of rice-azolla-fish system on weed growth. (Source: Liu 1987b).

Treatment	Weed density (no./m^2)	Weed weight (g/m^2)
Rice	48.2	450
Rice-azolla	9.3	63
Rize-azolla-fish	1.8	11

Some herbivorous fish feed on weeds, thus reducing the number of weedings needed (Vincke and Micha 1986). In search of food in the mud, fish till the soil. By doing this, submerged weeds have little chance to anchor their roots in the soil and their growth and reproduction will be hampered. Fish consume large quantities of weeds and algae, among other pests, which are directly or indirectly injurious to rice (Datta et al. 1986). Arce (1977, cited in Campos 1986) reported that fish eat weed seeds as well as some aquatic plants such as *Ipomoea* sp.

In Japan, carp reared in ricefields perform useful tillage, eat weeds and insects which cause damage to rice plants (Schuster et al. 1954). In Malaysia, the rearing of *T. pectoralis* with rice has a beneficial effect on rice production because the fish eat algae covering the surface of the soil (Soong 1954). Fish such as *O. niloticus*, which may develop rapidly in ricefields are known to ingest great quantities of blue-green algae (Anon. 1979).

Satari (1962) reported that about 73% of the total weed biomass was produced during the period from transplanting until the first weeding. He found that when *C. carpio* was cultured with rice, there was a decrease of about 30% in the total weight of weeds produced. Only the growth of weeds with their roots anchored in the soil, mostly of the Cyperaceae and Poaceae families, was checked by the *C. carpio*. All free-floating weeds, such as *Azolla pinnata*, *Eichhornia crassipes* (Mart.) Solms and *Salvinia natans* (L.) were not affected. Grasses and sedges comprised 60% of the weed flora on a net weight basis when there were no fish in the field. When fish were present they accounted for only 26–29%, while free-floating weeds accounted for 64–72%. The production of weeds after the first weeding seemed to be decreased more by the increased shading effect of the rice plants than by the presence of *C. carpio*. Weed production was reduced by 40–47% when a mixed stocking of *C. carpio* and tilapia was used (Table 2). Weeds such as *Salvinia*, *Pistia* and *Eichhornia* cause a serious problem in fish culture in Kerala, India (Kulkarni et al. 1986).

Liu (1987b) reported that deficiency of fodder was one of the limiting factors affecting fish growth in traditional systems of raising fish in ricefields. He reported that the problem can be solved by using azolla as a fish fodder. With good water management, the dual culture of rice and azolla provides many benefits such as limited evaporation of water, minimized competition from weeds, and yield increases over two rice cycles of as much as 50% (Reynaud and Franche, n.d.). The azolla blanket must be sufficiently developed to suppress weed growth but limited enough to avoid damage to rice seedlings (Scharpenseel and Knuth 1987). Liu (1987b) recommended the growing of duckweeds (*Lemna minor* L. and *Wolffia arrhiza* (L.) Wimm.) for fish fodder in places where it is difficult to grow azolla in summer because of high temperatures.

Pheang (1975, cited in Soewardi et al. 1979) reported that grass carp (*Ctenopharyngodon idella* Val.) could control dense populations of *Hydrilla verticillata* (L.f.) Royle and *Salvinia molesta* D.S. Mitchell, and retarded the growth of *E. crassipes*. However, *C. idella* also cause some damage to rice plants. Bardach et al. (1972, in Soewardi et al. 1979) noted that the use of *C. idella* entails the risk of their escape into natural waterways and possible damage to valuable wetlands. Soewardi et al. (1979) reported that the presence of *H. verticillata* significantly reduced the consumption of rice by *C. idella* but that rice was still severely damaged, while the presence of *S. cucullata* Roxb. and *E. crassipes* did not decrease rice damage. Dwarf rice cultivars were damaged more than taller cultivars.

RICE-FISH ROTATIONS

There was an abundant growth of *Hydrilla* sp. in ricefields stocked only with *O. niloticus*, and a relative absence of

Table 2. Effect of introducing fish at varying periods in transplanted rice on grass weed weight (t/ha). (Source: Satari 1962).

Treatment	Weeding		
	First	Second	Total
C. carpio (5 days after transplanting [DAT] to first weeding)	1.7	0.6	2.3
C. carpio + tilapia (5 DAT to first weeding)	1.7	0.6	2.3
C. carpio (5 DAT to second weeding)	1.8	0.4	2.2
C. carpio + tilapia (5 DAT to second weeding)	1.7	0.2	1.9
C. carpio (5 DAT to 1 month after second weeding)	1.5	0.5	2.0
C. carpio + tilapia (5 DAT to 1 month after second weeding)	1.5	0.2	1.7
No fish	2.4	0.9	3.3
Least significant difference (LSD at 5%)	0.6	0.4	0.9

weeds and algae when combinations of *O. niloticus* and *C. carpio* were used (dela Cruz 1980). This was attributed to the higher turbidity of the water caused by the feeding habits of the carp. *C. carpio* may also reduce rice production cost by cleaning the soil surface sufficiently to allow direct seeding or transplanting. Cleaning would save the costs of plowing and harrowing. However, Satari (1962) reported that fish grown in the period before transplanting rice appeared to cause a slight increase in weed growth until the first weeding.

Satari (1962) reported that the culture of fish before transplanting rice, or the culture of fish with the rice crop preceded by the culture of fish before transplanting rice, stimulated the growth of net plankton such as Chloromonadinae (*Euglena*), Diatomeae (*Navicula*), Volvocales (*Volvox*), Cyanophyceae, Conjugales (*Spirogyra*), and Protozoa (*Difflugia*). During the first eight weeks after transplanting (WAT) fish culture stimulated the growth of *Anabaena*, *Nostoc* and *Oscillatoria* (all net plankton), and also the growth of *Nostoc* in the mud. In another trial, at four WAT there was increased production of *Nostoc* (as net plankton and in the mud), *Anabaena* (as net plankton) and *Oscillatoria* (as net plankton and in the mud) in fields where fish had previously been cultured.

TADPOLE SHRIMP

In Japan, tadpole shrimp (*Triopus longicaudatus* Le Conte, *T. granarius* Lucas and *T. cancriformis* Bosc.) have been used to control weeds in transplanted ricefields (Matsunaka 1976, 1979). The small crustaceans feed on weed seedlings and disturb their roots by mechanical agitation of the soil. Total weeding labor has been reduced by 70–80% in initial field trials (Matsunaka 1979).

Tadpole shrimp do not injure transplanted rice seedlings (Matsunaka 1976, 1979) but cause severe damage to rice seeded directly into water (Matsunaka 1979; Catizone 1983; Templeton 1983).

Mechanical and Chemical Control

Weeds can be controlled mechanically or chemically. Ricefields are usually weeded by hand two or three times during the growing season. This causes no harm to fish which may even benefit from the temporary agitation and aeration of the water (Kuronuma 1980). Hand weeding and the use of rotary weeders have no adverse effects on fish (Singh et al. 1980). However, Vincke (1979, cited in Vincke and Micha 1986) cautioned that mechanical weeding, especially in shallow water, may be dangerous to fish because it makes the water very muddy.

Although herbicides are extensively used and reach waterways through direct application and runoff (Bovey et al. 1974), little is known about their distribution throughout the environment or their effects on organisms other than plants (Schober and Lampert 1977). The possibility of toxic effects of herbicides to fish cannot be ruled out although there is little information available on the subject (Singh et al. 1980). They may cause immediate reductions in population numbers, either directly because of acute toxicity to invertebrates or indirectly because of changes in water quality (Cowell 1965, cited in Sanders 1970). According to Gangstad (1986), acute toxicity of herbicides to fish is proportional to the concentration, is a direct function of the time of exposure and is dependent upon temperature. One of the most important points to be kept in mind when using herbicides is to ensure that they are nontoxic to fish in the fields because many farmers depend on them as their daily protein source (Cheam 1974).

Microcrustaceans such as those of the genus *Daphnia* are of worldwide distribution and represent an extremely important link in the aquatic food chain (Crosby and Tucker 1966), being important food items for both young and adult fish (Sanders 1970). *Daphnia magna* Straus and *Daphnia pulex* are particularly abundant and form a significant part of the diet for both young and adult fish in ponds and lakes of the temperate zone (Pennack 1953, cited in Crosby and Tucker 1966). *D. magna* was generally most sensitive to the herbicides tested by Sanders (1970), followed in descending order of sensitivity by the seed shrimp [*Cypridopsis vidua* (O.F. Muller)], glass shrimp (*Palaemonetes kadiakensis* Rathbun), sowbug (*Asellus brevicaudus* Forbes), scud (*Gammarus fasciatus* Say), and crayfish [*Orconectes nais* (Faxon)]. Sigmon (1979) reported that neither temperature nor herbicide application rate had an effect on oxygen consumption of *D. pulex* exposed to 2,4-D [(2,4-dichlorophenoxy) acetic acid]. Wagela and Dubey (1987) reported that oxygen consumption of *D. pulex* increased with increase in pendiamethalin [N-(1-ethylpropyl)- 3,4-dimethyl- 2,6-dinitrobenzenamine] concentration. Death occurred at a concentration of 2 ppm. Nitrofen [2,4-dichloro-1-(4-nitrophenoxy)benzene] killed *D. pulex* at 0.5 ppm.

Several herbicides could present a very real danger to *D. magna* under field conditions (Table 3). Molinate (*S*-ethylhexanhydro-1 *H*-azepine-1-carbothioate) and propanil [*N*-(3,4-dichlorophenyl) propanamide] may be used at field rates in excess of the median toxic dose for *D. magna*. Other common herbicides, such as 2,4-D, seemed to be completely innocuous (Crosby and Tucker 1966). The herbicide 2,4-D does not concentrate in food chains, is rarely detectable in food, and then only in insignificant amounts (Gangstad 1986). However, Sanders (1970) reported that the propylene glycol butyl ether ester of 2,4-D exhibited a wide range of toxicities to crustaceans, with TL_{50} values of 0.10 mg/l for *D. magna*, to no apparent effect at 100 mg/l for crayfish. In contrast, 2,4-D acid was not toxic to *D. magna* at a concentration greater than 100 mg/l.

Table 3. Toxicity, in terms of median immobilization concentrations (LC_{50}), of aquatic herbicides to *D. magna*. (Source: Crosby and Tucker 1986).

Herbicide	LC_{50} (ppm)[a]		Field use (ppm)
Molinate	0.70	(0.46-1.05)	3.5
Propanil	4.8	(3.8-6.6)	7.0
Paraquat	11.0	(9.1-12.2)	2.0
2,4-D		>100	2.0
MCPA		>100	2.0

[a]Figures in parentheses are ranges.

The alkanolamine salt of 2,4-D has very low acute toxicity to red swamp crayfish (*Procambarus* sp.), but propanil and molinate are moderately toxic (Cheah 1978).

The toxicity of 2,4-D to fish is variable. The ester derivatives are the most toxic. However, under field conditions, toxicity at maximum recommended rates has seldom if ever been observed and can be avoided with proper precautions (Gangstad 1986). Cheam (1974) indicated that 2,4-D appears to be nontoxic to fish in the concentrations used for weed control in rice.

Herbicides such as 2,4-D (dela Cruz 1980; Arce 1985) and butachlor [*N*-(buthoxymethyl) -2-chloro-*N*- (2,6-diethylphenyl) acetamide] (dela Cruz 1980), which are commonly used in rice production in the Philippines, do not harm fish. However, dela Cruz and Cagauan (1981) reported that butachlor was relatively toxic to *C. carpio*, *Macrobrachium* sp. and *Corbicula manilensis*, with *C. manilensis* being the most tolerant. Derico (1951) reported that shrimp (*Atya* sp.), fish fingerlings (*Ophiocara aporos* Bleeker), corixid bugs, and small freshwater snails (*Ampullaria luzonica* Reeve) were not affected by 2,4-D. *C. carpio*, *Macrobrachium* sp. and *C. manilensis* had high tolerance limits for MCPA [(4-chloro-2-methylphenoxy) acetic acid] (dela Cruz and Cagauan 1981).

Propanil is slightly toxic to fish and contamination of streams should be avoided (Anon. 1987). However, Hashimoto (1970) reported that no danger of toxicity to fish is expected with propanil if it is used according to directions on the label (Table 4).

Table 4. Classification and examples of herbicides by toxicity to fish. (Source: Hashimoto 1970).

Classification	Herbicides
A = No danger of toxicity to fish is expected when used according to the directions on the label.	Chlornitrofen MCPA-Na Paraquat-dichloride Propanil
B = Danger of toxicity to fish is not usually expected when used according to the directions on the label; but considerable care should be taken if used on a large scale.	2,4-D-ethyl MCPA-ethyl Nitrofen Swep
C = Danger of toxicity to fish is expected unless extreme care is taken so that the chemical will not contaminate lakes, rivers or other bodies of water; not permitted to be used in ricefields.	Ioxynil

The toxicity of bentazon [3-(1-methylethyl)- (1H)- 2,1,3,-benzothiadiazin-4(3H)-one 2,2-dioxide] to fish is low; 500 ppm produced no reaction in guppies (*Lebistes reticulatus*) (Luib et al. 1973), while quinclorac (3,7-dichloro-8-quinolinecarboxylic acid) is not toxic to fish (Wuerzer and Berghaus 1985). Shinohara et al. (1973, cited in Yusa and Ishikawa 1979) reported that thiobencarb [*S*-(4-chlorophenyl)] diethylcarbamothioate) had no adverse effects on carp.

Agarkov (1978) reported that when molinate was applied aerially to premoistened soil in the rice shooting period, significant fish migration (up to 19% or more) into the irrigation water was observed. As a result, large-scale death of weed-eating fish was observed in the discharge canals. Molinate is more toxic to bluegill sunfish (*Lepomis macrochirus* Rafinesque) than to *D. magna* and crayfish (Sanders 1970).

A combination of ioxynil (4-hydroxy-3,5-diiodobenzonitrile) and 2,4-D is very effective for the control of broadleaf weeds in deepwater rice in Thailand (Vongsaroj et al. 1987). In Japan, ioxynil cannot be used in ricefields because of the danger of toxicity to fish (Table 4). Therefore, ioxynil should be used with extreme caution in ricefields.

In lower Bengal (especially in the Sundarban area), *Chara* is a problem where rice-fish cultivation is practised. Mukherjii and Ray (1966) reported that *Chara* and other algae could be controlled by fentin acetate (triphenlytin acetate) at rates well below 1 ppm. However, fentin acetate is highly toxic to fish (Litsinger et al. 1987) and other aquatic animals, and should not be used for algal control.

Some farmers apply copper sulphate to control algae but it can be toxic to plants and animals especially if it is used over several years (Anon. 1971). A concentration of 0.08–0.10 ppm copper is toxic to a number of freshwater fish. Because of its possible toxicity to fish and rice, it seems inadvisable to use copper to control blue-green algae (Olsen 1957).

Olsen (1957) reported that Delrad applied to ricefields before the appearance of algae on the soil gave promising results for algal control. However, caution should be exercised with the use of Delrad where fish are concerned. A concentration of 0.7 ppm is toxic to *L. macrochirus*, goldfish (*Carassius auratus*) and young largemouth black bass (Lawrence 1954, cited in Olsen 1957). The toxicity of Delrad increases three-fold when temperatures increase from 18 to 21°C (Olsen 1957).

References

Agarkov, V.D. 1978. Conditions for the use of herbicides in rice paddies. Vestn. S-kh. Nauki 6:71-76. [In Russian].

Anon. 1971. Algicide for direct-seeded rice. IRRI Reporter 2/71:2-3.

Anon. 1979. Algal biofertilizers for rice. All India Coordinated Project on Algae. Division of Microbiology, Indian Agric. Res. Inst., New Delhi, India. 61 p.

Anon. 1987. Handbook on the use of pesticides in the Asia-Pacific region. Asian Development Bank, Manila, Philippines.

Arai, M. 1963. Theory of rice crop plant protection. I. Weed control. p. 228-251 *In* M. Matsubayashi, R. Ito, T. Nomoto, T. Takase and N. Yamada (eds.) Theory and practice of growing rice. Fuji Publishing Co. Ltd., Tokyo, Japan.

Arce, R.G. 1985. Rice-fish farming systems. p. 446-460. *In* Report of the 16th Asian Rice Farming Systems Working Group Meeting. Bangladesh Rice Research Institute, Joydebpur, Bangladesh and International Rice Research Institute, Los Baños, Philippines.

Bovey, R.W., E. Burnett, C. Richardson, M.G. Merkle, J.R. Baur and W.G. Knisel. 1974. Occurrence of 2,4,5-T and picloram in surface runoff water in the blacklands of Texas. J. Environ. Qual. 3:61-64.

Campos, A.C. 1986. Rice-fish culture in the Philippines: state of the art, p. 315-322. *In* Trinh Ton That (ed.) Rice: progress assessment and orientation in the 1980s. International Rice Commission Newsletter. Vol. 32, No. 2. FAO, Rome, Italy.

Catizone, P. 1983. Farmers' weed control technology in rice in southern Europe, p. 183-191. *In* Weed control in rice. International Rice Research Institute, Los Baños, Philippines.

Cheah, N.L. 1978. Some effects of thirteen rice pesticides on crawfish *Procambarus clarkii* and *P. acutus*. Louisiana State Univ., Baton Rouge, Louisiana. 83 p. M.S. Thesis.

Cheam, A.H. 1974. Current status of aquatic weed problems in Peninsular Malaysia. Paper No. 1.1 presented at the Southwest Asian Workshop on Aquatic Weeds, 25-29 June 1974, Malang, Indonesia. 14 p.

Crosby, D.G. and R.K. Tucker 1966. Toxicity of aquatic herbicides to *Daphia magna*. Science 154(3746):289-291.

Datta, S., K.D. Konar, P.K. Banerjee, S.K. De, S.K. Mukhopadhyay and P.K. Pandit. 1986. Prospects of increasing food production in India through different systems of paddy-cum-fish culture in freshwater areas: a case study, p. 31-39. International Rice Commission Newsletter Vol. 35, No. 2. FAO, Rome, Italy.

dela Cruz, C.R. 1980. Integrated agriculture-aquaculture farming systems in the Philippines, with two case studies on simultaneous and rotational rice-fish culture, p. 209-223. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

dela Cruz, C.R. and A.G. Cagauan. 1981. Preliminary study on the bioassay of seven pesticides and five weedicides with tilapia, carps, clam and shrimp as test species. Fish. Res. J. Philipp. 6(1):11-18 (SEAWIC Annotated Bibliography 2:4).

Derico, T.R. 1951. Experimental control of cogon (*Imperata cylindrica* [Linn] Beauv.), water hyacinth (*Eichhornia azurea* Kunth.), *Lantana camara* Linn. and other noxious weeds with 2,4-D and other herbicides. Philipp. Agric. 34:189-201.

Gangstad, E.O. 1986. Freshwater vegetation management. Thomas Publications, Fresno, California.

Garcia, M.B. 1931. Weeds in rice paddies: germination of seeds and resistance of the young plants to submergence in water. Philipp. Agric. 20:217-231.

Hashimoto, Y. 1970. Evaluation of fish-toxicity of agricultural chemicals. Jap. Pest. Info. 3:15-18.

Khoo, K.H. and E.S.P. Tan. 1980. Review of rice-fish culture in Southeast Asia. p. 1-14 *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Kulkarni, K.R., L. Suseela Devi, M.K. Jagannath and T.K.P. Setty. 1986. Studies on rice farming systems in India, p. 357-408. *In* Report of the 17th Asian Rice Farming Systems Working Group Meeting. Philippine Ministry of Agriculture and Food, Manila, and International Rice Research Institute, Los Baños, Philippines.

Kuronuma, K. 1980. Carp culture in Japanese rice fields, p. 167-174. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Litsinger, J.A., O. Mochida, H.T. Guevarra and R. Basilio. 1987. Golden apple snail *Pomacea canaliculata*: an introduced pest of rice. Paper presented at the 11th International Congress of Plant Protection, 5-9 October 1987, Manila, Philippines.

Liu Chung-chu. 1987a. Reevaluation of *Azolla* utilization in agricultural production. p. 67-76. *In* Azolla utilization. International Rice Research Institute, Los Baños, Philippines.

Liu Chung-chu. 1987b. Rice-azolla-fish system. Paper presented at the International Rice Research Conference, 21-25 September 1987, Hangzhou, China.

Luib, M., S. Behrendt, S. Haaksma and B.G.M. Kamp. 1973. Trials with bentazon in rice,

p. 140–144. *In* Proceedings of the 4th Asian-Pacific Weed Science Society Conference, Rotorua, New Zealand.

Manna, G.B., M.S. Chaudhury and A.R. Bedekar. 1969. Control of weeds in ricefields. Oryza 6(2):90–94.

Matsunaka, S. 1976. Tadpole shrimp: a biological tool of weed control in transplanted rice fields, p. 439–443. *In* Proceedings of the 6th Asian-Pacific Weed Science Society Conference, Tokyo, Japan.

Matsunaka, S. 1979. Further researches on tadpole shrimps for biological control, p. 447–450. *In* Proceedings of the 6th Asian-Pacific Weed Science Society Conference, Jakarta, Indonesia.

Mochida, O. 1983. Rice-fish culture and pesticides used in lowland ricefields in the Philippines. Paper presented at a meeting of an advisory group of experts on The Use of Isotopes in Studies of Pesticide Residues in Rice-Fish Ecosystems, 27 June-1 July 1983, Vienna, Austria.

Moody, K. and V.G. Cordova. 1985. Wet-seeded rice, p. 467–480. *In* International Rice Research Institute. Gower Publishing Co., Ltd., Aldershot, Hants, England.

Mukherjii, S.K. and B.K. Ray. 1966. Algal weeds of paddy fields of coastal West Bengal and their control by a new chemical. Z. PflKrankh. PflPath. Pfl Schultz. 73:35–40.

Olsen, K.L. 1957. "Scum" control in ricefields and irrigation canals, Rep. Ser. No. 69. Agric. Exp. Sta., Coll. Agric., Univ. Arkansas, Fayetteville, Arkansas. 20 p.

Reynaud, P.A. and C. Franche. n.d. *Azolla pinnata* var. *africana*. ORSTOM, Paris. 15 p.

Sanders, H.O. 1970. Toxicities of some herbicides to six species of freshwater crustaceans. J. Water Pollut. Control Fed. 42: 1544–1550.

Satari, G. 1962. Wet rice cultivation with fish culture. A study on some agronomical aspects. Univ. Indonesia, Bogor, Indonesia. 126 p. Ph.D. Thesis. (In Indonesian, English summary).

Satari, G. and A. Trimarini. 1974. Some notes on fish production with lowland rice as a biological method to control weeds. Paper presented at the Southeast Asian Workshop on Aquatic Weeds, 25–29 June 1974, Malang, Indonesia.

Scharpenseel, H.W. and K. Knuth. 1987. Use and importance of *Azolla-Anabaena* in industrial countries, p. 153–167. *In* Azolla utilization. International Rice Research Institute, Los Baños, Philippines.

Schober, U. and W. Lampert. 1977. Effects of sublethal concentrations of the herbicide atrazin on growth and reproduction of *Daphnia pulex*. Bull. Environm. Contam. Toxicol. 17:269–277.

Schuster, W.H., G.L. Kesteven and G.E.P. Collins. 1954. Fish farming and inland fishery management in the rural economy. FAO Fisheries Study, No. 3., 64 p. Rome, Italy.

Sigmon, C. 1979. Oxygen consumption in *Daphnia pulex* exposed to 2,4-D or 2,4,5-T. Bull. Environm. Contam. Toxicol. 21: 822–825.

Singh, V.P., A.C. Early and T.H. Wickham. 1980. Rice agronomy in relation to rice-fish culture, p. 15-34. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Soewardi, K., M.L. Nurdjana and I.J.B. Lelana. 1979. Some ecological impacts of the introduction of grass carp (*Ctenopharyngodon idella* Val.) for aquatic weed control, p. 451–458. *In* Proceedings of the 6th Asian-Pacific Weed Science Society Conference, Jakarta, Indonesia.

Soong M.K. 1954. Fish culture in paddy-fields in the Federation of Malaya. Paper presented at the 4th session of the FAO International Rice Commission, 11–19 October 1954, Tokyo, Japan.

Templeton, G.E. 1983. Integrating biological control of weeds in rice into a weed control program, p. 219-225. *In* Weed control in rice. International Rice Research Institute, Los Baños, Philippines.

Tubb, J.A. 1961. A note on the cultivation of milkfish (*Chanos chanos*) in ricefields in Thailand. Int. Rice Comm. Newsl. 10(2):3–4.

Vincke, P. and J.C. Micha. 1986. Fish culture in rice fields. p. 297–314. *In* Int. Rice Comm. News. 34 2. FAO, Rome, Italy.

Vongsaroj, P., D.W. Puckridge, S. Chinawong and S. Chomvilai. 1987. Assessment of some weed control methods for deepwater rice. Paper presented at the International Deepwater Rice Workshop, 26-30 October 1987, Bangkok, Thailand.

Wagela, D.K. and P.S. Dubey. 1987. The effect of alcohol plant effluent and a few herbicides on oxygen consumption in *Daphnia pulex*. Sci. Cult. 53:147–149.

Wrigley, G. 1969. The problem of weeds in rice, p. 27–31. *In* Rice. Technical Monograph No. 1. CIBA Limited, Basle, Switzerland.

Wuerzer, B. and R. Berghaus. 1985. Substituted quinolinecarboxilic acids - new elements in herbicide systems, p. 177–184. *In* Proceedings of the 10th Asian-Pacific Weed Science Society Conference, Chiangmai, Thailand.

Yusa, Y. and K. Ishikawa. 1979. Disappearance of benthiocarb herbicide in irrigation water, p. 596–602. *In* Proceedings of the 6th Asian-Pacific Weed Science Society Conference, Jakarta, Indonesia.

Rice-Fish Farming System in Malaysia: Fertility and Productivity

AHYAUDIN BIN ALI
School of Biological Sciences
Universiti Sains Malaysia
11800, Minden
Penang, Malaysia

ALI, A.B. 1992. Rice-fish farming in Malaysia: fertility and productivity, p. 193–200. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Water quality parameters affecting fertility and productivity of rice-fish farming systems in Kerian, North Perak, were studied for three growing seasons from September 1985 to January 1987. Parameters were obtained for both sump ponds and ricefields. Temperature and dissolved oxygen were higher (5.5 ± 0.3 mg/l) in the more exposed ricefields than in the sump ponds (1.7 ± 0.2 mg/l) and both environments have slightly acidic pH (6.3 ± 0.2 and 6.0 ± 0.2, respectively). However, these parameters did not affect the native fish species which have evolved to adapt to these extreme environments. Both the hardness (55.6 ± 7.7 and 51.0 ± 6.0 mg/l as $CaCO_3$ for the ricefields and the sump ponds, respectively) and alkalinity (29.4 ± 2.2 and 31.1 ± 2.6 mg/l as $CaCO_3$, respectively) levels were not low to affect phytoplankton production. Liming (2,240–5,833 kg/ha) increased temporarily the concentrations of the two parameters. Nitrate-N (0.22 ± 0.02 and 0.23 ± 0.02 mg/l, respectively) and orthophosphate (0.07 ± 0.01 and 0.08 ± 0.02 mg/l, respectively) were rather low, in spite of frequent fertilizations at 56 kg/ha urea and 112 kg/ha NPK. Chlorophyll *a* concentrations were 33.6 ± 5.9 and 45.2 ± 13.5 µg/l, respectively. Benthic populations fluctuated in response to fertilizations and, in general, the benthic populations in the ricefields were higher (0.54 ± 0.06 g/m²) than in the sump ponds (0.186 ± 0.035 g/m²).

Introduction

Rice farmers in Malaysia practise the capture method of rice-fish farming to supplement their seasonal incomes (Tan et al. 1973). The system is low-cost, requiring no stocking or feeding of fish, and depends primarily on the natural fertility of the ricefields to provide food for the fish. At the beginning of the rice-growing season, wild fish that enter the ricefields with the floods are trapped, grown and later harvested. To facilitate harvest and to provide shelter for fish during the growing season, a sump pond is dug at the lowest end of each field. Since the system requires no biological and little economic inputs, it is important to understand the basic ecological principles that sustain the system so that modifications to the system, if necessary, can be made to improve yields. Previously, except for some descriptive and economic studies (Tan 1973; Tan et al. 1973; Khoo and Tan 1980), no studies on the biology and ecology of the capture method of rice-fish farming have been done. Starting 1985, intensive studies on the biology and ecology of the capture method of rice-fish farming practised in the Kerian District of North Perak, Malaysia are being conducted (Ali 1988a, 1988b, 1988c, 1988d, 1989, 1990a, 1990b). This paper aims to discuss some aspects of fertility and productivity of the ricefields and sump ponds used in rice-fish farming. Some initial data obtained during a preliminary study has been published elsewhere (Ali 1988e).

Materials and Methods

The study was conducted in the rice-growing region of Kerian, North Perak, about 60 km south of Penang. This is the only rice-fish farming region in Malaysia and was famous in the 1960s and the early 1970s for its ricefield fishes such as the snakeskin gourami (*Trichogaster pectoralis*), catfish (*Clarias macrocephalus*) and snakehead (*Channa striatas*) (Soong 1948, 1949; Tan et al. 1973). Starting mid-1970s, when double cropping of rice began and was followed by the widespread use of herbicides and pesticides, fish yields declined (Tan et al. 1973).

For the study, three ricefields averaging 0.96 ha and sump ponds ranging from 6.5 to 8.0 m diameter and 1.98 m deep, were used. During the study, fields were prepared for rice cultivation by farmers using the prevailing methods (Ali, this vol.). In December 1985, prior to the start of the second season, lime was applied to the study sites at the rate of 2,240–5,833 kg/ha.

Sampling started on September 1985 until January 1987. Three crops of rice were grown during the period. Water samples were obtained biweekly from both the ricefields and the sump ponds at 15 cm below the surface, stored in a cooler packed with crushed ice and analyzed within six hours in the laboratory for chlorophyll *a*, hardness, alkalinity, nitrate-nitrogen (nitrate-N) and soluble orthophosphate using methods of Boyd (1979). Dissolved oxygen (DO), water temperature and pH were measured *in situ* using a Yellow Spring Oxygen Meter (Model 57) and a Hanna pH meter (Model 8314), respectively, whereas a Secchi disk was used to obtain visibility readings from the sump ponds. Concurrently, benthic samples from the sump ponds and the ricefields were also obtained using an Ekman Grab. The benthos were screened using a bucket filled with a US Standard No. 30 bottom sieve, separated using saturated salt (NaCl) solution, stained with rose benzol and preserved in a 5% formalin solution. The samples were later identified (Pennak 1978), counted and the dry weight (oven-dried at 103°C for 24 hours with partially opened door) obtained in order to calculate the biomass.

Results and Discussions

The mean values (± s.e.) of water quality and biological parameters measured in the sump ponds and ricefields of North Kerian, Perak, Malaysia for three consecutive seasons from 1985 to 1987 are presented in Table 1 and illustrated in Figs. 1–10.

The DO values were significantly ($P<0.05$) higher in the exposed fields (5.5 ± 0.3 mg/l) than in the more protected ponds (1.7 ± 0.2 mg/l) (Fig. 1). Photosynthesis by algae, various kinds of aquatic weeds and phytoplankton contributed to the high DO in the fields than in the ponds. In the ricefields, the DO generally declined as the growing season progressed due to shading by the

Table 1. Mean seasonal values (± s.e.*) of water quality and biological parameters measured in the sump ponds and ricefields of North Kerian, Perak, Malaysia, for three consecutive seasons, 1985–87.

Parameters	Season I	Season II	Season III	Mean
Dissolved oxygen (mg/l)				
sump ponds	1.6 ± 0.1	1.7 ± 0.6	1.8 ± 0.2	1.7 ± 0.2
ricefields	7.0 ± 0.2	5.1 ± 0.8	4.7 ± 0.3	5.5 ± 0.3
Water pH levels				
sump ponds	5.3 ± 0.1	6.1 ± 0.4	6.5 ± 0.2	6.0 ± 0.2
ricefields	5.7 ± 0.1	6.3 ± 0.2	6.9 ± 0.3	6.3 ± 0.2
Water hardness (mg/l as $CaCO_3$)				
sump ponds	27.9 ± 2.0	46.4 ± 4.3	72.3 ± 12.7	51.0 ± 6.0
ricefields	28.5 ± 1.7	47.0 ± 3.9	83.0 ± 16.8	55.6 ± 7.7
Alkalinity (mg/l as $CACO_3$) concentrations				
sump ponds	24.6 ± 3.2	39.5 ± 6.4	28.9 ± 2.3	31.1 ± 2.6
ricefields	21.6 ± 3.3	35.2 ± 3.4	30.4 ± 3.5	29.4 ± 2.2
Nitrogen-nitrate concentrations (mg/l)				
sump ponds	0.37 ± 0.02	0.18 ± 0.05	0.16 ± 0.01	0.23 ± 0.02
ricefields	0.36 ± 0.03	0.15 ± 0.02	0.17 ± 0.01	0.22 ± 0.02
Orthophosphate (mg/l)				
sump ponds	0.12 ± 0.03	0.08 ± 0.04	0.06 ± 0.01	0.08 ± 0.02
ricefields	0.08 ± 0.01	0.05 ± 0.01	0.06 ± 0.01	0.07 ± 0.01
Chlorophyll *a* (µg/l)				
sump ponds	12.39 ± 0.76	30.11 ± 10.53	82.49 ± 31.57	45.20 ± 13.50
ricefields	15.36 ± 1.29	17.86 ± 3.81	60.33 ± 11.49	33.60 ± 5.90
Secchi disk visibility (cm)				
sump ponds	32.9 ± 0.9	36.8 ± 1.1	34.9 ± 1.5	34.8 ± 0.8
Biomass (kg/ha)	88.3 ± 16.6	128.0 ± 27.6	174.6 ± 6.0	130.3 ± 24.9
Abundance (no./ha)	1,424 ± 402	3,101 ± 1,124	3,777 ± 431	2,767 ± 700

*s.e. = Standard error

rice plants. However, the seasonal decline and the diel fluctuations of the DO are not important factors since native ricefield fish species can tolerate low DO and are atmospheric air breathers (Ali 1988e, 1990a). Species such as catfish possess arborescence organs that enable them to use atmospheric air (Lagler et al. 1977).

Both the ricefields (6.3 ± 0.2) and sump ponds (6.0 ± 0.2) have slightly low pH and although the difference is not significant (P>0.05), the sump ponds consistently have lower values (Fig. 2). The acidity is primarily due to tannic/humic acids resulting from the decomposition of aquatic weeds and rice stalks leftover from field preparation and harvesting. Farmers in this area do not practise liming and this contributed to the perpetually low pH levels in both habitats. Furthermore, ricefields are not plowed mechanically because of the extremely soft and boggy bottoms. Field preparation only includes spraying the fields with herbicides and then manually removing the weeds. The resulting mulch does not decompose quickly in the boggy habitats, resulting in acidic environment. Low pH does not have any detrimental effect on the fish. In fact, some species such as *T. pectoralis* seem to prefer slightly acidic water (Soong 1948).

Lime application in the second season resulted in a temporary increase in pH to above 8.0 for about one month, after which the pH soon declined to the pre-liming levels. Its ineffectiveness is probably due to the swampy nature and the proximity of the ricefields to the coast, resulting in acid sulfide soils (Boyd 1979).

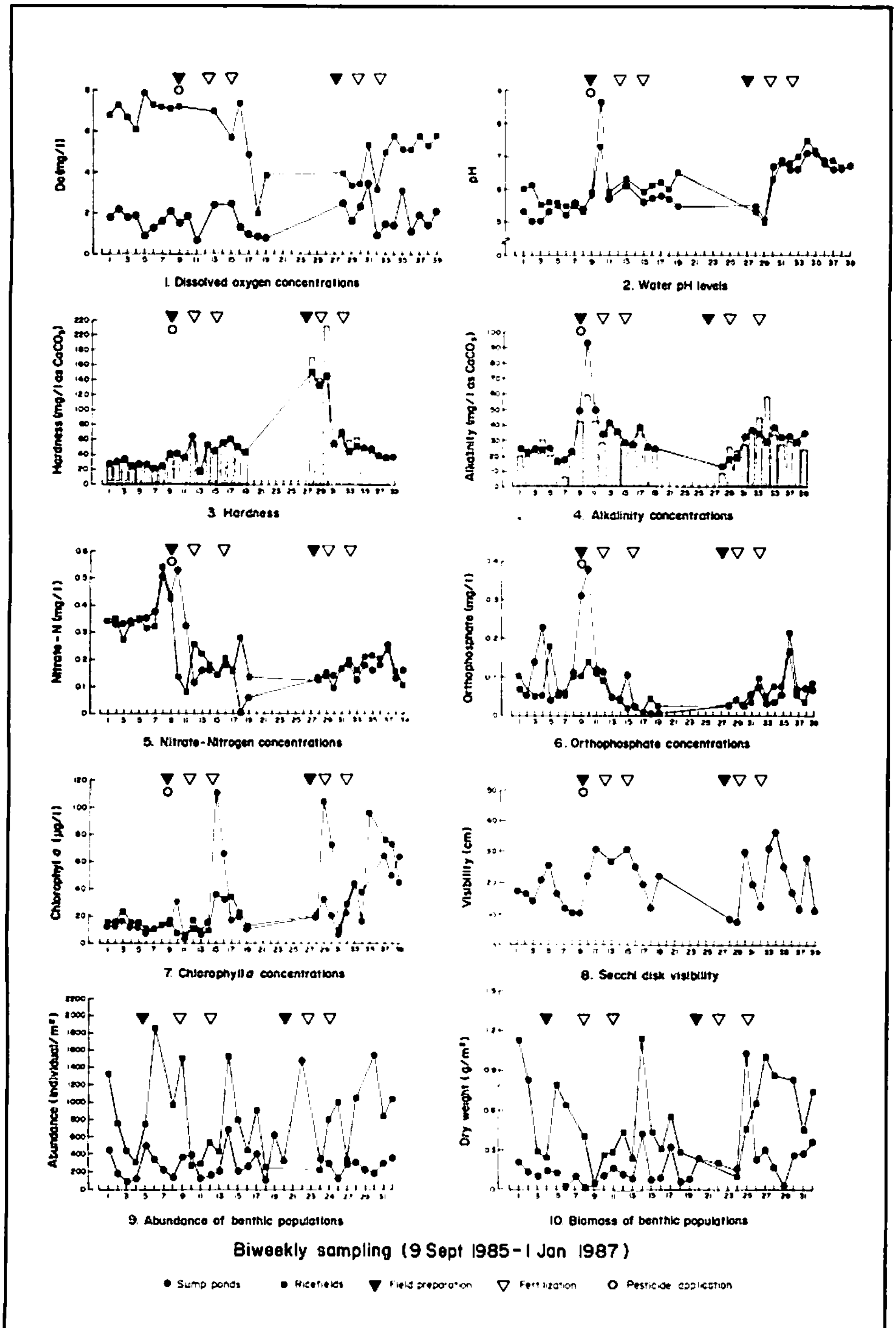
Mean alkalinity and hardness are not overly low in both habitats (29.4 ± 2.2 and 55.6 ± 7.7 mg/l as $CaC0_3$ in ricefields and 31.1 ± 2.6 and 51.0 ± 6.01 mg/l as $CaC0_3$ in sump ponds, respectively) (Figs. 3 and 4). There is also no significant difference (P>0.05) in the concentrations of the two parameters detected in both habitats. Liming initially caused an increase in alkalinity from a pre-liming range of 23.8–53.8 to 41.9–93.0 mg/l as $CaCO_3$ for ricefields and 23.3–77.5 to 46.5–139.5 mg/l as $CaC0_3$ for sump ponds, but did not result in any big increment in hardness levels (24.0–42.3 to 28.0–61.1 mg/l as $CaC0_3$ and 25.3–53.8 to 22.0–66.1 mg/l as $CaC0_3$ for ricefields and sump ponds, respectively). Therefore, liming was stopped for the subsequent seasons since the purpose of liming (to increase both pH and alkalinity and result in increases in phosphorous and carbon dioxide for phytoplankton) (Boyd 1979), was not achieved.

In general, the water in both the sump ponds and ricefields can be considered as soft (Sawyer and McCarty 1967). Why there is a big increase in hardness immediately after fallow in the third season is not yet known. It could be due to a number of factors, one of which is the field preparation by neighboring farmers since the nature of on-farm research means that access to and control of the study area is not restricted. Except after liming, the total hardness levels in both sump ponds and ricefields were higher than total alkalinity indicating the dominance of non-carbonate hardness (Boyd 1979).

The nitrate-N concentrations in both sump ponds and ricefields were fairly high in the first season (0.22 to 0.72 and 0.23 to 0.59 mg/l for ricefields and sump ponds, respectively). The concentrations peaked shortly after liming (30 November and 12 December 1985), but the levels declined thereafter (Fig. 5). The mean concentrations for both the ricefields and sump ponds are 0.22 ± 0.02 and 0.23 ± 0.02 mg/l, respectively, and the difference in concentrations between the two habitats was not significant (P>0.05). The concentrations detected (0.25 mg/l) were about equal to those in fertilized fishponds (Boyd 1974). However, the concentrations should be higher because fertilizers (urea and NPK) are applied twice every season. Thus, the relatively low nitrate-N levels were probably due to the high utilization rate by the growing rice plants, aquatic weeds and phytoplankton, leaving low concentrations in the water (Ali 1988c, 1988e).

Soluble orthophosphate levels were also relatively low considering the amount of fertilizers applied during the season (Fig. 6). Means for both the ricefields (0.07 ± 0.01 mg/l) and sump ponds (0.08 ± 0.02 mg/l) were not significantly different (P>0.05). The levels detected were about the same as those observed in fertilized ponds, where the orthophosphate levels can range from 0.07 to 0.09 mg/l (Zeller 1952). The orthophosphate reached maximum concentrations following liming, however, the levels declined quickly thereafter. There is probably little orthophosphate left in the water due to high utilization rate by the rice plants, aquatic weeds and phytoplankton, and the peak observed was probably the result of orthophosphate being released from the mud following liming. Frequent fertilizations will result in residual orthophosphate existing in the mud and the orthophosphate released from this layer is a source of phosphorus for phytoplankton (Chiou and Boyd 1974).

Chlorophyll *a* concentrations in both ricefields (33.6 ± 5.9 µg/l) and sump ponds (45.2 ± 13.5 µg/l) were low throughout the study (Fig. 7). The difference in values for both habitats was also not significant



Figs. 1-10. Water quality and biological parameters measured from the sump ponds and ricefields of North Kerian, Perak, Malaysia, for three consecutive seasons, 1985-87.

(P>0.05). The concentrations increased only slightly after liming, however, major peaks occurred after fertilization. The concentrations observed declined in the first and second seasons. However, the levels increased to above 60 µg/l for both the sump ponds and ricefields in the third season. The overall concentrations were rather low when compared to the mean value of 62.7 µg/l obtained by Boyd (1973) in fertilized fishponds. The poor phytoplankton growth is probably due more to shading than nutrient availability (Ali 1988e). Phytoplankton production in the ricefields declined as the rice plants began to grow and shade out the water, whereas in the ponds the low phytoplankton productivity is due more to shading by water hyacinth.

Mean Secchi disk value for the sump ponds was 34.8 ± 0.8 cm (Fig. 8), however, the coloration (yellow to dark brown) observed was due to tannin associated with vegetative breakdown. This condition is commonly observed in the swampy areas of Malaysia (Johnson 1967).

The benthic populations in both sump ponds and ricefields consisted primarily of chironomids, oligochaetes and ceratopogonids. The population's abundance and biomass fluctuated in relation to field preparations and fertilizer applications (Figs. 9 and 10). Both the biomass and abundance were higher in the ricefields (0.54 ± 0.06 g/m^2 and 815 ± 94 individual/m^2, respectively) than the sump ponds (0.19 ± 0.04 g/m^2 and 332 ± 49 individuals/m^2, respectively). The shallower water and the higher DO concentrations in the ricefields prevented the surface soil from becoming anoxic. Furthermore, the frequent upturning of the soil during field preparation conditioned the soilwater interface and resulted in greater population of benthic invertebrates as compared to the sump ponds.

Effects on Fish Culture

Physical and chemical parameters of water such as temperature, DO, pH, turbidity and depth will determine species that can survive in ricefields (Ali 1990a). In the Malaysian system, the native species are very well adapted to these conditions, and thus, should be used for rice-fish farming. For example, *T. pectoralis* prefers acidic water and its fry can survive even at pH 4.6 (Sitasit 1969); whereas species such as *C. striata* and *C. macrocephalus* which can breath atmospheric air, can tolerate very low DO (Lagler et al. 1977). Exotic species might not be able to adapt to the local environment well enough to result in high yields. In the Malaysian system, farmers are reluctant to do any improvements since these will involve extra costs. The system does not have features such as perimeter trenches or deepwater pools to provide shelter for fish. Only sump ponds, which in most cases were dug 60–70 years ago, provide shelter. Thus, in this low input system, native species tend to perform better than introduced ones.

Fertility and primary productivity are important in the capture system of rice-fish farming because they affect food availability for fish. The linkage between nutrients (nitrate and phosphate) and fish is through phytoplankton, zooplankton, aquatic insects and macrophytes, whereas the detritus linkage is probably through zooplankton, aquatic insects and benthos. Although zooplankton is important as fish food especially in the initial stages of growth (Boonsom 1984), the role played by detritus is equally important. Groups such as the oligochaetes (*Tubifex* sp.) and chironomids convert the detritus to biomass for utilization by fish. The grazing by zooplankton on *aufwuchs* and detritus also enable this important food source to be linked with fish. Organic fertilization program could help in enhancing the availability of detritus and further increase the overall productivity of the system.

Although ricefields are fertilized regularly during the growing seasons, the fertilizers are quickly taken up by the rice plants, aquatic weeds or tied-up in the mud, leaving relatively small amount for the phytoplankton. In the Kerian area, the weeds are so dominant that they exert negative effects on fish productivity by providing hiding places for zooplankton, thus, making it difficult for larval and juvenile fish to hunt and feed (Ali 1990b). Furthermore, the weeds are so effective in using up the available nutrients that phytoplankton production is reduced (Ali 1988c), hence affecting fish yields. In this case, herbivorous fish are more seriously affected, resulting in reduced condition and lower yields (Ali 1988d, 1990a). During the study, *T. pectoralis* was more seriously affected by low food availability, while *C. macrocephalus*, a benthic omnivore, is affected less and the carnivorous *C. striata*, the least affected (Ali 1990a).

The study on fish productivity indicated that the mean seasonal yield obtained (174.6 kg/ha) is probably the maximum that can be obtained without supplementary feeding (Ali 1990a). Thus, to increase yields, farmers should apply organic fertilizers to promote plankton growth and provide supplementary feeding to the fish (Ali 1990b). To overcome the problem of low fecundity, larval survivability and shorter growing season due to double cropping, stocking of larger juveniles must be done (Ali 1988d). Currently, this is not necessary since the size of fish harvested (*T. pectoralis* ≥ 14 cm; *C. macrocephalus* ≥ 20 cm; *C. striata* ≥ 25 cm) can still be marketed (Ali 1990a).

Studies are being done to determine the best methods for rice-fish farming in Malaysia. These involve manipulating the biological and the physical aspects of the system. Fertilization with manures, stocking with larger fingerlings, providing supplementary feeds, improving the sump ponds and building perimeter trenches will be done. However, the status of rice-fish farming system in Malaysia will not change much for the next five to ten years. At the moment, farmers are reluctant to carry out this new technology because of the extra costs and doubts that this might reduce rice yields. Also, the rice subsidy program which provides fertilizers and harvests subsidies, does not help to encourage farmers to venture into other areas to supplement income. This, in fact, puts a damper on improving rice-fish farming system since farmers obtain better returns from rice farming alone. To overcome this, there must be a socioeconomic survey to determine the real impact of rice-fish farming on the rural economy. Based on these, proper planning can be done to promote and to encourage farmers to participate in this ecologically efficient, integrated farming system.

Acknowledgement

The author is grateful to the International Foundation for Science (IFS) for providing a grant for the rice-fish farming research and a travel grant to attend the workshop.

References

Ali, A.B. 1988a. The ecology of fish culture in ricefields: some biological aspects of fish culture system of North Kerian, Perak, Malaysia, p. 17–20. *In* M. Mohinder Singh (ed.) Agricultural and biological research priorities in Asia. International Foundation for Science and Malaysian Science Association, Kuala Lumpur.

Ali, A.B. 1988b. Yields obtained from the Kerian method of ricefield fish culture monitored for three consecutive growing seasons, p. 21–28. *In* M. Mohinder Singh (ed.) Agricultural and biological research priorities in Asia. International Foundation for Science and Malaysian Science Association, Kuala Lumpur.

Ali, A.B. 1988c. The impact of aquatic weeds on primary and secondary productivity in the captural method of rice-fish farming, p. 115–127. *In* R. Suwanketnikom, A. Yothasire and C. Rojanaridpiched (eds.) Proceedings I: The second tropical weed science conference. Kasetsart University and Weed Science Society, Bangkok, Thailand.

Ali, A.B. 1988d. Some ecological aspects of snakeskin goramy, *Trichogaster pectoralis* (Regan) populations harvested from ricefield-fish culture system. Indo. Malay. Zoo. 5:101–110.

Ali, A.B. 1988e. Water quality in ricefields and sump ponds and its relationship to phytoplankton growth in rice field fish culture system. Trop. Ecol. 29:63–70.

Ali, A.B. 1989. Ecological principles of the rice-cum-fish farming systems, p. 24–35. *In* E.A. Huisman, N. Zonneveld and A.H.M. Bouwmans (eds.) Aquacultural research in Asia: management and techniques. Pudoc, Wagenigen, The Netherlands.

Ali, A.B. 1990a. Seasonal dynamics of microcrustaceans and rotifer communities in Malaysian rice fields used for rice-fish farming. Hydrobiologia 206:139–148.

Ali, A.B. 1990b. Some ecological aspects of fish populations in tropical rice fields. Hydrobiologia 190:215–222.

Boonsom, J. 1984. Zooplankton feeding in the fish *Trichogaster pectoralis* Regan. Hydrobiologia 113:217–221.

Boyd, C.E. 1973. Summer algal communities and primary productivity in fish ponds. Hydrobiologia 41:357–390.

Boyd, C.E. 1974. Water quality in catfish ponds. Mar. Sci. 2:19–30, Alabama.

Boyd, C.E. 1979. Water quality in warmwater fish ponds. Agric. Expt. Stat., Auburn University, Auburn, Alabama.

Chiou, C. and C.E. Boyd. 1974. The utilization of phosphorous from muds by the phytoplankter, *Scenedesmus dimorphus*, and the significance of these findings to the practice of pond fertilization. Hydrobiologia 45:345–355.

Johnson, D.S. 1967. Distributional patterns of Malayan freshwater. Fish. Ecol. 48:722–730.

Khoo, K.H. and E.S.P. Tan. 1980. Review of rice-fish culture in Southeast Asia, p. 1–14. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Lagler, K.L., J.E. Bardach, R.E. Miller and D.R.M. Passino. 1977. Ichthyology. John Wiley & Sons, New York.

Pennak, R.W. 1978. Freshwater invertebrates of the United States, 2nd edition. John Wiley & Sons, New York.

Sawyer, C.N. and P.L. McCarty. 1967. Chemistry for sanitary engineers. McGraw Hill Book Co., New York.

Sitasit, P. 1969. Tolerance of fish fry in different pH water, p. 153–164. *In* DOF. Annual Report. Fish Culture Section, Freshwater Fish Division, Department of Fisheries, Bangkok, Thailand.

Soong, M.K. 1948. Fishes of Malayan paddy field: Sepat siam (*Trichogaster pectoralis* [Regan]). Malay. Nat. J. 3:87–90.

Soong, M.K. 1949. Fishes of Malayan paddy field: Keli-catfishes. Malay. Nat. J. 5:88–91.

Tan, C.E., B.J. Chong, H.K. Sier and T. Moulton. 1973. A report on paddy and paddyfish production in Kerian, Perak. Min. Agric. & Fish. Bull. No. 128. Kuala Lumpur.

Tan, E.S.P. 1973. The significance of sump ponds in harvesting paddy-field fishes in North Kerian, Perak. Malay. Nat. J. 26:26–31.

Zeller, H.D. 1952. Nitrogen and phosphorous concentrations in fertilized and unfertilized farm ponds in Central Missouri. Trans. Am. Fish. Soc. 82:281–288.

Resource Utilization in Rice-Fish Farming

FIRMANSJAH SASTRADIWIRJA
Freshwater Aquaculture Development Centre
Sukabumi, P.O. Box 67
Indonesia

SASTRADIWIRJA, F. 1992. Resource utilization in rice-fish farming, p. 201–206. *In* C. Lightfoot, B.A. Costa-Pierce, C.R. dela Cruz, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Data were collected from several districts in West Java, Indonesia, to determine management inputs in rice-fish farming. Inorganic fertilizer was more commonly applied than organic manure. In concurrent rice-fish culture, average application of inorganic fertilizer per hectare was: 99.3 kg N; 71.4 kg P_2O_5; 36.9 K_2O; and 16.7 kg S. Rice bran is the only supplemental feed given at a daily rate of 10–210 kg/ha in 20- to 70-day culture periods. In rotational rice-fish culture, rice bran is fed about 150–200 kg/ha/20–40 days and 300–525 kg/ha/75 days for *penyelang* and *palawija* methods, respectively. Insecticide applications of small amounts (500–1,000 ml/ha) are tolerated by fish.

Introduction

Rice-fish culture in West Java, Indonesia, has been practised since the 19th century (Satari 1962). Rice-fish farming plays an important role in the rural areas of Indonesia especially in Java, due to the added income compared with rice culture alone. Experience shows that practising rice-fish farming, which requires little additional capital input, increases income per unit area of ricefield.

In 1985, total fish production obtained from rice-fish farming in Indonesia was about 63,218 t, or 21% of total production from fish culture. West Java contributed approximately 40%. The total area of ricefields was estimated around 41,635 ha. Fish production provided rice-fish farmers approximately US$38,654. Of this amount, 54% was contributed by West Java (DGF 1987).

The two main types of rice-fish farming in Indonesia are the concurrent and rotational culture. In the concurrent culture or the *minapadi,* fish are cultured with the rice crop for one to two months, with one to two crops of fish. In the rotational culture, fish are cultured in ricefields between one or two rice crops. Rotational culture can either be the *penyelang* where fish are cultured between two rice crops for about one month or when the ricefield is being prepared for the next crop; or the *palawija* where fish are cultured as a single crop for two to three months after the second rice crop or during the fallow period after one rice crop.

Resource utilization in rice-fish farming greatly depends on the type of culture. Hence, this paper discusses the use of fertilizer, feed, water and pesticides for different culture methods. Since West Java makes the dominant contribution to fish production from rice-fish farming in Indonesia, information was collected from farmers in this province.

Fertilizer Rates

The widely used inorganic fertilizers in rice-fish farming are urea, triple superphosphate (TSP) and potassium chloride (KCl). Organic fertilizers are rarely used; of the 11 farmer respondents, only three used organic fertilizer (Table 1). In concurrent culture, fertilizer applications are usually carried out three times: before transplanting; 15-20 days after transplanting (DAT); and 40-50 DAT. Fertilizers are usually applied the day after weeding.

Farmers applied inorganic fertilizer at different rates, even in the same district. The average rates per hectare consist of 203 kg urea; 159 kg TSP; 61.5 kg KCl and 65 kg ammonium sulfate (ZA), or equal to 99.3 kg N/ha; 71.4 kg P_2O_5/ha; 36.9 kg K_2O/ha; and 16.7 kg S/ha (Table 1).

The nitrogen requirement for high-yielding varieties (HYV) of rice ranges from 35 to 135 kg N/ha (Watanabe 1977; Surowinoto 1980). Efficiencies of nitrogen utilization are 50-80%; losses may be due to volatilization, denitrification and leaching.

Most farmers broadcast fertilizer on the soil surface, despite the availability of better application techniques such as deep root zone placement, soil incorporation and slow release fertilizers (Singh et al. 1980; Surowinoto 1980). Also, there is only a slight difference in the amount of fertilizer applied in wet (87.6-95.4 kg N/ha) and dry (89.0-96.8 kg N/ha) seasons (Table 2). The recommended rates for the dry and wet seasons are 60-100 kg N/ha and 100-160 kg N/ha (Surowinoto 1980). Nitrogen applications in rice-fish are only 7-8% rice monoculture.

The total amount of P_2O_5 applied by farmers varied from 45.0 to 121.5 kg/ha. Six out of 11 farmers surveyed exceeded the range of 30-60 kg P_2O_5/ha stated by Singh et al. (1980) (Table 1).

Potassium (K) applications ranged from 13 to 64 kg K_2O/ha. Some farmers believed that as rice straw residues are returned to the soil, only a small amount of K is needed. Nevertheless, it is recommended that 10-45 kg K_2O/ha is sufficient.

In rotational culture for both *penyelang* and *palawija*, most farmers did not apply fertilizers. In *penyelang*, a few applied organic fertilizer (goat or chicken manure) at the rate of 1,500-3,000 kg/ha (Table 3); while in *palawija*, most farmers applied 150-300 kg/ha organic manure and 23-40 kg N/ha (Table 4). Most farmers also incorporated rice straw into the soil to serve as fertilizer when it decomposes.

Feeds and Feeding

In rice-fish farming using both concurrent and rotational methods, fish utilize the abundance of natural foods enhanced by fertilizers and fish feces. Satari (1962) reported that the feces of common carp may promote the growth of blue-green algae (Cyanophyceae), especially *Nostoc*, *Anabaena* and *Oscillatoria*. Generally, fish production in rice-fish culture relies on water fertility. Artificial feeds are only given as supplements. Seven of the 11 respondents fed fish with rice bran (Table 5). The amount of rice bran given varied widely according to the rearing period and location, ranging from 10 to 490 kg/ha over rearing periods of 20-70 days. In Subang District, rice bran application rates averaged 81 kg/ha in a 45-day fish culture period (Dani 1987). The feeding frequency of rice bran ranged from one to three times per week. The fish culture in *penyelang* was shorter, about 20-40 days.

Table 1. Fertilization rates and rice production per hectare per crop in rice-fish culture.

Farmer no.	Location	Rice varieties	Amount of fertilizers: 0 day after transplanting (DAT)					15-20 DAT				40-50 DAT				Total fertilizer				Rice culture period (DAT)	Rice production (kg/ha)
			Organic	N	P_2O_5	K_2O	S	N	P_2O_5	K_2O	S	N	P_2O_5	K_2O	S	N	P_2O_5	K_2O	S		
1	Majalaya, Bandung	*Sokan*	2,700	-	16	-	-	41	40	54	-	41	41	14	-	81	97	64	-	105	7,142
2	Majalaya, Bandung	IR 64	2,644	-	-	-	-	72	-	-	-	-	41	16	-	72	122	16	-	117	7,555
3	Majalaya, Bandung	IR 64	-	23	63	30	8	90	-	12	-	15	45	17	17	128	108	42	25	106	8,571
4	Ibun, Majalaya, Bandung	IR 64	-	-	45	36	-	45	-	12	-	56	-	12	12	105	45	48	12	110	3,500
5	Ibun, Majalaya, Bandung	IR 64	-	22	45	-	-	50	45	15	-	56	-	12	12	128	90	27	12	110	7,000
6	Majalaya, Bandung	IR 64	-	45	45	-	-	45	45	15	6	-	-	-	-	90	90	15	6	115	8,333
7	Cicadas, Binong, Subang	IR 64	-	27	45	13	-	45	-	-	-	18	-	-	-	90	45	13	-	115	7,000
8	Cicadas, Binong, Subang	IR 64	-	27	45	13	-	45	-	-	-	18	-	-	-	90	45	13	-	115	7,000
9	Cimaragah, Ciamis	*Cisadane*	-	16	47	42	-	32	-	-	-	47	-	-	-	95	47	42	-	145	3,928
10	Benda Tasikmalaya	*Cisadane*	-	22	47	63	-	-	-	-	-	56	-	-	-	78	47	63	-	143	8,571
11	Bayongbong, Garut	*Seri A*	-	23	47	-	26	56	-	-	-	56	47	63	12	136	95	63	28	115	-

Table 2. Comparison of fertilizer rates (kg/ha) in the wet and dry seasons in rice-fish and rice monoculture systems at Subang Subdistrict. (Source: Dani 1987).

Type of culture	Wet season: N	P_2O_5	K_2O	Total	Dry season: N	P_2O_5	K_2O	Total
Rice-fish	95.4	74.0	7.1	176.5	96.8	75	5.4	177.2
Rice monoculture	87.6	65.7	11.4	169.7	89.0	68	5.8	162.8

Table 3. Fertilizer and feeding rates and fish production in rotational (*penyelang*) rice-fish culture. (n = 10; feed = rice bran; feeding frequency = once a day except farmer #2.

Farmer no.	Location	Fertilizer application (kg/ha) Organic	Inorganic N	P	K	Stocking Density ('000 fish/ha)	Size (g)	Feeding rate (kg/ha/day)	Culture period (day)	Harvest Yield (kg/ha)	size (g/ha)	Survival rate (%)
1	Boyongbong, Garut	0	0	0	0	5.0	11	0	22	120	40	60
2	Benda, Tasikmalaya	1,500	0	0	0	75.0	larvae	5	30	150	5	40
3	Chimaragah, Ciamis	3,000	0	0	0	3.0	20	0	30	59	28	70
4	Cicadas, Binong, Subang	0	34	52	3.6	25.0	5	5	40	337	30	45
5	Cicadas, Binong, Subang	1,500	34	0	0	15.0	2	6	30	90	15	40
6	Majalaya, Bandung	0	0	0	0	140.0	larvae	0	30	231	5	33
7	Majalaya, Bandung	0	11	11	0	130.0	larvae	0	30	162	5	25
8	Majalaya, Bandung	0	0	0	0	5.0	5	0	30	110	40	55
9	Karang Tengah, Cianjur	0	0	0	0	48.0	2	0	20	106	5	44
10	Karang Tengah, Cianjur	0	0	0	0	9.8	4	0	20	146	20	75

Table 4. Utilization of fertilizers and feed, and fish production in rotational rice-fish culture (*Palawija*) in Cicadas, Binong, Subang. (n = 10; feed = rice bran; culture period = 75 days)

Farmer No.	Fertilizer application Organic (kg/ha)	Inorganic, N (kg/ha)	Fish stocking Rate ('000 fish/ha)	Size (g)	Feeding Amount (kg/day)	Frequency	Harvest Yield (kg/ha)	Size (g)	Survival rate (%)
1	200	34	15	2	4	once	480	80	40
2	300	38	30	5	7	twice	1,013	75	45
3	150	23	15	5	6	twice	607	90	45
4	250	15	20	4	5	once	750	75	50
5	150	20	25	3	6	once	750	75	40
6	300	40	20	5	6	twice	760	100	38
7	300	36	20	5	5	twice	720	80	45
8	200	25	15	4	7	twice	390	65	40
9	250	35	25	5	5	twice	828	85	39
10	200	30	15	4	6	twice	525	70	50

Table 5. Feed (rice bran) application rates and fish and rice production per hectare per crop in rice-fish culture system.

Fish stocking		Feed application		Fish				Rice	
Density ('000 ha)	Size (cm)	Amount	Frequency	Culture period (day)	Production (kg/ha)	Mean weight (g)	Survival rate (%)	Culture period (day)	Production (kg/ha)
270	larvae	2 kg/ha	twice a week	40	367	5	27	105	7,142
300	larvae	5 kg/ha	once a week	35	440	5	29	117	7,555
10	3-5	5 kg/ha	once a week	15	160	20	80	106	8,571
120	larvae	0	-	27	186	5	31	110	3,500
130	larvae	0	-	30	201	5	31	110	7,000
200	larvae	7 kg/ha/day	once a day	30	375	5	37	115	8,333
25	3-5	6 kg/ha/day	twice a day	20	206	11	75	115	7,000
25	3-5	6 kg/ha/day	twice a day	22	178	11	65	115	7,000
7.5	8-12	7 kg/ha/day	twice a day	70	300	100	40	145	3,928
15	3-5	0	-	30	132	11	80	143	8,571
5	1-3	0	-	37	83	11	50	115	-

Only three of 10 respondents applied rice bran at 150-200 kg/ha in 30-40 days (Table 3). In *palawija* 300-525 kg/ha of rice bran was given in 75 days (Table 4).

Insecticide Applications

Insecticides applications were only done in concurrent rice-fish culture. The Department of Agriculture has recommended several insecticides for rice-fish culture: Mipcin 50 WP, Hopcin 50 EC, Baycarb 50 DC, Dharmabas 50 EC, Kiltop 50 EC, Bassa 50 EC and Applaud 50 WP.

Of those recommended by the government, only Mipcin 50 WP was used by the respondents. Sumithion 55 EC and Diazinon 60 EC, although prohibited for rice, were also used. However, with respect to fish production, Sumithion and Diazinon were not harmful since low dosages were applied. Dosages for each application used by the respondent farmers were: 446–1,000 g/ha for Mipcin; 1,000 mg/ha for Sumithion and 500–750 ml/ha for Diazinon. However, the manufacturer's recommended dosages are: Mipcin, 1,000–1,400 g/ha; Sumithion, 750–1,000 mg/ha; and Diazinon 320–720 mg/ha. Applications were done at 15–40 DAT and at 40–60 DAT. Before spraying or broadcasting insecticide, the ricefield was drained until water was retained in the trenches, where fish took refuge. With these methods, fish mortalities were low.

Water Management

There are three ways of providing the required water to rice: continuously, continuous submergence and intermittent irrigation. Continuously flowing water, the most common in Indonesia, is only possible if the water source is abundant, i.e., for ricefields in valleys. In continuous submergence, the ricefields are kept flooded starting a few days after transplanting until one to two weeks before harvest. These two ways of providing water are most compatible with rice-fish culture. They have the advantages of controlling weeds more effectively and saving labor costs incurred in managing water.

In intermittent or rotational irrigation, the ricefield is alternately flooded and drained, and the soil surface is allowed to dry prior to the next application of water. This method has a number of advantages from the point of view of rice culture itself, such as good aeration of the soil and savings on irrigation water. However, it is not generally suitable for rice-fish culture (Singh et al. 1980).

With respect to the culture of high yielding varieties (HYV) of rice, the standing water depth is gradually increased from 5 to 10 cm throughout the rice-growing period. This depth is also suitable for concurrently culturing fish. In rice-fish culture, however, additional efforts have to be taken to strengthen the dikes and install a water screen at both the inlet and outlet to avoid fish escape. Trenches, 40–50 cm in width and 20–30 cm in depth, must also be built. This occupies about 2–4% of the total ricefield area. If the water source is abundant, water may be added continuously at the rate of 2–5 l/second/ha (dela Cruz 1986). It is very important in rice-fish culture to check the water level daily. Water levels may decrease as a result of leakage or the shortage of inflow which may lead to high water temperatures. On the other hand, water in the field might overflow especially after a heavy rain, resulting to fish escapes. Leakage and clogging of the screen must be attended to prevent the decrease or overflow of water.

Production of Fish and Rice

In rice-fish culture, fish can be stocked at the larvae (hatchlings) to fry (1–3 and 3–5 cm) stage. With a stocking density for 120,000–300,000 larvae/ha, the average production was 394 and 194 kg/ha with and without supplemental feeding, respectively, for a culture period of 30–40 days. However, at a stocking density of 10,000–25,000 (3–5 cm) fry/ha. Average production were 181 kg/ha in 15–22 days with supplemental feeding and 132 kg/ha in 30 days without. Survival rates of stocking fry at 1–3 or 3–5 cm ranged from 50 to 80%, much higher than stocking larvae (27–37%). Only one respondent who stocked 8–12 cm had a 40% survival rate. The corresponding rice production (wet state) under this rice-fish system was around 3,500–8,571 kg/ha/crop (average of 6,860 kg/ha).

The average fish production in *penyelang* (mostly without supplementary feeding), was about 151 kg/ha in 20–30 days. In *palawija,* the average production was about 682 kg/ha in 75 days with supplemental feeding of 300–525 kg/ha of rice bran (Table 4).

References

Dani, A.M. 1987. The added value analysis on rice-fish culture in irrigation rice field (case study at Subang district). Faculty of Fisheries, Bogor Agricultural University, Bogor, Indonesia. (In Indonesian).

dela Cruz, C.R. 1986. Rice-fish culture manual. Small-Scale Fisheries Development Project. United States Agency for International Development and Directorate General of Fisheries, Jakarta, Indonesia. 29 p. (In Indonesian).

DGF. 1986. Fisheries statistics of Indonesia No. 5, 1985 Directorate General of Fisheries, Department of Agriculture, Jakarta, Indonesia.

Satari, G. 1962. Wet rice cultivation with fish culture: a study on some agronomical aspects. Bogor Agricultural University, Bogor, Indonesia. 126 p. Ph.D. dissertation. (In Indonesian).

Singh, V.P., A.C. Early and T.H. Wickham. 1980. Rice agronomy in relation to rice-fish culture, p. 15–34. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Surowinoto, S. 1980. Wet rice production technology. Department of Agronomy, Faculty of Agriculture, Bogor Agricultural University, Bogor, Indonesia. 95 p.

Watanabe, I. 1977. Biological nitrogen fixation in rice soil. Paper presented at the IRRI Symposium on Soils and Rice, 20–25 September 1977, Los Baños, Laguna, Philippines. 15 p.

The Economics of Rice-Fish in Asian Mixed Farming System – A Case Study of the Philippines*

MAHFUZUDDIN AHMED
MARY ANN P. BIMBAO
International Center for Living Aquatic Resources Management
MCPO Box 2631
0718 Makati, Metro Manila
Philippines

RUBEN C. SEVILLEJA
Freshwater Aquaculture Center
Central Luzon State University
Muñoz, 3120 Nueva Ecija, Philippines

AHMED, M., M.P. BIMBAO and R.C. SEVILLEJA. 1992. The economics of rice-fish in Asian mixed farming system – a case study of the Philippines, p. 207-216. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Production of fish on rice lands as a viable option for increasing farm cash and protein levels has begun to attract many Asian governments and policymakers. The economics of rice-fish culture on a mixed farm in Central Luzon, Philippines, is examined through linear programming (LP) models. Results show that a shift from rice monoculture to rice-fish culture requires 17% more labor and 22% more working capital, but the additional fish output generates 67% more farm income. Simulation of optimal farm plans for different rice-fish production scenarios shows that there is still an economic incentive for expansion even at lower fish productivity. Moreover, even if the relative price of rice increased by 50%, rice-fish culture would still pay off.

Introduction

A technological limit may have been reached to further intensification of rice cropping systems. Farmers are looking for more diversified practices to meet dietary and income demands. Population and other factors have increased the pressure on land use. In the seventies, the percentage of Philippine farms <3 ha

*ICLARM Contribution No. 727.

increased from 61 to 72%. Integration of fish on rice-based farms may alleviate dietary and income deficiencies.

Although an old practice in China and India, rice-fish culture in the Philippines is only 15 years old (Bimbao et al. 1990). Adoption has been low due to technical and social constraints. Indiscriminate application of pesticides and short rice production cycle have resulted in small fish at harvest. Unavailability of fingerlings, inadequate water supply, fish poaching and the risk-averse attitude of most farmers, also play a part. If these constraints can be overcome even on 5% of the existing irrigated rice lands, adoption of rice-fish could increase fish production by 29,340 t, generate income of US$35 million and provide 5,868 t of protein (Table 1). We know that the profitability and productivity indices generated in rice-fish are higher than rice monoculture (Arce and dela Cruz 1978; dela Cruz 1980; Arevalo 1987; Bimbao et al. 1990; Sevilleja, this vol.). Less well known is how rice-fish culture impacts on the whole farming system. This paper analyzes the economic impact of introducing rice-fish production technology into traditional rice-based farms in the Philippines, specifically, the effects on farm income, employment and resource-use patterns.

Materials and Methods

Analytical Framework

A mathematical programming technique was used to analyze the effects of rice-fish adoption on a rice-based farm (Heady and Srivastava 1975). The structure of the linear programming (LP) model developed here is given in Table 2. The farmer is assumed to maximize annual farm gross margin, i.e., total sales minus total purchases. Sales consist of farm produce net of family consumption, seed production and other deductions; while purchases consist of buying inputs for production operations and outputs for consumption needs over a year.

The Data

The model is derived from farm level studies of rice-fish production in Guimba, Nueva Ecija, Central Luzon. Farm resources represent an average farm in

Table 1. Targets in rice-fish area, fish production, income and protein availability when rice-fish culture is adopted over 5 and 10% of the 1988 irrigated rice lands in the Philippines.

Item	Amount/Level
Total rice land (ha)[a]	3,392,670
Irrigated rice land (ha)[a]	1,956,030
% Irrigated over total rice land	58
Rice-fish area targets (ha)	
5% of irrigated rice lands	97,802
10% of irrigated rice lands	195,603
Fish production targets in rice-fish area ('000 kg)[b]	
5% adoption	
@300 kg/ha/year	29,341
@500 kg/ha/year	48,901
10% adoption	
@300 kg/ha/year	58,681
@500 kg/ha/year	97,802
Fish income targets derived from rice-fish culture ('000 US$)[c]	
5% adoption	
@300 kg/ha/year	34,915
@500 kg/ha/year	58,192
10% adoption	
@300 kg/ha/year	69,830
@500 kg/ha/year	116,384
Protein availability from rice-fish culture ('000 kg)[d]	
5% adoption	
@300 kg/ha/year	5,868
@500 kg/ha/year	9,780
10% adoption	
@300 kg/ha/year	11,736
@500 kg/ha/year	19,560

[a]Source: BAS 1987.
[b]Computed based on fish yields of 300 and 500 kg/ha/year.
[c]Computed at US$1.19/kg of fish. Original values in Philippine Pesos were converted to US$ at the rate of US$1 = P21 as of 1989.
[d]Computed at 20% protein production rate per fish weight.

Table 2. Structure of the linear programming model used for the economic analysis of rice-fish farms.

Maximize gross margin	Crop activity			Period 1: Input			Period 1: Output					
	$Crop_1$	...	$Crop_N$	$Labor_1$	$Input_1$	$Seed_1$	$Sale_1$	$Consumption_1$	$Seed\ production_1$	$Buying_1$	$Credit_1$	$Cash\ transfer_1$
Objective function coefficient	0		0	$-w_1$	$-c_1$	$-s_1$	p_1	0	0	$-p_1$	$-r_1$	0
Period 1												
Labor 1	l_{11}	...	l_{1N}	-1								
Input 1	i_{11}	...	i_{1N}		-1							
Seed 1	s_1	...	s_{1N}			-1			-1			
Production 1	$-q_{11}$	...	$-q_{1N}$				1	1	1			
Consumption 1								1		1		
Cash balance 1				w_1	c_1	s_1				p_1	-1	1
Period 2												
Labor 2	l_{21}	...	l_{2N}									
Input 2	i_{21}	...	i_{2N}									
Seed 2	s_{21}	...	s_{2N}									
Production 2	$-q_{21}$	...	$-q_{2N}$									
Consumption 2												
Cash balance 2							$-p_1$				-1	
Period 3												
Labor 3	l_{31}	...	l_{3N}									
Input 3	i_{31}	...	i_{3N}									
Seed 3	s_{31}	...	s_{3N}									
Production 3	$-q_{31}$	...	$-q_{3N}$									
Consumption 3												
Cash balance 3												
Cash maintenance											$-(1+i_1)$	

(continued)

Table 2 Continued

Maximize gross margin	Period 2								
	Input			Output					
	Labor$_2$	Input$_2$	Seed$_2$	Sale$_2$	Consumption$_2$	Seed production$_2$	Buying$_2$	Credit$_2$	Cash transfer$_2$
Objective function coefficient	$-w_2$	$-c_2$	$-s_2$	p_2	0	0	$-p_2$	$-r_2$	0
Period 1									
Labor 1									
Input 1									
Seed 1									
Production 1									
Consumption 1									
Cash balance 1									
Period 2									
Labor 2	-1								
Input 2		-1							
Seed 2			-1			-1			
Production 2				1	1	1			
Consumption 2					1		1		
Cash balance 2	w_2	c_2	s_2				p2	-1	1
Period 3									
Labor 3									
Input 3									
Seed 3									
Production 3									
Consumption 3									
Cash balance 3									
Cash maintenance				$-p_2$				$-(1+i_2)$	

Table 2 Continued

Maximize gross margin	Period 3										R.H.S.
	Input			Output							
	$Labor_3$	$Input_3$	$Seed_3$	$Sale_3$	$Consumption_3$	Seed $production_3$	$Buying_3$	$Credit_3$	Cash $transfer_3$	Year end balance	
Objective function coefficient	$-w_3$	$-c_3$	$-s_3$	p_3	0	0	$-p_3$	$-r_3$	0		
Period 1											
Labor 1											$\leq L_1$
Input 1											≤ 0
Seed 1											≤ 0
Production 1											≤ 0
Consumption 1											$\geq C_1$
Cash balance 1											$\leq B_1$
Period 2											
Labor 2											$\leq L_2$
Input 2											≤ 0
Seed 2											≤ 0
Production 2											≤ 0
Consumption 2											$\geq C_2$
Cash balance 2											$\leq B_2$
Period 3											
Labor 3	-1										$\leq L_3$
Input 3		-1									≤ 0
Seed 3			-1			-1					≤ 0
Production 3				1	1	1					≤ 0
Consumption 3					1		1				$\geq C_3$
Cash balance 3	w_3	c_3	s_3				p_3	-1	1		$\leq B_3$
Cash maintenance				$-p_3$				$-(1+i_3)$	1	-1	

that area, as do the farm resource constraints and other limitations. Input-output coefficients for different rice-fish production activities were derived from results of on-farm and on-station experiments (dela Cruz and van Dam 1988, 1989). Data on traditional cropping activities were taken from surveys conducted by the Philippine Department of Agriculture (DA 1982) and Central Luzon State University (CLSU 1989). Data on farm subsistence requirements of different food crops were based on surveys done by the Ministry of Agriculture (MA 1980).

The farm is a 2.3-ha irrigated land. Production alternatives in the dry (January-June) and wet (July-December) seasons are rice monoculture, fish monoculture or rice-fish culture either using the trench or pond method, with or without intercrops (mungbean, watermelon and cowpea). Maximum feasible areas for these alternatives are: rice-fish culture, 1.5 ha; mungbean, 0.5 ha; watermelon, 0.1 ha; and cowpea, 0.3 ha. Sources of farm labor are family and hired, with the latter valued at US$2 per man-day. There are three sources of working capital: own (US$286); institutional credit (US$476 at 16% interest rate); and informal credit (unlimited at 20% interest rate). The model was divided into wet season (period 1), interseason (period 2) and dry season (period 3) to accord with existing cropping seasons and to account for cash flow from one period to the other. At period 1, farm funds consist of money owned and borrowed from institutional or informal sources. At periods 2 and 3, funds generated from sales in previous periods are added.

It was assumed that the farm needs a minimum amount of rice (2,000 kg), fish (70 kg), mungbean (100 kg) and cowpea (60 kg) for subsistence. This requirement would be met from farm production or purchase and as such, would compete for farm cash. It was assumed that all watermelons harvested are sold. Poultry, livestock and off-farm activities were not included in the model because their requirements are minimal and do not compete with crop production activities.

Results and Discussion

Several LP models were developed around a base model of rice monoculture with intercrops of mungbean, watermelon and cowpea; and rice-fish models initially with 1.5-ha farm area under rice-fish. Results show that the optimal farm plan for this initial rice-fish model chooses the entire 1.5 ha available for rice-fish (Table 3). The introduction of rice-fish using 1.5 ha increased farm gross margins by 67%, while farm requirements for cash and labor increased by 22 and 17%, respectively. Cropping patterns under rice-fish devote 0.8 ha to rice monoculture, 1.4 ha for rice-fish pond without intercrop, 0.1 ha for rice-fish pond with intercrop in the wet and dry seasons, and 0.9 ha for intercrops (0.5 ha, mungbean; 0.1 ha, watermelon; and 0.3 ha, cowpea). This optimization, however, did not pick up rice-fish trench or fish monoculture which means returns from these activities are less attractive.

Farm Plans for Different Levels of Rice-Fish Adoption

Farm plans for different areas of rice-fish adoption were developed to examine effects on farm gross income, cropping patterns, and resource and production mix. A maximum gross margin of US$3,406/year can be realized when the entire 2.3-ha farm is devoted to rice-fish (Table 3). While the farm becomes more labor-intensive as it goes to full adoption of rice-fish, the proportion of hired labor to total labor increases only slightly from 55 to 57%. The pattern of farm labor monthly requirements is shown in Fig. 1. Points above the available farm family labor curve signify the need for hired labor. Conversely, points below the available farm family labor curve reflect family labor surplus. More working capital is also required as more area is

Table 3. Comparison of farm gross margin, output, cropping pattern and production inputs in an optimal farm plan at different levels of rice-fish adoption by a farm in Guimba, Nueva Ecija, Philippines, 1989.

	Base model	Rice-fish models				
	0 ha	0.5 ha	1 ha	1.5 ha	2 ha	2.3 ha
Farm income (US$)[a]						
Gross margin	1,784	2,200	2,595	2,971	3,207	3,406
Total sales	3,817	4,257	4,781	5,362	5,690	6,058
Total purchase	2,033	2,057	2,185	2,391	2,483	2,652
Output						
Rice (kg)	21,275	21,275	21,275	21,275	21,275	21,275
Fish (kg)	0	200	200	592	752	840
Fingerling ('000 pcs)	0	48	95	141	179	201
Mungbean (kg)	500	500	500	500	500	500
Watermelon (kg)	900	900	900	900	900	900
Cowpea (kg)	2,398	2,398	2,398	2,398	2,398	2,398
Cropping pattern (ha)						
Wet season	2.3	2.3	2.3	2.3	2.3	2.3
Rice monocrop	2.3	1.8	1.3	0.8	0.3	0
Rice-fish pond without intercrop	0	0.5	1.0	1.4	1.4	1.4
Rice-fish pond with intercrop	0	0	0	0.1	0.6	0.9
Interseason	0.9	0.9	0.9	0.9	0.9	0.9
Mungbean	0.5	0.5	0.5	0.5	0.5	0.5
Watermelon	0.1	0.1	0.1	0.1	0.1	0.1
Cowpea	0.3	0.3	0.3	0.3	0.3	0.3
Dry season	2.3	2.3	2.3	2.3	2.3	2.3
Rice monocrop	2.3	1.8	1.3	0.8	0.3	0
Rice-fish pond without intercrop	0	0.5	1.0	1.4	1.4	1.4
Rice-fish pond with intercrop	0	0	0	0.1	0.6	0.9
Production inputs						
Labor (man-days)	360	372	401	421	442	454
Own	162	163	180	188	197	197
Hired	198	210	220	233	245	257
Working capital						
(pesos)	696	736	805	852	950	962
Own	286	286	286	286	286	286
Institutional credit	410	451	476	476	476	476
Informal credit	0	0	43	90	188	200
Fertilizer (t)	3	8	14	18	22	26
Inorganic	2	2	2	2	2	2
Organic	1	6	12	16	20	24
Fuel/Oil (l)	530	696	830	980	1,130	1,220

[a]Original values in Philippine Pesos were converted to US$ at the rate of $1 = P21, as of 1989.

devoted to rice-fish. In all scenarios, farmers must exhaust all working capital. Above 0.5 ha of rice-fish, farm loans go beyond institutional sources to informal sources at a higher interest rate. Two tonnes of inorganic fertilizers were used at all levels of rice-fish adoption. Organic fertilizer use increased from 1 to 24 t with adoption level.

Effects of Lower Productivity

The effects of a 10% drop in rice and 10, 20, 30 and 40% drop in fish yields with concurrent expansion of rice-fish area were also examined. Table 4 shows farm gross margin and output for different levels of rice-fish adoption and alternative production scenarios. The farm

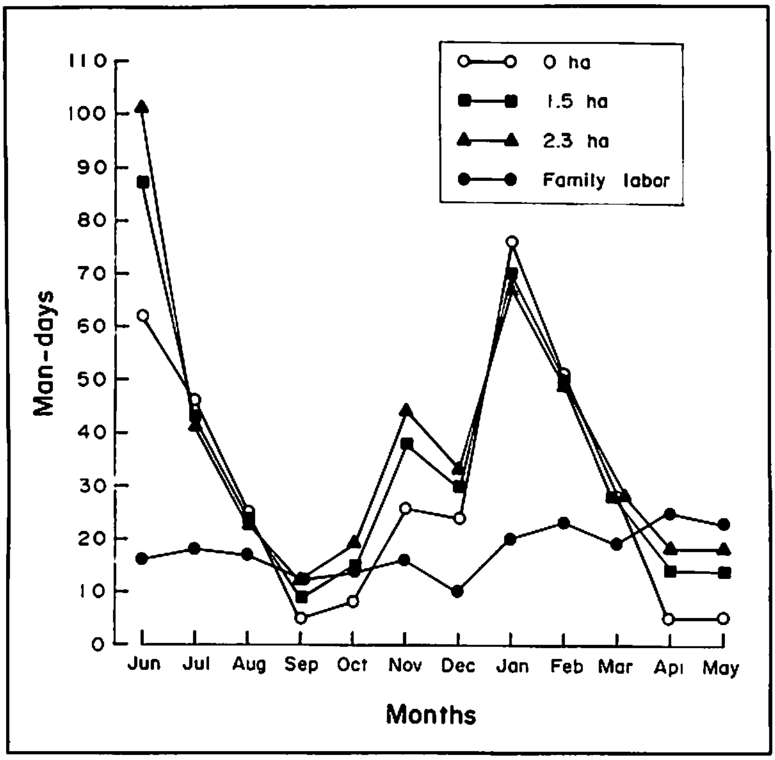


Fig. 1. Monthly labor requirements and available family labor at various sizes of rice-fish enterprise in the farm.

Table 4. Farm gross margin and output for different levels of adoption of fish on rice farms corresponding to alternative production scenarios.[a]

Item	Production scenarios					
	Base model (0 ha)[b]	Scenario 1 (0.5 ha)[b]	Scenario 2 (1 ha)[b]	Scenario 3 (1.5 ha)[b]	Scenario 4 (2 ha)[b]	Scenario 5 (2.3 ha)[b]
Gross margin (US$)[c]	1,784	2,131	2,336	2,400	2,288	2,074
Total sales (US$)[c]	3,817	4,207	4,566	4,790	4,840	4,726
Total purchases (US$)[c]	2,033	2,077	2,230	2,391	2,552	2,652
Output						
rice (kg)	21,275	20,813	20,350	19,888	19,425	19,148
fish (kg)	0	210	360	474	526	509
fingerling (100 pcs)	0	480	860	1,130	1,250	1,210
mungbean (kg)	500	500	500	500	500	500
watermelon (kg)	900	900	900	900	900	900
cowpea (kg)	2,398	2,398	2,398	2,398	2,398	2,398

[a]Scenario 1 = drop in productivity from the base model: rice, 10%.
Scenario 2 = drop in productivities from the rice-fish models: rice, 10%; fish, 10%.
Scenario 3 = drop in productivities from the rice-fish models: rice, 10%; fish, 20%.
Scenario 4 = drop in productivities from the rice-fish models: rice, 10%; fish, 30%.
Scenario 5 = drop in productivities from the rice-fish models: rice, 10%; fish, 40%.
[b]Levels of rice-fish adoption.
[c]Original values in Philippine Pesos were converted to US$ at the rate of $1 = P21, as of 1989.

Table 5. Optimal size of rice-fish enterprise and farm gross margin for various relative prices of rice under alternative production scenarios.[a]

Production scenarios	Base model price (US$0.19/kg)		25% increase (US$0.24/kg)		50% increase (US$0.28/kg)	
	Size of rice-fish (ha)	Gross margin (US$)[b]	Size of rice-fish (ha)	Gross margin (US$)	Size of rice-fish (ha)	Gross margin (US$)
Base model	0	1,784	0	2,420	0	3,055
Scenario 1	2.30	2,226	2.30	3,719	2.30	4,384
Scenario 2	2.30	2,360	2.30	3,475	2.30	4,140
Scenario 3	2.30	2,445	2.30	3,229	2.30	3,894
Scenario 4	2.30	2,320	2.30	2,985	2.30	3,650
Scenario 5	2.30	2,074	1.40	2,754	1.40	3,454

[a]Scenario 1 = drop in productivity from the base model: rice, 10%.
Scenario 2 = drop in productivities from the rice-fish models: rice, 10%; fish, 10%.
Scenario 3 = drop in productivities from the rice-fish models: rice, 10%; fish, 20%.
Scenario 4 = drop in productivities from the rice-fish models: rice, 10%; fish, 30%.
Scenario 5 = drop in productivities from the rice-fish models: rice, 10%; fish, 40%.
[b]Original values in Philippine Pesos were converted to US$ at the rate of $1 = P21, as of 1989.

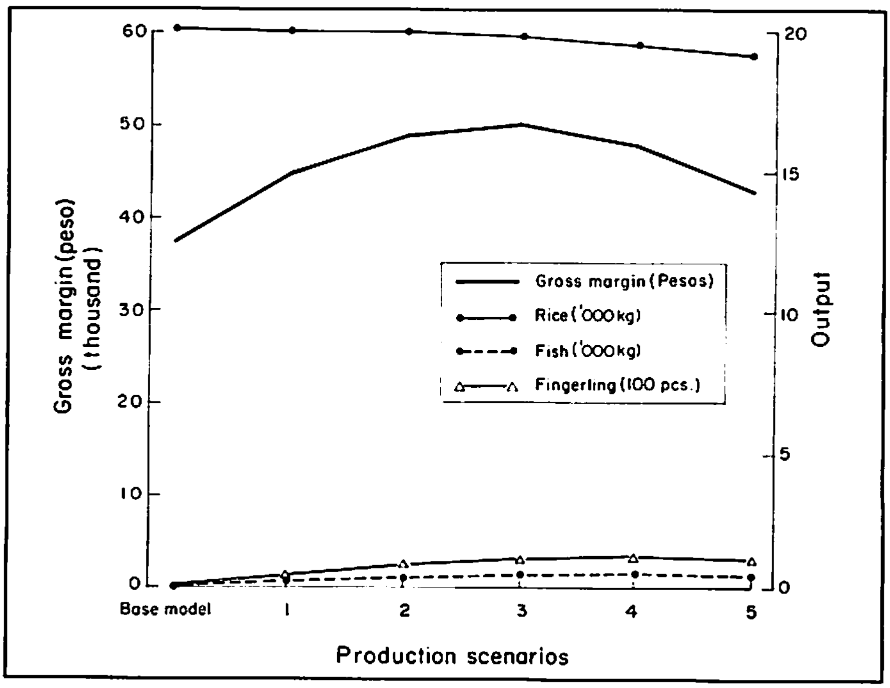


Fig. 2. Farm gross margin and outputs under alternative production scenarios.

realized its highest gross margin (US$2,400) using 1.5 ha to rice-fish with rice and fish yields per hectare lower by 10 and 20%, respectively. Beyond 1.5 ha, optimal gross margin decreased (Fig. 2). Nevertheless, gross margins for all areas are higher compared to rice monoculture. Intercrop production remained at maximum allowable area in all scenarios which implies they are very profitable.

Effects of Relative Price Change

Table 5 shows the effects of 25 and 50% increases in the price of rice on the optimal area for rice-fish at different yields of rice and fish. Optimal rice-fish area is reduced to 1.4 ha when the relative price of rice is increased by 20 and 25%, and rice and fish productivities drop at 10 and 40%, respectively. The remaining 0.9 ha will be devoted to rice monoculture. This implies that rice-fish is more renumerative for a wide range of rice and fish yields even at higher relative prices of rice.

Conclusions

Models indicate considerable economic incentives for rice-fish culture under current conditions of yields, costs, prices and farm resource endowments in the Philippines. Farmers will benefit from rice-fish even if both rice and fish production rates are lower, and the relative price of output rises in favor of rice. However, sustaining this practice in the long run will require good resource management especially in irrigation water. Fingerlings produced in rice-fish systems should be marketed for fish growout systems in ponds, pens and cages. Moreover, the constraints of inadequate water supply, unavailability of fingerlings, and fish losses due to predators and theft are still to be solved for wider-scale adoption of rice-fish culture in Philippine farms.

References

Arce, R.G. and C.R. dela Cruz. 1978. Improved rice-fish culture in the Philippines, p. 136–145. *In* Proceedings of the ICID Second Regional Afro-Asian Conference. International Commission on Irrigation and Drainage Tech. Pap. No. 10.

Arevalo, T.Z. 1987. The rice-fish culture program. Paper presented at the First Fisheries Forum for 1987, Seminar on Developments in Integrated Agri-Aquaculture Farming Systems, 27 March 1987, Bureau of Fisheries and Aquatic Resources, Quezon City, Philippines.

BAS. 1987. Development indicator in Philippine agriculture. Bureau of Agricultural Statistics, Department of Agriculture, Quezon City, Philippines.

Bimbao, M.P., A.V. Cruz and I.R. Smith. 1990. An economic assessment of rice-fish culture in the Philippines, 241-244. *In* R. Hirano and I. Hanyu (eds.) The second Asian Fisheries Forum. Asian Fisheries Society, Manila, Philippines. 991 p.

CLSU. 1989. Technoguide for mungbean, cowpea and watermelon. Technical Brochure. Research and Development Center, Central Luzon State University, Nueva Ecija, Philippines.

dela Cruz, C.R. 1980. Integrated agriculture-aquaculture farming systems in the Philippines with two case studies on simultaneous and rotational rice-fish culture, p. 209–224. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

dela Cruz, C.R. and A.A. van Dam. 1988. Rice-fish farming systems research project. Semi-Annual Report. 1 July-31 December 1988. International Center for Living Aquatic Resources Management, Manila, Philippines.

dela Cruz, C.R. and A.A. van Dam. 1989. Rice-fish farming systems research project. Semi-Annual Report. 1 January-30 June 1989. International Center for Living Aquatic Resources Management, Manila, Philippines.

DA. 1982. Farm site description of Guimba. Regional Integrated Agricultural Research Systems (RIARS), Department of Agriculture, Quezon City, Philippines. (Mimeo)

Heady, E.O. and U.K. Srivastava. 1975. Spatial sector programming models in agriculture. Ames Iowa State University Press, Iowa.

MA. 1980. Food consumption patterns: a summary of nine economic surveys. Special Studies Division and National Grains Authority, Ministry of Agriculture, Quezon City, Philippines.

Overview of Pesticide Use in Rice-Fish Farming in Southeast Asia

ARSENIA G. CAGAUAN
RODOLFO G. ARCE
Freshwater Aquaculture Center
Central Luzon State University
Muñoz, 3120 Nueva Ecija
Philippines

CAGAUAN, A.G. and R.G. ARCE. 1992. Overview of pesticide use in rice-fish farming in Southeast Asia, p. 217-233. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

The constraint posed by pesticides due to its detrimental effects to fish and to the aquatic biota remains an essential research subject in rice-fish farming. This paper is a review of the effects of pesticides in ricefields with reference to fish in rice-fish farming. Methodologies are described while research results on fish toxicity, rate of degradation and residues of selected pesticides, are presented. Fish toxicities of major groups of pesticides ranked from the most to least toxic are insecticides, molluscicides and herbicides. Insecticides such as carbamates and organophosphates were less toxic to fish than organochlorines and synthetic pyrethroids. Acute toxicity data generated from laboratory bioassays can be extrapolated for field use. Suitability of pesticides for rice-fish culture depends mainly on the persistence of chemical, formulation, manner and time of application before releasing fish to the ricefields. Granular form of pesticides applied before fish introduction to ricefields seem to be suitable. Applying pesticides seven to ten days before fish introduction to ricefields was sufficient for degradation of the chemicals and resulted to no fish mortality. Generally, residues of commonly applied insecticides were not detectable in water and fish tissues at seven days after application in ricefields.

Introduction

Pesticide use is one of the major constraints to rice-fish farming. While pesticides offer a panacea to pest problems in rice, they pose danger to fish in rice-fish farming. It has also been recognized that the indiscriminate use of pesticides in rice farming can be an environmental health hazard.

The increase in pest and plant disease outbreaks and in pesticide resistant strains of insects due to the misuse of pesticides is one of the most serious environmental problems associated with the adoption of high-yielding varieties (HYV) of rice (Spiller 1985). Most of the pesticides are used in irrigated rice areas where HYVs have been introduced.

Use of pesticides in the Asian region has increased by an average of 4.6% from 1971 to 1981 (Staring 1984). Imports dramatically increased in Bangladesh, Korea and India (Table 1). The average supply of active ingredients of agropesticides per hectare of arable land in 1971 is shown in Fig. 1. Most of these are used in rice. In the Philippines, the total area planted to rice is 3,600,000 ha, 35% of which is treated with granular insecticide, 25% with liquid herbicide (Magallona 1980).

Increased pesticide use in most Asian countries has been reported to have caused the decline in rice-fish culture. In Indonesia, an estimated two million kg of insecticides applied annually to more than one million ha (Hardjamulia and Koesoemadinata 1972) have caused fish mortalities which resulted to significant financial losses (Saanin 1960). Since 1972, ricefield fish production declined by 67% (Spiller 1985), attributed to increased pesticide use in Malaysia (Lim and Ong 1985). In Vietnam, increased pesticide use from 1958 to 1983 steadily decreased population of frogs, fish and crabs in ricefields since the early 1960s. Vincke (1979) noted that concurrent rice-fish culture was not possible in a Vietnamese commune in 1979 due to heavy DDT applications on rice.

While pesticide use has steadily increased in most Asian countries, there has been a trend toward the development and use of pesticides less toxic to fish and mammals (Fig. 2). For example, a substitute for the highly toxic parathion is

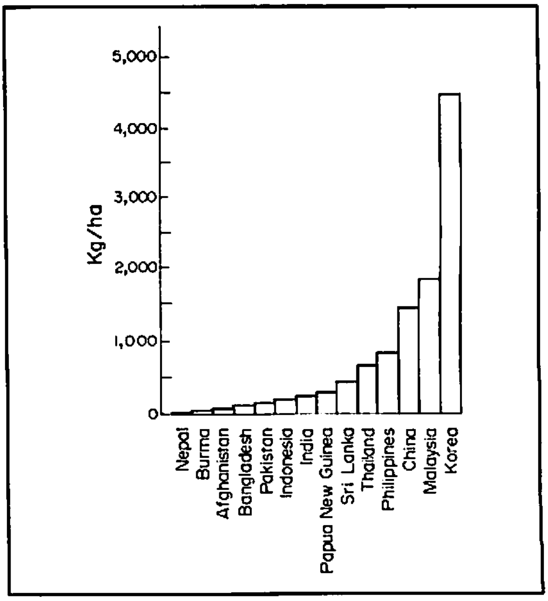


Fig. 1. Average supply of agropesticides (active ingredients) per hectare of arable land, 1973. (Source: JPPA 1982).

Table 1. Pesticide imports (t) in selected Asian countries. (Source: FAO 1983, in Spiller 1985).

Country	1977	1982	Average annual increase (%)
Bangladesh	2,455	9,749	57.8
Burma	1,912	2,500	6.1
India	13,928	45,000	44.6
Indonesia	36,064	45,197	25.3
Japan	44,243	61,688	7.9
Korea	3,861	14,752	56.4
Malaysia	17,883	40,956	25.8
Pakistan	43,902	24,155	- 9.0
Philippines	15,893	15,226	- 0.8
Thailand	32,329	59,724	16.9

fenitrothion, having less than 1% the mammalian toxicity (96-hour LC_{50} = 8 ppm) (FAO 1984, in Spiller 1985). In Vietnam, many farmers have switched from using pyrethroids which are comparatively safe for humans but highly toxic to fish, to methyl parathion because it is cheap and less toxic to fish (Vincke 1979). Methyl parathion, however, is very toxic to humans.

This paper presents an overview of the different pesticides used in ricefields and their effects on fish in rice-fish farming in Southeast Asia. Information gathered on the effects of pesticides include mainly data from the Philippines, Indonesia and Malaysia on fish toxicity, rate of degradation and applications to rice-fish culture. Data from China where pesticide applications have been shown to be compatible with rice-fish culture (Spiller 1985), are also reported.

General Classification and Effects of Pesticides

Pesticides are classified into insecticides and herbicides. There are six main groups of insecticide compounds: carbamate, organophosphate, organochlorine, synthetic pyrethroid, biological and botanical. Herbicides are grouped into phenoxy-aliphatic compounds and substituted amines. Carbamates are less toxic to fish than the organochlorines and organophosphates, although the reverse is true for zooplankton and some insect larvae (Holden 1972). Synthetic pyrethroids offer some distinct advantages due to their high mammalian safety factor and higher biological activity against insects compared to other insecticidal groups. Biological insecticides are those insecticides based on biological organisms such as *Bacillus thuringiensis* (BT) and nuclear polyhedrosis virus (NPV). Biological insecticides appear very promising as components of integrated pest control (IPC) (Magallona 1980). Botanical insecticides come from plants that possess insecticidal properties such as the neem tree (*Azadirachta indica*), lagundi (*Vitex negundo*), sambong (*Blumea balsamifera*) and oregano (*Coleus amboinicus*).

The Fertilizer and Pesticide Authority (FPA) (1986), a regulatory body in the Philippines on the importation and use of fertilizers and pesticides, lists two major groups of insecticides for rice: carbamates and organophosphates. Most organochlorines have been phased out. However, endosulfan is still prescribed for rice but on a restricted basis. Another organochlorine registered under FPA is gamma-BHC in three forms: soluble concentrate, granule and wettable powder. Fifty-one per cent of these insecticides are emulsifiable concentrates (EC), 18.6%

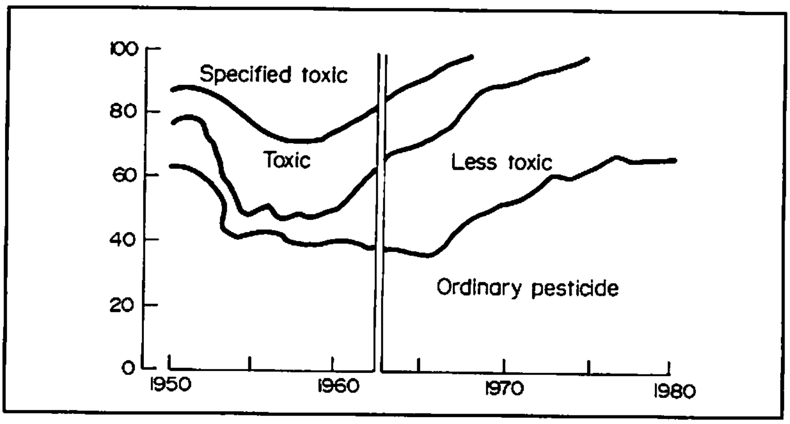


Fig. 2. Annual change of pesticides classified by mammalian toxicity. (Source: JPPA 1982).

granular (G), 16.3% wettable powders (WP) and the rest soluble concentrates (SC) in ultra-low volumes (ULV) and low concentrates (LC).

Carbofuran granule, a carbamate form, is prescribed for rice-fish culture based on the low amount of residues detected from fish fillets, which were less than 0.01 ppm, the recommended carbofuran limit in edible products (Seiber and Argente 1976a, 1976b). In recent years, liquid carbofuran, usually applied during the last insect infestations in rice, has been phased out from the market due to its extreme toxic effects to fish. Farmers find the cost of granular carbofuran expensive, leading to the use of less expensive insecticides such as endosulfan. Proper timing of endosulfan applications did not result in fish mortality in rice-fish fields. Arce et al. (1984) reported that 18 rice-fish farmer-cooperators from Nueva Ecija, Philippines, used insecticides such as carbamate-carbofuran, carbaryl, methomyl and MIPC; organophosphate-methyl parathion and monocrotophos; and synthetic pyrethroid-cypermethrin and permethrin.

In Malaysia, the most frequently used insecticides to control rice stemborers are endosulfan, malathion, BHC and carbaryl (Khoo and Tan 1980). Commonly used organophosphates for rice-fish culture in North Sumatra, Indonesia, are Sumithion EC or Agrothion EC (both fenitrothion), Lebaycid (fenthion) and Diazinon 60 EC (diazinon) (dela Cruz 1986).

Organochlorine compounds for rice are also widely used in Indonesia, Malaysia and China. In Indonesia, large-scale endosulfan applications (450 t in 1969 and 850 t in 1969/70) over an area of 133,000 ha were followed by fish kills in ponds and rivers, resulting in considerable losses to farmers (Koesoemadinata 1980). Garbach et al. (1971) analyzed the insecticide residues from the Brantas River system, fishponds and the Strait of Madura. They found endosulfan residues of 0.00046 ppm in rivers and canals, 0.0008 ppm in fishponds, and less than 0.0003 ppm in the sea water of the Madura Strait. Another organochlorine insecticide, endrin, had a downstream effect for more than a hundred meters from an experimental application site (Harjamulia and Koesoemadinata 1972).

Li (1986) reported that derris, toxaphene and pentachlorophenol (a fungicide) are prohibited in rice-fish culture in China because of their extreme toxicity to fish. Chinese field trials indicated that chlorinated hydrocarbons can be less toxic to fish than what lethal concentration values might indicate if applications are made carefully. However, bioaccumulation of some of the pesticides in the fish may be a problem. A trend to reduce pesticide use in China has resulted in the phasing out from 1981 to 1986 of organochlorine compounds such as BHC (Spiller 1985).

Molluscicides are another group of pesticides used in the Philippines to control an introduced South American herbivorous freshwater snail (*Pomacea* sp.) in ricefields. The snail was introduced in the country in 1980 (Juliano et al. 1989) and 1982 (Mochida 1987) as a cheap source of human food, but became a major aquatic pest in rice farming. Yield loss from snail infestation can be as much as 40% (Escalada 1989). Chemicals to kill the snails usually applied before rice transplanting are probably the most effective (Basilio 1989). These chemicals (tin and aquatin compounds) are reported to have adverse effects to humans like itchiness, bruises/cuts, delayed healing of wounds, and nail discoloration and distortion (Adalla and Morallo-Rejesus 1989; Cheng 1989; Escalada 1989). Organostannous molluscicides were used to control these snails but were banned in 1990.

Toxicity Tests of Pesticides to Fish

Results from studies on toxicities of different insecticides and herbicides to different freshwater fish species and invertebrates are presented in Tables 2 and 3. Singh et al. (1980) and Ca (1983) have data on the toxicity of some pesticides to nonspecific fish species in Indonesia and China, respectively. All findings indicated that insecticides belonging to the organochlorine and synthetic pyrethroid groups, in general, are highly toxic to fish.

Standard methods used to evaluate pesticide toxicity to fish in irrigated rice-fish fields and results obtained in some Southeast Asian countries and China are described below.

Philippines

All pesticide toxicity tests done at the Freshwater Aquaculture Center of the Central Luzon State University (FAC-CLSU) are generally based from Taras et al. (1971) and Greenberg et al. (1980) and modified according to existing conditions. The weights of experimental animals used ranged from 1.2 to 13.5 g for Nile tilapia (*Oreochromis niloticus*), 4 to 14 g for Java tilapia (*O. mossambicus*), 1.8 to 14 g for crucian carp (*Carassius carassius*), 5.0 g for common carp (*Cyprinus carpio*), 10.0 g for freshwater shrimp (*Macrobrachium* sp.) and 0.7 g for freshwater clam (*Corbicula manilensis*). The modified procedure for static bioassay tests are described in dela Cruz and Cagauan (1981).

Toxicity tests of insecticides to *O. niloticus* (Tables 2 and 3) revealed that MTMC + phenthoate, and cypermethrin and permethrin were extremely toxic;

Table 2. Toxicity of different insecticides expressed as 48- and 96-hour LC_{50} to *O. niloticus*, *O. mossambicus* and *C. carassius* tested at the Freshwater Aquaculture Center-Central Luzon State University, Philippines. (Sources: dela Cruz and Cagauan 1981; Ordanza and dela Cruz 1979; Ponce and dela Cruz 1979; Magisa and dela Cruz 1978; Arce et al. 1985a; Arce and Cagauan 1984; Guerrero 1976).

	48-hour LC_{50} (ppm of formulated product)						96-hour LC_{50} (ppm of formulated product)		
Insecticide group/common name	*O. niloticus*	Toxicity rank[a]	*O. mossambicus*	Toxicity rank[a]	*C. carassius*	Toxicity rank[a]	*O. niloticus*	*O. mossambicus*	*C. carassius*
Carbamate									
BMPC	5.6-6.7	ht	-		28.3	mt	6.4-6.12	-	25.2
Carbaryl	3.10	ht	-		-		2.93	-	-
Carbofuran	2.27	ht	2.4	ht	-		1.97	1.72	-
MTMC	68.0	mt	52.0	mt	-		50.0	46.9	-
MTMC + Phenthoate	0.56	et	-		-		0.47	-	-
PMC	6.05[b]		6.0[b]		34.75[b]		-	-	-
PMP	59.0	mt	-		34.8	mt	47.1	-	19.6
Organophosphate									
Azinphos ethyl	0.028[b]		0.023[b]		0.009	et	-	-	0.002
Chlorpyrites	2.0	ht	1.34	ht	-		1.3	1.19	-
Diazinon	45	mt	-		40.7	mt	2.2	-	15.2
Methyl parathion	25.7	mt	-		13.4	mt	19.0	-	11.0
Monocrotophos	1.2	ht	47.60	mt	0.31	et	-	33.10	-
Triazophos	5.6	ht	-		-		-	-	-
Organochlorine									
Endosulfan	5.8	ht	-		1.3	ht	1.3	-	1.6
Synthetic pyrethroid									
Permethrin	0.75	et	1.3	ht	-		0.75	-	-
Cypermethrin	0.63	et	-		-		0.63	-	-

[a]Ranking of pesticides from Koesoemadinata and Djajadiredja (1976) for 48-hour LC_{50}: <1 = extremely toxic (et); 1–10 = highly toxic (ht); 10–100 = moderately toxic (mt); and >100 = low toxic.

[b]24-hour LC_{50}.

Table 3. Toxicity of different herbicides expressed as LC_{50} (ppm of formulated product) tested on different freshwater organisms at the Freshwater Aquaculture Center-Central Luzon State University, Philippines. (Sources: dela Cruz and Cagauan 1981; Santiago and Recometa 1981).

Brand name	Common name	LC_{50} (ppm of formulated product) *O. niloticus* 48-hour[a]	*O. niloticus* 96-hour	*C. carassius* 48-hour[a]	*C. carassius* 96-hour	*C. carpio*	*Macrobrachium* sp.	*C. manilensis*
Agroxone	MCPA	-	-	-	-	520	1,840	4,600
2, 4-D Amine	2, 4-D Amine	-	-	-	-	800	920	5,300
Rilof H		27.5 mt	-	-	-	-	-	-
Machete	Butachlor	1.4 ht	1.3	-	-	-	-	-
Modown	Bifenox	149.0 lt	127.0	128.0 lt	102.0	-	-	-
Treflan	Triflularin	71.5 mt	54.4	53.5 mt	49.5	-	-	-
Eptam D	EPTC	308.0 lt	225.0	190.0 lt	170.0	-	-	-

[a]Ranking of pesticides from Koesoemadinata and Djajadiredja (1976) for 48-hour LC_{50}: <1 = extremely toxic (et); 1–10 = highly toxic (ht); 10–100 = moderately toxic (mt); and >100 = low toxic.

BPMC, carbaryl, monocrotophos, triazophos and endosulfan were highly toxic; and MTMC, diazinon and methyl parathion were moderately toxic. Insecticides MTMC and monocrotophos were moderately toxic to Java tilapia; BPMC, PMP, diazinon and methyl parathion to crucian carp.

C. carpio, *Macrobrachium* sp. and *C. manilensis* showed high tolerance limits to herbicides such as MCPA and 2,4-D Amine. Based from the 48-hour LC_{50}, butachlor was highly toxic to *O. niloticus*. Rilof H and Treflan R were moderately toxic; while Modown and Eptam D were less toxic to *C. carassius* (Table 4).

In all toxicity tests on insecticides and herbicides, temperature values varied by 1–3°C (Taras et al. 1971; APHA/AWWA/WPCF 1974; Greenberg et al. 1980). Generally, changes in pH did not exceed one unit in all tests. Dissolved oxygen (DO) in the test solutions declined towards the end of the test period to as low as 0.1 ppm, except in the control which remained high. Aeration was not introduced in the course of the test to avoid probable reduction of the toxicity of the solutions. Marked reduction in DO is always observed in static bioassay tests where continuous aeration is not employed.

Safe concentrations of chemicals may be derived from the LC_{50}. To determine a safe concentration of insecticide, the user should compare it with estimated values of 1/10 of the 48-hour LC_{50} for a given fish species (dela Cruz and Cagauan 1981). For example, to protect *O. niloticus* in a rice-fish culture system, the concentration to be applied should not exceed 1/

10 of its 48-hour LC_{50}. The safe level of pesticide can be derived by multiplying the 96-hour LC_{50} values by an application factor which varies depending on the compound (Sprague 1970, 1971). FAO (1969) suggests an application factor of 0.1 to 0.01 for less persistent pesticides such as organophosphates and carbamates.

Results on the acute toxicity concentrations (LC_{50}) of two organostannous molluscicides to *O. mossambicus* at 24- and 96-hour and their confidence intervals were: 24-hour LC_{50} = 4.01 ppm (3.83–4.19) and 96-hour LC_{50} = 2.58 ppm (1.95–3.67) for Aquatin; and 24-hour LC_{50} = 0.345 ppm (0.229–0.523) and 96-hour LC_{50} = 0.092 ppm (0.064–0.135) for Brestan (Cruz et al. 1988). The increased exposure of the fish to lethal concentrations of both molluscicides caused a reduction in hemoglobin and histological damages to gills, intestines, liver and kidney.

Indonesia

Pesticide toxicity testing has been carried out in Indonesia by the Inland Fisheries Research Institute since 1973 following a standardized testing procedure employing 48- or 96-hour LC_{50} determined under specified conditions following APHA/AWWA/WPCF (1974); Duodoroff et al. (1971); Koesoemadinata and Djajadiredja (1976) and Koesoemadinata (1980). Flow and static tests are used but the latter are more widely employed (Koesoemadinata 1980).

Koesoemadinata (1980) showed that carbamates (methomyl and carbaryl) were less toxic than organophosphate (dichlorvos and fenitrothion) and organochlorines (endrin and endosulfan).

Malaysia

Toxicity and persistence of various pesticides used in ricefields are summarized by Singh et al. (1980). Organochlorine compounds tested such as endosulfan 8-BHC, endrin and DDT were extremely toxic to fish, followed by malathion. Carbaryl was the least toxic to fish with a 48-hour LC_{50} equal to 2,000–2,500 ppb.

Toxicity tests of some insecticides to catfish (*Clarias batrachus*) revealed that endrin, endosulfan and gamma-BHC were extremely toxic, with a 96-hour LC_{50} values of 6.3 x 10^{-4} ppm, 2.8 x 10^{-3} ppm and 0.13 ppm, respectively; followed by fenthion (an organophosphate) with a 96-hour LC_{50} of 1.8 ppm and carbaryl with a 96-hour LC_{50} of 20 ppm (Khoo and Tan 1980).

China

Among the most toxic insecticides to fish in ricefields was toxaphene, an organochlorine (48-hour LC_{50} = 0.005 ppm), followed by two botanicals, pyrethrum dust (48-hour LC_{50} = 0.075 ppm) and derris dust (48-hour LC_{50} = 0.1 ppm). A fungicide (penta-chlorophenol) was also considered highly toxic with 48-hour LC_{50} of 0.1-0.5 ppm (Ca 1983). Another botanical (nicotine sprays) had a 48-hour LC_{50} of 2.0 ppm (Table 4).

Persistence and Degradation

Application of pesticides in rice-fish culture is done several days before stocking fish. The number of days which the chemical would persist in water is valuable information to prevent fish mortality during stocking in ricefields.

It was observed in Indonesia that granular organophosphates were lethal to fish in ricefields four days after application, and that application of two granular organochlorines (endrin and endosulfan) caused fish kills in ricefields within 11 and 18 days, respectively (Koesoemadinata 1980). Further experiments demonstrated that the emulsifiable concentrates of these organochlorines killed fish within 5–50 days (Hardjamulia and Koesoemadinata 1972).

Table 4. The LC_{50} of several chemicals to fish in ricefields. (Source: Modified from Ca 1983).

Group	Pesticide	LC_{50} in 48 hours (ppm)	Normal concentration[a] (ppm)	Damage[b] 100% soluble in water	30%
Organophosphate	parathion sprays	2.8	0.2-1.6	±	+
Organophosphate	parathion sprays	5.1	2.3	+	+
Pyrethroid	pyrethrum dusts	0.075	0.13-0.20	-	±
Botanical	derris sprays	0.016	0.03	-	±
Botanical	derris dusts	0.1	-	+	+
Botanical	nicotine sprays	2.0	1.5-3.8	+	±
Organochlorine	toxaphene	0.005	5-8	-	-
Organophosphate	trichlorfon	740.0	70.0	+	+
Organochlorine	DDV sprays	3.4	6.0	-	+
Organophosphate	fenitrothion sprays	3.0	2.3	+	+
Organophosphate	cyanophos	secure	0.3-1.0	+	+
Organophosphate	demeton methyl sprays	12.0	1.6-6.8	+	+
Organophosphate	malathion sprays	3.8	3-4	-	+
Inorganic copper	Bordeaux mixture	40.0	15.0	-	-
Fungicides	nitrofen sprays	27.0	4-6	+	+
	dusts	21.0	4-6	+	+
Phenols (fungicides)	pentachlorophenol	0.1-0.5	10-20	-	-
Herbicides	2, 4D	5.0	5-10	-	±
Chlorophenoxyl and chlorobenzoic acids	prometryne	10.0	0.05-0.5	+	+

[a]The concentration is measured according to the effective constituents; the normal concentration is at depth of 5 cm when all the chemicals are added to the water.
[b]Harm is noted for *C. carpio* and *C. carassius*; + means not dead; - dead; ± possibly dead.

Results of tank degradation tests in the Philippines are summarized in Table 5. Degradation period was determined when test fish attained 100% survival. Insecticides that degraded after more than 20 days under sunlight-exposed conditions were carbaryl, malathion, permethrin and fenvalerate. Under shaded conditions, these insecticides were more persistent, degrading at 21–75 days.

Degradation after 10 days of exposed conditions was observed for IPMC, methomyl, chlorpyrites and methyl parathion. In shaded conditions, the degradation period was 17–41 days for these insecticides.

Endosulfan (an organochlorine) and coumatetralyl (a rodenticide) were observed to be the most persistent among the pesticides tested. Endosulfan (0.21 ppm a.i.) was persistent for six days when 50% of *O. niloticus* survived. Coumatetralyl (0.07 ml/80 l) lost its efficacy in nine days in exposed conditions and 14 days in shaded conditions. At higher concentration of the same rodenticide, persistence was observed beyond 50 days in shaded and exposed conditions.

From the insecticides tested, three carbamates (carbofuran, at 0.59 ppm f.p. IPMC, and MTMC + phenthoate) and two organophosphates (diazinon and monocrotophos) degraded in less than 10 days. As these insecticides have already degraded by the time fish are stocked (about 10–14 days), they can be recommended.

Field degradation tests in unplanted fields in Table 6 showed that azinphos ethyl and triazophos (both organophosphates) were degraded in 12 days, followed by a synthetic pyrethroid-permethrin which was degraded in six days. Degradation periods of three to four days were observed in one carbamate (MTMC + phenthoate), two organophosphates (monocrotophos and methyl parathion), and one synthetic pyrethroid (cypermethrin).

Table 5. Degradation and persistence of different pesticides using tilapia (*Oreochromis niloticus* and *O. mossambicus*) as test fish in tanks at the Freshwater Aquaculture Center-Central Luzon State University, Philippines. (Sources: Reyes and dela Cruz 1982-83; dela Cruz and Lopez 1982; Arce et al. 1985c).

Insecticide group/ common name	Concentration[a]	Test species length (cm) or weight (g) in parentheses	Degradation time (days)	Average survival at n^{th} day after application of pesticides (%/day)
I. Insecticides				
Carbamates				
Carbaryl	10.88 ppm f.p.	*O. niloticus* (6.5 - 10 cm)	26 38–39 (shaded)	-
Carbofuran	0.56 ppm f.p.	*O. niloticus* (2.2 - 8.5 g)	5	-
		O. mossambicus (2.6 - 9 g)	4	-
IPMC	0.59 ppm f.p.	*O. niloticus* (2.2-8.5 g)	6	-
		O. mossambicus (2.6 - 9 g)	8	-
	1.279 ppm f.p.	*O. niloticus* (6.5 - 10 cm)	16–20 20–22 (shaded)	-
Methomyl	66.16 ml/19 l	*O. niloticus* (4.5 - 11 cm)	13–15	-
MTMC + Phenthoate	1.02 ppm a.i.	*O. niloticus* (1.7 g)	4	-
Organophosphates				
Azinphos ethyl	0.11 ppm a.i.	*O. niloticus* (1.7 g)	-	50/5 and 83.3/6
Chlorpyrites	1.32 ppm f.p.	*O. niloticus* (2.2 - 8.5 g)	17	-
		O. mossambicus (2.6 - 9 g)	19	-
Diazinon	0.13 ppm a.i.	*O. niloticus* (1.7 g)	1	-
Malathion	44.10 ml/19 l	*O. niloticus* (4.5 - 11 cm)	15–22 31-33 (shaded)	-
Methyl parathion	30 ml/19 l	*O. niloticus* (4.5 - 11 cm)	16–19 27–41 (shaded)	-
	44.10/19 l	*O. niloticus* (6 cm)	10–17 (shaded) 17–24 (shaded)	-
Monocrotophos	2.27 ppm f.p.	*O. niloticus* (2.2 - 8.5 g) *O. mossambicus* (2.6 - 9 g)	1	-
Organochlorine				
Endosulfan	0.212 ppm a.i.	*O. niloticus*	-	50/6
Synthetic pyrethroids				
Permethrin	0.140 ppm f.p.	*O. niloticus* (6.5 - 10 cm)	19–28 75 (shaded)	-
Fenvalerate	14.7 ml/19 l	*O. niloticus* (6 cm)	19–24 21-35 (shaded)	-
II. Rodenticide				
Coumatetralyl	0.08 ml/80 l	*O. niloticus* (6 cm)	9 14 (shaded)	-
	29.4 ml/19 l	*O. niloticus* (6 cm)	> 50 > 50 (shaded)	-

[a]f.p. - formulated product; a.i. = active ingredient.

Table 6. Degradation period of some insecticides in unplanted ricefields (Sources: Arce et al. 1986, 1987).

Group	Insecticide	% a.i.	Application rates (kg a.i./ha)	Degradation period (days)
Organophosphate	Azinphos ethyl	40	1.0	12
Organophosphate	Triazophos	40	0.6	12
Organophosphate	methyl parathion	50	1.25	4
Carbamate	MTMC + phenthoate	6	1.02	3
Organophosphate	Monocrotophos	28.5	0.7125	3
Synthetic pyrethroid	Cypermethrin	5	0.05	3
Synthetic pyrethroid	Permethrin	10	0.10	6

Carbofuran insecticide stays much longer in water (10–11 days) under low temperature conditions. Under these conditions, one should allow 10 days after insecticide treatment before stocking fish. When rice plants are fully grown and water is deeper, water temperatures decrease. In cases where toxicity of insecticide is doubtful, an on-the-spot check can be done. Prior to stocking fish, a pail of water should be scooped from the area and treated with carbofuran, then a number of fish put in the pail and observed for several hours if they will survive (dela Cruz 1980).

Field Trials on the Use of Insecticides in Rice-Fish Culture

Trials at the FAC-CLSU, Philippines, utilized 50-, 100- and 200-m^2 rice plots. Recommended practices for lowland irrigated trench-type rice-fish culture were employed. In some experiments, water was drained from plots to the trench area during application of insecticides. The plots were filled with water the next day up to the desired level. In other experiments, increasing the depth instead of draining the water was done during the application of insecticides.

Varying sizes of *O. niloticus* fingerlings were used and stocked at 5,000/ha. Fish stocking was done at least 7–10 days after the first application of insecticides in most experiments. In other experiments, fish stocking was done prior to the first application of insecticides.

Granular insecticides were usually broadcast or applied basally at rice transplanting. Sprayable insecticides were applied according to the manufacturers' prescribed intervals of application. Most test concentrations used were based on the recommended rates.

Fish mortalities at 24, 48, 72 and 96 hours after each application of insecticides were monitored. Growth rate, yield and recovery of fish at harvest were evaluated. Selected water quality parameters (temperature, pH and DO) were analyzed immediately after insecticide application.

Most tests at FAC-CLSU demonstrated that the first application of insecticides at least 6–10 days prior to fish introduction in the ricefields did not cause any fish mortality (Table 7). This could be attributed to degradation of insecticide toxicity prior to fish stocking. Subsequent applications of insecticides in some tests resulted to fish mortality. This may be attributed to insecticidal drift in the water and trench not deep enough for fish to take refuge during the application of insecticide. In rice-fish culture with trenches 0.75 m deep and 1 m wide, the trench depth becomes shallow towards the end of rice growth due to erosion. The subsequent insecticide applications: 3%

granular carbofuran (1 kg a.i./ha), carbaryl (2.125 kg a.i./ha), monocrotophos (0.4275 kg a.i./ha), chlorpyrite (0.63 kg a.i./ha), triazophos (0.60 kg a.i./ha) and 10% cypermethrin (0.125 kg a.i./ha). Arce and Circa (1982) also demonstrated that application of 0.75 and 1.0 kg a.i./ha of BPMC at late tillering stage after fish stocking resulted to mortality.

The insecticides used where there was 100% fish survival in subsequent applications were: MTMC + phenthoate (0.255 kg a.i./ha) (Arce et al. 1985b); 5% cypermethrin (0.05 and 0.10 kg a.i./ha) and lambdacyhalothrin (0.00625, 0.0125 and 0.025 kg a.i./ha) (Cagauan and Valle 1986).

Fish stocking before the first insecticide application was shown possible without causing mortality in tests using synthetic pyrethroids (dela Cruz and Circa 1981; Cagauan and Valle 1986; Arce et al. 1987; Sevilleja et al. 1989). These synthetic pyrethroids were: permethrin (0.05 and 0.10 kg a.i./ha), 5% cypermethrin (0.0125, 0.025 and 0.05 kg a.i./ha), 10% cypermethrin (0.025 and 0.05 kg a.i./ha), lambdacyhalothrin (0.00625 and 0.0125 kg a.i./ha), cyfluthrin K + L (0.00625 and 0.0125 kg a.i./ha) and cyfluthrin (0.0125 and 0.025 kg a.i./ha). However, higher rates of permethrin (0.125 to 0.50 kg a.i./ha) and 10% cypermethrin (0.25 kg a.i./ha) produced fish mortality.

The use of pyrethroid for rice is a recent trend in the Philippines. Current interest in this chemical is due to its low mammalian toxicity and high effectivity to insects at low concentrations. Residue problems are expected to be minimal. Its cost per hectare is competitive with other insecticides (Magallona 1980). Pyrethroid concentrations in natural aquatic environments show a rapid decline with time, initially due to absorption to bottom sediments, suspended particles, plant materials, etc., and in the slightly longer term from degradative process. In the aquatic environment, the toxicity of the parent compound rather than the degradation products is of concern (Leakey 1985). The wide spectrum of biological activity of pyrethroids to target pests indicates that these insecticides are likely to be highly toxic to a range of aquatic invertebrates and fish.

In China, field trials employed different methods of pesticide applications such as mixed with soil, broadcast, sprayed and as fumigant. Fish mortalities occurred in all pesticide treatments including control (Table 8).

Li (1986) reported that before or during application of insecticides, the: l) field may be drained and fish driven to the trenches and sumps; 2) volume of water increased; or 3) water continuously changed. Chemicals in powder form should be applied in the early morning during the dew period, while sprays should be applied after the dew has dried.

Chronic toxicity is a long-term effect possibly related to changes in the growth rate of *O. niloticus* grown in rice-fish culture applied with insecticides. Reduced growth rate is one indication of the chronic toxicity of the insecticide.

Several experiments done at the FAC-CLSU indicated that the mean daily weight gain of *O. niloticus* grown in ricefields without supplemental feeding ranged from 0.33 (Cagauan and Valle 1986) to 0.37 g/day (dela Cruz 1980). The mean daily growth of *O. niloticus* from all experiments using pyrethroids, organophosphate (triazophos), carbamate (carbofuran) and control (no insecticide) treatments were all within this range (Arce et al. 1987; Cagauan and Valle 1986).

Insecticide Residues

Residual effects are major considerations in choosing a pesticide for rice-fish culture. Pesticide residues in the aquatic environment could be biomagnified in the foodchain. Thus, an investigation of the amount of residues present in the water and fish tissues is valuable to assess the ecological effects of insecticides in use.

Table 7. Effects of several insecticides on fish in rice-fish culture trials at the Freshwater Aquaculture Center-Central Luzon State University, Philippines.

Group	Insecticide: Trade name	Insecticide: Common name	Formulation[a]	% a.i.	Application rate (kg a.i./ha): FPA (1986) requirement Min.	Max.	Experiment	Type and period of application[b]	Fish stocking[c]	Observed effects on fish	Source
Carbamate	Furadan	Carbofuran	G	3	0.5	1.0	1	Broadcasted 3 DAT	6 DAIA$_1$	No fish mortality observed	Arce and Fermin (1977)
							1	Broadcasted, 3, 23, 43 and 63 DAT	6 DAIA$_1$	All fish died during the second application of insecticides	
			EC	20.3	-	-	1	Rootzone injection	6 DAIA$_1$	No fish mortality observed	
							2	Rootzone injection	6 DAIA$_1$	No fish mortality observed	
	Sevin	Carbaryl	WP	85	1.0	1.5	2.125	Sprayed twice	7-10 DAIA$_1$	Fish recovery and yield between the control treatment and the 5 insecticide treatments demonstrated the toxic effects of insecticides to fish when applied by spraying	Arce et al. (1978)
	Hyto	MIPC	WP	50	0.25	0.5	1.0	Sprayed twice	7-10 DAIA$_1$		
	Baycarb	BPMC	EC	50	0.5	0.75	0.75	Sprayed once during late tillering stage of rice	(N.A.)[e]	0.67% of fish stock died 2 days after spraying	Arce and Circa (1982)
	Shellcarb	BPMC	EC	50	0.5	0.75	1.0	Sprayed once during late tillering stage of rice	(N.A.)	1.33% of fish stock died 3 days after spraying	Arce and Circa (1982)
	Carbophen	MTMC + phenthoate	G	6	1.02	2.04	1.02	Broadcasted 12 DAT and during the middle of rice culture period	7 DAIA$_1$	2% of fish stock died 24 hours after first application of insecticide, 4.67% of fish stock died 24 hours after second application	Arce et al. (1985b)
							0.51	- do -	7 DAIA$_1$	0.67% died 24 hours after application	
							0.255	- do -	7 DAIA$_1$	No mortality observed	
Organo-phosphate	Azodrin 202 R	Monocrotophos	EC	28.5	0.25	0.5	0.4275	Sprayed twice	(N.A.)	Fish recovery and yield between the control treatment and the five insecticide treatments demonstrated the toxic effect of insecticide to fish when applied by spraying	Arce et al. (1978)
	Brodan	Chlorpyrite	EC	31.5	0.246	0.346	0.630	Sprayed twice	(N.A.)		
	Bionex	Azinphosethyl	EC	40.0	0.400	0.600	0.400	Sprayed once during late tillering stage of rice	(N.A.)	79.67 % of fish stock died after spraying	Arce and Circa (1982)
	Parapest M50	Methyl parathion	EC	50.0	0.5	0.75	0.5	Sprayed once during late tillering stage of rice	(N.A.)	2.33% of fish stock died after spraying	Arce and Circa (1982)
	Hostathion	Triazophos	EC	40.0	0.25	0.4	0.6	Sprayed 15 and 29 DAT	7 DAIA$_1$	Average fish mortality from 3 trials was 53.39% occurring 24-72 hours after application	Arce et al. (1986b, 1987)
Synthetic pyrethroids	Kafil	Permethrin	EC	10	-	-	0.05	Sprayed 7, 22 and 42 DAFS	7 DBIA	No fish mortality observed	dela Cruz and Circa (1981)
							0.10	Sprayed at 7 and 35 DAT	7 DAIA	No fish mortality	Arce et al. (1987)
							0.125	Sprayed 7, 22 and 42 DAFS	7 DBIA	Fish mortality observed during the 3 periods of application but only in one replicate	dela Cruz and Circa (1981)
							0.25	- do -	7 DBIA	Fish mortality observed during the first and second application	dela Cruz and Circa (1981)
							0.50	- do -	7 DBIA	Fish mortality observed during the first and second application	dela Cruz and Circa (1981)
	Cymbush	Cypermethrin	EC[d]	10	-	-	0.025	Sprayed 7, 22 and 42 DAFS	7 DBIA	No fish mortality	dela Cruz and Circa (1981)
							0.05	- do -	7 DBIA	No fish mortality	dela Cruz and Circa (1981)
							0.05	Sprayed at 7 and 35 DAT	7 DAIA	No fish mortality	Arce et al. (1987)
							0.125	Sprayed 7, 22 and 42 DAFS	7 DBIA	Fish mortality during the second and third application but only in one replicate	dela Cruz and Circa (1981)
							0.25	- do -	7 DBIA	Fish mortality observed during first application	dela Cruz and Circa (1981)

[a]G = granular; EC = emulsifiable powder; WP = wettable powder.
[b]DAT = days after transplanting; DAFS = Days after fish stocking.
[c]DAIA$_1$ = days after insecticide application; 1 refers to first application; DBIA = Days before insecticide application
[d]FPA (1986) lists cypermethrin, EC, 5% a.i. with allowable limit of 0.025 - 0.075 kg a.i./ha
[e]N.A. = not available information

Table 8. Insecticide applications in rice-fish culture trials in Jiangsu Province, China. (Source: Liao 1980).

Pesticide	Method[a]	Pesticide soil or water (kg)	Rate (kg/ha)	Fish mortality (1 day) (%)	Fish mortality (90 days) (%)
Organophosphate + Organochlorine					
1.5% Parathion + 3% BHC dust	SM	0.5:15 soil	11.25	-	13
	B	1:400 water	15.0	-	14
Organochlorine					
90% Chlordineform	SM	1:15 soil	1.50	-	9
	B	1.5:400 water	2.25		16
Carbamate - 40% Dimethoate	SM	1:15 soil	1.50	-	11
	B	1.5:400 water	2.25	-	15
Carbamate - 50% Carbaryl	B	-	2.25	-	16
Organochlorine					
90% Trichlorfon	B	0.5:750 water	0.09	-	19
Carbamate - 25% Carbendazol	S	0.5:250 water	2.25	-	9
Organochlorine					
10% BHC (emulsified)	S	0.5:200 water	2.25	-	12
Fumigant	F	-	11.25	-	16
Organochlorine - 25% DDT emulsion	S	0.5:125 water	3.75	100	-
Organochlorine					
1.5% Sulfotep + 3% BHC dust	SH	0.5:15 water	11.25	100	-
Sulfotep emulsion	S	0.5:1,000 water	0.53	100	-
Control	-	-	-	-	15

[a]SM = mixed with soil; B = broadcast; S = spray; F = fumigant.

Generally, residues of some insecticides in water and fish tissues in planted and unplanted fields were not detectable seven days after application (Table 9). These insecticides were carbamate-MTMC + phenthoate; organophosphates azinphos ethyl; monocrotophos; triazophos and methyl parathion; synthetic pyrethroids-permethrin; cypermethrin; cyfluthrin and cyfluthrin K+L. Most insecticides showed residues in water and fish tissues commonly occurring within 24 to 96 hours of application and become nondetectable after that period.

Trace amounts of triazophos (0.60 kg a.i./ha) residues were detected in *O. niloticus* tissues seven days after the insecticide application in unplanted fields. However, in planted fields, no detectable concentration of triazophos was observed in fish tissues from 24 to 96 hours after application (Arce et al. 1987). Thus, degradation of insecticides is faster in planted fields than in unplanted fields. In ricefield condition, the absorption of pesticide particles by the soil, plants and suspended particulate organic matter in water can help reduce pesticide toxicity.

Celino et al. (1987) suggest that carbofuran is hydrolyzed to its phenol which is immediately bound to soil constituents. Most of the carbofuran absorbed by rice is accumulated in the leaves, and maximum residues found in the rice grain were 0.085 ppm lower than the US Environmental Protection Agency tolerance level. Fish were safe for human consumption as there were no significant residues at harvest time. Seiber and Argente (1976a, 1976b) found the same result for *O. mossambicus*.

Table 9. Residue levels of some insecticides in water and fish tissues in unplanted and planted rice-fish fields.

Insecticide	Application rate (kg a.i. per ha)	No. of trials	No. of reps/No. of fish per plot	Fish species (Weight range, grams)	Water/ Fish tissues	Residue levels (ppm) at a period of application								Source
Unplanted fields						24 hour	48 hour	96 hour	120 hour	6 days	7 days	8 days	9 days	
Permethrin	0.10	1	2/50	*O. niloticus* (5.20-6.04 g)	Fish tissue	T	T	N.D.	N.D.					Arce et al. (1987)
MTMC + Phenthoate	1.02	1	2/50	*O. niloticus* (6.2-7.5 g)	-do-	T	N.D.							-do-
Triazophos	0.60	1	2/50	*O. niloticus* (6.7-7.9 g)	-do-	4.253-4.367	0.584-0.861	0.0149-0.041	0.022-0.029	T	T	N.D.	N.D.	-do-
Planted fields						Just after application at 14 DAT	7 days after 14 DAT							
Azinphos ethyl	1.0	1	4/100	*O. niloticus* (5-10 g)	Water	0.1322-0.2713	N.D.							Arce et al. (1987)
					Fish tissues	0.0910-0.2112	N.D.							
Methyl parathion	1.25	1	4/100	-do-	Water	0.0578-0.0644	N.D.							-do-
					Fish tissues	0.0479-0.0621	N.D.							
Monocrotophos	0.7125	1	4/100	-do-	Water	0.0110-0.0228 (20 DAT)	N.D.							-do-
					Fish tissues	0.010-0.0143 (20 DAT)	N.D.							
						48-hour after 35 DAT	96-hour after 35 DAT	7 days after 35 DAT						
Triazophos	0.60	2	3/100	*O. niloticus* (6.3-11.9 g)	Water	N.D.	N.D.	-						-do-
			-do-	-do-	Fish tissue	-	N.D.	-						
Permethrin	0.10	2	3/100	*O. niloticus* (6.3-11.9 g)	Fish tissue	N.D.	N.D.	-						-do-
						-	N.D.	-						
Cypermethrin	0.025	1	3/100 at 7:3 ratio	*O. niloticus* (15-20 g) and *C. carpio* (3-6 g)	Water	0.025 (+/-0.0132)	0.0051 (+/-0.0018)	N.D.						Sevilleja et al. (1989)
	0.05	2	3/100	*O. niloticus* (6.3-11.9 g)	Water	N.D.	N.D.	-						Arce et al. (1987)
					Fish tissue	-	N.D.	-						
Cyfluthrin K + L	0.0625	1	3/100 at 7:3 ratio	*O. niloticus* (15-20 g) and *C. carpio* (3-6 g)	Water	0.0264 (+/-0.0074)	0.0064 (+/-0.0038)	N.D.						Sevilleja et al. (1989)
Cyfluthrin K + L	0.0125	1	-do-	-do-	Water	0.0281 (+/-0.0040)	0.0058 (+/-0.0052)	N.D.						-do-
Cyfluthrin	0.0125	1	-do-	-do-	Water	0.0220 (+/-0.0073)	0.0038 (+/0.0028)	N.D.						-do-
Cyfluthrin	0.025	1	-do-	-do-	Water	0.0121 (+/-0.0116)	0.005 (+/-0.0036)	N.D.						-do-

Notes:

Control treatment (0 ppm insecticide) showed no residues.
T = Trace quantity.
N.D. = Not detectable.
Water temperature in unplanted fields = 24-38°C; water pH = 6.9-8.5.
Water temperature in planted fields = 26-30°C; water pH = 6.9-8.7.

Conclusions

Generally, toxicities of major groups of pesticides to fish, ranked from the most toxic to least toxic, are insecticides, molluscicides and herbicides. Little information exist on the fish toxicity of other groups of pesticides such as fungicides, acaricides, etc. Insecticides such as carbamates and organophosphates were less toxic to fish than organochlorines and synthetic pyrethroids.

Toxic levels of pesticides obtained from laboratory assessments have been proven not toxic to fish in field conditions. Acute toxicity data can be extrapolated for field use. Suitability of pesticides for rice-fish culture depends mainly on the persistence of the chemical, formulation and manner of application, and time of application before releasing fish to the ricefield. Organochlorines are not desirable for rice-fish culture because of their persistence in the aquatic environment. Pesticides that degrade in less than five to seven days are desirable for rice-fish culture. There is a lack of information on the residue levels of pesticides except for carbofuran that are safe for human consumption; hence, residue levels of pesticides reported in this paper can not be evaluated along the term safe for humans. There seems a lack of information on the toxicity and residues of degradation products of parent compounds especially for persistent pesticides. Chronic toxicity of pesticides is also a valuable information that should be addressed in future studies.

Acknowledgements

The authors thank Dr. C.R. dela Cruz for providing significant information on pesticide use in selected Asian countries; D.M. Gamboa, chemist and co-worker; and N. Andres for typing the manuscript. Lastly, we dedicate this paper to the late Dr. C.M. Lucero, our co-researcher, who provided all the analyses on pesticide residues.

References

Adalla, C.B. and B. Morallo-Rejesus. 1989. The golden snail *Pomacea* sp., a serious pest of lowland rice in the Philippines, pp. 417–422. *In* I. Henderson (ed.) Slugs and snails in world agriculture (Proceedings of the Symposium, 10–12 April 1989, University of Surrey, Guilford, UK). British Crop Protection Council and Malacological Society of London, London.

APHA/AWWA/WPCF. 1974. Standard methods for the examination of water and wastewater. American Public Health Association, American Water Works Association and Water Pollution Control Federation, Washington, DC.

Arce, R.G. and A.V. Circa. 1982. Further study on the effect of different insecticides on the culture of *Tilapia Nilotica* in paddy fields planted to IR-52. Freshwater Aquaculture Center (Philippines) Tech. Rep. 22:61–66.

Arce, R.G. and A. Fermin. 1977. Effect of carbofuran placement on fish survival in ricefields. Freshwater Aquaculture Center (Philippines). Tech Rep. 2:34.

Arce, R.G., C.R. dela Cruz and E.A. Lopez. 1978. Effect of different insecticides on the survival of *T. nilotica* cultured in ricefields. Freshwater Aquaculture Center (Philippines) Tech. Rep. 13:22–27.

Arce, R.G. and A.G. Cagauan. 1984. Bioassay of Nuvacron, Hostathion, Carbophen and Trithion on *T. nilotica* and *Carassius carassius*. Central Luzon Agricultural Research Complex Eval. Rep. 1984.

Arce, R.G., C.M. Lucero, D.S. Gamboa, S. Bulacso and J. Natividad. 1984. Pesticide residue analysis of fish from rice-fish farms and fishponds in Central Luzon (Terminal Report of the Research Project). United States Agency for International Development, Manila; Freshwater Aquaculture Center, Nueva Ecija; and Bureau of Fisheries and Aquatic Resources, Quezon City.

Arce, R.G., A.G. Cagauan and E.M. Vera Cruz. 1985a. Bioassay of Carbophen using *T. nilotica* fingerlings as test animals. Central Luzon Agricultural Research Complex Eval. Rep. 1985.

Arce, R.G., A.G. Cagauan and E.M. Vera Cruz. 1985b. Effects of different levels of Carbophen applied in rice-fish culture during the dry season. Central Luzon Agricultural Research Complex Eval. Rep. 1985.

Arce, R.G., A.G. Cagauan and E.M. Vera Cruz. 1985c. Degradation of Bionex, Basudin WEC, Carbophen, Baycarb and Thiodan in water with *T. nilotica* fingerlings as test animals. Central Luzon Agricultural Research Complex Eval. Rep. 1985.

Arce, R.G., A.C. Cagauan, D.S. Gamboa and C.M. Lucero. 1986. Degradation of permethrin, MTMC + phenthoate and triazophos in paddies. Central Luzon Agricultural Research Complex Eval. Rep. 1986.

Arce, R.G., A.G. Cagauan, D.S. Gamboa and C.M. Lucero. 1987. The effects of permethrin, cypermethrin, lambdacyhalothrin and triazophos in rice-fish culture system during wet season (Aug-Oct 1986) and dry season (Feb-Apr 1987). Central Luzon Agricultural Research Complex Eval. Rep. 1987.

Basilio, R.B. 1989. Problem of golden snail infestation in rice farming, p. 11–12. *In* B.O. Acosta and R.S.V. Pullin (eds.) 1991. Environmental impact of the golden snail (*Pomacea* sp.) on rice farming systems in the Philippines. ICLARM Conf. Proc. 28, 34 p.

Ca, R. 1983. Rice-field fish culture. Agricultural Publisher, China. 66 p.

Cagauan, A.G. and R.C. Valle. 1986. Field trials of synthetic pyrethroids Karate 2.5 EC (lambdacyhalothrin) and Cymbush 5 EC (cypermethrin) in the culture of Nile tilapia (*Oreochromis niloticus*) in rice-fish culture (Terminal Report Research Project). ICI-Jardine Davies, Inc., Manila, Philippines.

Celino, L.P., N.P. Gambalan and E.D. Magallona. 1987. Fate of carbofuran in rice-fish ecosystem. Paper presented during the 11th International Congress of Plant Protection, 5–9 October 1987, Manila, Philippines.

Cheng, E.Y. 1989. Control strategy for the introduced snail *Pomacea lineata* in rice paddy, pp. 69–75. *In* I. Henderson (ed.) Slugs and snails in world agriculture (Proceedings of the Symposium, 10–12 April 1989, University of Surrey, Guilford, UK). British Crop Protection Council and Malacological Society of London, London.

Cruz, E.R., M.C. dela Cruz and N.A. Suñaz. 1988. Hematological and histopathological changes in *Oreochromis mossambicus* after exposure to the molluscicides Aquatin and Brestan, p. 99–110. *In* R.S.V. Pullin, T. Bhukaswan, K. Tonguthai and J.L. Maclean (eds.) The Second International Symposium on Tilapia in Aquaculture. ICLARM Conf. Proc. 15, 623 p.

dela Cruz, C.R. 1980. Integrated agriculture-aquaculture farming systems in the Philippines with two case studies in simultaneous and rotational rice-fish culture, p. 209–223. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) 1980. Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

dela Cruz, C.R. and A.G. Cagauan. 1981. Preliminary study on bioassays and seven pesticides and five weedicides with tilapia, carp, clam and shrimp as test species. Fish. Res. J. Philipp. 6(1):11–18.

dela Cruz, C.R. and A.V. Circa. 1981. Toxicity of Kafil IOEC (Permethrin) and Cymbush 10 EC (Cypermethrin) in rice-fish culture. Freshwater Aquaculture Centre (Philippines) Tech. Rep., 19:35–47.

dela Cruz, C.R. and E.A. Lopez. 1982. Rate of degradation in water of Folidol M50, Malathion and Lannate with tilapia fingerlings as test species. Freshwater Aquaculture Centre (Philippines) Tech. Rep. 22. 76–82.

dela Cruz, C.R. 1986. Small-scale fisheries development project: rice-fish culture subproject for the Republic of Indonesia. USAID, Jakarta. 226 p.

Duodoroff, P., B.G. Anderson, G.E. Burdick, P.S. Galtsoff, W.B. Hart, R. Patrock, E.R. Strong, E.W. Surber and W.M. van Horn. 1971. Bioassay methods for the evaluation of acute toxicity of industrial wastes to fish. Sewage and Industrial Wastes 23(11):1380–1397.

Escalada, M.M. 1989. The strategic extension campaign in snail (kuhol) control in the Philippines. DA-FAO Workshop on Extension Campaign Planning, Message Design and Natural Development. 105 p.

FAO. 1969. Report of the committee on water quality criteria. Food and Agriculture Organization. Federal Water Pollution Control Administration, US Department of the Interior, Washington, DC. Facsimile of Section II-Fish. Tech. Pap. 94.

FPA. 1986. FPA pesticides use pattern. Fertilizer and Food Authority, Manila, Philippines.

Garbach, S.R., W. K. Haarring and H.J. Werner. 1971. Residue analysis in the water system of East Java (River Brantas, ponds, sea water) after continued large scale application of Thiodan in rice. Bull. Environ. Contamin. Toxicol. 6(11):40–47.

Greenberg, A.E., J.J. Connors and D. Jenkins, Editors. 1980. Standard methods for the examination of water and wastewater. Washington, DC.

Guerrero, R.G. 1976. Bioassay of synthetic pyrethroid on Java tilapia (*Tilapia mossambica*) and Thai catfish (*Clarias batrachus*). Freshwater Aquaculture Center (Philippines) Tech. Rep. 10:146–150.

Hardjamulia, A. and S. Koesoemadinata. 1972. Preliminary experiments on the effect of Thiodan and Endrin on fish culture in Indonesia. Proc. Indo-Pacific Fish. Coun. 15(11):56–64.

Holden, A.V. 1972. The effects of pesticide on life in freshwater. Proc. R. Soc. Lond. B. 18:383–394.

JPPA. 1982. Japan Pesticide Information No. 40. Japan Plant Protection Association. The Association of Japanese Agricultural Scientific Societies, Japan.

Juliano, R.O., R.D. Guerrero III and I. Ronquillo. 1989. The introduction of exotic aquatic species in the Philippines, p. 83–90. *In* S.S. de Silva (ed.) Exotic aquatic organisms in Asia (Proceedings of the Workshop on Introduction of Exotic aquatic organisms in Asia. Asian Fisheries Society.) Spec. Publ. 3, 154 p. Manila, Philippines.

Khoo, H.K. and E.S.P. Tan. 1980. Review of rice-fish culture in Southeast Asia, p. 1–14. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) 1980.

Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Koesoemadinata, S. and R. Djajadiredja. 1976. Some aspects on the regulation of agricultural use of pesticides in Indonesia, with reference to their effects on inland fisheries. Inland Fisheries Research Institute Cont. 3. 14 p.

Koesoemadinata, S. 1980. Pesticides as a major constraint to integrated agriculture-aquaculture farming systems. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) 1980. Integrated agricultural-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Leakey, J.P. 1985. The pyrethroid insecticides. Taylor and Frances, London.

Li, K. 1986. A review of rice-fish culture in China. Freshwater Fisheries Research Centre. Chinese Academy of Fish Sciences. Wuxi, China. Network of Aquaculture Centres in Asia, Bangkok, Thailand. 13 p.

Liao, K.T. 1980. Rice paddy fish culture. Pearl River Fisheries Institute, Bureau of Aquatic Products. Guandong Science and Technology. Publishing Comp., Guandong. (In Chinese).

Lim, C.S. and Ong Seng-Hock. 1985. Environmental problems of pesticide usage in the Malaysian ricefield - perception and future consideration. Paper presented at the 4th International Meeting (1985), Chiang Mai, Thailand.

Magallona, E.D. 1980. Pesticide management. Fertilizer and Pesticide Authority, Philippines. 193 p.

Magisa, R. and C.R. dela Cruz. 1978. Study on the toxicity and efficacy of four insecticides on Crucian carp (*Carassius carassius*), Nile tilapia (*Tilapia nilotica*) and Java tilapia (*T. mossambica*). Freshwater Aquaculture Center (Philippines) Tech. Rep. 15:44–54.

Mochida, O. 1987. *Pomacea* snails in the Philippines. Int. Rice Res. Newsl. 12(4):48–49.

Ordanza, W. and C.R. dela Cruz, 1979. Bioassay of Azodrin 202 R EC, Brodan EC, Furadan F and Tsumacide 50 WP with *T. nilotica* and *T. mossambica* as test species. Freshwater Aquaculture Center (Philippines) Tech. Rep. 16.

Ponce, B. and C.R. dela Cruz. 1979. Bioassay of Basudin 20 EC, Thiodan 35 EC, Mipcin and Diagram 5G with Crucian carp and Nile tilapia as test species. Freshwater Aquaculture Center (Philippines) Tech. Rep. 15:70–82.

Reyes, I.D. and C.R. dela Cruz. 1982–83. Degradation rate in water of four agricultural pesticides. Central Luzon State University Scient. J. 3(2):60–67.

Saanin, H. 1960. Toxicity of insecticides and herbicides to some Indonesian cultivable fish species, p. 293-303. *In* Proceedings of the Fourth Pan-Indian Ocean Science Congress, Section B: Biological Sciences. India.

Santiago, L. and R.D. Recometa. 1981. Bioassay: evaluation of three agricultural herbicides on the survival of Nile tilapia (*Tilapia nilotica*) and Crucian carp (*Carassius carassius*) fingerlings. Freshwater Aquaculture Center (Philippines) Tech. Rep. 20:19–29.

Seiber, J.N. and A. Argente. 1976a. Carbofuran residues in paddy-reared *Tilapia mossambica* from CLSU. Trial 1 International Rice Research Institute (Philippines) Research Report. 5 p.

Seiber, J.N. and A. Argente. 1976b. Carbofuran residues in paddy-reared *Tilapia mossambica* from CLSU. Trial 2. International Rice Research Institute (Philippines) Research Report. 5 p.

Sevilleja, R.C., P.M. Monje and A.G. Cagauan. 1989. Fish toxicity trial of selected synthetic pyrethroids under field conditions using Nile tilapia (*Oreochromis niloticus*) and common carp (*Cyprinus carpio*). Research Project Terminal Report. Central Luzon State University, Philippines.102 p.

Singh, V.P., A.C. Early and T.H. Wickham. 1980. Rice agronomy in relation to rice-fish culture, p. 15–34. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Spiller, G. 1985. Rice cum fish culture environmental aspects of rice and fish production in Asia. FAO, Bangkok, Thailand. 69 p.

Sprague, J.B. 1970. Measurement of pollutant toxicity to fish. Rev. Paper II. Utilizing and applying bioassay results. Water Res. 4:3–32.

Sprague, J.B. 1971. Measurement of pollutant toxicity to fish. Rev. Paper III. Sublethal effect and safe concentration. Water Res. 5:245–266.

Staring, W.D.E. 1984. Pesticides data collection systems and supply distribution and use. ESCAP, Bangkok, Thailand.

Taras, J.M., A.E. Greenberg, R.D. Hoak and M.C. Rand, editors. 1971. Standard methods for water and wastewater analyses. American Public Health Association, American Water Works Association and Water Pollution Control Federation, Washington, DC.

Vincke, M.M.J. 1979. Aquaculture en riziere: situation et role futur. *In* T.V.R. Pillay and W.A. Dill (eds.) Advances in aquaculture. FAO, Rome.

Role of Fish in Pest Control in Rice Farming

XIAO QING YUAN
Hunan Academy of Agricultural Sciences
Changsha, Hunan, China

XIAO, Q.Y. 1992. Role of fish in pest control in rice farming, p. 235–243. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Preliminary results obtained from recent experiments evaluating the role of fish in the control of rice pests in ricefields are reviewed. Rice planthoppers (fourth generation) were reduced from a maximum of 104,000 to 70,776/ha. Rice leafrollers at the rice booting stage decreased from 210,000 to 120,000/ha. Grass carp (*Ctenopharyngodon idella*) were particularly effective in controlling sheath blight. Incidence of rice sheath blight decreased from 13.5–78.7% (rice monoculture) to 7.0–42.3% (rice-fish) in early and late rice, respectively.

Chemical control of rice pests is still essential in China when crop-threatening diseases occur. Methods used in China for the selection of suitable pesticides at safe dosages, and application methods which include consideration of water temperature, rice growth stage and protecting fish are outlined.

Introduction

Raising fish in ricefields can be done at low cost over short culture periods and produce high returns. It can combine rice and fish culture without reduction in rice yields. Rice-fish culture not only increases the area of freshwater fish farming and production of aquatic food, but also helps solve the problem of fish shortages in rice-growing areas, especially in places with no ponds or water bodies.

In China, raising fish in ricefields has rapidly developed. Development has been supported by the First National Conference on Fish Farming in Paddy Fields in September 1983 (APB 1983).

When fish are raised in ricefields, ecological conditions greatly change. Changes influence the relationships among the population of organisms in the field. In recent years, research has been initiated in China to: 1) explore the occurrence, growth and decline of pests in rice-fish culture; 2) provide guidelines for integrated pest control in rice-fish culture; and 3) reconcile the contradicting requirements of fish and rice for pesticides. However, since research has just started and the institutes responsible for this work are few, the scope and depth of research are incomplete. Hence, only preliminary results are briefly reported in this paper.

Fish Used as Pest Control in Rice Farming

Fish in Insect Control

PLANTHOPPERS

Results have shown that the number of rice planthoppers in ricefields with fish is less than those without fish (Table 1). Counts on 10 July indicated a peak in the number of fourth generation rice planthoppers of 15.9 million/ha. In the ricefields without fish, the number of planthoppers reached 23.4 million/ha or about 50% greater than ricefields stocked with 6.6-cm common carp (*Cyprinus carpio*). During the fifth generation (10 August), the ricefields with fish had 9.6 million/ha, whereas the ricefields without fish had 15.3 million/ha or nearly twice as much as the former. In the sixth generation (10 September), the occurrence of rice planthoppers in the ricefields with fish was 150,000/ha less than without fish.

STEMBORERS

An investigation conducted during the rice tillering stage on 12 July showed that the number of rice stemborers in the ricefields with fish was 6,000/ha, and the percentage of dead hearts 0.33% (Table 2). Percentage of dead hearts was 0.37% in the ricefields without fish. The occurrence and number of third generation stemborers were small and damage was slight, likely due to drought. An investigation conducted on 25 August showed that there was no damage caused by rice stemborers in the ricefields with fish, while the percentage of dead hearts in the ricefields without fish was 0.29%.

LEAFFOLDERS

An investigation on the occurrence of fourth generation larvae of leaffolders on 5 August showed that rolled leaves in the control ricefields (no fish) was 4.4% (Table 3). More than half the number of pests were counted in the control compared to the ricefields with fish.

Fish in Disease Control

Based on many years of research by the Taoyuan County Agricultural Bureau, Hunan Province, raising grass carp (*Ctenopharyngodon idella*) in ricefields can control rice sheath blight disease (Table 4). Early and late rice in ricefields with fish infected with sheath blight

Table 1. Effects of 6.6-cm common carp (*Cyprinus carpio*) on rice planthoppers in rice-fish culture. (Source: Ji and Yu 1987).

Investigation date	Growth stage of rice plant	No. of hills investigated	Insect population density ('000/ha)[a] Rice-fish	Rice monoculture
25 Jun	First phase of tillering stage	100	38	84
10 Jul	End of tillering stage	100	15,900	23,400
10 Aug	End of panicle initiation stage	100	9,600	15,300
10 Sep	End of filling stage	100	210	360
10 Oct	Ripening stage	100	0	300

aOriginal figures in mu were converted to hectares using 1ha = 15 mu.

Table 2. Effects of 6.6-cm common carp (*Cyprinus carpio*) on rice stemborers in rice-fish culture. (Source: Ji and Yu 1987).

Investigation date	Growth stage of rice	No. of hills investigated	Cropping pattern	No. of rice plants investigated	Rate of dead hearts (%)	Insect stage
12 Jul	Tillering	200	Rice-fish	2,384	0.33	2nd generation
			Rice monoculture	2,148	0.37	2nd generation
			Rice-fish	2,120	0	3rd generation
25 Aug	Filling stage	200	Rice monoculture	2,086	0.29	3rd generation

Table 3. Effects of 6.6-cm common carp (*Cyprinus carpio*) on fourth generation rice leaffolders in rice-fish culture. (Source: Ji and Yu 1987).

Investigation date	Growth stage	Cropping pattern	Insect population density (no./000 ha)	Rate of rolled leaves (%)
5 Aug	Booting stage	Rice-fish	120	1.59
		Rice monoculture	210	4.40

Table 4. Effects of fish on rice sheath blight in rice-fish culture (Species: *Ctenopharyngodon idella*, *Oreochromis niloticus*, *Cyprinus carpio* and Hunan Crucian carp; fish size: 5.0 cm). (Source: Tao Yuan Agricultural Bureau, Tao Yuan, China).

Year	Cropping season	Treatment[a]	Incidence of disease (%)	Rate of diseased plants (%)	Incidence index
1983	Early rice	Rice-fish	73.3	42.3	34.2
		Control	93.3	72.1	55.0
	Late rice	Rice-fish	72.2	36.0	26.4
		Control	94.4	78.7	41.7
1984	Early rice	Rice-fish	70.0	25.7	8.5
		Control	97.5	50.2	24.1
		Rice-fish	18.3	7.0	2.4
	Late rice	Control	34.5	13.5	4.7

[a]Control = rice monoculture.

disease were 24.5–29.8% and 6.5–42.7%, respectively, than in ricefields without fish.

The possible ways by which grass carp inhibits sheath blight disease were investigated. Preliminary results showed that the fish eats directly the sclerotia of sheath blight and digests them after 24 hours. Grass carp also eats the hyphae germinating on the sclerotia. A fish secretion did not inhibit germination of sclerotia, but sclerotia treated with a fish secretion germinated hyphae more slowly than the normal sclerotia. In addition, infection by hyphae are reduced. The control of sheath blight by fish occurs only when sheath blight disease spreads along the water surface. When sheath blight disease spreads vertically up the rice plant, fish are ineffective.

Factors Limiting the Role of Fish in Rice Pest Control

Some hydrological, biological and agricultural factors limit the effectiveness of fish to control rice pests.

Restricted Movements of Fish in the Water Area

The species and quantity of pests eaten by fish are closely related to their life histories. Only those pests which inhabit the plant base or fall into the water can be eaten by fish. Pests eaten by fish come from three sources: from the adult and larval pests whose entire life cycle passes in water; from pests which inhabit the rice plant base (rice planthoppers and leafhoppers usually rest on the middle or lower parts of rice plants to suck plant juices during the day and climb to the upper part of the leaf to feed at night or early morning); and from pests which fall into the water during migration, e.g., rice planthoppers, leafhoppers and armyworms. Their larvae (after three instars) tend to roll up and feign dead if they fall into the water. When rice stemborers and ant borers migrate from one plant to another and fall into the water, they are eaten by fish. Fish help control pests by eating the pests that fall into the water. However, such a role is somewhat fortuitous and it is probably not great.

Species, Size, Eating Habits and Number of Fish Stocked

Experiments with different fish species have shown that grass carp more than 6.6 cm in length ate the greatest number of rice leafhoppers.

Effect of Rice Culture Practices

The occurrence of rice sheath blight disease is related to field moisture and application rates of NPK fertilizers, especially excess nitrogen. Improper fertilizer rates and poor water management may cause growth imbalances in rice, making it susceptible to pests and diseases.

Feedback Adjustment Mechanisms of Insect Populations

Although fish may unceasingly prey on insects, the negative feedback action of density-reproduction and density-migration of insect populations counteracts these effects. On the other hand, when the number of pests is great, the number of their natural enemies also increases. Natural population balance and adjustment mechanisms may decrease the effect of fish on pests. When the capacity of fish to eat pests is not enough to effectively break the adjustment mechanisms of pest populations, eating a large part of the pest population may not have a significant influence on the growth and decline of that population. Thus, the role of fish in pest control should be carefully evaluated and not be overestimated.

Chemical Control of Pests in Rice-Fish Farming

There are many kinds of rice pests and their life histories can be quite long. Experiments and production practices in China have shown that chemical control of rice pests is essential in ricefields stocked with fish. Although fish play a role in pest control, when serious crop-threatening pests or diseases occur, chemical control is essential. Care should be taken, however, that pesticide applications are conducted in a manner to control not only the spread of rice pests or diseases, but also to protect fish from being poisoned (Mao et al. 1985).

Toxicity of Pesticides to Fish

Pesticides, based on their toxicity to fish, may be classified into acute, subacute and chronic toxicity. The level of acute toxicity is expressed in terms of the median tolerance limit (TLM), which refers to the concentration of pesticide where half of the fish die at 24, 48 or 96 hours after treatment. In general, if the 48-hour TLM for *C. carpio* of a pesticide is >10 ppm, it is regarded as low toxicity; 1–10 ppm, medium toxicity; and <1 ppm, a high toxicity pesticide (Mao et al. 1985, Liu 1986). The TLM to fish of some common pesticides are listed in Tables 5 and 6. More information on the 96-hour LC_{50}

Table 5. Median tolerance limits (TLM) of fish (*Cyprinus carpio*, red carp and *Salmo salar*) and toxicity levels of various pesticides. (Source: Mao et al. 1985).

Pesticide name	Form of pesticide	Toxicity grade	Test species
Trichlorfon	80% crystal	medium	*C. carpio*
Dichlorvos	80% emulsion	medium	*C. carpio*
Rogor	40% emulsion	medium	*C. carpio*
Tetrachlorvinphos	25% liquid	low	red carp
Chlordimeform	25% liquid	low	*C. carpio*
Methamidophos	50% emulsion oil	low	*S. salar*
Etrofolan	50% emulsion oil	medium	*C. carpio*
Carbendazol	50% wettable powder	low	red carp
IBP	40% emulsion	medium	*C. carpio*
EBT	50% emulsion	medium	*C. carpio*
Kasugamycin	40% liquid	low	*C. carpio*
Tsumacide	25% wettable powder	low	*C. carpio*

Pesticide name	TLM (ppm) 46 hours	TLM (ppm) 96 hours	No. of applications	No. of days between last pesticide applications and fish harvest
Trichlorfon	6.2		3	Not < 7 days
Dichlorvos	4.0		3	Not < 7 days
Rogor	4.0		4	Not < 7 days
Tetrachlorvinphos	27.9		3	Not < 15 days
Chlordimeform	15.2			Not < 15 days
Methamidophos		51.0		Not < 15 days
Etrofolan	4.2			Not < 7 days
Carbendazol		96.6	3	Not < 30 days
IBP	5.1		5	Not < 20 days
EBT	5.0			Not < 20 days
Kasugamycin	100			Not < 20 days
Tsumacide	15.3			Not < 20 days

Table 6. Median tolerance limits (TLM) of fish (*Cyprinus carpio*, *Salmo salar*, trout and red carp) to various pesticides. (Source: Liu 1986).

Type	Pesticide	Test species	TLM (ppm) 48 hours	TLM (ppm) 96 hours	Toxicity grade	Remarks
Pesticide	Trichlorfon	*C. carpio*	6.2		medium	low for silver carp (*Hypophthalmichtys molitrix*)
	Dichlorvos	*C. carpio*	4.0		medium	medium for silver carp
	Fenitrothion	*C. carpio*	4.4		medium	
	Malathion	*C. carpio*	9.0		medium	medium for silver carp
	Rogor	*C. carpio*	<40.0		low	low for silver carp
	Methyl Parathion	*C. carpio*	6.0		medium	high for silver carp
	Methamidophos	*S. salar*		61.0	low	
	Phosmet	*C. carpio*	5.3		medium	medium for silver carp
	Phenthoate	*C. carpio*	2.0		medium	
	Baytex	*C. carpio*	2.0		medium	
	Tsumacide	*C. carpio*	15.3		low	
	Landrin	*C. carpio*	38.1		low	
	Matalamate	*C. carpio*		1.03	medium	
	Furadan	trout		0.28	high	high for *Ctenopharyngodon idella*
	Bassa	*C. carpio*	12.6		low	
	Etrofolan	*C. carpio*	4.2		medium	
	Tetrachlorvinphos	red carp	27.9		low	
	Chlordimeform	*C. carpio*	15.2		low	low for silver carp
	Rotenone	*C. carpio*	0.032		high	high for silver carp, *C. idella*
	Brumoxymil octamoate	*C. carpio*	0.03		high	high for fish
	Mevinphos	trout	0.007		high	high for fish
Bactericide	EBP	*C. carpio*	5.0		medium	medium for silver carp
	IBP	*C. carpio*	5.1		medium	
	Edinphensoph	*C. carpio*	1.3		medium	
	Oryzon	*C. carpio*	6.7		medium	
	Plictran	*C. carpio*	14.6		low	
	Carbendazol	red carp		96.6	low	thiophanate has similar effects
	Thiophanate methyl	*C. carpio*	11.0		low	
	Blasticidin	*C. carpio*	>40.0		low	
	Kasugamycin	*C. carpio*	>100.0		low	
	CAMA	*C. carpio*	10.0		medium	
	Phenazin	*C. carpio*	>10.0		low	
	Cellocidin	red carp	660.0		low	applies for TLM 24-hours
	Triram	*C. carpio*	4.0		medium	
	Seedvax	fish	0.4-1.8		high	
Herbicide	2,4-D	*C. carpio*	>40		low	
	DMNP	*C. carpio*	14.0		low	
	Propanil	*C. carpio*	0.42		high	
	Nitrofen	*C. carpio*	2.1		medium	high for silver carp
	Benthiocarb	*C. carpio*	3.6		medium	
	Amino methan-carrsonates	*C. carpio*	3.72		medium	
	GS 13633	*C. carpio*	0.86		high	
	Hedazhuang	*C. carpio*	34.0		low	
	Oradiazon	*C. carpio*	3.2		medium	
	Prometryne	*C. carpio*	23.5		low	
	Glyphosate	*C. carpio*	119.0		low	
	Pentachlorophenol	*C. carpio*	0.35		high	high for silver carp and *C. idella*
Others	Zinc phosphide	*C. carpio*	80.0		low	
	Propargite	*C. carpio*	1.0		medium	
	Lime	*C. carpio*	140.0		low	

of various pesticides to *C. carpio* are given by Koesoemadinata and Costa-Pierce (this vol.).

Safe Application of Pesticides

It is important to choose the proper kind of pesticide for rice-fish culture, control its dosage, apply it at a suitable time with appropriate methods and prevent the pesticide from mixing with the water. In addition, a safe interval of time after pesticide application must be observed to reduce the residual toxicity on fish. Estimates of routine and maximum dosages of some pesticides and their concentrations in 10-cm water are given in Table 7. Some guidelines on the proper use of pesticides in rice-fish culture are outlined.

PROPER SELECTION OF SUITABLE PESTICIDE

In rice-fish systems, suitable pesticides possess a high toxicity to rice pests and a wide spectrum of influence, but a low toxicity to fish, with low residual toxicities. Examples are plictran and carbendazol for controlling rice blast, kasugamycin for sheath blight disease, cellocidin for bacterial leaf blight, and tetrachlorvinphos or chlordimeform for rice leaffolders and striped rice borers.

SELECTION OF A SAFE DOSAGE OF PESTICIDE

An experiment conducted by the Hunan Aquatic Products Institute showed that at water temperatures below 21.5–26.0°C, the safe concentration of 45% malathion emulsion for *Oreochromis niloticus* is 2.1 ppm; for hybridized species of crucian carp and *C. carpio*, 6.9 ppm; and for lotus carp, 10.6 ppm. Also, at water temperatures below 21.5–26.0°C, the safe concentration of 25% tetrachlorvinphos for *O. niloticus* is 31.5 ppm; for hybridized species of crucian carp and *C. carpio*, 25.2 ppm; and for lotus carp, 31.5 ppm. The experiments also showed that the pesticides with low toxicity to fish would do less harm to fish in ricefields, if their application dosage is well controlled. But those pesticides which possess medium toxicity to fish would have adverse influence on the normal growth of fish, if applied in a wrong way.

ADOPTION OF SAFE METHODS OF PESTICIDE APPLICATION

Generally, pesticides can be applied by mixing the pesticide with fine soil and are broadcast to the ricefields; splashing or pouring; rough spraying; or fine or mist spraying. If pesticide mixed with fine soil is broadcast to the ricefield, the resulting concentration in the water will be very high. If it is applied by splashing or pouring, about 70–80% of the pesticide will mix with the water of the ricefield and will cause harm to the fish. If rough spraying or high-volume spraying (about 750 kg/ha of liquid pesticide is needed) is done, less pesticide will adhere to the rice leaves and more will mix with the water due to the large size (>399 mm) of the pesticide droplet. Spraying of fine mist (droplets <250 mm) or low-volume spraying (about ≥187.5 kg/ha of pesticide) gives a strong adhesion to rice leaves. With low-volume spraying, the amount of pesticide falling in the water is decreased, and less harm is done to fish. For these reasons, the fine or mist spraying methods are recommended to control pests staying on the rice leaves. To control pests resting on the lower parts of rice plants, it is necessary to increase the amount of water being mixed with liquid pesticides. Another good practice is to strengthen pest control during the seedling period. Rice seedlings may be treated with pesticides when they are transplanted. Thus, the frequency of pesticide applications may be reduced.

Spraying of Pesticides at Appropriate Periods

The water temperature in the ricefield increases or decreases depending on the

Table 7. Common and maximum dosages and concentrations (ppm) of pesticides in ricefield waters.[a] (Source: Liu 1986).

Pesticide name	Form of pesticide	Common dosage g/ha	Common dosage last concentration 100%	Common dosage last concentration 30%	Common dosage Safety[b]	Maximum dosage g/ha	Maximum dosage last concentration 100%	Maximum dosage last concentration 30%	Maximum dosage Safety[b]
Trichlorfon	90% crystal	1,125	1.52	0.46	3	1,500	2.03	0.61	3
Dichlorvos	80% emulsion	1,125	1.04	0.31	3	1,500	1.38	0.42	4
Fenitrothion	50% emulsion	750	0.51	0.15	3	1,125	0.76	0.23	3
Malathion	50% emulsion	750	0.53	0.16	3	1,125	0.79	0.23	3
Rogor	40% emulsion	750	0.43	0.13	2	1,125	0.64	0.19	2
Methyl parathion	50% emulsion	750	0.51	0.15	3	1,125	0.77	0.23	3
Tsumacide	25% soluble dust	1,500	0.56	0.17	2	2,250	0.84	0.25	2
Etrofolan	10% soluble dust	3,000	0.45	0.14	3	3,750	0.56	0.17	3
Tetrachlorvinphos	25% water solution	2,250	0.67	0.20	2	3,000	0.88	0.26	2
Chlordimeform	25% water solution	750	0.25	0.08	2	2,250	0.75	0.23	2
EBP	40% emulsion	1,500	0.45	0.14	3	225	1.38	0.41	4
Edinphensoph	40% emulsion	750	0.43	0.13	3	1,125	0.65	0.19	4
Oryzon	40% emulsion	1,125	0.63	0.19	3	1,500	0.84	0.25	3
Plictran	20% soluble dust	750	0.23	0.07	2	1,500	0.45	0.14	2
Carbendazol	50% soluble dust	750	0.56	0.17	1	1,500	1.13	0.34	1
Kasugamycin	5% water solution	1,125	0.08	0.02	1	1,500	0.10	0.03	1
CAMA	20% soluble dust	375	0.11	0.03	3	1,875	0.56		4
Phenazin	10% soluble dust	2,250	0.34	0.10	3	3,750	0.56	0.17	3
Cellocidin	20% soluble dust	1,125	0.34	0.10	1	1,500	0.45	0.14	1

[a]Calculated on 10 cm of water.

[b]1 = Applications at this concentration are safe; 2 = pesticide may be applied when water depth >10 cm; 3 = pesticide application is allowed when plant and fish are large in size, and only when last application is at a concentration 30% below the first application; and 4 = not safe.

change of air temperature. During summer, water temperature in ricefield is high. When pesticide is sprayed at this time, chemical reactions are more rapid, volatility is increased, and pesticides become highly toxic to fish.

During its vegetative stage, rice plants are short and small. When pesticide is applied, most mix with the water, especially during the early growth stage in double cropping or late rice. Not only will most of the pesticide mix with the water, but water temperature is also high during this period. These conditions act together and can greatly harm fish. When pesticide is applied during the reproductive stage of rice (i.e., when rice plants are large and luxuriant), most of it stick to the rice plant, greatly reducing the concentration of pesticides in the water. However, if pesticide application is not done properly during the heading and flowering stages of rice, fish in the ricefield may eat florets contaminated with pesticide. In this case, although the pesticide may be of low toxicity and at a low concentration in the water, fish in the ricefields may still be poisoned.

For these reasons, it is better to apply pesticides in the morning or evening (before 0900 or after 1600 hours). Furthermore, if pesticide is to be applied during the heading and flowering stages of rice, it should be applied in the morning and not after 1600 hours. Pesticide in powder form should be applied in the morning or before noon when there are still dewdrops on rice leaves. Liquid pesticide should be applied in the afternoon when rice leaves are dry for easy adherence.

Prevention of Fish Poisoning During Pesticide Application

Before applying pesticides, water in the ricefield must be drained. Fish may be driven to the fish sump with a temporary dike built around it to prevent entry of water from the ricefield. When the toxicity of the pesticide has been totally drained, fish are returned to the ricefield.

Water depth of the ricefield may also be increased. When a low toxicity pesticide is applied, deep water (>8 cm) may be maintained to prevent fish from being poisoned.

Another safety measure is to flush water through the ricefield. Before applying pesticide, water inlets and outlets are opened to allow water to flow freely. Pesticide application should begin at the water outlet. After half of the ricefield is sprayed, discontinue application to let water containing pesticides flow out of the ricefield. Then continue spraying the remaining half towards the water inlet.

Observing a Safe Interval Between Pesticide Applications

The safe interval between pesticide applications should not only consider the rice plants, but also its adverse effects on fish to reduce mortalities and residual toxicity. Moreover, avoid harvesting and eating fish right after pesticide or any chemical is applied. The appropriate intervals for different pesticides are listed in Table 5.

References

APB. 1983. Selection of materials from the national on-the-spot meeting for exchange of experience in the rice-fish farming system. Aquatic Products Bureau. Ministry of Agriculture, Husbandry and Fishery, Cheng du, China.

Ji, X.M. and A.Y. Yu. 1987. Occurrence of diseases, pests and weeds in raising fish in rice field and their investigation. Lishui Agricultural Science and Technology, Lishui, China.

Liu, C. 1986. Rice-*Azolla*-fish system. Fujian Academy of Agricultural Sciences, Fujian, China.

Mao, Z.Y., W. Wu, S.Y. Shu, J.D. Xu, L.H. Huang, D.F. Chen, J.L. Yang and Z.Y. He. 1985. Techniques for raising fish in the paddy field. Zhejiang Science and Technology Publishing House, Zhejiang, China.

Comparative Economics of Pesticide Use in Rice and Rice-Fish Farming

HERMANN WAIBEL*
Division of Agricultural and Food Engineering
Asian Institute of Technology
G.P.O. Box 2754
Bangkok 10501, Thailand

WAIBEL, H. 1992. Comparative economics of pesticide use in rice and rice-fish farming, p. 245–254. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

This paper aims to establish a link between integrated pest management (IPM) and rice-fish culture by comparing the economics of both systems. It is argued that rice-fish culture can be used as a tool in IPM as insecticide applications on pest-resistant rice varieties are largely uneconomical, and as the opportunity cost from a decision not to stock fish in the ricefield will shift the economic threshold (the main decision criteria in IPM) to a level that is very unlikely to be reached by pests. In this way, fish in ricefields can serve as a vehicle to speed up diffusion of IPM technology, as a 'do-not-spray' strategy could be changed to a more attractive strategy – 'grow fish'.

Introduction

There are two main constraints to increased productivity in integrated rice-fish farming systems – water control and pesticides. The latter can be considered as the more serious constraint because in rice-growing areas where the water problem can be solved, potential rice yields are also high, justifying the use of chemical inputs. Pesticides are used as a means to protect these potential yields. Moreover, in the green revolution package of technology for rice, pesticides are an indispensable input to be applied on a calendar basis. Governments have encouraged the use of pesticides in rice through subsidies as an instrument of food policy in order to attain self-sufficiency in rice. Examples of these interventions include the *Masagana* 99 Program in the Philippines where pesticides have been promoted

*Present address: Institut für Agrarökonomie, Platz der Göttinger Sieben Nr. 5, Georg August Universität, 3400 Göttingen, Federal Republic of Germany.

through subsidized credits and the BIMAS (Mass Guidance Program) in Indonesia where selected manufacturers had been contracted by the government to provide pesticides at substantially reduced prices.

The implications of pesticide use in rice for rice-fish farming have stimulated research on the toxicity effects of different pesticides on freshwater fish (Koesoemadinata 1980). It was found that some organophosphates frequently used in rice, such as azinphos ethyl and monocrotophos, are highly toxic to fish (Cagauan and Arce, this vol.). Other research looked for pesticides which are less toxic to fish. For example, the insecticide carbofuran has been reported safe for use in rice-fish culture (Estores et al. 1980). Also, it has been reported that farmers have switched to methyl parathion, which is less toxic to fish yet extremely toxic to humans (Spiller 1985).

The question that has not been asked so far with regard to pesticide use in rice and its relationship to rice-fish culture is: "How necessary or economical is the use of insecticides under farmers' conditions?" This issue is particularly relevant to the advancement of Integrated Pest Management (IPM) in rice.

Economics of Pesticide Use in Rice

Pesticides, in particular insecticides, are used to prevent yield losses from insect pests and virus diseases transmitted by insect vectors. In Asia, pesticide usage grew at an annual rate of 5–7% in 1980–85; with the highest growth (30%) recorded in Indonesia (ADB 1987). Although it is not known what proportion was used for different crops, it is realistic to assume that it was largely used on rice, as rice is the most dominant crop in the region.

With the spread of high-yielding, fertilizer-responsive rice varieties, pesticides have been considered as an indispensable input for rice production, often being applied in a fixed proportion with fertilizers. Estimates of yield losses by various researchers have induced this assessment of pesticide needs. The most frequently quoted study is Cramer's (1967) global loss assessment. Accordingly, yield losses in rice due to insect pests alone were assumed to be 36%. As these figures are rough estimates, it is worth taking into consideration other sources. In analyzing data on yield loss, one has to be satisfied with secondary data taken from experiments that have been carried out for purposes other than crop loss assessment. However, treatments in the trials listed in Table 1, with the exception of the IRRI experiments, have always included an unsprayed and a so-called completely protected field. Loss then is defined as the yield difference expressed in per cent of the yield of the protected field. A direct comparison of past experiments is of limited use but lower losses were observed as one moves from the experiment station into farmers' fields. Data based on insecticide evaluation trials of the pesticide industry show the highest losses because highly susceptible varieties were used. Note the high proportion of experiments where it was not possible to arrive at any significant difference between the unsprayed field and the completely protected field in Table 1.

More refined methods of loss assessment based on multivariate regression functions using pest infestation data from untreated fields, confirmed the results of experiments in farmers' fields. Depending on the location, average losses over several years ranged from 8 to 14% but rarely exceeded 20% (Waibel 1986).

As it is safe to assume that losses due to rice pests are much lower than previously assumed, the main justification for excessive use of pesticides is removed. This does not automatically mean that their use is uneconomical altogether. Farmers usually spend less than 10% of the total cash costs on insecticides and

Table 1. Rice crop loss due to insect pests in the Philippines.

Type/Source of experiment	Period of experiment	Measured yield loss (%) Maximum	Average	Nonsignificant trials[a] (%)
Pathiak and Dyck (1973)	1968–72	32	22	na[b]
Insecticide evaluation trials (Waibel 1986)	1972–81	91	34	11
Yield constraint experiments of IRRI (Waibel 1986)	1975–79	27	11	na
Loss assessment in farmers' field (Litsinger et al. 1980)	1976–80	40	8.6	51
Loss assessment in farmers' field (Waibel 1986)	1960–81	28	8.9	60

[a]In per cent of the total number of trials conducted.
[b]na = not available.

generally spray only when they see some infestation.

On-farm trials replicated over farms and seasons that compare farmers' treatment with an untreated control are one way of finding out whether farmers' pest control practices pay off. Various research and extension organizations have carried out such trials, but results were rarely documented. On-farm trials conducted by the author in the Philippines during 1980–81 and in Thailand during 1984–86, showed that farmers' pesticide applications paid off in less than 50% of the cases in the Philippines (Zeddies and Waibel 1982) and incurred a loss of US$3.7/ha in Thailand (Waibel and Engelhardt 1988).

Results of these studies have to be assessed in view of the limitations which are common in conducting on-farm research: how to prevent farmers from spraying control plots and how to maintain field trials over a sufficient number of seasons. Thus, to obtain more detailed insights, a simple computerized decision model has been used (Waibel 1986). The model uses historical data on pest attacks (events) taken from unsprayed plots of experiments in farmers' fields together with technical parameters on alternative control strategies, represented by a linear control function and relevant economic parameters such as costs of the strategies and output prices (Fig. 1). The model computes net returns for all possible combinations between pest events and control strategies, and thus allows the difference in returns and costs over the 'do-not-spray' strategy to be derived.

Results are based on pest population events during the period 1976-81 in three Philippine provinces: Nueva Ecija, Camarines Sur and Iloilo. Computations of net returns are based on 1980 prices. Results vary considerably with the different provinces. On the average of all infestation events, insect control had the highest marginal rate of return (MRR) of 1.92 in the province of Nueva Ecija, the maximum MRR being 4.5 (Table 2). In 31% of

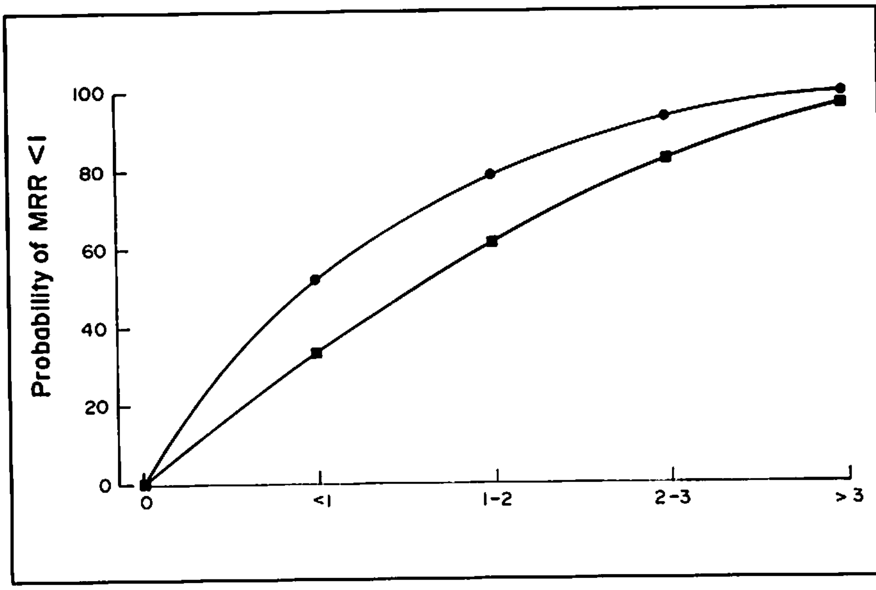


Fig. 1. Basic components of a model for the economic analysis of pest control strategies.

Table 2. Marginal rate of return (MRR) of farmers' insecticide use in three provinces of the Philippines, 1976–81. (Source: Calculated from Waibel 1986).

	Province		
Parameter	Nueva Ecija	Camarines Sur	Iloilo
Average MRR	1.9	1.2	negative
Maximum MRR	4.5	5.6	2.5
Cases with MRR<1 (%)	31	30	87

all events, the use of insecticides did not pay off, i.e., the cost of control was higher than additional returns. In Iloilo province, the farmers' use of insecticides rarely paid off, only 13% of all cases had an MRR>1, thus making insect control uneconomical on the average. Camarines Sur ranks in between with a higher maximum MRR but a poor average performance.

The analysis considered only insecticide costs incurred by farmers and not economic costs. There is a considerable difference between the two because governments generally subsidize pesticides. A study conducted by the World Resources Institute (Repetto 1985) showed that subsidies can lower pesticide costs by 50%. The impact of subsidies applying this margin to the above data set pooled across all three provinces is shown in Fig. 2. The chance of achieving an MRR value of at least 1 using subsidized insecticides is around 50%, but is reduced to 30% when the subsidy is removed.

In summary, these results clearly demonstrate that the use of insecticides with the pest-resistant rice varieties presently available is far less economical than

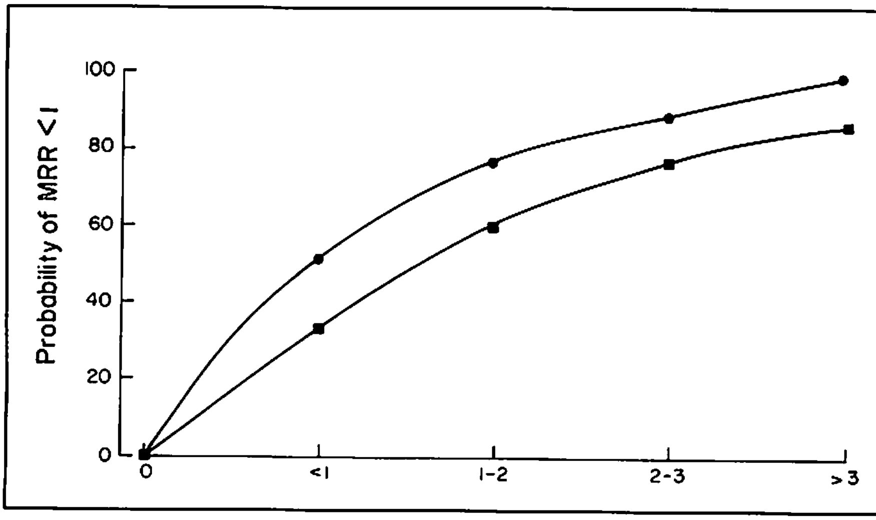


Fig. 2. Cumulative probability distribution of the marginal rate of return (MRR) of pesticide applications in rice in the Philippines, 1976-81; with (■) and without (•) pesticide subsidy.

previously anticipated, and that as a result, much less insecticides are needed. Litsinger (1984) estimated that rice production in the Philippines can be maintained with roughly half of the present level of pesticide use.

This fact spurred the development of IPM in rice which has gained widespread recognition in Asia. Indeed, IPM has been declared by the governments of Indonesia and the Philippines as their national pest control strategy. The basic element of this approach is the concept of the economic threshold, which is defined as that pest population level which economically justifies control action. Thus, unlike conventional pest control, insecticides are only needed when the economic threshold is reached. The main questions now become: In how many cases does this happen? If an insecticide is to be applied, what is the chance that it pays off for the farmer?

Data from on-farm trials mentioned before suggest that the chance of the economic threshold being reached is very small (Table 3). On the other hand, there is also a chance that the farmers' practice is yielding higher net returns than IPM, ranging from 25 to 39%. This means that there is still room for improving the specification of the threshold. Evidence from Indonesia (FAO 1988) shows that through IPM, the average number of applications can be reduced from 4.5 to 0.5. The latter figure could probably be reduced further if the pesticide subsidy was completely removed.

Economics of Rice-Fish Culture

Spraying pesticides and stocking fish in ricefields are two activities which seem difficult to combine. Thus, an attempt to synthesize both systems must be preceded by an analysis of the economics of rice-fish culture. The rationale for this compares two alternative systems – rice-fish culture with no insecticide use, and the existing intensive rice systems at the present level of insecticide use.

Recent economic studies of rice-fish culture are presented by Amaritsut et al. (1988), Fujisaka and Vejpas (1990), and other authors in this volume (Table 4). It is interesting to note that most of these studies have been carried out in farmers' fields, allowing realistic conclusions to be drawn. On the other hand, most of these studies have been carried out in rainfed

Table 3. Probability to justify an insecticide application in rice from on-farm trials in the Philippines (1980–81) and Thailand (1984–86). (Sources: Zeddies and Waibel 1982; Waibel and Engelhardt 1988).

	Pest population level	
	Above threshold	Below threshold
Probability of event		
Thailand	0.10	0.90
Philippines	0.13	0.87
Probability of success[a]		
Thailand	0.25	0.30
Philippines	0.29	0.39

[a]The chance that IPM is better than farmers' practice.

Table 4. Selected economic indicators on rice-fish culture in Asia.

Source/Author	Country	Indicator/Parameter	Value (%)
Syamsiah et al. (this vol.)	Indonesia	Increase in rice yield equivalent[a] due to fish	20
Ahyaudin (this vol. [a])	Malaysia	Income from fish as part of total farm income	
		- Tenant farmer	9
		- Owner	7
Cagauan and Arce (this vol.)	Philippines	Decrease in fish yield due to insecticide use	43
Sevilleja (this vol.)	Philippines	Increase in net returns of rice production	28
Amaritsut et al. (1988)	Thailand	Increase in net returns from fish culture	
		- Research station	35
		- Farmers' field	18
Fujisaka and Vejpas (1990)	Thailand	Difference in rice yield equivalents[a] between adopters and non-adopters	65
Thongpan et al. (this vol.)	Thailand	Cases where net return was higher than rice monoculture	80

[a]Gross returns from fish divided by price of rice.

rice environments, where little, if any, pesticides have been used. In these areas with very limited opportunities to increase rice yields, rice-fish culture is almost a natural solution to increase returns per unit of land (Middendorp 1985). Also, decrease in wild fish production has stimulated cultural systems. For example, in Northeast Thailand, the area under rice-fish culture has increased from 700 ha in 1978 to 2,500 ha in 1986 (DOF 1988).

A summary of the empirical evidence on the economics of rice-fish culture is presented in Table 4. It must be stated that the conclusions which can be drawn from these results are somewhat limited, as studies were carried out in different countries using different parameters as indicators for the economics of rice-fish culture. Paired comparisons between rice-fish culture and rice monoculture showed a considerable relative increase in net returns due to fish. These were reported to be higher on research stations (Amaritsut et al. 1988) as compared to farmers' conditions (Sevilleja, this vol.). An indicator which demonstrates the stability of the rice-fish technology was presented by Thongpan et al. (this vol.) showing that in 20 out of 25 farm trials, rice-fish culture resulted in a higher net income.

Fujisaka and Vejpas (1990) reported 65% higher average net returns between adopters and non-adopters of rice-fish culture in Thailand. This, however, must be considered as a soft indicator, as adopters of rice-fish culture might be altogether better farmers. Other authors (Ahyaudin, this vol. [a]) provided different economic indicators showing that income from rice in Malaysia accounts for a small proportion of the total farm income. In Indonesia (Syamsiah et al., this vol.), it was found that stocking fish in ricefields increases rice yields; and in the Philippines (Cagauan and Arce, this vol.), the yield-decreasing effect of pesticides on fish yields was shown.

These results appear to confirm that the ricefield is a good environment for fish culture with an economic potential for integration with rice. This, however, is only possible if the agronomic requirements of rice can be met, with water control being the most crucial factor (Singh et al. 1980). This is often not possible where supplementary irrigation facilities are missing. Thus, considering water management alone, irrigated areas in the absence of pesticides will have a much higher potential for fish culture than rainfed areas. Therefore, the possibilities of fish culture should be assessed in view of the results from the economic analysis of pest control.

Rice-Fish Culture as a Tool of Integrated Pest Management

Although it has been reported that fish can act as a predator of insect pests (Chapman et al. 1987) this is not considered to be its main role in IPM. Rather, we should consider potential income from fish as an opportunity cost due to the use of insecticides. This means that the real cost of applying insecticides in rice is the net income foregone due to the decision not to stock fish. In terms of IPM, this means that the economic threshold could be shifted to a higher pest population level if the potential income from fish is considered.

The economic threshold level which is the breakeven point between costs and returns of a control measure can be expressed in terms of units of pest. This is done by dividing the cost of a control measure with the price of the crop. The result must be further divided by the effectiveness of a control measure as the latter will never be 100%. Considering these factors, farmers' threshold will be ET_1 in Fig. 3. The threshold can be calculated using the following formula:

$$ET_1 = (c/p) + (1/e) \qquad \text{...1)}$$

where ET_1 = economic threshold level;
c = cost of control;
p = price of rice; and
e = effectiveness of control.

A farmer who stocks fish in his ricefields faces a different situation as regard to pest control. If he intends to apply pesticides, there will be a trade-off between the pest loss prevented and the loss of fish incurred. Consequently, the loss from fish has to be considered as

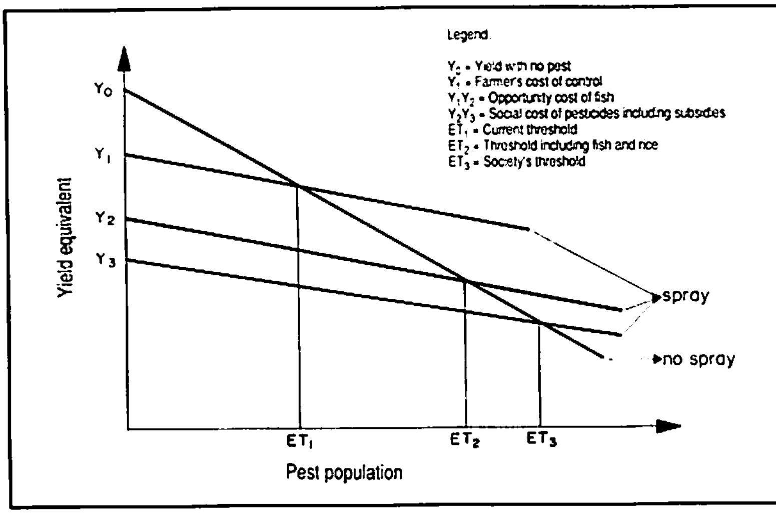


Fig. 3. Economic threshold levels using pesticides in rice-fish culture.

additional cost of pest control. Hence, the threshold will be shifted to ET_2 (Fig. 3).

We can recalculate the threshold for an insecticide application as follows:

$$ET_2 = ET_1 + ([Y_f + s]\text{-cf}) + (p_f/p_r) \qquad ...2)$$

where ET_2 = economic threshold level including net yield from fish;
Y_f = potential yield of fish;
p_f = price of fish;
p_r = price of rice;
s = survival coefficient of fish; and
cf = cost of fish production.

If we also include external effects or health and environmental costs which are usually associated with insecticide use, the threshold will increase even further to ET_3 in Fig. 3.

The following example illustrates this effect. Suppose a control measure costs US\$15/ha and the price of rice is \$0.15/kg, while the effectiveness of the pesticide application under farmers' conditions is 50%. The amount of rice that has to be saved if control shall pay off is 200 kg/ha or 5% for a potential yield of 4 t/ha. In Fig. 3, this leads to ET_1, the point where control becomes economically superior to no control, while the distance from Y_0 to Y_1 represents the cost of control in kilogram of rice. If we assume that a fish yield of 300 kg/ha can be reached, the latter will have to be corrected by the fish mortality due to insecticide use. Using the information given in Table 4, 60% of the fish would survive, leaving a net yield of 180 kg/ha. Assuming a benefit cost-ratio of fish production of 2.5, the cost of fish production would amount to 72 kg. With a price ratio of rice to fish at 1:3, the net returns of fish expressed in rice equivalents will be 324 kg. As a result, the threshold will be increased by more than 100%. Clearly, a farmer who stocks fish in his ricefield can tolerate a higher level of pest infestation before spraying is economically justified.

The implications of this upward shift in pest threshold is that the probability of a pest population reaching its threshold will decline. This decline is likely to occur at an increasing rate with every shift in the threshold. Using the probabilities of pest events explained earlier, a cumulative distribution function as shown in Fig. 4 will result. For the Philippine data (Table 3), the chance that a pest population will be below the economic threshold when the opportunity costs from fish are not considered is 0.87. When that cost is included, the chance that an insecticide application becomes necessary moves close to zero. This is also likely to be true for the Indonesian situation where

IPM. In fact, a major breakthrough for IPM could result as one of IPM's obstacles – a non-action extension message of 'do-not-spray' – could be changed into a more attractive message which is 'stock fish'. To arrive at practical extension information acceptable to a farmer, 'fish people' need to listen to 'pest people' and vice versa.

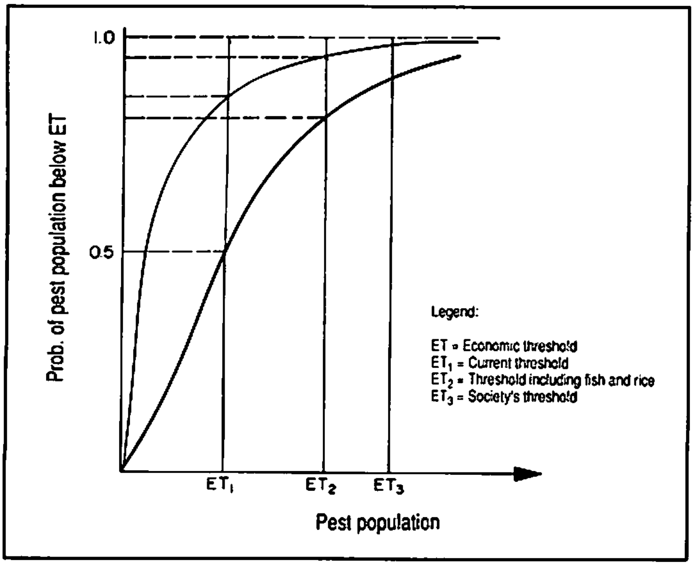


Fig. 4. The probability that the pest population is below the economic threshold (ET) based on on-farm trials in the Philippines, 1980–81 (thin curve) and Indonesia, 1988 (thick curve).

after the introduction of IPM, the chance of a pest population being below the threshold was 50% considering farmers' cost of the control without the opportunity cost from fish (Fig. 4).

One must emphasize that more empirical evidence is needed in order to verify these initial investigations. Pooling data on pest attacks from various organizations involved in pest management trials in farmers' fields would be one option. An alternative would be to use the expert's subjective assessment. Such data could be subjected to the kind of analysis already presented. Results could serve as a basis for further adaptive on-farm research using fish culture as a tool for

References

ADB. 1987. Handbook on the use of pesticides in the Asia-Pacific Region. Asian Development Bank, Manila, Philippines.

Amaritsut, W., W. Prasartsri and I.A. Craig. 1988. Crop protection and IPM in rainfed cropping systems in Northeast Thailand. *In* P.S. Teng and K.L. Heong (eds.) Pesticide management and integrated pest management in Southeast Asia. Maryland, USA.

Chapman, G., N. Bhasayavan, S. Tangpoonpol and S. Chautraniyom. 1987. The role of common carp, Nile tilapia and common silver barb as agents of rice insect pest and disease control in lowland paddies of Sakon Nakon, Thailand. Farming Systems Research Institute, Department of Agriculture, Bangkok, Thailand.

Cramer, H.H. 1967. Pflanzenschutz und Welternte. Pflanzenschutz-Nachrichten Bayer 20:1–523.

DOF. 1988. Freshwater fish production. Department of Fisheries Annual Report, Bangkok, Thailand.

Estores, R.A., F.M. Laigo and C.I. Adordionisio. 1980. Carbofuran in rice-fish culture, p. 53–59. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

FAO. 1988. Integrated pest management in rice in Indonesia: status after three cropping seasons. Unpublished project report, Food and Agriculture Organization. Jakarta, Indonesia.

Fujisaka, S. and C. Vejpas. 1990. Capture and cultured paddy fisheries in Khu Khat, Northeast Thailand. Thai J. Agric. Sci. 23:167–176.14.

Koesoemadinata, S. 1980. Pesticides as a major constraint to integrated agriculture-aquaculture farming systems, p. 45–53. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Litsinger, J.A., M.D. Lumaban, J.P. Bandong, P.C. Bantua, A.T. Barrion, R.F. Apostol and Ruendi. 1980. A methodology for determining insect control recommendations. IRRI Res. Pap. Ser. 46.

Litsinger, J.A. 1984. Assessment of need-based insecticides applications for rice. Paper presented at the MA-IRRI Technology Transfer Workshop, 15 March 1984, Los Baños, Laguna, Philippines.

Middendorp, A.J. 1985. Integrated rice-fish culture: practice and prospects. Working group report on Small Scale Integrated Aquaculture. International Agricultural Center, Wageningen, Netherlands.

Pathiak, M.D. and A.V. Dyck. 1973. Developing an integrated method of insect control. Pest Articles News Summary 19:4.

Repetto, R. 1985. Paying the price: pesticide subsidies in developing countries. World Resources Institute, Washington, DC.

Spiller, G. 1985. Rice-cum fish culture. FAP/WP-15, DOF/CIDA, Thailand.

Singh, V.P., A.C. Early and T.H. Wickham. 1980. Rice agronomy in relation to rice-fish culture, p. 15–35. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Waibel, H. and T. Engelhardt. 1988. Criteria for the economic evaluation of alternative pest management strategies in developing countries. FAO PPB 36 (1):27–33.

Waibel, H. 1986. The economics of integrated pest control in irrigated rice. *In* J. Kanz (ed.) Crop protection monographs. Heidelberg. 191 p.

Zeddies, J. and H. Waibel. 1982. Organisation und Evaluierung eines Pflanzenschutz-Beratungsprojektes in einem Entwicklungsland, GEWISOLA 23:525–553.

Chapter 4
Country Research and Extension Programs

On-Farm Research in Deepwater Rice-Fish Culture in West Bengal, India

PRATAP K. MUKHOPADHYAY*
D. N. DAS
B. ROY
ICAR/IRRI Deepwater Rice Pest Management Project
Rice Research Station, Chinsurah 712 102
West Bengal, India

MUKHOPADHYAY, P.K., D.N. DAS and B. ROY. 1992. On-farm research in deepwater rice-fish culture in West Bengal, India, p. 255–272. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

India has about 2.3 million ha of deepwater ricefields under cultivation. Farmers catch a limited amount of fish from this resource through traditional methods. Research efforts to use this resource by integrating aquaculture with deepwater rice farming have been ongoing.

On-farm rice-fish research focused recently on the deepwater ricefields of West Bengal, and covered physical surveys, ecological studies and fish production trials in farmers' fields. The activities included improvisation of methods in fish feeding and sampling. The studies revealed that a large potential exists for substantially increasing fish production in the deepwater rice areas of West Bengal.

Introduction

Deepwater rice is grown in areas where floodwaters rise more than 50 cm for more than one month during the growing season (Khush 1984). Since flooding must be sustained for at least one month, deepwater areas are distinguished from tidal wetlands (where water may rise more than 50 cm but only for a very short period) and flash flood areas (where rice may be submerged 50 cm or more for up to 7–10 days) (Catling et al. 1987). India has the largest area under rice cultivation in Asia (39 million ha) and also the largest area under deepwater rice (2.3 million ha) (Swaminathan 1978). Deepwater rice areas are located mostly in West Bengal, Assam, North Bihar, Eastern Uttar Pradesh and Orissa. About 0.46 million ha of the total deepwater rice area is in West Bengal. The immense variability in the area's hydrologic conditions, due to the variation in the

*Present address: Central Institute of Freshwater Aquaculture, Kausalyaganga, Bhubaneshwar, 751 002, Orissa, India.

flood timing, depth and duration of submergence depending on rainfall, topography and flood overflows from different sources, results in low productivity of the deepwater rice (Saran and Sahai 1979). The average range of deepwater rice yield in West Bengal is 0.8–1.0 t/ha (Singh 1981). The vast fertile water areas are potentially capable of supporting the production of fish and prawns.

Fish have long been harvested from deepwater rice areas usually by indigenous traps or constructing drainage ditches where fish collect as the area dries out. Water depths in ditches range from 0.5 to 2.0 m for five to six months a year.

A fisheries working group for the formulation of a seventh five-year plan (1985–90) set the target for total fish production from inland water bodies of 1.8 million t by the end of the plan period (Jhingran 1988). To ensure optimum utilization of all available inland water resources in the country, the culture of fish along with deepwater rice needs to be developed fully. Several studies to work out integrated rice-fish production system were initiated.

In this paper, a review of the traditional deepwater rice-fish farming and the past and recent studies on integrated rice-fish farming in deepwater areas are presented.

Traditional Deepwater Rice-Fish Farming and Constraints

The empirical understanding to harvest a crop of fish from deepwater ricefields is prevalent in many parts of India. Ricefields form the natural habitat for the large variety of indigenous species of fish which gain entry from nearby perennial water bodies. Fish grow on natural food. Farmers usually collect the fish during the rice-growing season and/or when the water level subsides. In some large, saucer-shaped fields, sumps are sometimes dug in a deep portion where fish gather towards the end of the rice-growing season. These fish are either netted out or reared for a further period of two to three months beyond the rice-growing season to harvest a better yield. The fish species caught are *Chanda* spp., *Colisa* spp., *Mystus* spp., *Apolocheilus* sp., *Amblyopharygodon* sp., *Rasbora* sp., *Macrognathus* sp., *Nandus* sp., *Channa* spp. and various prawn species. In some instances, rice plots are often bound with dikes to trap the naturally occurring species and rear them until the end of the rice-growing season. Instead of depending on nature, some farmers stock their plots with carp fry/fingerlings without any consideration of stocking density and species ratio. A yield of 200-300 kg/ha/season is generally obtained from such rice plots.

In West Bengal, traditional (*Agniban, Luxmidigha, Kalomota, Sadamota, Bakoi, Meghi, Khayersal* and *Jaladhi*) and improved rice varieties (NC 492, NC 491, CN 704–7–3, CN 705–18, NC 493 and CN 570–652–39–2) are cultivated. In Bihar, traditional varieties cultivated are *Janaki* and *Sudha*; in Assam, the *Bao* variety; in Uttar Pradesh, the *Jalmagna* variety; and in Orissa, Khajera, Tulashi Khajera, the *Mahipal* varieties. The production of traditional rice varieties range from 1.0 to 1.5 t/ha while those of improved varieties range from 2.0 to 3.5 t/ha.

In the states of Bihar, Assam and southern part of West Bengal, ricefields sometimes provide an ideal habitat for successful breeding and nursery for catfish and murrel. Considerable seed resources of these fish are available from such ricefield environments (Dehadrai 1979). Irrigated ricefields in east Godavari district of Andhra Pradesh, get naturally stocked with seed from Godavari River system and as they grow to fingerling size, the farmers collect fish in traps fixed at the inlets and outlets of the field.

The traditional deepwater rice-fish farming is constrained by: 1) the lack of rice-fish production technology; 2) reluctance to incorporate fish in deepwater because of lack of knowledge, fear from pesticidal damage to fish and the change of flooding or occurrence of drought; and 3) social problems such as multiple ownership and absentee farmers. Thus, deepwater rice-fish farming has not expanded in spite of the enormous opportunity for fisheries development, and the availability of seed fish even in the remotest rural areas.

Past and Recent Studies on Deepwater Rice-Fish Farming

A review of studies on rice-fish farming conducted revealed that relatively little research has been made on the development of aquaculture in deepwater ricefields. The rice varieties grown (floating or traditional tall) in deepwater rice areas generally have low yields (0.8–1.0 t/ha) (Singh 1981) in contrast to ordinary rice varieties cultivated in shallow rainfed conditions. The deepwater rice often experience a wide range of fluctuating environmental conditions from drought (during early growth period), submergence (during late growth period) to flood. Except in a few instances, the deepwater rice farmers cannot go for double cropping with improved rice varieties (*boro* rice) or for *"rabi"* crop like mungbean, sesame, lentil mustard, wheat and vegetables because they do not generally have irrigation facilities during the dry season. Thus, an integrated farming system involving aquaculture and improved deepwater rice with cropping patterns that are within the means of the limited-resource farmers, will increase the productivity of deepwater ricelands and improve nutrition of the people. It will also generate income for a large section of rural residents in several parts of the country.

Trials with the deepwater rice variety (*Jaladhi* 2), silver carp (*Hypophthalmichthys molitrix*) and prawn (*Macrobrachium rosenbergii*) in a sewage-treated field were conducted at the Central Inland Fisheries Research Institute (CIFRI) at Rahara in 1982. The yields obtained were 1,700 kg/ha of rice, 500 kg/ha of prawn and 200 kg/ha of fish in eight months (fish culture period was extended beyond rice cultivation period). The maximum growth of a male prawn was 125 g, while the female was 59 g (CIFRI Annual Report 1982, 1983).

Datta et al. (1986) reported results of rice-fish culture with the deepwater rice (*Jaladhi* 1) in a plot of 2.0 ha. The fish species were silver carp, catla (*Catla catla*), rohu (*Labeo rohita*) and mrigal (*Cirrhinus mrigala*). The maximum water depth attained was 160 cm. Fish yield of 1.1 t/ha was achieved in seven months. The yield of *Jaladhi* 2 rice after five months was 2.1 t/ha.

A current cooperative project on on-farm deepwater rice-fish research was initiated in 1986 by the International Rice Research Institute (IRRI), Indian Council of Agricultural Research (ICAR) and the Directorate of Agriculture (DA), government of West Bengal. The project aims to develop a better understanding of fish production in deepwater rice and identify new methods for farmers to exploit the full potential of this large resource. The project focuses on the deepwater areas of West Bengal. It includes a survey of deepwater rice areas, fish culture experiments and ecological studies.

Survey of West Bengal Deepwater Rice Areas

A preliminary survey of deepwater rice areas suitable for integrated agriculture/aquaculture operations was undertaken in 1986. The objectives of the survey were to find locations of deepwater areas suitable for fish culture; obtain general information on the environment; and investigate traditional rice-fish culture systems and indigenous technologies used by farmers. Field trips were made to major deepwater rice areas and to farmers and agricultural officers at the district, subdivision and block level.

Farmers commonly exploit wild fish and prawns from the deepwater ricefields. Fish grow on natural food and are harvested when the water recedes. The traditional capture fishery of this kind requires very little modification as regard field management. Farmers obtain fish at a subsistence level ranging from 50 to 100 kg/ha/season. Several such capture fisheries in deepwater rice areas were identified during the survey in West Bengal. Culture fisheries in conjunction with deepwater rice were found in some areas during the survey at Bhaluka (Harishchandrapur block in Malda) and at Simlon (Kalna block in Burdwan).

Capture fisheries in deepwater rice areas are found in Moina, Nandigram, Mahisadal blocks in Midnapore; Khargram and Bharatpur blocks in Murshidabad; Kalna block in Burdwan; Harishchandrapur block in Malda; Nimpith and Gosaba blocks in 24-Parganas (South); Haroa and Malancha blocks in 24-Parganas; and Chanditala I and II blocks in Hooghly.

Fish culture fisheries is virtually non-existent in West Bengal. Hence, fish culture trials and ecological studies were conducted in deepwater ricefields.

Fish Culture Trials and Ecological Studies

After the preliminary survey and some on-station trials, on-farm fish culture trials were undertaken to: 1) standardize and improvise the culture system of important food fishes (mainly carps) along with deepwater rice; 2) work out the effects of fish on growth and yield of deepwater rice and vice versa; 3) test the combined effects of growing diverse genotypes of rice along with different fish species to determine the best combination of rice and fish species and their interaction towards higher productivity; and 4) determine the cost-benefit ratio of such an integrated culture system. Ecological studies were undertaken simultaneously to have an understanding of the flora and fauna of a typical deepwater ricefield (at village Pearapur, near the base station Chinsurah: Latitude 22°52'N, Longitude 88°24'E, Altitude 8.62 m AMSL) as well as to examine the physico-chemical features of water in the same field. These studies would provide baseline data on the ecology of deepwater rice with regard to its suitability for integrated fish culture.

Fish Culture Experiments

Two sets of experiments were completed. The first experiment compared rice and fish yields using treatments of deepwater rice alone; rice with fish; and rice with fish plus supplementary fish feed. The second experiment compared rice and fish yields from plots applied with dried poultry droppings and composted cowdung. These experiments were conducted during the *kharif* season, 1987. The trials in the first experiment were conducted at four sites in West Bengal – Chinsurah (Hooghly), Gosaba (sites i and ii) (24 Parganas-South), Sabang (Midnapore) and Girirchalk (Midnapore); while second experiment trials were at Sabang and Girirchalk (Midnapore) only (Fig. 1).

Experiment 1

LAYOUT

At Chinsurah, the four plots used measured 200 m^2; at Gosaba (sites i and ii), the two plots measured 450 m^2 and 1,248 m^2; at Sabang, 180 m^2 each; and at Girirchalk, 600 m^2 each. Each plot had a central sump which provided a shelter for fish and facilitated periodic fish sampling for monitoring growth. The sump area

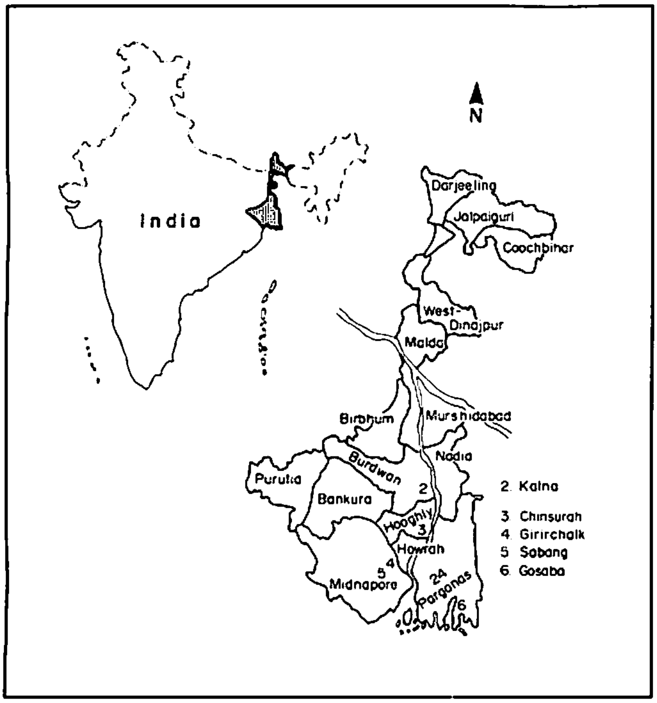


Fig. 1. Outline map of West Bengal, showing sites for deepwater rice-fish culture trials, 1987 (*kharif* season).

was 2.25 m^2 and 1 m deep. Standard agronomic practices for cultivation of deepwater rice was followed. Plots were prepared by the middle of April 1987 and each plot was provided with a water depth gauge fixed in a suitable location. An elongating-type deepwater rice variety (NC-492 Sabita) was sown by dibbling (done at Chinsurah on 13 April 1987; at Gosaba on 29 May 1987; at Sabang on 1 June 1987; and at Girirchalk on 14 June 1987). With monsoon showers causing gradual accumulation of water in the field, deepwater rice plants grew rapidly, keeping pace with water accumulation. Rice stand count was taken monthly from July onwards. Water quality parameters (dissolved oxygen, pH, specific conductivity and temperature) were monitored every week; water depth was recorded daily and samples were analyzed for various plankton species. At Chinsurah, the maximum water depth attained was 105 cm and water remained above 50 cm for more than eight weeks; at Gosaba, 106 cm and 12 weeks; at Sabang, 90 cm and 10 weeks; and at Girirchalk, 92 cm and 13 weeks.

After the rice seedlings were established, various species of fingerlings (10–12 cm) were released into the plots at 1 fish/m^2 in all sites (Table 1). The fish were released on 8, 12, 16, and 24 August 1987 at Sabang, Chinsurah, Girirchalk and Gosaba sites, respectively. Species stocked comprised 15% surface feeder, 35% column feeder and 50% bottom feeder. The fish culture period in all the sites ranged from 110 to 130 days.

FISH SAMPLING

To monitor fish condition and growth, periodic fish sampling was done in the experimental fields by netting. Sampling by netting was not very effective and it was felt necessary to evolve a suitable device for sampling fishes from deepwater rice-fish culture experiments. A preliminary trial using a local fish trap with a lamp inside was tried. This was placed in the central sump in the field. The attempt was partially successful; further tests to improve the trap for farmers' use will be done.

FEEDING SCHEDULE

In the feeding treatment, the fish were provided with supplementary feeds 11 days after stocking. An inexpensive feed mixture of ground nut oil cake (50%), rice bran (25%), fish meal (5%), soybean meal (18%) and vitamin mineral pre-mix (2%) was given at 2% of the total fish biomass per day, six days a week. The amount of feed was adjusted after each sampling. Feeds were administered in dough and in granular forms to enable uniform feeding by surface-, column- and bottom-dwelling fishes.

FABRICATION OF A FISH-FEEDING DEVICE

To economize on feeding, a feeding device was fabricated. The idea was to determine: 1) the optimum utilization of feed to prevent waste; and 2) the proper feeding time of various carp species to improve feed assimilation.

The device was prepared from a hollow bamboo with an inside diameter of 6–7 cm, with its bottom portion (30 cm long) made into a comb-like structure along the circumference, and the inside filled a with granular feed mixture. The whole bamboo structure was then tied to a peg and securely fixed in the middle of the sump in the experimental field in such a way that the bottom end of the feeder remained at the level of the field. The sound made when the fish flock around the device and eat the feeds can be captured by the vibrating movement of the upper end of the bamboo pole. When fish nibble at the feed, their body contacts caused a water movement similar to that caused by a float attached to an angling rod. Observations were recorded for a 12-hour period (from dawn to dusk) daily for seven days when the level of water in the ricefield was about 70 cm. The amount of feed consumed was determined by weighing out the leftover feed (after one hour) in the feeder. Preliminary results from a single site indicated that fish preferred to be fed in the afternoon. However, no definite feeding pattern by fish could be established.

HARVESTING OF RICE AND FISH

Rice yields were evaluated following the recommended crop cut method (Clay et al. 1978) wherein rice panicles were quantitatively collected from a randomly selected area (5 m²) in the field. These were then sundried and the grains collected after careful threshing. Rice grains were cleaned and dried to moisture content of 10–12%. Total grain weight was then determined and the dry crop yield expressed on the basis of 14% moisture content. After rice harvest, fish were harvested by draining the field.

RESULTS

The stocking and production data of rice and fish are shown in Tables 1 to 3. Tables 1 and 2 show that common carp (*Cyprinus carpio*) and silver barb (*Puntius javanicus*) generally had the best growth vis-a-vis the other species in both rice-fish treatments (control and with fish supplemental feedings). This was the case except in Girirchalk and in other sites where common carp was not part of the stock. Calbasu, rohu and catla were next to common carp and silver barb. From Table 3, rice yields in rice-fish systems with and without feeding increased slightly (1.0–10.6%) in all the sites except Sabang where yield decreased by 2.2%. Net fish yield ranged from 85 to 535 kg/ha in the control treatment and 186 to 945 kg/ha with supplemental feedings. The increase in yield of fish that had feeding over those that were unfed ranged from 77 to 119%.

Experiment 2

LAYOUT

Three plots of 180 and 600 m² area were used in Sabang and Girirchalk, respectively. Treatments were: deepwater rice alone; rice with fish plus composted cowdung; and rice with fish plus dried poultry droppings. The amount of nitrogen from each organic manure was equal (isonitrogenous). Nitrogen content was analyzed and found to be 1.8% in the poultry droppings, while composted cowdung had only 0.6%. The application rate for composted cowdung and poultry droppings at Sabang were 15 and 5 kg/week, respectively; while at Girirchalk 50 and 16.5 kg/week, on wet weight basis.

Plots were provided with trenches 1.5 m wide and 1.0 m deep at two sides of

Table 1. Stocking and production data from Experiment 1 investigating the effects of fish supplemental feeding in deepwater rice-fish culture, kharif season 1987. (Deepwater rice variety: NC-492 *Sabita*; stocking rate: 1 fish/m^2; fish culture period: 110-130 days).

Experimental site	Rice yield (kg/ha)	Fish species	No. stocked	Stocking		Harvesting		Net weight gain (g)	Fish yield (kg/ha)	Contribution by weight (%)
				Length (cm)	Weight (g)	Length (cm)	Weight (g)			
Chinsurah, Hooghly	1,741	Rohu (*Labeo rohita*)	30	11.4	20.5	19.5	122.5	102.0	1,215	14.3
		Catla (*Catla catla*)	10	14.3	57.9	18.3	128.5	70.6		4.6
		Mrigal (*Cirrhinus mrigala*)	20	14.9	10.5	19.6	116.6	106.1		4.9
		Bata (*Labeo bata*)	40	4.6	5.2	15.6	60.0	54.8		4.4
		Silver carp (*Hypophthalmichthys molitrix*)	20	20.0	135.0	24.8	262.5	127.5		11.9
		Common carp (*Cyprinus carpio*)	20	13.3	33.3	26.3	425.0	391.7		33.3
		Calbasu (*Labeo calbasu*)	40	8.0	8.0	18.0	150.0	142.0		17.7
		Puntius (*Puntius javanicus*)	10	9.0	11.3	22.8	250	238.7		9.0
Sabang, Midnapore	1,640	Rohu (*L. rohita*)	27	12.2	30.3	20.0	91.6	61.3	755	18.7
		Catla (*C. catla*)	9	16.2	62.0	16.8	70.0	8.0		4.8
		Mrigal (*C. mrigala*)	18	12.7	21.5	15.9	40.0	18.5		14.7
		Bata (*L. bata*)	36	10.0	11.0	13.0	20.0	9.0		4.6
		Silver carp (*H. molitrix*)	18	26.2	186.0	28.3	213.0	27.0		30.2
		Common carp (*C. carpio*)	18	10.8	32.0	18.2	140.9	108.9		20.6
		Puntius (*P. javanicus*)	9	12.0	19.2	18.6	87.5	68.3		6.4
Girirchalk, Midnapore	2,950	Rohu (*L. rohita*)	90	13.7	38.7	23.3	119.6	80.9	941	17.6
		Catla (*C. catla*)	30	17.5	90.6	23.0	183.3	92.7		8.0
		Mrigal (*C. mrigala*)	60	18.4	78.7	22.9	82.8	4.1		8.1
		Bata (*L. bata*)	120	13.1	25.2	14.8	46.1	20.9		7.9
		Silver carp (*H. molitrix*)	60	17.0	77.8	19.7	85.4	8.4		8.3
		Common carp (*C. carpio*)	60	16.0	83.5	25.8	144.7	61.2		14.3
		Calbasu (*L. calbasu*)	120	16.2	87.5	21.9	175.0	87.5		30.7
		Puntius (*P. javanicus*)	30	14.6	52.0	19.2	129.4	77.4		5.2
Gosaba (i) 24 Parganas(s)	2,145	Rohu (*L. rohita*)	135	12.5	20.0	21.0	140.8	120.8	361	42.5
		Catla (*C. catla*)	25	13.2	40.2	21.2	139.6	99.4		14.8
		Mrigal (*C. mrigala*)	225	9.5	14.7	15.6	68.5	53.8		19.8
		Silver carp (*H. molitrix*)	45	9.1	14.5	24.0	148.6	134.1		13.9
		Puntius (*P. javanicus*)	23	8.5	11.3	20.2	184.8	173.5		9.0
Gosaba (ii) 24 Parganas(s)	2,115	Rohu (*L. rohita*)	375	12.5	20.0	17.7	91.8	71.8	361	33.9
		Catla (*C. catla*)	63	13.2	40.2	20.2	125.0	84.8		21.1
		Mrigal (*C. mrigala*)	625	9.5	14.7	13.7	30.6	15.9		31.4
		Silver carp (*H. molitrix*)	125	9.1	14.5	12.5	22.7	8.2		1.8
		Puntius (*P. javanicus*)	63	8.5	11.1	18.0	94.4	83.3		11.8

Table 2. Stocking and production data in rice-fish treatment (no fertilizers, supplementary feed or organic manure) from Experiment 1, *kharif* season, 1987.

Experimental site	Rice yield (kg/ha)	Fish species	No. stocked	Stocking		Harvesting		Net weight gain (%)	Fish yield (kg/ha)	Contribution by weight (%)
				Length (cm)	Weight (g)	Length (cm)	Weight (g)			
Chinsurah	1,729	Rohu *(Labeo rohita)*	30	11.4	20.4	17.1	75.0	54.6	813	11.1
		Catla *(Catla catla)*	10	14.4	57.9	18.3	114.3	56.4		4.9
		Mrigal *(Cirrhinus mrigala)*	20	5.0	10.6	18.9	81.2	70.6		4.9
		Bata *(Labeo bata)*	40	4.6	5.2	13.8	33.3	28.1		5.0
		Silver carp *(Hypophthalmichthys molitrix)*	20	20.0	135.0	22.6	186.1	51.1		17.0
		Common carp *(Cyprinus carpio)*	20	13.3	33.3	24.83	350.0	316.7		31.0
		Calbasu *(Labeo calbasu)*	40	8.0	8.0	17.5	125.0	117.0		13.2
		Puntius *(Puntius javanicus)*	10	9.0	11.3	21.7	228.6	217.3		12.9
		Nile tilapia *(Oreochromis niloticus)*	10	9.2	16.0	-	-			
Gosaba (i)	2,141	Rohu *(L. rohita)*	135	12.5	20.0	18.5	107.7	87.7	267	41.8
		Catla *(C. catla)*	25	13.3	40.2	19.89	128.4	88.2		15.5
		Mrigal *(C. mrigala)*	225	9.5	14.8	15.3	66.7	51.9		30.6
		Bata *(L. bata)*	0	-	-		-			
		Silver carp *(H. molitrix)*	45	9.1	14.5	18.0	73.3	58.8		3.6
		Common carp *(C. carpio)*	0	-	-		-			
		Calbasu *(L. calbasu)*	0	-	-		-			
		Puntius *(P. javanicus)*	25	8.5	11.1	19.9	122.2	111.1		8.4
		Nile tilapia *(O. niloticus)*	0	-	-		-			
Gosaba (ii)	2,102	Rohu *(L. rohita)*	375	12.5	20	17.3	85.7	65.7	268	25.0
		Catla *(C. catla)*	62	13.5	57.9	18.3	84.2	26.3		15.8
		Mrigal *(C. mrigala)*	625	9.5	14.8	14.0	29.6	14.8		41.5
		Bata *(L. bata)*	0	-	-		-			
		Silver carp *(H. molitrix)*	125	9.1	14.5	10.5	21.2	6.7		-
		Common carp *(C. carpio)*	0	-	-		-			
		Calbasu *(L. calbasu)*	0	-	-		-			
		Puntius *(P. javanicus)*	62	8.5	11.1	47.5	83.3	72.2		45.5
		Nile tilapia *(O. niloticus)*	0	-	-	-	-	-		

Table 3. Stocking weights and estimated yields (kg/ha) in rice-fish and control treatments from Experiment 1.

Experimental site	Crop	Rice only (control)[a]	Rice-fish[b]			Rice-fish plus supplementary feed[c]		
			Stocking weight	Harvest weight	Net gain	Stocking weight	Harvest weight	Net gain
Chinsurah	Rice	1,574		1,729			1,741	
	Fish	-	278	813	535	270	1,215	945
Gosaba (i)	Rice	2,100		2,141			2,145	
	Fish	-	177	267	90	175	361	186
Gosaba (ii)	Rice	1,978		2,102			2,115	
	Fish	-	183	268	85	175	361	186
Sabang	Rice	-		-			1,640	
	Fish	-	-	-	-	348	755	407
Girirchalk	Rice	-		-			2,950	
	Fish	-	-	-	-	595	941	346

[a]No fertilizers, organic matter or supplementary feed.
[b]Rice plus fish without fertilizers, supplementary feed or organic manure.
[c]Crude protein (Nx6.25) - 31.1%; crude lipid (ether extract) - 10.2%; crude fiber - 11.6%; crude ash - 9.1%; nitrogen free extract - 38%.

each plot. Plot preparation, deepwater rice variety, fish species combination, proportions and stocking densities remained similar. Details of stocking, culture conditions and harvesting are shown in Table 4. Periodic data collection on both rice and fish were done as in the first experiment.

During the experimental period at Sabang, the silver carp and catla species developed gill rot disease. This was detected during sampling in mid-October 1987. However, the disease was controlled with the application of lime at 60 kg/ha. Poultry droppings and composted cowdung were applied eight days after fish stocking and continued weekly thereafter until two weeks before rice harvest.

HARVESTING OF RICE AND FISH

The same procedures in harvesting rice and fish were done as in experiment 1. Harvest of rice and fish at Sabang was done on 13–14 December 1987 and at Girirchalk on 15–16 December 1987.

RESULTS

Rice and fish production data and net fish yields are shown in Tables 4–5. *Puntius javanicus* and common carp also performed well at Girirchalk and Sabang under treatment conditions of composted cowdung and dried poultry droppings. Among other species, rohu grew better at Girirchalk and tilapia (*Oreochromis* sp.) at Sabang. Rice yields, however, did not show any significant change in all the treatments.

Data on pest and disease incidence are presented in Table 6. In plots with deepwater rice and fish, the incidence of damage by various pests were less, compared to the respective controls (plot with deepwater rice only). This indicated that stocking of fish in deepwater rice might lead to better crop production.

CONTROL OF CRABS IN DEEPWATER RICEFIELDS

The freshwater crabs *Paratelphusa hydrodomus* and *P. spinigera* pose a serious problem in deepwater rice cultivation

Table 4. Stocking and production data from Experiment 2 comparing composted cowdung and dried poultry droppings in deepwater rice-fish culture, *kharif* season 1987.

Experimental site	Treatment	Rice yield (kg/ha)	Fish species	No. stocked	Stocking		Harvesting		Net weight gain (g)	Fish yield (kg/ha)	Contribution by weight (%)
					Length (cm)	Weight (g)	Length (cm)	Weight (g)			
Sabang, Midnapore	Composted cowdung	1,602	Rohu (*Labeo rohita*)	27	12.2	30.3	17.4	72.3	42.0	757	14.3
			Catla (*Catla catla*)	9	16.2	62.0	20.6	133.3	71.3		7.7
			Mrigal (*Cirrhinus mrigala*)	18	12.7	21.5	13.0	42.6	21.1		11.7
			Bata (*Labeo bata*)	36	10.0	11.0	13.3	28.8	17.8		5.9
			Silver carp (*Hypophthalmichthys molitrix*)	18	26.2	186.0	28.3	217.8	31.8		28.5
			Common carp (*Cyprinus carpio*)	18	10.8	32.0	16.6	119.4	87.4		16.5
			Calbasu (*Labeo calbasu*)	36	12.1	30.0	16.4	66.6	36.6		3.7
			Puntius (*Puntius javanicus*)	9	12.0	19.2	19.0	122.2	103.0		8.7
			Nile tilapia (*Oreochromis niloticus*)	9	10.5	25.0	16.3	83.3	58.3		3.0
Girirchalk, Midnapore	Composted cowdung	2,850	Rohu (*L. rohita*)	90	13.7	38.7	16.8	70.0	31.3	802	11.0
			Catla (*C. catla*)	30	17.5	90.6	17.5	103.0	12.4		6.2
			Mrigal (*C. mrigala*)	60	18.5	78.7	21.4	86.9	8.2		11.7
			Bata (*L. bata*)	120	13.1	25.2	15.7	41.6	16.4		10.6
			Silver carp (*H. molitrix*)	60	17.1	77.8	20.5	83.3	5.5		25.7
			Common carp (*C. carpio*)	60	16.1	83.5	23.0	222.7	139.2		18.0
			Calbasu (*L. calbasu*)	120	16.2	87.5	17.7	88.0	0.5		10.6
			Puntius (*P. javanicus*)	30	14.6	52.0	18.6	104.2	52.2		6.2
Sabang, Midnapore	Dried poultry droppings	2,399	Rohu (*L. rohita*)	27	12.2	30.3	15.7	58.0	27.7	692	10.5
			Catla (*C. catla*)	9	16.2	62.0	17.5	75.0	13.0		5.3
			Mrigal (*C. mrigala*)	18	12.7	21.5	16.1	34.0	12.5		16.1
			Bata (*L. bata*)	36	10.0	11.0	12.5	27.7	16.7		7.4
			Silver carp (*H. molitrix*)	18	26.2	186.0	29.2	235.0	49.0		30.5
			Common carp (*C. carpio*)	18	10.8	32.0	16.0	100.0	68.0		14.0
			Puntius (*P. javanicus*)	9	12.0	19.2	21.5	200.0	180.8		15.3
Girirchalk, Midnapore	Dried poultry droppings	3,160	Rohu (*L. rohita*)	90	13.7	38.7	22.8	130.0	91.3	922	16.6
			Catla (*C. catla*)	30	17.5	90.6	22.8	176.5	85.9		7.4
			Mrigal (*C. mrigala*)	60	18.5	78.7	23.1	130.0	51.3		9.5
			Bata (*L. bata*)	120	13.1	25.2	17.7	40.0	14.8		6.9
			Silver carp (*H. molitrix*)	60	17.0	77.8	21.6	110.3	32.5		11.1
			Common carp (*C. carpio*)	60	16.0	83.2	24.6	284.0	200.8		23.6
			Calbasu (*L. calbasu*)	120	16.2	87.5	16.7	110.0	22.5		14.9
			Puntius (*P. javanicus*)	30	14.6	52.0	18.5	250.0	198.0		10.0

Table 5. Stocking weights and estimated yields (kg/ha) from Experiment 2.

Experimental site	Crop	Rice only (control)	Rice-fish plus composted cowdung			Rice-fish plus poultry droppings		
			Stocking weight	Harvest weight	Net gain	Stocking weight	Harvest weight	Net gain
Sabang,	Rice	1,677	-	1,602	-	-	2,399	-
Midnapore	Fish	-	420	757	337	348	692	344
Girirchalk,	Rice	2,920	-	2,850	-	-	3,160	-
Midnapore	Fish	-	595	802	207	595	922	327

Table 6. Summary of pest and disease incidence in rice-fish culture plots.

Experimental site	Plant stage	Diseases and pests[a]	
		Control plot (Deepwater rice only)	Experimental plot (Deepwater rice-fish)
Girirchalk	Early elongation	GH, GLH, WM, BLS (3.3), LTD (16.1)	GH, GLH, WM BLS (8.8), LTD (21.2)
	Grain filling	GLH, Rat, Ear cutting caterpillar, SB (17.4), FS (11.6), KB (4.7)	GH, Rat, SB (8.9), FS (2.7), KB (7.3)
Sabang	Early elongation	GM, LF, GLH, GH, SB	WM, LF, GLH, GM, GH
	Grain filling	SB (41.1) FS (14.3), KB (9.6)	SB (25.7) FS (2.6), KB (6.5)
Gosaba	Flowering	SB (31.3), HISPA	SB (14.3), HISPA, GH

[a]GH = grasshopper; GLH = greenleaf hopper; WM = whorl maggot; GM = gall midge; LF = leaffolder; SB = stemborer; BLS = bacterial leaf streak; LTD = leaf tip drying; FS = false smut; KB = kernel bunt. Figures in the parentheses denote per cent damage of stem, leaves or panicles.

in West Bengal. The infestation is more acute when fish culture is integrated with deepwater rice cultivation. Generally, the crabs cut the stem with their sharp chelicerae during the growing phase of the deepwater rice, thereby decreasing the total yield. Attempts were made to deal with this problem during the experiments. One was by using a simple device normally used by the farmers in capturing wild fish and prawns from the ricefield. The device consisted of a box-like structure (Fig. 2) made of thin bamboo sticks hand-woven with nylon thread. This has one or more smooth entry points made in such a way that they cannot be used as exit by the trapped organisms (i.e., the small bamboo sticks projecting inside the box prohibit them from getting out). Several such boxes (with snail's meat as baits) were placed in the experimental field under submerged conditions near the dikes. These were placed at night and lifted out the next morning. On the average, 30–40 crabs/trap can be collected daily. This device helped in minimizing to a great extent the crab menace in the deepwater ricefield without using insecti-

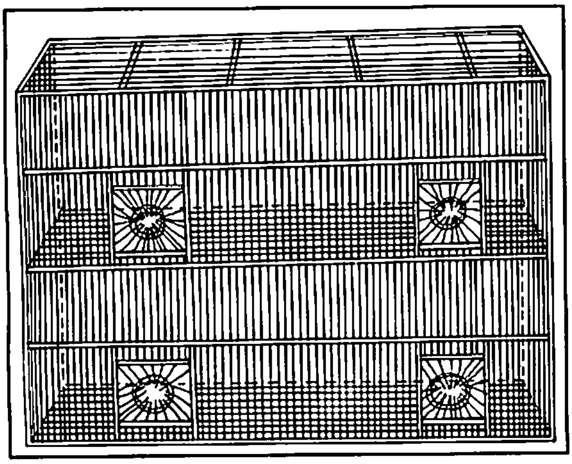


Fig. 2. A device used to trap field crabs.

cides or other chemical poisons. The crabs, being edible, provided an additional protein food for the farmers at virtually no input cost.

Ecological Studies

This component of deepwater rice-fish research was done in the deepwater ricefield at Pearapur near Chinsurah, the base station. On 28 July 1987, when water depth was 20 cm, monitoring started: dissolved oxygen, pH, specific conductivity and water temperature by week; and water depth, rainfall and light intensity per day. Monitoring continued until 24 November 1987 when water depth receded to 21 cm from 144 cm during flooding. Physico-chemical characteristics of water were recorded 10 cm below the water surface; light intensity was measured on the surface beneath the rice canopy.

Wild fish and prawns were collected daily using locally made fish traps positioned at 10 different places in the field from 22 July until 29 November 1987. The species composition of fish and prawns caught are presented in Table 7. In addition to the use of local traps, fish catch was made through treatment of rotenone in bamboo mat enclosures (600 m^2). Rotenone was applied at 4.0 ppm mixed with a dough made of wheat flour. Collections of plankton were randomly made with a one-liter mug from the field once a week from July to November. In each collection, 50 liters of water taken from about 10 cm from the surface were filtered through a plankton net. The plankton were preserved in 4% formalin and identified within 15 days. During analysis, collected water samples were concentrated to a volume of 10 cc. Then 1-2 drops of the homogeneous mixture from this concentrate were placed on glass slides, counted, and the number expressed in cells/liter. First collection was made on 28 July and weekly thereafter until 24 November 1987.

Aquatic macroorganisms were sampled weekly using a special sampling net devised for the purpose and preserved in 4% formalin. These were identified and their numbers counted.

For collection of benthic organisms, a set of six polyethylene trays (each measuring 30 x 25 x 6 cm) were placed in the field with proper markings at different places on 28 July; 4 and 28 August; 8 and 29 September; and 27 October 1987 then lifted out on 28 August; 8 and 29 September; 6 and 27 October; and 1 December 1987, respectively. The trays were filled with soil covering one fourth of their volume and then left in the field for one month. After the trays were taken out of the water, the large organisms were separated, their numbers recorded and identifications by family done. To study the periphyton community, clean glass slides were hung randomly into the water from bamboo sticks from various places in the field. After about 40 days, slides were taken out and studied under a microscope. Besides this, few rice stems were also collected to study qualitatively the attached organisms.

RESULTS

As the amount of rainfall intensified during the season (Fig. 3), the water depth in the deepwater ricefields increased from 20 cm (28 July 1987) to a

Table 7. Fish and prawns collected from 22 July to 29 November 1987 from deepwater ricefields at Pearapur, Hooghly, West Bengal.[a]

Species	Number	Total catch biomass[b] (g)	Percentage (%)
Fish			
Chanda ranga			
C. nama	4,054	7,290	21
Puntius ticto			
P. sophoro			
P. sarana			
Puntius sp.	3,743	36,494	19
Colisa pectoralis			
C. fasciata	2,691	10,091	14
Rasbora daniconicus	1,774	2,661	9
Aplochelus punchax	520	525	3
Channa punctatus	373	22,380	2
Mystus vitatus	310	1,550	2
Others	2,004	55,310	10
Freshwater prawns (including *M. rosenbergii*)	3,837	12,662	20
Total	19,306	148,963	100

[a]Sampling was done using local devices or fish traps which were emptied on alternate days.
[b]Calculated from preserved specimens.

maximum depth of 144 cm (31 August 1987). From September to 12 October, a static water level condition prevailed (115–144 cm). From then onwards, water receded from 95 to 45 cm until 6 November. On 24 November, water level decreased to 21 cm.

Variations in water depth, dissolved oxygen, pH, specific conductivity, temperature and light intensity are depicted in Fig. 4. Physico-chemical studies indicated that the environment was well-suited for fish culture. Catches of wild fish and prawns revealed that a large variety of fish are available. The monthly catch was highest during the month of November (55% of the total catch) and lowest in the month of July (1%). A similar result was obtained from the catch through rotenone treatment.

Analysis of the plankton population showed that phytoplankton was predominant in the field (Fig. 5). Of the total phytoplankton, Chlorophyceae constituted 36%; Cyanophyceae, 26%; and

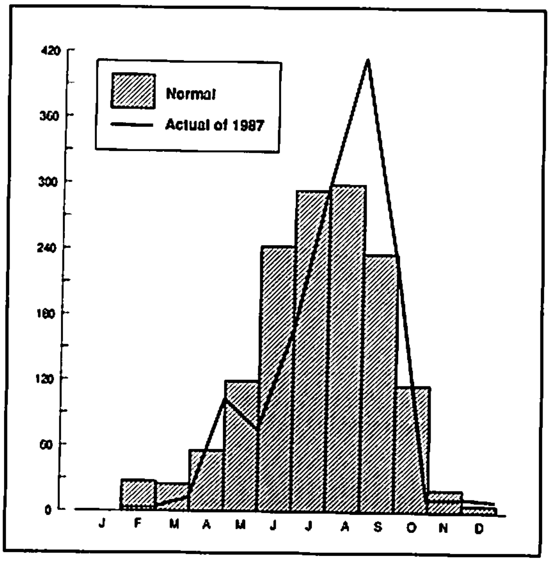


Fig. 3. Rainfall data (mm) at the Chinsurah rice-research weather station. (Recorded at the crop weather station, Rice-Research Station, Chinsurah.)
Latitude : 22°52'N
Longitude : 88°52'E
Altitude : 8.62 m AMSL

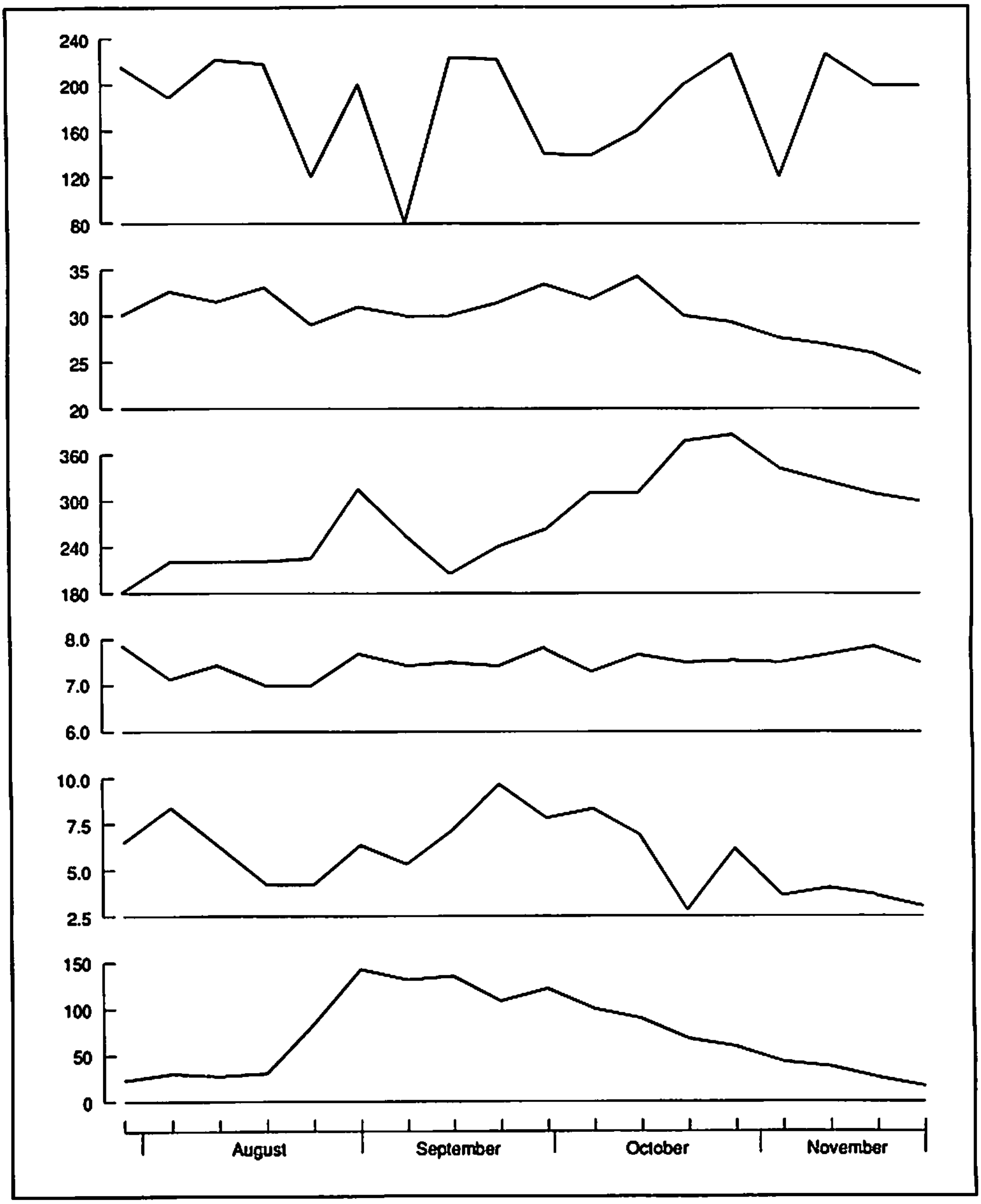


Fig. 4. Physico-chemical characteristics of water from a deepwater field in Pearapur, Hooghly, West Bengal, *kharif* season, 1987.

Bacillariophyceae, 38% (Fig. 6). The common forms of zooplankton like protozoa, rotifera, cladocera, copepoda and ostracoda were encountered (Fig. 7).

Studies on other forms of aquatic macroorganisms besides piscine and planktonic forms revealed that molluscan population was abundant. Arthropods were also recorded in high amounts. About 74 and 22% of the total catch during the season were molluscs and arthropods, respectively (Fig. 8).

The soil fauna collected from the field by tray method revealed that mollusca

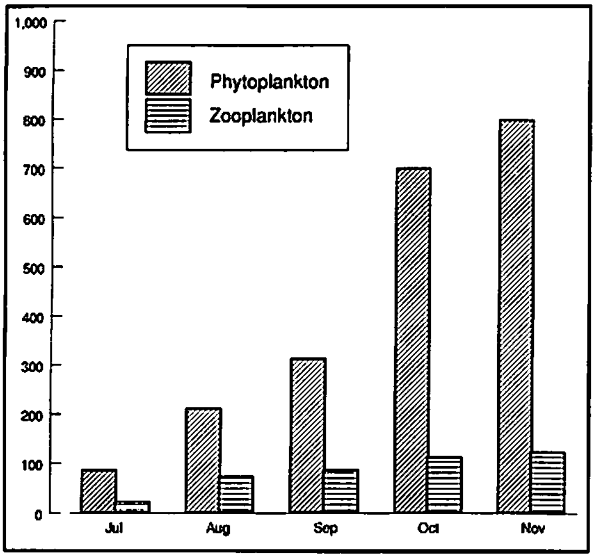


Fig. 5. Plankton populations from a deepwater ricefield at Pearapur Village, Hooghly District, West Bengal, *kharif* season 1987.

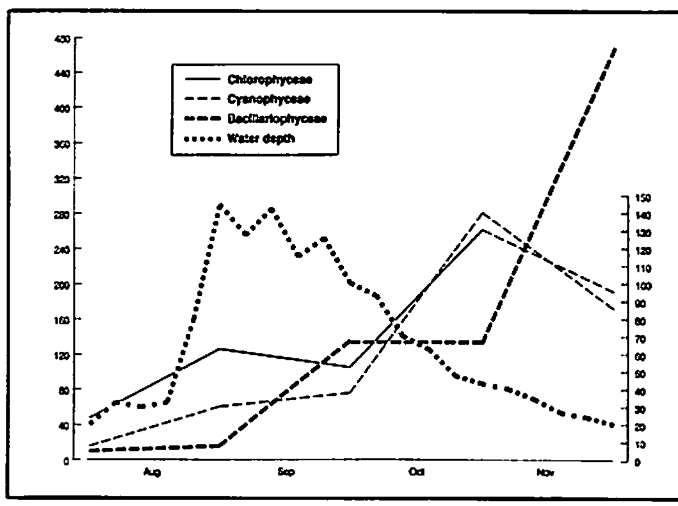


Fig. 6. Different groups of phytoplankton populations from a deepwater ricefield in Pearapur Village, Hooghly District, West Bengal, *kharif* season 1987.

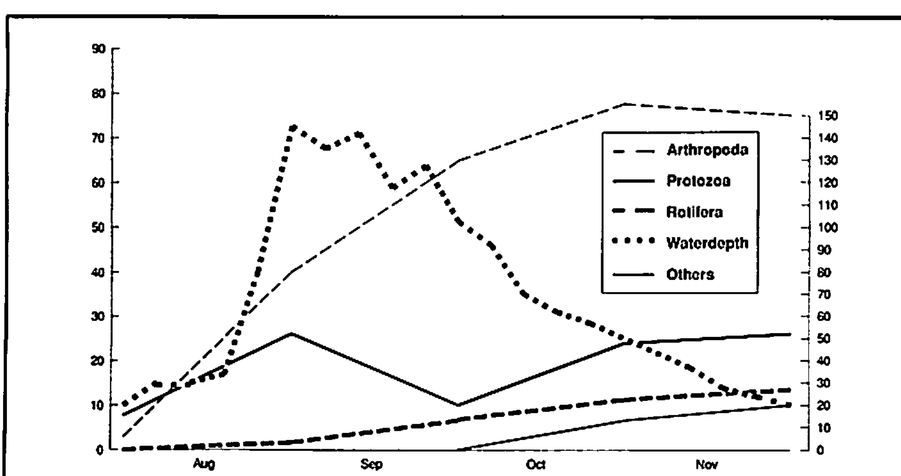


Fig. 7. Different groups of zooplankton from a deepwater ricefield in Pearapur Village, Hooghly District, West Bengal, *kharif* season 1987.

and annelida contributed 68 and 21%, respectively (Fig. 9). A qualitative study of the periphyton community revealed that most available epiphytic algae were: *Anabaena*, *Oedogonia*, *Melosira*, *Spirulina*, *Characium*, *Rivularia*, *Gleotrichia* and *Navicula*. Besides all these, a major biotic feature of deepwater ricefields was the aquatic vegetation (weeds). Fifteen such weeds were identified from the deepwater ricefield. A list of major species of the flora and fauna encountered is presented in Table 8.

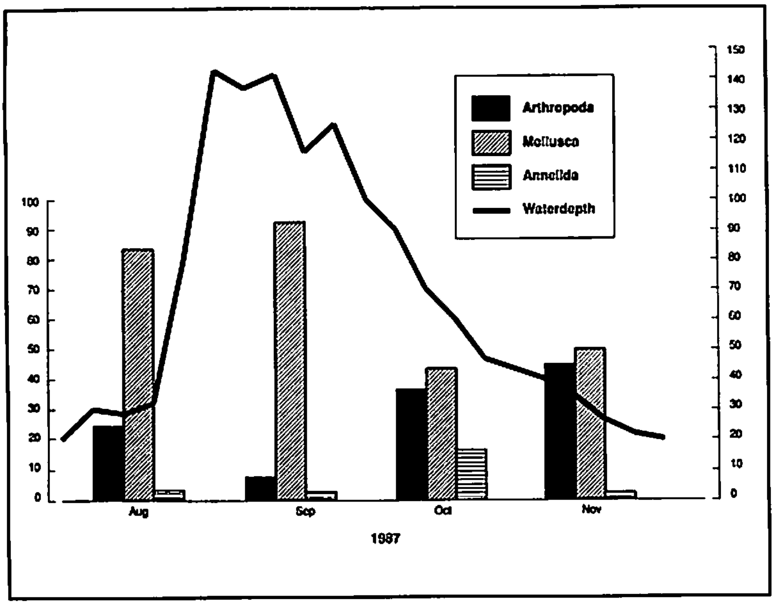


Fig. 8. Seasonal variation of aquatic macroorganisms in a deepwater ricefield in Pearapur Village, Hooghly District, West Bengal, *kharif* season 1987.

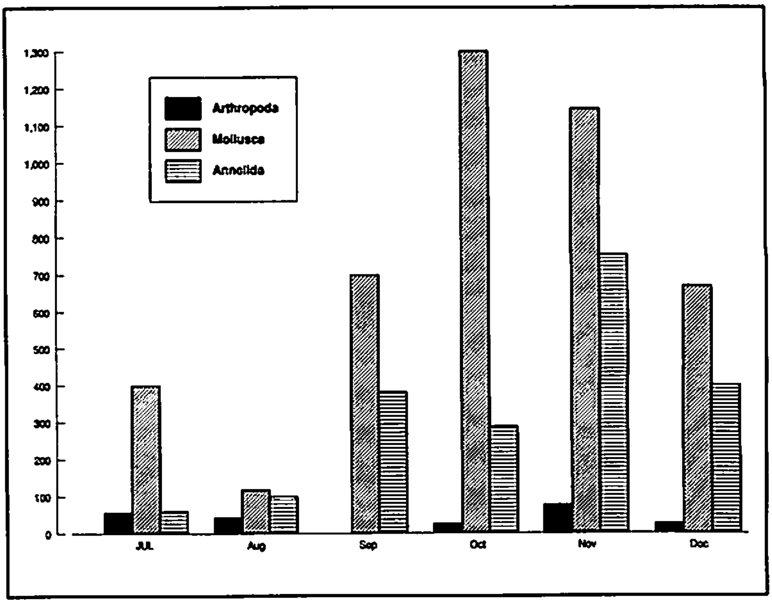


Fig. 9. Certain benthic organism from a deepwater ricefield in Pearapur Village, Hooghly District, West Bengal, *kharif* season 1987.

Table 8. Some dominant aquatic flora and fauna in a deepwater ricefield at Pearapur, West Bengal, August-November 1987.

Plants		*Oryza sativa* (deepwater rice) *O. rufipogon* (wild rice) *Myriophylum indicum* *Ipomoea aquatica* *Limnophila heterophyla* *Nymphaea pubescens* *Najas foveolata*
Algae	Bluegreens	*Anabaena, Gloeotrichia, Rivularia, Oscillatoria, Nostoc*
	Greens	*Microspora, Microstarius, Cosmarium, Oedogonium*
	Diatoms	*Navicula, Synedra, Nitzchia*
Protozoa		*Arcella, Centropyxis, Amoeba*
Rotifera		*Rotaria, Keratella, Lecane*
Annelida	Oligochaeta	
Crustacea	Cladocera	*Bosmina, Daphnia, Moina*
	Copepoda	*Diaptomus, Cyclops*
	Ostracoda	*Cypridae*
	Miscellaneous	Nauplii larvae
	Crab	*Paratelphusa spinigera*
	Prawn	*M. rosenbergii*
Insecta	Hemiptera	*Micronecta, Anisops, Plea, Ranatra, Diplonicus*
	Ephemeroptera	Mayfly larvae
	Coleoptera	*Dystiscus, Hydrovatus, Canthydrus, Donacia*
	Diptera	Mosquito larvae, Chironomus Larvae
	Odonata	Damselfly larvae
Mollusca		*Pila, Gyralus, Bellamya*
Fish		*C. ranga, C. nama, P. ticto, P. sophoro, P. sarana, C. pectoralis, C. fasciata, R. daniconius*

Conclusions

The deepwater ricefields of India have to be used more efficiently. Integrating fish production with rice is a logical way of achieving this. To do this, past and recent efforts aim at increasing fish production and profits over traditional methods.

Studies revealed that a large potential exists for substantially increasing fish production in the vast deepwater rice areas of West Bengal. The ecological studies at Pearapur indicated that a large amount of fish food organisms are available which wild fish species could use more efficiently. Very few farmers are presently using any culture technique for fish production from such fertile waters. If only 10% of the area is intensively farmed, an enormous increase in the fish harvest would be achieved.

Acknowledgements

The authors express their indebtedness to Dr. H.D. Catling, formerly Project Leader, Deepwater Rice Project, IRRI, for his unstinted support; Drs. K. Mitra and A.C. Nandi, Senior Scientists of CIFRI, Barrackpore; and Dr. B.K. Mandal, Head, Rice Research Station, Chinsurah, West Bengal, for providing laboratory and farm facilities during the period of study.

References

Catling, H.D., D.W. Puckridge and D. HilleRisLambers. 1987. Characterization of the deepwater rice environment. Paper presented at the International Workshop on Deepwater Rice, 26–30 October 1987. Bangkok, Thailand.

CIFRI Annual Report. 1982 and 1983. Central Inland Fisheries Research Institute, Barrackpore, West Bengal.

Clay, E.J., H.D. Catling, P.R. Hobbs, N.I. Bhuinyan and Z. Islam. 1978. Yield assessment of broadcast aman (deepwater rice) in selected areas in Bangladesh in 1977. Report submitted to BRRI/ODM Deepwater Rice Pest Management Project. Bangladesh Rice Research Institute, Joydebpur, Bangladesh.

Dehadrai, P.V. 1979. Breed magur in paddy fields. Indian Fmg. 12:7–9.

Datta, S.K., D. Konar, P.K. Banerjee, S.K. Dey, P.K. Mukhopadhyay and P.K. Pandit. 1986. Prospects of increasing food production in India through different systems of paddy-cum-fish culture in freshwater areas: a case study. Int. Rice Comm. Newsl. 35(1):11–39.

Jhingran, A.G. 1988. A general review of the inland capture fisheries status in India. Souv. Inland Fish. India. p. 31–41.

Khush, G.S. 1984. Terminology for rice growing environments. International Rice Research Institute, Los Baños, Laguna, Philippines.

Saran, S. and V.N. Sahai. 1979. Progress of research and prospects of deepwater rice improvements in India, p. 13–20. Proceedings of the 1978 International Deepwater Rice Workshop, Calcutta, India. International Rice Research Institute, Los Baños, Laguna, Philippines.

Singh, U.S. 1981. Deepwater rice in India: problems and prospects, p. 355–362. *In* Proceedings of the 1981 international deepwater rice workshop, Bangkok, Thailand.

Swaminathan, M.S. 1978. International Seminar on Deepwater Rice. Keynote Address, p. ix-xviii. *In* Proceedings of the 1978 International Deepwater Rice Workshop, Calcutta, India. International Rice Research Institute, Los Baños, Laguna, Philippines.

Rice-Fish Farming Research in Lowland Areas: The West Java Case

ACHMAD M. FAGI
S. SURIAPERMANA
IIS SYAMSIAH
Sukamandi Research Institute for Food Crops
Sukamandi, Subang
West Java, Indonesia

FAGI, A.M., S. SURIAPERMANA and I. SYAMSIAH. 1992. Rice-fish farming research in lowland areas: the West Java case, p. 273–286. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Rice-fish farming systems, in line with Indonesia's agricultural diversification strategy, offer good development prospects. To improve the traditional rice-fish systems, on-station and on-farm research has been conducted for Binong, Subang, West Java, by the Sukamandi Research Institute for Food Crops. On-station experiments investigated the effects of four rice varieties (*Cisadane, Ciliwung,* IR 64 and *Dodokan*) on fish production; and of rice-fish, mechanical and chemical weed control on rice production. Moreover, research on the effects of trench sizes varying from 4 to 17% of the ricefield area combined with spacing of rice plants; fish stocking densities from 1,000 to 5,000/ha (at 500 increments); triple superphosphate (TSP) fertilizer rates and water management (stagnant, intermittent and continuous flow irrigation) on fish and rice production were also done. Common carp (*Cyprinus carpio*) was used in all the experiments. On-farm research involved working with 27 farmers in evaluating five cropping patterns: 1) rice-rice-fallow; 2) rice-rice-fish; 3) (rice+fish)-(rice+fish)-fish; 4) (rice+fish)-fish-(rice+fish)-fish; and 5) (rice+fish-duck)-(fish-duck)-(rice+fish-duck)-(fish-duck).

Results showed that fish raised together with rice did not decrease grain yields of all rice varieties tested, both in wet and dry seasons. *C. carpio* grew faster and attained larger sizes in a rice-fish system in the dry season. Rice-fish pattern gave higher yields than rice monoculture. Rice cropping pattern of either IR 64 or *Ciliwung* during wet season followed by *Cisadane* during dry season would sustain rice production better than two crops of IR 64 in both seasons or two crops of *Ciliwung*. Weed populations were highest in the rice monoculture plots without weeding in both seasons. *C. carpio* suppressed weed populations by about 30% in the dry season and much more in the wet season. It is as effective as weeding once in the rice monoculture plots. Agroxone application was as effective as weeding twice.

Trench sizes, arrangements and plant spacing did not show significant effects on IR 64 and *C. carpio* yields in both seasons, due to abundant supply of water during the year. The trenches, however, showed positive border effects on rice yield. Highest total fish and rice yields in both seasons were obtained at stocking densities within the range of 2,500 to 3,000/ha. The inclusion of *C. carpio* in rice cultivation increased phosphorus availability to rice. At the same TSP level of 100 kg/ha, *Ciliwung* in a rice-fish system yielded 1.3 t/ha more than rice monoculture.

Intermittent irrigation and stagnant methods were found to use the least amount of water. Continuous flow irrigation, aside from being the highest water consumer, slightly suppressed rice growth. Evaluation in the farmer-cooperators' fields showed that all the rice-fish patterns tested had increased farm income vis-à-vis rice monoculture. Among the rice-fish systems, the most profitable was the (rice+fish-duck)-(fish-duck)-(rice+fish-duck)-(fish-duck) pattern where net returns were 49% higher than rice monoculture.

Introduction

Farm income and sustainability of rice production in lowland areas are critical issues. Current intensive rice cultivation requires high fertilizer levels, because of the limited genetic potential of rice varieties used, the creation of imbalanced soil nutrients, and the emergence of new biotypes or strains of rice diseases (Manwan and Fagi 1989). Additional inputs or introduction of new rice technology without considering land suitability may cause low economic efficiencies.

Realizing the situation, Indonesia has changed its agricultural development strategy from a single commodity approach to diversification of agricultural commodities for sustaining food self-sufficiency and increasing farm income. Rice-fish farming is an ideal practice that utilizes agricultural resources more efficiently in lowland rice areas.

Early studies showed that fish raised together with rice increased the availability of nitrogen, phosphorus, calcium and magnesium in ricefield water – increasing grain yields of traditional rice varieties (Satari 1962). Rice-fish experiments demonstrated that the profits from fish could be used to cover some of the operational rice production costs (Syamsiah et al., this vol.). Thus, rice-fish farming is relevant to Indonesia's agricultural development programs as it sustains land productivity, increases farmer's income and improves food situation of rural people. Freshwater fish production from rice-fish farming systems increased from 17,710 t in 1977 to 33,495 t in 1980 and 52,165 t in 1983. In 1984, total fish production in ricefields was 58,880 t, equivalent to US$50 million.

Irrigation water consumption in traditional rice-fish farming systems is generally higher than in rice monoculture. Concern over the contamination of fish from insecticides under intensive rice cultivation, the quality and availability of fry or fingerlings and fish marketing are other constraints to the expansion of rice-fish farming. To improve the component technology of rice-fish farming systems, field studies have been conducted by the Sukamandi Research Institute for Food Crops (SURIF) and the Research Institute for Freshwater Fisheries (RIFF) of the Agency for Agricultural Research and Development (AARD) in collaboration with the International Development Research Centre (IDRC) of Canada. Initial funds for preliminary on-farm data collection were granted by the International Rice Research Institute (IRRI). This paper summarizes research results conducted by SURIF at Binong Subdistrict and at the Sukamandi Experimental Farm, Subang District, West Java.

Profile of Rice-Fish Farming Systems at Binong Subdistrict

Binong Subdistrict and the surrounding coastal parts of Subang District represent the most productive agricultural lands in West Java. Agricultural lands occupy 12,929 ha, 80% are irrigated.

The irrigated areas receive water from the Jatiluhur Reservoir and the Cimacan Dam. Although the climate is dry with an annual rainfall of 1,364 mm, high soil alluvial fertility (Aquic Tropaquepts) in combination with abundant irrigation water make the land highly productive. Several times, farmers from Binong Subdistrict have won first place in rice production contests at either national or provincial levels.

Binong Subdistrict is the home of 97,658 people. More than 88% of the population are in agriculture (food crops, fishery, animal husbandry, estate, agricultural service or landless labor). Those who cultivate lowland areas comprise 54% of the population.

Aquaculture in lowland ricefields was introduced to the Binong Subdistrict in 1979. At present, there are three components of rice-fish farming systems:

1. Rotational fish culture (*palawija ikan*). After harvesting dry season rice, the ricefield is converted to a fishpond; fingerlings (5–8 cm) are cultured as an alternative to agricultural crops for two to three months.
2. Sequential fish or fish in between crops (*ikan penyelang*). Fish are reared after the wet season rice harvest. Fish are harvested before planting the dry season rice. This system is just a fattening of fish.
3. Concurrent rice-fish (*minapadi*). Fry or fingerlings are raised together with rice for 40–45 days or longer depending on use of the fish.

Patterns of rice-fish farming systems commonly practised by farmers are: rice followed by rice followed by fish or (rice-rice-fish); (rice+fish)-(rice+fish)-fish and (rice+fish)-fish-(rice+fish)-fish. Economic evaluation of the four patterns indicated that fish culture in lowland ricefields increased net returns over a rice-rice-fallow pattern (Table 1). Highest net returns were obtained from the (rice+fish)-fish-(rice+fish)-fish pattern.

A few years after the introduction of aquaculture in ricefields in the study area, the rice-rice-fish pattern has emerged as the most popular. However, the (rice+fish)-(rice+fish)-fish pattern is now equally popular. The concurrent rice-fish system, however, offers a better prospect in terms of water availability, since rotational fish culture is very much dependent on water from the Jatiluhur Reservoir and the Cimacan Dam. The adoption of the concurrent rice-fish systems have increased steadily at an average rate of 14%/year. Fish production from concurrent rice-fish at Binong Subdistrict and the surrounding areas contributed 61% of the total freshwater fish production in Subang District (Table 2).

Despite the popularity of the concurrent rice-fish system, fish production is still far behind its potential. The factors that constrain fish production in a concurrent rice-fish system are the absence of trenches, poor quality of fry or fingerlings, no feeding, short duration of fish growth and harvesting problems as both crops are harvested at the same time. Farmers believe that fish grow better when raised with *Cisadane* rice than other varieties and they may be disappointed if other varieties are grown.

Landless farmers generally rent fallow riceland in the dry season to grow fish. Therefore, they have low bargaining

Table 1. Comparative economics (US$/ha) of three rice-fish farming systems and rice monoculture at Nangerang Village, Binong Subdistrict, Subang, West Java, 1987/88.[a] (Farm size; 0.32-0.87 ha; rice variety: IR 64).

Production system[a]	Input costs	Value of output	Net returns
Rice-rice-fallow	841.13	1,850.85	1,009.72
Rice-rice-fish	894.24	2,130.17	1,235.93
(Rice+fish)-(rice+fish)-fish	914.56	2,314.19	1,399.63
(Rice+fish)-fish-(rice+fish)-fish	1,012.19	2,442.33	1,430.14

[a]Original values in Indonesian Rupiah were converted at the rate of US$1 = Rp1,770 as of 1988.

Table 2. Area and fish production from pond, running water and rice-fish culture in Subang District, West Java, 1984–88.[a] (Source: SDFS 1988).

Production system	1984	1985	1986	1987	1988
Area					
Pond culture (ha)	638	638	638	638	638
Running water culture (no. of units)	162	165	165	165	165
Rice-fish (ha)	3,642	3,952	4,615	5,656	5,660
Fish production (t)					
Pond culture	2,034	2,154	2,187	2,251	2,310
Running water culture	521	490	462	579	554
Rice-fish	3,191	3,465	3,671	3,985	4,407
Total production	5,746	6,109	6,320	6,815	7,271
Contribution from rice-fish (%)	56	57	58	58	61

[a]Rice-fish is widely adopted at Binong Subdistrict and the surroundings.

position (Anon. 1989). The land is returned if the land owner wishes to use it for land preparation for wet season rice.

Several component technologies of concurrent rice-fish have been investigated at the Sukamandi Experimental Farm and at farmers' fields in Nangerang Village, Binong Subdistrict. Trials involved farmers and field extension workers in identifying the treatments. Field operations by farmers are supervised by researchers with minimal interference.

Research Results of Component Technologies in Rice-Fish Farming Systems

On-Station Research

Six experimental areas on component technologies of concurrent rice-fish system were identified based on a field survey at Binong Subdistrict, and on review of previous activities in Sumatra (dela Cruz 1986). Experiments on about 15 ha of land under controlled environments were conducted at the Sukamandi Experimental Farm. Both Sukamandi and Binong are irrigated by the Jatiluhur Irrigation System. Soil from the Sukamandi Experimental Farm (Vertic Tropaquults) is less fertile compared to the soil from test sites in Binong.

EFFECT OF RICE VARIETIES ON FISH GROWTH AND PRODUCTION

Four rice varieties, *Cisadane* (135-140 days), *Ciliwung* (120 days), IR 64 (>115 days) and *Dodokan* (<100 days) were planted in 250-m^2 plots that were unstocked or stocked with fish during the 1988/89 wet and 1989 dry seasons. Four treatments composed of four rice varieties were planted by conventional methods without fish and another four with fish. The control treatment had fish only. Plots were arranged in completely randomized design and each treatment was replicated three times.

All rice crops received urea, triple superphosphate (TSP) and potassium chloride (KCl) at 200, 100 and 100 kg/ha, respectively. Urea was applied equally at planting, at maximum rice tillering and at panicle initiation. All the TSP and KCl were broadcast and incorporated at planting, together with 1/3 of the urea.

Common carp (*Cyprinus carpio*) fingerlings (12.5 g) were stocked in the rice-fish fields 10 days after rice transplanting. Stocking rates were 3,600 and 3,000/ha in the wet and dry seasons, respectively. A center trench was provided for fish movement and refuge.

Results showed that *C. carpio* grew faster and reached larger sizes in a rice-fish system in the dry than in the wet season (Fig. 1). Fish raised together with

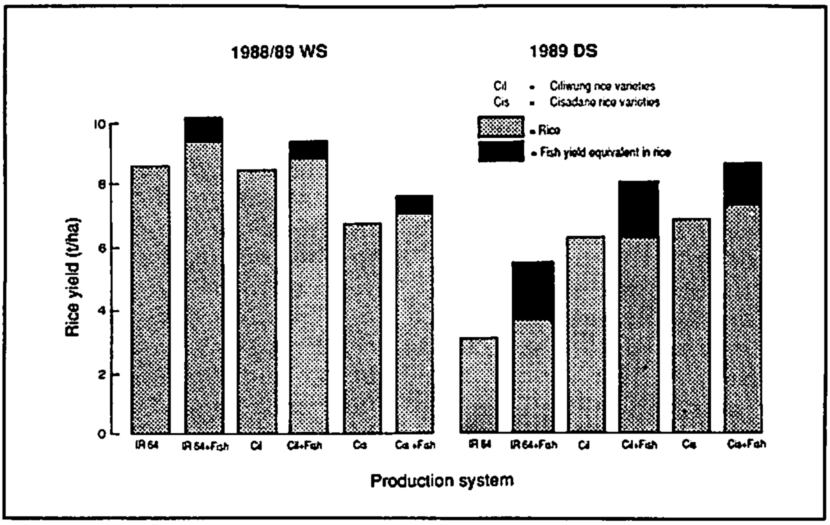


Fig. 1. Comparison of rice yields in rice monoculture and concurrent rice-fish systems at the Sukamandi Experimental Farm, 1988/89 wet (WS) and 1989 dry (DS) seasons.

rice did not decrease grain yields of all the rice varieties tested, both in the wet and dry seasons. When compared with rice monoculture, rice-fish gave higher total yields expressed in equivalent rice yields. Rice varieties with different phenotypes and maturities did not significantly affect fish production.

Grain yields of IR 64 and *Ciliwung* were higher in the wet season than in the dry season. A significant drop in yield of IR 64 was caused by a serious infestation of bacterial leaf blight in the dry season. *Cisadane*, however, maintained its productivity under dry season conditions. This suggests that rice cropping pattern IR 64 followed by *Cisadane* or *Ciliwung* followed by *Cisadane* would sustain rice production better than IR 64 followed by IR 64 or *Ciliwung* followed by *Ciliwung*. *Cisadane*-fish and *Ciliwung*-fish in the dry season gave a total equivalent rice yield of more than 8.0 t/ha.

Dodokan failed to give grains, because of serious rat and bird damages during booting and ripening stages, respectively. Isolated crops of *Dodokan* that flower early must be avoided because of pest damages.

EFFECT OF TRENCH SIZE AND LAYOUT ON RICE AND FISH PRODUCTION

Trenches in rice-fish systems are constructed to provide more space as refuges for fish, and for ease of feeding and harvesting (Ruddle 1980; dela Cruz 1986). Trenches, however, reduce the area planted to rice. Therefore, farmers generally think that trenches will reduce rice production. To clarify this, rice-fish systems with various trench sizes and arrangements were evaluated: center trench, cross trench, peripheral trench, and a combination of peripheral and center trenches. Rice hills eliminated by the trenches were either planted along the adjacent rows to maintain the normal plant populations, or removed (normal spacing). Combination of factors tested were: 1) rice-fish, no trench, normal spacing (25 x 25 cm); 2) rice-fish, no trench, with closer spacing; 3) rice-fish, center trench (4% of total area), normal spacing; 4) rice-fish, center trench (4%), with thickening; 5) rice-fish, cross trench (7%), normal spacing; 6) rice-fish, cross trench (7%), with thickening; 7) rice-fish, peripheral trench (11%), normal spacing; and 8) rice-fish, a combination of middle and peripheral trench (17%), normal spacing. Percentages refer to the area of trenches in proportion to total ricefield area.

IR 64 and *Ciliwung* were planted at 25 x 25 cm spacing in the wet and dry seasons, respectively. Fertilizer and insecticide applications and management were similar to experiment 1. *C. carpio* fingerlings were released into the ricefields 10 days after rice transplanting at an average weight of 16.5 g at the rate of 3,600/ha in the wet season, and 12.5 g at 3,000/ha in the dry season.

Results show no significant effects of trench sizes and arrangements on grain yield of IR 64 and *C. carpio* yield, expressed as rice equivalents in the wet and dry seasons (Table 3). The wet season was long during the 1988/89 crop season such that the experiment had abundant water in both wet and dry seasons, hence the trench gave no seasonal advantage. Again, the experiment demonstrated that higher fish yields in the dry season compensated to some extent the lower dry season grain yield of IR 64.

Trenches had a border effect: the two rice crops rows nearest the trench grew better and yields were higher than those farther from the trench. If the rows are labelled 1–5 according to proximity to the trench, then the differences between the

Table 3. Rice (IR 64 and *Ciliwung*) and fish yields (t/ha) expressed as rice equivalent and total production in rice-fish systems with different trench sizes and arrangements at the Sukamandi Experimental Farm, 1988/89 wet (WS) and 1989 dry (DS) seasons. The data in all columns are not significantly different (P>0.05).

Rice-fish production system	Rice grain yield		Fish yield equivalent in rice		Total	
	1988/89 WS	1989 DS	1988/89 WS	1989 DS	1988/89 WS	1989 DS
No trench, normal spacing	7.60	5.10	0.49	1.25	8.09	6.35
No trench, with thickening	7.68	5.35	0.69	1.27	8.38	6.62
Middle trench, normal spacing	7.49	5.03	0.68	0.98	8.18	6.01
Middle trench, with thickening	7.27	5.47	0.53	1.09	7.79	6.57
Cross trench, normal spacing	7.68	5.63	0.58	1.28	8.26	6.96
Cross trench, with thickening	7.68	6.11	0.51	1.03	8.18	7.15
Periphery trench, normal spacing	8.40	5.28	0.62	0.93	9.02	6.21
Middle and periphery trench, normal spacing	7.31	5.34	0.59	1.15	7.85	6.49

[a]Fish yield equivalent in rice, kg = $\frac{\text{fish yield, kg x fish price}}{\text{rice price}}$

rice price = Rp200/kg;
fish price = Rp1,750/kg.

yields from the two row 1s and the yields from rows 2, 3, 4 and 5 are clear (Table 4). The higher grain yields of the two row 1s compensated the lower yields of other rows, possibly due to mutual shading.

Table 4. Rice yields of the rice rows nearest to the fish trench (1+1) with other rows farther away from the trench at the Sukamandi Experimental Farm, 1989 dry season.

Two rows	Grain yield (g/m)	Index (%)	Difference
1+1	454.9	100	
2+2	359.4	79	-21
3+3	335.0	74	-26
4+4	313.3	69	-31
5+5	320.7	71	-29

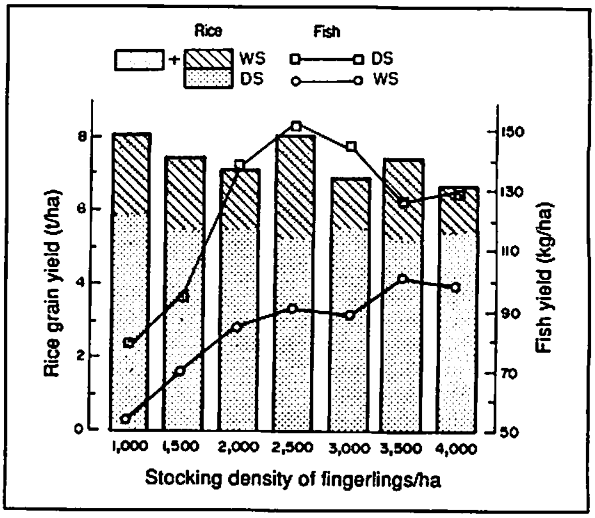


Fig. 2. Comparison of fish and grain (IR 64) yields at various stocking densities in concurrent rice-fish system at the Sukamandi Experimental Farm, 1988/89 wet and 1989 dry seasons.

EFFECT OF STOCKING RATE ON RICE AND FISH

An experiment to determine the optimum stocking density in a rice-fish system was conducted. Stocking densities from 1,000 to 5,000/ha (at 500 increments) were evaluated in an IR 64-fish system in the wet season and *Ciliwung*-fish in the dry season. A randomized complete block design with three replications was used.

Cultural practices, fertilizers, insecticide applications and management for rice followed those used in experiments 1 and 2. *C. carpio* fingerlings (25 g) were released into the plots seven days after rice transplanting. Cross trenches were established in each plot.

In the wet season, fish yield was highest at 3,500/ha stocking density, and was accompanied by a relatively high grain yield of IR 64. In the dry season, however, highest fish yields were obtained at 2,500/ha stocking density (Fig. 2).

This experiment demonstrates that an optimum stocking density is necessary to get a complementary interrelationship between rice and fish. Farmers will not use high fish stocking densities if it will cause negative effects on rice yields.

EFFECT OF BIOLOGICAL (RICE-FISH), MECHANICAL AND CHEMICAL WEED CONTROL ON THE PRODUCTIVITY OF LOWLAND RICEFIELDS

Weed infestations are serious problems in intensive rice cultivation. High fertilizer applications induces weed growth and high weed densities. In places of limited water supply, weeds compete with rice for nutrients and for water itself. There are weed species that can stand either wet or very dry conditions.

C. carpio in a rice-fish system is believed to suppress weed growth but no quantitative data are available. Therefore, experiments were conducted to compare the effects of rice-fish culture (biological control), mechanical control (hand weeding) and chemical control (Agroxone applications) on weeds (Table 5).

IR 64 and *Ciliwung* were planted in the wet and dry seasons, respectively. Farming practices (rice, fertilizers, insecticide applications and management) followed those used in experiment 1. Hand weeding was done 20 days after rice transplanting or 20 and 35 days after transplanting, depending on the treat-

Table 5. Effects of weed control by mechanical, chemical and biological (rice-fish) methods on rice and fish yields (t/ha) at the Sukamandi Experimental Farm, 1988/89 wet (WS) and 1989 dry (DS) seasons. Data in the same columns having different letters are significantly different ($P<0.05$).

Production system and weeding methods	1988/89 WS IR 64 yield	1988/89 WS Fish yield equivalent in rice	1988/89 WS Total	1989 DS *Ciliwung* yield	1989 DS Fish yield equivalent in rice[a]	1989 DS Total
Ordinary rice cultivation, no weeding	5.43 b			3.43 d		
Rice-fish, no weeding	6.62 ab	0.34	6.96	4.22 cd	1.21	5.43
Ordinary rice cultivation, weeding once	6.70 ab			4.17 cd		
Rice-fish, weeding once	7.13 a	0.38	7.51	4.69 bc	0.96	5.65
Ordinary rice cultivation, weeding twice	7.30 a			5.28 ab		
Rice-fish, weeding twice	7.38 a	0.47	7.85	5.57 a	0.85	6.42
Ordinary rice cultivation, Agroxone	6.97 a			4.56 bc		
Rice-fish, Agroxone	7.26 a	0.43	7.69	4.97 abc	1.03	6.00

[a]Fish yield equivalent in rice, kg = $\frac{\text{fish yield, kg x fish price}}{\text{rice price}}$

rice price = Rp200/kg
fish price = Rp1,750/kg.

ments. Agroxone was sprayed five days after transplanting at a dose of 1.5 l/ha. *C. carpio* fingerlings (16.5 g) were released into the rice-fish plots at 2,600/ha.

Weed populations were highest in the rice monoculture plots without weeding in both seasons. In the rice-fish plots in the dry season, even without weeding, fish suppressed weed populations as effectively as weeding once in the rice monoculture plots. Agroxone application was as effective as weeding twice both in the rice-fish system and in rice monoculture cultivation (Fig. 3). Ricefields with fish increased rice grain yield, particularly in the dry season (Table 5). *C. carpio* suppressed weed populations by about 30% in the dry season, and much more in the wet season. The dry season results confirm previous reports (Satari 1962; Ruddle 1980).

Using the summed dominant ratio (SDR) of each weed species, the preference of *C. carpio* may be predicted. *C. carpio* was particularly effective at controlling *Fimbristilis miliaceae, Cyperus iria, Leptochloa chinensis, Echinochloa colona* and *Ludwigia octavalvis* (Table 6). These weeds declined gradually and disappeared 45 days after rice transplanting in the rice-fish plots. In unstocked plots, weeds existed until 82 days after transplanting.

EFFECT OF TSP LEVELS ON RICE AND FISH YIELDS

Some lowland rice soils in Java have accumulated phosphorus because of continuous application of TSP (Adiningsih et al. 1988). The same was observed at the Sukamandi Experimental Farm where IR 36 does not respond to TSP applications. There is, however, no information on the effects of accumulated phosphorus on rice-fish farming. Fish excreta can supply phosphorus.

An experiment was conducted in the 1989 dry season to clarify the phenomenon. Applications of TSP at 0, 25, 50, 75, 100, 125 and 150 kg/ha were tested on rice-fish fields planted with *Ciliwung*. A standard plot of rice

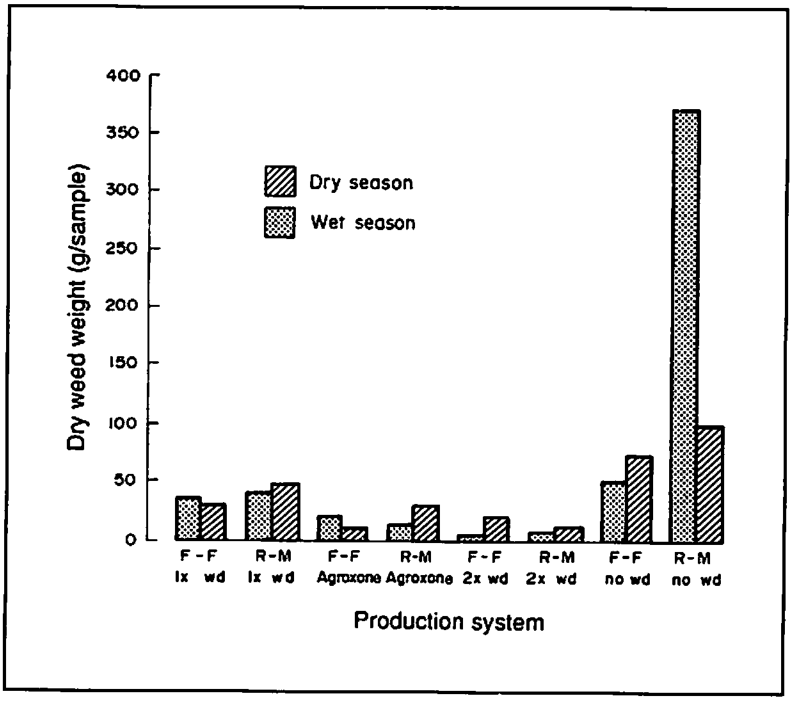


Fig. 3. Effects of mechanical, chemical and biological (rice-fish) weed control on total dry weed weight at the Sukamandi Experimental Farm, 1988/89 wet and 1989 dry seasons.

Table 6. Summed dominant ratio (SDR) of weed species in rice-fish (RF) and rice monoculture (RM) plots without weeding at various days after transplanting (DAT) at the Sukamandi Experimental Farm, 1989 dry season.

Weed species	20 DAT		30 DAT		45 DAT		82 DAT	
	RF	RM	RF	RM	RF	RM	RF	RM
Fimbristilis miliaceae[a]	5.98	5.81	7.45	9.48	0	12.90	0	7.54
Monochoria vaginalis	21.20	34.70	33.40	62.10	37.70	43.00	52.00	63.20
Cyperus iria[a]	12.20	7.50	0	0	0	10.10	0	8.17
Scirpus sp.	5.98	2.30	9.26	6.91	0.00	7.59	19.80	12.10
Cyperus difformis	0	0	0	11.50	0	12.20	0	0
Paspalum vaginatum	2.99	0	0	0	0	0	0	0
Echinochloa colona[b]	2.99	5.21	0	2.56	0	4.28	0	0
Leptochloa chinensis[a]	8.98	7.51	0	8.68	0	4.73	0	9.23
Ludwigia octavalvis[b]	8.98	6.90	6.85	8.29	0	3.75	0	0
Ludwigia adscendens	4.63	4.60	0	0	0	0	0	0
Marcelia crenata	15.80	13.30	10.60	14.30	4.73	12.50	7.36	5.63
Sphenoclea zeylanica	10.00	9.63	0	3.16	5.00	31.50	0	9.60
Rotala leptopetala	0	2.30	0	0	0	0	0	0
Cyperus pulacherimus	0	0	0	5.23	5.85	0	0	5.21
Lindernia sp.	0	0	0	0	0	3.75	0	0
Limnocharis flava	0	0	0	0	0	0	0	0

[a]Highly preferred by *C. carpio*.
[b]Moderately preferred by *C. carpio*.

monoculture receiving 100 kg/ha was the control. All plots received 200 kg urea and 100 kg KCl/ha. Other practices and fertilizer management followed those used in experiment 1. *C. carpio* fingerlings (16.5 g) were released into the rice-fish plots at 3,000/ha. A cross trench was provided in each rice-fish plot.

As for IR 36 in previous long-term fertility experiments, *Ciliwung* in this experiment did not respond to TSP application (Table 7). At the same TSP level (100 kg/ha), Ciliwung in a rice-fish system yielded 1.3 t/ha more than rice monoculture. Even without TSP application, *Ciliwung* in a rice-fish system gave higher grain yield than rice monoculture plots receiving TSP at 100 kg/ha. This proves that the presence of fish in ricefields increases phosphorus availability to rice. Phosphorus has been reported to be more available to rice in rice-fish systems (Satari 1962). Under the present government policy to reduce TSP levels applied to rice in soils where phosphorus has accumulated, rice-fish is an alternative solution. Mechanisms that maximize efficiency of phosphorus use in rice-fish systems need long-term evaluation.

EFFECT OF WATER MANAGEMENT ON RICE AND FISH PRODUCTION IN RICE-FISH SYSTEMS

Water management is one of the important factors in a rice-fish system. In a traditional rice-fish system, farmers usually use a continuous-flow irrigation technique to maintain adequate oxygen concentrations in the water. Under limited supply of irrigation water, fish may suffer from stress. Irrigation techniques, implemented by the irrigation authority, however, are often intermittent. Thus, water supply sometimes becomes a problem. However, in a rice-fish system, the rice structure helps move oxygen. The rice plant has aerenchyma that facilitate oxygen transport from leaves to roots. Therefore, the rice root zone may contain adequate oxygen for fish. Under such conditions, continuous-flow irrigation may not be necessary.

To clarify this, experiments were conducted in the 1988/89 wet and 1989 dry seasons. A split-plot design with three replications were used, with management as the row factor (intermittent irrigation at 5 cm minimum and 10 cm maximum

Table 7. Comparative yields of *Ciliwung* rice and fish and total equivalent rice yields in a rice-fish system at various triple superphosphate (TSP) levels and in rice monoculture at the Sukamandi Experimental Farm, 1989 dry season. Data in the same column having the same letters are not significantly different (P>0.05).

TSP level (kg/ha)	Rice grain yield (t/ha)	Actual fish yield (t/ha)	Total yield equivalent rice (t/ha)[a]
Rice-fish			
0	6.69 b,c	0.14 b	7.78
25	6.62 b,c	0.13 b	7.63
50	6.65 b,c	0.14 b	7.56
75	7.14 b	0.14 b	8.28
100	7.36 b	0.14 b	8.56
125	7.21 b	0.15 b	8.47
150	6.58 b,c	0.16 b	7.63
Rice monoculture			
100	6.06 b		6.06

[a]This total excludes the fish yields equivalent in rice.

water levels; stagnant water at a 10 to 15 cm water level; continuous flow at a 15-cm water level with 10% overflow), and stocking density as the column factor (0; 1,600; 2,880 and 4,160 fingerlings/ha in the wet season; 0; 2,000; 3,000 and 5,000 fingerlings/ha in the dry season). IR 64 and *Ciliwung* were planted in the wet and dry seasons, respectively. All practices for rice and fish, fertilizers and insecticide application followed those used in experiment 1.

Table 8 shows that continuous flow irrigation at 15-cm water level slightly suppressed rice growth, hence it decreased rice grain yield. The effect was more pronounced in the wet than in the dry season. On the contrary, continuous flow irrigation increased fish yields in both seasons. Fish yield was highest at stocking densities of 4,160–5,000 fingerlings/ha for all irrigation techniques.

Intermittent irrigation used the least water followed by stagnant conditions, while continuous-flow irrigation was the highest water consumer (Table 9). Based on water consumption and rice yields, stagnant irrigation with a stocking density of about 3,000 fingerlings/ha may be recommended. Intermittent irrigation with a stocking density of 5,000/ha may be appropriate in the dry season to get high yields, and perhaps save irrigation water.

High water levels in ricefields (>10 cm) cause water loss through cracks along the dikes. It is known that high water levels suppress rice tillering and consequently reduce grain yield.

On-Farm Research

Twenty-seven farmer-cooperators in Nangerang Village, Binong Subdistrict, were involved in the experiment which evaluated the following cropping patterns: rice-rice-fallow; rice-rice-fish; (rice+fish)-(rice+fish)-fish; (rice+fish)-fish-(rice+fish)-fish; and (rice+fish-duck)-(fish-duck)-(rice+fish-duck)-(fish-duck). The first four patterns involved six farmers; the last had three farmers.

IR 64 and *Ciliwung* in a rice-fish plot were planted in the wet and dry seasons, respectively. Rice farming practices followed the *Supra Insus* (Super intensive rice production) recommendation (spacing 22 x 22 cm; urea, TSP, KCl and ammonium sulfate at 200, 100, 100 and 50 kg/ha, respectively; Furadan 3G 20 kg/ha was broadcast and incorporated at plant-

Table 8. Effects of irrigation techniques and stocking densities of common carp on rice grain yield and fish yield at the Sukamandi Experimental Farm, 1988/89 wet (WS) and 1989 dry (DS) seasons.

Irrigation method	Stocking rate (fish/ha) 1988/89 WS	1989 DS	Rice grain yield (t/ha) 1988/89 WS	1989 DS	Fish yield (kg/ha) 1988/89 WS	1989 DS
Intermittent	0	0	8.30	6.03	0	0
(5–10 cm water level)	1,600	2,000	8.35	5.75	57	124
	2,880	3,000	7.73	5.60	100	114
	4,160	5,000	8.25	5.80	87	179
Stagnant	0	0	7.45	6.00	0	0
(10–15 cm water level)	1,600	2,000	7.72	5.80	10	80
	2,880	3,000	8.00	5.57	100	115
	4,160	5,000	8.00	5.67	111	181
Continuous-flow	0	0	7.43	5.95	0	0
(15 cm water level,	1,600	2,000	7.78	5.53	81	132
10% overflow)	2,880	3,000	7.48	5.58	100	149
	4,160	5,000	7.62	5.53	119	192

Table 9. Water balance with different irrigation techniques (average of three stocking densities in rice-fish systems and in rice monoculture) at Sukamandi Experimental Farm, 1988/89 wet (WS) and 1989 dry (DS) seasons.

	Water losses	Total water use		Rainfall	Water consumption
	mm/day	m^3/ha (35 days)	l/second/ha	m^3/ha (35 days)	m^3/ha (35 days)
1988/89 WS					
Intermittent irrigation (5–10 cm water level)	17	5,950	1.97	3,677	2,273
Stagnant irrigation (10–15 cm water level)	18	6,335	2.10	3,677	2,658
Continuous-flow irrigation (15 cm water level)	20	6,965	2.31	3,677	3,288
1989 DS					
Intermittent irrigation (5–10 cm water level)	9	3,115	1.03	1,450	1,665
Stagnant irrigation (10–15 cm water level)	17	5,915	1.96	1,450	4,465
Continuous-flow irrigation (15 cm water level)	18	6,160	2.04	1,450	4,710

ing). *C. carpio* fingerlings (40–60/kg) were stocked seven days after rice transplanting at 2,600/ha. Rice bran was given at 100 kg/ha every five days. A cross trench, occupying 2% of the total rice area, was used in each plot.

For raising fish in between wet and dry season rice crops, *C. carpio* fingerlings (5–8 cm) were stocked in the plots after the wet season rice harvest (straw was cut and removed). Rice bran was given at 100 kg/ha every two days. The fish farming practices after dry season rice were similar to those for fish in between crops except for stocking density (3,000/ha) and feeding schedule.

The (rice+fish)-fish-(rice+fish)-(fish+duck) pattern had 25 ducks/ha. A bamboo fence was constructed around the ricefield. Ducks were allowed to enter the ricefield two weeks after rice transplanting. Additional feed in the form of rice grains was given at 0.2 kg/duck every day.

Results showed that the highest productivity with equivalent rice yields of more than 20 t/ha/year, was obtained from the (rice+fish-duck)-(fish-duck)-(rice+fish-duck)-(fish-duck) pattern. The second highest was the same pattern without ducks followed by (rice+fish)-(rice+fish)-fish (about 19.5 t/ha/year). Economic analysis of the data presented in Fig. 4 confirms the survey data for 1988/89 (Table 10). Rice-fish farming systems were more profitable than rice monoculture.

The inclusion of ducks in (rice+fish)-(fish)-(rice+fish)-(fish) increased farm income by only US$83. However, the other advantage with duck integration is that income from ducks was almost evenly distributed throughout the year (except in August) since farmers harvest eggs every day (Fig. 5).

Pesticide residues in fish samples taken from on-station and on-farm research were below the permissible toxicity level according to the Food and Agriculture Organization standards, confirming a previous report (Sudarmadji 1985).

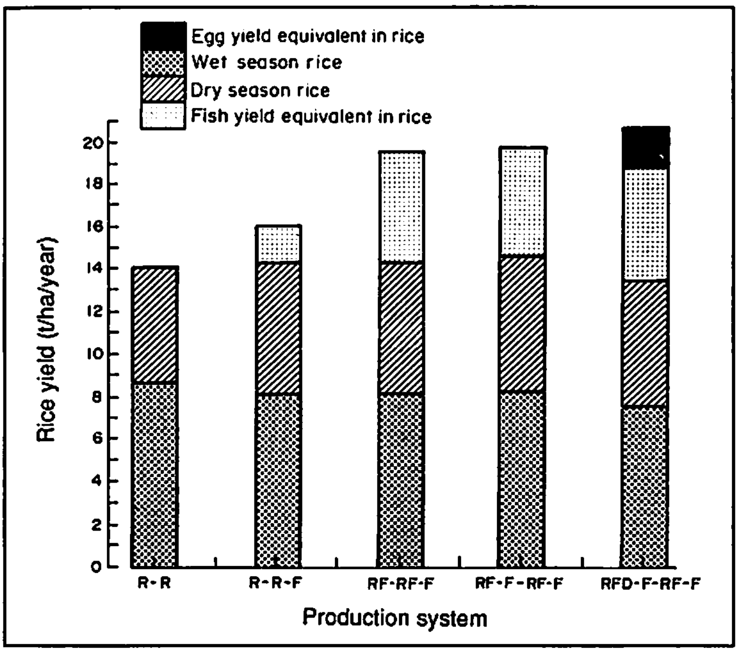


Fig. 4. Total rice yields in rice monoculture and rice-fish systems at Nangerang Village, Binong Subdistrict, 1988/89 wet and 1989 dry seasons.

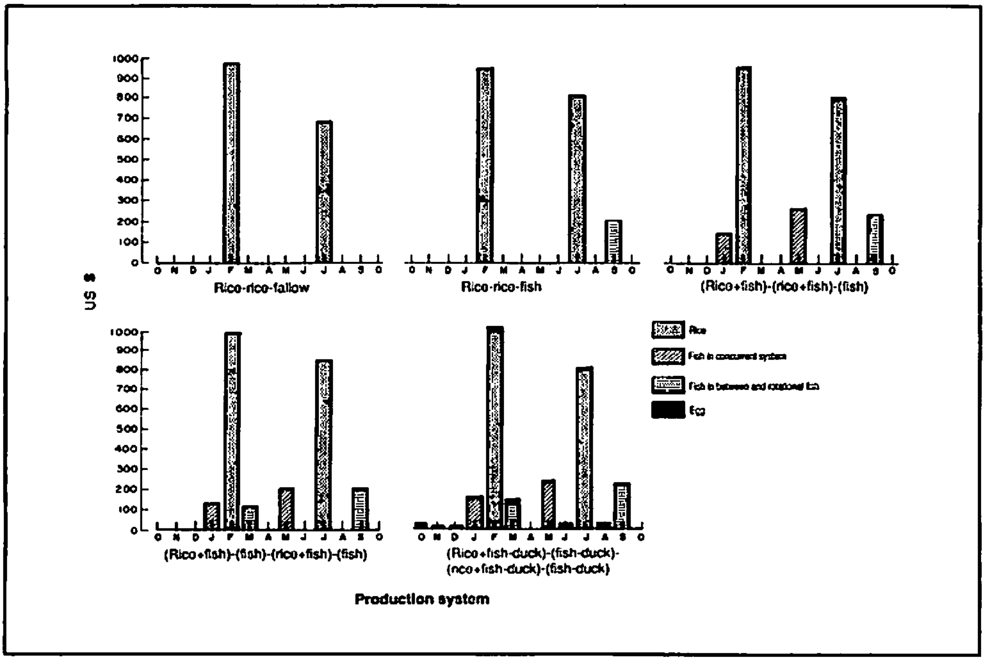


Fig. 5. Farm income distribution in rice monoculture and rice-fish farming systems at Nangerang Village, Binong Subdistrict, 1988/89 wet and 1989 dry seasons.

Table 10. Comparative economics (US$/ha) of rice monoculture and rice-fish cropping patterns based on data from farmer-cooperators and from a socioeconomic survey at Nangerang Village, Binong Subdistrict, Subang, West Java, 1988/89.

Production system	Input costs		Value of output		Net returns	
	Farmer-cooperators	Survey	Farmer-cooperators	Survey	Farmer-cooperators	Survey
Rice-rice-fallow	651.13	841.13	1,657.65	1,850.85	1,006.54	1,009.72
Rice-rice-fish	689.36	894.24	1,885.99	2,130.17	1,196.63	1,235.93
(Rice+fish)-(rice+fish)-fish	920.48	914.56	2,306.65	2,314.19	1,386.17	1,399.63
(Rice+fish)-fish-(rice+fish)-fish	952.36	1,012.19	2,366.78	2,442.33	1,414.42	1,430.14
(rice+fish-duck)-(fish-duck)-(rice+fish-duck)-(fish-duck)	824.09	-[b]	2,340.14	-[b]	1,498.05	-[b]

[a]Values in Indonesian rupiahs were converted to US dollars at US$1 = Rp1,770 as of 1988.
[b]New introduction, thus no survey results.

Conclusions

Rice-fish farming systems offer good prospects in the agricultural development program of Indonesia. Research conducted at the Sukamandi Experimental Farm suggests that fish (*C. carpio*) in a rice-fish system increase lowland productivity and farm income. Higher fish production in the dry season compensates for the lower dry season rice yield. Moreover, fish increase the efficiency of phosphorus use and suppress weed populations. This implies reduced rice production costs when fish is grown with rice.

Appropriate component technologies of rice-fish systems were also reported, such as optimum stocking density, trench sizes and arrangements and suitable rice varieties in rice-fish systems during the wet and dry seasons.

Water management techniques of the rice-fish systems depend on the objective of the culture and water availability. Intermittent and stagnant (5 to 10- and 10 to 15- cm water levels, respectively) irrigation techniques save water and give high rice yields. On the other hand, continuous-flow irrigation increases fish production but reduces rice yield. For large-scale adoption of rice-fish systems, the first two methods are recommended for having high total equivalent rice yields.

On-farm experiments showed that farm income is higher in rice-fish farming systems compared with rice monoculture. Among the rice-fish cropping patterns, the integration with ducks was more profitable.

References

Adiningsih, M., M. Sudjadi and A.M. Fagi. 1988. Evaluation on phosphate requirement for intensified rice cultivation in Java. Paper presented at the National Workshop on Efficient Use of Fertilizer, 21 November 1988. CSR/IFDC/APPI, Cipayung, Bogor, Indonesia. (In Indonesian).

Anon. 1989. Prospect and constraints to the development of food-based farming systems in Subang District, West Java. Sukamandi Research Institute for Food Crops/Agency for Agricultural Research and Development/International Rice Research Institute Project, Bogor, Indonesia. (Unpublished report, in Indonesian).

dela Cruz, C.R. 1986. Final report: small-scale fisheries development project. Rice-Fish Culture Subproject. USAID/ARD Project No. 497-0268, United States Agency for International Development, Jakarta, Indonesia.

Manwan, I. and A.M. Fagi. 1989. N, P, K, and S fertilization for food crops: present status and future challenges. Paper presented at the Seminar on Sulfur Fertilizer for Lowland and Upland Rice Cropping System in Indonesia, 18–20 July 1989. MOA-ACIAR/AIDAB, Jakarta, Indonesia.

Ruddle, K. 1980. A preliminary survey of fish cultivation in ricefields, with special reference to West Java, Indonesia. Bull. Nat. Mus. Etnol. 5(3).

Satari, G. 1962. Lowland rice cultivation with fish. Research on several agronomic aspects. Faculty of Agriculture, University of Indonesia, Bogor, Indonesia. Ph.D. dissertation. (In Indonesian).

SDFS. 1988. Annual report. Subang District Fisheries Service, Subang District, West Java, Indonesia. (In Indonesian).

Sudarmadji. 1985. Carbofuran and diazinon residues in rice from rice-cum-fish systems. Friday Seminar, 17 October 1986. Sukamandi, West Java, Indonesia. (In Indonesian).

Research on Rice-Fish Culture: Past Experiences and Future Research Program

IIS SYAMSIAH
S. SURIAPERMANA
ACHMAD M. FAGI
Sukamandi Research Institute for Food Crops
Subang, West Java
Indonesia

SYAMSIAH, I., S. SURIAPERMANA and A.M. FAGI. 1992. Research on rice-fish culture: past experiences and future research program, p. 287–293. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Rice-fish culture systems have been practised by Javanese rice farmers for centuries. Despite good prospects in terms of efficient utilization of natural resources, increased farm income, providing job opportunities, and improved production, studies on rice-fish systems are very limited. Fish production from traditional rice-fish culture is generally low (120–150 kg/ha/year). Yet consumption of irrigation water in rice-fish culture is three times as much as rice monoculture.

Preliminary studies conducted at the Sukamandi Experimental Station, Subang, West Java, showed that improved management of rice-fish culture doubled fish production over traditional techniques. When compared with rice monoculture, concurrent rice-fish or *minapadi* gave higher rice yields of 1.3 t/ha. Duck raising is also practised by Javanese rice farmers. The integration of rice, fish and ducks gave a net profit of US$2,060/year, while the rice-rice monoculture sequence gave only US$950/year.

Future research programs will focus on improvement of rice-fish agroecosystems to determine the complementary interrelationships between the two commodities.

Introduction

Integrating aquaculture into rice farming systems makes efficient utilization of natural resources in irrigated areas. One of such systems is the rice-fish culture which has been practised by rice farmers in Java, Indonesia for centuries (Ardiwinata 1957).

There are three traditional rice-fish culture systems practised in Indonesia (Ruddle 1980; Taslim and Syamsiah 1987). The *palawija ikan* system converts the ricefield to fishpond after harvesting the dry season rice. Fingerlings (5–8 cm) are cultured as an alternative to the secondary crops for two to three months. The *ikan penyelang* system stocks larger fingerlings than those in *palawija ikan* and cultured between the wet and dry season rice crops for one month. The *minapadi* or the concurrent rice-fish system cultures fish together with rice for about 40 days or more. Fingerlings (20–

30/kg) are cultured from transplanting to first weeding or up to second weeding.

In general, the common carp is the most popular species used in rice-fish culture. Its production in the traditional *minapadi* system is quite low (120–150 kg/ha).

Early studies showed that fish excretion increased the availability of nitrogen, phosphorus, calcium and magnesium in ricefield waters which results to increased rice yields (Satari 1962). Thus, rice-fish culture systems – as a help to sustain rice production, increase farmer's income and improve food availability for rural people – are compatible to the agricultural programs of Indonesia.

Preliminary Research Results

For the past few years, areas used for rice-fish culture in the Subang District, West Java, have expanded steadily. In Binong Subdistrict alone, rice-fish culture covers approximately 3,000 ha. The average fish production is less than 100 kg/ha, while consumption of irrigation water sometimes reaches three times as that used for rice monoculture.

The Sukamandi Research Institute for Food Crops (SURIF) has established ricefields of similar size as those in Binong Subdistrict. Four hectares of ricefields were divided into 16 blocks of equal size. Sixteen SURIF staff interested in rice farming were allocated one block of 0.25 ha each. Ten persons practised *minapadi* intensively, while the others grew rice twice a year.

The irrigation water used by each staff-collaborator was recorded by using rectangular weirs. Other data collected were inputs-outputs, effects of insecticides, etc. The research results are summarized below.

Minapadi *vs. Rice Monoculture*

Among the 10 collaborators following *minapadi*, only six were successful. These six were diligent, always present in the fields day and night, particularly at the critical stages of fish growth.

Table 1 shows a simple economic analysis of the *minapadi* system. Rice yields ranged from 800 to 1,500 kg/0.2 ha or 4,000 to 7,500 kg/ha, while fish yields ranged from 56 to 80 kg/0.05 ha or 1,120 to 1,600 kg/ha.

Fish mortalities ranged from 20 to 40%, and was attributed to bird and snake predators. Flamingos preyed on fish at the early stages of growth, i.e., when fish were 1–8 cm. The high temperatures of standing water in ricefields also contributed to fingerling mortality.

Evaluation was continued in the 1985 dry season. Rice and fish production were averaged and expressed per hectare (Table 2). The total equivalent rice production was higher in the *minapadi* block by 1.3 t/ha, and *minapadi* was more profitable than rice monoculture. The total water consumption for *minapadi* was 1.5 times higher than rice monoculture, confirming the information gathered from farmers in Binong.

Effect of Palawija Ikan *on the Succeeding Rice Production*

Four collaborators were involved in *palawija ikan*, instead of growing *palawija* crops such as mungbean, soybean or vegetables. Fish losses were high, ranging from 22 to 51% and the causes were unknown (Table 3).

Although profits from *palawija ikan* were relatively low (US$1.39/day), positive effects on the subsequent rice production were obtained. *Palawija ikan* reduced land preparation cost and use of urea for the succeeding rice crop, and rice production was increased (Table 4). Continuous flooding after the dry season rice for fish culture made the soil soft and easy to till. Fish excretion and flooding itself might have enriched soil nitrogen, thus minimizing urea application needed for high rice production.

Table 1. Economics of *minapadi* at the Sukamandi Experiment Station, 1984/85 wet season. (Farm size = 0.25 ha: 0.2 ha was planted to rice and 0.05 ha was stocked with *C. carpio*).

Farm	Yield Rice (kg)	Yield Fish (kg)	Production costs for rice (US$)	Net returns from fish (US$)	Total returns Rice+fish[b] (US$)
A	1,500	80	60.34	66.82	170.11
B	1,200	57	69.09	47.73	109.54
C	1,200	58	46.18	58.98	143.70
D	1,300	69	53.41	63.41	151.82
E	800	56	60.91	55.45	81.82
F	1,000	62	39.18	40.00	109.91

[a]Original Values in Indonesian Rupiah were converted to US$ at the rate of US$1 = Rp1,100 as of 1985.
[b]Rice price=$0.11/kg; fish price = $1.36/kg.

Table 2. Comparative land productivity and water consumption between *minapadi* and rice monoculture at the Sukamandi Experiment Station, 1985 dry season.

Parameter	Rice monoculture	Rice-fish culture
Total area (ha)		
rice	1.0	0.78
fish	-	0.22
Yield (kg)		
rice	6,619	5,503
fish	-	178
Total equivalent rice yield (kg)[a]	6,619	7,929
Irrigation water consumption (m^3)	1,812	5,440
Total water consumption + rainfall (m^3)[b]	7,432	11,060

$$^{a}\text{Fish yield in rice equivalent, kg} = \frac{\text{Fish yield, kg x fish price, Rp}}{\text{Rice price, Rp}}$$

[b]Rainfall = 5,620 m^3.

Table 3. Economics of *palawija ikan* and fish losses per hectare at the Sukamandi Experiment Station, after the 1986 rice crop. Fish species: *C. carpio*; culture period: 2 months; stocking density: 5,000 fingerlings (3–5 cm)/ha; harvest size: 75–100 g. (Source: Syamsiah et al. 1988)

Farm	Fish production (kg)	Value of output (US$)	Production costs (US$)	Net returns (US$)	Losses (%)
A	235	235	176	59	44
B	275	275	176	99	51
C	259	259	176	83	22
D	269	269	176	93	35

[a]Original values in Indonesian Rupiah were converted to US$ at the rate of US$1 = Rp1,100 as of 1985.
[b]Fish price = US$1/kg; fingerling price = US$1.02/piece.

Table 4. Comparative analysis of production inputs and rice yields before and after *palawija ikan*, 1986/87 (n = 4). (Source: Syamsiah et al. 1987).

Item	Before *palawija ikan* (1985/86 WS)	After *palawija ikan* (1986/87)
Operation (US$)		
Land preparation	55.45	26.91
Seedbed	14.54	14.54
Transplanting	27.27	27.27
Hand weeding	18.18	18.18
Spraying	5.45	5.45
Fertilizer application	3.64	3.64
Fertilizer (kg/ha)		
Urea	205	175
TSP	100	100
KCl	50	50
Pesticide		
Furadan (kg/ha)	16	16
Baycarb (l/ha)	1	1
Rice yield (kg/ha)	4,435	6,284

[a]Original values in Indonesian Rupiah were converted to US$ at the rate of US$1 = Rp1,100 as of 1985.

Effect of Insecticides

The effect of insecticides applied to rice in *minapadi* on the quality of fish flesh was studied in 1985 (Table 5). Furadan 3G, CLFG-45 and diazinon were applied to rice at recommended dosages and times of application. Residues of carbofuran and diazinon were analyzed at SURIF's laboratory. Results showed that insecticide residues in the fish flesh were only 0.07 ppm, which is lower than the Food and Agriculture Organization's allowable standard, indicating the fish is safe for human consumption.

Rice-Fish-Duck Farming Systems

A 1-ha section of irrigated rice-fish field was tried with duck integration in the system. Ducks are commonly raised by Javanese farmers to increase their income. The field was modified as shown in Fig. 1. The small shed can accommodate 100 ducks. Banana trees were planted as shade for ducks during daytime and as a place for laying eggs.

Results of a one year operation (1986–87) are presented in Table 6. The net returns from the rice-fish-duck system was US$2,060/year, while rice monoculture earned US$950/year. Ducks produced 17,031 eggs/year and this contributed considerable income to the farmer. Fish production of 180 kg/ha was much higher than in the traditional systems.

Future Research Program

Unsettled Problems

Not all rice-fish production systems are suitable to farm conditions. Water availability, rice growing season, seed fish production systems and markets are the factors that affect the feasibility of *palawija ikan, ikan penyelang* or *minapadi* systems.

Fish mortality rates are high. These are caused by predation, disease, water quality, food quality and availability, and adaptability of the species. The tolerance of fish to pesticides differs according to its age.

The irrigation water requirement for rice-fish culture, particularly for *minapadi*, is very high. Continuous flow of water is the cause of inefficient water use in *minapadi*. Although it is favorable for fish growth, methods of regulating its use without impairing fish production should be developed to save water. Besides, rice does not need flowing water because it has aerenchyma which provides movement of oxygen from the air to the rice root systems.

An intensive farm survey addressing the above concerns will be carried out in major areas of rice-fish culture. Based on the results of the survey, on-farm experiments will be conducted.

Table 5. Residue of rice insecticides in fish flesh in *minapadi* system at the Sukamandi Experiment Station, 1985. (Source: Sudarmadji 1986).

Treatment	Days after application	Residue (ppm)	
		DS	WS
Carbofuran 0.6 kg a.i./ha (Furadan 3G)	60	0.028	0.049
Carbofuran 0.6 kg a,i./ha (CLFG-45)	60	0.039	0.026
Diazinon 1.2 l a.i./ha	30	nd[a]	nd[a]
Control	60	0.015	0.027

[a]nd = undetected.

Proposed Research Areas

ON-FARM RESEARCH

This research will be conducted jointly by the technical team from SURIF and the Research Institute for Freshwater Fisheries (RIFF) in the villages of Binong (Subang, West Java). Binong has 10,234 ha of irrigated ricefields. Its topography is generally flat with some undulating areas. In 1985, farmers in this area practised a rice-rice-fish cropping pattern in 1,578 ha; (rice+fish)-(rice+fish)-fish in 197 ha and rice-rice-fallow in the rest of the area. Binong is located about 30 km from SURIF, with elevation of 20–30 m above mean sea level.

Table 6. Comparative economics between a rice-fish-duck system and rice monoculture per hectare for a one year operation at the Sukamandi Experiment Station, 1986-87.[a] (Source: Suriapermana et al. 1988).

Cropping system	Production			Production costs (US$)	Value of output (US$)	Net returns (US$)
	Rice (kg)	Duck (no. of egg)	Fish (kg)			
Rice-rice-fallow	11,268	-	-	812.50	1,762.25	949.75
(Rice+fish-duck)-(rice-duck+fish)-duck	11,708	17,031	185	1,632.56	3,692.29	2,059.73

[a]Original values in Indonesian Rupiah were converted to US$ at the rate of US$1 = Rp1,100 as of 1985.

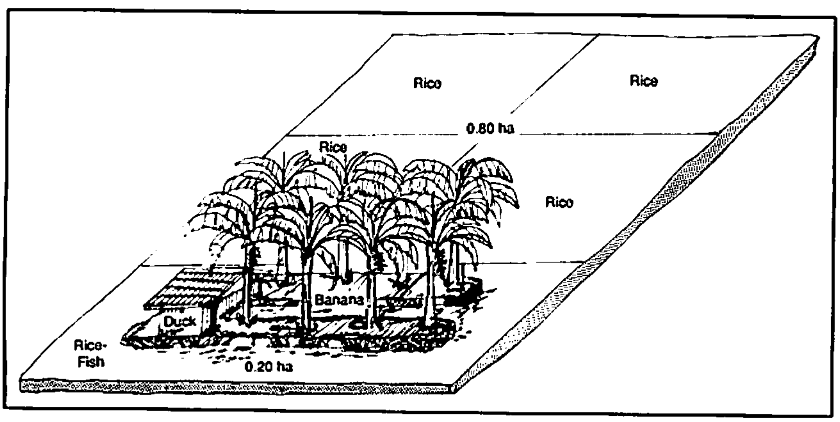


Fig. 1. Field arrangement in a rice-fish-duck systems, Sukamandi Experiment Station, West Java.

A survey will be conducted by the technical team to: 1) study the socioeconomic conditions in the area, the physical and chemical conditions of the soil and irrigation water, and its ecosystems; 2) determine the existing production systems; 3) identify the constraints to production and increase of farm income; and 4) determine the available farm resources.

The evaluation of different production systems in rice-fish farming. Based on the results of the survey, replicated experiments in farmers' fields will be conducted on the different production systems/patterns involving improved technologies for rice and fish. Six potential production systems will be tested in this preliminary evaluation which were chosen based on discussions with extension officials and farmers. These patterns are: rice-rice-fallow; rice-rice-fish; (rice+fish)-(rice+fish)-fallow; (rice+fish)-(rice+fish)-fish; (rice+fish)-fish-in between-(rice+fish)-fish; and (rice+fish)-(rice+fish)-soybean.

In the first year, evaluation of rice-fish production systems using technologies based on the survey results and earlier research will be done. In the second and third years, testing of improved rice-fish technology components obtained from on-station research will be conducted. Information on: inputs for each production pattern, total production of rice and fish; and economic analyses and evaluation of the most profitable production pattern will be obtained.

Evaluation of fish culture in small backyard ponds as an integral part of a rice farm. The performance of several species in monoculture and polyculture systems will be evaluated. The species are the common carp (*Cyprinus carpio*), Java carp (*Puntius gonionotus*), Nile tilapia (*Oreochromis niloticus*), Sepat siam (*Trichogaster pectoralis*), catfish (*Clarias batrachus*), gourami (*Osphronemus gouramy*) and nilem carp (*Osteochilus hasselti*). Yields from these production systems will be compared with traditional cultivation methods practised by the farmers.

Agroeconomic evaluation of rice-fish culture systems as practised by rice farmers. A number of farmers engaged in different production systems will be monitored for three years. Fifteen farmers will be selected to represent each production pattern or system. Socioeconomic comparisons will be done between these 15 farmers and farmers that will be involved in the introduced production systems described above.

ON-STATION RESEARCH

This research will be conducted at the experimental farms of SURIF at Sukamandi and RIFF at Bogor. Studies on rice agronomy, water management and rice pests control will be carried out at SURIF, while studies on fisheries and environmental aspects of rice-fish farming system will be done at RIFF.

Control of rice pests in rice-fish culture. The effects of fish on rice pest infestations as well as the effects of insecticides on fish survival in rice-fish culture, will be determined. Experiments will use three species and two different flooding depths. Five groups of insecticides (group to be represented by two different compounds), will be evaluated for their effects on fish growth and mortality, rice parasites and predators of rice pests and other living organisms. Residues in soil, irrigation water and fish will also be determined.

Effects of fish size, stocking density and feeding on fish growth. This study will evaluate the effects of fish stocking size, stocking density and feeding on the fish growth rate of different species and their growth rates in different rice-fish culture patterns.

Water quality and productivity in rice-fish farming systems. These will determine the water quality and the corresponding productivity of the ricefield under different rice-fish farming systems patterns.

Effects of rice maturity on fish growth and yield. These will be tested using early rice varieties (100 days), medium rice varieties (120 days) and late rice varieties (135–150 days). The data to be collected are fish growth rate, fish size at harvest, fish yield and rice production.

Effects of water management techniques on fish growth and water requirements in different rice-fish culture patterns. These will be determined on the concurrent rice-fish systems, *palawija ikan* and *ikan panyelang*. Treatments will be composed of stagnant water at varying depths versus continuous water flow at varying depths.

Use of herbicides vs. hand weeding in rice-fish culture. The effect of rice-fish culture on the amount of hand weeding in concurrent rice-fish culture will be determined. At various frequencies of hand weeding, rice-fish systems and rice monoculture will be compared in terms of fresh biomass produced, composition of weed species, and fish and rice yields. This will be followed by experiments on the effects of herbicides on fish mortality, growth and yield including rice production in concurrent rice-fish systems. Two groups of herbicides will be tested on three species.

Evaluation of soil fertility in relation to rice-fish culture. The soil fertility and fertilizer needs of rice and the effect of fish on the succeeding rice crops will be evaluated. The treatments are the rates of NPK applications in rice-fish culture and for the rice succeeding fish as a secondary crop. Information that will be monitored will include data on soil chemical analyses before and after the experiment, rice production, fish growth and fish yields.

References

Ardiwinata, R.O. 1957. Fish culture on paddy fields in Indonesia. Proc. Indo. Pac. Fish Counc. 7 (II-III):119–154.

Ruddle, K. 1980. A preliminary survey of fish cultivation in ricefields, with special reference to West Java, Indonesia. Bull. Natl. Mus. Ethnol. 5(3).

Satari, G. 1962. Budidaya padi sawah dengan ikan. Penelitian tentang beberapa aspek agronomi. Disertasi untuk memperoleh gelar doktor ilmu pertanian. Universitas Indonesia, Bogor, Indonesia. Ph.D. dissertation. (In Indonesian).

Sudarmadji. 1986. Residu insektisida karbofuran dan diazinon pada ikan budidaya minapadi. Paper presented at the Friday Seminar, 17 October 1986, Balittan Sukamandi, Subang, West Java. (In Indonesian).

Suriapermana, S., I. Syamsiah, A.M. Fagi and Atmadja. 1988. Optimasi daya dukung lahan dengan sistem minapadi-itik pada lahan sawah beririgasi. Makalah disajikan pada Simposium Tanaman Pangan II, 21–23 Maret 1988, Bogor, Indonesia. (In Indonesian).

Syamsiah, I., H. Taslim and K. Pirngadi. 1988. Usahatani palawija ikan setelah padi sawah pada lahan irigasi dalam meningkatkan pendapatan petani. Reflektor 2(1). (In Indonesian).

Taslim, H. and I. Syamsiah. 1987. Rice-fish farming systems at Binong, West Java. Indonesia. Paper presented at the 18th Meeting of the Asian Rice Farming Systems Working Group, 30 August-4 September 1987, Islamabad and Lahore, Pakistan.

On-Farm Rice-Fish Farming Systems Research in Guimba, Nueva Ecija, Philippines

JOSE N. TORRES
NEMESIO A. MACABALE
JESIBETH R. MERCADO
Provincial Research Service
Department of Agriculture
Cabanatuan City, Philippines

TORRES, J.N., N.A. MACABALE and J.R. MERCADO. 1992. On-farm rice-fish farming systems research in Guimba, Nueva Ecija, Philippines, p. 295–299. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Results of three-season on-farm experiments and one-season pilot production program in rice-fish in Guimba, Nueva Ecija, Philippines, are presented. On-farm experiments focused on evaluation of alternative systems for rice-fish production and organic fertilization in rice-fish. The pilot production program was implemented to verify the results of these experiments. Pond refuge were found to produce more fish than trench refuge systems. Addition of farm manure had only slight positive effects on fish production. In all experiments, rice yields were neither positively nor negatively affected by the presence of fish. Pilot production programs highlight the risks farmers face when adopting rice-fish systems.

Introduction

A concerted effort to extend rice-fish to farmers was initiated through the national rice-fish culture pilot testing program of the Department of Agriculture (DA) in 1979 (Arevalo 1987). The program attained some initial success when in 1982 rice-fish adoption covered 1,397 ha. Since then, areas have declined and the program was discontinued in 1986. This program, however, identified the major constraints to widespread adoption. Among these were fingerling supply, pesticide contamination, water control, short growth period and credit.

The DA's Regional Integrated Agricultural Research System (RIARS) in Region III has been conducting on-farm research on rice-fish culture since 1986. The work has benefitted from collaboration with the ICLARM/IRRI/CLSU Rice-Fish Farming Systems Research Project. On-farm trials under this collaboration are focused on the development and evaluation of alternative systems of rice-fish farming and organic fertilization in rice-fish culture.

Methodology for On-Farm Trials

A total of 36 farmer-cooperators from four municipalities in two provinces of Central Luzon were involved in the on-farm trials (Table 1). However, only the results from Guimba are reported here.

Table 1. Number of farmer-cooperators involved in the rice-fish on-farm trials by municipality and province.

Municipality	Province	No. of cooperators
Guimba	Nueva Ecija	12
Jaen	Nueva Ecija	10
Licab	Nueva Ecija	4
Arayat	Pampanga	10
Total		36

Experimental Plots

Experimental plots of 300 m^2 were prepared for concurrent rice-fish culture using trench or pond refuges. Peripheral trench refuges were dug with a width of 1.0 m and a depth of 0.3–0.4 m. Pond refuges had about 10% of the ricefield excavated at one end to a depth of 0.75–1.0 m.

Each cooperator had three or four 300-m^2 rice-fish plots depending on the number of treatments. Replications were across farms. Six farmers cooperated in each of the two studies.

Rice Agronomy

Ricefields were prepared with one plowing and three harrowings. Rice was transplanted at random spacing 25–30 days after plowing. Inorganic fertilizers were applied during the last harrowing and five days before panicle initiation. The following chemicals were applied: for weed control - Machete EC sprayed after transplanting at the rate of 0.6 kg a.i./ha; for insect control - Furadan 3G applied basally during the last harrowing at the rate of one bag (16.7 kg)/ha, and Parapest or Cymbush EC sprayed at the rate of 0.4 kg a.i./ha and 500 ml/ha, respectively.

Fish Culture

Fingerlings of tilapia (*Oreochromis niloticus*) were stocked at 5,000/ha in the trench refuge and 7,500/ha in the pond refuge. Stocking was done 10–14 days after rice transplanting. Feeds such as rice bran and soybean by products were given when available. Fish were harvested from trench refuges about one week before rice harvesting. The fish culture period was extended after rice harvesting in pond refuges.

Results and Discussion

Study 1. Alternative Systems for Rice-Fish Farming

As rice-fish culture is dependent upon the culture period of rice and water availability, there is a need to develop systems for overcoming these limitations. In this study, an experiment was conducted to compare pond and trench refuge systems with rice monoculture. Pond refuges allow the fish culture period to be extended beyond rice harvesting.

Total fish production was higher in pond refuge system at 73.3 kg/ha compared to the 53.3 kg/ha for the trench refuge system. Low yields were due to small size of fingerlings stocked and short culture period. Average weight at harvest and survival rate were also higher in the pond refuge system (Table 2). It is interesting to note that the presence of fish did not significantly affect rice yields.

Table 2. Summary production data in rice-fish on-farm trials stocked with mixed sex *Oreochromis niloticus* using pond and trench refuge systems, January-May 1989.

Production parameter	Trench refuge	Pond refuge	Rice monoculture
Stocking density (fish/ha)	5,000	5,000	
Mean stocking weight (g)	2.15	2.56	
Mean harvest weight (g)	14.57	18.42	
Mean weight gain (g)	12.42	15.86	
Survival (%)	75.00	85.00	
Culture period (days)	60-70	80-90	
Fish yield (kg/ha)	53.3	73.30	
Rice yield (t/ha)	6.3	6.1	6.2

Study 2. Organic Fertilization in Rice-Fish Culture

In this study, three similar experiments were conducted. Fertilization treatments consisted of inorganic fertilizers only (treatments I and II) and combination of inorganic fertilizers and animal manure (treatments III and IV) for the two experiments conducted during the wet season. An additional 50 kg/ha of urea was applied as top dressing in all the treatments in the dry season (Table 3). Culture period of *O. niloticus* for all experiments were 60–70 days. The main difference was that experiments 1 and 2 used a trench refuge and a stocking density of 5,000/ha, while experiment 3 had a pond refuge and stocking density of 6,000/ha.

Fish yields were low over the three experiments and lowest in the dry season because only 2-g-fingerlings were stocked, survival was slightly lower and adequate water level was difficult to maintain (Table 4). Treatment effects on fish yields were only marked in the third experiment. Here, farm manure increased yields by about 50 kg.

Rice yields varied only between 5.4 and 6.8 t/ha across experiments (Table 4). Similarly, treatment effects were insignificant. If anything, rice yields tended to be slightly lower in manured plots.

Rice-Fish Pilot Production Program

Awareness and interest in rice-fish generated by on-farm experiments was sufficient to start a pilot production program in three barangays (Caballero, Maturanoc and Triala) of Guimba, Nueva Ecija. Work started during the wet season of 1988. Farmer-cooperators were selected on their willingness to try out the rice-fish technology. Other criteria, such as availability of irrigation water and accessibility, were also taken into consideration.

All farm activities, like land preparation, transplanting, plant care and provision of farm inputs were the cooperators' responsibility. Only fingerlings of *O. niloticus* were provided by the Bureau of Fisheries and Aquatic Resources (BFAR). A total of four hectares involving 17 cooperators was covered by the program.

During the first year of operation, no significant results were achieved due to a

Table 3. Experimental treatments of the studies on organic fertilization in rice-fish on-farm trials.

Treatment	Kind of fertilizer	Method of application	Experiment 1 Jun-Oct 1988 Wet season trench	Experiment 2 Jan-May 1989 Dry season trench	Experiment 3 Jun-Oct 1989 Wet season pond
I Control	16-20-0	basal	200	200	200
	45-0-0	basal	50	50	50
	45-0-0	top dress	50	100	50
II	16-20-0	basal	300	300	300
	45-0-0	basal	50	50	50
	45-0-0	top dress	50	100	50
III	16-20-0	basal	200	200	200
	45-0-0	basal	50	50	50
	45-0-0	top dress	50	100	50
	+ animal manure	basal	5,000	5,000	5,000
IV	16-20-0	basal	200	200	200
	45-0-0	basal	50	50	50
	45-0-0	top dress	50	100	50
	+ animal manure	50% basal	3,750	3,750	3,750
	+ animal manure	50% topdress	3,750	3,750	3,750

Table 4. Summary production data in rice-fish on-farm trials on organic fertilization using trench and pond refuge systems (1988–89).

	Experiment 1 1988 Wet season trench n = 5				Experiment 2 1989 Dry season trench n = 6				Experiment 3 1989 Wet season pond n = 3			
Production parameter	I	II	III	IV	I	II	III	IV	I	II	III	IV
Mean stocking weight (g)	16.4	16.1	14.8	15.1	2.3	2.4	2.3	2.4	10.5	10.2	10.9	11.8
Mean harvest weight (g)	32.6	32.7	32.4	31.4	13.0	13.1	11.9	14.2	34.6	38.5	40.5	41.2
Mean weight gain (g)	16.2	16.6	17.6	16.3	11.7	10.7	9.6	11.8	24.1	28.3	29.6	29.4
Survival (%)	80.0	78.0	82.0	83.0	67.0	67.0	78.0	81.0	74.0	77.0	78.0	82.0
Fish yield (kg/ha)	130.3	127.0	132.7	129.7	43.7	44.0	46.3	59.7	147.7	169.0	180.0	200.0
Rice yield (t/ha)	6.5	6.6	6.1	6.1	6.6	6.8	5.8	6.2	5.9	6.0	6.0	5.4

destructive typhoon that hit the province. Flooding of the ricefields resulted in fish escape. Nevertheless, farmers remained convinced of the potential benefits of rice-fish. They continued to participate in the pilot production program.

Conclusions

Our on-farm experiments suggest that the pond refuge system appears to be more productive than the trench refuge system. Ponds are more productive because fish culture can be extended almost independently of rice culture, and more fish can be stocked. Simply allowing fish to grow longer increases fish production. Farmers also prefer this design because it is easier to carry out land preparation. Rice production did not appear to be negatively or positively affected by fish. One disadvantage, however, is that fish can get trapped when pond refuges are far away.

During the pilot testing of the program, it was frequently observed that farmers did not exactly follow the recommendations. Usually, farmers applied less than the recommended rates of inputs. The reason given was the high costs of these inputs and the associated risks of crop loss from poaching and natural calamities, especially typhoons.

Acknowledgements

The research team of the project wishes to extend their sincere appreciation to Dr. C.R. dela Cruz of ICLARM and Prof. R.C. Sevilleja of CLSU-FAC for unselfishly sharing their scientific expertise in the design and implementation of the on-farm experiments, and for their comments and suggestions in the preparation of this report. The continued support of IRRI is likewise acknowledged. Lastly, the team recognizes the wholehearted and unrelenting cooperation manifested by the farmer-cooperators without whom this endeavor would not have been possible.

Reference

Arevalo, T.Z. 1987. The rice-fish culture program. Paper presented during the Fisheries Forum on the Development of Integrated Agri-Aquaculture Farming Systems, 27 March 1987, Bureau of Fisheries and Aquatic Resources, Quezon City. 12 p.

On-Farm Rice-Fish Farming Research in Ubonrachathani Province, Northeast Thailand

NIRAN THONGPAN
MATSYA SINGREUANG
CHATCHAI THAILA
SUPRAMIT MANKHENG
SUPARAT KAEOWSAWAT
JOHN D. SOLLOWS*
Ubon Farming Systems Research and Development Unit
P.O. Box 79, Ubonratchathani 34000
Thailand

THONGPAN, N., M. SINGREUANG, C. THAILA, S. MANKHENG, S. KAEOWSAWAT and J.D. SOLLOWS. 1992. On-farm rice-fish farming research in Ubonratchathani Province, Northeast Thailand, p. 301–313. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

On-farm rice-fish farming trials began in Ubonratchathani in June 1984 at two sites, one irrigated and one rainfed. Research thrusts during the first three years included the economics of rice-fish culture and rice monoculture, effects of rice-fish culture on rice yields, and appropriate fish stocking densities and species composition. From 1987 onwards, the project conducted more extensive multilocation testing of rice-fish culture at three other rainfed sites.

The practice appears to give appreciable benefits to farmers. Net benefits per hectare and per man-day are higher for rice-fish culture than for rice monoculture. Rice yields per hectare in fields stocked with fish are generally higher than fields without fish. The effects of stocking density and species composition on production and growth were less clear. There was no single best stocking density nor species composition. Common carp (*Cyprinus carpio*) grew larger than the Nile tilapia (*Oreochromis niloticus*) and silver barb (*Puntius gonionotus*). Small seed fish (2–3 cm), particularly common carp, are much more vulnerable to loss than larger seed fish under on-farm conditions. Tests on the interrelationships between the effects of chemical fertilizer and fish stocking densities on rice yields were not conclusive.

Multilocational trials using on-farm research techniques can be an effective way to determine the socioeconomic and environmental appropriateness of rice-fish technologies. Between 1987 and 1989, two technologies were studied on three different topographies in the same ecological zone in Ubonratchathani Province. The first year's study showed that direct release of 5–7-cm fingerlings to ricefields gave positive economic results in all

*Present address: ICLARM Bangladesh Office, House No. 20, Road No. 9/A, (New) Dhanmondi R/A, Dhaka 1209, Bangladesh.

trials, despite the high costs. Rice yields were consistently higher in fields grown with fish. In the second year, the establishment of nursery ponds for raising 2-3-cm fingerlings for later release to ricefields showed a general improvement of returns on investment than the previous technology (fixed costs of pond digging not included). Both technologies produced the best yields on flat topography with a gentle slope.

Introduction

Rice farmers in Northeast Thailand make up an important proportion of the country's agricultural producers. They face many problems including poor soil, uncertain rainfall, severely limited finances, unstable market prices and fluctuating availability of protein for their own consumption. A major source of protein for these people has been naturally occurring fish, many of which come from ricefields. Growing population, environmental degradation and a virulent epizootic disease have decimated some of these wild species in many areas. This has adversely affected the income, as well as the nutrition of farmers and their families, since the species most affected were those with the highest market price.

Rice-fish culture, then, seemed to be a technology worth trying by Northeast Thai rice farmers. It is technologically similar to traditional ricefield fisheries. Pesticides are used very sparingly by most of these farmers. The practice places a modest demand on scarce resources, particularly money. Important adverse effects on existing systems were not expected. All these factors implies that rice-fish culture is a low-risk technology.

The fish species introduced are resistant to environmental stress, feed low on the trophic pyramid and grow to reasonably large sizes. They were expected to achieve high productivity per hectare at modest feeding costs, and command a reasonably high market price. They were made further attractive by their greater resistance to the disease which had seriously affected some important wild species.

As defined here, rice-fish farming is the rearing of fish in flooded fields seasonally planted with rice. Generally, fish and rice are grown concurrently, but rotational systems are practised on some irrigated farms in the dry season. Our definition covers systems in which fish are both fed and unfed.

This paper reports the results from two rice-fish farming research projects in Ubonratchathani Province. The first project which ran from 1984 to 1987 were at the Lam Don Noi irrigated area at Pibulmangsaharn District and at Ban Khoo Khad, a rainfed village in Kheuang Nai District. After an initial year of working with six farmers at Dom Noi and seven at Khoo Khad, the number of participating farmers was increased to 12 and 13, respectively. The main research was to determine the relative economics of rice-fish culture and rice monoculture. The effects of rice-fish culture on rice yields, appropriate fish stocking densities and species composition and the interrelationships between the effects of chemical fertilizer and rice-fish culture on rice yields were also investigated.

Under the second project which began in 1987, multilocational testing has been used to study the flexibility of rice-fish technologies under three topographic conditions in Det Udom, Kheuang Nai and Amnart Charoen Districts. The topographies represent most of the range found in the Northeast. All areas were in the same agroecological zone, and had in common low-grade soils with poor water retention, low fertility and erratic rainfall (Fig. 1). During the first year of the second project, the studies investigated the feasibility of the direct release of 5–7-cm fingerlings to ricefields and the effects of the practice on rice yields. In the second year, the research focused on the feasibility of nursing 2–3-cm fry prior to their release in ricefields.

On-farm research techniques were used in both projects. This approach produces a wide range of apparently disconnected data. It is therefore necessary to

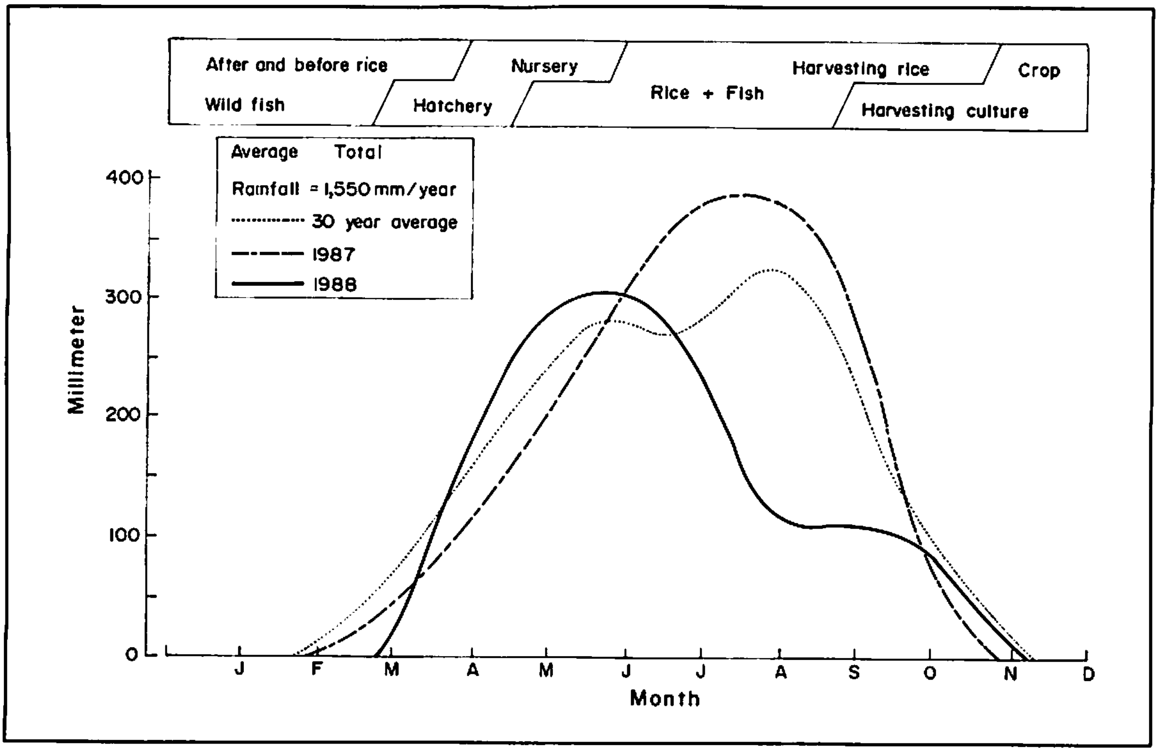


Fig. 1. Monthly rainfall and activities in Ubonratchathani. (Source of rainfall data: Ubonratchathani Agricultural Weather Station 1987 and 1988).

maintain frequent and informal contact with the farmer to understand the relationships of the farming system. Such constant interactions are the real value of on-farm research, since they reflect the real concerns and needs of the farmer.

Objectives

The specific objectives of the two projects were to compare or investigate the following:

1. Economics of rice-fish culture versus rice monoculture (1984–87).
2. Appropriate fish stocking densities and species composition for concurrent rice-fish system (1984–86).
3. Effects of rice-fish culture on rice yields (1984–88).
4. Interrelationship between the effects of chemical fertilizer and rice-fish culture on rice yields (1986–87).
5. The growth rates of different sizes of fingerlings in specific time frames in nursery ponds (1988–89).
6. The suitability of technology packages under three different topographical conditions in Northeast Thailand (1987–89).

Materials and Methods

Economics of Rice-Fish Culture and Rice Monoculture

On each farm, two plots or series of plots were examined. One of these was stocked with fish and the other without. All comparisons were made on-farm over a number of farms. For comparisons involving rice, plots planted with the same variety or combination of varieties were compared. Most data were gathered from interviews with participating farmers, each of whom were visited about once a week.

Experimental plot areas were estimated by measuring the sides of the plot with a tape measure, making a scaled drawing and breaking this drawing into a series of triangles and rectangles, whose individual areas could be summed.

Time, money and manpower consumed by each component activity were recorded during the weekly interviews. Species, size, number and weight of fish caught were similarly recorded. Farmers' units of inputs (such as buckets of dung) and samples of fish caught when the researcher was present were weighed with spring balances of 5- and 20-kg capacity, as appropriate.

Rice yields were either calculated based on the farmer's total plot estimates or by samples taken on all farms. A farmer-specific estimation error applies in the former procedure as many farmers could not provide such estimates. For the latter procedure, within each experimental plot, 25 samples of 8 m^2/ha each were marked with normally not less than two samples per plot. Within each sample, the number of hills was counted, plant heights and number of tillers for 10 hills recorded, and 10 panicles were collected. Each panicle was measured, the number of full and empty seeds per panicle counted and the total number of the full seeds from the 10 panicles weighed. Finally, after the entire sample was harvested, threshed and winnowed, the moisture content of the harvested rice was recorded.

For the economic assessments, a time and/or money value was placed on every input. While those paid for by the farmer could be assigned money values directly, the time demands of nonfinancial investments were not easily equated to money. Some activities demand large, uninterrupted chunks of time and can compete with other activities. Others, such as fish feeding, involved frequent, short visits and competed with no other activity, but could occupy a respectable number of man-days per year. Rather than equating man-days with money, assessing net return per man-day seemed a better way of accounting for these inputs.

Money values were placed on fish and rice production, using appropriate sales data. When possible, prices were specific for farmer, variety and month (in the case of fish). Overall averaging and more rarely, the informed judgement of the researcher sometimes had to be used to estimate appropriate unit price. For each farmer, net returns were calculated by subtracting money inputs from the appropriate production value. Net returns per hectare and per man-day could then be calculated.

The basic comparison made was between treatments on each farm, over a number of farms. The data could then be summed among farms, by location. When annual results for Dom Noi were compared with those for Khoo Khad, those from Dom Noi were combined for two seasons, starting with the rainy season.

Fish Stocking Density and Species Composition

In 1984, three irrigated farms received 2,500 fish/ha and three others received 5,000 fish/ha. The stock consisted of 20% common carp *(Cyprinus carpio)*, and 40% each of Nile tilapia *(Oreochromis niloticus)* and silver barb *(Puntius gonionotus)*.

During the second year at each site, four farmers each tried stocking densities of 2,500, 3,750 and 5,000 fish/ha. Fifty per cent of the fish were common carp, 25% silver barb, 20% tilapia and 5% bighead carp *(Aristichthys nobilis)*.

The treatment design was modified during the second year for these reasons. First, wide interfarm variation completely obscured any effects of density among the small sample of farmers participating during the first year. Second, common carp grew better than the other two species in the first year, but were stocked at lower densities. Thus, its performance at higher densities seemed worth studying. Third, some farmers were interested in trying Chinese carp, and bighead carp was easily available. The stocking density was based on how much money the farmers are willing to invest for testing the species.

Most of the relevant data were gathered as described in the first experiment. Periodic sampling from ricefields to check growth was impractical. Preplanned stocking densities were often modified by circumstances, so that trials were actually conducted over a range of densities, which is to some degree are controlled by the researcher. The resulting data could be plotted on scattergrams to possibly indicate trends. Statistical analyses were not attempted.

Effects of Rice-Fish Culture on Rice Yields

Data were gathered and compared as described in the first experiment on rice-fish economics.

Interrelationship Between the Effects of Chemical Fertilizer and Rice-Fish Culture on Rice Yields

On each farm, four plots were selected. These were as near one another and as similar in all respects as possible. Two plots received fish and two were unstocked. The two plots stocked with fish received one level of chemical fertilizer and the other two, a much lower level or none.

Production data were gathered using the rice sampling procedure described in the first experiment. An analysis of covariance was used to assess the response to fertilizer under stocked and unstocked conditions.

Multilocation Testing: Farmer and Site Selection

Three topographical areas were chosen for the trials. The first site was at Det Udom. Its area is undulating with steep slopes and many small, natural waterways. Ricefields are restricted in size, occur at many elevations and occupy about 36% of the available area. Water retention is best at lower elevations. The second site was at Kheuang Nai. This area is flat, with a very gentle slope leading to natural waterways. Water retention is poor and there are scattered patches of saline soil. Ricefields can be large and occupy about 46% of the available area. The area is prone to both flooding and drought. The third site, Amnart Charoen, has a low, undulating slope with large areas of lowland. Up to 70% of the area are ricefields.

General meetings were held, regarding the project, with fisheries officials, extension workers, village and Tambon leaders and farmers, in February 1987. Meetings were held in Det Udom, Kheuang Nai and Amnart Charoen Districts. Farmers were invited to participate in the project. All volunteer farmers were visited at their farms. The final farmer selection was based on the degree to which the farm represented topographic, socioeconomic and environmental criteria. The number of participants increased from the first year to the second year: 7 to 17 in Det Udom, 9 to 17 in Kheuang Nai and 12 to 18 in Amnart Charoen.

Topographic data from some participants were incomplete for both years because of a change in research staff and some farmers stopped certain activities. Data presented in Tables 1 and 2 come from situations where activities were completed.

Meetings were held each year to brief farmers, extension workers and fisheries officials on new, cooperative-designed research objectives. All research was conducted on-farm and was farmer-managed.

Table 1. Average fish yields and returns from rice-fish farming, 1987-88.

Location; no. of farmers	Area (ha)	No. of days	Yield (kg/ha)	Investment (US$)	Income (US$)	Return on investment
1987						
Amnart Charoen; 3	0.24 (±0.07)	139 (±22.07)	146.3 (±71.79)	41.9 (±5.00)	104.4 (±16.90)	2.3 (±1.40)
Kheuang Nai; 8	0.34 (±0.11)	134 (±20.48)	363.3 (±275.31)	100.9 (±68.73)	235.4 (±217.57)	2.4 (±1.41)
Det Udom; 4	0.26 (±0.24)	126 (±22.46)	219.6 (±92.16)	106.9 (±33.70)	112.7 (±67.75)	1.0 (±0.52)
1988						
Amnart Charoen; 9	0.39 (±0.17)	100 (±16.38)	87.7 (±42.85)	26.8 (±1.60)	60.8 (±42.59)	2.3 (±1.55)
Kheuang Nai; 6	0.48 (±0.22)	110 (±12.29)	263.6 (±163.27)	57.7 (±29.16)	206.0 (±149.76)	3.9 (±3.26)
Det Udom; 7	0.31 (±0.15)	129 (±20.49)	181.7 (±111.55)	53.7 (±3.03)	128.3 (±108.97)	2.3 (±1.81)

[a]Fish price = US$1/kg.
Figures in parentheses are standard deviations.

Table 2. Comparative economics of rice-fish farming and rice monoculture in Lam Dom Noi irrigated area, 1984–85. (Source: Sollows and Thongpan 1986).

Item	Rice-fish			Rice monoculture		
	Rainy 1984[a]	Dry 1985[b]	Both seasons	Rainy 1984[a]	Dry 1985[b]	Both seasons
Area (ha)	0.825	1.64	NA[c]	1.746	2.21	NA
Value of production (US$)	207.00	300.28	426.76	215.24	161.48	344.36
Production costs (US$)	240.96	82.44	289.84	38.60	93.16	103.92
Net returns (US$)	-33.96	217.84	137.72	176.64	68.32	240.44
Net returns per hectare (US$)	-41.16	133.20	120.80	101.16	30.96	159.88
Labor inputs (man-day)	134.00	124.00	222.00	99.00	113.00	154.00
Net returns per man-day (US$)	-0.25	1.76	0.62	1.78	0.60	1.56

[a]Data from three farms.
[b]Data from six farms.
[c]NA = not applicable.

Feasibility of Direct Stocking of Large Fingerlings to Ricefields

Fingerlings (5–7 cm) were purchased from private hatcheries and released directly to the ricefields. Nile tilapia, common carp and silver barb were stocked at 3,750/ha with a ratio of 1:2:2, respectively. Culture period is around 133 days. Feeds included rice bran, broken rice, termites and manure. Some farmers had previously dug ponds in their ricefields, but fish were released only after the ricefield was flooded. The trials were replicated at all three topographies.

Effects on Rice Yields on Three Topographies

Rice was grown with and without fish. Rice was transplanted at all test sites. The varieties grown were selected by the farmers, which included native and developed varieties: RD 6, RD 8, KDML 105, San Pa Tong and a local variety. Fingerlings were released to the ricefields about 15 days after transplanting when the water was no longer turbid. Water level was increased from 15 to 30 cm as the rice grew. By harvest time, 60% of the ricefield areas had become dry from natural causes. In late October, yield samples of rice were taken as described in the first experiment. Trials took place at all the three topographies.

Feasibility of Nursing Small Fry in Rice-Fish Systems (1988)

Nursery ponds were established in fields to rear small fingerlings before allowing them access to the ricefield. Some farmers had previously dug ponds, while others dug ponds for the first time. Seed fish were contained in these ponds surrounded with a nylon net. To standardize the investment criteria of the representative farmers, pond construction costs were excluded in the economic analysis.

Fry (2–3 cm) of Nile tilapia, common carp and silver barb, purchased from a private hatchery, were stocked at 3,750/ha with a ratio of 1:2:2, respectively. Data on the size and weight of fingerlings were collected from middle of June through July and August 1988 in five periods: 15–30 days, 31–45 days, 46–60 days, 61–75 days and over 75 days. The fish stayed in ricefields for 85–172 days (Table 1). Feed given in the nurseries included rice bran, broken rice, animal manure and termites. After release from the pond, the fish were raised in the ricefield until harvest. Trials were replicated at all three topographies.

Results and Discussion

Economics of Rice-Fish Culture and Rice Monoculture

By the end of 1984, initial investments in rice-fish culture had not yet been recovered by most irrigated farmers, who had been practising for only six months. While it was too early to conclude on the relative profitabilities of rice-fish culture and rice monoculture, the following observations were pertinent:

1. The efficiency of the farmer-cooperators was expected to increase with experience.
2. Three of the six participants had paid for labor to help in dike and trench construction. Subsequent experience suggests that such hiring would not have occurred under normal circumstances.
3. Fingerlings costs were a considerable investment, which individual self-sufficiency could greatly reduce.
4. A couple of farmers used significant amounts of rice bran as fish feeds. If the farmer must pay for the bran, the use of bran in large quantities becomes questionable.

Data from Dom Noi in the 1985 dry season and for a couple of new participants in the 1985 rainy season gave the most credible picture of the relative economics of the two practices. In all cases, rice yields were based on farmers' total plot estimates.

The close of the 1985 dry season marked the end of one year of rice-fish farming for the original six Dom Noi farmers. Data are summarized in Table 2. During the dry season, net returns per hectare and per man-day are higher for rice-fish culture than for rice monoculture even if the costs of fingerlings and rice bran and the value of the remaining fish in the ricefield were not yet accounted. However, for the entire year, net returns from rice-fish culture was lower than rice monoculture which was caused by the large initial investments in rice-fish culture.

Similar data were generated from two other farms in the 1985 rainy season. While this is an extremely small sample, it is worth noting that net returns in rice-fish culture were higher than in rice monoculture on both farms.

Economic comparisons involving all 25 farms must incorporate data which is less empirical than desired. Only five of these farmers reported lower net returns per hectare from rice-fish culture than from rice monoculture. In three of these cases, initial investment costs depressed net returns; one farmer had severe fish poststocking mortalities; and the other had low rice yields and modest fish harvest. Lower net returns per man-day were observed in three cases where the farmer spent considerable time feeding and transferring fish and where there were severe poststocking fish mortalities.

Considering only the fish component of the system for the 25 farms, the pattern of variation in net returns differs little from that found in earlier work (Table 3). Net returns per man-day invested in fish culture tend to be much higher than local wage rates for hired farm labor, particularly in Khoo Khad, where systems were more extensive and fish capture techniques less time-consuming.

Over a three-year period, there was a steady increase in area devoted to fish culture on a per farm basis in Dom Noi, where previous experience in the practice was limited. Production values per farmer also rose from 1984 to 1987, despite a drop in fish prices over this period. Financial investments over the same period declined, with occasional exceptions for major seed fish purchases or pond construction costs. The trend for time investments is less clear. Improvements to and expansion of fish culture areas are time-consuming activities which different farmers do at different times. If only one or two farmers carry out pond construction in the course of a season, these investments will have a strong effect on the overall average. Average net returns per hectare and per man-day all have upward trends over three years.

To compare results from Dom Noi with those from Khoo Khad, totals by season from Dom Noi had to be combined to give annual figures. In most cases, this could be done by simple addition, except in the cases of annual area (not calculated) and annual net benefits per man-day, where annual net benefits were divided by time invested over the year.

Strong trends were not expected in Khoo Khad, where farmers had been culturing fish in ricefields long before the advent of the project. Overall net returns per family were similar in both areas. This may be an artefact of the stocking

Table 3. Three-year trends in rice-fish economic parameters (US$), by farm site and season.

Season[a]	Site	Area (ha)	Value of production	Production costs	Labor inputs (man-day)[b]	Net returns	Net returns (per hectare)	Net returns (per man-day)
Rainy 1984	Dom Noi	0.248	8.12	53.08	31.38	-44.96	-181.29	-1.43
Dry 1985	Dom Noi	0.272	35.88	8.38	24.38	27.50	101.10	1.13
All 1984	Dom Noi	-	44.00	61.48	55.75	-17.48	-80.25	-0.31
All 1984	Khoo Khad	0.832	46.60	11.48	n.d.[c]	35.12	42.21	
Rainy 1985	Dom Noi	0.624	48.88	21.92	7.62	26.56	42.50	3.46
Dry 1986	Dom Noi	0.693	54.16	18.92	13.62	35.24	50.85	2.59
All 1985	Dom Noi	-	103.04	40.84	21.25	61.80	73.35	2.91
All 1985	Khoo Khad	0.946	52.28	20.12	2.68	32.16	34.00	12.02
Rainy 1986	Dom Noi	0.792	50.16	11.08	8.12	39.08	49.34	4.81
Dry 1987	Dom Noi	0.536	35.80	0.72	5.75	35.08	65.44	6.10
All 1986	Dom Noi	-	79.88	11.68	12.88	68.04	114.50	5.28
All 1986	Khoo Khad	0.854	69.24	15.60	6.62	53.60	62.76	8.09

[a]Dry season 1987 data are for three months only, not six, and for five farmers only, not six. Similarly, "All 1986 Dom Noi" data are for five farmers only and nine months. Otherwise, Dom Noi sample consists of original six farmers and Khoo Khad sample, original seven farmers. All years begin in June of the year named.
[b]One man-day = 8 man-hours.
[c]n.d. = no data.

program, since fish were stocked on a similar per hectare basis in both areas. Since Khoo Khad fields are larger than those in Dom Noi, they got more fish. In Dom Noi, fish can be cultured through the dry season, so returns from the practice accrue over a greater portion of the year. Net returns per hectare were higher for Dom Noi than for Khoo Khad, while net returns per man-day were higher in Khoo Khad.

Fish Stocking Density, Size and Species Composition

Initial results from the 1984 trial were highly inconclusive; the sample of farmers was too small and interfarm variation was too great to give any indication of a density effect on growth or production. Common carp reached a larger size than the other two species stocked, but had been stocked at lower densities.

In 1985, the number of participants was doubled, and the proportion of common carp was increased from 20 to 50%. While results did not show effects clearly, they indicated the range of responses possible under on-farm conditions. Densities ranged from 637 to 10,375/ha and yields from 7.5 kg to 238 kg/ha and 38-214 in Dom Noi and Khoo Khad, respectively. While stocking density may have affected yields in a few cases, other factors more often limited fish catch.

As opposed to other factors, fish production is most likely to be limited by density. The highest productions were reported for higher densities. However, as these maxima rise with density, the increase is dampened as densities increase above 3,000/ha. Low production is also very possible at high densities, which imply higher investments. Hence, higher densities can imply higher risks.

When average individual weight at harvest was plotted against stocking density by species, no clear evidence of density effect on growth was indicated. Common carp tended to reach a larger size than the other two species, although stocked at higher densities. Fish caught at Khoo Khad were larger than those from Dom Noi, possibly because fields at Khoo Khad had better water retention.

Thus, these findings show that there is no single optimal stocking density. What is best depends upon the farmer's constraints, needs, preferences and resources. However, a stocking density of 3,000/ha with common carp, silver barb and tilapia stocked at a 5:3:2 ratio is a reasonable starting point. If very small seed fish are stocked, the farmer should stock more to compensate losses.

Fairly precise data were kept on the number and size of fish stocked, by farmer and species. In the weekly interviews, it was not difficult to monitor the number of each species caught by each farmer. Data for common carp and silver barb were available, but figures for stocking sizes above 5 cm were sparse.

Risk of low recovery was greater for small stocking sizes. Small common carp were more vulnerable to loss than small silver barb.[1] It is meaningless to recommend farmers to stock larger seed fish as these are not available. At times of peak demand, this normally means small seed fish. Under such circumstances, establishing nurseries especially for common carp seed looks attractive.

Effects of Rice-Fish Culture on Rice Yields

In 1984, there was consistent evidence for higher rice yields from fields stocked with fish than nonstocked fields in Dom Noi. These differences were especially high in fields stocked with higher densities of fish. In Khoo Khad in 1984, rice yield differences between the two treatments were slight and inconsistent. Fish

[1]For *C. carpio* stocked under 2 g, only in three out of 15 cases did recovery rates exceed 10%. For *P. gonionotus* stocked under 2 g, only in one out of 13 cases was the recovery rate below 10%.

culture systems in Dom Noi were more intensive in terms of density and feeding. This may have favored rice yields to a greater extent.

Two Dom Noi farmers were able to give yield estimates for several nonstocked and stocked plots in the 1984 rainy season. These nonstocked plots received fish for the first time in the 1985 dry season, at the end of which plot yield estimates were again forthcoming.

If rice-fish farming has no effect on rice yields, seasonal changes in yield should not differ consistently between stocked and nonstocked conditions. Hence, on each farm, the percentage change in yield for the plot(s) stocked in both seasons was used as a predictor for the percentage change in yield in the newly stocked plots. On this basis, rice yields were higher than expected in all newly stocked fields. When the data were subjected to two-way analysis of variance, these differences were found to be barely nonsignificant ($0.05<P<0.1$).

Using total plot yield data from the 1984 rainy season and the 1985 dry season in Dom Noi, ratios of yields per hectare from stocked fields to yields per hectare from nonstocked fields were calculated on a plot by plot basis, within each farm. These ratios were then plotted against probable fish stocking density. The regression based on this plot indicated a significant positive effect of fish stocking density on rice yields (Table 4). It is not possible to indicate the extent to which the observed relation is due to fish stocking density per se, as opposed to other influences. Some of the heavily-stocked plots, for instance, received more feeds, which undoubtedly contributed to enhanced rice yields.

After sample yield data had been gathered for the 1985 rainy season, average sample yields were calculated for stocked and nonstocked fields, by farmer and variety of rice. The ratio of average rice yield from stocked fields to average rice yield from nonstocked fields was then calculated for each farmer/variety combination. When a farmer grew more than one variety, the lowest ratio was used to represent his farm.

On this basis, eight farmers at each site had higher rice yields from their fish fields, or 64% of the total sample of 25 farmers. Yields per unit area averaged 9.08% higher in Dom Noi (with a range of -29% to +98%). Similarly, in Khoo Khad, yields from fish fields averaged 9.54% higher, with a range of -26% to +36% (Table 5).

Interrelationship Between the Effects of Chemical Fertilizer and Rice-Fish Culture on Rice Yields

Levels of fertilizer application were very low in all but one farm. When this farm was not included, neither the main effects nor the interaction effect was significant on yields or net returns, on a site

Table 4. Probable fish stocking density per hectare versus ratio of rice production for each field to rice production for comparable unstocked fields.[a] (Source: Ubon Project Report 1985).

Stocking Density	Ratio	Stocking Density	Ratio	Stocking Density	Ratio
9,375	2.02	4,850	1.88	2,706	1.17
9,375	1.85	4,850	1.37	2,500	1.48
9,375	1.79	4,000	1.14	2,387	0.81
7,569	2.46	2,750	0.62	1,700	1.04
7,569	1.79	2,706	1.62	431	0.97
5,000	1.47				

[a]If R = ratio and D = density, then $R = 0.658 + 0.0105\ (D/10)$; student's t-test = 2.28; $P<0.05$.

Table 5. Rice yields in fish fields and unstocked fields, 1985 rainy season.

Dom Noi				Khoo Khad			
Farmer	Fish field (t/ha)	Un-stocked field (t/ha)	Differ-ence (%)	Farmer	Fish field (t/ha)	Un-stocked field (t/ha)	Differ-ence (%)
1	1.35	1.32	3	13	1.85	1.75	6
2	1.93	0.78	98	14	1.59	1.20	33
3	2.08	2.33	-11	15	1.66	1.73	-4
4	2.22	2.26	-1	16	1.43	1.82	-26
5	1.93	1.74	10	17	1.61	1.79	-18
6	1.78	1.83	-3	18	1.31	1.35	-3
7	1.51	1.41	8	19	2.11	1.55	36
8	1.33	1.87	-29	20	2.07	1.82	13
9	1.33	0.91	17	21	1.77	1.95	-9
10	2.22	2.05	8	22	1.19	0.97	22
11	2.68	2.58	4	23	1.36	1.32	3
12	2.32	2.22	5	24	1.60	1.26	27
				25	1.60	1.15	35
Average	1.89	1.79	9.08	Average	1.63	1.51	9.54

by site basis. When the data are combined, fertilizer and fertilizer-stocking interaction have significant effects on yields, but not on net returns. Rice yields appear more positively responsive to fertilizer application in stocked fields, but this is a very tentative inference.

Further analyses confirmed the importance of interfarm variation. Variation among plots within-farm, while more controllable, also affected the results. Under on-farm conditions, it is probably not realistic to expect an experiment of this complexity to yield conclusive results, particularly in the absence of replicates within-farm. The frequent nonsignificance of the effect of fertilizer on net returns suggests that recommendations on fertilizer applications should be flexible. The original experimental question remains an open one.

Feasibility of Direct Stocking of Large Fingerlings in Ricefields

The average yield from all the three topographies was 234.1 kg/ha. The highest average yield (336.3 kg/ha) was from Kheuang Nai and the lowest at Amnart Charoen (146.3 kg/ha).

The average return on investment (ROI) for all fields was 1.9 (Table 1). The highest ROI was 2.4 in Kheuang Nai and the lowest was at Det Udom (1.0). Two farmers in Kheuang Nai had ROIs of 4.6 and 4.7. They had previously established large, deep nursery ponds, and each had only one stocked field. Water levels were stable all year because of a high water table. All locations were able to maintain water in their fields while fish were being cultured.

Direct stocking of large fingerlings interfered with rice planting. Farmers had to travel to purchase fingerlings when they were busy planting rice. Costs were considered high, but all the participating farmers made profits. Interest in reducing costs was shown.

Effects on Rice Yields at Three Topographies

Yields of rice from all fields with fish were better than from fields without fish.

Yields were 26% higher in Amnart Charoen where topography consisted of slow undulating slope. The highly undulating land in Det Udom showed the second greatest response, while the flat topography at Kheuang Nai showed the lowest. The rice variety which responded best to rice-fish culture was KDML 105, with average yields higher by 14.8%; RD 6 had the second highest yield (Table 6). There were no problems maintaining water in levels while fish were in the fields in all the locations.

Under all topographic conditions, rice yields were higher in stocked fields. These data were conclusive enough, thus, it was not necessary to do a follow-up research on rice yields the next year.

Feasibility of Nursing Small Fry in Rice-Fish Systems

The average fish yield from all sites was 178 kg/ha, while the maximum yield obtained at Kheuang Nai was 264 kg/ha (Table 1). The average ROI at Kheuang Nai was 3.9, the highest of the three sites. The highest ROIs ranged from US$25 to 62/ha. The greatest growth rate of fingerlings before 45 days was reported from Det Udom (Table 7). By 45 days, all species have achieved lengths of at least 5 cm.

Nursing small fry did not interfere with the planting of rice. Pond construction and fingerling purchases were done before rice transplanting. The fry are

Table 6. Rice yields in fish fields and unstocked fields, 1987.

Variety	Amnart Charoen			Kheuang Nai			Det Udom		
	Fish field (kg/ha)	Unstocked fields (kg/ha)	Yield increase (%)	Fish field (kg/ha)	Unstocked fields (kg/ha)	Yield increase (%)	Fish field (kg/ha)	Unstocked fields (kg/ha)	Yield increase (%)
RD 6	2,347.5	2,141.3	9.6	2,971.9	2,731.3	8.1	2,301.9	1,980.0	16.3
RD 8	2,825.0	2,812.5	0.4	-	-	-	-	-	-
SPT	2,418.8	1,937.5	24.8	1,812.5	1,812.5	-	-	-	-
KDML 105	2,963.8	2,426.3	22.2	2,936.3	2,571.3	14.2	2,930.0	2,716.3	7.9
Native	2,125.0	750.0	183.3	-	-	-	2,720.0	2,585.0	5.2
Average	2,536.9	2,013.8	26.0	2,573.6	2,371.7	8.5	2,650.6	2,427.1	9.2

Table 7. Growth (cm) of 2–3-cm fingerlings at different topographies, 1988.

Time frame (days)	Amnart Charoen				Kheuang Nai			
	Tilapia	Common carp	Silver barb	Average	Tilapia	Common carp	Silver barb	Average
15–30	7.1	5.1	6.7	6.3	-	-	5.2	5.2
31–45	-	5.4	8.0	6.7	9.9	9.6	5.4	8.3
46–60	10.3	8.2	6.9	8.5	12.0	7.4	8.4	9.3
61–75	8.1	6.9	5.6	6.9	-	11.2	8.0	9.6
> 75	9.3	7.5	8.8	8.5	-	-	-	-

Time frame (days)	Det Udom				Average (3 sites)			
	Tilapia	Common carp	Silver barb	Average	Tilapia	Common carp	Silver barb	Average
15–30	-	10.0	-	10.0	7.1	7.6	6.0	6.9
31–45	12.0	6.6	6.6	8.4	10.9	7.2	6.7	8.3
46–60	-	6.8	8.4	7.6	11.2	7.5	7.9	8.5
61–75	-	9.2	7.2	8.2	8.1	9.1	6.8	8.2
> 75	8.5	11.3	7.9	9.3	8.9	9.4	8.4	8.9

released to the field about 15 days after transplanting. Fingerlings should not be held longer in nursery than 45 days. This technology provided security for the fish – if rainfall was poor, fish could retreat to the pond.

Conclusions

The research suggests that fish nurseries are best established in areas where the topography is undulating with steep slopes, large ponds can be constructed and higher volume of water implies that fingerlings may have less competition for space and food. Where topography restricts nursery pond digging, 5–7 cm fingerlings can be released directly to fields.

The nursing of fry before releasing them to the ricefields had better returns on investment than direct release of large fingerlings. Although the data do not reflect the cost of pond construction, the ponds are a fixed cost which will decrease in succeeding years. Farmers who had already dug ponds had already successfully absorbed their pond investment. Both technologies generated the best fish yields in areas with a gentle, flat slope.

There were some constraints encountered during the trials. First, on-farm research is always subject to limited control of the variables. Pond sizes vary. Farmer management changes. Environmental conditions differ between sites. Data must always be considered approximate. Second, high rainfall and prolonged drought affected fish growth in ricefields. Lastly, changes in project staff and reduced numbers of participating farmers affected the collection of data, perspective and continuity.

However, the results of the research in 1987 and 1988 suggest that rice-fish culture technologies studied are suitable to extend in other areas of northeast Thailand with similar physical, biological, and socioeconomic conditions as Ubonratchathani Province. The system appears viable under harsh environment without further degrading natural resources.

References

Sollows, J.D. and N. Thongpan. 1986. Comparative economics of rice-fish culture and rice monoculture in Ubon Province, Northeast Thailand, p. 149-152. *In* J.L. Maclean, L.B. Dizon and L.V. Hosillos (eds.) The First Asian Fisheries Forum. Asian Fisheries Society, Manila. 727 p.

Ubonratchathani Agricultural Weather Station. 1987 and 1988. Monthly rainfall data. Ubonratchathani, Thailand.

Ubon Project Report. 1985. Farming systems research institute investigations on rice-fish culture. Ubon Province June 1984-June 1985 Project Report, Ubonratchathani, Thailand.

Rice-Fish Farming Systems Research in China

XU YUCHANG
GUO YIXIAN
Institute of Crop Breeding and Cultivation
Chinese Academy of Agricultural Sciences
China

XU, Y. and Y. GUO. 1992. Rice-fish farming systems research in China, p. 315–323. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

The history, development and potential of rice-fish culture in China are reviewed. Rice-fish farming systems research was strengthened in the 1980s as it became a key program of the National Rice Farming Systems Project supported by the International Rice Research Institute (IRRI) and International Development Research Centre (IDRC) of Canada. Various rice-fish systems such as field pool, ridged field, rice-azolla-fish and rice-fish rotations have been adopted. Component technology research in Hunan Province indicated a fish species proportion of 30% grass carp (*Ctenopharyngodon idella*), 20% common carp (*Cyprinus carpio*) and 50% crucian carp (*Carassius carassius*) gave the highest rice yield (8.98 t/ha); and a 50% grass carp, 30% common carp and 20% crucian carp combination gave the highest fish yield (1,896 kg/ha) and net returns (US$1,582/ha).

Introduction

China has a long history of fish culture in ricefields which can be traced back to the Eastern Han Dynasty (25–220 AD) (Guo 1986). It was popular in the provinces of southeastern and southwestern part of China, particularly in the hilly areas. Rice-fish area declined during the 1950s as a result of improved agricultural technologies and the application of insecticides and chemical fertilizers. Since the late seventies, fish culture in ricefields has been considered important to increase the freshwater fish supply in China.

Rice-fish farming systems research has been conducted based on surveys and farmers' experiences of fish culture in ricefields. In recent years, traditional techniques for rice-fish farming system were improved, related engineering facilities were built in ricefields and the symbiosis between rice and fish enhanced. Furthermore, various rice-fish farming systems suitable to local agroecological environments were generated.

Fish culture in ricefields has been included in the National Agricultural Technique Extension Program of the Ministry of Agriculture, Animal Husbandry and Fisheries (MAAHF). Since 1984, the target area covered 18 provinces including Sichuan, Hunan, Guizhou, Anhui and Fujian. From 1984 to 1986, new area approximately 67,000 ha were brought into rice-fish culture, with fish production of 20,000 t and an average yield of 300 kg/ha. Through extension, rice-fish production in these provinces expanded rapidly, with the area in the 18 provinces reaching 985,500 ha in 1986, 175% of the area in 1983 (Li, this vol.). Sichuan and Hunan had the largest ricefield areas under fish culture with 333,300 and 227,000 ha, respectively, in 1986.

Research on fish culture in ricefields is being carried out separately by aquaculture, agriculture and biology research institutions such as the Institute of Hydrobiology, the Chinese Academy of Sciences, an institution affiliated with the Chinese Academy of Agricultural Sciences (CAAS) and the Chinese Academy of Fisheries Sciences (CAFS). The China National Rice Cropping Systems Network has included rice-animal and rice-fish farming in their research programs and receives technical and financial support from the International Development Research Centre (IDRC) of Canada and International Rice Research Institute (IRRI).

Methodology

The basic working groups for agricultural research in China are the laboratory, experimental farm; on-farm research; and scientists, cadres and farmers. The same also applies to on-farm rice-fish research. The main steps in conducting the research are outlined below.

Survey

A survey in the target areas is undertaken to assess the local natural environments; major crops cultivated; cropping systems; current production levels; farmer's economic situation; main constraints on agriculture production and their solutions; and to identify the research priorities and procedures to be followed.

Site Selection

Research sites are selected by taking the village or towns as the basic unit based on survey results, requirements laid by the national and local key construction projects, local research forces, and the goals of the experiments and research.

Designing and Testing

Designing and testing are focused on the main constraints to agricultural development and utilizes previous research results and experiences with the purpose of increasing crop yields, returns and benefits to farmers. Scientists discuss with local cadres and farmers, to collect ideas and suggestions. For research where no appropriate or valid research findings are available, testing is conducted first on-station before testing on farmers' fields.

Demonstration

If satisfactory results are obtained, activities move to an on-farm research demonstration phase consisting of multilocational testing in areas having similar environments. Testing involves two to three treatments and is designed with the help of scientists and technicians. However, there is no replication, plots are larger in size and are managed by farmers.

Extension

Extension workers organize farmers in the target areas to participate in meetings and discussions to exchange experiences to disseminate research results producing high yields and good economic benefits.

Research Programs, Objectives and Projects

At present, China can supply her people with the required grains and clothing. However, the agriculture sector is facing new challenges. Farmers tend to divert their interests to seek more income. On the other hand, cities need more diversified agricultural products, animal and aquatic products for national economic development and improvement of urban people's lives apart from the increasing need for food grains. Fish culture in ricefields can help meet the above needs.

China has more than 20 million ha of ricefields. Although in recent years fish culture in ricefields has developed rapidly, there were only 1.3 million ha used for fish culture in 1986, or 6% of the total area for rice cultivation. During this period, fish production per unit area are low. Based on statistics of six provinces and one municipality in southeast China, the average fish yield was only 187 kg/ha in 1985, the highest yield obtained was 286 kg/ha in Anhui Province (Table 1). However, a farmer at Xindu County, Sichuan Province harvested 865 and 460 kg of rice and fish, respectively, from a 1,333-m^2 ricefield equivalent to 6.48 (rice) and 3.45 (fish) t/ha.

The long-term targets for the rice-fish farming program are to conduct inter- and multidisciplinary research to develop rice-fish farming patterns and technologies for different ecological environments; to get bumper crops of rice and fish on large-scale cultivation; to raise the living standards of rice farmers; and to satisfy the demands of national economic deve lopment. Research projects and their short-term objectives are outlined below.

Evaluation and Utilization of the Existing Patterns and Modes of Rice-Fish Farming

The purpose of this research is to evaluate the advantages and disadvantages of different rice-fish patterns and identify their adaptability to different agroecological environments in order to extend research results suitable to local conditions. The major rice-fish patterns are the rice-fish rotations and mixed rice-fish culture.

In rice-fish rotations, fish are raised separately before or after rice. The cropping patterns are a single rice crop followed by single fish crop (rice-fish); two rice crops and one fish crop in between rice, (rice-fish-rice); and two crops of rice and two crops of fish (rice-rice-fish-fish).

Mixed rice-fish culture in double cropped ricefields is one of the major rice-fish farming models in China. The fish raised in the field of first rice crop are transferred immediately and raised continuously in the field of second rice crop.

Table 1. Yields of fish in ricefields of selected provinces in East China. (Source: Fishery Bureau 1985).

	1984			1985		
Province	Area (ha)	Production (t)	Yield (kg/ha)	Area (ha)	Production (t)	Yield (kg/ha)
Jiangxi	37,100	5,655	152	61,300	12,880	210
Fujian	24,700	2,405	97	36,000	4,860	135
Anhui	10,000	2,750	275	22,700	6,500	286
Zhejiang	17,700	1,310	74	24,300	2,750	113
Jiangsu	3,100	470	152	13,300	2,500	188
Shanghai	22	2	77	80	6	79
Shandong	66	6	93	40	3	75

Rice-based mixed culture involving single rice crops is mainly practised in wheat-rice, rapeseed-rice patterns. Most of these fields have year-round water sources. Yields are stable during drought and waterlogged conditions. Mixed rice-fish culture is also done under a rice-fallow pattern, followed by raising fish after rice harvest. The pattern becomes (rice+fish)-fish.

Component Technology Research on Fish Culture in Ricefields

This research aims at enhancing both the agronomic practices for rice and for fish in ricefields to increase total production and income. The specific objectives of this research are 1) to improve ecological conditions in ricefields and resolve the incompatibilities between rice and fish; 2) to find appropriate fish species composition; stocking sizes, rates and time; proper amount of fodder; fish disease control; water management and fertilizing techniques; 3) to study the symbiotic relationships between rice and fish in rice-fish farming systems; to identify the beneficial effects of fish on increasing rice yields, improving socioeconomic efficiencies and ecological conditions; and 4) to evaluate the economic efficiencies of fish culture in ricefields and determine the effects of increased yields and improved socioeconomic and ecological conditions in increasing farmers' income.

Major Research Achievements

Evaluation of Different Models of Rice-Fish Farming

Before 1981, the traditional model which was just plain ricefields without any ridges or ditches was mostly practised. In 1981, the rice-fish field-sump combination (or field-sump model) was introduced which later developed to fish culture in ridged ricefields (ridged field model), combined rice-fish and rice-azolla, and rice-azolla-fish systems.

FIELD-SUMP MODEL

There are a number of incompatibilities in the requirements of rice and fish. The fish culture practices contradict with the rice's needs for field drainage, application of fertilizers, insecticides and other chemicals particularly in the double rice-double fish pattern. With this cropping pattern, farmers need to catch fingerlings, harvest early rice, harrow fields, transplant seedlings of a second rice crop, reopen ditches and restock fingerlings. During the season for double transplanting and harvesting, days are usually sunny which sometimes results in extremely high temperatures which affect fish. Combination of ricefields and sumps have resolved the incompatibilities in double rice cropping regions.

The fundamental characteristic of this model is a sump within or adjacent to the field. The depth of the sump/pond is 1 m and its area takes up 5–7% of the field. This can be used as a breeding pond for fingerling production. After transplanting early rice, ditches are dug to connect the sump with the field, and fish are driven into the ricefield where they remain until harvesting of early rice. Fish are concentrated and collected in the pond, followed by harvests of early rice. Afterwards, the field is prepared again and transplanted with the late rice; ditches are reopened and fish are driven into the ricefield again.

A farmer in Guangji County, Hubei Province, raised fish for 384 days in a 170-m^2 field connected to an existing 200-m^2 pond. Rice and fish were grown for 117 days (61 days for early rice and 56 days for late rice). Per hectare yields were 9.5 t rice and 1,119 kg fish, with a net income of US$582.7/ha (Table 2).

FISH CULTURE IN RIDGED RICEFIELDS

Alternate ridges and ditches are constructed in ricefields. Rice are grown on the ridges and fish kept in the ditches.

This method was developed for waterlogged areas and was initiated by Hou Guangjiong, a famous soil scientist in China. It was done to improve yields in swamps with low water temperatures and deep muds. It increases the soil surface in contact with the atmosphere and improves the relationship among water, air and heat flow. Deep ditches increase the water storage area for the ricefield and expand the space for fish.

A farmer in Hanshou County, Sichunan Province, has a low-lying 0.147-ha ricefield. He had been growing rice alone until 1984 obtaining an average yield of 7,500 kg/ha and US$608 income for double cropping of rice. In 1986, this pattern was changed into a ridged-ditch ricefield with fish culture. Widths of ridges and ditches are 20 and 80 cm, respectively. The depth of ditches is 50 cm. Rice seedlings were transplanted on ridges on 4 July at a spacing of 50–60 cm (19 hills per m^2), while fingerlings were stocked on 20 May. On 11 October, 7.8 t/ha of rice and 1,572 kg/ha of fish were harvested, generating a net income of US$732 (Table 2).

RICE-AZOLLA-FISH

Rice is grown in the soil, azolla on the water surface and fish in the water. Azolla are used as fish feed and fish wastes are used for fertilizing the soil. This pattern is also done in fields with and without ridges/ditches. The Fujian Academy of Agricultural Sciences (FAAS) extended the rice-azolla-fish system without ridges/ditches at Jian Ning County, Fujian Province. More than 6,500 ha or 45.5% of the total ricefield area in the province adopted this system after three years (1983–86) of testing.

A research team from the Hunan Academy of Agricultural Sciences (HAAS) has undertaken research on rice-azolla-fish farming in ridged fields using double and single rice croppings from 1984 to 1987. Survey in 15 counties in 1986 showed that the double cropping of rice yielded 11.4 t/ha and 760 kg/ha of fish, with a net return of US$528 from fish. Single rice cropping yielded 8 t/ha of rice and 730.5 kg/ha of fish, with a net return of US$507 from fish (Table 2).

ROTATION OF RICE AND FISH IN LOW-LYING RICEFIELDS

Fish culture is undertaken after the harvest of a single rice crop in the low-lying fields. The research on rotation of rice and fish was initiated in a 1.32-ha low-lying ricefield at Guangji County, Hubei Province from 1982 to 1983. A ditch measuring 50 cm in width and 27 cm in depth was dug on 2 July 1982. The

Table 2. Performance of different patterns of rice-fish culture.

Pattern	Cropping pattern	Rice yield (t/ha)	Fish yield (kg/ha)	Gross returns from fish (US$/ha)	Net returns (US$/ha)	Province	Source
Field-pond	Double rice	9.5	1,119	906	582.7	Hubei	Nie 1986
Fish culture (ridged)	Single rice	7.8	1,572	1,274	731.5	Sichuan	Deng 1985
Rice-azolla-fish	Double rice	11.4	760	616	528.2	Hunan	Hunan Research
(non-ridged)	Single rice	8.0	731	592	507.4		Team 1987
Rice-fish rotation in swampland	Single rice	4.3	1,312	1,064	529.0	Hubei	Nie 1986

next day, rice seedlings were transplanted and fry were stocked on 16–21 October. After 11 months of culture period, the average rice yield obtained was 4.3 t/ha from the late rice and 1,312 kg/ha of fish. A net return of US$529/ha was realized from fish (Table 2).

Research on Component Technology of Rice-Fish Farming Systems

PROPER WIDTH OF DITCHES FOR FISH CULTURE IN RIDGED FIELDS

Rice-fish farming in ridged ricefield deepens the cultivated layer of soil, raises soil temperatures and oxidation-reduction potentials which consequently increases rice yields. For fish, the ridged field pattern enlarges the water body and increases the water-retaining capacity of the soil. In 1986, a research was conducted by the HAAS on ditch width using rice-azolla-fish combination in ridged ricefields (Table 3). Research indicated that the rice and fish yields in ridged fields were higher than the traditional models without ridges/ditches. A width of 39.6 cm gave the highest rice (4.96 t) and fish (200.3 kg) yields per hectare. Total gross returns of the ditches with 39.6-cm width was $1,269/ha, 122% higher than nonridged fields. The rice yield increase was due to greater number of panicles in the 39.6-cm treatment than the 46.2- and 52.8-cm ditch width and the nonridged fields.

The width of the ditch varies from region to region due to differences in climates and ecological conditions. Narrow ditches are used in Sichuan Province. Zhang (1985) reports results from the Chengdu Agrometeorological Station that a ridge width of 30 cm and a ditch width of 50 cm produced 9.25 t of rice/ha. The nonridged fields gave 9.14 t of rice/ha not significantly different from ridged fields. However, fish yield in ridged fields was 480 kg/ha or two times greater than nonridged fields.

FISH SPECIES COMPOSITIONS AND STOCKING DENSITY

Yields from rice-fish culture are affected by fish species composition. The Soil and Fertilizer Institute of the HAAS showed that rice yields increased as the proportion of grass carp (*Ctenopharyngodon idella*) in the total stock decreased. A proportion of 30% grass carp, 20% common carp (*Cyprinus carpio*), and 50% crucian carp (*Carassius carassius*) gave the highest rice yields (8.98 t/ha). This result suggested that grass carp damage rice tillers as their number increases. Excessive irrigation water may

Table 3. Effects of different ditch and ridge width on rice and fish yields in Hunan Province. (Source: Hunan Research Team 1987).

Ditch width (cm)	Rice					Fish yield (kg/ha)	Total gross returns	
	No. of panicles/m^2	No. of grains /panicle	Full or plump grains (%)	Weight of 1,000 grains (g)	Yield (t/ha)		(US$/ha)	(%)
39.6	283	162.4	83	29.2	4.96	200.3	1,269	122
46.2	237	167.9	86	29.2	4.94	187.5	1,197	115
52.8	248	160.7	86	29.2	4.88	177.8	1,168	112
No ditch (control)	273	154.6	82	28.7	4.82	117.0	1,039	100

also be another factor causing reduction in rice yields in rice-fish culture. Decreases in rice yield are caused by a reduction in the number of panicles. The highest fish yield (1,896 kg/ha) was obtained using 50% grass carp, 30% common carp and 29% crucian carp (Table 4). This species composition of 50% grass carp, 30% common carp and 20% crucian carp also gave the highest net return of US$1,582/ha which was 1.5% and 12.3% higher than other treatments.

Table 4. Effects of species composition on fish and rice yields and net returns in Hunan Province. (Source: Hunan Research Team 1987).

Species Composition (%) (G-C-Cr)[a]	Fish yield (kg/ha)				Rice yield (t/ha)	Fish		Rice		Total returns (US$/ha)	Net returns (US$/ha)
	G	C	Cr	Total		Gross returns (US$/ha)	Material costs (US$/ha)	Gross returns (US$/ha)	Material costs (US$/ha)		
30-50-20	918.8	420.0	243.8	1,582.6	8.85	742.9	219.2	1,203.1	322.8	1,946	1,404
50-30-20	1,320.0	322.5	253.5	1,896.0	8.33	699.6	219.2	1,459.9	358.4	2,160	1,582
30-20-50	967.5	343.8	498.8	1,740.0	8.98	754.4	219.2	1,297.4	274.4	2,052	1,558

[a]G = Grass carp; C = Common carp; Cr = Crucian carp.

FISH STOCKING RATES AND SIZES

Fingerling stocking rates were closely related to the yields of rice and fish. The HAAS indicated that 22,500 fingerlings/ha gave the highest rice yield (12.3 t) which was 7.8 and 6.6% greater than other treatments. Stocking rates had direct relationships with fish yields. A rate of 30,000 fingerlings/ha produced the highest fish yield (747 kg/ha) which were 38.7 and 14.0% higher than other treatments (Table 5).

Sources of natural fish feeds, variety of fish feeds applied, depth and quality of irrigation water in ricefields should be carefully considered in determining fish stocking rates. Increasing stocking rates is one approach to increase fish yields where abundant manure, feeds and good water quality are available.

Stocking size is closely linked with fish yield. Generally, large-sized fingerlings should be stocked in ricefields because of the short culture period.

Table 5. Effect of stocking rates of fish on rice and fish yields in Hunan Province. (Source: Hunan Research Team 1987).

Stocking rate (no./ha)	Rice yield (t/ha)	Fish yield (kg/ha)
15,000	11.4	588.5
22,500	12.3	655.5
30,000	11.6	747.0

FISH FEEDING RATE

Supplementary feeding increases fish yields in ricefields. At Fan Yu County, Guangdong Province, it was shown that fish yields reached 1,500–2,000 kg/ha when feeding rates exceeded 7,500 kg/ha. If less than 7,500 kg/ha of feeds are given, fish yields would be less than 1,000 kg/ha.

Symbiotic Relationships Between Rice and Fish

Bumper harvests of rice and fish can be obtained by selecting the appropriate composition of fish species and stocking rates. Research on fertility improvement and weed and disease control by fish in ricefields was conducted by the HAAS and FAAS.

THE EFFECT ON SOIL FERTILITY

Results of nutrient determinations after a late rice harvest (Table 6), shows that N content for rice-fish culture without ridges was 6.9 ppm higher than rice monoculture; while the content in fields with ridges was 7.2 ppm higher than without ridges. The available P_2O_5 content for rice-fish culture under no ridges was 2.5 ppm higher than rice monoculture; while the content with ridges was 3.4 ppm higher than no ridge. The available K_2O content under no ridges was 1.9 ppm higher than rice monoculture; with ridges, it was 10.3 ppm higher than no ridges. Organic matter also increased. These results suggest that fish culture in ricefields stimulates the activities of microorganisms and the availability of organic matter, and increases release of nutrients for better rice growth.

EFFECTS ON CONTROLLING RICE WEEDS, PESTS AND DISEASES

Results obtained by the FAAS show that less weed were found in rice-fish and rice-azolla-fish ricefields (Table 7). Weeding the field once may be enough, or no weeding at all. The incidence of pests and diseases in rice-azolla-fish culture is usually lower than that in rice monoculture fields, especially in controlling rice striped disease and plant leafhoppers (Table 8). It has been noted that, besides the plant leafhopper being eaten by fish, the environment of rice-azolla-fish culture enhance the survival of natural enemies of the leafhopper. It has been observed that populations of natural enemies such as spiders and black ants are greatly increased by this cropping system (Liu Haoguang, pers. comm.).

Economic Benefits of Rice-fish Culture

The HAAS indicated that the economic benefits of rice-fish culture are higher than rice monoculture for the double and single rice croppings (Table 9). Comparing rice-fish systems, the rice-azolla-fish (ridged) treatment generated

Table 6. Effects of rice-fish culture on soil nutrients in Hunan Province. (Source: Hunan Research Team 1987).

Treatment	Alkali N (ppm)	Available P_2O_5 (ppm)	Available K_2O (ppm)	Organic matter (%)
Rice-fish culture, ridged	154.0	34.2	70.0	2.8
Rice-fish culture, non-ridged	146.8	30.8	59.7	2.6
Rice monoculture (control)	139.9	28.3	57.8	2.6

Table 7. Effects of rice-fish culture on weed control in Fujian Province. (Source: Liu 1987).

Treatment	No. of weeds	Fresh weight (g)	Weed type	Composition (%)
Rice monoculture (control)	48	455	duckweeds	80
			waterweeds	20
Rice-fish	9	64	duckweeds	50
			waterweeds	25
			other weeds	25
Rice-azolla-fish	2	9		

Table 8. Effects of rice-fish culture on pest and disease control in Fujian Province. (Source: Liu 1987).

Treatment	Insect population: Plant leafhoppers	Insect population: Spiders	Rice striped disease: Incident index	Rice striped disease: Control effect (%)
Rice-fish	1,407.5	74.7	4.398	-66
Rice monoculture	11,413.5	25.1	12.780	-

Table 9. Economic benefits of rice-fish culture in Hunan Province. (Source: Hunan Research Team 1987).

Treatment	Gross returns (US$/ha)			Difference from rice monoculture	
	Rice	Fish	Total	US$/ha	%
Double cropping systems					
Rice-azolla-fish (ridged)	960.6	527.7	1,488.3	506.7	53
Rice-fish (non-ridged)	954.5	329.8	1,284.3	312.7	32
Rice monoculture (non-ridged)	971.6	-	971.6	-	-
Single rice cropping					
Rice-azolla-fish (ridged)	720.5	361.2	1,081.7	406.6	60
Rice-fish (non-ridged)	682.5	203.3	885.8	209.7	31
Rice monoculture (control)	675.1	-	675.1	-	-

greater gross returns due to higher fish yields than the rice-fish (non-ridged) model. Rice yields in all treatments and rice croppings were not significantly different from each other.

References

Deng, Z. 1985. A new way of rural economics development, p. 159–164. *In* MAAHF. A selection of rice-fish farming experiences in China. Fishery Bureau, Ministry of Agriculture, Animal Husbandry and Fishery, China. (In Chinese).

Fishery Bureau. 1985. A brief report on the Fifth Workshop of Six Provinces and One Municipality on Rice-Fish Farming Network in Eastern China, p. 1–5. *In* A selection of rice-fish farming experiences in China. Fishery Bureau, Ministry of Agriculture, Animal Husbandry and Fishery, China. (In Chinese).

Guo Q. 1986. Lao Dao Si Han Dynasty Tomb in Mian County, Shaanxi Province. Agricultural Archaeology, Vol I.

Hunan Research Team. 1987. The summary report on research on rice-azolla-fish farming systems in ridged fields. Rice-Azolla-Fish Farming Research Team of Hunan Province, China. (Unpublished, in Chinese).

Liu, Z. 1987. The "rice-azolla-fish" systems. RAPA Bull. (1988)4.

Nie, D. 1986. The advancements of Rice-Fish Farming Systems in China. *In* Proceedings of the National Meeting on Rice-Fish Farming Systems in China, 10–13 October 1988. Wuxi, Jiangsu Province. (In Chinese).

Zhang, D. 1985. Climate ecological study on rice-fish farming in ridged fields. Agricultural Meteorology 6(4):inside backcover.

Methodology in Extending Rice-Fish Farming Systems in China

WANG JIANGUO
Institute of Hydrobiology
Academia Sinica
Wuhan, Hubei, China

WANG, J. 1992. Methodology in extending rice-fish farming systems in China, p. 325–331. *In* C. Lightfoot, B.A. Costa-Pierce, C.R. dela Cruz, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

China's fish culture in ricefields has reached 1 million ha. The methodologies used to develop rice-fish farming in China are: traditional methods; strengthening research such as using grass carp (*Ctenopharyngodon idella*) in ricefields; advising local leaders; disseminating the successful examples of rice-fish culture; coordinating products, supplies and marketing needs; and finding suitable methods to culture fish in ricefields.

Introduction

With a 2,000-year history of rice-fish culture, China is the first country in the world to culture fish in ricefields. Before 1949, fish culture in ricefields was limited to the mountainous areas where there were fish shortages. In 1958, the great demand for fingerlings for the extensive development of pond fish culture led to the use of ricefields to rear fingerlings. Rice-fish culture area reached 700,000 ha. In the 1970s, due to changes in the rice farming system, fish culture in ricefields was almost totally abandoned. In 1979, experiments on rearing grass carp (*Ctenopharyngodon idella*) fingerlings as a means to reduce labor in eradicating weeds in ricefields, and to increase rice production, were done (Nie and Yang 1976). By 1986, rice-fish culture in China spread quickly to almost one million ha (Table 1). There are no reports on how China's fish culture in ricefields expanded to this level. The extension methodology followed in the development of rice-fish farming is presented in this article.

Investigations in Rice-Fish Culture

Professor Nie Dashu has compiled traditional experiences of fish culture in ricefields. In the 1950s, he toured rice-fish farming areas in various counties to

Table 1. Ricefield area ('000 ha) with fish culture by province, China, 1981–86. (Source: Nie and Wang 1988).

Province/District	1981	1982	1983	1984	1985	1986
Beijiang			0.00147	0.02066	0.00667	0.00733
Hebei				0.01533	0.01467	0.10
Shanghai			0.001	0.02666	0.08333	0.023
Jiangsu			0.026	3.13	10.89	14.00
Anhui			2.67	10.00	22.67	34.00
Zhejiang			13.35	17.73	20.49	18.73
Jiangxi	3.33		18.67	37.80	52.00	47.00
Fujian			14.05	19.11	22.35	28.43
Henan				0.02086	8.77	6.67
Hubei	1.00	2.33	3.33	13.33	28.13	21.65
Hunan		79.67	112.61	167.10	188.75	227.00
Guangdong		4.33	4.00	5.30	8.12	13.33
Guangxi	20.00	35.33	31.85	34.55	45.52	54.20
Shanxi			0.14	0.73	1.51	5.70
Sichuan		156.67	246.47	314.06	360.19	413.33
Guizhou	94.67	100.67	106.67	100.00	66.92	87.33
Yunnan			8.54	11.56	10.58	14.00
China	119.00	379.00	731.48	730.49	846.98	985.52

investigate how rice-fish culture practices can be improved. He wrote a paper entitled "Fish Culture in the Paddy Fields" in the book *Freshwater Fish Aquaculture in China* (CFFC 1973).

In August 1981, Professor Nie petitioned the General Secretary of the Central Party Committee, suggesting that twofold increases in freshwater fish and rice production in China is possible, if they will expand and intensify fish culture in ricefields. Several days later, the Chinese National Aquatic General Bureau issued a document to all concerned units asking them to take note of Professor Nie's suggestion, support it, experiment with it and take part in the reform of rice production.

In 1983, Professor Nie conducted studies on the culture of grass carp fingerlings in ricefields and their ecological functions. He recognized five merits of fish culture in ricefields and developed practical techniques and operating rules. This achievement was approved by the Chinese Academy of Sciences, and won the second prize for Important Scientific Achievements by the Chinese Academy of Sciences.

Dissemination of Rice-Fish Culture to Chinese Organizations

In China, scientific achievements have to be accepted by the government before it can bear economic benefits. But once endorsed, it can bring great amounts of economic benefit (Nie 1983; Nie and Wang 1983).

On 11–15 August 1983, the Chinese Agricultural Ministry held a national meeting to exchange rice-fish culture experiences in Sichuan. It was an unprecedented meeting wherein scientists from 16 provinces and districts attended, and representatives from 11 provinces and districts reported their experimental results in rice-fish culture (Fig. 1) (Li 1988). Reports were compiled. On 14 September 1983, the Chinese Agricultural Ministry issued a special document calling on leaders at all levels in rice producing areas throughout the country to note the importance of fish culture in ricefields.

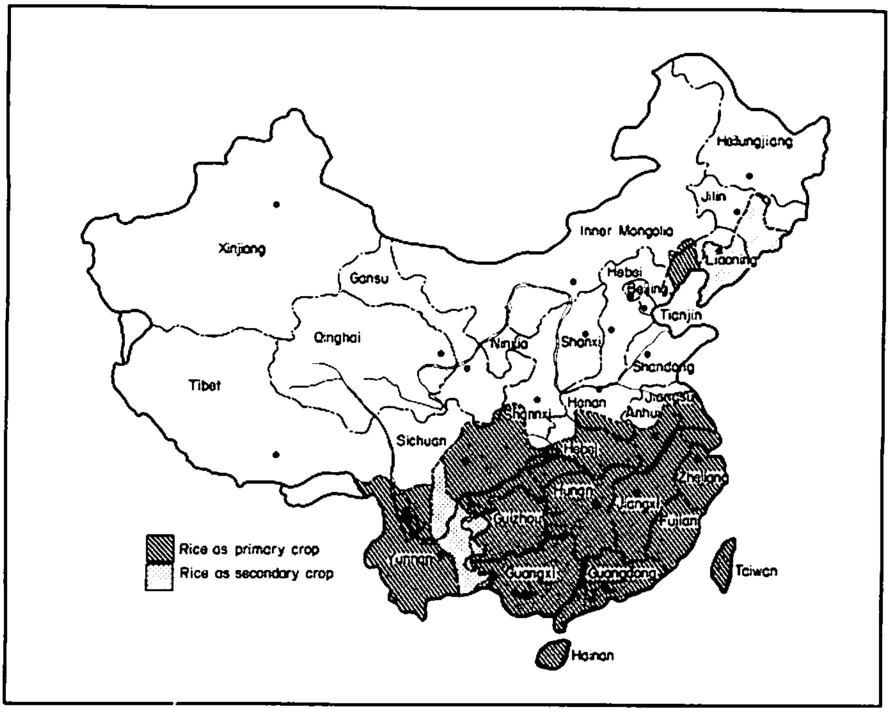


Fig. 1. Area under rice in China. (Source: adapted from Geography Research Institute 1983).

The document clearly pointed out that rice-fish culture is a very promising system. Rice-fish culture does not only increase rice production but also freshwater fish production. It enriches riceland areas and is a means to diversify the economy. The Chinese Agricultural Ministry ordered all agricultural and aquaculture units to cooperate and organize to improve and develop rice-fish production. As a result, China's rice-fish culture entered a new era. In 1984, the Chinese Aquatic Bureau organized 17 provinces and districts (Li, this vol.) to disseminate rice-fish culture. Special leading groups were set up, scientists were organized and new funds provided. Rice-fish culture increased from 26,000 ha in 1982 to 140,000 ha in 1986 in the eastern region. By 1984, rice-fish culture in China was practised in more than 730,000 ha and reached about 1 million ha in 1986 (Fig. 2).

Rice-fish culture has shown its economic, social and ecological benefits. These results won first prize in the Agricultural Ministry for Technological Achievement and second prize in the National Technological Achievement Board.

Dissemination of Rice-Fish Techniques to Local Levels

In 1981, the Chinese Aquatic Academy compiled 2,600,000 copies of scientific materials on rice-fish culture, which were distributed nationwide to provinces, cities and counties. All provinces and cities held special meetings and training classes on rice-fish culture techniques. People were sent to learn from the advanced units, after which they tried it in their own fields. When people were convinced of the economic benefits from rice-fish culture, they tried their best to adopt it. In some counties such as Dayi and Chongqing in Sichuan Province, every family cultured fish in ricefields.

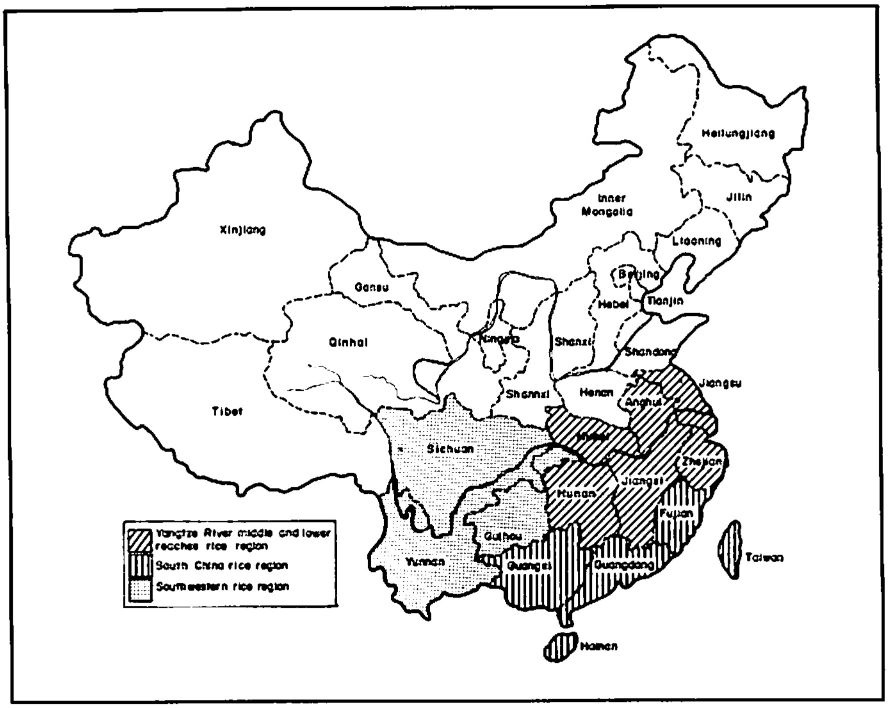


Fig. 2. Three main rice regions suitable for rice-fish culture in China. (Source: adapted from Geography Research Institute 1983).

Government Policies Encouraging Rice-Fish Culture

The government has adopted special policies to encourage rice-fish culture: whoever cultures fish in the ricefields, owns the fish; income from fish sales is not taxed; and severe punishment is given to whoever ruins or steals fish. Many local insurance companies support rice-fish culture. They compensate peasants' losses due to natural disasters such as flood or drought. Leaders at all levels also help farmers to solve their problems. All these contribute to the rapid development of rice-fish culture.

Coordination of Supplies and Marketing

Summer fingerlings are especially important to rice-fish culture. Rice-fish farmers get their summer fingerlings from nursery farms. Cities and farms are linked. In the countryside, some families began to culture fingerlings as well. This helped solve the problem of fingerling supply. Large fish produced in ricefields are sold in the markets. Fingerlings are sent either to large ponds or rivers for further rearing.

Rice-Fish Culture Techniques

Guided by the principles of rice and fish mutualism and rotational croppings of rice and fish, seven fish culture systems in ricefields have evolved in China.

FINGERLING PRODUCTION IN RICEFIELDS

Farmers stock grass carp fry at 45,000/ha in ricefields planted with early rice. Feeding is not necessary because there are enough zooplankton, thus, farmers save both labor and money. After planting middle rice seedlings, the field is stocked with approximately one-third of these summer fingerlings (3.5–5.5 cm) taken from the early rice-fish fields, with the remainder left in the original fields. This method, used in Hunan, Hubei, Jiangxi, Anhui, Jiangsu and Zhejiang Provinces, is simple and economical. Early rice planting season in these provinces coincides with the fish production season, i.e., in late April. After planting rice seedlings, digging ditches and building fences, fry can be stocked. Plankton, which are growing very rapidly at this time, become rich food for the fry.

The following details the breeding of fry in ricefields. Before stocking fry, raise and compact the dike to 50–70 cm. Control destructive organisms and adjust the pH by applying 5,625 kg/ha of quick lime. After six to eight days, apply manure, plow, irrigate and level the field, then transplant the rice seedlings, dig ditches and sumps. Small plots can be shaped as "田" figure, and large fields as "▥" or "▦". The ditch is about 30 cm wide and 30 cm deep. At the intersection of two ditches, a fish sump is dug at 1 m long, 70 cm wide and 80–100 cm deep. Rice seedlings that were dug from the ditches and sump must be retransplanted thickly as a hedge along the outer margin of the field just below the dike. This helps prevent fingerlings from escaping when it rains. Screen the water inlets and outlets of the ricefields with bamboo strips or other materials, which should be 100 cm wide and 80–90 cm high. The diameter of the fence holes should be 0.2 cm and the fence be arched. After all these have been done, the fry can be stocked. Before draining the field for harvesting, the ditches are dredged and the water is drawn off slowly at night to let the fish move into the sump. In the morning, fish can be easily caught from the sump using a long-handle scoop net (Nie et al. 1984).

Grass carp fingerlings easily acquire diseases when raised in ponds, with survival rates of about 20 to 30%. Culturing grass carp fingerlings in ricefields solves the problem of inadequate fingerling supply and even increases rice yields by an average of 10%. From 1982 to 1984, the rice-fish area engaged with fingerling production in Sanming City, Fujian Province increased from 60,000 to 150,000 ha; fingerling production from 2,000,000 to over 8,000,000 pieces, and rice yields from 6.4 to 17.1%.

PLANTING RICE ON RIDGES AND CULTURING FISH IN DITCHES

The practice of growing rice on ridges and culturing fish in ditches improves low-producing ricefields. Production is enhanced through better contact of rice roots between soil and the air – harmonizing the water, air and heat mixture to keep microclimate stable which is needed to accelerate the growth of rice roots. When fish are cultured in wide ditches, their movements mix surface and bottom waters. This hastens the decomposition of nutrients and maintains or increases soil fertility. Deep ditches increase the amount of water stored in ricefields and also give more living space for fish. Putting manure in the ditches increases water fertility which serves as nutrients to the fish and rice crop.

Ridges are made in low-producing areas, rice are planted on the ridges and fish are cultured in the ditches. The surface and bottom widths of ditches are 50 and 30 cm, respectively; depth is 50 cm. The surface width of the ridge is 30 cm and is planted with two rows of rice seedlings on each ridge. Each row is located in a favorable position and rice yields from these compensate the lost space devoted to ditches. Mud from the ditches is put onto the ridges and rice seedlings are transplanted without plowing. Fingerlings of 16–17 cm long are stocked into ricefields at 4,500/ha. With this area, 100 grass carp, 75 silver carp (*Hypophthalmichthys molitrix*), 50 bighead (*Aristichthys nobilis*), 75 common carp (*Cyprinus carpio*) and crucian carp (*Carassius auratus*) can be added. While green grass are given to feed the grass carp, nothing is required by the other fish species.

In 1986, the Dong and Miao Autonomous Regions of southeast Guizhou Province practised the ridge and ditch techniques in 87 sites in 16 counties with an aggregate area of 154,785 ha. For 4.47 ha of experimental land, yields obtained were 10,350 kg/ha (rice) and 472 kg/ha (fish). In Chongqin City, Sichuan Province, yields ranged from 6,750 to 7,448 kg/ha (rice) and 705 to 765 kg/ha (fish). This method has also benefited economically and ecologically the provinces of Hunan, Hubei and Jiangxi.

COMBINATIONS OF RICE, FISH AND AZOLLA

The Academy of Agricultural Science of Hunan and Fujian Provinces obtained good results using duckweeds (*Azolla* spp.). The techniques for constructing ridges and ditches are the same as described above. Duckweeds are cultured first in the ditches before rice are planted and grass carp and tilapia (*Oreochromis* spp.) are stocked. The fish feed on duckweeds and fish droppings fertilize the rice. This triple combination has multiple benefits: 1) it helps improve to some extent the farming system; 2) it keeps the field aerated; and 3) it makes full use of light resulting to vigorous growth of rice in all rows. Therefore, it has high economic, social and ecological advantages for the farmer and environment. Weeds on the ridges became scarce and plowing of the field was not needed. Less pesticides were used because disease and harmful insects have been already reduced. Fertilizer rates also decreased. In Jiannin County, Fujian Province, 66,667 ha were devoted to duckweed-rice-fish culture in 1986. Fish production was 1,150 t in 1985 which increased to 1,500 t in 1986.

CULTURE FISH IN RICEFIELDS WITH WIDE DITCHES

A ditch 1 m in width and depth is constructed at the water entrance of the ricefield occupying about 10% of the area. The ditch's dike should be 25 cm higher than the ricefield surface. At every 2 m, a 30-cm wide opening is provided for fish to move freely in and out from the ricefield and ditch. Before spring plowing, large fingerlings are temporarily stocked into the wide ditch and when the early rice seedlings turn green, fish are allowed to swim into the ricefield to graze on the weeds and other natural food. Before harvesting, the fish are gathered to the wide ditch. In 1985 and 1986, Jiangxi Province had 6,667 to 9,333 ha under this system. On the average, rice production is increased by 20% but can reach up to 50%.

CULTURE FISH IN SUMPS AND RICEFIELDS

A wide ditch and a sump are situated outside the ricefield. The sump may be large or small (10–30 m^2 and 1.5 m deep). Before planting early rice, common carp fry or small grass carp fingerlings are reared in the sump. As in the wide ditch system, fish are allowed to enter the ricefield at the proper time. This system avoids harvesting early rice, plowing the ricefields and then transplanting late rice, etc. – all of which must be done at the same time during the hot and busy season. After the early rice seedlings had been transplanted, the dike connecting the ricefield and sump is opened to allow fish to enter the ricefield. When harvesting early rice, fish are herded into the sump. After the transplanted late rice turns green, the water level at the sump is increased and fish swim into the ricefield.

In Guangji County, Hubei Province, a family that specialized in fish breeding tried this method in a 4.5-ha natural sump located near a 39-ha ricefield. Fish were stocked in the ricefield for 348 days and fish and rice grew together for 117 days (61 days for early rice; 56 days for late rice). A total of 2,143 fish were stocked. Only 1,770 fish (216 kg) were harvested, representing a recovery rate of 83%. Rice yields were 5,432 kg/ha (early rice) and 4,072 kg/ha (late rice), 6%

higher than yields from the ricefields without fish. In 1983, net income was US$643/ha.

FISH CULTURE IN WINTER-FREE OR WATER RESERVOIR FIELDS

Winter-free fields (fields that are left fallow during winter) are used to store water for the next spring rice and fish culture season. These are common in many parts of Fujian Province.

In 1983 winter, the Fujian Institute of Freshwater Fisheries conducted an experiment in Jinjiang County. Some 58 kg of grass carp, common carp, silver carp and bighead carp fingerlings were stocked in a 0.25–ha winter-free field on 20 November. After 122 days, 85 kg of fish were harvested. The fish net weight was 28 kg. Common carp gained weight at 0.2 g/day and its survival rate was 89%.

FISH CULTURE IN LOW-LYING RICEFIELDS

Low-lying ricefields used to have only a single crop per year. In Guangji County, Hubei Province, a 1.3-ha low-lying field was used to grow rice and fish together. On 2 July 1982, after levelling the ricefield, rice-fish farmers dug a ditch of 50 cm wide and 30 cm deep. The next day, late rice seedlings were transplanted with 13 x 26 cm spacing. They did not hoe, weed or use pesticides during the rice culture period. Ammonium bicarbonate and urea were top dressed at 232 and 109 kg/ha, respectively. Rice harvested was 5,530 kg, 10% more than the target production.

On 23 July 1982, 6.6-cm summer fingerlings (19,690 pieces) were stocked into the fields at 15,300 fish/ha. Of these, 84% were grass carp, 5% were black carp (*Mylopharyngodon piceus*), 10% silver carp and 1% bighead carp. No feeds were given during the 64-day culture period. About 10,094 fish, weighing 229 kg, of different sizes were harvested: under 10 cm (10%); 10.1–20 cm (70%); and over 20 cm (20%). Thirty days after fish harvest and after the ricefield was tilled, 15.6-cm grass carp fingerlings (10,787 pieces weighing 279 kg) were stocked into the fields at 8,385 fish/ha. The fingerlings were injected twice with a hemorrhagic vaccine. The following inputs were given during the whole rotation period: 40 kg urea, 1,450 kg night-soil, 600 kg beanseed cake, 3,508 kg duckweed, 1,831 kg green grass and 5,500 kg rice straw. After 244 days since the previous fish harvest, the gross fish yield obtained was 1,689 kg/1.3 ha, and net yield was 1,095 kg/ha.

References

CFFC. 1973. Freshwater fish aquaculture in China. China Freshwater Fish Committee. Science Publishers, Beijing, China. 598 p. (In Chinese).

Geography Research Institute. 1983. Distribution of agriculture in China. Agricultural Publisher, Appendix.

Li, K. 1988. Rice-fish culture in China: a review. Aquaculture 71:173–186.

Nie, D. and X. Yang. 1976. Fish culture in ricefields to increase rice yields. Chinese J. Zool. (2):22–24. (In Chinese).

Nie, D. 1983. On the theory of rice and fish mutualism. Fisheries Science and Technology Information (6):1–4. (In Chinese).

Nie, D. and J. Wang. 1983. Discussion on mutualism between rice and fish ecosystem and value of usefulness. Fisheries Science and Technology Information (6):1–4. (In Chinese).

Nie, D., Y. Chen and J. Wang. 1984. Technique of fish culture in ricefields. Fishery of Reservoir (2):2–4. (In Chinese).

The Adaptation of Rice-Fish Farming Technology: The Case of Mang Isko in Cavite, Philippines

FRANKLIN V. FERMIN
Appropriate Technology Unit
International Institute of Rural Reconstruction
Silang, Cavite, Philippines

FERMIN, F. 1992. The adaptation of rice-fish farming technology: the case of Mang Isko in Cavite, Philippines, p. 333–338. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

A 60-year old farmer, Mang Isko, of Cavite, Philippines, adapted rice-fish technology. He raised tilapia (*Oreochromis niloticus*) and common carp (*Cyprinus carpio*) along with rice on an experimental basis. In his rice-fish experimental area of 800 m^2, rice yields increased from 400 to 600 kg and produced 48.5 kg of fish. This initial success prompted him to expand his rice-fish area to 2,200 m^2 and make other adaptations to the technology. Economic analysis of the technology showed that net farm profits increased from US$26 to 86 (1987). His success has been shared with other farmers in the area, with the help of the International Institute of Rural Reconstruction (IIRR). This case demonstrates the vital role farmers can play in the adaptation and spread of rice-fish technology.

Introduction

Rice-fish technology can provide alternative sources of income and at the same time improve family nutrition. Rice-fish technologies were developed more than a decade ago at the Freshwater Aquaculture Center of Central Luzon State University in Nueva Ecija, Philippines. The technology developed was implemented nationwide in the latter part of the 1970s, however, up to now, there has been limited adoption of the rice-fish technology. This implies a need to further adapt not only the technology but also the extension approaches.

In 1987, the International Institute of Rural Reconstruction (IIRR) began multilocational trials on rice-fish culture in farmers' fields in Cavite.

Mang Isko, a 60-year old Filipino farmer, was approached by the IIRR team. He was trying to get help raising freshwater fish in his small pond. The IIRR technical specialist in aquaculture suggested that he try out the rice-fish technology as it was simple, easily learned and offered many benefits. Mang Isko seemed to be reluctant at first to try the rice-fish technology on his farm. He said, "This is the first time I heard about the technology. I can't believe that fish will grow in ricefields with very shallow water." He was encouraged to think it over. One week later, he informed the technical specialist that he had changed his plan for raising freshwater fish in his pond and wanted to try out rice-fish. He said he was willing to invest in the project and ready to face the risks.

The adaptation trials were managed and implemented by the farmer with technical assistance from the IIRR team. The inputs were provided by the farmer, fish fry were acquired from Laguna de Bay at the farmer's own expense.

The Rice-Fish Technology Adaptation

Site Selection

The area selected was fairly free from flood and water seepage. The sequence of operations in a rice-fish farm as shown in Fig. 1 are described below.

Construction of Trench

The trench was dug before the rainy season started. It was constructed in the lower portion of the ricefield along one of the dikes. The dimension of the trench was 1.0–1.5 m wide and 0.5–1.0 m deep. It occupied 8–10% of the ricefield area. The trench served many purposes. It provided a refuge for the fish during any drop in water level due to spraying or drought. It was the site for feeding the fish, where plankton bloomed and where fish were harvested.

A small pond was dug near the irrigation canal and stocked with a few fish to detect whether the water supply was free from toxic substances before allowing it to enter the ricefield.

Dike Construction

Dikes were approximately 50 cm to 1 m wide at the base and 30–50 cm at the top. They varied from 70 to 80 cm in height.

Installation of Outlet, Inlet Pipes/ Water Gates

Bamboo inlet and outlet pipes were installed and screened with 0.5-cm mesh wire or net to prevent the fish from escaping and predators from entering the ricefields.

Fertilization

The trench was fertilized with chicken manure before stocking fingerlings at the rate of 0.5 kg/m^2. More chicken manure was applied to one corner when the color of the water was no longer greenish. Urea was applied at the rate of 2.5–3.0 bags/ha (50 kg/bag) at 20 days after transplanting.

Stocking

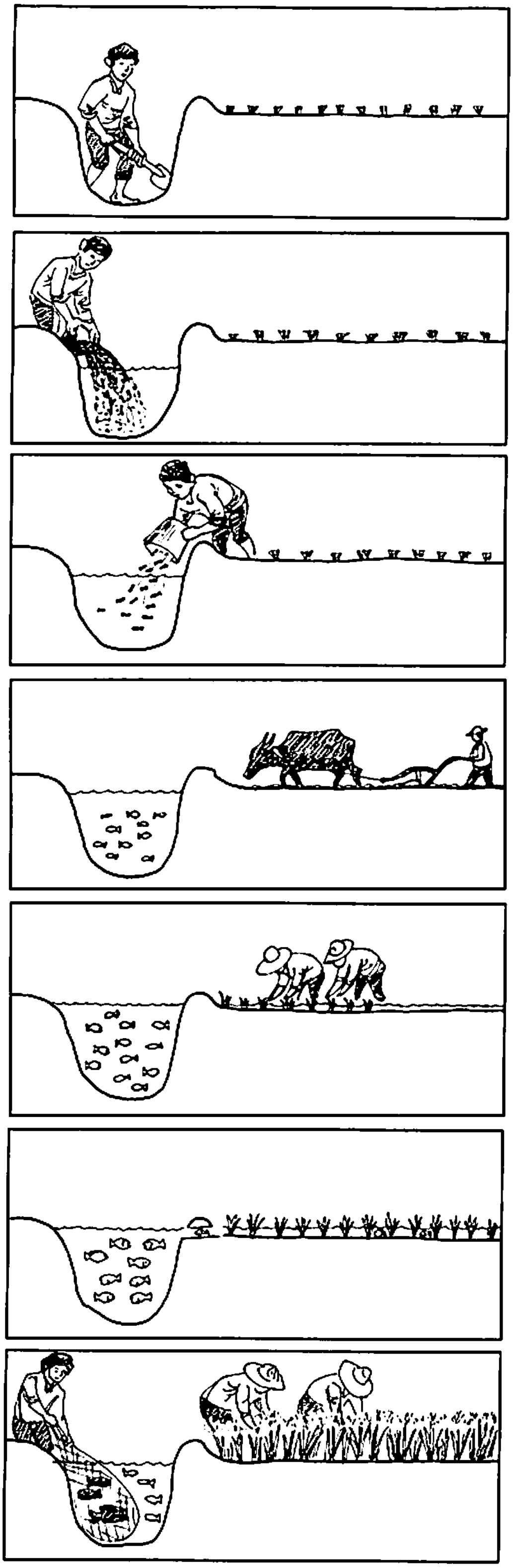
The species stocked were Nile tilapia (*Oreochromis niloticus*) and common carp (*Cyprinus carpio*) at a rate of 8,000–10,000/ha with 85–90% tilapia and 10–15% carp.

Supplemental Feeding

The fish were fed with rice bran whenever this was available. The total applied over the growth period was approximately 30 kg/season.

Transplanting of the Rice Seedlings

After the land was prepared and fertilized and the dikes constructed, the field was transplanted with IR 66.



1. **Trench construction**
   - This should be done before the onset of the rainy season. The trench is 1.0-1.5 m wide and 0.5-1.0 m deep.

2. **Fertilization**
   - When there is enough water in the trench (from initial rains or from irrigation canal), apply any of the following: chicken, hog or cow/carabao manure.

3. **Stocking**
   - Stock the trench with fingerlings 15 days after the application of the manure.

4. **Land preparation**
   - During the onset of rains, plow and harrow the land.

5. **Transplanting**
   - Transplant the seedlings after thorough preparation of the land. Maintain 2.5-cm water level.

6. **Opening the dike**
   - One month after transplanting, make three or more openings on the dike to allow the fish from the trench to go into the ricefield. Maintain the water level in the ricefield at 10-15 cm deep. Increase water depth to 20-30 cm after rice tillering.

7. **Harvesting**
   - By the time the rice crop is ready for harvesting, so are some of the fish. Harvest only the big fish (50 g or more). Extend the culture period of the smaller ones for the next rice crop.

Fig. 1. Basic operations in rice-fish farming.

Opening the Dikes on the Trench

One month after transplanting the rice seedlings, four openings on the dikes were made to allow the fish from the trench to pass into the ricefield. Water depth was maintained at 10–15 cm and increased to 25 cm after rice tillering.

Maintenance and Management of Rice-Fish Field

Regular maintenance of dikes included trimming the plants on the dikes to prevent rodents from making holes in them, and regular checking of screens, inlet and outlet pipes, and water gates to reduce fish escape. Water depth was maintained between 15 and 25 cm. The trench was fertilized regularly with chicken, hog or cow/carabao manure to insure the growth of plankton.

Harvesting

Fish were harvested just before the rice by draining the ricefield to gather the fish into the trench. Fish of 50 g and above were caught by seining the trench. Smaller fish were left to grow through the next rice crop. Fish were sold live in the town market.

Benefits and Opportunities from Rice-Fish Culture Technology

The direct benefits to Mang Isko from the introduction of rice-fish technology compared to the previous year's rice monoculture were: supply of fish for consumption and sale, and higher rice yields (Table 1). Some 48.5 kg of fish worth US$47 were harvested. Rice yields rose from 400 to 600 kg. On a per hectare basis, rice-fish technology gave a profit equivalent to US$1,074/season which greatly exceeded that of rice monoculture at US$322. Direct benefits of this magnitude prompted him to expand his rice-fish enterprise to 2,200 m^2 the following year. Again, benefits in yield and profit compared to the previous year were dramatically increased.

Indirect benefits from rice-fish included the reduction in the use of chemical fertilizers, weedicides and insecticides. He believed that fish droppings served as fertilizer for the rice crop, and that fish eat aquatic weeds and insect pests of rice.

Farmers and Technology Transfer

Mang Isko is considered an outstanding farmer-cooperator in rice-fish farming and is now often requested by the IIRR to be a training resource person. A lot of farmers and rural development officers both at the national and international levels visit Mang Isko's farm to observe and learn from him the various techniques of rice-fish technology.

Officers of people's organizations continue to promote and recruit farmer-cooperators in their respective villages for training in rice-fish technology. Trainees, not only put into practice what they learn, but also share the technology with other farmers. More experienced farmers serve as resource persons during farmer to farmer trainings. Moreover, they help other farmers resolve technical problems. The farmer resource persons are taught not only about rice-fish technology but also skills on how to become effective trainors.

To date, there are 12 farmer-cooperators in the IIRR social laboratory in Cavite who are engaged in rice-fish culture and a total of 35 farmers have been trained. The number of farmer-cooperators permits regular follow-up on technical difficulties and assistance to trainees.

Promotion and demonstration of rice-fish technology is being carried out in

Table 1. Operating costs and returns from rice monoculture (RM) and rice-fish culture (RF) in Mang Isko's farm, San Jose, Dasmariñas, Cavite, Philippines, 1986–88[a].

	Original area		Expansion area	
	Jul-Oct 1986 RM (US$)	Jul-Oct 1987 RF (US$)	Jul-Oct 1987 RM (US$)	Jul-Oct 1987 RF (US$)
A. Per ricefield area (m^2)	800	800	2,200	2,200
Yield (kg)				
rice	400.00	600.00	1,000.00	1,475.00
fish	-	48.50	-	140.00
Gross income	58.45	133.17	168.27	375.39
• cash	58.45	130.77	168.27	344.93
rice	58.45[b]	86.54[b]	168.27[c]	241.89[c]
fish	-	44.23[d]	-	103.04[e]
• non-cash	-	2.40	-	30.46
fish (consumed at home; given away)	-	2.40	-	30.46
Expenses	32.36	47.23	85.79	124.08
• cash	27.49	34.26	72.56	76.29
inorganic fertilizer (urea)	3.51	1.68	9.42	3.26
land preparation	4.87	4.81	13.46	13.12
transplanting	7.31	7.21	19.23	18.74
harvesting and threshing	3.65	4.90	10.34	17.43
weedicide	0.97	-	2.64	-
insecticide	1.07	-	2.74	-
land rent	4.26	4.21	11.54	11.25
irrigation fee	1.85	1.83	3.20	3.12
fingerlings (*Cyprinus carpio*)	-	9.62	-	9.37
• non-cash	4.87	12.97	13.22	47.79
seeds	1.46	1.44	4.09	3.98
weeding	3.41	-	9.13	-
trench and dike construction	-	6.73	-	18.74
organic fertilizer (chicken manure)	-	1.92	-	5.62
fingerlings (*Oreochromis niloticus*)	-	-	-	11.95
feeds (rice bran)	-	2.88	-	7.50
Income				
Net cash farm income (cash income minus cash expenses)	30.96	96.51	95.70	268.64
Net return to own inputs of labor and capital (gross income minus cash expenses)	30.96	98.91	95.70	299.10
Pure economic profit (gross income minus total expenses)	26.09	85.94	82.48	251.31
B. Per hectare (extrapolated from A)				
Yield (kg)				
rice	5,000.00	7,500.00	4,500.00	6,700.00
fish	-	606.25	-	636.40
Gross income	730.64	1,664.66	757.21	1,705.76
rice	730.64	1,081.73	757.21	1,098.88
fish	-	582.93	-	606.88
Total expenses	404.59	590.44	390.32	564.04
rice	404.59	326.02	390.32	322.29
fish	-	264.42	-	241.75
Pure economic profit	326.05	1,074.22	366.89	1,141.72

[a]Original values in Philippine Pesos were converted to US$ at the rate of US$1 = P20.53 (1986), P20.80 (1987) and P21.34 (1988).
[b]Unhusked rice price = P3.00/kg.
[c]Unhusked rice price = P3.50/kg.
[d]Fish price = P20.00/kg.
[e]Fish price = P20.35/kg.

other provinces of the Philippines, such as Albay, Quirino and Negros Occidental.

Conclusions

Raising fish with rice appears to increase income and improve nutrition for the farmer's family. However, the contribution fish makes to rice pest control and fertility remains unclear. Moreover, the technology could be further improved to overcome the problem of small fish at harvest. One idea is to extend the fish culture period by constructing the trench prior to land preparation, and stock fingerlings when it is filled with water. Another idea is to establish a nursery/breeding pond in the ricefield so that larger fingerlings would be available for stocking.

Perhaps the most important conclusion that can be drawn from Mang Isko's experience is the potential within the farmers themselves to adapt and transfer technologies.

Rice-Fish Farming Systems Development and Extension in Thailand: Tales from One Project

WATTANA LEELAPATRA
Kalasin Fisheries Station
P.O. Box 18, Kalasin, Thailand 46000

JOHN D. SOLLOWS*
Northeast Fishery Project
Khon Kaen Fisheries Research and Development Centre
Khon Kaen, Thailand 40000

LEELAPATRA, W. and J.D. SOLLOWS. 1992. Rice-fish farming systems development and extension in Thailand: tales from one project, p. 339-344. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Rice-fish farming is expanding rapidly in Thailand, particularly in the Northeast, where local ecological, economic and social circumstances have become highly conducive to its spread. A number of government and non-government agencies are becoming increasingly involved in promoting rice-fish through different approaches. The example elaborated here is from the Northeast Fishery Project of the Thai Department of Fisheries. This project stresses the farmer's perspective. The approach involves two-way communication between the Department and farmer target groups. Within the "Fish in the Ricefield" program, the main extension mechanism is training and demonstration complemented by follow-up.

Introduction

Thailand's rice-fish development began during the 1930s with the Department of Fisheries (DOF) extension program in the Central Plains. Activities subsequently expanded to the northern and northeastern regions of the country. Research to support extension began in 1955, mainly at the Chiang Mai Fisheries Station. Rice-fish farming received a further boost in 1959, when loans were made available to Central Plains farmers. The area cultivated with rice-fish peaked at an estimated 3,000 ha. Species cultured included common carp (*Cyprinus carpio*), snakeskin gourami (*Trichogaster pectoralis*), Java

*Present address: ICLARM Bangladesh Office, House No. 20, Road No. 9/A, (New) Dhanmondi R/A, Dhaka 1209, Bangladesh.

tilapia (*Oreochromis mossambicus*) and walking catfish (*Clarias batrachus*).

Over the past 15 years, however, the intensification of agriculture had conflicted with fish culture. Increased use of pesticides in rice farming has made fish culture impractical in many areas. Many farmers have quit. In addition, the relative abundance of fish in the Central Plains has further dampened fish culture (C. Martin, pers. comm.). Nevertheless, in a few low-lying, infertile areas, the culture of fish in ricefields prevails. In many cases, farmers have stopped growing rice and culture snakeskin gourami or walking catfish.

The picture is quite different in North and Northeast Thailand. Pesticides are used sparingly, if at all, in rice crops. Many captured wild fish species are decreasing. A rapidly spreading disease has decimated wild stocks. Demand for fish is rising and where investments required to dig ponds are prohibitive, rice-fish farming is becoming a popular alternative. Expansion is most rapid in the Northeast because farmers use few chemicals, ricefield fisheries are traditionally important, and income sources are few. Major species cultivated include Thai silver barb (*Puntius gonionotus*), common carp and Nile tilapia (*O. niloticus*).

Agencies Involved in the Rice-Fish Extension

The government has supported the development and extension of rice-fish farming for over 40 years. In the last few years, non-government organizations (NGOs) have become involved as well. A review of their activities follows.

Government Agencies

DEPARTMENT OF FISHERIES (DOF)

Since the early days, the DOF has had direct responsibility for research and extension in rice-fish farming. In the North, the Chiang Mai Fisheries Station has been involved with rice-fish research and extension since 1955. From 1967 to 1977, its special unit in Chainat, Central Plains, extended rice-fish technology. Over the same period, experiments were conducted at two fisheries stations--Udonthani and Surin, and at the Northeast Agriculture Centre, near Khon Kaen.

Research in the northeast investigated trench configuration, feed quantity and quality, fertilizers, stocking rates, stocking sizes, fish species mix, rice varieties, and effects of different factors on survival, growth and production. After 1977, research efforts were cut back in favor of extension.

Under the DOF's Freshwater Fishery Development Project, rice-fish farming has received support for 40 fisheries stations and 65 provincial fisheries extension offices. In the northeast, a number of area-specific projects associated with the DOF have put considerable efforts into rice-fish farming research and extension. These include the US Agency for International Development-assisted Northeast Rainfed Agriculture Development Project (NERAD), the Thai-Australia Thung Kula Ronghai Project, the DOF's Accelerated Aquaculture in Irrigated Areas Development Project, and the Canadian International Development Agency-aided Northeast Fishery Project (NFP).

DEPARTMENT OF AGRICULTURE EXTENSION (DOAE)

The extension of crops and cropping systems dominates the DOAE's work. In 1988, the DOAE decided to extend rice-fish technologies in all 17 northeastern provinces in recognition of their potential. Farmer-operated demonstration plots are the chief extension tools used; progress is closely followed by subdistrict extension officers.

The large number of DOAE officers working at subdistrict levels complements the extension efforts of the DOF, which lacks this resource. Information cooperation between the two departments was considerable throughout 1989. Cooperation on an official level, with a budget to support rice-fish extension in North and Northeast Thailand, will begin in 1991.

DEPARTMENT OF AGRICULTURE (DOA)

The DOA conducts agricultural research. A number of rice experimental stations have conducted rice-fish trials on rice varieties and pesticide applications. Since 1984, the Farming Systems Research Institute (FSRI) has conducted rice-fish on-farm research at sites in the Northeast, North and Central Plains. Research topics included system descriptions in various environments, economics, effects on rice yields, appropriate rice planting methods, effects on rice pests and diseases, and fish feeding habits.

KHON KAEN UNIVERSITY (KKU)

KKU's Farming Systems Research Project began conducting on-farm experiments in 1985. Fish culture was found to be one activity which fits in many circumstances, with rice-fish farming as one important component of the farm system. Since 1988, research results have been widely tested through multilocation trials.

Non-Government Organizations (NGOs)

Many national and international NGOs in Thailand include rice-fish farming development and extension as one of their activities. Most NGOs concentrate their work within specific, circumscribed areas, which ensures success but offers little impact on a wide scale. Cooperation with government agencies could increase the benefits generated by NGO efforts. At least, the results of and lessons from their work deserve to be communicated.

APPROPRIATE TECHNOLOGY ASSOCIATION (ATA)

ATA, a Thai NGO, has had a number of very successful extension activities in rice-fish farming. Their work in villages of Khon Kaen Province has been utilized by various agencies including the DOF. Moreover, its rice-fish extension booklet and view are increasingly being used, as described by Siriphat (this vol.).

ASIAN INSTITUTE OF TECHNOLOGY (AIT)

The AIT, with assistance from the British Overseas Development Administration, has begun the Aquaculture Outreach Project in cooperation with the DOF. The aim of this project is to develop appropriate and practical techniques for raising fish in areas of Asia where rice is the major agricultural crop. The project is finding rice-fish farming to be an important activity in many circumstances.

CANADIAN UNIVERSITY OF SERVICES OVERSEAS (CUSO)

CUSO supports the efforts of many Thai NGOs involved in rice-fish farming. Over the last 10 years, it has stimulated the development of rice-fish, particularly in the northeast, among various government and non-government agencies. From 1984 to 1988, CUSO volunteers worked with the DOA's FSRI in the northeast, north and central plains.

The Northeast Fishery Project (NFP) Approach

The NFP aims to increase the farmers' perspective and efficiency of the DOF's extension efforts. The DOF has limited manpower, with its officers responsible for a number of projects over a wide geographic area. The NFP complements traditional person-to-person approaches in which a one-way flow of information from an officer to a client predominates. To reach more clients, the project uses farmers as paraprofessionals and a diversity of media like leaflets, booklets, flip charts, display boards, slides, videos and radios. These are put to use in a variety of extension activities, examples of which follow:

- A radio broadcast of five-minute anecdotes and technical passages, supported by other materials and village visits.
- A farmer's newsletter, sent out to selected farmers who have indicated their commitment to culturing fish; which includes anecdotes, technical information, letters from farmers and responses to these letters.
- A farmer's conference and "External Extension Manpower" training where farmers are trained by one another and by the DOF to promote aquaculture among other farmers in their localities, provide feedback to DOF personnel and act as community contacts for DOF extension officers.
- A recent university graduate is employed as a temporary extension worker to conduct extension activities within the DOF workplan in a limited geographic area.

Fish in the Ricefields Program

The Fish in the Ricefields program incorporates to varying degrees of the activities discussed, but focuses its efforts through demonstration, training and follow-up.

DEMONSTRATIONS

Since 1986, 150 rice-fish demonstration plots have been dug in farmers' fields in four provinces. The project tractor dug peripheral trenches a meter wide and a meter deep on two to four sides of each plot; the excavated earth was used to raise the enclosing dikes above flood level. Trenches were set about 1m from the dikes in order to stop dike soil from eroding into the trenches. A square pond about 25 m^2 was dug in the lowest corner of the field.

The progress of each farmer was followed closely in the first year of operation. Demonstrations of the effects of various factors on fish growth and production were conducted with the help of temporary technicians. Demonstrations included stocking size, stocking density, levels of manure and rice bran, and water depth.

TRAINING

During the past year, farmers in each of the six provinces where NFP is concentrating have received training. A target of 40 farmers was set for each province.

Each training took two days in one village and involved 20 to 60 farmers. On the first day, rice-fish farming was introduced through lecture, videos and discussion. Slides, handouts and display boards were used to varying degrees. Farmers were taken on a field trip to rice-fish sites on the second day. Management problems and benefits were discussed with the owner-operator.

FOLLOW-UP

Follow-up with the farmers involved in the training and demonstrations are undertaken to assess their effects, explore ways of improving their effectiveness and increase understanding of the factors influencing farmers' decisions. The exchange of ideas emerging from this activity enhance the extension effort as well.

Lessons from the NFP

Many lessons, both positive and negative, were learned by the NFP. The following paragraphs discuss those related to selecting sites and farmers, and reactions of farmers to trainings and on-farm demonstrations.

A number of criteria is important in selecting sites and farmers. Biophysical potential of a site is usually given priority but the degree of farmer interest and need should be given similar weight, as should the abilities of individuals to absorb and manage the technology. Officers selecting sites and farmers must rely on intuition to identify those willing to help themselves and take initiative.

Farmers prefer trainings to be in their own village. Reasons given were that: interested villagers of limited mobility could still attend; trainers could better understand and take into account the circumstances peculiar to the village; and fields of interested farmers could be visited easily.

Farmers with little prior experience felt that longer training sessions would be more effective. A "motivational" session one week to one month before the main training overcame this problem. These half-day sessions typically involved slides and guest farmer-speakers. The benefits from such sessions were many. Since basic concepts had already been introduced, subsequent training was better understood. Farmers could better decide whether or not they wanted to invest two days attending the main training session. More farmers could learn about the main training and make time for it.

Post-training follow-up was considered helpful because it consolidated what individuals had learned, allowed officers to respond to the unique circumstances of each farmer, and allowed timely responses to problems. Many farmers said that such visits boosted morale among practitioners as well.

The structuring of the two days, with lecture and videos on the first day, followed by a field trip on the second, was positively received. Videos that provided visual examples established points more effectively than lectures. Field trips added variety to the training which was welcomed by all. Indeed, field trips received top marks for getting home the message. The fact that farmers could study examples of rice-fish systems at their own pace and discuss management problems and benefits with the operator helped. Farmers recognized the value of the first day's work to a full understanding of the field trip. Field trips did not work well where trainees were taken to sites whose circumstance differed greatly from theirs. Rainfed farmers when taken to irrigated sites commonly found that much of what they saw could not be applied.

A realistic, applicable demonstration is usually effective and sometimes an essential component of extension. The project demonstration plots have consistently attracted attention and interest, and in some cases, stimulated other villagers to try the practice. Interest, however, does not always lead to action.

One "model" demonstration cannot fit every situation. Efforts were made to fit each demonstration to local circumstances but the tractor imposed limits to adaptability to farmer- and site-specific conditions. This limitation is exacerbated when several demonstrations are placed in one locality. Adjacent plots share similar risks and advantages - if one fails, all tend to fail. Moreover, when all succeed, the results are less convincing to farmers whose situation differed from those of the demonstration.

Conclusions

Project activities are still in progress, and it is too early to make definite recommendations. However, one can say that the "right" way to extend a technology depends on the circumstances of the place, the people and the resources of the extension agency. We know that close, personal follow-up on individual practitioners, especially beginners, can be very effective. However, agencies with limited resources will run into difficulties here. A subsample of individuals selected for closer attention might help in some cases. In others, the agency's effectiveness might be enhanced by using in-village training and on-farm demonstrations. Two-day training sessions were well-received by villagers in the NFP. A motivational session held well beforehand makes training more effective.

NFP on-farm demonstrations worked when farmers' interests, needs and ability to manage were considered along with biophysical potential of the site. There is no doubt that demonstrations of a technology, whether developed by the farmers themselves or introduced by an outside agency, can be a highly effective extension tool. Care should be taken that demonstrations are applicable to the circumstances of the target farmers. Thus, investments made in any demonstration should reflect farm reality, as should their locations.

Whatever extension approach an agency selects, maintaining a continuous two-way communication with its farmer clients will enhance effectiveness and efficiency.

Acknowledgements

The authors wish to emphasize that the work reported in this paper is the result of the efforts by many individuals, including the DOF officers, NFP team members and participating farmers. We would like to mention in particular the contributions made by Damrong Silpachai, Ravadee Prasertcharoensuk, Oraphin Chindasatharporn and Tasani Kabkratoke.

Rice-Fish Development and Extension in Tung Kula Ronghai, Northeast Thailand

CHRISTOPHER LEE*

Thai-Australian Tung Kula Rong Hai Project
1/4 Prempracharas Road
Roi Et 45000, Thailand

LEE, C. 1992. Rice-fish development and extension in Tung Kula Ronghai, Northeast Thailand. p. 345–357. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Farmers in Northeast Thailand have adopted rice-fish culture more readily than any other fish production systems. The fisheries development approach of the Thai-Australian Tung Kula Ronghai Project Phase IV was found to be consistent with the rationale behind the farmers' decision to adopt rice-fish farming. This paper discusses the approach of the project, the rationale for rice-fish farming, and the socioeconomic and physical environments in which it operates. It offers recommendations for future development of rice-fish farming in the region.

Introduction

The Thai-Australian Tung Kula Ronghai Project Phase IV (TATKRP) is a resource area development project in Northeast Thailand. This project has its roots in the Poverty Area Program of the National Economics and Social Development Bureau's (NESDB) Five-Year Plan. Phase IV or the project implementation phase began in 1984 after three research and exploration phases. The fisheries development component was one of the four production components; others being land remodelling, ground water and upland rehabilitation. In addition, there were three supporting components: agricultural research and extension, community development and water resources study. The TATKRP's overall goal was to provide an equitable improvement in the standard of living of the rural people through improved net income, food supply and community participation (MGI 1983a).

The fisheries development component aimed to improve the nutrition of the people living in the project area through cost effective fish production. Development of culture fisheries was found to be the only viable course of action, as the potential for an improvement of the capture fisheries

*Present address: Bribie Island Aquaculture Research Centre, Bribie Island 4507, Queensland, Australia.

from restocking and rehabilitation of the natural environment was considered very limited (Lee 1989). A fisheries development program which focused on resource-based aquaculture, training and extension was implemented by the Department of Fisheries (DOF) in collaboration with the TATKRP. Several fish production systems, which used available resources, were tried and promoted in the project area. These programs included the village fishpond, school fishpond, backyard pond, cage culture and rice-fish farming. Farmers in Tung Kula Ronghai have adopted rice-fish culture more readily than the other fish production systems. The development approach of the culture fisheries component of this project is found to be totally consistent with the rationale behind the farmers' decision to accept and adopt rice-fish farming.

This paper discusses the philosophy of the fisheries development component, the rationale behind the farmers' decision to adopt rice-fish farming and the physical, social and economic environments in which it operates. It also offers recommendations for the future development and extension of rice-fish farming program for Northeast Thailand.

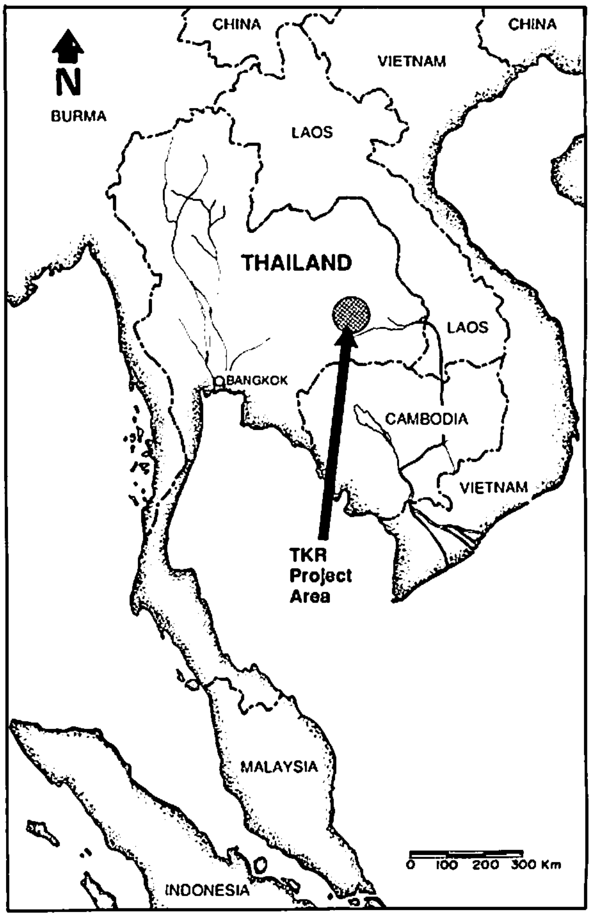


Fig. 1. Location of TATKRP area.

General Background

Tung Kula Ronghai or the Plain of the Weeping Kulas is a 3,400-km^2 floodplain. The Kulas were ancient nomadic people who are renowned for their stoic and resilient nature. Tung Kula Ronghai therefore is a singularly inhospitable region in Northeast Thailand (Fig. 1). The Poverty Area Program identified Tung Kula Ronghai as one of the five special areas in Thailand for accelerated rural development.

The dominant characteristic of Tung Kula Ronghai is its extreme climate, flat topography and infertile soil. The average annual rainfall is 1,400 mm and is unevenly distributed over the year where 80% of it occurs from May to October. The average rainfall distribution shown in Fig. 2, however, does not give a true indication of the situation experienced by the farmers. The five to six months rainy season is often interrupted by a short drought lasting from six to ten weeks. This dry period is both unpredictable and variable in severity and duration. A prolonged dry spell can significantly reduce rice yields and in extreme cases, can destroy the entire season's crop. The bulk of the monsoon rain comes in August and September and frequently causes flooding in the plains. Since the land is extremely flat, the flood water inundating the fields drains slowly and this adversely affects rice production. The dry season starts in November and continues for six to seven months.

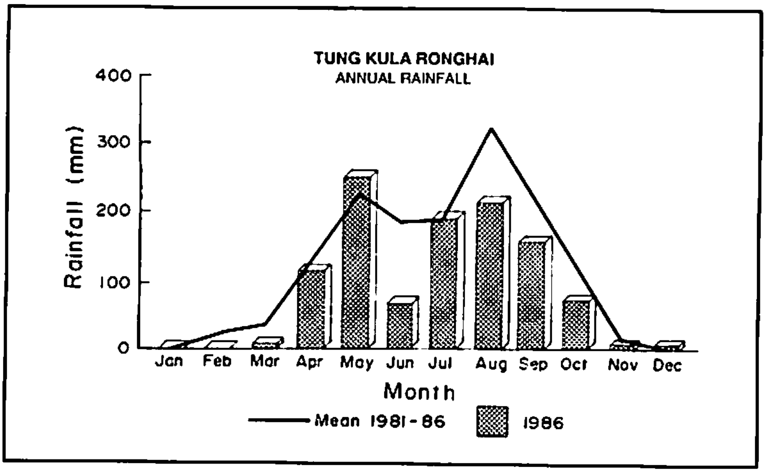


Fig. 2. Average annual monthly rainfall in Tung Kula Ronghai, 1981–86.

The ricefields have 10–20 cm layer of top soil overlaying several meters of clay subsoil. The infertile silty top soil has a pH of ≤5, and is poor in organic matter. It is estimated that only 6% of the soil in Tung Kula Ronghai are totally free of salt (MGI 1983b).

Tung Kula Ronghai is the home of 400,000 Esarn people whose ancestors are either Laotian or Cambodian. The average household is five to six members (Prapertchob et al. 1986). In the past, the Lao-Esarn farmers were found predominantly in the northern part, while the Cambodian or Khmer Esarn communities lived in the southern part of the plain. This has changed due to the rapid improvement of the highway and transport systems. Although there are language and subtle cultural differences between these two ethnic groups, the relationships between them are good and intermarriage is not uncommon.

The rural economy is to a large extent semisubsistence. Rice growing and fishing are the main occupation and preoccupation in Northeast Thailand. Only one rice crop is grown in a year. Tung Kula Ronghai's average production per hectare is lower (1,200 kg) compared to the Northeast (1,350 kg) and the national (2,000 kg) levels (MGI 1989). Despite the lower productivity of their fields, the income of the farmers compares favorably with other farmers in the Northeast. This is partly attributed to the larger (5.7 ha/household) land holdings in Tung Kula Ronghai compared to the Northeast (4.5 ha/household). Crop failures due to flood and drought also occur more frequently in this plain than in other parts of the region. As a consequence, the life of Tung Kula Ronghai farmers is more difficult than other Northeast farmers whose gross per capita product was estimated to be 40% of the national average in 1980. The socioeconomic characteristics of the Tung Kula Ronghai farmer have been described in greater detail in various studies (CUSRI 1981; Prapertchob et al. 1986).

Rice and fish are dietary staples of the region. The people of the Northeast consume four times as much fish as what they are producing (Biwater House 1987). Even so, the average animal protein intake in the region is still <9 kg/capita/year compared with the national average of 20 kg/capita/year (Envirocon 1986). But, in general, Tung Kula Ronghai farmers are better off in terms of health and nutrition considering their poor resource base. Malnutrition among the preschool children, for example, is lower than the average in the Northeast, being only 28.9% for degree one, 5.6% for degree two and 0.3% for degree three malnutrition (Prapertchob et al. 1986). In Tung Kula Ronghai as elsewhere in the Northeast, the people have developed food culture and food gathering skills in response to the low agricultural productivity.

Most people catch fish for their family from the ditches and ricefields during the rainy season. In recent years, the catch of wild fish has declined considerably as a result of the combined pressures of increasing population, increasing use of agricultural chemicals and increasing water control measures and roads (Kvam 1988; Lee 1989). Water control infrastructures and flood-free roads and highways interfere with the natural dispersal of wild fish which has caused an irreversible decline of the capture fisheries in this area. In the past, farmers have exclusive access to their fishing grounds, but with the construction of better roads and improved transport system, these local resources have become readily accessible to more people. Between 1981 and 1986, over 700 km of highways and roads were constructed across Tung Kula Ronghai (MGI 1989). Modernization of the rural areas will continue as long as the overall outcome of progress is seen as beneficial and desirable for the people.

Restocking programs are being carried out in many areas, but as long as the primary causes remain, the decline in natural fish population will continue. A solution to this problem is to convince the farmers to change from their traditional role as fishers to the new role of fish farmers.

In Tung Kula Ronghai, community fish farming activities consist of village and school fishpond projects. The private fish farming activities comprise of hatchery, backyard fish culture, river-based cage culture and rice-fish farming. The species cultured are Nile tilapia (*Oreochromis niloticus*), common carp (*Cyprinus carpio*), Indian carp (*Labeo rohita*), Chinese carp (*Aristichthys nobilis*) and Thai carp or silver barb (*Puntius gonionotus*). The majority of the Tung Kula Ronghai farmers prefer to culture silver barb because it is better adapted to the local pond environment. Moreover, it is a traditional food fish of the region and farmers find it more delicious than other species. However, farmers also stock other species into their ponds when fingerlings are available. They do this more for culinary reasons, than for economic or any other considerations. All species mentioned are relatively fast-growing and require little investments, but do not command high prices (US$1.00–1.20/kg).

Problems of Aquaculture Development

Fish production technology per se is not a problem, since there already exists within the DOF adequate fish production technology which can be directly applied in Tung Kula Ronghai. Fish farming is a relatively new food production and income-generating activity in the area. In the past, there was no need to culture fish, as the vast floodplains provided adequate supply of wild fish. Besides, the physical environment is not conducive to fish farming. Consequently, there is no real fish farming tradition in the area and most farmers have little appreciation for the potentials of fish farming. The lack of basic fish farming skills and poor pond management practices are responsible for low pond productivity in Tung Kula Ronghai. Rice farming, on the other hand, is a traditional and a stable occupation of most farmers. Despite the low productivity of the soil, most people will remain as rice farmers in the probably future.

For most of their life, rice farmers live with constant uncertainties. The drought, flood, pest infestations, government policies, and prices of fertilizers and rice are all beyond their control. This rationalizes their cautious approach to a new investment such as fish farming and until they are fully confident of it, they will be reluctant to risk capital and labor (Heim et al. 1983).

A baseline study conducted for TATKRP in 1986 (Prapertchob et al. 1986) shows that the average yearly saving per household was US$190, whereas the debt per household is around US$315. Most of the loans were obtained for agricultural purposes. Therefore, pond culture competes with rice growing for capital, labor and other farm inputs. Farmers in this area lack capital and thus, cannot carry out fish farming with the same level of intensity as practised in other parts of the world.

The potential income from fish production in the dry season cannot compete with wages from off-farm employment which accounts for 43% of the total family yearly income. About 58% of the farmers leave the village for off-farm employment (Prapertchob et al. 1986). Labor migration to the urban centers increases dramatically after a poor rice-growing season. Social considerations, like the opportunity to travel, experience a new way of life, and or have fun (particularly among the teenagers and young adults), also play a part.

Thai rice farmers are strong and independent; preferring to work as individuals or in small family units rather than in large formal groups (Heim et al. 1983). Although there are successful community fish farming projects in the northeast (with the exception of the school fishpond programs), private fish farms are significantly more successful in the long term. The lack of social cohesion of Tung Kula Ronghai farmers is regarded as a social constraint to development (CUSRI 1981; MGI 1984).

In Tung Kula Ronghai, water for fish culture is available only for five months in one year. To maintain adequate water throughout the year since 1 m of water can be lost through evaporation, the pond must be constructed at least 2 m deep. During August and September, floods frequently inundate fishponds, allowing the fish to escape into the surrounding ricefields. Rainwater washes the silt from the top soil into the ponds, causing high and persistent turbidity. Visibility depth of <5 cm caused by turbidity is common and this condition can persist in the ponds for several years if corrective measures are not done. Only herbivorous and planktivorous fish are suitable for small-scale farming. Turbid water prevents adequate photosynthesis for algae and plankton production. High turbidity, low pH, stagnant pond condition and short growing period are responsible for poor fish production in Tung Kula Ronghai. Stillwater culture system also causes large variation in fish sizes.

Although a number of village communities and individuals sell their surplus products to farmers and middlemen from outside the village, true commercial production is limited to a handful of private hatchery operators. Production of fish on a commercial scale is severely limited by the lack of water. The combination of unreliable rainfall and poor water quality means that the dominant characteristics of fish farming in Tung Kula Ronghai are low production and highly variable yields.

Development Approach: The Tao of Development

Lee (1989) and Suttanuruk (1989) adopted the ancient Chinese principle of Tao philosophy in their approach to fisheries development. This philosophy believes that any phenomenon arises as a result of a dynamic interplay of two primal forces: the yielding force *(Yin)* and the unyielding force *(Yang)* (Fig. 3). When they coexist in a state of balanced harmony, peace and contentment rule the

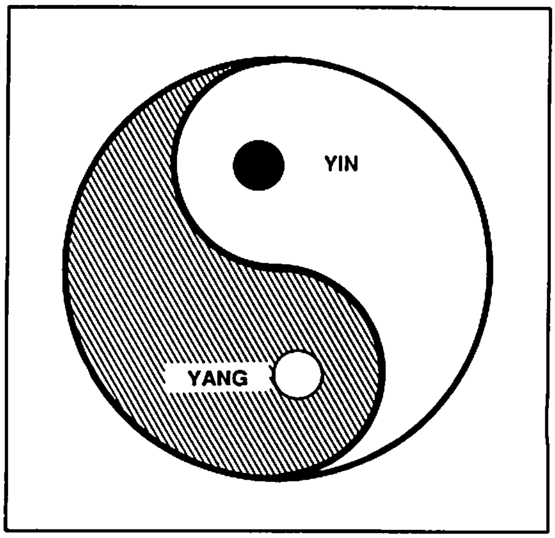


Fig. 3. The dynamic interplay between the yielding force (*Yin*) and the unyielding force (*Yang*). The dot in each half of the circle represents the seed from which an opposite force will grow when a situation reaches its climax.

day. The underlying concept of Taoism is the idea of cyclical changes of all natural systems: everything exists in a constant state of change and returning unto itself (Wilhelm 1968).

This dynamic equilibrium of nature is easily upset. Men can and often do disturb this fragile balance, often with catastrophic consequences. But just as the human race is responsible for many of the world's problems, they also have the capacity to restore the natural order of the world. Development is, therefore, seen as a way of restoring this imbalance.

Although every situation is in a continuous process of changing and becoming, in the short life of a project, situations can be conveniently regarded as being either relatively unchangeable, changeable or in a process of changing. Lee (1989) defines the changeable barriers to progress as constraints to development, and the unchangeable problems as the prevailing environment within which the project must operate. The cost to change any situation is inversely proportional to its changeability (Fig. 4). Here, the cost in terms of effort, time and money refers to farmers' cost as well as the project's development cost. To be cost effective, a development project must confine itself to changing only what is changeable, and to bring the situation forward to a stage where change becomes inevitable, irreversible and self-generating (Fig. 5a). In the present context, the low and highly variable pond production are the real and unchangeable characteristic of the area because the lack and unpredictability of water supply, poor soil quality and lack of capital during the course of this project will remain unchangeable.

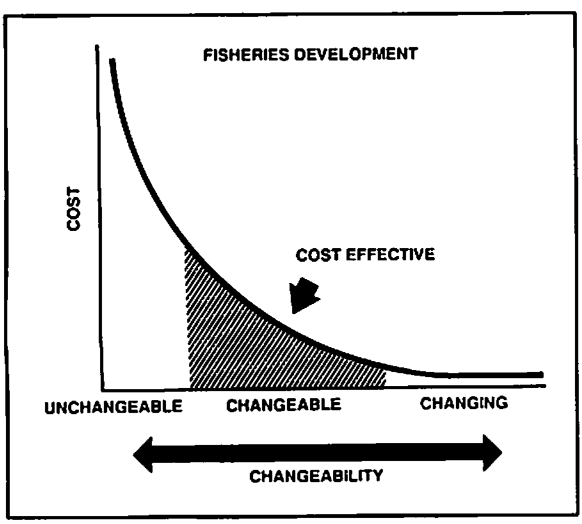


Fig. 4. The cost of development is inversely proportional to the changeability of the situation. Cost effective development can only come from changing what is changeable.

Grandstaff (1988) regarded individualism as a survival mechanism of the Esarn people. Labor and migration are also unchangeable, for as long as the income derived from the dry season off-farm employment is significantly higher than that from on-farm activities, people will continue to migrate annually from the villages to cities. Therefore, the first step in designing a project is to identify the changeable and unchangeable components of the situation. For a sustained development to occur, progress or change must be built on a stable or unchangeable foundation. A summary of the changeable and unchangeable components of the situation found in Tung Kula Ronghai is presented in Table 1 and Fig. 5b.

Tully (1966) defines extension as the communication of appropriate solutions to farmers' problems which is relevant to their resources, goals and situations. This ideal applies equally to development where the primary objective is to remove or reduce the constraints to progress. Thus, extension and development depend heavily on a thorough and sympathetic understanding of the farmers' resources, aspirations and situations. These are closely interrelated to one another but differ from farmer to farmer and from village to village. Since these also change with time, extension and development must also be constantly reviewed and revised. To gain a real understanding of the dynamic interrelationships among the farmers' situations, goals and resources, development workers must become

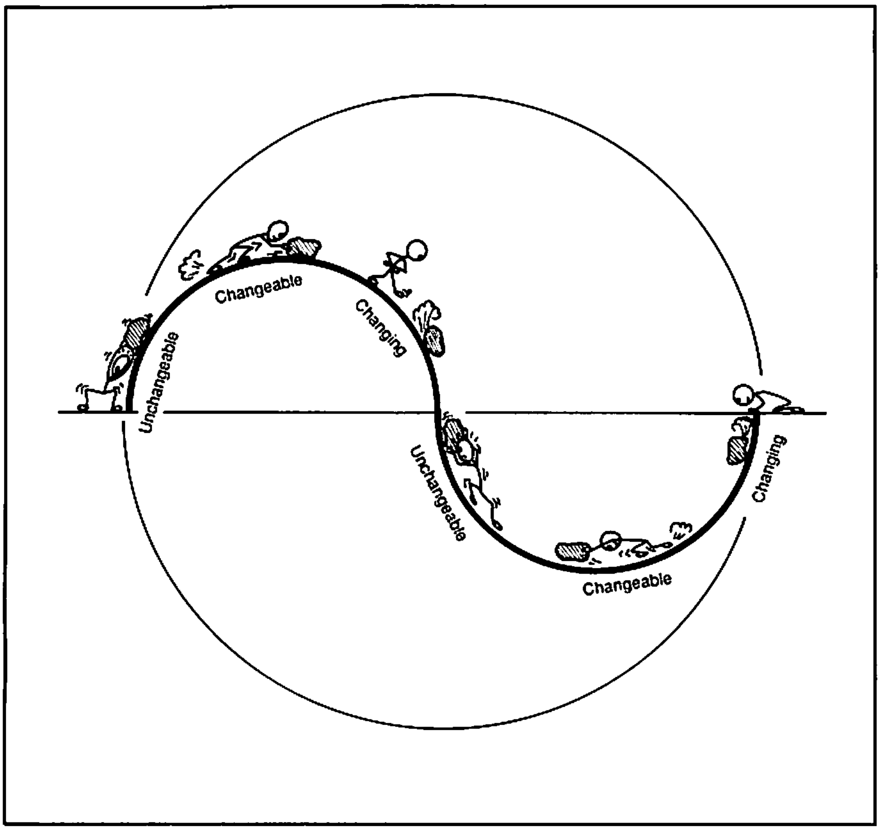


Fig. 5a. Within a brief project life, the situation can be conveniently regarded as being either unchangeable, changeable and in a process of changing. The aim of a development project is to transform a changeable situation into a stage where change becomes inevitable.

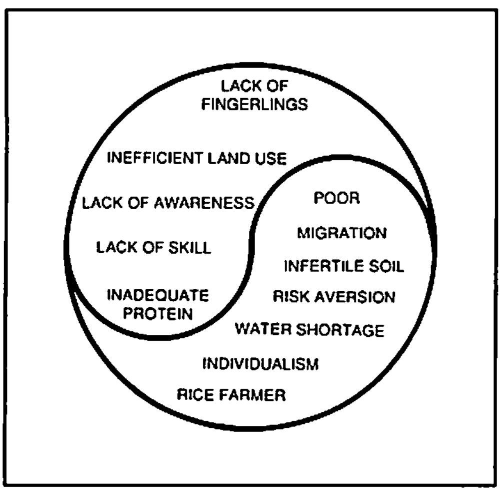


Fig. 5b. The changeable is essential for progress; the unchangeable is necessary to sustain it. Strong extension and accessibility of fingerlings are essential for rapid fisheries development in Northeast Thailand.

involved in day to day village life. Development workers must, like the farmers, become an integral part of the development process rather than mere spectators. The Tao approach to development is summarized in Fig. 6.

Fisheries Development Implications

Although many farmers are now able to improve their income through fish farming in Tung Kula Ronghai, it will be unrealistic to expect that aquaculture will significantly increase the income of the majority of the people. For most farmers, fish farming is only a means of

Table 1. Changeable and unchangeable components of fisheries development in Tung Kula Ronghai.

Changeable	Unchangeable
Lack of animal protein resource	Declining natural fish
Underutilization of land resource	Lack of reliable water
Underemployment	Poor water quality
Lack of awareness and basic fish farming skills	Lack of capital
Lack of confidence	Aversion to risks
Poor accessibility to good quality fingerlings	Strongly individualistic
	Dry season migration
	Traditional rice farmers

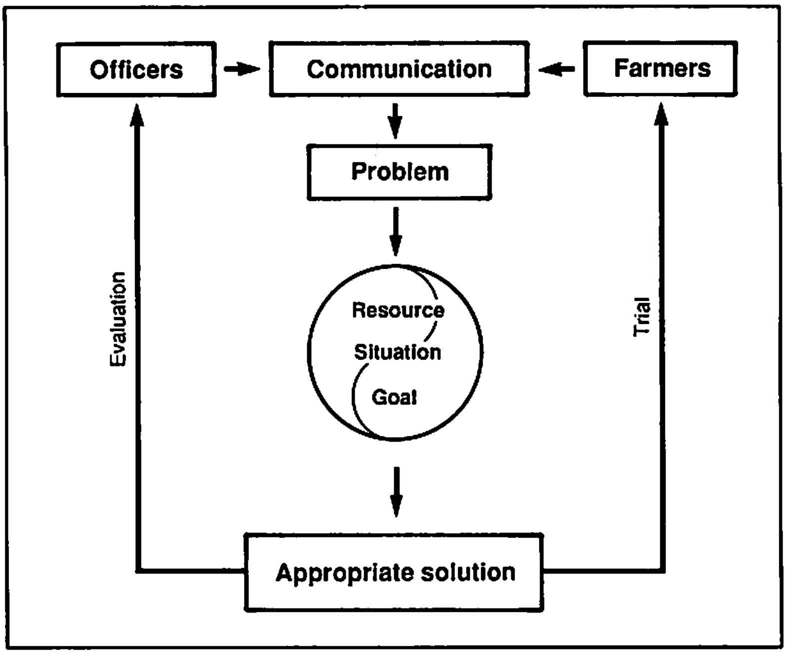


Fig. 6. The underlying concept of Tao is change and returning; thus, appropriate solutions will come from constant review and revision of the farmers' situations, resources and goals.

supplementing their income and providing their families with adequate protein.

Northeast farmers are highly efficient users of their land. To cope with their harsh environment, they adapt and diversify the use of their land to buffer the poor return of any one activity (Grandstaff 1988). Therefore, if aquaculture is to be accepted by the people, it must be presented to them as a more rational way of utilizing and diversifying available resources.

In order to survive in this harsh environment, farmers must constantly assess, evaluate and adapt to their changing environment. Their response to any new situation develops carefully and gradually over a period of time; and given adequate time, the people of Tung Kula Ronghai will respond appropriately to most changes. But capture fisheries is now declining faster than the rate with which the farmers can effectively respond.

Therefore, the primary objective of the fisheries development project should be to provide timely encouragement and guidance so that they will be able to come up quickly with solutions. Analysis of the resources and the situation (Table 1; Fig. 5b) indicates that extension and training are the key to rapid fisheries development.

Most farmers do not have permanent water on their land for keeping broodstocks, thus, fingerlings are bought from the DOF or private hatcheries from their villages at the beginning of every rainy season. To overcome this problem, the DOF must actively promote the development of small-scale fish hatcheries. Private small-scale farms are collectively less risky than large community undertakings. This is not to say that community fisheries programs should not be developed. On the contrary, successful community fishponds play an important role in fisheries extension in the region. However, because unsuccessful community ponds can discourage prospective fish farmers, the selection process of community fisheries development projects must ensure higher chances of success. Assessment should be more rigorously based on the previous history of cohesiveness of the communities. Older and well-established villages are generally more likely to be successful in implementing community activities than younger villages. Matrilocality in the northeast, where new husbands move and live with the wives' families, suggests that within a village community, women's groups will be more stable than the men's (Kvam 1988).

In summary, the factors that should be considered in fisheries development in the region are:

1. Small-scale private fishfarm development is the most viable solution to the lack of animal protein caused by the decline of capture fisheries.
2. The introduction of fish farming technology must consider the overriding influences of climatic factors especially the inadequate and highly variable water supply.
3. The low and variable fish production are the key issues that need attention.
4. Aquaculture development should be based on low capital and low risk fish farming systems.
5. Fish farming should complement rather than compete with off-farm working opportunities.
6. Fish farming should complement rather than compete with rice-growing in terms of labor, time and capital.
7. Training and extension are the key to fisheries development.
8. Fisheries extension and training programs should involve and encourage women participation.
9. The availability of good quality fingerlings is crucial for accelerated aquaculture development.

Rice-Fish Farming in Tung Kula Ronghai

Rice-fish farming is the most widely accepted fish production system in Tung Kula Ronghai. The average size of a rice-fish farm is 0.8–1.0 ha. The most common cultured species are the common carp, tilapia and silver barb, with strong preference toward the silver barb. Factors that influence farmer preference are taste, fingerling availability and fish yield. Farmers observe that common carp and tilapia do not thrive and grow as well as the silver barb in the ricefields. Pond construction is usually done by men but women frequently participate.

The basic design of rice-fish farms in Tung Kula Ronghai is shown in Fig. 7. It has a 1 x 1 m deep trench excavated along the inside perimeter of the ricefield. This trench may be constructed along one, two, three, or all four sides of the field. The soil from the trench is used to increase the width and the height of the bund around the field. Ideally, a deeper refuge pond should also be provided at the lowest part of the field. Many ricefields in Tung Kula Ronghai already have trap ponds which can be readily converted into refuge ponds. Trap ponds are traditional

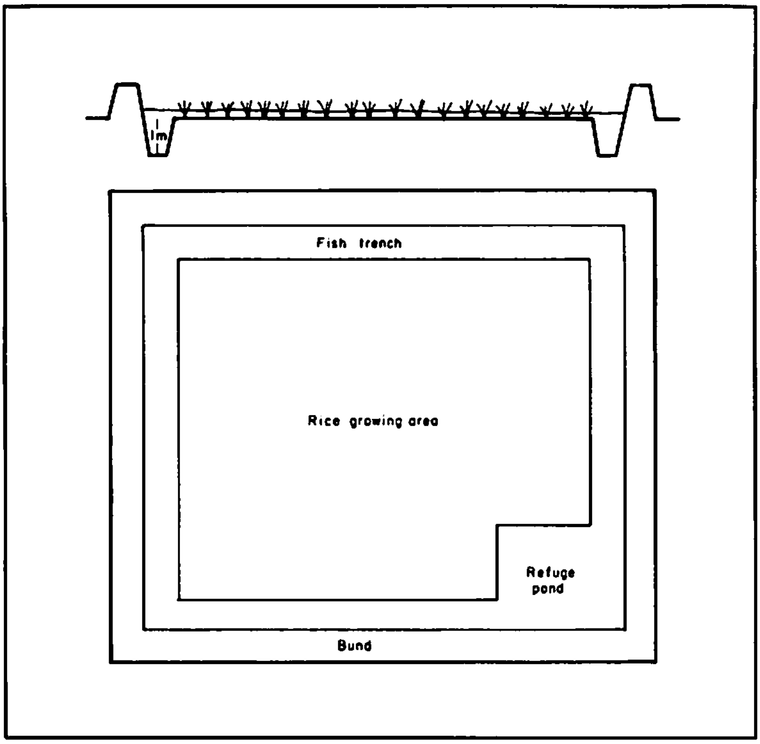


Fig. 7. The design of rice-fish farms in Northeast Thailand.

ponds found in many ricefields in the floodplains of Northeast Thailand. Wild fish enter the fields and are trapped as water recedes. Farmers do not provide any management input into the pond other than tree branches and sticks to discourage thieves from using their cast nets. Branches and sticks also act as shelters for the wild fish during the day. After the rice has been harvested, the trap pond is drained and the fish collected. The yields of trap ponds are highly variable and the dominant species are catfish (*Clarias batrachus*), snakehead (*Channa striata*) and climbing perch (*Anabas testudineus*). These trap ponds usually measure 6 x 3 x 2 m. The trap ponds can be easily modified into a refuge trench by connecting it to the trench.

The advantage of this rice-fish field design is that the trench and refuge pond provide a large volume of water with adequate depth for the fish when the ricefield is dry. The refuge pond can be used as a nursery pond at the beginning of the rainy season and a fish collecting sump at the end of the rainy season. As farmers gain experience and confidence, they modify and enlarge their rice-fish farms to suit their particular needs. It is interesting to note that many of the successful rice-fish farms in Tung Kula Ronghai bear little resemblance to their original designs.

The recommended stocking rate for rice-fish farming is 3,000–5,000 fingerlings/ha. The size of the fingerlings varies between 2.5 and 5.0 cm depending on their availability. The cost of fingerlings is about US$4 per thousand. Higher stocking rates are used to compensate for the greatly variable survival rates. The poor condition of the fingerlings, the major cause of mortality during the initial period, results from stress during transport. Farmers often do not take the necessary steps to prevent the water from becoming overheated during transport. The absence of local fingerling suppliers means longer time to bring the fingerlings to the fields. It is not uncommon for farmers to spend an entire day buying and transporting fingerlings. To some extent, predatory fish (snakehead, catfish and climbing perch) also contribute to fingerling mortality despite the precautions taken.

Supplementary food consists mainly of rice bran which is given only when available. Generally, very little fertilizer is applied. The most popular chemical fertilizer used in the ricefield is 16–16–8. Fertilizer application rates per hectare vary greatly from one village to another, ranging from as high as 179 kg to a low 13 kg. Only 20% of the farmers in Tung Kula Ronghai use insecticides, although 75% use crab poison and 45% use rat poison (Prapertchob et al. 1986).

Most farmers found that growing fish in the ricefield increases rice yields because fish reduce insect pest population. Farmers tend to spend more time and care tending their ricefields with fish. Leelanonda et al. (1988) found that 100% of the rice-fish farmers went to their fields more often, and 81% of them increased fertilizer rates. Many farmers do not use insecticides in their rice-fish farms and those who do have stopped when they adopted rice-fish farming. Daily fish farming operations and harvesting are shared among the members of the family.

Fish production from the ricefield varies from farmer to farmer and from year to year. As expected, experience in fish farming has a great influence on productivity; but climate is, without doubt, the single greatest source of the variability in fish production. A survey conducted shows that the average fish production for a first year operation of a new entrant in Tung Kula Ronghai was 94 kg/ha (OAE 1987). This low yield was attributed to muddy water, inadequate feeding, and the pond was relatively new. Surveys conducted by the Department of Fisheries (Thiancharoen 1987; Leelanonda et al. 1988) showed that the average fish production in 1987 was 120 kg/ha, but could reach 450 kg/ha. These surveys also showed that most farmers did not sell their fish, but used them for their own consumption. This implies that a farmer operating on the average 0.8-ha rice-fish farm can provide at least 17 kg of fish per family member. Despite low fish production, farmers in Tung Kula Ronghai were satisfied and continued rice-fish farming (OAE 1987). Since it brings food directly to the table without the need of much additional inputs, it is not surprising that it has attracted considerable interest among married women.

Farmers indicated the added advantages of rice-fish farming are: the trench and refuge ponds are important emergency water storage for their rice nursery during the intervening dry period; and that the higher bund can, in most cases, prevent flood water from inundating their fields and damaging their crops.

Rice-Fish Development and Extension

There is a growing awareness of the benefits derived from rice-fish culture for the rural economy of the Northeast. Although this region represents only 47% of Thailand's total riceland area, about 80% of the rice-fish farms in the country in 1982 are located in the northeast (Fedoruk and Leelapatra 1985).

Rice-fish farming was easily promoted in the northeast because it does not unduly disrupt the normal routine of the farmers, and the added economic and social costs are small. It does not compete with off-farm or on-farm activities in terms of time, labor and capital. Rice-fish culture does not require an occupational change from traditional rice farming into fish farming, but allows rice farmers to grow fish simultaneously in the same field. It gives rice farmers the opportunity to further diversify, so that inputs are shared and the risks are minimized. All the attributes of rice-fish farming is consistent with the fisheries development approach of TATKRP.

The number of rice-fish farmers in Northeast Thailand is still very small and there exists a considerable scope for expansion and acceleration. Tung Kula Ronghai's experience can serve as valuable guidelines for future fisheries development in the region. The lesson clearly indicates that strong extension and training programs and the availability of good quality and low-cost fingerlings are crucial to the rapid development of rice-fish farming in the region. Women's participation in fisheries extension and training programs must be encouraged because they play an important role in improving family nutrition.

The issues identified in the "Development Approach" of this paper are critical and should form the framework for rice-fish extension and development programs in general. Since the passion for beauty, good food, enjoyment and fun or *sanuk* are dominant characteristics of the Thais, these extra-rational values can be used to promote rice-fish farming. In the northeast, where uncertainties are facts, the primary thrust of extension must be to reduce the perceived and real risks by building farmers' skills and confidence. Confidence can be developed through direct and constant interactions of extension officers with farmers. Therefore, an extension program especially during the initial stage of development should allow frequent communication between the extension officers and the farmers.

Many basic aspects of rice-fish culture such as the relationships between stocking rates to various species and the ratio of surface to volume of water, polyculture versus monoculture and the pond dynamics of rice-fish fields, are still not fully understood. Research on these are needed, and should be done within the context of the economic and physical resource base of the area. The need for further research must not in any way interfere with the rice-fish promotion. With regard to extension, this writer fully agrees with Gabriel Ardant, who says that "coverage must come before perfection" (Schumacher 1973). Fisheries development should aim to facilitate a lasting change in the attitude of the farmers, make them aware of the possibilities and potentials of their own resources which could increase their confidence to achieve new goals. Therefore, the relevant question at the conclusion of a development project is not what the return on project investment is, but rather how close was the project able to bring the situation toward a stage where the farmers can continue to develop by themselves.

Some readers may say that this is just another case of reinventing the wheel and that the findings and the approach outlined in this paper are nothing more than common sense. This paper does not claim any new discovery of development or extension methodology since the origin of the principle of Tao is perhaps as ancient as the discovery of the wheel itself. What it tries to do is to bring to attention the indispensability of the void at the center of the hub or the nonwheel in the overall utility of the cart. It is a plea to consider the importance of extra-rational values in development, and to examine development constraints and process from a more realistic and humane point of view.

The chance of success of development projects is high if there is a genuine concern for the people whose well being we are endeavoring to improve. Care and concern are not blind emotions but as King Bhumibol of Thailand once explained:

> "...the Thai spirit of *metta* is always based on a well reasoned judgment and is constantly reviewed and revised against the background of changing circumstances."

References

Biwater House. 1987. Biwater House Survey. Green Esarn project development master plan sector study: fisheries. Biwater House, Surrey.

CUSRI. 1981. Kula Ronghai project. Review for implementation. Vol. II. Chulalongkorn University Social Research Institute. Bangkok, Thailand.

Environcon. 1986. Thailand-Canada Northeast fisheries project: inception report. Part I: the work plan. Envirocon International Pty. Ltd., Bangkok, Thailand.

Fedoruk, A. and W. Leelapatra. 1985. Ricefield fisheries in Thailand. Fisheries Advisory Project DOF/CIDA (906/08201), Bangkok, Thailand.

Grandstaff, T.B. 1988. Environment and economic diversity in northeast Thailand. *In* T. Charoenwatana and A.T. Rambo. Sustainable rural development in Asia. Selected papers, Fourth Suan Regional Symposium on Agrosystem Research. Khon Kaen, Thailand.

Heim, F.G., A. Rhabibhadana and C. Pinthong. 1983. How to work with farmers: a manual for field workers. Research and Development Institute, Khon Kaen, Thailand.

Kvam, R. 1988. From gatherer to farmer: aquaculture in northeastern Thailand. Network Aquaculture Centres in Asia, Bangkok, Thailand.

Lee, C. 1989. Fisheries development in Tung Kula Ronghai: the role of aquaculture development in community nutrition. A paper presented at the first Australian conference on tropical health and nutrition, October 1989. Brisbane, Australia.

Leelanonda, Y., C. Thongprapai, M. Boonyaratpalin, C.P. Lee and K.C. Chong. 1988. Socioeconomic study of rice fish farming in Tung Kula Ronghai development region. National Inland Fisheries Institute, Bangkok, Thailand.

MGI. 1983a. Thai-Australian Tung Kula Ronghai Project Phase 4 Project document. McGowan International Pty. Ltd. and Australian International Development Assistant Bureau. Canberra, Australia.

MGI. 1983b. Tung Kula Ronghai salinity study. McGowan International Pty. Ltd.; Australian International Development Assistant Bureau; Department of Land Development; and Royal Irrigation Department. Canberra, Australia.

MGI. 1984. Thai-Australian Tung Kula Ronghai Project Phase 4 feasibility analysis report. McGowan International Pty. Ltd. and Australian International Development Assistant Bureau. Canberra, Australia.

MGI Pty. Ltd. 1989. Thai-Australian Tung Kula Ronghai Project (TATKRP) Phase 4 project completion report. McGowan International Pty. Ltd. and Australian International Development Assistant Bureau. Canberra, Australia.

OAE. 1987. Summary of the Thai-Australian Tung Kula Ronghai Project (TATKRP) fisheries component, 1986–1987. Office of Agricultural Economics. Bangkok, Thailand. (Unpublished).

Prapertchob, P. P. Kachamat, J. Virakul, W. Pakuthai, and P. Thirangoon. 1986. Baseline study of farmers in Tung Kula Ronghai. Thai-Australian Tung Kula Ronghai Project, Roi Et Fisheries Station, Thavatburi, Thailand.

Schumacher, E.F. 1973. Small is beautiful. Perennial Library, London.

Suttanuruk, S. 1989. Fisheries extension in Tung Kula Ronghai. Roi Et Fisheries Station, Thavatburi, Thailand.

Thiancharoen, P. 1987. A survey of rice-fish culture in Tung Kula Ronghai, Surin Province. Surin Fisheries Station, Surin, Thailand. (Unpublished).

Tully, J. 1966. Towards a sociological theory for extension. Human Relations 19(4). Plenum Press, London.

Wilhelm, R. 1968. I Ching - the book of changes. Routledge and Kegan Paul, London.

Farmers' Acceptance of Rice-Fish Culture in Northeast Thailand

DECHA SIRIPHAT
Village Freshwater Fishery Project
Appropriate Technology Association
143/171-172 Pinklao-Nakornichaisri Road
Bangkok No.1 Bangkok 10700
Thailand

SIRIPHAT, D. 1992. Farmers' acceptance of rice-fish culture in Northeast Thailand, p. 359–365. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Rice-fish farming in Northeast Thailand has rapidly expanded in the past five years, after an epidemic that began in 1983 which affected the fish all over the country. Farmers in the Northeast found it easy to raise fish in ricefields. Rice-fish culture was compatible with traditional production techniques and it used locally available resources. Farmers have benefitted from the practice. The effectiveness of horizontal transfer of rice-fish technology using innovative farmers based on the experiences from Khon Kaen and Buri Rum Provinces are presented.

Introduction

Northeast Thailand (Fig. 1) is the largest region of the country, representing approximately one-third of the total 16.8 million ha with 17 million people. Most agricultural lands (53%) are used for rice production; over 90% are rainfed and 6.3% are irrigated. Even with sufficient rainfall (approximately 1,300 mm/year), there may be long dry periods. Average rice yield (1,560 kg/ha) is the lowest in the country due to irregular rainfall and poor soils (sandy, acidic or saline, low organic content). Thus, northeast farmers are the poorest in the country with an average annual per capita income of US$107.

The basic diet of the people from the northeast is glutinous rice, fish and vegetables. Rice and vegetables are obtained from farming. Traditionally, almost all fish are obtained from natural waters. People have been accustomed to its taste and are familiar with fish preparation methods for food. Attempts to change to other sources of protein such as soybean have not been successful.

Population increases and depletion of natural resources (forests, soil, water

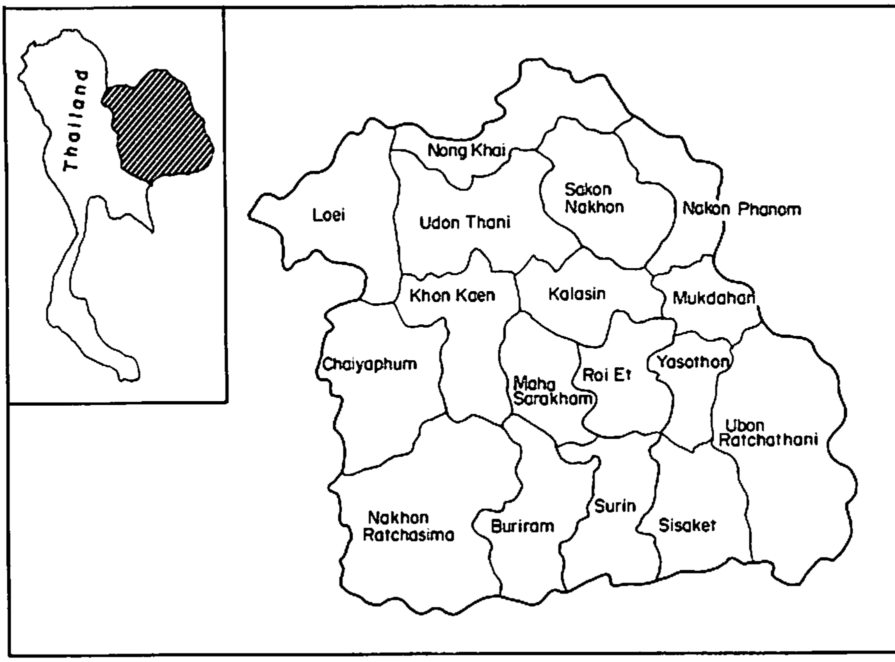


Fig. 1. Map of Northeast Thailand and its 17 provinces.

sources, etc.) in the Northeast have reduced fish stocks. The fish epidemic in 1987 compounded this shortage. The lack of fish from natural waters has a great impact since fish is the most important and cheapest source of protein. Child malnutrition in the region is increasing due to protein deficiency which is partly attributed to the lack of fish.

Government (Village Fisheries Project) and non-government organizations (NGOs) promoting fish culture in ponds in the Northeast have not been successful due to many constraints. However, acceptance of rice-fish culture by northeast farmers was better. The basic goal of raising fish in ricefields is to provide fish for family consumption, substituting catches from natural waters. Since 1984, rice-fish culture has expanded in both rainfed and irrigated areas. Fish production from ponds and rice-fish culture in the region are presented in Table 1.

This paper outlines the reasons why rice-fish culture has been easily accepted by farmers in Northeast Thailand, based on the experiences of the Appropriate Technology Association (ATA) in promoting rice-fish farming in the region from 1984 to 1987.

Compatibility with Existing Production Methods

Most farmers in Northeast Thailand are in rainfed areas. Rice is grown by flooding fields with rainwater from June to October. Transplanting seedlings is done in July to early September. The level of water in the ricefields must be constantly maintained until harvest. Fish are grown in ricefields by digging ditches, raising bunds, or building refuge ponds to keep more water for raising fish. Farmers use very little chemical fertilizers and pesticides (against insects, disease and weeds), so that there is little danger to fish in ricefields. Fish culture in ricefields

Table 1. Fish production (t) in ponds and ricefields, by species, Northeast Thailand, 1985. (Source: DOF statistics for 1980–87).

Province	Ponds[a]			Ricefields		
	Oreochromis spp.	*Cyprinus carpio*	*Puntius gonionotus*	*Oreochromis* spp.	*Cyprinus carpio*	*Puntius gonionotus*
Zone 1						
Khon Kaen	269.48	343.99	418.65	69.88	119.42	180.76
Udon Thani	535.40	204.10	283.97	33.32	4.79	7.66
Nong Kai	159.40	109.47	224.62	0	0.16	7.06
Nakhon Ratchasima	84.35	45.37	190.05	12.32	1.06	6.85
Mahasarakham	7.45	9.54	48.10	2.85	8.81	48.92
Zone 2						
Loei	82.54	113.33	101.08	4.39	5.76	0.45
Chaiyaphum	43.25	21.19	80.06	2.95	0	15.86
Sakon Nakhon	48.95	9.76	20.81	0.21	0.18	0
Nakhon Phanom	18.69	7.31	7.15	7.28	2.14	4.20
Ubon Ratchathani	13.63	28.14	11.96	0.05	19.88	18.74
Zone 3						
Kalasin	32.13	47.67	22.77	5.67	39.09	34.88
Mukdahan	27.79	10.93	26.00	0.6	0	0
Roi Et	8.03	2.88	32.70	3.11	0	11.44
Yasothon	19.07	11.06	5.42	0.66	4.46	4.26
Buri Rum	42.48	10.82	11.18	0.35	0.17	0.91
Surin	20.57	40.27	19.65	3.35	10.72	3.16
Sisaket	4.90	11.86	39.52	0.18	0	0
Total	1418.11	998.23	1533.69	147.17	216.64	345.15

[a]Pond culture areas: Zone 1, >200 ha; Zone 2, >100-200 ha; Zone 3, <100 ha.

does not restrict traditional rice farming practices even with the introduction of improved rice varieties.

Effective Use of Local Resources and Multiple Benefits

Raising fish in ricefields largely uses locally available resources such as family labor, land, water and plants. Fingerlings are the only purchased inputs, and almost no other extra expenses. However, farmers receive many benefits. Apart from the fish, they report higher rice yields even with the use of less chemical fertilizers and pesticides. Fish help control insects and worms, reduce the incidence of rice diseases and control weeds. Moreover, its feces acts as a fertilizer for rice.

Rice-fish farming also allows the growing of vegetables around ricefields, planting of trees on the dikes, raising of animals (pigs, chickens and ducks), and storing water in the ditches and refuge pond, which can be used for vegetable-growing and animal-raising after rice harvest. Farmers gain greater benefits from integrating their existing land, water resources and labor.

Farmers take more interest in managing their ricefields when they engage in rice-fish farming. For example, water is carefully controlled at appropriate levels for fish. There is an increased use of animal and green manures as fish feed so that the rice, indirectly, receives more fertilizer. Field maintenance is more managed through regular visits, or through construction of shelters in the ricefields.

Farmers perceive that raising fish in ricefields give the following benefits: there is available fish for family consumption; it solves the problem of malnutrition; and there is increased possibilities for agricultural activities such as vegetable growing, tree planting and animal raising. The extension of water resources during the dry season reduces the rate of labor migration during the dry season. Moreover, rice-fish farming helps to maintain better ecological conditions on the farm, i.e., by increasing organic matter and maintaining moisture levels in the soil. Growing annual plants, raising animals and planting of perennial trees also create an environmental balance.

Horizontal Transfer of Technology Using Innovative Farmers

Fish culture in ricefields was introduced and promoted in the Northeast before 1984, but did not expand because of many constraints. There were, however, some farmers who improved and locally adapted methods and production systems on their own. These farmers became successful and served as models for new entrants to rice-fish farming. This group of model farmers is an important force that had a role in expanding rice-fish culture over wide areas of the Northeast in the past five years. Farmers are encouraged to visit model farms to learn techniques used by successful farmers.

The role of the government and NGOs in introducing and promoting rice-fish farming in the Northeast has largely been to create links between model and prospective farmers. The mechanism for this are through farm visits and direct observations of practices in rice-fish culture. This horizontal transfer of technology among farmers is considered a highly effective and appropriate method. The initial group of model farmers will encourage more groups, with methods and techniques being refined in the process to suit the local socioeconomic, cultural and environmental conditions.

The process and effectiveness of horizontal transfer of rice-fish technology are best illustrated by the two case experiences in Khon Kaen and Buri Rum Provinces.

Case 1: The Khon Kaen Experience

Redd Barna, an NGO, began a development program aimed to reduce poverty in several rural villages of Khon Kaen in 1984. Its activities were directed to improve health, education, food production, etc., which was carried out through a development worker assigned in the village. The integration of farming systems which included rice-fish culture to Redd Barna's program was proposed by the ATA. Porn-sa-wan Village, where the adoption of rice-fish culture is very high, was selected as the rice-fish project site. Although drought was a serious problem, farmers succeeded in the cultivation of fish in ricefields.

Towards the end of 1984, Redd Barna workers organized a field trip to integrated farms in Surin. Two farmers from Porn-sa-wan Village were very interested in rice-fish culture. One of them, Mr. Songka, persuaded six other neighbors to modify their ricefields in early 1985. Family and exchange labor were used, thus, no cash cost was incurred. They worked very hard despite being ridiculed by neighbors.

ATA assistance included providing technical advice to the Redd Barna program on how to modify the ricefield, on fish stocking densities, nursery management and feeding techniques. Technical information was disseminated through the key leader and the farmer-to-farmer approach. By 1986 to 1988, there were spontaneous adopters of rice-fish culture. The practice expanded both within and to neighboring villages (Fig. 2).

Informal discussions, trainings, field trips and seminars were organized every year. The trainings and field trips mostly promoted the local techniques of experienced farmers in Surin, Ubon and Si Sa Ket. The trainings also included other farming activities. Local experts were considered very important in transferring technologies.

In 1987, a large number of interested farmers from various areas of the Northeast visited Porn-sa-wan Village to learn about the success of low-cost integrated farming systems. Farmers not only raised fish in their ricefields, but also grew fruit trees and vegetables on the bunds. The availability of adequate food for the farm family was the main concern, rather than the added income from integrated farming.

The visits by outsiders, at least once a month, had two great effects on villagers. First, this boosted the self-confidence of the farmers, reaffirming that development using their own resources was possible. Second, farmers who had not tried rice-fish farming were encouraged to try the technology. At present, only eight farmers have not yet adopted rice-fish either because they had no riceland or their parents had not yet divided the family land. It should be noted, however, that some farmers felt the visits interrupted work schedules.

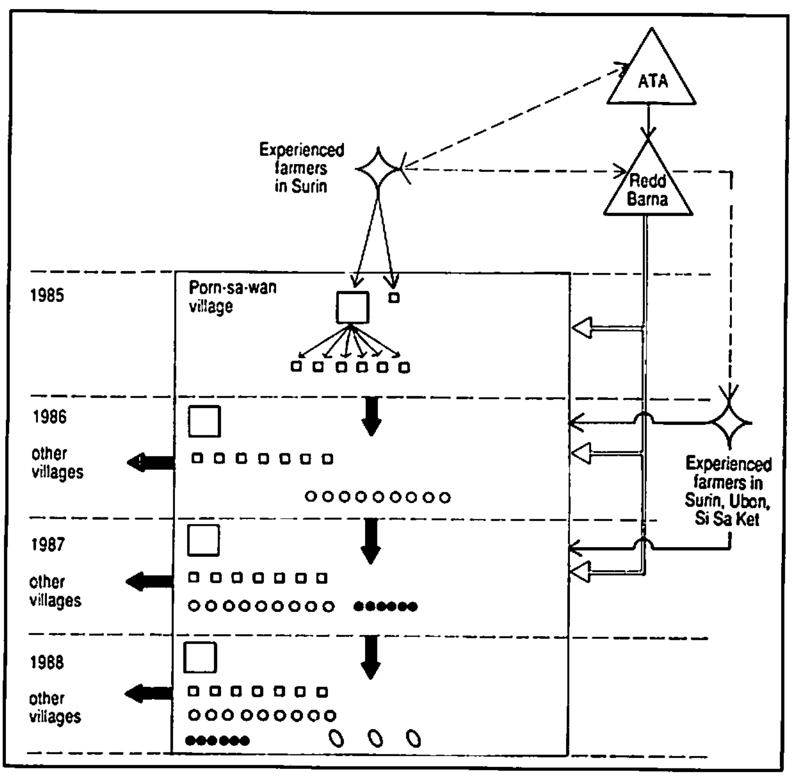


Fig. 2. Redd Barna's rice-fish farming extension process in Khon Kaen, Northeast Thailand, 1985-88.

Case 2: The Buri Rum Experience

Mr. Pai, headman of Sa-coon Village, was well known among various NGOs in the Northeast for his success in developing his village through the support of his people. Mr. Pai was elected a member of the TICD board in 1984. This gave him an opportunity to visit integrated farms in Surin. The idea to promote rice-fish production was developed from these visits.

Upon returning home, Mr. Pai immediately persuaded seven of his neighbors to start integrated farming. To minimize production costs, family labor was used for modifying the ricefields. "Start small-scale and simple," was what he learned from experienced farmers in Surin.

In the following year, only four people practised rice-fish culture. But in the dry season of 1987 (without any promotion), 141 farmers spontaneously started modifying their ricefields for rice-fish culture. In 1988, 12 farmers joined and the extension process is outlined in Fig. 3. Only 24 people continued growing rice without fish for nontechnical reasons: they had no land; the land was not yet legally divided; or their land was very far from the village.

The extension process developed naturally from farmer to farmer. Although the most influential person behind this process could not be identified clearly, Mr. Pai had been recognized as the key leader of rice-fish development in the village. The process expanded rapidly both within the village and to neighboring villages even without funds or hired workers to organize trainings, field trips or seminars. Eleven villages in the same subdistrict

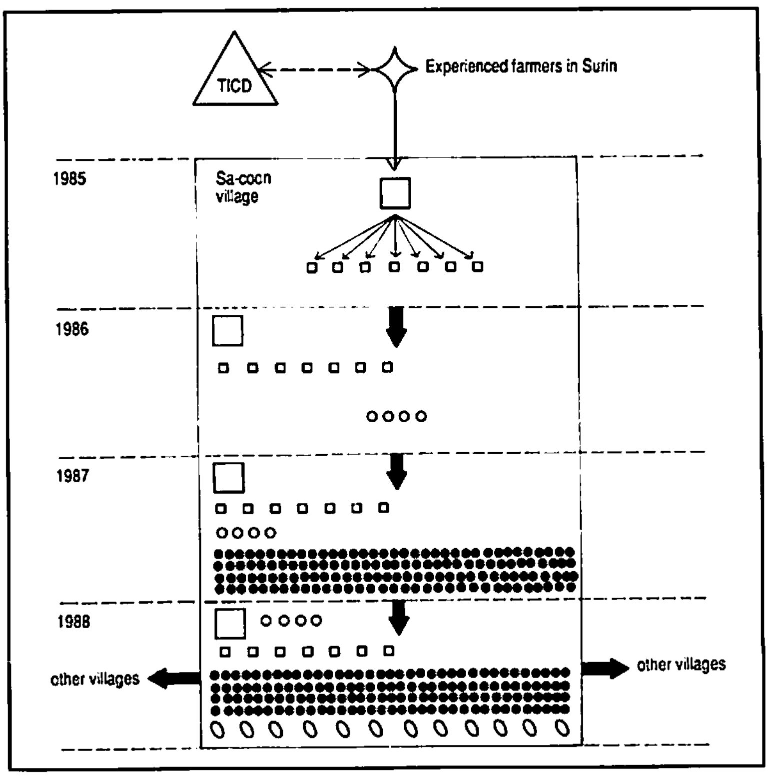


Fig. 3. Farmers' rice-fish farming extension process in Buri Rum, Northeast Thailand, 1985-88.

started rice-fish farming after the village headman and his group visited Sa-coon Village in 1987-88. Groups from other provinces also have visited Sa-coon Village to learn their experiences in rice-fish culture.

Acknowledgement

Thanks are due to C.R. dela Cruz for expanding the section on "Horizontal Transfer of Technology Using Innovative Farmers" from materials provided by the author.

Opportunities for Women in Rice-Fish Culture

P.V. DEHADRAI
Indian Council of Agricultural Research
New Delhi, India

DEHADRAI, P.V. 1992. Opportunities for women in rice-fish culture, p. 367–372. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Women comprise 26% of the labor force in agriculture and contribute 69% of the total household income in rural India. Women play a pivotal role in five of the eight types of rice-fish farming systems. It is argued that promotion and training of women on fish culture in ricefields are more culturally acceptable and economically beneficial than any introduction of labor-saving technologies in the rice agroecosystem.

Introduction

In the chain of human relationships, women are a stable link. She is a pivot around which families and societies revolve. The woman is the custodian of the family, its welfare, perpetuation and its status. She is often meticulous and easily understands the intricacies of nature instinctively be they associated with land, forest, animals, agriculture, home, children or even man. In the process of adopting skills, she is capable of demanding perfection. The welfare of women is essentially the welfare of farm families which are the economic units of rural communities.

Women in Rice Farming and Fisheries

Agriculture still remains the largest employer of women in India (Anon. 1979). Women constitute 26% of the labor force in agriculture, including livestock, forestry, plantations, orchards, fisheries, etc. Their contribution in the total household rural income through agriculture is 69% (Table 1). Nevertheless, discrimination in wages even for similar functions performed by both men and women, lack of security, fluctuating periods of unemployment, malnutrition from poverty and hard labor characterize women's lives. Women's

Table 1. Contribution of women to total household rural income through agricultural labor. (Source: Bahauddin 1975).

States	Contribution of women in total agricultural income (%)
Bihar	84.4
Madhya	80.5
Karnataka	78.8
Assam	78.8
Orissa	73.2
Andhra Pradesh	70.9
Punjab	70.9
Gujarat	70.8
Uttar Pradesh	65.7
Tamil Nadu	64.1
Haryana	62.4
Rajasthan	63.3
Maharashtra	59.5
Kerala	54.6
India	68.6

problems are hardly quantitative, however. Their predicament is the classification of their work as of low or of little social or economic value.

Management of a rural family is so complicated that one wonders how women manage their family's demands, especially when their knowledge and resources are limited. Money is one of the least available resources in the average farm family. However, with recent efforts in creating additional avenues of income through dairy, poultry, fisheries, etc., the women have been contributing increasing amounts of income to the family. But in this process, their quantum of work is increased more than it should, in addition to their regular responsibilities in the family.

The versatility of women from poor communities is, however, evident from their dominant involvement in a variety of agricultural sectors and allied fields. For example, a large number of women are being recruited in the fish processing industry in India. In manual shrimp processing, skilled or semiskilled labor is required. In a sector exporting about 65,000-75,000 t of shrimp, at least 100,000-120,000 t of raw materials are handled. This industry is estimated to have provided employment to at least 125,000 women in India. Nevertheless, their wages are far below the wages of male workers employed in similar jobs in the same sector.

In India, the retail fish trade is heavily dominated by women as a tradition and because women have the essential skills in handling fresh fish preferred by retail consumers. For example, the Andheri retail fresh fish market that caters to the urban population of Bombay is handled largely by women. Traditional involvement of women in the retail fish trade has made them indispensable in the sector. The retail fish trade involves aspects of fish handling, preservation, processing, marketing, pricing, credit, borrowing, accounting and savings. Women have shown their capabilities and adaptability to all aspects of the skilled profession. In the process, their knowledge and interest are being passed on from generation to generation in a natural manner as if it is a genetically acquired trait.

Rural women in the Puri District of Orissa in India are expanding their activities to nontraditional livelihoods and are undertaking new opportunities, including fish culture. Rural women in the area comprise 53% of a surveyed population consisting of 229 farm families in Bhubaneshwar/Pipili. The literacy rate in the survey population was 8% for women and 19% for men. Women in the area under Krishi Vigyan Kendra of the training program organized by the Indian Council of Agricultural Research, are improving their livelihoods by developing entrepreneurial skills that will enable them to improve their socioeconomic conditions. The fisheries-related activities are net weaving and mending, fish breeding and commercial aquaculture. All these activities promise higher returns for their labor.

In Asia, the participation of women in rice production is dominant, as indicated by a daily time utilization pattern in rice farming (Table 2). However, recent studies indicate that the introduction of labor-saving technologies in rice cultivation in Asia has already decreased the demand for women labor. Generating a new kind of employment would require enormous investments. It may be more sensible to preserve existing employment options and add to them certain compatible components capable of enhancing their scope for income generation. Rice-fish farming is one such avenue, wherein the integration of fish as a familiar and naturally compatible component could be introduced in the rice agroecosystem without disturbing the usual operational calendar or social nexus of Indian rural areas.

Table 2. Per capita daily time utilization patterns of rural women in farm activities. (Source: Bahauddin 1975).

Farm activity	Average time spent by rural women (hour/day)	(%)
Nursery practices	0.75	3.13
Transplanting rice	0.13	0.54
Land preparation	0.46	1.92
Weeding and gap-filling	0.56	2.33
Fertilizer applications and plant protection	0.17	0.71
Harvesting	1.78	7.42
Drying, cleaning and storage	0.56	2.33
Supervision of servants on farm	3.49	14.54
Total	7.90	32.92

Rice-Fish Farming

Culture of fish in ricefields has been practised from time immemorial in China, Indonesia, India and many other Southeast Asian countries. With the advent of modern agriculture and the use of high-input technologies involving heavy fertilization and repeated pesticide application for high-yielding rice varieties, the fishery component has suffered. However, with the existing productive resources such as waterlogged ricefields, there is considerable potential for increasing rice and fish production, employment and nutrition, particularly for the poorer communities.

India is predominantly a rice-producing country with large scope for integrating fish culture into many of its 39-million ha ricefields grown only for the low-yielding, deepwater or monocropped (*kharif*) rice. The ricefields have sufficient water resulting from either heavy rainfall or the low-lying nature or other topographical features of the land. There are opportunities to utilize more than 2 million ha of such ricefields in the states of West Bengal, Assam, Tripura, Meghalaya, Orissa, Manipur, Bihar and Uttar Pradesh. Traditionally, wild fish harvest from these ricefields reaches around 3 kg/ha/year (Hora 1951). As technologies in aquaculture in ricefields have evolved for the past two decades, fish yields have increased to as high as 1,200 kg/ha/year (Ghosh et al. 1985) without any substantial loss in rice yields. Rice-fish farming would support the participation of more people in the rice agroecosystem including women.

The vastness of India has produced a diversity in agroclimatic conditions and topography of the various states, so that many different kinds of rice-fish culture systems are possible (Jhingran 1983). Some of the major types of rice-fish systems with their area, productivity and roles of women are presented in Table 3.

Although an empirical understanding of the art of rice-fish farming is prevalent in most countries, there is a need to impart a scientific basis to the entire operation to formulate specific technology packages. Specific aspects of standardization and improvement of rice-fish culture practices using a multidisciplinary approach are currently under investigation in India. These are:

1. Identification, characterization and cataloging of rice cultivation practices in terms of rice varieties, cropping duration, water level requirements, fertilizer/pesticide application packages and compatibility of various fish species.

Table 3. Rice-fish farming systems and women's involvement in India.

Systems	Location	Area ('000 ha)	Rice variety	Rice production (kg/ha/crop)	Fish species	Fish production (kg/ha/crop)	Remarks
Pokkali	Kerala	16	salt-resistant local	700-1,000	tiger prawn *Etroplus suratensis* mullets	885-2,135	80% shrimp; alternate cropping of rice and shrimp; women involved
Khazan	Goa	18	salt-resistant local	500-1,500	shrimps perches	500-2,000	mixed cropping of fish and rice; women involved
Bhasabhada (Wetlands)	West Bengal	800	salt-resistant modern varieties	3,000	shrimps mullets carps	900-1,200	mixed cropping of fish and rice; women involved
Irrigated/ rainfed	Andhra Pradesh West Bengal Tamil Nadu Karnataka Utter Pradesh Manipur Orissa Madhya Pradesh	1,000	modern varieties	2,700	murrels catfish carps	500-700	raised dike, cross trenches, peripheral canals; alternate or mixed crops; women not organized
Deepwater	Assam Bihar Manipur Orissa Tripura Utter Pradesh West Bengal South India	2,300	deepwater rice	2,000-5,000	Indian major and Chinese carps, catfish	1,100	mixed cropping; women not organized
Terrace cultivation	Arunachal Meghalaya		traditional local	277	*C. carpio*	28-186	experimental data; women involved
Valley fields	North Eastern India		deepwater rice	1,000-2,000	Indian major carps	500-800	women not organized
Beels	Assam Bihar Orissa Andhra Pradesh Madhya Pradesh Utter Pradesh West Bengal	600	modern varieties	1,000-3,000	murrels catfish carps	20-80	capture fisheries from dried river courses, canals and ox-bow lakes; rice in adjoining areas; women involved

2. Trials on various fish species such as common carp (*Cyprinus carpio*), *Clarias*, *Heteropneustes*, brackish-water and freshwater shrimp species, *Etroplus suratensis*, silver carp (*Hypophthalmichthys molitrix*), *Catla* sp., *Labeo* sp., *Cirrhinus* sp. etc., in different combinations with different rice varieties under changing water availabilities, management systems and cultivation practices.
3. Interrelationships of fish and rice during concurrent culture.
4. Scope of intercropping rice and fish/shrimp alternately, and the status of the soil/water regime in relation to agroclimatic factors.
5. Adjustments of timing and duration of rice cultivation with those of fish culture for effective integration.
6. Effects of fertilizers and pesticides on fish metabolism/growth/survival.
7. Harvesting strategies for rice and fish under mixed and alternate cropping systems.
8. Integration of fisheries with mini-watersheds for additional crops of rice and fish.

Women involved in rice-fish farming can be trained in the following aspects of the technologies:

1. Fish seed production.
2. Larval rearing up to fry.
3. Release of fry in ricefields.
4. Feeding of fry up to fingerling stages.
5. Harvesting of fingerlings during rice culture.
6. Rearing of fingerlings to table size fish.
7. Management and feeding of fish stocked in peripheral canals or central waters of the ricefields during/after rice harvest.
8. Management and survival of fish stocks during the second rice crop.
9. Management of fish stocked during the second rice crop.
10. Harvesting of fish during the second rice crop, or after its harvest.
11. Timing of pesticide applications and awareness of its effects on fish and humans.
12. Preparation of ricefields for specific types of rice-fish farming.
13. Maintenance of broodstock during the third rice crop (*aman*).

Advantages of Rice-Fish Farming Systems for Women

The integration of rice and fish culture is not likely to cause any occupational disorientation or disruption in their way of life since rice and fish farming are traditional activities of the rural folks in India. Rice-fish farming should be promoted because of its many advantages especially to women. It consolidates the existing income-generating activities with no displacements of labor. It needs no special adjustments of labor with time and period of employment. The sex-related discrimination in favor of men in farm labor selection is minimized. Rice-fish technology is not sophisticated and could easily be adopted by women. It is possible to teach the skills of fish culture in the rice environment through different stages of operations so that women can gradually learn the technology until they become completely self-reliant. Rice-fish farming will ensure a solution to women employment, enhancing income in terms of cash or fish protein in diet.

On a general note, rice-fish culture promotes self-sufficiency in essential commodities such as fish and rice. It enhances demand for local production. Finally, the technology uses local raw materials to preserve ecological balances.

Conclusions

Although integration of rice with fish culture is gradually emerging as a technology for extensive development, there are no socioeconomic data to help promote the technology. The present article only raises some issues and possibilities for women in rice-fish culture.

Integration of fish culture with rice would be a labor-using technology through its several phases, from preparation of the ricefields with trenches, making embankments, seed fish production to the management of the fish stock and harvesting; in addition to the labor required for rice planting, tending and harvesting. Women's involvement in crop cultivation activities could identify them as an ideal target group for training in rice-fish culture. The fish harvest could be entrusted to women for marketing and postharvest handling operations. Rice-fish culture would, thus, raise the demand for women labor as well as the productivity of the rice agroecosystem.

The entire logistics of the projected new opportunities for women in rice-fish farming emanates largely from the known and well documented involvement of women in the management of rice in Asia. The positive impact of the added production of fish in the ricefields is hardly disputable.

References

Anon. 1979. ICAR research complex leaflet for golden jubilee. Indian Council for Agricultural Research, India.

Bahauddin, A. 1975. Krishak mahilayen aur vigyanik krishi [Involvement of women in scientific agriculture]. Kheti 28 (9):67–88 (In Hindi).

Ghosh, A., S.K. Saha, R.K. Banerjee, A.B. Mukherjee and K.R. Naskar. 1985. Rice cum fish farming system. Aquaculture Extension Manual, New Series No. 4, December 1985.

Hora, S.L. 1951. Fish culture in ricefields. Curr. Sci. 20 (7):171–173.

Jhingran, V.G. 1983. Fish and fisheries of India. Revised and enlarged edition. Hindustan Publishing Corp., New Delhi.

Chapter 5
On-Station and On-Farm Research

Component Technology Research in Rice-Fish Systems in the Philippines*

RUBEN C. SEVILLEJA
ARSENIA G. CAGAUAN
EDUARDO A. LOPEZ
Freshwater Aquaculture Center
Central Luzon State University
Muñoz, Nueva Ecija, Philippines 3120

CATALINO R. DELA CRUZ
ANNE A. VAN DAM**
International Center for Living Aquatic Resources Management
MCPO Box 2631
0718 Makati, Metro Manila
Philippines

SEVILLEJA, R.C., A.G. CAGAUAN, E.A. LOPEZ, C.R. DELA CRUZ and A.A. VAN DAM. 1992. Component technology research in rice-fish systems in the Philippines, p. 373–384. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

This paper presents initial results from rice-fish research, including experiments on border rice planting, the use of animal manure, and comparison of rice-fish trench refuge and pond refuge systems. Border planting and adding animal manures produced encouraging but inconclusive results. In all concurrent rice-fish systems studied, Nile tilapia (*Oreochromis niloticus*) produced low yields attributed to the small size of stocked fish, variable survival rates and the short duration of fish culture. The trench refuge had less water stored and appeared risky in sustaining fish growth. It appeared that these constraints can be largely solved with a modified pond refuge for concurrent rice-fish system. This system allows stocking of small fingerlings, a much longer fish culture period and more water availability. The trench refuge and pond refuge systems have increased water requirements vis-à-vis rice monoculture of about 23.3 and 26.3%, respectively. The common carp (*Cyprinus carpio* Majalaya strain) appears to be better suited to ricefield environments than Nile tilapia. The paper concludes with a discussion of these results, some suggestions for further work and a comment on the inadequacy of standard pond monitoring methods for rice-fish systems research.

---

*ICLARM Contribution No. 924.

**Present address: Thorbeckestraat 60, 6702 BS Wageningen, The Netherlands.

Introduction

An Asian Development Bank (ADB) technical assistance (TA) for research on rice-fish farming systems was initiated in August 1987 under the joint collaboration of the International Center for Living Aquatic Resources Management (ICLARM), International Rice Research Institute (IRRI) and the Central Luzon State University (CLSU). The on-station research component of the project is located at the Freshwater Aquaculture Center (FAC) of CLSU. One of the major objectives is the evaluation of options for integrating rice and fish production. This paper presents the general research highlights and important findings of the completed experiments under this project.

Research Design and Procedures

The immediate thrusts of the on-station research program are to enhance the compatibility of rice agronomy and fish in concurrent culture; and to provide a solution to the problem of small-sized harvested tilapia in growout, concurrent rice-fish culture. A list of the completed and ongoing studies conducted under the project is presented in Table 1. A total of 10 experiments have been carried out and five studies are ongoing.

Experimental Units

All experiments were conducted in ricefields modified according to rice-fish culture specifications. Dikes have base widths of 0.5 m, top widths of 0.3–0.4 m and heights of 0.4 m. A longitudinal center trench with a dimension of 0.75–1.0 m wide and 0.3–0.5 m deep is provided for ricefields with areas of 100–400 m^2. A pond-type refuge consists of a small pond, about 10% of the area of the plot and 1.0 m deep, excavated and connected to one end of the ricefield (Fig. 1). The ricefields are provided with separate screened water inlets and outlets. Water is supplied by both the Pantabangan Reservoir, about 30 km away from the FAC, through gravity irrigation canals, and a shallow well located near the ricefields.

The total area of experimental plots is 4.08 ha. Table 2 shows the number of experimental units by size.

Land Preparation and Rice Agronomy

Land is prepared by one plowing and four harrowings. In general, IR rice varieties are used in the experiments. Seedlings grown under wet-bed method at a seeding rate of 100 kg/ha are transplanted when 25–30 days old. Standard planting method is by straight-row planting at 25 cm between rows and hills with 3–4 seedlings/hill, unless specified otherwise in the detailed study proposals. The planting method may change as a result of the experiments in planting distances. Standard FAC practices for application of inorganic fertilizer involve one basal application one to two days before transplanting, and one topdressing one month after transplanting. Organic fertilizers are applied by soil incorporation one to three days before transplanting and/or topdressed one month after transplanting or at regular intervals as per specific experimental protocol. Whenever required and necessary, the following pesticides are applied according to recommended rates and practices: Furadan 3G for protection against insect infestation applied basally at the rate of 1–3 bags/ha (16.7 kg/bag); 2–4 D or Machete EC for weed control at the rate of 17.4 and 0.4 kg a.i./ha, respectively; and Brestan for eradication of snails at the rate of 330 g/ha.

Table 1. Completed and ongoing studies under the ICLARM/IRRI/CLSU Rice-Fish Farming Systems Project.

Research study/experiment
Completed
• Planting distances and methods of planting in rice-fish systems.
Fish production and border method synergism in rice-fish culture.
Supplemental feeding in rice-fish culture with border method of planting and increased fish stocking density.
• The use of animal manure in rice-fish culture.
Evaluation of pig and chicken manure.
Combined use of inorganic fertilizer and pig or chicken manure.
• Growth performance of *Cyprinus carpio* (Majalaya strain) in: Experiment 1 - concurrent system; Experiment 2 - rotational system.
• Fish and biological control of weeds.
• Comparison of trench refuge and pond refuge systems in rice-fish culture.
• Water management aspects of rice-fish culture.
Ongoing
• Production trials of border pattern of planting, organic fertilization and polyculture in rice-fish culture.
• Preliminary growth performance of different strains of *Oreochromis niloticus* in rice-fish culture.
• Food ecology in rice-fish culture.
• Evaluation of the pond refuge systems.
• Fish and biological control of weeds.

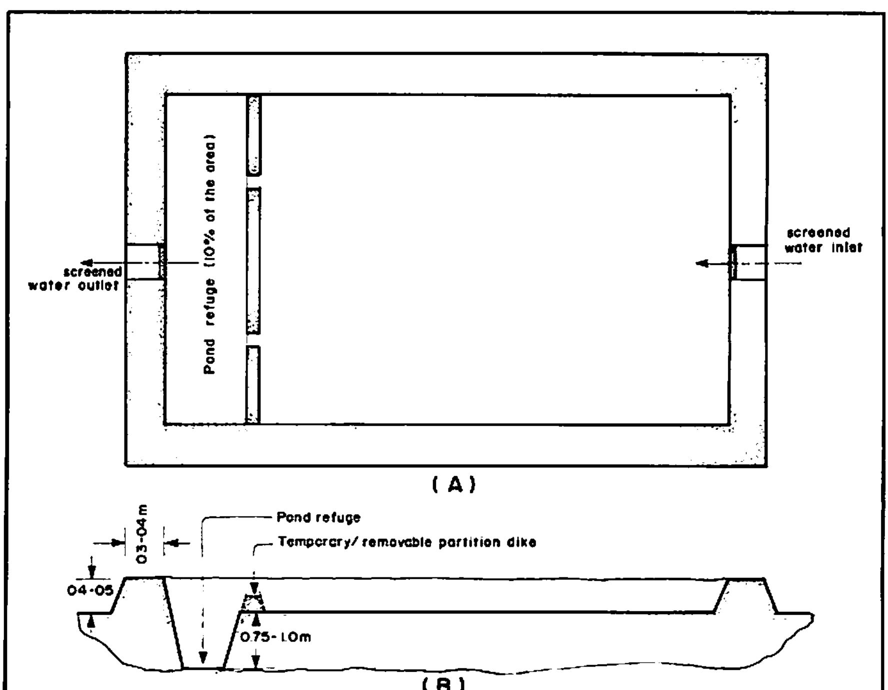


Fig. 1. A rice-fish field with a pond refuge system. Top view (A) and longitudinal cross-section (B). (Not drawn to scale)

Table 2. Number of available experimental units for rice-fish plots by type of refuge and by size.

Type of refuge	Size/plot (m^2)	No. of plots	Total area (m^2)
Longitudinal center trench	100	18	1,800
	200	21	4,200
	300	34	10,200
	400	24	9,600
Pond refuge	1,000	7	7,000
No refuge (for rice monoculture)	500	10	5,000
	1,000	3	3,000
Total area			40,800

[a]Except for the 100- and 200-m^2 plots, all other experimental units were constructed at a newly developed site where scraping of topsoil was done.

Fish Culture

In general, fingerlings are stocked 7–14 days after transplanting. Stocking weights and densities vary according to species and experimental objectives. For fish harvesting, ricefields with trench refuge are drained completely so that the fish can collect in the lowest part of the trench and be easily caught. Fish harvesting is done five to seven days before the rice harvest. For ricefields with pond refuge, the time of fish harvesting depends on experimental objectives.

Design and Evaluation of Experiments

In general, majority of the experiments are components of concurrent rice-fish technology intended to answer the questions on how to improve the system and which are of primary interest to farmers. The priority research area is the development of methods and techniques for increasing productivity and optimizing resource utilization.

Data and information collected from these experiments include biological, physical and economic measurements which are used in explaining differences and/or interactions among the different experimental treatments. A general description of the data collection and analytical procedures of experiments conducted at FAC is presented in Table 3.

The experiments conducted have at least three replications per treatment. These are also replicated over time or season. There are studies which are duplicated exactly or with slight modifications during the succeeding season to substantiate and verify previous results.

Fish production data are expressed based on the gross yield (standing crop); net yield (net production); gain in weight; and percentage recovery or survival. A detailed explanation of these measures are given by Shell (1983). Rice production is estimated based from total plot harvest at 14% moisture content.

Experimental designs and statistical evaluation of production data generally involve the standard analytical procedures such as student's t-test or the analysis of variance ("F" test). Other appropriate statistical analysis such as correlation or regression techniques are applied depending on the nature of the data and the type of evaluation desired. For example, van Dam (1990) applied multiple regression technique in analyzing the accumulated FAC rice-fish experimental data to detect fish growth limiting and promoting factors.

Results

Results of the completed studies are presented in general terms, with emphasis on the important results and findings which are expected to affect and influence the refinement, modification and development of rice-fish culture technology.

Table 3. Data collection and related analytical procedures in rice-fish experiments.

Parameter	Sampling time and frequency	Method of analysis
• Water		
Dissolved oxygen	0600 hours, 1400 hours weekly	DO meter, Winkler titration
Temperature		Thermometer
pH		pH-meter
Total ammonia		Phenate method with spectrophotometer
Nitrite	biweekly	Sulfanilic acid method with spectrophotometer
Orthophosphate		Method of Owen T. Lind
Depth	daily	Measuring device in plot
Total solids	triweekly	Evaporation
Phytoplankton	biweekly	Secchi-disk reading in trench; identification and count with microscope and Sedgewick-Rafter cell
Zooplankton		Identification and count with microscope and Sedgewick-Rafter cell
Zoobenthos		Identification and count using Ekman grab
• Fish		
Stomach contents	at inventory, at harvest	Three fish per plot are killed and stomach contents identified
Growth and survival	at stocking, at inventory	Length and weight data, numbers are recorded
• Rice		
Yield	at harvest	Determine moisture percentage of sample; calculate harvested weight at 14% moisture total yield estimated based from total plot harvest
Weeds	35–40 days after transplanting	Identification and counting of sample; determination of week dry weight/area by overdrying at 55°C for 24 hours
Insects	biweekly	Field sampling (using standard methods) of counting and identification
• Soil		
Organic matter	before planting, after harvest	Dry matter minus ash content
Total N		Macrokjeldahl method
Total P		Acid-NH_4-soluble phosphorous
• Climate		
Evaporation	daily	Data are obtained from the CLSU/PAG-ASA Agromet Station
Humidity		
Rainfall		
Air temperature		
Wind speed		
Wind direction		
Daily sunshine		
• Economics		
Economic analysis	after experiment	Simple costs and returns analysis; partial budgeting; marginal analysis; linear programming

Border Pattern of Planting

Results of the two completed experiments are presented in Table 4. In both experiments, no significant treatment differences were observed with respect to the different fish production parameters. Rice production decreased significantly with two rows missing at constant planting distances. Thus, even with higher stocking

Table 4. Summary data of fish and rice yields obtained from experiments on border pattern of planting. Fish species: *Oreochromis niloticus*; rice variety: IR 66; plot size; 200 m^2; n = 3; fish culture period: 70–72 days.

Treatment	Stocking density (fish/ha)	Fish: Planting method	Fish: Feeding	Fish: Mean weight (g) Initial	Fish: Mean weight (g) Final	Fish: Recovery (%)	Fish: Growth rate (g/day)	Fish: Yield (kg/ha) Gross	Fish: Yield (kg/ha) Net	Rice yield (t/ha)
Experiment 1										
I	5,000	standard planting (25 x 25 cm)	yes	6.9	29.9	68	0.33	105.0	70.5	4.7
II	6,500	1 row missing between 3 rows (25 x 25 cm)	yes	9.2	30.8	60	0.31	111.5	51.7	4.2
III	7,500	2 rows missing between 3 rows (25 x 25 cm)	yes	8.7	37.1	50	0.41	139.5	74.3	3.6
IV	5,000	standard planting (25 x 25 cm)	no	6.1	35.2	79	0.42	138.6	108.1	5.1
V	6,500	1 row missing between 3 rows (25 x 25 cm)	no	5.9	28.1	61	0.32	105.6	67.2	3.6
VI	7,500	2 rows missing between 3 rows (25 x 25 cm)	no	11.3	38.2	68	0.38	195.2	110.4	3.5
Experiment 2										
I	5,000	standard planting (25 x 25 cm)	yes	7.5	45.4	63	0.54	143.0	105.5	2.7
II	5,000	1 row missing between 3 rows (25 x 20 cm)	yes	7.4	45.6	65	0.55	148.3	100.8	3.2
III	5,000	2 rows missing between 3 rows (25 x 17 cm)	yes	8.8	45.7	70	0.53	160.4	94.4	2.7
IV	5,000	standard planting (25 x 25 cm)	no	9.1	45.8	67	0.51	152.6	104.6	2.8
V	5,000	1 row missing between 3 rows (25 x 20 cm)	no	6.7	41.2	55	0.48	113.1	69.5	2.5
VI	5,000	2 rows missing between 3 rows (25 x 17 cm)	no	6.7	37.0	80	0.42	147.8	98.3	2.5

densities (from 5,000 to 7,500/ha), the anticipated increase in fish production did not compensate losses in rice yield (experiment 1). Fish production data were also similar among the different treatments in experiment 2. Rice production (which was lower compared to experiment 1 due to a typhoon) was similar for all treatments because of the constant plant population despite the missing rows or borders. In experiments 1 and 2, treatment II (one row missing and with fish feeding) had the second and highest rice yields, respectively; an indication that treatment II might work well as a border pattern of planting, with some modifications. In both trials, feeding had no effect on fish production.

Use of Animal Manure

Fish and rice yields are shown in Table 5 for experiment 1 (use of pig and chicken manure). Fish recovery ranged from 24 to 61%. Fish growth rates ranged from 0.27 to 0.54 g/day. On the average, the highest growth rates were achieved in treatment III with eight weekly pig manure applications. This treatment also showed the highest gross and net fish yields, and gave a considerable fingerling harvest. Rice yields were relatively low, probably caused by the newness of the experimental site and water shortage during the first week of growth.

*Growth Trials with Common Carp (***Cyprinus carpio***, Majalaya strain)*

Results of the experiment using concurrent culture systems showed that rice yields were low (Table 6). This was caused mainly by water shortage when the rice plants were newly transplanted, planthopper infestation and the newness of the site. Fish recovery was satisfactory, with only two plots showing fish recovery below 50%. Fish losses were caused by low water levels and bird (herons) predation. In the treatment with inorganic fertilizer, fish recovery rate decreased with increased stocking density. Fish growth rate, likewise, declined with increasing stocking density. With inorganic fertilizer, highest gross and net yields were obtained at 3,000 carp/ha, while with chicken manure, 4,000 carp/ha gave the highest yields.

In the rotational culture system, fish recovery was excellent in both treatments. Fish growth rate and gross and net yields were higher in plots fed with rice bran. Average gross and net fish yields were 326 and 189 kg/ha for treatments with feeding, and 278 and 116 kg/ha, respectively, for treatments using cattle manure.

Compared to rice-fish experiments using Nile tilapia and without animal manure, common carp showed good growth and survival. It seemed that the carp was much better suited to the rice-fish environment than tilapia. Fish yields from the rotational experiments were very high, considering that the culture period was only one month. Water availability was a crucial factor here.

The effect of manure on rice yields was not clear, but combinations of inorganic fertilizer and animal manure might be better for good rice and fish yields.

Comparison Between Trench Refuge and Pond Refuge Systems

Results showed that fish production indicators were all in favor of the pond refuge system. However, the yields from both systems were low due to low recovery rates: 27 and 134 kg/ha for the trench refuge and pond refuge system, respectively. Extending the fish culture period by 61 days in the pond refuge system, increased gross fish yield to 396 kg/ha (Table 7).

Table 5. Summary data of fish and rice yields using animal manure (pig manure [PM], chicken manure [CM]). Rice variety: IR 64; fish species, *Oreochromis niloticus*; fish culture period: 72 days.

Treatment	Fertilizer and method of application[a]	Fish: Mean weight (g) Initial	Final	Recovery (%)	Growth rate (g/day)	Yield (kg/ha) Gross	Net	Fingerling	Total net	Rice yield (t/ha)
I	IF	10.2	30.4	56	0.28	87.0	36.1	11.1	47.2	1.6
II 1 topdress	PM	9.3	39.6	51	0.42	102.9	56.4	10.0	66.4	2.1
III 8 topdress	PM	10.9	50.2	61	0.54	152.3	97.8	44.4	142.2	1.9
IV 1 topdress	CM	10.1	29.3	42	0.27	61.5	11.0	16.7	27.7	2.1
V 8 topdress	CM	8.9	56.7	24	0.66	58.3	13.6	31.1	44.7	1.5

[a]IF = inorganic fertilizer (22.5 kg/ha of 45–0–0 and 375 kg/ha of 14–14–14), control; PM = pig manure (10.5 t/ha - 50% basal, 50% top dressing); CM = chicken manure (3 t/ha - 50% basal, 50% top dressing).

Table 6. Summary data of fish and rice yields on growth performance experiments of *Cyprinus carpio* (Majalaya strain). Rice variety: IR 64; n = 3.

Treatment	Type of fertilizer[a]	Fish: Stocking density (fish/ha)	Mean weight (g) Initial	Final	Recovery (%)	Growth rate (g/day)	Yield (kg/ha) Gross	Net	Rice yield (t/ha)
Experiment 1[b]									
I	IF	2,000	7.1	59.4	71.1	0.76	85.2	71.0	2.0
II	IF	3,000	7.0	58.3	60.4	0.74	104.4	83.5	1.7
III	CM	4,000	6.1	47.0	50.0	0.59	88.9	64.4	1.6
IV	CM	2,000	5.6	79.2	69.4	1.07	109.3	98.2	1.8
V	CM	3,000	7.1	56.3	70.0	0.71	115.5	94.2	1.6
VI	CM	4,000	7.2	49.4	75.6	0.61	148.7	119.9	1.8
Experiment 1[c]									
I	RB	3,000	45.6	109.0	99.6	2.1	325.6	189.4	-
II	CaM	3,000	55.6	91.8	98.9	1.2	277.8	116.2	-

[a]IF = inorganic fertilizer (44 kg/ha of 45–0–0 and 286 kg/ha of 14–14–14); CM = chicken manure (3 t/ha basal application); RB = rice bran (given at 5% of body weight; CaM: cattle manure (4 t/ha).
[b]Concurrent system; fish culture period, 69 days.
[c]Rotational system; fish culture period, 30 days.

Table 7. Summary data of fish and rice yields obtained from studies on trench refuge and pond refuge systems. Rice variety: IR 64; fish species: *Oreochromis niloticus*.

Treatment	Fish								Rice yield (t/ha)
	Mean weight (g)		Recovery (%)	Growth rate (g/day)	Yield (kg/ha)				
	Initial	Final			Gross[1]	Tilapia fingerling	Others[2]	Total	
I (trench)	3.9	12.8	30	0.14	19.2	7.8	0	27.0[3]	1.6
II (pond)	3.3	24.0	44	0.24	52.8	59.5	21.2	133.5[3,5]	2.3
		38.0		0.25	335.5	55.5	5.0	396.0[4,5]	

[1]Nile tilapia (*O. niloticus*) only stocked at 5,000/ha.
[2]Prawns (*Macrobrachium* sp.), *Carassius carassius* and leftover *Cyprinus carpio* (Majalaya strain).
[3]Fish culture period, 89 days.
[4]Fish culture period, 150 days.
[5]Mean values from two replicates only.

Water Management Aspects

This study consisted of a theoretical comparison of the water requirements of rice monoculture and rice-fish culture; and field measurements to estimate the various terms of the water balance (especially percolation and seepage [P & S]).

For a rice monoculture field with a continuous water layer of 5 cm, the total water requirement for a 90-day growing period is 1,500 mm (450 mm for evapotranspiration [ET] and 1,050 mm for other losses) and 200 mm for land preparation (Kampen 1970; de Datta 1981). In rice-fish culture, an additional 50 and 100 mm is required during land preparation for the trench refuge and pond refuge systems, respectively. To get a water depth of 10 cm instead of 5 cm, an extra 5 cm is required; thus, water required for land preparation is 300 mm for the trench refuge system and 350 mm for the pond refuge system.

P & S and leakage (L) increase with rice-fish culture. By interpolation, a water layer of 10 cm results in a loss of 1,300 mm or 14.5 mm/day, whereas a 5-cm water layer gives a loss of 1,050 mm or 11.7 mm/day; thus, resulting in an extra water requirement of 250 mm for rice-fish culture. Assuming further that with rice monoculture, the soil is merely saturated for 10 days during the growing season, the total water requirement becomes 11.7 mm/day for 80 days and 6.0 mm/day for 10 days, i.e., 996 mm for the whole season. The final comparative total water requirements become 1,662 mm for rice monoculture, 2,050 mm for the rice-fish trench refuge system and 2,100 mm for the rice-fish pond refuge system. The water requirement for the rice-fish trench and pond refuge systems is higher by about 23.3 and 26.3%, respectively, over rice monoculture.

In field measurements using sloping gauges, the water depth in 27 experimental plots was recorded two times a day (0800 and 1600 hours), during a 27-day culture period. Together with evaporation and rainfall data obtained from a nearby weather station, the water depth measurements were used to calculate water balances for all plots and to estimate P & S. Water losses through holes or cracks represented by L in the dikes was also calculated. In Table 8, P & S, ET and L

Table 8. Water balance measurements on rice-fish experimental plots using trench refuge (TR) and pond refuge (PR) systems: average values of rainfall (Rn), irrigation (Irr), percolation and seepage (P & S), evapotranspiration (ET) and leakage (L) by plot size.

	Plot size (m^2)			
	Rice-fish			Rice monoculture
	300 (TR)	1,000 (PR)	1,000 (TR)	500
Values (mm/day)				
Rn	1.4	1.5	1.5	1.5
Irr	34.4	55.7	32.5	44.8
P & S	24.8	36.7	22.0	28.7
ET	4.7	4.6	4.5	4.5
L	7.3	14.0	8.8	6.8
As percentage of (Rn + Irr)				
Rn	4	3	4	3
Irr	96	97	96	97
As percentage of (P & S + ET + L)				
P & S	67	66	62	22
ET	13	8	13	11
L	20	25	25	17

are given as percentages of their sum. On the average, L accounted for 21%, ET 12% and P & S 67%. In general, the absolute value of the total water requirement was quite high: amounting to about 3,300 mm over the 88-day growing period. This is roughly three times as much as the requirement for a regular lowland rice crop (de Datta 1981).

Losses from P & S take a big part of the water requirement but it is very difficult to reduce these. Perhaps, thorough puddling during land preparation may reduce them. The L loss could be lessened by good maintenance of the dikes and proper sealing of inlets and outlets. The high water requirements for rice monoculture may be due to seepage losses to the adjoining fallow plots. This problem will gradually lessen when the soil recovers from scraping. For the pond plots, the extra loss of 50% was probably caused by the removal of the topsoil and exposure of lower sandy soil during excavation.

Discussions and Conclusions

These experiments were mainly carried out in an area newly developed for concurrent rice-fish culture research, where the topsoil had been scraped during land furrowings and dike partitioning which probably caused low soil fertility. Water availability was limited by irregular and delayed irrigation water delivery and frequent electric power interruptions. Although stocking of large fingerlings (15–25 g) was desired, these were not available from hatcheries. All these factors contributed to the low fish yields.

In general, tilapia yields were very low. Some treatment comparisons were possibly negated by the small-sized tilapias used for stocking. Under a concurrent rice-fish trench refuge system, where the regular fish culture period is about 70 days, stocking small-sized fingerlings (<10 g) cannot produce the fish of 50 g or above required by Philippine markets. This problem is exacerbated by the limited water availability prevalent in a trench refuge system. Larger-sized fingerlings (15–25 g) must be stocked or the culture period must be extended to produce marketable fish. However, these results indicate that concurrent rice-fish systems can be efficiently utilized as fish nurseries. This is a promising area and techniques for tilapia fingerling production in ricefields should be further developed and refined.

The pond refuge system also has great promise. The advantages of this system are: the fish culture period can be made longer since fish can be stocked even before transplanting rice or the fish can be left to grow further after rice harvest; there is also greater volume of water; and small-sized fingerlings can be stocked. Results showed higher fish production and larger-sized fish at harvest from the pond refuge system than the trench refuge system. However, there is a need to improve further and evaluate the productivity and profitability potentials of this system in terms of higher stocking rates, fertilization and feeding.

The common carp (Majalaya strain) was found to be better suited to ricefield environments than the tilapias. Given a good market for carps, rice-carp culture in the Philippines could stand a good chance of success.

Experiments on border planting and on the use of animal manure in rice-fish culture yielded rather inconclusive results. In the manure experiment, the average recovery of *O. niloticus* hardly exceeded 50% and the average growth rate was 0.24 g/day. On the other hand, fairly large amounts of fingerlings were harvested from the fields. Somehow, the potential for the production is there, but the ricefields do not produce market size fish. A tentative conclusion from the experiments may be that manure does not increase rice yields as effectively as inorganic fertilizers, at least not in the short-term. It may, however, increase fish yields as shown here. In the experiment on pig manure, the application rate was very high (10.5 t/ha) and probably not technically and economically feasible for farmers. Animal manure should be viewed as an input to benefit the fish, in addition to inorganic fertilizers used for the rice. The amount and type of manure will depend on availability and cost, and these should be thoroughly assessed before any recommendations are made.

The pond refuge has resolved a number of constraints encountered with the trench refuge system. However, there are also some problems associated with the former. If constructed in flat or low areas, drainage can be a problem especially during fish harvest. Since the pond refuge area is large and holds a large volume of water, the fish tend to stay most of the time in the refuge, thus grazing in the ricefields will be limited. This defeats the purpose of stocking fish to benefit rice. Moreover, the pond refuge will not be attractive to countries with strict policy on intensified rice production, i.e., where all ricefields must be planted to rice.

Acknowledgements

The FAC-CLSU expresses its deep gratitude to the ADB for its financial support for this project. Much of the accomplishments achieved from this project are results of the team efforts by numerous individuals. Sincere appreciation are due to: the graduate research students (Liselot van Dam and Sawai Poolket); the research assistants and laboratory aides (Philip Florblanco, Ela Cruz, Noel dela Cruz, Digna Nortado and Charina Cajucom); the computer operator, Willie Pascual; and especially the laborers (Jose Pagaduan, Frankie Florblanco, Jimmy dela Cruz, Hilario Nortado, Igmedio Nortado, Pablo Pagaduan and Rodrigo Arcega).

References

de Datta, S.K. 1981. Water use and management practices for rice. John Wiley and Sons, New York.

Kampen, J. 1970. Water losses and balance studies in lowland rice irrigation. Cornell University, Ithaca, New York. Ph.D. dissertation.

Shell, E.W. 1983. Fish farming research. Agricultural Experiment Station, Auburn University, Alabama.

van Dam, A. 1990. Multiple regression analysis of accumulated data from aquaculture experiments: a rice-fish culture example. Aquacult. Fish. Manage. 21(1):1–15.

Problems in Rice-Fish On-Station Research*

ANNE A. VAN DAM*
CATALINO R. DELA CRUZ
International Center For Living Aquatic Resources Management
MCPO Box 2631
0718 Makati, Metro Manila
Philippines

VAN DAM, A.A. and C.R. DELA CRUZ. 1992. Problems in rice-fish on-station research, p. 385–391. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Common problems of on-station rice-fish research include growth and production assessment of fish populations in the ricefield environment; effective design and analysis of experiments; interdisciplinarity of the research; and application of on-station results to farmers' fields. It is argued that on-station research should take advantage of its controlled environment and its access to resources to test hypothesis for which the farm situation is not suitable.

Introduction

On-station research on fish production in rice-based farming systems is remarkably diverse and must draw on methods from agriculture and aquaculture. Detailed descriptions of standard methods are not given here because they have been described adequately elsewhere; and their application varies with the system under study. Here we discuss problems we encountered with these methods in our own research at the Freshwater Aquaculture Center of Central Luzon State University in the Philippines.

Problems on Research Methodology and Management

Plot Size and Experimental Design

Rice-fish production trial plots must be 200–400 m^2 because border effects become too strong and the number of fish stocked is very small in smaller plots. This is not necessarily true for more basic research where plots can be smaller.

Large plots need a large experimental area thus driving up research costs. For a relatively simple 2-factorial design with

*ICLARM Contribution No. 724.
**Present address: Thorbeckestraat 60, 6702 BS Wageningen, The Netherlands.

three levels of both factors and three replications, 27 plots are necessary, not counting the control. Using 200-m² plots, this is more than half a hectare, whereas in a rice experiment with plots of about 20 m², the area would be only 500 m². Moreover, variation in fish production warrants more than three replications to enable differentiation between treatments with statistical significance.

Ways to cut down the number of experimental plots must be found. Experiments can be replicated in time if analyzed with multiple linear regression (van Dam 1990) or a multivariate statistical technique, using climate data as additional variables. Simulation models may become powerful tools for incorporating results from separate experiments into a larger framework for analysis (Cuenco 1989). See Pauly and Hopkins (1983) for a proposed method for analysis of fish growth in ponds, and Gomez and Gomez (1984) for more on designing agricultural experiments.

Fish Growth Studies, Fish Sampling and Harvesting

Little is known about fish growth in different rice-fish environments. Similar to pond aquaculture research, regular (e.g., biweekly) sampling of fish should be done to establish growth curves (fish weight/length against time), detect fish growth patterns and determine food preference (stomach analysis). Similarly, regular sampling should yield information about fish survival which is especially important for tilapia (*Oreochromis* spp.). Attempts to sample Nile tilapia (*O. niloticus*) from ricefields using different fish traps (Fig. 1) yielded very few or no fish (Table 1). Methods for sampling tilapia in ricefields without disturbing the ricefield need to be developed.

One alternative to regular sampling is one midperiod inventory of all fish stocked by draining the water and netting the fish. This technique suffered because the fish hide in the mud. The number of fish caught during inventory was smaller than at harvest, obviously, not all were caught. Loss of water and nutrients is a further disadvantage of draining the field for sampling. Indonesian farmers flush out the remaining 5–10% of the common carps (*Cyprinus carpio*) after draining by refilling the field and draining it again. Where the smallest or biggest fish may not have been caught, the modal class of a size-frequency distribution can be used to estimate average weight.

Alternative methods for growth assessment need to be tested for use in rice-fish culture. The CIRC technique for tilapias (Doyle et al. 1987; Padilla 1989) or fish tagging may provide more information about the size distribution of fishes.

Too often, experiments report only gross fish yield or standing stock which is misleading when the biomass stocked was large. Net fish production (biomass harvested minus biomass stocked) should always be reported. For tilapia, the yield of fingerlings can be considerable and should be reported separately. Other data worth collecting are given in Table 2.

Table 1. Number of fish (*Oreochromis niloticus*) caught on three sampling dates using different fish traps. Plot size: 300 m²; stocking density: 150 fish/plot; n = 5).

Method	No. of fish caught (percentage of population stocked)					
	29 Aug		11 Sep		25 Sep	
Tubular trap (*bubo*)[a]	2	(0.3)	0	(0)	0	(0)
Cover pot (*salakab*)[b]	10	(1.3)	1	(0.1)	0	(0)
Scissor net[c]	12	(1.6)	8	(1.1)	3	(0.4)

[a]A traditional fish trap placed in the water inlet of the plot.
[b]A type of basket that is placed over the fish, after which the fish is taken out by hand. This requires a lot of walking through the plot.
[c]Used after partially draining the field.

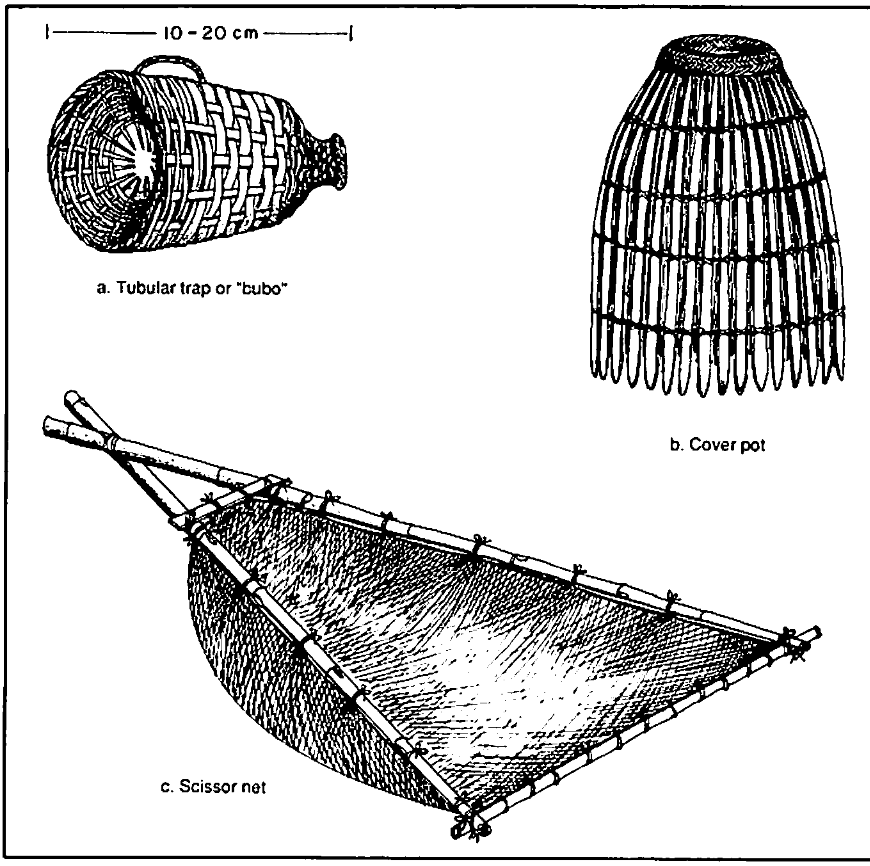


Fig. 1. Fish traps used in fish sampling.

Water Quality and Aquatic Ecology

Measuring water quality is important because it affects fish growth and is strongly influenced by rice management. Some considerations in determining sampling procedures follow.

Water quality fluctuates strongly both diurnally and seasonally. Phytoplankton and macrophyte photosynthesis and respiration cause diurnal fluctuations. Weather and growth of both rice and fish cause seasonal fluctuations (Watanabe and Roger 1985; Roger 1989). Long-term variation can be handled by sampling water weekly or biweekly at the same time on every sampling day. Extreme values of dissolved oxygen and pH occur at sunrise (low) and during mid-afternoon (high). Diurnal fluctuations can be captured by taking samples at two-hour intervals, twice or thrice during the growing period.

Because water quality fluctuates within the field, multiple samples should be bulked into one composite sample. Fish refuge (pond or trench) samples should not be mixed with those from the field.

More detailed ecology experiments require various biotic factors (phyto- and zooplankton, etc.), to be analyzed in a laboratory. See Table 2 for suggested data collection requirements.

Water Depth

Water depth and renewal rate are among the main factors determining productivity in wetland ecosystems

Table 2. Suggested basic data collection requirements for rice-fish on-station research.

Parameter	Frequency	Remarks
Fish (general) -number -bulk weight -average weight -length of culture period	At stocking At harvest	Calculate: -recovery percentage -standing crop -net production -specific growth rate
Tilapia -fingerlings (bulk weight, average weight, number) -scales for CIRC-measurement	At harvest	See Bagenal (1978); Doyle et al. (1987); Ricker (1968); Shell (1983)
Rice -grain yield and moisture -plant height -tiller number		See Gomez (1972)
Water depth	Daily	Use sloping gauge See Giron and Wickham (1976)
Site description -soil (texture, pH, nutrients) -water supply (source composition) -climate (rainfall, temperature, etc.) -elevation	If variable, more samples during culture period	
Ecology -water quality (dissolved oxygen, temperature, pH, N-components, phosphorus, many others) -biotic factors (phytoplankton, zooplankton, benthic organisms, bacteria/detritus, weeds insect pests -soil	Depending on purpose Take into account diurnal and seasonal fluctuations	See Anon. (1989); APHA (1975); Boyd (1979); Downing and Rigler (1984); Golterman et al. (1978); Heckman (1979); Lind (1979); Roger (1989); Rosenthal and Gershey (1989); Vollenweider (1969); Watanabe and Roger (1985)

(Gosselink and Turner 1978). Continuous fluctuations in water depth through seepage, drainage, irrigation and rainfall lead to loss of dissolved nutrients. In tilapia, such stress can stunt growth through an early switch from growth to reproduction (Lowe-McConnell 1982). Moreover, phytoplankton do not develop when water movements are strong. Routine measurement of water depth provides useful background information. The sloping gauges shown in Fig 2. are simple to make and use (Giron and Wickham 1976).

Maintaining water depth in large experimental areas is not easy, and lining water supply canals and constructing good control structures are mandatory. Where big differences in water depth are observed, water depth should be analyzed as a co-variable.

Fish Behavior

Fish behavior is difficult to observe in muddy ricefields, thus it is neither clear how much time Nile tilapias forage in the

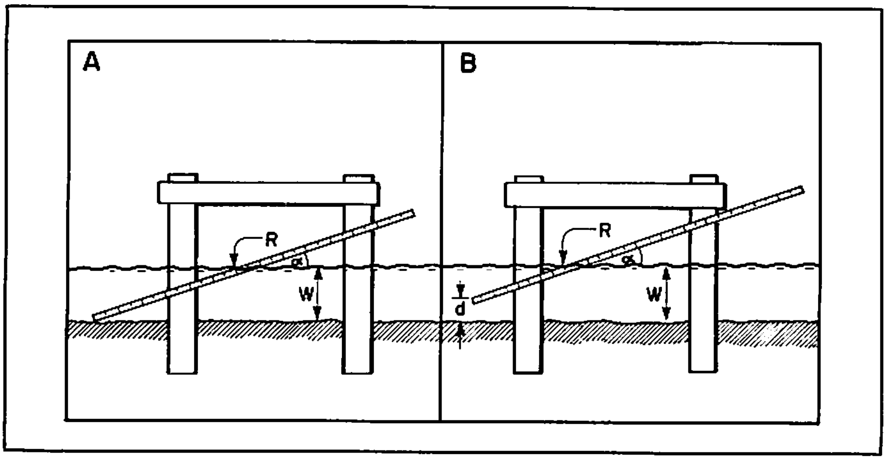


Fig. 2. Sloping gauge for water depth measurements. R=reading meter on stick; W=actual water depth; α=angle between meter stick and water surface.

When zero on the stick (R=0) corresponds with W=0 (see A), depth is calculated as: $W = \sin \alpha \cdot R$. Usually, $\sin \alpha = 1/5$, or $\alpha = 11.5$ degrees. If R=0 corresponds with W=d (see B), then in general, $W = d + \sin \alpha \cdot R$, where d can be positive or negative. Calculation of d can be done if both R and W are measured at the same theme.

ricefield nor what they eat. It may even be that the high temperatures (39–40°C) cause them to stop feeding altogether. A few fish placed in glass aquaria partially filled with puddled soil and planted with rice might throw some light on fish behavior. Experiments would allow the introduction of rice pests to see whether fish actively feed on them.

Data Management: Processing, Storing and Analyzing

Computers have become indispensable tools for prompt processing, sorting and analyzing data. Ideally, the person who gathers the data should enter it, if not, he or she should work closely with the computer operator. Data should be entered every week to prevent data from accumulating to undecipherable amounts; and forgetting the circumstances in which they were gathered. Fixed formats for data entry and regular backup copies of data-files on diskette and printouts all help. For more details see Gomez (1987), Hopkins et al. (1988), and Prein and Milstein (1988).

What Should On-Station Research Do?

What determines whether an experiment should be conducted on-station, rather than on-farm? Who formulates the hypotheses to be tested in an on-station experiment? What is the practical translation of the "consultancy and referral role" of scientists and research stations in a "farmers-first-and-last" approach (Chambers and Ghildyal 1985)?

On-station experiments should not attempt to imitate farms. Rather, they should exploit their advantage in controlled environment, access to all necessary resources, better assessment of influencing factors, etc., to obtain more insight into the process underlying production. Rice-fish ecosystems comprise many sub systems – rice, fish, soil, water, each with its related disciplines – agronomy, soil science, aquatic ecology and zoology. Successful interdisciplinary research requires that everybody supports the experimental objectives and setup, regular meetings to monitor progress and problems are held, and agreement about the output of the research, e.g., about reports/papers are established early. With the right models and in collaboration with farmers and on-farm researchers, on-station researchers must contribute to the solution of resource-poor farmer problems.

Acknowledgements

The authors are grateful to Liselot van Dam for drawing Fig. 1, and Felipe Flor Blanco and his workers for collecting the data in Table 1. The ICLARM/IRRI/CLSU Rice-Fish Integrated Farming Systems Project is a Regional Technical Assistance Project funded by the Asian Development Bank. The first author at the time of the study was seconded to ICLARM by the Directorate General for International Cooperation, Ministry of Foreign Affairs, The Netherlands.

References

Anon. 1989. Reliability of field test kits for use in aquaculture studied. Aquabyte 2(2):11-12.

APHA. 1975. Standard methods for the examination of water and wastewater, 14th ed. American Public Health Association, Washington.

Bagenal, T., Editor. 1978. Methods of assessment of fish production in freshwaters. IBP Handbook No. 3, 3rd ed. Blackwell Scientific Publications, Oxford.

Boyd, C.E. 1979. Water quality in warmwater fishponds. Agricultural Experiment Station, Auburn University, Auburn, Alabama. 359 p.

Chambers, R. and B.P. Ghildyal. 1985. Agricultural research for resource-poor farmers: the farmer-first-and-last model. Discussion Paper 203, Institute of Development Studies, University of Sussex. 29 p.

Cuenco, M.L. 1989. Aquaculture systems modelling: an introduction with emphasis on warmwater aquaculture. ICLARM Stud. Rev. 19, 46 p.

Downing, J.A. and F.H. Rigler, editors. 1984. A manual on methods for the assessment of secondary productivity in freshwaters. IBP Handbook No, 17, 2nd ed. Blackwell Scientific Publications, Oxford.

Doyle, R.W., A.J. Talbot and R.R. Nicholas. 1987. Statistical interrelation of length, growth and scale circulus spacing: appraisal of a growth rate estimator for fish. Can. J. Fish. Aquat. Sci. 44:1520-1528.

Giron, O.B. and T. Wickham. 1976. New techniques for measuring seepage and percolation and water use efficiencies in irrigated areas. Paper presented at the IRRI Saturday Seminar, 10 July 1976, Los Baños, Laguna, Philippines.

Golterman, H.L., R.S. Clymo and M.A.M. Ohnstad. 1978. Methods for physical and chemical analysis of freshwaters. IBP Handbook No. 8, 2nd ed. Blackwell Scientific Publications, Oxford.

Gomez, K.A. 1972. Techniques for field experiments with rice. International Rice Research Institute, Los Baños, Laguna, Philippines.

Gomez, K.A. and A.A. Gomez. 1984. Statistical procedures for agricultural research, 2nd edition. John Wiley and Sons, New York.

Gomez, K.A. 1987. Data management for farming systems research. Discussion paper presented at the 18th Asian Rice Farming Systems Network Working Group Meeting, 30 August-4 September, Islamabad, Pakistan.

Gosselink, J.G. and R.E. Turner. 1978. The role of hydrology in freshwater wetland ecosystems, p. 63-78. *In* R.E. Good, D.F. Whingham and R.L. Simpson (eds.) Freshwater wetlands: ecological processes and management potential. Academic Press, New York.

Heckman, C.W. 1979. Ricefield ecology in N.E. Thailand. Dr. W. Junk Publishers, The Hague. 228 p.

Hopkins, K.D., J.E. Lannan and J.R. Bowman. 1988. Managing a database for pond research data - the CRSP experience. Aquabyte 1(1):3-4.

Lind, O.T. 1979. Handbook of common methods in limnology. The C.V. Mosby Co., London.

Lowe-McConnell, R.H. 1982. Tilapias in fish communities, p. 83-113. *In* R.S.V. Pullin and R.H. Lowe-McConnell (eds.) The biology and culture of tilapias. ICLARM Conf. Proc. 7, 432 p.

Padilla, J.S. 1989. Growth estimation of *Oreochromis niloticus* (L.) cultured in rice-paddies using CIRC-technique. Institute of Graduate Studies, Central Luzon State University, Muñoz, Nueva Ecija, Philippines. 67 p. M.Sc. thesis.

Pauly, D. and K.D. Hopkins. 1983. A method for the analysis of pond growth experiments. ICLARM Newsl. 6(1):10-12.

Prein, M. and A. Milstein. 1988. Techniques for handling large pond and farm datasets. Aquabyte 1(2):4-5.

Ricker, W.E., Editor. 1968. Methods for assessment of fish production in freshwaters. IBP Handbook No. 3. Blackwell Scientific Publications, Oxford.

Roger, P.A. 1989. Biology and management of the floodwater ecosystem in tropical wetland rice fields. International Network on Soil Fertility and Sustainable Rice Farming (INSURF). Handout for the 1989 training course.

Rosenthal, H. and R.M. Gershey. 1989. A preliminary study on the reliability of field test kits for the determination of inorganic nitrogen species in waters from aquaculture facilities. *In* K. Lillelund and H. Rosenthal (eds.) Fish Health Protection Strategies, 299 p.

Shell, E.W. 1983. Fish farming research. Alabama Agricultural Experiment Station, Auburn University, Alabama. 108 p.

van Dam, A.A. 1990. Multiple regression analysis of accumulated data from aquaculture experiments: a rice-fish culture example. Aquacult. Fish. Manage. 21(2):1-15.

Vollenweider, R.A., Editor. 1969. A manual on methods for measuring primary production in aquatic environments, IBP Scientific Publications, Oxford.

Watanabe, I. and P.A. Roger. 1985. Ecology of flooded rice fields, p. 229-243. *In* Ecology of flooded rice fields. Proceedings of the workshop on "Wetland Soils: Characterization, Classification and Utilization", 26 March-5 April 1984, International Rice Research Institute, Los Baños, Laguna, Philippines.

Why Do Rice-Fish Research On Farms?

KENNETH T. MACKAY*
Environment and Sustainable Resource Management
Agriculture, Food and Nutrition Sciences Division
International Development Research Centre
250 Albert Street, P.O. Box 8500
Ottawa, Ontario
Canada K1G 3H9

MACKAY, K.T. 1992. Why do rice-fish research on farms?, p. 393-397. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

On-farm research in Asia has evolved over the last 15 years. Today, methods that are being institutionalized in many countries and backed up with training and networking at national and international levels are relevant to rice-fish research. On-farm research is a more efficient process for doing research and helps break down barriers between farmers and researchers, resulting in more effective feedback. It can help assess real problems and determine farmers' priorities. One of the challenges of working on-farm is to learn from farmers' indigenous practices and experiments. On-farm experiments also allow testing in a wide range of environments in the farmers' world. There are problems but most can be overcome through changes in attitude among farmers, researchers and administrators.

Introduction

Farming Systems Research (FSR) in Asia owes much to the International Rice Research Institute (IRRI) in the Philippines. Bradfield's early research on multiple cropping showed the high productivity potential of tropical ecosystems (Brady 1977). The introduction of shorter season, photoperiod insensitive rice varieties permitted the growing of more than one crop per year. Through the work of scientists in the Asian Rice Cropping Systems Network, a methodology for testing and adapting these technologies on farmers' fields evolved (Zandstra et al. 1981; Harwood 1986).

Cropping systems research has had considerable success in introducing new technologies to farmers in rice-based

*Present address: International Center for Living Aquatic Resources Management, MCPO Box 2631, 0718 Makati, Metro Manila, Philippines.

systems. In Iloilo Province, Philippines, crop intensification increased farm production and income (Barlow et al. 1983). Indeed, the methods developed by the Asian Rice Farming Systems Network (ARFSN) of IRRI have now been institutionalized in the Philippine Department of Agriculture's Regional Integrated Agricultural Research Systems (RIARS) (Quisumbing 1982). Experience in Indonesia shows similar contributions in both partially irrigated and rainfed conditions (AARD 1986). Methods have been particularly successful in designing new cropping patterns for transmigration areas.

More recently cropping systems methods have been expanded to consider the whole farm. Animals including fish are incorporated into FSR.

FSR usually involves small multidisciplinary teams in the following activities:

1. Site selection and description.
2. Experimental design to test both system and component technologies.
3. Researcher-managed or farmer-managed on-farm trials.
4. Preproduction multilocational trials of successful patterns or technologies over wide areas.
5. Pilot production programs involving close cooperation with extension.

This methodology is now used in the 14 Asian countries involved in the ARFSN. One of ARFSN's major impacts has been to institutionalize and popularize this on-farm methodology.

Why On-Farm Research

Efficiency

The main reason for doing on-farm research is that it is more efficient than conventional on-station work. Technologies perfected and packaged on-station for transfer to farmers via the extension system rarely get adopted. Is this the farmers' and fishers' fault? Are they conservative and stubborn? Won't they modernize and take risks? Now we know that the technology is often to blame – it is too costly, requires too much labor and does not fit into existing systems. Rhoades (1986) gives a classic description of the mistakes made by researchers at the International Potato Center while trying to promote potato storage. Only after researchers started asking farmers what their problems were did they realize that storage of seed potatoes was the problem, and not storage of tubers for market. Today, diffuse light stores have been adopted and adapted by farmers around the world. The non-adoption of station-developed fishpond aquaculture in Northeast Thailand versus the rapid spread of farmer-developed rice-fish is another example. One of the lessons of FSR is that farmers very seldom adopt a whole package; they select parts and adapt these to their system. Farmers need a basket of options and not a package of technology (Aran 1987).

Social Barriers

A large social distance separates researchers from farmers. Differences in education, income, culture, language or dialect, means of transport and dress increase the gap. How do you think farmers react to safari-suited, shoe-clad city dwellers complete with soft hands and long fingernails who arrive in four-wheel-drive vehicles and proceed to tell them how to grow rice or fish? Doing research on farms forces researchers to talk with farmers and learn their techniques in order to succeed.

Research Priorities

Researchers and farmers often have completely different research priorities. An example from Northeast Thailand compares the two priorities.

Researchers' priorities are pesticides, stocking rates and trench or pond designs (FSRI 1986). Farmers find this list irrelevant because: a) while aware of problems of pesticides on fish, they cannot afford to use them; b) stocking rates are not determined by optimal production, rather by the number of fingerlings available from their own broodstock, nearby commercial hatcheries and carryover from the previous season; and c) rice farmers are excellent hydraulic engineers and use a considerable variety of trenches, sumps, ponds, etc. depending on water security, labor and costs (Chapman and Bhasayayan 1985; MacKay et al. 1986). They also use natural depressions and connect ricefields to enable fish to move into ponds as water level decreases.

Clearly in this case, researchers' priorities would not benefit many farmers. Rather, farmers want to know the effects of fish culture on family income and nutrition, labor use and pest control. They want information about backyard hatcheries. Closer specification of research needs in these areas follows.

Fish can increase farm income up to 50% in some cases (MacKay et al. 1986) through increased yields and decreased fertilizer costs. Farmers also view fish in ricefields or ponds as money in the bank to be harvested when needed. Every size has a value. In fact, in Northeast Thailand there is no such thing as market size. No doubt, large sizes get better prices, but home consumption accounts for 35% of production and even fingerlings are eaten or fermented for fish sauce. This is certainly at variance with aquaculture researchers' concerns about market size.

Trench preparation and maintenance require sufficient labor to constrain the rice-fish area on any one farm. There are some advantages: having fish close to home is less laborious than catching them from the wild; and most labor demands of fish production integrate well with existing activities.

Farmers in Northeast Thailand use few pesticides on rainfed rice because they have observed fish contributing to the control of some pests. Such observations have prompted research on the effects of fish on insects and weeds (Chapman et al. 1987).

Backyard hatcheries make sense to farmers not only because fingerling supply is unpredictable and transportation difficult, but also because it is a major cost. Breeding carp and tilapia is no problem but *Puntius* is an area of priority research for them.

Indigenous Technology

Farm households manage complex systems with very limited resources. Much of their decisionmaking on risk minimization, food and cash needs of the family is based on a large amount of indigenous technical knowledge. Indigenous knowledge provides the foundation on which researchers must mold new interventions. Rapid adoption of rice-fish in Northeast Thailand is a good example of this. Initially discovered in Surin Province by non-government organizations (NGOs), rice-fish spread by bringing farmers to see and learn for themselves. Only in the last few years has there been government research and extension efforts. Farmer-to-farmer approaches have not only increased the efficiency of technology transfer but also suggested areas for research (Jintrawet et al. 1985).

Experimenters

Farmers are experimenters. Research in the Philippines has shown the value of understanding and monitoring indigenous research (Lightfoot 1987). Farmers' own experimentation with new varieties of upland rice and sweet potatoes distributed as disaster relief yielded new information on the performance of these varieties in environments researchers did not think to test. It was only because researchers were working with farmers that they were able to see and hear of this research. When allowed to experiment freely, farmers are very good at identifying complex linkages and unanticipated interactions in new technologies (Lightfoot et al. 1987a, 1987b).

Range of Environments

Each tropical farm covers a wide range of micro environments. Multilocational trials on farms are an effective method for experimenting over this range. Moreover, if these trials are farmer-managed, they encourage farmer innovation. In addition to the variability in space, farms are dynamic and change over time. Weather and climate change as do markets and development projects. Farmers constantly adjust to survive, which conflicts with the researchers' need to standardize for comparison over time. Today in Ubonratchathani Province, Northern Thailand, for example, there are more farmers using pesticides on watermelon, and as a result others are not able to grow fish. Farmers who three years ago had no animals now have buffaloes, pigs and chickens from a government project and thus have manure to add to fishponds. An even more dramatic change has occurred in some rainfed villages of nearby Roi Et and Sakon Nakorn Provinces. Normally, farmers live some distance from their farms, where they maintain only a temporary home. Now families are staying longer on their farms to guard their fish. Year-round presence on the farm has increased food production. The dry season pond provides water for crops, chickens and ducks. Researchers need to be aware of these changes, which can only come from close contact with farmers.

Problems with On-Farm Research

Researcher Attitudes

On-farm research requires a change in the attitudes of researchers. They must learn that they are no longer the experts and that they are not going to the farmer with the answers. Research priorities will change and researchers' ideas will be challenged. Researchers will have to work as part of a team. This is not an easy process because it requires humility and an open attitude.

Farmer Knowledge

Farmers may have considerable indigenous knowledge, but they do not know everything. Recent work on farmers' perception of pest control indicates that farmers' knowledge on insects that are hard to see or whose damage is not obvious, is weak (Litsinger and Canapi 1987). Furthermore, they cannot be expected to evaluate new crops without first experiencing them. This does not mean their perceptions should not be fairly evaluated.

Conclusion

On-farm research offers an opportunity to learn from farmers, it offers a place in the farmers' world to do experiments, and it offers an excellent feedback mechanism. However, it is not just a tool but a process whereby farmers and researchers can work closely together. The final outcome is the kind of partnership envisaged by the proponents of farmer-first-farmer-last approaches (Chambers and Ghildyal 1985; Chambers and Jiggins 1987). In a very real sense, the development of rice-fish farming is a tribute to that approach.

References

AARD. 1986. Indonesian farming systems research and development. Agency for Agricultural Research and Development. Jakarta, Indonesia. 131 p.

Aran, P. 1987. Farming systems and legume research: a national perspective. Paper presented at the Symposium on the Contribution of Biological Nitrogen Fixation to Plant Production, 3-7 August 1987. Cisarua, Indonesia.

Barlow, C., S. Jayasuriya and E.C. Price. 1983. Evaluating technology for new farming systems: case studies from Philippine rice farms. International Rice Research Institute. Los Baños, Laguna, Philippines. 110 p.

Brady, N.C. 1977. Increased food production through expansion and intensification of soil and land use, p. 3-18. *In* (SEFMIA) Proceedings of the International Seminar on Soil Environment and Fertility Management in Intensive Agriculture. Japan Society of the Science of Soil and Manure, Tokyo.

Chambers, R. and B.P. Ghildyal. 1985. Agricultural research for resource-poor farmers: the farmer-first-and-last model. Agricultural Administration 20:1-30.

Chambers, R. and J. Jiggins. 1987. Agricultural research for resource-poor farmers, part II: a parsimonious paradigm. Agricultural Administration and Extension 27:109-128.

Chapman, G. and N. Bhasayayan. 1985. Rice-fish culture systems and practices in Sakon Nakorn, northeast Thailand. Paper presented at the Department of Agriculture Annual Conference, 24-28 April 1985, Bangkhen, Bangkok.

Chapman, G., N. Bhasayavan, S. Tangpoonpol and S. Chantraniyom. 1987. The role of common carp (*Cyprinus carpio*), Nile tilapia (*Oreochromis niloticus*) and silver carp (*Puntius gonionotus*) as agents of rice insect pest and disease control in lowland paddies of Sakon Nakorn, Thailand. Farming Systems Research Institute, Department of Agriculture, Bangkok.

FSRI. 1986. Rice-fish culture project. Proceedings of the workshop on Rice-Fish Culture, 21 October 1986. Farming Systems Research Institute, Department of Agriculture, Bangkhen, Thailand.

Harwood, R.A. 1986. A Winrock perspective of the evolution of farming systems research and extension: lessons for Indonesian consideration. Proceedings of the International Farming Systems Workshop, 10-13 December 1985, Sukarami (West Sumatra), Indonesia.

Jintrawet, A., S. Smutkupt, C. Wongsamun, R. Katawetin and V. Kerdsuk. 1985. Extension activities for peanuts after rice in Banm Sum Jan, northeast Thailand: a case study in farmer-to-farmer extension methodology. The Farming Systems Research Project, Khon Kaen University, Khon Kaen, Thailand.

Litsinger, J.A. and B.L. Canapi. 1987. Farmers' perceptions of mungbean pests and their control practices in field and storage in Cagayan, Philippines, a high-risk environment. Paper presented at the Second International Symposium on Mungbean, 16-20 November 1987, Bangkok, Thailand.

Lightfoot, C. 1987. Indigenous research and on-farm trials. Agric. Admin. Ext. 24:79-89.

Lightfoot, C., O. de Guia, A. Aliman and F. Ocado. 1987a. Participatory methods for identifying, analyzing and solving systems problems. Paper presented at the Farming Systems Research Symposium, 18-23 October 1987, University of Arkansas, Arkansas.

Lightfoot, C., G. Pielago, O. de Guia and R. de Pedro. 1987b. Participatory method for upland research: systems-problems in shifting (*kaingin*) cultivation. Paper presented at the Second National Conference on Research in the Uplands, 1-6 December 1987, Visayas State College of Agriculture, Leyte, Philippines.

MacKay, K.T., G. Chapman, J. Sollows and N. Thongpan. 1986. Rice-fish culture in northeast Thailand – stability and sustainability. Paper presented at the Sixth IFOAM International Scientific Conference, 18-21 August 1986, California.

Quisumbing, R.E. 1982. The emerging research system of the Ministry of Agriculture: part III. Ministry of Agriculture, Philippines. 39 p. (Mimeo)

Rhoades, R.E. 1986. Storing seed potatoes in Peru, p. 186-202. *In* IDRC. With our own hands: research for third world development: Canada's contribution through the International Development Research Centre, 1970-1985. International Development Research Centre, Ottawa.

Zandstra, H.G., E.C. Price, J.A. Litsinger and R.A. Morris. 1981. A methodology for on-farm cropping systems research. International Rice Research Institute, Los Baños, Laguna, Philippines. 147 p.

Doing Research in the Farmers' World

JOHN D. SOLLOWS*
Northeast Fishery Project
Khon Kaen Fisheries Research and Development Centre
Khon Kaen, Thailand 4000

SOLLOWS, J. 1992. Doing research in the farmers' world, p. 399–401. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

On-farm research must accommodate a variety of traditional disciplines and be flexible in approaching questions it aims to answer. It exists in order to test hypotheses in, and raise questions on the farmers' world. Under such circumstances, researchers must work with, rather than against large, uncontrollable variation. Researcher-imposed control is best kept to a minimum, and experimental designs best kept simple. Precise estimates of parameters are difficult to obtain; so sample size must compensate for this. Research operations must also accommodate the farmers' timetable. Teams are ideally based within a day's travel so that weekly visits are easy. Frequent communications are essential. Researchers and farmers should work as colleagues, reaching their decisions through equal consultations.

Introduction

Most information in this paper is based on experience arising from a project which investigated rice-fish farming systems in Ubonratchathani Province, Northeast Thailand, from 1984 to 1987. In the course of this project, it was found that conventional research approaches and methods sometimes fail to respond to the needs of the target farmers. On-farm research is often called upon to adopt nontraditional methods.

This paper assumes the risky task of trying to generalize from one particular project and set of circumstances. It will not review the considerable literature on on-farm research methods. Research at this level is not clearly separable from extension. While a research program tests hypotheses and extension transfers technologies, farmers invariably learn and modify new technologies.

Why Do Research in the Farmers' World?

On-farm research tests hypotheses under the circumstances and resource

*Present address: ICLARM Bangladesh Office, House No. 20, Road No. 9/A, Dhanmondi RA, Dhaka 1209, Bangladesh.

base of farmers. Methodological ramifications of this are considered later, here some examples of where this sort of research may be appropriate are given.

It is important to understand the processes underlying a given farming system before interventions are tested. This can only be done with farmers on their farms.

Before a new technology is considered for extension, its appropriateness must be assessed. The question of appropriateness cannot normally be answered satisfactorily unless the technology is tested with the cooperation of and in the circumstances of the target farmers.

Unforeseen and long-term problems with a technology can be identified through on-farm research. On-farm research can investigate treatment responses under many different circumstances and subsequently identify where a technology is likely to be appropriate and where it is not.

The following comments refer particularly to this very important aspect of appropriateness of modifications to a technology.

On-Farm Research Methods

A Fundamental Premise

Great and uncontrollable variation exists in the farmers' world. Researchers testing hypotheses in this world do best to acknowledge this variation and work with, not against it. Some specific suggestions in designing on-farm experiments to reduce or accommodate variations are discussed below.

Variation makes conventional on-station research methods difficult, especially as the on-farm researcher must exert control sparingly and cautiously.

Control of parameters should be limited to those under investigation, for every factor under research control reduces farm realism. Comparisons with farmers' existing technology are best made when included in the same experiment. An experiment controlled mainly by researchers will not test the appropriateness of technology and will provide little about its behavior in the farmers' world.

Sometimes, even the treatment levels are best kept under minimal control. Fixed "treatment" levels can easily be planned, but in practice, a continuum of "treatment" levels may have to be analyzed. This does not prevent researchers from defining an acceptable range and distribution of "treatment" levels. However, letting farmers set the level on a given treatment reduces frustration.

Experimental designs should normally be kept simple. Results from complex on-farm experiments may often be inconclusive because of uncontrolled background variation. Accommodating this variation can be prohibitively expensive or otherwise places excessive demands on the farmers' resources.

Very precise estimates of experimental variables may not always be attainable on-farm. One must decide what range of "error" is acceptable and in doing so, judge if the degree of precision is adequate to test the hypothesis.

Appropriate sampling procedures can reduce some of the problems of variation. In general, researchers should aim to work with the largest manageable sample of farmers. Small samples run the risks of being unrepresentative of the target group, and of vulnerability to missing values. A large sample is particularly important if different "treatments" on different farms are to be compared. Such comparisons are risky because variation between farms tends to be so great that treatment differences are easily obscured.

Farmers selected to participate in a project should represent the target group reasonably well. Selection should take the farmers' attitude into consideration. If cooperative farmers are hard to find, the researcher should probably question the basis of the trial and not the attitude of the farmers. Research operations must accommodate the farmers' timetable not only because it helps assure realism, but also because it reduces frustration and encourages cooperation. Experiments which use farmers' resources should be low-risk. New practices, which demand unaffordably high inputs, will normally be accepted with difficulty anyway. Geographical proximity to research sites and adequate transport are important because trials must be visited frequently to monitor progress and make on-the-spot management decisions. Moreover, visits improve communications, enhance mutual understanding and reduce the temptation to "fudge" data.

Relations with Farmers

Relations with farmers should be such that they must consider each other as colleagues. Right at the start, farmers can be an excellent source of relevant research ideas. No matter who is the source of the research topic, subsequent consultation is highly advisable because farmers can normally indicate whether the proposed research is relevant and workable.

While the experiment is underway, management decisions are best left to the farmers. Researchers obviously advise, but the farmers should have veto power. After all they are probably the best assessors of risks incurred. Moreover, giving them veto power encourages them to respond immediately to emergencies which is more likely to occur if no restrictions are placed on them. A further consequence is that the test technology is more likely to be adopted because the farmers have already had experience in managing it.

Farmers should be encouraged to record data about their research. Experience indicates that such records provide useful supplements to records kept by researchers.

Relationships work best if researchers and farmers accept that neither has all the answers and so they can learn from each other. An important requirement for on-farm research is an open mind.

Target farmers are likely to be poor so researchers must avoid fostering dependencies which can create serious problems when they depart.

The Northeast Thailand Experience

Researchers' attempts in Northeast Thailand to control treatment levels serve here to exemplify some of the points made earlier.

Treatments on fish stocking levels were rarely achieved. They could not be approximated because residual stocks were present. The area occupied by fish changed with minor floods and restricted water supply. Poststocking mortalities presented problems because farmers added more fish. Monitoring what actually happened and treating the data accordingly made more sense than following the preset plan.

Initially, it was planned that all fish caught by the farmers would be counted and weighed by the researcher. Since farmers tend to harvest fish continuously on as need basis, the plan was dropped. Instead, farmers were visited each week and asked about catches since the last visit. Production figures of acceptable accuracy were obtained. Had the initial plan been adopted, either catch estimates would have been underestimated, or the farmers would have benefitted less. In either case, the potential benefits from rice-fish would have been underestimated in a desire for precision.

Conclusions

The advice and suggestions given here have worked. While they may need modifying in other situations, experience suggests that they will, by and large, apply. While on-farm research is undoubtedly hard work, the load can be lightened by bringing the skills and talents of farmers into the process. There is no escaping the need for direct and frequent participation. Even though statistical nonsignificance may result, this does not compromise the relevance of the research, nor prevent it from indicating important questions.

On-Farm Data Collection and Analysis

JOHN D. SOLLOWS*
Northeast Fishery Project
Khon Kaen Fisheries Research and Development Centre
Khon Kaen, Thailand 40000

SOLLOWS, J.D. 1992. On-farm data collection and analysis, p. 403–413. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Abstract

Research on rice-fish farming should be interdisciplinary. The right approach will depend on circumstances and research topic. Based on on-farm experiences, below are suggestions on how to collect and analyze data from rice-fish farms.

The researcher must balance the need for high precision against the basic goals of the research program. Credibility of farmers' estimates can be checked by frequent visits of reasonable length and by maintaining a sincere interest in their welfare. Participating farmers and field assistants should be involved in assessing the results. This will usually increase insight for all concerned. Communication among senior research staff, field staff and farmers should be good. Both farmers and field staff need enough autonomy to deal promptly with unexpected events.

Data collection and analysis must be interactive. Problems in data collection may force changes in planned analyses, which can then improve data collection methods. Data should be analyzed promptly. When conflicts arise between timing of data collection and analyses, priorities must be set. Data collection, however, cannot be delayed if they are to be accurate. The researcher should be ready to make use of unforeseen information which arises in the course of the work. Its importance may be as great as that from the planned, formal research program.

Popular experimental designs and statistical analyses are often applied with difficulty in on-farm trials. Statistical nonsignificance does not disprove the hypothesis being tested. The researcher must be prepared to be more qualitative when he interprets results. Experiments should be simple in design with few treatments. On-farm, complex experimental designs and related analyses will often lead to inconclusive results.

Different treatments are best compared within each farm. Interfarm variation is likely to confound any treatment effects, and is best considered a main effect on par with and independent of other treatments. Data representing averages or sums over farms have value, but the variation among farms must be considered in the final interpretation. Computers can accelerate data processing. The person entering the data must be aware of any relevant qualification to make an informed decision on what action to take. Consultation with field personnel or participating farmers is advisable.

*Present Address: ICLARM Bangladesh Office, House No. 20, Road No. 9/A, Dhanmondi R/A Dhaka 1209, Bangladesh.

Introduction

Rice-fish farming systems research is of particular interest because it is interdisciplinary, and combines different relevant aspects of more traditional fields of study. As a result, nontraditional approaches are sometimes needed.

Often, research involves comparisons. In the course of such comparisons, the various phenomena under study should be assessed by the same researcher in the same way. In an interdisciplinary study, a researcher may not feel qualified to assess some items of interest because of weaknesses in his background. Consultation with specialists in the appropriate field is normally the best way of coping with the situation.

In this paper, specific suggestions related to the collection and analysis of rice-fish farming data are described. These will have an on-farm bias because most are based on experiences gained from an on-farm rice-fish farming systems research project from 1984 to 1987 in Ubonratchathani Province, Northeast Thailand. A brief history of this project is given.

Project History

The Ubonratchathani rice-fish farming project commenced research activities in June 1984. Work was concentrated on six farms in the Lam Dom Noi irrigated area, Pibulmansaharn District, and one farm at Ban Thung Kasem, Warinchamrab District. Monthly visits were also made to seven farmers at Ban Khoo Khad, a rainfed rice village in Kheuang Nai District.

The project's research topic was an economic comparison of rice-fish farming and rice monoculture. Fish stocking densities and species compositions were investigated as well as the possible effects of fish on rice yields. For the second year of the study, research topics were not substantially changed, but the sampling setup was modified. For various reasons, activities were stopped at the single Ban Thung Kasem farm. Results from the first year's study on fish stocking densities were inconclusive, so the sample size of participating farmers was increased to 12 in Dom Noi and 13 in Khoo Khad. Research activities were intensified at Khoo Khad.

No changes in farmer sample size were made in the third year of the project, but secondary research topics were changed. It was felt that little would be learned from continuing the fish stocking densities and species composition studies. Earlier research results, expressions of interest from farmers and ease of incorporation into the economic study, led us to investigate the interrelationships between rice-fish farming and chemical fertilizers in their effects on rice production.

Some of the important findings from this project were not a formal part of the research outline just described. The on-farm researcher is in a position to gain important insights which are not part of the planned research program. His/her eyes, ears and mind must therefore be always open.

Data Collection

General Considerations

Various data categories were collected during the project (Table 1). While not an exhaustive list, it may be of some use to the researcher in setting up rice-fish trials. Some observations on data collection are given below.

The question of precision in data collection merits consideration, particularly in farmer-managed on-farm research trials. The more precise the estimates are, the better. Precision can be accomplished through direct measurement by the researcher. However, when applied too strictly, this approach can lead to problems especially in on-farm conditions. Such an approach can place excessive

Table 1. List of data collected in the rice-fish farming systems project.[a]

Rice seedling
- Date
- Variety
- Weight
- Cost or value of rice seeds (farmer's estimate)
- Fertilizer (formula; amount; cost and date applied)
- Number of persons and time spent for plowing/harrowing/seeding
- Hiring costs/time (if applicable)
- Get information for whole farm and experimental plots

Rice transplanting
- Plowing
- Harrowing
- Pulling
- Transplanting
- Number of persons (including hired) and time/costs in each operation
- Get information for whole farm by parcel and experimental plots
- Fertilizer (formula, amount, cost and date applied)
- Variety in experimental plots

Weeding and other activities
- Number of persons, time/costs
- Get data for whole farm by parcel and variety and for experimental plots

Rice harvest and postharvest operations
- Harvesting
- Gathering
- Threshing
- Cleaning
- Number of persons (including hired) and time/costs for each operation
- Record for whole farm by parcel and variety and for experimental plots

Special preparations for rice-fish
- Digging trenches/ponds and raising dikes
  - Number of persons and time spent
  - Number of persons (including hired), time/costs
  - Other costs
- Dimensions of trenches or ponds (if applicable)
  - Installation of traps, filters or drains
  - Number of persons and time/costs
  - Other costs
- Equipment used for fish
  - Number of persons and time/costs (if applicable)
  - Lifetime of equipment
  - Other costs

Field maintenance
- Date and operation done
- Number of persons and time/costs
- Other costs

Fish stocking
- Type of species (number; size/weight and cost)
- Location/plot stocked
- Date released to field (if applicable)

Fish feeding
- Type of feed, amount, date applied (if applicable)
- Location/plot applied
- Time spent in buying, preparation and application
- Other costs

Fish harvesting (stocked/wild species)
- Costs of equipment/hiring (if applicable)
- Number of persons and time/costs
- Date
- By species: number/weight (will usually have to depend on farmer's estimate)

Rice yield
- Farmer's estimate by variety and plot
- Yield component data (in each plot)
  - Height of ten plants
  - Number of tillers in ten hills
  - From ten panicles
    - Length of each number of full and empty seeds in each
    - Weight of all full seeds in ten panicles
  - Harvest date of sample
  - Number of hills per sample
  - Weight of harvested and threshed sample
  - Moisture content of threshed sample

Sales
- Rice (date; variety; amount sold, unit price and income)
- Fish (date; number; weight or size, unit price and income; utilization)

Other costs

Other relevant information

[a]Most data listed here were recorded in the course of our project. Other relevant data may have been omitted from this list. The best rule of the thumb for the research is: when in doubt, record!

demands on the resources of the research team. Performing all the required measurements may become impossible. In other cases, the team may ignore important, relevant information because they are spending too much effort to achieve unnecessary high precision. Such an attitude can also interfere in the activities of the participating farmers. Results from such a study could then lead to erroneous conclusions or even jeopardize the basic aims of the research.

An example will illustrate this. In our project, assessing fish production was an important part of the data collection process. Initially, we had hoped to count and weigh all fish caught by each participating farmer. However, farmers caught fish whenever they felt the need. If we insisted on the original plan, one of the two things would have happened: either 1) farmers would have cooperated, thereby eating protein less frequently and possibly missing opportunities to dispose of their fish profitably, and would have risked high fish mortalities or excessive standing stock at the end of the growing season; or 2) more likely, they would not have cooperated, and to preserve harmonious relations, would have led us to believe otherwise! In either case, the value of the research program would have been open to serious question.

We decided to use farmer's estimates. These will be less precise than direct measurements and will tend to make comparisons of different phenomena among farms highly inadvisable. Error in farmer estimates can be reduced by visiting farmers frequently and calibrating farmers' estimates by measuring samples when possible.

Are farmers' estimates credible? Since they were the most important single source of data in our project, this question can be addressed at some length. The researcher can sometimes check these estimates but it should be done cautiously for diplomatic reasons. The farmer himself will sometimes provide data for such checks. During our project, separate and independent estimates of the same quantity sometimes came from different members of the same family, or from the same individual at different times. These estimates were usually very similar and often coincided. When there was an important difference between estimates, the estimate from the individual most directly involved in the activity was used. In another example, farmers often estimated the size of fish caught by guessing the number per kilogram. If fish were caught when the researcher was present, this guess could be easily checked against the measured weight of the fish. Farmers' guesses were normally highly accurate.

The accuracy of the farmers' estimates will depend on the amount of time the researcher spends with the farmers. Field workers should be strongly encouraged to spend their time in the field rather than in the office. If they can spend part of their nonworking time with farmer-cooperators, so much the better. Visits must be frequent. People tend to recall recent events more accurately and in more detail than those of the more distant past. In our project, farmers were visited roughly every week. This was not often enough. More visits would have resulted in better understanding of the farmers' situations, more conclusive research, and more effective servicing of their needs.

The researcher should spend a reasonable length of time per visit with each farmer. Time spent in casual conversation is rarely wasted. The farmer is in a much better position than the researcher to make relevant observations on his farm. Spending more time with the farmers gives the researcher a better intuitive understanding of their situation and problems, and a better feeling for the appropriateness of possible solutions to their problems. As the farmer and researcher become better acquainted, the two-way flow of beneficial information is bound to increase. Finally, if the researcher is sincerely interested in the farmer's welfare, the farmer normally will not take long to recognize this and see that it is to his advantage to keep the researcher well informed.

In some cases, a farmer may deliberately obscure or distort information. When this happens, the causes are worth considering. If the farmer in question appears to be a pathological case, it is probably better not to work with him. On the other hand, people are not likely to work against what they see to be helpful to them. In cases of deliberate noncooperation, the researcher should consider the possible consequences of his work. Building trust can take time.

The problem which the experiment addresses must be of noticeable importance for experimental results to have much meaning. Hence, research on the effects of fish on a particular rice pest or disease should be conducted at a time and place where the problem is important. Otherwise, as Chapman (pers. comm.) indicates, the results will not show much. On-station research is better able to provide precise answers to specific questions.

Control of background variation and precision in estimation are more easily achieved on-station. Such research, however, is not likely to be a good predictor of how a new technology will perform once extended to farmers. Researcher-managed on-farm research allows the experiments of interest to be conducted over a wider range of agroecological conditions. Greater background variation and reduced precision in estimating may apply, relative to conventional on-station research. However, unless a genuinely farmer-managed trial is included in such research, the data collected cannot be said to apply to genuine on-farm conditions. They are, perhaps, better considered as on-substation trials.

It is unwise to draw a distinct line between data collection and analysis in on-farm research. The two should be interactive. More than in on-station research, the senior researcher should be regularly involved in field work. Surprises must be expected and accommodated. If the researcher cannot spend adequate time in the field, field workers should have the freedom to make necessary decisions. They should also be involved in data analysis, as they have the best intuitive understanding of the factors affecting the results.

Data Collection in the Project

The equipment needed to conduct rice-fish research varies. Reliable transport is normally required, particularly in on-farm situations, although there are exceptions. The absence of reliable transport can sometimes lead to positive results. In 1984 and 1985, our project delivered almost all the seed fish raised by participating farmers. Since there was no truck based at Ubonrachathani, we normally had to depend on the kindness of others. We encouraged farmers to get their own fish during the last year of the project because of transport problems. Farmers who followed this suggestion received their fish more promptly and had fewer problems with poststocking mortalities than in previous years. The benefits derived from their fish culture systems were enhanced because we did not help.

When a research team is faced with limited resources, equipment must sometimes be shared. In our project, field workers did not need a measuring tape at all times and scheduling its use caused no problems. However, each field worker should be equipped with spring balances (5-and 20-kg capacity) at all times.

No matter what the research topic was, estimating areas of experimental plots was an important part of the data collection. All sides of the field were first measured. Angles between adjacent sides should also have been measured with a compass, but this was not done. Instead, the shape of the field was sketched at the time of measuring. Next, a scaled drawing of the field was made. If problems arose at this point, the field could be rechecked. Given a satisfactory drawing and a field of irregular shape, the field could then be divided into a number of triangles and rectangles whose areas could be summed to provide an estimate of the entire field. When the shape of a field approximated a triangle or a rectangle, this task was considerably easier.

Inputs were monitored by type, amount, time and/or money spent. Most data were based on farmers' estimates. When possible, the farmer's units of input were used. Hence, a farmer could say the number of buckets of manure he had applied to his system. By weighing one bucketful, the researcher could estimate the weight of manure applied. The number, size and cost of fingerlings by species were easily available. Farmers could remember the costs of purchased inputs with considerable precision.

As previously described, fish production estimates were based primarily on farmers' estimates, supported by weighing samples caught when the researcher was present. The researcher normally should be interested in the number and average and total weights by species, in a catch. If the farmer can provide two of these quantities, the researcher can calculate the third. When few fish are caught for a meal or sale, the number of fish and their sizes are usually given. When larger catches are made, total weight and average size by species are more commonly estimated empirically. Estimating the relative importance of each species in a large catch is more challenging but farmers can normally give a reasonable estimate of catch, percentage by species and by number or weight. This job is facilitated if the catch is sold, since the farmer usually remembers with fair precision how much he received for the fish, and fish price per kilogram or per hundred fish.

It would be desirable to know the total rice yield from each experimental plot. In practice, this is not easily achieved in on-farm trials. Rice harvesting season is of limited duration. Both farmers and researchers are very busy at this time. Neither side needs additional tasks. Despite this, few farmers could provide estimates of total plot yield. In ideal situations, the rice harvested from each plot was threshed separately and the number of buckets counted as it was stored. More often, farmers could count the number of bundles of rice harvested from a plot and estimated yield on this basis. In most cases, however, no such estimate was available. Therefore, in the experimental plots on each farm, project personnel took samples in order to compare overall rice yield and various yield components among treatments. Four stakes connected with rope were used to mark each rectangular 8-m^2 (4 x 2 m) sample. Four samples were normally taken per 1,600-m^2 plot, with a minimum of two samples taken unless the plot was extremely small. The sample yields were counted, measured or weighed, and the average multiplied by the plot size to obtain total yields.

To place monetary values on fish and rice production, sales data were monitored. Data of interest for fish included: farmer, sale date, species, number, size, weight, price and utilization. Variety, sale date, weight, unit price and income were recorded for rice. When possible, time and money spent by the farmer in the course of the sale was noted.

As part of the study on fish stocking densities, we attempted to monitor the growth of the fish through regular sampling. In practice, this did not work out. Catching an adequate sample of fish from a ricefield proved challenging beyond our resources.

Data Analysis

General Observations

Rice-fish farming research will normally be interdisciplinary. Scientists, technicians and farmers should work together to interpret the results. Here are general observations on data analysis.

Data are best analyzed as soon as possible after they are collected, while memories are fresh. This also allows everyone to benefit from the findings as quickly as possible. When personnel are limited, conflicts can arise between data collection and analysis. The researcher must decide, in such a case, which gets the priority. He/she must remember that the data, once collected, can be analyzed later, while the collecting cannot be delayed if the research is to proceed.

In on-farm research situations, nontraditional approaches will sometimes be needed in analyzing and collecting the data. The researcher should also take note of any other related phenomena encountered in the course of the research and apply these in interpreting results. Such peripheral information may be more important than the originally planned research questions. Researchers should be flexible to use additional, relevant data. Circumstances may render the researcher unable to address the original research question or may force analysis of the data in a way other than planned. These possibilities should be anticipated.

While statistics can often be applied to on-farm research data, this should be done with caution. Statistical nonsignificance can be expected to occur frequently. This should not be taken as evidence that there are no differences between treatments being tested. The data can still be used or reworked to reduce uncertainty, suggest probable tendencies and pose questions which can be addressed in subsequent research. Nontraditional ways of answering some research questions will be needed.

An increasingly popular way of assessing the appropriateness of a new technology is to quantify the level of adoption of the technology by the target group. The researcher attempting to address such a question will need to have a comprehensive approach. Important insights can be missed if researchers insist on a traditional means of assessment.

When results are being interpreted, they should be discussed with the farmers who participated in the work. This can only be mutually beneficial and is especially important if the findings may have an immediate or great influence on the farmer's situation.

Interfarm variation is great and uncontrollable. The on-farm researcher is advised to take this as an axiom, and conduct all aspects of his research accordingly. While variation may be great within a farm, it is normally more controllable. Hence, unless the point of the research is to compare different farms in some way, the researcher is advised to make research comparisons within a farm and to repeat these over a number of farms. Comparing the effects of two different treatments from two different farms will normally not show much. If such interfarm comparison must be made, the researcher will normally need a large sample of farms in each treatment. If the researcher considers the farms as simple treatment-by-treatment replicates, treatment differences will normally be obscured. While such pooling of farms can be done as an intermediate step in the analysis, the researcher will be making a serious mistake if he does not consider interfarm variation at par with treatment effects as factors in the analyses.

Data Analysis in the Project

To assess the economics of rice-fish farming, the first step, once the data were collected and assembled, was to place time and/or money values, as appropriate, on all production inputs. Some may argue that all time inputs should be equated to money before proceeding further. This could have been done but it seemed more worthwhile to assess time-related factors in other ways. Some time inputs required considerable, uninterrupted blocks of time and could have competed with other activities. Others, particularly fish feeding, required frequent, short time investments which did not compete with other farm activities but whose seasonal sum could be very important. Assigning the same opportunity cost to both types of investment was clearly inappropriate and guessing the costs of noncompeting inputs did not seem worth the effort.

Assigning monetary values to purchased inputs could be done directly. If only part of a purchase was used in the experimental plots, farmers' estimates were used to generate the required data. Once all inputs had been equated to units of time or money, total time and money inputs were summed by farmer and treatment.

Fish catch values depend on location, farmer, year, month, species, size and utilization of the fish. While sales data could be used directly to estimate the value of many catches, no representative sales were made in many cases. Formula based on overall averages could often be applied, but these data had to be balanced by common sense. Sometimes values had to be assigned somewhat arbitrarily.

Assigning monetary values to rice yield was normally less complicated. Most farmers sold at least a little of every important rice variety grown. At times, a number of sales were made from the same crop. Overall price per kilogram was then calculated by dividing total sales income by total weight sold. This unit price was multiplied by plot yield to estimate the value of rice production. When possible, expenses incurred by the farmer in the course of sales were subtracted from sales income, before estimating the yield value.

On each farm, the economics of each treatment could thereby be assessed, based on plot area, time inputs, monetary inputs, and values of fish and rice yields. Net benefit was calculated by subtracting monetary inputs from yield values. Net benefit per unit area and per man-day invested were then calculated by dividing net benefit by the appropriate quantity.

The economics of rice-fish farming and rice monoculture were compared. Net benefit per man-day invested were also compared with the prevailing daily wage rate at the project site.

Farmer-by-farmer comparisons are important. These data should still be summarized for the entire sample of farmers by location. Such summary can also be done by grouping farmers in other ways. Group totals for area, inputs, production values, and net benefit can be generated by simple addition. These sums can be divided by the number of farmers in the group to get averages per farmer. To assess group tendencies for net benefit per unit area or per man-day, total group net benefit was divided by total group area or total time invested by the group, as appropriate.

Our project operated at rainfed and irrigated sites. Farmers at rainfed sites had only one growing season to culture fish, but caught fish also in the dry season. Farmers from irrigated farms raised fish all year, although this could be divided conveniently into two seasons, separated by predictable water shortages in December and May. The economic performance of the two sites had to be compared on an annual basis. Figures from the rainfed area could be used directly. The calculations for irrigated farmers had to be done first by season. Figures for the rainy season and the subsequent dry season are combined to compare with the rainfed situation for the same period. Annual values were the sum of both seasons, except in the case of net benefit per man-day, where annual net benefit was divided by annual time invested.

Not all farmers in a given sample could supply the required data. For instance, while net benefit could be calculated for the entire sample, estimating plot area for every farmer was not always possible. The sample of farmers used in assessing area-based figures had to be reduced accordingly.

If two practices are being compared for each of a group of farmers, the caution in using statistics applies. Interfarm variation will be important. The difference in net benefit between two practices may be consistent from farm to farm and this will be the mean reflected in net benefit per farmer for the two practices. Sample standard deviation, however, may well obscure this important variation.

With increased farmer sample sizes in the second and third years of the project, the economic performance of rice-fish farming and rice monoculture became more difficult to assess. Fish inputs were normally monitored with acceptable accuracy, but those to unstocked plots were based on inputs of the entire farm prorated to the area of the plot. This was a problem at the rainfed site, where the entire farm often consisted of two or three parcels of land which varied greatly in nature and treatment. It became clear that more attention had to be paid to specific unstocked plots. Another problem was that most farmers could not give estimates of total plot yield. Sampling the yield was of some help, but sampling error was considered too important for much credence to be given to sample-based yield estimates in the economic analysis. Hence, the main thrust of the research which is the comparative economics of rice-fish culture and rice monoculture should be modified to an assessment of the economics of fish farming in ricefields. In some cases, the planned comparisons can still be valid, but overall, they are better considered exercises.

On-farm trials on fish stocking densities with various species compositions were done. It came as no surprise, therefore, that when growth and production estimates were plotted against stocking rate, the scatter of points was so great as to make conventional statistical analyses superfluous. Nonetheless, trends were suggested and could be put to good use. The most important was the data showing the range of responses achieved under genuine on-farm circumstances. From the farmer's viewpoint, they were made aware of the potentials and the risks associated with different stocking practices.

In on-farm studies, data often lead to unplanned analyses which add to the value of the research. Throughout our project, for instance, fairly good records of the size and number of fish stocked and of the number of fish recovered by farmers and species were kept. The resulting data gave clear evidence of species dependent effects of stocking size on recovery rates. Farmers can use such knowledge when they buy seed fish.

The effect of rice-fish farming on rice production was assessed in different ways. Comparisons were made between stocked and unstocked plots for the same variety of rice, on the same farm, and then repeated for other farm/variety combinations.

At the close of the 1984 rainy season, two farmers were able to give plot-by-plot estimates of rice yields from a number of stocked and unstocked fields. In the following dry season, the previously unstocked fields received fish for the first time. When fish yield estimates were given at the end of the dry season, expected rice yields for the newly stocked fields were calculated.

For each field which had been stocked in the previous rainy season, the ratio of dry season rice yield to rainy season rice yield was first calculated. If rice-fish farming had no effect on rice yield, this ratio can be used to predict yields from other fields. Hence, it was multiplied by the rainy season yield for each unstocked plot to estimate expected yield in the dry season when the plots in question were newly stocked with fish. In all of five cases, rice yields in the newly-stocked plots were higher than expected.

It is inappropriate to use rice yield component sampling data to project absolute plot yields. Comparisons between treatments, however, could still be made. This was done, because these were the only data available for all 25 farms. Average sample yield could be calculated by treatment for each variety on each farm. The ratio of fish yield to unstocked field was then calculated for each farmer/variety combination. If a farmer grew more than one rice variety with fish, the lowest ratio was used in the analysis that followed. A frequency distribution of these ratios was then plotted, and the mean ratios for each site and for both sites together were calculated.

The means for each of the two sites differed from the overall mean by less than a percentage point. Rice yields averaged about 10% higher in rice-fish fields. In 64% of the farms (16 out of 25), yields from rice-fish fields were higher than from unstocked fields. Percentage differences in yield between rice-fish and unstocked fields ranged from -29% to +98%. Despite misgivings about yield component sampling, these figures seem to reflect reasonably well the real conditions. The need to apply more sophisticated statistical analyses is questionable.

Computers

The computer is a very valuable tool which can hopefully be put to increasingly widespread use. Computers work well when all the data in a given category are to be processed in the same way. They do not, however, accommodate qualifying footnotes to some of the data. The researcher generating the data and the one entering them into the computer must be aware of the nature of the data and the importance of such qualifiers. Only then can they decide whether to enter the qualified data as is, modify them, or eliminate them from the computer analysis.

Data should be processed promptly. If there are delays or long distances between data generation and processing, some details may be forgotten despite the best intention and the most careful recordkeeping.

By using a computer, the researcher will tend to spend less time thinking about his raw data and the circumstances under which they were generated. To compensate for this, the field worker who generated or collected the data should somehow be involved in processing the data and interpreting the results.

Computers should be used with caution when there are isolated, nonsystematic instances of missing data. When such data are frequently missing, making the necessary corrections to the computer's results can be time consuming and confusing.

Computer logic works well in applying a sample statistic to a population from which the sample was taken. How to estimate the parametric value for a population for which no sample is available is more challenging. At times, some sort of overall averaging can be used. However, as indicated earlier regarding fish catch values, the computer must sometimes be helped along by the judgment of the researcher.

Role of Project Personnel

Roles will depend upon the circumstances surrounding the project, and must normally be defined by the senior researcher in charge of the project. While such roles can be nicely planned on paper, difficulties can arise when these plans are implemented. Often the senior researcher is prevented from adequately participating in the research by other responsibilities. The important work of data-generating or data-collecting is then delegated to junior field assistants with limited responsibilities. By accepting these statements, we may be accepting that the value of the research may be compromised. If we are realistic, however, we must accept that the situation will not change overnight.

One possible solution is to assign the senior researcher in charge of the project, to a location as near as possible to the research site. In this manner, the researcher could respond to circumstances reasonably and promptly, would not be excessively distracted by other responsibilities, and thus could spend more time in the field. Field assistants should be delegated adequate freedom and responsibilities. While they may be lacking in background or experience, they are in the best position to respond immediately to unexpected changes and to make on-the-spot decisions.

The senior researcher can provide the field staff with training and direction. The field staff should be expected to submit written reports regularly, in order to allow all concerned to evaluate the progress. The senior researcher should regularly meet and communicate with farmer-cooperators and field personnel.

Chapter 6
Working Group Reports

Working Group Reports on On-Station Research Methodology*

BARRY A. COSTA-PIERCE**
CATALINO R. DELA CRUZ
International Center for Living Aquatic Resources Management
MCPO Box 2631
0718 Makati, Metro Manila, Philippines

COSTA-PIERCE, B.A. and C.R. DELA CRUZ, Compilers. 1992. Working group reports on on-station research methodology, p. 415–424. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Introduction

Two working groups on on-station research methodologies in rice-fish farming systems were convened at Ubonratchathani Province, Northeast Thailand (chaired by B.A. Costa-Pierce) and Nueva Ecija, Philippines (chaired by C.R. dela Cruz). This report is a summary of the findings.

Researchers working on-station should understand, monitor and continually update their knowledge of the rapidly changing dynamics of rice-fish farming systems being operated by farmers. There is an abysmal lack of knowledge about the transferability of existing rice-fish farming systems from one climatic, soil, or socioeconomic region to another. Adaptive research and the potentials of south-south technology transfer have not been carefully considered. An example of this is taking the best available lowland, irrigated concurrent rice-fish system from Indonesia to India.

There is a danger that if on-station research exists in a vacuum, e.g., without routinely updated information from the field (on-farm surveys), improper or irrelevant research topics could be chosen. There is therefore a continuum of research efforts and dialogue needed between workers on-farm and on station.

Surveys collected from farmers should be conducted over the long term (three to five years) in a continuous monitoring program in order to capture the biological and economic dynamics of existing production systems in not only seasonal, but yearly cycles. Too many studies of rice-fish systems to date have been one-shot glimpses (static surveys) of the stocking, harvest and associated net technical margins from rice-fish systems. Long-term

*ICLARM Contribution No. 476.
**Present address: 6 Hale Ohia Road, P.O. Box 1050, Volcano, Hawaii 96785, USA.

socioeconomic and biological surveys of existing rice-fish systems are urgently needed to capture the variabilities in the bioeconomic production dynamics; and how these are influenced by technological, economic, social and political changes occurring at regional and national levels and in the larger economies of nations where rice-fish culture is important. This dynamic information is essential to set a meaningful long-term research agenda for on-station work in rice-fish culture in Asia for the next twenty years.

In the shorter term, regular and small-scale surveys of rice-fish farms can help researchers working on-station to define short-term research agenda important to farmers in the region of the station which has similar climatic, soil and technical characteristics. Regular, interactive sessions between researchers conducting these surveys and those on-station conducting applied research should be made so that no major event in the production systems comes as a surprise to workers on-station. Researchers working on-station must always stay at the cutting edge, e.g., their results must have realistic values to farmers.

It was concluded by the working groups that on-station research should be a continuum with on-farm surveys. Careful monitoring of the existing rice-fish farming systems and on-station research are essential interactive enterprises.

The working group discussions defined constraints to rice-fish farming development, identified priority research areas to eliminate the constraints, and outlined possible on-station research methodologies. Identification of the role of the Asian Rice Farming Systems Network (ARFSN) in assisting on-station research in national programs was attempted.

Constraints to Rice-Fish Farming

Constraints to rice-fish culture development were defined in order to allow more effective design of on-station research. Constraints were identified as general ones, those specific to a country or region; and those specific to a particular type of system or researchable constraints. General constraints were thought to be the very broad, system-wide or institutional constraints which limited widespread adoption of rice-fish culture in the nations represented.

Surveys of the nations represented usually referred to the "thousands of hectares of ricefields available" for the "widespread adoption of rice-fish culture", as if fish culture was possible in every ricefield. In reality, each country has some general or system-wide constraints that greatly limit widespread adoption of rice-fish culture. It was felt that, while it was important to air these constraints as a matter of record, there was nothing that researchers working on-station could do to eliminate them, such as: 1) land ownership problems in the Philippines and Bangladesh; 2) seasonal flooding in India, Bangladesh and Thailand; and 3) theft/poaching in all countries.

The working group felt it very important to state that a wide diversity of rice-fish systems exists; and these systems are extremely site- or region-specific. The diversity of rice-fish culture systems and traditional management systems developed was considered important and in need of preservation and improvement, rather than any massive inputs of new technology. In this regard, the working group undertook a country-by-country assessment of research needs to define more specifically the diverse regional needs that exist. Specific constraints to the improvement and further development of rice-fish culture were then reviewed, and the three most important constraints prioritized in each of the nations represented (Table 1). The constraints identified apply to shallow water rice-fish farming environments.

A review of the constraints posed by the working group shows, quite unexpectedly, that pesticides and modern rice

Table 1. Constraints to rice-fish farming systems research in participating countries.

Country	Constraints
Bangladesh	Basic ecology of fish culture in ricefields not known; lack of knowledge of the best fish species and stocking rates; no knowledge of the size of seed fish to be stocked for highest production; natural cycle of flooding makes fish difficult to contain in ricefields; pesticides not considered a major constraint.
India	Field engineering technology (trench design, land topography, gates, etc.); water management; lack of knowledge of the existing aquaculture production systems in rice-fish farming; availability of seed fish; no rice-fish technology for acidic and saline soils; limited knowledge on economics and lack of hard data to provide to banks for credit; pesticides not cited as a major constraint.
Indonesia	Low fish and rice production due to poor soils in many areas; optimal rice-fish system in terms of engineering (for both fish and rice) not known; water management; enhancing compatibility and management between rice and fish; genetically good quality of fry/fingerlings for rice-fish culture; fish predators; fish parasites and diseases; toxic insecticides still used in intensive rice production; selection of fish species outside West Java which may not be optimal; pesticides not cited as a major constraint since 1980, but had a national impact from 1974 to 1979.
Philippines	Small tilapia at harvest and low recovery rate; availability of quality seed fish; water management; rice pest control in rice-fish farming; financing and economics of rice-fish farming; profitability level; pesticide use (although methods have been developed to identify pesticides that will not harm fish).
Thailand	Fish culture in the ricefields not well developed or known, especially on stocking rates, fingerlings size, and the most suitable species as well as combinations; economics of rice-fish farming still not known or is suboptimal; fish diseases; pesticide use was not considered a major constraint although pesticides were used in some lowland irrigated areas and not in upland rice-fish systems;

technology (mainly the widespread adoption of high-yielding varieties [HYV] of rice) were not major constraints to the adoption of rice-fish culture in all nations represented except the Philippines. The rapid development and promising economic results of rice-fish systems that can thrive within the short production periods of HYV rice such as intensive rice-fish nursery systems (Indonesia), use of ricefields as fish hatcheries (Indonesia, Thailand) and prawn nursery systems (India) were cited as examples.

Priority Research Areas

The working groups identified research topics that could be addressed on-station to help solve the three major constraints identified earlier. Discussions were also held on research needs in the general field of rice-fish culture, e.g., topics that were of interest to all countries and transcended any specialized national or regional interests.

During the second working group session, participants identified three major research areas: ecology, culture systems and rice-fish field engineering as priority research topics. This group also worked out two examples of research methodologies.

Bangladesh

- Methods to enhance and manage natural fish stocks that enter ricefields during floods. Studies of interactions between cultured and wild fish stocks that enter ricefields during floods are needed.

- Integration of fish into existing farming systems. Research on the amount of inputs available on-farm and those entering the farming system are needed, including a calendar for all farming activities.
- Development of profitable rice-fish systems in rice-producing regions where irrigation systems exist. Research on economic yields rather than simply biology. It was felt that the development of rice-fish farming in rainfed regions be conducted on-farm rather than on-station.
- Development of rice-fish culture as nursery systems that support and complement the full development of inland aquaculture.
- Research into predatory/prey relationships in rice-fish culture, and methods to prevent the predation of cultured fish by wild predators.

India

- Development of a model for rice-fish culture within each of the country's major agroclimatic zones, focusing on the most economically optimum land use and plot size. The goal is to attain the highest rice and fish production within, and consistent with, prevailing social, economic and environmental conditions. Special attention must be given to water management and economics of water usage.
- Engineering and economics of harvesting fish from ricefields. This would include research on harvesting when rice is still in the field as well as harvest of fish after rice harvest.
- The effects of water management and fish on soil fertility and biological control. Comparisons of rice-fish and rice monoculture in terms of the effects on soil properties important for optimal rice production under various environments. Integrated approaches to enhance rice-fish system productivities without affecting rice production; studies on nutrient and energy flows.
- Ecology of wetland ricefields especially aquatic ecology, detrital food webs and rice stem-associated fish-food organisms. Research on available natural food niches that exist in the aquatic ecosystem that could be managed to ensure high fish production in ricefields. Design of profitable polyculture systems based on analysis of these ecological results.
- Fish biology and stress factors with respect to the increasingly short fish production cycles dictated by the HYV rice, and the contribution of these stress factors to fish yields with and without supplemental feeds.

Indonesia

- Bioeconomics of supplemental feeds in the various and diverse rice-fish culture systems in the country.
- Ecological carrying capacity of fish in ricefields to understand the optimal stocking and harvesting times for fish.
- Economic optimization of the area of trenches and sumps in a ricefield to attain high fish and rice production.
- Optimization of water management for high economic yields of rice and fish under continuous and intermediate water flow conditions.
- Rice pest and disease control by fish. Integrated pest management versus chemical control on fish and rice.
- The effects of HYV rice on fish production. Effects of different fish species on rice production.

Thailand

- Proper stocking density, fish size and choice of fish species giving the most profitable system.
- Polyculture of *Puntius* and tilapia (*Oreochromis* spp.) and stocking densities.
- Technology and economics of integrated chicken-rice-fish systems.
- Effects of commonly used pesticides on fish in ricefields.
- Use of grass carp (*Ctenopharyngodon idella*) for weed and pest control in ricefields.
- Development of ricefield hatchery and nursery systems (rearing fry/postfry to fingerlings).
- Lime requirement as buffer for alkalinity.
- Lifting fertile mud from ponds to fields.
- Harvesting and herding techniques.
- Water management, storage and distribution.
- Fish control in seasonally flooded areas.

Philippines

On-station research in the Philippines was mentioned as somewhat of a special case since the ICLARM/IRRI/CLSU Rice-Fish Culture Project funded by the Asian Development Bank (ADB) and, having a regional emphasis, is based there. However, many of the regional goals of the rice-fish project are also the most important research topics in rice-fish culture in the Philippines.

- Proper use of organic fertilizers and pesticides.
- Fish as biological controls on weeds and pests using mono-culture and polyculture systems.
- Evaluation of different rice planting patterns in relation to fish production in ricefields.
- Evaluation of water use and management in relation to fish and rice crops.
- Evaluation of new fish species and tilapia strains.
- Monosex culture (hormonal manipulation).
- Supplemental feeding (farm wastes and by-products).
- Use of ricefields as nurseries for economically important fish species.
- Nutrients cycle/energy flows.
- Feed ecology, food habits of fishes and growth assessment.
- Pond refuge for seed and growout systems.
- Fertilization method for rice-fish system.
- Fish sampling and harvesting techniques.

Korea

- Selection of appropriate rice varieties.
- Spraying method and time.
- Polyculture of tilapias and catfish in ricefields.
- Planting pattern/market size and market analysis.
- Fertilizer levels.
- Rice-fish models.
- Stocking densities.
- Methods of preventing fish escape.
- Method of increasing water temperature and management.
- Food chain.
- Harvesting methods.

Malaysia

- Food web in rice-fish.
- Nutrient cycle, fish feeding habits and rice growth.
- Dynamics of primary and secondary productivity.
- Weed ecology in ricefields (rainfed).
- Indicators of probable yield.
- Role of fish refuge (pond and trench) to increase productivity.
- Size of refuge in relation to rice-fish field.
- Dikes, feeder, trenches.
- Size and length of pond refuge.

Special Research Topics

The working groups defined some special topics that need concentrated, long-term on-station research efforts. These special topics were identified as those that transcended regional or national interests, and have great importance in Asia. Unfortunately, a representative from China was not present during the sessions to assist the working group in choosing relevant topics.

The group noted the heavy bias towards identifying important research topics concerning the fish subsystem of rice-fish culture. Some possible research areas mentioned to improve and better understand the rice subsystem were:

1. Investigation of the best fish species, stocking rates, cropping systems, etc., to improve rice yields and grain quality.
2. Development of new rice varieties for different rice-fish systems, e.g., develop a rice variety that would flourish in ricefields where increased soluble organic nutrients rather than inorganic fertilizers are more concentrated due to fish bioturbation activities.
3. Development of a stumpy rice that will have more of its above-ground biomass under the water so that fish could get more habitat, and rice predators could be more effectively controlled by fish.

It was mentioned that a critical review of the published literature on the biological aspects and reputed advantages of rice-fish farming would likely show little sound scientific basis for many of the claims made. In particular, reports claiming higher rice yields or higher rice yields per number of remaining rice plants in the ricefield (fewer rice plants are usually present in rice-fish culture) due to nutrient mobilization by fish bioturbation of ricefield sediments; reduction of weed infestation; and rice pests and diseases need to be verified for future planning and systems design.

Furthermore, other important biological research to be accomplished on-station were discussed as follows:

1. Efficient use and division of labor in different rice-fish systems.
2. In regions where labor is a problem, research into the mechanization of rice-fish culture systems.
3. Low-cost diversification of rice-fish systems for greater economic benefits, e.g., including farm animals.
4. Full assessment of coastal environments for their potentials for brackishwater rice-fish farming.
5. Rice varieties compatible with sufficiently long fish production cycles.
6. Culture of frogs in rice-fish systems as a means of increasing profits and controlling insect pests. The use of frogs for insect pest control is, however, questionable because they also eat friendly insects such as spiders and can eat small fish.
7. Development of a rice-fish nursery system technology for tilapia, *Puntius*, Indian major carps and Chinese carps.
8. Development of technologies to increase the poor recovery rates of fish from rice-fish systems.

An important general comment was made by the group. If the primary goal of rice-fish systems is to increase the nutrition of rural people, then systems that provide the largest total biomass of fish in the shortest possible culture period should be researched. In other words, research emphasis should be based upon production of "small fish" in short production cycles. The choice of fish species and systems used could be greatly affected by policy decisions made by rural planners and officials promoting rice-fish culture. Researchers should be aware of this, and take a role in supporting national and regional goals.

The priority research areas identified by the group were heavily weighted towards recommendations for lowland, irrigated ricefields. The research needs of rice-fish systems for deepwater (0.5–2.0 m or deeper) and brackishwater environments, including the management of these and other seasonally important ricefield fisheries, were not discussed. No guidelines have been developed for these potentially important systems and, in some cases, no technologies exist. Small, specialized research stations located in areas where these systems are of potential importance could make a great impact at a very low cost.

Research Methodology

Discussions on research methodology were held. It was stressed that in many cases, successful research had been carried out but that development had not followed. At the experimental design stage, sufficient information (a database) must exist about current farming situations and systems in order to design meaningful on-station research. Experiments must be designed while considering both the existing traditional knowledge and management systems (ecological and social). Research methods which preserve and enhance the existing diversity and flexibility of rice-fish culture and ricefield fisheries are recommended. It was mentioned that rice-fish research culture has rarely (or never) been conducted as a team effort but has been (often) dominated by biologists. An ideal research team in this regard would compose a fisheries production biologist, a rice agronomist, a sociologist and an economist.

It was suggested that rice-fish farming systems that incorporate the best available or most socially acceptable, most profitable existing technology be replicated on-station in each of the major climatic zones of the countries in the region. This, of course, requires knowledge about the existing, workable and highly profitable systems available in the region. Once set up, however, researchers in the region could standardize data collection and analysis systems as best as possible so that interregional biological and economic comparisons could be drawn and experiences shared.

The group addressed what type of specific biological and economic data should be collected in the rice-fish systems set up across the region. It was felt that once the best available and accepted systems were set up on-station, the types and frequencies of biological and economic data collected should be standardized throughout the region. However, when pressed by the chairman to provide specific details, the group felt strongly that specific research methods and protocols could not and should not be formulated in a few hours in a very broad-based and pioneering workshop such as this. It was suggested that methodologies could be the subject of an entirely separate workshop which will review past as well as currently operating methodologies in the region, and formulated a plan of action. It was also felt that the methodologies, goals of projects and their donors were so diverse, and likely applicable to a local level only. Specific methodologies should be formulated only at the time of funding and localized to each nation represented.

An important concern was expressed that the current rice-fish systems will not last more than 10-20 years due to rapid technological changes. For sustainability and relevance, on-station research should be focused on, stay in touch with, ahead of, or accommodate changes in the existing agroecosystem into the rice-fish systems at all times.

During the second working group session, the group worked on examples of two methodological outlines for two sample research topics.

Example 1. Fish as biological control agent for pests (weeds)

1. Site description

   Information given are: the nature of ricefield environment (irrigated/ rainfed); water resource; soil and climate data; and other relevant information about the prevailing conditions at the site.

2. Materials and methods

The experimental site is described in terms of size of the development units, area and method of preparation. The fish and rice planting are related to each other, i.e., time indication of fish stocking, sampling and harvesting in relation to date of rice transplanting.

Procedures on fertilizer application, frequency and amount as well as water management which includes depth and irrigation schedule should be described.

3. Minimum data set

Information needed for fish are the species or strain; initial and final sizes; and density, recovery and yields (gross and net).

Rice data includes variety; planting distances/population/spatial arrangement; and final yield, yield components and weed impurities in grain. For weed and related information, data on weed population (initial and final species and numbers); water depth (effects of fish/weeds); turbidity (fish cause this and affect the weeds); and fish stomach contents should be recorded.

4. Research approach

Possible components of the actual research are literature reviews and experimentation. The objective of the literature review is to find out what research has been done so far on the study area and what are the important variables. Three approaches for experimentation are possible: observational studies; replicated, randomized physical experiments; and abstract experimentation.

Observational studies consist of data collection on one or a few interesting/representative experimental units. The result is a multivariate dataset consisting of a time series of physical, chemical and biotic factors (e.g., water quality, weed population, plankton populations, etc.). Replicated, randomized physical experiments follow the conventional agricultural experiments setups, where hypotheses regarding management options can be tested (e.g., the result of certain treatments compared to a control treatment). Well known samples are factorial designs, randomized complete block designs, etc. Abstract experimentation includes statistical analysis of datasets and theoretical modelling using every possible source of information (Cuenco 1979, in van Dam and dela Cruz, this vol.).

For these approaches, a variety of experimental units can be used, such as field plots, aquaria or tanks. As the traditional replicated design often does not lead to satisfactory analysis, more attention should be given to observational studies that can be analyzed with multivariate statistics.

5. Data analysis

Replicated, randomized experiments are analyzed with well known statistical methods such as analysis of variance (ANOVA) and regression analysis. Standard texts describing these methods are readily available (Gomez and Gomez 1984, in van Dam and dela Cruz, this vol.). For analysis of observational studies, multivariate statistical methods can be used. Examples are principal component analysis and cluster analysis. Applications to rice-fish datasets using these methods are rare. A few application to aquaculture and aquatic ecology are known (Milstein and Hepher 1985, in van Dam and dela Cruz, this vol.). These techniques should also be used in rice-fish research.

6. Reporting

Reports should be written immediately after each experiment/trial. This should consist of introduction, materials and methods, results and discussion, and conclusions/recommendations/plans.

7. Funding

Adequate funding must be made available before starting an experiment. It is probably better to delay the implementation of an experiment with insufficient funds than to modify the design or limit the scope just to suit the available fund.

Example 2. Rice-fish field engineering

Engineering research method on rice-fish field system was also discussed. The rationale behind rice-fish system design, construction and operation shall be known. This information will lead to how a rice-fish field system developed on-station may find application in on-farm situations.

This situation applies to a farm practising rice monoculture. At the station, when fish is introduced, changes have to be made: physical changes on the land to suit the intended rice-fish system; technical changes to make rice and fish culture compatible; and the operational changes.

From the station, the designed system has to be transferred to an on-farm system. The transfer may lead to the design of a modified system or subsystem as long as the principle behind the development of the original system is known. Certain minimum information about the new site must be obtained by the extensionist. This may lead further to examining rainfall data, evaluating the probability of getting water and other related factors.

A guide on how to approach it before starting and/or deciding how to start, needs setting the background to the problem by following a certain classification system (Fig. 1). When thinking about a new or an old system to be improved, one must always think of flows in the system. In this case, these are flows of water, fish, labor, cash and information.

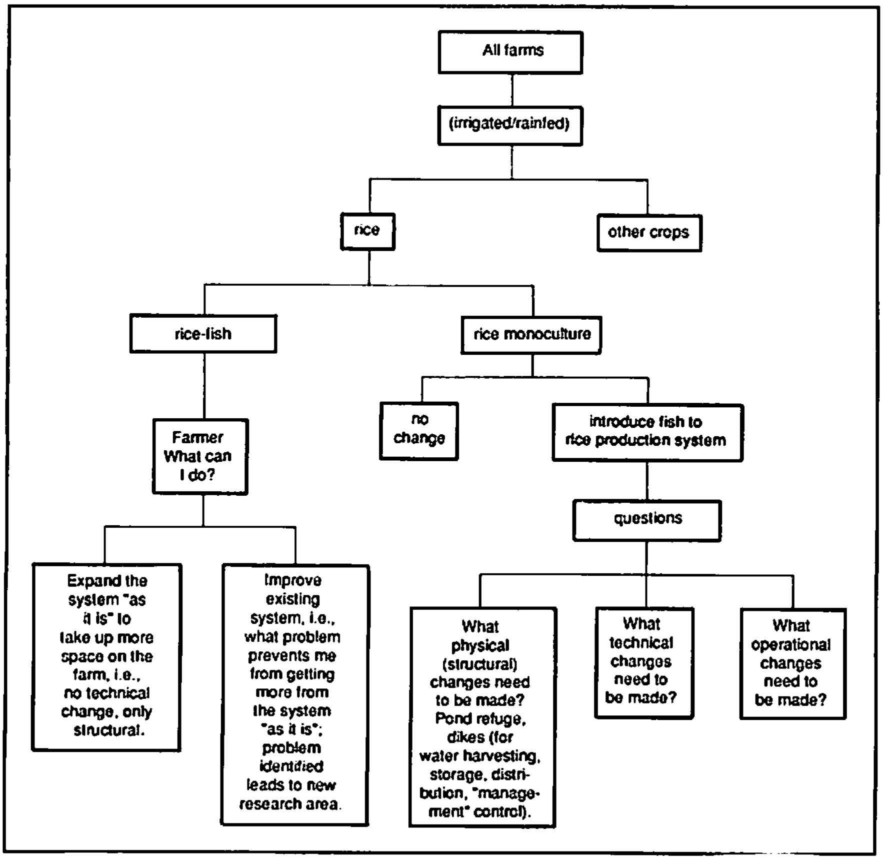


Fig. 1. An example of a classification system on how to integrate rice-fish culture in the farm.

The Role of the ARFSN

The participants expressed their views on how the network can assist them in their research:

1. Network scientists/resource persons (e.g., from IRRI, ICLARM or other organizations) can help national program scientists in setting up their research agenda.
2. The network can facilitate the exchange of information among national programs, especially between national scientists working on the same problem areas in different countries. Information would comprise research results and methodologies.
3. The network can assist national scientists with data analysis. Visits to the research sites by network scientists/resource persons can be made. On the other hand, national scientists can also visit the headquarters of international organizations. They can bring their data and analyze them with the assistance of the headquarter staff. Moreover, small workshops or trainings on methods of analysis (e.g., multivariate techniques) can be organized. Here, national scientists could analyze their data, produce a technical paper and present to the group.
4. The network scientists can provide national programs with relevant information on their research areas; help them determine research priorities based on recent developments; and raise the profile of national researchers to increase their credibility to national governments, which could result in additional national funds for research.

Recommendations for On-Farm Research Methodology*

CLIVE LIGHTFOOT

International Center for Living Aquatic Resources Management
MCPO Box 2631
0718 Makati, Metro Manila
Philippines

JOHN D. SOLLOWS**

Northeast Fishery Project
Khon Kaen Fisheries Research and Development Centre
Khon Kaen, Thailand 40000

LIGHTFOOT, C. and J.D. SOLLOWS, Compilers. 1992. Recommendations for on-farm research methodology, p. 425–432. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Introduction

Areas of importance to the utility and success of on-farm research were discussed in both workshops. On-farm research experiences discussed by the working groups raised the following issues: Farm to farm variation highlights the fact that there are many different rice-fish systems, and yet no standardized framework exists for characterizing and quantifying them. Ad hoc on-farm experimental techniques suggest the need for guidelines for on-farm research. That farmers experiment is well known and yet ways to utilize indigenous experimentation and knowledge go undeveloped. Inconclusive results from on-farm experiments prompt the examination of analytical techniques that provide greater explanatory power. On-farm research often raises questions that cannot be answered through on-farm experiments, thus a link with laboratory on-station researchers is needed.

Characterization of Rice-Fish Systems

Many kinds of rice-fish systems are found in Asia. While on one hand such diversity provides researchers with new

---

*ICLARM Contribution No. 726.

**Present Address: ICLARM Bangladesh Office, House No. 20, Road No., 9/A, (New) Dhanmondi R/A, Dhaka 1209, Bangladesh.

ideas; on the other, it makes for confusion in the reporting of results. It is very difficult to compare fish growth rates when systems vary as much as they do. Quantitative methods for clustering or grouping data could be used to characterize rice-fish systems. These methods, however, require fairly comprehensive data sets. The kinds of data required for rice-fish systems are given in Table 1.

Guidelines for On-Farm Research

Guidelines for on-farm research should not be fixed. Circumstances should modify operations and their sequence. Moreover, operations are interactive. The results from some later operations may lead to changes in, or repetitions of, earlier ones.

Selection and Surveys of Target Area

Once a target area can be defined and a target group is tentatively identified, secondary data and consultations with concerned officials and other workers can suffice for a research site to be selected.

After site selection, secondary data may continue to be useful for giving benchmark information on the area. Often, "Rapid Rural Appraisal" (RRA) provides the research team important intuitive understanding of the site and

Table 1. Data needs for rice-fish system characterization.

Physical environment	
	Water quality, dissolved oxygen (DO), temperature (air and water)
	Source of water, pH, salinity, alkalinity, acidity
	Turbidity, water hardness, water depth
	Water in trenches and on field – depth fluctuations and area of sump
	Climatic data - rainfall (amount and pattern), temperature, sun hours, length of growing season
	Landscape and physiography – relative position and slope
	Biotic (phytoplankton, zooplankton, predator population)
Human environment	
	Source of fry (buy, breeding, source of seed)
	Availability of hired labor
	Access to credit
	Distance to market, distance to fertilizer and pesticide supply, sale of fish/rice
	Theft
	Availability of extension service, farmer organization membership
Farm resources	
	Total (land, pond), status (owner, renting)
	Labor (number of labor, sex, age, education)
	Capital (cash, noncash)
Production	
	Rice yield
	Fish yield (total, distribution of size, percentage survival, farmgate price related to market prices)
	Yields of other crops, animals, distribution of farm products
Inputs	
	Rice seeds cultivated
	Chemicals (fertilizers, pesticides, weedicides)
	Fish species released, ratios, stocking rate
	Fish feeds, rice bran, fertilizer (organic and inorganic)
	Man-hour labor for fertilizer, insect/pest and weed control practices, and land preparation methods
	Accessories (nets, screen, pipes)

residents therein, and the perceived needs of the target group. RRA also helps make the ensuing formal survey more relevant and streamlined.

Formal surveys allow a more quantitative assessment of the local situation to be made. Data to be collected should be decided in recognition of the findings of the initial RRA. Examples of the type of information that might be included in a survey are given in Table 2. This is not an exhaustive list.

Site Description

Site description is always needed prior to commencing research. The effort put into this may vary, but the team must understand the biophysical and socioeconomic circumstances of the target group before proceeding further.

Site descriptions can be compiled using RRA as well as formal surveys. Agroecosystem analysis is one qualitative method widely used for this purpose.

Using data from both types of survey, a baseline reflecting the "undisturbed" situation of the target group is constructed. Subsequent surveys compare changes in farm systems and monitor progress.

Research Topic Formulation

In formulating a research topic, the team must consider many elements. The whole target area must be considered. Available technologies and the environment where it will be used should be taken into account. Relevance of the technology to the target group is an important element in formulating research. Technical feasibility, economic viability and social acceptability of the intervention must be assessed. Priority setting of technology options requires consultation with the target group that encourages them to suggest suitable research topics. Their opinion on proposed research, no matter what the source, must be sought. Finally, agreement from each participating farmer is necessary before trials can be started.

Selection of Research Cooperators

Farmers' interests and attitudes are important selection criteria. "Is the farmer only interested in free handouts?" and "Is

Table 2. Typical survey data.

Physical	Biological	Socioeconomic
Rainfall- amount and pattern	Rice varieties	Fish species and size preference
Irrigation	Weeds/importance	Prices of rice varieties/fish species
Water holding capacity of soil	Pests/importance	Availability at home and at market
Plot areas	Other living commodities/ importance	Farming/fishing/fish culture practices
Plot situations	Indigenous fish species/ importance	Land ownership patterns
Depth, volume, flow rate	Disease	Income sources/importance
Percentage/duration of inundation	Trends	Supply of seed fish
Topography of whole area covered	Cultured fish species/ importance	Security of fish price against theft, pests, floods, droughts
Soil pH	Management and inputs	Mechanism for marketing
CEC		Compensation for loss
Organic matter		Availability of credit
Soil nitrogen		Sources/availability of farm inputs
PO_4		
K^+		
Conductivity		
Salinity		

he/she capable, diligent and honest?" are important questions. Cooperators should closely represent the target group. One must avoid the situation where the sample does not represent the original target. At times, a bias towards more needy farmers may be acceptable, but such farmers normally assume additional risks with difficulty. Hence, including "progressive" farmers in the sample may provide a better test. In addition, since people's attitudes and circumstances change with time, the group represented by the original sample is also likely to change with time. Farmer selection must, finally, be a flexible process.

Farmer- and Researcher-Managed Trials

The line dividing farmer- and researcher-managed trials is not a clear one. Who should manage and to what extent depend on circumstances.

In farmer-managed trials, simple designs are advised. Between-farm variation will be great and uncontrollable. This must be accepted and should be considered a main effect like any treatment effects. Within-farm variation is also important but is somewhat more controllable. The number of treatments should be few, ideally, two: the farmer's existing practice and the new technology. Treatment levels should be flexible, but similar within each farm. The largest manageable sample of farmers should be used. Designs can sometimes be more complex, i.e., involve more treatments, but their results are likely to be less conclusive. If different treatment effects are being compared among farms, a large sample of farmers per treatment will be needed before the data will reveal significant treatment effects.

Researcher-managed trials can accommodate more complex designs, but the researcher must participate in the work frequently. However, designs should not spread researchers' efforts too thinly. Not all questions can be answered at once.

On-farm trials, especially farmer-managed ones, tend to give relatively imprecise results. A large sample size of farmers can accommodate some of the error here. Conducting trials across a range of environments can also help. While precision should be as high as prudently possible, it should not interfere in the farmer's management.

Research Inputs

Researcher-managed trials should set production input levels to reflect what farmers can afford or will be willing to invest. Under farmer-managed situations, investments should be as low as possible to give the technology a chance to be adopted after the trial period.

Any financial risks associated with experimentation should be absorbed by the researcher. On-farm research should not inflict excessive risk on cooperating farmers. An intervention which threatens existing systems or which could entail heavy losses is better tested on-station.

Farm Visits and Research Implementation

Trials that are jointly undertaken must be visited frequently. It is best if the research team can be based at the site not more than one day's travel away. Long-distance, on-farm research is not worth conducting.

Visits must accommodate the farmer's timetable. They can be short and direct-to-the-point if the farmer is very busy, but longer casual conversations make for more effective collaboration. Moreover, when visits are frequent, the farmers are less likely to forget information and data will be more precise and accurate. Good human relations are important. If researchers respect farmers, it will be reciprocated.

Reporting and Results Analysis

Results should be assessed promptly. Monthly or quarterly reports facilitate timely assessment. Computers can also save time in data analysis. Better statistical analyses, methods and techniques for data recording are needed for rice-fish data.

Results from the first season's work should never be considered conclusive, no matter how clear. Trends over a longer period and responses to annual fluctuations must be checked to assess stability and sustainability.

Field staff and farmers should be involved in assessing the results. To exclude their direct observation and experience can result in misleading or impractical findings.

Case Studies in On-Farm Research

Farmers normally adapt technologies to their own situation through their own informal experiments. Case studies are a useful tool for following up this indigenous research.

A format for documenting indigenous technical knowledge using case studies follows:

1. Describe the area and situation of the case farm. Points of interest fall mainly under environmental and resource-based categories. Examples of environmental parameters include water-source (rainfed or irrigated), degree of slope, rainfall and soil. Examples of resource-based parameters are farm area, tenure status, off-farm employment activities, livestock capital and labor capacity.
2. Steps farmers use to adapt the technical model (e.g., dikes and trenches) to his/her own circumstances.
3. Management and maintenance operations of the system.
4. Production from the systems and its utilization.
5. Whole farm economic analysis, comparing before and after scenarios. Ideal conditions for economic analysis exist if comparisons are made within farms, between treatment and control areas. If the farmer does not maintain a control, historical data can be used. Inputs, production and income are parameters commonly compared.
6. Farmers' plans for future expansion and other modifications to the technology.

Analytical Techniques for On-Farm Data

On-farm research activities frequently generate results which are inconclusive when conventional statistical techniques are used on them. One reason for this is the enormous variations which occur among and within farms. In the interest of realism and applicability to subsequent extension programs, it is better to accept this variability and try to measure it. There are statistical tools for dealing with data sets of this sort – one of them is multivariate analysis.

The first step is to identify which variables are likely to affect the dependent variable of interest (e.g., production). Independent variables must be independent as any interrelationships will affect the analysis. Sophisticated and precise measurements are not always necessary. Weed infestation, which is often an important variable, can be scored "low" and "high". Even in the absence of such measurement some variables can be quantified using the farmers' observations.

Finally, the data is arranged in a matrix containing all estimated variables for each case. Each case would normally be one farmer. The matrix is then subjected to multivariate analysis which indicates the relative importance of each independent variable.

Data collectors should be involved in the interpretation of results because exposure to farm situation helps avoid erroneous interpretations. The participation of farmers in interpretation of results is highly desirable for similar reasons.

On-Farm Research Topics

Asian experience in on-farm testing of rice-fish technology permits the identification of research topics of importance in the countries concerned. A list of topics for on-farm research in selected Asian countries follows:

Bangladesh

- Ecology of deepwater ricefield environment.
- Design of ricefield for rice-fish farming.
- Suitable species combinations and fish stocking rates for shallow irrigated and enclosed deepwater ricefield environments.
- Suitable rice variety for rice-fish farming in shallow and deepwater environments.
- Development of rice-fish farming systems suitable for open deepwater ricefield and coastal water environments.
- Organizing cooperatives of rice-fish farmers.

India

- Development of rice-fish system suitable for enclosed deepwater ricefield environment focused on stocking size and density, and combination of fish species.
- Testing of fish cage or pen culture in open deepwater ricefield environment.
- The effect of fish on rice pests particularly for insect and weed control.
- Development of suitable fish sampling devices for deepwater ricefield environment.
- Trials on growing suitable rice varieties in trenches/sumps to minimize unplanted space in rice-fish system.

Indonesia

- Acceptance/rejection of rice-fish farming.
- Monitoring of indigenous rice-fish farming systems.
- Evaluation of the different rice-fish production systems (like fish nursery and growout under concurrent and rotational systems).
- Development of rice-fish farming systems in coastal and water-logged areas.

Philippines

- Use of organic and inorganic fertilizers in rice-fish farming.
- Socioeconomic evaluation of concurrent and rotational rice-fish farming systems.
- Development of alternative systems of rice-fish farming such as ratooned rice-fish cropping.
- Integrating fish in rice farming for weed and insect pest control.
- New or improved strains (tilapia or carp) in rice-fish farming.

Thailand

- Development of fish culture practices for rice-fish farming in rainfed environments including stocking rate and species composition, fertilization, supplemental feeding and trench/sump/pond design.
- Use of organic fertilizers like farmyard and green manure in rainfed and irrigated rice-fish farming.
- Water management in rainfed and irrigated rice-fish farming.
- Low-cost seed fish production in ricefields.

China

- Large-scale research on rice-azolla-fish pattern.
- Develop techniques to increase yield of aquaculture products and farmers' economic benefit with increased rice production.
- Develop rice-fish farming system research methodology, identify data to be collected and investigate methods to further improve research efficiency.

Malaysia

- Develop baseline data research for various ecological aspects of rice-fish farming systems.
- Improvement of capture systems in rice-fish farming through increasing natural fish yields.
- Monitoring negative effects of pesticides on fish growth and aquatic ecology.
- Evaluation on the importance of rice-fish farming to the rural economy.

Links with On-Station Research

On-farm research often raises questions that cannot be answered through on-farm experiments. On-farm researchers need laboratory or station research to support or back-up their work. A set of relevant research topics for on-station work identified by on-farm experiences follows.

Methods
-Checking fish health.
-Fish sampling techniques.

Pest management
-Control of predators, mainly snakes, birds and cats.
-Bioassay of pesticides to determine which are safe for fish and minimize losses from pests.
-Alternatives to insecticides especially in deepwater rice areas.
-Disease/treatment for seed fish prior to transport.

Fish feed
-Stomach content studies to determine diet compositions.
-Suitable plant species grown around dike for fish feed.
-Supplemental feeding through increasing natural forage production.
-Kind of feeds: pellets, manure, hulled rice.

Socioeconomic
-Economic conditions for which credit facilities should be extended to farmers for buying seed fish.
-Impact assessment on farmers' well-being (nutrition, health, etc.) of rice-fish technology.
-Socioeconomic causes of poaching.
-Economic analysis of various rice-fish patterns.
-Economic feasibility of banning highly toxic pesticide.

Seed fish
-Techniques to improve seed quality.
-Fish species and stocking density.
-Techniques for mortality improvements in fish transport and stocking.

Water
-Effect of water depth on fish growth and production.
-Effect of water quality on fish growth (pH, temperature, alkalinity, etc.).
-Effect of sudden changes in water salinity on fish.

Rice breeding and agronomy
-Percentage of trench used and design efficiencies.
-Interaction between rice variety and fish species.
-Rice planting spatial arrangements to minimize area loss to rice.

Fish breeding and culture

- Inbreeding and introduction of new broodlines.
- Crosses between foreign and local stocks.
- Techniques to increase growth of fry in nurseries.
- Utilization of heterosis through hybridization and monosex culture to increase growth rates.

Links With Extension

It is very difficult to draw a line between on-farm research and technology dissemination or extension. The two are on a continuum. Farmer-cooperators, researchers and extensionists are part of this continuum. Nevertheless, some distinctions between on-farm research and extension can be made. Improved practices being applied in an on-farm trial cannot be regarded as recommendations. These technologies are always changed and improved during the testing process. Technologies must produce positive and repeatable results over a wide area before extension and development efforts may confidently begin.

A smooth transition from on-farm research to extension is afforded by farmer-to-farmer training. New entrants are taken to visit research collaborators to see what they have done and learn the technology. Frequent interactions between researchers, extensionists and farmers that involve mutual teaching and learning, are crucial to successful transition. Awareness of a new technology will often lead to interest in trying it out and subsequent adoption. Positive farmers' reactions among research cooperators to the new technology can also be used to forge links with extension.

Working Group Report on Pest Management in Rice-Fish Farming

JAMES A. LITSINGER
Entomology Department
International Rice Research Institute
P.O. Box 933
Manila, Philippines

LITSINGER, J.A., Compiler. 1992. Working group report on pest management in rice-fish farming, p. 433-436. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Introduction

Fish kills arising from pesticide applications to rice have discouraged Asian farmers from raising fish in ricefields. Moreover, pesticides applied upstream can affect fish in lower ricefields. While herbicide usage in Asia is rising, insecticides, which are more toxic, are being used less than before. The adoption of pest resistant varieties, the high cost of insecticides relative to rice, the resurgence of pest problems after application, and the decline of calendar spraying in favor of economic thresholds, are the main reasons for this decline.

Pesticides can be used safely and the dual goals of controlling pests and raising fish can be met. China and Indonesia regularly use pesticides in rice-fish culture. Indeed, fish may act as agents in pest control.

Pest Control by Fish

That fish control pests in ricefields is frequently cited. They do eat weeds, but some may also eat rice plants. Grass carp (*Ctenopharyngodon idella*) are reported to feed on rice seedlings, while rice panicles are reported in Thailand to be eaten by silver barb (*Puntius gonionotus*). Nevertheless, grass carp successfully control weeds in China. Fish also catch and consume insects. Some farmers even drag a rope across the rice foliage to knock insects into the water for fish to feed on. Medically important pests such as mosquitoes have been controlled by fish. Whether pests are eaten in preference to their natural enemies is, however, unknown. Gut analysis of wild and cultured fish could determine this. Fish may reduce snail population (vectors of schistosomiasis) in ricefields because black carp

(*Mylopharyngodon piceus*), for instance, are known to eat snails. Two reports indicate that fish may eat the sclerotia of sheath blight. One negative consequence of rice-fish is that the necessary higher bunds shelter more rodents.

Effects of Pesticides on Fish

Acute toxicity

Pesticide companies regularly determine toxicity levels on fish. However, as susceptibility to pesticides differ between fish species and age, some results may not apply. While mosquito-eating *Gambusia* is resistant to many pesticides, the adult fish are more so than the young, and newly hatched larvae and fry are most sensitive. With few exceptions, chemicals considered safe from laboratory acute toxicity evaluation will be safe in the field, and some of those considered toxic in the laboratory may be less toxic in the field as pesticides become bound to soil and plants. As many species of fish need to be considered, representative species from different fish guilds (bottom detritus feeders or medium water filter feeders) should be selected for tests.

The tests themselves may have built-in deficiencies. Acute toxicity is determined by measuring the concentration lethal to 50% of the population (LC_{50}) or the tolerance level for 50% survival (TL_{50}) in aquaria over 24, 48 and 96 hours after exposure (Table 1). Unfortunately, not only are some compounds more toxic if exposed to sunlight but also, toxicities in water differ with temperature, pH, hardness, salinity, turbidity and dissolved oxygen. Moreover, LC_{50} rates are also lower if fish are stressed. Tests are more accurate when sprays are used, rather than active ingredients, since the emulsifiers and solvents used in their formulation aid the entry of pesticides into fish.

Table 1. Pesticides ranking according to toxicity. (Modified after Koesoemadinata 1980)

Class	48-hour TL_{50} (ppm a.i.)
A Relatively safe	>10
B Moderate	0.5–10
C Highly toxic	<0.5

Ideally, pesticides should first be screened in the laboratory and abnormal behavior of the fish noted. Those found safe should then be screened in the field where detailed studies on weight gains and delayed development can be carried out. Determination of sublethal effects should be carried out by a flow-through system.

Despite the shortcomings of laboratory tests, a safe level for rice-fish farming may be 0.10 times the LC_{50}. FAO reports that a safe level of pesticide residue in the water may be 0.05–0.1 times the 96-hour LC_{50}, depending on the persistence of the material in the environment. However, others say a safe level in tropical condition may be higher at 0.3 times the 96-hour LC_{50}.

Sublethal Effects

Sublethal effects manifest themselves after two weeks of exposure. They are divided into subchronic effects which occur within the first third of the organism's life cycle and chronic effects which occur much later. The effects pesticides have on fish include lower weight gains, delayed development, abnormalities in appearance, lower resistance to diseases and greater vulnerability to predators.

Persistence

Chemicals like organochlorines and organosphosphorous or carbamate insecticides persist in the environment because they break down slowly. These chemicals end up as residues in fish and in the aquatic food chain. Pesticides sprayed on vegetables that are grown near rice often contaminate the ricefields. Organophosphates like fenitrothion, fumadol and trichlorfon used in fish hatcheries and nurseries to kill aquatic insect predators of young fry can also contaminate nearby ricefields. Pesticides may also affect fish indirectly by killing off or contaminating their food. Pesticides entering phytoplankton and zooplankton are concentrated in the fish that eat them.

Pesticide Management

Pesticides pose their greatest problems in irrigated ricefields. Rainfed rice farmers cannot afford to buy pesticides, and the diluting capacity in deepwater areas nullifies the negative effects of pesticides. Pesticides are not a major constraint in these environments to the development of rice-fish farming. Indeed, enthusiasm for rice-fish farming might even force pesticide usage down. Certainly, the negative effects of pesticides can be minimized.

Governments could ban highly toxic and persistent substances. The FAO-WHO Codex Alimentarius may regulate pesticide standards in aquaculture for export items. Use of only the safest chemicals (Class A, $TL_{50}>10$ ppm), preferably as wettable powders which are less soluble and not as emulsifiable concentrates, could be promoted along with special insecticide formulations that encapsulate the active components and are less toxic to fish. Farmers should be encouraged to replace cyanide and endrin with safe compounds such as rotenone to clean up unwanted fish in ricefields. Lastly, chemicals which are easily detoxified by fish and break down quickly in the environment with least effects on food chains, should be chosen.

Methods of pesticide application could be improved in the following ways:

a. Minimum effective dosage of pesticides should be used.
b. Insecticide granules should be incorporated into the soil rather than broadcast into the water so that release of chemicals is slower.
c. Electrostatic sprayers that charge the spray droplets causing the insecticide to be attracted to plants and not the water surface would be useful, particularly when the crop is young.
d. Insecticides should be applied in the late afternoon when the water is cooler and the detrimental effect of sunlight is less.
e. Confining the fish to trenches and draining the field or raising the water level to dilute the toxicity during spraying can help.

All management options require education of farmers on how pesticides can be used safely, on how pesticide residues occur and how pesticides enter food chains. Color paper reactions of fish blood may be a novel way that farmers could monitor pesticide levels in fish to decide if another pesticide application is safe or not. Community management of the watershed would also help to prevent pesticide abuses. In the future, if fish can be shown to effectively control pests, farmers could use them to minimize pesticide usage in rice.

Recommendations

1. Compile a list of safe pesticides from the available literature.
2. Determine acute toxicities of common rice pesticides to key fish species and major groups cultured in ricefields.
3. Determine sublethal effects on fish of pesticides that are least toxic.
4. Determine the effect of pesticides in the aquatic food chain, particularly the growth regulators or chitin inhibitors which even at low dosages may be highly toxic to arthropods such as shrimp.
5. Evaluate the effectiveness and toxicity of botanical pesticides on fish.
6. Develop economic threshold levels of insect pests that account for the value of fish.

7. Determine the mechanism by which wild and cultured fish control pests.
8. Develop easy methods to monitor pesticide levels in fish as a management guide.
9. Develop management methods to reduce toxic levels of pesticides in rice-fish culture.
10. Organize a network of people equipped to determine pesticide toxicities on fish in the region.
11. Educate farmers on effects of pesticides on fish.
12. Encourage governments to regulate pesticide companies to determine if their products are not highly toxic to fish and ban the most dangerous products.
13. Encourage governments to monitor pesticide residue levels in marketed fish.

Reference

Koesoemadinata, S. 1980. Pesticides as a major constraint to integrated agriculture-aquaculture farming systems, p. 45-51. *In* R.S.V. Pullin and Z.H. Shehadeh (eds.) Integrated agriculture-aquaculture farming systems. ICLARM Conf. Proc. 4, 258 p.

Working Group Report on Extension in Rice-Fish Farming

CHRISTOPHER LEE*
Thai-Australian Tung Kula Ronghai Project
1/4 Premprachoras Road
Roi Et 45000, Thailand

CHRISTOPHER, L. 1992, Compiler. Working group report on extension in rice-fish farming, p. 437–443. *In* C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao (eds.) Rice-fish research and development in Asia. ICLARM Conf. Proc. 24, 457 p.

Introduction

The primary purpose of this group discussion was to initiate and stimulate exchanges of ideas and information among scientists and field workers on rice-fish farming extension approach and methodology. The approach and methodology of extension were discussed in relation to the resources and constraints of individual countries. The specific objectives of the discussion were:

1. To identify the basic types of rice-fish farming systems which can be confidently extended to the farmers.
2. To identify the problems of each rice-fish production system and recommend research to overcome these problems.
3. To identify the constraints of rice-fish extension and recommend ways and means to improve the situation.
4. To identify appropriate extension strategy and methodology for rice-fish farming.

The participants of this discussion group came from Indonesia, the Philippines, Bangladesh and Thailand. The group discussed, in general terms, the existing rice-fish farming systems in their countries. Therefore, the findings presented here are intended only as a basis for future discussion.

Rice-Fish Farming Systems

INDONESIA

Rice-fish farming has a very long history of practice in Indonesia. Many rice farmers have adopted this integrated farming system because it involves mini-

*Present address: Bribie Island Aquaculture Research Centre, Bribie Island 4507, Queensland, Australia.

mal change to the existing rice cultivation practices and it requires little material and labor inputs. In concurrent rice-fish culture, rice production is increased by 10% and total income, by 25–30%.

Most of the rice-fish farms in Indonesia are in irrigated ricefields. Three rice-fish farming systems are practised in Indonesia: *minapadi* (concurrent), *palawija ikan* (rotational) and *penyelang* (intermediate). In *minapadi,* fingerlings are cultured concurrently with rice; while in *palawija ikan*, fish are grown alternately with rice. In the *penyelang* system, fish is cultured between the harvest of the wet season rice and before the planting of the dry season rice.

In concurrent rice-fish culture, the water level in the ricefield is maintained between 5 to 10 cm above the soil. Shallow peripheral, cross or middle trenches or a combination of these are sometimes constructed to provide more space for the fish. These trenches occupy 4–6% of the ricefield area.

High-yielding IR 64 and Cisadane rice varieties are cultivated in the wet and dry seasons, respectively. Chemical fertilizer rates per hectare are 200 kg urea, 100 kg triple superphosphate (TSP) and 100 kg potassium chloride (KCl).

The main species cultured in the ricefields is the common carp (*Cyprinus carpio*). Fingerlings are stocked at a rate of 2,500–3,000/ha. Fish are given a supplementary feed of rice bran every five days. In the *minapadi* system, the fingerlings are raised for 40–50 days.

The rapid adoption of rice-fish farming in many parts of Indonesia is causing serious concern for the irrigation authority. Most irrigation systems were designed for rice monoculture farming. The authority fears that the existing irrigation systems will not cope with the additional demand for water from rice-fish farming. There is also a grave concern that the rapid interest in rice-fish farming may reduce national rice production.

Lack of fingerlings, in terms of timely availability and good quality, is a major limitation for the expansion of rice-fish farming in many areas. Concern is also expressed on the use of pesticides in rice-fish culture. There are still no definitive findings on the effects of pesticide use in rice-fish farming on the health of the fish consumers.

PHILIPPINES

In the Philippines, rice-fish farming is carried out in irrigated ricefields. Fish is grown concurrently with rice. The size of rice-fish farms ranges from 2,000 to 10,000 m^2. A fish refuge pond is constructed either at the center or at the end of the field to provide shelter for the fish during the day or when the water level drops below the field level. The refuge is also used to concentrate the fish at harvest time and during insecticide application. The fish refuge occupies about 8–10% of the ricefield's total area. The depth of the fish refuge range from 0.5 to 1.0 m. The construction of peripheral trenches are not well accepted by the farmers. Initially, water depth is maintained at 10–15 cm. After the rice tillering stage, it can be increased to 20 cm.

High yielding IR rice varieties are used in rice-fish farming. Fertilizer applications consist of 100 kg/ha urea, 200 kg/ha ammonium phosphate and farmyard manure.

The main fish species cultured in the ricefields is the Nile tilapia (*Oreochromis niloticus*). Fingerlings (10–15 g) are stocked at 5,000–7,000/ha. The fish culture period is from 60 to 70 days. Fish food consists mainly of rice bran and application rates vary for each farmer. Rice production increases by 10% when rice is grown concurrently with fish, while total income increases by 15%.

The major constraint of rice-fish farming in the Philippines is the lack of irrigated ricefield areas. Poaching is also a serious problem of most rice-fish farmers. Also, the spraying of toxic pesticides on neighboring irrigated rice farms often cause problems to those practising rice-fish culture.

THAILAND

For over 30 years, rice-fish farming has been practised in irrigated and rainfed areas in Thailand. In both environments, fish are raised concurrently with rice. In the rainfed area, only one crop of rice is grown in any one year.

In irrigated areas, the ricefield often dries up for a short period of time under intermittent irrigation water supply. Therefore, trenches and a fish refuge pond are essential parts of the rice-fish farm. Trenches are dug along one, two, three or all sides of the field and a small refuge pond is constructed at the lower part of the field. The pond is connected to the trenches. The size of the trenches and the refuge pond varies from farm to farm. In most cases, the trench is not less than 40 cm wide and 30 cm deep. The refuge ponds are about 1 m deep. The total area of the trenches and the pond occupies 5–10% of the ricefield. The size of a manageable rice-fish farm is estimated to range from 3,200–8,000 m^2.

Rice varieties cultivated in the irrigated system are Sanpathong, KMLD 105, RD 6 and RD 7. Both inorganic fertilizers and farmyard manure are used.

Common carp, tilapia (*Oreochromis niloticus*), silver barb (*Puntius gonionotus*) and rohu (*Labeo rohita*) are the main species cultured in the ricefields. The number of fingerlings released into the ricefield is 5,000/ha. Both polyculture and monoculture systems are practised in Thailand, but the best species composition is yet to be determined. In reality, however, the species composition and the stocking rates are largely determined by the availability of fingerlings. Ideally, fingerlings should be stocked at 5–7.5 cm or larger, but in most cases, they are stocked when 3–5 cm long.

Fish production from irrigated ricefields ranges from 300 to 600 kg/ha. At the end of the rice-growing season, the fish sizes are: 100–200 cm for common carp; 80–200 cm for silver barb and 50–150 cm for tilapia. Rice production increases by about 10% over rice monoculture production in irrigated areas.

Rice-growing in northeast Thailand is mostly in rainfed environment. Rice-fish farming in this area is subject to frequent drought and flooding. Even in the rainy season, the fields are often without water for a prolonged period of time. Consequently, both rice and fish production are low and unpredictable.

The design of the rice-fish farm in the rainfed areas is similar to those in irrigated areas, except that trenches and the refuge ponds are bigger and deeper. The interconnecting peripheral trenches are generally 1 m wide and 1 m deep. The refuge pond is 1.5–2.0 m deep. The trenches and pond are used to store water at the beginning and at the end of the wet season. The size of the farm is generally between 3,200 to 8,000 m^2. Although larger fields are common, fish production ranges from 100 to 300 kg/ha.

Despite the successes enjoyed by many farmers, rice-fish farming is not universally accepted. Many farmers believe that the outbreak of epizootic ulcerative syndrome (EUS) will affect fish production in ricefields. Poaching is also a problem in some areas as farmers generally live away from their field. In irrigated areas, the use of pesticides in the neighboring farms causes some concern among potential rice-fish farmers. Pesticides have not become a major problem in the rainfed areas, where there is relatively little usage of them. The demand for fingerlings is highly seasonal. Very little additional inputs are given to the fish. Rice bran and agricultural wastes are given only when available. The fish are harvested as required although the bulk is harvested at the end of the rice-growing season. The short growing period, lack of good quality and right sized fingerlings, and inadequate feeding are the constraints in the development of rice-fish farming.

BANGLADESH

Concurrent rice-fish systems in both irrigated and rainfed environments are practised in Bangladesh. Although rice-prawn farming is practised in Bangladesh, this discussion is limited to rice-fish farming only.

Fundamentally, there is little difference between the two rice environments. High yielding rice varieties are used in both irrigated and rainfed areas. The refuge pond occupies 5–10% of the ricefields.

Fingerlings of rohu, Nile tilapia and silver barb are stocked at 5,000/ha at sizes between 5 to 7.5 cm. The fish are fed with rice bran.

Most of the ricefields are subject to annual flooding, thus many farmers cannot culture fish in their ricefields. The average land holding is also small and farmers are reluctant to sacrifice their ricefields for fish trenches and ponds.

Extension Strategy

Extension Approach

PEOPLE- OR PRODUCT-ORIENTED APPROACH

Both people- and product-oriented approaches have their own merits. The approach used in extension should be largely dictated by the social, economic and cultural environments in which it operates, as well as the available physical and human resources. For example, where credit or subsidy is given to farmers, the authority should be able to insist on certain methods of implementation.

The community-oriented approach is appropriate and essential in a situation where the activities of the farmers can adversely affect the well-being of their neighbors. This situation is more often found where farmers must share a common resource such as irrigation water. On the other hand, if the farms are self-contained and do not have to rely on outside assistance, they must be able to decide the method which is most appropriate for their situation. Situations and resources change continually and extension should adapt quickly to these changes. The construction of an irrigation system in an area, for example, will necessitate a change in the extension approach from an individual approach into a more community-oriented approach if benefits and opportunities are to be equally shared by every farmer.

SPECIALIST AND GENERALIST EXTENSION AGENTS

The discussion group could not reach an agreement as to whether specialist extension agents are more effective than generalists or vice versa. This is to be expected because members of the group came from diverse work, organizational and cultural backgrounds. It is agreed however, that both generalist and specialist extension methods have their own merits and shortcomings.

SUBSIDY AND CREDIT

Incentives are often appropriate and necessary to secure farmers' cooperation in establishing demonstrations in a new area. Only the necessary amount of subsidies or incentives should be provided to motivate the cooperators, otherwise it may create a wrong expectation among the rest of the community and be counter-productive to development.

Credit is not recommended in situations where rice or fish productions are variable, such as that found in the rainfed areas of Northeast Thailand. It is appropriate in those areas where rice or fish productions are more stable, such as in the irrigated areas of Indonesia and the Philippines. Borrowers should be given incentive of a one year repayment holiday. Group insurance should also be promoted to safeguard against any unforeseen calamity.

OTHER NEEDS

Regardless of the approach used in extension, it is essential that appropriate trainings are provided for extension and training officers. Field officers must know the social and economic environment of their working area and of the technical fields. Extension officers must also understand the market environment and be able to help farmers assess the profitability of their farm operations.

Extension Constraints

The problems in extension are closely interrelated. Farmers are reluctant to accept advice from extension officers because poor farmers are conservative and nonrisk takers. Also, many farmers had bad experiences with the service and advice of extension agents among which include:

1. Poor attitude of extension officers towards farmers. They are often arrogant, impersonal, officious and domineering. Extension officers often fail to recognize and respect farmers' wealth of experience and wisdom.
2. Advice is often inconsistent, incorrect and contradictory.
3. Extension officers are often very young, inexperienced and have a very low status in the organization. Consequently, they lack credibility among farmers.
4. Extension services are given at the convenience of the officers, rather than when it is most needed by the farmers.

Not everyone can become a good extension officer. Better selection and screening procedures of officers being recruited will reduce the number of unsuitable extension officers. Officers should develop a proper working attitude before they are allowed to come into direct contact with the farmers. They should first work closely with a good senior extension officer. Only until they have gained some experience and credibility of their own that they can be effective with farmers.

Intensive technical training can check against giving inconsistent and incorrect advice. Adequate written materials must also be made readily available. Field extension officers must be constantly encouraged to discuss their works and problems with specialists and experts.

Infrequent visit is a common problem of extension in developing countries. The lack of manpower and financial resources combined with the vast working area, are responsible for poor extension services. A more focused extension program through a better site selection procedure will enable officers to concentrate their efforts. Mass media should play an important extension role in remote areas.

Extension Methodology

FARMER PARTICIPATION

In many parts of Asia, women play an important role in decisionmaking concerning financial investment and family farm activities. Therefore, extension and training programs should be targeted equally towards women, as well as the men. Timing and duration of the extension and training must be such that it would allow women to receive an equal opportunity to participate. In Indonesia and the Philippines, special courses in economics are conducted for women; in Thailand, women are given postharvest trainings.

MASS MEDIA

Television and radio are important mass media for extension in Indonesia and Thailand. In Thailand, many schools have integrated rice-fish farms, and schoolchildren play important roles in promoting the rice-fish culture to the community. In the Philippines, newspaper and radio are considered effective channels for extension.

AUDIO VISUAL MATERIALS

It was suggested that priority should be given to the development of video extension materials in Thailand and Indonesia; while flip charts were considered more appropriate in Bangladesh and the Philippines. A slide extension program was not considered by the group.

OTHER EXTENSION MATERIALS

Other extension materials considered by the group were leaflets and booklets. Written material should be illustrated with numerous pictures and graphics. The use of local dialects was recommended for Indonesia and Thailand.

FARMER TRAININGS AND WORKSHOPS

The need for intensive farmer trainings was emphasized. Intensive farmer trainings are best conducted at the government stations where there are adequate facilities. However, only very few government stations have adequate accommodation and training facilities for farmers. There is also a need for less intensive, but more subject specific trainings which can be conducted in the villages.

In some cases, farmer workshops can be used effectively to stimulate farmers to transfer their knowledge to one another. The number of participants must be kept small so that all farmers can participate in the discussion. Farmer workshops should be conducted in an atmosphere where there is minimal interference from the officers. Officers can take this opportunity to learn from the farmers, therefore the discussions that take place in the workshops must be recorded.

Research Priority

INDONESIA

- At present, Indonesia does not have major problems in promoting rice-fish culture.

PHILIPPINES

- Integrated pest management (IPM).
- Optimum stocking rate of fingerlings.
- Mortality rate and the causes of mortality.
- Water management.
- Food and feeding.
- Farmer's attitude toward rice-fish farming and what motivates farmers to adopt the system.

THAILAND

- IPM.
- Preventive and curative methods for fish diseases.
- Water management in rainfed areas and other uses of water including supplementary irrigation for the rice

nursery and dry season crops.

- Documentation of successful practices and verification of their replicability.
- Effectiveness of mass media use in extension.
- Fine tuning of existing technology.

In general, adequate information is available to confidently promote rice-fish farming in Northeast Thailand. Individual farmers must develop the technology to suit his/her farm situation.

BANGLADESH

- IPM.
- Chemical fertilizer doses needed for optimum production.
- Suitability of various species of shrimps and fish under different environments.
- Supply, availability and the optimum size of fingerlings.
- Flood management for rice-fish farming.

Recommendations

- Future discussions on rice-fish extension must be conducted in a more structured form.
- All countries should be equally represented by experienced extension specialists, as well as by rice-fish scientists and technologists.
- Whenever possible, women participants should be present for their views.
- Participants must be given adequate time to prepare and gather relevant information for the discussion.
- Participants should be encouraged to bring relevant extension materials from their countries.

LIST OF PARTICIPANTS

PROF. TERESO A. ABELLA**
Freshwater Aquaculture Center
Central Luzon State University
Muñoz, Nueva Ecija 3120
Philippines

MR. MAX AGLIBUT**
Bureau of Agricultural Research
Department of Agriculture
Diliman, Quezon City
Philippines

DR. MAHFUZUDDIN AHMED**[a]
International Center for Living Aquatic Resources Management
MCPO Box 2631
0718 Makati, Metro Manila
Philippines

MR. M. AKESTER*
c/o British High Commission
Abu Bakar House, P.O. Box 6079
Dhaka
Bangladesh

DR. AHYAUDIN BIN ALI
School of Biological Sciences
Universiti Sains Malaysia
11800, Minden, Penang
Malaysia

MR. LEOPOLDO ANTONIO**
Provincial Farmers Training Center
Agricultural Training Institute
Maligaya, Muñoz, Nueva Ecija
Philippines

DR. RODOLFO G. ARCE
Freshwater Aquaculture Center
Central Luzon State University
Muñoz, Nueva Ecija 3120
Philippines

MS. KULJEET K. BHANOT**
Central Institute of Freshwater Aquaculture
Bhubaneswar, Orissa
India

MR. NATAVUDH BHASAYAVAN*
Khon Kaen Farming System
Research and Development Unit
Khon Kaen, Thailand 40000

MS. MARY ANN P. BIMBAO**
International Center for Living Aquatic Resources Management
MCPO Box 2631
0718 Makati, Metro Manila
Philippines

MR. JAMES T. BRUNTON*
68 Lindhurst Crescent
Ottawa, Ontario
K26 OT7
Canada

PROF. ARSENIA G. CAGAUAN**
Freshwater Aquaculture Center
Central Luzon State University
Muñoz, Nueva Ecija 3120
Philippines

---

* Attended the Rice-Fish Farming Research and Development Workshop, Ubon, Thailand, 21-25 March 1988.
** Attended the Rice-Fish Farming Systems Research and Development Workshop, Central Luzon State University, Muñoz, Nueva Ecija, Philippines, 23-27 October 1989.
The unmarked names attended both workshops.
[a] Please refer to respective papers (see Author Index) for present addresses.

DR. ARSENIO S. CAMACHO**
Bureau of Agricultural Research
Department of Agriculture
Diliman, Quezon City
Philippines

DR. VIRGILIO R. CARANGAL
International Rice Research Institute
P.O. Box 933, Manila
Philippines

MR. GREG CHAPMAN**[a]
Sakon Nakhon Rice Experiment Station
A. Muang, Sakon Nakhon 47000
Thailand

MR. SUPARAT CHATJARIYATVAT**
Ubon Fisheries Research and
Development Center
Ubon Ratchathani Province 34000
Thailand

MS. THITIMA CHITKASIKORN**
Rajamangala Institute of Technology
Ayutthaya Province 13000
Thailand

DR. BARRY A. COSTA-PIERCE*[a]
PPSDAL (IOE) UNPAD
Jl. Sekeloa Selatan 1
Bandung 40132
Indonesia

LAIN A. CRAIG*
T.A. Team, NERAD
Khon Kaen, Thailand

DR. CATALINO R. DELA CRUZ
International Center for Living Aquatic
Resources Management
MCPO Box 2631
0718 Makati, Metro Manila
Philippines

MR. ANNE A. VAN DAM[a]
International Center for Living Aquatic
Resources Management
MCPO Box 2631
0718 Makati, Metro Manila
Philippines

MS. LOUREEDA C. DARVIN**
Philippine Council for Aquatic and Marine
Research and Development
Los Baños, Laguna
Philippines

MR. HERBERT A. DAVIS*
Canadian International Development Agency
200 Promenade du Portage
Hull, Quebec
Canada K1A OG4

DR. BRIAN DAVY*
International Development Research Centre
250 Albert Street, 11th Floor
Ottawa, Ontario K1G 3H9
Canada

DR. P.V. DEHADRAI*
Indian Council of Agricultural Research
Krishi Bhavan, Dr. Rajendra Prasad Road
New Delhi 110 003
India

MR. SOMEN DEWAN
Department of Aquaculture and Management
Bangladesh Agricultural University
Mymensingh
Bangladesh

MR. TENZIN DHENDUP*
National Warm Water Fish Culture Centre
Gaylephug
Bhutan

DR. ACHMAD M. FAGI**
Sukamandi Research Institute
for Food Crops
Sukamandi, West Java
Indonesia

MR. FRANK FERMIN**
International Institute for Rural
Reconstruction
Rm. 38 Elena Apts.
Romero Salas St., Ermita, Manila
Philippines

MR. ABUNDIO M. GALICIA, JR.**
Bureau of Fisheries and Aquatic Resources
880 Marcelo Bldg.
Quezon Ave., Quezon City
Philippines

DR. JOSEPH A. GARTNER
Asian Institute of Technology
G.P.O. Box 2754
Bangkok 10501
Thailand

MR. M. GERVIS*
c/o British High Commission
Abu Bakar House, P.O. Box 6079
Dhaka
Bangladesh

DR. APURBA GHOSH*
Central Inland Fisheries Research Institute
Barrackpur
India

DR. LEONARDO A. GONZALES**
International Food Policy Research Institute
17176 Massachusetts Ave., N.W.
Washington, DC 20036
USA

MR. RICK GREGORY*
c/o British High Commission
Abu Bakar House, P.O. Box 6079
Dhaka, Bangladesh

DR. MODADUGU V. GUPTA**
ICLARM Bangladesh Office
House No. 20, Road No. 9/A
Dhanmondi R/A, Dhaka 1209
Bangladesh

MR. MATTHIAS HALWART**
Institute of Plant Production in the
Tropics & Subtropics
7000 Stuttgart 70
Federal Republic of Germany

MR. HEE DONG KIM**
Kyonggi Provincial Rural Development
Administration
315 Gisan-Ri, Taean-Up, Hwasong-Gun
Kyonggi-Do 445-970
Republic of Korea

MR. ISAGANI O. HERRERA**
Department of Agriculture
Region III
San Fernando, Pampanga
Philippines

MR. M.G. HUSSAIN*
Fisheries Research Institute
Mymensingh, Bangladesh

MR. N.L. INNES-TAYLOR*
Asian Institute of Technology
G.P.O. Box 2754
Bangkok 10501
Thailand

MS. ORAPINT JINTASATAPORN**
Department of Fisheries
Ministry of Agriculture and Cooperatives
Rajadamnern Ave., Bangkok
Thailand

MS. MARAYAT KAMBUT**
Department of Fisheries
Ministry of Agriculture and Cooperatives
Rajadamnern Ave., Bangkok
Thailand

DR. KEE CHAI CHONG*
NACA/FAO
NACA, UNDP
G.P.O. Box 618
Bangkok 10200
Thailand

DR. BYEONG HYEON KIM**
Kyonggi Provincial Rural Development
Administration
315 Gisan-Ri, Taean-Up, Hwasong-Gun
Kyonggi-Do 445-970
Republic of Korea

MR. SANTOSA KOESOEMADINATA*
Research Institute for Freshwater Fisheries
Jalan Sampur No. 1
Bogor
Indonesia

DR. TAWEE KUPKANCHANAKUL**
Huntra Rice Experiment Station
Ayuthaya 13000
Thailand

MR. ROLANDO LABIOS**
International Rice Research Institute
P.O. Box 933, Manila
Philippines

PROF. HARLAN C. LAMPE
International Center for Living Aquatic Resources Management
MCPO Box 2631
0718 Makati, Metro Manila
Philippines

MR. CHRISTOPHER LEE
Thai-Australian Tung Kula Ronghai Project
1/4 Premprachoras Road
Roi Et 45000
Thailand

MR. WATTANA LEELAPATRA
Kalasin Fisheries Station
P.O. Box 18,
Kalasin Province 46000
Thailand

MR. LI KANGMIN**
Wuxi Chinese Academy of Fisheries Sciences
Wuxi City, Jiangsu Province 214081
People's Republic of China

DR. CLIVE LIGHTFOOT**
International Center for Living Aquatic Resources Management
MCPO Box 2631
0718 Makati, Metro Manila
Philippines

DR. J.A. LITSINGER*
International Rice Research Institute
P.O. Box 933, Manila
Philippines

PROF. EDUARDO LOPEZ**
Freshwater Aquaculture Center
Central Luzon State University
Muñoz, Nueva Ecija
Philippines

MS. MALI LUMNAMTIENG**
Nakorn Ratchasima Fisheries Station
Department of Fisheries
Nakorn Ratchasima
Thailand

MR. NEMESIO A. MACABALE**
Department of Agriculture
Region III
Maligaya Research Office
Muñoz, Nueva Ecija
Philippines

DR. DON MACINTOSH*
Overseas Development Administration
c/o Asian Institute of Technology
G.P.O. Box 2754
Bangkok 10501
Thailand

DR. KENNETH T. MACKAY*[a]
International Development Research Centre
Tanglin, P.O. Box 101
Singapore 9124

MR. WILFREDO C. MALDIA**
Land Bank of the Philippines
Regional Office I
Cabanatuan City
Philippines

MR. ORLANDO B. MAPALO**
Department of Agriculture, Region III
Maligaya Research Office
Muñoz, Nueva Ecija
Philippines

MS. CAROLE MARTIN*
Farming Systems Research Institute
Suphanburi Rice Experiment Station
Amphur Muang, Suphanburi Province
Thailand

DR. ANDREW MCNAUGHTON**
International Development Research Centre
Tanglin, P.O. Box 101
Singapore 9124

MS. JESIBETH R. MERCADO**
Department of Agriculture
Region III
Maligaya Research Office
Muñoz, Nueva Ecija
Philippines

MR. MIGUELITO A. MERCADO**
Department of Agriculture
Region III
Maligaya Research Office
Muñoz, Nueva Ecija
Philippines

DR. PRATAP K. MUKHOPADHYAY
Rice Research Station
Chinsurah 712 102
Hooghly, West Bengal
India

MS. RALAMBOMANANA ODETTE**
Department of Forestry and Fishery
Research
FOFIFA, BP 1690
Antananarivo
Madagascar

MR. PAN YINHE**
Freshwater Fisheries Research Centre
Wuxi Chinese Academy of Fisheries Sciences
Wuxi, Jiangsu Province 214081
People's Republic of China

DR. ARAN PATANOTHAI*
Faculty of Agriculture
Khon Kaen University
Khon Kaen, Thailand

DR. OOPATHAM PAWAPUTANON*
Nonkai Inland Fisheries Station
Srichiengmai District
Nongkai, Thailand

MR. ERNST PETERSEN*
Asian Development Bank
P.O. Box 789, Manila
Philippines

DR. ROBERT PHILLIPS**
California State University
6000 J. St.
Sacramento, CA 95819
USA

MR. C. PRICE*
c/o British High Commission
Abu Bakr House, P.O. Box 6079
Dhaka 12
Bangladesh

DR. ROGER S.V. PULLIN**
International Center for Living Aquatic
Resources Management
MCPO Box 2631
0718 Makati, Metro Manila
Philippines

DR. MAI VAN QUYEN**
Institute of Agri-Technology
121 Nguyen Binh Khiem Street
Hochiminh City
Vietnam

DR. CHANUEN RATANAWARAHA*
Farming Systems Research Institute
Department of Agriculture
Bangkhen, Bangkok
Thailand

MR. ROLANDO O. RETALES**
Philippine Rice Research Institute
Maligaya, Muñoz, Nueva Ecija
Philippines

MS. LILIAN M. RUECA**
Department of Agriculture
Region III
San Fernando, Pampanga
Philippines

MR. PRADUNGCHAI SAENGWONG**
Nakorn Phanom Provincial Office
Department of Fisheries
Nakorn Phanom
Thailand

MR. BOONLERT SANCHAI**
Kalasin Provincial Office
Department of Fisheries
Kalasin
Thailand

MR. FIRMANSJAH SASTRADIWIRJA*
Freshwater Aquaculture Development Center
Balai Budidaya Air Tawar
Jalan Selabintana 17, Sukabumi
West Java
Indonesia

MR. SUKMANA SATJANATA**
Department of Agriculture
Jalan Harsono, Room No. 3
Jakarta Selatan
Indonesia

NUALCHAN SERMSAI-GREGORY*
Buriram Agricultural College
Buriram 31000
Thailand

PROF. RUBEN C. SEVILLEJA
Freshwater Aquaculture Center
Central Luzon State University
Muñoz, Nueva Ecija 3120
Philippines

DR. V. PAL SINGH**
International Rice Research Institute
P.O. Box 933, Manila
Philippines

DR. PALARO SINHASENI*
Faculty of Pharmaceutical Sciences
Chulalongkorn University
Bangkok 10500
Thailand

MR. DECHA SIRIPHAT
Village Freshwater Fishery Project
Appropriate Technology Association
143/171-172 Pinklao-Nakornichaisri Road
Bangkok No. 1, Bangkok 10700
Thailand

MR. PRASERT SITASIT**
National Inland Fisheries Institute
Kasetsart University Campus
Bangkhen, Bangkok 10903
Thailand

MR. JOHN D. SOLLOWS[a]
Khon Kaen Fisheries Station
Khon Kaen 40000
Thailand

DR. SOMBATH SOMPHONE*
Azolla Project
P.O. Box 2147
Vientiane
Laos

MR. PAITOON SRISOMSUP**
National Inland Fisheries Institute
Kasetsart University Campus
Bangkhen, Bangkok 10903
Thailand

MR. PRAJONG SUDTO**
Farming Systems Research Institute
Department of Agriculture
Bangkhen, Bangkok
Thailand

MR. SADELI SURIAPERMANA**
Sukamandi Research Institute
for Food Crops
Sukamandi, West Java
Indonesia

MS. I. SYAMSIAH*
Sukamandi Research Institute for Food Crops
Sukamandi, West Java
Indonesia

MR. SHAWN R. TAYLOR*
Asian Institute of Technology
G.P.O. Box 2754
Bangkok 10501
Thailand

MR. NIRAN THONGPAN
Ubon Field Crops Research Center
P.O. Box 79
Ubon Province 34000
Thailand

MR. ROBERT J. TOMICH*
Canadian International Development Agency
Northeast Fisheries Project
Khon Kaen Fisheries Station
Thailand

MR. JOSE N. TORRES
Department of Agriculture, Region III
Maligaya Research Office
Muñoz, Nueva Ecija
Philippines

MS. DEBORAH TURNBULL*
Canadian International Development Agency
200 Promenade du Portage
Hull, Quebec
Canada K1A OG4

MR. MORAKOT UKSORNSAWART**
Farming Systems Research Institute
Department of Agriculture
Bangkhen, Bangkok 10900
Thailand

MR. ARBSAK UMPIN**
Department of Fisheries
Ministry of Agriculture and Cooperatives
Rajadamnern Avenue, Bangkok
Thailand

MR. BERNARDO M. VALDEZ**
Department of Agriculture
Region III
Maligaya Research Office
Muñoz, Nueva Ecija
Philippines

DR. VICHIEN
Huntra Rice Experiment Station
Thailand

MR. SURESH K. WAGLE**
Aquaculture Centre for Training and Allied Research
Janakpur, Dhanusha
Nepal

MR. HERMANN WAIBEL**[a]
Asian Institute of Technology
G.P.O. Box 2754
Bangkok 10501
Thailand

MR. WANG JIANGUO**
Institute of Hydrobiology
Academia Sinica
Luo-Jia-Shan, Wuhan City 430072
Hubei Province
People's Republic of China

MR. E.C. WATERS*
CARE International
Kho Wang
Yasothorn, Thailand

DR. PRAPHAS WEERAPAT*
Rice Research Institute
Department of Agriculture
Bangkhen, Bangkok 10900
Thailand

MR. WEIDONG ZHOU**
Asian Development Bank
P.O. Box 789, Metro Manila
Philippines

MR. XIAO QINGYAN*
Chinese Academy of Agricultural Sciences
Beijing
People's Republic of China

MR. XU YUCHANG*
Chinese Academy of Agricultural Sciences
Beijing
People's Republic of China

MR. MOCHAMAD YUNUS**
Research Institute for Freshwater Fisheries
Jalan Sempur No. 1, P.O. Box 51
Bogor, West Java
Indonesia

ADDITIONAL THAI PARTICIPANTS

From the Department of Agriculture
Bangle, Bangkok
Thailand:

MR. CHANCHAI AUNSA-ARD*
Farming Systems Research Institute

MR. WITTAWAT KUNCHORN NA AYUTHAYA*
Office of the Inspector

MR. WINUS BOONYARATANPRIN*
Office of the Inspector

MR. DAMKHEONG CHANDRAPANYA*
Planning and Technical Division

MS. BOONTUEN CHOMDONG*
Farming Systems Research Institute

MR. SOMSOT DAMNERN-NGAM*
Farming Systems Research Institute

MR. BUNLUE FROMSRI*
Farming Systems Research Institute

MS. PETCHARAT IT-RAT*
Farming Systems Research Institute

MR. NIYOM JIW-JIN*

MS. SUPHARAT KEAWSAMUT*
Farming Systems Research Institute

MS. SUWAREE KETSAYOM*
Farming Systems Research Institute

MR. RASAMEE KIRITHAVEEP*
Farming Systems Research Institute

MR. RUANGCHAI KONGSRI*
Farming Systems Research Institute

MR. SONGSAK KULPADHI*
Farming Systems Research Institute

MR. SUPPAMIT MONKONG*
Farming Systems Research Institute

MR. PHAJONCHIT NUANPEW*
Farming Systems Research Institute

Mr. Charuwat Pommithi*
Office of the Inspector

Ms. Ket-la-ou Sawadhiraksa*
Finance Division

Mr. Pravet Seangpet*
Farming Systems Research Institute

Mr. Chalit Serthabut*
Farming Systems Research Institute

Ms. Musaya Singruang*
Farming Systems Research Institute

Ms. Somchai Singsa*
Canadian International Development Agency

Mr. Vanrat Sompeaw*
Ubon Rice Research Center

Mr. Sukee Sornchai*
Ubon Rice Research Center

Mr. Pathiarapong So-Yai*
Farming Systems Research Institute

Mr. Chalerm Sukapong*
Farming Systems Research Institute

Mr. Chartchai Thaila*
Farming Systems Research Institute

Ms. Theeraporn Tumbuacha*
Farming Systems Research Institute

Mr. Chirawat Wetchapeat*
Ubon Rice Research Institute

Mr. Suwat Youthanakarn*
Canadian International Development Agency

From the Department of Fisheries
NIFI Building, Kasetsart University
Bangkhen, Bangkok 10900
Thailand:

Mr. Sompotch Kribkratok*

Mr. Kriengsak Meangampan*
Northeast Fisheries Development Project

Mr. Boonrak Prathumchart*

Ms. Re-Nu Sirimongkonthaworn*

Mr. Phatoan Srisomsrap*
Northeast Fisheries Development Project

From Other Agencies:

Mr. Pornchai Charuratjamorn*
Khon Kaen University

Mr. Navarat Chitpiromsri*
Surin Freshwater Fisheries Station

Mr. Annu Harnprasit*
Kalasin Freshwater Fisheries

Mr. Narong Hu-Tanuwat*
Khon Kaen University

Mr. Jirachai Junthia*
Ubon Freshwater Fisheries Research and Development Center

Mr. Tawee Kupkanchanakul*
Huntra Rice Experiment Station
Ayuthaya, Thailand 1300

Mr. Vinit Makornpan*
Ubon Freshwater Fisheries Research and Development Center

Mr. Prasert Munsiri*
Nakornratchasima Freshwater Fisheries Station

Mr. Somkiet Phongsirichan*
Ubon Freshwater Fisheries Research and Development Center

Ms. Re-Nu Pitipornchai*
Ubon Freshwater Fisheries Research and Development Center

Mr. Chumnarn Pongsri*
Sakonnakorn Freshwater Fisheries Station
Sakonnakorn, 4700

Mr. Kiethichai Prasarthinphimai*
Office of Provincial Agriculture

Mr. Somsak Rongtongbaisuri*
Nongkai Freshwater Fisheries Station

Ms. Ubonrat Soontornrat*
Loei Freshwater Fisheries Station

Mr. Pradit Sripataprasite*
Khon Kaen Freshwater Fisheries
Research and Development Center

Mr. Narongsak Sririchaipan*
Kalasin Freshwater Fisheries

Ms. Penpun Srisakultiew*
Roi-et Freshwater Fisheries Station

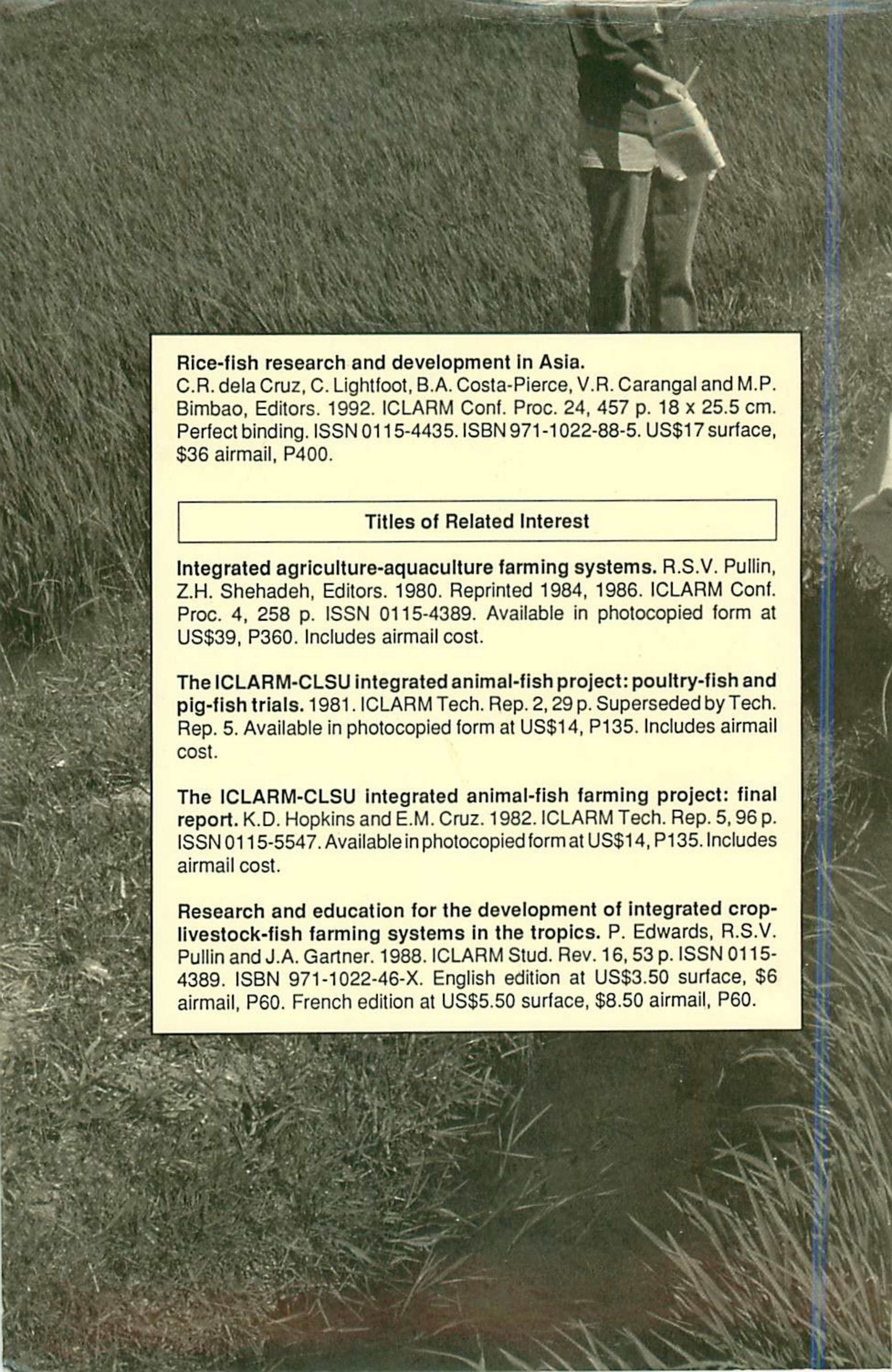
Mr. Chirdsak Vongkamolchoon*
Khon Kaen Freshwater Fisheries
Research and Development Center

Fish Species Index

*Local name.

Author Index

Country Index



Rice-fish research and development in Asia.
C.R. dela Cruz, C. Lightfoot, B.A. Costa-Pierce, V.R. Carangal and M.P. Bimbao, Editors. 1992. ICLARM Conf. Proc. 24, 457 p. 18 x 25.5 cm. Perfect binding. ISSN 0115-4435. ISBN 971-1022-88-5. US$17 surface, $36 airmail, P400.

Titles of Related Interest

Integrated agriculture-aquaculture farming systems. R.S.V. Pullin, Z.H. Shehadeh, Editors. 1980. Reprinted 1984, 1986. ICLARM Conf. Proc. 4, 258 p. ISSN 0115-4389. Available in photocopied form at US$39, P360. Includes airmail cost.

The ICLARM-CLSU integrated animal-fish project: poultry-fish and pig-fish trials. 1981. ICLARM Tech. Rep. 2, 29 p. Superseded by Tech. Rep. 5. Available in photocopied form at US$14, P135. Includes airmail cost.

The ICLARM-CLSU integrated animal-fish farming project: final report. K.D. Hopkins and E.M. Cruz. 1982. ICLARM Tech. Rep. 5, 96 p. ISSN 0115-5547. Available in photocopied form at US$14, P135. Includes airmail cost.

Research and education for the development of integrated crop-livestock-fish farming systems in the tropics. P. Edwards, R.S.V. Pullin and J.A. Gartner. 1988. ICLARM Stud. Rev. 16, 53 p. ISSN 0115-4389. ISBN 971-1022-46-X. English edition at US$3.50 surface, $6 airmail, P60. French edition at US$5.50 surface, $8.50 airmail, P60.