Preface

The Global Imperative to Develop New Models of Open Ocean Aquaculture for Accelerating Large-Scale Food and Energy Production

This edited volume "Aquaculture Perspective of Multi-Use Sites in the Open Ocean: The Untapped Potential for Marine Resources in the Anthropocene" comes at a critical time for our planet. A 2015 article in *Science* updated the long-range population projections of the United Nations in 1992. In contrast to the 1992 UN estimate, the Science paper showed no stabilization of the world's population by 2100, and that there was an 80% chance that the world's population, currently 7.2 billion, will reach 9.6 billion by 2050, and up to 12.3 billion in 2100. Much of the increases result from growth in Africa and Asia. Many of the nations on these two continents consume aquatic foods as their main sources of animal proteins. Accelerated demands for aquatic proteins in these regions will mean that in the future they will not export their products to Europe and North America anymore but use them in domestic markets.

Adding to a projected increased demand for aquatic foods is the recent call from the World Committee on Food Security that aquatic foods from fisheries and aquaculture be included in dietary planning to fight malnutrition in low income and food deficient nations (High Level Panel of Experts 2014).

Unprecedented—really shocking—ocean warming is causing the movement of temperate species north into the peri-Arctic seas and has led to the development of new fisheries, notably in the Barents Sea. For example, the Norwegian-Russian Fisheries Joint Commission allocations for cod and haddock for 2015 is 1,072,000 MT (Barents Observer 2015), nearly equal to the entire aquaculture production of the continent of Africa (FAO 2016). Alarmists of the late 2000s did overly exaggerate the global collapse of nearly all marine fisheries, and the downward trends of overfished stocks seem to be stabilizing. The recent models of Barange et al. (2014) show that by 2050 global capture fisheries will likely remain within +/- 10% of present global yields. But it is clear that the world's oceans and large lakes

cannot take any more fishing pressure, and they cannot (and will not) produce any more aquatic foods for humanity, and that seawater aquaculture (mariculture) is the only solution to the world's food supply but also to avoid a major biodiversity crisis (Costa-Pierce 2016).

Most of the planet's population has decided that its primary habitat in the Anthropocene is on the world's coasts, there are fewer and fewer coastal options to develop coastal marine aquaculture. A *New York Times* series of articles on polluted seas a few years ago, see especially their article "In China, Farming Fish in Toxic Waters" (Barboza 2007) brings the challenge clearly to the world. In the world's "seafood nations" where aquatic foods are the most important to people, coastal oceans and large lakes are damaged from land-based pollutants and toxicants, making these most nutritious, nutrient-dense protein foods…toxic!

Global food security, human health and overall human welfare are in serious jeopardy as the production of living marine/aquatic resources can no longer be sustained by aquatic ecosystems and natural fisheries production. Expansion of agriculture cannot meet future these protein needs without massive impacts on forests, wildlife, nature reserves and parks (Zabel et al. 2014; Costa-Pierce 2016). The only way we can proceed as an educated species is to develop mariculture that does not harm capture fisheries, promote unsustainable agriculture, or damage the integrity of aquatic ecosystems.

The drivers for open ocean aquaculture and offshore energy production are not only food, trade, electricity, and technology. There are powerful social and ethical concerns afloat. In some sort of weird "food insanity", many Western nations import most of the seafood they eat, and export most of what they catch or produce. These nations are far too dependent on imports from aquaculture systems in nations where aquaculture is threatened by coastal urbanization, industrialization, water pollution, and overall environmental degradation. Such "food insane nations" also have a moral and ethical responsibility to develop large-scale open ocean aquaculture to feed their own people and not take these valuable foods from undernourished, food scarce nations. Similarly, a continued reliance on fossil fuels by developed and developing nations is causing massive global climate change, a path that is neither environmentally sound nor economically sustainable.

There are valuable examples in this book of the development of robust submerged technologies; but there remains an urgent need to accelerate the education and training of open ocean aquaculture engineers; and to open wide the "aquaculture toolbox" to greater amounts of innovation. Norway leads the way globally in this regard; and New Zealand too, with that country now having about 10,000 ha of permitted areas for open ocean shellfish farming.

The use of offshore wind farms as multi-use platforms appears to be especially promising. A chapter in this volume reports that a 10% reduction in of O&M costs is possible for wind farms if aquaculture was combined. As shown in Germany's pioneering efforts, such combined food-energy systems in the offshore requires a high level of research and development funding as not only the development of innovative technologies is required, but also the need for marine spatial planning, and transparent, adaptive management processes to ensure economies of scope and

scale, for spatial efficiency and conflict resolution, and for the development of innovative policies and financial instruments.

There are few interdisciplinary departments or learned academic R&D centers focused on the multiple disciplines that intersect with open ocean aquaculture, and even fewer looking into multiple uses of offshore structures. Education and training networks are needed to provide the required multidisciplinary and interdisciplinary expertise for the safe and professional operations of multi-use systems. Aquaculture and energy production should align with planned ocean monitoring networks since these systems have significant potential to serve as oceanic environmental quality monitoring stations. Ecological design, engineering, and ecosystem based management approaches to develop open ocean aquaculture research and education innovation centers would produce design and performance optimizations that could potentially benefit all stakeholders plus increase research and development funding and boost the regional innovation economy. The Bremerhaven Declaration on Offshore Aquaculture clearly states that these priorities can only be met by the example of Germany who is funding an internationally important offshore experimental platform (Rosenthal et al. 2012).

Offshore aquaculture developments, alone or in conjunction with other uses will require much higher inputs of capital and new levels of cooperation from a wide range of social, technological, economic, and natural resource users, and a greater degree of cooperation and collaboration with other industry sectors. Transparent strategies need to be developed with the strong participation of all affected stakeholders interested in the social-ecological design and engineering of innovative offshore multi-use systems. In this context, multi-use systems if intelligently designed can be incorporated into programs for cooperative fisheries restoration and aquatic ecosystem management strategies. In this regard, multi-use systems that incorporate aquaculture development need to be guided by international policy instruments such as the FAO Code of Conduct for Responsible Fisheries (FAO 1995) and the FAO Guidelines for an Ecosystems Approach to Aquaculture (FAO 2010).

The Editors and authors of this volume are among a select group of pioneers who over the past 20+ years have studied, spoke about, and practiced open ocean aquaculture, and have recognized the many opportunities for combining uses of the ocean such as energy and food production. They have garnered wisdom from direct experiences, from many a day operating aquaculture systems on the rough waters of the Northwest Atlantic Ocean, the North Sea, and elsewhere. They have gathered in this volume a diverse group of interdisciplinary aquaculture scientists and engineers to discuss what they consider are the most important recent science and policy developments. Their views as thought leaders are globally important for the future of protein and nutrient-rich foods on Earth, not only for the future of open ocean aquaculture in combination with other offshore uses. It is our desire that this volume stimulate further research and development into the combined production of energy and seafood in open ocean environments. Success in this endeavor is paramount to the sustainability of systems critical to maintaining healthy oceans,

meeting the nutritional needs of a growing world population, and to the very survival of the Earth's ecosystems good and services.

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