Chapter 14
Epilogue—Pathways Towards Sustainable Ocean Food Production

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Abstract While there is a great deal of global interest in the development of combined uses of open ocean installations, for commercial scale multi-use platforms for food and energy production and other potential applications, the transition from concept to reality has yet to come to fruition. While much is known about the economics, environmental, political and societal effects of individual production sectors, there are many unknowns and challenges with regard to economics, engineering, liability and social aspects of multi-use. Mutually agreed upon principles, such as those articulated in the Bremerhaven Declaration, and EU directives and grant funding opportunities to advance research and development indicate that progress, although measured, is being made. The development of true commercial-scale multi-use offshore platforms will require investment in demonstration projects and multi-national cooperation and collaboration across public and private sectors.

14.1 Introduction

In putting together this volume, we have attempted to capture the various aspects and complexities of implementing open ocean aquaculture as an additional use of offshore platforms. As we have stated in our introduction, we see great potential for

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maximizing the productivity of ocean installations for seafood, energy and scientific pursuits, and there has been a considerable amount of thinking and discussion that has taken place globally in recent years to realize this goal. We are deeply grateful for the contributions of the co-authors of this volume, as their expertise and experience represents the state of knowledge on the topic of aquaculture as a potential multi-use of ocean platforms.

We have covered technical, operational, biological, economic, social and political considerations, as well as case studies, where aquaculture was implemented at pilot scale on offshore oil rigs and wind turbine platforms.

One important area that was not covered in this book was environmental and ecological risks associated with aquaculture. While we acknowledge that environment issues are extremely important, we felt that they have been covered exhaustively over the past three decades and that further discussion would not have added new information for this volume. A recent review paper by the US Department of Commerce's National Oceanic and Atmospheric administration (Price and Morris 2013) does an excellent job of synthesizing thirty years of literature on all environmental aspects of marine fish cage culture, so we recommend that report to readers with interest of this topic. While most environmental impacts have been associated with marine finfish culture, there are some concerns with shellfish and macroalgae culture though to a much lesser extent. These issues are also covered extensively in the literature (Fabia et al. 2009; Hatcher et al. 1994; Langan 2007, 2012; Lloyd 2003; Paul 1999; Plew et al. 2005; Price et al. 2015)

14.2 What We Have Learned

While we have extensive knowledge of the technical, social, political, environmental and biological aspects of aquaculture and offshore energy as separate entities, we have less knowledge and experience with these activities taking place within the same ocean footprint. Though there are several projects in planning stages. Particularly in the EU, most of the projects to date have been small scale and have essentially been opportunistic retrofits on existing structures or hypothetical scenarios that have yet to be realized. We do know that there are complexities in site assessment and selection as well as permitting and licensing for aquaculture and energy installations as stand-alone activities, however, we do not know if the process would become even more complex if the two activities were proposed for the same project location, though we suspect they might.

We also know that there is potential for mutual benefits and cost savings for things like maintenance and operations, though the greatest advantage would be for aquaculture due to the robust structure provided by energy platforms to serve as attachment points for e.g. fish cages and bivalve and/or seaweed longlines and potential inclusion of feeders and possibly even hatcheries and nurseries mounted on the platforms. Additionally, any power requirements of the fish, shellfish and macroalgae farms could be provided by wind turbines.

14.3 What Still Needs to Be Learned

14.3.1 Technologies and O&M

The installation of aquaculture devices offshore, either in close proximity to or direct attachment to the offshore wind farm or oil rig, needs as a first step a full complement of oceanographic, environmental and site-specific data set as well as a full understanding of the water motions on the farm structure as well as its associated candidates. To avoid the major stress on the installation induced by storm conditions the aquaculture installations should be submergible. That means that a significant part of the entire culture unit is located beneath the surface and/or in direct contact to the multi-use platform, while the bulk of the structure's mass is mounted below the surface to allow buoyancy and stabilization. This mooring component should be below the zone of turbulence and wave action (Starchild 1980). None of these technologies and system designs are available on the market, nor are they currently in development.

Depending on the species and culture designs, more insight into the operation and maintenance including deployment and harvest by taking local site-specific criteria into account. As none of these multi-use devices currently exist or are only on pilot scale, O&M strategies cannot be developed except theoretically (see Chap. 4). To get more insight into this emerging issue, large-scale multi-use platforms have to be installed (see Sect. 14.5.1 below).

For some uses such as aquaculture, floating platforms already exist. However, for other uses such as wind farms and service platforms the floating design is in development. The combination of floating platforms in a multi-use concept is a new challenge and still in its initial stages (e.g. wind farm and desalination = Stefanakou et al. 2016; wind farms and aquaculture = TROPOS 2016; MERMAID 2016).

14.3.2 Environmental Impacts

As already mentioned above, volumes of information on risks from any type of aquaculture on the local ecosystem in the nearshore and offshore realm are available. However, potential risks originating from a combination of uses following the co-use concept is not known, especially when it comes to potential cumulative effects from wind energy turbines or oil rigs in association with aquaculture. The compilation of Beiersdorf and Wollny-Goerke (2014) provides information on ecological impacts resulting from offshore wind energy installations on the seabed and its associated organisms (Gutow et al. 2014). In addition, information on potential impacts on the pelagic habitat including invertebrates, ichthyofauna (Krägefsky 2014) and mammals (Dähne et al. 2014; Skov et al. 2014) as well as on avifauna and bat fauna (Damian and Merck 2014; Hill et al. 2014; Mendel et al.

2014) is available (Krause 2014; Kühn and Schneehorst 2014). A similar collection of information regarding the impact of oil rigs on the environment exists (e.g. Kingston 1992; Olsgard and Gray 1995) as well as from other offshore structures. However, when decommissioning these structures after their expected lifetime, the impact on the ecosystem can be quite diverse. That includes the fact that restoration of habitats may lead to a severe impact of organisms associated with the reef structure (Claisse et al. 2015; see also "Rigs-to-Reefs" program in Chap. 1 of this volume; Reggio 1987). Therefore, not only the impact of structures on marine habitats alone but also in combination depending on their respective use should be taken into account in future projects and/or commercial realisation.

14.3.3 Ownership and Insurance

As already addressed in Chaps. 10 and 13 ownership is an emerging issue currently not solved. Krause et al. (2011) indicated the importance of the social dimension of the different mariculture-wind farm integration processes and how this develops with regard to the various forms of ownership and management such a venture might take. The ownership versions discussed in Chap. 13, (1) sole owner, (2) negotiated contract, and (3) legislated contract, are only three possibilities among even more. Finally, for all current offshore users the political allocation of ocean space is licensed for specific purposes only not in combination with multi-users. In the future, there should be a new version of assignments of ocean space to avoid a complex mix of ownership, associated commons and private property.

The issue of having a shared insurance or every stakeholder its own insurance has not been addressed. This is even more complicated if the multi-use installation is owned or operated by one legal entity and a problem arises with one use having an effect on the other use (e.g. aquaculture installations will be dislodged during storm conditions and get entangled in the ships propeller of the wind farm maintenance vessel). There is an urgent need to come up with potential solutions.

14.4 Future Challenges and Opportunities

The combination of several activities (e.g. renewable energy, aquaculture, maritime transport, and related services) in the same marine space, including in multi-use platforms, it is quite possible that the costs of offshore operations and the demand on the space needed can be reduced. The research on multi-use platforms funded under the EU-Initiative FP7 call "The Oceans of Tomorrow" has already provided promising designs, technological solutions and models for combining activities in terms of economic potential and environmental impact. However, before reaching a

demonstration pilot stage, further research is needed, which will be funded under the umbrella of two larger calls for proposals described below.

One barrier to multi-use the offshore realm is that different environmental, safety and regulatory regimes and practices apply to different sectors and to different national jurisdictions. Furthermore, there is a lack of common understanding of the nature of operations within different sectors and the feasibility of combining these in a way that provides mutual benefits. The first proposal call, "Multi-use of the oceans' marine space, offshore and near-shore: compatibility, regulations, environmental and legal issues" (BG-03-2016, 2 million Euros per proposal) was started in November 2016 (e.g. Project No. 17 "MUSES" in Chap. 13). The challenge is to identify the real and perceived barriers to integration. Therefore, there is a need for a clear overview of compatibility, regulatory, environmental, safety, societal and legal issues within the context of the maritime spatial planning directive and how they impact on the combining of different marine and maritime activities (EU 2016).

In the second proposal call, it is postulated that technological research and innovations are needed to reduce risks for operators and investors. Therefore, the call "Multi-use of the oceans marine space, offshore and near-shore: Enabling technologies" (BG-04-2017, 8 million Euros per proposal) was initiated in October 2016. The scope of the proposals should cover aspects with regard to combinations of innovative, cost-effective technologies and methods including automation and remote monitoring technologies, flexible structures and facilities in order to test concepts of multi-use platforms leading to pilot demonstration phases. Tests of the sustainable operability of co-located maritime activities around coastal or deep sea environments as well as health and safety issues associated with multi-use marine platforms should be addressed as well as environmental and economic viability and societal acceptance (EU 2016). However, as this call more or less covers a vast collection of emerging issues (offshore to nearshore, technology, economy, environmental issues, social issues, and many suggested multi-use combinations, etc.) we recommend to focus on the most promising multi-uses resulting from previous nation and international projects.

14.5 Recommendations to Accelerate Development in the Future

14.5.1 International Test Station

Scientists working in the field of offshore platforms, either for marine bio-resources or renewable energy and oil, agree that it is a very cost-intensive plan to install a larger aquaculture multi-use installation, which needs to be scaled up from scientific pilot scale to a size that simulates commercial production. It is therefore necessary to pool national and international expertise and resources to co-finance an offshore

multi-use platform to allow the next step of research and development. This is even more important for other stakeholders interested in moving offshore, such as offshore (container) terminals for commercial shipping as well as offshore energy suppliers (used by energy consumers off the coast to avoid long sea passages to coastal harbours, such as fisheries, fish processing platforms, deep-sea mining, etc.), and other related services.

14.5.2 Bremerhaven Declaration

The initial concept for preparing the "Bremerhaven Declaration" was conceived at the "Marine Resources and Beyond Conference" conducted in 2011 and finalized in 2012 during the "International Workshop on Open Ocean Aquaculture", both held in Bremerhaven, Germany. Recognizing that the gap between demand and supply is increasing on a global scale, it is not surprising that the pressure to pursue offshore aquaculture development is growing. This is of prime importance in countries which are not able to install aquaculture operations nearshore. Some of these countries foster the concept of co-using offshore space. To better organize the wide range of scientific work in social, technological, economic and natural resources disciplines with focus on the co-use internationally, the Bremerhaven Declaration gathers issues on open ocean farming systems in co-management with the strong participation of other stakeholders interested in offshore natural resource uses, such as wind farms, oil rigs or other offshore installations. One major goal was to support inter- and transdisciplinary cooperation on local, national and international level and to avoid cost-intensive overlap of research. The participants believed that this would have the best output this agreement offers ample opportunities to bring aquaculture production to new levels.

A number of pertinent issues related to open ocean aquaculture and multi-use with other offshore installations was discussed, by

- **recognizing** that global food security, human health and overall human welfare are in serious jeopardy since the production of living marine resources for vital human foods cannot be sustained by natural fisheries production, even if these resources are properly managed at levels of optimum sustainable yields;
- **realizing** that the gap between seafood supply and demand is increasing at an alarming rate as these are nutrient-dense foods are considered extremely important for human health and well-being. On the other hand, the development of aquaculture has been remarkable and today provides more than half of all seafood destined for human consumption;
- **confirming** that conventional land-based and coastal aquaculture will continue to grow, thereby playing in the future a growing role in quality food supply. However, this much needed development will only delay the widening of the gap in seafood supply and new and modern technologies such as offshore farming systems are required to significantly assisting in closing this gap;

- **noting** that the world is too dependent, however, on aquaculture development and its exports, as aquaculture is threatened by coastal urbanization, industrialization, and water pollution. Weighing these trends we believe that it is urgent that the world develop offshore aquaculture, while complying with the FAO Code of Conduct for Responsible Fisheries and Aquaculture as well as with other environmental regulatory frameworks in support of sustainable aquaculture development;
- **finding** that Offshore aquaculture will require much higher inputs of capital but also needs a new level of cooperation from a wide range of social, technological, economic, and natural resource users;
- **discovering** that over the past decade major advances and new concepts have evolved, and several of them have been successfully tested at the pilot scale level, while others have failed.
- **learning** that these experiments and scale-up trials have led us to believe that offshore aquaculture does have substantial potential to bring global aquaculture production to new levels to meet future human needs;
- **believing** firmly that strategies need to be developed with strong participation of all affected stakeholders interested in the social-ecological design and engineering of innovative offshore aquaculture food systems;
- **recognizing** that the integration of offshore food and energy systems (e.g. aquaculture systems and windfarms; oil and gas) appear to be especially promising, but will require a high level of innovative technology, the use of marine spatial planning, and transparent, adaptive management for spatial efficiency and conflict resolution;
- **concluding** also that open ocean aquaculture if intelligently designed can be incorporate into overall cooperative fisheries restoration and management strategies.

The participants, which included a core group of the global expertise on the subject, formulated a series of specific recommendations and called upon national, international, intergovernmental agencies, as well as the industries, potential investors, scientists, regulators and NGOs of the respective countries to strongly support these recommendations with the aim to provide a healthy and environmentally sustainable bio-resource system that can substantially contribute to meet the future demands of our societies. All recommendations and justifications are summarised in Rosenthal et al. (2012a, b).

14.6 Conclusion

When we began this project several years ago, we were motivated by our firm conviction that a sustainable seafood supply for future generations is dependent on expansion of marine aquaculture and that open ocean environments are likely the best option for increasing production. We also recognized that maximizing the

output of goods and services, in this case energy and food, from a human developed footprint of seafloor is key to wise ecological use of our oceans. While we concede that this is an enormous challenge that requires unprecedented commitment from a wide range of public and private sectors, we believe that the beneficial outcomes will far exceed the effort and investment. We applaud all efforts to move the multi-use concept forward and were pleased to see a recent article in an international aquaculture online publication encouraging its development (Holmyard 2016).

Our intent with producing this volume was to inform governments, research institutions and private industry about the potential for the multi-use concept, and to inspire these entities to continue the pursuit of transforming concept into reality. We hope that our efforts will contribute to the quest for creative solutions to food and energy production to the benefit of human health and well-being, and to ecologically sound and sustainable use of our oceans.

It is apparent that the orchestration of a multi-use concept, such as an integration of marine aquaculture with wind energy or oil production in the offshore realm, is still in its infancy. The major issue extracted from this volume clearly indicates that practical multifunctional use of offshore areas requires technical and economic feasibility as a basic prerequisite to assure that all operators will support a multi-use concept. Consequently, more information on the economic and technical viability of this joint venture is the key factor. If these issues will get more insight and result in best solutions, this will be a practical approach towards rationalizing marine stewardship in the offshore setting. The current initiatives on EU level are a perfect pre-condition to achieve this goal.

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