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Materialien

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Short Expertise on the Potential Combination of Aquaculture with Marine-Based Renewable Energy Systems

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SeaKult
sustainable futures in the marine realm

Short Expertise on the Potential Combination of Aquaculture with Marine-Based Renewable Energy Systems

Commissioned by the AWI / WBGU to

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Summary

Spatial competition for aquaculture sites along coastal seas has encouraged the initiative of moving aquaculture into the open ocean at exposed sites, particularly within the Exclusive Economic Zone (EEZ). These offshore sites require an understanding of the adaptive capabilities and limitations in growth potential for species at these sites, the development of new technologies capable of withstanding these high energy environments and the necessary institutional arrangements (e.g. marine spatial planning). It is also essential in site selection to consider biotic and abiotic factors in association with economic, ecological and socio-economic perspectives, whether in the coastal zone or at offshore locations. Beside basic investigations on these parameters, conditions of a preferred site can be investigated by analyzing the overall health status, growth and survival performance of species grown in different areas as a bio-indicator of site suitability.

Since aquaculture operations tend to move far off the coast special focus is brought to the combination of aquaculture devices with other fixed structures in place to save costs as well as to have stable connections to prevent losses. Past experiences and trails have shown that the problem of fixation and continuous operation and maintenance are crucial for the success of offshore aquaculture operations. Several combinations are possible, among which to date offshore wind farms and aquaculture appears to be most promising to date.

The expertise covers the various aspects of such a multi-use approach, starting with an overview of the potential offshore candidates and the current state of the biological investigations and their possible environmental interactions. Technical and Design considerations are crucial to the success, since depending on the candidate, different cultivation techniques are necessary which must withstand in a reliable manner the harsh offshore site conditions. The marcoalgae ring is a case in point. Monitoring and surveillance are important out of twofold reasons; for one, they are – in Europe – mandatory under the Marine Strategy Directive and Water Framework Directive, as well as the Habitats Directive. Second, through the establishment of a framework for environmental monitoring one is be able to assess the effects and to propose appropriate remediation actions. Next, several parameters, such as meteorological and ocean currents are important for the offshore site-selection process. Socio-political considerations cover the whole range of stakeholders and their type of involvement in the establishment and operation of multi-use offshore systems. Indeed, pre-existing social networks can provide significant political leverage for governance transformations as required for the move offshore. In contrast, the economic considerations focus on simple gross margin calculations and enterprise budget analyses with the calculation of break-even prices and yields for different species, as blue mussel, macro algae and finfish. Furthermore, among others, investment appraisals and sensitivity analyses with the variation of key parameters must be conducted when assessing the economics of offshore multi-use system.Thus, combining offshore wind farming and marine aquaculture is an opportunity to share stakeholder resources and can lead to greater spatial efficiency in the offshore environment. However, a range of organizational and social challenges related to the collective use of a defined ocean territory have to be taken into account, the creation and compliance with defined responsibilities and duties or the introduction of cross-sectoral management lines, such as an offshore co-management, that integrates the different demands and practices of the involved parties within a operation and maintenance scheme on a practical day to day manner.

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1. Introduction and Scope

Over the course of the last decade, the race to move wind farms offshore has drawn the attention on the development of designs to further optimize the benefit from this move into the remote waters. Thus, considering multiple uses of such offshore renewable energy systems in the design phase so that the economic benefits from a unit area of sea can be maximized in a sustainable way has been a central research subject over the last years. These are of interest where they are suitable, acceptable and economically viable. Thus, the slogan "Maximizing the benefit of a 'piece of land" (Buck 2009) is a potential solution to foster offshore multi-use concepts of renewable energy systems.

Most prominently, this has been the case for the establishment of offshore aquaculture in combination with offshore wind farms (see e.g. Buck & Krause 2012). Initially, the idea was to combine wind farms with the installation of extensive mariculture for native bivalves and macroalgae (e.g. Buck 2002, Buck & Buchholz 2004, Buck et al. 2008, Lacroix & Pioch 2011, Buck et al. 2012a). Further expansion towards finfish culture has since then been proposed.

The Alfred Wegener Institute for Polar and Marine Research (AWI) in Bremerhaven (Germany) and its marine stations on the islands of Helgoland and Sylt (former Biological Institute Helgoland - BAH) pioneered this scientific field worldwide starting in the year 2000 when the first wind farms in the North Sea were set-up. Later, the Institute for Marine Resources (IMARE) – a spin-off of the AWI – took over the applied science within this research field. Today, many other research institutes follow these initial ideas of the AWI and IMARE scientists and conduct feasibility studies within their coastal and EEZ waters, such as Denmark, The Netherlands, Belgium, the UK, USA and others.

For this rather risky and expensive move to happen in practical terms, however, an understanding of basic needs, such as design-requirements, data acquisition, site specifications, operation and maintenance issues, etc. is required. Offshore equipment will need to be adapted to co-exist with the other uses to which the platforms may be put. Indeed, this move further from shore and into higher energy environments has created the demand for new vessels for installation, operation and maintenance and decommissioning. While it is clear that multi-uses will require multiple types of service vessels, there will be areas of overlap where economies can be made, (e.g. in the transport of technicians). For instance in the case of aquaculture, equipment has been developed for more benign environments and as such is still in the redesign-phase for harsher conditions.

Box 1 – The Term "Offshore"

Offshore aquaculture (OA), also described as open ocean aquaculture (OOA), refers to culture operations ongoing in frequently hostile open ocean environments. There are various definitions on what can be considered as "real" offshore aquaculture. In the implementation of strategies of marine spatial planning within EU member states, as well as in the development of internationally operating industries off the coast, such as the extraction of gas and oil and the massive construction of offshore wind turbines, "offshore" is declared as being a site which is beyond the twelve nautical mile zone of the coastal sea. However, for any aquaculture enterprise "offshore" is defined as being a marine environment fully exposed to a wide range of oceanographic conditions (Ryan 2005), such as strong currents, swell and/or high waves. This increased exposure to higher wave energy is often linked to distance from shore or lack of shelter by topographical features such as islands or headlands that can mitigate the force of ocean and wind-generated waves. Following Buck (2004, 2007), offshore sites are at least eight nautical miles off the coast to avoid manifold stakeholder conflicts in nearer coastal areas (Dahle et al. 1991). However, exposed sites are also existent in nearshore areas. Therefore, the term "offshore" should be defined specifically on a case to case basis.

The WBGU has contracted SeaKult to provide a short expertise on the subject on the potential combination of aquaculture and marine-based renewable energy systems. The following document pulls the different strands of investigations in this new emerging field together and provides an overview of the current state-of-the-art of the research fields involved. Out of an array of different possible offshore renewable energy systems, offshore wind farms are most advanced in practical terms. Thus, the expertise focuses strong on these systems and its potential link with offshore aquaculture. The document closes with a brief summary on the present research efforts on EU and international level.

2. Moving off the coast: Development of offshore multi-use concepts

The development of "offshore aquaculture" or "open ocean aquaculture" has often been described as the "Blue Revolution", which puts aquaculture development on the same scale as the advances made in agriculture during the so-called "Green Revolution". A shortage of marine proteins due to commercial fisheries having reached their capacity threshold while demand continues to increase, will, in the longer-term, render a significant expansion of aquaculture of various species. However, the rationale for the emergence of scientific considerations and semi-commercial trials to develop aquaculture operations off the coast is quite diverse. Further expansion of aquaculture, land-based and/or nearshore, is limited for various reasons, such as political, environmental, economic, technical and resource constraints as well as limited knowledge on the "metoecan" conditions. With the exception of hatchery and nursery production, the space required to grow market-size aquaculture products in land-based systems is significant, and therefore not yet economically viable for all species. Space for the expansion of cultivation enterprises is mainly the limiting factor a farmer has to cope with due to competition with a variety of other marine coastal commercial or recreational based stakeholders,. However, when moving off the coast there are several advantages, especially when combining the aquaculture system design with other stable structures in the marine realm.

In developing countries, the installation of coastal aquaculture systems benefits from the often weak enforcement of integrated coastal management schemes, which regulate equal access to the coastal resources (Adger & Luttrell 2000; Davis & Bailey 1996). Thus, the rise of aquaculture production has specifically taken place in developing countries, especially in Asia, which holds approximately 93% of the global production share (Lee & Turk 1998; Rana 1997) (FAO 2012). In addition, overlapping use of coastal habitats adds to the increasing pollution of coastal waters and gives rise to spatial conflicts, thus leaving little room for the expansion of modern coastal aquaculture systems. In contrast, the number of competing users within offshore regions is relatively low, thus favouring the offshore environment for further commercial development. This has triggered the movement of aquaculture to offshore areas, where little spatial regulations have

Box 2 – The Term "Metocean"

In order to successfully design and operate offshore multi-use installations in a safe and efficient manner it is essential that a good knowledge is available of the "metocean" (meteorological and oceanographic) conditions to which the installation may be exposed. Moreover, the characteristics of the sea-bed, the proximity to access points for i.e. electricity grids, processing centers for aquaculture products, shipping lanes, fishing grounds and a whole range of other technical, social, political and environmental concerns must be considered. Readily applicable tools which assess the suitability, acceptability and financial viability of sites for multiple purposes are, however, yet lacking.

been established so far and clean water can be expected (Buck et al., 2004). There is an enormous economic potential for extensive as well as intensive marine aquaculture in these exposed areas.

A detailed overview of the main drivers for the development of offshore aquaculture is listed in the last ICES report of the Working Group for Marine Shellfish Cultivation (WGMASC) (ICES 2012).

Reasons to combine these offshore aquaculture devices with other structures or other benefits when co-using these sites are reviewed by Buck (2005). The diverse utilizations offshore can be classified in six main groups, such as (1) Renewable Energy, (2) Marine Resources & Environment, (3) Monitoring, Surveillance & Communication, (4) Presentation & Training, (5) Maritime Traffic, and (6) Others (see Table 1).

However, the multi-use concept is not new. Various combinations have existed for decades, coincidentally (e.g. fishing ↔ shipping), tolerated (e.g. nature conservation ↔ mussel fishery) as well as well-organised (e.g. tourism ↔ research; artificial reefs ↔ angling). Some other potential co-uses have been established at the decommissioned oil platforms in the Gulf of Mexico, which are

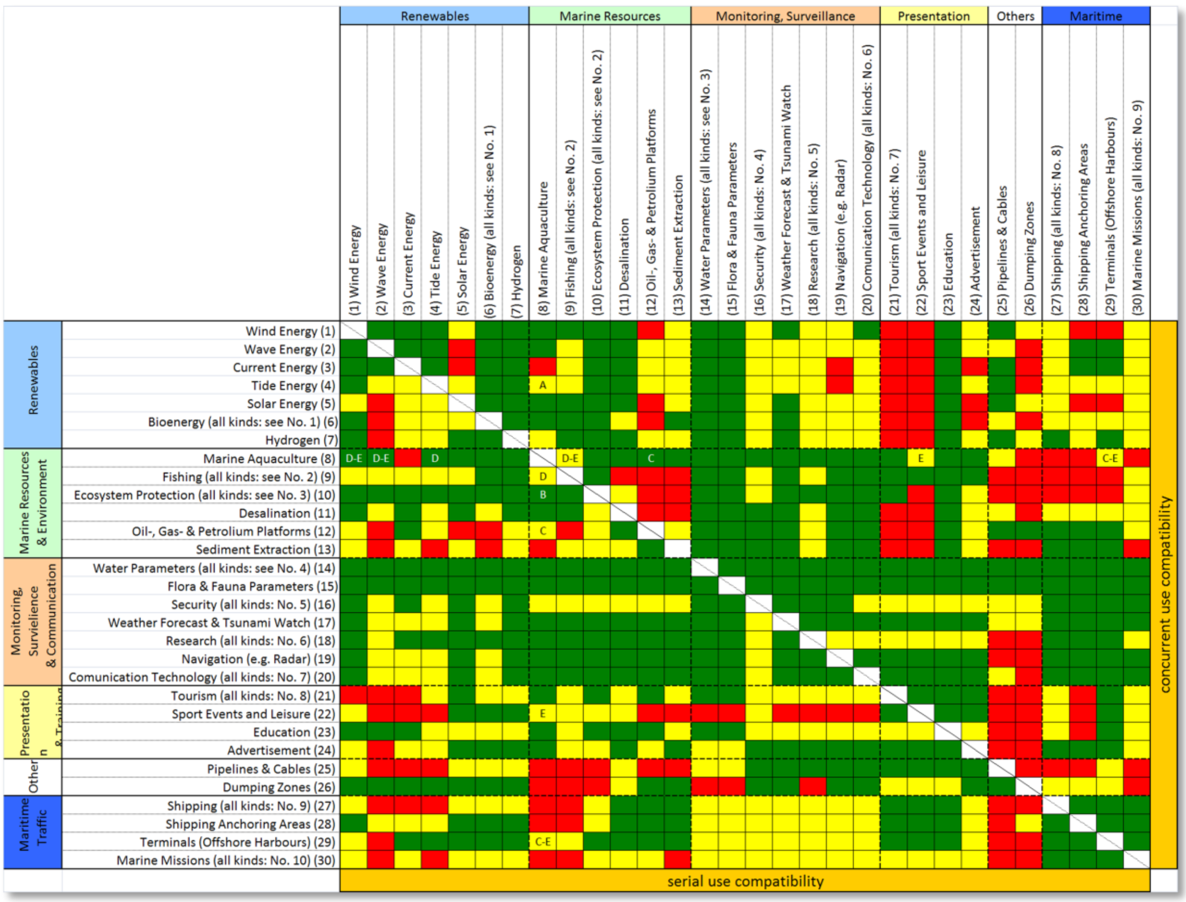

Table 1 – Multi-use compatibility matrix: Current uses of offshore areas around Europe and their potential compatibility. Green boxes = good potentials for a combined use, yellow boxes = there are some limitations but still with a potential compatibility, red boxes = no compatibility. The compatibility also depends on the water depth of the location. Not every compatibility shown in this table can be realised in every water depth. Additionally, some combined uses can be realized by attaching one to the other or by installing one use in the vicinity of the other or both. Potential limitations: A = not in a floating mode, B = extractice aquaculture only, C = only if there is no pollution, D = depends on the techniques used, E = in the vicinity only.

today used for private fishing (Heitt et al. 2002) or aquaculture purposes such as finfish farming (Midget 1994; Chambers 1998; Wilson et al. 1998). The following section provides a brief overview of central research efforts in the past.

3. Past experiences in offshore farming in combination with other stakeholders

3.1 Experimental Trials

The first synergy of offshore platforms with aquaculture was initiated in the Caspian Sea (27 km off the Turkmenian shore) in 1987 (Fig. 1), but high operating costs led to a shutdown of this enterprise at a very early stage (Burgov 1992; Burgov 1996). However, over the past 25 years more than 1,000 oil and gas structures were installed in the same area and more than 300 in the Black Sea. The amount of time to decommission takes on average one year and international experience in disassembling those platforms showed that the average cost of disassembly works is several million Euros (Burgov 1991).

Figure 1 – Submersible cage complex «Sadco-Kitezh» (consisting of 6 individual cage modules) disposed near an offshore oil-rig in the Caspian Sea in 1988 (Burgov 2006).

The cumulative costs of a total removal had reached an estimated $1 billion in the Gulf of Mexico by the year 2000 (Dauterive 2000). In this respect the search for a way of conversion of such structures became more important and initiated the search for alternatives. Operators have recognized that during a rig's productive years, significant marine life aggregates on and around its structures. This is also caused by the fact that marine areas used for offshore platforms are no longer suitable for vessels operating with active gear mainly due to safety reasons (Berkenhagen et al. 2010). This logically entails an increase in biomass of fish or other species and/or a greater number of species in this area than before. These areas then can be considered as more or less a marine protected area (MPA). Marine scientists have therefore suggested preserving much of this marine life and encouraging further growth (Jensen et al. 2000). Whilst thus the operator benefits by avoiding the substantial cost of removal, additionally, artificial reefs with lots of marine organisms were established. These findings encouraged recreational fisherman, divers, offshore oil and gas operators, aquaculturists and others who could benefit from the increased density to realize the "Rigs-to-Reefs" program in American and European Seas (Reggio 1987), where decommissioned offshore oil and gas rigs were turned into artificial reefs. Since then many scientists have reported that these artificial reefs increase the number and diversity of marine organisms adjacent to these sites (e.g. Bohnsack et al. 1994; Zalmon et al. 2002) including many commercially important fish, shellfish and crustacean species (Bohnsack et al. 1991; Jensen 2002).

Figure 2 – Ocean Spar Cage Deployed in Federal Waters 22 miles off Mississippi in the Gulf of Mexico (Buck 2002).

To this point, some efforts have been carried out to successfully install offshore aquaculture constructions as pilot systems even in the open Pacific but none have so far reached a continuous commercial operation. In particular, projects carried out in the US were of prime importance for the successful installation of various offshore systems (e.g. Loverich 1997, Loverich & Gace 1997, Braginton-Smith & Messier 1998, Loverich 1998, Loverich & Forster 2000). These efforts led to the idea to include various disused oil platforms in the Gulf of Mexico in a multi-use concept (Miget 1994, Wilson & Stanley 1998) (Fig. 2). The National Sea Grant College Program funded such research projects to explore offshore regions for mariculture purposes. The Open Ocean Aquaculture Program at the University of New Hampshire is one of the few attempts made so far (Ward et al. 2001) as well as the Hawaiian Offshore Aquaculture Research Project (HOARP) (Ostrowski & Helsley 2003). Due to the technological capacity of the US and their extended marine areas, the movement of aquaculture activities into offshore areas gained momentum (e.g. Dalton 2004) and has caused other western countries to follow.

Several studies have estimated that tons to tens of tons of wild fish congregate in the immediate area around fish farms in both warm and cold-temperate environments (e.g. Dempster et al. 2004; Dempster et al. 2009; Leonard et al. 2011). For some species artificial reefs can increase the effective habitat availability (e.g. Polovina et al. 1989) and be utilized for reproductive purposes (Jensen 2002) as well as to reduce the detrimental impacts on existing habitats by trawl exclusion and the enhancement of faunal biodiversity by creating new habitats (Claudet et al. 2004). Additionally, these constructions can be helpful in developing cost effective fishing practices by reducing displacement cost for the inshore fleets and reducing competition for territory between fishermen. The question whether artificial reefs close to aquaculture sites would decrease the impact of cultured fish waste on the surrounding ecosystem has been suggested as a topic of research.

In the late nineties another combination in New England was discussed by co-using OSPREY (Ocean Swell Powered Renewable Energy) and WOSP (Wind and Ocean Swell Power) stations for the use of farming fish (Braginton-Smith et al. 1998). In Germany, the plans for the massive expansion of wind farms in offshore areas of the North Sea triggered the idea of a combination of wind turbines with installations for extensive shellfish and macroalgae aquaculture (e.g. Buck 2002; 2004). Due to the fact that offshore wind farms provide an appropriately sized area free of shipping traffic (as most offshore wind farms are designed as restricted-access areas due to hazard mitigation concerns), projects on open ocean aquaculture have been carried out since 2001 in Germany only. However, the combination of wind energy and aquaculture enterprises was already proven in China in the early

1990s (Chunrong 1994). Nevertheless, these wind turbines were land-based and used to enhance dissolved oxygen in the water column as well as to increase fishpond temperature.

Other combinations of uses offshore are possible, thus supporting the trend to combine expensive infrastructure and collocate it in offshore areas (Buck 2009a). In this respect a great deal of discussion has begun on moving various kinds of uses to regions where more space is available, focusing specifically on resources, which could become scarce in the near future (e.g. production of food). However, one has to keep in mind that plausibility and profitability is an incontrovertible constraint to any enterprise offshore, especially when combining them into a multi-use concept. Some concepts to move industrial interests off the coast did not fulfil these requirements. For instance, the ChevronTexaco Corp plan to construct a US$ 650 million offshore liquefied natural gas

Figure 3 – Research Platform "Nordsee" about 100 km off the German mainland (left) and dismantling of the platform 20 years later (modified after IMS 1972; IMS 1993).

receiving and re-gasification terminal with accommodation for personnel (to be located 13 km off the coast of Baja California, Mexico) (Chevron Texaco 2003) could not be realized as originally conceived due to high rising expenses. The *Forschungsplattform Nordsee* (Research Platform "North Sea"), which was constructed in 1974 about 100 km off the mainland of Germany for marine research harbouring 25 people and a helicopter landing site as well as a little jetty (see Figure 3) met, over the course of time, a similar fate. The platform was dismantled in 1993 due to high maintenance costs (Dolezalek 1992). Hundreds of offshore future visions, such as the concepts for space, land and sea of *Agence Jacques Rougerie Architecte* (Rougerie 2011) or the carbon-neutral self-sufficient offshore farming platform, called *Equinox* (FDG 2011), exist on paper, but are yet far away from practical realization. Other uses would have an economic potential but have not been realized so far, such as passive fishing in combination with other uses in the open ocean. Futhermore, there is strong interest in the production of freshwater off the coast at areas with a significant lack of freshwater supply (He et al. 2010). Although there has been plenty of research into the use of renewable energy to power the desalination process (Carta et al. 2003; Forstmeier et al. 2007; Heijman et al. 2010) no offshore demonstration has been carried out so far.

3.2 Conferences and feasibility studies on offshore aquaculture and the combination with other uses

A number of international meetings regarding the prospect of offshore aquaculture have taken place in recent years. In 1997 and in 2004 the International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM) organised workshops on Mediterranean Offshore Aquaculture at the Mediterranean Agronomic Institute of Zaragoza (IAMZ) in Zaragoza (Spain) (Muir & Basurco 2000). In 1998, the Faculty of Mediterranean Engineering in Haifa (Israel) ran a workshop entitled Offshore Technologies for Aquaculture (Biran 1999). The best-known meetings on offshore aquaculture were probably the four international conferences on Open Ocean Aquaculture held in Maine (US) in 1996 (Polk 1996), in Hawaii (US) in 1997 (Helsley 1998), in Texas (US) in 1998 (Stickney 1999) and in New Brunswick (Canada) in 2001 (Bridger & Costa-Pierce 2003). The US Sea Grant Programme was the main sponsor of the first three events, and the World Aquaculture Society ran the fourth conference. In 2009, a conference also sponsored by Sea Grant and German Research Institutions on "The Ecology of Marine Wind Farms: Perspectives on Impact Mitigation, Siting, and Future Uses" was held in Rhode Island (US) with a main focus on shellfish farming (Costa-Pierce 2009).

In Europe, similar conferences were organized by various institutes and universities. For instance in Germany, two workshops were held regarding the combination of offshore facilities with offshore aquaculture in Emmelsbüll-Horsbüll in 2003 (Ewaldsen 2003) and in Bremerhaven in 2004 (Michler 2004), respectively. In the Netherlands three workshops took place on similar aspects in Amsterdam in 2003 (Emmelkamp 2003) and 2006 (van Beek et al. 2008) as well as in Den Haag in 2007. In London (UK) a stakeholder meeting was organised in 2005 for the suitability of offshore aquaculture in existing offshore structures (Mee & Kavalam 2006) and in Ireland a conference on "Farming the Deep Blue" was held in 2004 (Ryan 2004). Finally, a series of biennial conferences called "Offshore Mariculture" were held in St. George's Bay (Malta) in 2006, in Alicante (Spain) in 2008, in Dubrovnik (Croatia) in 2010 and will take place in Izmir (Turkey) in late 2012. Some workshops in 2010 and 2011 included or even specifically focused on offshore aquaculture, such as the Kiel Institute for World Economy with international experts in aquaculture in Kiel (Germany), the DTU-Aqua "Perspectives for sea based production of food – The blue revolution" in Copenhagen (Denmark), the Ministry of Economic Affairs Agriculture and Innovation of the Netherlands "Offshore Mussel farming in the North Sea" in The Haque (The Netherlands) as well as the North Sea Marine Cluster (NSMC) "Marine Protected Areas: Making them happen" in London (UK) in 2011. Furthermore, organised by the Institute for Marine Resources (IMARE) the "Marine Resources and Beyond 2011" conference was held in Bremerhaven (Germany) and a stakeholder workshop on the combination of offshore wind and aquaculture in Ostend (Belgium) was organized by eCOAST in 2011, respectively. In 2012 offshore mussel farming was also presented on the North Atlantic Seafood Forum (NASF) conference in Oslo (Norway). Finally, the Aquaculture Forum on "Open Ocean Aquaculture Development: From Visions to Reality, the Future of Offshore Farming" was an important step not only for presenting the state of the art science but also for passing the "Bremerhaven Declaration" for the future of global open ocean aquaculture (see appendix A).

Most of these above conferences and workshops presented the current research in proceedings. Further publications on the feasibility of offshore aquaculture were published regarding aquaculture enterprises in the German North Sea by Buck (2002; 2007), Michler-Cieluch (2009), Brenner (2009) and Pogoda (2012). For the Belgium Atlantic Coast Delbare (2001), MUMM (2005) and Van

Nieuwenhove (2008) published reports on offshore aquaculture as well as the recent study by Vanagt et al. (2012) on the potential opportunities and pitfalls. For the Netherlands studies that explore possibilities for mussel culture were reported by Steenbergen et al. (2005) and Kamermans et al (2011) and for the French coast a report has also been published (Mille 2010). Finally, in Denmark a report by Christensen et al. (2009) was written concerning the potential for production of mussels associated with wind farms in the Baltic Sea.

4. Central considerations of a multi-use strategy with marine aquaculture

Following Troell et al. (2012) and North (1987), considerable controversy has emerged over the proper development of offshore aquaculture and its actual advantages over existing nearshore aquaculture. In general, many of the challenges for offshore aquaculture engineering involve adaptations of farm installation designs and operation protocols to a variety of physical factors, such as currents and wave actions: The robustness of the aquaculture systems to withstand harsh oceanographic conditions is one challenge, while the difficulties in anchoring and/or submerging structures in deep water is another. Major shipping routes have to be considered as well as migration routes of marine mammals. Logistic difficulties of transport and the operation and maintenance of offshore platforms of any farming enterprise must be evaluated. Due to the scarcity of space even in the open ocean island territories or countries with relatively short coastlines, the concept of "multiple use" needs to be addressed (Buchholz et al. 2012).

4.1 The Offshore Environment

Like elsewhere, the utilisation of the marine waters is manifold and quite competitive, such as shipping (trade or private), recreational activities, extraction or disposal of gravel, marine missions, fisheries, mariculture, offshore wind farms, cable and pipelines, establishment of nature reserves and other marine and coastal protected. In contrast, the number of competing users within offshore regions is relatively low, thus favouring the offshore environment for further commercial development (e.g. offshore wind farms, open ocean aquaculture). Contrary to coastal inshore areas where beaches and their adjacent nearshore zones act as buffers to absorb wave energy, offshore regions can be described as high energy environments, fully exposed to waves, weather and currents. Numerous studies have shown that in offshore areas, waves can reach remarkable heights (e.g. Führböter 1979, Führböter & Dette 1983, Becker et al. 1992). High wind speeds occur regularly in offshore areas giving rise to the idea for renewable energy utilisation in offshore wind farms, as it is planned and already set in many countries in Europe as well as in the US. Currently in Germany[1] a major political incentive exists to install offshore wind farms (BMU 2002, Tiedemann 2003). The major reasons are the policy to reduce the dependence on conventional fossil energy resources as well as the need to reduce the environmental harmful CO_2-loads.

[1] Wind energy continues to be the world's most dynamically growing energy source. The first initiative towards an economy based on renewable energy resources in Germany was set by the governmental decision to gradually reduce the use of nuclear energy. It is common belief that the use of renewable energies contributes towards a sustainable development, contrasting with the gradually diminishing fossil-nuclear energy reserves. This national policy also reduces simultaneously the output of CO_2 to the atmosphere (Kyoto protocol), while fostering the efforts to produce more wind-generated energy in Germany. So far, this development has been successful to such an extent that almost 15% of the energy needs are covered by this technology. To date, Germany invested heavily in windmills, especially along its northern coast.

In the North Sea, strong tidal currents exist (Mittelstaedt et al. 1983) and in the higher latitudes ice movements during winter are frequent phenomena (Strübing 1999). Water temperatures are linked to the seasons (BSH 2003) and salinity, however, varies only little over the year (except for some estuarine areas) (BLMP 2002). In comparison to inshore areas, the water quality offshore is regarded as very good (Dougall 1998, Takayanagi 1998; BSH 2003). Especially the latter is considered a key incentive to move offshore with aquaculture operations and to use pylons or the jacket groundings of the offshore wind turbines as possible attachments to secure moorings of the mariculture constructions in this harsh environment. Over the last decades, substantial insight has been gained on the forces active in the offshore environment. This allows addressing the potentials and constraints of the selected candidates for commercial viable offshore aquaculture. Further, resistant cultivation techniques have to be tested in various modes (e.g. floating, suspended, submerged, different mooring designs) adapted to the offshore environment.

4.2 Offshore Candidates and Biological Investigations

Several species have been identified as candidates who can be farmed successfully in offshore hostile environments within or in the vicinity of wind farms or oil and gas platforms. Such organisms are macroalgae (Buck & Buchholz 2004, Buchholz et al. 2012), bivalves (mussels: Buck 2007, Brenner et al. 2012; oysters: Pogoda et al. 2011, Pogoda et al. 2012), and fish (Polk 1996; Bridger & Costa-Pierce 2003; Hesley 1997; Stickney 1998; Buck et al. 2012a). Biological based investigations to identify the suitability of candidates include consideration of growth performance, larval abundance, settlement, resistance to harsh conditions, and health and fitness aspects. Most experiments and work to date have focused primarily on seaweed and mussels and, to a lesser extent, on oysters. Mussels are the preferred organisms to be cultured because they are native species in most parts of the northern hemisphere and attach tightly to structure in the water with a “byssus”. Furthermore, they are robust, readily seed themselves in the wild and are available year-round (Seed & Suchanek 1992; Gosling 2003; Buck et al. 2010).

4.2.1 Macroalgae

Seaweed aquaculture research in offshore sites is on a lesser scale and focusses mainly on growth performance and culturing techniques. Longline systems installed in harsh offshore conditions, to where farms could be expanded, were not robust enough as there is a considerable stress on support material and algae (Buck 2004; Buck & Buchholz 2004). Plans to connect such culture devices to offshore foundations of wind mills are still in their infancy. As the idea of utilizing the grounding structures of offshore wind generators for the fixation of aquaculture systems is intriguing (e.g., Buck 2002; Krause et al. 2003; Buck et al. 2004). First experiments on Laminaria species show that adapted to strong currents as young individuals, they grow well at exposed sites (Buck & Buchholz 2005). Projects to combine *Saccharina latissima* cultures within a planned wind farm off the coast of Woods Hole (Massachusetts, USA) in Nantucket Sound are existent and currently commercially under proof being beneficial on a large scale (Ebeling et al. in review). Among the various suggestions for cultivation structures that have been made (Polk 1996; Hesley 1997; Stickney 1998; Bridger & Costa-Pierce 2003) a ring design, first set up off the Island of Helgoland in 1994, did withstand strong currents and wind waves after and is still the most promising technical design concept (Buck & Buchholz 2004; Buck 2009b).

As there is an increasing concern about the negative consequences of intensive and constantly spreading aquaculture of fish, shrimps, and molluscs the remediation of negative consequences has been a field of intensive research during the last decade. Two strategies to meet the requirements for more space allotted to aquaculture have been and will continue to be tested: One is the offshore aquaculture that to date seems very expensive and technically demanding, but will allow considerable mass production. The other is the very promising but likewise complicated Integrated Multi-Trophic Aquaculture (IMTA) approach. A combined design of fish cages in the foundation of the turbines in addition to the extractive components of IMTA systems was first discussed on the World Aquaculture Conference in Korea in 2008 (McVey & Buck 2008). This led to a new project in German Bight (Offshore Site-Selection, Buck et al. 2012b), where for the first time *Laminaria* species will be tested in an IMTA approach offshore with partners from the offshore wind industry.

4.2.2 Bivalves

Mussels cultivated in offshore areas, for the most part, show high growth rates compared to those grown in nearshore sites (e.g. Buck 2004; 2007). This is due to the fact that water quality (e.g. urban sewage) and oxygen concentrations are more suitable and the infestation of parasites is low or non-existent. However, in areas under estuarine influence exposure to fluvial transport points to a comparable probability for high contamination loads similar to nearshore areas, thus potentially reducing fitness (Brenner et al. 2012). Larval abundance tends to decrease with increasing distance from shore (Walter et al. 2002), but at some offshore sites it is still sufficient enough to facilitate adequate natural seeding (Buck 2007). Alternatively, a limited spat availability may be viewed as an advantage when moving offshore. The benefit for a low settlement can lead to a one-step cultivation technique (no thinning procedure) if collecting and grow-out sites are similar in the vicinity of offshore structures. The lower settlement success on one hand results in a limited commercial potential, but on the other hand eases handling and maintenance. However, Belgian mulit-use experiments have shown a massive settlement at the offshore cultivation lines making thinning essential (Van Nieuwenhove 2008).Thus, in areas with low settlement success it is, without the calculation of the economic potential at a certain site, recommened to collect the spat traditionally in nearshore areas and then transfer it to the offshore site (Christensen et al. 2008). In Brittany, local offshore spat contains hybrids of *M. edulis* and *M. galloprovincialis*. The hybrid mussels have the advantage of better byssal attachment, but have a lower commercial value (Bierne et al. 2002). In contrast, oysters (*C. gigas*, *O. edulis*) do grow well at exposed sites (Pogoda et al. 2011), do have a suitable fitness (Pogoda et al. in press) but do not exceed growth rates known from nearshore environments. Similar to offshore cultivated mussels, oysters grown offshore show no infestations by macro-parasites (Pogoda et al. 2012).

The resistance of mussels to strong currents as well as high waves and swell depends on the degree and duration of these forces and also on the repective species- For instance, *M. galloprovincialis* is more resistant than *M. edulis* at offshore locations. Information on the hydrodynamic conditions is important due to the fact that e.g. mussels and oysters do adapt to harsh conditions but do not automatically grow fast. Even when flow rates are increasing and consequently deliver more food, which stimulates mussels and oysters to feed intensively, at a certain current velocity threshold growth is reduced due to a pressure differential between inhalant and exhalent siphons (Wildish & Kristmanson 1988; Rosenberg and Loo 1983). Further, exposure to high waves/swell also reduces production rates due to the loss of mussels through detachment (Scarratt 1993). In addition, oyster mortality occurrs when exposed to extreme wave action due to shell abrasion (Pogoda 2012). Even if mussels cultivated in a high energy environment could sooner or later adapt to the permanent physical stress by increasing the strength and number of byssal thread attachments system design adapted from sheltered environmnets, such as collector devices, have to modified to prevent detachment (Brenner & Buck 2010).

In nearshore intertidal areas, mussels are potentially exposed to high concentrations of pollutants, pesticides, estuarine runoff, etc., which can pose a threat to consumer health. The scope of growth, i.e. the energy available for growth, of an organism is usually directly and positively correlated to their overall health condition (Allen & Moore 2004). But organisms with high growth rates and a healthy appearance are no guarantee of a healthy food product for human consumption. For example, in waters eutrophicated by urban sewage, mussels show good growth performance but the microbial status of these mussels would most likely exclude them from consumption, since they may carry various human pathogens. Even in developed countries with strict legislation for the treatment of wastewater, mussels can function as carriers of serious microbial agents. This risk should be reduced with offshore cultivated mussels, where the environment is cleaner due to dilution of contaminants.

All known micro- and macro-parasites found in European coastal waters are harmless to consumers, but may have negative condition effects (macro-parasites) and cause higher mortalities (micro-parasites) in infested hosts (Brenner et al. 2009). Beside the potential harmful effect on a host, some macro-parasites pose an aesthetic problem, since they are visible due to their bright colour (*Mytilicola intestinalis*) in raw mussels or due to their size (*Pinnotheres pisum*) (Brenner & Juetting 2009). In Blue Mussels in some intertidal and nearshore areas parasites can be numerous. Buck et al. (2005) and Pogoda et al. (2012) have shown that offshore grown mussels and oysters were free of macro-parasites and that infestation rates increased with proximity of the sites to shore, respectively; intertidal mussels showed the highest numbers of parasites. The debate over the effects of parasites on the energy status and overall health of the host is still open as robust data needed to elucidate these issues is still lacking.

4.2.3 Crustaceans

There are only a few species on the check-list for cultivation within wind farms, such as the American lobster *Homarus americanus* as well as the European lobster *H. gammarus* (Buck 2002). However, none of the species were yet tested in offshore wind farms. Krone and Schröder (2010) investigated various artificial reefs (e.g. wind farms, wracks) to proof if these installations would provide a lobster habitat. From these insights Krone (2002) developed various habitat designs connected to foundations of offshore wind mills which allow lobsters to live in or hide. These new designs could be beneficial for lobster cultivation but there are no artificial habitats in place yet.

4.2.4 Fish

Fish as a candidate for offshore multi-use concepts is new. Most of the studies on aquaculture in offshore wind farms concentrated on invertebrates and algae. Since three years the interest in offshore fish cultivation is increasing (Buck & Krause 2012). There are a few studies on culture techniques, system design as well as on the commercial potential and the management of a fish cultivation in wind farms (Buck et al. 2012a). There are a lot of studies on the biology of fish when cultivated offshore, however, none of the studies direcly deal with fish cultivation in co-use with wind farms. Hundt et al. (2012) provided a list of potential candidates for the cultivation in wind farms in the EEZ of the German Bight (*Dicentrarchus labrax*, *Gadus morhua*, *Hippoglossus hippoglossus*, *Psetta maxima*), in the Mediterranean (*Dicentrarchus labrax*, *Sparus aurata*, *Diplodus puntazzo*, *Psetta maxima*, *Thunnus thynnus*) as well as in the Gulf of Mexico (*Rachycentron canadum*, *Thunnus thynnus*). Furthermore, Buck et al. (2012a) conducted studies on the welfare of fish within net pens in RAS conditions that were similar to exposed conditions offshore. These results demonstrated, that clear a understanding of the dependance of fish fitness on strong hydrodynamic conditions is important.

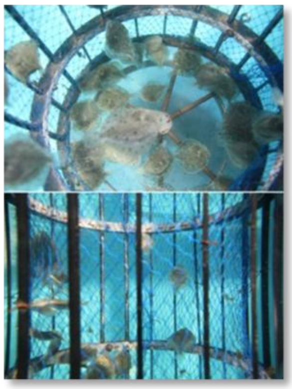

Figure 4 – Investigations on fish welfare (stress) in cages within a RAS system (Buck et al. 2012a).

4.2.5 Offshore Environmental Interactions

For any kind of offshore aquaculture in combination with renewable energy systems the effects and interactions with the surrounding environment must be considered. The following subchapters briefly outline the different issues that pertain to this subject.

Ecological Engineering by Extractive and Suspension Species

Environmental impacts from cage aquaculture include organic and inorganic nutrient loading from feed and faecal pellets and other excretory products (Braaten et al. 2007; Tett 2008). For example, it is estimated that more than 60% of the feed used in salmon cage aquaculture is released as excess nutrients to the marine environment (carbon, nitrogen, phosphorous) (Troell et al. 2003; Islam 2005; Olsen et al. 2008). Excess nutrients are dispersed as particulate organic matter (POM) or dissolved inorganic nutrients (DIN). Sedimentation of particular matter may cause organic enrichment of sediments (Stigebrandt et al. 2004; Kutti et al. 2008) and POM may affect the benthic community negatively if sedimentation rates exceeds the turn-over rate of the benthic community (Holmer et al. 2005), in the same way as DIN from salmonid aquaculture may cause eutrophication (Nixon 1995; Cloern 2001; Folke et al. 2004) and nitrification, if the nutrient loading rate exceeds the assimilation capacity of the food web (Olsen et al. 2008; Tett 2008). The cultivation of non-fed candidates could have an impact on the surrounding environment too, however, to a lesser extent (Aure et al. 2007).

The cultivation of inorganic extractive species such as seaweeds, organic extractive species such as bivalves, as well as suspension feeders, such as polychaetes, may consume and convert waste nutrients from fish cage aquaculture into valuable biomass (Troell et al. 2003). This technological development has also successfully increased the production of the macroalgae when integrated in fin-fish cultivation (Chopin et al. 2001). These cultivation concepts, where waste nutrients from fed species are incorporatedby species, at lower trophic levels are also defined as ecological engineering or bioremediation. In combination it is defined being the “Balanced Ecosystem Approach” commonly called IMTA. These technique has the promise to contribute to a more sustainable aquaculture production (Chopin et al. 2001; Neori et al. 2004; FAO 2006) and at present, IMTA is seen as a production strategy that meets the negative public perception of cage aquaculture (Barrington et al. 2010). Such IMTA concepts do play a role in offshore areas, especially in combination with wind farms, as any fish cultivation benefits from the extractive capability as well as acting as a "defence line" around wind farms-fish culture combinations (McVey & Buck 2009).

Escapes

The effects of escapes are acknowledged as a key environmental problem related to on-growing of fish in sea-pens (Soto et al. 2001; Naylor et al. 2000). Several literature reviews on the effect of salmon escapees (Weir & Grant 2005; Jonsson & Jonsson 2006), have concluded that strong evidence of genetic and phenotypic differences between farmed and wild salmon exists, that genetic change has occurred in some wild populations with which escapees have mixed, and that this may to some extent increase the mortality of wild salmon and decrease their adult size, growth rate and consequently, their reproductive output (Jonsson & Jonsson 2006), thus hampering biodiversity and effecting the variety of different genetic strands.

Most escapes of fishes originating from cage aquaculture are caused by technical and operational failures of fish farming equipment (Jensen et al. 2010). Salmonids primarily escape after structural failures of containment equipment, while a far greater proportion of cod escape through holes in the nets. A five component strategy for how to prevent escapes of fish from fish farms is suggested, which includes improved operations and technical equipment, as well as regulatory measures. It is widely believed that most of the technical failures can be solved if the system design used is more stable and able to withstand harsh weather conditions. In case of a combination of wind mill foundations with sea-cages a more stable installation may be possible.

4.3 Technical Considerations

Prior to moving offshore, a series of planning steps of different design aspects of a multi-use platform/installation needs to be tackled (see Box 3, 4 and 5). Especially in view of the harsh weather conditions present in the offshore realm, these considerations are instrumental for the success of the entire endeavour - more often than not unfavourable "metocean" conditions will limit the regular access to the offshore facility. Hence, the question of the design of the offshore foundation structure is of utmost importance as they are the central element providing the base for a multi-use system.

Relocating cultivation systems offshore into high energy environments requires the development of suitable culture techniques able to withstand the harsh conditions and minimize risk of economic loss (Brenner 2009). One of the interesting possible linkages of aquaculture is the combination with offshore wind farms as these would provide stable fixing structures for the cultivation systems. This is especially relevant from an economic point of view, since so far the costly infrastructure for offshore aquaculture systems is one of the major drawbacks in the development (Buck & Krause 2012). However, major difficulties in the development of suitable techniques for open ocean aquaculture are, next to adverse environmental conditions that limit accessibility of the device, related to the connection capability of wind will foundations for aquaculture devices since these place an enormous additional stress on materials. However, depending on the acting hydrodynamic forces, different technical setups can be distinguished.

So far, several techniques exist to cultivate aquatic organisms either in co-culture or in single culture. Basically, most organisms are cultured in a suspended manner in the water column, floating or submerged. The use of rafts, longlines, longtubes, rings, lanterns and cages as well as net pens dominate in this cultivation branch. Thus, to operate the suspended culture phase with extractive species (bivalves and macroalgae), an appropriate system design has to be deployed and securely moored in order to resist the stress forces of incoming waves and tidal currents as well as swell situations.

Depending on the acting hydrodynamic properties, different technical setups were regarded as favourable. Longlines and rings were the main cultivation techniques used in test trials for macroalgae growth in offshore wind farm areas (Buck 2007; Buck & Buchholz 2004; Hickman 1992) (Fig. 5). These two offshore aquaculture systems were identified as being best suited for offshore operations from a biological point of view. They withstood rough weather conditions and allowed easy handling (Buck & Buchholz 2004). It was found that the longline design for blue mussel culture should ideally be installed 5 m below the water surface and should be connected to foundations of offshore windmills (Fig. 6) (Buck et al. 2006). However, the construction of the grounding construction of offshore wind turbines must be considered in the assessment. So far, modelling and experimental validation of a submerged 50 m longline aquaculture construction mounted between two steel piles, 17 nautical miles off the coast, show significant forces of up to 90 kN (equivalent to 9 tons) induced by waves of up to 1.8 m significant wave height and tidal currents of up to 1.0 m/s (Zielinski et al. 2006). Given the high-energy environment in the North Sea and the non-linear relationship between water movement and its resulting forces, even higher mechanical loads are to be expected within the life-cycle of such an arrangement. These must be taken into account and appropriately calculated when developing techniques for larger scale offshore cultivation within wind farms.

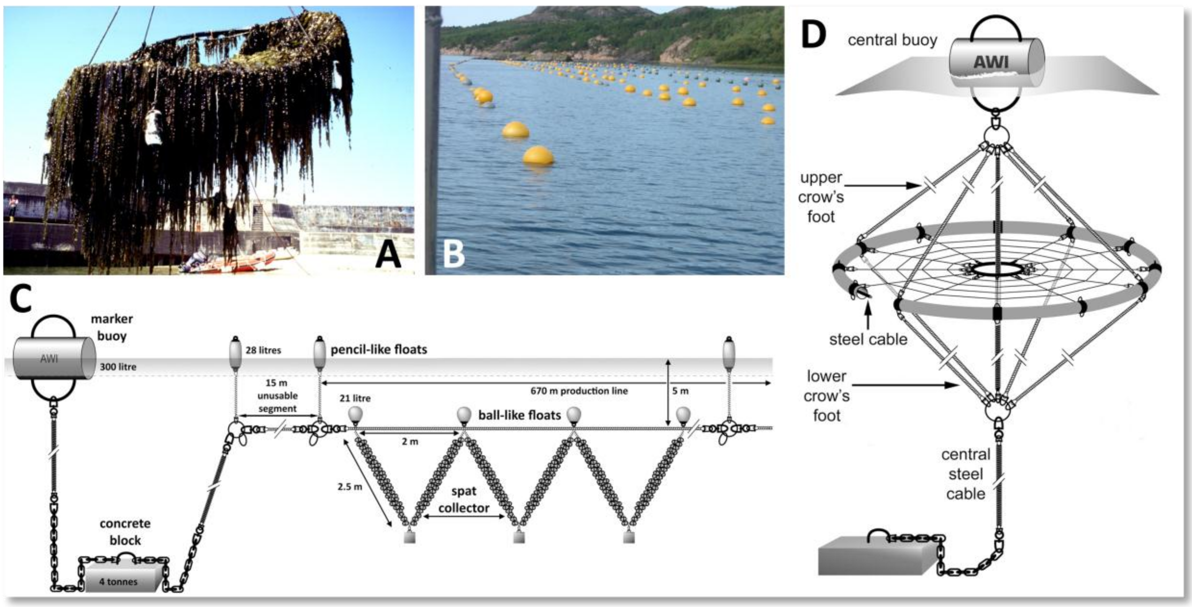

Figure 5 – Aquaculture constructions suitable for the cultivation in high energy environments. (A) Offshore ring design for the cultivation of macroalgae (here: harvesting after grow-out in the harbour of Helgoland), (B) example of a nearshore submerged longline design for mussels and oysters, (C) schematic drawing of a submerged longline suitable for exposed sites, and (D) a technical illustration of the ring design and its mooring system (modified after Buck & Buchholz 2004, Buck 2007).

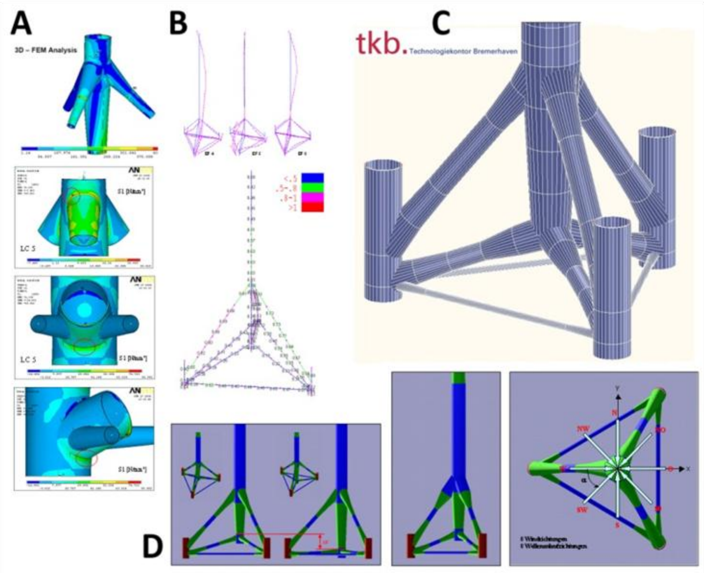

Figure 6 – Modelling of potential attachment points for the combination of longline connections to a tripod foundation. (A) displays alternative connection points, (B) shows the generation of representative loads on the wind energy installation including vibrations, (C) shows the respective tripod foundation for offshore use in depths of about 20-50 meters, and (D) shows the development of a static model (3-5 megawatt class) (modified after Buck et al. 2006).

Next, it is necessary to assess what kind of technical structure supports best the growth of the organisms (e.g. prevention from loss or mortality) while also assessing whether such systems provide reasonable production returns.

When cultivating fish intensive cultivation processes for the offshore regions are still in the testing phase. Various candidates, such as seabass, seabream and some flatfish species are discussed for aquaculture in fish cages below windmill platforms at different offshore sites worldwide. Fish will be reared in land-based facilities first and will then be transferred as fingerlings to the offshore site and released into submergible fish cages. After reaching marked-size the fish will be harvested and removed to the land and will undergo normal processing procedures.

The first offshore aquaculture project with a connection to a wind mill foundation is the OOMU-Project (Buck et al. 2012). Here, a new cage design project was initiated, by which it will be investigated whether aquaculture of fish inbetween a tripile construction below an offshore windmill

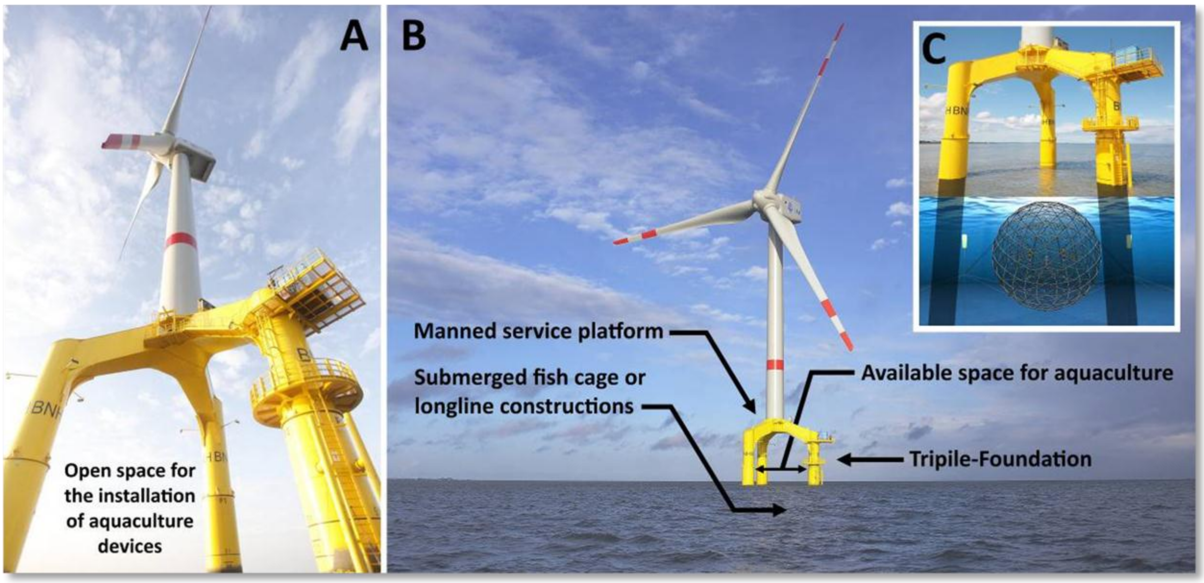

Figure 7 – Tripile foundation for the secondary use for fish cages. (A) shows the open space within a tripile foundation to be used for aquaculture purposes, (B) displays a lateral view of the Bard-Wind turbine and the access to the fish cage, and (C) is a edited photo to give an idea how a fish farm, such as an *Aquapod*, could be moored below (Buck & Krause 2012).

has the potential to enlarge the diversity of candidates to be grown offshore (next to bivalve and seaweed) as well as widening the potential of offshore farming within wind farms by and large. First insights are shown in Figure 7 (Bard 2010, OFT 2010). Several studies on the cage devices, such as cylinder as well as spheres, were conducted, predominantly in tripile foundations (Fig. 8). Oscillation measures for the cage and the foundation itself were undertaken (Fig. 9, Schaumann & Dubois 2012). Additionally, the combination of these two installations was tested on their effects on the local environment, especially on the scouring of the foundation mud zone (Fig. 10, Goseberg et al. 2012).

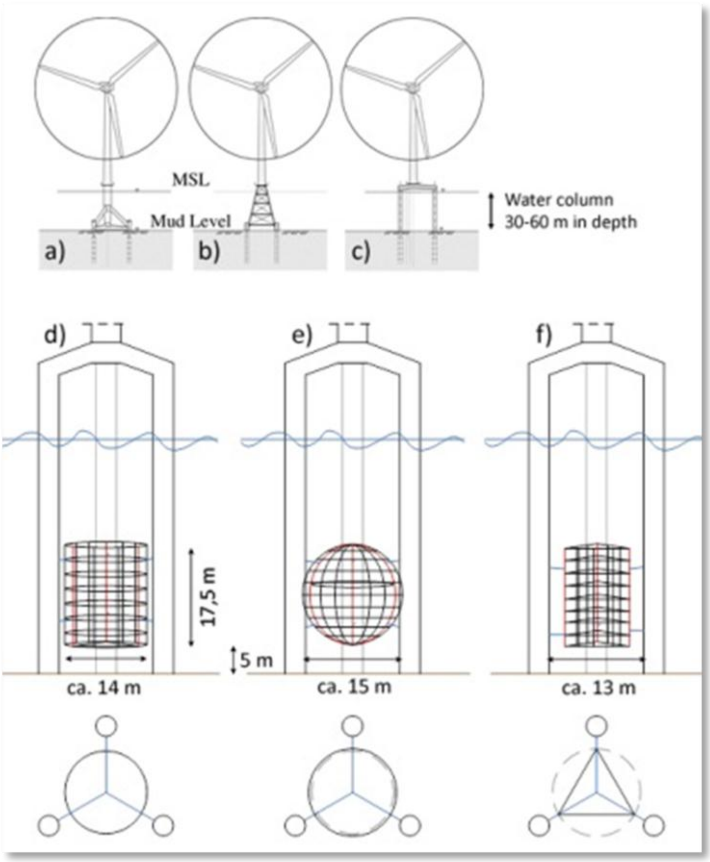

Figure 8 – Lateral view of foundations used for offshore wind energy turbines and different cage designs: a) Tripod; b) Jacket; c) Tripile; d) Cylinder; e) Sphere; and f) triangular prism; MSL = Mean Sea Level. (modified after Schaumann & Dubois 2012; modified after Buck et al. 2012).

4.4 Monitoring and Surveillance

Offshore installation of multi-use platforms will impose impacts on the marine environment not only in the area of the installation, but also in the vicinity of these. Such impacts may be recognized in both, the benthic and pelagic communities, and there is therefore a need to establish a framework for environmental monitoring to be able to assess the effects and to be able to propose appropriate remediation actions. The OSPAR commission is addressing topics related to the use of marine areas and the impacts on the environment from maritime activities, pollution, oil and gas extraction and emerging threats like climate change and has been a driving force in establishing joint assessment monitoring programs within the member states. Also the EU directive 2008/56/EC (Marine Strategy Framework Directive; MSFD) and Commission decision 2010/477/EU, as well as the Habitats Directive 94/43/EEC (HD) and Water Framework Directive 2000/60/EC (WFD) are important pieces of legislation to be considered when establishing a monitoring program for multi-use platforms. ISO (International Organization for Standardization) is establishing international standards on marine water quality parameters, which have to be considered when designing monitoring programs. Most environmental monitoring programs are based on field surveys (Keith 1996) giving discrete information on the situation at a given time and site due to restricted sampling both in time and space (Stuer-Lauridsen 2004; Hernando et al. 2007). This method has the obvious drawback that the analysis of the sample can only provide a snapshot of the environmental state at the sampling time (Hernando et al. 2007; Stuer-Lauridsen 2004). Passive sampling devices instead can reliably detect and quantify contaminants over time spans ranging from weeks to months (in terms of time-

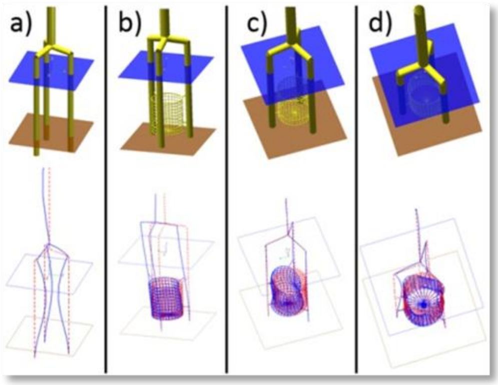

Figure 9 – Tripile-Foundation in combination with cylinder-like cage model: Self-oscillation and local oscillation of the piles of the foundation. a) Tripile model: 3. cross bending with local oscillation; b) 2. Tripile cage model: 3. cross bending with cage force; c) Tripile cage model: 3. cross bending with cage force; d) Tripile cage model: 3. cross bending with cage force model (modified after Schaumann & Dubois 2012; modified after Buck et al. 2012).

weighted average concentrations), do not require any energy source or service and are therefore particularly useful in environments where maintenance work is difficult. Within the past 10 years passive sampling methods have gained acceptance as being useful tools for measuring concentrations of various kinds of pollutants within aquatic ecosystems (Greenwood et al. 2007) and have also been shown to be helpful with respect to marine aquaculture operations (Hernando et al. 2007). Also the use of blue mussels (*Mytilus edulis*) as indicator organisms has proven to be an efficient way to detect possible sources of contamination (Small & Widows 1994; Small et al. 1991). Today testing procedures for changes in lysosomes of blue mussels are regarded as core biomarkers and are recommended by ICES, OSPAR and AMAP (Moore et al. 2004).

4.5 Offshore Site-Selection

Next to the assessment of metocean parameters, a whole range of other aspects need to be considered when being in the process of selecting suitable sites for offshore multiple uses.

A successful establishment of offshore aquaculture in wind farms necessitates, as necessary for any form of aquaculture, that basic site selection criteria are met. This includes meeting the requirements for carrying capacity compliance, which endorses the respective local physical, economical, ecological and social capacities. Furthermore, it must be ensured that the production of high quality products that are safe and healthy for human consumption. More generally, offshore aquaculture should preferably fulfill the ecological, economical and social requirements of sustainable aquaculture. This supports, last but not least, the overall public acceptance and justification of moving offshore within a multi-use context.

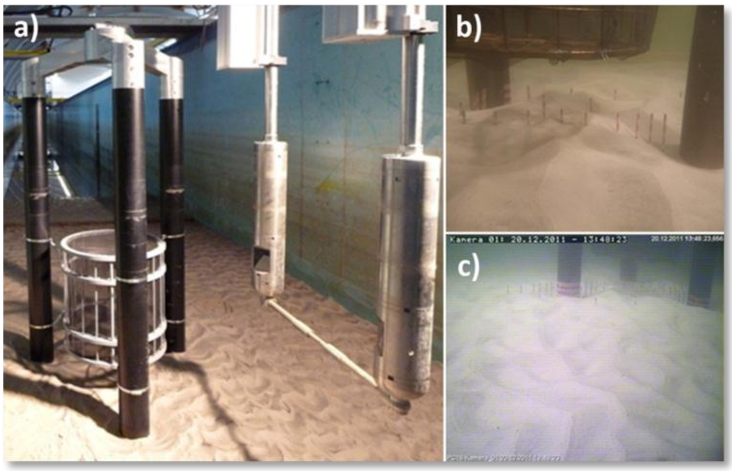

Figure 10 – Tripile-Cage measurements: a) Submergible PIV-Camera device with a passive reflector to detect horizontal level signals in ahead the tripile; b) and c) Investigations on the development of scouring and/or erosion at the pile-mud-zone via imaging recordings with underwater cam-eras and dip sticks at selected sites (modified after Goseberg et al. 2012; modified after Buck et al. 2012).

There are several specific criteria for aquaculture in particular, which have to be taken into account, such

Box 3 – Offshore Oil, Gas & Wind

Manned Platforms: Offshore manned oil & gas platforms range from the large 1970's and 1980's module support frame and modules concept with manning levels of up to 250 to the 1990 and 2000 generations with 50 – 100 personnel on board. The former operate with full day and night shift, and maintenance carried out as required by personnel on board. The latter 'leaner', manned platforms operate with a full day shift, and a reduced 'operation supervision' night shift. The majority of maintenance is carried out in batches or campaigns for which additional labour and supervision is brought in. The crew is transported exclusively by helicopter. Equipment, supplies, containers, diesel and potable water (if required) are transported by supply vessels.
Remote support from land is constantly increasing, facilitated by transfer of real-time process and condition data to land and high quality audio-video links. The aim is to achieve better/faster decisions for improved production, through optimal use of manning, technology, organization and work processes. This is variously called "Integrated Operations", "Smart field", "Fields of the Future" etc.
Offshore Wind farms: Autonomous construction of wind farms in the marine offshore regions to generate electricity from wind. Key incentive for this move is the availability of better and more constant wind speeds as compared to on land. This makes the offshore wind power's contribution in terms of electricity supply higher. However, key disadvantage of this move are the costs which entail the permitting, operation and decommission of the offshore wind farms which make them relatively expensive. The leading turbine suppliers to date in the North Sea offshore realm are Siemens, Repower and Vestas, whereas Dong Energy, Vattenfall and e.on are the main offshore operators. In Europe, the UK and Germany are the two leading markets, while internationally China and the USA are increasing their efforts to venture into this emerging field.

as bio-technical criteria as well as physio-chemical and biological conditions. In the case of multi-use concepts the typical practical procedure of looking for the most suitable site will be confined to those sites where offshore wind farms are planned or already in place. This is due to the fact, that aquaculture acts as "secondary newcomer", since the current momentum of moving activities offshore steams from the political will to enforce renewable energy systems in the first place (Buck et al. 2003) Therefore, the typical site-selection criteria catalogue applicable for aquaculturecannot be implemented. Hencem criteria for the selection process must be tailored to capture the relevant local parameters of the conditions around and within a offshore wind farm.

Nevertheless, there are some factors which still are important, such as compatibility of the technical design, as well as the mode of shipping and management of the running procedures of the wind farm operation. As there is no commercial wind farm-aquaculture enterprise existing to date, these criteria so far have a rather theoretical nature and are presented in the operation and maintenance section in more detail.

4.6 Socio-political Considerations

Technical and environmental barriers and the economic viability are the principal research topics when moving towards the creation and exploitation of new ventures, such as offshore wind farms or open ocean aquaculture (Michler-Cieluch & Krause 2008). In recent years, studies have also started to consider public or specific stakeholder groups' perceptions in relation to the fledgling offshore wind industry and/or to aquaculture development in the open ocean (examples given in (Nichols et al. 2003) and (Robertson & Carlsen 2003). It has been recognized that powerful stakeholder groups, in particular those directly involved in or affected by innovations, exert a great influence on new developments: they can imperil entire projects (Tango-Lowy & Robertson 2002) but also contribute positively to the course of management processes (Dalton 2006; Apt & Fischhoff 2006). A first stakeholder analysis by Krause (2003) and Michler-Cieluch (2009) for the North Sea area of Germany revealed that there are different types of actors involved in the offshore realm as compared to nearshore areas. Different types of conflicts, limitations and potential alliances surface. These are rooted in the essential differences in the origin, context and dynamics of nearshore- versus offshore resource uses (Krause 2003).

Nearshore areas have been subject to a long history of traditional uses through heterogeneous stakeholder groups from the local to national levels (e.g. local fisheries communities, tourism industry, port developers, military, etc.), in which traditional user patterns emerged over a long time frame. In contrast, the offshore areas have only recently experienced conflict. This can be attributed to the relatively recent technological advancements in shipping and platform technology, both of which have been driven by capital-strong stakeholders that operate internationally. Whereas there is a well-established organizational structure present among the stakeholders in the nearshore areas in terms of social capital and trust, as well as tested modes of conduct and social networks, these appear to be lacking in the offshore area. Indeed for the latter, a highly political representation by these stakeholders can be observed, that possesses some degree of "client" mentality towards decision-makers in the offshore realm. These fundamental differences between the diverse stakeholders in nearshore and offshore waters make a streamlined approach to multi- use management very difficult (Krause 2003; Krause et al. 2011). Thus far, studies have largely focused on local resource user networks, but few have attempted to study co-management networks (Marín et al. 2010). A corollary to this is that an integrated facility could be perceived as a sign of good faith and cooperation by wind energy producers in the often contentious socio-political landscape of exclusionary utilization of offshore commons. To date, the offshore wind farm operators hold "client" ties with the decision-makers, in which other users and their interests are not included in development considerations. By finding solutions which could be perceived as "win-win" for multiple stakeholders in the offshore setting, the wind energy operator may improve their public perception (Gee 2010).

Attitudes and perceptions of the involved stakeholders prior to implementation are shaped by their views on the possible synergies in production and organizational structure (Michler et al. 2007). However, if venturing offshore, different actors' relative power to bring about system change must be considered in investigating plausible future organisational structures (Krause et al. 2011). A number of recent studies have focused on the role of social networks in coastal and marine resources management (Marín et al. 2010; Calanni et al. 2010; Gelich et al. 2010). Pre-existing social networks can provide significant political leverage for governance transformations as research for example from Chile (Gelich et al. 2010) has shown. This also includes decisive legislative bodies that determine the specific constitutional rules to be used, such as marine spatial

Box 4 – Offshore Platform Design

There are four key areas where cost of offshore wind installations can be reduced; foundations, access, electrical connections and wake effects. Foundations are considered to be of prime importance as they account for almost half the capital costs. For instance, monopiles cannot be used in water depths that exceed 30m for turbines rated above 1 MW. In addition, diameters are limited to 6m which means that the current 5MW turbines are uneconomical beyond 20m water depth. Due to these constraints the wind industry has been considering alternatives such as concrete gravity based structures, adaptations of monopiles such as tripods and tri-piles and jacket structures which have been used successfully by the oil and gas industry. For depths exceeding 60m floating structures are currently being tested. For instance, Bard Group (e.g. in the North Sea) champions a tri-pile foundation system which is being used in commercial offshore wind farms in the German North Sea called "Bard Offshore 1" or "Veja Mate" as well as off the Netherlands. It is suitable for water depths of 25-50m and it is more compact, lighter and cheaper than other offshore foundation systems.

planning[2] (MSP), in crafting the framework and scope for multiple-use settings. However, the "social embeddedness" (Granovetter 1985) and the role of discreet informal social networks must be considered therein to address the probability of collectively concerted action in the offshore realm.

The current situation demonstrates clearly, that within the vast variety of regulations inside the EU, the EU Member States as well as in North America, their implementation is as yet incipient and examples of best practice in multi-use scenarios are needed (ICES 2012). These need to combine different knowledge systems (e.g. authorities, decision-makers, local communities, science, etc.) to generate novel insights into the management of multiple uses of ocean space and to complement risk-justified decision-making.

Box 5 – Offshore Vessel Design

Vessel design for the offshore market has seen many innovations in recent years, primarily developed to address the emerging requirements to service and support offshore wind farms, but also aquaculture. Both industries rely on a multi-purpose vessel that is suitable to perform maintenance works and able to transport personal and equipment (Michler-Cieluch et al. 2009).

During the last 10 years, vessels used in the aquaculture industry have gone through a gradual specialization, with an increasing number of professionals performing specific tasks, e.g. service, surveys and fish transportation. Live fish is now routinely transported between land base and fish farm using well boats. Well boats are sea-going vessels, but loading and unloading in open sea conditions are still a challenge using current designs. In addition, the industry also relies on a large number of work boats, to assemble and maintain the fish farms. To date, fast monohull boats are used to some extent for personnel transportation. Boats used for maintenance operations are typically a catamaran generally shorter than 15 meters, outfitted with generic handling equipment, usually a crane, capstans and a winch. Open-sea operations will however require different boats and on-board systems than those in use today.

4.7 Economic Considerations

As with technical aspects of site selection economic aspects for single use sites have received a significant amount of attention, e.g. aquaculture (James & Slaski 2009), wind (Starling 2006), wave (Previsic et al. 2004). Studies consider the whole lifecycle through installation, operations and maintenance and decommissioning. However the economics of multiple uses has received considerably less attention with the work of Buck and collaborators concentrating on aquaculture and wind power being a notable exception (Buck et al. 2010).

There are several tools which allow developers and financial backers to assess the financial viability of single use offshore installations, such as SLOOP (Shilling et al. 2006), MCOST (Strattford 2007), OWECOP (Zhang et al. 2010). MCOST and OWECOP systems address the offshore wind industry and cover the whole area from project development, wind farm layout, restriction areas, geological items, cable route, grid connection and operation and maintenance in different detail.

In the aquaculture community the concept of an Ecosystem Approach to Aquaculture is being pursued. Among the ideas promoted by this development is to look at economics of aquaculture production from a broader social and environmental perspective (Krause et al. 2011; Knowler 2008). For instance, the work of Knowler (2008) proposes the use of an agro-ecosystem framework and introduces the concept of marginal opportunity cost, which measures what society must give up to obtain a little more of some particular good or service (e.g. farmed shrimp). Recognizing the full set of costs incurred from production, regardless of where they occur or on whom they fall, captures the idea of an EAA from an economic perspective.

[2] The terms marine spatial planning and maritime spatial planning are used interchangeably in this document.

Consideration must also be given to markets. Currently conventional power generation is in general more economic than renewable solutions like wind (EWEA 2009). However, the uncertainties related to future fossil fuel prices imply a considerable risk for future generation costs of conventional plants. Conversely, the costs per kWh generated by wind power are almost constant over the lifetime of the turbine, following its installation. Thus, although wind power might currently be more expensive per kWh, it may account for a significant share in the utilities' portfolio of power plants, since it hedges against unexpected rises in prices of fossil fuels in the future. In terms of aquaculture the main products currently produced (and showing fastest growth) in mariculture on a global scale are marine plants and molluscs, with crustaceans (mainly shrimps) and finfish comprising a relatively small proportion on the basis of live weight.

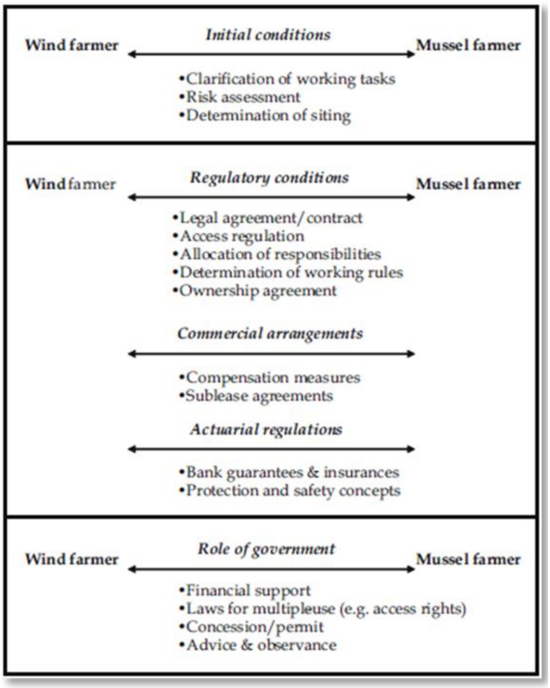

Figure 9 – Framework requirements for managing 'wind farm–mariculture integration' (Krause et al. 2011).

Assessing the potential of co-use option in wind farm areas has been a key issue in the project Open Ocean Multi-Use (OOMU; Buck et al. 2012a). Methods applied include simple gross margin calculation and enterprise budget analyses with the calculation of break-even prices and yields for different species, as blue mussel, macro algae and finfish. Furthermore investment appraisals and sensivity analyses with the variation of key parameters have been conducted. Results show the economic feasibility of blue mussel co-use (Buck et al. 2010). Algae aquaculture has economic potential if uses are made of the high value ingredients e.g. for pharmaceutical and cosmetic uses (Ebeling et al. 2012a). Co-use of the offshore wind farm area for finfish aquaculture showed economic potential for mid- and high value species, like halibut and turbot (Ebeling et al. 2012b).

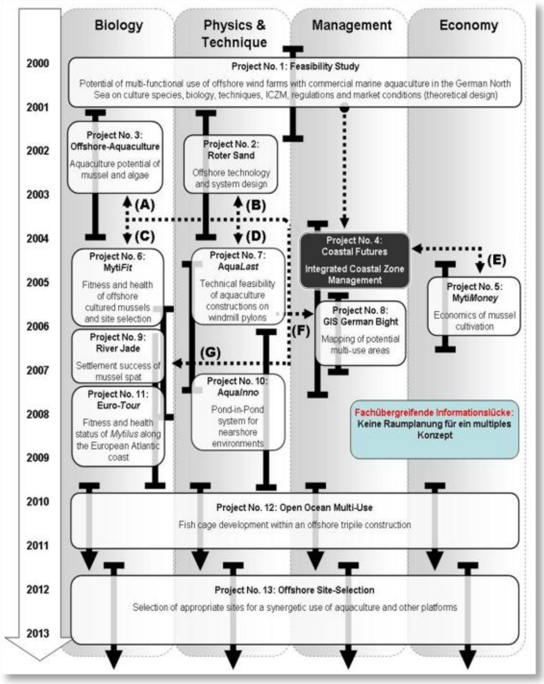

Figure 10 – Chronological order of completed and ongoing research projects dealing with the combination of offshore wind farming and open ocean aquaculture in Germany (modified after Buck et al. 2008).

4.8 Offshore Cooperative Operation & Maintenance Considerations

Combining offshore wind farming and marine aquaculture is an opportunity to share stakeholder resources and can lead to greater spatial efficiency in the offshore environment. Although biological and technical studies have demonstrated the general feasibility of this approach, the novelty of this combination involves a wide range of remaining challenges: (a) in *technology*, such as developing special culture devices that withstand the hydrodynamic conditions at offshore locations without endangering or damaging wind turbines and (b) in *infrastructure*, e.g. designing areas free of cables where mariculture devices can be installed or providing a service platform geared to the need of both parties. In addition, a range of (c) *organizational and social* challenges related to the collective use of a defined ocean territory have to be taken into account (Figure 9) the creation and compliance with defined responsibilities and duties or the introduction of cross-sectoral management lines, such as an offshore co-management, that integrates the different demands and practices of the involved parties. These prospected challenges endorse that the participating social actors will have to negotiate agreements and management regulations for elaborating and coordinating their individual tasks in a reliable fashion (Michler-Cieluch & Krause 2008; Krause et al. 2011).

5. On-going Activities

5.1 Germany

In Germany, no commercial offshore aquaculture farm exists yet. The commercial mussel cultivation in Germany is based on an extensive on-bottom culture (Seaman & Ruth 1997) and depends entirely on natural resources for food, spat and space. Other techniques such as suspended designs (e.g. longlines, longtubes) do exist. Commercial oyster farming is carried out on a small scale in the nearshore (Buck et al. 2006). Nevertheless, due to stakeholder conflicts (e.g. Buck et. al 2004) and a lack of spat availability (Walter & Liebezeit 2003), mussel farmers will need to move offshore where space will not be the determining factor and adequate settlement of spat is more likely. Various projects are underway to test the feasibility of offshore farming in the EEZ of the German Bight.

To date all attempts to move bivalve aquaculture off the coast to a more hostile environment within wind farm areas are on a pilot scale. Various projects including scientific studies on the biology, techniques and system design, economic potential, ICZM, and the regulatory framework as well as potential synergy with offshore wind turbines have been investigated (Figure 10; for review see e.g. Buck 2004; Buck et al. 2008; Michler-Cieluch 2009; Brenner 2009; Pogoda 2012).

5.2 Other countries in Europe

As the Belgian part of the North Sea is used intensively by dredging, military, shipping, wind farm and fisheries activities almost no space is left for offshore mariculture. Therefore, the four mussel areas that were appointed by the “Ministerieel Besluit” (Ministerial Decree) MB 97/16166 were identified because they were not suitable for other activities. The area D1 is situated near a shipwreck, the areas of Oostdyck and Westhinder are located in the proximity of a measurement or radar pole and the area “open achter de Thorntonbank” (on and behind the Thorntonbank) is appointed as an area for wind farms.

The Thorntonbank area is a large area with a depth ranging from 12 to 30m and is located 24 to 58 km from the harbor of Zeebrugge. As this area is also appointed as wind farm area there may be an opportunity to combine offshore shellfish farming with wind farms. However, Belgian policy makers are convinced that it is unsafe to allow shipping traffic in a wind farm area and it will be completely forbidden by the new "Koninklijk Besluit" (Royal Decree). The Institute for Agricultural and Fisheries Research (ILVO) is currently working on a desk study to combine wind farms, passive fishing and aquaculture. This study might help the policy makers and wind farm concession owners to allow aquaculture in this area.

In the Netherlands no offshore farms are present but they show a lot of interest in offshore shellfish farming as an alternative to inshore spat collection. Examples of this interest are the development of various offshore constructions such as the "Mosseldobber" and the construction developed by Gafmar Seafood. A desk study and sampling of buoys of shipping lanes was carried out to study possibilities for off-shore mussel farming. This yielded a report which included a map with potentially suitable areas (Steenbergen et al. 2005). More recently, 2 reports were made by TNO and IMARES for the Ministery of Agriculture, Nature and Food Quality (Reijs et al. 2008) and the Ministry of Economic affairs, Agriculture and Innovation (Kamermans et al. 2011) which also deal with the potential co-use of wind farms. In 2012 the government has opened a call for offshore mussel farming experiments. This has yielded five proposals.

The Danish Government agreed on a development plan in 2006 and 2009 that supports a significant growth in mariculture. Increased production of fish will, in the future, be located in exposed sites in order to reduce impact on the surrounding ecosystems, and furthermore nutrients will be extracted by combining fish production and production of compensation cultures extracting nutrients. The Danish Aquaculture Association has identified offshore production as a solution in conflicts with an increased production and its correlation with the ongoing competition for areas at sea. Two pilot projects are initiated. The first evaluates the potential for use of offshore wind farms for shellfish aquaculture and the second project is conducting a general evaluation of the potential for offshore aquaculture in Danish waters. In 2011 a R&D project was initiated, aiming to develop and test offshore aquaculture, including finfish and blue mussels. All projects are conducted in cooperation between industry and research institutions.

5.3 Efforts on EU Level

While a significant body of research exists covering individual uses for offshore platforms, the interaction between these multiple uses has not been covered to a full extend on a European scale. This has changed with the recent call of the European Commission "Ocean of Tomorrow", issued under the FP7 in 2011, which reflects the current state of "European Strategy for Marine and Maritime Research". In a first step, the aim is to establish offshore platforms that can combine many functions, such as eco-friendly aquaculture (i.e. IMTA systems), Green Technologies (i.e. wind and solar energy), and transport maritime services within the same infrastructure. It is believed that this could offer significant benefits in terms of economics, optimizing spatial planning and minimizing the impact on the environment. Subsequent to this recent initiative, several large scale European projects are currently running or under way which have a direct focus on aquaculture and its potential integration with other uses, specifically with renewable energy systems in the offshore realm. In the following, these are briefly presented with their key features and objectives and expected outputs.

5.3.1 MERMAID[3]: Innovative Multi-purpose offshore platforms: planning, design and operation

The project MERMAID aims to develop concepts for the next generation of offshore platforms which can be used for multiple purposes, including energy extraction, aquaculture and platform related transport. The project does not envisage building new platforms, but will theoretically examine new concepts, such as combining structures and building new structures on representative sites under different conditions. Within this approach it is crucial that the economic costs, the use of marine space and the environmental impacts of these activities remain within acceptable limits. Hence, offshore platforms that combine multiple functions within the same infrastructure offer significant economic and environmental benefits.

28 partner institutes form the MERMAID consortium. Of these, 11 are partners from various universities, 8 research institutes, 5 industry partners as well as 4 SMEs, from many regions in EU (Belgium, Cyprus, Denmark, Germany, Greece, Italy, Norway, Poland, Spain, Sweden, The Netherlands, Turkey, UK). The group represents a broad range of expertise in hydraulics, wind engineering, aquaculture, renewable energy, marine environment, project management as well as socio-economics. They have received a financial contribution of 5.5 million Euro from the EU-FP7 funds. The following key questions are central in MERMAID, all of which shall help to contribute directly towards real design concepts and industrial applications. For this reason test sites will be studied to develop innovative plans and designs for harvesting ocean energy, aquaculture and logistic support:

- What are the best practices to develop a project on multi-use platforms?
- What are the accumulated effects of large scale structures on the marine environment?
- What are the best strategies for installation, maintenance and operation of a multi-purpose offshore platform?
- What is the economic and environmental feasibility of multi-use platforms?

In order to be able to develop real design concepts, four different sites that represent different environmental, social and economic conditions have been selected:

1. The Baltic Sea - a typical estuarine area with fresh water from rivers and salt water.
2. The trans-boundary area of the North Sea-Wadden Sea - a typical active morphology site
3. The Atlantic Ocean - a typical deep water site
4. The Mediterranean Sea - a typical sheltered deep water site.

With the results from these field studies, MERMAID aims to create a verified procedure to select the most appropriate design options for a given offshore area. This procedure should be generic so stakeholders and end users can use it for marine planning strategies. In addition, considering the large scale of coming offshore developments for aquaculture and renewable energy extraction the accumulated effect of various large scale structures in interaction with waves, currents, seabed, mixing and dispersion processes will be analysed in detail by MERMAID. Further, the effects from

[3] http://www.mermaidproject.eu

multi-trophic aquaculture and large scale aquaculture on the marine environment will be assessed. These end products will be beneficial to designers, manufacturers and contractors.

One central expected outcome of MERMAID is the assessment of the economic and environmental feasibility of such multi-use concepts. These will be compared to the single use approach of ocean space. Will the environmental impact decrease or increase? Will the funding for aquaculture be easier since risks are reduced? Will the multi-use approach lead to a better exploration of ocean space for aquaculture? It is hoped by the project consortium that addressing such key questions will be of large interest to Governmental agencies, spatial planners (private and public), investors and NGO's.

5.3.2 TROPOS[4]: Modular multi-use deep water offshore platform harnessing and servicing Mediterranean, subtropical and tropical marine and maritime resources

TROPOS is a European collaborative project which aims at developing a floating modular multi-use platform system for use in deep waters, with an initial geographic focus on the Mediterranean, Tropical and Sub-Tropical regions, but designed to be flexible enough so as to not be limited in geographic scope. Under the coordination of PLOCAN[5] (Spain) TROPOS consists of 18 partners from 9 countries (Spain, the United Kingdom, Germany, Portugal, France, Norway, Denmark, Greece and Taiwan). Central focus is placed on the EU Outer-Most Regions (OMRs) – namely the Azores, the Canary Islands, Guadeloupe, Guiana, Madeira, Martinique and Reunion – which represent a specific geographical and economic reality due to their remote location and reduced dimensions. Indeed, contrary to the rest of Europe, their scarce territory, limited resources and restricted market dimensions cannot be compensated by the nearby presence of significant markets. These elements have led the OMRs to consider the surrounding ocean as an outstanding location of resources and available space, which can be exploited and could strengthen both economic growth and job creation. Within this scope, TROPOS focuses primarily on four different sectors, namely energy, aquaculture, transport and tourism. The following objectives are central:

1. To determine, based on both numerical and physical modelling, the optimal locations for multi-use offshore platforms in Mediterranean, sub-tropical and tropical latitudes;
2. To explore the relations and integration into the platform of a broad range of sectors including energy, aquaculture and related maritime transport;
3. To research the relations between oceanic activities, including wind energy, aquaculture, transport solutions for shipping, and other additional services;
4. To develop novel, cost-efficient, floating and modular multi-use platform designs, that enable optimal coupling of the various services and activities;
5. To study the logistical requirements of the novel multi-use platform;
6. To assess the economic feasibility and viability of the platform;
7. To develop a comprehensive environmental impact methodology and assessment;
8. To configure at least three complete solutions, for the Mediterranean, Sub-tropical and tropical areas.

Especially for the case of offshore aquaculture, the TROPOS project aims to develop a new fish culture module taking advantage from the facilities that the platform offers. Hereby focus is on the

[4] http://www.troposplatform.eu
[5] http://www.plocan.eu/es

integrated exploitation of resources, within which it is hoped that the platform will provide offshore aquaculture with important synergies in energy exploitation, protection for the cages, mooring, logistics and transport, among others. The application of different technologies for offshore aquaculture will be possible, both due to its potential integration with Ocean Thermal Energy into electricity (OTEC) and other renewable energy supply, and due to the joint use of infrastructures, that will also optimize operation costs. In addition, a renewable energy mix shall be integrated to the multi-purpose platform: wind energy, solar energy (through photovoltaic technology) and ocean wave energy conversion.

As an expected outcome of these activities TROPOS shall contribute to increase the knowledge and efficiency regarding the exploitation of oceanic resources in Mediterranean, tropical and subtropical regions by the diversification of the use of marine resources. Notably this shall be done through improving the knowledge related to energy resources exploitation, aquaculture, transport and recreational activities. TROPOS intended to use a real offshore platform under the auspice of PLOCAN in the offshore region of the Canary Islands. However, due to the current difficulties of Spain in the wake of the on-going EU financial crisis, this platform construction has lacked funding. It remains to date open, whether TROPOS will be able to meet its objectives and outputs.

5.3.3 H2OCEAN[6]: Development of a wind-wave power open-sea platform equipped for hydrogen generation with support for multiple users of energy

H2OCEAN is the third project financed under the 2011 EU call "Ocean of Tomorrow" and has been granted a financial contribution of 4.5 million EUR. The research consortium is composed of 17 partners from 5 European countries (Spain, United Kingdom, Denmark, Germany and Italy). H2OCEAN started on the 1st of January, 2012 and will end on the 31st of December, 2014. The partnership builds up on the expertise and experience of a group of 10 innovative SMEs, one large enterprise and 6 leading public research organizations (4 universities and 2 institutes). The team shows a multi-sectorial profile, including renewable energy technologies, fluid mechanics engineering, offshore engineering, desalination engineering, hydrogen generation, electrolysis engineering, offshore aquaculture, aquaculture equipment and management, maritime transport and economics, logistics systems, safety and risk assessment, environmental and economic impact and information and communication technology.

H2OCEAN aims at developing an innovative design for an economically and environmentally sustainable multi-use open-sea platform. Hereby, wind and wave power will be harvested and part of the energy will be used for multiple applications on-site, including the conversion of energy into hydrogen that can be stored and shipped to shore as green energy carrier. In addition, a multi-trophic aquaculture farm shall be developed.

The H2Ocean work plan is structured around three interdependent and multidisciplinary components: the *design* of the platform concept, the *development* of technical solutions and the *assessment* of impact at different levels. The work structure has been designed to ensure the appropriate involvement and contribution from all partners, the accurate integration of the different activities and the assessment of the platform as a whole. H2OCEAN builds on already on-going Research and Development (R&D) and commercial activities of a partnership involving European

[6] http://www.h2ocean-project.eu

leading industrial and academic partners from 5 countries within the fields of renewable energy, hydrogen generation, fish farming, maritime transports and related research disciplines.

Besides the integration of different activities into a shared multi-use platform, the H2OCEAN concept holds a novel approach for the transmission of offshore-generated renewable electrical energy through hydrogen. This concept allows effective transport and storage of the energy, decoupling energy production and consumption, thus avoiding the grid imbalance problem inherent to current offshore renewable energy systems. Additionally, this concept also circumvents the need for a cable transmission system which takes up a significant investment share for offshore energy generation infrastructures, increasing the price of energy.

It is believed that the integrated concept will permit to take advantage of several synergies between the activities within the platform. It is hoped that the outputs of H2OCEAN will significantly boost the environmental, social and economic potential impact of new maritime activities, increasing employment and strengthening European competitiveness in key economic areas.

5.3.4 COEXIST[7]: Interaction in coastal waters: A roadmap to sustainable integration of aquaculture and fisheries

A fourth EU programme also has aquaculture in the centre of its research agenda. However, within COEXIST the key question is on how to integrate aquaculture with current fisheries practices within Europe.

Key motivation for COEXIST is the observation that Europe's coastal zones are of great socio-economic value, they are, however, also under pressure to balance competing activities and face potential conflict for space allocation. Stakeholder groups are diverse and represent diverse sectors, particularly fisheries, aquaculture, tourism, wind farm operation, and nature conservation in marine protected areas. Above all this is the requirement to preserve a valuable natural resource and meet environmental protection rules and regulations. COEXIST is a project using a broad multidisciplinary approach to evaluate interactions between competing activities and protection in the coastal area focusing on fisheries and aquaculture in particular.

The project looks at six different case studies: the Hardangerfjord in Norway, the Atlantic Coast of Ireland and France, the Algarve Coast of Portugal, the Italian part of the Adriatic Sea, the Coastal North Sea of Netherlands, Germany and Denmark and the Archipelago Sea of Finland in the Baltic Sea. These case studies, representing the specific conditions and combinations of activities of European coastal areas of particular importance for aquaculture and coastal fisheries, will provide data for further analysis and evaluation. Case study results will be compiled in order to identify benefits and bottlenecks for concomitant development

The ultimate goal of the project is to provide a roadmap for better integration, sustainability and synergies among different activities in the European coastal zones. It is a multidisciplinary project with thirteen partners from ten European countries, coordinated by the Norwegian Institute of Marine Research. COEXIST, which started in April 2010, is also funded by the European Commission Seventh Framework Programme for a duration of 36 months.

[7] http://www.coexistproject.eu

The central outputs of COEXIST are expected to be as follows

1. Characterization of relevant European coastal marine ecosystems, their current utilization and spatial management.
2. Evaluation of spatial management tools for combining coastal fisheries, aquaculture and other uses, both now and in the future.

By using a European-wide case study approach, COEXIST expects the following impacts:

- To contribute to the maintenance and development of coastal fisheries and aquaculture
- To contribute to the knowledge based economy
- To provide a framework to assist with the resolution of the existing and future conflicts related to interactions between aquaculture, fisheries and other sectors
- To contribute to the formulation, implementation and assessment of the current EU policies and legislation
- To improve the management tools based in ecosystem approach
- To contribute to the sustainable development at local and regional levels and to the growth of aquaculture and fisheries sectors
- To improve the relationship and communication among stakeholders, scientist and civil society
- To support new knowledge transfer across Europe

5.4 Efforts in the USA

In 1998, the University of New Hampshire initiated the Open Ocean Aquaculture Demonstration Project to investigate the commercial potential of environmental responsible seafood production, employment opportunities, engineering solutions and operational methodologies of offshore aquaculture (Bucklin & Howell 1998). As part of the project Langan & Horton (2003) deployed two 120 m submerged longlines for shellfish culture 10 km off the coast of Portsmouth (New Hampshire) in the south western Gulf of Maine, where the biological and commercial feasibility of *Mytilus edulis* cultivation were tested. Additionally, some test trials were conducted in the vicinity of Block Island off the coast of the State of Rhode Island where offshore wind turbines are planned in a traditional mussel spat collecting area. Similar plans exist for the area around *Cape Wind*, a nearshore wind farm off Wods Hole (Massachusetts).

6. Conclusions

The strong expansion of offshore wind farms in the marine environment, such as in the North Sea, increases the stress on sea areas that have formerly been used for other purposes, such as for fishery or shipping activities, or that are still seemingly free of human activity. Hence, the emerging offshore wind industry is quickly becoming a large stakeholder in the offshore arena, leading to conflicts of interest among the different user groups. In its wake, it has encouraged research on the prospects of integrating marine aquaculture with designated wind farm areas might provide chances to combine two industries in the frame of a offshore multiple-use concept.

It is apparent however that the orchestration of such a multi-use concept will be difficult. First results indicate that practical multifunctional use of offshore areas requires technical and economic feasibility as a basic prerequisite to assure that both, offshore wind farm operators and mariculturists, will support a multi-use concept. Risk and uncertainty associated with starting new businesses are particularly high in such emerging and innovative industrial sectors.

Thus a common understanding of uncertainty factors impacting a prospected offshore multiple-use of aquaculture with renewable energy systems is a first step towards turning some factors into more "controllable" and thus less risky elements. Besides pursuing appropriate management strategies that acknowledge the many uncertainties involved in a new and complex venture, management framework requirements should account for fair, effective, reliable and efficient implementation. Only then participants are willing to enter into a mutual learning process.

Thus, to foster this development to be a successful and sustainable move into the offshore realm requires a two-track policy approach, since such a pursued strategy aims at long-term social change. Thus, it should be more oriented towards progress, a '*process-oriented'* co-management of this development. In contrast, economic-technical elements demand for quick responses so that a strategy should focus stronger on immediate short-term results, a '*results-oriented*' co-management with framework requirements revealed by recent research.

A concurrent use of ocean territory demands from the respective actors that they move beyond the common path of business entrepreneurs and obtain a more complex picture of the multiple-use challenges. In this sense, 'comprehensiveness' implies to take a wide scope and full view of all issues, including those of the other parties involved. It entails that information is assimilated, which goes beyond the own day-to-day tasks. Additionally, an insight into the existing underlying ideas, interests and normative considerations has to be generated to understand complex problems and to overcome misunderstandings. This is, for example, relevant for coordinating cross-sectoral activities such as operation and maintenance within the same ocean territory.

Therefore, 'process-oriented' offshore co-management should be considered as learning-oriented strategy that constructs the web of cross-sectoral relations and focuses on recombining the different forms of knowledge by and by. However, focusing only on the process character of co-management is not sufficient enough when it comes to technical or economic issues that demand for tangible solutions. At present, available 'technical capacity' is perceived as a highly uncertain and consequently restraining factor for integrating both sectors. Here, a strategy of co-management should be rather 'results-oriented', suggesting concrete solutions for the more factual elements of uncertainty.

In summary, the two-track approach should be seen as a set of alternative management strategies each of which is appropriate in certain situations, under particular conditions and with respect to the set goals. Still, for certain perceived elements of uncertainty, such as 'political support', it may not be sufficient to pursue solely either one or the other strategy. These critical issues remain, for example the government's role to politically support multiple-use of marine territory and to provide the umbrella for consultation, new reliable arrangements, and procedural rules.

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Aquaculture Forum
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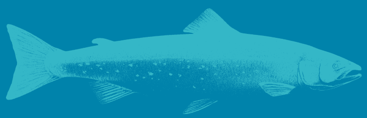

Bremerhaven Declaration
on the Future of
Global Open Ocean Aquaculture

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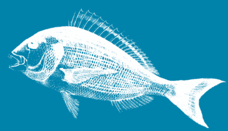
Part I

Preamble and Recommendations



Workshop I **March 26 – 27, 2012**

OPEN OCEAN AQUACULTURE DEVELOPMENT

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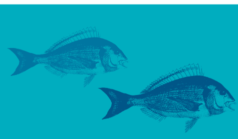

BREMERHAVEN DECLARATION
on the Future of Global Open Ocean Aquaculture

PREAMBLE

Workshop I of the Aquaculture Forum Bremerhaven was attended by about 100 participants from 16 countries, representing experts from industry, science, investors, regulators, and consumers. The initial concept for preparing the declaration was conceived at the "Marine Resources and Beyond Conference" held in 2011 and finalized in 2012 during the "International Workshop on Open Ocean Aquaculture", both held in Bremerhaven, Germany.

The participants of the workshop discussed a number of pertinent issues related to open ocean aquaculture while

- **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 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 fish 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 developoment will only delay the widening of the gap in seafood supply and unconventionally 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 huamn 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 especialy promising, but will require a high level of innovative technology, the use marine spatial planning, and transparent, adaptive management for spatial efficiency and conflict resolution;

- **concluding** also that open ocean aquaculture if intelligently designed can be incorporat into overall cooperative fisheries restoration and management strategies.

Following these discussions the undersigning Workshop participants (which included the core group of the global expertise on the subject) formulated a series of specific recommendations. We call 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. We herewith request immediate action to provide the means and resources for implementing the recommendations listed below.

RECOMMENDATIONS

Recommendation 1

Compliance of Open Ocean Aquaculture with the United Nations Convention of the Law of the Sea (UNCLOS) and other global, national, and regional legal requirements is needed.
A legal framework for Open Ocean Aquaculture should have clear standards and thresholds according to best environmental practices and best available technologies while also addressing issues of public trust, ownership, and liabilities.

Recommendation 2

Planning for Open Ocean Aquaculture for both research as well as for commercial enterprises should, from the start, consider the economies of scale required for its sustainable development in regard to its social and economic viability.

Recommendation 3

There is an urgent need to address how societal values and policies affect the acceptance, structures, and types of offshore aquaculture.

Recommendation 4

There is an urgent need to plan for the comprehensive development of land- and water-based infrastructures needed for the technical and logistical support and supply of Open Ocean Aquaculture that incorporates the multi-dimensional interacting factors for successful operations.

Recommendation 5

Priority should be given to the culture of species well-established in aquaculture (preferably natives) which can provide large quantities of seafood for which aquaculture technologies are known and have the potential to become acclimated to offshore farming conditions.

Recommendation 6

Organize international research and development platforms involving countries active or intending to initiate Open Ocean Aquaculture development projects.

Recommendation 7

Investigate whether the cultivated species can provide high value marine products other than foods which can also be simultaneously obtained thereby contributing substantially to the economic viability of offshore operations.

Recommendation 8

Create education and training networks to provide the required multidisciplinary and interdisciplinary expertise for safe and professional operations of Open Ocean Aquaculture systems.

Recommendation 9

Utilization of Open Ocean Aquaculture systems as potential environmental quality monitoring stations should be promoted as part of the international ocean observing systems networks.

Bremerhaven, March 27, 2012

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Contributions to the Bremerhaven Declaration on "Open Ocean Aquaculture Development" were received from Members of the Programme Committee, Session Chairs and speakers as well as from Workshop participants who presented their views during the Panel discussion on day two of the workshop.
These views were accommodated as much as possible by the Editorial Committee (Rosenthal, Costa-Pierce, Krause, Buck). Those participants who offered support to the views expressed in this Declaration are listed at the end of Part II of the Declaration.

2012 – 2013

Aquaculture Forum BREMERHAVEN

Business and science for a sustainable European aquaculture

WORKSHOP STRUCTURE AND CONTENT

The workshop series 2012–2013 of the „Aquaculture Forum Bremerhaven“ includes three additional events as announced on this page. These workshops will bring together speakers and participants from industry, science and administration.

Several keynote lecturres relevant to each of the central themes plus a series of contributed papers will be included in the programmes. A social evening event will provide ample opportunity for participants to exchange views and discuss future concepts. An extended Panel discussion on day two will provide ample opportunity to debate the future of aquaculture in Europe, addressing obstacles and opportunities in view of the globalized and highly competitive markets.

The outcome of the Panel discussions will be reflected in jointly formulated specific recommendations which will be published and distributed to industry, European agencies as well as regional and national authorities for further considerations.

The organizers will provide space for poster presentation for companies (including small exhibits).

Workshop II — October 15–16, 2012

2 AQUACULTURE PRODUCT QUALITY AND CONSUMER DEMANDS

The Djungel of Labelism: Do we need to label the labellors?

Product quality control and consumer safety is of prime interest to society. During the pioneering phase (last century) modern quaculture has seen little standardization of production processes. With increasing consumers awareness for quality and safety, national and regional regulations evolved often in parallel but with little standardization across production systems and jurisdictions. Also, enforcement of regulations was initially limited, offering little transparency, thereby failing to built consumer confidence. A new market for certification evolved to respond to the consumer demand.
The workshop will receive keynote presentations from the certification industries and regulatory authorities, to learn from experiences of producers with such labelism. Additionally, the processing industry will express their views on how to cope with the variety of labelling procedures. Numerous labelling philosophies and procedures have evolved and continue to appear with good intention, however, with little coordination, sometimes even with competing objectives. Develop many new codes and certificates may create a DJUNGEL of labelling options that confuses rather than convinces the consumer while making monitoring and enforcement measures less transparent for all involved.
An excursion to one of the largest processing plants in Germany can be organized (optional)

Workshop III — February 18–19, 2013

3 FINFISH NUTRITION AND AQUACULTURE TECHNOLOGY AT THE CROSSROADS

The future of fish nutrition; high versus low tech systems or integrated aquaculture?

With the expansion of the industry it is obvious that fishmeal replacement is a must. New protein sources may not be the prime concern but marine fats are to meet the demanded quality and provide the required level of unsaturated fatty acids. What are the future solutions? Further, the trend towards intensification will continue and water will be at the premium in most resource systems. Recycling of water is one issue but integrated recycling systems where wastes become valuable resources, providing options for optimizing the utility of natural resources (water, nutrients, energy.

Visits to exprimental facilities and to commercial producers can be organized (optional)

Workshop IV — September 23–24, 2013

4 DEVELOPMENTAL TRENDS AND DIVERSIFICATION IN EUROPEAN AQUACULTURE

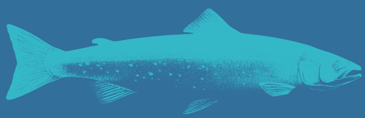
New species and/or new products from established aquaculture species?

The rapid growth of the industry in several parts of the world has been based on a limited number of species. Several new species are now in production, the names of which were largely unknown by the consumers 10 years ago. Can we expect this trend to continue? Should we try to investigate in option to diversify aquaculture through the development of culture know-how for new species?

Alternatively, should we diversify products derived from a limited number of species for which our knowledge on reproduction, growth, nutrition, and health is well established? Does future aquaculture produce only for the food market or will aquaculture species become increasingly the bioreactors to extract additionally high-prized substances needed by others than the food markets? Will freshwater or marine species dominate the future mass production systems?

The workshop will focus on these and related issues.

Aquaculture Forum
BREMERHAVEN



Bremerhaven Declaration
on the Future of Global Open Ocean Aquaculture

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Part II

Recommendations on subject areas and justifications

Workshop I **March 26–27, 2012**

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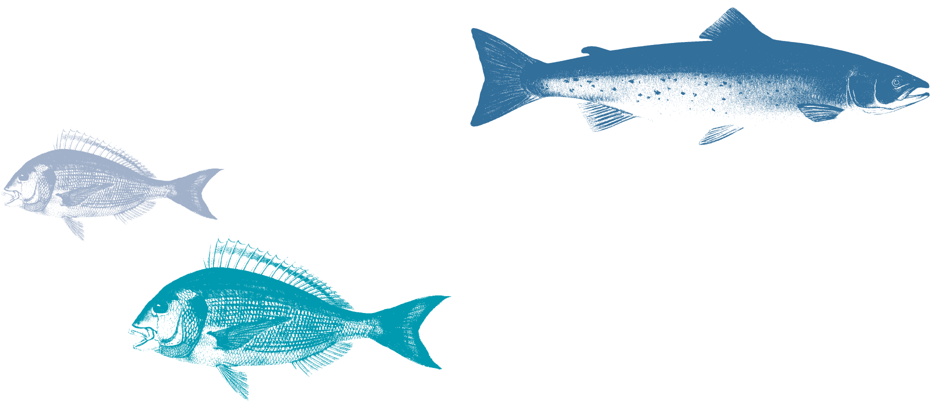
Testing new structures for offshore seaweed farming:

Preparation of Laminaria harvest from the ring formerly located at Helgoland Roads in the harbour of Helgoland. The ring was lifted from the water by a land-based crane.



BREMERHAVEN DECLARATION Part II
Recommendations on subject areas and justifications

Recommendation 1

Compliance of Open Ocean Aquaculture with the United Nations Convention of the Law of the Sea (UNCLOS) and other global, national, and regional legal requirements is needed.
A legal framework for Open Ocean Aquaculture should have clear standards and thresholds according to best environmental practices and best available technologies while also addressing issues of public trust, ownership, and liabilities.

Justification

At present there is an incomplete legal framework available for the development of aquafarming in open waters. Based on the UN Convention of the Law of the Sea (UNCLOS) using the terms "Open Ocean Aquaculture" as well as "offshore" seem to be questionable, and may have no legal relevance.

To date, offshore aquaculture has been defined as being in exposed sites, or in high energy environments (Ryan 2005), and not by distance from the coast, but this term has no legal meaning. Legally it is critical whether marine aquaculture is located within the territorial waters of the coastal state, in the EEZ, or on the High Seas. Therefore, precise definitions of offshore aquaculture orientated to zoning as defined in the UNCLOS is more appropriate to develop a common legal framework. Thus, marine aquaculture which is operated in the territorial seas of a state can only legally be described as "coastal aquaculture".

For aquaculture operations in the EEZ and the continental shelf the term "EEZ aquaculture" is a more appropriate legal term that is defined clearly in an international legal framework. Besides this basic definition, there remain numerous unsolved legal aspects in many jurisdictions as to the licensing procedures. We believe it is time for governments to resolve these in order to offer potential investors a clear legal structure from the beginning, and to develop appropriate terminology to match the legal situation in compliance with international and national rules and standards. There are also many regulations in existence for many other coastal and open ocean operations with regard to technologies and logistics such as navigation and safely standards, both for equipment and operators. These should be carefully checked, adopted, or amended as appropriate.

There is an urgent need to establish an international working group that addresses these legal issues to provide the necessary guidance for legal frameworks. The terms of reference should elaborate on options to harmonize and simplify the application process to achieve a more uniform licensing format applicable to various jurisdictions.

At present there are differing and confusing permit procedures in place that are not only time consuming, but also prevent development. Zoning in the context of marine spatial planning should be incorporated into legal frameworks to better facilitate licensing and monitoring obligations (see also justification under recommendation 3 as well as 6).

Recommendation 2

Planning for Open Ocean Aquaculture for both research as well as for commercial enterprises should, from the start, consider the economies of scale required for its sustainable development in regard to its social and economic viability.

Justification

Many trials in the past focused on technical feasibility by developing various technological details for best performance in harsh environments without due consideration of the minimum scale of production needed to bring the investment and operational costs per production unit down to realistic levels in order to reach profitability.

Furthermore, the necessary infrastructure development offshore and related onshore infrastructure needs have not yet been sufficiently considered in relation to scale in space and time. These issues need urgent attention in research and development efforts, which should be done at a larger scale in order to provide the needed data for sound economic feasibility assessments. This should include the assessment of infrastructure co-use, e.g. together with offshore wind farms, in order to create possible economies of scope.

Recommendation 3

There is an urgent need to address how societal values and policies affect the acceptance, structures, and types of offshore aquaculture.

Justification

In the development and implementation of offshore aquaculture projects, considerable progress has been made in methods and tools that assess biophysical and economic pre-conditions in terms of site selection and adaptive technologies.

On the other hand, social, cultural or political conditions surrounding aquaculture projects are seldom explicitly addressed in marine spatial planning. As a consequence, the implementation of projects and establishment systems fail due to factors that could have been foreseen if a more thorough analysis would have been employed that paid sufficient attention to the socio-economic dimensions of aquaculture. Besides general criteria and strategies to be employed, there are regional and local differences in the social-economic settings that need to be addressed in order to minimize the risks for undesirable outcomes. Especially in the offshore realm, stakeholders of aquaculture projects encompass a wide range of actors with different and often contrasting views, objectives and capacities that can act as detrimental forces to the overall sustainability of offshore aquaculture projects and investments.

There is a need to take also a more holistic approach including appropriate risk assessment methodologies as outlined in the GESAMP 2008 (Report and Studies No 76) on "Assessment and communication of environmental risks in coastal aquaculture", where risk communication between stakeholders and consensus building is one of the key issues in conflict resolution.

Along the same line of arguments it seems advisable to also involve farmer organisations and governing bodies of regional environmental agreements[1] to develop rules, standards and thresholds. Close reference to the FAO Code of Conduct on Responsible Fisheries and Aquaculture and the FAO Ecosystems Approach to Aquaculture are recommended.

1 HELCOM, ICES, OSPAR in European waters and other respective agreements in other jurisdictions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Recommendation 4

There is an urgent need to plan for the comprehensive development of land- and water-based infrastructures needed for the technical and logistical support and supply of Open Ocean Aquaculture that incorporates the multi-dimensional interacting factors for successful operations.

Justification

Aquaculture in exposed sites and in the open ocean requires efficient support systems in the ocean as well as ashore that must support effective logistics for both transportation and storage. Additionally, specific equipment permitting a high level of automation is needed to minimize service and maximize safety at sea. Furthermore, extended lifetimes for both instrumentation and structural materials will be needed to permit ease of handling under adverse environmental conditions.

The social acceptance of aquaculture in general and offshore farming in particular may change with increasing food concerns. These issues must be addressed. It can be anticipated that job opportunities will most likely be very important in the aquaculture onshore support sectors in technology development, supplies, transportation, feed production, and hatcheries and less so in the grow-out offshore facilities where maintenance and services will be reduced to a minimum and most likely replaced by largely automated systems. This will require decisionmakers to be aware of the large potential for job creation if more comprehensive land-water infrastructure planning is conducted for the full development of Offshore Aquaculture.

Recommendation 5

Priority should be given to the culture of species well-established in aquaculture (preferably natives) which can provide large quantities of seafood for which aquaculture technologies are known and have the potential to become acclimated to offshore farming conditions.

Justification

Using species already well-established in aquaculture has the advantage that most of their physiological, behavioural and stress responses are well understood. The use of species with known performance characteristics helps to make appropriate technology adjustments to species needs in offshore settings without extensive and expensive lead times. Furthermore, using such well-known species may allow to combine them in various trophic assemblages following the FAO Ecosystems Approach to Aquaculture protocols that details social-ecological concepts with the goals of optimal benefits for economic and ecological interactions with marine ecosystems.

Recommendation 6

Organize international research and development platforms involving countries active or intending to initiate Open Ocean Aquaculture development projects.

Justification

Going offshore is costly and risky and needs large investments. In order to realize synergetic effects, common use of infrastructure and logistics could lead to more effective and timely developments, involving all major countries presently active or intending to initiate Open Ocean farming developments. Because of the large scale, multi-disciplinary and interdisciplinary approaches needed, and because of the need for large teams to address the very complex and interacting factors that determine success, it is unlikely that a local or national project alone would be cost effective.

Testing the complex design criteria and various operational parameters needs to be studied simultaneously to achieve full comparability of results. Such development platforms would allow operations to be scaled at commercially viable scales while also combining past experiences. This would enhance greatly the chances for success, thereby saving time and resources while greatly reducing the risks of failures. An additional spin-off would be the development of common standards for both technology and environmental certification.

Recommendation 7

Investigate whether the cultivated species can provide high value marine products other than foods which can also be simultaneously obtained thereby contributing substantially to the economic viability of offshore operations.

Justification

Operating Open Ocean Aquaculture systems is expensive. Besides the economies of scale, the diversification of products gained from the same species can contribute to economic sustainability. Therefore, species should not only provide high quality products for food markets but also be researched to serve as bioreactors for products urgently needed by other industries.

There are a wealth of substances that may be extracted or specifically produced from these species for use in industries such as cosmetics, pharmaceuticals, general chemistry, energy and other specific production lines. So far, little emphasis on products other than for food markets have yet been explored in aquaculture, although the use of skin, bones, cartilage, intestines and other by-products are traditionally used from fish and shellfish. Recently, several new products have been developed from algae, invertebrates and fish, often using processing wastes, which are considered as new resources rather than as wastes.

Innovative research and development has great potential to open new markets but also to enhance cost-effectiveness of operations. Such multi-product concepts would also need to be properly accommodated by the respective certification and labelling systems as new criteria will be required in terms of both economy and ecology.

Recommendation 8

Create education and training networks to provide the required multidisciplinary and interdisciplinary expertise for safe and professional operations of Open Ocean Aquaculture systems.

Justification

There are substantial opportunities to investigate the interactions between potential multiple uses of ocean observations, fisheries, aquaculture, reserves, and their ecological, economic, social and technological interactions. Marine technology research parks in an ocean area could attract considerable funding. Some marine scientists have touted the considerable ancillary benefits of increases in non-consumptive use values for research, multidisciplinary education, hands-on training at realistic scale, diving, photography, tourism, and conservation of marine biodiversity. Use of ecological design and engineering principles and practices could allow design optimization of energy generation, seafood production, biodiversity, and marine ecosystem health in research and education centers that could potentially benefit all stakeholders and increase research and development funding to boost the “innovation economy” [2].

2 One model is an innovative R&D strategy recently announced in Ireland at a recent meeting titled, “Harnessing Ireland’s Potential as a European and Global Centre for Ocean Technology”. Ireland plans to develop 10 “Ocean Innovation Test Platforms” that will allow companies to form partnerships in order to test new concepts, equipment, technologies, and solutions in real-life situations. Called “SMARTOCEAN Innovation Clusters” they seek to target newly emerging niche markets (marine renewable energy, environmental monitoring, and water management), as well as established markets (oil and gas, aquaculture, maritime transport, tourism, coastal erosion) to develop innovative and competitive production systems and service models and target both niche and high value markets.

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Recommendation 9

Utilization of Open Ocean Aquaculture systems as potential environmental quality monitoring stations should be promoted as part of the international ocean observing systems networks.

Justification

Offshore aquaculture systems need environmental monitoring for both system management and meeting standards of environmental regulations. There are also expensive global, regional and local environmental monitoring networks, often using remote sensing, submersible vehicles, drifters, ship-born data profiles, and other means. The option should be explored to align the development of Open Ocean Aquaculture with the international Open Ocean Observing Systems organizations that would enlarge the worlds' ocean observations station density for better environmental monitoring of the ocean.

Bremerhaven, March 27, 2012

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Contributions to the Bremerhaven Declaration on "Open Ocean Aquaculture Development" were received from Members of the Programme Committee, Session Chairs and speakers as well as from Workshop participants who presented their views during the Panel discussion.

These views were accommodated as much as possible by the editorial committee (Rosenthal, Costa-Pierce, Krause, Buck). Participants offering support to the views expressed in this Declaration are listed as follows:

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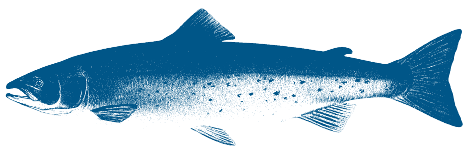


A
Open space for the installation of aquaculture devices
(e.g. feed, equipment)
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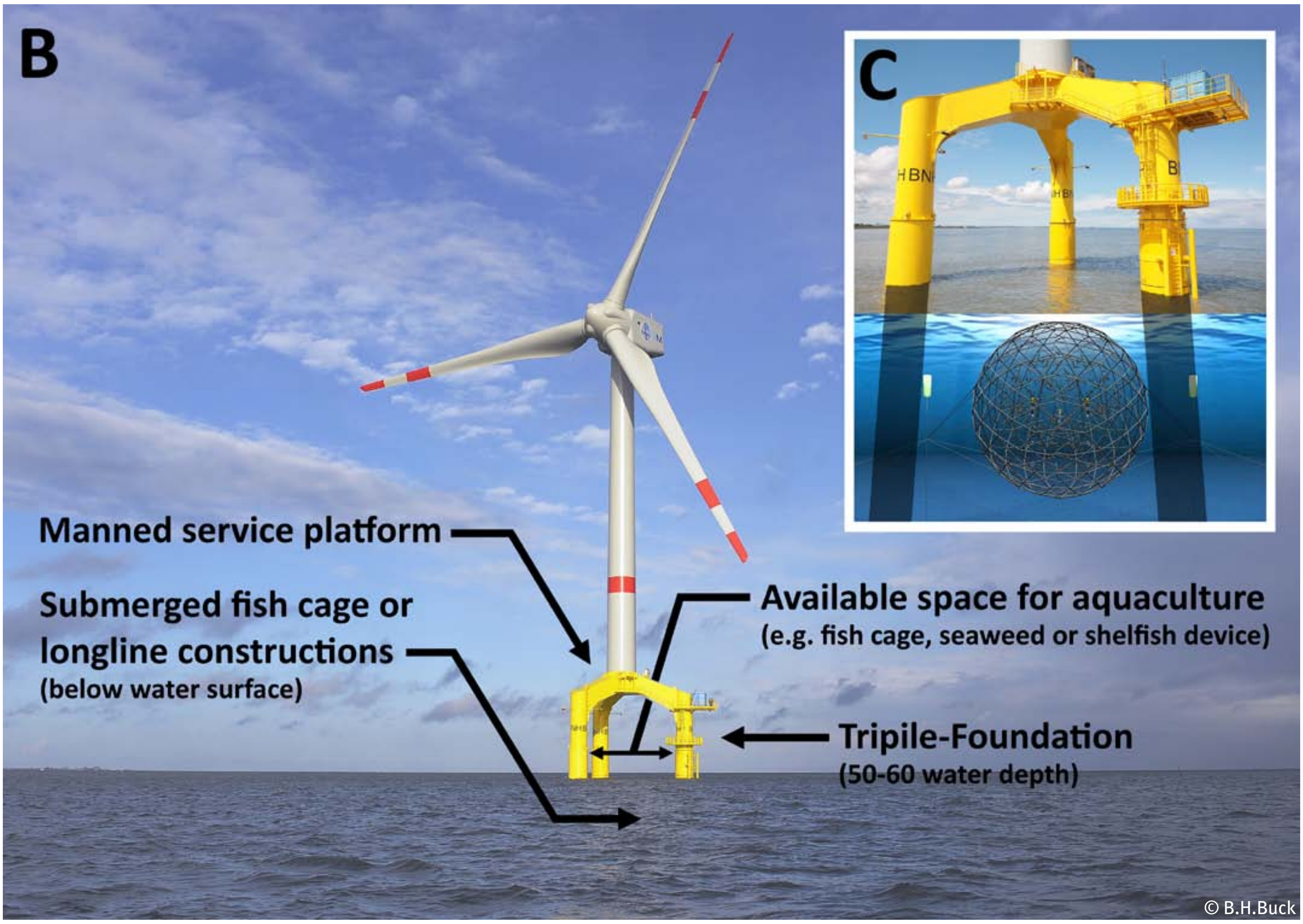
B
C
Manned service platform
Submerged fish cage or longline constructions
(below water surface)
Available space for aquaculture
(e.g. fish cage, seaweed or shelfish device)
Tripile-Foundation
(50-60 water depth)
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2012 – 2013 Aquaculture Forum BREMERHAVEN

Business and science for a sustainable European aquaculture

WORKSHOP STRUCTURE AND CONTENT

The workshop series 2012–2013 of the „Aquaculture Forum Bremerhaven“ includes three additional events as announced on this page. These workshops will bring together speakers and participants from industry, science and administration.

Several keynote lecturres relevant to each of the central themes plus a series of contributed papers will be included in the programmes. A social evening event will provide ample opportunity for participants to exchange views and discuss future concepts. An extended Panel discussion on day two will provide ample opportunity to debate the future of aquaculture in Europe, addressing obstacles and opportunities in view of the globalized and highly competitive markets.

The outcome of the Panel discussions will be reflected in jointly formulated specific recommendations which will be published and distributed to industry, European agencies as well as regional and national authorities for further considerations.

The organizers will provide space for poster presentation for companies (including small exhibits).

Workshop III — February 18–19, 2013

3 FINFISH NUTRITION AND AQUACULTURE TECHNOLOGY AT THE CROSSROADS

The future of fish nutrition; high versus low tech systems or integrated aquaculture?

With the expansion of the industry it is obvious that fishmeal replacement is a must. New protein sources may not be the prime concern but marine fats are to meet the demanded quality and provide the required level of unsaturated fatty acids. What are the future solutions? Further, the trend towards intensification will continue and water will be at the premium in most resource systems. Recycling of water is one issue but integrated recycling systems where wastes become valuable resources, providing options for optimizing the utility of natural resources (water, nutrients, energy.

Visits to exprimental facilities and to commercial producers can be organized (optional)

Workshop II — October 15–16, 2012

2 AQUACULTURE PRODUCT QUALITY AND CONSUMER DEMANDS

The Djungel of Labelism: Do we need to label the labellors?

Product quality control and consumer safety is of prime interest to society. During the pioneering phase (last century) modern quaculture has seen little standardization of production processes. With increasing consumers awareness for quality and safety, national and regional regulations evolved often in parallel but with little standardization across production systems and jurisdictions. Also, enforcement of regulations was initially limited, offering little transparency, thereby failing to built consumer confidence. A new market for certification evolved to respond to the consumer demand.
The workshop will receive keynote presentations from the certification industries and regulatory authorities, to learn from experiences of producers with such labelism. Additionally, the processing industry will express their views on how to cope with the variety of labelling procedures. Numerous labelling philosophies and procedures have evolved and continue to appear with good intention, however, with little coordination, sometimes even with competing objectives. Develop many new codes and certificates may create a DJUNGEL of labelling options that confuses rather than convinces the consumer while making monitoring and enforcement measures less transparent for all involved.
An excursion to one of the largest processing plants in Germany can be organized (optional)

Workshop IV — September 23–24, 2013

4 DEVELOPMENTAL TRENDS AND DIVERSIFICATION IN EUROPEAN AQUACULTURE

New species and/or new products from established aquaculture species?

The rapid growth of the industry in several parts of the world has been based on a limited number of species. Several new species are now in production, the names of which were largely unknown by the consumers 10 years ago. Can we expect this trend to continue? Should we try to investigate in option to diversify aquaculture through the development of culture know-how for new species?

Alternatively, should we diversify products derived from a limited number of species for which our knowledge on reproduction, growth, nutrition, and health is well established? Does future aquaculture produce only for the food market or will aquaculture species become increasingly the bioreactors to extract additionally high-prized substances needed by others than the food markets? Will freshwater or marine species dominate the future mass production systems?

The workshop will focus on these and related issues.

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Titel: Short Expertise on the Potential Combination of Aquaculture with Marine-Based Renewable Energy Systems
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