

Evaluation of the promotion of

Offshore Aquaculture Through a Technology Platform





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Executive Summary

The project objective was “To investigate the opportunity and usefulness for the aquaculture industry of promoting offshore aquaculture through a technological platform”. The general methodology of the approach was to form a consortium of service providers, manufacturers, aquaculture practitioners with offshore experience, research and development organisations and agencies from the sector which would pool the available knowledge and experience by the most efficient and practical methods available. The goal was to ensure that the stated objective above is addressed accurately, comprehensively and efficiently.

Promoting the development of Offshore Aquaculture through the activities of an initiative group of the European Aquaculture Technology Platform and through representation on the IWG of the EATP is considered the most effective, efficient and appropriate method of ensuring a consolidated and coordinated approach to developing a European strategic research agenda for aquaculture. While there is ambiguity regarding the definition there is considerable clarity as to what is required in order to make the move to offshore.

In general Offshore Aquaculture may be defined as taking place in the open sea with significant exposure to wind and wave action where there is a requirement for equipment and servicing vessels to survive and operate in severe sea conditions from time to time. The issue of distance from the coast or from a safe harbour or shore base is often but not always a factor.

The vision of potential for the offshore sector derived from the various stakeholder consultations and with inputs from the consultative committee is of a vibrant, technologically driven, sustainable industry supplying fish and quality fish products to an ever-increasing world population.

The key factors underpinning the unit cost of production and ensuring it is competitive with the international benchmark are:

- Production is being carried out at an appropriate scale
- The strains being cultivated are the best available

- There is good vertical integration within the industry
- The industry is organised in nodes or clusters & has a high degree of co-operative use of common facilities, both within the industry and with related sub-sectors (fisheries, food processing)
- The industry is highly automated and the employees have a high skills base.
- Remote telemetry is a key to monitoring and the management and control of process within the industry.
- Health management has been developed and consolidated into a holistic code of practice, which is underpinned by effective vaccines for key problem areas.

The major gap areas, which need to be addressed, can be categorised as follows:

1. Development of customised technology solutions across a range of areas particular to operating the harsh offshore environment.
2. Introduction of systems and adopting a systems analysis approach to solving husbandry and work practice issues in the context of offshore.
3. The application of remote monitoring technology and telemetry to both site management and routine activities at offshore installations.
4. The implementation of an Appropriate Regulatory Framework to encourage and underpin the commercial development of a sustainable and “green” aquaculture sector in European coastal seas.
5. Development of additional sustainable sources of oil and protein for feedstuffs for a range of culture species.

The RTDI priorities particular to Offshore Aquaculture are outlined in an analysis of the goals, objectives and requirements in terms of RTDI to underpin the development of offshore aquaculture in Europe (Appendix III).

Introduction

With its 70,000 km of coastline along two oceans and four seas, Europe's maritime regions account for around 40% of the European Union's GDP and provide employment to over five million people in the maritime sector. The sector has significant growth potential due to increasing demand for energy, international trade, tourism, seafood production, etc (Fisheries and Aquaculture in Europe, 2008). However, over-exploitation and depletion of traditional fisheries, has led to a consequential reduction in fishing quotas and a re-structuring of the fleet all over Europe, which in turn, has caused a loss of traditional jobs and increased unemployment in many coastal communities. Aquaculture meanwhile has diversified significantly, and today aquaculture constitutes an important and flourishing industry with high expectations for the future.

Many groups are struggling to define what they mean by Offshore aquaculture. The 'Farming the Deep Blue' report (2004) defines 'offshore' as any site exposed to ocean swell and suggested two classes of offshore site; Class 3 with local topographical features providing some shelter and Class 4 sites exposed to open ocean conditions. Muir (1988) identifies key distinctions of offshore aquaculture i.e. 2+ km from shore, generally within continental shelf zones, possibly open ocean, significant wave height (Hs) 5m or more, regularly 2-3m, oceanic swells, variable wind periods, possibly less localised current effect. Usually > 80% accessible with remote operations. The Norwegian Government classifies offshore sites using significant wave heights (Ryan 2004) and offshore is defined in the US as occurring "from the three mile territorial limit of the coast to two hundred miles offshore".

While there is ambiguity regarding the definition there is considerable clarity as to what is required in order to make the move to offshore. In general Offshore Aquaculture may be defined as taking place in the open sea with significant exposure to wind and wave action, and where there is a requirement for equipment and servicing vessels to survive and operate in severe sea conditions from time to time. The issue of distance from the coast or from a safe harbour or shore base is often but not always a factor.

As competition for coastal space increases the fish farming industry is looking to move further offshore in the future. Many believe that by moving the aquaculture industry offshore, we can move into cleaner, deeper waters, we can reduce conflicts with coastal users and we can provide a much better environment for aquaculture operations to exist. Many others feel that we know so little at this point in time about the consequences and requirements that it would be foolhardy to take this next step immediately, at least at a full commercial scale.

However, aquaculture is the fastest growing food producing sector in the world and as the 2006, FAO Status of World Aquaculture report indicates, it will need to increase from its current 45.5 million tonnes to approximately 80-90 million tonnes by 2030 to continue to supply up to 50% of the world's total fish requirements.

Although over the past three decades outputs have substantially increased within most EC countries, the competition for space in the coastal zone is limiting the increase in production in this area. The development towards offshore aquaculture in Europe has been variable and largely driven by the practical need to move offshore. Historically, much of the technology and many of the practical approaches to aquaculture were developed in Northern Europe and transferred to Southern Europe. However, in more recent time Southern Europe has become an important player in the development of new technologies and systems.

By investing in research, technological development and innovation the European aquaculture sector can contribute substantially to achieving the European Union's goal of becoming "the most competitive and dynamic knowledge based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion" (Lisbon European Council, March 2000). The EU Commission has signalled its support for the industry by launching in May 2007 a review of the 'Strategy for the sustainable development of European aquaculture', 2002, with a view to up-dating the strategy. The Green Paper on a future Maritime Policy for Europe has also highlighted aquaculture as one of the growth sectors in Europe. Indeed Commissioner Borg committed his

support by stating that “the development of new technologies like offshore aquaculture and recirculation systems are also highly promising avenues to address the lack of space for aquaculture activities and we will continue to support their development through research and pilot projects”, (Commissioner J Borg, AQUA2007).

The Commission also identified the potential of European Technology Platforms (ETP) as a means of identifying new research priorities. While the Commission encourages this use of the bottom-up approach through ETPs it points out that it neither owns or is it bound by them. To date approximately 20 ETPs have produced their vision for their sectors. The European Aquaculture Technology Platform was established at a meeting in Brussels November 8-9, 2007. This group observed that in order for the industry to stay ahead and realise its potential, a substantial increase in investment in research, technological development and demonstration activities would be required. The central aim of the platform will be to promote the transformation from a resource-intensive to a knowledge-intensive industrial basis - knowledge intensive products, processes and services. Achieving this will both improve the industry’s competitiveness and its economic contribution to society - and thus supporting the Lisbon strategy.



OATP Project Participants Rosa Fernandez, Arne Fredheim and Dave Jackson with Seán O’Neachtain MEP at the OATP International Workshop, Dublin 2007

Evaluation of the Promotion of Offshore Aquaculture Through a Technology Platform (OATP)

The project objective was “To investigate the opportunity and usefulness for the aquaculture industry of promoting offshore aquaculture through a technological platform”. The general methodology of the approach was to form a consortium of service providers, manufacturers, aquaculture practitioners with offshore experience, research and development organisations and agencies from the sector which would pool the available knowledge and experience by the most efficient and practical methods available. The goal was to ensure that the stated objective above is addressed accurately, comprehensively and efficiently. This was achieved by:

- A survey by way of a bespoke questionnaire, administered by direct interview. The survey covered

all members of the consortium and additional stakeholders in the EU/EEA regions.

- Hosting of informal seminars in key regions to identify key areas for future discussions. These provided an interim report for circulation in advance of the international workshop. Hosting of an International Workshop for partners and stakeholders.
- Production of a final report, with recommendations and roadmap of way forward. This report reflects the proceedings of the workshop and the considered views of the partners on the functions of a technology platform is achieving goals set out above.

Potential impact

In the course of carrying out a thorough evaluation of the objectives, the project achieved a number of clearly defined goals, which will of themselves have a measurable impact beyond the achievement of the stated objective of the project. These impacts will include the following:

- Development of a widely based consensus on RTDI priorities in the Offshore Aquaculture sector. This will inform strategic planning at various levels including EU, National and Corporate. Feedback will be efficient, thorough and immediate through the gateway of the participants & partners in the project.
- An increase in the overall investment in the offshore aquaculture development sector (in terms of EU, member states, private funding and venture capital) by showing a common vision of the potential and the intermediate steps required to achieve it.
- Strengthen networks and encourage the development of clusters and centres of excellence. In particular the facilitation of cluster development between public and private organisations and across disciplines in this sector, which is very much in the phase of early development and is as yet quite fragmented in nature, will be of critical benefit to realising future potential.
- Identify areas of current strengths, areas of weakness which require strengthening, and gap areas where there is a lack of capability or expertise within the ERA.
- At a regional level, assist regions in identifying and addressing challenges and in particular opportunities in this developing sector.
- Identify and catalogue the pre-requisites for development of a consistent and coherent policy and regulatory framework for Offshore Aquaculture in the EU and EEA.
- An increase in public awareness, understanding and acceptance of the technologies concerned and the benefits accruing to the wider public through their appropriate deployment.

The Offshore Aquaculture Technology Platform signed a Memorandum of Understanding with the European Aquaculture Technology Platform (EATP) in March 2007. This MoU (Appendix II) outlines the cooperation in developing RTDI visions, research agenda, deployment strategies and projects relevant to the European aquaculture industry under the concept of Technology Platforms. The outputs from the OATP project will be put at the disposal of the EATP Interim Working Group (IWG) and will also be disseminated via the EATP web portal.

The MoU also sets out how OATP outputs will contribute to an overarching vision for the development of aquaculture in Europe. The EATP has been established as a coordinating organ to facilitate initiatives and operations within aquaculture and the OATP is one of the first initiative groups of the European Aquaculture Technology Platform. The OATP findings and conclusions will form part of the developing EATP visions, strategic research agenda and deployment strategy. Promoting the development of Offshore Aquaculture through the activities of an initiative group of the European Aquaculture Technology Platform and through representation on the IWG of the EATP is considered the most effective, efficient and appropriate method of ensuring a consolidated and coordinated approach to developing a European strategic research agenda for aquaculture.

Promotion of Offshore Aquaculture through a Technology Platform

Promoting the development of Offshore Aquaculture through the activities of an initiative group of the European Aquaculture Technology Platform and through representation on the IWG of the EATP is considered the most effective, efficient and appropriate method of ensuring a consolidated and coordinated approach to developing a European strategic research agenda for aquaculture.

European Aquaculture Sector Vision and Gap Analysis

In 2004 the EU aquaculture industry produced approximately 1.38 million tonnes with an estimated value of € 2.8 billion. This production accounted for 2.3% of the world aquaculture production. EU shellfish production represented 5.7% of world shellfish production by weight, 1.3% of freshwater production and 10.9% for marine production (FAO Yearbook 2005-2006). Global production rose by 10% during the period from 1995 – 2004. European production however, only grew by approximately 4% over the same period and may be considered to have stagnated since then.

While the EU is very well placed to capitalise on the increased demand for fish products, the sector faces a number of difficult challenges. Competition for space and good quality water along with the need to ensure protection of public health and the natural environment through the high standards set by the EU makes it difficult to compete with developing nations producers. In order to overcome these challenges the new Integrated Maritime Policy will strive to ensure the aquaculture sector will be seen in the broader context of the maritime sector as a whole.

The majority of European marine finfish production is in Norway, Scotland, Ireland and the Faroe Islands. Other countries such as Finland, Iceland, Sweden and Denmark do have some marine cage production and there is a growing industry based on sea bass, sea bream and captured tuna in the Mediterranean and Canaries. While there are major differences between the countries production environments, the cage systems employed are essentially uniform in terms of the technology used. The greatest improvements in recent years have been through the development of genetic programmes and the development of vaccines. There is currently great interest in the aquaculture industry with many European countries developing strategies for their marine sectors.

Vision for Offshore Aquaculture in Europe

Domestic production of marine fish sufficient to meet European market requirements with a growing export market worldwide.

To make offshore aquaculture attractive to inward investment with sustained profitability underpinned by transparent regulation inspiring both consumer and investor confidence.

Security of tenure provided for through appropriate licensing, regulations and competitive production costs maintained through the application of technology and advanced husbandry techniques.

Vision

Offshore sites with a moderate to high degree of exposure are being exploited successfully. Production is organised in a small number of operating units producing large volumes. These are either large offshore units or clusters of smaller units. Landings of product are handled through specialist processing and packing facilities, with over 90% of exported product receiving at least primary processing (fillets or darts). All processing is carried out to EN45011 or ISO65 standards.

Synergies have been developed with the offshore energy industry, the fisheries industry, bio tourism and marine biotech sectors. Close links have been developed with the mainstream food processing industry and seafood is increasingly included in ready to eat meals and “healthy meals”. Europe’s industry is a “test bed” for offshore technology development and for hi-tech recirculation systems for juvenile production.

The sector is competitive producing high quality product in structures shared with offshore wind energy platforms.

Domestic production of juvenile marine fish is sufficient to meet the home market and there is a growing export market both within Europe and worldwide.

The industry is attractive to venture capital and attracts significant inward investment. Key factors are:

1. Profitability is good and sustained.
2. There is transparent regulation, giving confidence to consumer and investor alike.
3. Licenses and regulations combine to ensure there is security of tenure and the production sites are regarded as solid assets.

Costs of production are competitive. The key factors underpinning the unit cost of production and ensuring it is competitive with the international benchmark are:

- Production is being carried out at an appropriate scale
- The strains being cultivated are the best available
- There is good vertical integration within the industry
- The industry is organised in nodes or clusters & has a high degree of co-operative use of common facilities, both within the industry and with related sub-sectors (fisheries, food processing)
- The industry is highly automated & the employees have a high skills base.
- Remote telemetry is a key to monitoring, managing and controlling of processes within the industry.
- Health management has been developed and consolidated into a holistic code of practice, which is underpinned by effective vaccines for key problem areas.

The outputs from the OATP consultation process have been fed into the EATP via the Interim Working Group and the draft Vision statement of the EATP is very much in line with the OATP stakeholders' views of a vision for offshore aquaculture.

Strengths and Gaps

The maritime sector in Europe is large, well developed and technologically advanced. Furthermore, in a global context Europe is viewed as a world leader in many aspects of the maritime economy, including salmonid finfish aquaculture. The consultation process underlined the existence of a huge opportunity for technology transfer within the European maritime sector to the benefit of aquaculture in general and offshore aquaculture in particular. There are also major opportunities for product substitution within the seafood industry and the food processing industry generally. What is required to unlock this potential is a focused approach on marine food production and related technologies and capabilities. To date this focus has been lacking and the offshore aquaculture sector in particular has been suffering from both the consequences of this lack of focus and the fragmented nature of the industry itself, both geographically and in terms of species and production processes.

The RTDI requirements are outlined in the section on stakeholder feedback and are summarised in tabular form in Appendix III. The major gap areas which need to be addressed, can be categorised as follows:

1. Development of customised technology solutions across a range of areas particular to operating the harsh offshore environment.
2. Introduction of systems and adopting a systems analysis approach to solving husbandry and work practice issues in the context of offshore.
3. The application of remote monitoring technology and telemetry to both site management and routine activities at offshore installations.
4. The implementation of an Appropriate Regulatory Framework to encourage and underpin the commercial development of a sustainable and “green” aquaculture sector in European coastal seas.
5. Development of additional sustainable sources of oil and protein for feedstuffs for a range of culture species.

This last item is not particular to offshore aquaculture, rather it is a common challenge facing the aquaculture industry as a whole, both in Europe and worldwide.

From a technology perspective, containment systems such as cages and the associated nets and moorings were identified as an area in need of greatest development. Developments are required both in terms of the ability of the structures to survive and function in the harsh offshore environment and in terms of their suitability for incorporation in integrated systems for husbandry and farm management. Key areas identified were mooring systems for supply and service vessels, remote monitoring and feeding solutions, harvesting techniques and suitability in terms of both worker safety and animal welfare.

The need for further investment and research into the development of remote monitoring technology and integrated management systems has been highlighted both through the consultative process and in various reports including Molner and

Van den Ven (2006) and Lee & O'Bryen (2006). The ability to operate in a predictable safe and cost effective manner in the offshore environment will be acutely dependant on the availability of robust relatively low cost technology and operating systems for the various aspects of food production including containment, health monitoring, feeding, biomass estimation and harvesting operations.

The question of developing a mature regulatory framework, which balances the requirements environmental management and monitoring, security of tenure for producers and the provision of an appropriately regulated business environment conducive to the competitive production of quality food came through very strongly from all sources consulted. Many of the RTDI requirements identified in Appendix III address various aspects of the deficits in regard to the regulatory and legislative environment for marine food production in Europe. These cover issues relating to development of monitoring regimes, guidelines and codes of practice and the requirement to underpin a coherent Coastal Zone Management and MSP framework for European maritime waters.

Required Impacts

In order to ensure that the realisation of the vision for offshore aquaculture in Europe is possible, there are a number of key prerequisites, which must be in place. These will require that the RTDI component is successful to allow their delivery. Thus the required impacts of the RTDI effort have been identified as follows:

1. The development of suitable tools to underpin monitoring, regulation and ICZM/MSP initiatives.
2. Production units have been developed to an appropriate scale.
3. The strains and species available for cultivation are appropriate and the best available.
4. Good vertical integration within the industry.
5. The industry is organised in nodes or clusters & has a high degree of co-operative use of common facilities, both within the industry and with related sub-sectors (fisheries, food processing & offshore energy)



Offshore databuoy, Galway Bay, Ireland.

6. The industry is highly automated & the employees have a high skills base.
7. The development of remote telemetry as a basis for monitoring & the management and control of processes within the industry.
8. The development of Animal Welfare and Health management into a holistic code of practice, which is underpinned by effective vaccines for key problem areas.

The EATP Vision for European Aquaculture

The vision of the European Aquaculture Technology Platform is that efficient implementation of strategically focused R&D within the European research community is necessary to support the sustainable development of European aquaculture. The innovations and knowledge generated must be incorporated effectively within all components of the sector, using appropriate supportive mechanisms.

Not only will aquaculture's products provide health benefits for European consumers, they will also complement lifestyle changes in society. Through transparent communication, European aquaculture will demonstrate its contributions and role in society. These activities will provide the foundations for technical and economic excellence, which will be the basis of the leadership potential of European aquaculture at the global level.

There are 3 core priorities within the EATP's vision of innovative R&D and its incorporation. These are:

- Establishing a strong relationship between aquaculture and the customer.
- The assurance of a sustainable industry.
- Consolidation of the role of aquaculture in society

Each of these priorities contains thematic constituents. A range of horizontal measures, which apply to each priority, are envisaged and which include the assessment of the environmental interactions of the sector, innovation (including technology

transfer and training) and integration in society. The RTDI priorities particular to Offshore Aquaculture are outlined in the following sections.

Stakeholder Consultation Feedback Introduction

Consultation with stakeholders was co-ordinated by four project partners and sub-partners, covering: Ireland & the UK; Scandinavia; Spain & Portugal; and the Eastern Mediterranean. These participants represented: finfish and shellfish producers; agency representatives with aquaculture, wild fisheries and conservation remits; specialists involved with the aquaculture and marine technology industries; veterinarians; representatives of other coastal user organisations; non-governmental organisations involved with environmental protection and coastal development. Participants were engaged in the process through the dissemination of questionnaires, participation in regional and international workshops, or through direct contact and interview via phone, email or meetings.

	Number of participants	
	Workshops	Questionnaires
Ireland & UK	43	44
Scandinavia	26	36
Spain & Portugal	42	39
Eastern Mediterranean Interviews	n/a	24
International Seminar participants	79	n/a

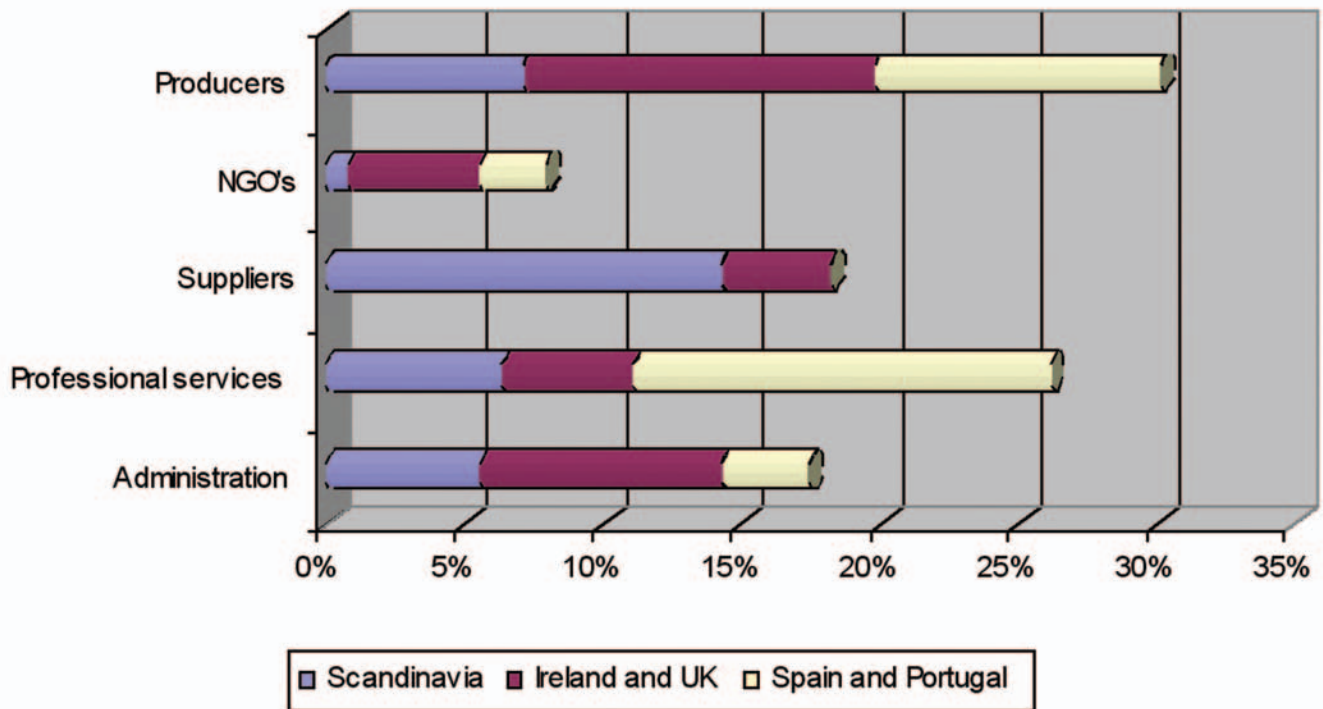


Figure 1 (a): Breakdown of respondents to the questionnaire in the partner regions

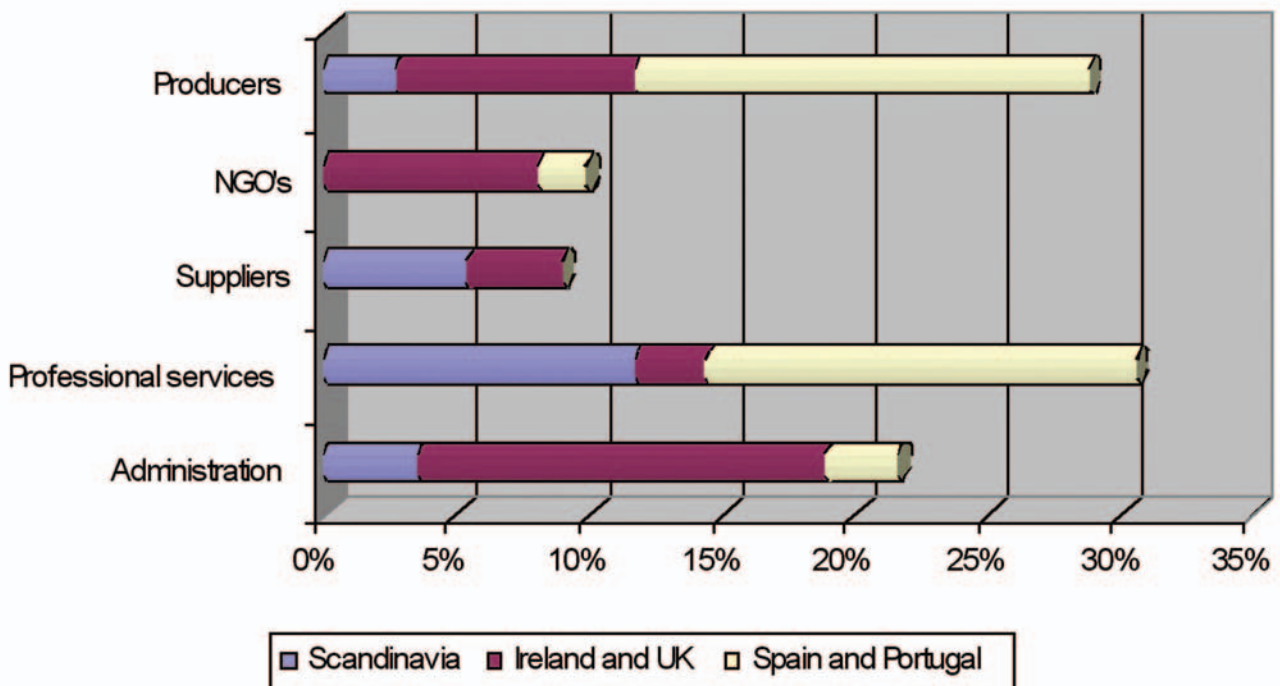


Figure 1 (b) : Breakdown of participants who attended the regional seminars in the partner regions

There is broad consensus that growth expectations for aquaculture on a global level are extremely encouraging. FAO forecasts for the demand for fish products, based on world population growth estimates and consumption trends for these types of product (rising from 11.0 kg/per capita in 1970 to 16.2 kg/per capita in 2002), together with a tendency towards the stagnation of catches in the extractive sector, indicate that there is a need for a considerable increase in cultured fish production.

In terms of a vision for offshore aquaculture the majority of participants felt that offshore aquacul-

ture could go a long way in meeting increased global seafood consumption demands, particularly in light of the fact that capture fisheries are thought to remain stagnant at best. In Spain & Portugal 97% of respondents agreed that offshore aquaculture could provide a solution to meeting the FAO forecast for global seafood consumption. In Ireland and the United Kingdom while the majority agreed with this, 50% of the NGO's believed offshore aquaculture would not meet these demands. Figure 3 below shows how the participants in Ireland & the UK responded to this issue.

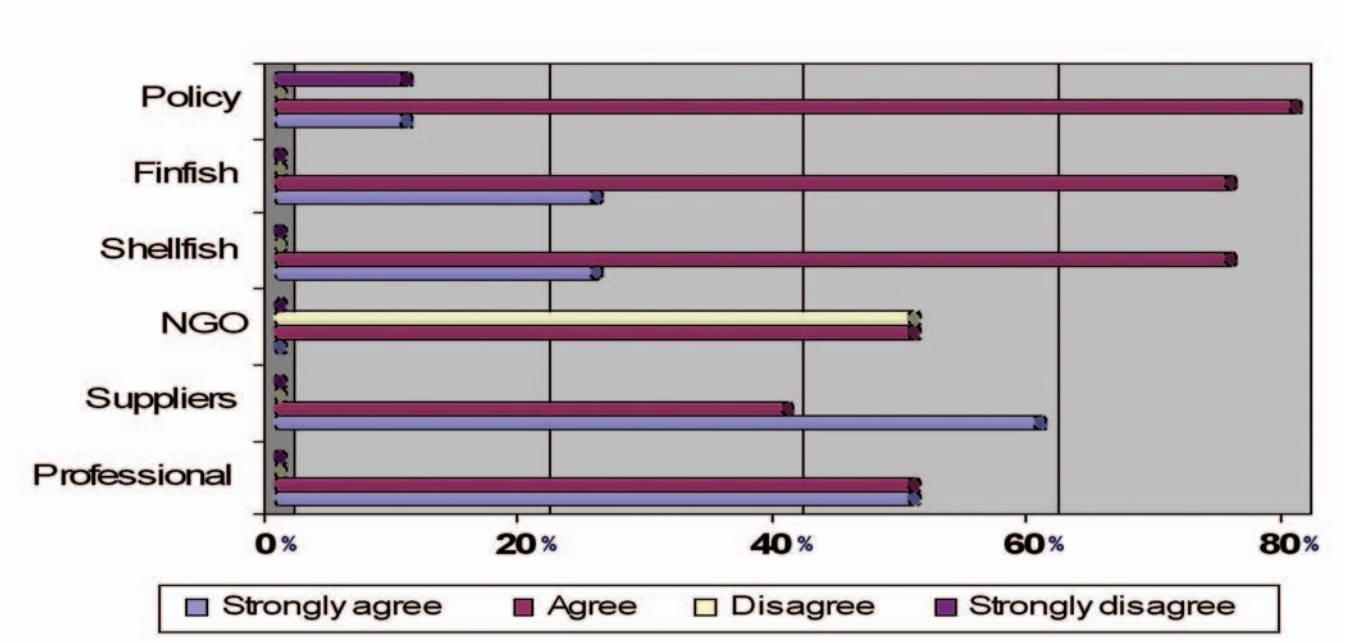


Figure 3: Views of the respondents to the questionnaire on whether they thought offshore aquaculture could go a long way to meeting global seafood consumption demands into the future

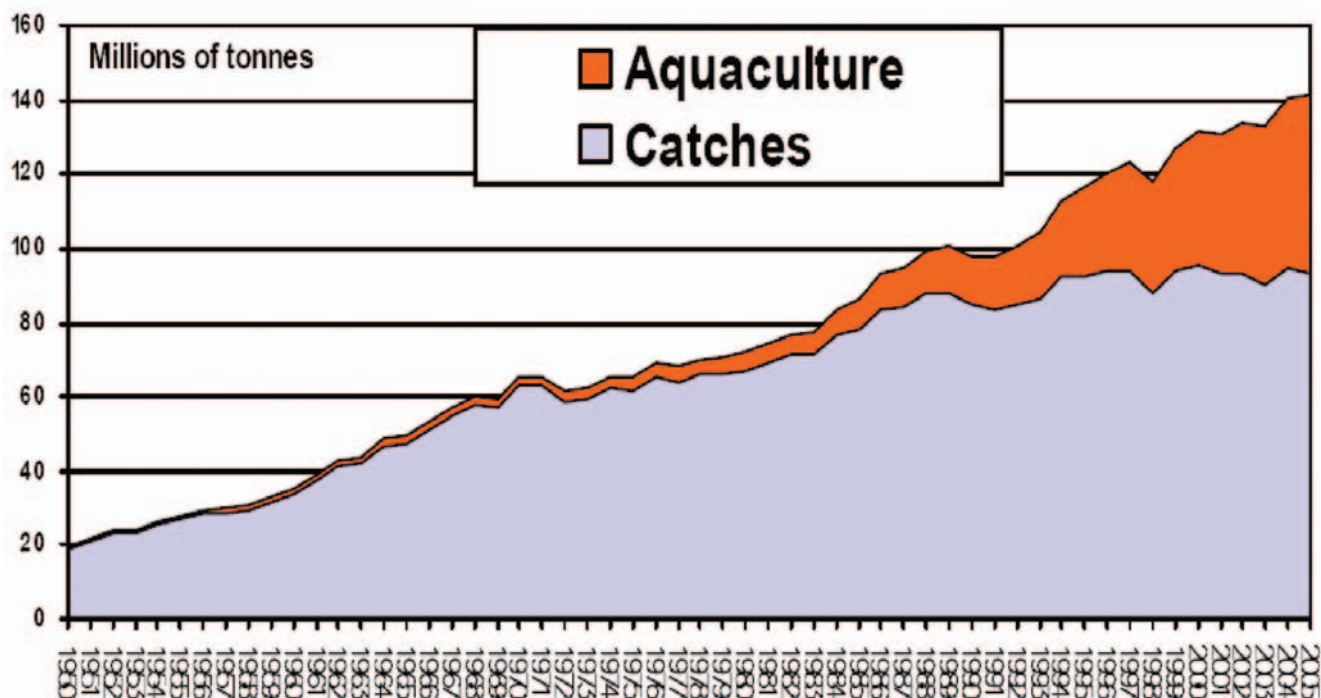


Figure 2: Global fishery and aquaculture production (source FAO).

When it came to the public's perception of the aquaculture industry, most stakeholders were concerned with the ethical issue of sustainability. There must be further research into alternatives to fish oils in fish feed for aquaculture. Replacing fish oil with vegetable extracts promotes the protection of wild fish resources and promotes sustainability. Animal welfare issues must continue to be addressed through stocking standards, fish health protocols and improved monitoring capabilities for offshore areas.

Overall the greatest area where public confidence needs to be improved, according to respondents, was in the area of environmental impacts. Environmental management encompasses the regulatory framework, monitoring programmes, industry management frameworks (and the development of Codes of Best Practice) and improved technology to aid remote, real-time monitoring in offshore locations. It is widely accepted, however, that moving offshore could help mitigate many of the environmental impacts and perceived impacts associated with aquaculture.

The area of food safety is an area of concern for producers and consumers alike. This refers to the use of medicines, microbial contamination and toxic algal blooms. Conversely, the health benefits

of eating seafood products needs to be highlighted as a means to improve the public image of the industry. Bio-security issues, such as farmed-wild interactions, are even more relevant in the offshore scenario. Industry will need to work closely with fish health specialists and equipment designers to ensure that every effort is made to develop codes of practice, which promote the protection of wild fish species.

There was quite a mixed view on what participants considered the greatest challenges to the development of offshore aquaculture. When taken together, safety issues and weather conditions (exposure) were of great concern to respondents, particularly the finfish and shellfish producers. Environmental challenges were of most concern to the NGO's, as well as the technology challenges and exposed nature of the sites.

There was quite a mixed view on what participants considered the greatest challenges to the development of offshore aquaculture. When taken together, safety issues and weather conditions (exposure) were of great concern to respondents, particularly the finfish and shellfish producers. Environmental challenges were of most concern to the NGO's, as well as the technology challenges and exposed nature of the sites.

When asked more specifically what the greatest safety concerns associated with offshore aquaculture production were, the opinions varied between the actual physical infrastructure, personal training and navigational safety. All participants strongly rated personal training as an important factor in safety. The producers, policy & professional service representatives and NGO's were concerned with cage, equipment and boat design. Accident

& emergency concerns increase the more you move offshore in terms of exposure and response time to emergencies. Other safety issues raised were navigation and safe passage, relative experience of workers on site and actual distance offshore of the sites. The issue of danger of collisions was also raised particularly in the Mediterranean area where a number of incidents of ships colliding with cages had occurred.

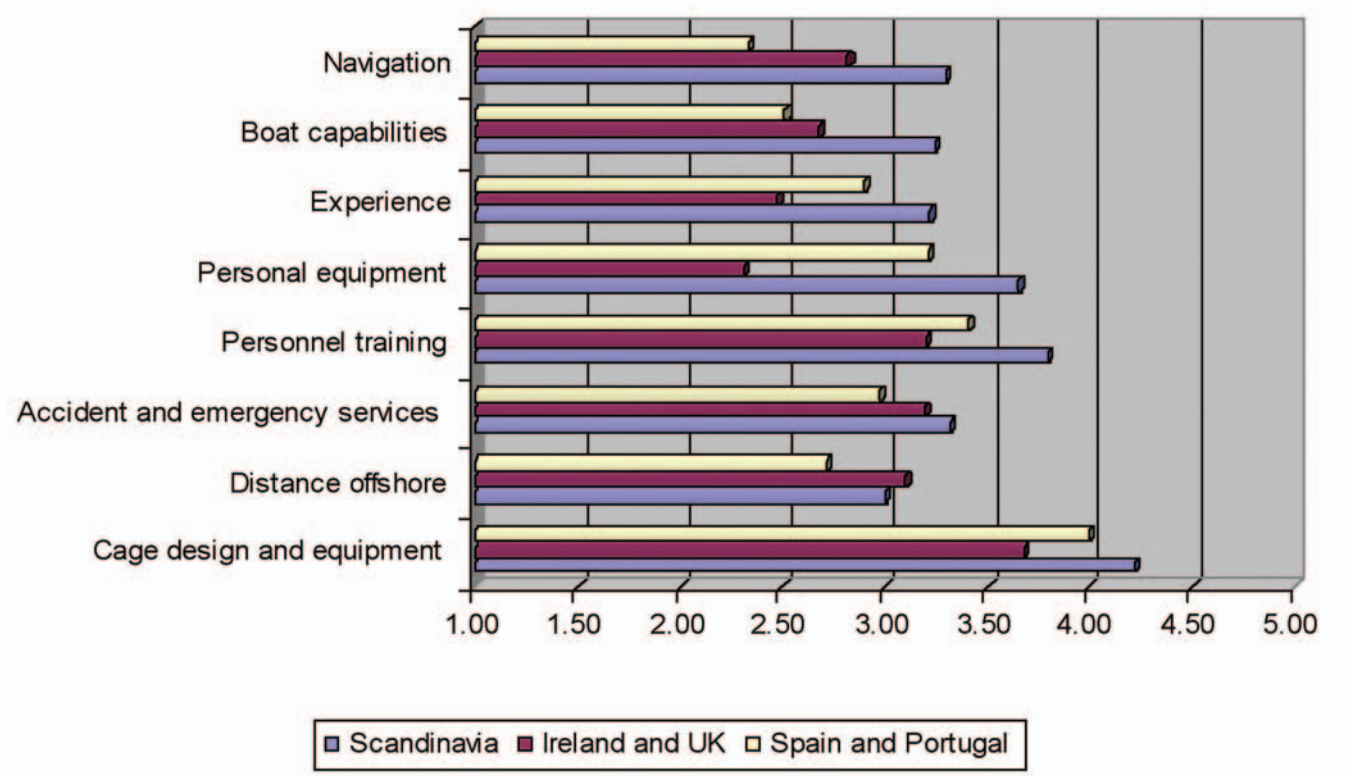


Figure 4: The areas in relation to safety which participant's felt needed greatest attention.

Potential species

The development of offshore aquaculture locations will serve predominantly to alleviate space conflict in inshore regions. There are regional differences in the types of species, which are suited to culturing in offshore locations, based on water temperature and prevailing climactic characteristics. In general cooler northern Atlantic regions are suitable to culturing of Cod (*Gadus morhua*), Atlantic Salmon (*Salmo salar*), blue mussels (*Mytilus edulis*) and rainbow trout (sea trout – *Onchorynchus mykiss*). These species are already commercially important species in northern European locations. In Spain and Portugal sea bream, sea trout, sea bass, turbot, halibut, mussels and oysters are species with the greatest potential. Some seaweeds such as

Laminaria spp., *Alaria* spp. and *Ulva lattissima* were also highlighted.

There may be certain site characteristics associated with offshore aquaculture which are more suited to culturing of some of these species. For example, greater current movement and water column mixing could serve to prevent large temperature fluctuations for finfish culturing. It may provide added benefits of dispersing nitrogenous waste and supplying oxygen rich water to the fish. The offshore water body's generally lower content of nutrients might result in lower carrying capacities for shellfish culture at certain locations offshore. However, enrichment in inshore locations can have a

negative effect with an increased potential for algal blooms and bacterial loading associated with inshore sites. The main challenge, as highlighted, is the infrastructural and technology requirements associated with moving offshore.

There is a need for increased R&D into novel species for culturing in offshore regions. These include Sea Urchins, Pollack, Tuna, Cod, Hake, Halibut, Sea bream and Sea bass. Research into improved on-growing techniques is necessary, particularly the adaptation and development of inshore technology and management routines to offshore locations. Detailed knowledge on hatchery design

and techniques is vital and knowledge transfer between European areas of expertise should promote best practice in rearing and on growing. The potential for polyculture should be researched and this could lead to the sharing of space and resources. This would have obvious cost cutting benefits for industry and the positive environmental benefits should be investigated and promoted. Another major challenge is the transfer of technology knowledge between finfish and shellfish producers, inter-regionally and between other users of offshore sites outside of the food-producing sector (such as the wind energy industry and oil industries).

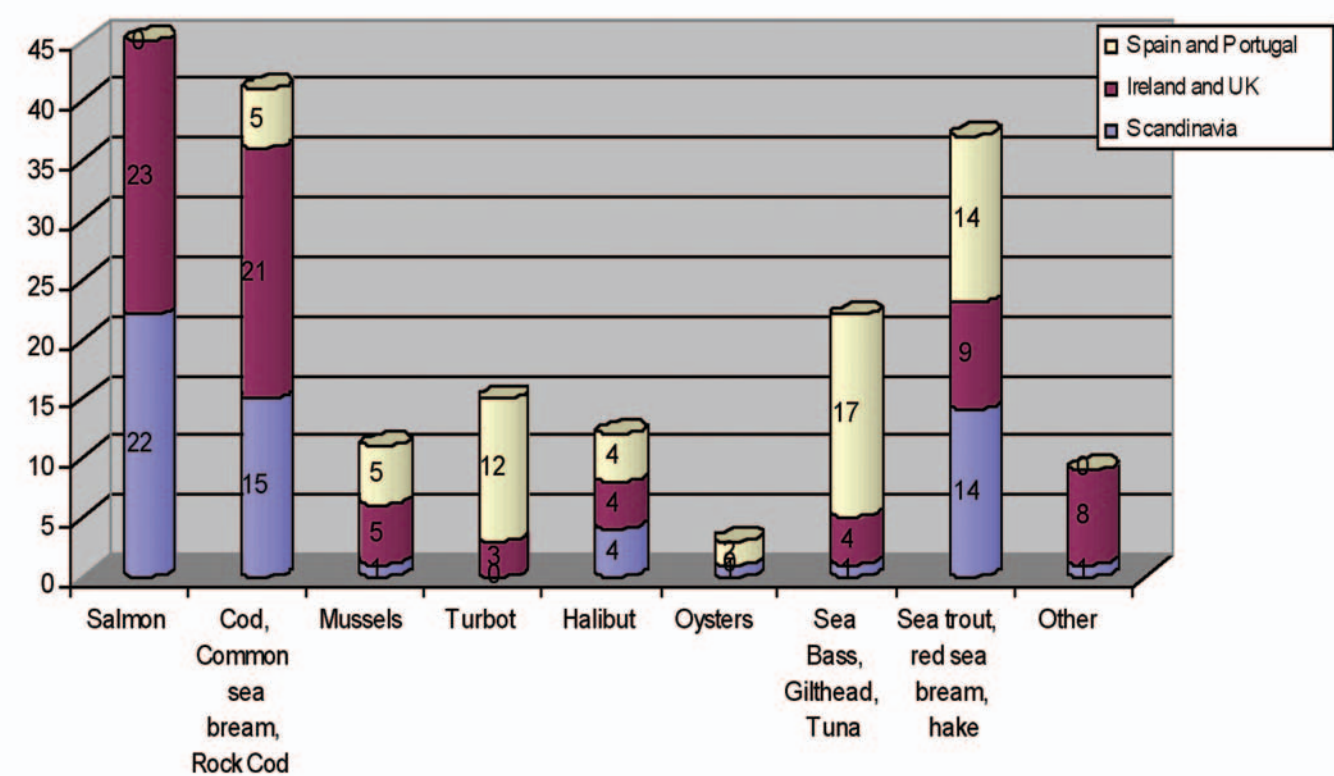


Figure 5: Potential species for culturing in offshore locations in Europe.

Regulation and Planning Frameworks

There was much confusion among participants in the OATP consultation process about whether national or regional regulatory frameworks for offshore aquaculture existed or not. Some of this may arise from the lack of clear definition as to what constitutes ‘offshore’. Does it refer, for example, to distance from shore or to exposure? It is necessary to have an agreed definition for offshore aquaculture or at least a clear understanding of what is meant by the term Offshore.

What is Offshore Aquaculture?

While there is ambiguity regarding the definition there is considerable clarity as to what is required in order to make the move to offshore.

In general Offshore Aquaculture may be defined as taking place in the open sea with significant exposure to wind and wave action where there is a requirement for equipment and servicing vessels to survive and operate in severe sea conditions from time to time. The issue of distance from the coast or from a safe harbour or shore base is often but not always a factor.

The reality is that some current commercial operators are working in ‘offshore’ locations in terms of high-energy sites and the remote nature of the sites. This is true for Atlantic salmon farming in Northern Europe, sea bream operators in continental Europe and tuna farming in the Eastern Mediterranean.

The current legislative framework that exists for aquaculture near shore will probably encompass offshore aquaculture operations also. The licensing process is unlikely to alter greatly either, but conditions of licensing will need to address the greater safety issues and monitoring requirements associated with offshore locations. The perceived problems with the regulatory framework in the offshore context echo inherent problems with the current framework closer in-shore. This includes the length of time for license processing and the lack of proactive approaches in coastal planning involving marine spatial planning (MSP) and site designation.

MSP was highlighted in the EU Maritime Policy Green Paper as a tool for development of plans for integrated coastal zone management. It is an effective tool aimed at redressing the balance between resource exploitation and environmental protection. Spatial planning relies heavily on high-level knowledge of the potential resource. This means: understanding the assimilative and dispersal capacities of potential production locations; having detailed information on the oceanographic characteristics of the location (currents,waves, etc) obtaining sufficient baseline information on environmental parameters such as temperature, oxygen, nutrients. The importance of increased knowledge of resources was highlighted by respondents as a major factor in the designation of sites for offshore aquaculture. It is important, in this context that every use is made of key national resources such as national seabed surveys, baseline state monitoring datasets as well as habitat mapping involving

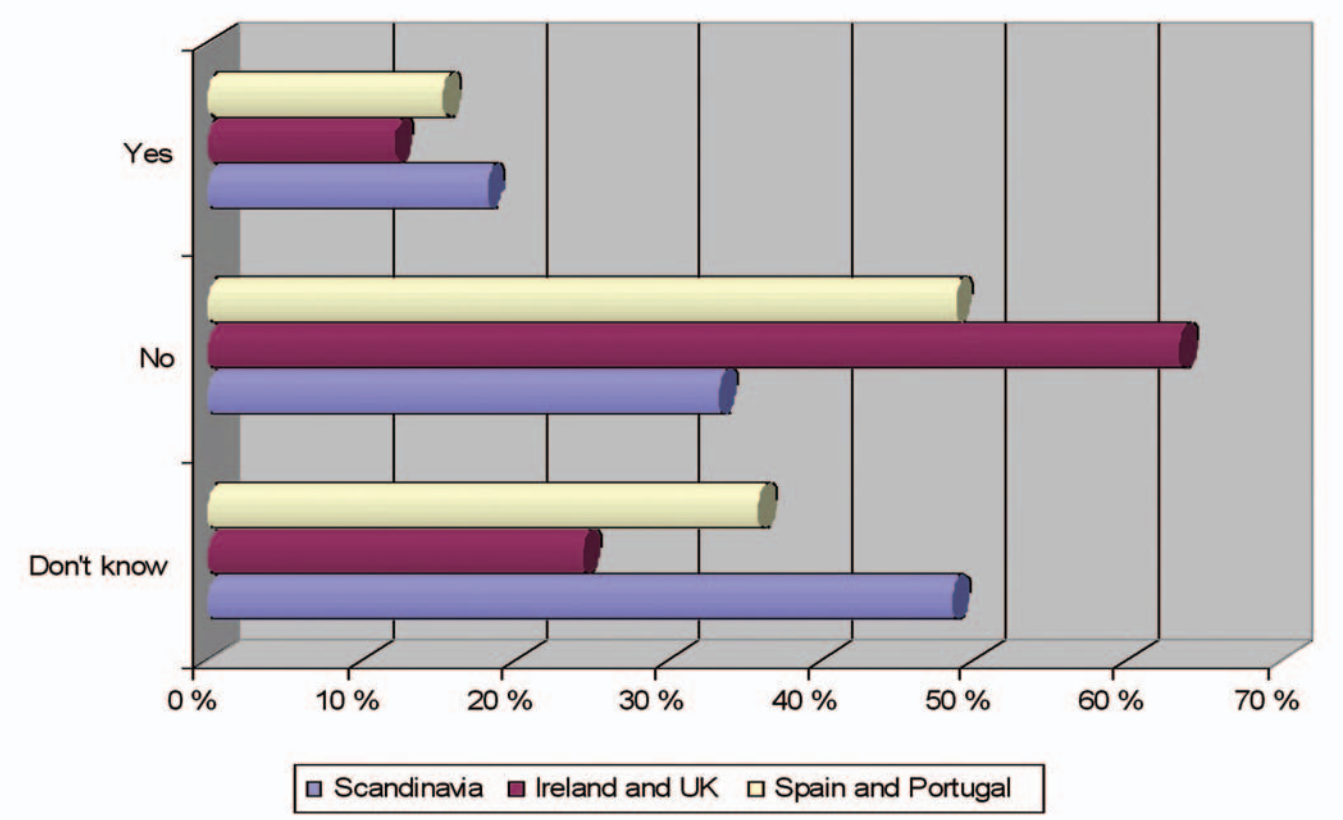


Figure 6: Thoughts of respondents on whether they thought the regulatory framework were in place to deal with offshore aquaculture.

input from traditional users of an area. The characterisation of sites in terms of acquiring oceanographic and environmental data at potential offsite locations will be an important component in providing policy makers and prospective investors with detailed information on a potential production location. Other factors critical in the MSP process are the socio-economic characteristics of the proposed regions. In many peripheral communities aquaculture is an important economic activity and as such would be considered an important “sustainability indicator” in the wider integrated coastal zone management context.

Currently public consultation in the aquaculture licensing process is dealt with through the Environmental Impact Assessment (EIA) process. Proactive approaches such as marine spatial planning will need to provide for public participation in the development of local coastal plans. This can be achieved through active participation in the collection of information (monitoring programmes, habitat mapping, etc.) through to a public forum for input into the development of the coastal plans.

This provides for a holistic approach to coastal planning, which in turn helps avoid conflict at a later stage and ensures openness and transparency in the process.

In many European countries, Atlantic Canada, and the United States, industry specific management initiatives covering defined geographic areas have been established. These provide for information exchange frameworks between producers and policy makers, provide for the development of industry codes of practice (covering fish health, sea lice control, harvesting, etc.), and provides for a description of the regions in terms of navigation and GIS based interactive databases. Most respondents believed that it is important to extend these initiatives to encompass offshore aquaculture. Many of the codes of practices covering harvesting, sea lice control, fallowing, contingency plans in the event of escapees, etc., apply equally to the offshore area. In fact the establishment of dynamic industry management frameworks could be more important when operating in more remote locations.

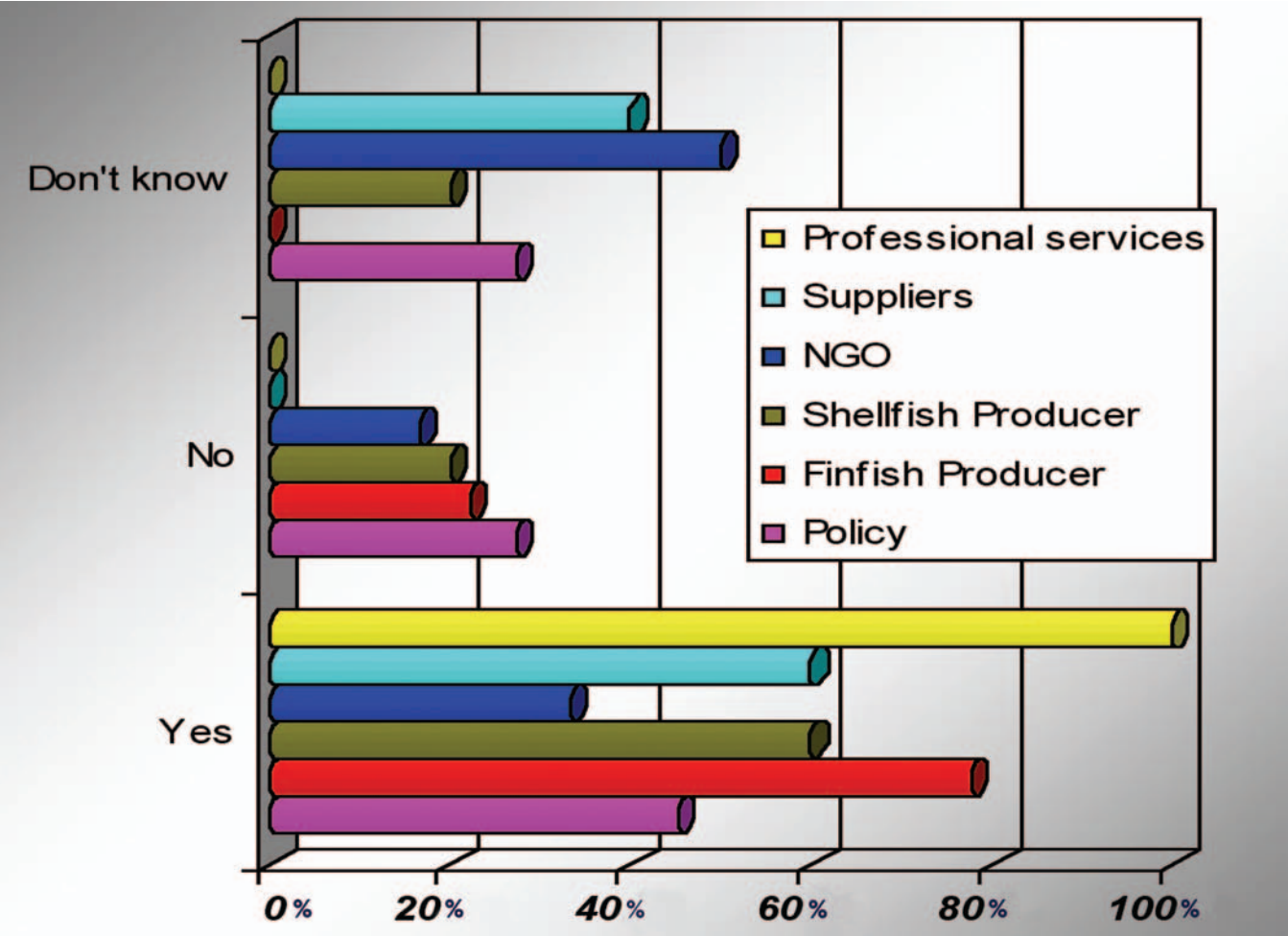


Figure 8: Opinions of the different representatives in Ireland & the UK on whether they thought Industry Management Frameworks such as Area Management Agreements should encompass offshore operators.

Safety

Safety issues are an important component in the regulation of aquaculture activities, regardless of where the activity is located. It becomes an increasing priority, however, in the offshore context both in terms of personal safety and navigational concerns. Standardisation of navigational markings is important to decrease the incidents of collision with ships and the potential escaping of farmed stock. The use of transponders on cages and updating of navigational charts are measures suggested which will help avoid unnecessary collisions. Zonation of areas for aquaculture could potentially assist with navigation. Safety inspections may be necessary for offshore

production to ensure navigation plans are adhered to and to ensure that containment equipment on site is to a satisfactory standard. With regard to personal safety, a number of initiatives including, legislation, training, equipment/technology development and service boat development will be required. The use of technology to reduce dependence on manual labour for many labour intensive activities is necessary, particularly in relation to diving activities (cleaning nets, removing fish, etc), harvesting activities (finfish & shellfish). The design of remote operating vehicles (for cleaning and inspection activities) and monitoring equipment (to monitor fish behaviour and environmental parameters) could greatly decrease the risks of injury.

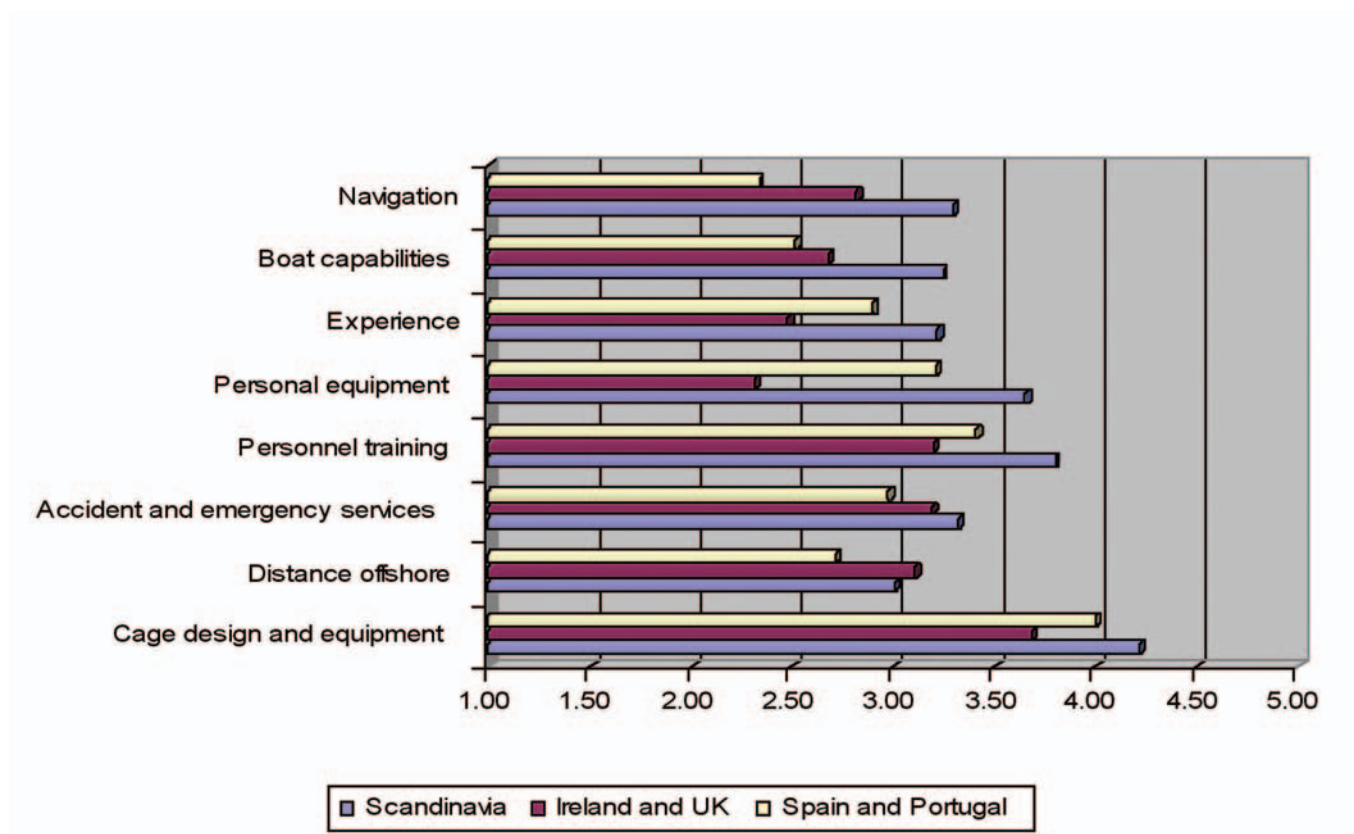


Figure 7: Important development areas to ensure safety in offshore aquaculture operations

Environmental Considerations

The greatest environmental challenges facing aquaculture currently include: sustainability issues, escapees, stock management and enrichment of inner coastal water bodies. Some of these issues are mitigated when moving offshore but other issues such as escapees and wild stock management will remain highly relevant at more exposed/offshore locations.

The sustainability issue refers largely to the source of feedstuffs for aquaculture and was highlighted by many NGO's as a particular challenge for the aquaculture industry into the future. There needs to be considerable research into alternatives to wild resources for fish oils. More investigations need to be carried out into farmed sources, additional marine resources and land sourced vegetable oil substitutes in feedstuffs for aquaculture.

The aquaculture industry in Europe is both regulated and protected by major European statutes such as the Water Framework Directive (WFD), Bathing Waters Directive and statutes covering shellfish water classification and placing on the market of shellfish species. Further inshore, the anthropogenic effect of nutrient enrichment from municipal treatment outflows and non-point source pollution may compound naturally occurring algal bloom events. This can result in economic losses to the aquaculture industry due to shellfish bay closures and mortalities in fish.

Although the WFD provides a legislative solution to improving water quality status in European waters, the sensitivities of these inner locations results in strong competition for limited resources.

It is likely that moving offshore will help mitigate many of the nutrient and bacterial contamination problems associated with inshore areas. The effects from bacterial and nutrient run off from municipal sewage will be less of a problem the further off shore you go. This doesn't mean that initiatives to prevent the effects of nutrient loading are not required. Improved surveillance techniques are needed to prevent excess nutrients hitting the sea bed through wasted feed pellets. The Marine Strategy Directive (pending) will set specific targets, like the WFD, extending clean water targets and monitoring requirements beyond the one nautical

mile limits set by the WFD. Utilising off shore locations will require greater participation by industry in monitoring programmes and there is a strong need for improved developments in remote monitoring technology. Further research into the causes and effects of both phytoplankton and zooplankton blooms is required.

With the potentially more exposed nature of offshore sites bio-security issues will need to be addressed. This can be achieved through legislation, codes of practices & international co-operation, industry management frameworks, revised monitoring, health management plans, development of containment structures and contingency plans for dealing with escapees. Many respondents were particularly concerned with interactions between wild fish and escapees from fish farms. It is true that greater exposure increases the risk of damage to cages and nets with storm events and increased wave activity. Accidental collision from ships also poses a risk to the containment of fish. License conditions must provide for the use of appropriate equipment by offshore operators and safety checks must be a part of compulsory monitoring programmes. Standardisation of navigation markers around the installations and a regime of regular safety checks were seen as key initiatives required. The use, where possible, of indigenous stock should be promoted to minimise the impact of escapees on indigenous wild stocks in sensitive areas. Research into fish sterilisation techniques and hatchery techniques is necessary to provide alternative sources or fish for stocking purposes. Identifying the technology infrastructure gaps is important to alleviate potential escape events, which occur as a result of fish behaviour, weather conditions or operational procedures on farms.

Animal Health and fish disease, this was highlighted as another important research area in the consultation exercise. Many initiatives have been taken by the EU Commission on the legislative front to combat disease spread between trading nations and to maintain good disease free status in European countries. Monitoring programmes covering fish health, biotoxins, shellfish water classifications and bathing waters are well established and legislated for in EU countries and internationally. Similarly there has been much international co-operation in the development of codes of best practice to help combat important diseases such as Pancreas Disease and Infectious Salmon

Anemia. Area Management Agreements and similar management frameworks adopt these guidelines and promote important practices like, biosecurity zones, fallowing, single-generation stocking and early harvesting of fish. These are recognised practices in the prevention and control of diseases.

The majority of respondents felt that these management frameworks should be extended to encompass offshore locations.

Figure 9 below highlights the concerns of the stakeholders in relation to environmental effects and offshore aquaculture.

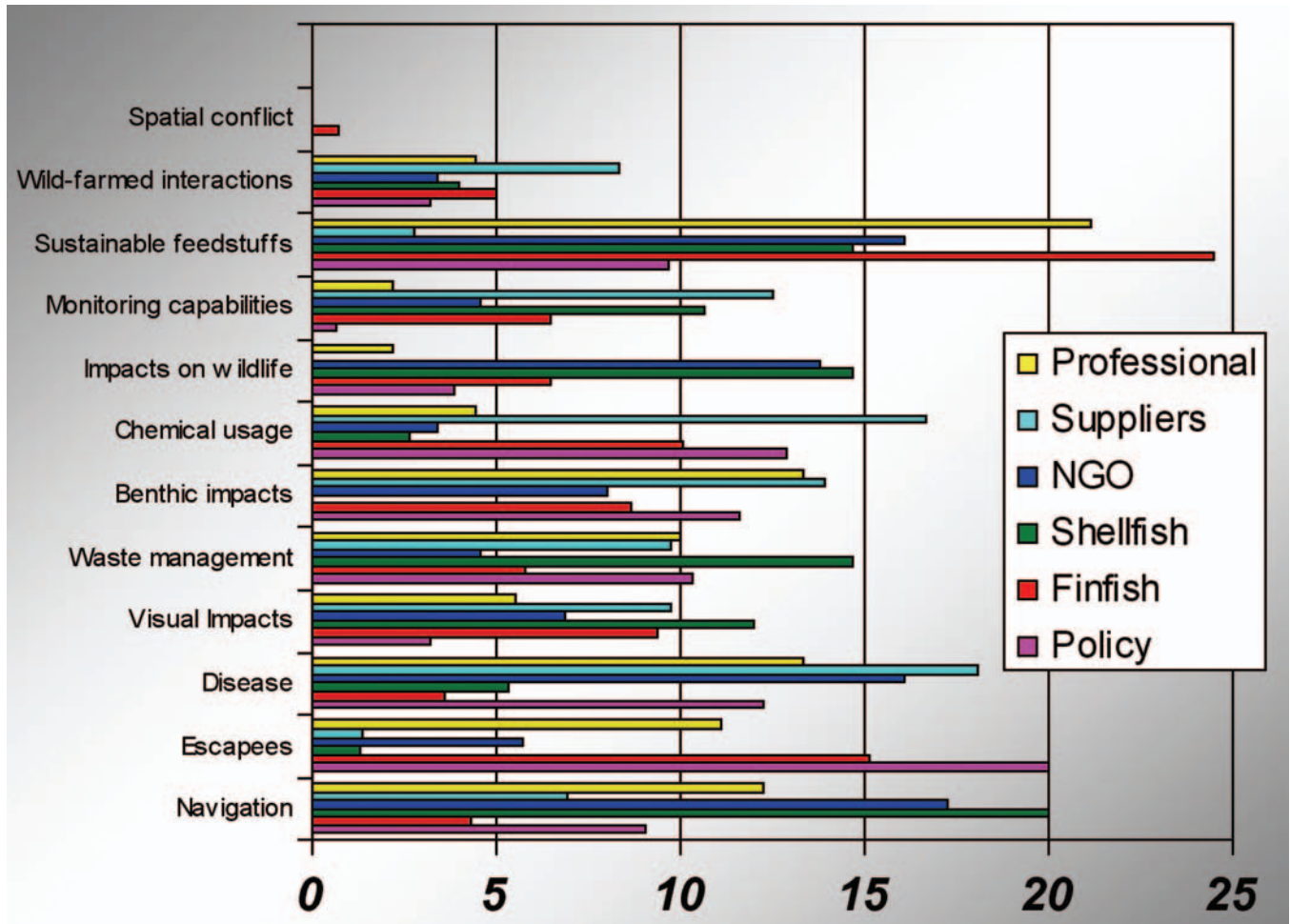


Figure 9: Views of different participant groups on the major impacts of aquaculture on the marine environment.



Servicing offshore sites

A document recently published by the IUCN in collaboration with the Spanish Ministry for Agriculture, Fisheries and Food and the FEAP, entitled “Guide for the Sustainable Development of Mediterranean Aquaculture - Interactions between Aquaculture and the Environment”, made the following recommendations on environmental protection:

- Greater progress should be made in the domestication of species.
- Prevention of escape events and management should be improved to minimising potential impact.
- Native species should be cultured wherever feasible, following the recommendations of organisations such as the IUCN itself or the ICES in the case of the culturing of alien species¹.
- Research (on the closing of life cycles, the functioning of the ecosystem, etc.) should be encouraged in order to guarantee that aquaculture should not endanger either the stock of wild populations (e.g. bluefin tuna) or biodiversity in general.
- Guidelines are put forward (with particular reference to coastal production systems) to reduce or eliminate the negative impact associated with the organic content of effluents from aquaculture farms. In the case of offshore cages, the dispersion of this organic content is generally higher and therefore the impact occurring, although it cannot be ignored, is, under normal conditions, potentially lower.
- The production of aquafeeds should be a sustainable activity, diversifying the sourcing of raw materials for formulated feeds and encouraging the development of aquaculture as an integrated activity.
- Strategies should be developed to minimise the transfer of pathogens between farmed species and wild stock populations in both directions.
- Strategies should be developed to ensure the correct management of the use of antibiotics and to minimise possible detrimental effects on the natural environment.

- Eco-friendly antifouling coatings and products should be developed.
- Strategies should be developed to ensure the thorough analysis of possible impacts on the flora and fauna of the areas where aquaculture facilities are to be deployed (in this regard, offshore aquaculture normally has less impact than other kinds of systems).

Technology

A central theme running through all the discussion groups during the stakeholder consultation phase of this project was that of improving our knowledge of our coastal resources. From a technology perspective this involves the development of improved remote sensing and transmission of results in real time. From the planning perspective it involves utilising current datasets, predictive modelling capabilities, application of habitat mapping and seabed surveys and finally the incorporation into GIS for use in spatial planning. The ultimate goal is to select, using the best available tools, for appropriate resource utilisation to ensure activities co-exist and operate in a sustainable manner.

For development of offshore aquaculture, many characteristics of a site could be obtained from national datasets relating to seabed mapping and national monitoring programmes. Once applied, these datasets can give valuable information on a specific location, including: bathymetry information; sediment type; substrate type (for anchoring); wave/current information; carrying/assimilative capacity; and various environmental parameters relating to the water column.

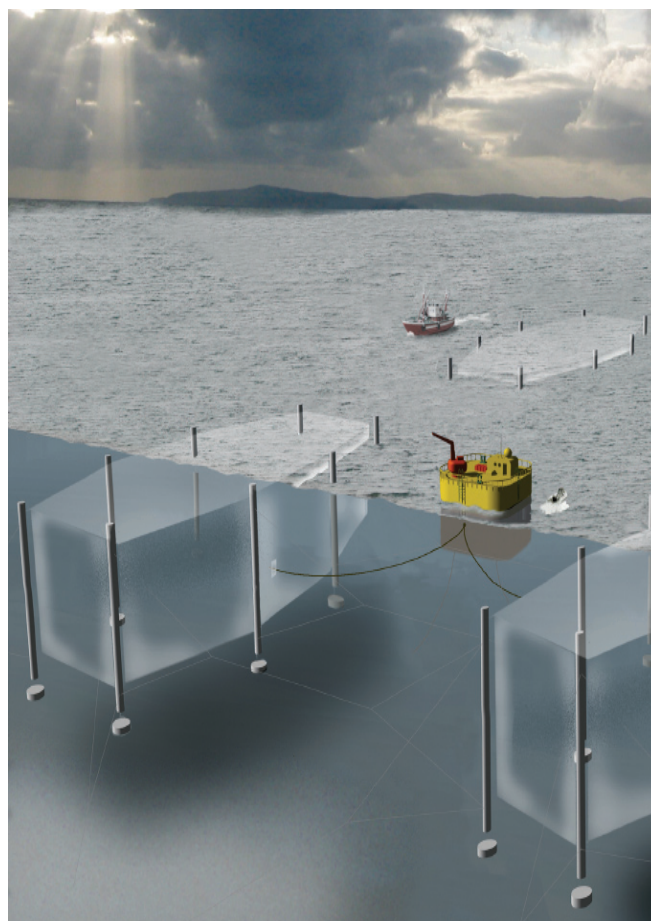
It is important therefore, that methodologies are developed that show how thematic information can be extracted from these datasets for application to the offshore aquaculture industry. Research into methods for characterising offshore sites in terms of the exposed nature is fundamental in order to test the best available technology in-situ.

One of the most fundamental areas where development is needed is in the actual containment systems for aquaculture species. This refers to a suite of structures which house the cultured species at sea such as cages, rafts, barrels, nets, ropes, anchors and buoys. Working in more exposed conditions results in greater stresses on the physical

structures at sea. New innovative designs for fish cages and shellfish structures are required to help against economic losses and environmental concerns associated with escapees. Navigation and warning systems must be developed as well as an integrated navigational plan involving port authorities and seafarers.

Cage types and designs will also vary depending on the species and the stage of development of the fish. Larger species like Tuna, for example, require larger volumes and pose a greater challenge in terms of handling. Behavioural aspects of the fish also dictate the net structures and farm operating/handling procedures. At offshore sites with greater depth and possibly larger cages special anchoring designs are required. Design and development of suitable anchoring patterns is important for a number of reasons. The most important requirement is that they are sufficient to retain the structures in place but also that systems are in place to allow for moving/changing of cage/barrels, to allow workboats access around cages and not to interfere with the cage area containing the fish. Obviously, greater exposure will result in greater loads on these systems. Larger boats will be required to access these sites so R&D is not only required for the containment systems themselves but also necessary in development of new vessels specially designed for fish farming in rough conditions at exposed sites. More intelligent automatic feeding systems will be an essential piece of equipment at offshore sites. There is room for improvements in all feed related operations, from delivery of feed, storage, dosing, pumping as well as the technology infrastructure to allow for a reliable and precise remote operation. Other important equipment areas in need of development include fish handling and operational equipment. Routine operations on site involve grading, treating, harvesting and sampling of fish. Improved automated techniques for handling fish in these situations is required to reduce escapes, make more efficient use of suitable weather conditions and to transfer fish from larger cages used in offshore locations. Particularly this requires development of fish pumping equipment, grading systems and sub-sampling equipment.

Monitoring equipment and communication systems are another area that will require further development and application to offshore aquaculture. Currently, there has been much innovation in automated systems by the aquaculture industry, including



Concept for offshore farm



Mussel longlines

automated fish feeding systems and stock monitoring equipment. Reduced access to offshore locations makes these systems a necessity in the day-to-day management of offshore sites. Remote access to feeding systems allows immediate manipulation of feeding regimes to individual cages and allow for intervention in the case of damage or loss of appetite of the fish. This has both health

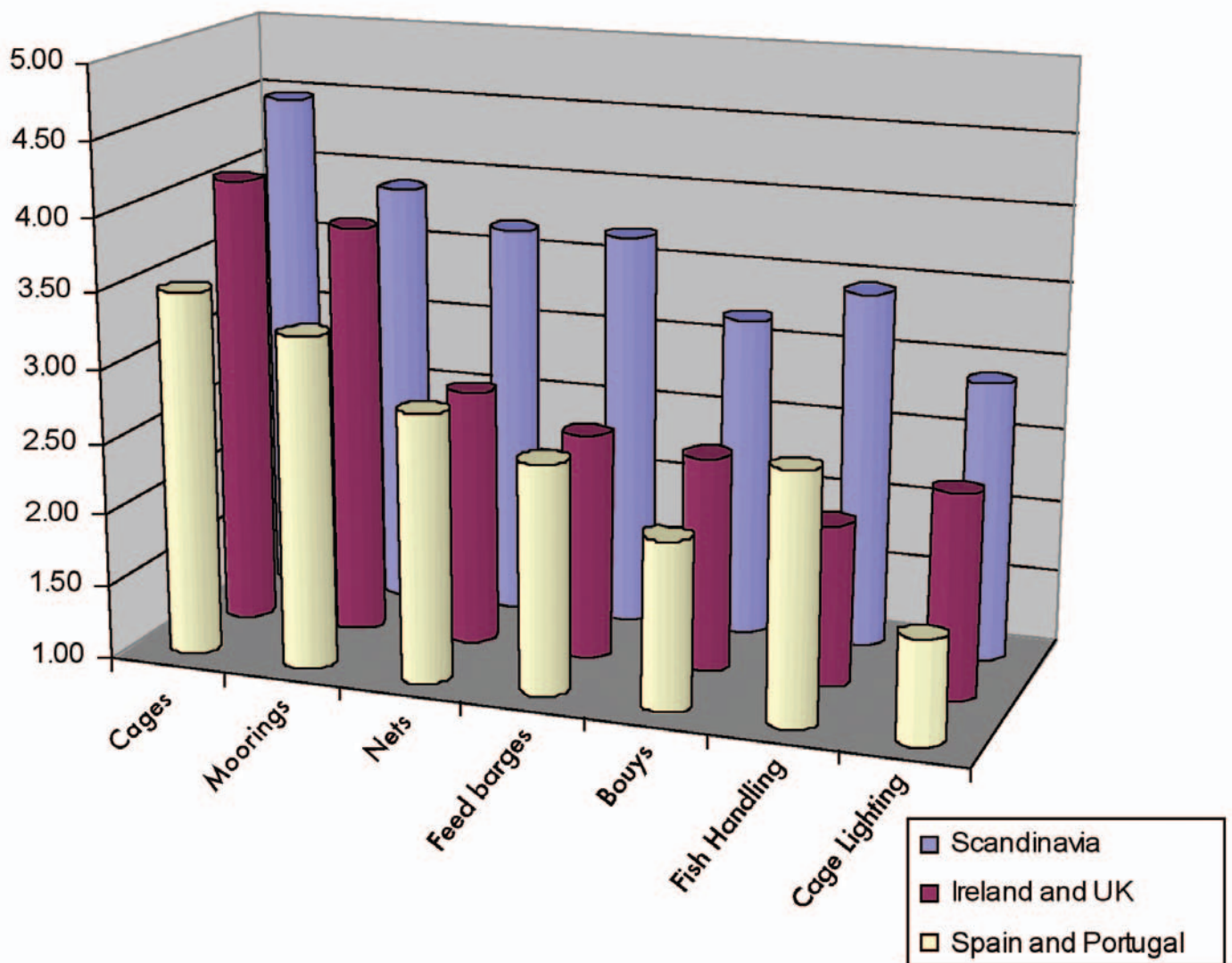


Figure 10: Aspects of the physical infrastructure, which most requires development, in the opinion of participants from the OATP regions.

and environmental implications for the site, ensuring that during times of stress, waste feed doesn't contribute to organic loading of the benthos. Video cameras and sensors, which shut off feed supply at critical levels, contribute to an integrated feed management system improving feed conversion ratios or FCR's and environmental management of the site. Development of integrated environmental monitoring equipment is also crucial. From a farm management perspective, real-time access to temperature and oxygen data is important. Many parameters are also required as part of national monitoring programmes. As such, it is

important that monitoring at offshore locations occur as part of an integrated monitoring programme for the region, with the offshore structures acting as a platform for monitoring equipment where possible. Considerable R&D into the monitoring and identification of causes and effects of marine events (such as phytoplankton blooms) is required. The graphic (Figure 11) highlights the variety of technology development requirement for offshore aquaculture production. The fact that none of the technology areas listed below particularly stands out, emphasises the fact that there are development requirements in each area.

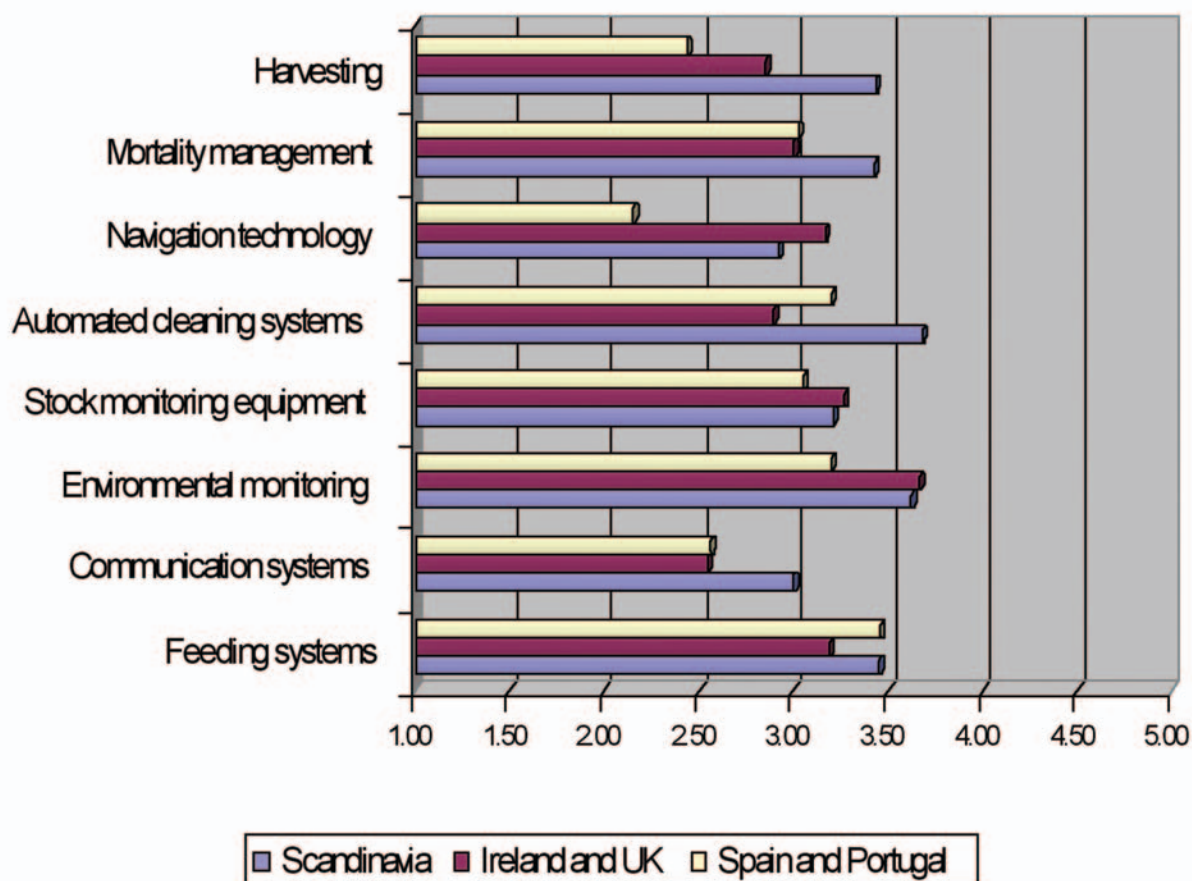


Figure 11: The important equipment and technology systems, which need development for operating in offshore locations

Recommendations

Ethical Issues

Offshore aquaculture can go a long way towards meeting increased global seafood consumption demands, particularly in light of the fact that future output from capture fisheries is predicted to remain stagnant at best.

Further research into alternatives to fish oils in fish feed for aquaculture is required. Replacing fish oil with vegetable extracts promotes the protection of wild fish resources and promotes sustainability. Animal welfare issues must continue to be addressed through stocking standards, fish health protocols and improved monitoring capabilities for offshore areas.

Overall the greatest area where public confidence needs to be improved, according to respondents, was in the area of environmental impacts. It is widely accepted that moving offshore could help mitigate many of the environmental impacts associated with aquaculture.

Conversely, the health benefits of eating seafood products needs to be highlighted as a means to improve the public image of the industry.

Bio-security issues, such as farmed-wild interactions, are even more relevant in the offshore scenario. Industry will need to work closely with fish health specialists and equipment designers to ensure that every effort is made to develop codes of practice on containment and biosecurity, which promote the protection of wild fish species.

Potential Species

There is a need for increased R&D into novel species for culturing in offshore regions. Priority species include sea urchins, pollack, tuna, cod, hake, halibut, sea-bream and sea-bass. Research into improved on-growing techniques is necessary, particularly the adaptation of inshore culture to offshore locations.

Detailed knowledge on hatchery design and techniques is vital and knowledge transfer between European areas of expertise should promote best practice in rearing and ongrowing in order to ensure an adequate supply of suitable quality juveniles.

The potential for polyculture should be researched and this could lead to the sharing of space and resources. This will have obvious cost cutting benefits for industry and the positive environmental benefits should be investigated and promoted.

A major challenge is the transfer of knowledge on the technology side between finfish and shellfish producers, inter-regionally and between other users of offshore sites (such as the wind energy industry and oil industries).

Regulation & Planning

Offshore aquaculture needs to be properly defined in terms of exposure or distance offshore. This is necessary in the context of regulation, planning and development requirements for an Offshore Aquaculture industry.

The current legislative framework that exists for aquaculture near shore will probably encompass offshore aquaculture operations also.

The perceived problems with the regulatory framework in the offshore context really echo inherent problems with the current framework closer in-shore. This includes the length of time for license processing and the lack of proactive approaches in coastal planning involving marine spatial planning (MSP) and site designation.

MSP was highlighted in the EU Maritime Policy Green Paper as a tool for delivering integrated coastal zone management. Improving the knowledge gap on potential resources is an important factor in the process of designating sites for offshore aquaculture. It is important, in this context that use is made of key national resources such as national seabed surveys, baseline state monitoring datasets as well as habitat mapping involving input from traditional users of an area.

The characterisation of sites in terms of acquiring oceanographic and environmental data at po-

tential offsite locations will be an important component in providing policy makers and prospective investors with detailed information on a particular location.

The principles/components of current area management agreements (aquaculture management initiatives) should be extended to encompass offshore aquaculture with the purpose of developing codes of practice for the industry and to ensure good environmental practice.

Safety

The personal training of site staff is an important factor in safety for the offshore aquaculture industry. Accident & emergency concerns increase the more you move offshore in terms of exposure and response time to emergencies.

Navigational planning needs to be a fundamental part of the licensing process, to provide for the increased potential of collisions in the offshore scenario.

Environmental considerations

The greatest environmental challenges facing aquaculture currently include: sustainability issues; escapes; stock management; and enrichment of inner coastal water bodies.

There is a requirement for considerable research into alternatives to wild fish resources for fish oils in aquaculture feed. More investigations need to be carried out into farmed sources, additional marine resources and land sourced vegetable oil substitutes in feedstuffs.

Improved surveillance techniques are needed to prevent excess nutrients hitting the seabed through wasted feed pellets.

The Marine Strategy Directive (pending) will set specific targets extending clean water targets and monitoring requirements beyond the one nautical mile limits set by the WFD. Utilising offshore locations will require greater participation by industry in monitoring programmes and there is a strong need for improved developments in remote monitoring technology.

Further research into the causes and effects of both phytoplankton and zooplankton blooms is required.

With the potentially more exposed nature of offshore sites, bio-security issues will need to be addressed.

This can be achieved through: legislation; codes of practice & international co-operation; industry management frameworks; revised monitoring; health management plans; development of containment structures; and contingency plans for dealing with escapees.

License conditions must provide for the use of appropriate equipment by offshore operators and safety checks must be a part of compulsory monitoring programmes.

Navigation markers around the installations should be standardised and also be part of regular safety checks.

The use, where possible, of indigenous stock should be promoted to minimise the impact of escapees on indigenous wild stocks.

Research into fish sterilisation techniques and hatchery techniques is necessary to provide alternative sources or fish for stocking purposes.

Identifying the technology infrastructure gaps is important to alleviate potential escape events, which occur as a result of fish behaviour, climatic conditions or operational procedures on farms.

Improved R&D into causes and effects of fish diseases is required and recommendations should feed into policy, industry codes of practice and farm management practices.

“Guide for the Sustainable Development of Mediterranean Aquaculture - Interactions between Aquaculture and the Environment”, made the following recommendations on environmental protection:

- Greater progress should be made in the domestication of species.
- Escapement prevention and management should be improved with a view to minimising potential impact.
- Native species should be cultured wherever feasible, following the recommendations of organisations such as the IUCN itself or the ICES in the case of the culturing of alien species¹.
- Research (on the closing of life-cycles, the functioning of the ecosystem, etc.) should be encouraged in order to guarantee that aquaculture should not endanger either the stock of wild populations (e.g. bluefin tuna) or biodiversity in general.
- Guidelines are put forward (with particular reference to coastal production systems) to reduce or eliminate the negative impact associated with the organic content of effluents from aquaculture farms. In the case of offshore cages, the dispersion of this organic content is generally higher and therefore the impact occurring, although it cannot be ignored, is, under normal conditions, potentially lower.
- The production of aquafeeds should be a sustainable activity, diversifying the sourcing of raw materials for formulated feeds and encouraging the development of aquaculture as an integrated activity.
- Strategies should be developed to minimise the transfer of pathogens between farmed species and wild stock populations in both directions.
- Strategies should be developed to ensure the correct management of the use of antibiotics and to minimise possible detrimental effects on the natural environment.
- Eco-friendly antifouling coatings and products should be developed.
- Strategies should be developed to ensure the thorough analysis of possible impacts on the flora and fauna of the areas where aquaculture facilities are to be deployed (in this regard, offshore aquaculture normally has less impact than other kinds of systems).

Technology

A central theme running through all the discussion groups during the stakeholder consultation phase of this project was that of improving our knowledge of our coastal resources. From a technology perspective this involves the development of improved remote sensing and transmission of results in real time.

From the planning perspective it involves utilising current datasets, predictive modelling capabilities, application of habitat mapping and seabed surveys and finally the incorporation into GIS for use in spatial planning.

The ultimate goal is to select, using the best available tools, for appropriate resource utilisation to ensure activities co-exist and operate in a sustainable manner.

Research into methods for characterising offshore sites in terms of the exposed nature is fundamental in order to test the best available technology in-situ. Characteristics of a site could be obtained from national datasets from seabed mapping programmes and national monitoring programmes.

It is important that methodologies are developed that show how thematic information can be extracted from national datasets (such as seabed survey information and core national datasets) for application to the offshore aquaculture industry.

One of the most fundamental areas where development is needed is in the actual containment systems for aquaculture species. This refers to a suite of structures which house the cultured species at sea such as cages, rafts, barrels, nets, ropes, anchors and buoys.

New innovative designs for fish cages and shellfish structures are required to help against economic losses and environmental concerns associated with escapees.

Navigation and warning systems must be developed as well as an integrated navigational plan, involving port authorities and seafarers.

R&D is not only required for the containment systems themselves, but also necessary in designing

birthing areas for vessels and work platforms to provide for access to the fish.

Development of automated feeding systems both from the point of view of the barges and pumping systems as well as the technology infrastructure to allow remote operation is a key requirement. Other important equipment areas in need of development include fish handling and operational equipment.

Improved automated techniques for handling fish in these situations is required to reduce escapes, make more efficient use of suitable weather conditions and to transfer fish from larger cages used in offshore locations. Particularly this requires development of fish pumping equipment, grading systems and sub-sampling equipment.

Monitoring equipment and communication systems require further development and application to offshore aquaculture. Currently, there has been much innovation in automated systems by the aquaculture industry including automated fish feeding systems and stock monitoring equipment. Video cameras and sensors, which shut off feed supply at critical levels, contribute to an integrated feed management system improving FCR's and environmental management of the site. From a farm management perspective, a real-time capability for access to temperature and oxygen data is important.

It is important that monitoring at offshore locations occur as part of an integrated monitoring programme for the region, with the offshore structures acting as a platform for monitoring equipment where possible.

Considerable R&D into the monitoring and identification of causes and effects of marine events (such as phytoplankton blooms) is required.

Sector Overview

Current marine cage aquaculture

Norway's development of salmon farming in the 1970's pioneered the commercial marine farming of aquatic organisms in caged enclosures. So this development can be considered relatively new. Since then the technology has developed and spread to many nations across the globe.



Africa

While Egypt is one of the most productive countries in terms of aquaculture in Africa it is almost entirely from fresh water production. Libya Arab Jamahiriya has had various marine cage experiments undertaken since the 1990's. A number of open sea cages are currently in use producing European seabass and gilthead seabream. The official production for seabass and seabream in 2004 was 170 and 61 tonnes respectively. In Tunisia the cage production of seabass and seabream in 2004 accounted for 14 percent of the whole national production for these species (678 tonnes of seabream and 466 tonnes of seabass). The production of Atlantic bluefin tuna has also expanded in recent years. In 2004 Morocco's cage production of seabass and seabream was approximately 720 tonnes divided equally between the species. Cage production accounted for 42% of the total production of 1,718 tonnes. Spain is the main export market for these species.

While there is potential for marine and brackish cage culture in sub-Saharan Africa as yet there has been no sustained commercial development of this sector (Blow and Leonard 2007).



Asia

While it is estimated that over 95 percent of marine finfish farming in Asia is in cages, offshore aquaculture is not common. It is also suggested that "the large-scale, capital-intensive, vertically integrated marine cage-farming practices seen in northern Europe (e.g. Norway) and South America (e.g. Chile) are unlikely to occur in Asia. Instead of large-scale farms, clusters of small farms generating synergies, acting in unison and thereby attaining a high level of efficacy are likely

to be the norm, well into the foreseeable future. Offshore cage farming is unlikely to become widespread in Asia, as its development is likely to be hampered by availability of capital and the hydrography of the surrounding seas, which does not allow for the technology available elsewhere to be easily transferred" (De Silva 2007). Marine cage culture in Asia is small scale and carried out in the inshore area. Due to the shallowness and surface and bottom currents experienced in the South China Sea a different cage technology to what is currently employed in Norway, Ireland and Chile would be required.

The number of traditional marine fish cages in China in 2004 was estimated to be in the region of 1 million (Guan and Wang 2005). However, the majority of these are small structures measuring 3 x 3 m to 5 x 5 m. They are often constructed from locally available materials such as bamboo, timber or steel pipes which could not withstand significant winds or waves and are therefore sited in sheltered inshore sites. Most inshore sites have now reached capacity and if the expected increase in farmed marine fish output is to increase to 1 million tonnes (Wang 2000) then the only option left available is to move offshore.

During the 1990s local governments initiated projects looking at offshore cages. Cages were imported from Norway, Japan, Denmark and the US. In 2007, Chen *et al* reported that there were about six models of offshore cages being manufactured by local companies and research institutes. More than 3,000 sets of offshore cages were being installed along the coastal provinces. The Central government and provincial authorities are strongly supporting the development of offshore aquaculture through the funding of R&D projects and the purchase of offshore cages (Chen et al, 2007).



Australia

Aquaculture is the fastest growing primary industry in Australia. It is almost entirely a regional industry and is a key growth area for regional employment. Imports from China, Vietnam and Thailand and the strengthening of the Australian dollar have recently put the Australian industry under pressure. In 2005-06, aquaculture production rose by 16 per cent (7500 tonnes) to 54,076 tonnes of

which finfish production account for 32,812 tonnes (ABARE, Australian Fisheries Statistics, 2006.) More than 95 percent of Australian aquaculture production is from marine waters. Marine production for the most part focuses on four species, Atlantic salmon (*Salmo salar*), Southern bluefin tuna (*Thunnus maccoyii*), Barramundi (*Lates calcarifer*) and Yellowtail kingfish (*Seriola lalandi*). Over the decade to 2006-07, aquaculture production almost doubled from 29,300 tonnes to 57,800 tonnes. Although there were 19 licences for marine production of rainbow trout (*Oncorhynchus mykiss*) in 2006, the Atlantic salmon makes up the bulk of salmonid cage culture. Salmon and trout production, together accounted for 44 per cent of total aquaculture production in 2006-07. There were 44 licensed marine cage producers in 2006, which have sites in Tasmania and South Australia. In 2006-07, aquaculture farmed salmon from Tasmania emerged as Australia's most valuable single species fishery, overtaking Western Australia's rock lobster fishery, "This follows four years of rapid growth, during which the value of Tasmania's farmed salmon more than doubled. Based on preliminary estimates, over 23,600 tonnes of Atlantic salmon was produced in 2006-07, worth an estimated AU\$272 million," (ABARE 2008). Other major aquaculture species in Australia include southern bluefin tuna (17 per cent of value in 2006-07), pearls (15 per cent), oysters (11 per cent) and prawns (6 per cent)(Newton 2008).

In 2004 there were only 3 marine cage sites producing barramundi, this has since risen to 6 licences in 2006, all in the Northern Territory. There are also 37 licences for marine cage production of Yellowtail kingfish (ABARE, Australian Fisheries Statistics, 2006.). This is only a recent development and has arisen due to the need for the Bluefin tuna operators to diversify.

The Southern bluefin tuna are caught under a quota system. The caught fish are transferred into 'towing cages', which can measure from 30 to 50 meters diameter. In 2005 there were fifteen tuna farms on eighteen sites. In 2006, 35 licences accounted for the production of 8,806 tonne of tuna.

Because of Australia's traditional links with the United Kingdom and Europe most of the cage system technology is similar to those used in these regions.

There is a need to address the public concerns regarding cage aquaculture in Australia if there is to be significant development in offshore aquaculture. However, the recent 'Sustainable Aquaculture: Australian Aquaculture Industry Development Strategy', targets the Development of Offshore Aquaculture. It has recommended a feasibility study of offshore production systems for Australian conditions and an assessment of what is required at both State and Federal level to support its development.



Surrounded by the Arctic, Atlantic and Pacific Oceans and home to the Great Lakes, Canada boasts the world's longest coastline (244,000 km), representing 25 per cent of the entire coastline in the world. With more than 755,000 square kilometres of fresh water, Canada has 16 per cent of the world's area of fresh water and four of the largest lakes in the world. (Agriculture and Agri-food Canada).

Salmon aquaculture is now a major industry in Canada, operating year round and creating wealth and jobs in coastal communities. Salmon farming is one of New Brunswick's largest food industries while farmed salmon has become British Columbia's most significant agricultural export.

After two years of successive decline in 2003 and 2004, the value of the total Canadian farmed-raised production of finfish and shellfish now shows signs of recovery. Total aquaculture production in 2005 reached 153,995 tonnes, up more than 6% from the year earlier reflecting a moderate increase in total finfish output. Salmon production rose to 98,441 tonnes, 2% above 96,774 tonnes a year earlier. Farm-raised shellfish production during 2005 reached 38,195 tonnes, up 1% from 37,925 tonnes tons during 2004.

Canadian aquaculture production is dominated by the production of farmed-raised salmon, mussels and oysters, which combined, accounted for 87% of total farmed-raised production in 2005. On a regional basis, British Columbia, New Brunswick and Prince Edward Island accounted for 48%, 24%, and 12% respectively of total farmed-raised output.

Despite many innovative concepts in marine cages the vast majority of cages employed in Canada can be classed as “gravity” type cages generally constructed of steel or high-density polyethylene (HDPE). These cages have proved suitable for the intricate Canadian coastline of bays, inlets and fjords. The use of increased technological development has enabled the Canadian producers to increase the scale of their operations. However, the industry trend in both Canada and the US is for expansion to more exposed open ocean conditions where they experience fewer human conflicts. Near shore technologies and operational management cannot simply be transferred to these new high-energy environments (Masser 2007).

Currently, Canada is leading the way in North America in expansion of commercial cage aquaculture and in developing policies, regulations and public perceptions that accept and promote the future growth and sustainability of its industry (Masser 2007). With its extensive coastline given an appropriate regulatory policy framework coupled with increased environmental stewardship and consumer confidence, conservative projections for anticipated growth expects an increase in aquaculture products value from Can\$0.5 billion in 2000 to Can\$ 2.8 billion by 2010 – 2015 (OCAD 2003).



Chile

The world's second largest supplier of farmed Atlantic salmon (*Salmo salar*), Chile is estimated to have suffered a decreased in production of 2.7% in 2007 (down to 358,900t), compared to 368,700t in 2006) This decline is mainly a result of the severe impact of the Infectious Salmon Anaemia (ISA) fish disease that continues to plague the Chilean industry. Due to this situation some experts predict a further drop of 8% in 2008.

Most salmon development in Chile has occurred in relatively sheltered inshore waters, and therefore, there is a high proportion of metal cages in use. This may change as the industry may look to move to more exposed sites.

However, Chile is now officially recognized as positive for the ISA virus. In February 2008 there were 19 sites impacted – 13 of which belonging to Marine Harvest; 4 to Mainstream, 1 to Aqua Chile

(Chile's number 1 salmon producer) and 1 to Aguas Claras (owned by AquaChile). The list of ‘suspected’ cases is 17 with an expected increase (Seafood-intelligence.com, March 2008). The situation has led to a significant downsizing of its salmon production operations. As a consequence of this situation it is unlikely that the Chilean industry will look to move offshore in the near future.



Croatia

Research into new technologies for the culture of European seabass (*Dicentrarchus labrax*) and gilt-head seabream (*Sparus aurata*) began at the end of the nineteenth century and the beginning of the twentieth century. In the late 1960s, state-owned institutes started research projects to develop these highly profitable marine species; as a result, several new commercial companies were founded, setting up production of fish fry and ongrowing them to commercial size in floating cage farms. Since that time, a major innovation has been the ability to control spawning of seabass and seabream (FAO Fisheries and Aquaculture Department). Croatia produced 1,600 tonnes of farmed Seabass and 1,000 tonnes of farmed Seabream in 2005.

The rearing (fattening) of bluefin tuna (*Thunnus thynnus*) only began recently in Croatia and is still growing. The cages in this rearing process are large structures usually 30 to 50 m in circumference, although sometimes up to 150 m, with a fish density of 2-4 kg/m³.

Croatia has huge potential for aquaculture thanks to its 5,800km long coastline and its 1,100 islands. Its objective is to produce annually some 10,000 tonnes by 2015 (Monfort, FAO 2007).



Cyprus

The main type of aquaculture carried out in Cyprus is marine aquaculture and the outlook for its expansion is positive. In 2004, the total aquaculture production reached 3,174 tonnes, comprising mainly of 1,863 tons seabream and seabass and 1,242 tonnes bluefin tuna. Mariculture is currently carried out exclusively on the southern coasts of the country and the culture method utilized is open sea cage culture. In 2004 the main marine species commercially cultured were the gilthead seabream

(*Sparus aurata*), European seabass (*Dicentrarchus labrax*), and Northern bluefin tuna (*Thunnus thynnus thynnus*). In the framework of diversification of aquaculture, a license for the culture/fattening of bluefin tuna was given in 2004.

The on-growing units in marine fish production operate on an intensive basis, using offshore cages. In 2004 there were 6 commercial offshore cage farms in operation. These units have licences from the Department of Fisheries and Marine Research for production that ranges from 120 – 300 tonnes/year/unit. The production units are located at a distance of 1-3 kilometres from the shore at water depths ranging from 20-45 metres and 3 kilometres apart. The strong competition for using coastal land and sea areas is the main reason for adopting this culture method but also the fact that this system is considered to have the least impact on the environment and provide the best possible conditions for the fish in terms of animal welfare. The lack of closed bays and the open sea conditions, characterized mainly by strong currents and great depth, contribute to better dispersion of the released nutrients that are produced during grow-out activities. The impact is limited to the bottom below the cages and to a lesser extent up to 50-100 metres from the farms. Almost all existing types of open sea cages are used by the private sector and the farms are gradually employing mechanized systems for feeding and harvesting. They are also adopting new cage technology in an effort to cut down production costs and become more efficient and competitive nationally and internationally. Being a predominantly tourist destination, Cyprus is very conscious of all environmental issues. Thus, the State policy has focused on a gradual development (precautionary approach) of aquaculture and the use of open sea cage farming technology.

Source: (Aquaculture Annual Report. 2004 . Department of Fisheries and Marine Research, Republic of Cyprus).



France

Marine fish production in France is well distributed among the different regions. Seabass and seabream are reared close to the North Sea (utilising heated water from a nuclear power plant), along the Atlantic coast and in the Mediterranean (Côte

d'Azur and Corsica). The Atlantic coast has seen the establishment of turbot farms and salmon farming is found mainly in Normandie and the Bretagne regions. European seabass (*Dicentrarchus labrax*), gilthead seabream (*Sparus aurata*) and turbot (*Psetta maxima*) dominate the marine aquaculture sector in France. Today the best potential for development of Mediterranean species exists in Eastern "PACA" (Provence Alpes Côtes d'Azur) and Corsica but these regions are also subject to strong pressures from the tourism sector. In addition to this competition for space, production capacity for marine finfish continues to increase in the countries of the Eastern Mediterranean, causing a levelling out of the price on European wholesale markets.



Greece

Greek aquaculture consists mainly of the production of European seabass (*Dicentrarchus labrax*) and gilthead seabream (*Sparus aurata*). The industry has seen a rapid development as seabass and seabream, have only been farmed since the beginning of the 1980s. Approximately 80 percent of Greek aquaculture production is exported, mainly to Italy and Spain. The third largest agricultural export after olive oil and tobacco is fish, principally farmed seabass and bream, and is seen as a strategic product by the Greek Government. The farming of these species is mostly conducted in marine cages and the production costs are among the lowest in Europe. Production sites are located all around the Greek coast, although most prevalent in the central regions close to good infrastructure and export routes.

Greece currently holds the position of main supplier of seabass and seabream to Italy and the EU in general. Approximately 340 Greek farms produced a total 100 000 tonnes of fish in 2006, equivalent to a turnover of €760 million. Greek production thus accounted for over half (53 percent) of the Mediterranean farmed seabass and seabream. The output is expected to grow in the coming years (Camillo Catarci, 2007 FAO Globefish).

Most of the Greek seabass and seabream production is carried out in sea cages, large square or circular floating plastic structures from which a net bag is suspended. In the last few years there has been a trend towards large, round cages that can

reach 120 meters circumference and hold 250–300 tonnes of fish. Many fish farms have now acquired automated feeding systems and there is a trend for larger cages, mimicking the trends in the salmon and trout industries. However, most small companies, (producing <500 tonnes/year) have not invested in new technologies and are based on manual labour for most of the farm operations. Also, and compared with the salmon or trout industries, the seabass and seabream farms use very little technology for biomass management, feeding optimisation, grading, etc. Source:(FAO Fisheries and Aquaculture Department).



Ireland

Because of its gently sloping continental shelf, most of Ireland's sheltered inshore water is too shallow for finfish cage farming and nearly all of the farming companies operate a mixture of inshore and offshore sites. Irish farmers are only too familiar with the unsuitability of inshore technologies for offshore use, and were amongst the earliest to test cages specifically designed for use in exposed sites. Expansion in the salmon farming sector in Ireland has been significantly curtailed in recent years. Farmed salmon output increased from 18,000 tonnes in 1999 to reach a peak production of 23,312 tonnes in 2001. Thereafter production has steadily declined to 11,174 tonnes in 2006. On this basis, it is estimated that the salmon-farming sector is currently operating at less than half of its production capacity (Offshore aquaculture development in Ireland, Next Steps 2007).



Italy

The majority of Italian fish farming production consists of freshwater species (e.g. trout, catfish and sturgeon) and of marine species of seabass and gilthead seabream, followed by eel and sharpsnout seabream. The aquaculture of European seabass and gilthead seabream only started at the end of the 1980s. In Italy, private and independent seabass and seabream farms were established at the beginning of the 1990s. These companies were initially oriented towards the development of land-based units located along coastal areas; the first offshore farms were established in the second half of the 1990s. In 2004 total aquaculture production was 232,800 tonnes of which the mussel segment

accounted for around 70 percent whilst the marine finfish production represented around 9 percent in volume.

Since 2003 Italy has also developed the fattening of northern bluefin tuna (*Thunnus thynnus*) using cages in coastline areas, located in the southern regions (Sicily, Calabria, Puglia, Campania). In 2006, nine active tuna farming plants were monitored in Italy by ICCAT (the International Commission for the Conservation of Atlantic Tunas). Until recently Italy's marine finfish sector has undergone rapid expansion thanks to reliable reproduction procedures for seabass and seabream. However, efforts to improve production have partly been met by competition from other Mediterranean countries, which, thanks to better environmental factors and lower labour costs, are able to produce at lower costs than the Italians.



Malta

Aquaculture in Malta is primarily marine-based. It consists of the culture of European seabass (*Dicentrarchus labrax*) and gilthead seabream (*Sparus aurata*) and the fattening of wild-caught Atlantic bluefin tuna (*Thunnus thynnus*). The Atlantic bluefin tuna is mainly exported to Japan, whereas the European seabass and gilthead seabream are exported to Europe, mainly Italy. In 2005 total production of European seabass and gilthead seabream was 772 tonnes. Gilthead seabream production was 567 tonnes, of which 529 tonnes were exported. European seabass production was 205 tonnes. Of which 174 tonnes were exported. In the case of Atlantic bluefin tuna, production is currently around 3,000 tonnes, with an estimated value of € 46,000,000 (MCFS, 2006).

All aquaculture takes place in floating cages, approximately one kilometre offshore. Various types of on-growing cages are used, namely Dunlop, Corelsa and Farmocean cages for offshore sites and Floatex and Kames cages for inshore nursery sites.

Due to the small size of the island of Malta (approximately 320 sq/km) there is strong competition for space and resources and the Government has become very conscious of environmental issues. The Fisheries Conservation and Control Division within the Ministry for Rural Affairs and the

Environment (MRAE) regulates and administers the capture fisheries and aquaculture industries and is directly responsible for issuing aquaculture permits. Due to the conflict between tourism and aquaculture, the MRAE is creating an aquaculture zone, six kilometres off the east coast of Malta, so that tuna farming operations will move further offshore.



New Zealand

The aquaculture of king or chinook salmon developed in the 1980s from fish introduced from Sacramento, California in the late 1890s for initiating a sport fishery in New Zealand (Jeffs, 2003). The New Zealand industry has since grown into one of the largest producers of farmed king salmon in the world (FAO, 2007). The majority of fish are grown out in marine sea cages in coastal waters, with a small proportion grown out in freshwater. The production of farmed salmon was 7,450 tonnes in 2004 rising to approximately 10,000 tonnes in 2005. In 2005 the salmon farming industry consisted of 14 on growing sites and 12 hatcheries (Gillard and Boustead, 2005). As is the case in Australia there is a need for the finfish industry in New Zealand to establish its credentials with the environmental groups and the general public in order to develop confidence in the industry. There are currently widespread concerns regarding the sustainability of aquaculture.



Norway

The aquaculture industry in Norway is in a phase of steady expansion. In 2005, 1137 farm installations existed in the sea for Atlantic salmon and sea trout, 415 sites produced other species such as cod, halibut and arctic char (Norwegian Fisheries Directorate 2007a).

All concessions used 'gravity' nets, which retain their shape based on gravity with a series of weights, suspended from plastic rings or steel platforms. Net cage volumes are most typically 10,000 to 20,000 m³ and each individual cage may contain from 10,000 to 200,000 fish (Sunde *et al.* 2003). The recent years has shown a development towards the use of even bigger units, plastic rings with circumference 157 m are growing more popular. Cages of this size have a volume of up to

60,000 m³ and can potentially hold 1100 tonnes of fish. There is a tendency towards the use of steel cages in the southern parts of Norway where one might find sites at more sheltered locations, further north we see more use of plastic cages. Though Norway finds itself blessed with a vast and sheltered coastline the industry might soon see a shortage of possible new locations. Offshore sites, as they normally come with stable and favorable water conditions, may present an eligible option for the continued growth of Norwegian aquaculture.

In 2006, salmon and sea trout production reached 598,000 tonnes and 57,000 tonnes, respectively, representing an increase of approximately 4% from 2005 for salmon. Cod production is expanding rapidly; 9,500 tonnes was produced in 2006 with 15,000 tonnes forecast for 2007 (Torrissen 2007).



Scotland

Marine cage production in the UK is almost exclusively carried out in the coastal waters of Scotland. The two main species in production are Atlantic salmon and rainbow trout, with increasing interest in cod production. The salmon production tonnage in marine sites increased from 129,588 tonnes in 2005 to 131,847 tonnes in 2006. While the number of production sites decreased from 277 in 2005 to 251 in 2006. The trend towards increasing the size of producing sites continued. The estimated harvest for 2007 is 142,566 tonnes. Sea reared rainbow trout production also increased from 1,242 tonnes in 2005 to 2,341 tonnes in 2006. The number of sites had also doubled from 5 in 2005 to 10 in 2006. In their report entitled "Appraisal of the opportunity for offshore aquaculture in UK waters," Mark James and Richard Slaski suggest that while "offshore aquaculture is fundamentally appealing and could be strategically important in the UK in the future, the evidence provided suggests that careful consideration of properly justified calls for R&D is merited in support of aquaculture development in more exposed locations with a view to better defining the prospect for full offshore operations in the future."



Spain

Spain is the first aquaculture producer in the EU context, with a production level which is more than three times the European average. However, it is

important to take into account that 90% of the total Spanish aquaculture production is mussel production. According to data provided by JACUMAR (Advisory Board of Marine Culture, Spanish Ministry of Agriculture, Fisheries and Food), Spain produced 308,682 tonnes of mussels in 2006 and 37,737 of finfish, out of a total of 346,630 tonnes, including molluscs, crustaceans and finfish.

Data from the same source shows that the employment level in aquaculture is also significant, with almost 1,900 jobs in 2006, of which more than 1,600 were permanent, representing an increment of 12.4% on employment levels the year before. Employment in the sector is also characterized as being highly specialized and stable.

The number of aquaculture installations keeps growing every year, although in a slower rate than production. In 2006 there were 14 hatcheries and 109 finfish farms were operating in Spain, as well as 3,720 rafts, of which 3,537 are mussel rafts located in Galicia.

Offshore aquaculture is seen as a complement for the development of aquaculture production in Spain. Currently almost 60% of total fish production takes place in cages. Growth expectations are considered to be extremely encouraging for this kind of farming system, although there is a need to understand that a change of scenario towards one in which the majority of production comes from truly exposed areas should be gradual, since there are still a multitude of issues to be addressed which could affect the viability of the activity, not only in relation to new technologies but also to issues affecting the market, company size, the value chain (the supply of fry, feedstuffs, etc.) and planning and regulation, amongst others.



Turkey

Turkish aquaculture is dominated by finfish production, mostly seabream and seabass farms located on the southern Aegean coast. This area provides many sheltered sites suitable for mooring conventional floating cages. Approximately 95 percent of the total seabass and seabream production currently come from the Aegean region accounting for 45 percent of the total Turkish aquaculture production. Some areas along the Aegean coast are

overloaded with farms and conflicts exist with the tourism sector and other resource users.

The most widely employed intensive system for seabream and seabass is floating cages, these can be squares measuring from 5x5x5 m or circular, hexagonal or octagon shaped cages up to 12–50 m in diameter. More recently marine farms have been relocating towards more exposed areas or secondary bays and thus types and sizes of the cage systems employed are changing. There are also seabass and seabream farms, which utilize earthen ponds and only one high-tech (recirculation) land-based farm. Semi-intensive culture has also been practiced in some lagoons using large sized earth ponds. Large 50–75 m diameter cages are used for tuna fattening.

The lack of coastal zone management plans and subsequent aquaculture site allocation has led to conflicts of interest and competition between the tourism and aquaculture sectors. The Government of Turkey has gone to great effort since 2000 to resolve these conflicts; site and area allocation plans have been prepared along the Mediterranean and Aegean coasts involving various stakeholders. Most of the marine farms have already left the well protected, near shore shallow waters and moved to relatively exposed offshore areas in order to implement a governmental regulation of January 2007. This has led to a shift in technology towards larger HDPE (High Density Polyethylene) circular cages (10–24 m in diameter) rather than the smaller locally made wooden cages. Source: Ministry of Agriculture and Rural Affairs (Gozogozoglu, 2004).



U.S. of America.

The United States of America currently has a great deal of opposition to the development of marine cage aquaculture. Continuous anti aquaculture protests in Maine and Washington have undermined the development of marine cage production. Due to the continuous conflict and the lack of suitable sheltered sites the USA has invested in the development of open ocean production technology. Interest in open ocean production began in the late 80's, which led to the emergence of designs and prototypes for open ocean culture. In the early to mid 90's pilot projects commenced in the Northeast (University of New Hampshire) and the Gulf of Mexico. The first commercial open ocean

farm was established in Hawaii in 2001. Currently there is no clear authority for the permitting of aquaculture in federal waters i.e. waters three to 200 miles off shore. The National Oceanic and Atmospheric Administration (NOAA) has proposed the establishment of the National Offshore Aquaculture Act 2007. It is hoped that this Act will establish the legal framework regarding permits, enforcement, and monitoring of offshore aquaculture. However, to date the process has met with strong opposition from NGO's and fishermen's organisations.

Recently the Ocean Stewards Institute was established in the USA. This is a trade organization advocating for the emerging open ocean aquaculture industry.



Break out discussions during the regional Workshop in Galway, Ireland in 2007

Offshore Aquaculture in Europe - 'Next Steps'

International Workshop
24th September 2007, Dublin, Ireland
Venue: Crowne Plaza Hotel, Dublin

The Offshore Aquaculture in Europe - 'Next Steps' International Workshop will provide stakeholders with an interest in Offshore Aquaculture to submit their thoughts on the next steps for the development of the offshore industry. The workshop is funded under the EU 6th Framework OATP project.

The output from this foresight exercise will be a comprehensive report outlining the way forward for the European aquaculture industry. This report will be submitted to the European Commission in February 2008.

Avail of this opportunity to have your thoughts and opinions included in the foresight planning for Offshore Aquaculture while attending the World Seafood Congress taking place in Dublin the same week!
www.worldseafoodcongress07.com

For more information or to register for this workshop see:
www.marine.ie
or contact:
Alan Drumm, Marine Institute, Newport, Ireland.
Phone: + 353 98 42300 Email: alandrumm@marine.ie

Flyer for the OATP International Workshop in Dublin, Ireland in 2007

Appendix I

Table 1: Existing aquaculture sea water based research facilities in the EU (U: University; PUB RI: public research institute; PRIV RI: private research institute; COMP: company)

	CITY	OWNER	NAME INFRASTRUCTURE	WEB SITE	TYPE INFRASTRUCTURE	EXPERTISE
1	CRO Split	PUB RI	Institute of Oceanography and Fisheries	www.izor.hr	specialised laboratories	mariculture, environmental impact, physiology, population genetics, reproduction
1	CRO Dubrovnik	U	University of Dubrovnik, Department of Aquaculture	www.unidu.hr	shellfish hatchery, ongrowing fields, fish culture unit	shellfish, production optimisation
2	CYP Nicosia	PUB RI	Department of Fisheries and Marine Research (DFMR)	www.moa.gov.cy	land based marine aquaculture research station for conducting applied research	diversification, fish biology, benthic ecology, pollution
3	DK Charlottenlund	PUB RI	Danish Institute for Fisheries Research (DIFRES)	www.difres.dk	on-land experimental facilities with recirculation systems, laboratories for digestibility, physiology	nutrition physiology of fish larvae, use of live feed, health and welfare, nutrition, growth (advice to Ministry)
4	DK Hirtshals	PRIV RI	SINTEF North Sea Centre Flume Tank	www.sintef.dk	on-land experimental facility for testing models of fishing gear	fishing technology
5	EL Heraklion; Faros	PUB RI	Hellenic Centre for Marine Research (HCMR), Institute of Aquaculture	www.hcmr.gr	land based indoor and outdoor (Faros field station) facilities: larval rearing, nursery, weaning, pre-growing and broodstock	broodstock management, hatchery technology, nutrition, control of fish development, fish diseases
6	ES El Toruño, Puerto de Santa María (Cádiz), Agua del Pino (Huelva)	PUB RI	Centro de Investigacion y Formacion Pesquera y Acuicola (CIFPA), Regional Government of Andalusia	www.juntadeandalucia.es	land based facilities, specialised laboratories, pilot plants for flat fish production	optimisation of culture systems, diversification of species (fish, molluscs, cephalopods), genomics, reproduction and larval breeding
7	ES Vilanova de Arousa	PUB RI	Centro De Investigacións Mariñas. Xunta de Galicia	www.cimacoron.org	land based facilities, experimental hatchery facilities	production optimisation of fish and molluscs, new species, pathology and parasitology, identification of mussel larvae abundance; coastal oceanography
8	ES Punta do Couso, Aguiño	PRIV RI	Centro tecnologico Gallego de Acuicultura -CETGA, Cluster de la Acuicultura de Galicia	www.cetga.org	aquaculture pilot plant: land based facilities for larval prod, growout and reproduction; specialised laboratories	pathology, feeding, Artemia, automation, effluent treatment, new species

9	ES	Mazarrón	PUB RI	Centro Oceanográfico de Murcia - Instituto Español de Oceanografía	www.mu.ieo.es	indoor land based rearing facilities for larvae, juveniles, on growing and broodstock; specialised laboratories	nutrition, reproduction, culture techniques for new species
10	ES	Vigo, Castellón, Puerto Real -Cádiz, Barcelona	PUB RI	Consejo Superior de Investigaciones Científicas (CSIC) - Instituto de Investigaciones Marinas; Instituto de Acuicultura Torre de la Sal; Instituto de Ciencias Marinas de Andalucía; Institut de Ciències del Mar.	www.csic.es	land based rearing facilities for fish, molluscs and crustaceans and specialised laboratories	fish larval biology and nutrition, fish pathology, reproduction, physiology, genetics and nutrition, mussel culture, ecotoxicology, marine ecology
11	ES	Las Palmas	PUB RI	Instituto Canario de Ciencias Marinas	www.iccm.rcanaria.es www.grupoinvestigacionacuicultura.org	land and sea based facilities for research; experimental activities and training	fish nutrition and feeding; culture techniques for new species; new hatchery techniques; genetics
12	ES	Monte Cantabria, Murcia, Vigo, Tenerife, A Coruña	PUB RI	Instituto Español de Oceanografía	www.ieo.es	land based rearing facilities (incl. large-scale) for fish, bivalves, algae; specialised labs	nutrition; culture techniques for new species (fish, bivalves, algae), larval rearing, reproduction, genetics
13	ES	Illa de Arousa. Vilanova de Arousa	PUB RI	Instituto Galego de Formación en Acuicultura. Xunta de Galicia	www.xunta.es	experimental sea based facilities: sea rafts for molluscs and fish cages, computer science applications and a intertidal production area	educational purposes
14	ES	San Pedro del Pinatar. Murcia	PUB RI	Instituto Murciano de Investigación y Desarrollo Agrario y Alimentario.	www.wsiam.carm.es	land based facilities	nutrition, environmental impact, production systems, new species
15	ES	Valencia	U	University of Valencia, Unidad de Zoología Marina. Instituto Cavanilles de Biodiversidad y Biología Evolutiva	www.uv.es	land based facilities, pilot plant and specialised labs	marine mammals; turtles and fish parasitology

16	F	Palavas-sur-mer	PUB RI	IFREMER - Station Expérimentale d'Aquaculture	www.ifremer.fr	land based tanks for fish and mollusc culture, recirculation systems	physiology, immunology-pathology, genetics, technology of recirculation systems
17	F	Plouzané	PUB RI	IFREMER, Laboratoire ARN	www.ifremer.fr	land based rearing facilities and specialised laboratories	adaptation, reproduction, nutrition of marine fish
18	F	Plouzané	PUB RI	IFREMER, METRI	www.ifremer.fr	deep wave basin, water circulation basin, laboratories for testing materials and sensors	behaviour in marine environment of materials, equipment, sub-marine vehicles, instrumentation, physical sensors
19	F	St-Pee, Donzacq, Lees-Athas	PUB RI	INRA	www.inra.fr	laboratory facilities	aquaculture nutrition and metabolism
20	FIN	Rymättylä	PUB RI	Finnish Game and Fisheries Research Institute (FGFRI)	www.rktl.fi	experimental sea cages with monitoring and feeding control systems; land based recirculation fish rearing facilities	fish nutrition and feeding, fish quality, physiology
21	I	Messina	PUB RI	Istituto Sperimentale Talassografico	www.ist.me.cnr.it	land based rearing installations	environmental studies, fish farming environments, monitoring
22	I	Lecce	U	Marine Aquaculture and fisheries Research Centre - DiSTeBA - Università di Lecce	www.siba2.unile.it	land based rearing facilities (hatchery, raceway tanks), specialised laboratories	food safety and quality control, water treatment, physiology, genetics, feeding and nutrition
23	IL	Eilat	PUB RI	Israel Oceanographic and Limnological Research, National Center for Mariculture	www.ocean.org.il	land based systems for rearing fish in seawater ponds	reproduction, larval rearing, genetics, feed development, rearing systems, integrated systems
24	IRL	Cork	U	Aquaculture and Fisheries Development Centre (AFDC), University College Cork	www.ucc.ie	Land based freshwater and marine fish rearing facilities, laboratories	growth, feeding regimes, disease, genetics, recirculation, environmental impact; coldwater fish and shellfish
25	IRL	Newport	PUB RI	Marine Institute	www.marine.ie	freshwater hatchery and salmon rearing facilities	salmon and trout research, feeding, vaccines, broodstock, design of facilities in commercial situation

26	IRL	Carna	U	National University of Ireland - Galway (NUI/UCG), Martin Ryan Institute Carna	land based small, medium and large-scale flow through rearing facilities, finfish hatchery, shellfish rearing and broodstock facilities, seaweed hatcheries	production of ornamental fish, invertebrates, shellfish, marine finfish, recirculation technology, hatchery and system design, phycodepuration
27	ISL	Saudarkrokur	U	Holar University College	www.holar.is	selective breeding, feed and nutrition, water quality, environmental effects, fish ecology, evolution, physiology, behaviour
28	ISL	Reykjavik	PUB RI	Marine Research Institute	www.hafro.is	juvenile production, broodstock, selective breeding, cultivation of new species
29	N	Sunddalsøra, Averøy	PUB RI	AKVAFORSK	www.akvaforsk.no	selective breeding and genetics, nutrition, welfare and the environment, product quality, molecular biology, marine species
30	N	Hemne, Tingvoll	COMP	Aqua Gen AS	www.aquagen.no	selective breeding, production of brood fish and fertilized eggs, fish health
31	N	Hjelmeland	COMP	Center for Aquaculture Competence AS (CAC) (Skretting, Marine Harvest, AKVAsmart)	www.skretting.no	fish health, feed production and use, food safety, feed and sensor technology, production economy, documentation
32	N	Dirdal, Lønningdal	COMP	Ewos Innovation AS	www.ewos.com	fish feeding and feed development
33	N	Dønna	COMP	Fjord Forsøksstasjon Helgeland AS	www.fjordseafood.com	feed development and technology, environmental impact of feed
34	N	Gildeskål	PRIV RI	GIFAS - Gildeskål Forskningsstasjon AS	www.gifas.no	biology and technology related to e.g. feed, sea cage experimental studies
35	N	Austevoll, Matre	PUB RI	Institute for Marine Research	www.imr.no	breeding, first feeding, welfare, ethology, cod larvae production, new species, fish health, physiology

36	N	Gurskøy	COMP	Nordvest Fiskehelse AS	www.nvf.no	salmon grow out sea based facilities	bacteriology, parasitology, hematology, analyses of water quality
37	N	Kraknes, Røsneshamn	PUB RI	Norwegian Cod Breeding Centre	http://en.norut.no/	land based broodstock and larval facilities, sea cages for cod production	measuring, weighing, marking, vaccination of fish
38	N	Sandnes	PUB RI	Norwegian Institute for Nature Research (NINA)	www.nina.no	land based facilities for smolt rearing	marine, coastal and freshwater ecology, environmental and impact assessments
39	N	Solbergstrand	PUB RI	Norwegian Institute for Water Research (NIVA)	www.niva.no	salmon grow out sea based facilities, water quality database	water quality, water treatment, monitoring of algae, effects of aquaculture
40	N	Trondheim	U	Norwegian University of Science and Technology (NTNU)	www.ntnu.no	land based seawater facilities for larval rearing	physiology, nutrition, cultivation systems for marine species, shellfish
41	N	Nærøy	COMP	Pharmaq AS	www.pharmaq.no	salmon grow out sea based facilities	fish health management
42	N	Trondheim	PRIV RI	SINTEF Fisheries and Aquaculture AS - SEALAB	www.sintef.no	land based marine hatchery, environmental impact laboratory	aquaculture engineering, marine resources and processing technology
43	N	Stavanger	COMP	Skretting Aquaculture Research Centre (ARC)	www.skretting.no	salmon grow out sea based facilities	fish nutrition and feed development
44	N	Kårvika	PUB RI	The Aquaculture Research Station in Tromsø	www.havbruksstasjon.no	land based plant, fish health laboratory, full-scale marine farm	broodstock management, larval rearing, feeding, nutrition, fish diseases
45	N	Val	PUB RI	Val Akva	www.val.vgs.no	grow out unit for salmon and trout	educational purposes
46	N	Namsos	COMP	VESO Viken Akvavet	www.veso.no	salmon grow out sea based facilities	fish health
47	N	Vikebukta	PRIV RI	Villa AS (Cod Farm and Miljølaks)	www.leppefisk.no	cod farm and salmon grow out sea based facilities	development of production methods for cod and for salmon using wrasse as treatment against sea-lice
48	NL	Texel	PUB RI	Royal Netherlands Institute for Sea Research (NIOZ)	www.nioz.nl	large-scale land based aquarium facilities, acclimatised with running seawater and variable temperature and salinity	marine ecology and evolution in marine ecosystems
49	NL	IJmuiden	PRIV RI	Wageningen IMARES b.v. Institute for Marine Resources & Ecosystem Studies	www.rivo.wageningen-ur.nl	land based seawater tanks and aquaria	production of new fish species, nutrition, recirculation technology, bio-economical modelling

50	PL	Faro	U	Algarve Center of Marine Sciences (CCMAR), University of Algarve	www.ualg.pt	land based marine aquaculture station of Ramalhete	new species, physiology, broodstock management, production systems, feeding regimes
51	PL	Lubiatowo	PUB RI	Coastal Research Station	www.ibwpan.gda.pl	marine station with permanent measuring structures	research on coastal phenomena: waves, currents, coastal morphodynamics
52	PT	Porto	PUB RI	Interdisciplinary Centre for Marine and Environmental Research (CIIMAR)	www.cimar.org	land based facilities with closed circuits	aquaculture biology, nutrition and pathology, environmental impacts, integrated aquaculture, offshore mariculture
53	PT	Lisboa	PUB RI	National Institute of Agronomy and Fisheries Research (IPIMAR)	www.iniap.min-agricultura.pt	specialised laboratories (field station)	physiology, anguiculture, mussel culture, pathology, histology, nutrition
54	ROM	Constanta	PUB RI	National Institute for Marine Research and Development "Grigore Antipa"	www.rmri.ro	long-line systems for mussel breeding, research vessel, small-scale land based rearing facilities	marine ecology and environmental monitoring and managing; marine and freshwater rearing of fish and bivalves
55	SE	Norrbyn	U	Swedish University of Agricultural Sciences	www.vabr.slu.se	land based brackish water rearing facilities, specialised laboratories and equipment	fish behaviour, feeding and nutrition, physiology, molecular biology
56	TUR	Izmir	U	Dokuz Eylül University, Institute of Marine Sciences and Technology	www.deu.edu.tr	no sea based facilities, model basin at the Technical University of Istanbul	design of offshore fish farm structures, aquaculture impact on the marine environment, fish farm planning
57	UK	Lowestoft, Weymouth	PUB RI	Centre for Environment, Fisheries and Aquaculture Scienc (CEFAS)	www.cefass.co.uk	flexible on-land rearing facilities and specialised laboratories	fish health and medical treatment, food safety, environmental impact, management tools
58	UK	Aberdeen, Aultbea	PUB RI	Fisheries Research Services (FRS) Marine Laboratory	www.frs-scotland.gov.uk	land based facilities: rearing facilities, challenge units and behavioural units	fish health, pathology, virology, molecular genetics, epidemiology, immunology, fish behaviour
59	UK	Scalloway (Shetland)	PUB RI	North Atlantic Fisheries College (NAFC) Marine Centre	www.nafc.ac.uk	land-based marine hatchery, sea-based facilities for salmonids, marine finfish, shellfish	brood stock management, larval rearing, on growing production, antifouling, harmful algae

Source: DesignACT Deliverable 1. Inventory of infrastructure and knowledge gaps in aquaculture technology.

Appendix II

MEMORANDUM OF UNDERSTANDING

Between the projects:

Towards enhanced and sustainable use of genetics and breeding in the European aquaculture industry (AquaBreeding)

represented by Istituto Sperimentale Italiano Lazzaro Spallanzani, Milan, Italy

Evaluation of the Promotion of Offshore Aquaculture Through a Technology Platform (OATP)

represented by The Marine Institute, Galway,
Ireland
and

European Aquaculture Technology Platform (EATP)

represented by SINTEF Fisheries and Aquaculture Ltd, Trondheim, Norway

regarding cooperation in developing RTDI visions, research agenda, deployment strategies and projects relevant to the European aquaculture industry under the concept of Technology Platforms.

The Istituto Sperimentale Italiano Lazzaro Spallanzani, coordinator of the project Towards enhanced and sustainable use of genetics and breeding in the European aquaculture industry (hereafter referred to as ISILS), The Marine Institute, coordinator of the project Evaluation of the Promotion of Offshore Aquaculture Through a Technology Platform (hereafter referred to as MI) and the SINTEF Fisheries and Aquaculture Ltd, coordinator of the project European Aquaculture Technology Platform (hereafter referred to as SINTEF) having mutual interest in advancing European aquaculture recognize that there is a need to operate in consort hence a coordinating organ would be useful, have agreed to foster cooperation as defined in this Memorandum. To this end all Parties agree to undertake the activities and procedures as set forth below.

The Parties have agreed as follows:

1. To establish EATP as a coordinating organ that will facilitate coordination of technology platform initiatives and operations within aquaculture. Under this umbrella the offshore and breeding initiatives (AquaBreeding and OATP) are considered the first initiative groups of the European Aquaculture Technology Platform.

2. The Parties shall, to the extent it is relevant and to mutual benefit, cooperate on creating and conducting operations. The objective is to strengthen the relevance and scientific basis for research within European aquaculture, and to consolidate the basis for coordinated operations. This infers developing coordinated visions, strategic research agenda deployment strategies and projects and conducting transfers and exchanges of information, findings and knowledge.

3. At the outset the following tasks are selected for direct cooperation between the Parties:

- a. In cooperation with the Federation of European Aquaculture Producers (FEAP) to organize a Profet Policy Workshop with key representatives of all stakeholders in a future EATP to develop and adopt a management plan and its terms of reference
- b. A presentation will be made by the EATP to the projects OATP and AquaBreeding during their first kick-off meetings
- c. Participation of one EATP, AquaBreeding and OATP representative at management and thematic meetings of each project as appropriate.
- d. Facilitate the information flow between initiatives (access to the intranet website, newsletters, vision papers, address book of project participants, a.o.).
- e. Joint meetings during the coming years.

4. AquaBreeding, OATP and EATP will establish cooperation with other relevant Technology Platforms including the new pillars (or initiative groups) established under the EATP umbrella.

5. The EATP will take on board the findings and conclusions of the AquaBreeding and OATP to form part of the EATP visions, strategic research agenda and deployment strategy.

6. It is agreed that the intention of this cooperation is not to restrict or otherwise detract from the relationships which already exist between the Parties and their clients or partners.

7. This Memorandum of Understanding is valid from the date of signing. Any Party wishing to terminate this Understanding must notify the other Parties in writing at least three months in advance. This Memorandum of Understanding is signed in Brussels on March 22nd 2007, in three originals, each being authentic.

Appendix III

RTDI Requirements

Goals	Objectives	RTDI Requirements
1. To address the issue of sustainability of food sources for aquaculture particularly in terms of alternative sources for fish oils and to ensure best environmental practices in order to ensure the viability of the industry and promote public confidence	<ul style="list-style-type: none"> > The production of aqua feeds should be a sustainable activity, diversifying the sourcing of raw materials for formulated feeds and encouraging the development of aquaculture as an integrated activity. 	<ul style="list-style-type: none"> > There needs to be considerable research into alternatives to wild fish resources for fish oils in aquaculture feed. > More investigations need to be carried out into farmed sources, additional marine resources and land sourced vegetable oil substitutes in feedstuffs. > Replacing fish oil with vegetable extracts promotes the protection of wild fish resources and promotes sustainability.
2. Ensure Offshore Aquaculture plays a substantial role in helping meet increased global seafood consumption demands, particularly in light of the fact that capture fisheries are likely to remain stagnant at best.	<ul style="list-style-type: none"> > Offshore aquaculture must provide suitable alternatives to inshore culture to provide for increased production and utilisation of alternative sites. > The potential for polyculture should be researched and this could lead to the sharing of space and resources. This will have obvious cost cutting benefits for industry and the positive environmental benefits should be investigated and promoted. 	<ul style="list-style-type: none"> > Research into improved on-growing techniques is necessary, particularly the adaptation of inshore culture to offshore locations. > Detailed knowledge on hatchery design and techniques is vital and knowledge transfer between European areas of expertise should promote best practice in rearing and on growing. > Increased R&D into novel species for culturing in offshore regions. These include sea urchins, pollack, tuna, cod, hake, halibut, seabream and seabass.
3. Improved public perception of the aquaculture industry in the areas of environmental management and the health benefits of eating seafood	<ul style="list-style-type: none"> > Relevant information must be easily accessible to help in the area of openness & transparency > Participation by industry in monitoring programmes is essential > Health benefits of eating sea foods should be promoted > Initiatives in aquaculture CZM should be publicised 	<ul style="list-style-type: none"> > Development of improved methods of information dissemination to stakeholders > Research into effective media campaigns > Development of real time monitoring reporting > Aquaculture installations developed as suitable platforms for monitoring equipment
4. Harmonisation of Licensing Procedures and a more proactive approach to licensing	<ul style="list-style-type: none"> > The perceived problems with the regulatory framework in the offshore context echo inherent problems with the current framework closer in-shore. This includes the length of time for license processing and the lack of proactive approaches in coastal planning involving marine spatial planning (MSP) and site designation. 	<ul style="list-style-type: none"> > The current legislative framework that exists for aquaculture near shore should encompass offshore aquaculture operations also, with certain license conditions applying to offshore locations. > A definition of Offshore Aquaculture needs to be adopted > License applications processing must be streamlined and involve more proactive approaches such as site designations and improved agency co-ordination > Site designations should occur in the wider ICZM context and utilise available technology to inform the decision making process. > The principles/components of current area management agreements (aquaculture management initiatives) should be extended to encompass

Goals	Objectives	RTDI Requirements
		offshore aquaculture with the purpose of developing codes of practice for the industry and to ensure good environmental practice.
5. The regulatory and monitoring framework for offshore aquaculture should be harmonised with key EU environmental and biodiversity directives.	<ul style="list-style-type: none"> > The Marine Strategy Directive (pending) will set specific targets extending clean water targets and monitoring requirements beyond the one nautical mile limits set by the WFD. Utilising offshore locations will require greater participation by industry in monitoring programmes and there is a strong need for improved developments in remote monitoring technology. > With the potentially more exposed nature of offshore sites bio-security issues will need to be addressed. 	<ul style="list-style-type: none"> > The development and implementation of a consultation process with the aquaculture industry for the purpose of informing the drafting of the Marine Strategy Directive (MSD) >Legislative monitoring requirements for fish farms must be integrated with requirements under the MSD. > Biosecurity improvements must be put in place through: legislation; codes of practices & international co-operation; industry management frameworks; revised monitoring; health management plans; development of containment structures; and contingency plans for dealing with escapees. This will require relevant R & D support
6. Insure Navigational Planning is a fundamental part of the licensing process, to reduce the potential of collisions in the offshore scenario.	<ul style="list-style-type: none"> > License conditions must provide for the use of appropriate equipment by offshore operators and safety checks must be a part of compulsory monitoring programmes. > Navigation markers around the installations should be standardised and also be part of regular safety checks. 	<ul style="list-style-type: none"> > Develop protocols for standardisation of navigational markers > Design integrated aquaculture navigation plans on a local basis > Navigation and warning systems must be developed as well as an integrated navigational plan, involving port authorities and seafarers. > Carry out audits of installations and navigational markers
7. Enhancement of Personal Safety of workers in offshore aquaculture locations through a variety of legislative and management approaches.	<ul style="list-style-type: none"> > Legislative requirements are necessary placing the onus on offshore operators to provide suitable equipment and training. > R&D into safe fish containment systems, work platforms and personal safety devices is necessary. 	<ul style="list-style-type: none"> > The personal training of site staff is an important factor in safety for the offshore aquaculture industry. Accident and emergency concerns increase the more you move offshore in terms of exposure and response time to emergencies. Evaluation of the requirements to offset potential increases in risk are required > Industry training programmes are necessary to train staff in safe work practices in offshore locations these will require careful development and evaluation > Development of suitable cages, anchoring systems, navigational systems and fish handling equipment is necessary. > Technology development in the area of remote communications is crucial in emergency situations
8. To minimise the release of nutrients from aquaculture installations	<ul style="list-style-type: none"> > Requirements under the WFD and MSD (pending) should be strictly adhered to. > Monitoring programmes covering aquaculture industry should deal sufficiently with these requirements > Developments in remote sensing technology and real time reporting is necessary 	<ul style="list-style-type: none"> > Guidelines must be developed and implemented (with particular reference to coastal production systems) to reduce or eliminate the negative impact associated with the organic content of effluents from aquaculture farms. > Permitted parameter levels should fall within EU requirements and monitoring protocols to provide for adequate monitoring in this context will be required > Advantages of polyculture should be investigated in terms of the benefits to nutrient loading of co-location finfish and shellfish units

Goals	Objectives	RTDI Requirements
		<ul style="list-style-type: none"> > Utilising offshore locations will require greater participation by industry in monitoring programmes > Industry Codes of Practice (COPs) to deal with environmental management concerns will be required. > Technology development is required in the area of remote monitoring and real time reporting > Development of farm surveillance technology is required to help supplement farm environmental management plans and provide for greater access to data from remote locations
9. The effects of organic loading on the benthos from fish feed and nitrogenous waste should be minimised.	<ul style="list-style-type: none"> > Adequate processes for siting of aquaculture units must be adopted > Statutory requirements for fallowing & monitoring is necessary > Integrated farm environmental management plans must deal with the conservation of biodiversity. 	<ul style="list-style-type: none"> > Proactive designation (through Marine Spatial Planning) will help select suitable areas for culturing. > Statutory monitoring programmes at various stages of production will be necessary to validate the site designation process. > Fallowing requirements should be provided for through license conditions and through the provision of sufficient space or sites for separation of generations > Strategies should be developed to ensure the thorough analysis of possible impacts on the flora and fauna of the areas where aquaculture facilities are to be deployed (in this regard, offshore aquaculture normally has less impact than other kinds of systems). > Development of remote surveillance technology (such as cameras and sensors) is required, to mitigate the possibility of feed or other sources of organic inputs falling to the seafloor. > Eco-friendly antifouling coatings and products should be developed.
10. Development of Best Practice in biosecurity to promote stock health and to minimise wild – farmed interactions	> Industry will need to work closely with administrations, fish health specialists and equipment designers to ensure that every effort is made to develop codes of practice, which promote stock health, and the protection of wild fish species.	<ul style="list-style-type: none"> > Native species should be cultured wherever feasible, following the recommendations of organisations such as the IUCN or ICES in the case of the culturing of alien species. > Research (on the closing of life cycles, the functioning of the ecosystem, etc.) should be encouraged in order to guarantee that aquaculture should not endanger stocks (e.g. bluefin tuna) or biodiversity in general. > Research into fish sterilisation techniques and hatchery techniques is necessary to provide alternative sources of fish for stocking purposes. > Contingency plans must be developed (as part of COPs) in the event of accidental escape of fish.

Goals	Objectives	RTDI Requirements
11. Maintaining a good health status and disease free status for aquatic species requires added incentives for an offshore aquaculture	<ul style="list-style-type: none"> > EU & National legislative requirements should be strictly adhered to and certification for fish transfers must be compulsory. > Research into causes, spread, effects and treatments of disease is required through the establishment of expert groups on national and inter-regional level. > The rational licensing of treatment products is necessary in terms of proactive approaches to deal with aquatic diseases/parasites in a timely fashion. 	<ul style="list-style-type: none"> > Certification for transfer of all live species must be a fundamental requirement > Strategies should be developed to minimise the transfer of pathogens between farmed species and wild stock populations in both directions. > Strategies should be developed to ensure the correct management of the use of antibiotics and to minimise possible detrimental effects on the natural environment. > Inter-regional liaisons are necessary in the development of global COPs dealing with the health management and containment of the spread of economically important diseases. > Further research into the causes, threats, treatment and containment of such diseases as Pancreas Disease, Infection Salmon Anaemia, Infection Pancreas Necrosis (IPN) <i>Gyrodactylus</i>, (and parasites such as sea lice) is important for a viable aquaculture industry. > Industry COPs should be developed to ensure maximum efficacy of treatments in the event of aquatic diseases and parasites.
12. Promotion of Inter-regional co-operation on R&D to help narrow the wide technology gaps that exist for the commercial realisation of offshore aquaculture	<ul style="list-style-type: none"> > International co-ordination of R&D into containment systems, fish handling equipment, remote monitoring and surveillance equipment and MSP tools is required to help develop practical solutions in each of these areas. 	<ul style="list-style-type: none"> > Identifying the technology infrastructure gaps is important to alleviate potential escape events, which occur as a result of fish behaviour, climatic conditions or operational procedures on farms. > The practicalities of various containment systems used around the globe must be assessed for different geographic locations > Technology transfer and application of designs to different potential species must be assessed > Knowledge transfer between different users of offshore locations (e.g. oil and wind energy industries) would help provide practical solutions for offshore aquaculture > Experiences in the application of MSP tools for site designations should be assessed and applied for the planning of offshore aquaculture.
13. The development of a mature process of ICZM with a strong MSP component to underpin the rational development of Offshore Aquaculture as was highlighted in the EU Maritime Policy Green Paper	<ul style="list-style-type: none"> > The characterisation of sites in terms of acquiring oceanographic and environmental data at potential offsite locations will be an important component in providing policy makers and prospective investors with detailed information on a particular location. > Integration of datasets into GIS is crucial for a better understanding of resource use 	<ul style="list-style-type: none"> > Research into methods for characterising offshore sites in terms of the exposed nature is fundamental in order to test the best available technology in-situ. Characteristics of a site could be obtained from national datasets from seabed mapping programmes and national monitoring programmes. Categorisation of these characteristics will be a very important step in their utilisation for planning. > It is important that methodologies are developed that show how thematic information can be extracted from national datasets (such as seabed survey information and core national datasets) for application to the offshore aquaculture industry.

Goals	Objectives	RTDI Requirements
		<ul style="list-style-type: none"> > Knowledge transfer on the technology side between finfish and shellfish producers, inter-regionally and between other users of offshore sites (such as the wind energy industry and oil industries). > The development of data collection through integrated monitoring programmes and layered GIS based databases
14. By 2020 innovative cage and equipment designs must provide for the expansion of aquaculture to offshore locations and provide for the diversification of farmed species.	<ul style="list-style-type: none"> > Escapement prevention and management should be improved with a view to minimising potential impact. 	<ul style="list-style-type: none"> > One of the most fundamental areas where development is needed is in the actual containment systems for aquaculture species. This refers to a suite of structures which house the cultured species at sea such as cages, rafts, barrels, nets, ropes, anchors and buoys. > New innovative designs for fish cages and shellfish structures are required to mitigate economic losses and environmental concerns associated with escapees.
15. Support for continued technological innovation is required in the wider infrastructure areas, which are necessary to provide safe working platforms, improved access to more exposed locations and which minimise manual labour in more treacherous locations	<ul style="list-style-type: none"> > Improved automated techniques for handling fish in exposed locations is required to reduce escapes, improve the safety of workers and to compensate for access issues in exposed locations > Sustained national and European support, including funding mechanisms for such R&D will be required to due to the high costs associated with the prototype technology. 	<ul style="list-style-type: none"> > R&D is not only required for the containment systems themselves, but also necessary in designing birthing areas for vessels and work platforms to provide for access to the fish. > Designing of automated feeding systems is essential from the point of view of the barges and pumping systems as well as the technology infrastructure to allow remote operation. > Other important equipment areas in need of development include fish handling and operational equipment. > Public private partnership may be the most appropriate mechanisms to design and test the technology and to bring it through to commercial realisation.
16. To develop a focus on the innovation and development of environmental and farm monitoring equipment to meet statutory environmental requirements and to enhance farm management practices.	<ul style="list-style-type: none"> > Monitoring equipment and communication systems require further development and application to offshore aquaculture locations. > Remote access to data and information is important due to access issues in more exposed locations. 	<ul style="list-style-type: none"> > From a farm management perspective, a real-time capability for access to temperature and oxygen data is important. > An improvement to the durability of physical sensors and the number of parameters that they can measure is required. > IT systems, which provide for remote intervention in feed administration, oxygen supply and control of the height of containment systems, require development. > Monitoring at offshore locations must occur as part of an integrated monitoring plan for the region, with the offshore structures acting as platforms for monitoring equipment where possible. > Considerable R&D into the monitoring and identification of causes and effects of marine events (such as phytoplankton blooms) is required. > Development of video cameras and sensors, which shut off feed supply, is critical and contributes to an integrated feed management system, improving FCR's and environmental management of the site.

Appendix IV

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