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Executive summary

The meeting (Chair: Pauline Kamermans) was held on 29 March – 2 April 2010 and was attended by nine participants from six countries. It had two objectives (1) to have a joint meeting with the WGEIM to discuss topics of mutual interest and to increase collaboration and (2) to work on the Terms of Reference. The ToRs were addressed separately, followed by plenary sessions.

ToR a) A discussion of WGMASC and WGEIM on the Second Draft of the Bivalve Aquaculture Dialogue Standards was carried out. The management framework takes a market-based approach with the associated costs largely borne by industry. This is a simplified ecosystem-based approach and, as such, excludes many ecosystems services that the cultured bivalves provide that may mitigate negative effects. Other emerging shellfish aquaculture issues were identified: - restoration of cultured shellfish populations, nutrient trading by culturing shellfish, use of shellfish compounds to cure disease, co-management in shellfish aquaculture (Section 3).

ToR b) Offshore aquaculture requires an understanding of the capabilities and limitations for species, development of new technologies, necessary institutional arrangements (e.g. marine spatial planning), information on biotic and abiotic factors and socio-economic perspectives. This new ToR aims to: assess site selection criteria in ICES countries; provide an overview of current research and commercial operation on offshore shellfish farming, and assess the potential for combining shellfish culture with other offshore constructions (Section 4).

ToR c) Information was gathered on guidelines for and records of the transfer of cultured shellfish in ICES countries. Potential implications and effects of the introduction and transfer of alien species were reviewed together with the identification and ranking of risks (Section 5).

ToR d) Potential implications of the introduction and translocation of live shellfish from hatcheries and field sites to wild and cultured stocks include diseases occurrences, impacts on recruitment, reduced fitness, increased competition and predation, and change in genetic composition, diversity and polymorphism. Recommendations were made to help minimize impacts, to guide farmers and policy makers (Section 6).

ToR e) Cumulative effects of climate change through changes in; runoff of freshwater and contaminants, waves and coastal erosion, storm frequency and intensity, water temperature, oxygen levels, primary production, microalgal biodiversity, predators, parasites, diseases, the presence of nuisance species, ocean acidification etc. on shellfish aquaculture are expected. Knowledge is needed to more fully identify the threats and potential opportunities. (Section 7).

ToR f) Implications and relevance of Marine Spatial Planning for shellfish aquaculture where assessed. Critical social dimensions are involved in the process of marine planning,in particular the rights and duties of the involved parties, ownership of the decision-making process and participation therein (Section 8).

ToR g) WGEIM and WGMASC agreed to have joint meetings every 3 years. Chairs of both groups invite key members to the annual meetings to work on overlapping ToRs together. Chairs will exchange draft reports immediately after their respective meetings. The groups identified SSGHIE expert groups where there may be potential for collaboration (Section 9).

1 Opening of the meeting

The ICES Working Group on Marine Shellfish Culture [WGMASC], chaired by Pauline Kamermans (Netherlands), held its eighth meeting in Galway (Ireland) on 29 March–2 April 2010 at the Marine Institute. It was attended by nine members (Annex 1). The meeting was held at the same location and during the same days as the ICES Working Group on Environmental Interactions of Mariculture [WGEIM]. The meeting was opened at 9.00 am Monday 29 March with the host Francis O'Beirn, member of both WGMASC and WGEIM, giving housekeeping information and John Evans, director of Marine Environment and Food Safety Services, welcoming the groups at the Marine Institute. The chair welcomed the members to the meeting and thanked their respective institutions for allowing time and money to participate. It is becoming increasingly difficult for institutes to allocate resources for the ICES WGs. Two members from the US and Canada were not able to come because of lack of funds. However, a new member from Iceland (Gudrun Thorarinsdottir) was welcomed.

The first day of the meeting was devoted to identification of overlap and subjects of mutual interest between WGMASC and WGEIM and ways to cooperate during the meeting. In addition, the roles of WGEIM and WGMASC within ICES were discussed. This is reported on in Section 8 (ToR g). Also, the Draft for Final Public Comment Period of the Bivalve Aquaculture Dialogue Standards coordinated by the World Wildlife Fund (WWF) was discussed in a plenary session at the beginning of the second day with both groups. Both the WGMASC and the WGEIM have worked on sustainability indices for bivalve aquaculture and have a view on the document. The outcome of this discussion and further discussions with the separate groups is presented in Section 3.1.1.

2 Adoption of the agenda and appointment of rapporteurs

The agenda (Annex 2) was formally accepted. A general discussion on plans for each WGMASC Term of Reference was held. The WGMASC decided to continue the past practice of addressing most ToRs separately within subgroups, followed by plenary sessions where subgroup activities are discussed by the full WGMASC and the draft report is formally accepted. The discussions on ToRs overlapping with WGEIM were supplemented with members from the WGEIM (see Section 8). Subgroup leaders appointed by the WGMASC Chair acted as rapporteur for preparing draft reports from the work of subgroups and reported on their group's activities during plenary sessions.

Since there were only 9 members present, the ToRs were critically reviewed to see how the work could be best organised. There were three new ToRs in 2010, and three ToRs that had been worked on in 2009. As in other years it was decided to address ToR a (*identify emerging shellfish aquaculture issues and science advisory needs*) in plenary sessions with the chair as rapporteur. ToR b (*Site selection criteria in molluscan aquaculture*) was started in 2010. The subgroup leader for this ToR was Bela Buck. ToR c and d) (*aquaculture transfers between sites/countries – guidelines and records (ToR c) & impact on wild stock (ToR d)*) was started in 2008 as one ToR. Both concern bivalve aquaculture transfers and are closely related. It was decided to aim for completing ToR c (*guidelines and records*). Kris Van Nieuwenhoven was the subgroup leader. For ToR d (*impact on wild stock*) Matthias Brenner was the subgroup leader. ToR e (*effects of climate change on shellfish aquaculture*) started in 2008 and was continued with Peter Cranford as the subgroup leader. ToR f (*Potential and current contributions of MASC to* *the Strategic Initiative on Coastal and Marine Spatial Planning (SICMSP)*) was officially cancelled by ICES for 2010. However the WGMASC felt that they can already contribute to the subject by summarising what they have produced earlier in relation to Coastal and Marine Spatial Planning. This was thought to be important as the EU will bring out new policies that may have an effect on aquaculture in the near future. Gesche Krause was subgroup leader. And finally, having a joint meeting with WGEIM fits well into ToR g (*Plans to promote cooperation between EGs covering similar scientific issues*). The Chair reported on this ToR.

3 Identify emerging shellfish aquaculture issues and related science advisory needs for maintaining the sustainability of living marine resources and the protection of the marine environment (ToR a)

3.1 Emerging shellfish aquaculture issues

The purpose of this ToR is to briefly highlight new and/or important issues that may require immediate additional attention by the WGMASC and/or other Expert Groups.

One high priority issue identified in the 2009 WGMASC report is the certification of cultured shellfish. Sustainability issues related to consumption of cultured shellfish receive a lot of attention presently. In response to consumer requests for organic and sustainable products, certification of cultured shellfish is starting. Shellfish make an excellent candidate for an organic product as it does not need input of feed other that naturally occurring phytoplankton and can be produced locally. In addition, cultured shellfish do not only represent a valuable food product, during their life in the coastal zone, they also have a role in ecosystem services such as reducing nutrients in the water column and acting as a carbon sink. Furthermore, shellfish cultivation can enhance alternative livelihoods' in rural areas and provide social welfare. However, shellfish cultivation can have adverse effects on the ecosystem, such as bottom disturbance when dredging for seed (or harvest), enhanced deposition of organic material in local areas and reduction of the carrying capacity for other filter feeding organisms. A variety of organisations use different standards for organic certification. These need to be evaluated and unresolved questions (such as the role of shellfish in ecosystem services) need to be identified and addressed. The importance of this subject was highlighted by the appearance of the Draft for Final Public Comment Period of the Bivalve Aquaculture Dialogue Standards just prior to the meeting. This opportunity was seized to get feedback from both WGMASC and WGEIM on the document (see 3.1.1). The matter also received attention in the last Aquaculture Europe Journal (Vol. 35 (1), March 2010). Furthermore, the other emerging issues identified in 2009 were revisited. One subject raised in 2009 concerns the social conflicts between stakeholders (shellfish farmers, nature conservationists, recreation, fisheries). This is now being treated in the framework of ToR f (*Potential and current contributions of MASC to the Strategic Initiative on Coastal and Marine Spatial Planning (SICMSP)*). In addition, other emerging shellfish aquaculture issues were identified in 2010 (see 3.1.2).

3.1.1 Joint ICES WGMASC and WGEIM Comments on Draft Document: "Environmental and Social Standards for Bivalve Aquaculture" prepared by the World Wildlife Fund Bivalve Aquaculture Dialogue (1 February 2010)

The joint 2010 meeting of the WGMASC and WGEIM included a discussion on this document and the comments below reflect the general scope of these discussions. The WWF standards outlined in this document are designed to minimize key social and environmental issues associated with shellfish farming while permitting the industry to remain economically viable. Overall, the WGEIM and WGMASC (hereafter, "the groups") support the WWF initiative to establish codes of good conduct for all types of aquaculture, including bivalve aquaculture. Such initiatives can provide incentives to promote a sustainable aquaculture industry and consumer confidence. Both ICES expert groups have provided advice on the evaluation of the effects of shellfish aquaculture activities in previous annual reports and numerous other ICES groups have provided guidelines on methodologies for the evaluation of human impacts in the marine environment.

Some of our comments on the WWF Bivalve Aquaculture Dialogue (BAD) certification standards (herein defined as "the standards") rely on the WGMASC recommended framework for the integrated management of shellfish aquaculture (WGMASC, 2009[1]) as a means of comparing our previous recommendations with the content of the WWF standards. It is recognized that the management framework recommended by the WGMASC and the WWF BAD differ fundamentally in that the former represents a potential governance-approach to ensuring sustainable culture practices for potential use by regulatory agencies while the latter takes a market-based approach with the associated costs largely borne by industry. Although both approaches share many of the same principles, we recognize that a cost-effective approach is needed to provide smaller operators and less developed countries with an opportunity to obtain certification.

Certification schemes for shellfish culture need to cover all the aspects of ecosystem-based management, including considerations of the social, economic and environmental impact. The WGMASC (2009) framework recommended an ecosystem approach be taken to aquaculture management that is comprehensive and based on the best available scientific knowledge of the ecosystem and its dynamics. Actions are designed to be taken on the influences of aquaculture developments that are critical to the health of ecosystems, thereby achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity.

Ecosystem interactions with bivalve aquaculture are well known to be highly complex and both positive and negative environmental effects can occur simultaneously as a result of bivalve husbandry practices. The groups thought that the standards do not fully encompass the complexities of the interactions between bivalve culture and the environment. For example, the potential for some positive effects on biodiversity due to bottom culture are not also considered for off-bottom culture. In addition, it was recognized by the groups that aquaculture is typically not the sole stressor in areas where bivalve culture is conducted and that these too must also be addressed and considered when evaluating the influence of bivalve culture in the environment. For example, the potential for a positive net cumulative effect of different human activities, such as mitigation of eutrophication through the introduction of bivalve filter feeders, are not included in the analysis of the effects of culture sites.

The WWF standards represent a simplified ecosystem-based approach in which performance standards were developed to address a reduced subset of environmental issues (particularly Principles 2, 3 and 4) that were identified as being critical during the open WWF BAD dialogue process. Again, this excludes many ecosystem services that the cultured bivalves provide that may mitigate the specific negative effects identified during the dialogue process. While it can be assumed that cost considerations for small aquaculture operations were instrumental in the development of this simplified approach, the rationale for omitting a wide range of known environmental interactions with bivalve culture (both positive and negative) should be more fully described in the preamble to the standards document.

The WGMASC (2009) recommendations noted that "it is essential that the development of a management framework should be inclusive with diverse stakeholder participation, transparency and communication." Although science has an important role in advising managers and policy-makers on the ecological consequences related to available management options, sustainability decisions need to be made within a framework that is both science- and ecosystem-based, but which also incorporates societal values. The WWF standards were developed based on wide stakeholder participation in multiple dialogue workshops and in the global decision-making body. The open participatory approach utilized by the WWF, which included science input at all stages, was an iterative multi-stakeholder process that provided an outcome that reflects this diverse input. Although scientists can identify areas for improvement, we also respect the fact that the recommended process was followed for the development of the standards and that the outcome reflects both science and socio-economic perspectives. Nonetheless, there was a concern from some members within the groups that the Bivalve Aquaculture Dialogue process in general did not fully consider social issues with respect to setting standards for sustainability. There were concerns that the application of the standards could be used as a mechanism by which producers that do not wish to subscribe to the standards (whether they would meet them or not) could be negatively affected due to public perception. The groups acknowledge the stated goal of the authors to achieve bay-wide compliance and participation in the programme, however, this goal may not be practical. Consequently, non-subscription by some producers within an area may have implications on adjacent or near-by producers that may wish to apply for standardization. An example of an attempt to consider social issues with respect to setting standards for sustainability is the EVAD programme (Guide to the co-construction of sustainable development indicators in aquaculture) developed by INRA with IFREMER contribution[1]. Indicators must be developed by various stakeholders based on substantial feedback, evaluated, and reformulated as needed to address the 'local' issues of concern.

The groups noted that the draft standards show inconsistencies with respect to the approach and quantitative nature described for assessing the different principles and criteria. Some standards are very specific with defined thresholds whereas others are more directional. For example, limits for sulphides under some circumstances are set at 3000 μm whereas other risks are suggested to be manageable "with appropriate designs and monitoring".

A large focus of our discussions was on Principle 2 of the standards (Avoid, remedy or mitigate significant adverse effects on habitats, biodiversity, and ecological processes). This principal was seen by the groups as both the strength and weakness of the document. It provides clear limits on two metrics to which producers must adhere. The groups acknowledged that this broad approach has been recommended in

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[1] http://www.inra.fr/coordination_piscicole/groupes_de_travail/systeme_d_elevage/evad

the past by ICES for a number of topics, and is correctly applied in the development of these standards. However, it was thought by some members within the groups that the suggested limits are too prescriptive (i.e., the setting of very precise limits for certain metrics applied on a global scale) whereas others though that a good balance was met and this approach has been recommended numerous times by ICES for a number of topics. Although limits are needed to make any standard a standard, some members of the groups thought that there should be increased flexibility in the proposed standards to make allowances for regional or site-specific realities of culture sites in some areas. That being said, specific methods that are being used regionally and that show equivalent levels of condition of the environment are admissible to be used in lieu of prescribed metrics where available and, as such, the prescriptive nature of the principle is offset by this in some way.

The link between sediment organic loading and benthic communities and chemical indicators, such as sulphides, is well established and the latter may be used to monitor the degree of organic loading. A single indicator of the potential effects of seabed organic enrichment on benthic habitat and communities was identified (total 'free' sulphide). This indicator was recommended by the WGMASC (2009), but in conjunction with supporting information by other indicators. The use of at least two environmental performance indicators was encouraged to address this issue as a precaution towards preventing erroneous certification decisions. It was noted that the indicator of impact due to organic enrichment does not respond solely to biodeposition from bivalve aquaculture. The monitoring programme associated with this document has yet to be made available and so the group cannot comment on this aspect of the document. It was generally recognized that this may be one of the most important aspects in this process. As written, it is difficult to assign cause and effect based on available sampling approaches for evaluating benthic effects. Off-bottom sites are often located in the deepest areas of culture areas; locations that are also naturally the richest in organic material as they are often depositional in nature. Therefore, sampling reference (control) sites located outside of the aquaculture site(s) is potentially confounded. In addition, plankton depletion by farms may occur over large spatial scales such that sedimentation rates outside of farms are decreased below the normal values. This would result in decreasing organic loading outside of farm areas and decreased sulphide levels, further confounding comparison between farm sites and reference sites. The farm monitoring program design is critical and the standards cannot be practically implemented until a consensus is reached on the applicability and scientific effectiveness of the selected design. Some additional considerations in deriving the design of sampling methodologies include:

- Geographic and topographic location (e.g. Rias, Fjords, bays, estuaries…);
- Seasonal and spatial variation in an indicator;
- Sampling intensity required to prevent type I and II statistical errors in different environments;
- Scientific peer review of the monitoring program is an essential step in this process.

Some discussion by the groups focused on using alternate indices of phytoplankton depletion. One suggestion was the use of meat yield of farmed bivalves based on the logic that the farmers want this maximized to ensure the greatest return on their investment. This approach focuses on the product itself, the production of which requires good growing conditions including adequate food supply and quality of water. This approach may help address systems that are organically enriched and within which primary productivity and standing stock are great enough to support the proposed biomass of bivalves in the system. However, it was felt that bivalve growth and stock yield is responsive to numerous environmental variations that vary over temporal and spatial scales, and every producer would not be open to sharing meat yield data. In addition, the methods needed to evaluate this indicator and make clear cause-effect links to environmental condition have not been developed. Again, scientific peer review of these proposed monitoring approaches is essential in this process.

A comparison of the current certification standards with other similar documents (e.g., the draft WWF Salmon Aquaculture Dialog - SAD) suggests that the indices selected for bivalve certification are relatively restricted. In contrast, bivalve culture is arguably much more complex in terms of its interactions with the environment than is fish cage farming. The SAD has been ongoing for some time and yet the BAD is moving forward with insufficient time to comment on it appropriately. Similarly, additional time is needed to evaluate the effectiveness of benthic effect monitoring protocols when they become available. Although the current BAD process had an extensive outreach component to seek input from various groups during its development, some members in the groups were not aware of the dialogue until very recently. It was felt that the process is moving too quickly for the groups to have meaningful input. The WWF standards can be improved by continuing the dialogue process and by the continued provision of stakeholder knowledge.

In summary, we feel that it is good that the WWF has initiated this dialogue. Although we may not wholeheartedly endorse the restricted number of indicators they have selected to measure, clear criteria have been selected. The feeling was fairly unanimous within the groups that the metrics they have chosen are the simplest but that this provides a very truncated view of the interactions between bivalve aquaculture and the environment. Notwithstanding our concerns, it is, after all, up to the WWF and the process they have put in place to identify the criteria to measure. Ultimately, this is their decision based on the dialogue process.

3.1.2 Other emerging shellfish aquaculture issues

(<u>not</u> listed according to priority)

- <u>Restoration of cultured shellfish populations</u> is practiced in the United States for the American oyster. In France, oyster farmers faced with oyster mortalities consider restocking *Crassostrea gigas* from Japan as a means to genetically rejuvenate the population, in spite of lack of scientific proof. Identification of the right conditions for restocking is necessary. E.g. the scallop fishery in "Rade de Brest" (France) is largely dependent on hatchery production and restocking because the wild stock never recovered from severe depletion after 1963 cold winter, and following competition with *Crepidula*. Furthermore, development of a protocol is needed. Restoration, or rebuilding of spawning biomass for aquaculture purposes may be a solution for the European oyster *Ostrea edulis*. This species became extinct in a number of areas as a result of human activities. The Belgian oyster beds around the Hinderbanken were completely depleted by fishermen around 1870. This was due to the introduction of steamships which are capable of faster oyster harvest and transport (Slabbinck *et al.*, 2008) Slabbinck B., Verschoore K., Van Gompel J., Hugenholtz E. 2008. Natuurgebieden in de Noordzee voor Natuur en Mensen (in Dutch), 22p). It is a high valued species for fisheries and aquaculture. Restoration of the native population may not only benefit aquaculture, but it can also increase the value of the ecosystem. For *O. edulis* in *Bonamia* infested areas it needs to be investigated if a *Bonamia* resistant stock can be used. In addition, social-economic issues such as who will pay the restoration need attention.

- Nutrient trading as a mitigation measure for coastal eutrophication is a relatively new topic that is gaining considerable support from different industries and regulators. It entails trades between companies discharging excess nutrients to coastal waters (e.g. fertilizer run-off and organic waste discharge) and aquaculture farms that produce shellfish that can help to moderate phytoplankton concentrations act as a nutrient sink when harvested. This gives added value to shellfish aquaculture and increases shellfish production. However, there are still unresolved questions such as: to what extend do shellfish act as nutrient sinks relative to the nutrient supplies; are there contaminants associated with the nutrient inputs that would affect the production and marketability of cultured shellfish; social questions such as who pays the farmers; and under what circumstances is this trading scheme actually effective. The latter consideration is related to the site-specific nature of the relative importance of many environmental interactions with shellfish culture. It is important to balance the positive effect of the nutrient removal in the shellfish harvest with the potential negative effects of nutrient retention in the coastal zone that may occur as a result of the biodeposition activities of the introduced shellfish (e.g. Cranford *et al*., 2007. Influence of mussel aquaculture on nutrient dynamics in a nutrient enriched coastal embayment. Mar. Ecol. Prog. Ser. 347: 61-78).
- Recently some new discoveries on the use of shellfish compounds to cure diseases were made that can change some public perceptions on the impact on human health of shellfish consumption. Despite severe regulations concerning toxic algae and bacterial contamination, shellfish suffer from an image that consumption involves a risk of becoming ill. On the other hand, an extract of *Mercenaria mercenaria* is a strong growth inhibitor of cancer in mice (Bo Leng, Xiao-Dan Liu, Qing-Xi Chen* :Inhibitory effects of anticancer peptide from Mercenaria on the BGC-823 cells and several enzymes, FEBS Letters 579 (2005) 1187–1190); poalin, a drug made from abalone juice, is an effective inhibitor of penicillin resistant strains of bacteria; oyster juice has been found to have anti-viral properties; and mussel extracts can protect against nuclear contamination (http://www.manandmollusc.net/beginners_uses/3.html). These and other claims that shellfish extracts can cure diseases need to be reviewed to identify if they are incidental or more common.
- Co-management is defined as "a situation in which two or more social actors negotiate, define and guarantee amongst themselves a fair sharing of the management functions, entitlement and responsibilities for a given territory, area or set of natural resources" (Borrini-Feyerabend *et al*., 2000). Co-management arrangements are apparent in different cases worldwide and is becoming more relevant for shellfish aquaculture, but is often not institutionalized. The participating stakeholder groups (e.g. shellfish associations, scientists, decision-makers, governmental bodies) all have different and sometimes diverging interests on why they engage in this process. Thus, it is are often subject to dispute and conflict if the respective management regimes are not established properly. The new policy and man-

agement advancements at the EU level, such as the recent marine spatial planning framework, focus strongly on stakeholder participation on all levels in a devolution process within a more institutionalized context. To address the respective technical, economic, social, and political challenges of shellfish cultivation, specific co-management strategies are needed that are either more results-oriented (e.g., for integrating technical knowledge of the participating sectors) or more process-oriented (e. g., for establishing new linkages between different groups) (Michler-Cieluch and Krause, 2008). However, it remains to be seen if this arrangement is applicable for shellfish cultivation.

3.2 Recommendation

The WGMASC recommends to continue ToR a to identify and report on emerging shellfish aquaculture issues and related science advisory needs for maintaining the sustainability of living marine resources and the protection of the marine environment.

3.3 References

Borrini-Feyerabend, G., Farvar, M. T., Nguinguiri, J. C., and Ndangang, V. A. 2000. Co-management of Natural Resources: Organising, Negotiating and Learning-by-Doing. GTZ and IUCN, Kasparek Verlag, Heidelberg, Germany http://nrm.massey.ac.nz/changelinks/cmnr.html.

Michler-Cieluch, T., and Krause, G. 2008. Perceived concerns and possible management strategies for governing “wind farm–mariculture integration”. Marine Policy, 32(6): 1013–1022.

4 Review the state of the knowledge of site selection criteria in molluscan aquaculture with particular reference to accessing and developing offshore facilities (ToR b)

4.1 Background

Spatial competition for aquaculture sites along coastal seas has encouraged the initiative of moving shellfish aquaculture into the open ocean at exposed sites, particularly within the European Economic Zone. These offshore sites require an understanding of the adaptive capabilities and limitations in growth potential for species at these sites, the development of new technologies capable of withstanding these high energy environments and the necessary institutional arrangements (e.g. marine spatial planning). It is also essential in site selection to consider biotic and abiotic factors in association with economic, ecological and socio-economic perspectives, whether in the coastal zone or at offshore locations. Beside basic investigations on these parameters conditions of a preferred site can be investigated by analysing the overall health status of shellfish grown in different areas (e.g. blue mussels) as a bio-indicator of site suitability. This ToR aims to: assess site selection criteria in ICES countries; provide an overview of current research and commercial operation on offshore shellfish farming, both for spat collection or for ongrowing to market size. In addition, it is intended to investigate the sustainable use of oceans by integrating aquaculture and fisheries and assess the potential for combining shellfish culture with other offshore constructions such as renewable energy facilities or any other.

ToR B “Review the state of the knowledge of site selection criteria in molluscan aquaculture with particular reference to accessing and developing offshore facilities” is a very complex subject and was the first time discussed in the WGMASC at the annual meeting in Galway (IRL) 2010. During the meeting and the ongoing work on this ToR we decided to present an introduction into "Offshore Shellfish Cultivation". Further, an overview on the current status of offshore shellfish cultivation will be presented. Due to the number of ToRs in 2010 and the limited time, ToR b will be discussed in more detail during the following meetings.

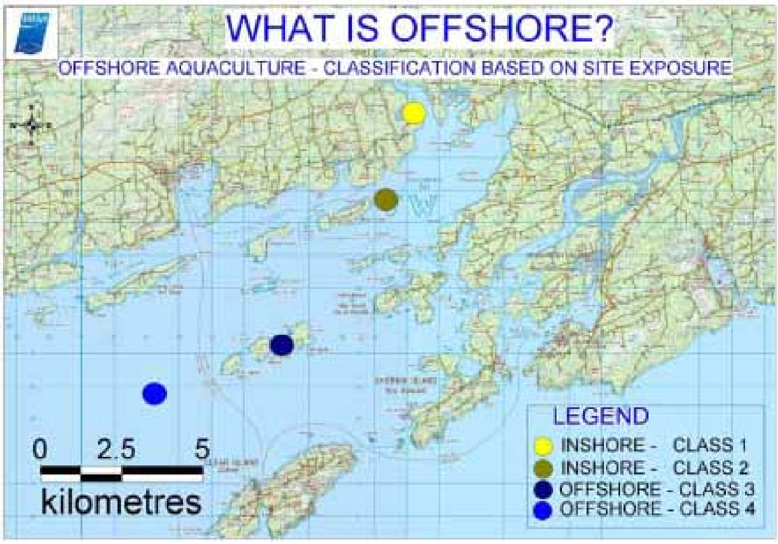
4.2 Workplan

In this first year (2010) the topic of site-selection criteria with particular reference to offshore areas has to be defined. Further, the state of the art of offshore shellfish culture has to be reviewed as well as the various intentions to move off the coast into high energy environments in ICES countries. In addition, biological, technical, and economic records are to be reviewed with special focus on site-selection. In Year 2 (2011) the collection and collation of data has to be continued, especially for ecological site-selection criteria. ToR b will be completed in Year 3 with a final report including recommendations on scientific tools for decision support and of shellfish culture in offshore areas in general.

4.3 Definition of the term "offshore aquaculture (OA)"

Offshore aquaculture (OA), also described as open ocean aquaculture (OOA), is a culture operation in a frequently hostile open ocean environment. It is defined as being in a marine environment fully exposed to a wide range of oceanographic conditions (Ryan, 2004), such as strong currents and swell as well as high waves. This increased exposure to higher wave energy is linked to distance from shore or lack of shelter from topographical features such as islands or headlands that can mitigate the force of ocean and wind-generated waves. Following Buck (2004), offshore sites are at least eight nautical miles off the coast to avoid tremendous stakeholder conflicts in nearer coastal areas (Dahle *et al.*, 1991). However, exposed sites are also existent in nearshore areas. Therefore, the term "offshore" should be defined specifically from case to case. Figure 4.1 will help to classify if certain sites are located offshore.

The classification scheme of the Norwegian government for offshore fish farms is based on significant wave heights (Table 4.1) and does not include factors such as wave periods and water current speed. Therefore, this classification is less desirable for use in site-selection for offshore shellfish cultivation.



Class	1	2	3	4
Conventional Description (In relation to site exposure)	Sheltered Inshore Site	Semi-Exposed Inshore Site	Exposed Offshore Site	Open Ocean Offshore Site

Figure 4.1. Site classification as a definition for the term "offshore" (modified after Ryan 2004).

Table 4.1. Norwegian Aquaculture site classification scheme (in Ryan, 2004).

Site Class	Significant Wave Height (Metres)	Degree of Exposure
1	<0.5	Small
2	0.5-1.0	Moderate
3	1.0-2.0	Medium
4	2.0-3.0	High
5	>3.0	Extreme

4.4 Summarise the reasons to move offshore

The development of "offshore aquaculture" or "open ocean aquaculture" has often been described as the "Blue Revolution", which puts aquaculture development on the same scale as the advances made in agriculture during the so-called "Green Revolution". The rationale for the emergence of scientific considerations and semi-commercial trials to develop aquaculture operations off the coast is quite diverse. Table 4.1 gives an overview of the main reasons for the offshore development.

Table 4.2. Overview of the main reasons for the development of offshore shellfish aquaculture.

No.	Group	Reason to move off the coast
1	SPACE/ ACCEPTANCE	Trends towards larger production unit sizes and lack of inshore sites for aquaculture expansion and/or development (especially in countries where capital for aquaculture development is available).
		Perceived constraints on carrying capacity and increasing pressures on coastal habitats from many resource users, making site acquisition for mariculture development increasingly difficult.
		In some regions there may be reduced conflicts with other user groups (such as shipping [trade or private], recreational activities, extraction or disposal of gravel, marine missions, fisheries, mariculture, offshore wind farms, cable and pipelines, establishment of nature reserves and other marine and coastal protected areas) and therefore better acceptance among stakeholder groups.
		Potential multifunctional use of sites of other stakeholders.
2	WATER QUALITY/ IMPACT ON ECOSYSTEM	Higher exchange of oxygen.
		Lower exposure to human sources of pollution (e.g. urban sewage) and therefore cleaner water column.
		Constant temperature due to larger water body (less stress).
		Higher mixing, availability and renewal of phytoplankton.
		Moving offshore could potentially reduce environmental impacts, reduce disease and improve candidate performance.
		The potential to reduce some of the negative environmental impacts of coastal shellfish farming, and optimal environmental conditions for various marine species through the larger carrying and assimilative capacities.
3	DEMAND/ PRODUCTION	World demand for seafood increases annually or by 40% to approximately 180 million tonnes by the year 2030.
		The development of offshore aquaculture can lead to an increase in production and could therefore be a party solution.
4	EQUIPMENT/ TECHNIQUES/ DESIGN	Operating and infrastructure costs (vessels, land-based facilities) as well as the infrastructure support systems are similar to existing inshore farming systems (however, some retrofitting might be necessary).
		Offshore systems can be constructed in a different design than installations nearshore (more space and therefore larger farm potential, deeper water allows submergible designs => less conflicts with shipping operations).
		Potential to connect aquaculture installations with existing infrastructure (e.g. oil and gas platforms, offshore wind farms).
5	CO-USE WITH EXISTING OFFSHORE INSTALLATIONS	See in 4 above.
		Infrastructure for regular servicing may be shared (both industries require multi-use sources of transportation, preferably with lifting capacities to install and change plant components) - this provides an opportunity for both enterprises to share these high-priced facilities.
		Options to link individual activities of various offshore installations (for instance, charter contracts for specially-designed mussel harvesting vessels could be aimed as a solution for transporting e.g. wind farm technicians to the offshore location at times of planned, preventive operation and maintenance activities).
		Placement of mariculture devices in defined corridors between e.g. wind farm turbines reduces the special need through multiple use of ocean territories.

No.	Group	Reason to move off the coast
		seabed topography offshore (with an increasing distance from the shore) changes into deeper water which allows the submersion of equipment thus reducing the drag and load (due to wave action) on the entire system
6	MISCELLANEOUS	Submergible systems allow the overstay during severe winter periods thereby saving money.
		In some regions offshore shellfish aquaculture can provide a new product to the market. This new product can support other sectors such as tourism (tourists come to the Belgian village Nieuwpoort to eat the Belgian mussels), fish auctions (Belgian mussels are an important new product for the Nieuwpoort fish auction).

4.5 How can one deal with the offshore situation being in a high energy environment: potentials and constraints

A review of the French situation of shellfish culture in "deep water" was recently presented at the Aglia conference in Nantes, France (Mille, 2010). Two species are concerned: mussels mainly, and cupped oysters more recently. Different techniques are used for "deep water" culture in France, but suspension technique is dominant as far as real OA is concerned. Lots of trials and projects have existed, but few large scale operations are still running. Mussel culture in the Mediterranean Sea along the French coast was the first operation and produced 10,000 tons in 1995, but production dropped down to 3,000 tons mainly because of sea bream predation. The other large OA operation was mussel culture in "Pertuis Breton" on 244 longlines. This site was devoted to spat collection, pre-growing and market size production.

In Germany, no commercial offshore farm exists yet. The mussel cultivation in Germany is based on an extensive on-bottom culture (Seaman and Ruth, 1997) and depends entirely on natural resources for food, spat and space. Due to stakeholder conflicts (e.g. Buck *et al*., 2004) and a lack of spat availability (Walter and Liebezeit, 2003), mussel farmers tend to move offshore where space is not limited and adequate settlement guaranteed. Newcomers – the offshore wind farmers – are covering large areas in the German Bight which in contrast give the opportunity to use these areas in a multifunctional way by accepting mussel cultivation within the wind farms. All attempts to move mussel aquaculture off the coast to a more hostile environment are on pilot scale yet.

In Iceland there were no attempts yet to move shellfish operations off the coast into the open ocean.

As the Belgian part of the North Sea is used intensively by dredging, military, shipping, wind farm and fisheries activities almost no space is left for offshore mariculture. Therefore, the 4 mussel areas (Figure 4.2) that were appointed by the "Ministerieel Besluit" (Ministerial Decree) MB 97/16166 were chosen because they could not be used for other activities. The area D1 is situated near a shipwreck, the areas Oostdyck and Westhinder are located in the proximity of a measurement or radar pole and the area "op en achter de Thorntonbank" (on and behind the Thorntonbank) is appointed as an area for wind farms.

The area D1 is located 10 km from the harbor of Nieuwpoort and, as it is the closest area to the coast, is preferred by the farmers. The main disadvantage of the area is the depth of only 8 meters, which makes the use of submerged longlines impossible. This forced the farmers to find alternative technologies such as buoys and cages (Figure 4.3). A disadvantage of the buoys was their weight (about 7 tonnes without mussels) which required an expensive and slow working vessel with a crane. Another structure, a pontoon with cages, did not have this disadvantage. At the moment this area is the only commercially used offshore shellfish area in Belgium.

The area Oosdyck is located 25 km from the harbor of Nieuwpoort and is even shallower than the D1 area (only 7 m). The area is located on top of the sandbank and therefore exposed to breaking waves as on a beach. The area is characterized by a low spatfall and slow mussel growth (Van Nieuwenhove 2008). This area is only used for experimental trials.

As the Westhinder area is a little deeper (11 m) farmers try to use submerged longlines in this area. The area is located 32 km from the harbor of Nieuwpoort and is only used for experimental trials.

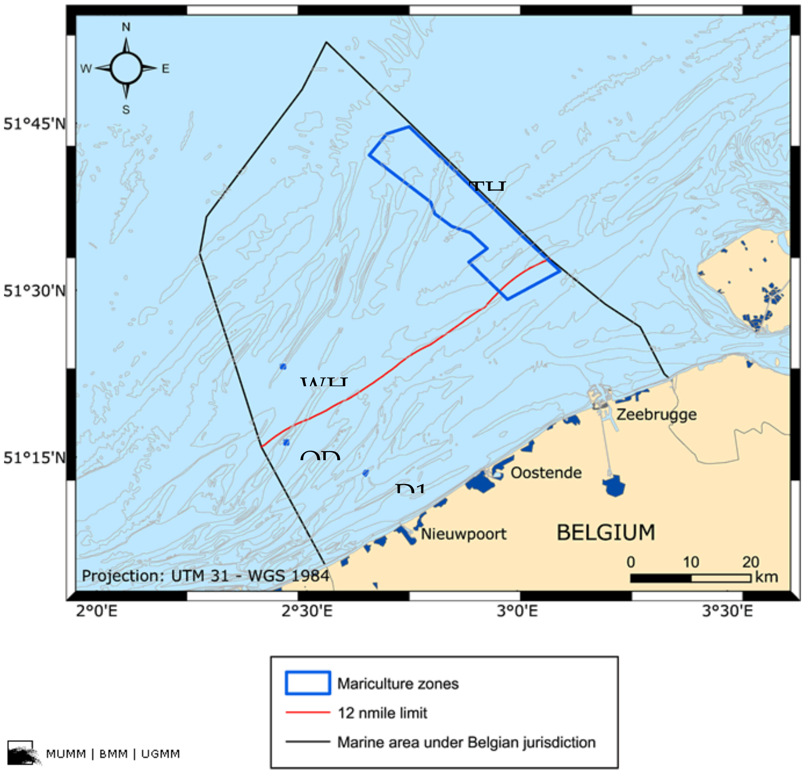


Figure 4.2. Location of the Belgian mussel areas D1, Oostdyck (OD), Westhinder (WH) and Thorntonbank (TH) (source: www.mumm.ac.be).

Figure 4.3. Example of a D1 mussel cage.

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

Canada has some experience in offshore fish farms. The fourth conference on Open Ocean Aquaculture was held in Canada too (see above). However, offshore shellfish farming in Canada is a new option. One mussel farm company just received funding for the development of a submersion system for offshore (exposed) mussel farms.

In The Netherlands no offshore farms are present. A desk study and sampling of buoys of shipping lanes was carried out to study possibilities for off-shore mussel farming . This yielded a report which included a map with potentially suitable areas (Steenbergen *et al*., 2005).

Information from the USA, Ireland, Norway, and Spain will be included in next year's report.

4.6 Current stage of OA in ICES countries and beyond

4.6.1 Conferences and feasibility studies on offshore aquaculture with special focus on shellfish cultivation

A number of international meetings regarding offshore aquaculture took place in recent years. In 1997 and in 2004 the International Centre for Advanced Mediterranean Agronomic Studies (CIHEAM) organised workshops on Mediterranean Offshore Aquaculture at the Mediterranean Agronomic Institute of Zaragoza (IAMZ) in

Zaragoza (Spain) (Muir and Basurco, 2000). In 1998, the Faculty of Mediterranean Engineering in Haifa (Israel) ran a workshop entitled Offshore Technologies for Aquaculture (Biran, 1999). The best-known meetings on offshore aquaculture were probably the four international conferences on Open Ocean Aquaculture held in Maine (US) in 1996 (Polk, 1996), in Hawaii (US) in 1997 (Helsley, 1998), in Texas (US) in 1998 (Stickney, 1999) and in New Brunswick (Canada) in 2001 (Bridger and Costa-Pierce, 2003). The US Sea Grant Programme was the main sponsor of the first three events, and the World Aquaculture Society ran the fourth conference. In 2009, a conference also sponsored by Sea Grant and German Research Institutions on "The Ecology of Marine Wind Farms: Perspectives on Impact Mitigation, Siting, and Future Uses" was hold in Rhode Island (US) with a main focus on shellfish farming (Costa-Pierce 2009). In Europe, similar conferences were organized by various institutes and universities. In Germany, two workshops were held regarding the combination of offshore facilities with offshore aquaculture in Emmelsbüll-Horsbüll in 2003 (Ewaldsen, 2003) and in Bremerhaven in 2004 (Michler, 2004), respectively. In the Netherlands three workshops took place on similar aspects in Amsterdam in 2003 (Emmelkamp, 2003) and 2006 (van Beek *et al.*, 2008) as well as in Den Haag in 2007. In London (UK) a stakeholder meeting was organised in 2005 for the suitability of offshore aquaculture in existing offshore structures (Mee and Kavalam, 2006) and in Ireland a conference on "Farming the Deep Blue" was held in 2004 (Ryan, 2004). Finally, a series of conferences called "Offshore Mariculture" were held in St. George's Bay (Malta) in 2006 and in Alicante (Spain) in 2008. The 2010 meeting will take place in Dubrovnik (Croatia). Other further meetings are organised by e.g. the Kiel Institute for World Economy in 2010. Most conferences and workshops presented the current research in proceedings. Further publications on the feasibility of offshore aquaculture were published regarding aquaculture enterprises in the German North Sea by Buck (2002, 2007a), by Michler-Cieluch (2009) and by Brenner (2009). For the Belgium Atlantic Coast Delbare (2001), MUMM (2005) and Van Nieuwenhove (2008) published reports on offshore aquaculture, for the Netherlands a study that explores the possibilities for mussel culture was written by Steenbergen *et al*. (2005) and for the French coast a report was published too (Mille, 2010).

4.6.2 Biological Research on OA

Biological based investigations include growth performance, larval abundance, and settlement, resistance to a harsh conditions, as well as health and fitness.

Mussels cultivated in offshore areas mostly show high growth rates (e.g. Buck 2004; Buck 2007b). This is due to the fact that water quality (e.g. urban sewage) and oxygen concentration are suitable and the infestation of parasites is low or not existent. Larval abundance decreases with increasing distance from shore (Walter *et al.*, 2001) but is still sufficient at existing offshore farm sites (Buck, 2007). The resulting settlement can lead to a one-step cultivation technique (no thinning procedure. The lower settlement success on one hand results – of course – in a limited commercial potential but on the other hand eases handling and maintenance.

The resistance of mussels to strong currents as well as high waves and swell depends on the degree and duration of these forces. Mussels cultivated in a high energy environment will sooner or later adapt to this permanent physical stress. The growth performance of byssus threats changes in a stronger attachment as well as in the development of more threats.

In nearshore intertidal areas, mussels are particularly exposed to high concentrations of pollutants, pesticides, near surface agents and estuarine runoffs etc, which can pose a threat to consumer health. The scope of growth, i.e. the energy available for growth, is usually directly and positively correlated to a good overall health condition of the respective organism (Allen and Moore, 2004). But organisms with high growth rates and a healthy appearance are no guarantee of a healthy food for human consumers. In waters, eutrophicated by urban sewage, mussels show good growth performance. The microbial status of these mussels, however, excludes them most likely from consumption, since they might carry various human pathogens. Even in developed countries with strict legislation for the treatment of wastewater, mussels can function as carriers of serious infections. Whether this is also true for offshore cultivated mussels, where the environment is cleaner due to dilution of contaminants, remain open.

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

4.6.3 Technical Research on OA

Traditional longline techniques cannot cope with the increased exposure to wave action, currents and wind as a result from moving offshore. The challenge in developing offshore shellfish systems is to create a combination between a system that is strong enough to withstand the offshore conditions and that is easy to access and to manipulate by the farmers. Rather than using very strong and heavy materials there is a need for smart solutions such as keeping the tension on cables low, prevent the occurrence of sudden peak forces on the cables and prevent the excursion of the structure under sea state and current forcing (Hampson *et al*., 2010).

In 1998, the University of New Hampshire initiated the Open Ocean Aquaculture Demonstration Project to investigate the commercial potential of environmental responsible seafood production, employment opportunities, engineering solutions and operational methodologies of offshore aquaculture (Bucklin & Howell 1998). As part of the project Langan & Horton (2003) deployed two 120 m submerged longlines for shellfish culture 10 km off the coast of Portsmouth (New Hampshire) in the south western Gulf of Maine, where the biological and commercial feasibility of *Mytilus edulis* cultivation were tested. Since then submerged or subsurface longline systems are the used in pilot projects over the world (Hampson *et al*., 2000; Buck 2007b) (Figure 4.4). These are longline systems where the backbone rope is submerged to a depth were wave action has less impact on the system A disadvantage of these systems is the depth needed: the backbone rope must be at least 5 meters below sea surface and therefore it cannot be used in shallow offshore areas (e.g. the Belgian offshore area D1 has a depth of 8 m only). To minimise wave impact on the longlines all surface-reaching objects on the backbone rope such as buoys could be submerged

(Figure 4.5). In this case special attention should be given to surface guard buoys to prevent vessels from destroying the systems. Another submerged construction is the logline system in a segmental design with a variety of different buoys (Buck 2007). This system was tested in hostile environments 17 nautical miles off the coast and withstood waves up to 8m and current velocities up to 1.5 m/s (Figure 4.6–4.7).

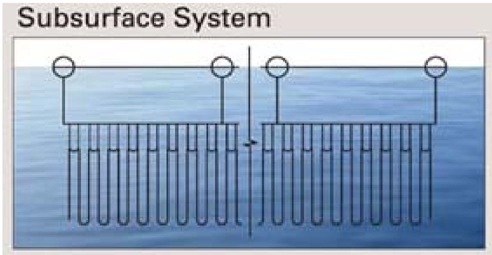


Figure 4.4. Example of a subsurface system for shellfish cultivation (e.g. mussels).

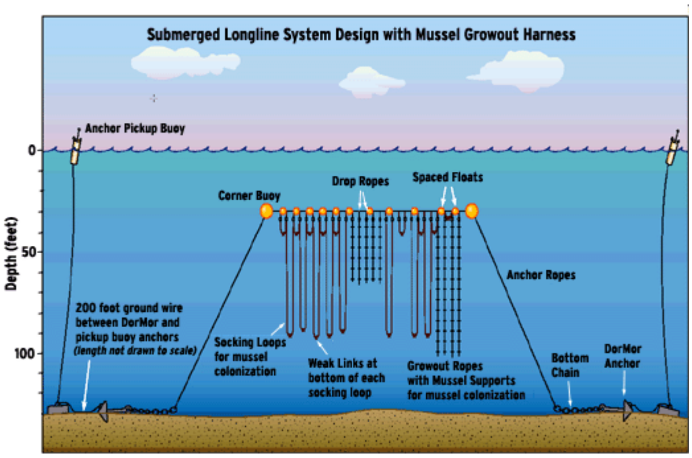


Figure 4.5. Subsurface longlines. No buoys attached to the backbone rope reach the surface to minimise wave impact. Source: Hampson *et al.*, 2010.

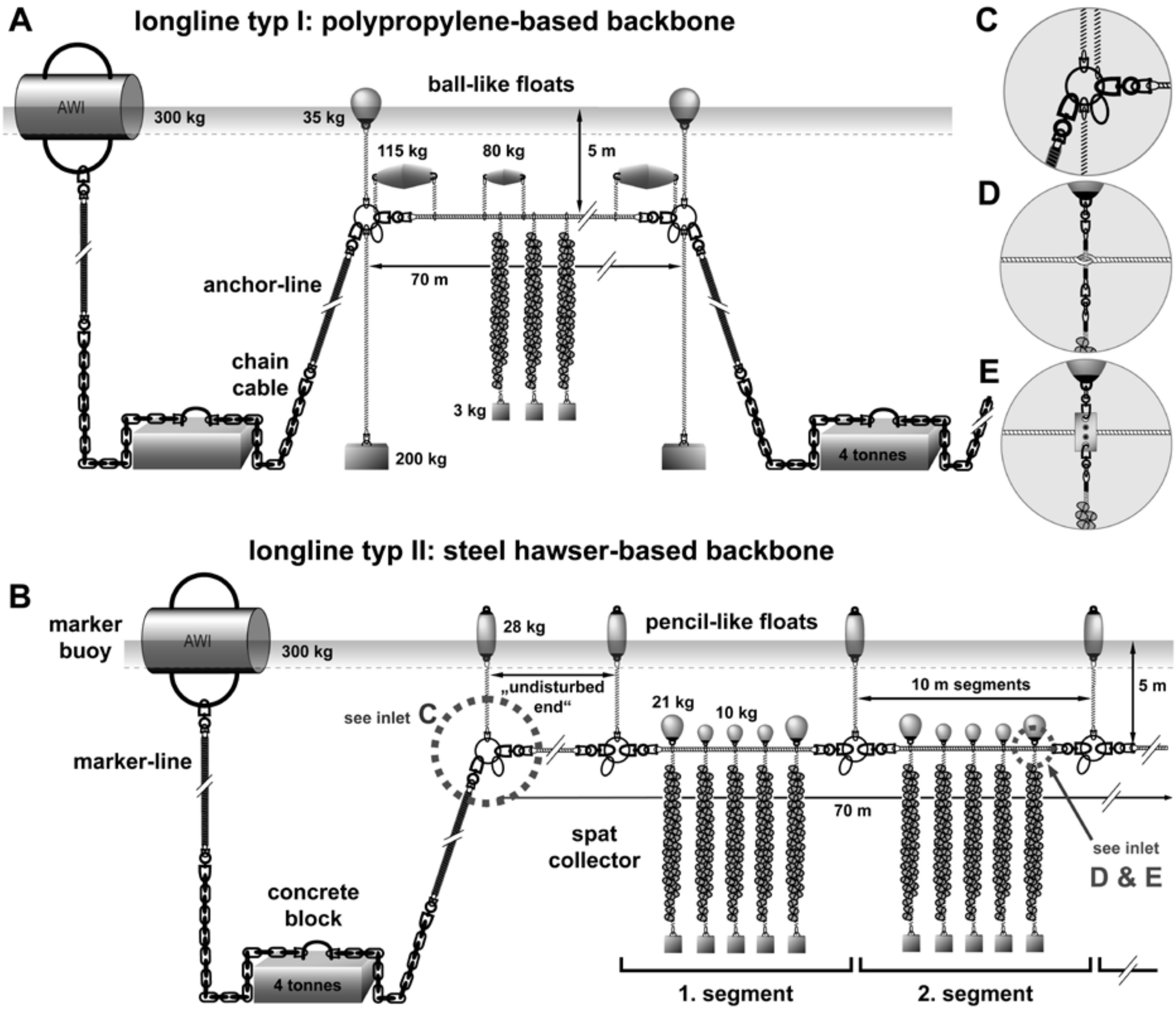


Figure 4.6. Submerged longline system designs with spat collector harness a polypropylene-based longline above (longline I) and b a steel hawser-based longline. The insets show the c coupling elements and d, e the connection of floats and collectors. c Polypropylene and steel hawser, d, e steel hawser (Buck, 2007).

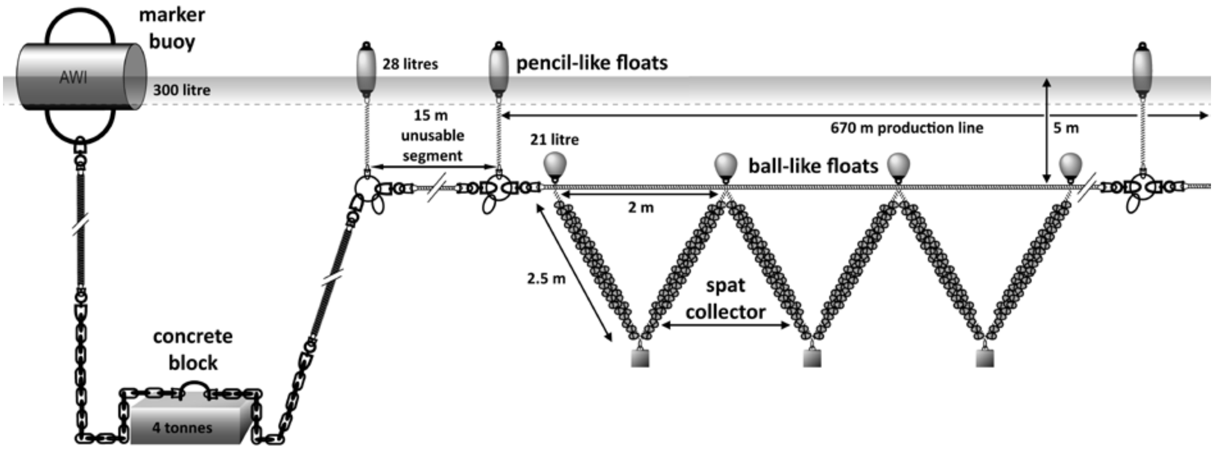


Figure 4.7. Example of a submerged longline system design with a V-shaped spat collector harness. In this image only a part of the 700 m long longline is presented (not to scale) (Buck *et al.*, 2010).

After trials with surface longlines, Belgian offshore mussel farmers tried to use different types of cages and buoys carrying the mussel ropes (Van Nieuwenhove and Delbare, 2008). However constructions that could withstand the offshore conditions had high operational costs and farmers are now thinking about using longlines for their production.

Because of the strong forces working on the culture systems anchoring is a typical problem for offshore shellfish farms. Different anchoring types are in use including heavy concrete or granite blocks, anchors, poles drilled into the sea bed, available constructions such as windmills, etc. The anchoring type used depends on the nature of the sea bed, presence of available constructions and legal restrictions.

Due to the fact that very often weather conditions are harsh and hamper the installation of common technologies offshore wind farming has been proposed for co-use with aquaculture (Buck 2002; 2004). Establishment of offshore wind farm turbines provides space and attachment devices for mariculture facilities and therefore minimizes the risks originating from high-energy-environments (Buck *et al*., 2006). Potential synergies are the placement of mariculture devices in defined corridors between wind farm turbines or the attachment to the foundations of windmills.

4.6.4 Economic potential of OA

More than 50% of the annual worldwide harvest of mussels is produced in nearshore or sheltered areas in Europe. Offshore mussel farms running on commercial scale are not existent yet. The only commercial operated offshore farm running outside of Europe is off the coast of New Hampshire. Therefore, calculating the economic potential of farms within Europe when moving offshore is only possible on a theoretical basis. Buck *et al*. (2010) calculated the potential and economic feasibility of mussel cultivation as a co-use in offshore wind farms. This study compiles the basic data for offshore mussel cultivation in close vicinity to a designated offshore wind farm in the open sea of the German Bight and employs different case-scenario calculations to illustrate the impact of changing parameter values on overall profitability or non-profitability of this activity. Primary focus was placed on the production of consumer mussels but seed mussel cultivation was also taken into consideration. This study concludes with providing some recommendations on how favorable terms or actions could further improve profitability of offshore mussel cultivation. Altogether, the results are intended to shed some light on business management topics that future offshore mariculture operators such as traditional mussel farmers should follow in order to be efficient.

4.7 Site-Selection Criteria

Offshore aquaculture, like any other, should fulfil the requirements for carrying capacity compliance (physical, economical, ecological and social) and ensure the production of high quality products safe and healthy for consumption. Further, more generally, offshore aquaculture should fulfil the requirements for sustainable aquaculture (divided into 3 columns: ecological, economical, social). The following sections, which will be expanded at future WGMASC meetings, may help to define site-selection criteria.

4.7.1 Bio-technical criteria (for animals and human equipment)

"Bio-technical" opportunities and constraints derive from crossing between the requirements (or demand) for/of the cultivated species and husbandry gear/equipment on one hand, and the availability (offer) of environmental conditions of sites. Parameters to be considered are physical (exposure conditions, hydrodynamics), chemical (temperature, salinity…), and biological (food, toxic algae, predators and parasites…), and include:

- Special collector types to be used offshore (e.g. low drag design);
- No antifouling;
- Capacity of mussels conglomerates to adapt to strong currents. If available AND native, use strains which resist strong environments (*M. galloprovincialus* ⇔ *M. edulis*);
- Quantity, and quality of suspended particulate matter including the organic and inorganic sediment load;
- Physical oceanography controlling water temperature, salinity the flux and mixing of suspended particulate matter (shellfish food, pathogens/parasites, particle reactive contaminants) and dissolved materials (oxygen and some contaminants);
- Cleaner environment (oxygen, urban sewage, lower tidal level, constant temperature, permanent mix, availability and renewal of phytoplankton).

4.7.2 Consumption suitability

A detailed analysis of the overall health of cultivated candidate together with data about e.g. parasite infestation, bacteria, virus and toxic algae concentrations can be used to characterise site conditions (Brenner *et al.*, 2009). Organisms growing under optimal water conditions achieve high growth rates and provide best product quality for consumers. Using these data, reliable predictions are possible and economic risks for potential offshore farmers could be reduced.

4.7.3 Ecological criteria

Possible interactions between aquaculture and wildlife preservation, particularly species at risk, and critical habitat have to be considered. In the case of OA, these interactions might be reduced in most cases.

4.7.4 Economical criteria

Offshore culture systems will certainly cause higher investments costs. Therefore, site criteria of a culture plot should be well known to calculate economic risks. The specific conditions of OA have a direct impact on costs of production (investment in adapted boats and equipments, energy costs of transport…). The over-cost or reduced lifespan of the equipment for cultivation (e.g. longlines, buoys, …) or transportation (ships), or eventually the work conditions (harsh environment) or limited time at sea (due to harsh weather conditions) are a specific constraint that may be a limiting factor.

In the case of opportunistic use of existing offshore facilities (e.g. wind turbines or oil and gas platforms), the over-cost should be reduced (e.g. Buck *et al*., 2010). The particular productivity of such sites may also enhance production levels. And then, a better quality of OA products (eventually recognized through labels or certifications) may yield better commercial prices (e.g. bio-products, differentiation).

4.7.5 Social and ICZM criteria

As with any site of the public domain, OA potential zones require collective agreement before allocation (with specific local rules of decision). For such sites, conflict uses should be reduced compared to onshore or nearshore aquaculture (less amenity and patrimony issues). Anyway, traditional former users like fishermen will probably be initially reluctant, even if some of them are part of the project. A solution could be a joint operation such as co-management (and participation).

4.8 Marine Spatial Planning

To be included in 2011.

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5 Review knowledge and report on the significance of bivalve aquaculture transfers between sites (local, national, international) to wild and cultured bivalve stocks: records and guidelines (ToR c)

5.1 Background

Movement of shellfish around the world is an activity that has a long history (Wolff and Reise, 2002). The objective is always economic, to develop a sustainable food supply, to replenish a depleted stock, or to start a new culture. ICES Member Countries import live organisms from 32 countries and molluscs are among the most important taxa transported (WGITMO, 2006). The transport of different shellfish species including life stages from hatcheries, from field sites to new culture or wild fishery sites, often crossing international boundaries, has potential implications - through the introduction of shellfish and their associated organisms. These can include non-indigenous species, potentially toxic algae, viruses, bacteria, disease agents or parasites. Potential implications can be interactions with wild and cultured stocks (impact on recruitment, loss of cultivated organisms, sterilization, reduced fitness and fecundity, less meat content, competition, risk of predation, or change in genetic composition, diversity and polymorphism, and physiological and morphological traits; Ambariyanto and Seed, 1991; Calvo-Ugarteburu and McQuaid, 1998; Camacho *et al*., 1997; Desclaux *et al*., 2004; Dethlefsen, 1975; Taskinen, 1998; Tiews, 1988; Wegeberg and Jensen, 1999; Wegeberg and Jensen, 2003).

The movement of bivalve by humans for aquaculture purpose can be usefully categorized into *transfers* and *introductions* (Beaumont, 2000). A transfer is the movement of a sample of individuals from one area to another within the natural range of the species. The term transfer would also include the restocking of a habitat once known to have been occupied by a particular species. In contrast, the movement of individuals to another geographical region where that species has never been present before is referred to as an introduction. Tor d is focussing on transfers with their resultant impacts and is considering the long term impacts of introductions and transfers of shellfish, such as *Crassostrea gigas* within and amongst ICES countries.

The concerns expressed regarding transfers and introductions are generally related to ecological impacts, genetic aspect and spreading of pathogenic agents. There should be a presumption against routine introductions and transfer of molluscan shellfish; these should only occur through necessity and only be made following a full risk assessment. Current legislation appears incomplete and not 'joined up' in dealing with the introduction and potential spread of alien species, associated hitch hikers and pathogens, unless listed within fish health or environmental regulation.

5.2 Guidelines

5.2.1 Introduction

Legislation and industry codes of practice exist worldwide to control environmental impacts and diseases associated with transfers of molluscan shellfish species, both cultured and wild. Although worldwide regulations exist, this ToR focuses on the situation in Europe and more specifically the European Union. These regulations include: the ICES code of practice; OIE guidelines; natural heritage organisations (e.g. English Heritage & Scottish Natural Heritage in Britain) concerning conservation and sustainability of resources, and EU council directives related to both shellfish and human health, e.g. Directive 2006/113/EC of the European parliament and of the council of 12 December 2006, on the quality required of shellfish waters. In addition, in the absence of statute or CoPs, negotiation between industry and authority is often used at the local level to help protect the environment. A review of these guidelines is intended to show where and how controls are implemented and how these may be integrated and developed to minimise the risk of environmental influences including disease.

The United Nations Convention on Law of the Sea (UNCLOS) is an international agreement which defines the rights and responsibilities of nations in their use of the world's oceans, establishing guidelines for businesses, the environment, and the management of marine natural resources. To date 155 countries (including the European Union) have joined in the Convention. A management role is played by organizations such as the International Maritime Organization, the International Whaling Commission, and the International Seabed Authority

The international law of the sea includes the exploration and exploitation of the exclusive economic zones (EEZ) of all countries in which these countries are able to exploit (e.g. harvest) their resources (including aquaculture). The exploration and exploitation of the exclusive economic zones (EEZs) has become of major importance for maritime countries. The knowledge of sub-bottom potential requires innovative underwater tools for optimisation of research and exploitation. Technologies used are, in the main, drawn from different fields such as: imagery, bathymetry, marine seismic, current profiling, underwater positioning, magnetometry and subbottom analysis. EEZ exploitation requires the analysis of areas for industrial applications as well as scientific analysis. Seafloor analysis and mapping are of prime importance for fluid migration and margin structural analysis. One of the major steps in surveying is the use of bathymetry and imagery analysis, which allows geologists to analyze the seabed structure. Bathymetric surveying is of great importance too, for cable and pipe laying (Denis, 2001).

Fish farming has an impact on the environment and that impact can be minimised by statute, consultation and good work practice. Most EU countries employ a complex aquaculture planning consultation process to minimise the environmental impact of developments and ensure the deposit and cultivation of aquaculture animals does not conflict with rights of others, e.g. an application for a farm lease in Scotland involves consultation with: Fisheries Research Services on the feasibility, environmental and disease implications of proposals; The Scottish Environmental protection Agency (SEPA) on discharge consents; Wild fishery interests by the Fisheries protection Agency and Fishermen's associations; potential conflicts of interest by local Harbour Authority, Scottish Pelagic Fishermen's Association, Scottish Anglers National Associations District Salmon Fisheries Boards and the Ministry of Defense; Scottish Natural Heritage who consider the ecosystem and aesthetic impact of an application; Health & Safety executive whose aim is to to protect people against risks to health or safety arising out of work activities, and local press on public awareness, where seeking valid objections to a development. Local authority planning departments in Scotland coordinate the consultations process and decide its outcome, which is reported to the Scottish Government.

If a lease is granted, the weight of statute helps set standards, e.g. Under the Environmental Impact Assessment (Fish Farming in Marine Waters) Regulations 1999. An application is likely to involve an environmental statement and an Environmental impact assessment (EIA). In addition industry codes of practice are designed to encourage sustainability with minimum impact, e.g. the Association of Scottish Shellfish Growers Code of Best Practice for shellfish aquaculture (http://www.assg.co.uk/).

5.2.2 European legislation

With the adoption of the single European market in 1992, in order to promote trade among Member States, including that in live fish and shellfish, an EU Fish Health Regime was established to receive reports on any abnormal mortalities in shellfish farm sites and limit the introduction and spread of the most serious diseases across Europe. This was based on Council Directives 91/67 EEC, 95/70/EC and subsequent Directives and Decisions, subsequently implemented by current fish health regulations. They listed controls that may be applied by member countries for certain diseases of shellfish, and established the concept of Approved Zones and Farms for serious (list II) diseases (*Bonami*a and *Marteilia*), and introduced controls on movements to such Approved Zones and Farms, which were restricted to shellfish from sources of equivalent or higher health status. With EU agreement national programmes could then be established to prevent, control, contain or eradicate the disease. This legislation was replaced by directive 2006/88/EC, in the latter half of 2008 and implemented in Scotland by The Aquatic Animal health (Scotland) regulations 2009

5.2.1.1 Council Directive 91/67/EC

The EU fish health regime requires that movements of molluscan shellfish susceptible to *Marteilia* and *Bonamia* are only made between zones or farms of equivalent health status and that movements of non-susceptible molluscs do not include sick or dead animals or carry the risk of transfer of these pathogens or hitch hiker species to approved zones or farms.

Criteria for listing diseases and current lists of specific shellfish diseases and susceptible species are listed in Annex IV Parts I & 2 of council Directive 2006/88/EC.

Consignments of susceptible shellfish species, for relaying or placing in depuration facilities prior to consumption into approved zones, must be accompanied by movement documents confirming the health status of the consignment. Each document must be signed by the Official Service in the region of origin and be drawn up at the place of origin within 48 hours prior to loading, in the language of place of destination, valid for 10 days of travel. All other species of molluscan shellfish must originate from *Marteilia* and Bonamia Approved Zones or Farms, or from other farms that do not hold species susceptible to *Marteilia* and *Bonamia* and which are not connected to any other water (using non susceptible species certificate as per 2003/390/EC, Annex 1, to be signed 24 hours prior to loading). *Crassostrea gigas*, *Mytilus edulis*, *Mytilus galloprovincialis*, *Ruditapes decussate* and *Ruditapes philippinarum* are recognised as not susceptible to or responsible for the transmission of *Bonamia*. *C. gigas* was recognised as not susceptible to or responsible for the transmission of *Marteilia*. This certificate has a specific statement that at least 1000 molluscs must be inspected and no hitch-hikers be seen and that they should show no signs of clinical disease on the day of loading. This certificate allows for *C. gigas* to originate from areas known to be infected with *Bonamia* and *Marteilia*. Certification is being updated in light of the new directive EC2006/88. Inspectors must inspect and sign consignments prior to export, ensuring no clinical disease or the presence of hitch hiker species. If hitch hikers cannot be removed details must be provided on the certificate to prevent their introduction.

5.2.1.2 EC Directive 2006/88/EC

This directive on the animal health requirements for aquaculture animals came into force in 2008, when it replaced 91/67/EEC and 97/70EC. Amongst the significant changes to previous requirements, the new legislation adopts the following approach:

- a risk-based approach, notably for official surveillance for disease;
- requirement for "Aquaculture Production Businesses" (APB) to comply with conditions of authorisation;
- controls on movements of potential vector and non-susceptible species;
- a structure for declaring the health status of Member States and compartments, in addition to zones;
- the facility for Member States to self-declare disease freedom for zones and compartments.

Specifically, APB's are required to:

- Keep a record of all movements of aquaculture animals and products, including dead fish;
- Keep a record of mortalities occurring on the farm;
- Participate in a risk based surveillance scheme and keep records of the results of any such scheme;
- Implement and maintain good bio-security practices (referred to in the Directive as good hygiene practice).

The Directive requires that competent authorities have measures in place that will prevent the introduction and control the spread of certain listed diseases. These diseases have been divided into two categories; exotic and non-exotic. For bivalve molluscs the exotic diseases are listed as: infection with *Bonamia exitiosa*, infection with *Perkinsus marinus* and infection with *Microcytos mackini*. The non-exotic diseases are listed as: infection with *Bonamia ostreae* and infection with *Marteilia refringens*.

Under 2006/88/EC, under the draft certificate, all susceptible and vector species must be accompanied by a health certificate stating that each consignment be inspected on the day of loading. There is facility for the quarantine, controlling the movement of potential vector species, where these are considered to pose a risk to the health status of member nations.

5.2.1.3 The Water Framework Directive WFD (2000/60/EC)

The Water Framework Directive (WFD) requires member states of the EU to characterise the pressures on river basin water bodies, by identifying the impact of ecological and chemical parameters on these aquatic ecosystems. The overall aim is to further improve European waters to meet the environmental objectives of the Directive. Specifically, the WFD requires that surface waters should meet "good ecological and chemical status" by 2015, ensuring in the meantime that no deterioration takes place. The Directive incorporates both chemical and environmental standards, which means that any activities that lead to biological changes, such as the introduction of alien species, must be taken into account during the risk assessment undertaken during the characterisation process.

Risk assessments for individual water bodies will need to take into account the existence, or risk of introduction of alien shellfish species that have the potential to affect the environment. Among the species of interest in Europe that have been associated with aquaculture are: the slipper limpet *Crepidula fornicata*, which has been shown to be a hitch-hiker species carried with introductions of seed mussels; the Manila clam *Tapes philippinarum* and the Pacific oyster *Crassostrea gigas*, both species introduced to replace failing supplies of native species of shellfish. When assessing the impact of the introduction of these and similar species into new waters, the requirements of the Directive need to be taken into account in order to allow the establishment of an environmentally sound aquaculture industry.

5.2.1.4 Marine strategy framework directive (Directive 2008/56/EC)

The aim of the European Union's ambitious Marine Strategy Framework Directive (adopted in June 2008) is to protect more effectively the marine environment across Europe. It aims to achieve good environmental status of the EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend.

The Marine Strategy Framework Directive constitutes the vital environmental component of the Union's future maritime policy, designed to achieve the full economic potential of oceans and seas in harmony with the marine environment.

The Marine Strategy Framework Directive establishes European Marine Regions on the basis of geographical and environmental criteria. Each Member State - cooperating with other Member States and non-EU countries within a marine region - are required to develop strategies for their marine waters.

The marine strategies to be developed by each Member State must contain a detailed assessment of the state of the environment, a definition of "good environmental status" at regional level and the establishment of clear environmental targets and monitoring programmes.

Each Member State must draw up a programme of cost-effective measures. Prior to any new measure an impact assessment which contains a detailed cost-benefit analysis of the proposed measures is required.

Where Member States cannot reach the environmental targets specific measures tailored to the particular context of the area and situation will be drawn up.

The goal of the Marine Strategy Framework Directive is in line with the objectives of the 2000 Water Framework Directive 2000 which requires surface freshwater and ground water bodies - such as lakes, streams, rivers, estuaries, and coastal waters - to be ecologically sound by 2015 and that the first review of the River Basin Management Plans should take place in 2020.

5.2.1.5 Hygiene controls on movements of live bivalve molluscs

The European legislation on shellfish hygiene controls are summarised in Directives 852/2004EC and 853/2004EC. These require that transfers of shellfish between areas do not compromise the microbiological quality of either the source or destination. These Directives only apply to consumption shellfish and not to spat.

5.2.2 International conventions regulating introduced species

The *United Nations Convention on the Law of the Sea* came into force in 1994. Article 196 on the use of technologies or introduction of alien or new species requires states to take all measures necessary to prevent, reduce and control "the intentional or accidental introduction of species, alien or new, to a particular part of the marine environment, which may cause significant and harmful changes thereto".

The 1992 *Convention on Biological Diversity* (CBD): "Each Contracting Party shall, as far as possible and as appropriate - prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species".

The 1995 FAO *Code of Conduct for Responsible Fisheries*: "9.2.2 States should, with due respect to their neighbouring States, and in accordance with international law, ensure responsible choice of species, siting and management of aquaculture activities which could affect transboundary aquatic ecosystems. 9.2.3 States should consult with their neighbouring States, as appropriate, before introducing non-indigenous species into transboundary aquatic ecosystems." … "9.3.1 States should conserve genetic diversity and maintain integrity of aquatic communities and ecosystems by appropriate management. In particular, efforts should be undertaken to minimize the harmful effects of introducing non-native species or genetically altered stocks used for aquaculture including culture-based fisheries into waters, especially where there is a significant potential for the spread of such non-native species or genetically altered stocks into waters under the jurisdiction of other States as well as waters under the jurisdiction of the State of origin. States should, whenever possible, promote steps to minimize adverse genetic, disease and other effects of escaped farmed fish on wild stocks. 9.3.2 States should cooperate in the elaboration, adoption and implementation of international codes of practice and procedures for introductions and transfers of aquatic organisms. 9.3.3 States should, in order to minimize risks of disease transfer and other adverse effects on wild and cultured stocks, encourage adoption of appropriate practices in the genetic improvement of broodstocks, the introduction of non-native species, and in the production, sale and transport of eggs, larvae or fry, broodstock or other live materials. States should facilitate the preparation and implementation of appropriate national codes of practice and procedures to this effect."

The threat from introduced species was also emphasised in the *Plan of Implementation of the World Summit on Sustainable Development*, Johannesburg 2002, which called for actions at all levels to: "Strengthen national, regional and international efforts to control invasive alien species, which are one of the main causes of biodiversity loss, and encourage the development of effective work programme on invasive alien species at all levels".

5.2.3 ICES Code of Practice on the Introductions and Transfers of Marine Organisms

This document offers advice and best practice guidance on reducing the risk arising from the introduction of non-indigenous marine species, and includes sections discussing policies for on-going introductions established as part of commercial practice. This guidance sets out a framework for evaluating the risks from such introductions, together with specific procedures for minimising these risks. In doing this, the document repeats some of the requirements covered in the EU legislation and the OIE

Aquatic Animal Health Code, as well as describing more detailed methods of inspection of consignments.

5.2.4 National Policy

5.2.4.1 Policy for bivalve transfers in the Netherlands

1) Transfer bivalves into the Wadden Sea is not permitted, except for mussels from the Danish or German parts of the Wadden Sea.

2) To minimize the risks in the Eastern Scheldt, the following precautions are taken:

- Molluscs from risk areas inside the boreal area (from the English channel to the south of Norway and Sweden) may only be transported to the Eastern Scheldt, under licence. Mussel spat from the Dutch part of the Wadden sea can be transferred to the Eastern Scheldt without permission.
- It is not permitted to transfer molluscs from outside the boreal area into the Eastern Scheldt.
- Processing water and tarra from outside the boreal area must be depurated before discharging it.

A new line of policy concerning the displacement of shellfish came into effect in 1997. Since then the transfer of mussels from the Irish and Celtic Sea into the Oosterschelde has not been permitted. Also the process effluent water and the tare from the consumption mussels originating outside the boreal waters needed to be purified before being discharged into the Oosterschelde (Snijdelaar *et al*., 2004). In 2003, the Raad van State (Highest Court in the Netherlands) withdrew the ban for import on mussels from the Irish and Celtic Sea. It was brought forward that the ban was conflicting with the EC guidelines for freedom of trade. Also it was substantiated that the precaution principle was formulated as being too general (Snijdelaar *et al*., 2004). From that period, the Dutch Ministry of Agriculture, Nature and Food Quality, issued permits for the displacement of mussels from the Irish and Celtic Sea into the Oosterschelde. However, the applicant had to prove that mussels originated from a particular production area in the Irish Sea, or have been in that production area for at least one year. The Oosterschelde is part of the Natura 2000 network based on both the Bird (79/409/EEC) and the Habitat (92/43/EEC) directives. Any plan or project in the area likely to have a significant effect thereon is subject to an appropriate assessment of its implications for the site in view of the site's conservation objectives.

In the Netherlands, the production of mussels in the Wadden Sea and the Oosterschelde fluctuates due to varying recruitment and survival rates. Production does not meet the demand for mussels. To meet this demand, seed mussels and adult mussels are imported from other Euopean countries. Wijsman and Smaal (2006) and Wijsman *et al*. (2007a, b) reviewed the risks of transport of mussels from Ireland, the UK, Sweden and Norway to the Dutch production areas. Based on the results of the study, a permit was given to the corporation of shellfish importers to import mussels and oysters from 12 production areas in Ireland and the UK into the Oosterschelde. The imports of consumption mussels from these areas are monitored for the presence of exotic species by means of regular sampling upon arrival in Yerseke. Similar studies have been conducted by Wijsman *et al*. (2007a, b) on the risks in transporting mussels from Norway and Sweden to the Dutch Wadden Sea. The corporation of shellfish importers have received a permit for import of mussels and oysters from Norway and Sweden to the Dutch Wadden Sea, but transport have not taken place yet.

5.2.4.2 Belgian policy

The user conditions as decided by the government of the four bivalve areas in the Belgian North Sea only permit the use of naturally settled spat, obtained by suspended cultivation methods. There are no guidelines for transfers between these areas. The concession owners have to report every notification of non-indigeous species, parasites or diseases to the Management Unit of the North Sea Mathematical Models. A small amount of oyster (both *C. gigas* and *O. edulis*) spat is imported every year for growout in the Spuikom in Ostend. These oysters are subjected to a veterinary controll (Belgian law MB 97/16166).

5.2.4.3 Norwegian policy

According to the Aquaculture Act, transfer of biological material (in this case bivalve) between licensed sites should be approved by the Norwegian Food safety Authority. The approval is based on an evaluation of risk for disease transfer between salmonids and marine fish where the bivalves potentially can act as a vector.

Sea ranching of the scallop (*Pecten maximus*) licensed under the Aquaculture Act requires use of seeded scallops that originate from local stock. This implies that transfer of scallops between licenses for the purpose of producing seed for sea ranching can only be done when documentation is given on origin of broodstock in case of for intensive production of spat or area for natural collection of spat.

5.2.4.4 German policy

Blue mussels

Mussels in Germany are displaced on local, regional and international scale for cultivation and export purpose. Transfers are conducted with either seed and market sized mussels. Seed mussels are transferred by the fishermen from their natural wild beds to the licensed cultivation plots. Usually the distances between these two locations are short and mussels remain in the same water body. Since mussels are fished obligatory from subtidal wild habitats and placed only subtidal culture plots a vertical transfer is likely to be minimized. Recently, however, spat cultivated on hanging cultures in the Jade estuary is transferred regionally and vertically to on-bottom culture plots to the Wadden Sea areas in North Friesland. On international scale several thousand tons per year of mussels spat is transfered since 2006, owing to poor recruitment and failed spatfall in recent years within the German Bight. Spat is transferred from the Netherlands, UK and Ireland to German culture plots. The largest part of mussel spat is coming from British channel and North Sea islands.

Transfers of mussels are allowed if the introduction of epidemical diseases can be excluded. This exclusion is given if the area of origin is a legally approved cultivation area, analysed prior to the transfer according to CD 2006/88/EC. In addition, benthos communities of the areas of origin have to be assessed and recorded bi-monthly during time of spat extraction.

Complains of the German National Park authorities against these practices were dismissed by the administration court of Schleswig-Holstein (Germany). In a comparable case the restrictive Dutch practice against seed mussel imports was condemned as violating EU-laws by the European Court of Justice.Transport is permitted under the Natura 2000 rules.

Market sized mussels are exclusively exported from Germany mainly to the Netherlands, France and Belgium. There, mussel are sometimes relayed e.g. in the Oosterschelde (NL) until they are sold on the market. Transfers of adult mussels from other places to Germany are unlikely at present, since the market for mussel products is saturated and current mussel price low. However, data on mussel exports and processing are not completely available, but are listed in the annual publications of the Federal Agency for Agriculture and Food (e.g. BLE 2001). Small scale transfers of mussels between the Baltic and the North Sea were conducted for seed mussels. In a re-try, seed mussels are planned to be produced in the bight of Kiel (Baltic Sea) and eventually transferred to the North Sea.

Since seed mussels are placed at least for one season on the culture plots and not used directly for human consumption they are not subject to official hygienic control. Thus, all seed mussel imports are not monitored for their genetic homogeneity, microbial purity, viral or parasitic status, biotoxins or for the import of non-indigenous species either in their mantle cavity or on their shell. Due to the lack of control no detailed data are currently available on amounts and their distribution to target sites from seed imports, despite the fact that cultivation is conducted within or in the vicinity of the two National Parks of the German Wadden Sea (Lower Saxony Wadden Sea National Park, Schleswig-Holstein Wadden Sea National Park).

Oysters

The Pacific Oyster (*C. gigas*) is cultivated only at one farm in the tidal backwaters of the island of Sylt. The spat for this farm is imported from an Irish hatchery. As for blue mussel seed, these young oysters are not presently monitored by any official German authority.

5.2.4.5 Icelandic policy

Mussel culture industry is new in Iceland (Gunnarsson *et al*., 2005; Thorarinsdóttir *et al*., 2007). The interest for culture is growing and in the year 2010 experimental culture on a small scale is located at 17 sites all around the island, except off the south coast.

In most cases naturally settled spat on collectors are used, but transfers do occur both with seed and market sized mussels. Fishermen transfer the mussels from their natural sites to licensed culture sites. Until now transfers are only done from Hvalfjördur, south-west Iceland and Breidifjördur, west Iceland to a licensed culture site in Eyjafjördur in the north. This transfer is done to shorten the culture time. There are no guidelines for transfer of spat between areas and no legislation exists yet.

5.2.4.6 French policy

- **Cupped oysters**: a few 1000 tons of *C.gigas* are imported annually (e.g. from Ireland…) and exported (e.g. to Italy…). But most exchanges are between French regions: most spat is collected in Arcachon and Marennes-Oléron basins, and transported to growing sites from Mediterranean coast, Brittany and Normandy. Hatchery spat is also a growing source of transfers. On the other hand, a large part of Breton and Normand commercial oysters go back to Marennes-Oléron area for “affinage” (in “claires”) and marketing.

- **Flat oysters**: Production (around 2000 tons annually) and exchanges are limited. Most spat transfers occur within the same region (Brittany). Some are exported from South Brittany to Spain. Few adults are exported or imported with reimmersion.
- **Mussels**: Spat is collected from South-Loire areas and transferred to rearing sites in North Brittany or Normandy. Adult mussels are mostly imported for market, but some may be re-immersed.
- **Clams**: hatchery spat may be transferred to stocking sites. Some young or pre-adult clams have been (and continue to be) transferred from Italian lagunas to French rearing sites.
- **Pecten maximus**: one hatchery transfers spat for experimental seeding trials, in different parts of France.
- **Abalones**: very small production and exchanges.
- **Snails**: used to be imported from Scotland so as to be stocked on bottom oyster plots, as green algae feeders.

The main regulations depend on European Directives and their application texts (preventing disease spreading mainly). Few additional national regulations have been applied until now (under discussion). Recently, oyster transfers were prohibited due to abnormal mortalities and Herpès-virus prevalence. Areas may also be closed for sanitary reasons (bacteria, virussen or HAB like recent ASP-Pseudo-Nitzchia occurrence in Charentes).

5.3 Records

5.3.1 Legislation

5.3.1.1 Disease records

The Directive required that competent authorities have measures in place to prevent the introduction and control the spread of certain listed diseases. These diseases have been divided into two categories; exotic and non-exotic. For bivalve molluscs the exotic diseases are listed as: infection with *Bonamia exitiosa*, infection with *Perkinsus marinus* and infection with *Microcytos mackini*. The non-exotic diseases are listed as: infection with *Bonamia ostreae* and infection with *Marteilia refringens*.

Record Keeping requirements under Article 3 of 95/70/EC states that Member States shall ensure that all farms rearing bivalve molluscs:

1) are registered by the official service; this registration must be kept constantly up to date; and

2) keep a record of:

  - live bivalve molluscs entering the farm, containing all information relating to their delivery, their number or weight, their size and their origin;
  - bivalve molluscs leaving the farm for re-immersion, containing all information relating to their dispatch, their number or weight, their size and destination; and
  - observed abnormal mortality.

This record, which shall be open to scrutiny by the official service at all times, on demand, shall be updated regularly and kept for four years.

Movements of shellfish from outside the EU are required to be accompanied by a suitable animal health certificate, signed by the competent authority

5.3.1.2 Requirements for record keeping under recently introduced legislation 2006/88/EC

This new Directive not only requires that aquaculture production businesses keep records of all movements of shellfish to and from their sites, but that these records be kept by shellfish businesses, including depuration plants and potentially by transporters and some processing plants. These records would include all movements of seed shellfish to shellfish farms, movements between farms and also movements from farms to the place of final processing. However, there is a provision in the regulations that would allow shellfish farmers who share the same mollusc farming areas to apply for a shared authorization. This reflects the spatial distribution of farms within hydrographic areas, and the effect of this on the potential spread of disease within these areas.

Based on this new directive the Irish authorities decided that all shellfish transfers should be reported to the Marine Institute. The Marine Institute collects all transfers in a national database.

5.3.1.3 Record keeping under the EU Food Hygiene regulations

This legislation requires that each consignment of live bivalve molluscs is accompanied by a movement document which states the place and date of harvesting together with the details of the harvester. This is to allow full traceability in the event of a human health disease outbreak in the consumers of harvested shellfish. There are controls on the harvesting of shellfish, which cannot be taken from areas where there is no known microbiological classification, unless they are "seed" shellfish not destined for immediate consumption.

5.3.2 Movements of shellfish (what species are transported where?)

Movements of shellfish for aquaculture can broadly be divided into five categories:

1) movement of wild caught seed for relay onto managed farms;
2) movement of hatchery cultured seed;
3) movement of farmed stock to other farms for ongrowng to final market size;
4) movements of farmed or wild stock relayed for depuration or at a dispatch centre prior to sale; and
5) movement of live shellfish to the final market (human consumption), which may be relayed at destination to improve condition.

Typical movements that take place within the aquaculture trade may include:

- native and Pacific oyster seed from hatcheries to nursery and ongrowing sites;
- part grown native and Pacific oysters from nursery sites to ongrowing sites;
- clam seed from hatcheries to ongrowing sites;
- scallops and queens from natural spat collection sites to ongrowing sites;
- mussels from natural seed beds to ongrowing sites; and
- shellfish relaid for depuration or held at a dispatch centre prior to sale

- shellfish for human consumption which may be relayed at destination to improve condition

These movements may take place either locally within shellfish harvesting areas (= local), between shellfish harvesting areas within a region/country (= national), between countries within economic regions (Europe; = regional), or internationally between economic regions (USA – Europe; = international). Examples of international movements include the introduction of oysters to Europe from America during the 19^{th} and 20^{th} centuries, and more recently large-scale translocation of seed mussel from UK to Eire, and Ireland to the Netherlands.

Although the majority of movements of shellfish for aquaculture are arguably all driven by economic reasons (Mortensen *et al.*, 2006), some recent stock transfers have been made because there is a shortfall in local supply. This reflects both the variable nature of recruitment to wild sources of stocks of seed shellfish and the lack of commercially cultivated juvenile shellfish for some species, which are often uneconomic to produce.

Details of movements between ICES countries are hard to collate, largely as there is no formal arrangement for all of these transfers to be recorded, and data has to be extrapolated from what information is available. The information offered in the table below is either from data annually presented to the EU reference laboratory at La Tremblade or from intelligence gained by members of the MASC, and whilst it does give an idea of the extent of these movements, should not be considered definitive (Table 5.1).

Table 5.1. Shellfish Movements within ICES Countries. Information from Estonia, Finland, Latvia, Lithuania, Poland and Russia is still missing.

	Local	National	Regional	International
Belgium	X	X		
Canada	X	X		
Denmark	X	X	X	
France	X	X	X	X
Germany	X	X	X	X
Iceland	X	X		
Ireland	X	X	X	
Netherlands	X	X	X	
Norway	X	X	X	
Portugal	X	X		
Spain	X	X		
Sweden	X	X	X	
UK	X	X	X	X
USA	X	X		X

5.4 Risk Assessment

To minimise the impact of shellfish transfers a proper risk assessment should be made. The strategy and principles to be followed by Directive 2006/88/EC involve; prevention of introduction and transmission of disease, such that the burden to the public and private sectors is proportionate, finding the balance between control of pathogens and over-regulation and ensuring that regulation and surveillance is based on a transparent assessment of disease risk. An essential part in development of any risk based assessment (rba) model is to ensure that it accurately identifies and quantifies those risks associated with all farms within a zone and provides early detection of disease. Risk assessment requires regular review as industry practices evolve, increasing or decreasing risk on farm sites.

Each farm is to receive a ranking (high, medium or low) based on criteria developed at the surveillance work stream workshop, frequency of inspection to be determined by the ranking of each site (Annex III of 2006/88/EC).

- The list of high risk factors included; risk of introduction, risk of spreading, farms importing live animals from third country or approved zone/compartment and super spreaders (movements to more than 10 destinations).
- Medium risk factors included; importing live animals from an approved member state, proximity to processors, high contact through animal movements (3 or more source/destinations sites), and high contact through water, e.g. farms less than 1 km apart in coastal zone or downstream of other farms on a river.
- Low risk factors included, poor biosecurity or husbandry, i.e. those farms promoting conditions conducive to disease expression.

The CEFAS (UK) IMPASSE project (Copp, 2008) is an example of arisk assessment for the transfer and introduction of aquaculture species. The risk assessment is based on 4 pillars: an organsm risk assessment, a pathway risk assessment, a facility risk assessment and a receptor risk assessment. In this approach the possible impact of the organism is assessed on different levels (environmental, social, economic, genetic and diseases) (Figure 5.1). In order to meet to the specific situation of shellfish transfers WGMASC would suggest to include hitch hiking species in this risk assessment.

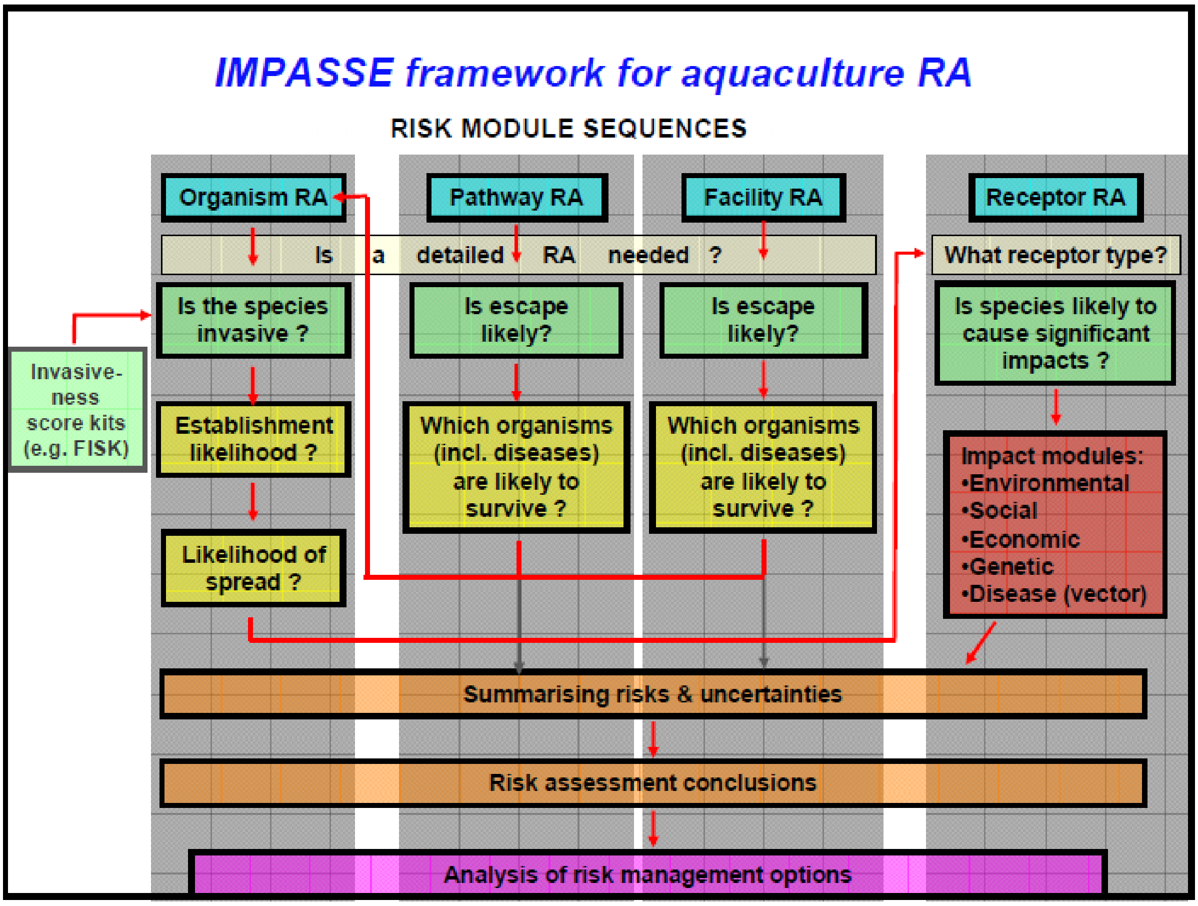

Figure 5.1. The IMPASSE framework for aquaculture risk assessment.

5.5 Conclusion

There has been a move towards a more targeted, risk-based, assessment of movements of bivalve molluscs for relaying, that take place for commercial purposes. There is an understanding from legislators that such movements pose a potential for spread of serious disease, however the potential for environmental impacts other than certain diseases and hitch hiking species is currently not addressed within the existing legislation.

Powers are needed to prevent introductions and subsequent transfers of alien species, ensure a disease (both parasites, viruses and bacteria) free status by introducing only from disease free sources and prevent genetic contamination of bivalve stocks. Where necessary, allow for the set up of temporary quarantine facilities through the F1 generation for the introduction of disease free stocks of species- and only those which will not reproduce nor change in genetic composition and seed or prevent seed to the wild, and prevent the inadvertent introduction of pests and hitch hiker species with consignments.

If there are good commercial reasons for the introduction of a species, a robust standard of risk assessment should be applied, prior to release, to ensure that ecosystems are protected. Risk based surveillance is now an animal health requirement under Council Directive 2006/88/EC in the prevention and control of certain diseases and models produced by each country should be designed to identify and quantify risks of disease introduction and spread. Transfers of shellfish are made routinely at all levels, local, etc.; by countries of differing environmental and disease status, highlighting the real risks of introducing pests, parasites and diseases, There is a need for coordination of the application of legislation and codes of practice within and between countries; to minimise introduction and spread of invasive species and pathogenic organisms.

However shellfish transports should be recorded by the aquaculture production businesses the WGMASC recommends a collection of the data on a national level as it is done today in Ireland.

The potential for transfer of hitch hiker species and diseases, the potential genetic implications for wild stocks, the impact on recruitment to existing stocks by large-scale transfers and scientific tools for the decision support on cultured shellfish transfer issues is treated in ToR d.

5.6 Recommendations

1) Proper risk assessment should be undertaken, to ensure safety to ecosystems, as the long term environmental and financial costs from introductions is unquantifiable in the long term.
2) There is a need to regularly review and update regulations to account for and minimize the potential impact of emerging environmental or disease issues.
3) Monitoring of translocation of spat inter and between countries should be implemented to minimize transfer related risks and minimize the impact of e.g. Germany who routinely imports mussels from Ireland, UK and the Netherlands, with resultant concerns regarding speciation or the introduction of pests or diseases. Data on shellfish transfers should be collected into national databases.
4) Scientific tools for decision support are needed. WGMASC is looking for these tools in ToR d.

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6 Review knowledge and report on the significance and implications of bivalve aquaculture transfers between sites (local, national, international) to wild and cultured bivalve stocks: implications (ToR d)

6.1 Background

Movement of shellfish around the world is an activity that has a long history (Wolff and Reise, 2002). The objective is always economic, to develop a sustainable food supply, to replenish a depleted stock, or to start a new culture. ICES Member Countries import live organisms from 32 countries and molluscs are among the most important taxa transported (WGITMO, 2006). The transport of different shellfish species including life stages from hatcheries, from field sites to new culture or wild fishery sites, often crossing international boundaries, has potential implications - through the introduction of shellfish and their associated organisms. These can include non-indigenous species, potentially toxic algae, viruses, bacteria, disease agents or parasites. Potential implications can be interactions with wild and cultured stocks (impact on recruitment, loss of cultivated organisms, sterilization, reduced fitness and fecundity, less meat content, competition, risk of predation, or change in genetic composition, diversity and polymorphism, and physiological and morphological traits; Ambariyanto and Seed, 1991; Calvo-Ugarteburu and McQuaid, 1998; Camacho *et al.*, 1997; Desclaux *et al.*, 2004; Dethlefsen, 1975; Taskinen, 1998; Tiews, 1988; Wegeberg and Jensen, 1999; Wegeberg and Jensen, 2003.

The movement of bivalve by humans for aquaculture purpose can be usefully categorized into *transfers* and *introductions* (Beaumont, 2000). A transfer is the movement of a sample of individuals from one area to another within the natural range of the species. The term transfer would also include the restocking of a habitat once known to have been occupied by a particular species. In contrast, the movement of individuals to another geographical region where that species has never been present before is referred to as an introduction. Tor d is focussing on transfers with their resultant impacts and is considering the long term impacts of introductions and transfers of shellfish, such as *Crassostrea gigas* within and amongst ICES countries.

The concerns expressed regarding transfers and introductions are generally related to ecological impacts, genetic aspect and spreading of pathogenic agents. There should be a presumption against routine introductions and transfer of molluscan shellfish; these should only occur through necessity and only be made following a full risk assessment. Current legislation appears incomplete and not 'joined up' in dealing with the introduction and potential spread of alien species, associated hitch hikers and pathogens, unless listed within fish health or environmental regulation.

A more dynamic and transparent system is needed, with standard guidelines including risk assessment, management advice and the identification of research goals. Because of the unknown risks of certain introductions the emphasis should be on precaution, if a species is allowed in it should be in quarantine – even through the F1 generation to assess reproductive behaviour and danger of disease transmission, prior to release.

Financial consideration should be secondary to ecological impact, if a company wishes to profit from an introduction they should be prepared to undertake proper scientific assessment of risk as long term impacts can be serious and wide ranging. Here, the guideline on best environmental practice (BEP) for the regulation and monitoring of marine aquaculture defined in MARAQUA (Read *et al*., 2001) for the European Union as well as for all countries defined by the FAO (FAO, 1999) should be taken into account. These guidelines also include best available technique (BAT) and best management practice (BMP).

Consultation on an introduction should be full, objective, be universally applied, follow full risk assessment and if approved, be so under quarantine. Imports of shellfish susceptible to notifiable diseases must be held in quarantine when the disease status of country of origin is uncertain; and the holding of shellfish for scientific purposes may be permitted provided that the animals are held in containment as quarantine conditions. A guideline to quarantine conditions is given below.

Presently, a number of ICES working groups are concerned with the topic of transferring marine organisms. The Study Group on Ballast and Other Ship Vectors (SGBOSV) work on specifically identified vectors of ballast water and hull fouling. The Working Group on Introductions and Transfers of Marine Organisms (WGITMO) documents the spread of intentionally imported and/or invasive species introductions via the use of National Reports from many ICES countries. WGITMO's work focuses on the aquaculture vector and what happens when an invasive species is found in a water body (no matter what vector is involved) – origin and status of the invasion, potential impacts, options for mitigation and/or eradication, and sharing information with other countries. The WGITMO deals mainly with intentional introductions for e.g. aquaculture purposes, and works to reduce unintentional introductions of exotic and deleterious species such as parasites and disease agents through a risk assessment process and quarantine recommendations. The Working Group on Environmental Interactions of Mariculture (WGEIM) is examining the potential importance of bivalve culture in the promotion and transfer of exotic species (i.e. alien or introduced) and the resulting implications for bivalve culture and the environment. The WGEIM is also examining management and mitigation approaches for invasive and nuisance species that have been transferred to aquaculture sites.

The WGEIM (2006) report recommended to the Mariculture Committee that key representatives from ICES Working Groups dealing with aquatic exotic species, including the WGMASC, should meet to, among other tasks, identify information gaps and recommend specific research goals. The MASC working group concurred with this recommendation and recommended in 2007 to the MCC that the WGMASC undertake a new ToR on this high priority topic, beginning in 2008, to avoid overlap between Terms of Reference. The relevant reports of WGEIM and WGITMO are summarised below.

6.2 Related reports of WGITMO and WGEIM

6.2.1 2007 of the WGITMO[2]

Some sections within this report can be referenced within ToR c of the WGMASC, such as the ToR f "Status of development of ICES Alien Species Alert reports" including the evaluation of impacts and to increase public awareness. The aim is to finalize

[2] Other reports from previous meetings were not available via the ICES homepage.

the ToR F report at next year's meeting. In subsequent years additional taxonomic groups may be identified those more likely to be introduced deliberately as food, or accidentally by other vectors.

The report focuses on various species, especially on the Pacific oyster *Crassostrea gigas* (including the biology, the introduction for aquaculture purposes, the consequences of Pacific oyster introduction, mitigations and restorations, and finally a prospective). Further the question of the introduction of *C. ariakensis* to some areas of the US, primarily as nonsterile triploids, can be considered (including an environmental impact statement with alternatives, scientific contributions in support of the EIS, and a review concerning the utility of ICES Code of Practice guidelines in the current process). This deliberate introduction offered an opportunity to evaluate: how well the Code of Practice (ICES) is being followed; the Code's strengths and weaknesses, and what can be said about the risks involved in the process that the US adopted.

6.2.2 2008 of the WGITMO

In the report new species introductions, via shellfish movements or transfers, are mentioned. For example a few specimens and egg capsules of the American oyster drill, *Urosalpinx cinerea*, have been found in October and November 2007 at Gorishoek in the Oosterschelde, an area of shellfish culture in The Netherlands. One possibility is that *U. cinerea* was introduced with imported shellfish from south-east England.

Further, it was again highlighted that human activity within the shellfish industry, including the discharge of ballast water from ships, are major vectors in dispersals of non-indigenous species. This supports the hypothesis that the species have been inadvertantly introduced outwith their natural range as a probable result of mariculture trade and shipping activities.

The Pacific oyster *Crassostrea gigas*, which was introduced in the early seventies in many shellfish production areas in Europe, Canada and the USA, was mentioned as a case example of an organism that established successfully, rapidly reproduced and settled to the wild, ie outwith farm areas constituting "natural populations" in many areas.

6.2.3 2009 of the WGITMO

At the end of the WGITMO report 2009 there is a table displayed including non-native species identified as considered problematic. Some of the listed species were transferred or introduced by shellfish originating from aquaculture. Annex 5 of the report contains an alien species alert on *Crassostrea gigas*. One of the sections in this alert concerns the worldwide introduction of *C. gigas* for aquaculture purposes and sections on the consequences of this introduction.

6.2.4 2005 report of the WGEIM

The potential effect of transfer of non-indigenous species on wild and cultured stocks of bivalve was **<u>not</u>** discussed in the terms of references. However, in Annex 3[3] the international trade rules from the World Trade Organization (WTO), by the Office

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[3] "State of knowledge" of the potential impacts of escaped aquaculture marine (non-salmonid) finfish species on local native wild stocks and completes the risk analyses of escapes of non-salmonid farmed fish - a Risk Analysis Template.

International des Epizootic (OIE) and the Code of Practice for the Introduction and Transfer of Marine Organisms (ICES 2003) are mentioned (see description field below). This text can be adapted to shellfish aquaculture issues also.

> ***Use of Risk Analysis Internationally***
>
> In response to concerns about disease transfer and control, WTO accepts the risk analysis protocols developed by the Office International des Epizootic (OIE) as the basis for justifying trade restricting regulatory actions including restriction on movement of commercial and non-commercial aquatic animals. The intent of developing the OIE protocols was to provide guidelines and principles for conducting transparent, objective and defensible risk analyses for international trade. ICES has embraced this approach in their latest (2003) Code of Practice for the Introduction and Transfer of Marine Organisms (hereafter referred to as the ICES Code). One part of the ICES Code is specifically designed to address the "ecological and environmental impacts of introduced and transferred species that may escape the confines of cultivation and become established in the receiving environment". Unfortunately, examples of the application of risk analysis to the development of regulations have not been generally published in the primary scientific literature.

Finally, ToR g of the recommendations "investigate the hazards associated with mariculture structures in terms of habitat change/modification and assess their potential for accommodating invasive/nuisance species in a system - proposed in consultation with WGITMO should be investigated" will be of use for shellfish aquaculture issues.

6.2.5 2006 report of the WGEIM

The potential effect of transfer of non-indigenous species on wild and cultured stocks of bivalve was discussed in the terms of references f (former ToR g). Their aim was to "examine the **potential importance** of bivalve culture in the **promotion** and **transfer** of exotic aquatic species as well as the importance of these exotic species to **bivalve culture and the environment**". The focus was on exotic species with an emphasis on those that become invasive and nuisance. Management implications and mitigation strategies are also addressed. The information presented is largely based on oyster-oriented literature but has been expanded where possible to include other taxa. The report covers many aspects that are important to shellfish culture such as the effects of exotic species - including exotic macrospecies – animals and algae -, exotic phytoplankton and disease species, on fouling, competition, predation, algae smothering shellfish, introduction of phytoplankton that causes harmful algal blooms, mass mortality due to disease transfer (viruses, bacteria, protozoans, higher invertebrates) on cultured bivalves.

Here, it was recommended by the WGEIM to organize a meeting with the appropriate members of other working groups (WGMASC, WGITMO, and SGBOSV) to discuss these topics and to prepare a joint document.

6.2.6 2007 report of the WGEIM

The potential effect of transfer of non-indigenous species on wild and cultured stocks of bivalves was not discussed. However, in ToR d (Further investigate fouling hazards associated with the physical structures used in Mariculture and assess their potential for the introduction of invasive/nuisance species into the local environment.) the concept of Integrated Pest Management is mentioned to decrease the impact of non-indigenous (and pest) species.

6.2.7 2008 report of the WGEIM

Following ToR a "Indices for the environmental effects of mariculture" which also deals with the ddevelopment of practical indices related to the sustainability of aquaculture the WGEIM decided not to continue to include the transfer of diseases from farmed to wild stocks, declaring these issues to be outside the remit of WGEIM.

6.3 Focus of WGMASC

The focus of ToR d is on the significance and impacts of bivalve aquaculture transfers between sites (local, regional, national, and international) to wild and cultured bivalve stocks. The transported shellfish are the vector for any associated organisms, while the target species (the wild and cultured shellfish) are monitored to assess any impact prior to and post deposit. Information is being collected on current *guidelines in place and records kept* in ICES countries related to the transfer of cultured species to assess those impacts. Effects of shellfish relocations (including epi-/endofauna, epiflora, associated organisms, diseases, parasites and viruses): on the *geographic distribution of marine organisms*; *indigenous shellfish stock traits* (impact on recruitment, loss of cultivated organisms, sterilization, reduced fitness and fecundity, less meat content, competition, risk of predation, or change in genetic composition, diversity and polymorphism, and physiological and morphological traits), and the *potential implications* for regional shellfish culture operations are considered. In addition, suggestions for *scientific tools to support policy decisions* and *recommendations to farmers and policy makers* on cultured shellfish transfer issues will be given. Since many of the topics mentioned above are already covered in part by the 2006 report of WGEIM, the work of WGMASC can be seen as an addition to this report.

6.4 Work plan

In 2008 the role of WGMASC was defined; following the screening of the SGBOSV, WGIMTO and WGEIM reports and considering risks not covered by those terms of reference. At the following meeting in Bremerhaven, current guidelines and records were reviewed together with a summary of shellfish movements not covered by those reports. The data collection and the legal background concerning shell fish movements were updated at the joined meeting in 2010 using new available data of working group members. In Section 5 a brief overview about transfer activities and legislation of some of ICES member countries are given. As a result WGMASC could show that transfer activities take place on all levels (local, regional and international) in most of the ICES member countries given strong evidence to adjust current regulations. However, collection of data on transfer records was not considered a core action of WGMASC and therefore further updates of data collection was not given priority at the current meeting and ToR c was closed. Future efforts should be focussed on the implications of transfers on all scales. Since WGEIM has provided already detailed insides about the implications of bivalve aquaculture and the introduction and spread of exotic species hitchhiking as fouling organisms, WGMASC will concentrate on transfer effects concerning the spread of organisms travelling inside of bivalves' shells (intervalval water, water of mantle cavern) and tissues. Further, we will focus more detailed on genetic and recruitment impacts resulting from transfer actions. The assessment of resulting implications and the development of scientific tools for decision support will be continued.

6.5 Potential effects and implications

In this section the effects of shellfish relocations on the *geographic distribution of marine organisms*, *indigenous shellfish stock traits* and the *potential implications* for regional shellfish culture operations are reviewed and reported on. Topics to be covered in the meeting 2011:

1) What are the effects on recruitment, loss of cultivated organisms, sterilization, reduced fitness and fecundity, less meat content, competition, risk of predation, or change in genetic composition, diversity and polymorphism, and physiological and morphological traits?
2) Scientific tools to support policy decisions on cultured shellfish transfer issues (e.g. risk assessment of shellfish transfers).
3) Recommendations to farmers and policy makers
4) Conclusions

6.6 Related studies and reports of transfer/introduction impacts

In this section related studies concerning the impacts of transfers and introduction resulting from bivalve aquaculture activities are given.

6.6.1 Examples of introductions and resultant impacts:

Transfers in marine aquaculture occur routinely, frequently moving shellfish (transplanted) from one location to another within their native distribution range. This section gives some examples of introductions and their impacts which make it clear that there are more risks associated with shellfish transfers then diseases and hitch hiking species alone.

- Historically, slipper limpets or carpet shells were introduced to England, carpeting areas of the foreshore, replacing the natural fauna there. Despite its impact no controls were sought – it established itself very quickly, destroying ecosystems. Under current EU health legislation, pests such as *Urosalpinx cinerea*, *Crepinula fornicata* and *Mytilicola* sps are not listed, being recognized as serious pests within certain member states but not controlled. Such species can be relayed with host aquaculture shellfish within and between member states and third countries, uncontrolled.
- The introduction and transfer of marine molluscs from fisheries and aquaculture includes the risk of transporting competitors, predators, parasites, pests and diseases which have compromised intended molluscan culture and wild fisheries. Introductions as well as transfers, in the course of normal trade, particularly of half-grown oysters, have been responsible for the establishment of several harmful and nuisance non-native species. Once established at a new locality these may continue to be moved by various means or by natural expansions of their range. *Crassostrea gigas* was introduced to Ireland from France, under 91/67 EC (a species recognized as be-

ing non-susceptible to *Bonamia* (*O. edulis* is susceptible)), the deposit was made and after the event non indigenous species and indigenous species capable of transmitting serious disease were found; including the pest *Mytilicola orientalis,* and *Ostrea edulis* which is capable of transmitting *Bonamia*. (Minchin, 1996; Minchin, 1998).

- More recently when checking guidelines on introduction of *Crassostrea gigas* (gigas) spat to Scotland from Jersey in the Channel Islands for ongrowing, current legislation (guidance under EC Directive 91/67 and the Wildlife & Countryside Act) allows the movement to an approved zone; following screening for signs of ill health, pathology or the presence of hitch hiker species, evident by visual inspection. Fish health legislation considers listed pathogens and susceptible species but no clear guidance on emerging disease or infectivity by pests or parasites not obvious during inspection, and in the absence of abnormal mortality. Shellfish being moved from a country infected with a non listed pathogen may have developed immunity to pathogens with the potential to transmit the pathogen to naïve populations; having a long term detrimental effect on multiyear classes in the area of destination and beyond. The *C. gigas* introduced from Jersey to Scotland originated from a French hatchery under proper certification, however the majority of (if not all) French hatcheries are suspected to be infected with Oyster Herpes Virus (OHV) and *Vibrio* sps such as *V. splendidus*, pathogens found naturally in the aquatic environment, and closely associated with summer mortality in *Crassostrea gigas*; causing high mortality and affecting all year classes of oysters in many areas of France. These recent introductions of *C. gigas* from France via Jersey could potentially have a long term detrimental effect on naïve cultivated *C. gigas* in Scotland and elsewhere; however current legislation allows such movements, allowing free trade at the expense of a precautionary approach.
- There is the also possibility that *Crassostrea virginica*, the American oyster may be introduced to Europe to complement/replace Pacific oyster cultivation. It is a species susceptible to serious the exotic disease listed under 2006/88/EEC, *Perkinsus marinus;* and also the non listed *Haplosporidium nelsoni*. These diseases would be a serious threat to Pacific Oyster and clam stocks. The best preventative measure would be to prevent the introduction of *Virginica* into Scotland.
- The blue mussel *Mytilus edulis* is the endemic and dominant species of mussel in Scotland, and production was until recently thought to consist exclusively of this species. However, blue mussels are now recognised as including three distinct species: *Mytilus edulis*, the commonly cultivated species in the north Atlantic and the North Sea; *Mytilus galloprovincialis*, the target species for aquaculture in the Mediterranean, and *Mytilus trossulus*, which is most common in the Baltic and in areas of Canada where it is of lesser commercial interest due to its generally thinner shells and lower meat contents Dias *et al*., 2008. The three species are able to interbreed and produce hybrids which potentially could be fertile. Coupled with the potential influence of environmental conditions on growth, this makes it difficult to distinguish the species and their hybrids based on shell shape alone. Recent research on the distribution of *Mytilus* species in Europe has been greatly facilitated by modern molecular tools which, based on the animal's DNA are able to reliably distinguish between species and hybrids

in both wild and cultivated populations Dias *et al*., 2008. Recent reports by Scottish growers of fragile-shelled *Mytilus trossulus* which would break during grading, together with the identification of *Mytilus galloprovincialis* in cultivation areas, has raised important questions relating to sustainability of blue mussel cultivation in certain countries, and the risks associated with transfers of seed. In a few sea lochs in Scotland, *M. trossulus* appears to be moved from place to place with transfers for cultivation purposes, all of which seem to have connections through movement of mussel stock.

It is also found in some west coast marinas, suggesting that it might be movable on vessels. It has not yet been found in wild populations, even where adjacent cultivation ropes contain large proportions of *M. trossulus*.

There is no evidence of displacement or damage to wild populations, and therefore it does not presently fall into the definition of invasive.

- Beaumont (2000) reviewed the potential genetic consequences of transfers and introductions of scallop species. (There have been a number of introductions of scallop species in recent years, for example *Argopecten irradians* has been introduced to China from the USA, and *Patinopecten yessoensis* has been introduced into France and Western Canada from Japan. Details of known introductions of scallops are given in Appendix Table 1 and the known instances of transfer of scallops are given in Appendix Table 2.)
- To predict the genetic consequences of transfers, information on genetic differences between source and recipient populations is vital (Beaumont, 2000). This may be expressed by morphological, allozyme and DNA based data on genetic differentiation of scallop populations and scallop subspecies. Other considerations considered are the numbers of individuals transferred and whether they are wild stock or hatchery product. Loss of genetic diversity is difficult to avoid in hatchery conditions although there are also ecological advantages to using disease-free hatchery seed. Examples are given on how mitochondrial DNA data indicating significant genetic consequences of the introduction of *Argopecten irradians* from the USA to China, and on *Patinopecten yessoensis* introduced from Japan to Canada. Beaumont (2000) recommends that potential risks and consequences of hybridisation should be experimentally assessed before introductions of scallops are carried out. Hybridisation is unpredictable and can lead to loss of genetic diversity or breakdown of co-adapted gene complexes. The use of sterile triploid scallops for introductions to avoid hybridisation and reduce ecological impact has merit but reversion to diploidy may occur.
- *Mytilus edulis* living intertidally is often infested by macroparasites such as copepods, trematodes and polychaets (Lauckner, 1980; 1983). With increasing distance from coast (subtidal and offshore) mussels infestation is reduced in prevalence and intensity (Buck *et al*., 2005). In some European countries juvenile blue mussels are dredged from the intertidal region and transferred to licensed plots subtidally when using the on-bottom cultivation technique. However, these local transfers of mussels originating from the intertidal are supporting the transfer of parasites subtidally.
- The transportation of toxin producing algal species and their resting cysts, e.g. from paralytic shellfish poisoning toxin producers (McMinn *et al*., 1997), either in a ship's ballast water or through the movement of shellfish stocks from one area to another, provides a possible explanation for the in-

creasing trend of harmful algal blooms (Hallegraeff *et al.*, 1995). This is also the current situation in certain ICES countries. Additional risks involve the resting cells of toxic algae, capable of surviving for years in the sediment (Tillmann and Rick, 2003) below or in the vicinity of aquaculture installations. When favourable growth conditions return, the cysts may germinate providing a reservoir capable of reinoculating the water with swimming cells that can subsequently bloom (Mons *et al.*, 1998). This can lead to extended or, at times, permanent closure of production areas.

- In the UK, recent guidance provided by the Alien Species Group on behalf of the United Kingdom Technical Advisory Group (UK TAG) outlines the background to how alien species are dealt with in relation to achievement of the Water framework Directive's (WFD) environmental objectives (http://www.wfduk.org/) . If a red list alien species such as *Crassostrea gigas* is found in a water body it will then have to be proved it is having more than a "slight adverse impact" and this will be carried out using monitoring results or risk assessment. If it is having more than a slight adverse impact then the water will be classified as moderate or worse and if not then the water will be classified as good. The question of how this will then affect the shellfish farmers is important as they are growing *C.gigas* legally under licence (and were encouraged to do so in the past) and they have little control of "wild" settlement outside their farm. If therefore the presence of *C.gigas* is deemed to downgrade the classification of the water body it should be clear what effect will this have on shellfish farming in the area. Natural England is considering production of a document outlining the reasons for leaving *gigas* on the red list as there was some disagreement as to whether there was scientific evidence to support it being on the list.

6.6.2 Potential genetic implications for wild and cultured stocks

Results of the EU project GENIMPACT are summarised below.

GENIMPACT; WP1 Genetics of domestication, breeding and enhancement of performance of fish and shellfish; Pacific cupped oyster – *Crassostrea gigas*

The pacific oyster was introduced in Europe after the viral disease that crashed the Portugese oyster (*Crassostrea angulata*) population. Currently there's contact between the species in two areas of the world, between France and the south of Portugal and between Japan and Taiwan. In these regions hybrids are found. This hybridisation has its impact on the *C. angulata* population in Southern Europe.

Pacific oyster spat is mainly obtained from captures but about 20% of pacific oyster spat is derived from hatcheries. Hatcheries mainly produce triploid spat, which is not considered as a safe genetic confinement tool as triploids occasionally breed. The effect of the partial sterility of triploids is poorly known. Another tread to wild populations is the use of tetraploid broodstock when they escape from quarantine, as their fitness relative to diploids and the impact of their breeding with diploids is still unknown.

Beaumont A., Gjedrem T., Moran P., Blue mussel – *Mytilus edulis*, Mediteranian mussel *M. galloprovincialis* (Genimpact final scientific report)

The mussel species *Mytilus edulis* and *M. galloprovincialis* have a huge overlap in space from France to Scotland. *M. edulis* is found to be homogeneous throughout its range while *M. galloprovincialis* is genetically subdivided into a Mediterranean and an Atlantic group. *Mytilus trossulus* also exists in discrete areas. On places where these species occur hybrids are found, but little is known about the precise distributions of both mussel species and their hybrids. Without this basic information it is impossible to estimate the genetic influence of mussel aquaculture on wild populations.

The three main cultivation methods for mussels (bottom culture, suspended culture and bouchot culture) have their own specific characteristics. Therefore there may be a genetic impact due to genotype-specific mortality in areas where aquaculture is the major source of mussel biomass.

Hatchery production of mussels is very low in Europe, for this reason the risk of genetic impact from hatchery mussels is currently negligible.

Lapègue S, Beaumont A., Boudry P., Foulletquer P, European flat oyster – *Ostrea edulis* (Genimpact final scientific report)

Ostrea edulis occurs naturally from Norway to Morocco in the North-Eastern Atlantic and in the whole Mediterranean basin. The species has also been introduced in the United States, from Maine to Rhode Island (1930s and 40s) and in Canada (about 30 years ago). Mediterranean flat oysters have more genetic variability than the Atlantic population. The North American populations were derived from the Atlantic population.

Most flat oysters are grown from wild captured seed but in France, the UK and Ireland hatcheries are producing flat oyster spat. Hatchery cultured spat has usually a reduced genetic variability and could reduce the variability of the natural population. Polyploid flat oysters could be produced but are currently not farmed.

No large selective breeding programmes have been started for *O. edulis*, but some experiments to improve resistance to *B. ostreae* have been carried out. Results show a higher survival rate and a lower prevalence of the parasite in selected stocks but also a reduced genetic variability in mass selected populations.

Beamont A., Gjedrem T. Scallops – *Pecten maximus* and *P. jacobaeus* (Genimpact final scientific report)

Scallop spat is obtained from wild-captures and from hatcheries. Hatchery scallops can easily escape from farms, but since scallop aquaculture is very small scaled in Europe (213 tonnes in 2004 whereas the landings of captured fisheries exceeded 50000 tonnes), the effect on wild populations is not significant.

6.6.3 Potential implications for wild and cultured stocks by introduced species

Wijsman and Smaal (2006): In Irish and UK marine waters, 74 exotic species are present, of which 22 are not found in the Oosterschelde. None of these 22 exotic non-indigenous species were either found on the mussel plots in Ireland and Wales, nor in the transport samples. This, however, does not completely exclude the possibility of their transport. From literature data and expert judgment we assessed that 14 out of these 22 species there is a chance to survive transport, and establish populations in the Oosterschelde. With respect to the effect, out of the 22 exotic non-indigenous species the possible negative impact is considered high for three species. These are the algae *Alexandrium tamarense* and *Gyrodinium aureolum* and the gastropod *Urosalpinx cinerea* (American oyster drill). The algae can lead to toxic blooms and the American oyster drill predates oyster spat and can have a devastating effect on oyster beds. The algae species already occur in and along the North Sea, and could be able to find their own way to the Oosterschelde. The American oyster drill has been found locally on the Essex and Kent coasts at the East coast of the UK, and precautions are taken to prevent dispersal to the mussel production areas.

Wijsman *et al.* (2007a): In total 51 exotic non-indigenous species are known for the Norwegian coastal waters. Fourteen of these species are new for the Dutch coastal waters and can be regarded as target species, which could potentially be introduced into the Wadden Sea with the import of mussels from Norway. Species with highest chance of successful introduction are the algal species *Aglaothamnion halliae*, *C. fragile* ssp *scandinavicum*, *Verrucophora farcimen*, *Karlodinium micrum* and *Olisthodiscus luteus*, the polychaete *Scolelepsis korsuni* (due to the lack of information on this species and the precautionary principle that is used in this study) and the goose barnacle (*Lepas anatifera*). Species with the highest potential impact once introduced are the algal species *Verrucophora farcimen* and *Olisthodiscus luteus*, the American lobster (*Homarus americanus*), the king crab (*Paralithodes camtschaticus*) and the Manila clam (*Ruditapes philippinarum*). Due to the lack of information also the polychate *Scolelepis korsuni* is scored as a species with potential high impact (precautionary principle).

Wijsman *et al.* (2007b): In total 41 exotic non-indigenous species are known for the Swedish coastal waters. Ten of these species are new for the Dutch coastal waters and can be regarded as target species, which could potentially be introduced into the Wadden Sea with the import of mussels from Sweden. Species with highest chance of successful introduction are the algal species *Verrucophora farcimen* and *Aglaothamnion halliae* and the crustacean *Pilumnus spinifer*. Species with the highest potential impact once introduced are the algal species *Verrucophora farcimen*, *Oxytoxum criophilum*, *Pleurosira laevis Codium fragile* and the trematode *Pseudobacciger harengulae*. The study shows that the algae *Dissodinium pseudocalani*, *Oxytoxum criophilum*, *Pleurosira laevis*, *Verrucophora farcimen* and *Codium fragile* and the trematode *Pseudobacciger harengulae* present most risks.

McKindsey *et al.* (2007): Bivalves have been grown and transported for culture for hundreds of years and the introduction of some species outside of their native range for aquaculture has been suggested to be one of the greatest modes of introduction of exotic marine species. However, there has yet to be a thorough assessment of the importance of aquaculture and bivalve culture in particular, to the introduction and spread of exotic species. This paper reviews some of the environmental and ecological implications of the relationship between bivalve aquaculture and the introduction and spread of exotic species, management implications and mitigation strategies. Two broad classes of introductions of exotic species may result from activities associated with bivalve aquaculture. First, the intentional introduction of exotic species into an area for aquaculture purposes, i.e. the ''target'' species. These are typically foundation or engineering species and may have a considerable influence on receiving ecosystems. Second, the introduction of species that are either associated with introduced bivalves or facilitated by aquaculture activities (i.e. structures or husbandry practices). These may include both ''hitchhiking'' species (organisms that grow in association with or may be transferred with cultured bivalves) and disease causing organisms. Management options should include the use of risk assessments prior to transfers and quarantines. Various types of mitigation for exotic species have been evaluated but are generally not very successful. Because the risk of exotic species to ecosystems and the bivalve farming industry itself may be great, effort should be directed to better predict and halt introductions of potentially harmful species.

Forrest *et al.* (2009): Oyster farming in estuaries is a globally important industry based primarily around the Pacific oyster *Crassostrea gigas*, for which a common technique is elevated culture on racks, trestles and other structures. We review literature on cultivation impacts, revealing a research focus and state of knowledge that largely parallels that for other aquaculture species and cultivation methods. Ecological studies of elevated culture effects have focused on changes to the benthos from biodeposition, and largely show that impacts are localized and minor by comparison with many other forms of aquaculture. The broader ecological issues associated with elevated oyster culture include the effects of pests (fouling pests, toxic/noxious microalgae, disease), creation of novel habitat (e.g. by fouling of farm structures and accumulation of shell), alteration to nutrient cycling, depletion of suspended particulate matter by oyster crops, and related effects on higher trophic level animals including fish, seabirds and marine mammals. These issues are less well understood for elevated culture systems, but ecological effects can be inferred from the few studies that have been conducted, from other forms of bivalve aquaculture (e.g. mussels), and to some extent from fundamental knowledge of the role of oysters as 'ecosystem engineers'. We use a risk ranking method to evaluate ecological risks (and associated uncertainty intervals) for each of the issues associated with estuarine oyster culture, based on subjective assessment of the likelihood and consequences (severity, spatial extent and duration) of adverse effects. Our assessment reveals that the introduction and spread of pest species are potentially important but often overlooked consequences of oyster cultivation. By comparison with most other sources of impact, the spread of pests by aquaculture activities can occur at regional scales, potentially leading to ecologically significant and irreversible changes to coastal ecosystems. We suggest that future studies of cultivation effects redress the balance of effort by focusing more on these significant issues and less on the effects of biodeposition in isolation. Furthermore, the acceptability of aquaculture operations or new developments should recognize the full range of effects, since adverse impacts may be compensated to some extent by the nominally 'positive' effects of cultivation (e.g. habitat creation), or may be reduced by appropriate planning and management. Even more broadly, aquaculture developments should be considered in relation to other sources of environmental risk and cumulative impacts to estuarine systems at bay-wide or regional scales, so that the effects of cultivation are placed in context.

6.7 Recommendations

1) Prior to introductions, all possible alternatives at a local scale should be investigated before consideration of introductions as a last resort, e.g. employing hatchery or spat collection methods rather than importation.

2) Consultation on applications should be vigorous, be universally applied and be objective; and there should be a presumption against them, unless good scientific evidence proves otherwise.

3) Consideration should also be given to the risk to native stocks from interbreeding. The resultant progeny invading ecosystems possibly being infertile, creating an imbalance within an ecosystem. If not infertile they may replace indigenous stocks

4) Risk assessments should include possible effects of diseases (parasites, viruses and bacteria), genetical contamination and hitch hiking species.

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Annex 1: A guide to temporary quarantine conditions

1) The facility must be authorised as an Aquaculture Facility and all movements of live animals into the facility are to be recorded in the official Movement Record Book supplied.

2) The facility will be open to inspection by inspectors as deemed necessary.

3) The animals should be held in isolation in a system approved by the competent authority.

4) No animals or eggs are to be released alive from the facility without prior written approval.

5) All unwanted biological material must be removed in leak-proof containers and destroyed by incineration or autoclaving.

6) Access to the facility must be limited and come under the supervision of a nominated person.

7) A sign should be placed at all entrances stating ‘Quarantine Area - Restricted Admittance’.

8) All effluent must be discharged to a tertiary treatment system or disinfected prior to discharge. There should be no direct drainage to prevent any accidental release of contaminated fluids.

9) All protective clothing, footwear, nets, buckets and other equipment must be solely dedicated to the facility and should not be removed without thorough disinfection.

Please refer to the competent authority for guidance and advice on disinfection procedures.

7 Review the state of knowledge on the evidence for and effect of climate change on shellfish aquaculture distribution and production in ICES and countries worldwide (ToR e)

7.1 Background

Climate change has been defined by the United Nations Convention on Climate Change as the "change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods". The Intergovernmental Panel on Climate Change (IPCC) defines climate change as "a change in the state of the climate that can be identified (e.g. using statistical tests) by changes in the mean and-or the variability of its properties, and that persists for an extended period, typically decades or longer" which includes changes resulting from both natural variability and human activity. The IPCC analyzed global climate observations and concluded that "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level". Recent mean temperatures in the Northern Hemisphere are likely the highest in at least the past 1300 years. Precipitation and the frequency of large precipitation events have increased significantly in many ICES countries. These changes are linked with high confidence to increased runoff and the occurrence of earlier spring discharges and shifts in the geographic distribution and abundance of algae, plankton and fish. The increased carbon dioxide would also cause an acidification of the oceans, which may reduce the shell growth of molluscs (Gazeau *et al.*, 2007). Consequently, climate changes will directly and indirectly influence numerous factors that are known to influence shellfish (University of Victoria 2000, Canadian Institute for Climate Studies 2000).

The WGAMSC focus is to consider the current scientific evidence for and effect of climate change on shellfish aquaculture in ICES countries and worldwide. To address this task, any available evidence on climate change impacts on cultured species needs to be accumulated and assessed. The ongoing work of the WGMASC on this ToR includes reviewing reports on present climate change patterns and on projected changes in marine parameters that may affect shellfish culture. A starting point was to examine predictions of potential changes in the marine environment as revealed by different model scenarios. Given the close interaction between shellfish production and numerous natural ecological variations, it is important to assess any available evidence of potential climate change effects from a critical perspective. For example, can observations of summer mortalities in the oyster *Crassostrea gigas* can be attributed to climate change in certain European countries or simply be a result of poor broodstock selection? Evidence on climate change impacts on shellfish culture should ideally be based on cause-effect linkage rather than correlations, which can reflect autocorrelations, anti-aliasing, and/or random processes. Consequently, our continued work on this topic will examine evidence that is consistent with a climate-change effect, but with an objective awareness of natural forcing factors.

This report will be further expanded in the coming years.

7.2 Related ICES activities on Climate Change

This WGMASC term of reference is related to other ICES expert group activities and with the OSPAR request for ICES "to prepare an assessment of what is known of the changes in the distribution and abundance of marine species in the OSPAR maritime area in relation to changes in hydrodynamics and sea temperature." Some relevant ICES activities are summarized in the following sections.

7.2.1 Workshop on Climate related Benthos Processes in the Noth Sea (WKCBNS)

The ICES Benthos Ecology Working Group (BEWG) initiated a Workshop on Climate related Benthos Processes in the North Sea (WKCBNS; December 8 to 11, 2008 in Wilhelmshaven, Germany) to discuss research activities concerning the North Sea benthic ecosystem. This workshop report (ICES 2009a) included a review of the results of the North Sea Benthos Project 2000 (NSBP), an evaluation and prioritization of climate-related benthic processes, the development of research approaches and recommendations for the study of key benthic processes affected by climate change, and the important role that modelling approaches will play in addressing this research area. A starting point for addressing their workshop objectives, as well for addressing shellfish aquaculture issues, was the prioritization of current climate change hypotheses as they relate to the benthos (see Annex 1). Information from this report (ICES 2009a) have been used in our ongoing efforts to review the available knowledge on climate change effects on shellfish culture.

7.2.2 Steering Group on Climate Change (SGCC)

SGCC met for the first time in 2008 (ICES 2009b). The remit and responsibilities of the group are:

- Encouraging ICES member countries to provide relevant data for the study of climate change (e.g. historical data and data from long-term sampling sites);
- Identify appropriate methods of assessing information located in the ICES Data Centre and in non-searchable repositories;
- Identify functions and services that ICES can assume and provide in relation to climate change in the North Atlantic, provide added value to existing activities and so meet a demand of services and assessment presently not addressed;
- Advise ICES on the selection and preferred sequence of services that we can offer;
- Actively promote ICES services and assessment in climate change to potential users and stakeholders;
- Establish liaisons with international organizations, convention and panels with interest in the effects of climate changes in the oceans.

SGCC is preparing a position paper on climate change and is recommending that a section on the socio-economic consequences of climate change in the North Atlantic be drafted during a workshop specifically tasked for this purpose. Inclusion of aquaculture-related perspectives has not been specifically identified, but should be considered within this workshop. The SGCC group recommends that their position paper on climate change (anticipated in 2010) should be seen as the official ICES view on climate change. This report will therefore serve as a critical reference point for planning future activities by the WGMASC within this term of reference.

7.2.3 Joint PICES/ICES Working Group on Forecasting Climate Change Impacts on Fish and Shellfish [WGFCCIFS]

A joint PICES and the ICES working group (WGFCCIFS) was formed to develop:

- frameworks and methodologies for forecasting the impacts of climate change on marine ecosystems, with particular emphasis on the distribution, abundance and production of commercial fish and shell-fish;
- methodologies applied in designated case studies;
- techniques for estimating and communicating uncertainty in forecasts;
- strategies for research and management under climate change scenarios, given the limitations of our forecasts.

These WGFCCIFS terms of reference include the promotion of research on climate change impacts on marine ecosystems, in collaboration with relevant expert groups in PICES and ICES, through coordinated communication, exchange of methodology, and organization of meetings to discuss and publish results (PICES/ICES 2009). The main objective of the 2009 meeting was to agree to the structure of a science symposium organized under the auspices of the WG in April 2010 (Sendai, Japan).

In summary, WGFCCIFS is focused on the development of standardized quantitative frameworks for forecasting climate change impacts on commercially important fish and shellfish while the WGMASC is documenting available evidence of shellfish responses to climate shifts. Both group activities are linked to the WKCBNS focus on the identification of possible mechanisms underlying shellfish responses. It is therefore important to integrate these activities through enhanced communication/linkage between expert groups.

7.3 Background on Climate Change and Effects on Marine Benthic Species

A first step towards understanding climate change effects on cultured shellfish in ICES countries is the identification of; (1) the magnitude of observed and forecasted climate change (meteorology, physical and chemical oceanography) in the North Atlantic and (2) hypotheses on direct and tropho-dynamic effects. Both activities must emphasize changes known to influence the production of high quality commercial shellfish products. Towards achieving the first objective, the following overview of climate change observations and scenarios is extracted, often verbatim, from an International Panel on Climate Change Synthesis Report (IPCC 2007), the ICES brochure "Climate Change: Changing Oceans", and the ICES review of the effect of climate change on the distribution and abundance of marine species in the OSPAR Maritime Area (Tasker *et al*., 2008).

"Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level" (IPCC, 2007). Global surface temperatures between 1995 and 2006 were among the twelve warmest years since 1850 and the temperature increase is greatest at higher northern latitudes. There is very high confidence in the conclusion that average Northern Hemisphere temperatures during the last 50 years were higher than during any other similar period in the last 500 years and are likely the highest in at least the past 1300 years. The global ocean has taking up over 80% of the heat being added to the climate system and average water temperature has increased to depths of at least 3000m. Global average sea level rose at an average rate of 1.8 mm per year over 1961 to 2003 and at an average rate of about 3.1 mm per year from 1993 to 2003. Between 1900 and 2005 precipitation has increased significantly in eastern parts of North America, northern Europe and northern and central Asia. It is likely that the frequency of heavy precipitation events (or proportion of total rainfall from heavy falls) has increased over most areas and the incidence of extreme high sea level has increased.

Upper ocean temperature variability in the OSPAR Commission Maritime Area has been observed with high-quality measurements over the last 50-60 years (Fig ure 7.1; Hughes and Holliday, 2007). The in situ measurements demonstrate an interdecadal Atlantic Water temperature increase of about 1°C from the 1970s to the present, consistent along the shelf break from Ireland to the Barents Sea and the Fram Strait. In the North Sea, the rate of warming is even greater (1–2°C), whereas the warming in the western OSPAR regions is less (0.4–0.8°C; illustrated for the surface layer in Figure 2.1.3).

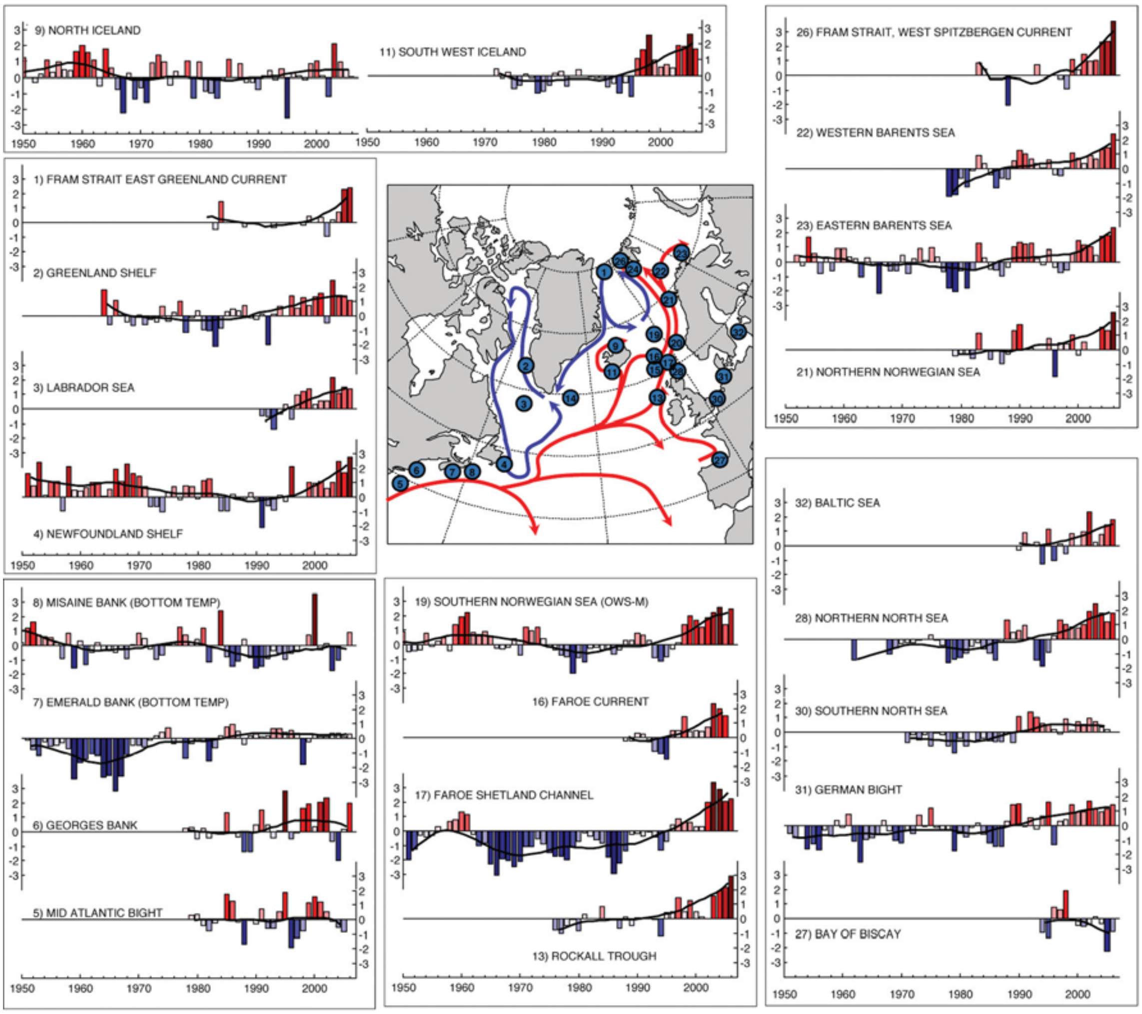

Figure 7.1. Overview of upper ocean temperature anomalies from the long-term mean across the North Atlantic. The anomalies are normalized with respect to the standard deviation (e.g. a value of +2 indicates 2 standard deviations above normal). The maps show conditions in 2006 (colour intervals 0.5; reds are positive/warm and blues are negative/cool). From Hughes and Holliday (2007) as published in Tasker *et al.* (2008).

Projections of future climate change in the near term, based on modelling of different scenarios, indicate that an atmospheric warming of about 0.2°C per decade over the next two decades. Assuming continued green house gas (GHG) emissions at or above current rates, further warming will occur during the 21st century and will induce many changes in the global climate system that would very likely be larger than those observed during the 20th century. The projected geographic patterns in warming trends and precipitation are expected to be similar to those observed over the past several decades. Larger peak wind speeds and more heavy precipitation will be associated with ongoing increases of sea-surface temperatures. Changes in precipitation lead to changes in runoff and seasonal runoff shifts. Runoff is projected with high confidence to increase by 10 to 40% by mid-century at higher latitudes. Anthropogenic warming and sea level rise would continue for centuries, even if GHG concentrations were to be stabilized, due to the time scales required for the removal of anthropogenic CO_2 emissions from the atmosphere.

For increases in global average temperature exceeding 1.5 to 2.5°C there are projected to be major changes in ecosystem structure and function, species' ecological interactions and shifts in species' geographical ranges, with predominantly negative consequences for biodiversity and ecosystem goods and services. The most vulnerable industries, settlements and societies are generally those in coastal and river flood plains, those whose economies are closely linked with climate-sensitive resources and those in areas prone to extreme weather events, especially were rapid urbanization is occurring. Coastal areas and industries are therefore projected to be exposed to high risks from climate change and sea level rise. Globally, the potential for food production is projected to increase with increases in local average temperature over a range of 1 to 3°C, but above this it is projected to decrease. This will increase the global need for aquaculture products at a time when coastal regions that currently support most of this activity are particularly stressed due to threat of sea level rise and increased risk from extreme weather events.

There is medium confidence that approximately 20 to 30% of all global species are likely to be at increased risk of extinction if increases in global average warming exceed 1.5 to 2.5°C (relative to 1980–1999). As global average temperature increase exceeds about 3.5°C, model projections suggest significant extinctions (40 to 70% of species assessed) around the globe. It is very likely that the meridional overturning circulation (MOC) of the Atlantic Ocean will slow down during the 21st century. Impacts of large-scale and persistent changes in the MOC are likely to include changes in marine ecosystem productivity, fisheries, ocean CO_2 uptake, and oceanic oxygen concentrations.

A meta–analysis of long-term datasets demonstrated that the changes in distribution, abundance, and other characteristics (particularly seasonality) of marine biota in this area are consistent with expected climate effects (Tasker *et al.*, 2008). This includes 85 cases of changes in the benthos and it was noted that if climate change results in temperature conditions outside the recent historical range of natural variation, major effects on at least some species and communities would be likely. This analysis was confined to sea temperature effects from climate change and the authors cautioned that this does not mean that all changes are consistent with a climate-change effect, nor that climate is the only cause, but it is undoubtedly a recognizably important factor. Other key interlinked climate variables that can affect biota include advection, vertical mixing, convection, turbulence, light, rainfall, fresh-water run-off, evaporation, oxygen concentration, pH, salinity, and nutrient supply. Changes in storm tracks, winds, rainfall, evaporation, sea ice, and river run-off will affect ocean currents, ocean fronts, and upwelling and downwelling, which, in turn, will profoundly affect the distribution and production of marine ecosystems at all levels, from plankton to fish.

It is expected that the largest changes in marine ecosystems will occur at the lower trophic levels, and evidence exists to suggest that phytoplankton seasonal cycles have shifted (Edwards and Richardson, 2004). Such a shift can have a large impact on community functioning if biologically associated linkages are disrupted and populations'cycles are shifted out of phase with seasonal temperature cycles, food production and predator abundance. For example, large scale climate changes have been shown to substantially alter estuarine zooplankton population dynamics owing to interspecies differences in life histories (Costello *et al*., 2006). It is thought that warmer sea temperatures have already caused significant changes in phytoplankton and zooplankton populations, including changes in abundance and distribution. Changing weather patterns are also predicted to increase the formation of vertically stratified water. The duration of a stable seasonal stratification is predicted to increase as a result of climate change, because higher rainfall will increase fresh-water inputs. Shellfish aquaculture is entirely dependent on the availability of natural trophic resources, including phytoplankton, which are dependent on nutrient supply to surface waters. In some regions, changes in plankton biomass and seasonal timing of blooms have been linked to the poor recruitment of some species whose life cycles are timed to make optimum use of these blooms.

Tasker *et al*. (2008) concluded "climate-related changes in a range of physical and chemical conditions in the sea will, in turn, affect species composition directly or indirectly and, therefore, the trophic structure of benthic communities. These effects are compounded in situations where the benthic species that are affected create distinct habitats, for example, coral reefs or mussel beds." The creation of habitat by the introduction of cultured ecosystem engineers (e.g. mussels and oysters) will be similarly impacted. The ICES workshop report on climate related benthos processes in the North Sea (WKCBNS; ICES 2009a) emphasized the need for enhanced research of climate influences on benthic communities owing to the complexity of benthic/pelagic coupling. Owing to the high intensity of some suspended and bottom bivalve culture activities, environmental interactions are highly complex, including numerous feedback mechanisms, and directed research is needed to understand and forecast additional changing climate influences.

Research carried out by ICES North Sea Benthos Surveys (NSBP 2000) related to climate change produced the following main findings:

- changes in the latitudinal distribution of some benthic species;
- changes in community composition; and
- the importance of large-scale hydrographic variables, such as bottom temperature, for the structuring of benthic (and fish) communities.

Some latitudinal shifts in distribution of benthic species, both northwards and southwards, have been documented and are related to the occurrence of warm and cool periods during the 20th century (reviewed by Tasker *et al*., 2008). These authors suggested that the strongest evidence of responses in benthic taxa that would be expected as a result of climate change is supplied in reports of:

- anomalously cold winter conditions leading to die-offs of species commonly associated with relatively warmer waters, or outbreaks of species commonly associated with relatively colder water; and
- benthic species expanding outside their historical ranges into more northerly or less coastal areas.

Such changes are likely to occur abruptly rather than incrementally over time owing to climate sensitivity in the benthos. An integration of large-scale benthos surveys (epifauna and infauna) into international survey programs was highly recommended (ICES, 2009a) to study distribution shifts of benthic species and communities in response to climate driven changes of the ecosystem.

7.4 Available Evidence on Climate Change Effects on Shellfish Aquaculture

The ICES workshop report on climate related benthos processes in the North Sea (WKCBNS; ICES 2009a) identified and prioritized hypotheses on the effects of climate change on the benthos (Annex 1). Table 7.1 summarizes these results and includes an additional column on the urgency of climate change issues from the perspective of its currently perceived influence on shellfish aquaculture. The following sub-sections report on the available evidence supporting some of these hypotheses.

Table 7.1. High priority hypotheses on climate change issues related to benthic structure and processes. All hypotheses identified were classified by importance (hot topic) and urgency of the issue from the perspectives of impacts on benthic communities (WKCBNS prioritization) and bivalve aquaculture (WGMASC prioritization). Adapted from ICES (2009a).

Hypothesis	Hot topic	Urgency (WKCBNS)	Urgency (WGMASC)
Frequency/intensity storms natural disturbance effect	yes	high	high
Production/biomass process changes driven by climate	yes	high	high
Community changes - habitat alteration through climate change	yes	high	high
Altered currents - frontal positions - primary production -food	yes	high	high
Cumulative effect of anthropogenic disturbance and climate change	yes	high	high
Effect of interaction in anthropogenic drivers and climate change drivers	yes	high	high
Change in timing of spawning and spatial distribution of settlement	yes	high	high
Stratification - temporal mismatch	yes	high	high
Changing wind directions - effect on larval transport and species distributions	yes	high	high
Changes in nutrient fluxes/advection	yes	negligible	negligible
Poleward shifts in latitudinal distributions of species	yes	negligible	high
Rising temp = greater invasive species	yes	negligible	high
Acidification effects	yes	negligible	high
Reduced mixing - deoxygenation	negligible	negligible	negligible
Parasites infection rates - consequences for survival and reproduction	negligible	negligible	high
Reduced mixing - HABs effect on benthos food web	negligible	negligible	negligible
Climatic induced changes in macro phytobenthic plants – influence on species composition	negligible	negligible	negligible
Change in pollutant runoff due to climate change effecting reproduction and local extinctions	no	no	*high
Alternative production export to deeper waters	no	no	no

*** The WGMASC also considered effects on shellfish product quality through contaminant bioaccumulation.**

7.4.1 Direct Effects of Temperature Change on Bivalve Culture

Water temperature is a key external factor mediating bivalve growth owing to the influence on a number of the physiological components of growth. However, it is often difficult to assign causality for growth changes to temperature variations owing to the complex interplay that exists between a wide array of exogenous and endogenous forcing factors that control growth. Ferreira *et al.* (2008) developed a modelling framework that enables integrated analyses of bivalve–environment interrelations affecting overall production at system-scales and used this approach to examine the potential effects of global climate change on mussel and oyster production. These authors considered an increase in water temperature of 1°C and 4°C for Strangford Lough (Northern Ireland) and predicted a reduction in aquaculture productivity and a decrease in both the mean weight and mean length of individuals. An increase of 1°C in the water temperature is predicted to lead to a reduction of about 50% in mussel production and less than 8% in Pacific oyster production, and an increase of 4°C could result in a reduction of 70% in mussel production and less than 8% in Pacific oyster production.

7.4.2 Geographic Shifts in Shellfish Species Distribution

As noted by Tasker *et al*. (2008), the strongest evidence of responses of benthic species (including cultured bivalve mollusks) that would be expected as a result of climate change is supplied in reports of benthic species expanding outside their historical ranges into more northerly or less coastal areas. This can result from the die-offs of species commonly associated with relatively warmer waters due to anomalously cold winter conditions and outbreaks of species commonly associated with relatively colder water. Intertidal shellfish are particularly susceptible to occasional mortality events during prolonged periods of hot weather and these would be likely to increase in frequency under warmer conditions For example, the recent disappearance of *Macoma balthica* from the Spanish part of the Bay of Biscay has been attributed to increased maintenance metabolic rates caused by short-term, but frequent exposure to elevated temperatures resulting in increasing summer maximal temperatures (Jansen *et al*., 2006). Although this is not a cultured species, possible latitudinal shifts in the geographic range of traditional and potential aquaculture species bivalves will affect aquaculture trends.

An examination of the temperature tolerance of different bivalve molluscs may serve as a first-order approximation of the susceptibility of aquaculture species to global warming trends. However, this approach is confounded by other factors that make it difficult to predict species responses to regional temperature variations. For example, a bivalve species residing in a more tropical climate is known to be less able to adapt to temperature variation than the same species residing in a temperate waters, owing to the wider thermal tolerance of the later (Compton *et al*., 2007). The detection of climate change effects on species distribution will more likely come from observed biogeographical changes.

The Pacific oyster *Crassostrea gigas*, which was first introduced to Europe by Dutch farmers in 1964, has developed explosively and is expanding its geographical range northwards. Diederich *et al.* (2004) studied how *C. gigas* became established on natural mussel beds in the vicinity of an oyster farm near the island of Sylt (northern Wadden Sea, eastern North Sea) where it was introduced. It took 17 years before a large population was established and analyses of mean monthly water temperatures indicate that strong recruitment coincided with above-average temperatures in July and August when spawning and planktonic dispersal occurs. It was concluded that the further invasion of *C. gigas* in the northern Wadden Sea will depend on high late-summer water temperatures. *C. gigas* were first discovered in the Norwegian Skagerrak in 2005 and recent surveys have revealed that they have become established in many areas along the Scandinavian coasts. Larval dispersal from other areas, combined with warmer summers, appears to be facilitating survival. *C. gigas* tends to settle in the same areas as *M. edulis* and these native species will likely diminish through overgrowth by oysters, food competition and consumption of mussel larvae (Nehring, 2003).

The native European flatoyster (*Ostrea edulis*) has its northern distribution in Scandinavia where it historically has been cultured mainly in habitats that have higher summer temperature than the coastal and oceanic environment (Strand and Vølstad, 1997). It is believed that increasing seawater temperatures and frequency of extreme warm summers during the last decade have supported the development of populations of the oyster in coastal waters of this region.

Berge *et al*. (2005; 2006) examined interannual variations in ocean temperatures and the increased northward volume transport of Atlantic water and suggested that a recently discovered population of *Mytilus edulis* L. in the high Arctic Archipelago of Svalbard represented a northward extension of the distribution range of blue mussels. This is the first observation of the presence of blue mussels since the Viking Age. These authors present data indicating that most of the mussels settled as spat in 2002, and that larvae were transported by the West Spitsbergen Current northwards from the Norwegian coast to Svalbard the same year. This extension of the blue mussels' distribution range was apparently made possible by the increased northward mass transport of warm Atlantic water resulting in elevated sea-surface temperatures in the North Atlantic.

The population dynamics of cold-water bivalve species are strongly related to temperature and mild winters in northwestern European estuaries have resulted in low bivalve recruit densities and small adult stocks (cockle *Cerastoderma edule,* Baltic tellin *Macoma balthica,* gaper clam *Mya arenaria* and the blue mussel *Mytilus edulis*; reviewed by Philippart el al. 2003). These authors suggest that the current rapid rate of temperature increase could lead to long periods of poor recruitment of wild bivalve stocks and an increase in warm-water species.

Latitudinal shifts in shellfish distribution and population dynamics may also result from climate change effects on predator/prey relationships. Mortality of juvenile bivalves appears to be related to food availability and reproductive strategies are closely linked to exploiting the spring phytoplankton bloom and avoiding peak predator abundance (Philippart *et al*., 2003). Temperature changes can cause a mismatch between spawning, phytoplankton production and predator abundance; resulting in high shellfish mortality, low recruitment and cascading effects through higher trophic levels (Philippart *et al*., 2003). Beukema and Dekker (2005) studied possible causes of recent bivalve recruitment failure in the Wadden Sea by comparing long-term data sets (1973 to 2002) of the annual abundance of spat of three of the most important species of bivalves (*Cerastoderma edule, Mya arenaria,* and *Macoma balthica*). They concluded that the recruitment trends are governed primarily by natural processes, in particular increases in predation pressure on early benthic stages, which in turn appear to be largely governed by the warming climate. Freitas *et al*. (2007) compared the temperature sensitivity of epibenthic predators with that of their bivalve prey and showed that crustaceans have higher temperature sensitivity and tolerance range compared with both their potential predators and with their bivalve prey. They suggested that a temperature increase can potentially lead to an overall higher predation pressure in these systems with negative impacts on bivalve recruitment. However, prevailing food conditions for bivalves and predators will determine to what extent the potential impacts of an increase in temperature will be realized.

As cultivated shellfish experience super-optimal thermal conditions, which will occur more rapidly for inter-tidally cultivated species, they will become more susceptible to bacterial, viral and parasitic infections (Gubbins, 2006). A case study revealing potential interactions between increased temperature, parasites and commercial shellfish is the Iceland scallop (*Chlamys islandica*) fishery, which started in 1970 in Breiðifjördur. This fishery provided yearly catches of about 9,000 tonnes between 1993 and 2000, but declined drastically between 2001–2008. Catch indices in 2008 amounted to only 13% of the average for 1993–2000 (Eiríksson 2009). The Iceland scallop is distributed within the Subarctic transitional zone at maximum sea temperatures of 12–15°C (Sundet, 1988; Hovgaard *et al*., 2001). The period from 1993 to 2003 was characterized by a steady increase in summer sea surface temperature in Iceland, with the highest estimated temperature of the previous century occurring in 2003 (Jónasson *et al*. 2006). The bottom sea temperature usually ranges from 0 to 10 °C on the scallop grounds (Eiríksson, 1986), however, the temperature data from these grounds show the highest recording of 12.2°C in Breiðifjördur at 15 m depths in August 2003 (Eydal, 2003).

An experimental study by Jonasson *et al*. (2004) showed that scallops collected during late summer can tolerate temperatures up to 13°C, at least for up to 21 d, but there is considerable mortality at 14°C. The rising temperature in Breiðifjördur during recent years has therefore brought the summer maximum temperature close to the apparent temperature tolerance of the stock, e.g. 12.2°C in August 2003 (Jonasson *et al*., 2004). However, it does not appear that the direct effects of temperature may be the sole factor responsible for the dramatic decline in the Iceland scallop stocks during the last years. Other factors, that are often temperature-dependent, such as diseases, may be equally or even more responsible (Jonasson *et al*., 2004). During the decline in the scallop fishery, nearly 100% of scallops greater than 60 mm shell height contained an apicomplexan parasite. The adductor muscles were most heavily infected and gonad development was impaired in infected individuals (Kristmundsson and Helgason 2009).The increase in temperature over the scallop grounds may have caused the scallops to be more susceptible to the infections and/or caused the increase in the number of the apicomplexan parasites in the area that caused mortality in the scallop stock. Furthermore, the warming trend could have created more favourable conditions for the parasite to proliferate inside the shells, resulting in increased natural mortality in the scallop stock.

7.4.3 Ocean Acidification Effects on Shellfish

Approximately one third of anthropogenic CO_2 emissions have been absorbed by the oceans (Sabine *et al*., 2004). As the oceans absorb CO_2, the dissolved CO_2 reacts with water to produce bicarbonate ions (HCO_3^-) by consumption of carbonate ions (CO_3^{2-}):

$CO_2 + H_2O + CO_3^{2-} \rightarrow 2HCO_3^-$.

This results is less carbonate and more bicarbonate in seawater. In addition, the depletion of carbonate results in much of the CO_2 remaining as CO_2 and the production of bicarbonate by reaction directly with water:

$CO_2 + H_2O \rightarrow H^+ + HCO_3^-$.

The resulting increase in hydrogen ions reduces pH. The pH of ocean surface water has declined by ~0.1, a 26% increase in acidity, since humans began emitting large quantities of CO_2 (Orr *et al*. 2005; IPCC, 2007a). It is estimated that the pH of the oceans will decline by an additional 0.3 to 0.4 pH units by 2100 (IPCC, 2007b). This change in pH will fundamentally altering the seawater chemistry to which marine life has adapted over millions of years.

Bivalve mollusks produce calcareous shells following the simplified reaction:

$CO_3^{2-} + Ca^{2+} \rightarrow CaCO_3$.

The calcification process mainly depends on the availability of CO_3^{2-}, which declines at elevated pCO_2. Bivalve mollusks require the availability of sufficient amounts of CO_3^{2-} for shell formation and excessive ocean acidification will decrease the ability of bivalves to build their shells. Research into the effects of increased ocean acidification on all marine calcifiers, as summarized by Kleypas *et al*. (2006), has concentrated on addressing:

- how calcification rates vary with calcium carbonate saturation state; and
- the effects of changing calcification and dissolution rates on the ocean carbon cycle and the capacity of the ocean to take up CO_2 from the atmosphere.

These authors noted that the question of how decreased calcification rates affect biological functioning or organism survival has been largely unstudied, although it is currently a "hot topic". The question of how economically important cultured and wild bivalve populations will respond to present and projected acidification levels is largely unknown and should be included in future studies in terms of: (1) calcification response, (2) organism response, (3) ecosystem response, and (4) socio-economic response.

To date, studies of the effects of elevated pCO_2 on marine calcifiers have been confined to just a few species (Kleypas *et al*., 2006), and there remain large gaps in knowledge of the physiological and ecological impacts of increasing pCO_2 on these organisms. Gazeau *et al*. (2007) was the first study to pCO_2 levels within the range of values projected by the IPCC (up to 1,250 ppmv in 2100). They showed that the calcification rates of important aquaculture species (*M. edulis* and *C. gigas*) decline linearly with increasing pCO_2 and that mussels dissolved at pCO_2 values exceeding a threshold value of ~1,800 ppm. It was projected that mussel and oyster calcification may decrease by 25 and10%, respectively, by the end of the century. Longer-term exposures of *Mytilus galloprovincialis* at pH = 7.3 (consistent with a pCO_2 of about 1900 μatm) also observed significant growth reduction and shell dissolution owing to reduced haemolymph bicarbonate levels (Michaelidis *et al.* 2005). However, Berge *et al.* (2006) showed that the growth of *M. edulis* at pH levels of 7.4 and 7.6 was not significantly different from growth at normal pH 8.1. This apparently contradictory result may be explained by adaptation by the mussels during a longer incubation period, respiratory production of pCO_2 in incubation chambers, which increases the capacity of the organism to fix CO_3^{2-}, and the use of less sensitive methods for detecting growth changes (Gazeau *et al*., 2007). Bibby *et al.* (2008) investigated the immune response in mussels (*Mytilus edulis*) exposed to acidified (using CO_2) sea water, and suggested that ocean acidification may impact the physiological condition and functionality of the haemocytes. Calcium carbonate shell dissolution could have a significant effect on cellular signalling pathways, and particularly those pathways that rely on specific concentrations of calcium.

Larval and juvenile bivalves are particularly sensitive to ocean acidification and high mortality rates have been linked to calcium carbonate dissolution (Green *et al*., 2004; Fabry *et al*., 2008). This and the other studies reported above give reason to speculate that recent declines in bivalve populations may be connected to ocean acidification. Two of the largest oyster hatcheries in the Pacific Northwest reported an 80% decline in production rates. It is suspected that wind-driven coastal upwelling events have exposed the bivalves to deep acidic waters (Miller *et al*., 2009). Feely *et al*. (2008) observed that during a 2007 upwelling event, surface waters in a region near the California-Oregon border reached the low pH level of 7.75; exposing juvenile oysters to corrosive conditions.

Studies on other marine calcifiers have provided some general conclusions on responses to acidification (based on review by Kleypas *et al*., 2006):

- Benthic calcifies have shown a significant calcification response from carbonate chemistry. For example, the average response of corals is a 30% decline in calcification in response to a doubling in CO_2.
- Exposure to elevated CO_2 can affect physiology as well as calcification rate in many benthic organisms.
- The interactive effects of saturation state, temperature, light, and nutrients, are important factors in calcification rates of reef organisms.
- Identification of cause-effect relationships is difficult because calcification rates in the field are a response to multiple variables (light, temperature, nutrients, etc.) and particularly to rising temperature.
- Several years may be necessary to determine whether benthic calcifiers can adapt or acclimate to different carbonate chemistry conditions.

Bivalves are a net source of dissolved CO_2 via respiration and the deposition of calcium carbonate in shell material, which induces a shift in the seawater carbonate equilibrium to generate CO_2. Using data on respiration and calcium carbonate production by the Asian clam, *Potamocorbula amurensis,* which is invasive to San Francisco Bay, Chauvaud *et al*. (2003) assessed their importance as CO_2 sources and provided compelling evidence that bivalve mollusks can markedly influence inorganic carbon cycling by generating CO_2 to the surrounding water. Increasing seawater temperature will hypothetically lead to an increase of respiration rates and therefore accentuate the effect of increasing pCO_2. This biogenic CO_2 source is increasing because of the continuing global translocation of mollusks, their successful colonization of new habitats and rapidly growing aquaculture production (Chauvaud *et al*., 2003). Cooley and Doney (2009) and Gazeau *et al*. (2007) both concluded that ocean acidification could lead to "substantial revenue declines, job losses, and indirect economic costs" as a result of loss of fishery revenues from shellfish and their predators.

7.5 Responsiveness of Existing Conservation and Protection Policies to Climate Change Issues

A EU report recently reviewed how European policy adapts to marine climate change. *The Water Framework Directive* (WFD) does not directly respond to the effects of climate change. The aim of the WFD is to obtain a "good status" of water bodies. However, this iterative management system with six-year cycles of monitoring, assessments, and planning is robust to responding to climate change effects. OSPAR Commission Contracting Parties will establish ways in which to incorporate both climate change and ocean acidification considerations into future work. The Assessment and Monitoring Committee (ASMO) is currently taking this work forward using the latest pan European overview of climate change, produced by the European Science Foundation as one starting point to critically evaluate future science needs and to identify the 'added value' OSPAR might provide in this area. The *NATURE 2000* legislation, designed to protect the most seriously threatened habitats and species across Europe, also does not directly address climate change. However, directives listing the habitat types and organisms protected can adapt in response to scientific advice. An important concept of both *The Common Fisheries Policy* and the Canadian *Oceans Act* is the precautionary approach. This approach may be used to adapt policy to the consequences of climate change.

7.6 Recommendations

1) ICES activities related to climate change issues are inherently linked but are not well linked within the current ICES organizational structure. The WGMASC continues to recommend an integrated expert group approach towards addressing specific aspects of this topic. In the interim, the WGMASC will continue to review outputs from other relevant expert groups and to integrate these results into our activities. In anticipation of the WGEIM also working on a similar ToR, we recommend that they focus, as a group, on finfish aquaculture and that key members of the WGEIM be invited to review our draft reports and actively participate in WGMASC meetings where this ToR is addressed. (SCICOM, WGEIM, WGFCCIFS, SGCC).

2) The WGMASC should continue to review the state of knowledge on the evidence for and effect of climate change on shellfish aquaculture distribution and production in ICES and countries worldwide (SCICOM, WGMASC, WGEIM). Several critical hypotheses on climate change interactions have not yet been adequately addressed including, but not limited to;

   a) effects on shellfish resulting from climate change related to the indirect effects of climate-related changes in primary production, run-off, salinity, nutrient dynamics, acidification of the ocean, etc.

   b) Temperature effects on susceptibility of shellfish to bacterial, viral and parasitic infections.

   c) potential for risk analysis approaches for assessment

   d) potential opportunities for positive effects such as exploiting new species for aquaculture in northern countries.

   e) contingency planning to minimize impact.

   f) Prioritization of research issues.

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Annex 1: List of climate change hypotheses

The following list of hypotheses related to climate change and the conceptual model illustrating climate effects on benthos is based on Annex 3 of the ICES WKCBNS REPORT (ICES, 2009).

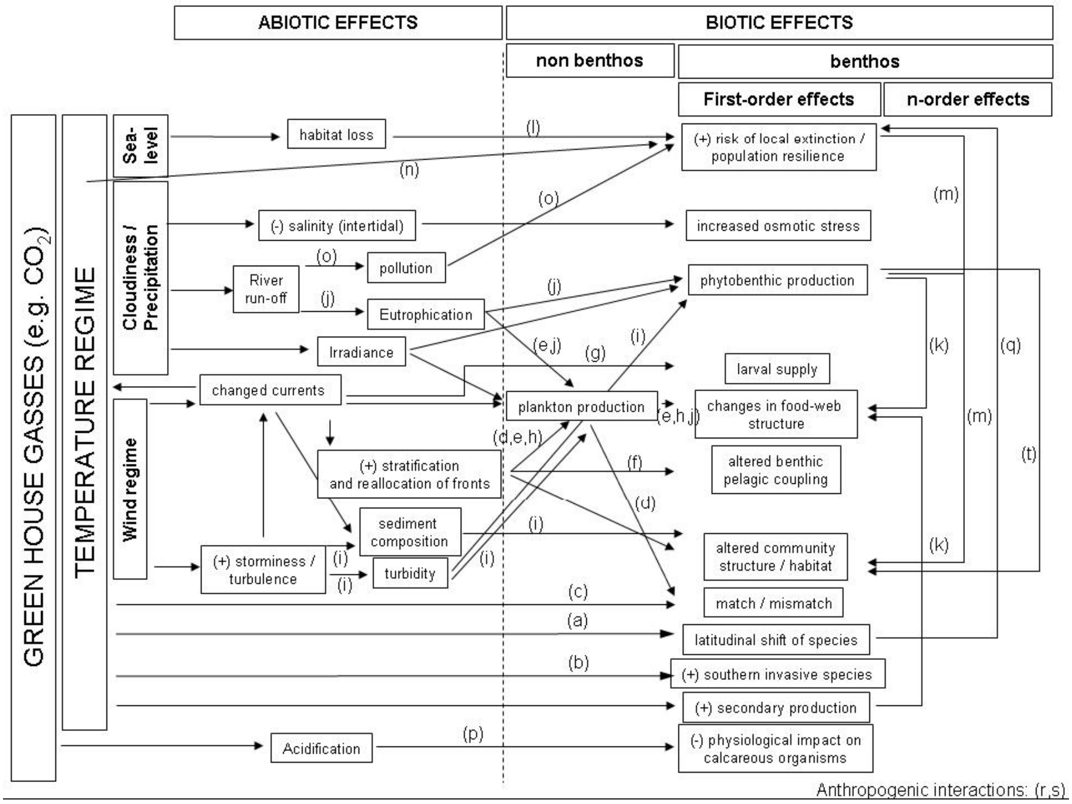

Figure A3.1. Conceptual model of the links between climate change and benthic communities (hypotheses indicated by the letter below).

(*a*) Poleward shifts in the latitudinal distributions of species, with consequent changes in species composition and species richness at any given location.

(*b*) Rising temperature could enable more human introduced species to invade and become established, replacing current native species.

(*c*) Climate change might result in changes in the timing of reproduction. This might result in a temporal mismatch between the larval period and/or settlement and the availability of food, i.e. the plankton bloom.

(*d*) Stratification and spring blooms of plankton in our shelf seas will occur earlier in a warmer climate. This might result in a temporal mismatch as mentioned above.

(*e*) Reduced mixing of the water column (increased stratification) may favour many Harmful Algae Blooms-causing species. This might have effects on the benthos food web relying on phytoplankton as primary food source.

(*f*) Reduced mixing may also enhance the risk of oxygen depletion and result in altered pelagic-benthic coupling.

(*g*) Changing wind directions may lead to changing local surface currents resulting in changes in larval transport and, thus, species distribution.

(*h*) Altered current conditions may lead to shifts in frontal areas and may change upwelling situation. This will influence primary production with consequences for the food supply to the benthos.

(*i*) Changes in the frequency and intensity of storms will change the wave energy which will have an impact on the benthic environment.

(*j*) Changes in nutrient fluxes due to advection, vertical diffusion and mixing, river flows and atmospheric deposition, leading to changes in primary production with consequences for the secondary production and biomass of the benthos.

(*k*) Changes in the production and biomass of benthic species will have implications for the food web dynamics.

(*l*) Sea-level rise may accelerate the loss of intertidal habitats also because of increased coastal defences (e.g. hard structures, islands, beach nourishment).

(*m*) Community changes including habitat forming species will result in altered habitats.

(*n*) Changes in the temperature regime might lead to extreme high temperatures in the intertidal, including runnels on beaches, leading to decreased survival of some species (e.g. juvenile shrimp).

(*o*) Climate change may influence terrestrial inputs of pollutants and the release of pollutants currently locked in seabed sediments with consequences for the benthos such as effects on reproduction and local extinctions.

(*p*) Future increases in ocean acidity will have major negative impacts on some shell/skeleton-forming organisms.

(*q*) An increased distribution of parasites (such as trematodes) will lead to higher infection rates of benthic species with consequences on survival and reproduction.

(*r*) Anthropogenic impacts caused by drivers such as fisheries and pollution may de-crease the resilience of the benthic community and/or of certain benthic species to changing climatic conditions, further endangering their populations (slightly altered to include community and species level effects).

(*s*) Synergistic and antagonistic effects of climatic and anthropogenic effects. (This hypothesis has been reformulated as the original formulation was ambiguous: "Changes of anthropogenic actions (e.g. fisheries, sand extraction) will have consequences for the benthic environment").

(*t*) Climatic induced changes in phytobenthic plant species composition and coverage will influence the associated faunal composition as well as animals seeking reproduction, nursery areas as well as food within the phytobenthic zone.

(*u*) Alternative production (e.g. the increase of opportunists) will increase the export of organic matter to the benthos of deeper waters, providing food, but also cause anoxia in the deeper waters.

8 Report to SSGHIE on potential and current contributions of your EG to the Strategic Initiative on Coastal and Marine Spatial Planning (SICMSP) (ToR f)

8.1 Background

Over the past decades, scientists and policymakers have become increasingly aware of the complex and manifold linkages between ecological and human systems, which generated a strong research effort into social-ecological systems analysis. Social-ecological systems are understood to be complex adaptive systems where social and biophysical agents are interacting at multiple temporal and spatial scales (Janssen and Ostrom, 2006). This has stimulated researchers across multiple disciplines to look for new ways of understanding and responding to changes and drivers in both systems and their interactions (Zurek and Henrichs, 2007). Integrated coastal zone management (ICZM) can be viewed as being part of this social-ecological system paradigm, in which special emphasis is placed on the complexities of coastal settings and their manifold drivers in ecological and human systems. Both, the social origins of unsustainable ecosystem management and the social repercussions of environmental management are central to these approaches.

Whilst addressing the interactions and feedbacks between issues (e.g. economic, social and environmental consequences) in a spatial planning context, it becomes evident that many of these play out over time (i.e. in past, present and future contexts) and space (i.e. at local, regional and ecosystem/global scale)—these are referred to as 'cross-scale' or 'multi-scale' processes. Processes commonly unfold at different geographical scales and over different time scales: the more aggregated the geographical scale (e.g. the regional ecosystem scale), the slower a system's dynamics unfold. Conversely, at a less aggregated geographical scale (e.g. the local scale) the social-ecological dynamics are more responsive. To capture this increased complexity in the context of decision-making, new tools in the planning process are in mandate. A number of research supported approaches to indicator and monitoring systems have been developed and advanced to better understand the current and future interaction of various driving forces (Carpenter and Brock, 2006). Recently indicator systems have also been used to address multi-scale processes or to link social-ecological systems developed at various geographical scales with each other in order to better understand the interaction of processes, objectives and institutional arrangements across scales (Carpenter *et al.*, 2008).

In the context of shellfish cultivation, larger scales are required to understand the *context* in which the activity works and the smaller scales support our understanding of the underlying *mechanisms* of the respective shellfish operation. The necessary interconnectedness of the different scales and time frames thus need to be captured by coastal and marine spatial planning initiatives.

8.2 An ecosystem approach for aquaculture

The 2009 report of the WGMASC described a recommended framework for the integrated management of coastal and marine shellfish aquaculture (WGMASC 2009). The foundation of this framework is an ecosystem approach for aquaculture (EAA), which has been defined as "a strategy for the integration of the activity within the wider ecosystem in such a way that it promotes sustainable development, equity, and resilience of interlinked social and ecological systems" (Soto *et al*., 2008). According to Costa-Pierce (2008), an ecosystem approach to aquaculture strives to balance diverse societal objectives. EAA applies an integrated approach to aquaculture by taking account of the knowledge and uncertainties of biotic, abiotic and human components of ecosystems, including their interactions, flows and processes within ecologically and operationally meaningful boundaries. Three scales/levels of EAA application have also been identified as the farm, the waterbody and its watershed/ aquaculture zone, and the global, market-trade scale. An ecosystem approach to the management of shellfish aquaculture should follow the same definitions and principles.

A goal of shellfish cultivation management is to have tools available that can predict and measure the capacity of an area to support the cultured species. So far a number of models/indices that focus on far-field effects (e.g. nutrient cycling, pelagic carrying capacity) have been developed that can provide industry and ocean management with the tools to efficiently and comprehensively assess effects associated with shellfish culture activities within an ecosystem-based management framework. Such tools and components include: hazard identification; environmental exposure and risk assessments (including predictive modelling); risk management; cost-benefit analysis; environmental indicator monitoring; impact management based on indicator threshold values (environmental targets); implementation of effective mitigation measures; decision support tools for responsive ecosystem management; and communication. With the development of the ecosystem approach to providing advice for the management of marine ecosystems, there has been a change in farm management beyond the recent focus on the development of tools for determining the maximum sustainable yield of the culture. This "production carrying capacity" approach reflected an economic and farm management perspective to aquaculture management. The present focus on ecological sustainability and EA requires consideration of significant changes in ecological energy flow, material fluxes, and the structure of the food web. These considerations are relevant to determining the "ecological carrying capacity" of an area for aquaculture development. The ecological carrying capacity can be defined as the level of culture that can be supported without leading to significant changes to ecological processes, species, populations or communities in the growing environment (Gibbs, 2007).

A global activity related to the development of an ecosystem approach for aquaculture is the creation of performance-based standards that are linked to certification schemes. These are designed to minimize the key social and environmental issues associated with shellfish farming while permitting the industry to remain economically viable. It is recognised that the implementation of certification schemes helps the industry sector to work toward more sustainable aquaculture, including reduced impacts. Certification schemes relevant in some way to aquaculture have been reviewed by Funge-Smith *et al*. (2007) and the World Wildlife Fund (WWF, 2007). Organisations active in this field include the FAO, WWF, Friend of the Sea, Naturland, Global Gap, and Aquaculture Certification Council. The WWF has identified key environmental and social issues related to mollusc production and is currently in the final stages of drafting certification criteria for shellfish aquaculture to reduce each issue. The underlining principle of certification is that a fully independent body from the production sector should be responsible for certification. Performance-based standards developed by the WWF will be given to a new organization (Aquaculture Stewardship Council) that will be responsible for working with independent, third party entities to certify farms that are in compliance with the standards.

The 2009 report of the WGMASC recommended the use of the DPSIR framework as a basis for integrating economic, societal and ecological principles for the management of coastal and marine shellfish aquaculture (WGMASC, 2009). This approach requires the identification of performance indicators for addressing issues related to each component of this framework (effect, impact and response). Interestingly, as surfaced in the WGMASC and WGEIM discussion on the bivalve aquaculture dialogues of the WWF certification process (see Section 3.1.1), the lack of consensus on the social dimension is particularly striking when compared with the more universally accepted general definitions that exist for the biological and economic dimensions. Capturing the social dimension within the DPSIR framework, or any other sustainable ecosystem management scheme, requires the development of associated management indicators and decision criteria. In the following, we elaborate more on this observation and draw critical issues that marine spatial planning needs to address in the future from a shellfish cultivation point of view.

8.3 Why the shortcoming in capturing the social dimension in an ecosystem approach?

Many past approaches to ecosystem management might be called "socially illiterate" (Glaser, 2006a). Even if beyond reproach in ecological terms, many ecosystem management proposals can be outright failures due to a lack of stakeholder participation and/or understanding of social influences on ecosystems and of ecosystems on humans and society. Most interpretations of the social dimension of ecosystem management are also highly context-specific and lack universal core and general applicability. This makes the issue of a general strategy for marine spatial planning so difficult.

For instance, shellfish cultivation is faced with increased social conflicts between stakeholders (farmers, nature conservationists, recreation, fisheries). In the Netherlands for example, the use of mussel seed capture systems is promoted as an alternative for bottom dredging. But the supports of the capture systems are floating on the water surface that affects the landscape and the space for recreation and fisheries. These types of interactions make shellfish culture an excellent example for Integrated Coastal Zone Management (ICZM). Planning tools and alternative solutions need to be reviewed. How can we evaluate effects of new established marine management strategies such as the Marine Spatial Planning Act? What are indicators of the status of social perception of shellfish culture that can help in avoiding conflicts? How do social values and administrative organizations in different countries/regions affect trends in the intensity, methodology, structure and type of aquaculture?

Thus, in a planning perspective, next to the issue of siting, and monitoring of any kind of activities in the coastal and marine waters, an issue yet not being addressed in depth pertains to the social dimension of resource use. The WGMASC identified primarily four overarching social dimensions in shellfish cultivation, namely (1) the social acceptability of the shellfish culture, (2) the supply availability to the market, (3) the livelihood security for the local communities, and (4) the economic efficiency of shellfish culture operations. However, the systematic description of the social elements relevant to the sustainable management of marine ecosystems is still in its infancy (IUCN 2001; Lass and Reusswig, 2001, Glaser, 2006b).

This lack has surfaced more prominently in the current ongoing debate on new forms of marine spatial planning. Although international maritime policies (e.g. Canadian *Oceans Act* and EU *Water Framework* and *Marine Strategy Directives*) include essential components; 1) a knowledge-based approach for decision making, and 2) an ecosystem-based approach for integrative management, a shortage is visible of the mostly environmentally motivated approaches to recognise the social functions of nature. Still now, making nature a commodity remains a moral problem even in a market-driven economy (McCay, 1998). Questions on who decides what and when as well as ownership issues remain unanswered. For instance for the latter, the large-scale offshore developments in Germany have triggered a debate on who decides on the future of the sea and what criteria are used to take such decisions.

Drawing on the experiences made with shellfish cultivation in several places within the ICES scope, unresolved issues of ownership in terms of process, which stakeholders are involved in the consent procedure and their relative influence appear to crucial. Social dimensions in shellfish cultivation operation, e.g. emotional ownership of the sea/coastal area by the local residents/stakeholders and the social values that drive this ownership are difficult to capture. However, precisely these stakeholders and their supporting values are not included in the decision-making process. Next it remains difficult to keep all stakeholders in agreement on the matter—the "contracting costs" (the cost, not necessarily in money, of getting a group of people to agree on an issue) that make it so difficult to enact major institutional change that affects natural resources (McCay, 1998). Thus, new marine planning initiatives must translate local ownership of the resource into greater ownership of process.

8.4 Marine spatial planning and shellfish cultivation – a snapshot on the status quo

As coastal populations and economies grow and the use of marine and coastal resources expands and intensifies, governance has become a key concern. International agencies, national governments, environmental organisations, and citizen movements have responded by organising international conferences, setting new policy agendas (like Integrated Coastal Zone Management or the EU Maritime Directive or Canada's Ocean Act), and devising rules to re-organise space (such as the Law of the Sea) or to protect vulnerable sites and species, as through the establishment of Ramsar sites and Marine Park or Protected Areas all over the world.

One critical example is the role of marine spatial planning; an area requiring considerable scientific support for decision-making that is quite different from the kinds of information used in traditional management schemes. Maritime spatial planning is necessary because increased activity on Europe's seas is resulting in heightened competition between different sectoral interests, such as shipping and maritime transport, offshore energy, port development, fisheries and aquaculture, and environmental concerns. This, in turn, is putting mounting pressure on already limited marine space. A more collaborative and integrated approach to decision-making is required to secure the sustainable development of marine areas in a healthy environment (ICES, 2009). Maritime spatial planning is a process, which is determined by the specific needs and challenges of a given marine region and in which well-defined guiding aims, stakeholder involvement and data collection all feature prominently. The adoption of a maritime spatial plan is only one step in this process. It continues with monitoring and evaluation activities to make sure that the plan is enforced properly. It must also be reviewed, and revised where necessary (ICES, 2009).

Important for shellfish cultivation is the fact that maritime spatial planning can promote efficient use of maritime space as well as taking into account the impacts of climate change whilst providing guidance and reliable data in seeking potential locations for aquaculture activities. Implementation of maritime spatial planning is the responsibility of Member States. However, action at the EU level can bring important added value; ICES could play an important role here in providing advice and possibly a recommended framework based on successful existing schemes (ICES, 2009). It provides a basis for Member States to develop, in conjunction with other instruments such as environment legislation, impact assessments or integrated management plans for specific sea basins or ecosystems. On all levels, participation of stakeholders is sought for. However, this implies that it is also an area involving large numbers of powerful stakeholders who have not traditionally participated in e.g. fisheries debates. In its wake, the scientific underpinnings of the European Common Fisheries Policy (CFP) are undergoing extensive revision. Hereby the EU calls for an inclusion of the views of stakeholders, as well as addressing social sustainable dimensions. Whereas Fisheries regulations tend to draw lines on maps and within communities by creating limited access permits and complex management structures, new demands have surfaced which will inevitably alter the way we use and view marine systems probably towards a more holistic approach. As one relevant issue concerning aquaculture, the new CFP considers aquaculture as an integral part of the policy that plays a complementary role vis-à-vis the catching subsector. That having being said, funding for aquaculture should be promoted, were the main criterions being their contribution to the social and economic development of coastal life.

These initiatives interact with national policymaking, and their implementation often depends on national and local political will and technical capacities. More often than not, issues of the access to, and ownership and distribution of the resources are cases where the appropriators of the marine and coastal resources are not being involved in decision-making. As reaction, the EU concept of maritime governance addresses some of the criticisms of other approaches to resource management by placing greater emphasis on diversity, complexity, dynamics, scale, principles and values. However, these constructions are contested and negotiated by coastal communities, whose actors developed their own diverse coastal spaces, according to their social practices, economic activities, and environmental perceptions, leading to a much more fragmented coast. This has serious implications, particular spatial distributions of access rights, as in the case shellfish cultivation as potential new stakeholder group in coastal and marine areas.

Shellfish cultivators have often little political representation, as shellfish cultivation is often a family-run business with only marginal links to key decision-makers. As exemplified for the case of Fishermen in Brittany, France, the continuation of family-based artisanal fisheries is at risk in the context of neo-liberal globalization. Neoliberal approaches favour rationalized economic models of governance in which individualized property, rationalized modes of production and concentrated ownership are prioritize over locality-based modes of harvest and governance (Menzies, 2003). Furthermore, as a result of the development of civil society into more and more separate branches of aquaculture production (e.g. fin fish cultivation on- and offshore; nearshore off-bottom and on-bottom shellfish cultivation, etc.) a manifold increase of stakeholder groups has been provoked. This in turn has caused that the shellfish aquaculture community has lost prominence and importance, fading into the wide spectrum of interests with which it is competing to make its voice heard in decision-making bodies and in the media. This results in what could be termed *the participation paradox*: the greater the number of actors, the smaller the role each plays, and the lesser the importance of traditional sectors (Suárez de Vivero, 2007). Thus, participation and devolution do not bear a linear relationship: greater devolution does not necessarily result in greater participation of those who are directly affected by the decisions made.

8.5 Critical issues needed to be address by marine spatial planning from the viewpoint of shellfish cultivation

The observed conceptual confusion on how to embrace in a concerted action economic, ecologic, social and cultural dimension in marine spatial planning appears to be one of the main reasons why so many nations have shown themselves unable to manage many marine ecosystems in a sustainable manner. The challenge is to find ways to ascertain the value of marine ecosystem goods and services bracing across all of the above-mentioned dimensions. It must be recognised, that fisheries and shellfish cultivation play important roles in the society such as not only food security, employment and economic opportunities in rural communities, but also in terms of culture, physical and mental well-being, providing opportunities for new activities and supporting environmental and national securities.

Acknowledgment of local ecological knowledge systems within management schemes are often considered to be critical to foster the development of respect for what people know and, as a result, do within local natural environmental and ecological settings. However, a close look in the examples given herein tells us that local ecological knowledge studies remains within the academia. An eminent question arising from these observations is "How and where should local ecological knowledge be effectively communicated and used to inform decisions when they are being made?" In this regard, building partnerships amongst actors and promoting 'social capital' can be considered as a way forward. Such an approach to localizing activities in marine spatial planning involves organizing a knowledge base of particular social, cultural, ecological and economic values related to the context of each marine activity. However, the dilemma remains to what kind of knowledge is needed since where to search for it is not obvious. Neither is it always clear, who should provide it, and how. Thus, a major challenge exists with regard to the provision of how to define an acceptable knowledge base for decision-making in coastal zone matters.

In most cases this has lead to the application of the precautionary principle that has gained an enormous importance in environmental policies. However, there is neither universal agreement on its conceptualization, nor on its practical implementation of operational rules and guidelines in specific contexts (e.g. see example given in Edwards and Leung, 2009 on eradication of nuisance species in shellfish cultures). To be of importance for management decisions, uncertainty must be framed. In this case, precaution is translated into a set of quantifiable risk parameters. The framing process, however, renders some forms of uncertainty visible while simultaneously excluding others from consideration. This raises the question about the extent to which the precautionary approach is practical for the emerging issues we face, e.g. to define what criteria we apply to reach an understanding of social sustainability in the marine realm. What is it that should be shaped and maintained? The ecological economist Daly (2003) contends that a concept to assess the ethical and social limits to growth is needed, analogous to the environmental sustainability measure of systemic 'throughput'. This idea is similar to concepts of social carrying capacity, which stress the social barriers to growth (Glaser, 2006b). Lehtonen (2004) proposes that the identification of social irreversibility, as for example in mortality and education, can be developed into a "social precautionary principle", to counterbalance possible adverse social consequences arising from a purely ecological interpretation of this principle (Ballet *et al*., 2003, Glaser *et al*., 2003).

A recurring bottleneck to the establishment of an operational framework for managing aquaculture is the need to define an "unacceptable" impact. While science has an important role in advising managers and policy makers on the ecological consequences related to available management options, this decision needs to be made within an integrated framework that is both science- and ecosystem-based, but which also incorporates societal values. A general analytical approach, which has a general validity regardless of geographical, ecosystem and economic differences, is required for the social dimension in ecosystem management. Such generic concepts are already available for the biological and the economic dimensions, whereas numerous long lists of context-specific criteria predominate for the social dimension (Glaser and Diele, 2004). Policy- and decision-makers require frameworks with a universal core which allow for interregional and international comparisons (Empacher and Wehling, 2002; Serbser, 2004). Until such universality is achieved for the social dimension it is likely to continue to lead a marginal existence in ecosystem management. The call for universality does not deny the importance of the local. Both the specific real 'life world' and the general system sides of the social dimension (Habermas, 1987; Glaser, 2006b) are pertinent to ecosystem futures. The need for analytical precision and for policy effectiveness requires that universal criteria be expressed through indicator frameworks, which represent the locally specific manifestations of the social dimension (McGregor and Kebede, 2003; McGregor, 2004). This is one of the major reasons for advocating local participation in the definition of priorities and indicators for ecosystem management (Glaser, 2006a).

Bearing this in mind, our perceived role as scientists in the development of a recommended ecosystem approach for managing shellfish aquaculture impacts is to provide science-based advice and recommendations on:

1) Effective performance-based approaches and indicators for characterizing ecosystem status and impacts of a highly diverse shellfish aquaculture industry;
2) Identifying the potential consequences to coastal marine ecosystems from changes in ecosystem status and impacts and identifying related thresholds of potential public concern);
3) Identifying effective measures for preventing or mitigating any impacts from shellfish aquaculture; and
4) Reviewing and assessing available management frameworks that facilitate ecological sustainability by considering their capacity to incorporate an ecosystem perspective, societal values and the economic viability for industry.

However, it is not solely the responsibility of ecological scientists to determine a framework for the integrated evaluation of the impacts of shellfish aquaculture activities in the coastal zone. Socioeconomic science considerations are paramount in setting critical decision criteria (e.g. what constitutes an unacceptable impact?). Although socioeconomic issues were generally considered outside the scope of our activities, deliberations on many components of a pragmatic shellfish aquaculture management framework required discussion of costs to industry and "potential" public concerns. To help define what level of impacts are acceptable, socio-economical sciences can help in clarifying the values and expectations of different groups, and contribute to the economic evaluation of environmental services. Furthermore, environmental conservation and protection and other legislations pertaining to the utilization of coastal areas are clearly important considerations for the selection of indicators, and particularly for the setting of regulatory triggers/thresholds.

That being said, marine spatial planning supports to move beyond the current impact assessments of shellfish aquaculture management by linking the available knowledge into the planning process. Hereby, the potential siting of a farm as well as providing flexibility in adjusting the locations according to emerging societal and ecological constraints appears to be most relevant to shellfish cultivation.

8.6 Recommendations

The Strategic Initiative on Coastal and Marine Spatial Planning should address the issues of:

- Capturing of interconnectedness of the different scales and time frames by coastal and marine spatial planning initiatives
- Spell out the mandatory and optional factors to be considered in making licensing and allocation decisions (for example, fishers' adjacency to the fishery and historical participation)
- Competing claims for space
- Rights and duties of shellfish farmers, coastal communities and institutional bodies
- Role and power of lead agencies
- Liabilities of shellfish cultivation
- Grants and duration of tenures
- Local ownership of process of decision-making and ownership of the decisions taken
- Provision of room for newcomers or change of marine use over the course of time
- The lack of a comprehensive legislative framework governing mariculture

The WGMASC encourages collaboration across EGs on this topic.

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9 Report to SSGHIE on plans to promote cooperation between EGs covering similar scientific issues (ToR g)

9.1 Joint meeting between WGEIM and WGMASC

Both the WGEIM and the WGMASC have established that there is considerable overlap in Terms of Reference they presently work on. Past and current overlapping ToRs are presented in Table 9.1. To address this question a joint meeting was organised and hosted by Francis O'Beirn, member of both groups. The first day of the meeting was devoted to discussing the overlap and develop ways to deal with this during the remainder of the coinciding meetings and in the future (Annex 2).

Table 9.1. ToRs overlapping between WGMASC and WGEIM.

WGEIM	WGMASC
(ToR a) Evaluate the examples of sustainability indices proposed for mariculture activities and critically evaluate those SI's recommended by WGEIM and other fora (started in 2005)	(ToR e) Develop a work plan to evaluate the current sustainability of shellfish culture and identify options to improve sustainability (2003 and 2004) (ToR b) Develop a recommended framework for the integrated evaluation of the impacts of shellfish aquaculture activities in the coastal zone (2006-2009)
(ToR b) Investigate and report on fouling hazards associated with the physical structures used in mariculture with a view to developing integrated pest management strategies (started in 2006)	(ToR d) Review and assess: the potential for transfer of non-indigenous species and diseases; the potential genetic implications for wild stocks; the impact on recruitment to existing stocks by large-scale transfers, and scientific tools for decision support on cultured shellfish transfer issues (started in 2008)
(ToR d) Review and report on the use of seed stock quality criteria in mariculture and their applications in term of ecological performance (started in 2008)	(ToR a) Provide a synthesis on the development of hatcheries, the proportion of cultured animals to wild conspecifics and the relative proportion of triploids and other selected strains produced by hatcheries (2003-2005) (ToR c) Prepare a report assessing the utility of hatchery reared seed to enhance wild scallop fisheries with the view of improving the management of this resource (2006-2007)
(ToR e) Assess the potential impact of climate change on aquaculture activities relevant to each ICES member state (started in 2009)	(ToR e) Review the state of knowledge of the evidence for and effect of climate change on shellfish aquaculture distribution and production in ICES and countries worldwide (started in 2008)

It was decided that, for the 2010 meeting, members from WGMASC and WGEIM would sit-in on discussions of the other group. Peter Cranford and Joseph Mazurie gave input to the WGEIM ToR a. Joseph proposed the group to examine the document "EVAD guide" for building sustainability indicators and evaluating aquaculture sustainability

(http://www.inra.fr/coordination_piscicole/groupes_de_travail/systeme_d_elevage/evad)

Pauline Kamermans discussed WGEIM ToR d with some members of the WGEIM. WGEIM did not work on ToR e) in 2010, but Matt Gubbins provided a report of his institute on effects of climate change on aquaculture that has some reference to shellfish to WGMASC. Chris McKindsey gave an overview of work done in the framework of WGEIM ToR b when WGMASC was discussing ToR d. And Thomas Landry gave input to WGMASC ToR f).

A general discussion was held on the roles of WGEIM and WGMASC within ICES. Four options were identified:

1) Leave things as they are with overlap in ToRs and limited direct cooperation.
2) WGMASC to focus on shellfish aquaculture husbandry and WGEIM to focus on environmental impacts of shellfish aquaculture.
3) WGMASC to focus on bivalves and WGEIM to focus on finfish.

4) Increase cooperation between WGMASC and WGEIM through joint meetings.

All options were considered. There was consensus that option 1 was not desirable. Option 2 poses problems for WGMASC as current shellfish husbandry cannot be viewed without giving attention to the environmental impacts. Option 3 has two complications: (1) what to do with Integrated Multi Trophic Aquaculture that includes both shellfish and finfish as well as algae, and (2) most presently active members of WGEIM have a shellfish background. Thus, it was agreed that option 4 is the most favourable one. In order to execute this it was proposed to have joint meetings every 3 years. In the meantime the chairs of both groups will stay in close contact through teleconferencing and videoconferencing about the ToRs being worked on to identify any overlaps. If this is the case they can then invite key members of the respective group to the annual meetings to work on the ToRs together or else address the specific ToR at future joint meetings. In addition, chairs will exchange draft reports immediately after their respective meetings and ask key members of their group to review the text on related ToRs.

9.2 Cooperation with other EG's of SSGHIE

WGEIM and WGMASC looked through the SSGHIE expert group list (and more widely) with a view to identifying those where there had been previous instances of collaboration and where there may be potential for collaborative activity in the future (Table 9.2).

Table 9.2. Overview of EGs with which WGEIM / WGMASC has had collaboration and those with which the WGs would envisage possible future interactions.

	Worked before?	Interested in joint activity?	Joint meeting potential?
WGPDMO	Y WGEIM	Y	Y
MCWG	N	Y	N
MSWG	N	Y	N
ICZM	Y WGEIM	Y	Y
SGONS	N	N	N
WGMASC	Y	Y	Y
WGEIM	Y	Y	Y
WGHABD	N	Y	N
WGEXT	N	N	N
WGFCCIFS	N	Y	N
WGAGFM	Y WGEIM	Y	N
WGBEC	N	Y (WGEIM)	N
WKIMM	N	Y	N
BEWG	N	Y	N
WGITMO	N	Y	N
WGNAS	Y WGEIM	Y	N
EuroShell		Y	N

WGPDMO: WGEIM are currently working with WGPDMO on the OSPAR request on impacts on fisheries. WGMASC regularly refers to documents from the group and sent recommendations to them. Common issues are climate change, transfer of shellfish seed / seed quality. There is potential to swap experts between groups when relevant ToRs arise.

MCWG: Potential interaction with WGEIM on monitoring chemical releases from finfish farms.

MSWG: Overlap with WGEIM on chemical contaminants from aquaculture in sediments.

ICZM: This group was formed from activity of WGEIM and is relevant to both groups, particularly sustainability indicators and MSP. Both groups deal with aquaculture aspects of ICZM.

WGHABD: Potential interaction with WGMASC on interactions of HAB toxins on cultured shellfish and WGEIM on HAB effects on farmed fish.

WGFCCIFS – This workshop activity may have already ceased, but groups may have been interested in outputs from both groups on climate change / aquaculture issues.

AGFM – WGEIM are currently working with this group on OSPAR request. There is potential future for interaction with MASC on transfer of shellfish stock ToR.

WGBEC: There is common ground with WGEIM on effects of contaminant discharges from finfish farms.

The groups noted that interactions on socio-economic aspects were largely missing, but that two ICES workshops - WKIMM (Introducing coupled ecological-economic modeling and risk assessment into management tools) and WKSECRET (..) were addressing this topic. The WGs felt that the output of these workshops and the history of how these workshops were initiated may be relevant.

WGIMTO – This group has produced risk assessments on transfer of organisms that have been of relevance to MASC and WGEIM.

BEWG – There is common ground between this group and both WGEIM and WGMASC on benthic interactions with fish / shellfish farming.

WGNAS – North Atlantic Salmon. WGEIM are working with this group this year on the OSPAR request on impacts of mariculture on fisheries.

EuroShell – This EAS group looking at aspects of shellfish culture has close interaction with WGMASC members.

9.3 Importance of aquaculture

Total production from capture fisheries has remained fairly constant since the late 1980's at about 90 million tonnes annually. In contrast, aquaculture production is increasing worldwide, growing from accounting for 3.2% of the total fisheries production in 1950 to 43% of the total in 2008, including 47% of the total fisheries production destined for human consumption (Figure 9.1). This marked increase in production from aquaculture has allowed total fisheries production to increase nearly linearly since 1950 at a rate of about 2.4 million tonnes per year to a record production of 159.1 million tonnes in 2008 (FAO Fisheries and Aquaculture Department 2009). The FAO also suggests that this trend will likely continue in the future, although the rate of growth of aquaculture production is slowing down. Within ICES member nations, growth in total fisheries production has been in decline since 1988, when it reached a maximum of 29.7 million tonnes, to 20.7 million tonnes in 2008 (Figure 9.2). Of this total, the absolute and proportional contribution from aquaculture has grown steadily over this period and in 2008 accounted for 2.7 million tonnes, or 13 % of the total fisheries production. A number of ICES nations have also stated that they have ambitious targets for increasing aquaculture production in the future and thus the importance of this activity will only grow in the future. Together, this highlights the current and growing importance of ICES EGs that address aquaculture issues, such as the WGEIM and the WGMASC.

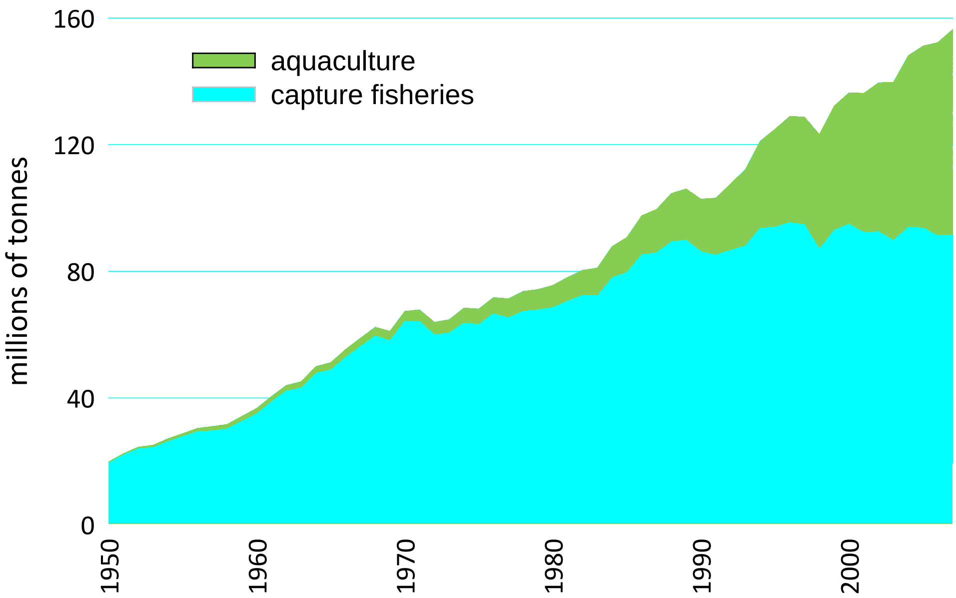

Figure. 9.1. Global fisheries and aquaculture production (data from FAO, 2010), 1950-2008. Note that the proportion of aquaculture production of the total of fisheries production destined from human consumption accounted 47% in 2008 and surpassed 50% in 2009.

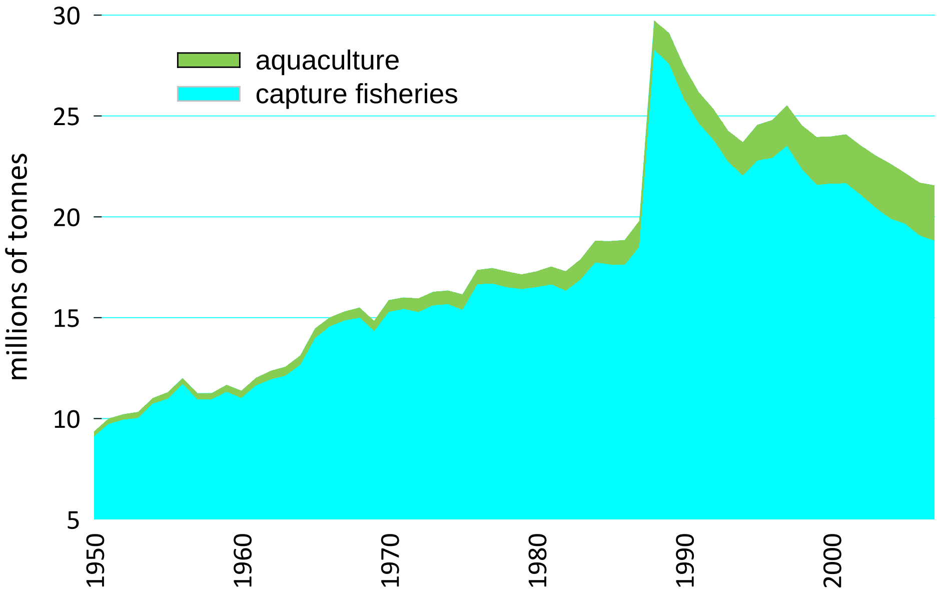

Fig. 9.2. Fisheries and aquaculture production by ICES member nations (data from FAO, 2010), 1950-2008. Note that the important increase in 1988 represents the addition of data from the Russian Federation and other Eastern European countries. Landings from capture fisheries have decreased thereafter whereas those from aquaculture have increased.

Annex 1: List of participants

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Annex 2: Agenda ICES WGMASC 2010 Annual Meeting Marine Institute, Galway, Ireland

Monday 29 March (Joint meeting with WGEIM)

09:00 Housekeeping information from Francis
09:30 Introductory round and adoption of the agenda
10:00 Presentation of 2010 ToRs of WGEIM and WGMASC by chairs
10:30 *Health Break*
11:00 Discussion on 2010 ToRs and identification of overlap and subjects of mutual interest
11.30 Discussion on roles of WGEIM and WGMASC within ICES
12:30 **Lunch**
13:30 Discuss to proceed for remainder of week
15:30 *Health Break*
16:00 Review list of other WGs to see where the two groups may contribute (ToR g: *Plans to promote cooperation between EGs covering similar scientific issues*)
17:00 Split up in working groups to discuss how to proceed for remainder of week within WGs
17:30-18:00 Wrap-up discussions

Tuesday 30 March

09:00 Discussion of Bivalve Aquaculture Dialogue
10:30 *Health Break*
11:00 Plenary update on ICES activities – Pauline Kamermans

- General discussion of ICES activities and Terms of Reference
- Adoption of agenda
- Develop work plan, identify subgroups, subgroup leaders and rapporteurs

Subgroups

- ToR b: *Site selection criteria in molluscan aquaculture*
- ToR c: *Aquaculture transfers between sites/countries – guidelines and records*
- ToR d: *Aquaculture transfers between sites/countries –impact on wild stock*
- ToR e: *Effect of climate change on shellfish aquaculture*
- ToR f: *Potential and current contributions of MASC to the Strategic Initiative on Coastal and Marine Spatial Planning (SICMSP)*

12:30 **Lunch**
13:30 ToR subgroup sessions
15:00 *Health Break*
15:30 – 18:00 Continue ToR subgroup sessions

Wednesday 31 March

09:00 Plenary overview of work status and start of ToR d and f
10:30 *Health Break*
11:00 Reconvene ToR subgroup sessions
12:30 **Lunch**

13:30 Reconvene ToR subgroup sessions
15:00 *Health Break*
15.30 Reconvene ToR subgroup sessions and prepare first drafts
17:00 – 18:00 Plenary discussion of ToR a: *Emerging shellfish aquaculture issues and science advisory needs*

Thursday 1 April

09:00 Plenary discussion on first drafts
10:30 *Health Break*
11.00 ToR subgroup sessions to revise text
12:30 **Lunch**

Trip to shellfish hatchery Cartron Point at New Quay in Co. Clare.

Dinner provided by Marine Institute in Galway.

Friday 2 April

09:00 Plenary Session:

- Review and adoption of the scientific text of the report
- Discussion and drafting of recommendations

10:30 *Health Break*
11.00 Plenary Session (cont.):

- Prepare Executive Summary
- Discussion on any new Terms of Reference
- Discussion on Theme Sessions for Annual Science Conference in 2011
- Location and time of next meeting

13:00 Meeting Adjournment
Transport back to Galway for l**unch**

Annex 3: WGMASC terms of reference for the next meeting

The **Working Group on Marine Shellfish Culture** [WGMASC] (Chair: Pauline Kamermans) will meet in La Trinité-sur-Mer, France from 5-8 April 2011 to:

a) Identify emerging shellfish aquaculture issues and related science advisory needs for maintaining the sustainability of living marine resources and the protection of the marine environment. The task is to briefly highlight new and important issues that may require additional attention by the WGMASC and/or another Expert Group as opposed to providing a comprehensive analysis.

b) Review the state of the knowledge of site selection criteria in molluscan aquaculture with particular reference to accessing and developing offshore facilities.

c) Review and assess: the potential for transfer of non-indigenous species and diseases; the potential genetic implications for wild stocks; the impact on recruitment to existing stocks by large-scale transfers, and scientific tools for decision support on cultured shellfish transfer issues.

d) Review the state of knowledge of the evidence for and effect of climate change on shellfish aquaculture distribution and production in ICES and countries worldwide.

e) Report to SSGHIE on potential and current contributions of your EG to the Strategic Initiative on Coastal and Marine Spatial Planning (SICMSP).

WGMASC will report by (DATE) 2011 (via SSGHIE) for the attention of the SCICOM.

Supporting Information

Priority	WGMASC is of fundametal importance to ICES environmental science and advisory process and addresses many specific issues of the ICES Strategic Plan and the Science Plan. The current activities of this Group will lead ICES into issues related to the ecosystem effects of the continued rapid development of shellfish aquaculture, especially with regard to the implications of changing environmental conditions on shellfish cultures Consequently, these activities are considered to have a high priority.
Scientific justification	**Term of Reference a)** For the WGMASC to be responsive to the rapidly changing science advice needs of aquaculture and environmental managers, important emerging shellfish aquaculture issues need to be rapidly identified and screened for potential science advisory needs to maintain the sustainable use of living marine resources and the protection of the marine environment. The intention is for this activity to flag issues that may require future attention and communication between one or several ICES Expert Groups. The Chair of the WGMASC will cross-reference all work with SCICOM and relevant Working Groups. **Term of Reference b)** Spatial competition for aquaculture sites along coastal seas has encouraged the initiative of moving shellfish aquaculture into the open ocean at exposed sites within the EEZ. These offshore sites require an understanding of the adaptive capabilities and limitations in growth potential for species at these sites, the development of new technologies capable of withstanding these high energy environments and the necessary institutional arrangements (e.g. marine spatial planning). It is also essential in site selection to consider biotic and abiotic factors in association with economic, ecological and socio-economic perspectives, whether in the coastal zone or at offshore locations. Beside basic

	investigations on these parameters conditions of a preferred site can be investigated by analysing the overall health status of shellfish grown in different areas (e.g. blue mussels) as a bio-indicator of site suitability. This ToR aims to: assess site selection criteria in ICES countries; provide an overview of current research and commercial operation on offshore shellfish farming, both for spat collection or for ongrowing to market size. In addition, it is intended to investigate the sustainable use of oceans by integrating aquaculture and fisheries and assess the potential for combining shellfish culture with other offshore constructions such as renewable energy facilities or any other. The Chair of WGMASC will cross-reference all work with SCICOM and relevant Working Groups. **Term of Reference c)** Different shellfish life stages are transported from hatcheries and field sites to new culture sites, and often cross international boundaries, with potential implications for the introduction of non-indigenous species and diseases and the potential for interactions with wild stocks (impact on recruitment, genetic composition, diversity and polymorphism, and physiological and morphological traits). There is a need to identify the significance of shellfish relocations on the geographic distribution of wild stock traits. Scientific tools for decision support on cultured shellfish transfer issues should be reviewed and assessed. The Chair of WGMASC will cross-reference all work with the Chairs of the WGEIM, WGPDMO and WGITMO. **Term of Reference d)** Climate variability affects the recruitment and production of important commercial species and affects site suitability for shellfish culture. Increased knowledge of the effects of climate change on shellfish culture is needed to predict and assess impacts on aquaculture distribution and production. The Chair of WGMASC will cross-reference all work with the Chair of the WGEIM. **Term of Reference e)** This strategic initiative is currently being planned and suggestions from Egs on their engagement in the SICMSP are sought.
Resource requirements	The research programmes which provide the main input to this group are already underway, and resources are already committed. The additional resource required to undertake additional activities in the framework of this group is negligible.
Participants	The Group is normally attended by some 10–12 members and guests.
Secretariat facilities	None.
Financial:	No financial implications.
Linkages to advisory committees	SCICOM
Linkages to other committees or groups	There is a working relationship with the WGEIM, WGIMTO, WGPDMO, and the work is relavant to WGICZM.
Linkages to other organizations:	The work of this group is aligned with similar work in GESAMP, WAS, and EAS and numerous scientific and regulatory governmental departments in ICES countries.

Annex 4: Recommendations

Recommendation	For follow up by:
1. WGMASC recommends to continue ToR a to identify and report on emerging shellfish aquaculture issues and related science advisory needs for maintaining the sustainability of living marine resources and the protection of the marine environment.	SCICOM
2. WGMASC recommends that SCICOM send the review on the Bivalve Aquaculture Dialogue that our groups conducted to the appropriate representative at WWF to aid and put ICES input in their dialogue process.	SCICOM
3. WGMASC recommends that the members of the WGMASC continue ToR b to review the state of the knowledge on site selection criteria in molluscan aquaculture with particular reference to accessing and developing offshore facilities.	SCICOM
4. WGMASC work on ToR c is considered complete with a report produced entltled "..".It is recommended that key members leading this ToR synthesise the content of this report with the purpose of publication in an appropriate international journal.	SCICOM
5. WGMASC recommends that data on shellfish transfers should be collected into national databases. These should include information on diseases and non-native hitchhiker species.	SCICOM
6. WGMASC recommends that ToR d remains active to complete a review on the significance of bivalve aquaculture transfers between sites (local, national, international) to wild and cultured bivalve stocks. The focus of the ToR will be on effects of shellfish relocations on the geographic distribution of marine organisms, indigenous shellfish stock traits (genetic, physiological, morphological, recruitment, competition, predation) and the potential implications for regional shellfish culture operations are reported. Scientific tools for decision support on cultured shellfish transfer issues will be reviewed and assessed.	SCICOM
7. WGMASC recommends that key persons of WGITMO dealing with the introduction of aquatic exotic species via shellfish transfers should be invited to the next WGMASC meeting to participate in preparing a joint report, identify information gaps and recommend specific research goals and management advice.	SCICOM, WGMASC
8. WGMASC recommends to continue ToR e to review the state of knowledge on the evidence for and effect of climate change on shellfish aquaculture distribution and production in ICES and countries world wide.	SCICOM
9. The implications of climate change to shellfish aquaculture exist within a much broader context of anticipated physical and biogeochemical alterations in coastal marine ecosystems. The WGMASC recommends the close linkage of knowledge and advise generated under our ToR e with all relevant ICES activities on related subjects such as the work planned by WGEIM , SGCC and the Joint PICES/ICES Working Group on Forecasting Climate Change Impacts on Fish and Shellfish.	SCICOM, WGMASC
10. WGMASC recommends to continue ToR f to report to SSGHIE on potential and current contributions of your EG to the Strategic Initiative on Coastal and Marine Spatial Planning (SICMSP). WGs dealing with aquaculture issues need more socio-economic experstise in their groups. The WGMASC recommends to invite someone from WGICZM for next meeting to work on ToR f.	Si Com WGMASC
11. WGMASC recommends to increase cooperation with WGEIM through joint meetings every 3 years. In the meantime the chairs of both groups will stay in close contact through teleconferencing and videoconferencing about the ToRs being worked on to see any overlaps. If this is the case they can then invite key members of the respective group to the annual meetings to work on the ToRs together or else address the specific ToR at future joint meetings. In addition, chairs will exchange draft reports immediately after their respective meetings and ask key members of their group to review the text on related ToRs.	SCICOM, WGMASC
12. WGMASC recommends that ICES encourages member states for better participation to WGs dealing with mariculture issues.	SCICOM