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Title: Background information for sustainable aquaculture development, addressing environmental protection in particular

Sub-Title: Sustainable Aquaculture Development in the context of the Water Framework Directive and the Marine Strategy Framework Directive

Part 1 Main Report & References

Authors: Jeffery, K.R., Vivian, C.M.G., Painting, S.J., Hyder, K., Verner-Jeffreys, D.W., Walker, R.J., Ellis, T., Rae, L.J., Judd, A.D., Collingridge, K.A., Arkell, S., Kershaw, S.R., Kirby, D.R., Watts, S., Kershaw, P.J., and Auchterlonie, N.A.

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Executive Summary

This project was commissioned in late 2013 to gather information on European aquaculture development in the context of environmental protection, through literature review and extensive stakeholder consultation. The focus was European environmental legislation, in particular the Water Framework Directive (WFD) and Marine Strategy Framework Directive (MSFD). This focus recognises that high quality aquatic environments and the prevention of their deterioration are fundamental to the sustainable development of European aquaculture.

The project will provide background information for a guidance document on the application of environmental legislation in relation to aquaculture that will be developed by the Commission. The need to develop such guidance was identified in the Commission Communication on Guidelines for the sustainable development of EU Aquaculture. The WFD and the MSFD were key items of legislation highlighted as being important for the sector, and especially worthy of attention. This project represents a response to the raising of that issue, and the Commission Services would like to have a better understanding of how the sector meets its legal obligations under WFD, MSFD and other environmental legislation, and how aquaculture can benefit from subsequent improvements in clean water availability. The timing of this study is important, coinciding with a period where Commission Services also wish to see sustainable development of European aquaculture, and sustained growth in quality seafood from European aquaculture businesses. Protection of the environment and maintenance of high quality aquatic ecosystems are core principles in realising the obvious potential of the sector.

The report provides an overview of EU-28 aquaculture including production data, the types of aquaculture systems used in the EU and their environmental impacts, the environmental legislation and its application, and the views on implementation of environmental legislation with direct relevance to aquaculture from abroad spectrum of stakeholders right across EU-28 and some EEA states.

Aquaculture activities can potentially exert pressures and impacts upon aquatic ecosystems, for example through increased nutrient load, from concentrations of faecal matter and uneaten feed, from dispersal of cleaning agents and medicines. In addition, aquaculture can itself be subject to pressures and impacts from other activities taking place in the aquatic ecosystem, for example pollution incidents, waste water treatment facilities upstream, and flow variations due to flow regulation in the river e.g. from dams and hydroelectric systems. Aquaculture producers require high quality waters, and are often the first in a river basin to detect problems with water quality, pathogens or introduced species in the aquatic environment. If properly managed, aquaculture can have positive impacts on the natural environment, such as retention of water in the landscape, buffering of extreme rainfall patterns with drought and flood protection (large ponds) and encouraging biodiversity. Aquaculture relies on, but does not consume, significant quantities of water.

Pressures and impacts of different aquaculture systems depend on multiple factors, including farm location, type of cultured organism, methods used, and the sensitivity or vulnerability of the environment to possible pressures. These pressures and impacts need to be monitored and managed closely in order to comply with the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD).

The WFD and the MSFD do not contain explicit obligations for aquaculture. However, the aquaculture industry has to comply with the requirements of the WFD and MSFD via the national legislation that implements those Directives in each Member State. With regard to the WFD, a significant issue is the current frequent lack of integration of aquaculture into the RBMPs. For the WFD, even if additional objectives and measures have not been explicitly included in all the relevant River Basin Management Plans (RBMPs), these objectives and measures may exist and apply. As the MSFD is in its early stages of implementation, it is too early to assess how aquaculture is being addressed under this Directive.

Strategic Environmental Assessment has been used to a very limited extent for aquaculture developments and two examples are given in the report. While Environmental Impact Assessment (EIA) is only mandatory for 'intensive fish farming', a large number of EIAs for aquaculture projects have been carried out across Europe. A finding from reviews of some of these EIAs shows inconsistent application of the EIA Directive between countries. Also, one review found "In many locations throughout Europe for example there appears to be an unnecessary and high level of bureaucratic involvement in the development of aquaculture activity. There is poor transparency in the implementation of EIA legislation as it relates to aquaculture, and differential treatment of aquaculture sectors, which may be an impediment to aquaculture development."

Emerging and future technologies for aquaculture are presented, covering systems such as recirculation, offshore aquaculture, aquaponics and others, alongside the potential changes in interactions with the environment, and hence the regulatory framework for environmental protection.

Key recommendations in relation to environmental regulation and impact mitigation for aquaculture across EU-28 were derived from the reviews carried out by the project and the input of stakeholders. These fall into four categories (1) for national administrators and regulators (2) for the aquaculture industry (3) for further research (4) for the EC.

Recommendations for national administrators and regulators have been brigaded under four headings: Licensing, Monitoring, Planning and Charging, as follows:

Licensing:

- Having a single point of contact for the aquaculture industry in the regulatory system to improve the efficiency of regulation i.e. a "one-stop-shop".
- To provide a permitting system that is flexible enough to include mitigation practices or new techniques for the management of environmental impacts. Aquaculture is a young and dynamic industry and technological developments occur relatively quickly.
- To include within any review of consents/licence applications an assessment of the use of mitigation tools or practices (e.g. for effluent water quality) and how these may improve environmental performance.
- National administrations or regulators develop specific good practice guidelines for managing the environmental impacts of aquaculture for the main types of aquaculture within their jurisdiction, and that this is developed in conjunction with the aquaculture industry to ensure that it is directly appropriate.
- The Precautionary Principle be applied to aquaculture consistent with EU guidance (COM 2000b; EEA 2001). The guidance that has already been provided by the EU, if followed correctly, should help clarify the requirements in the adoption of this approach to sustainable aquaculture development.
- Administrators should develop simple guidance to help regulators and industry assess whether plans for new or expanded aquaculture facilities will comply with obligations of the MSFD and WFD (building on existing WFD Common Implementation Strategy guidance for Article 4(7).

- Guidance on environmental flows, allowing access to water at the same level as other food production sectors, and the possibility of taxing contaminants (i.e. emissions) as the sector is not a consumer of water.
- National Administrations and regulators should consider the mechanism for and application of nutrient trading schemes (including co-location) for sites that are already heavily impacted or otherwise compromised to facilitate the continuing sustainable development of aquaculture.
- Member States keep the national instruments transposing the Shellfish Waters Directive, or, if necessary, develop new ones to ensure equivalent protection of aquaculture production areas.

Monitoring:

- A risk and evidence-based approach to determine monitoring requirements is adopted and standardised across EU-28, ensuring that the approach is based on robust scientific principles and best available working knowledge within an overall ecosystem management methodology.
- There be a greater clarity on which parameters or data the aquaculture industry should provide for licensing and monitoring, as well as the quality and quantity of the information required.
- Data on both emission and uptake of nutrients is required, and it is necessary to make improvements in monitoring to quantify and allocate proportional nutrient loads from different sources, identifying the contribution from aquaculture within an overall nutrient budget.
- The adoption of regulatory codes may support improvements in the effective and efficient environmental regulation of aquaculture.
- The development and application of technical standards for aquaculture systems to mitigate environmental impacts and the management of the risk of escape of stock, across a range of aquaculture systems and species. It would also support monitoring programmes by ensuring that systems and equipment are appropriate for the location and species farmed.

Planning:

- It is recommended that national administrations/regulators provide strategic planning for marine aquaculture development to inform spatial planning processes, ensuring linkage with other marine industries, and that within spatial planning approaches. It is also recommended that Allocated Zones for Aquaculture (AZAs) are provided.
- It is recommended that aquaculture be integrated into objectives and measures in the 2nd round of RBMPs.

Charging:

- National administrations and regulators ensure administration costs are proportionate to the sector/business that is being regulated with the 'Polluter Pays' principle applied.

Recommendations for the aquaculture industry have been provided, split into three categories, Technology, Management and Liaison:

Technology:

- The adoption of aquaculture production system types appropriate to the local environment should be followed to ensure that the type of system, the biomass of the farmed stock, and the environmental pressures are appropriate for the location, and the risk of serious environmental impact is reduced.
- Aquaculture should continue to adopt new practices that improve sustainability.

Management:

- The adoption of an approach to the management of aquaculture systems that incorporates a broader ecosystem-level approach encompassing all environmental impacts (e.g. fish health, emissions, alien species, veterinary medicines, abstraction) can provide frameworks within which industry may adopt such an approach.
- The practices of self-monitoring and reporting (e.g. Codes of Practice, certification schemes), especially those independently audited can help clarify the environmental obligations of the industry, albeit within a non-regulatory framework.

Liaison:

- Liaise directly with regulators to achieve a common level of understanding about responsible aquaculture operations.

Recommendations for further research have also been provided:

- Research that provides more accurate predictive models for the fate of nutrients that originate from aquaculture sites and their cumulative effects, as well as effective ways of mitigating those impacts.
- Research to improve monitoring techniques and support the development and use of best available technology to reduce environmental impacts.
- Research that supports the development of new, efficient and innovative water processing technology for land-based aquaculture systems (RAS).

Finally, Recommendations for the European Commission Services have been suggested:

- The development of guidance to address the biological impacts of aquaculture e.g. pathogens, non-native invasive species, sea lice in farmed salmonids, escapees and the risk of introgression with wild populations.
- That the EFLOWS working group considers both the environment and the development of the aquaculture sector with respect to the management of abstraction in relation to flow-through systems.
- That this project information is retained as a readily accessible and usable resource to provide information to national administrators, regulators, industry and NGOs in the future.

The approach in this project represents an extensive review across Europe of the issues surrounding the environmental regulation of the aquaculture industry, extensive stakeholder consultation and a forward look at how the sector will develop. It represents a valuable resource for those who seek good practice in regulation or management of the aquaculture industry, and will be used as the basis for Commission Services to develop guidance on that topic.

Acronyms

AA Appropriate Assessment
ARAD Areas for Regulated Aquaculture Development
AZA Allocated Zone for Aquaculture
AZE Allowable Zone of Effects
BEP Best Environmental Practice
BIM Bord Iascaigh Mhara (Irish Sea Fisheries Board)
BOD Biological Oxygen Demand
BQE Biological Quality Elements
BS SAP Black Sea Strategic Action Plan
CAQ Committee on Aquaculture
CAR Water Environment (Controlled Activities) (Scotland) Regulations 2011
CLAMS Co-ordinated Local Aquaculture Management System
CFP Common Fisheries Policy
CVMP Committee for Medicinal Products for Veterinary Use
EAS European Aquaculture Society
EATiP European Aquaculture Technology and Innovation Programme
ECASA An Ecosystem Approach to Sustainable Aquaculture
ECOPACT Environment Management System for Aquaculture
EEA European Environment Agency
EF Environmental flow
EFARO European Fisheries and Aquaculture Research Organisations
EIA Environmental Impact Assessment
EIHA Environmental Impacts of Human Activities
EQR Ecological Quality Ratio
EQS Ecological Quality Standard
ETPs European Technology Platforms
EU European Union
EU-28 Member States of the EU
FM Fishmeal
FCR Feed Conversion Ratio
FWFD Freshwater Fish Directive
GES-MSFD Good Environmental Status – Marine Strategy Directive
GES-WFD Good Ecological Status – Water Framework Directive
GESAMP Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection
GFCM General Fisheries Council for the Mediterranean
H2020 Horizon 2020
HELCOM Helsinki Commission
IAS Invasive Alien Species
ICES International Council for the Exploration of the Sea
ICZM Integrated Coastal Zone Management
IMTA Integrated multi-trophic aquaculture
JRC Joint Research Centre of the European Commission
MA Marketing Authorisation
MANPs Multi-Annual National Plans
MRL Maximum Residue Limit
MS Member State(s)
MSFD Marine Strategy Framework Directive
Natura 2000 Network of SAC and SPA sites
N Nitrogen
NGO Non-Governmental Organisation
NIS Non-Indigenous Species
nm nautical mile
OSPAR Oslo and Paris Conventions (of European Governments) protecting the North-East Atlantic marine environment
P Phosphorus
PARCOM Paris Convention for the Prevention of Marine Pollution from Land-Based Sources
PASM Areas of Informal Concentration of Units
PAY Aquaculture Development Areas
PE polyethylene
POAY Areas of Organized Development of Aquaculture
RAC/SPA Regional Activity Centre for Specially Protected Areas
RAS Recirculation Aquaculture System
RBSP River Basin Specific Pollutants
SACs Special Areas of Conservation
SBM Single Bay Management
SEA Strategic Environmental Assessment
SEPA Scottish Environmental Protection Agency
SMEs Small and medium enterprises
SPAs Special Protection Areas
SWD Shellfish Waters Directive
ToR Terms of Reference
VICH Veterinary International Conference on Harmonization
WB Water Body
WFD Water Framework Directive

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A separate document, Title: Background information for sustainable aquaculture development, addressing environmental protection in particular; Sub-Title: Sustainable Aquaculture Development in the context of the Water Framework Directive and the Marine Strategy Framework Directive; Part 2 Annexes & supporting documents, provides supporting information, and should be read in conjunction with this report.

1 Introduction

1.1 Background and policy context

In the EU, aquaculture production is an important economic activity in many coastal and inland regions (COM 2012a), often providing employment in marginal and remote areas. Whilst global aquaculture production is increasing by 6.9% p.a., this rate of growth is not being achieved within the EU, with production remaining static since 2000 (COM 2009). The sustainable development of European aquaculture has been identified as a priority under reforms of the Common Fisheries Policies (CFP) to strengthen long term food security (EU 2013). These regulations require actions to improve the competiveness of the sector, whilst ensuring its long term environmental, economic and social sustainability.

Independently, aquaculture has been identified as one of five value chains that can deliver sustainable growth and jobs within the blue economy (COM 2012b). The Commission recently published Strategic Guidelines for the Sustainable Development of EU aquaculture (COM 2013a) which highlighted four priority areas to unlock the potential of the sector: i) simplification of administrative procedures, ii) co-ordinated spatial planning, iii) competitiveness and, iv) a level playing field. Using these guidelines, Member States (MS) are now developing multiannual national plans for the development of sustainable aquaculture. The Commission had been alerted to issues with the application of environmental legislation through industry and national administrations across Europe. This project was commissioned to investigate environmental legislation specifically, and to determine exactly what the issues are in relation to the aquaculture industry’s regulation and development, and thus supports all four of the Strategic Guidelines’ priority areas.

The development of sustainable aquaculture is dependent on clean, healthy and productive marine and fresh waters. A prerequisite for sustainable aquaculture activities is compliance with EU Legislation. The Water Framework Directive (WFD) (EU 2000) and the Marine Strategy Framework Directive (MSFD) (EU 2008a) aim to protect and enhance aquatic environments and ensure that the uses to which they are put are sustainable in the long term.

The general objective of the WFD is to achieve good ecological status and good chemical status for all surface waters by 2015. The MSFD requires the application of an ecosystem-based approach to activities that have an impact on the marine environment, whilst enabling sustainable use of marine goods and services. The ecosystem approach has been described as "*a comprehensive integrated management of human activities based on the best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of the marine ecosystems, thereby achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity*"(ICES 2005). Other pieces of environmental legislation that are relevant for aquaculture include a dedicated legislative instrument on invasive alien species (EU 2014a)which builds on similar legislation specifically for aquaculture (EU 2011a) and the Environmental Impact Assessment (EIA) (EU 2014b) and Strategic Environmental Assessment (SEA) Directives (EU 2001).

The European Commission committed to producing guidance documents (COM 2013a) addressing the requirements of the WFD and the MSFD in relation to aquaculture in order to assist MS in the implementation of EU law and demonstrate how environmental protection can be compatible with the sustainable development of aquaculture.

This report refers to the term sustainable aquaculture throughout. The European Commission (COM 2002) defines aquaculture as "the rearing or culture of aquatic organisms using techniques designed to increase the production of the organisms in question beyond the natural capacity of the environment". Sustainable development was defined by the United Nations (UN 1987) as "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs". It is implicit within the text of this report that wherever sustainable aquaculture is referred to, the meaning is assumed to be a combination of these definitions.

1.2 Purpose of this background information document

The development of this background document was essentially a response by the Commission Services to an issue that had been raised by the aquaculture industry in Europe over the complexity and confusing nature of the application of environmental legislation to that sector. There was also a suggestion from the sector that aquaculture was disadvantaged in relation to environmental management, when compared against other industry and especially against other food producing sectors. The Commission Services sought to identify issues of importance for aquaculture environmental regulation in this work at a time when the sustainable development of the sector is being promoted through food security and economic generation agendas.

The overall aim of this document is to inform the study of that issue through provision of background information relevant to the implementation of environmental legislation (especially WFD and MSFD) in the context of the development of sustainable aquaculture. This background document outlines the environmental impacts of the range of aquaculture production systems seen across Europe, reflects good practice in managing the impacts and regulation of those activities, and thus provides support for the potential realisation of mutual benefits between aquaculture development and environmental protection. This document therefore builds on and complements recent guidance on aquaculture and Natura 2000 (COM 2012a) in the context of implementation of the Birds Directive (EU 2009) and Habitats Directive (EU 1992).

The target audiences for this document include:

- **National authorities** - to help facilitate implementation of the requirements of the Directives in relation to aquaculture;
- **Aquaculture industry** - to provide practical guidance on what producers can expect from the implementation of the Directives, and provide clarity on the industry's obligations;
- **Non-Governmental Organisations (NGOs) and civil society** - to provide an information resource and to demonstrate the options available for the sustainable development of aquaculture in the EU.

This background document will be the basis of the information to be used by the Commission Services in developing guidance on environmental regulation for use by national administrations, regulators and the aquaculture industry.

1.3 Delivery of the Project and the Document's Development

In order to have a far-reaching investigation into the issues being addressed, the work in this project was focused on wide consultation with industry, NGOs, and national authorities right across EU-28 and the EEA states such as Norway and Turkey for which aquaculture is an important sector. The consultation component of the project was regarded as essential in extracting the views of all stakeholders and determining the specific detail of the issues in implementation and application of environmental legislation, and it represented an approach that allowed for the inclusion of case studies, such as examples of good practice in mitigating environmental impacts by industry, and good practice by administrations and regulators in implementing environmental legislation.

The project commenced with a literature review of European aquaculture, systems and environmental impacts, covering scientific publications mainly, but also including grey literature and expert opinion. A review of European environmental legislation relevant to aquaculture was also undertaken in conjunction with the review of the science. European aquaculture encompasses a diverse range of species and production systems, and potential environmental impacts were categorised according to system types, covering the activities that are undertaken in contemporary European aquaculture. The environmental legislation was then viewed in the context of the system types and species farmed. The WFD and the MSFD were examined for provisions of direct relevance to aquaculture activities, as was other relevant EU environmental legislation (e.g. Environmental Impact Assessment (EIA), Strategic Environmental Assessment (SEA), invasive alien species regulation). The River Basin Management Plans (RBMPs) from across EU-28 and EEA states were examined for reference to aquaculture development and regulation and the results showed that in the first round of RBMPs aquaculture is inadequately addressed. Additional consultation on the sustainability of aquaculture was made with the Joint Research Centre of the European Commission, the European Environment Agency, and at a regional level with organisations such as HELCOM and GFCM.

For the WFD and the MSFD the impacts of aquaculture systems were categorised and viewed against the quality elements and descriptors. SEA and EIA were examined against their application to aquaculture development in EU-28. The document reports on the use of SEA and EIA to aquaculture, as well as the application of Appropriate Assessment (Habitats Directive). Alien species legislation was also examined, and the document outlines existing legislation, briefly describes obligations of administrators and regulators, and explains how alien species fit within WFD and MSFD.

Potential impacts from aquaculture on the environment which may affect status under the WFD include changes in: hydro-morphological quality elements (hydrology/typology- flow rates, wave exposure, habitat) - through abstraction and infrastructure (impoundment, storage, treatment or distribution of surface or groundwater); physico-chemical quality elements - through discharges of dissolved and particulate nutrients causing de-oxygenation, smothering and chemical contamination by synthetic and non-synthetic compounds (e.g. disinfectants, antibiotics); biological quality elements – through eutrophication (increased phytoplankton/algal levels, harmful algal blooms), changes in community structure (macro- algae, benthic invertebrates, fish), interbreeding with wild stocks, pathogen infections (e.g. sea lice), escapees and the introduction of non-native species.

At the current time, the key issue impacting potential restrictions to the development of aquaculture due to MSFD is the spatial scale at which the impact is likely to occur. Different aquaculture systems may impact the MSFD descriptors in different ways. A simple impact assessment shows that the environmental impacts of aquaculture in relation to the MSFD are possible from non-indigenous species, sea-floor integrity, eutrophication, and marine litter.

The WFD and the MSFD do not contain explicit obligations for aquaculture. The aquaculture industry has to comply with the requirements of the WFD and MSFD via the national legislation that implements those Directives in each Member States. Aquaculture activities therefore need to be monitored and managed, and could benefit from the development of European-level guidelines and identified good practices.

The reviews formed the basis of the background information document that has been produced. That detail was then enhanced through the information gathered from a consultation process, which was developed with input from policy-makers, regulators, industry and NGOs across the EU-28, and some EEA states at six stakeholder workshops. Two of these more strategic-level stakeholder workshops were held in Brussels at the start and the end of the consultation process, and attended by national administrators, regulators, NGOs and industry organisations to gauge views from across EU-28, as well as some EEA states where aquaculture is a significant sector (e.g. Norway and Turkey). Those workshops essentially provided a check to ensure that the direction of the work in the project was directly relevant to those parties that deal with the legislation and the industry in broader coordination roles, and represented a higher-level consultation above the specific detail that was discussed at the regional workshops.

Between the two more strategic-level stakeholder workshops, four regional good-practice workshops covering the North East Atlantic, Mediterranean, Black Sea/Danube and Baltic Sea regions, were held in Dublin, Athens, Vienna and Copenhagen respectively. The Black Sea/Danube workshop had a particular focus on freshwater aquaculture. At the regional workshops, attendees comprised the same stakeholder groups as at the Brussels workshops but they represented regional organisations and the focus was on environmental regulation of aquaculture at those regional levels. The four regional workshops included a total of 75 presentations relating to good practices for the

regulation and mitigation of the environmental impacts of aquaculture in EU-28 (and Norway and Turkey), discussions on those presentations, break-out sessions, and plenary discussions. The minutes, presentations and attendees from these meeting were recorded and have all been made available on the EU CIRCA website.
https://circabc.europa.eu/w/browse/bb9a4cea-7403-4091-8108-a1212a12bf23.

Further consultation was invited on the draft of this report, which was provided to attendees for review in advance of the second Brussels workshop on the 29th September 2014.

1.4 Limitations of this background information document

This background document is intended for information purposes and is bound by, and faithful to, the text from relevant WFD, MSFD, EIA and SEA Directives, the Invasive Alien Species Regulation, and the wider principles underpinning EU policy on the environment and aquaculture. The document is not legislative in character, it does not make new rules but rather provides background on the application of those that already exist. As such, it reflects only the views of the contractor and is not of a legally binding nature. It rests with the Court of Justice of the EU to provide definitive interpretation of EU law. The document does not replace any of the Commission's existing general interpretative and methodological guidance documents on any of these Directives or Regulations. Instead, it seeks to clarify specific aspects of these provisions and place them in the context of aquaculture activity. The background document recognises that the Directives are enshrined by the principle of subsidiarity and that it is for Member States to determine the procedures necessary to implement the requirements of the Directives.

The good practice procedures described in this document are not prescriptive in their intent, rather they aim to offer useful advice, ideas and suggestions based on extensive discussions with EU and national authorities, industry representatives, NGOs and other stakeholders.

2 Overview of EU-28 aquaculture and environmental impacts

In considering the environmental impacts of aquaculture within the work undertaken in this study, it is important to view both the scale of the sector in Europe as well as the diversity of systems that are used to produce this seafood. An overview of the sector in EU-28 is presented below.

2.1 Production from EU aquaculture

Regulation (EC) No. 762/2008 (EU 2008b) requires Member States to collect and submit statistics on both marine and freshwater aquaculture covering:

- harvest of each species (in tonnes and value) by environment (freshwater, seawater, brackish) and method (cages, tanks and raceways, ponds, enclosures and pens, recirculation systems, not specified, off bottom, on bottom, other methods);
- production of eggs for human consumption, and production of eggs and juveniles from hatcheries and nurseries;
- wild inputs to aquaculture, i.e. wild “seed” taken for ongrowing (e.g. mussels, Atlantic bluefin tuna and European eel) and adults captured for broodstock;
- size of production facilities (area in hectares, volume in 1000s m^3).

Such data could provide useful background for judging the scale of potential environmental impacts of aquaculture within EU-28. Available data (2008-2012) were downloaded (in mid June 2014) from the Eurostat website (http://epp.eurostat.ec.europa.eu/portal/page/portal/fisheries/data). Data on harvest are judged to be of sufficient quality to describe European aquaculture. However, data for other aspects were judged to be unreliable, due to limitations in reporting across species and countries, apparent large inter-annual variations and data entry errors.

Aquaculture occurs in 27 of the EU-28 Member States, with only Luxembourg not reporting production between 2008 and 2012. Reported EU28 production in 2012 was 1.06 million tonnes, with a farm gate value of €3.04 billion (N.B. these values are underestimates due to some missing values). Reported production from EU-28 countries was static around 1.3 million tonnes between 2008 and 2010, and decreased to 1.06 million tonnes in 2012. The available data therefore support the assumption that EU aquaculture production has remained static and not developed since 2009, although missing values do hinder evaluation. **Although not directly part of this study, it is recommended that Member States submit the required data on aquaculture to ensure reliable statistics are available.**

Although EU-28 aquaculture is very diverse with production spread across more than 100 species categories, a limited number of species dominate. In 2012, EU-28 reported aquaculture production comprised: 36.4% mussels (384,604 tonnes), 16.5% Atlantic salmon (175,009 tonnes), 13.6% other salmonids (mainly rainbow trout, 143,646 tonnes), 12.8% seabass and seabream (135,863 tonnes), 8.9% oysters (93,911 tonnes), 7.0% carp (74,363 tonnes), 2.5% other marine fishes (26,929 tonnes), 1.5% other freshwater fishes (16,124 tonnes) and 0.6% clams (6,803 tonnes). Although the reported harvest from freshwater (19%) appears to be small relative to harvest from seawater and brackish water (81%), it must be recognised that Atlantic salmon (and other salmonids harvested from seawater) are initially reared in freshwater. One reason suggested for static production is that increases in salmonid production have been cancelled out by reductions in freshwater carp production.

Five Member States dominate EU-28 aquaculture, accounting for 75% of production (Spain: 266,594 tonnes; United Kingdom: 205,594 tonnes; France: 205,107 tonnes; Italy: ca. 160,000 tonnes; Greece: 108,852 tonnes). The relative importance of the different aquaculture sectors varies between Member States, e.g.:

- Molluscs dominate production (>60% of national tonnage) in Spain, France, Netherlands and Ireland;
- Atlantic salmon and other salmonids dominate in the UK, Denmark, Finland, Sweden, Slovakia, Slovenia and Estonia;
- Marine finfish (including seabass and seabream) dominate in Greece, Malta and Cyprus;
- Freshwater finfish (including carp) dominate in Germany, Poland, Czech Republic, Hungary, Romania, Lithuania and Latvia.

2.2 Aquaculture cultivation systems

The environmental impacts of aquaculture will depend upon the species farmed, the cultivation system used, the level of production, and the sensitivity of the local environment. A variety of cultivation systems are used within the EU (Table 2.1) with the target species limiting the options, and local and economic factors determining the selection of an appropriate system.

Table 2.1: Aquaculture systems used in the EU.

Cultivation system	Environment	Species group cultured
Net-pen systems	Freshwater & marine	Finfish

Flow-through land-based systems	Freshwater & marine	Finfish
Land-based recirculation systems	Freshwater & marine	Finfish (crustaceans)
Extensive and static water earth ponds	Freshwater	Finfish (crustaceans)
Lagoon & valliculture	Marine	Finfish
Rafts and longlines	Marine	Bivalves
Intertidal shellfish culture	Marine	Bivalves
Sub-littoral bottom shellfish culture	Marine	Bivalves

2.2.1 Finfish cultivation systems

Net pen systems

Net pens (also termed cages) are open systems consisting of a large mesh bag suspended from a square or circular floating frame. Net pens are used in marine and freshwater environments where there is a sufficient depth of water, relatively low current speeds (to prevent deformation of the enclosed space) and shelter from excessive wave action. Individual cages are typically grouped together in rafts and secured by anchors. The frames are likely to house moorings (for boat access), walkways and hand-rails, feed stores and feeding equipment, and grading equipment. Cages vary in size (surface area and depth) and the number of cages in a raft can vary. In 2012, the average volume of a salmon net pen farm in Scotland was 8,116 m^3 in freshwater and 70, 153 m^3 in seawater (Munro and Wallace 2013). Water exchange is driven by residual and wind-driven currents and fish movements. Dissolved wastes pass out of the cages with the currents, and solid material (faeces and uneaten food) are either dispersed, utilised or settle to the bottom of the water body. For chemotherapeutic treatment, fish may be transferred to a well-boat, or treated in-situ by placing a tarpaulin around the net as an impermeable barrier which is removed after treatment to allow dispersal. When medicines such as antibiotics are required, they are prescribed by veterinarians, given within the feed, and the majority is taken up by the fish. Above water, mesh is suspended on rails to prevent escapees and exclude predators, and a secondary underwater mesh may perform similar functions. Due to practical limitations of mesh size, net-pens are used for ongrowing (i.e. fish > 5 g).

Flow-through land-based systems

Flow-through land-based systems are open systems constructed on land adjacent to natural water bodies from which water is diverted or pumped. The water supply is typically diverted from rivers using a gravity-driven flow, although pumped supplies (from groundwater, lakes or the sea) are also used. Fish are reared in tanks, raceways or earth ponds. In 2012, the average volume of a salmon land-based farm in Scotland was 895 m^3 for freshwater and 2950 m^3 for seawater (Munro & Wallace

2013). Stocking densities and productivity are typically higher than in net-pens due to the greater water exchange. Water may pass through one or more rearing units before discharge into a water body (downstream if gravity-driven flow). Aeration and oxygenation systems may be used to increase the oxygen content of the water. A variety of methods are used to reduce the suspended solids load in the effluent (e.g. settlement ponds, centrifugal concentrators, filters) based upon sedimentation and screening. Reduction in dissolved nutrients is more problematic due to the water volumes, although constructed wetlands provide an option. Chemotherapeutic treatments are flushed directly into the effluent stream. Screens on the water intake and discharge channels prevent escapees, but this function can be compromised by blockages or flooding. Flow-through land-based systems are used to rear all sizes of fish, i.e. hatchery, nursery, ongrowing and broodstock sites. Regulatory controls typically limit the volume abstracted and the volume of nutrient and organic matter discharged (Bergheim and Brinker 2003).

Land-based recirculation aquaculture systems

Land-based recirculation aquaculture systems (RAS) are largely self-contained systems in which water is recycled and technology is used to remove wastes and maintain oxygen levels. The water from the production units is circulated for treatment – removal of suspended solids (faeces and food) by mechanical filtration, conversion of dissolved chemical wastes by biological filtration, dissolved gas exchange (reduction in carbon dioxide and increase in oxygen), sterilisation (to remove pathogens and undesirable bacteria) and chemical buffering - before return to the production units. Water is typically taken from clean sources (i.e. mains, spring or borehole for freshwater; clean sites with low suspended solids loads for seawater) with 1.5%-10% of the system volume being replaced per day. Discharge is typically not direct to natural water bodies, but via a settlement tank or lagoon (or occasionally sewer for freshwater). As water is retained, heating may be cost-effective to increase the growth rate of temperate species or enable production of tropical species. RAS are used as nurseries for salmonids, and for all stages of certain food species.

Extensive and static earth ponds

Extensive freshwater earth ponds are widely used in Poland and other central European MS. Inputs of feed are often required to increase fish (mainly carp) production above the natural productivity of the pond. Crayfish cultured in pond systems in Northern Europe may not require inputs of food.

Lagoon culture

Lagoon culture (Ardizzone et al 1988) is a traditional coastal aquaculture activity mainly practiced in Northern Italy, but with some operations in other Mediterranean countries, particularly Greece. The systems enclose wild fry of sea bass (*Dicentrarchus labrax*), sea bream (*Sparus auratus*), mullet (*Mugil spp*.), sole (*Solea vulgaris*) and other species after they migrate into the lagoons in the spring, and prevent their return to the sea in the autumn. The fry are grown on until a harvestable size, primarily via feeding on the natural productivity.

Environmental pressures from finfish cultivation systems

There is a significant literature documenting the potential for finfish aquaculture to adversely impact the environment of natural water bodies through a variety of routes (summarised in Table 2.2). The pressures that have received the greatest attention, and are therefore judged to be of greatest concern, are effluent discharge (localised effects on physico-chemical quality with knock-on effects on biological quality), escapees and pathogen release (both potentially affecting biological quality) (SAMS 2002). It is apparent that finfish cultivation systems that are intensive and open (i.e. directly connected to natural water bodies) have a greater potential for environmental pressures than extensive, or intensive but closed (RAS), systems.

Mitigation of Environmental pressures from finfish cultivation systems

However, it should also be recognised that the aquaculture industry (and regulation) has evolved to lessen potential pressures, with examples including:

- Improved feeding systems, diet formulations and effluent treatment systems leading to reduced discharge of solids (uneaten food and faeces) and dissolved nutrients (Bergheim and Brinker 2003; Sindilariu 2007).
- A drastic reduction in use of antibiotics (Midtlyng et al 2011).
- Improved disease control (through vaccination, improved husbandry and practices e.g. fallowing, 'all-in-all-out' production, zoning to minimize horizontal spread), reducing potential transmission to wild stocks (Bergh 2007; Midtlyng et al 2011).
- Improved system designs to reduce escapes (Taylor and Kelly 2010).

Further information is provided on these areas within the good practices sections later in the document.

Environmental Benefits of Finfish Farming

The potential environmental benefits of finfish farming also merit recognition. Potential positive effects at local level include:

- fish ponds, and wetlands constructed for effluent treatment, providing breeding and foraging areas for amphibians and birds and contributing to biodiversity (Michael 2003; Kloskowski 2010; Kufel 2012). For example, a survey of the biota associated with 1500 ha of ponds in Gołysz reported more than 2105 plant and animal species (Sieminska and Sieminska 1967).
- coastal net-pen farms have been suggested to act as aggregating sites for wild fish, with residence periods of weeks to months. Due to prohibition of fishing within farm leasehold areas, these may act as small (up to 160000 m^2) pelagic marine protected areas (MPAs) (Dempster et al 2006).
- farms providing a source of feed for wild fish and predators (Rasmussen 1986; Lanszki et al. 2007; Fernandez-Jover et al. 2011; Skorić et al. 2012). For example, productivity of Mediterranean dolphins is higher in areas with fish farms (Piroddi et al 2011).
- fish ponds acting as reservoirs, retaining water for use for irrigation during dry periods and helping to manage flooding during periods of high rainfall (Kufel, 2012).
- fish ponds retaining nutrients, in particular phosphorous and possibly nitrogen (Kufel, 2012).
- fish farms (being dependent upon good quality water) acting as sentinels with farmers alerting authorities to environmental problems.
- enhancement of wild populations via restocking with hatchery-reared fish (Aprahamian et al 2003).

Table 2.2: Overview of potential environmental pressures from finfish cultivation systems on natural water bodies, with supporting references where available. N.B.: The fact that impacts have been observed or predicted does not mean that they will occur in all cases. On some issues there has been little direct research, or difficulty unequivocally validating all stages in the causal pathway in the field. Differences have been found between different geographical areas, sites and studies, and studies finding impacts are more likely to have been published than studies finding none.

Impact on	**Impact via**	**Cultivation system**				
		Net pens	**Flow-through land-based systems**	**Land-based RAS**	**Lagoon & valiculture**	**Extensive and static earth ponds**
Hydro-morphological quality	Changes to water volumes / flow due to abstraction		•	•		•
	Insertion of infrastructure in water body – net-pens and moorings, channels for water supply.	•	•			
Physico-chemical quality	Deoxygenation -due to finfish metabolism within farm, and/or organic load of effluents, or algal blooms associated with nutrient increase (Bergheim and Brinker 2003; Partridge et al 2006)	•	•			•
	Water chemistry changes - due to release of soluble nutrients such as phosphorous and nitrogenous compounds, leading to eutrophication (Macmillan et al 2003; Sugiura et al 2004; Partridge et al 2006).	•	•			•
	Sediment chemistry changes – due to settlement of particulate (organic) material (Rooney and Podemski 2010; Mayor and Solan 2011)	•	•			•
	Toxic (synthetic & non-synthetic) compounds in effluent: • Antifoulants (metals), antibiotics, parasiticides, anaesthetics, disinfectants (Burridge et al 2010)(Subasinghe and Reantaso 2013) • Persistent organic pollutants and trace metals from feed (Russell et al 2011).	•	•			
	Metabolically active compounds (i.e. natural hormones or pheromones) excreted in effluent (Kolodziej et al 2004)	•	•			•
	Temperature changes during impoundment		•			•
	Litter (e.g. feed sacks, buoys) from farm operations (Astudillo et al 2009; Hinojosa and Thiel 2009).	•	•			
	Noise (e.g. from boats, equipment, acoustic predator deterrents) and human disturbance may disturb wildlife (SAMS 2002; Wysocki et al 2005; Wysocki et	•	•			

	al 2007)					
Biological quality	Benthic impacts – changes in aquatic macrophyte and benthic macroinvertebrate populations due to organic enrichment, siltation, and/or smothering by particulate wastes (Roberts et al 2009; Živić et al 2009; Rooney and Podemski 2009; Camargo et al 2011)	•	•			
	Impacts on wild salmonids (assumed via water quality) at vulnerable stages (Prévost 1999; Dumas et al 2007; Waring et al 2012)		•			
	Release of pathogens, which may infect wild fish, at levels that compromise fitness. Notably sea-lice (Heuch et al 2005; Jones 2009; Gargan et al 2012; Middlemas et al 2013; Torrissen et al 2013) but also other pathogens (Lapatra 2003)(Chambers et al 2008)	•	•			
	Escapees –reducing fitness of wild fish via interbreeding (McGinnity et al 2003; Butler et al 2005; Thorstad et al 2008; Glover et al 2013), predation on (Walker 2005), and competition with, native stocks (Tatara and Berejikian 2012). Establishment of populations of non-native species (Fausch 2007; Gozlan 2008) (Rasmussen 1986)	•	•			
	Farmed stock predation on native species (e.g. amphibians) that access rearing systems (Kloskowski 2010).					•
	Predator control – culling of mammalian (e.g. seals) and avian (e.g. cormorants) (Quick et al 2004). Entrapment in anti-predator netting.	•	•			•
Aesthetic quality	Visual intrusion and landscape impacts of cultivation structures (Whitmarsh and Palmieri 2009)	•	•			

2.2.2 Crustacean culture systems

Crustaceans cultured within the EU include various species of crayfish, lobster and prawn. Crayfish are commonly cultured in Northern Europe (e.g. Sweden), traditionally in earth ponds or lakes, but more recently in RAS systems. Lobsters are cultivated in hatcheries for restocking into the wild; research is also underway to assess the feasibility of on-growing in sub-surface cages. Prawn culture is currently small scale and mostly confined to RAS systems.

2.2.3 Shellfish cultivation systems

Bivalve mollusc aquaculture has been practised globally for centuries, and records of oyster management in Europe date back to at least 77AD when Pliny the Elder described the process of relaying oysters for fattening (Pliny the Elder). The culture methods in use today range from modern, highly mechanised and intensive systems capable of producing thousands of tonnes of shellfish, through to low input, extensive systems that have changed little over the centuries. All take advantage of the low trophic level occupied by bivalve molluscs (Duarte et al 2009; National Research Council 2010), and are generally sited in estuarine and coastal areas with high levels of primary productivity. The three basic types of shellfish cultivation are described below.

Rafts and longlines

Rafts and longlines are anchored floating systems, used in open sea or estuarine environments, from which a variety of culture systems can be suspended. They are very adaptable (allowing for the cultivation of a wide variety of shellfish species) and highly efficient (the raft culture farms in Spain being the largest producers of mussels in Europe).

Rafts are solid floating platforms traditionally constructed of wood, although modern rafts can be made of steel or polyethylene (PE), with a structure of cross beams used to support the shellfish in cultivation. They are compact units allowing for large carrying capacity in a small area and are usually used in sheltered areas, although modern PE systems are now robust enough to be used in exposed offshore sites. They are more effective in areas of high current due to the high stock density achievable. Rafts are used to cultivate mussels on ropes, oysters in cages and scallops in lantern nets. They are often used to rear juvenile oysters prior to transfer to other systems.

A **longline** is a floating line anchored at both ends and supported along its length by a series of floats; this floating line can be at the surface or semi-submerged, the latter offering protection in exposed locations. The shellfish are suspended from this line on dropper lines. They are often used in offshore areas, or those with low current flows, where only a low stock density can be held. Longlines can be used to cultivate a variety of species; mussels attach directly to the dropper lines, and lantern nets or cages are used for other species.

New developments in longline technology include "SmartFarm" mussel systems using floating PE tubes supporting a length of square mesh net, to which the mussels attach. This design allows for more mechanisation and easier harvesting.

Intertidal shellfish culture

Shellfish culture between the high and low water marks can be either on-bottom culture (benthic) or near bottom (epi-benthic) culture. Epi-benthic systems include stakes, racks and intertidal longlines; these systems can be effective where the substrate is not suitable for shellfish cultivation, but are not limited to these locations. It is one of the oldest forms of shellfish cultivation: the bouchot culture system has been used in Europe since the 13th Century (Goulletquer and Heral 1997). The use of inter-tidal areas means easy access for stock management although, depending on the culture method in use, this can be limited to the period when the shellfish are exposed at low tide. The exposure time also affects the growth rate of shellfish, with those exposed for the least time having the highest growth rate, as they are able to feed for longer.

Sub-littoral bottom shellfish culture

In its simplest form, this is the relaying of shellfish directly onto the seabed, where the stock is left to grow until it reaches market size, with occasional stock thinning where required to encourage growth. Growth rates depend upon the size of seed shellfish, stock density and the productivity of the water body. Species cultivated by this method include mussels, oysters and clams.

Environmental impacts and benefits of shellfish cultivation

Recognised as eco-system engineers, reef-forming shellfish species such as oysters and mussels are capable of modifying the environment in which they are cultured, and other non-reef forming species may have similar effects when cultivated in commercial quantities. The resultant environmental pressures are complex, involving many processes, and are as varied as the sites where the activity takes place (Nugues and Kaiser 1996; Heffernan 1999; Forrest and Elmetri 2007; Bouchet and Sauriau 2008). A summary of the possible effects, negative and beneficial is given in Table 2.3.

Table 2.3: Overview of potential environmental impacts (negative and beneficial) of shellfish cultivation systems on natural water bodies, with supporting references.

N.B.: The fact that impacts or benefits have been observed or predicted does not mean that they will occur in all cases. On some issues there has been little direct research, or difficulty unequivocally validating all stages in the causal pathway in the field. Differences have been found between different geographical areas, sites and studies, and studies finding impacts are more likely to have been published than studies finding none."

Culture Type				Effect	Impact	
Rafts and longlines	Intertidal Shellfish Cultivation		Sub-littoral bottom shellfish culture		Beneficial	Negative
	Epi-benthic	Benthic				
•	•			Shading from farm structures	Provides shelter for aggregation of fish (Forrest et al 2009; National Research Council 2010)	Reduction in light reaching seabed, potentially suppressing submerged aquatic vegetation (SAV), including eelgrass (Beadman et al 2004; Forrest et al 2009)
•	•	•	•	Human disturbance		Physical disturbance of ground beneath cultivation area can cause negative effects on fauna and SAV (Heffernan 1999; Forrest et al 2009)
•	•			Alteration of seabed topography due to altered flows	Creation of 3 dimensional habitat leading to high biodiversity (Kaiser et al 1998; Heffernan 1999; Forrest and Elmetri 2007; Bouchet and Sauriau 2008; Forrest et al 2009; National Research Council 2010)	Elevated sedimentation beneath trestles due to lowering of current velocity leading to decrease in macrofauna (Nugues and Kaiser 1996; Heffernan 1999)
•	•	•	•	Biodeposition of organic rich faeces and pseudofaeces (rejected particles wrapped in mucus, expelled without passing through digestive tract)	On-bottom methods enhance oxygen / carbon fluxes at water/sediment interface. Moderating effects of excess nutrients. Sites that are well flushed by tidal currents can benefit from increased levels of productivity In less intensive systems, decomposition of organic matter can regenerate nutrients, stimulating phytoplankton production (Dame 1996; Nugues and Kaiser 1996; Heffernan 1999; Forrest and Elmetri 2007; Rice 2008; Bouchet and Sauriau 2008; National Research Council 2010)	Changes in benthic biota Decrease in oxygen levels in sedimentary matrix Increased ammonia and sulphur (Dame 1996; Nugues and Kaiser 1996; Heffernan 1999; Forrest and Elmetri 2007; Rice 2008; Bouchet and Sauriau 2008; National Research Council 2010)
•	•	•		Increased structural habitat	Increased structural habitat for algae leading to more abundant invertebrate assemblages compared to bare mudflats Increased food availability for birds attracted to fouling organisms (Kaiser et al 1998; Heffernan 1999; Forrest and Elmetri 2007; Bouchet and Sauriau 2008; Forrest et al 2009; National Research Council 2010)	Increase in substrate for settlement of harmful or pest species Stimulation of growth of macroalgae, negatively affecting eelgrass (Kaiser et al 1998; Heffernan 1999; Beadman et al 2004; Bouchet and Sauriau 2008; Forrest et al 2009)
•	•	•	•	Biosecurity issues due to	Introduction of disease resistant species to replace stocks	Introduction of disease

				introduction of shellfish	affected by disease	Introduction of non-native species (Kaiser et al 1998; Forrest and Elmetri 2007; Forrest et al 2009; National Research Council 2010)
		•	•	Damage to benthos by harvesting		Non-target species mortality Changes to infaunal invertebrate community Changes to seabed topography (Nugues and Kaiser 1996; Kaiser et al 1998; Forrest et al 2009; National Research Council 2010)
•	•	•	•	Removal of particle bound nutrients	Rehabilitation of coastal waters Mitigation of other anthropogenic activities (Dame 2005; Rice 2008; National Research Council 2010)	
•	•	•	•	Decrease in planktonic biomass	Increase in water clarity, increasing light penetration, removing intrinsic limitation to spread of eelgrass Control of eutrophication (Dame 1996; Rice 2008; National Research Council 2010)	Depletion of phtyoplankton available to other organisms (Bouchet and Sauriau 2008)
•	•	•	•	Litter	Farm debris may increase higher invertebrate densities, leading to improved foraging opportunities for sea birds (Forrest et al 2009)	Entrapment of wildlife Visual impact
•	•	•	•	Changes to waterfowl species	Positive effect on sea bird populations in proximity to farm operations Greater diversity of local and migratory species on (Connolly and Colwell 2005; Forrest and Elmetri 2007; Zydelis et al 2008; Forrest et al 2009)	Negative impacts on some species due to physical obstructions affecting visual feeding clues (Dame 1996; Kaiser et al 1998; Connolly and Colwell 2005; Forrest and Elmetri 2007; Zydelis et al 2008)
		•	•	Changes to aquatic species diversity	Increase in biodiversity observed in shellfish reefs Epifaunal and meiofauna diversity increases in some shellfish beds Higher abundance of some fish and crustacean biomass and/or species number Replacement for native shellfish reefs lost through effects of disease and over fishing (Heffernan 1999; Beadman et al 2004; National Research Council 2010)	Loss of eelgrass due to smothering effects of bottom culture and trestle farming systems Localised decrease in faunal communities at high mussel density Introduction of non native species Loss of genetic diversity through aquaculture introductions Translocation of species (Heffernan 1999; Diederich 2005; Rice 2008; Bouchet and Sauriau 2008; National Research Council 2010; Fey et al 2010)
•	•	•	•	Changes to environmental quality	Carbon sequestration through shell formation Habitat (shoreline) stabilisation Restoration of depleted shellfish resources lost through overfishing Stabilisation of ecosystems enhanced resilience to environmental change	Shell extraction by harvesting affecting carbonate budget of estuarine environments Localised organic enrichment of benthos and resultant oxygen depletion (Kaiser et al 1998; Heffernan 1999; Rice 2008;

					High densities of shellfish can counteract symptoms of eutrophication Low trophic level of bivalve molluscs leading to a reduced trophic footprint for shellfish aquaculture (Kaiser et al 1998; Diederich 2005; Rice 2008; National Research Council 2010)	National Research Council 2010)

3 Water Framework Directive (WFD) and Marine Strategy Framework Directive (MSFD)

3.1 An outline and a summary of the objectives of the WFD and the MSFD

This section presents information on the legal framework of how the directives work, their differences and overlap, in order to develop the investigation into issues surrounding these items of legislation and their implementation in relation to aquaculture.

The WFD aims to improve and protect the chemical and biological status of surface waters throughout a river basin catchment. This extends from rivers, lakes and ground-waters through to estuaries (transitional) and coastal waters. For ecological status, coastal waters extend to one nautical mile (nm) out to sea. Chemical status applies also to territorial waters (out to 12 nm). Article 4 of the WFD requires Member States to prevent deterioration of the ecological and chemical status (later as regards some of the chemical pollutants identified in WFD Annex X) of surface waters and restore polluted surface waters, in order to achieve good status in all surface waters by at the latest 15 years after the date of entry into force of the Directive (i.e. by 2015). Countries have to assess the susceptibility of the surface waters to impacts resulting from anthropogenic activities. They have to use any relevant information, including existing or specially collected environmental monitoring data, to assess the likelihood that surface water bodies within the River Basin District will fail to meet the environmental quality objectives set under Article 4 and to implement measures accordingly.

The WFD classification scheme for water body quality includes five ecological status classes: high, good, moderate, poor and bad, where good status represents a slight deviation from reference conditions (WFD Annex V). Classification of final ecological status is determined for each water body for a range of biological quality elements. These are supported by hydromorphological and physico-chemical quality elements; the physico-chemical elements include temperature and nutrient and oxygenation conditions (see Fig. 3.1), as well as specific pollutants (WFD Annex V, and Annex VIII). The chemical status is assessed against Environmental Quality Standards (EQS) for selected Priority Substances. The overall status of a water body is determined by the quality element showing the lowest status, i.e. a 'one out – all out' approach. "Deviations from good environmental status can be accepted in certain circumstances that could include socioeconomic ones. Under WFD Article 4.5, Member States may aim to achieve less stringent environmental objectives provided certain conditions are met" (EU Water Directors 2007).

The river basin management plans (RBMPs) are the key tools for the implementation of the Directive. The adopted model for water management is management by river basin - the natural geographical and hydrological unit - instead of according to administrative or political boundaries. Under the WFD, all river catchments (rivers, streams, lakes and the land that drains into them) are assigned to administrative River Basin Districts (RBDs) by member states. Within in each RBD, "water bodies" must be identified as ground water or as discrete and significant elements of surface water (rivers, lakes, canals, transitional waters and coastal waters). Member States must produce RBMPs covering all RBDs in the EU (WFD Articles 11 and 13). The planning process should include an economic analysis of all the water uses in each RBD, as well as determining the pressures and impacts on the water environment. The first RBMPs had to be submitted by 2009. They are valid for a six-year period, after which they need to be revised.

The RBMPs set out environmental objectives for all groundwater and surface water bodies and Protected Areas (such as water bodies used for drinking water abstraction, bathing and thise identified under the Habitats Directive) within a RBD. They have to contain a summary of the earlier implementation stages, such as an assessment of the status of water bodies, the objective to be reached in each water body and, if reaching them is not possible for particular reasons, explanation and justification for reliance on the relevant exemptions. The plans should include a programme of measures to meet these objectives that details which measures will be undertaken, where, and by when. Protected areas (such as for drinking water abstraction, bathing, and those identified under the Habitats Directive) need to be especially monitored; achievement of he criteria in the Habitats and other relevant Directives is central to achieving the objectives of the WFD (Art. 4.3, 6 and 7). Member States are obliged to cooperate with other Member States with whom they share a RBD.

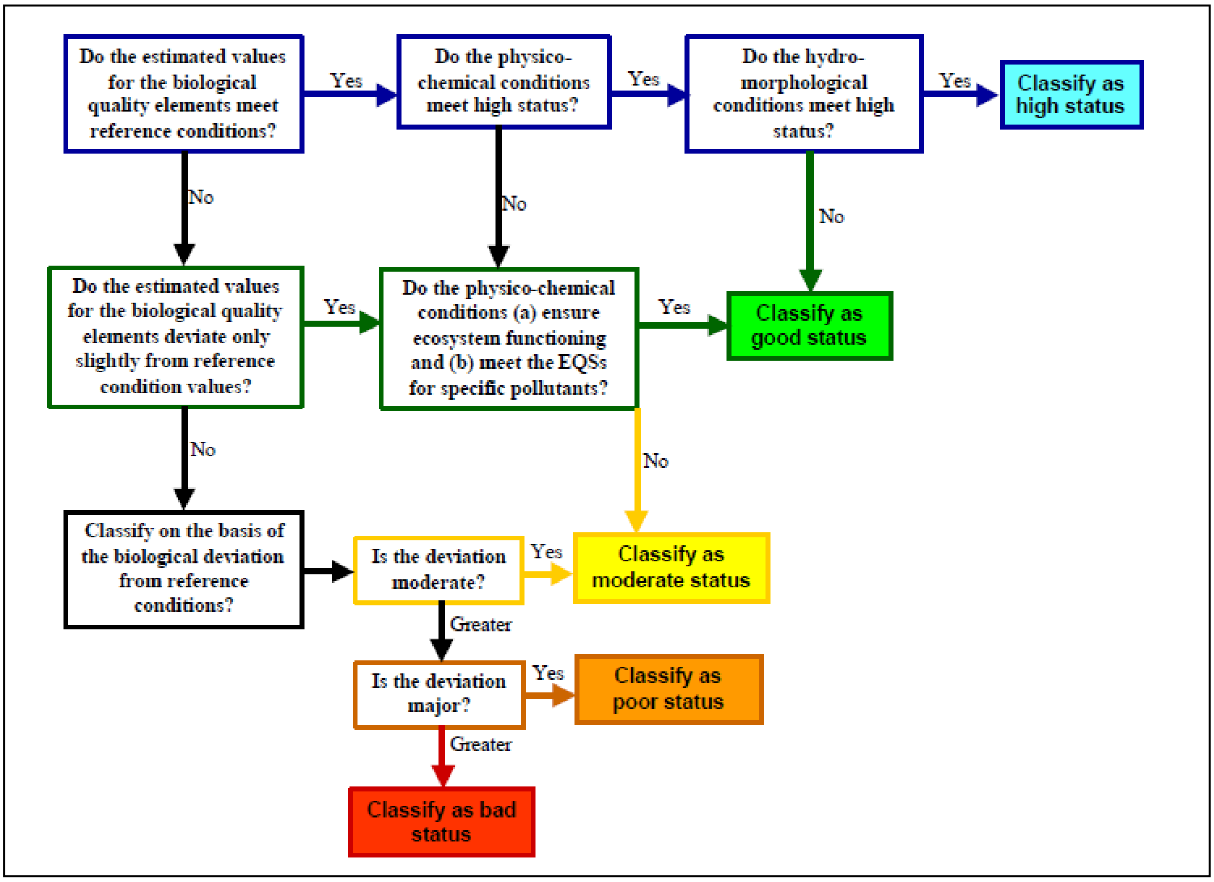

Fig.3.1: Classification of ecological status under the Water Framework Directive (WFD; (COM 2003a; COM 2005)*). The relative roles of biological, hydromorphological and physico-chemical quality elements according to the normative definitions are shown.*

The MSFD aims to achieve good environmental status (GES-MSFD) in marine waters by 2020. It was developed to provide a framework to protect the European marine environment more effectively by maintaining biodiversity and providing diverse and dynamic oceans which are clean and healthy whilst allowing the sustainable use of marine resources. Its scope of application extends to coastal waters on aspects of environmental status which are not already addressed by the WFD or other Community legislation, as well as the full extent of Member States territorial waters over which they have or exercise jurisdictional rights (MSFD, Article 3.1). To help achieve GES-MSFD, eleven descriptors of the state of the environment have been defined (i.e. biodiversity, non-indigenous species, commercial fish, food webs, eutrophication, sea-floor integrity, hydrographical conditions, contaminants, contaminants in fish and seafood, litter, and underwater energy such as noise). A detailed set of criteria and indicators have also been developed to help interpretation (COM 2010). Although good environmental status (MSFD) is not exactly equivalent to good ecological/chemical status (WFD), there are some significant areas of overlap between the two Directives, particularly with respect to chemical quality, the effects of nutrient enrichment, and aspects of ecological quality and hydromorphological quality.

The main differences between the WFD and the MSFD are that the scope of good environmental status within the latter is broader, covering a wider range of biodiversity components and pressures; and that assessment scales for the MSFD are larger, requiring assessment of environmental status at the scale of the relevant sub-regions (e.g. Greater North Sea, Celtic Seas) or subdivisions of these rather than at WFD individual water body scales. The two Directives also take different approaches to protecting the marine environment. MSFD has more quality elements to assess than WFD (eg. Birds, cetaceans, turtles, litter, noise) and has, as yet, not defined rules for aggregating assessments across the quality elements to define whether GES has been achieved or not, whereas WFD uses the one out all out principle where the worst element determines the overall status of the assessed area.

The boundaries for MSFD and WFD assessments overlap in coastal waters (Fig. 3.2). The MSFD makes it clear that in coastal waters, it is intended only to apply to those aspects of good environmental status which are not covered by the WFD (e.g. noise, litter, aspects of biodiversity).

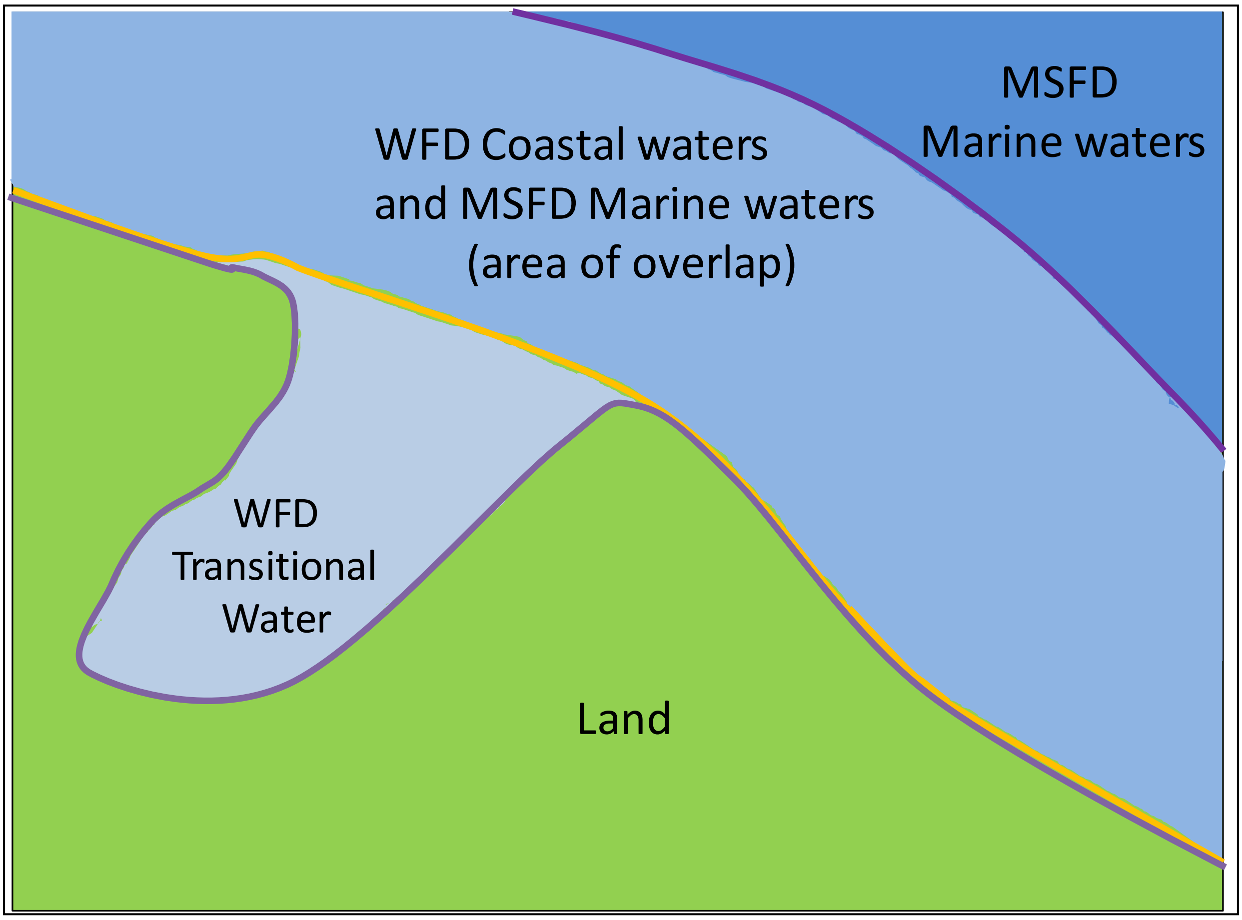

Fig.3.2: Diagram to indicate overlap between the WFD and the MSFD. The WFD applies to estuaries and coastal water bodies out to 1nm (baseline + 1nm) for ecological status, and 12nm for chemical status. The MSFD applies to marine waters and includes coastal waters not addressed by the WFD or other Community legislation, as well as the full extent of the territorial waters of Member States (see text). * 1nm = dark purple line; baseline = yellow line; 12nm = not shown, but would extend well into marine waters indicated here.*

3.2 River Basin Management Plans (RBMPs) and aquaculture

3.2.1 Introduction

The first River Basin Management Plans (RBMPs) were adopted by the majority of Member States in 2009. In 2012 the Commission published an assessment of these RBMPs as part of the 'Blueprint to Safeguard Europe's Water resources' (http://ec.europa.eu/environment/water/participation/map_mc/map.htm). RBMPs for 20 countries were accessed from the EU RBMP directory found on the above EU website (19 Member States [MS] and Norway). However, RBMPs from only 17 countries could be examined and 2 of those had no references to aquaculture.

3.2.2 Aquaculture and RBMPs

Aquaculture has been identified (within those River Basin Management Plans that have been examined) as exerting pressures on water bodies due to the issues listed in Table 3.1.

Table 3.1 – Issues where aquaculture is identified within RBMPs as exerting pressures on water bodies

Issues	**Countries**
A major user of water resources	CZ, EE, FR, HU, IT, ES
A point source of pollution	DE, EE, ES, FR, GR, HU, IE, LT, NL, NO, PL, UK
Localised reductions in benthic biodiversity	GR, IE
Significant dredging of water bodies	CZ, DE, HU, IT
Physical modification of land	Numerous
Changes in flow regimes	ES, IE
Introduction of alien species	GR, HU, IE, UK, NO
Introduction of exotic disease and parasites	IE, NL,NO, UK

Various MS have introduced specific strategies to manage the aquaculture industry. Such strategies include: the spatial zonation that is used in Greece and the prohibition of fish farms within a set distance from the coast in Malta; the introduction of limits for nitrogen/phosphorus loading, release of pollutants such as suspended solids and veterinary drugs (Greece; Italy) and of water abstraction (Poland); and the recommendation of good aquaculture practices in Hungary, Malta, Norway and the UK. The UK and Norway, two nations with particularly high aquaculture production, provide additional comprehensive guidance to producers, detailing strategies with measures that can be taken to reduce pollution and decrease the risk of disease or introduction of non-native species.

When comparing RBMPs, it is evident that there are significant disparities in the resources that MS can devote to reducing the impact of aquaculture production. Within the Lithuanian RBMPs, it is argued that given the scale of Lithuania’s aquaculture production (many very small scale producers with low profit levels and antiquated equipment) and country’s economic capacity, it would be difficult to implement modern approaches associated with measures such as fish disease control, or to purchase the modern equipment required to substantially reduce the industry's impact.

3.2.3 Shellfish culture and RBMPs

Although Directive 2006/113/EC on the Quality Required of Shellfish Waters was repealed in 2013 (see Chapter 3.8.1) the WFD requires Member States to provide at least the same level of protection to shellfish waters (which the WFD classifies as protected areas) as did the previous Shellfish Waters Directive. In the context of WFD implementation, Member States have indicated that they intend to ensure the same level of protection by maintaining the national regulatory instrument which transposed the Shellfish Waters Directive. To date there is no indication that any Member State has repealed the national transposition. By integrating the additional objectives for the protection of shellfish areas into the RBMPs the Member States should accordingly set monitoring programmes and put in place the additional measures necessary to achieve these additional objectives (beyond good ecological status).

In addition, commercially harvested shellfish intended for human consumption must comply with EU Food Hygiene Regulations which set standards for the quality of the shellfish flesh of designated Shellfish Production Areas.

In a number of RBMPs additional objectives and measures have been clearly described through the establishment of, for example, pollution reduction programmes (e.g. Ireland). For other MS, this information was not explicitly included in the RBMPs but could be inferred from other sources of information or established through national regulation (e.g. UK, France, Italy, Germany, or the Netherlands). In other cases, additional measures have not been defined at all as the objectives of the Shellfish Directive were assessed as having been met already (e.g. Germany). However, in a number of RBMPs, even if the objectives for protected areas had been established, there were no clear additional measures identified in the RBMPs to reach those objectives.

3.2.4 Looking forward to the second round of RBMPs

Even if additional objectives and measures have not been explicitly included in all the relevant RBMPs, these objectives and measures may exist and apply. The problem is the lack of integration into the RBMPs. The Commission Services have raised this in their assessment, have discussed this with MS (those for which shellfish aquaculture is relevant) and have requested that objectives and measures for aquaculture areas are better integrated into the river basin approach of next RBMPs (now under preparation) which are due in December 2015.

3.3 Explanation and clarification of areas from the WFD relevant to aquaculture.

Aquaculture activities can potentially exert pressures and impacts upon aquatic ecosystems, for example through increased nutrient load, from concentrations of faecal matter and uneaten feed, from dispersal of cleaning agents and medicines. In addition, aquaculture can itself be subject to pressures and impacts from other activities taking place in the aquatic ecosystem, for example pollution incidents, waste water treatment facilities upstream, and hydropeaking/flow variations due to flow regulation in the river e.g. from dams. It is important to remember that aquaculture producers require high quality waters, and are often the first in a river basin to detect problems with water quality, pathogens or introduced species in the aquatic environment. If properly managed, aquaculture can have positive effects on the natural environment, such as retention of water in the landscape, flood protection (large ponds) and encouraging biodiversity. Aquaculture relies on, but does not consume, significant quantities of water.

There are a range of criteria for assessing the ecological status of rivers, lakes, transitional waters and coastal waters set out in Annex V of the WFD but they all include consideration of:

- biological quality elements: composition and abundance of phytoplankton, aquatic plants, fish and benthic invertebrates;
- chemical and physicochemical quality elements that support the biological quality of the water body, including oxygenation, salinity, transparency, temperature, acidification and nutrient conditions and environmental quality standards for levels of specific pollutants (Annex VIII) that have been identified as being discharged into the water body;
- hydromorphological quality elements that support the biological quality of the water body, such as the quantity and dynamics of water flow (hydro-morphological quality).

The quality elements specified in Annex V of the WFD for each of the 4 surface water body types are summarised in Table 3.2.

Table 3.2: Quality elements for the classification of ecological status

	Rivers	Lakes	Transitional	Coastal
Biological elements				
• Phytoplankton	Y	Y	Y	Y
• Macrophytes and phytobenthos	Y	Y		

• Macroalgae			Y	Y
• Angiosperms			Y	*
• Benthic invertebrate fauna	Y	Y	Y	Y
• Fish fauna	Y	Y	Y	
Hydromorphological elements				
• Hydrological regime	Y	Y		
• River continuity	Y			
• Morphological conditions	Y	Y	Y	Y
• Tidal regime			Y	Y
Physico-chemical quality elements				
• General conditions	Y	Y	Y	Y
• Specific synthetic pollutants	Y	Y	Y	Y
• Specific non-synthetic pollutants	Y	Y	Y	Y
* Included with macroalgae for coastal waters				

Detailed objectives, measurement criteria and quality targets for each water body status category are developed in Annex V of the Directive. Annex V also includes definitions of ecological potential for heavily modified water bodies and artificial water bodies that may be relevant for aquaculture.

Pressures and impacts of different aquaculture systems depend on multiple factors, including farm location, type of cultured organism, methods used, and the sensitivity or vulnerability of the environment to possible pressures (COM 2012a). Aspects of aquaculture which may affect ecological and chemical status under the WFD, and activities which need to be monitored and managed closely as a result of WFD (and other) requirements include a range of pressures and impacts (COM 2012a):

Pressures from aquaculture which may have impacts affecting status under the WFD include:

- Infrastructure (containment, abstraction, discharge, harvesting)
- Input of dissolved and particulate nutrients (as excretory products and decaying food)
- Organic enrichment (by uneaten fish food, faecal material)
- De-oxygenation of the water column
- Contamination (e.g. by synthetic [disinfectants, antibiotics] and non-synthetic compounds [trace metals])
- Smothering of the seabed (e.g. by faecal material)
- Outputs (e.g. discharges, escapees, diseases/parasites)
- Reduction in plankton levels

Potential impacts from aquaculture on the environment which may affect status under the WFD include changes in:

- hydro-morphological quality elements (hydrology/typology- flow rates, wave exposure, habitat) - through abstraction and infrastructure (impoundment, storage, treatment or distribution of surface or groundwater)(Huntington et al 2006);
- physico-chemical quality elements - through discharges of dissolved and particulate nutrients causing de-oxygenation, smothering and chemical contamination by synthetic and non-synthetic compounds (e.g. disinfectants, antibiotics) (AQUAETREAT 2007)(COM 2012a)
- biological quality elements – through eutrophication (increased phytoplankton/algal levels, harmful algal blooms), changes in community structure (macro- algae, benthic invertebrates, fish), interbreeding with wild stocks, pathogen infections (e.g. sea lice), escapees and the introduction of non-native species.

3.4 Explanation and clarification of areas from MSFD (outside WFD) relevant to aquaculture.

The European Marine Strategy Framework Directive (MSFD) was developed to provide a framework for Member States (MS) to protect the marine environment more effectively (EU 2008a). This is to be done by maintaining biodiversity and providing diverse and dynamic oceans, which are clean and healthy, while allowing the sustainable use of marine resources (EU 2008a). The MSFD is based on an ecosystem approach and will, where necessary and appropriate, draw on existing regulation in order to achieve coherence between policy areas (e.g. CFP -(EU 2013), Habitats Directive -(EU 1992)). It came into force in 2008, and aims to allow MS to take the necessary measures to achieve or maintain Good Environmental Status (GES-MSFD) by 2020. European marine regions were defined for the purpose of monitoring water status and developing actions to achieve GES-MSFD (e.g. NE Atlantic Ocean, Mediterranean Sea, Black Sea, Baltic Sea), with sub-regions also defined in the North-East Atlantic and Mediterranean. In order to meet the requirements of the Directive, MS are obliged to cooperate with others in the same (sub-)region, including through the relevant Regional Sea Conventions (the Barcelona Convention in the Mediterranean, OSPAR Convention in the North-East Atlantic, Helsinki Convention in the Baltic Sea, and the Bucharest Convention in the Black Sea). Cooperation is also required between MSFD regions in order to ensure consistency and coherence across the EU.

The first phase of implementation of the MSFD has recently been completed, with MS having had to:

- provide an initial assessment of the status of their marine waters,

- determine GES-MSFD in respect of their marine waters, and
- establish a series of environmental targets in order to reach GES-MSFD.

In February 2014, the Commission reported on this first phase of implementation, highlighting a series of shortcomings, notably in relation to the need for greater regional cooperation, as well as integration of MSFD implementation with existing EU policies (COM 2014).

The next phase of implementation of the MSFD will see MS develop, in 2014, targeted monitoring programmes for the status of their marine waters, and in 2015, adopt programmes of measures to be undertaken in order to achieve GES-MSFD by 2020. It is important that MS take into account the pressures from existing and projected future aquaculture activities in their development of these programmes (EU 2008a).

3.5 Common interactions between aquaculture, the environment, and relevance to the MSFD

An assessment of the potential interactions between aquaculture, the environmental impacts of the industry, and the Descriptors of the MSFD has been carried out. This was done using:

a) the existing MS reporting under Articles 8, 9 and 10 of the MSFD and the JRC review of this documentation (Palialexis et al 2014),
b) the EC review of the MS implementation of the MSFD (COM 2014), and
c) products that map industries including aquaculture to pressures, ecological characteristics, and descriptors for MSFD developed in the EC Framework Programme project Options for Delivering Ecosystem-Based Marine Management (ODEMM) (Koss et al 2011), which mapped the linkages to all descriptors apart from the Descriptor on contaminants.

A simple impact assessment is presented (Table 3.3). Assessment of the MS documentation (accessed through EC Public Consultation - http://ec.europa.eu/environment/marine/public-consultation/index_en.htm) and the EC Article 12 Report and Annex (COM 2014) shows which Member States have linked aquaculture to specific MSFD descriptors. The numbers of countries identifying a particularly interaction should not be seen to represent the extent of the issues, but is presented only to highlight potential interactions. This simple impact assessment shows that the environmental impacts of aquaculture are possible from non-indigenous species, sea-floor integrity, eutrophication, and marine litter. Despite identifying potential impacts from aquaculture, the magnitude of these in comparison with other sources (e.g. agricultural runoff) is not assessed and it is difficult to gauge the proportionate scale of those impacts in relation to the overall anthropogenic inputs. A number of countries also identified fish and seafood contaminants, but this indicator should only be applied to the fish caught and harvested in the wild (COM 2014), although aquaculture may be a source of contaminants (see for example UK (HM Government 2012)). Hence, examples of aquaculture good practice and interactions with MSFD will focus on non-indigenous species, eutrophication, sea-floor integrity and marine litter. However, it must be noted that aquaculture is only one of many possible factors affecting these descriptors. The information presented in Table 3.3 is consistent with the outputs from the ODEMM project which showed that interactions between aquaculture and the descriptors are possible in almost all cases, noting that this did not take into account relative magnitude of the pressure (Koss et al 2011).

Different aquaculture systems may impact the MSFD Descriptors in different ways (Table 3.3). However, such effects are dependent on factors such as the hydrographic conditions at each aquaculture facility, the type of cultured organisms and production method and management practices. In broad terms, potential effects include habitat loss or deterioration, species disturbance and displacement and changes to local communities - all of which have implications for biodiversity, non-indigenous species, commercial fish and shellfish, foodwebs, eutrophication, seafloor integrity, hydrographic conditions, contaminants, fish and seafood contaminants, marine litter and underwater energy to a greater or lesser extent.

Table 3.3: Potential interactions between aquaculture, the environment, and MSFD descriptors based on MS initial impact statements. In MS mapping column standard two letter country codes are used.

Descriptor	MS identifying an interaction	Degree of interaction	Impact	Evidence & mitigation
1. Biodiversity	UK	Small	Low	If unmanaged, escapees, diseases and parasites may have localised effects on biodiversity. Effects are likely to be addressed through national legislation (e.g. implementing the EIA and Habitats Directives) and collaborative work in the Regional Seas Conventions. Siting is therefore a critical factor in reducing the potential impacts on biodiversity (COM 2012a).
2. Non-indigenous species	CY, DE, DK, GR, ES, FI, FR, IE, IT, NL, PT, SE, SL, UK	Large	High	Aquaculture provides a potential route for introduction of NIS with the Mediterranean and Black Sea prioritising NIS higher than other regions (Palialexis et al 2014), but this risk is managed through other legislation (EU 2007; COM 2013b). Effects are likely to be

				addressed through national legislation (e.g. implementing the EIA and Habitats Directives) and collaborative work in the Regional Seas Conventions.
3. Commercial fish & shellfish	None	Small	Low	If unmanaged escapees (gene flow), diseases and parasites may have localised effects on wild commercial fish and shellfish. Effects likely to be addressed through national legislation (e.g. implementing the EIA) and collaborative work in the Regional Seas Conventions.
4. Foodwebs	UK	Small	Low	If unmanaged escapees (gene flow), diseases and parasites may have localised effects on foodwebs. Effects likely to be addressed through national legislation (e.g. implementing the EIA and Habitats Directives) and collaborative work in the Regional Seas Conventions. Siting is therefore a critical factor in reducing the potential impacts on foodwebs (COM 2012a).
5. Eutrophication	CY, GR, ES, FR, UK	Small	High	Some impact at local scale, but unlikely to occur at sufficient scale at present to have significant impact (HM Government 2012; MANRE-DFMR 2012). In Greece, no specific targets opposite MSFD other than general reduction in nutrients and organic matters from point and diffuse sources. However, in enclosed seas like the Baltic that already have significant nutrient inputs, this may present a barrier to expansion of aquaculture with only nutrient-neutral schemes acceptable (e.g. Denmark, 2012). Collaborative work in the Regional Seas Conventions.
6. Sea-floor integrity	CY, GR, FR, IE, UK	Small	Med	Some impact at local scale due to siltation or scour, but unlikely to occur at sufficient scale at present to have significant impact (MANRE-DFMR 2012). This can be mitigated by moving cages and fallowing areas.
7. Hydrographical conditions	IE	Small	Low	Some impact at local scale due to formation of small scale features including eddies, but unlikely to occur at sufficient scale at present to have significant impact unless large scale facilities.
8. Contaminants	UK	Small	Med	Some impact at local scale due to contamination by hazardous substances and microbial pathogens (HM Government 2012), but unlikely to occur at sufficient scale at present to have significant impact (MANRE-DFMR 2012). Mitigation comes from the regulatory limits set within food safety legislation (EU 2006a; EU 2011b; EU 2011c).
9. Fish & seafood contaminants	CY, DK,GR, ES, NL, SL, UK	Small	Low	Some MS have included aquaculture species in the evaluation of potential risks for human health (Palialexis et al 2014). However, this is not supposed to cover aquaculture products

				as this is not in line with the Commission Decision, which refers to organisms "caught or harvested in the wild" (COM 2014). Even if this is not the case, impacts are assessed using regulatory limits set within food safety legislation (EU 2006a; EU 2011b; EU 2011c).
10. Marine litter	CY, FR, SL, UK	Small	Med	Some impact is listed by Slovenia as being a source of marine litter alongside urban discharges and fisheries (COM 2014). It is unclear what proportion of the litter comes from aquaculture activities, so difficult to assess mitigation measures, but it is definitely a source of marine litter and marine litter can have an impact on aquaculture activities (HM Government 2012).
11. Underwater energy (e.g. noise)	None	Small	Low	Some impact at local scale close to cages, but unlikely to occur at sufficient scale at present to have significant impact. Little information available on potential mitigation.

The key issue impacting potential restrictions to the development of aquaculture due to MSFD is the spatial scale at which the impact is likely to occur and the geographical scope. MSFD is set up to manage ecosystems at a (sub-)regional scale, but many of the impacts of aquaculture are at small scales (e.g. sedimentation in Cyprus - MANRE-DFMR, 2012). These impacts and mitigation are sometimes assessed as part of the marine licensing process (e.g. Scotland - http://www.scotland.gov.uk/Topics/marine/Fish-Shellfish/FHI/authorisation/apb) or under the WFD in coastal areas (COM 2000a). Hence, at the current scale aquaculture production is likely to have only a marginal impact on the achievement of GES-MSFD under the MSFD at a (sub-)regional scale unless the area is enclosed with limited exchange of water (e.g. Baltic Sea, as explained below), or the introduction is the important factor (i.e. non-indigenous species – NIS). There is often existing legislation that reduces the risk of these events. For example, in the case of NIS there is an existing regulation on alien species in aquaculture (EU 2007) (EU 2011a) and new Regulation adopted on 29 September 2014 to prevent the introduction and spread of invasive alien species(EU 2014a). However, despite the current scale of operations and the local impacts, it is probable that aquaculture, alongside all other sectors, will have to reduce impacts in order to reach MSFD targets. Hence, good practice examples described in later sections will also be relevant for MSFD.

The MSFD accounts for cumulative impacts from all pressures (aquaculture and others) to derive assessments for particular species and habitats. In this regard, aquaculture is one of a number of activities which might collectively influence the achievement / maintenance of GES under the MSFD. As such management measures for effects need to be assessed and applied proportionately against all the relevant activities, i.e. management of a sector such as aquaculture unilaterally may not be either fair or effective. We have shown that aquaculture contributes to these issues, so cumulatively with other activities is relevant for MSFD, however the difficulty arises as this document is specific to aquaculture hence the inference that aquaculture in isolation is at a scale unlikely to affect GES whereas if considered with other activities in areas sensitive to minor change (e.g. in the Baltic) it may tip the balance. A key consideration here is identifying the underlying causal factors (e.g. of eutrophication in the Baltic) and how the full suite of these contributing factors are managed.

It is possible that some regions are more sensitive to pressures from aquaculture due to the physical environment or hydrodynamic conditions. As indicated above, an example of this is the Baltic, where there is limited mixing with the North Sea and high levels of nutrient input from land, which has led to eutrophication and an anoxic bottom layer in some areas. The major sources of nutrients are sewage and agricultural run-off (see e.g. Denmark, 2012), so most of the Baltic is therefore classified as in poor or bad eutrophication status. As a result, it is not possible to site aquaculture facilities unless they are nutrient neutral – i.e. they must operate with no net nutrient input (see e.g. Denmark, 2012). This can be achieved in two ways: operating a land-based recirculation systems or nutrient offsetting (e.g. growing mussels and seaweed to offset nutrients produced by fish, and closing the nutrient loop by using fishmeal from the Baltic in feed).

There are two other ways that aquaculture is potentially relevant in the implementation of the MSFD:

- benefits of the MSFD on aquaculture production, e.g. a reduction of contaminants in the environment will reduce contamination in produce, and reduction in marine litter that can affect marine cages (HM Government 2012).
- benefits of sustainable aquaculture on delivering GES-MSFD, e.g. reduced pressure on commercial fish stocks and better ability to achieve GES-MSFD for commercial fish and shellfish; improvement in water clarity by mussel farms in the Baltic.

Although there is little increase in aquaculture production in Europe at present (COM 2009), the need for food security and new technology is likely to lead to significant expansion over the coming years (EU 2013) and the Commission recently published a revised strategy for the sustainable development of EU aquaculture (COM 2013a). The proportion of any (sub-)region that will be used for aquaculture will be assessed as part of the development of Multi-Annual National Plans (MANPs) for aquaculture development through to 2020. This is driven through the Commission's initiatives to develop the sector under CFP Reform. The MANPs are due to be published in 2014 and will indicate how the sector will change in the next 6 years, and will thus inform the discussion in relation to impacts relative to MSFD. With the move towards offshore cages, multi-trophic systems, algal production for biofuels, and the desire to increase aquaculture production to aid food security, it is likely that the interactions between aquaculture and the MSFD will increase over time. However, given the size of the geographical region covered by the MSFD and the relatively small scale of aquaculture facilities (as a proportion of the MSFD region) the potential risks from aquaculture as regards increased nutrient load, eutrophication and effects on sea-floor integrity are likely to be low. Changes in aquaculture technology and in the implementation of the MSFD are very difficult to predict, so it is difficult to assess future interactions between them; an evaluation is unlikely to be performed until the next cycle of the MSFD. However, if we assume that the pressures from aquaculture are likely to remain the same, there are a number of technologies and examples of best practice that can reduce the potential impact of aquaculture in the context of the MSFD. These centre on licensing, non-indigenous species, eutrophication, sea-floor integrity, and marine litter and are described below.

3.6 Obligations for aquaculture under WFD and MSFD

The WFD and the MSFD do not contain explicit obligations for aquaculture. The aquaculture industry has to comply with the requirements of the WFD and MSFD via the national legislation that implements those Directives in each Member State as set out in sections 3.1, 3.2 and 3.3 above. Other EU legislation relevant to the aquaculture industry is dealt with elsewhere in this report.

Annex II, section 1.4 of the WFD requires Member States to collect and maintain information on the type and magnitude of significant anthropogenic pressures on surface waters in each River Basin District. Member States should identify significant point source and diffuse source pollution, in particular substances listed in Annex VIII, from urban, industrial, agricultural and other installations and activities for the purposes of the initial River Basin Management Plan. Discharges from aquaculture will be regarded as point-source inputs and thus monitoring information is likely to be required as a precursor to management.

Aquaculture activities therefore need to be monitored and managed, and could benefit from the development of European-level best practice. In addition, as the aquaculture industry relies on good quality water, management measures which introduce and maintain best practices for the protection of the environment are also essential to the functioning of the industry.

3.7 Regulation of chemical discharges from aquaculture operations under WFD and MSFD

As with other agriculture production systems, diseases affect farmed fish and shellfish. A number of chemical and other substances are used as medicines, biocides, antifoulants and feed additives to improve the survival, performance and quality of farmed fish and shellfish (Table 3.4), particularly in intensive rearing systems (Burridge et al 2010)(GESAMP 1997). Medicines reduce losses during production, improve the welfare and quality of farmed fish and shellfish, and can reduce the spread of disease from farmed fish to wild fish (and vice-versa). Access to effective, cost-efficient medicines is a high priority for the aquaculture industry and wild fish interests alike.

Table 3.4: Examples of main types of chemicals used in European aquaculture. (: formalin, hydrogen peroxide and chloramine T are biocides that are also used as aquaculture treatments).*

Main groups of chemicals used in European aquaculture (by function/application)	Main actives used
Antibiotics	oxytetracycline, florfenicol, amoxicillin, potentiated sulphonamides, flumequine, oxolinic acid
Parasitical treatments	cypermethrin, ememectin benozoate, teflubenzuron, deltamethrim, azamethiphos, hydrogen peroxide*, praziquantal
Structural chemicals (contained in plastics)	stabilisers (fatty acid salts), pigments, (chromates, cadmium sulphate), antioxidants (hindered phenols), UV absorbers (benzophenoles), flame retardents (organophosphates)
Biocides	formalin*, quaternary ammonium compounds, peracetic acid, chloramine T*, hypochlorite (sodium or calcium), iodophores,
Antifoulants	copper oxide
Feed additives/ supplements	zinc, astaxanthin, canthaxathin, ethoxyquin, immunostimulants (e.g. β1-3 glucans, peptidoglycans), vitamin C, vitamin E
Anaesthetics	benzocaine, MS-222 (tricane methanesuphonate), phenxyethanol, isoeugenol, 2-propanone
Hormones	growth hormone (GH, somatotropin), 17 a-methyltestoterone
Soil and water treatments	disodium ethylediaminetetracacetic acid, gypsum (calcium sulphate), lime (agricultural limestone [calcite ($CaCo_3$) and dolomite ($Mg\ CO_3$)]) hydrated or slaked lime [$Ca\ (OH)_2$] and quick lime (Ca), zeoloite, rotenone (piscicide), herbicides and algicides

The use of veterinary pharmaceuticals and other chemicals to control diseases of aquaculture animals, or to keep equipment free of fouling organisms, poses a potential threat to the environment, particularly the areas immediately around or under the farms. Unless their use on farms is carefully managed, their discharge into the aquatic environment can pose a risk. This risk includes direct toxic effects (on benthic micro and meiofauna, algae, plankton and other aquatic organisms) and more subtle effects including potential modification of bacterial communities (and the promotion of antibiotic resistant organisms) as a result of discharge of antibiotics into the environment (GESAMP 1997).

The release of chemicals into the aquatic environment is regulated across Europe under a range of EU and national regulations. Under the Water Framework Directive and the Priority Substances or Environmental Quality Standards (EQS) Directive (2008/105/EC), as amended by Directive 2013/39/EU), environmental quality standards have been established for 45 priority substances and 8 other chemical pollutants of high concern across the EU. The WFD and EQS Directives replace the Dangerous Substances Directive (76/464/EEC) and the Freshwater Fish Directive (78/659/EEC) which were both repealed in late 2013. In addition, Member States should also set EQS for pollutants of national concern including those covered by Annex VIII of the WFD. Achievement of the WFD objective of good chemical status (and good ecological status) is supported by other EU legislation including:

- the Industrial Emissions Directive (Directive 2010/75/EU)
- the Urban Waste Water Treatment Directive (Council Directive 91/271/EEC)
- the REACH legislation (Regulation (EC) No 1907/2006; Directive 2006/121/EC)
- the Biocidal Products Regulation (Regulation (EC) No 528/2012)
- the Plant Protection Products Regulation (Regulation (EC) No 1107/2009)
- the Sustainable Use of Pesticides Directive (Directive 2009/128/EC)

The EQS in the EQSD apply to surface waters, i.e. inland waters, transition waters (estuaries and inlets) and coastal waters: chemical status is assessed out to 12 nm, unlike ecological assessment where water bodies are out to 1nm (although some countries may have limits beyond 1 nm). The EQSD includes biota standards for several substances including mercury (Hg), hexachlorobenzene (HCB) and hexachlorobutadiene (HCBD). Where possible and necessary, MS are expected to implement controls at national level on the discharge of chemicals. In terms of medicines used to treat aquaculture animals, it is a requirement under Directive 2001/82/EC (as amended) to undertake an EIA prior to obtaining a Marketing Authorisation (MA). In brief, testing follows VICH published guidelines and CVMP guidance (CVMP 2000; CVMP 2004), with EIA following a tiered approach, based on risk assessment. Depending on the physicochemical and other properties of the medicine, this can include extensive ecotoxicity testing to ensure that the environmental impacts of the medicine will be minimal when used as directed as per label.

EU law requires that foodstuffs, including aquaculture-derived products, obtained from animals treated with veterinary medicines, or exposed to biocidal products used in animal husbandry, must not contain any residue that might represent a hazard to the health of the consumer. In particular, Maximum Residue Limits need to be established for pharmaceutical products before an MA will be granted. Similarly, a safety assessment is undertaken for the active substances included in biocidal products for use in animal husbandry. For both types of substance, it must be included as an 'allowed substance' in table 1 of the annex to Commission Regulation (EU) No 37/2010 before it can be used. There are residue surveillance programs (both statutory and Member State specific non-statutory) in place to ensure that levels of authorised medicines and biocides in marketed seafood products in the EU are below allowed levels and also free of detectable levels of other potentially harmful chemicals (e.g. those listed are included in table 2 (prohibited substances) of the annex to Commission Regulation (EU) No 37/2010). These controls also act to greatly limit the range of chemicals that can be used in aquaculture, providing further environmental protection.

Of the original list of priority substances for which Environmental Quality Standards have been set, none are of direct relevance to aquaculture operations. However, the antiparasiticide cypermethrin and the antifoulant cybutryne were added to the list in 2013, and a number of substances covered by Annex VIII of the WFD as river basin specific pollutants are of aquaculture relevance. These include certain heavy metal (copper and zinc) compounds used as antifoulants, as well as chemicals that have been used as antiparasiticides (such as the sealice treatments diflubenzuron, cypermethrin and azimethiphos), formaldehyde (still widely used to control a range of diseases in aquaculture) and EDTA (Ethylenediaminetetraacetic acid, used to improve water quality by reducing heavy metal concentrations or remove organic substances in the water). Ammonia is a WFD Annex VIII listed substance that, as a compound excreted by aquatic organisms, is discharged into the aquatic environment from aquaculture operations.

As well as datasets of pollutant transfers from aquaculture operators maintained by national administrators or the regulators, information on discharge from intensive aquaculture operations can be found at the European Pollutant Release and Transfer Register http://prtr.ec.europa.eu/IndustialActivity.aspx. From this it can be seen that the main releases from registered facilities are copper and zinc compounds, with an estimated 92.1 and 108 tonnes respectively released in 2012.

Table 3.5. List of chemicals or substances listed under the WFD and its daughter Directives that are used in aquaculture

Chemical	Priority substance under WFD (European EQS set)	WFD Annex VIII	National EQS set (non statutory)	Aquaculture uses
Zn	No	Yes – point 7	Yes	
Cu	No	Yes – point 7	Yes	Antifouling
Diflubenzuron	No	Yes – point 9	Yes	Sealice treatment
Cypermethrin	Yes - PSD		Yes	Sealice treatment
Formaldehyde	No	Yes – point 9	Yes	Antiparaciticide and antifungal treatment
Azamethiphos	No	Yes – point 9	Yes	Sealice treatment
Ammonia	No	Yes – point 11	Yes	Effluent

Under the WFD, levels of priority substances in surface waters are allowed to exceed their EQS in designated mixing zones adjacent to points of discharge, as long as the rest of the water body still complies with the EQS. The designation of mixing zones involves defining a boundary beyond which the EQS should not be exceeded; the size of the mixing zone must be restricted to the proximity of the point of discharge and proportionate.

As well as these overarching controls, the release of chemicals from aquaculture operations is typically tightly regulated nationally, with most MS specifying what chemicals can be used as part of aquaculture operations and their maximum permitted discharge levels, irrespective of whether they are considered as River Basin Specific Pollutants (RBSP) under WFD.

3.7.1 Chemicals in the Marine Strategy Framework Directive

Discharge of chemicals into the aquatic environment from aquaculture operations is also of relevance to the MSFD, as they may affect the environmental status of the marine regions they are discharged into. Of particular relevance here would be GES-MSFD Descriptor 8 (Contaminants) and Descriptor 9 (Contaminants in seafood). In general, the good practice recommendations that are advised to help ensure compliance with WFD obligations will also apply to MSFD obligations here.

3.8 How the WFD replaced the repealed instruments (SWD and FWFD)

3.8.1 Repealed legislation: Shellfish Waters Directive

The Shellfish Water Directive (SWD) 2006/113/EC (codified version) (EU 2006b), adopted in 2006 repealed the original Shellfish Waters Directive 79/923/EC. Under Article 1 of the SWD, the legislation applied to those coastal and brackish waters designated by the Member States (MS) as needing protection or improvement in order to support shellfish (bivalve and gastropod mollusc) life and growth, and thus to contribute to the high quality of shellfish products directly edible by man.

The SWD implemented mandatory water quality standards to protect shellfish, including physical (pH, colouration, suspended solids, salinity, and dissolved oxygen) and chemical (petroleum hydrocarbons, organo-halogenated substances and metals). MS's were expected to '*endeavour to observe*' guideline standards, which included temperature and faecal coliforms. The SWD was repealed by the WFD with effect from 22 December 2013.

Certain shellfish producers and industry representatives (e.g. European Mollusc Producers Association- EMPA) expressed concern prior to the repeal of the SWD that the WFD would not provide adequate protection for shellfish waters post repeal of the SWD. However, at least the same level of protection afforded to shellfish waters under the SWD, should already have been established in Shellfish Protected Areas under the Water Framework Directive (WFD) Recital 51 and Articles 4.8 and 4.9 (EU 2000).

Improved water quality has already been achieved in some estuarine and coastal waters following implementation of EC legislation including the SWD, Urban Waste Water Treatment Directive 91/271/EEC (EU 1991) and WFD, and continued implementation of the WFD should ensure no deterioration of water quality in Shellfish Protected Areas, despite the repeal of the SWD. Under the first cycle of WFD, RBMPs (see section 3.1) were due for submission in 2009 and MS were required to register shellfish waters previously designated under SWD, as Protected Areas of the WFD. New shellfish waters are also to be designated as Protected Areas under the WFD. There is no reference to microbiology in Annex V of WFD (on the quality elements for classification of surface waters) therefore it is recommended that MS keep their own national legislation transposing the SWD or develop new national legislation if necessary and retain their existing microbiological standards for shellfish flesh. Some other standards implemented under the WFD are **more** stringent and protective of shellfish waters than SWD standards (e.g. the Environmental Quality Standard (EQS) for mercury is stricter than the SWD standard).

Although the majority of shellfish aquaculture occurs inshore (within the limits of the WFD), offshore shellfish aquaculture may increase in the future (Hedley and Huntington 2009), and protection under the MSFD needs to be considered. The MSFD (with broadly similar approaches and objectives to WFD) applies to marine waters which fall under MS jurisdiction (Article 3, including coastal and territorial waters covered by the WFD). Like the WFD, the MSFD incorporates the key principle of 'no deterioration' (Article 1 clause 8 and 43) and no microbiological standards for bacterial or viral pathogens (either in shellfish flesh or the water column) have been specified within Annex I of the MSFD. Therefore MS should consider retaining their national transposition of SWD legislation and standards, or develop new national legislation, to ensure compliance with the no-deterioration clauses of the MSFD and WFD and remain at least as protective of shellfish waters as was the case under SWD.

General aspects of the WFD and MSFD of particular relevance to shellfish aquaculture are: protection of aquatic resources; designation of protected areas including shellfish protected areas; managing human activity responsibly and encouraging sustainable use of aquatic/marine resources; protection of water quality by preventing and reducing pollutants including carrying out cost benefit analysis and funding improvements programmes according to the 'Polluter Pays Principle' where appropriate; protection of public health by setting environmental quality standards (EQS) for shellfish protected areas and setting monitoring programs; enabling healthy, diverse and productive waters (including limiting the spread of disease and non-native species).

3.8.2 Recommendations:

- The aim will be to better integrate the additional objectives, monitoring and measures in aquaculture protected areas in the whole river basin management, which should be reflected in the new round of RBMPs.
- It is recommended that Member States keep the national instruments transposing the SWD, or, if necessary, develop new ones to ensure adequate protection of aquaculture production areas.
- MS to be aware that viral standards are under consideration (e.g. Norovirus) and may be required for Shellfish Production Areas/Protected Waters, in the future.

3.8.3 Repealed legislation: Freshwater Fish Directive

The Freshwater Fish Directive (FWFD, 2006/44/EC) was repealed in December 2013 by the WFD. The FWFD laid down criteria on the quality of freshwaters needing protection or improvement in order to support fish life; although mainly relevant to natural waters, it is also relevant to some land-based systems and reservoirs in which net-pen systems were used. The quality of waters in such systems was covered by the Directive, with minimum standards stated for a set of parameters (including trace metals, organic contaminants, nutrients, temperature, pH and Biological Oxygen Demand (BOD)), together with a sampling protocol. The FWFD required MS to designate waters suitable for fish breeding, separated for salmonid and cyprinid fish as follows:

i) salmon *Salmo salar*, trout *Salmo trutta*, grayling *Thymallus thymallus*, and whitefish *Coregonus*;

ii) *Cyprinidae spp.*, pike *Esox lucius*, perch *Perca fluviatilis* and eel *Anguilla anguilla*.

Derogation from the provisions of FWFD was possible on the basis of special weather or geographical conditions, or the natural enrichment of water with certain substances. The FWFD had itself consolidated changes to Council Directive of 18 July 1978 on the quality of freshwaters needing protection or improvement in order to support fish life (78/659/EEC).

The WFD includes the parameters listed within the FWFD as well as additional parameters, so the overall impact should be to enhance water quality. Some MS have recognised that some FWFD schemes will need to be continued to ensure water quality is maintained.

4 Strategic Environmental Assessment (SEA) and Environmental Impact Assessments (EIA) for aquaculture

Although the project was set to address the implementation of the WFD and the MSFD specifically, in relation to aquaculture in Europe, additional environmental legislation of relevance was also included within the remit. Foremost in terms of importance are the Strategic Environmental Assessment (SEA) and Environmental Impact Assessment (EIA), and their application to aquaculture development. Information generated from the implementation of the Strategic Environmental Assessment Directive (EU 2001) and Environmental Impacts Assessment Directive (EU 2014b) may (to a greater or lesser extent) contribute to Member States determination and assessment of Good Environmental Status. Article 8, paragraph 1(b), (iii) of the MSFD states that *"… analysis of the predominant pressures and impacts, including human activity, on the environmental status of those waters … takes account of the relevant assessments which have been made pursuant to existing Community legislation …"*. Article 10 paragraph 1 states that "*When devising those targets and indicators, Member States shall take into account the continuing application of relevant existing environmental targets laid down at national, Community or international level in respect of the same waters, ensuring that these targets are mutually compatible and that relevant transboundary impacts and transboundary features are also taken into account, to the extent possible*."

4.1 Strategic Environmental Assessment (SEA)

Strategic Environmental Assessment is a process by which certain plans or programmes are assessed for environmental impact. SEA aims to fill the gap between single project developments (which may, or may not, be subject to an Environmental Impact Assessment) and effects resulting from large, complicated or multiple development activities (COM 2003b). Article 1 of the Directive (EU 2001) states "*The objective of this Directive is to provide for a high level of protection of the environment and to contribute to the integration of environmental considerations into the preparation and adoption of plans and programmes with a view to promoting sustainable development, by ensuring that, in accordance with this Directive, an environmental assessment is carried out of certain plans and programmes which are likely to have significant effects on the environment*."

SEA is used at an overarching strategic level to evaluate the environmental impacts of a number of similar projects in a region. Issues can be highlighted early in the planning and development process, so SEA can be a useful tool to inform licensing or marine spatial planning. With regards to aquaculture, if it is the subject of a national plan or programme, SEA could be used as a planning tool to assess the suitability of multiple aquaculture sites within a water body or region, as well as to assess aquaculture within the wider licensing and marine spatial planning framework.

SEA is a governmental responsibility, usually of the Member State's ministry for environment or planning. Article 2 of the Directive explains that the "*Plans and programmes covered are those, including those co-financed by the European Community, as well as any modifications to them, which are subject to preparation and/or adoption by an authority at national, regional or local level or which are prepared by an authority for adoption, through a legislative procedure by Parliament or Government, and which are required by legislative, regulatory or administrative provisions*".

Under the EU Directive on maritime spatial planning (2014/89/EU) Member States are obliged to prepare cross-sectoral maritime spatial plans by 2021. Where such plans are likely to have significant effects they are subject to the provisions of the SEA Directive (EU 2001).

4.1.1 Examples of SEA use with aquaculture

SEA has been used for aquaculture in Scotland to assess the impacts of the 'location / relocation of fish farms' programme (Scottish Government 2006); in Ireland (Povilanskas 2010) for an assessment of the aquaculture and shellfisheries management strategy; and in South Africa to identify development zones for culture of finfish in cages (Hutchings et al 2011). However, while SEAs for certain sectors are relatively routine (e.g. oil and gas and renewable energy), undertaking a SEA for aquaculture is fairly unusual.

4.2 Environmental Impact Assessments (EIA)

An Environmental Impact Assessment (EIA) is a procedure to systematically assess the likely significant effects of a certain project and the options for preventing, reducing and, where possible, offsetting any significant adverse effects. The EIA process ensures that the importance of predicted impacts is properly understood by developers and regulators before a decision is made on permitting the project.

EIA is required under the terms of the EU EIA Directive 2011/92/EU (EU 2012) as amended by Directive 2014/52/EU (EU 2014b). Projects are subject to a mandatory EIA if they are listed in Annex I of the Directive. If listed within Annex II, national authorities must decide whether an EIA is required through a process of screening, either through a case-by-case examination, the use of thresholds or criteria, or a combination of the two. Relevant screening selection criteria set out in Annex III must be taken into account as well. The only reference to aquaculture within the Directive is within Annex II, which lists intensive fish farming as a project which may require an EIA (determined by working through the criteria in Annex III). The recent EU Guidance on Aquaculture and Natura 2000 sites (COM 2012a) and Read & Fernandes (2003) define intensive fish farming as the farming of fish in cages with the addition of high quality artificial feed and medication.

The EIA Directive has been transposed into various national regulations and in some countries (e.g. the UK) there can be a large number of regulations and regulators, both terrestrial and marine, that cover all the different activities that may require EIA. Developers may therefore have difficulties in determining which national regulations they are subject to. National regulations also have differing thresholds across different countries for whether an EIA is required, which may cause further confusion to developers. For example, the AQUABEST project showed major differences in the permit systems related to thresholds for Finland, Åland, Denmark and Sweden with production tonnages varying between 2 and 40 tonnes p.a. (Paavola et al 2013). Different thresholds were also reported to be used in a number of European countries outside the Baltic region including Czech Republic, France, Italy, Poland and Turkey (Telfer et al 2009). Some European countries do not apply EIA to aquaculture development, but use alternative environmental management procedures and processes e.g. the Czech Republic and Poland (Telfer et al 2009). However, the picture is very complex across Europe, with different approaches applied to marine and freshwater systems, marine shellfish and marine finfish culture, and different regions of a country (Telfer et al 2009).

4.2.1 Examples of EIA use with aquaculture

Slaski (2010) undertook a review of EIAs carried out in Scotland between 1998 and 2007 by the seawater fish farming industry, to establish whether the screening thresholds in the EIA Regulations were appropriate. Of the 138 applications examined, 39% (54) were determined by the regulator to require an EIA. While none out of the 45 Environmental Statements (ESs) reviewed in detail identified significant environmental effects (as impacts identified could be managed), the author concluded that no recommendations on amending the EIA screening thresholds could be made as each proposal had a different set of environmental variables and therefore had to be considered individually. This document also provided useful guidance on what was required by developers in

Scotland and compared the Scottish regulations and application of the EIA Directive with other countries. Inconsistencies of EIA Directive application in different countries included:

- Different quantities for tonnage based thresholds (none in Scotland, 100 tonnes in Ireland, 780/900 tonnes in Norway and 1,000 tonnes in Turkey).
- Different terminologies
- Different approaches (single threshold system versus multi-tiered approach in Turkey)
- Area versus tonnage based thresholds (area based thresholds in Scotland, with other countries concentrating on tonnage/biomass thresholds)

Telfer et al. (2009) reviewed the requirements and practice for EIA for the Czech Republic, France, Greece, Hungary, Italy, the Netherlands, Poland, Spain, Turkey and the United Kingdom. All freshwater and marine species, other than marine salmon culture, were considered within this review. The review found that "…*despite common legislation in the European Union (EU) for implementation of the EIA process for impacts on aquatic systems, execution of this legislation within different EU countries is inconsistent …. In some countries there is no specific requirement for an EIA process for aquaculture development… In general it has been found that the closer the links between the regulatory system and actual practice at fish farms, the fewer objections, difficulties and misunderstandings occur. In many locations throughout Europe for example there appears to be an unnecessary and high level of bureaucratic involvement in the development of aquaculture activity. There is poor transparency in the implementation of EIA legislation as it relates to aquaculture, and differential treatment of aquaculture sectors, which may be an impediment to aquaculture development*."

4.3 Relationship between SEA, EIA and Appropriate Assessments (AA)

Where aquaculture activities are planned in or close to designated European Natura 2000 sites (Special Areas of Conservation (SACs) and / or Special Protection Areas (SPAs)), they may also need to be subject to an Appropriate Assessment (AA) under the Habitats Directive (COM 2012a).

SEAs / EIAs and AAs are similar procedures and can run concurrently with each other. However, it is important that the information submitted to inform an AA and the conclusions of the AA are distinct from the rest of the SEA / EIA, because a SEA or EIA cannot substitute or replace the requirement for an AA.

The main difference between SEAs / EIAs and AAs is that:

- An AA reaches a firm conclusion on whether or not a plan or project will adversely affect the integrity of a Natura 2000 site which dictates the decision on whether or not it is authorised.
- The conclusions of SEA and EIA should be taken into consideration in the decision making process on whether or not a plan, programme or project should be authorised.

These instruments are designed to make the regulator aware of all the environmental impacts of the proposed programme, plan or project, but it is the regulator that makes the final decision on whether to permit. However, if an AA cannot demonstrate that a programme, plan or project will not adversely affect the integrity of a Natura 2000 site, the regulator (based on the recommendation of the competent authority) cannot permit the activity to take place, unless under specific conditions (and there are no alternatives), or imperative reasons of overriding public interest can be demonstrated, and compensatory measures are taken.

The EU guidance on Aquaculture and Natura 2000 provides information concerning aquaculture activities and their potential impacts on protected habitats and species, and ways to mitigate those impacts, as well as guidance for developers and authorities on complying with AA requirements for Natura 2000 sites (COM 2012a).

5 Alien species legislation and aquaculture

The introduction of invasive alien species (IAS) is now globally recognised as a threat to indigenous biodiversity. The European Commission has adopted an ambitious new strategy COM (2011) to halt the loss of biodiversity and ecosystem services in the EU by 2020. One of six main targets of the Biodiversity Strategy is the tighter control of IAS with increased emphasis on prevention and reducing the risks from pathways for introductions. The pathways of introduction are numerous, e.g. movement in ballast water, on recreational vessels (Zenetos et al 2012), transport with human goods, as contaminants or hitchhikers.

The impacts and risks from alien species in aquaculture have been well documented (Hewitt et al. 2006; ICES 2009) and many recommendations made on minimising the risks (IUCN 2007; UNEP/MAP/RAC/SPA 2008a). This section outlines existing alien species legislation, briefly describes obligations of administrators/regulators, and explains how alien species fit within WFD and MSFD.

5.1 Current EU alien species legislation

The regulation of alien species within the aquaculture industry is well developed in comparison to other sectors. Regulation (EC) No708/2007 established a framework governing aquaculture practices in relation to alien and locally absent species to assess and minimise the possible impact of these and any associated non-target species on aquatic ecosystems. This Regulation requires Member States to appoint a Competent Authority to operate a permit system for the introduction of alien, and translocation of locally absent, aquaculture organisms. This Regulation recognises two types of stock movement:

1. Routine movements: where there is a low risk of transferring non-target organisms
2. Non-routine movements: where an environmental risk assessment has been carried out and has found the risk to be low, or where appropriate mitigation can be applied.

Certain alien species (with a long history of aquaculture within the EU and which do not have any major adverse ecological impacts) have been derogated from the main obligations of the Regulations, except where Member States believe that such controls are appropriate. These species are listed in Annex IV of the Regulation. In addition, Regulation (EC) No 304/2011, amending Regulation (EC) No708/2007, recognised that introductions to closed aquaculture facilities pose less risk (than introductions to open facilities) and have derogated such movements from the permitting system.

A new invasive alien species (IAS) regulation has been adopted on 29/09/2014 and enters into force in January 2015. This Regulation is not specific to aquaculture and covers a wider remit, including all IAS, activities and sectors. The Annex IV species listed in Regulation (EC) No708/2007 are excluded from the scope of the new IAS Regulation when used for aquaculture purposes.

Member States have been taking a number of measures to tackle IAS, but such actions have been predominantly reactive, seeking to minimise the damage already being caused without paying sufficient attention to prevent, detect and respond to new threats. IAS do not respect borders and can easily spread from one Member State to another. Consequently, the new IAS Regulation establishes a framework for action to prevent, minimise and mitigate the adverse impacts of prioritised IAS on biodiversity and ecosystem services. Prioritisation will be based on risk assessment. Some of the core obligations towards those prioritised IAS set out in the new IAS Regulation are linked to prevention, early detection and rapid eradication of IAS and management of established IAS.

5.2 Alien species in the context of WFD

In the original WFD text there was no mention of IAS, but work by the Commission supported the inclusion of alien species in implementation of the WFD (Shine et al 2010). MS should therefore take IAS impacts into account as part of WFD implementation and consider them a '*potential anthropogenic impact*' on biological elements listed in Annex V.

In 2009, building on common implementation documents, the consultative group ECOSTAT examined how alien species could be more consistently incorporated in WFD implementation (Adams 2009). This identified major constraints, complicated by the lack of adequate information tools. Subsequently, much work has been carried out on identification and risk assessment of alien species and how this may be applied to WFD assessments. In the Mediterranean Sea, guidelines have been produced on different vectors for introduction, how best to control these (UNEP/MAP/RAC/SPA 2008a; Zenetos et al 2012) and how to carry out risk analysis for assessing the impacts of any introduction (UNEP/MAP/RAC/SPA 2008b). In the Baltic region, HELCOM has been active looking at trends in IAS arrival (Rolke et al 2013) and have produced survey protocols and risk assessment tools (HELCOM 2013) although the main focus is ballast water in shipping rather than aquaculture.

The approaches taken by MS towards using IAS for Ecological Status Classification have varied; four of these options were considered at an ECOSTAT workshop (Adams 2009). One approach is carrying out risk assessments for an increasing number of alien species to assess if they are of high, medium, low or unknown impact and using this data in classifying ecological status (Fig. 5.1).

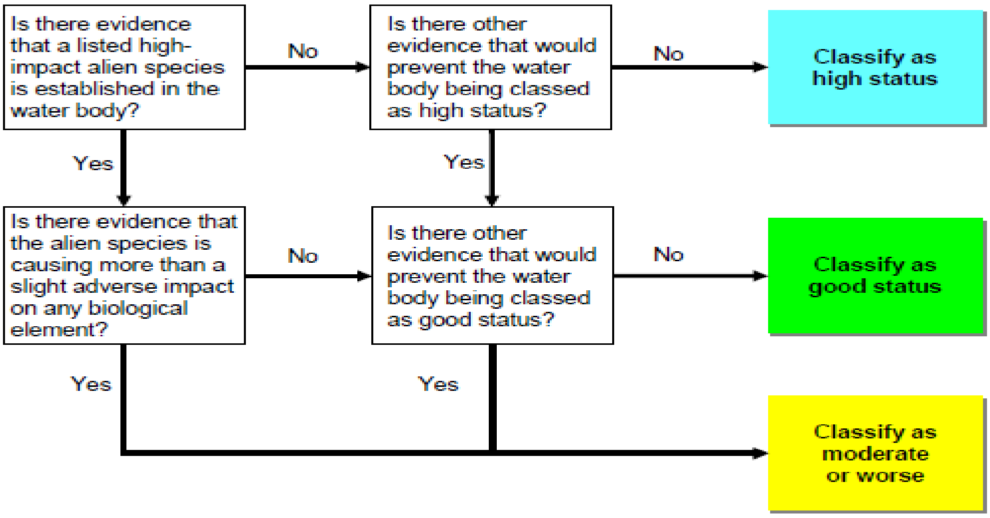

Fig. 5.1: Procedure for using alien species data in assessing ecological status. (UKTAG 2013)

The approach taken after identifying a high impact alien species would be to pursue eradication (where feasible and cost-effective) and/or focus on local containment to prevent spread into other water bodies within the same catchment or into neighbouring catchments.

An alternative approach favoured by HELCOM projects is to classify water bodies without explicitly taking account of alien species. A separate 'risk assessment' for alien species is undertaken, including various 'bio-pollution' indices for the risk and impact of alien species. This risk assessment is then published alongside the water body classification and used to influence the programmes of measures (Adams 2009; HELCOM 2013). Recent research has pointed to a need for further optimization of existing methods so that they address the full range of pressures exerted by IAS (Vandekerkhove et al 2013).

5.3 Alien species in the context of MSFD

Unlike the WFD, the MSFD (EU 2008a) explicitly covers IAS under one of the 11 Good Environmental Status (GES-MSFD) descriptors. Descriptor 2 requires that '*non-indigenous species introduced by human activities are at levels that do not adversely alter the ecosystem*'. Member States were requested to carry out an initial assessment by 2012 which should include an IAS inventory and an assessment of IAS as a biological disturbance pressure. Appropriate measures to achieve GES-MSFD could include IAS monitoring, control and/or eradication.

The Commission's criteria under Council Decision 2010/477 for IAS was:

- Abundance and state characterisation of non-indigenous species (invasive);
- Environmental impact of invasive non-indigenous species.

In recognition of the key implications of these proposals for relevant MS, a technical working group was established within OSPAR to develop common indicators across the NE Atlantic (OSPAR 2013). Candidate indicators put forward included:

- Reduction in the risk of introduction and spread of non-indigenous species and vectors through improved management of the main pathways;
- A surveillance indicator looking at the abundance and distribution of non-indigenous species (NIS) in areas which are at a high risk of new introductions (with a view to being able to develop a baseline for the rate of establishment of new IAS);
- Species-specific management plans for high risk IAS identified as already present or likely to be introduced into the Member State in place by 2020.

It was recognised that this would have the following requirements:

- Additional measures to achieve the targets – focussed on those industries which facilitate the introduction and spread of NIS;
- More research on key pathways of NIS introduction and spread to support development of appropriate measures;
- Additional monitoring at key locations.

Within the HELCOM area, the indicator follows numbers of non-indigenous species found in Baltic Sea sub-basins within an assessment period of 6 years. The indicator uses a baseline study to identify the number of already arrived non-indigenous species. Every new NIS arriving after the baseline year is counted as a new species. At the end of each assessment period, the number of new NIS is summed per assessment unit, and assessment for the next period starts again from zero (Rolke et al 2013).

A problem related to non-indigenous species is that once an aquatic organism has been introduced and becomes established in a new environment, it is often nearly impossible (or at least financially not feasible) to eradicate. At that stage, policy measures can practically only focus on containment and control. Consequently, defining areas as "bad" status, depending on the presence of invasive species, could mean that an area would stay that way without a possibility for remediation to "good" status (HELCOM 2014).

6 The needs of, and challenges for, EU aquaculture

To enable the sustainable development of European aquaculture it is important to identify the needs of the sector and then address how best those needs may be met in conjunction with the requirements of environmental legislation. This section examines: what has been identified and is being addressed at a strategic level; areas identified during the four regional good practice workshops; the R&D and sector requirements as identified by some major EU aquaculture organisations; and views raised by the Federation of European Aquaculture Producers (FEAP) and the NGO community.

6.1 Strategic guidelines for the sustainable development of EU aquaculture

To address the growing gap between seafood consumption in the EU and production from capture fisheries, the Commission produced strategic guidelines for the sustainable development of EU aquaculture (COM 2013a). It is hoped that development of the EU aquaculture industry will increase employment and contribute towards the EU's blue growth strategy (COM 2012b). The strategic guidelines focus on high-level needs to grow the sector sustainably, with four priority areas being:

- The simplification and improvement of *administrative procedures.* This priority aimed at reducing red tape and the time taken to obtain aquaculture licences, whilst ensuring environmental legislation requirements are still met.
- Targets for *co-ordinated spatial planning systems* to alleviate the difficulties of obtaining space for new aquaculture developments. An ecosystem approach is to be used, with special care being taken when dealing with vulnerable and protected areas.
- Improving *competitiveness of* EU aquaculture through plans to: improve the structure of aquaculture producer organisations; reform the Common Market Organisation; implement a new European Maritime and Fisheries Fund. The EU Market Observatory will help producers identify business opportunities (including diversification) and adapt their marketing strategies. Improving links between R&D and industry, as well as supporting educational and vocational programmes for the aquaculture sector will also aid in developing competitiveness.
- A *level playing field* is desired. Within Europe, some of the highest standards in environmental, animal health and consumer protection are maintained, which can increase production costs but potentially gives the EU industry a competitive marketing advantage which should be exploited.

Social responsibility is driving consumer demand for sustainable or certified fish products, and the demand for organic produce continues to grow in Europe.

6.2 Needs and issues identified during regional workshops

The needs and issues identified by stakeholders during the four regional workshops are listed below. More detailed explanations with suggested approaches, solutions and recommendations for further work are provided where appropriate in the good practice and recommendations sections later in the report and these are indicated by the section references in brackets.

Areas requiring clarification:

- How to apply the Precautionary Principle to aquaculture in a way that effectively manages environmental risk, whilst facilitating sustainable development of the sector (7.2.8 & 10.1);
- How to implement the Polluter Pays Principle to aquaculture in accordance with a cost recovery approach for regulators (7.2.9 & 10.1);
- The adoption of zero nutrient impact requirements for (some) new aquaculture sites where these occur, within the context of industry development and other sectors' emissions (8.1.2, 8.1.3 & b10.1);
- The issue of when an introduced species becomes naturalised in a particular location (e.g. Pacific oyster *Crassostrea gigas*), and what this means for regulation and further development of the sector (8.4.2).
- The application of WFD Article 4.7 to aquaculture, where "*failure to prevent deterioration from high status to good status of a body of surface water is the result of new sustainable human development activities*". How does aquaculture fit into this statement? (10.1)
- The adoption of zero nutrient impact requirements for new aquaculture sites, particularly in the Baltic, and site specific assessment of the impact, and how those emissions may be combined with evaluation of the significance of the nutrient emission compared to other sectors.

Areas where a standardised approach across MS is required:

- Ecological continuity, the removal of barriers in river catchments and the management of abstracted sections of rivers, allowing for free passage of wild fish (3.2.4 & 7.2.5)
- Access to freshwater for aquaculture, especially in comparison with other industries such as agriculture (7.2.5 * 10.1);

- Discharge parameters and emission permitting, determination of environmental /ecological flows within a river catchment, and what this means for permitting aquaculture production systems (7.2.5);
- Water use and charging for an industry that produces emissions in the effluent but is effectively a non-consumptive user of water (7.2.7);
- The application of WFD Article 9 to aquaculture: "*Recovery of costs for water services: 1. Member States shall take account of the principle of recovery of the costs of water services, including environmental and resource costs, having regard to the economic analysis conducted according to Annex III, and in accordance in particular with the polluter pays principle.*" (7.2.9);
- Consistency in approaches taken by regulators to monitoring emissions by the industry (7.2.6 & 10.1).

Areas requiring further R&D and standardisation across MS:

- Spatial planning and the availability of suitable locations for the growth of sustainable mariculture (7.2.4 & 10.1);
- The development, refinement, application and general acceptance of carrying capacity models for sustainable aquaculture development (7.2.4);
- Provision of Allocated Zones for Aquaculture (AZA), and the need for a coordinated approach to AZA management with clear responsibilities for regulators and stakeholders (7.2.4 & 10.1).

Areas where a level playing field is required:

- The aquaculture industry should have the same equal rights to space and water as other users (7.2.5);
- National Administrators and regulators should have common guidelines for environmental licensing (7.2.3 & 10.1);
- There must be a standard interpretation of EU legislation across the whole of the EU;
- Aquaculture should be awarded the same priority as agriculture since both are food production industries (7.2.5).

Issues that need resolution:

- The decision-making process in licences and permitting (under WFD) – who makes the decisions, how are they made, and over what timescale? (7.1, 7.2.1 & 10.1)

- The apparent inconsistency of interpretation of WFD monitoring results to the detriment of the industry;
- A lack of consistency of regulators between and within MS on aquaculture regulation (7.2.3 & 10.2);
- Recognition of the positive ecosystem services of some sectors and how management of such systems may benefit society (e.g. nutrient retention and reservoir functions of carp ponds; Italian valliculture systems, nutrient extraction by seaweed and bivalve mollusc production). (8.5.1)

6.3 R&D and sector requirements identified by European aquaculture associations and platforms.

Across Europe there are many aquaculture associations and research groups. This section focuses on the larger European umbrella organisations and their views of requirements for sustainable development. The key sector needs and R&D findings from are summarised in Table 6.1.

The European Aquaculture Technology and Innovation Programme (EATiP) was formed in 2007 when stakeholders in the European aquaculture industry met to identify gaps and needs in knowledge, technology, skills and policy. EATip consulted industry experts and stakeholders on where aquaculture can contribute to European development priorities and where knowledge gaps need to be overcome to allow successful innovation and development. They subsequently published a vision for research and innovation in European Aquaculture (EATIP 2012).

The **European Fisheries and Aquaculture Research Organisations (EFARO**) is an association of research institutes active in the field of scientific support to fisheries and aquaculture policy and proposes priorities in research that will strengthen the European aquaculture sector. EFARO recently reported on the key topics for scientific support for the European aquaculture strategy (EFARO 2013).   Many of the findings were broadly similar to the EATip vision but were also given a priority rating by the number of asterisks.

The **European Aquaculture Society (EAS)** also contributed its thoughts to the Commission on the future of aquaculture within the CFP reform, identifying industry needs relevant to these guidelines.

Table 6.1: Key sector needs and R&D findings from EATip, EFARO and EAS.

EATip (Eight prioritised themes)	EFARO (Number of asterisks = priority)	EAS (Relevant Industry needs)
Product Quality, Consumer Safety and Health	Food safety ***	
Technology and Systems	Production systems ** Escapees & biodiversity***	Continued on-farm investment in feeding equipment for automation, optimisation of feed distribution systems to minimise the amount of uneaten feed and collection and utilization of faeces. Minimising losses of fish through escapes.
Managing the Biological Life Cycle	Genomics, breeding & hatching *** New species **	
Sustainable Feed Production	Feed & nutrition ***	
Integration with the Environment	Spatial planning and carrying capacity **** Environmental management & governance ****	Pond farmers should be partners in wetland and water management. Support for ecological services. The development of integrated aquaculture models for European aquaculture.
Knowledge Management		A better understanding, acknowledgement and communication of the specificities of pond aquaculture.
Aquatic Animal Health and Welfare	Animal Diseases *** Animal Welfare **	
Socio-economics, Management & Governance	Food security, market & supply chains *** Sustainability & Consumer Standards **	Appropriate regulation, especially with regard to water charges. Availability of best available sites and not last available sites and recognition that food production is an important activity in coastal waters.

In addition, the **Animal Task Force white paper** (ATF 2013) identified resource efficiency, responsible livestock farming systems, healthy livestock and people, and knowledge exchange towards innovation as priority areas for research.

Within the Baltic region one project has published a series of recommendations to aid sustainable aquaculture development (Aquabest 2014). These have been grouped under the following areas:

- Regulatory improvements
- Spatial planning of aquaculture
- Closing the nutrient loop in aquaculture

- Implementation of new recirculation aquaculture system (RAS) technologies.

Some of the issues identified above by EU umbrella bodies are being taken forward under the Horizon 2020 work programme for 2014 and 2015. Addressing these industry needs will not only enable sustainable industry growth but also ease NGO concerns raised in the workshops (See annexes 1-9 in Part 2 of this Report), in chapters 7 and 8 below and elsewhere (Coalition Clean Baltic 2014) and help achieve the aims of environmental legislation such as the WFD, MSFD and the forthcoming Regulation on invasive alien species.

6.5 The view from FEAP, representing the interests of European trade associations across EU-28 and EEA states.

The **Federation of European Aquaculture Producers (FEAP)** presented their views on what is required to boost production in European aquaculture (FEAP 2012) which are broadly in agreement with the Commission's Strategic Guidelines and support the vision and R&D agenda laid out by EATiP. FEAP are concerned about the tightening of regulations around abstraction and minimum flows without any impact assessments being carried out. This has led to them issuing a resolution on access to water for freshwater fish farming (FEAP 2014). The project team also received updated information on aquaculture production, as well as a paper summarising the diversity of approaches to water charging for aquaculture systems across EU-28, during this project. FEAP were invited to present their views at the regional workshops.

6.6 The view from the NGO community.

The organisation "Seas at Risk" coordinated and published a paper in September 2014 'Priorities for environmentally responsible aquaculture in the EU' in which the views of twelve European NGOs are presented and prioritized in relation to the sustainable development of aquaculture (Seas at Risk 2014). This paper highlights the issues of importance from the NGO perspective, many of which are relevant to this project such as reducing the impact of chemicals used in aquaculture, as well as reducing the impact of aquaculture on biodiversity, the promotion of an IMTA approach, the use of aquaponics, and others. The NGOs, through Seas at Risk as well as other organizations, were invited to present on their views at the regional workshops. In addition, the project team also received the Coalition Clean Baltic's position paper "Principles and Requirements for Aquaculture in the Baltic Sea

Region" that highlights that organisation's views specifically on Baltic developments (Coalition Clean Baltic 2014).

7 Good practices for national administrators and regulators implementing WFD and MSFD legislation

Member States are obliged to develop and implement systems to transpose EU Directives into national legislation. Differences in national legislative structures mean that whilst there is a common interpretation of the requirements of EU Directives there are considerable differences in the national legislation used by Member States to transpose the Directives. Whilst this means that there is no common approach to implementing WFD and MSFD legislation it is possible to identify examples of good practice for national administrators and regulators in guiding, communicating and implementing the Directives requirements. This section draws on the findings from the four regional workshops but also includes results of the literature searches and expert knowledge, that commenced early in the project and continued throughout the duration. To enable the sustainable development of European aquaculture it is important to identify and implement the needs of the sector in a balance with environmental legislation, but with a clear focus on the sustainable development of the sector.

7.1 Need to provide clear systems and guidelines and an efficient licensing process that delivers decisions within a set time frame

The aquaculture industry has to comply with the requirements of the WFD and MSFD via the national legislation that implements those Directives in each Member State. The Directives do not contain explicit obligations for administrators to provide clear systems and guidelines and an efficient licensing process that delivers decisions within a set time frame. However, the 'Strategic guidelines for the sustainable development of EU aquaculture' (COM 2013a) encourage administrators to address these issues for aquaculture. The guidelines particularly address the simplification of administrative procedures and the time taken to complete licensing procedures. The guidelines state:

> *"Available information suggests that in several Member States authorisation procedures often take around 2-3 years to complete; examples of substantially longer times have also been reported. For comparison, data reported in a European Parliament study suggest that the average licensing time for aquaculture farms in Norway used to be 12 months and has been reduced to 6 months with the introduction of a 'single contact point'."*

The guidelines also point out that as most aquaculture producers are SMEs, they are disproportionately affected by red tape and reducing unnecessary regulatory burden remains on the top of the Commission's political agenda. The Commission has proposed an Action Plan to support entrepreneurship in Europe that invites Member States to reduce time for licensing and other authorisations necessary to start a SME business activity to one month by the end of 2015 provided that requirements of EU environmental legislation are met (COM 2007).

In addition, the guidelines point out that having spatial plans in place (that identify areas for aquaculture potential) can help by reducing uncertainty, facilitating investment and speeding up the development of sectors such as aquaculture. According to a European Parliament study (Hedley and Huntington 2009), assessing the environmental aspects of aquaculture in the frame of the spatial planning process that would normally be subject to an SEA, can reduce the administrative burden for private developers and limit uncertainty in the licensing procedures, thus making investments more attractive.

7.2 Specific examples of administrative good practice from regulators across Member States

As the WFD has been in force for some time with the development of the 2nd round of RBMPs now underway, there has been sufficient opportunity for good practices to be developed by national administrators and regulators, which can be disseminated. However, this is not the case for the MSFD with very few MSFD-specific examples being available as yet. Nevertheless, almost all of the examples of administrative good practice from regulators across Member States below are applicable to both the WFD and the MSFD. These examples are drawn from the presentations and discussions at the project workshops and are those that appeared to be most relevant and most often raised by participants.

7.2.1 One-stop-shops and streamlining of licensing processes

One-stop-shops, where applicants for aquaculture licences submit a single application to one authority which then passes it onto other relevant authorities for consideration and co-ordinates the response, are helpful in reducing bureaucracy. Such an approach is consistent with the 'Strategic guidelines for the sustainable development of EU aquaculture' (COM 2013a). A good example is the Norwegian licensing system for salmon farming which has reduced the licensing time for aquaculture farms from 12 months to 6 months. In Norway an application is made to the county, who copy the application and send it to the different sector authorities. The local municipality announces the application to public, a time limit applies (6 months) to responses from administrators and the final decision is distributed through the county. However, a one-stop-shop is not in itself a guarantee of an efficient and streamlined process. In Denmark, there is a clear process for marine licensing that aims to grant a license within 9-12 months after application (Anders Vedel presentation at the Copenhagen workshop) that indicates that a one-stop shop is not necessarily essential to an efficient process.

7.2.2 Development of strategies for aquaculture

Strategies for aquaculture that cover all relevant issues and are supported by all the relevant authorities and stakeholders are very useful in assisting sustainable development in general, as well as providing clarity about the application of the WFD and MSFD. Examples include Hungary for the freshwater environment , Scotland (with the Strategic Framework for Scottish Aquaculture), and Greece for spatial planning in the marine environment (see section 7.2.4 below). The development of a national aquaculture strategy in line with the WFD and the RBMPs in Hungary was the subject of a presentation at the Vienna workshop (Bardocz, see presentation No. 51, Annex 15) and is outlined in the box below. The main actions of the strategy are to simplify administration, enhance competitiveness, spatial planning and a level playing field.

Aquaculture Development Strategy for Hungary

The Aquaculture Development Strategy for Hungary includes:

- Improvement in feed conversion enabling more efficient fish production
- Using more efficient types of production systems to improve sustainability and reduce environmental impacts
- Encouraging producers to ‘borrow water’ and return it to the river instead of use and remove it.

Actions to develop aquaculture following guidelines from the Commission of how to develop an aquaculture Strategy including:

1) Simplification of administration (easy to say but main problems from European levels directives therefore try to refine guidelines e.g. easier for farms to get water in winter to encourage water retention. Aqua-environ measures to give clear rules to farmers

2) Simplified licensing process for integrated systems (currently takes only 5-6 months to process but still room for improvement) that should distinguish between intensive, extensive and combined farm technologies

3) Enhance competitiveness: - improve attractiveness of market for carp e.g. new law to introduce fish onto school menu once a week (pilot project)

4) New national law for freshwater fishery and angling – reduce poaching of fish from rivers and lakes- reduce black fish market

5) Research new technologies for Horizon 2020 programmes

6) Spatial planning (EU union suggestion) e.g. undertaken GIS map and database of unused existing geothermal wells and surface waters (incl. fish ponds)

7) Promote aquaculture as a side project for large investment e.g. use geothermal effluents and reuse wasted heat for aquaculture

8) Use results from WFD monitoring to decide where aquaculture can develop

9) Develop a level playing field

10) Promote EU sustainable fish e.g. carp, a Hungarian producers association could be created

11) Encourage labelling and certification to distinguish different aquaculture types.

The impacts of following this strategy include: production of more fish, higher environmental values, an increased market/demand, and diversification of activities. Hungarian aquaculture production could be increased by up to 8000 tonnes if this is carried out.

However, the development of strategies is not a guarantee of success, as external factors can inhibit aquaculture development despite an agreed strategy being in place. In the case of Galicia, as presented at the Dublin workshop, work began in 2008 on a new marine aquaculture plan covering land-based marine fish farming. However, the last new farm opened in 2004, and the last farm enlargement was in 2007. Some workshop participants pointed out that successive governments have tried to increase aquaculture without success as Spanish law restricts construction close to the coast, and they suggested that many rules that were not framed with aquaculture in mind nevertheless inhibit its development.

The EU Market Observatory will help producers identify business opportunities (including diversification) and adapt their marketing strategies. Improving links between R&D and industry, as well as supporting educational and vocational programmes for the aquaculture sector will also aid in developing competitiveness. Research and Development within the sector should be clearly linked to the objectives for national growth of the sector, such as may be communicated within the Multiannual National Plans for Aquaculture (MANPs). This will allow for more efficient targeting and implementation of R&D priorities in a manner that best addresses the sector's needs (REF. The effectiveness of European Fisheries Fund support for aquaculture, 2014)

7.2.3 Cooperation, dialogue and sharing of understanding between relevant authorities, fish farmers and other stakeholders

It is important that relevant authorities, fish farmers and other stakeholders develop a shared understanding of aquaculture issues, particularly with regard to the WFD and MSFD. This requires ongoing dialogue and cooperation, with the production of appropriate guidance documents, handbooks etc.. This also provides a means of sharing best practice information. The Co-ordinated Local Aquaculture Management System (CLAMS) approach in Ireland appears to be a good example as is the 'Scotland's Aquaculture' website (http://aquaculture.scotland.gov.uk/).

The public perception of aquaculture in Ireland is often quite negative, partly because of the influence of the media portrayal of aquaculture as environmentally damaging. The Coordinated Local Aquaculture Management Systems (CLAMS) process (BIM 1999) is a nationwide initiative to manage the development of aquaculture in bays and inshore waters throughout Ireland at a local level, and an explanatory handbook has been developed. In each case, the plan fully integrates aquaculture interests with relevant national policies, as well as:

- Single Bay Management (SBM) practices, which were initially introduced by salmon farmers to co-operatively tackle a range of issues, and have now been extended to all aquaculture species;
- the interests of other groups using the bays and inshore waters;
- Integrated Coastal Zone Management (ICZM) plans;
- County Development plans.

Case Study Example: Single Bay Management (SBM) arrangements for fin-fish farms (BIM 1999)(https://www.marine.ie/home/services/operational/sealice/single_bay_management.htm) are designed to co-ordinate husbandry practices in such a way that on individual farms best practice is followed and that stocking, fallowing and treatment regimes on individual farms are compatible with the arrangements on neighbouring farms. The goal is to ensure that practices on individual farms act synergistically to enhance the beneficial effects to the bay as a whole. A major component in this process is the build up of a communication network between the operators. The non-confrontational environment of SBM meetings between licensed operators has proved a valuable forum in the process of conflict resolution and avoidance, both within the industry and between the industry and it's neighbours. The SBM process has proved very effective, since its introduction in 1997, in enhancing the efficacy of lice control and in reducing the overall incidence of disease in the stocks. Single Bay Management plans are subject to revision for each production cycle. This arises out of changes in production plans related to: new license applications; in response to changing markets; new husbandry requirements; and both internal company restructuring and inter-company agreements.

Crucial elements in the success of this plan are identified as:

- Separation of generations.
- Annual fallowing of sites.
- Strategic application of chemotherapeutants.
- Good fish health management.
- Close co-operation between farms.

Implementation of environmental and water quality monitoring for WFD occurs through liaising with the CLAMS process groups. The process has been widely adopted where aquaculture is practised around the Irish coast, as a further proactive step by fish and shellfish farmers, to encourage public consultation on their current operations and future plans. Aquaculture producers get involved in CLAMS as a strong social driver to support employment and raise understanding.

CLAMS and SBM (salmon farming) involve Bord Iascaigh Mhara (BIM) and state agencies working with industry at a local level to make aquaculture accessible, provide common understanding and improve communication. The aquaculture industry is visible to policy makers, and individual plans are published/produced and lodged with local authority libraries to explain aquaculture to the public and local authorities. CLAMS groups also promote voluntary environmental management systems, e.g. signing up to ECOPACT or other aquaculture specific ecological label and organic certification, that can ensure inter alia better prices for produce.

7.2.4 Spatial planning for aquaculture

As the aquaculture sector grows, the potential for interactions between aquaculture and the WFD and MSFD will increase. Licensing affects the location of new sites, so can have an important impact on the potential growth of aquaculture. A good example of the marine licensing process is Scotland where new sites are licensed based on a mixture of data collection and models to predict potential impacts. Once built, the impact of the sites is checked by monitoring both within and outside the allowable impact zone. In Denmark, there is a clear process for marine licensing that includes an assessment of environmental impact (including modelling of the potential impacts) and the potential to impact on Natura 2000 sites (Anders Vedel presentation at the Copenhagen workshop). The Greek legislation sets out the process for aquaculture licences, but also encouraged the creation of Areas for Regulated Aquaculture Development (ARAD) (Greece 2011) – see below.

In July 2014, Directive 2014/89/EU establishing a framework for maritime spatial planning was adopted by the European Parliament and Council. Maritime Spatial Planning (MSP) provides the mechanism to manage when and where human activities take place at sea. In situations where there may be competition for space (e.g. aquaculture facilities and Natura 2000 sites both favour coastal sites of good water quality) MSP should be used to: reduce conflicts between sectors and create synergies between different activities; encourage investment by instilling predictability, transparency and clearer rules; increase coordination between administrations in each country via the use of a single instrument to balance the development of a range of maritime activities; increase cross-border cooperation and protect the environment through the early identification of impacts arising from the multiple use of space.

The development of spatial planning for aquaculture, together with associated tools (e.g. for assessing carrying capacity), are very valuable approaches that can integrate the requirements of the WFD and MSFD. Examples include the Greek ‘Specific Framework of Spatial Planning and Sustainable Development of Aquaculture’ and the Irish ‘CLAMS approach' (see above).

In Greece, a Joint Ministerial Decision No. 31722/4-11-2011 (O.J.G. No. 2505 II / 04-11-2011) has been issued: ‘’Adoption of Specific Framework for Spatial Planning and Sustainable Development for aquaculture and strategic environmental impact assessment of it''. This introduction of integrated spatial planning for aquaculture at a national level aims to: establish a clear framework of development guidelines for both licensing authorities and companies; orient developments to appropriate sites; reduce possible conflicts arising in the field; and protect the environment. Marine aquaculture activity is developed in broad marine areas with common characteristics which are called Aquaculture Development Areas (PAY). These already defined areas indicate their suitability for aquaculture development. In terms of spatial planning these broader areas constitute receptors for Areas of Organized Development of Aquaculture (POAY) or Areas of Informal Concentration of Units (PASM) and also individual units. In order to establish POAY, a Strategic Environmental Impacts Study was also carried out and adopted within the Framework. Spatial planning is incorporated into the licensing process to control where farms are located, including preventing farms being located near *Posidonia oceanica* seagrass beds.

A number of presentations were given at the workshops on the importance of site selection and the use of models to calculate carrying capacity of different sites. For example, in the case of Greece, these addressed:

• Allocated Zones for Aquaculture (AZAs) being introduced as a tool for sustainable management and development of aquaculture, supported by research, modelling and monitoring using environmental quality standards (EQSs);

• A carrying capacity formula (enacted in 2009) for adjusting production capacity of existing and new farms based on four parameters: occupied marine area, distance from shore, average depth of occupied areas, current speeds.

Computer-based modelling tools are useful for assessing carrying capacity of a system (Cromey et al. 2002; Gillibrand et al. 2002; Laurent et al. 2006; Weise et al. 2009; Giles et al. 2009; Tett et al. 2011; Ferreira et al. 2013). The Ecosystem Approach for Sustainable Aquaculture (ECASA) project toolbox is an internet based resource, containing tested tools for marine aquaculture environmental impact assessments. These tools include a range of indicators, models and procedures, tailored for differing culture methods and species grown across Europe. The ECASA toolbox contains a number of these computer-based modelling tools, see http://www.ecasatoolbox.org.uk/the-toolbox/informative/matrix-files/public-environment-management-assessing-potential.
In addition, the Horizon 2020 funding will provide further research into any cumulative effects of aquaculture(COM 2013c).

In salmon farming in Scotland, modelling is used as a guide to determine licensed discharge quantities of anti-parasitic chemicals as well as organic waste arising from marine fish-farm operations, see http://www.sepa.org.uk/water/water_regulation/regimes/aquaculture/marine_aquaculture/modelling.aspx.

7.2.5 Consistent and proportionate application to all sectors i.e. a level playing field

Aquaculture industry representatives from various countries asserted that WFD was not applied equally to aquaculture and non-aquaculture industries. An example given at the Athens workshop was from Galicia, Spain- participants indicated that aquaculture was not considered a priority, citing the fact that it was ranked as 5th in a priority list of water uses produced for the WFD, contrasting with agriculture which was ranked 2nd. Potential conflicts between aquaculture operations and projects, such as hydro-electric plants and reservoirs, were highlighted. It was stated that fish farms in Galicia were generally well run with minimal environmental consequences and that, compared to agriculture, aquaculture uses smaller volumes of water per unit of output and releases less nitrogen and phosphorus based pollutants. The methodology used to calculate Environmental flow (EF), which is frequently used as justification for water restrictions on aquaculture producers, was called into question by aquaculture producers.

FEAP issued a resolution on the 24th May 2014 requesting that the Industry be given fair and equal access to water to continue and develop sustainable aquaculture and that the European Commission provide guidance on the correct interpretation of the WFD directive regarding these issues (FEAP 2014).

7.2.6 Risk- and evidence-based approach to determining monitoring requirements

A risk- and evidence-based approach to determining monitoring requirements would take account of the specific circumstances of each farm and represent best practice. It should also be cost effective, efficient and utilise standardised methodologies to the extent appropriate. However, examples were provided in the break-out groups indicating that a one-size-fits-all approach is sometimes applied because it is administratively simple. Monitoring should be limited to parameters that could effectively detect adverse impacts from aquaculture and to parameters that are necessary to support aquaculture, e.g. to ensure the healthy functioning of the relevant aquaculture species. Examples of monitoring requirements currently in place considered as unnecessary by producers include the requirement to measure trace metals in water which, taking into account potential sources of trace metals within aquaculture facilities, would require an unrealistic level of contamination to exceed water quality standards i.e. the worst conceivable level of contamination could not possibly exceed water quality standards specified in the WFD.

7.2.7 Administrative costs

Administrative costs should be proportionate to administrative effort required, be fairly allocated across different sectors, and the 'Polluter Pays' principle should be applied. In discussions, the industry generally felt that no account was taken in the freshwater regimes that aquaculture does not consume significant quantities of water and that they often returned the water to rivers as clean as, or cleaner, than when abstracted. This was often not the case with other water users according to producers. Some producers claimed that they had to re-licence their activities every 5 years whereas in other Member States the period concerned could be up, or greater than, 20 years. More frequent re-licensing will impose additional costs on producers. Data submitted by FEAP showed that charging policy for water abstraction, use and discharge varies considerably across MS. Variations in water charging policies range from no charging at all to charges that make an operation economically non-viable. Inconsistencies within countries, and with regional administrations were highlighted. In addition, the duration taken for the renewal of a licence was considered an issue in some countries.

7.2.8 Appropriate use of the Precautionary Principle

The Precautionary Principle should be applied to aquaculture in a sensible and pragmatic manner consistent with the guidance provided from the EU (COM 2000b; EEA 2001). The application of the Precautionary Principle to aquaculture development and regulation was an issue that was brought up regularly in the regional workshops. Some producers believe that some regulators are applying the Precautionary Principle in a more stringent way to aquaculture development proposals than that which is applied to other activities, and that aquaculture development is restricted or inhibited as a result. From the discussions in the workshops, it seems that the industry believes that this is due, at least in part, to a lack of understanding of aquaculture by some regulators. In discussions and a number of presentations, some stakeholders took the view that there is a need for some regulators to rethink their application of the precautionary principle to aquaculture development to enable further activity to take place, while maintaining the underlying obligation to ensure that the development of the sector is sustainable. Practical examples on what was considered inappropriate use of the precautionary principle were submitted by FEAP to the project team in the course of this exercise. These specific examples have not been included within the text, however, but have been noted and their content considered within the development of the recommendations.

8 Minimising specific environmental impacts through good practices by administrators, regulators and the aquaculture industry

Chapter 7 described good practices in the implementation of the WFD and MSFD legislation. However, it is also important to understand the wider context of how aquaculture facilities are managed locally and to frame this in the context of the WFD and MSFD. The development and operation of aquaculture facilities is managed by various legislative and voluntary local/national systems to minimise environmental impacts (which may relate either directly or indirectly to the WFD and MSFD). Whilst legislation is the primary means of control, voluntary agreements (which sit outside the regulatory structure) may contribute to improvements in environmental performance. This section draws from the good practice examples provided at regional workshops and is supplemented with the findings from the literature review and information gathering process during the project.

8.1 Benthic impacts and nutrients

The pressures and benefits that can arise from aquaculture have been outlined in earlier sections and the relevance to the WFD and MSFD explained. This section gives further detail on current understanding of benthic impacts and nutrient enrichment issues and the progress made in developing models that minimise any pressures from aquaculture. It goes on to identify potential good practices that may be options for regulators and industry.

8.1.1 Current status of benthic impacts and nutrient enrichment by aquaculture

The effects of nutrient enrichment on benthic communities have been extensively documented in field-based studies (e.g. Delgado et al. 1999; Karakassis et al. 2000; Ruiz et al. 2001; La Rosa et al. 2001; Cromey et al. 2002; Cancemi et al. 2003; Holmer et al. 2003; Soto and Norambuena 2004; Hartstein and Stevens 2005; Dubois et al. 2007; Apostolaki et al. 2007; Sanz-Lázaro and Marín 2008; Díaz-Almela et al. 2008; Hargrave et al. 2008; Ysebaert et al. 2008; Roberts et al. 2009; Tomassetti et al. 2009; Mirto et al. 2010; Mckindsey et al. 2011; Mirto et al. 2014). Key findings have been synthesised in a number of in depth reviews and reports (AQUAETREAT 2007; McKindsey et al 2011; COM 2012a; Price and Morris 2013; Hadjimichael et al 2014).

In many regions, numerical models have been applied, to predict nutrient concentrations and impacts on benthic communities based on nutrient loading and/or hydrodynamics, or to help with site selection (Cromey et al. 2002; Gillibrand et al. 2002; Laurent et al. 2006; Weise et al. 2009; Giles et al. 2009; Tett et al. 2011; Ferreira et al. 2013). Based on extensive knowledge and understanding of the impacts of nutrient enrichment on benthic communities, the industry has been able to develop a number of good practices to mitigate against these impacts, such as biomass-limit modelling, fallowing, filtration and others (e.g. Macmillan et al. 2003; ASSG 2005; CRAB 2007; SSPO 2010; Taylor and Kelly 2010; Aquabest 2014; see also Troell et al. 2009). Many of these have been based on, or used to develop, guidance (COM 2006; IUCN 2007; IUCN 2009a; IUCN 2009b; Karakassis and Angel 2008; Karakassis 2009; Karakassis and Sanchez Jerez 2011; Karakassis et al. 2013; Stelzenmüller et al. 2013). However, there is still a need to share knowledge and further develop industry and regulatory good practice.

From the four regional workshops, and literature sourced during the project a number of regulatory and industry good practices were identified.

8.1.2 Regulatory good practice and recommendations

Good regulatory practices for mitigation against the impacts of organic enrichment and nutrient input include the issuing of consents/licences which:

- limit site biomass and production levels to a maximum level (e.g. set cap on feed input, Norway; set maximum biomass limit on site based upon predictive models of assimilative capacity of the receiving environment, Scotland);
- limit discharge (e.g. Sweden) or control discharges (e.g. England, Hungary, Austria, Denmark);
- restrict the use of fertilisers such as manure where these are in excess of what the ponds require and end up being discharged (e.g. Romania, Czech Republic).
- control stocking levels (e.g. Greece, Poland), where the loading of nutrients in aquaculture effluent is dependent on stock biomass (and feeding rate), and the level of emissions is related to the total farmed population on the site;

<u>Recommendations include</u>

1. Improved clarity on which parameters or data the industry should provide to show baseline loads;

2. Improved monitoring to quantify nutrient loads from different sources, including aquaculture;
3. The use of mitigation tools or practices (e.g. for effluent water quality) in the assessment of consents/licences.
4. A flexible regulatory framework (for re-location) of sites.
5. Use of modelling approaches to the location of new farms (see also section 7.2.5 above)

8.1.3 Industry good practice and recommendations

Good industry practices for mitigation against the impacts of organic enrichment and nutrient input include

- Use of efficient feeding systems to ensure that uneaten (waste) feed is minimised, e.g. by using camera systems or other mechanisms to monitor the feeding response. Camera systems are often used in conjunction with automatic feeders in the salmon farming industry. A presentation at the Vienna workshop showed the use of a solar-powered feed spreader in pond aquaculture that ensured a regular distribution of sufficient feed that led to improvements in the water quality in the ponds and the effluents.
- Use of good quality feed types that are highly digestible by the cultured organism and minimise the release of nutrients in the faeces and water. Where appropriate the use of binders that keep solids together for effective collection and settlement.
- Site management , such as fallowing (timing, impacts, area), treatments, exclusion zones (e.g. Greece and Ireland with its CLAMS approach set out in section 7.2.3), where a break in the production cycle allows for recovery of the seabed;
- Monitoring (e.g. Greece) to ensure that measured limits for nutrients and any EQS are within those determined by the licence conditions;
- Reduction in release of nutrients into the receiving environment through: the use of closed containment or partial recirculation where dissolved nutrients and solid waste is removed from the effluent; Land based/sediment traps, settlement ponds, and modern clean up technology such as drum filters, (e.g. France, Norway); the use of constructed wetlands (where space allows) to clean and process dissolved nutrients and example was provided in the Baltic workshop.
- Controlling use of fertilisers to minimise the introduction of nutrients directly into the river catchment (e.g. Romania, Czech Republic). An example was raised in the Vienna workshop.
- The use of integrated multi-trophic aquaculture (IMTA) systems. The concept of IMTA is that farms combine fed aquaculture (e.g. finfish, shrimp) with species that extract the nutrient (e.g.

seaweed) and suspended solids (e.g. shellfish) to create balanced systems for environment remediation (bio-mitigation). This type of compensatory aquaculture is of much interest to environmental groups and NGO's (Seas at Risk 2014) but functionality and viability is still questioned (Coalition Clean Baltic 2014). Compensatory systems are being taken forward and tested in many areas such as the Baltic Sea.

- The use of closed system cages in impacted areas, once they are fully tested.

Recommendations include

1. Collaboration at inter-departmental and inter-agency level, to achieve a common understanding about the existing situation and measures already in place, and to establish programmes that will allow for well-informed and responsible aquaculture operations;
2. Holistic management systems that incorporate a broader ecosystem-level approach to the management of aquaculture systems;
3. Utilising partial or full recirculating aquaculture systems (RAS, e.g. Baltic) in part or all of the production cycle;
4. Further consideration of the potential for management of systems by adopting a mass balance approach for nitrogen and phosphorous in any previously impacted locations, e.g. Baltic and Black Sea;
5. Further discussion of nutrient trading schemes (including co-location).

A combination of monitoring and the use of best available technology combined with best practices and codes of conduct will contribute towards reducing environmental impacts from nutrient enrichment and help to achieve good ecological and environmental status as set out in the WFD and MSFD.

Specific good practice example from workshops

A potential example of good practice currently being tested is that at Endelave in Denmark which produces around 2,100 tonnes p.a. of marine rainbow trout and emits 88 tonnes p.a. of nitrogen and 9.6 tonnes p.a. of phosphorous. Mussels and seaweed are grown in the same water body to offset the production of nitrogen and 70% of the phosphorous. No antifouling agents and organic cultivation of fish further reduce inputs. A monitoring programme is in place to account for the offset, and if the offset is insufficient then fish production must be reduced until the farm is nutrient neutral. There are some issues with this type of system in that a larger area is required to accommodate the mussel and seaweed farms and it is not an option in brackish waters where the seaweed and mussels do not grow well. A further proposed adaptation is to close the loop on nutrients, so that only fishmeal from the Baltic is used in feed, so nutrients are not introduced from outside the Baltic (see Aquabest 2014).

8.2 Chemicals good practice

8.2.1 Regulatory Example: Water Environment (Controlled Activities) (Scotland) Regulations 2011 (CAR).

These regulations provide the Scottish Environmental Protection Agency (SEPA) with powers to ensure that activities which may pose a risk to the water environment are controlled. These national regulations differ from many of those implemented by other national and regional administrations in that they explicitly cater for the unique requirements of aquaculture. SEPA set limits on the biomass of fish that can be held in the cages (and thus indirectly the amount of food) and the amounts of certain medicines that can be administered and discharged. In setting these limits, SEPA aims to ensure that fish farms operate within the capacity of the environment. One potential tension between meeting WFD requirements (to maintain or improve the ecological and chemical status of the aquatic environment) and allowing the development of aquaculture relates to the potential scale of effects. SEPA separate their assessments into 'near field effects' (i.e. in areas immediately adjacent to an operating or potential aquaculture site) and 'far field effects'. Essentially, some 'near field' impacts are tolerated if these are not widespread and do not affect the wider aquatic environment. The main aim is to maintain a functioning community of seabed animals to process waste and limit the area impacted by medicine residues. The assessment uses local tidal and bathymetric data in computer models to predict impacts, with the aim of setting relevant, site-specific conditions that ensure environmental protection. The approach embeds the principle of a mixing zone – Allowable Zone of Effects (AZE) or the footprint around the farm. Within the AZE, some exceeding of environmental standards is accepted, but at the AZE boundary, standards must be met to prevent adverse 'far field effects' to the surrounding water body.

The Scottish Government through SEPA and other agencies have also produced clear guidance documents for aquaculture producers that detail how an operator can apply for a licence under the Water Environment (Controlled Activities) (Scotland) Regulations 2011. They have also produced a website (http://aquaculture.scotland.gov.uk/default.aspx) where data on Scottish fish farms can be searched by anybody with an interest. This includes information on where the farms are located, maximum permitted biomass, treatments permitted and used, and results of environmental monitoring in and around the sites.

8.2.2 Aquaculture industry good practice examples

There are some aquaculture practices where use of chemicals is negligible. Examples include extensive freshwater pond culture systems in Poland and other central European MS, and traditional lagoon rearing systems in the Mediterranean, i.e. valliculture. The extensive cultivation methods employed in these systems do not lend themselves to the use of medicines because the stock densities are very low and the fish populations are often held in very large bodies of water.

8.3 Disease

8.3.1 Disease impacts

Disease is an issue with respect to WFD and MSFD for two reasons: 1) because of the potential impacts of pathogens on wild stocks (affecting biodiversity and thus ecological status); 2) chemicals and medicines which may be used for disease control are emitted into the local environment during and after treatments.

8.3.2 Regulatory good practice and recommendations

Control of diseases within EU aquaculture is regulated under the Aquatic Animal Health Directive 2006/88/EC. The following examples of recommended good regulatory and industry practice are drawn from published OSPAR (OSPAR 2006)(PARCOM 1994), HELCOM (HELCOM 2004), and

GESAMP (GESAMP 1997) recommendations, as well as from information provided in the four regional workshops:

1. Consider locating proposed open net-pen farms away from the entrances to rivers or narrow channels (to minimise interactions with migratory wild fish species);
2. Consider implementing zonal or area management plans that will reduce potential negative interactions between wild and farmed fish species, perhaps as part of river basin management plans. An additional advantage of such schemes is they are likely to reduce the overall disease burden on sites, thereby increasing productivity of businesses. Such area management plans can include:
    a. Specifying the maximum biomass of fish or shellfish that can be cultured in a particular area;
    b. Where practicable, implementing all-in-all-out production by synchronising year class production of any species within the managed area. Harvesting all the fish within a managed area within a defined period of time makes it easier to implement fallowing periods between rearing cycles (see below point d);
    c. Coordinating treatment schedules for farms within a managed area to ensure treatments are used in as effective way as possible;
    d. Coordinating fallowing periods between producers to ensure effective disease breaks between production cycles within a managed area.
3. Licensing of aquaculture producers should only proceed after it is demonstrated that the chemical impacts of the proposed activity will not adversely affect the ecological status (benthic fauna, phytoplankton) of the area. For open cage farms in the marine environment, particular consideration should be given to the use of modelling approaches (e.g. AutoDEPOMOD – a consenting model for biomass and therapeutants widely used for marine licensing applications) to assess likely chemical treatments spread, dilution rates, turnover time and their resultant impact.
4. During the licensing application process, the scale of any impacts should be an important aspect to be considered. In particular, ‘near’ and ‘far’ effects may need to be differentiated. Recognising here that any anthropogenic activity will have effects and part of the role of regulators is to balance the possible environmental effects of an activity (in this case aquaculture) against its possible benefits (economic, societal etc.).
5. The application of the principle of allowable zones of mixing should be considered whereby the concentrations of priority substances and the 8 other pollutants in the EQS Directive, and by

analogy of river basin specific pollutants, are permitted to exceed the EQS close to the discharge from an aquaculture activity but not to exceed these levels beyond a designated boundary.

6. It is important that regulators consider the cumulative impacts of aquaculture operations within a managed water body.
7. Transparency is important to ensure data on what chemical treatments farms are allowed and their potential environmental effects are made available to all stakeholders. In this regard, consideration should be given to publishing data on publicly accessible and readily searchable websites.
8. Ensure relevant environment agencies are linked up with national and European medicine regulators in evaluating medicinal products for veterinary use, as they work under different regulatory frameworks.

8.3.3 Industry good practice and recommendations

1. The application of the principles of integrated pest management, as implemented in agronomy, for the control of fish and shellfish pathogens is recommended, where the optimum strategy that includes medicine use, site management activities such as fallowing may be determined and implemented. Medicines should be used as advised on labels and under marketing authorisations (MAs), and in a manner that promotes optimal treatment efficiency. Optimal treatment efficiency often includes a reduced requirement for numbers of treatments, and hence total quantity of medicine released.
2. Consideration should be given to use of treatment strategies that result in minimal or no additional chemical impacts, particularly in areas where water bodies and associated benthic fauna are assessed to be of moderate or lower status.
    - Chemotherapeutants should not be the first option when combating disease but used only as a last resort after environmental conditions, nutrition and hygiene have been optimised.
    - Vaccination-based control methods should be used where possible (that have minimal environmental impact).
    - When multiple chemical alternatives are available, drug selection should be based not only on efficacy data but also on available information regarding environmental persistence, potential effects on non-target organisms, propensity to stimulate microbial resistance and rate of residue elimination.

- Develop and implement effective biosecurity processes (plans) to minimise the spread of disease agents within and between farms and into the wider environment. Rear animals using systems and methods that are near physiological and behavioural optima in order to minimise stress. (Stress is assumed to be an important factor predisposing cultured animals to disease).
- Careful consideration should be given to controlling factors such as stocking density, rearing temperature, dissolved oxygen level, turbidity, dissolved ammonia and nitrite etc.
- Where economically viable, consider using closed rearing systems (e.g. RAS) to minimise the release of chemical treatments into the environment (where the local environment is particularly sensitive) and to minimise pathogen exchange with wild fish and shellfish.
- Investigate and, where feasible and safe, implement biological control methods as an alternative to chemical treatments (e.g. use of cleaner fish for sea lice control)
- For net-pen aquaculture in the marine environment, as an alternative to use of potentially toxic antifoulants, washing and drying of nets at regular intervals should be considered. See (CRAB 2007) for further information on environmentally sustainable best practices to minimise fouling.
- The use of water jet operated underwater net cleaning devices is also an alternative to using antifoulants on netting.

3. Aquaculture producers have a duty of care to ensure that the seed they import onto their premises are free of diseases that may be transmitted to wild fish and shellfish species.
4. Selective breeding to increase disease resistance to lice (Shepherd and Little 2014).
5. Implementation of effective biosecurity processes and use of effective and environmentally safe treatment methods should form part of the Codes of Good Practice (CoP) adopted by producers. To ensure adherence to CoP, industry should consider implementing quality control processes, including audits.
6. Where animals are reared in the open water, consideration should be given to using contained treatment processes where practicable (e.g. well boat treatments). Care should then be taken to ensure the treated water is disposed or inactivated safely prior to discharge.
7. Aquaculture producers should not discharge to natural bodies any effluent containing chemical residues at concentrations likely to cause biological effects and should first reduce concentrations, preferably by residue removal or increased residence time, and/or by dilution with other effluent waste streams within the farm.

8. With concern over increasing resistance to some veterinary medicines used in sea lice treatments (CNL(11)11 2011) (EEA, Dublin workshop), industry should continue research and development into other emerging non-chemical methods of lice control such as treatment by heat, freshwater, laser or by cage depth and design. Recent R&D into the use of cages with built in snorkels has showed promising results for the significant reduction of lice numbers which are prevalent in the surface layers(Anon 2014).

8.3.4 Specific example from regional workshops: sea lice

Probably the most high profile example of pathogen exchange between wild and farmed fish populations is the transfer of sea lice (parasitic copepods of the family Caligidae, principally *Lepeophtheirus salmonis*) between wild and farmed Atlantic salmon (Boxaspen 2006). In Northern Europe in particular they are responsible for many outbreaks of disease in marine aquaculture, especially in intensive salmonid aquaculture. Sea lice can affect the growth, fecundity, and survival of their hosts because their feeding may cause skin lesions leading to osmotic problems and secondary infections. If untreated, they can reach a level that is highly detrimental to the host fish. Both wild and farmed salmonids can act as hosts to sea lice, and the possible interaction and transmission of the parasite between farmed and wild fish is causing much concern. The abundance of hosts available in farms can result in large sea lice production. Wild anadromous fish in areas with salmon farms may experience severe sea lice infestations, in some cases resulting in their premature return to freshwater or mortality at sea (Boxaspen 2006). However, it should be remembered that sea lice on freshly sea run fish and sea lice mortalities were known before the development of modern salmon farming (Shepherd and Little 2014) and that areas exist where sea lice are not a problem (e.g. the Baltic Sea due to low salinity). To control sea lice, aquaculture operations typically use a range of antiparasitic medicines, and these may pose some environmental risks if not applied carefully (Langford et al 2014).

There is debate about the significance of the impact on wild fish populations of sea lice from farmed fish (Bjørn et al. 2011; Jackson et al. 2013; Krkosek et al. 2013; 2014). However, to counter the potential threat posed by sea lice to wild fish species, regulators and producers in the main Atlantic salmon farming regions of Northern Europe have developed methods to control their proliferation and minimise chances of transfer. These include development of area management plans that regulate how the industry operates in particular zones, and development of improved treatment programmes. The international goal for sea lice as stated by NASCO is for 100% of farms to have effective sea lice management such that there is no increase in sea lice loads or lice-induced mortality of wild salmonids attributable to the farms (CNL(11)11 2011). Different MS and EEA countries currently vary in how they control sea lice within managed areas. For instance, in Ireland management of lice within management areas is coordinated by the Marine Institute through their Single Bay Management system (Marine Institute Ireland 2014).

Specific example from workshop: Case Study: Sea Lice

There is a statutory system in place for counting levels of sea lice undertaken by Irish Government Inspectors, with mandatory treatment programmes initiated across the Managed Area if levels exceed threshold values. Crucial elements in the success of this plan are identified as:

- Separation of generations and area management – only single year classes of salmon are stocked into the managed area, and are all harvested at the end of the production cycle over a limited period of time (so called 'all-in-all-out' production);
- Annual fallowing of sites - after a year class has been harvested within a managed area, a minimum period of time is required before the area can be stocked again. Fallowing helps break the life cycles of sea lice and other pathogens, limiting their potential for amplification over repeated production cycles;
- Strategic application of chemotherapeutants – Sea lice treatments are co-ordinated (i.e. the medicines used, timing of applications) across the whole managed area, to maximise the overall effectiveness of treatments and minimise the risk of resistant strains of lice emerging;
- Good fish health management -farms rear fish to minimise risks to health by using appropriate practices (e.g. husbandry, health surveillance);
- Close co-operation between farms: co-operation is encouraged between farms (where they are not owned by the same operator) to ensure they enter into binding agreements on important farming practices, including stocking and harvesting.

8.4 Containment (escapees/ wild fish interactions/ alien species)

The obligations of both the aquaculture industry and regulators have previously been discussed in relation to alien species legislation and the WFD and MSFD. However, the aquaculture industry, NGOs and regulators are all interested in minimising escape of any stock or species (whether alien or indigenous) and in reducing potential interactions with wild fish stocks. This section outlines the current status regarding containment in the European aquaculture industry, and obligations and good practices for regulators and industry.

8.4.1 Aquaculture industry containment: current status and common interests

The potential effects on the environment of escapees from aquaculture are well documented, studied and modelled (Hindar et al. 2006; Ford and Myers 2008) but conclusions are often disputed. Escapees of non-indigenous species may alter the structure and functions of marine ecosystems by habitat modification and competition for food and space with indigenous organisms; non-indigenous species may outcompete indigenous species, and reduce their abundance, biomass and spatial distribution (ICES 2009; IUCN 2009b; UNEP/MAP/RAC/SPA 2011). Farmed indigenous species are often selectively bred for many generations and may therefore differ genetically to wild populations; this raises concerns for the fitness and productivity of wild populations if interbreeding with escapees occurs (Hindar et al 2006).

However, escapees are equally undesirable for the aquaculture industry as they represent a financial loss. The combination of environmental concerns and costs to industry led to the EU PREVENT ESCAPE project. This project estimated escapees lost European aquaculture as much as €47.5 million p.a. at point of first sale, and produced a set of recommendations and guidelines (see: http://preventescape.eu/) to reduce both environmental impacts and financial losses (Fredheim et al 2013).

Perhaps the most significant area for reducing escape numbers is marine net-pen culture; improvements are already been implemented with the adoption of technical standards and specifications for pen design, mooring systems and nets. In Norway (an EEA country and by far the biggest aquaculture producer in Europe) there is a vision for zero escapes: the introduction of legislative standards for aquaculture cages led to a significant reduction in escapees (Fig. 8.1).

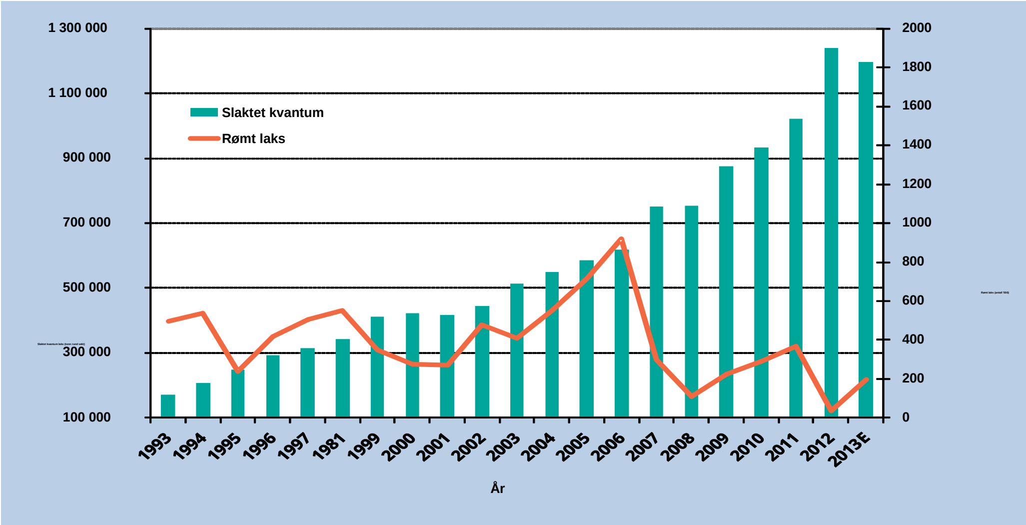

Fig 8.1 : Effect of introduction of technical requirements for farms (NYTEK) reducing annual escapee numbers from Norwegian salmon farms (red line), despite increased production (green bars). (Provided with permission from Norwegian Directorate of Fisheries/Norwegian Seafood Federation.)

Similar standards are almost finalised in Scotland following the development of best practice protocols (Taylor and Kelly 2010), and an ISO standard is due across Europe. Codes should also include regular inspection of facilities to check for early signs of chaffing or wear (SSPO 2010). One technique being developed in Norway (by the North Atlantic salmon working group) to assess the level of biological impact from escapees and genetic impacts has been the development of a quality norm for Norwegian salmon populations which assesses not only the conservation limits and harvest limits but also the genetic integrity of the salmon stocks(North Atlantic Salmon Working Group 2014). This may provide a good practice model for other MS.

Another area within marine cage farming with potential for escape is during farm management practices such as grading or stock transfer. Codes of good practice can address these by ensuring that employees have adequate training and are aware of correct procedures.

The development of contingency plans in the case of an escape event has been suggested (IUCN 2007) and can help deliver a rapid response to recapture and monitoring of the escapees.

For some species there are options of using sterile or single sex stocks which, should they escape, eliminate or reduce risks of interbreeding and genetic interactions with wild stocks. For example, producers of both rainbow trout and brown trout often use triploid or all female stocks. Whilst these techniques might not be currently applicable to all aquaculture species, new technology e.g. the use of egg dips (Zohar, Y. Gothilf and Wray 2007)) is in development might provide an alternative.

Results from the four regional good practice workshops suggest that, to build trust and confidence in the industry, data and information from regulators on aquaculture performance should be transparent and readily available to stakeholders. One example from Scotland demonstrating a spirit of openness and joined up governance was presented at the Dublin workshop (SEPA 2014):

Specific Example from workshops: Case Study: Containment

Scotland Aquaculture website provides information on numbers of escapees to interested stakeholders (Fig 8.2).

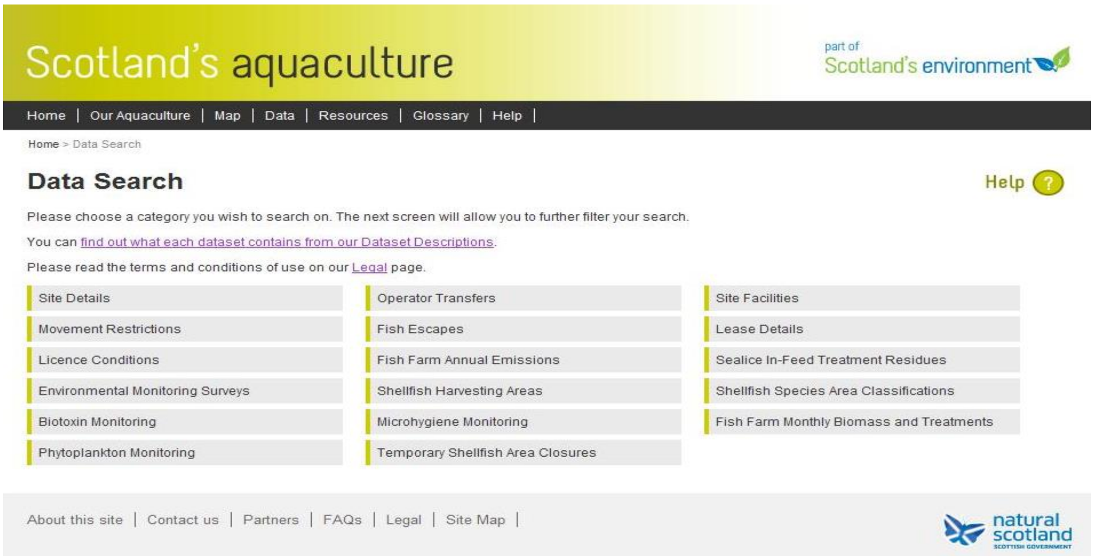

Fig. 8.2: Scotland's aquaculture website, with link to page on fish escape events.

The location of farms close to runs of wild fish often causes conflict between stakeholder groups due to fears of increased sea-lice numbers and the potential for impact on populations of wild migratory salmonids in the same location. In order to minimise contact and interaction with concentrations of wild fish, it may be possible to consolidate several smaller sites into a single larger one (with increased production) that is located further offshore, away from narrow river entrances (Adrian 2014).

Aquaculture techniques are a vital tool in the preservation of threatened stocks such as the various species of sturgeon found in the River Danube. The Danube Sturgeon Task Force (DSTF) recommends that species that are being reared for restocking and mitigation should genetically resemble wild populations as closely as possible, and these should be kept separate from stocks genetically selected for food production purposes (Reinartz 2014). They further recommend, with governmental support, the establishment of non-commercial live gene banks, i.e. ecological "hatcheries" (near-natural enclosures, located in the proximity of restocking sites, to allow wild brood-stock to adapt to captive conditions and captive-bred offspring to adapt to natural conditions before reintroduction into the river). Similar recommendations about gene banks are made in the Guide for the Sustainable Development of Mediterranean Aquaculture (IUCN 2007).

8.4.2 Alien species

Aquaculture industry reviews and codes of practice recommend that, where possible, the species farmed should be indigenous(IUCN 2007) (Hewitt et al 2006). However, the European aquaculture industry, in common with European terrestrial food producers, farms a range of species that are non-indigenous (e.g. rainbow trout, Pacific oyster). The industry wants to continue to farm such species sustainably without impacting on the environment. The recent European Commission document on blue growth (COM 2012b) recommended that the farming of new species should feature in the Horizon 2020 programme for research and innovation to unlock the growth potential of European aquaculture. Regulations EC 708/2007 and 304/2011 provide the legislative frameworks for non-indigenous new species. These regulations also includes, in its Annex IV, a list of species which are exempted from control unless the relevant Member State consider that they may pose an environmental risk. One area discussed as an issue at the Dublin workshop was at what point a species introduced historically becomes considered naturalised and therefore should be derogated from controls. The decision to include a species in Annex IV is taken by the European Commission through a delegated act, on the basis of principles defined in the relevant legislation: Regulation 708/2007 specifies that "an aquatic organism must have been used in aquaculture in certain parts of the Union for a long time (with reference to its life cycle) with no adverse effect, and its introduction and translocation must be possible without the coincident movement of potentially harmful non-target species". This is further specified in Commission Regulation 535/2008, clarifying that "long time" shall mean a minimum period of 10 years following the completion of two production cycles, while "adverse effect" shall mean case where scientific evidence shows that an aquatic species

causes, inter alia, significant: (i) habitat degradation; (ii) competition with native species for spawning habitat; (iii) hybridisation with native species threatening species integrity; (iv) predation on native species' population resulting in their decline; (v) depletion of native food resources; (vi) spread of disease and novel pathogens in wild aquatic organisms and ecosystems.
In order to ensure a coherent legal framework, the new alien species Regulation (EU 2014a)also stipulates that those species should be excluded from new rules when used for aquaculture purposes.

The project IMPASSE reviewed issues associated with the use of alien species in aquaculture and produced the European Non-native Species in Aquaculture Risk Assessment Scheme (ENSARS) which applies to all forms of aquatic organisms (Gollasch et al 2008). In addition to addressing the intentional introduction of alien species by aquaculture, the risks associated with accidental spreading of alien species by aquaculture need consideration.

Invasive alien species are a direct concern to the aquaculture industry, in addition to being of regulatory concern (under the WFD, the MSFD and Alien Species Regulation). For instance many shellfish producers fear that their production areas will be affected by pest species that have been spread or translocated through various pathways (e.g. carpet sea squirt *Didemnum vexillum,* the slipper limpet *Crepidula fornicata*, Chinese mitten crab *Eriocheir sinensis)* which can potentially reduce productivity or lead to restrictions in stock movement (Wilson and Smith 2008).

The aquaculture industry often needs seed stocks of juveniles to begin cultivation and this can require movement of stock from a hatchery, or of wild seed sourced in one area to another. When these moves involve alien species there are measures in place that reduce the risks of accidental transfer of alien passengers, e.g. containment in secure systems. However, where movements of indigenous seed sources are involved (often within a MS) then there is often no legal requirement to check for alien species as passengers. This is where the adoption of industry codes of practice and best practices becomes important in reducing risks.

8.4.3 Regulatory obligations and good practice recommendations

1. Implement Regulations (EC) No708/2007 and (EC) No 304/2011 for alien species in aquaculture.
2. Carry out inspections of premises to ensure that they meet conditions of the licence / permit with regard to containment of stock.

3. Ensure licence conditions for open net-pen aquaculture units stipulate that systems comply with technical standards.
4. Consider locating proposed open cage sites away from areas with any potential wild fish interactions, e.g. entrances to rivers or narrow channels.
5. Within the spirit of openness and accountability, publish transparent, easy to access data on escapees. (see figure 8.2 above)

8.4.4 Industry obligations and good practice recommendations

6. Develop or abide by existing codes of good practice or recommendations that address operational procedures at aquaculture units (SSPO 2010; Fredheim et al 2013; GFCM 2013).
7. Risk assess, document and train staff in high risk handling procedures such as transfer, grading and harvest (IUCN 2007).
8. Ensure that aquaculture seed stocks destined for table production come from domesticated hatcheries wherever possible and are not released into the environment (i.e. for mitigation restocking).
9. Ensure that fish for mitigation stocking are reared from sustainably caught wild brood-stock and that these are kept separate from domesticated stocks.
10. Use best available technology for the production of sterile fish where possible. Take up new technology when licensed and available.
11. Ensure land based flow-through systems have adequate screening for the size of the fish and that it is maintained regularly.
12. Develop contingency plans for the recovery of escapees.
13. Gene banks of wild species should be encouraged where possible.

A combination of good licensing, the regulation of alien species and the use of best available technology combined with best practices and codes of conduct will contribute towards reducing environmental impacts from escapees and achieving the alien species related targets set in the WFD and MSFD. The development of guidelines, sectoral codes of conduct and other awareness raising and educational campaigns will also be useful in the context of the new invasive alien species Regulation.

8.4.5 Specific related example from regional workshops

The following case study outlines a code of good practice developed by the Bangor Mussel Producers Association to avoid the accidental spread of IAS.

Specific example from workshops: Case Study: Industry Code of Practice Bangor Mussel Producers Association: Code of Good Practice for mussel seed movements

Development of Code

- Potential for mussel fisheries to contribute to the spread of Invasive Non-Native Species (INNS)
- Code of good practice developed between multiple stakeholders.
- Objective to allow continued import of mussel seed without contributing to the spread of INNS.
- Industry pledge to abide by the code. Memorandum of Understanding (MOU) developed.

Description of the code

- Draws upon the HACCP (Hazard Analysis and Critical Control Point) approach to assess levels of risk.
- Breaks down the various stages and operations involved in the sourcing, fishing and relaying of mussel seed.
- Evaluates how potential hazards will be handled at each stage of the entire process.
- Identified eight INNS as potential pests.
- Recognition that code may need to adapt and change to include other INNS.
- Uses red, amber and green zones to indicate the presence and proximity of INNS.

Operation of the code

- Vessels and dredges to be thoroughly cleaned and denuded of any living organism before moving from red to green zones.
- Any ballast water to be replaced before entry into a green zone.
- Mussel seed boats will have onboard identification cards for the eight named INNS.
- Mussel operators to ensure familiarity and vigilance maintained during fishing operations.
- Floodlights will be used to illuminate working decks during night time fishing.
- If INNS species are discovered amongst seed, it is **not** to be brought back for relaying.
- Reporting instructions on the pest identification cards should be followed.

Appendix D Schematic of Code of Good Practice for mussel imports into the Menai Strait.

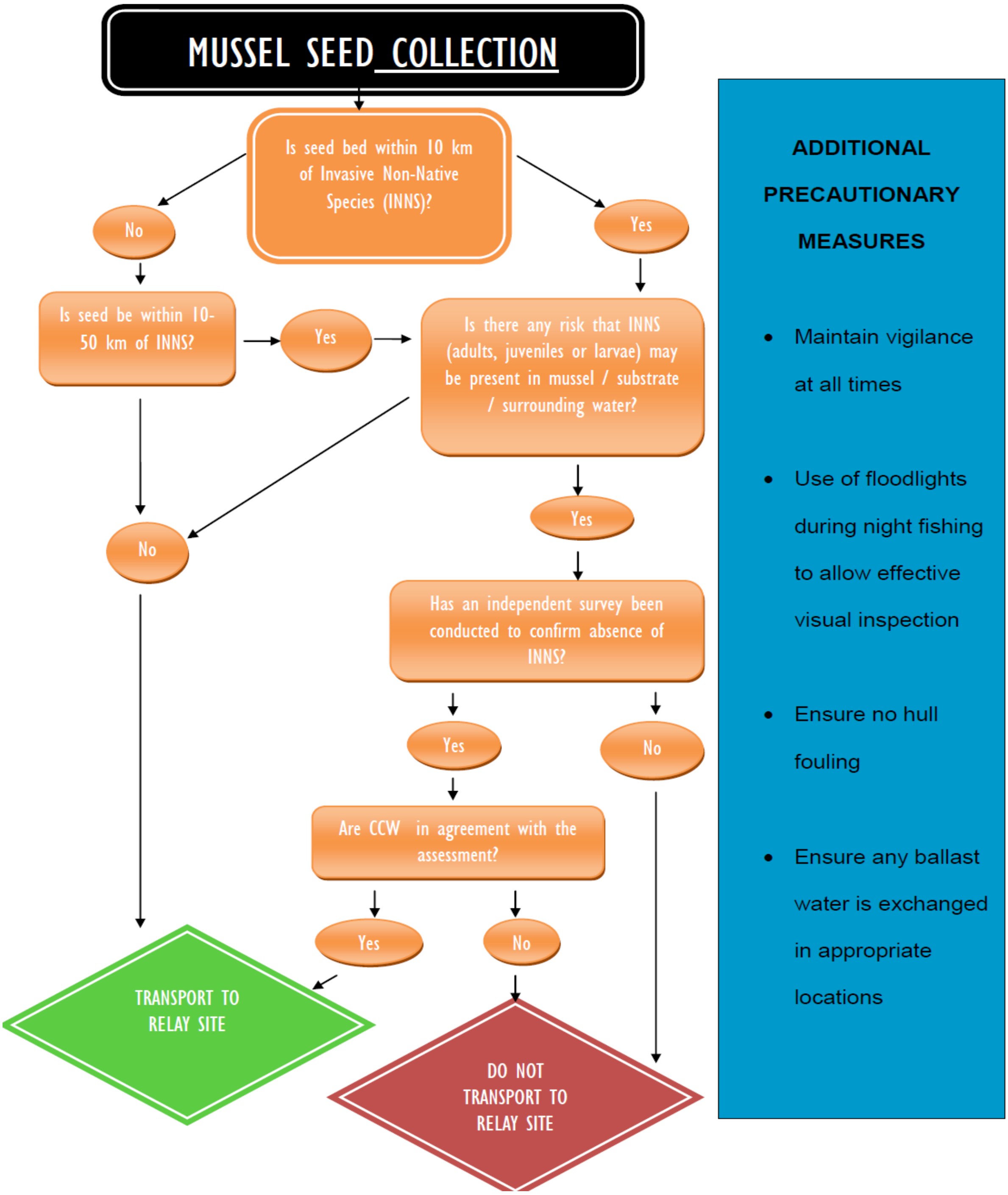

Fig. 8.3: Schematic of code of good practice for mussel seed to prevent transfer of invasive non-native species, produced by Bangor Mussel Producers Association, UK.

8.5 Physical impacts, disturbance and predator control

The following working definitions derived by Cefas have been used in this section:

- Physical impact: changes to the physical environment including prevailing hydrographic conditions, flow rates, morphology, and impacts on sedimentation.
- Disturbance: a temporary change in environmental conditions that causes a change in an ecosystem that may be short-lived or long-term.
- Predator control: predators include piscivorous fish, birds, and mammals, and can take the form of exclusion, deterrents or extermination.

From these definitions, it is possible to look at the interactions between these factors and environmental legislation like WFD and MSFD (Table 8.1). The WFD hydromorphological elements may be affected by physical impacts and disturbance, and the biological elements by predator control. This will impact on WFD Good Ecological Status (GES-WFD) where the element affected drops below the lowest status level for all other factors within the element. The MSFD descriptors of sea- biodiversity (D1), non-indigenous species (D2), foodwebs (D4), sea-floor integrity (D6), and hydrographical conditions (D7), are most likely to be impacted by changes in physical impacts, disturbance and predator control for aquaculture. Examples of the effects and potential mitigation for both are given in the sections below.

Table 8.1: Potential interactions between physical impacts, disturbance and predator control in aquaculture and WFD & MSFD descriptors.

Impact	**WFD**	**MSFD**
Physical impacts	Hydromorphological elements may be affected, including hydrological regime, river continuity and morphological conditions. Any change in the overall status of a water body will be dependent on reduction of the lowest status element(s). There may be advantages in relation to drought and flood management with some systems (e.g. extensive freshwater ponds; marine lagoons)	The MSFD descriptors that are most likely to be affected are sea-floor integrity (D6) and hydrographical conditions (D7).
Disturbance	Hydromorphological elements may possibly be affected, including hydrological regime, river continuity and morphological conditions. Any change in the overall status of a water body will be dependent on reduction of the lowest status element(s).	The MSFD descriptors that are most likely to be affected are biodiversity (D1), non-indigenous species (D2), and foodwebs (D4).
Predator control	Biological elements are likely to be affected that could relate to fish, birds, and mammals. Any change in the overall status of a water body will be dependent on reduction of the lowest status element.	The MSFD descriptors that are most likely to be affected are biodiversity (D1) and foodwebs (D4).

8.5.1 Physical impacts

There are many descriptions of the impact of structures on the hydrographic conditions and sedimentation. For example, marine windfarms have been shown to affect the hydrodynamics around structures leading to, for example, scour of sediment around the base and suspension of the sediment in the water column creating a sediment plume in the lea of each turbine (van der Molen et al 2013). Although typical aquaculture facilities are currently not solid structures, it is likely that the structures do affect the prevailing conditions. However, guidelines are in place to assess the effects of aquaculture on benthic communities that occur within the licence application for any new facility (IUCN 2007). These are generally in the form of Environmental Impact Assessments (EIA) that should be carried out to detect any possible effect on the wild ecosystem, with both hydrological and ecological studies conducted as part of the process of site selection. Areas which contain significant, sensitive, or unique communities (e.g. seagrass) are considered as part of this process and aquaculture facilities will be sited outside of these areas. Decisions to develop or stop further deployment of the facilities are site specific and are managed on a case-by-case basis (e.g. Scotland - http://www.scotland.gov.uk/Topics/marine/Fish-Shellfish/FHI/authorisation/apb). A similar licensing process that takes account of the potential physical, chemical and biological impacts of any new facility, including the impact on delivery of WFD targets is required for freshwater aquaculture systems.

Physical impacts of infrastructure are possible since facilities such as net-pens (finfish) and longlines (shellfish, macroalgae) may be anchored on the seabed, and could physically damage the seabed habitat. However, proper siting and design of aquaculture infrastructures can mitigate impacts by avoiding locating on sensitive habitats and considering the best technical solution for each type of area (e.g. adapting mooring structures to the conditions of the seabed substrate). This mitigates the impact of new aquaculture facilities through the avoidance and minimisation of potential adverse effects. In Scotland, for instance, some mooring anchors and equipment required for securing salmon farm pens are situated in deep water to avoid overlap between the farming activity and sensitive habitats (e.g. reefs). Large enclosures could also affect current circulation and water clarity. Risks can be managed, if necessary, by limiting the sizes of complexes and relocating them regularly (Nash et al 2005; COM 2012a). However, the effectiveness of fallowing in mitigation of biological effects is still under debate (see e.g. Lin and Bailey-Brock 2008).

There are two main issues with the marine licensing process for aquaculture: the timescales for acquiring the licence following submission of the application, and the provision of information that may support site location decisions. The latter point is specifically important in terms of managing the physical impact of aquaculture businesses on the environment.

In Denmark, there is a clear process for marine licensing that aims to grant a license within 9-12 months after application, and includes an assessment of environmental impact, modelling the potential impacts, and the potential to impact on Natura 2000 sites.

In Greece, issues were raised about the difficulties for aquaculture producers to identify suitable sites as they were not aware of all the legislation affecting marine spatial planning. Hence, the Greek legislation sets out the process for aquaculture licenses, but also encouraged the creation of Areas for Regulated Aquaculture Development (ARAD) (Greece 2011). The setting up of aquaculture zones is positively received by the industry, as they know where it is possible to obtain licences to site new farms, and reduces the financial risk of developing new farms.

A good example of the marine licensing process is used in Scotland where the licensing of new sites is based on a mixture of data collection and models to predict potential impacts at both the local (site), and regional (sea loch) levels. Models are used to predict the fate of nutrients, sediment, and veterinary medicines, prior to licences being granted, with the output from those models as fish biomass (maximum weight of fish permitted to be held on site) being determined by factors such as depth, mean current speed and prevailing tides. Once installed and operational, monitoring both within and outside the Allowable Zone of Effects (AZE) at the site checks the impact of the facility. All the data on the licensing of Scottish sites is freely available on the Scottish Aquaculture website to ensure transparency (Scotland's Aquaculture - http://aquaculture.scotland.gov.uk/).

In freshwater systems, the main physical impacts relate to changes in river flow, river continuity, and morphological conditions. Water abstraction is seen as one of the key challenges facing Europe (COM 2012c), so it is important that resource efficient methods are used in aquaculture to mitigate those impacts (COM 2012c). These will need to be addressed on a case-by-case basis generally through good farm design, but the potential for approval of new sites is very dependent on the individual location and the RBMP for that system (EU 2000). An example of reducing physical impacts is the Danish model farm approach (partial-recirculation) as discussed at Copenhagen workshop (Annex IV).
Lake and pond aquaculture generally use lower amounts of water than flow-through systems. Some systems, for example large extensive freshwater ponds, may help to manage the effects of drought

or flood within a river catchment, where they act as reservoirs or buffers in reducing extremes of flows.

The only way to completely remove the physical impacts of aquaculture is to use land-based recirculation systems which do not provide a barrier to water movement or change sedimentation. However, these are expensive to set-up and maintain (Varadi et al. 2009) and are unlikely solely to provide the increase in volume of seafood production required from aquaculture

Specific examples from workshops: Case study: Ecosystem services

At the Vienna good practice workshop a presentation was given by the WWF (Danube & Carpathian). The WWF is engaged in a project to maintain wetland ecosystem services through the development of responsible aquaculture practices. This basically involves the provision of economic incentives which aim at conserving benefits from ecosystem services. In the vicinity of Ciocanesti, there has been much drainage and loss of wetland habitat for birds. This means that birds relocate to other wetland areas, often meaning fish farms. The challenge is to retain the profitability of a fish farm when damage is being done through predation of stock by fish-eating birds that have been relocated into the last remaining wetland areas. The system aims to provide a balance between economic and biodiversity needs by creating fish farms that show wider environmental benefits, with additional advantages such as positive impacts for tourism. Further information may be found through the project website link (See presentation by Lucius, Annex 15).

8.5.2 Disturbance

Across Europe the clearing of pristine land areas for freshwater aquaculture is unlikely to be a problem. This is because most areas have already been cleared for agriculture and any remaining land is mostly designated for nature conservation. New freshwater aquaculture projects are most likely to use agricultural land and, depending on the type of aquaculture, may result in significant ecosystem services (e.g. wildlife areas). Aquaculture is also a very efficient user of space, in comparison to agriculture and other industries, so the net requirement for space for development is low (Gjedrem et al 2012) as is the area of aquatic environment impacted by disturbance from aquaculture.

Within the marine environment, any aquaculture development falling within nature designations (e.g. Natura 2000 sites) would require authorisation of a plan or project to be granted in accordance with Article 6(3) of the Habitats Directive. Therefore it is considered unlikely to adversely affect the integrity of the site concerned and, consequently, unlikely to give rise to deterioration or significant disturbances within the meaning of Article 6(2) (ECJ ruling on case C-127/02 para. 36) (COM 2012a).

Resistance is '*the ability of an ecosystem to withstand disturbance without undergoing a phase shift or losing structure or function'*(Odum 1989). Different species and habitats have different degrees of resistance to pressures. The degree to which a particular conservation unit is impacted by a particular pressure varies depending on the conservation unit and the pressure involved (Crowe et al 2011). Resilience is the capacity of the system to recover from change. Marine ecosystems have an inherent resilience to damage and loss, which varies depending on natural conditions and the nature and level of pressures impacting on them. Relatively exposed areas that naturally experience high levels of physical disturbance may recover from anthropogenic physical disturbance more quickly than those in sheltered areas (Crowe et al 2011).

It is has been stated that aquaculture activities can cause environmental disturbances (e.g. Chamberlain et al., 2001; Kaiser, 2001; Carvalho et al., 2006). A number of MSs have identified aquaculture as having an impact on seafloor integrity (Table 3.3) which can be related to physical disturbance from input of waste products and debris from the facility. These impacts can be controlled and mitigated by licensing procedures that identify an acceptable zone of impact and a further monitoring zone around the facility (SEPA 2014); in practice, the area of these zones will be no more than a few 100 m^2 reflecting the current size of net-pen and longline systems for finfish and shellfish cultivation. These zones are regularly inspected to ensure that the facility is not impacting outside of the acceptable zone (see Marine Harvest presentation from the Dublin workshop). In the Greek context, Posidonia beds are regarded as an important habitat and are afforded some degree of protection from disturbance (Karakassis et al 2013).

Examples and literature exist to show that aquaculture has been responsible for significant inputs of marine litter (Hinojosa and Thiel 2009). These examples are found where the industry is in an early stage of evolution and not using latest equipment technology or technical standards. For example in the more mature industry sectors the use of small plastic feed sacks has largely been replaced by feed barges and use of one tonne bags and purpose built mussels floats are now used.

Indeed, it has been flagged that litter can potentially impact on aquaculture production, rather than it being a pressure from aquaculture (HM Government 2012) (Mouat et al 2010). Litter should not be introduced into the environment at all, and voluntary codes of practice could be developed to help reduce inputs. As an example of inclusion within voluntary codes of practice, the management of litter is addressed in the Code of Good Practice for Scottish Finfish Aquaculture (CoGP) which advises in section 4.5.1 that "*All waste materials such as feed bags, lengths of redundant rope, etc. should be carefully collected from pen installations and brought back to shore where it should be properly segregated, stored, recycled or disposed of within a defined timescale*." In relatively shallow water, litter on the seabed can be removed by divers, but this is often difficult and only applies to litter that is negatively buoyant and remains in the vicinity of the site.

Visual impact concerns relate mostly to how visible the facilities are from the shore, or what the landscape impacts are in the case of land installations. Visual impact of aquaculture systems was investigated in a study commissioned to specifically address the impact of aquaculture on the tourism industry in Scotland (Nimmo and Cappell 2009). The results of a survey indicated that the majority of respondents did not think that aquaculture facilities spoiled the appearance of the coastline. Mitigation measures, should they be required, may relate to the size and colour of the cages, with a preference for black or blue cages, as well as reducing the size of above-water physical elements in order to reduce the seascape impact, but in all cases without prejudice to the regulations on the proper marking of the facilities for boaters. Mitigation measures may also include siting the cages far from the shore or using submersible cages (IUCN 2009b).
In the Dublin good practice workshops the example of Coordinated Local Action Management Systems (CLAMS) was provided as a methodology for both reducing visual impacts and removal of redundant equipment (BIM 1999).

Oyster farming may alter intertidal macrozoobenthic assemblages moderately, and off-bottom cultures may cause more disturbance than on-bottom cultures. Hydrodynamics and season interact with cultivation practices to affect dispersal and accumulation, and hence the extent of smothering and bio-deposition (Bouchet and Sauriau 2008). The future establishment of oyster long-line production in sub-tidal areas may reduce stocking biomasses on intertidal grounds with positive effects on intertidal benthic communities. However, the potential negative effects of these new culture practices on the sub-tidal areas needs to be assessed (Bouchet and Sauriau 2008). Shellfish-DEPOMOD can assess near-field effects and, in conjunction with other models/indices that focus on far-field effects (e.g. nutrient cycling, pelagic carrying capacity), can provide the industry and management with tools to assess the effects of shellfish culture activities within an ecosystem-based management framework (Weise et al 2009).

Finally, it is important to consider impacts, not just in terms of departure from baseline, but how they influence resilience, i.e. capacity of the system to withstand or recover from other shocks. Some anthropogenic disturbances - e.g. habitat removal via wetland diking and filling; hardening of surfaces in the watershed; nutrient additions; introductions of invasive species such as *Spartina;* food web modifications like removal or protection of large predators – are thought to have affected the resilience of aquatic environments. In U.S. West Coast estuaries, bivalve aquaculture was reported to have local and short term effects, but it was not implicated in shifts in, or reduced adaptive capacity of, the larger ecological system (Dumbauld et al 2009). Bivalve aquaculture does not physically remove areas from an environment or degrade water quality, and any disturbance is generally within the scope of existing “natural” disturbances (e.g. winter storms).

8.5.3 Managing Interactions with Predators

Farmed fish and shellfish stocks will inevitably attract the attention of wild predators including fish (e.g. pike), mammals (e.g. otters, seals), and birds (e.g. cormorants, herons, eider ducks). Invertebrates (e.g. starfish, crabs) can also predate shellfish in the subtidal zone (see e.g. Dankers and Zuidema 1995). Protection of stock from predators is good husbandry practice and the FAO definition of aquaculture recognises that farming implies interventions in the rearing process including protection from predators (IUCN 2007).

Predator control can be challenging since many predators are protected by Member States’ and EU legislation, especially within designated sites of conservation interest. For example, deliberate disturbance of wild birds particularly during the period of breeding and rearing is prohibited under the Birds Directive, and deliberate disturbance of protected animals during breeding, rearing, hibernation and migration is prohibited under the Habitats Directive. The form of protection employed will depend on the location, the aquaculture system, the species and the life-stage being cultured. The system of control chosen should attempt to minimise the impact on biodiversity and the predators, and may take the form of exclusion from sites (e.g. seal nets, otter fences), deterrents (e.g. noise, fake predators), or as a final resort, reducing numbers through licensed control methods (e.g. shooting). Closed and recirculatory systems can mitigate predation, but are expensive to set-up and maintain (Varadi et al. 2009).

Open aquaculture systems are subject to a diverse range of predators, as illustrated by a study of 195 salmon farms in Scotland (Marine Scotland 2010). Twelve species of predators were reported including seals (grey and harbour), seabirds (shags, cormorants, gulls, gannets, fulmars, guillemots), terrestrial birds (herons) and other mammals (otters, mink). The most commonly observed predators were seals and piscivorous birds. Many anti-predator devices were used including nets, traps, fences, noise and predator deterrents, and shooting. Top nets, cone nets, seal blinds, sinker rings, tensioned nets, and shooting to scare or kill were considered the most effective methods (Marine Scotland 2010). Shellfish farmers also use a combination of netting and scaring devices to protect their crop with varying degrees of success (Syvret et al 2013).

The European Fisheries Fund (EFF) has supported investments in the purchase of equipment aimed at protecting farms from wild predators (Varadi et al 2009), and this will continue under Article 48 of the successor programme, the European Maritime and Fisheries Fund (EMFF - http://ec.europa.eu/fisheries/cfp/emff/index_en.htm). Little research has documented the extent to which predators target wild fish around farms, but this would be useful for understanding ecological interactions between farming and marine life (Price and Morris 2013). Hence, it is important to increase knowledge of the potential positive and negative aquaculture interactions with fisheries and ecosystems, including wild life, predators and exotic species (EATIP 2012).

Some examples of the control of avian, mammalian and fish predation are highlighted below.

Avian predators

Avian predation, by cormorants in particular, is an important factor affecting pond-based finfish aquaculture production in certain regions. The EU has developed the EU Cormorant Platform which provides information on cormorant numbers, management, and interactions with aquaculture (http://ec.europa.eu/environment/nature/cormorants/home_en.htm). This platform is based on outputs from the INTERCAFE project (http://www.intercafeproject.net/). It defines a number of different management tools for managing the impacts of cormorants (see Table 8.2 and Russell et al. 2012) including

- scaring with audible and visual deterrents (e.g. in Greece). Visual deterrents, such as model falcons to scare herons, are regularly moved to different positions (Behrendt, 1994).
- protecting fish using nets (e.g. in Greece) and wires (e.g. in Germany). Nets are often positioned above cages to prevent predation by birds (IUCN 2009b).
- reducing fish availability (e.g. size of fish)

- reducing cormorant numbers through culling or reducing reproductive success (e.g. in Slovenia)
- financial compensation

Long-term results are usually achieved by using a combination of, and alternating, methods.

When considering options, it is important to recognise the protection of cormorants under the European Wild Birds Directive, the complexity of conflicts between cormorants and fisheries, and the efficacy of control measures. Culling of protected avian predators may be possible under Article 9 of Council Directive 79/409/EEC. The Birds Directive sets out a derogation system to protect fishery and aquaculture interests. Member States can make full use of the derogation provisions to prevent serious cormorant damage to fisheries or aquaculture. The Commission has recently published a guidance document to clarify the key concepts in relation to the implementation of the derogation system (COM 2013a).

The ecosystem services provided by extensive freshwater fish farms (e.g. carp ponds in Hungary) are becoming more widely recognised: these systems provide wetlands and often accept losses of fish to piscivorous birds including herons and cormorants. To mitigate the impact of such predators, farms often use combined intensive extensive systems (IES), i.e. a compartmentalised unit for intensive production placed within a traditional fishpond. The concentrated area for fish production is protected and reduces predator impacts (Varadi et al 2009).

Mussel farms may attract birds, with eider ducks and scoters seeming to cause the most concern. Canadian mussel farmers have likened their farms to unplanned duck enhancement projects (Pirquet, 1990). Many of the techniques used to control cormorants can also be applied to ducks and other birds.

Table 8.2: Cormorant management tools (see Russell et al. 2012 for more information)

Factor	Management measures
Scaring cormorants away from a fishery	Cormorants are startled sufficiently to encourage them to move to other foraging sites by means of auditory, visual or chemical deterrents. The effectiveness relies on deterrents being sufficiently frightening and an alternative site. Cormorants will over time realise that deterrents are not a real threat and ignore them. Successful use of auditory and/or visual deterrents is dependent on unpredictability by changing location, frequency, and technique.
Protecting the fish – exclusion techniques	Exclusion of birds is most effective where fish are concentrated in small areas, so are best suited to ponds or raceways where netting is permanent. Anti-predator netting can be hung in ‘curtains’ or

	underwater enclosures used to prevent diving birds. However, in large water bodies exclusion may be difficult, but ropes can be used to prevent take-off and landing.
Reducing fish availability to cormorants – fish stock management techniques	The quality of foraging opportunities can be altered by making fish less easy for the birds to catch, through the provision of fish refuges, for example. If fish are difficult to catch, then the birds may choose to feed on other waters where the fishing is easier.
Reducing fish availability to cormorants – habitat modification techniques	Roosting, nesting or feeding opportunities can be reduced by changing the habitat. This makes the site less attractive and prevents birds colonising, so encourages movement elsewhere.
Reducing cormorant numbers	Most non-lethal defence measures are effective on smaller bodies of still and running water, but are less effective on larger stillwaters and rivers. Shooting is often seen as the most effective control, but there can be problems as dead birds can be replaced by others.
Financial compensation	Many national authorities take the view that the stakeholders should cover the cost of management and compensation arrangements are generally considered inappropriate. However, financial compensation is used in some countries to offset the consequences for particular stakeholder groups.

Mammals

A number of mammals are active predators on finfish and are attracted to aquaculture facilities and fishing lakes. These include indigenous predators (i.e. seals, cetaceans and otters) and non-indigenous species (i.e. American mink). These predators can have a significant impact on the productivity of an aquaculture facility, and impacts are not limited to predation. For example, holes in nets caused by marine mammals were responsible for 26% of escape incidents in Scotland (Taylor and Kelly 2010).

Control measures for marine mammals are the analogous to those for birds:

- Scaring of marine mammals has focussed on acoustic deterrent devices; however, these devices have not been consistently useful against seals (and sea lions) and may have deleterious impacts on non-target marine mammals (Price and Morris 2013).
- Exclusion techniques (e.g. seal rings and net) are commonly used against marine mammals, and are also deployed at freshwater sites e.g. fences are erected to exclude otters (Jay et al 2008).The use of predator nets on cage sites to prevent seal attacks may cause difficulties for operators and lead to by-catch. However, adoption of technical specifications, including resistance to predator attacks, provides a solution. Studies on damage caused by marine mammals to nets at cage sites in Scotland have identified a number of operational requirements to reduce predator damage and escape incidents, e.g. regular inspections.

- Farm management strategies to deter predation include net tensioning, removal of mortalities, lower stocking densities and seal blinds at the bottom of the nets (Price and Morris 2013); (Taylor and Kelly 2010).
- Siting away from known predator aggregation sites is effective at reducing impacts (Price and Morris 2013), highlighting the importance of a good evidence base feeding into marine planning.
- Culling of mammalian predators is often difficult as many are protected. For example, otters receive full protection under the EC Habitats Directive (EU 1992). American mink are established throughout the UK following escapees from fur farms, and as a non-indigenous species culling is allowed by a number of means including trapping (Rural Development Service 2005). However, the effects of mink and otters are difficult to separate, so care must be taken in choosing this option (Jay et al 2008).

It is unclear whether mammalian predation is changing as the aquaculture industry develops. Surveys of salmon farm managers in Scotland indicate that seal predation has declined over the past decade, with less than 25% of farms reporting major problems with seals despite daily sighting near farms. Rogue individuals were thought to cause the most damage, and individual recognition techniques are being improved as a potential management tool (Northridge et al. 2010).

Predatory fish

Aquaculture facilities provide a source of food for predatory fish, although there are far fewer examples than for bird and mammal predators. Bluefish are reported to aggregate around and invade fish cages in the Mediterranean (Sanchez-Jerez et al. 2008). Of 23 farms surveyed, bluefish aggregations were detected at 16, but only 4 farms reported significant impacts: predation on the cultured fish, decreased productivity due to stress and additional costs associated with removal of bluefish and net repair (Price and Morris 2013).

Predatory fish can theoretically be controlled using the same mechanisms as other predators. There are also opportunities for the fishing and aquaculture sectors to work together, for example removal of seabream (akin to culling) decreases predation on farmed mussels (Stelzenmüller et al 2013). Predatory fish may not need to be controlled in some situations where co-existence may be beneficial e.g. pike are often left in freshwater to remove surplus or weak fish.

9 Emerging and future technologies

When planning how European aquaculture will progress over the coming decades in relation to environmental legislation (such as WFD and MSFD), it is important to consider potential developments and changes within the sector as it continues to develop and produce the ever increasing volumes of food required by the growing human population. New and emerging technologies and forms of aquaculture may be under development, at a pilot stage, or transferred from other parts of the world where they are already in use.

9.1 Offshore aquaculture

The development of offshore aquaculture (for finfish, bivalves and crustaceans) is seen as one of the most promising options for Europe. Offshore aquaculture sites are differentiated (from inshore) by increased distance from the shore (reducing accessibility) and increased exposure (i.e. greater wave action) (James and Slaski 2006) It is generally accepted that the carrying capacity and ability of offshore ecosystems to absorb and assimilate nutrients and organic inputs will allow licences to be granted for increased production, up to certain limits (IUCN 2009b). Offshore aquaculture therefore offers an opportunity for expansion with the advantages of increased availability of space, better background water quality, reduced environmental impacts, and less competition with other sectors. Nevertheless, concerns have been expressed over the unknowns of moving offshore, and the need for significant prior research has been highlighted (Holmer 2010) (Seas at Risk 2014). Despite progress in technical and engineering standards, challenges remain in mooring in deeper water and areas with strong subsurface currents, and operating in the more exposed offshore environment. Large areas of the offshore environment may be too deep for existing mooring technology.

9.2 Submersible net-pens

Social and environmental factors may restrict development of standard net-pen culture in many near-shore locations. The use of submersible cages would reduce visual impacts and as sub-surface cages are less exposed to wave damage, the risk of escapes due to storm damage is reduced. Submersible cages may also enable finfish farming in more exposed (offshore) environments, with the benefits of reduced visual and environmental impacts. Submersible cages may also enable culture of a broader range of species (Papandroulakis et al 2013). However, challenges remain regarding operation and management and in mooring if used offshore.

9.3 Closed freshwater and marine pens

Many closed floating pen projects (at various stages of development) are being trialled to reduce the impacts from open net-pens. All closed pen systems require water to be pumped in, rather than relying on free movement of water through a mesh in open net-pen systems. Potential benefits associated with a closed wall, controlled water supply and controlled discharge include: capture of solid wastes, reduction and control of nutrient and chemical discharge, containment of stock, and a physical barrier to pathogen ingress and egress. Flexible membranes (ClosedFishCage) and rigid materials surfaces (AquaDome) are being trialled as pen walls, and another concept is large rigid walled floating tubes (Preline).

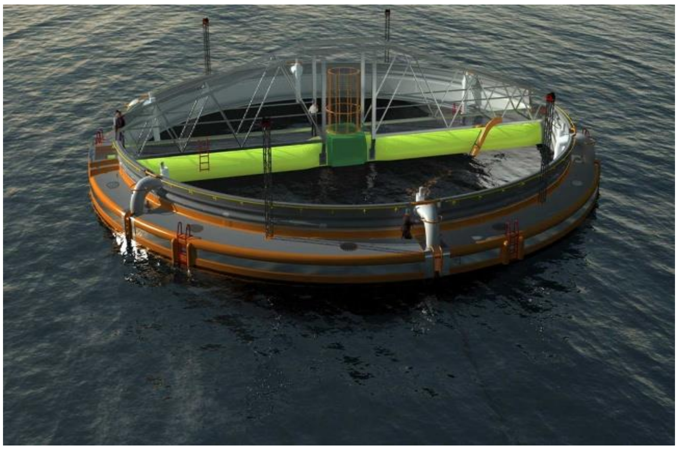

Fig. 9.1 AquaDome project, Norway.

9.4 Recirculation aquaculture systems (RAS)

Whilst RAS have been around for many years, the technology is still evolving, developing and improving. The evolution of RAS has seen many failures of farms along the way (Jeffery et al 2012) and their financial viability has been questioned (Boulet et al 2010). However, with technological improvements , reduction of capital costs, economies of scale and linkage with renewable energies, RAS still offer much promise for the future (Martins et al 2010). In Denmark, traditional flow-through trout farms have been converted into RAS or 'Model Farms'. These systems reduce water requirements, capture solids, clean up the discharge with wetlands and return any remaining flow to just below the intake point.

9.5 Bio-fuels, algae and seaweed culture

There is increasing interest in cultivating seaweed (macro-algae) and smaller microalgae to supply bio-fuels and provide alternative protein and nutrient sources (EFARO 2013). Seaweeds place low demands on the environment and reduce eutrophication (Hall et al 2011).

9.6 Integrated multi-trophic aquaculture

Integrated multi-trophic aquaculture (IMTA) manages the cycling of nutrients in a location through utilisation of the emissions from one farmed species as inputs (fertilizers, food) for another. The concept of IMTA is that farms combine fed aquaculture (e.g. finfish, shrimp) with species that extract the nutrients (e.g. seaweed) and suspended solids (e.g. shellfish) to create balanced systems for environment remediation (bio-mitigation). This type of compensatory aquaculture is of much interest to environmental groups and NGO's (Seas at Risk 2014) but functionality and viability is still questioned (Coalition Clean Baltic 2014), and such systems have yet to achieve commercial reality. Compensatory systems are being taken forward and tested in many areas such as the Baltic Sea, but some of these are not true IMTA systems in respect of the fact that the removal of nutrients through bivalve mollusc (mussel) or seaweed cultivation in the locale of a finfish farm do remove the nitrogen and phosphorus emitted into that location by the fish.   That does not discount the potential of such extractive aquaculture systems to manage nutrients in the coastal zone, but this is not IMTA in the true definition of the term.

IMTA can be land- or marine- based. Such systems could potentially be used in areas where there is concern about eutrophication and loss of good status. The bio-extraction of phosphorous and nitrogen can compensate for inputs from open net systems and close the nutrient loop in aquaculture (Aquabest 2014). To integrate aquaculture with the environment, it is necessary to determine the assimilative capabilities and hence the environmentally-acceptable loading rates of wastes (per volume and per area of sea-floor), and include the ecological services of the farmed shellfish and macro-algae (EATIP 2012).

There are still many challenges to integrating extractive systems with fed systems, e.g. securing seaweed systems in environments with a strong tidal drag (Troell et al 2009). EATiP, EFARO and NGO’s have identified these systems as potential options for the future (EATIP 2012)(EFARO 2013)(Seas at Risk 2014). R&D is required to advance the systems into commercially viable opportunities (Price and Morris 2013) and tools are currently being developed to help achieve this under a European project (IDREEM).

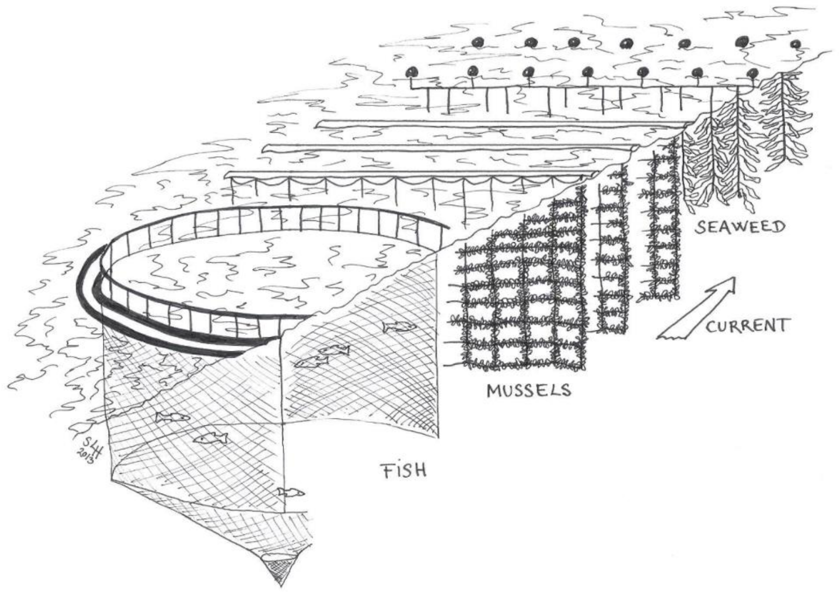

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Fig. 9.2: Illustration of an integrated multi-trophic aquaculture site.

9.7 Aquaponics

Aquaponics is the combined culture of fish and plants in recirculating systems where dissolved waste nutrients are recovered by plants, thus reducing discharge to the environment and extending water use (Rakocy et al 2006). The daily addition of the fish food provides the nutrients for the plant crops thus replacing the need for addition of chemical nutrients as in hydroponic systems. Aquaponic filters have been shown to provide better biological performance than traditional pond filters (Varadi et al 2009). These systems have a clean green image and have become popular among the "back-yard" community and hobbyists, producing food close to the markets. The challenge for aquaponics is to become commercially viable i.e. as competitive as either standalone aquaculture or standalone hydroponics (Taylor 2014). It is an area where both industry and NGO’s would like to see more support and encouragement (Seas at Risk 2014).

9.8 Co-location with renewable energy and offshore platforms

In order to find and make best use of available space, it has been proposed that aquaculture could co-locate with other industries in offshore environments. This presents considerable challenges, not only in terms of engineering, but also in how to share and operate in the same location. Several large research projects are currently taking place internationally e.g. (MERMAID)(H2OCEAN)(TROPOS).

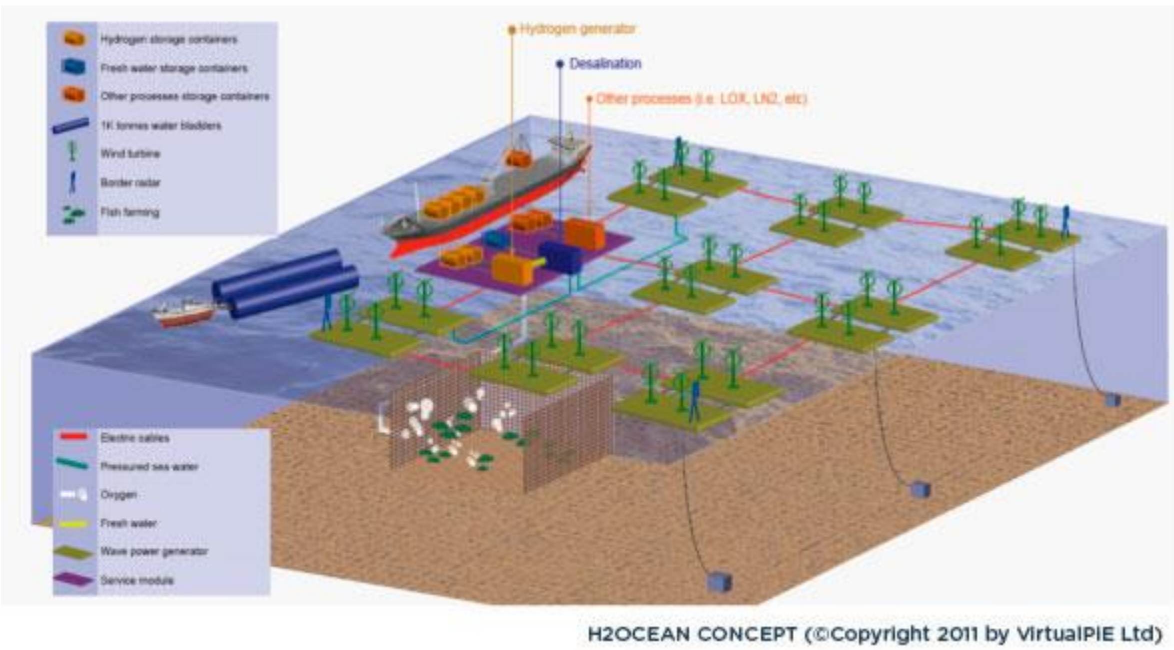

Fig. 9.3: H2OCEAN concept of co-location of aquaculture with other industries

The Welsh Government recently commissioned work on the co-location of aquaculture with renewable energy sectors (Syvret et al 2013) and research has been conducted along the German coast (Michler-Cieluch et al 2009). Co-location offshore may help reduce potential impacts on near-shore environments, whilst delivering on the blue growth agenda (COM 2012b). The procedures for doing this and the limited evidence base have recently been examined to assist with marine planning (MMO 2013). Furthermore, a framework for co-location has been commissioned but this is currently work in progress (MMO 2014).

10 Recommendations

This project adopted a process that involved the researching of the literature on issues regarding the environmental impact of aquaculture; an assessment of the issues of the environmental regulation of the sector through a broad information gathering process; an extensive consultation process across national administrations and regulators, industry and the NGO community; ultimately, issues of importance were identified that require addressing in order to manage the sustainable development of the sector across EU-28. The process reflects an approach that is all encompassing in relation to the sector's needs and a series of recommendations has resulted from the exercise. These recommendations represent the conclusions of the project team, and are not representative of the views of the Commission Services or any of the stakeholders invited to participate in the project.

Key recommendations in relation to environmental regulation and impact mitigation for aquaculture across EU-28 are summarised below and these should be read in relation to the outputs of Chapters 7 and 8. These recommendations are summarised within four sections (1) for national administrators and regulators (2) for the aquaculture industry (3) for further research (4) for the EC.

10.1 Recommendations for national administrators and regulators

In reviewing the information presented on the issues regarding the environmental regulation of the aquaculture industry in EU-28, the subject areas fall into four categories: Licensing, Monitoring, Planning and Charging. Whilst the recommendations have been separated into each of these four categories below, there is a degree of overlap between these headings and the overall objectives of improving the regulatory situation must be kept in mind i.e. the recommendations should not be read in isolation.

R1. **Licensing:** During the consultation process in this project, the potential improvements that may be made in the regulation of the industry were highlighted and a key issue that came to the fore was the importance of having a single point of contact for the aquaculture industry in the regulatory system. As such, a **"one-stop-shop" approach to improve the efficiency of regulation** is emphasised, where one agency becomes the contact point for industry to reduce time for processing applications**.** This recommendation was raised at regional workshops in relation to efficient handling of initial licence applications (rather than monitoring environmental impacts once operational). An example of the implementation of a one-stop-shop approach was provided from Norway: "*One application is made at the county level (local authority), who then copy the application and send it to different sector authorities. Local municipalities announce the application to the public, and a time limit applies (6 months) for responses from administrators. The final decision is distributed through the county. Expansion of Norway's aquaculture industry has been possible through discussion, transparency, and solution driven cooperation, between authorities and aquaculture industry, science and nature as well as political ambition to increase production of food, safeguard fisheries and aquaculture industry, improve knowledge and techniques in farming and monitoring.*" Addressing this point also helps the Commission Services to develop actions against the "reducing administrative burdens" priority area in the Strategic Guidelines for the Sustainable Development of EU Aquaculture. In addition, this issue was also identified in the national administrators' questionnaires (see Annex 6, Q10), where it was stated that "Different government Departments deal with environmental legislation and regulation (responsible for implementation of WFD and MSFD), and Aquaculture licensing".

Aquaculture is a young and dynamic industry and technological developments occur relatively quickly and may become industry practice at a rate that is beyond the capability of relatively rigid regulatory frameworks to adopt and manage. Examples of such a rate of development include new systems for farming aquaculture species, e.g. RAS, partial RAS, aquaponics, extractive aquaculture (seaweed). It is also recommended to **provide a permitting system that is flexible enough to include mitigation practices or new techniques for the management of environmental impacts.** This recommendation allows for a proportionate increase in aquaculture production if technologically proven methods to mitigate environmental impacts are introduced. Advances in nutrient removal, e.g. through improved filtration and water processing systems, are likely to be a key component of such an approach, but other possible advances such as development of vaccines for disease control, biological control of disease (e.g. cleaner fish for sea lice control, see 8.3.4) improved engineering to manage containment, and the production of stock that are unable to reproduce in the wild if they escape, may all contribute. The issues raised in relation to monitoring (see Section 7.2.6) also highlighted that some authorities currently monitor parameters that are not relevant to aquaculture, and this is obviously both costly and inappropriate, highlighting again at least some lack of understanding of the industry's environmental impacts by some regulators. Linked to this point, it is also recommended to

include within the review of consents/licence applications an assessment of the use of mitigation tools or practices (e.g. for effluent water quality) and how these may improve environmental performance. This project has provided many examples that stakeholders regard as good practice in managing the environmental impacts of aquaculture for a broad range of systems and species types in locations across EU-28 and EEA states. Knowledge (or guidance) of these diverse approaches and how they can be implemented for certain systems/locations/species) would help regulators to suggest where improvements could be made to industry operations or applications.

In this report the project team has reported on the variety of aquaculture systems that exist across EU-28, as well as a range of species cultivated, and many approaches that may be regarded as good practice. It is clear that some of the aquaculture industry's environmental impact issues are specific to regions, an example of which would be the management of the industry's impacts on Posidonia beds in the Mediterranean (see sections 7.2.4 and 8.5.2). The development of guidance for different systems/species is therefore unlikely to be appropriate across EU-28, although there is a real need to develop guidance at the regional level. It is recommended that national administrations/ regulators **develop specific environmental good practice guidelines for the main types of aquaculture within their jurisdiction, and that this be developed in conjunction with the aquaculture industry to ensure that it is directly appropriate**. This approach would simplify the requirements of the aquaculture industry to manage the environmental impacts of their activities.

A regularly occurring point was made in the project workshops about the application of the Precautionary Principle to aquaculture. The NGOs see the application of the Precautionary Principle as essential to manage the sustainable development of aquaculture, but the views expressed from industry indicate that there are tensions in the way this has been managed across EU-28 (see section 7.2.8). In order to address this point in aquaculture development, it is recommended that **the Precautionary Principle be applied to aquaculture consistent with EU guidance** (COM 2000b; EEA 2001)**.** The guidance that has already been provided by the EU, if followed correctly, should help clarify the requirements in the adoption of this approach to sustainable aquaculture development.

In connection with licensing aquaculture developments, regulators should **develop simple guidance to help regulators and industry assess whether plans for new or expanded aquaculture facilities will comply with obligations of the MSFD and WFD (building on existing WFD Common Implementation Strategy guidance for Article 4(7)**(EU Water Directors 2007)**)**. Particular areas of importance include guidance on environmental flows, allowing access to water at the same level as other food production sectors, and the possibility of taxing contaminants (i.e. emissions) as the sector is not a consumer of water. National Administrations and regulators should also **consider the mechanism for and application of nutrient trading schemes (including co-location) for sites that are already heavily impacted or otherwise compromised to facilitate the continuing sustainable development of aquaculture.** The concept of nutrient emissions trading was raised regularly at the Copenhagen workshop in relation to the Baltic Sea environment, a region that may be regarded as a case study for aquaculture development in a heavily impacted water body. As a general point, a mass balance approach which includes nutrient inputs from all sources helps to identify the contribution from aquaculture and ways of managing that contribution at the ecosystem level.

There has been some discussion of the transposition of the SWD into the WFD in this project and, specifically in relation to shellfish cultivation, it is recommended that **Member States keep the national instruments transposing the SWD, or, if necessary, develop new ones to ensure adequate protection of aquaculture production areas**. MS should also be aware that viral standards are under consideration (e.g. Norovirus) and may be required for Shellfish Production Areas/Protected Waters, in the future.

R2. **Monitoring:** It is recommended that **a risk and evidence-based approach to determine monitoring requirements is adopted and standardised across EU-28**, ensuring that the approach is based on robust scientific principles and best available working knowledge within an overall ecosystem management methodology. This project unearthed the different approaches to the regulation of the environmental impact of aquaculture in different MS. Examples of this are the different approaches to the management of sea lice in farmed salmon adopted by Ireland, Scotland and Norway, and the nutrient emissions trading approach to aquaculture licensing seen in the Baltic in comparison to the management of nutrient emissions in marine finfish farming in the Mediterranean and the North East Atlantic. In developing a standardised approach across EU-28, it should be noted that the successful application of such an approach is dependent on the provision of suitable data and models. Although this is a recommendation for regulators, there may well be a role for industry to provide data to inform such an approach. It is also recommended that **there be a greater clarity on which parameters or data the aquaculture industry should provide for licensing and monitoring, as well as the quality and quantity of the information required**. Data on both emission and uptake of nutrients is required, and it is necessary to make **improvements in monitoring to quantify and allocate proportional nutrient loads from different sources, identifying the contribution from aquaculture within an overall nutrient budget**. Any requirements for approaches such as zero nutrient impact for new aquaculture sites must be based on a scientific and site-specific assessment of the impact and an evaluation of the significance of the nutrient emission compared to other industries. It should also be noted that forms of extractive aquaculture (bivalve molluscs, seaweed) have the potential to remove nutrients from the ecosystem and may be beneficial in managing the nutrient emissions of other industries.

The **adoption of regulatory codes** (Better Regulation Delivery office 2014) **may support improvements in the effective and efficient environmental regulation of aquaculture**. Such an approach may be general covering regulation as a whole, or specific to environmental management or aquaculture regulation. A variable attitude towards the regulation of aquaculture was identified in MS in this project, emanating from the regional workshops (see section 6.2), and it is hypothesised that the adoption of regulatory codes would help to address this issue.

The **development and application of technical standards for aquaculture systems** will also support the aims of national administrations and regulators in managing the risk of escapes from aquaculture systems and any subsequent potential impact on biodiversity. The application of technical standards would manage the risk of escape of stock from aquaculture facilities and good practice examples for finfish have been provided from Norway and Scotland. The adoption of technical standards across the whole aquaculture industry may help to mitigate environmental impacts across a range of aquaculture systems and species and the implementation of standards such as these supports monitoring programmes by ensuring that systems and equipment are appropriate for the location and species farmed.

R3. **Planning:** Planning is a key issue in relation to the strategic development of the marine aquaculture sector and has been raised within this project as an opportunity to manage the environmental impacts of the industry in a manner that optimises the management of the marine resource and provides best possible mitigation of the environmental impacts. Specifically for marine planning, it is recommended that national administrations/regulators p**rovide strategic planning for marine aquaculture development to inform spatial planning processes, ensuring linkage with other marine industries, and that within spatial planning approaches**. It is also recommended that **Allocated Zones for Aquaculture (AZAs) are provided**. A strategic view is important to ensure that aquaculture develops in the most suitable areas and that the sector complements other marine industries and stakeholders. The adoption of GIS or other mapping systems and planning techniques can support a more strategic vision for the aquaculture industry's sustainable development. The provision of AZAs complements an ecosystem approach to the management of the sustainable development of aquaculture. Also relevant to freshwater aquaculture, as well as marine, it is recommended that **aquaculture be integrated into objectives and measures in the 2nd round of RBMPs.** This investigation has shown that aquaculture has lacked prominence in RBMPs, and specific mention in the next round of RBMPs would help ensure parity with other industries. Regulators need to ensure that the aims of reducing nutrient emissions and enabling industry development are balanced and one aim does not override the other. Aquaculture also merits recognition for its potential positive contributions towards achieving good ecological status.

R4. **Charging:** The point about the charges levied on industry for licence applications and regulation was raised by industry stakeholders at the regional workshops, and it was argued that this should be proportional in relation to the impacts of aquaculture viewed in comparison with other industry (see sections 6.2 and 7.2.7). Within this project charging for access to water has been raised by both administrators/regulators and industry and the fact that aquaculture does not consume significant quantities of water has been to the fore in those discussions. It is recommended, therefore, that national administrations and regulators **ensure administration costs are proportionate to the sector/business that is being regulated with the 'Polluter Pays' principle applied**. During the course of the project, it was suggested that charging systems are really designed for other industries and aquaculture suffers as such systems lack relevance. NGOs raised the issue of the application of the Polluter Pays principle to ensure a common approach to managing the environmental impacts across all industries.

10.2 Recommendations for the aquaculture industry

The results of the information reviewed in this project, reflecting good practice and what may be achieved by the aquaculture industry in improving the situation with respect to environmental regulation, covers subject areas that may be grouped under three headings: technology, management and liaison.

R5. **Technology:** In terms of the technology used by the aquaculture industry it is clear that as a first principle the **adoption of aquaculture production system types appropriate to the local environment** should be followed. This recommendation ensures that the type of system, the biomass of the farmed stock, and the environmental pressures are appropriate for the location, and the risk of serious environmental impact is reduced. Examples of this approach would be the adoption of robust aquaculture equipment appropriate for offshore locations as the industry develops in more exposed areas in marine sites. Within the licensing process such an approach ensures greater efficiency in processing applications. Other areas that have been highlighted in this work include: utilising partial or full recirculating aquaculture systems (RAS, e.g. Baltic) in part or all of the production cycle for finfish and use of wetland systems to manage environmental impacts and create potential biodiversity benefits. Aquaculture should also **continue to adopt new practices that improve sustainability**. As a comparatively young food production industry aquaculture has shown steady improvements in areas such as feed composition and utilisation (e.g. improved feed utilisation efficiency; new sources of raw materials), health management (e.g. use of vaccinated stock), water use efficiency (e.g. through RAS, partial recirculation, filtration). It is important that the momentum for continuing improvement is maintained. Although some technological advances will derive from academic research, the industry and supporting sectors (feed, equipment and pharmaceutical suppliers) will be the major route for these advances.

R6. **Management:** Looking at the management of aquaculture systems from an industry operator's perspective, the **adoption of an approach to the management of aquaculture systems that incorporates a broader ecosystem-level approach encompassing all**

environmental impacts (e.g. fish health, emissions, alien species, veterinary medicines, abstraction) is a step towards improving the level of environmental impact of the activities of the site. Approaches such as voluntary codes of practice, or certification schemes can provide frameworks within which industry may adopt such an approach. A combination of monitoring and the use of best available technology combined with best practices and codes of conduct/practice will contribute towards reducing environmental impacts from nutrient enrichment and help to achieve good ecological and environmental status as set out in the WFD and MSFD. Further consideration of the potential for management of systems by adopting a mass balance approach for nitrogen and phosphorous in any previously impacted locations e.g. Baltic and Black Sea together with further discussion of nutrient trading schemes (including co-location). In addition, the **practices of self-monitoring and reporting (e.g. Codes of Practice, certification schemes), especially those independently audited** can help clarify the environmental obligations of the industry, albeit within a non-regulatory framework. Such schemes also provide reassurance to customers and wider stakeholders on the production processes that have been adopted as well as transparency (if results are published). It is recognised, however, that such schemes do incur additional costs and those costs are borne by the industry.

R7. **<u>Liaison:</u> Liaise directly with regulators to achieve a common level of understanding about responsible aquaculture operations.** It was clear from the consultation process that sharing of information between industry and regulators would better inform the licensing process and regulation of the sector. Such liaison would improve regulators' understanding of industry impacts, developments and aspirations, and industry understanding of the requirements for environmental regulation. There is overlap with recommendation R1, above, where regulators are suggested to work with the industry to develop specific good practice guidelines for aquaculture. Improved liaison between both parties can only be helpful in clarifying the responsibilities of the sector and the objectives and interactions of aquaculture production systems. The new Aquaculture Advisory Council, as mentioned in the Strategic Guidelines for the Sustainable Development of Aquaculture in the EU (COM 2013a), has a role to "to provide recommendations to policy-makers, to help adopt evidence-based decisions", and is likely to work well as an interface between industry, national administrations and regulators, and policy makers.

10.3 Recommendations for further research

Key areas of research were identified in this project that were very broad in nature, and some were out of scope (e.g. feed). Those recommendations included are subjects for further research that will specifically support the study/identification of environmental impacts of the aquaculture sector in relation to WFD and MSFD.

R8. **Research that provides more accurate predictive models for the fate of nutrients that originate from aquaculture sites and their cumulative effects, as well as effective ways of mitigating those impacts.** The application of such models across EU-28 would help to standardise the approach to environmental regulation, where common or similar systems management may be regulated by the adoption of predictive models. An example of an urgently required model is that for offshore marine netpens for finfish cultivation, given the interest the sector has in developing in more exposed locations. More accurate predictive models for higher energy, exposed site will help to manage the nutrient emissions and other impacts of finfish farming in these locations, as the sector develops. The application of coastal models is unlikely to be relevant to these new locations. Alongside the requirement for better predictive models, monitoring may be supported through **research to improve monitoring techniques and support the development and use of best available technology to reduce environmental impacts.** This research should encompass all aspects of the environmental impacts, from nutrient emissions, to pathogen release and managing the risk of escapes and introgression with wild stocks.

R9. Although recirculation, whether as is a partial or full system approach, is often regarded as an answer to managing the environmental impacts of aquaculture – and was often referred to in the regional workshops- those systems have (mostly) yet to prove economic viability at this stage and there are questions regarding the volume of production that may be developed in such systems. **Research that supports the development of new, efficient and innovative water processing technology for land-based aquaculture systems (RAS)** will support the development of this technology, potentially partially mitigating the environmental impacts of the aquaculture industry during a period of growth. Capital and running costs remain, essentially, a major restriction to the uptake of RAS . Further development of RAS, improving efficiency and reducing costs, will support an increased in commercial production from these systems.

10.4 Recommendations to the European Commission Services for inclusion in the guidelines document to be produced as a result of this background document

Included, for consideration, are suggestions of key areas for the Commission Services to address in relation to aquaculture. These are points which do not fall within the responsibility of national administrations or regulators, nor are they areas that the industry can address directly. Some of these are contentious and need a strategic overview in order to make progress.

R10. Within the consultation component of this project, there have been some areas that have prompted extensive debate between the industry representatives and the NGO community, and there is a clear need to work on these topics to address confusion, misinformation and identify a way forward that supports the sustainable development of aquaculture. We highlight the **biological impacts of aquaculture e.g. non-native invasive species, sea lice in farmed salmonids, escapees and the risk of introgression with wild populations** in this regard and recommend that the Commission Services consider how the development of guidance may address these impacts**.** A broad range of views persists on some of the biological impacts of aquaculture. The key outcome of this recommendation would be clear, standardised approaches to managing biological impacts (e.g. how are pathogens managed according to the risk of transfer between farmed and wild stock?) that the industry and all stakeholders could understand.

R11. A specific issue related to the management of freshwater aquaculture facilities has been raised that is outside the area of responsibility of national administrations or regulators, and so logically falls to the Commission Services to address. That is the issue of **access to freshwater for aquaculture and, specifically, the management of abstraction in relation to flow-through systems.** The guidance delivered by the EFLOWS working group is very relevant to this point, and it is **recommended that the EFLOWS working group considers both the environment and the development of the aquaculture sector**. In freshwater systems the management of flow between the point of abstraction and the point of return of water to the river is a subject area of great importance to the industry and for environmental management.

R12. This project represents a very large information gathering exercise, not just on the types of aquaculture operated across EU-28 and the associated environmental impacts, but also in relation to the consultation with the national administrations, regulators, the industry and the NGOs across Europe. An enormous amount of information has been produced which may be helpful to the Commissions Services (and others) in developing guidance documents and associated material in the future. The project team recommends that **the project information be retained as a readily accessible and usable resource to provide information to national administrators, regulators, industry and NGOs in the future**. That information is a valuable resource that could potentially form the basis of an information portal on good practice in sustainable aquaculture development and regulation in relation to environmental protection. It is important that this information is retained and made available in an accessible manner.

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14 List of annexes in Part 2

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