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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 Water Framework Directive and Marine Strategy Framework Directive

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

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Executive Summary

To be completed

Acronymns

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
EU28 Member States of the EU
FM Fishmeal
FCR Feed Conversion Ratio
FWFD Freshwater Fish Directive
GEcS Good Ecological Status
GEnS Good Environmental Status
GES Good Environmental Status
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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Executive Summary

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 2013a). 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 2013a). 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 development of sustainable aquaculture is dependent on clean, healthy and productive marine and freshwaters. 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 2008) aim to protect and enhance aquatic environments and to ensure that the uses to which they are put are sustainable in the long term. 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 general objective of the WFD is to achieve good ecological status and good chemical status for all surface waters by 2015. Other pieces of environmental legislation that support the WFD and MSFD include: a dedicated legislative instrument on invasive alien species (COM(2013) 620 final) which builds on similar legislation specifically for aquaculture (EU 2011); and the Environmental Impact Assessment (EIA) (COM 2014a) and Strategic Environmental Assessments (SEA) Directives (CEC 2001a).

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 the sustainable development of aquaculture must begin with a healthy aquatic environment.

1.2 *Purpose of this guidance document*

The overall aim is to provide guidance on the implementation of environmental legislation (especially WFD and MSFD) in the context of the development of sustainable aquaculture. This guidance document outlines how best to manage the environmental impact of aquaculture activities, and to support the potential realisation of mutual benefits between aquaculture development and environmental protection, in the context of the legal obligations under EU legislation. 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 (CEC 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 producers** - to provide practical guidance on what they can expect from the implementation of the Directives and what is expected of them;
- **Non-Governmental Organisations (NGOs) and civil society** - to demonstrate the options available for the sustainable development of aquaculture in the EU.

1.3 *Document development*

Although this document is based upon literature searches, it has been developed with input from policy-makers, regulators, industry and NGOs across the EU28, as well as a number of third countries. To facilitate knowledge exchange, two-day good-practice workshops were held in the four European regions (North East Atlantic, Mediterranean, Baltic and Black Sea/Danube, with the latter having a particular focus on freshwater aquaculture). These workshops brought together relevant stakeholders to build up a clear picture of activities taking place on the ground, and to discuss opportunities and challenges presented by the current legislative framework (WFD and MSFD in particular). To ensure that the document is fit for purpose, two further workshops were held at the start and the end of the consultation process; invitees were Member State experts responsible for implementing environmental legislation and development of the aquaculture sector, and relevant aquaculture experts from both industry and civil society.

1.4 ***Limitations of this guidance document***

This guidance document is intended to be 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 guidance 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. Wherever relevant, existing case law has been included when a clear position has already been taken by the Court. Furthermore, 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.

Finally, the guidance recognises that the Directives are enshrined by the principle of subsidiarity and that it is for Member States to determine the procedural requirements deriving from 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 EU28 aquaculture and environmental impacts

2.1 *Production from EU aquaculture*

Regulation (EC) No. 762/2008 (COM 2008) 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 EU28. 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 is 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 EU28 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 EU28 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. **It is recommended that Member States submit the required data on aquaculture to ensure reliable statistics are available.**

Although EU28 aquaculture is very diverse with production spread across more than 100 species categories, a limited number of species dominate. In 2012, EU28 reported aquaculture production comprised: 36% mussels (384,604 tonnes), 17% Atlantic salmon (175,009 tonnes), 14% other salmonids (mainly rainbow trout, 143,646 tonnes), 13% seabass and seabream (135,863 tonnes), 9%

oysters (93,911 tonnes), 7% carp (74,363 tonnes), 3% other marine fishes (265,929 tonnes), 2% other freshwater fishes (16,124 tonnes) and 1% 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.

Five Member States dominate EU28 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 & marine	Finfish
Lagoon & valiculture	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 open 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 salmon net pen farms in Scotland was 8,116 m^3 in freshwater and 70, 153 m^3 in seawater (Munro & 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) settle to the bottom. For chemotherapeutic treatments, 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. 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 salmon land-based farms 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 not required as the fish (mainly carp) production typically corresponds to the natural productivity of the pond.

Lagoon culture

Lagoon culture (Ardizzone GD, Cataudella S 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. 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).

The potential environmental benefits of finfish farming also merit recognition. Putative positive effects that act at local levels 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).
- 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).
- 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.: Impacts should be viewed as potential rather than actual, due to lack of direct research, difficulties of unequivocally validating all stages in causal pathways in field studies, differences between geographical areas, sites and studies, changes over time, and bias favouring publication of studies highlighting impacts.

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 Reantas 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 (Rasmussen 1986b; Fausch 2007; Gozlan 2008).	•	•			
	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 *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 a lower stock density can be achieved. 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; Hefferman 1999; Forrest and Elmetri 2007; Bouchet and Sauriau 2008). A summary of the possible effects 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.

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 (Hefferman 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; Hefferman 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; Hefferman 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; Hefferman 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; Hefferman 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; Hefferman 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; Hefferman 1999; Beadman et al 2004; Bouchet and Sauriau 2008; Forrest et al 2009)
•	•	•	•	Biosecurity issues due to introduction of shellfish	Introduction of disease resistant species to replace stocks affected by disease	Introduction of 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 Replacement for native shellfish reefs lost through effects of disease and over fishing (Hefferman 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 infaunal communities at high mussel density Introduction of non native species Loss of genetic diversity through aquaculture introductions Translocation of species (Hefferman 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 High densities of shellfish can counteract symptoms of eutrophication Low trophic level of bivalve molluscs leading to a reduced trophic	Shell extraction by harvesting affecting carbonate budget of estuarine environments Localised organic enrichment of benthos and resultant oxygen depletion (Kaiser et al 1998; Hefferman 1999; Rice 2008; National Research Council 2010)

					footprint for shellfish aquaculture (Kaiser et al 1998; Diederich 2005; Rice 2008; National Research Council 2010)	

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

3.1 ***Outline and objectives of WFD & MSFD, how they work, their differences and overlap.***

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 to territorial waters (out to 12 nm)**.** The general objective of the WFD is to achieve 'good ecological status' and 'good chemical status' in all surface water bodies by 2015. The WFD classification scheme for water body quality includes five status classes: high, good, moderate, poor and bad, where good status represents a slight deviation from reference conditions (WFD Annex V). Classification of final status is determined for each water body for a range of biological quality elements. These are supported by hydromorphological, chemical and physico-chemical quality elements; the chemical and physico-chemical elements include temperature and nutrient and oxygenation conditions, as well as specific pollutants (WFD Annex V, and Annex VIII). The overall status of a water body is determined by that of the lowest value of the quality element used, i.e. a 'one out – all out' approach (see Fig 3.1).

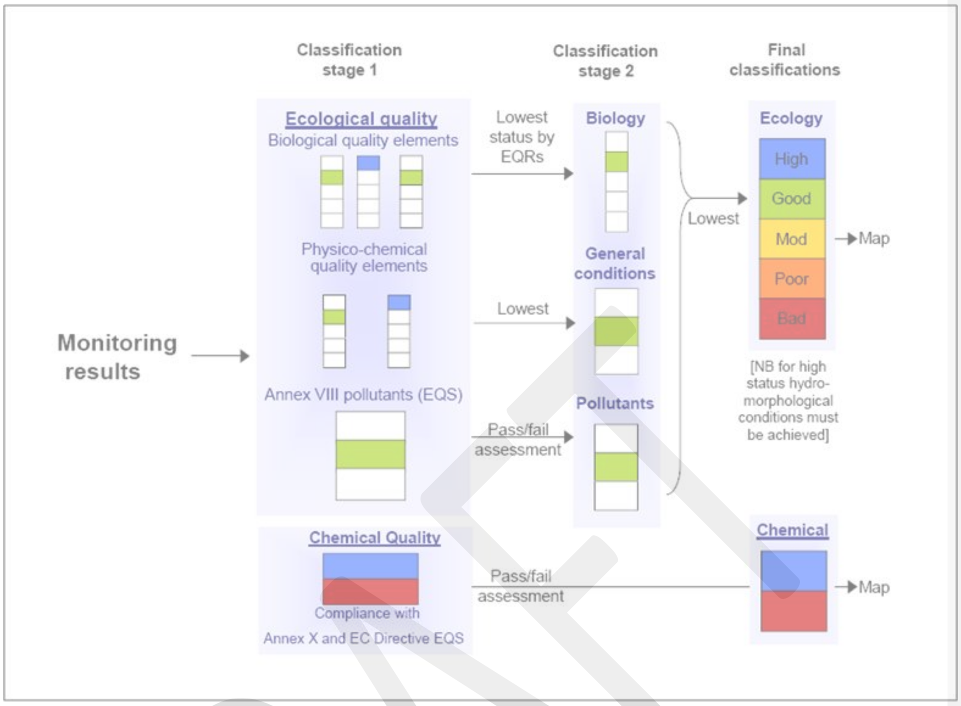

Fig.3.1: Classification of surface water bodies under the Water Framework Directive (WFD, from Jacklin 2007). Biological elements are compared against reference conditions and are used to determine ecological status in one of 5 categories (bad to high). The final assessment takes account of hydromorphological conditions and supporting physico-chemical and chemical elements, including specific pollutants (Annex V and VIII). For chemical elements, status is expressed by an Ecological Quality Standard (EQS). The overall status of a water body is determined by that of the lowest value of the quality element used. Biological elements include phytoplankton, macroalgae, benthic fauna, fish fauna. Physico-chemical elements include temperature and oxygenation and nutrient conditions. EQR (used by some countries) = Ecological Quality Ratio, a ratio of measured vs reference values.

The MSFD aims to achieve good environmental status (GEnS) 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 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 jurisdiction (MSFD, Article 3.1). To help achieve GEnS, 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 (see Fig. 3.2); and that assessment regions of the MSFD are broader, requiring achievement of good environmental status at the scale of the relevant sub-regions (e.g. Greater North Sea, Celtic Seas *vs* WFD individual water bodies). The two Directives also take different approaches to protecting the marine environment (Fig. 3.2). The MSFD approach takes account of the structure, function and processes of constituent ecosystem, focussing on 11 descriptors which together indicate environmental status, whereas the WFD splits the ecosystem into constituent parts and assesses the individual quality of each part separately, with the final classification determined by the quality of the worst element.

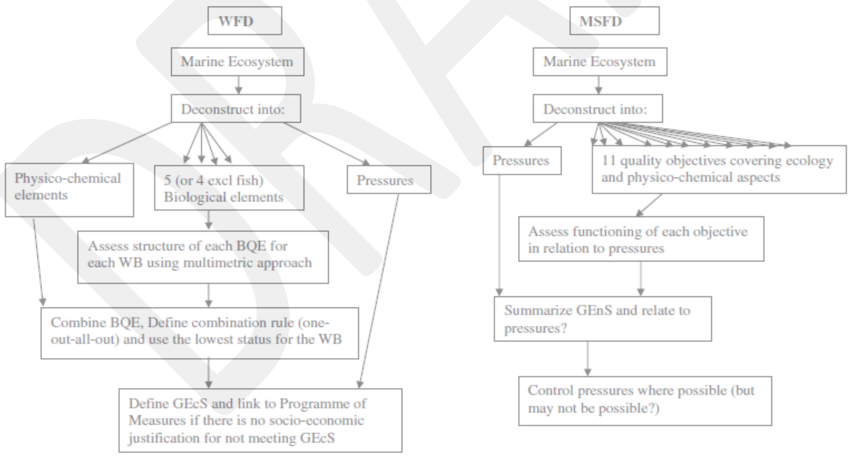

Fig. 3.2: Comparison of the process for assessments under the Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD). BQE = biological quality elements, WB = water body, GEcS = good ecological status, GEnS = good environmental status (from Borja et al. 2010).

The boundaries for MSFD and WFD assessments overlap in coastal waters (Fig. 3.3). 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).

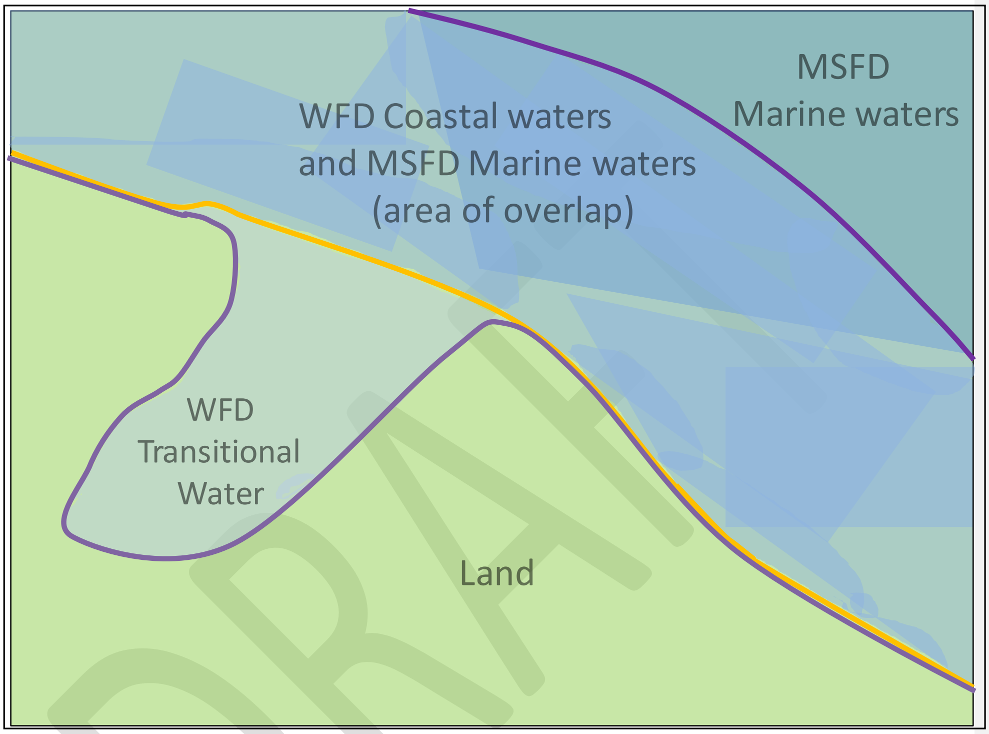

Fig.3.3: Diagram to indicate overlap between the WFD and the MSFD. The WFD applies to estuaries and coastal water bodies out to 1nm (baseline + 1nm) for biological status, and 12nm for chemical status. The MSFD applies to marine waters and includes coastal waters not addressed by the WFD or other Community legislation, as well as the full extent of the territorial waters of Member States (see text).

3.2 *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 as well as dispersal of cleaning agents/medicines. In addition, aquaculture can itself be the subject of pressures and impacts from other activities taking place in the aquatic ecosystem, for example pollution incidents, waste water treatment facilities upstream of aquaculture production areas 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 is principally a non-consumptive industry, i.e. water is not permanently removed.

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 (including presence or absence of various algae, plants, fish and invertebrates);
- physical and chemical quality (including oxygenation and nutrient conditions) that support the biological quality of the water body;
- environmental quality standards for levels of specific pollutants such as pesticides (Annex VIII) that are specific to the particular river basin district and support the biological quality of the water body; and
- physical aspects 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 for each of the 4 surface water body types are summarised in Table 3.1.

Table 3.1: 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 impact upon ecological and chemical status requirements 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 impact upon status requirements 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 which may impact upon 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).

3.3 *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 2008). 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 2008). 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, 2013a, Habitats Directive - CEC, 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) by 2020. European marine regions were defined for the purpose of monitoring water status and developing actions to achieve GES (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 in respect of their marine waters and
- establish a series of targets in order to reach GES.

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 2014b).

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 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 2008).

3.4 *Common interactions and requirements between aquaculture and MSFD*

An assessment of the potential interactions between aquaculture 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 2014b), 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 3.2). 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 2014b) shows which Member States have linked aquaculture to specific MSFD descriptors. This simple impact assessment shows that the aquaculture impacts 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 may be very limited. 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 2014b), although aquaculture is a source of contaminants (see for example UK (Defra 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 one of many factors affecting these descriptors and is far from being a significant contributor to non-indigenous species, eutrophication, sea floor integrity and marine litter. The information in Table 3.2 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 3.2, Evidence & mitigation column). However, such effects are dependent on 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 3.2: Potential interactions between aquaculture and MSFD 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, EL, 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 (COM 2007; COM(2013) 620 final). 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		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, EL, 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, EL, 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 (CEC 2006; COM 2011a; COM 2011b).
9. Fish & seafood contaminants	CY, DK, EL, 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 2014b). Even if this is not the case, impacts are assessed using regulatory limits set within food safety legislation (CEC 2006; COM 2011a; COM 2011b).
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 2014b). 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)		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 issues 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 2000). Hence, at the current scale aquaculture production is likely to have only a marginal impact on the achievement of GES 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 this is regulation on alien species in aquaculture (COM 2007a) (EC 2007) and the forthcoming Regulation to prevent the introduction and spread of invasive alien species (COM(2013) 620 final). 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.

It is possible that some regions are more sensitive to pressures from aquaculture due to the physical environment or hydrodynamic conditions. As anticipated 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 for the implementation of the MSFD:

- positive 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).
- positive benefits of sustainable aquaculture on delivering GES, e.g. reduced pressure on commercial fish stocks and better ability to achieve GES 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 2013a) 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 potential 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 on increased nutrient load, eutrophication, sea floor integrity are expected to be low. It is very difficult to say how this interaction might affect aquaculture as the technology is changing and as such any evaluation of this is unlikely to occur until the next cycle of the MSFD. Changes in technology and implementation of MSFD are very difficult to predict, so it is difficult to assess future interactions. However, if we assume that the pressures from aquaculture are like to remain the same, there are a number of technologies and examples of best practice that can reduce the potential impact of aquaculture on MSFD. These centre on licensing, non-indigenous species, eutrophication, sea floor integrity, and marine litter and are described below.

Comment [CA1]: This is a strange link to the CFP regulation. There is not any other reference?

3.5 *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. As such, any discharges from aquaculture will be regarded as point-source inputs and thus monitoring information is likely to be required as a precursor to management.

Article 4 of the WFD requires Member States to prevent deterioration of ecological quality and pollution 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. Countries have to assess the susceptibility of the surface waters to impacts resulting from anthropogenic activities. They will 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.

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.

3.6 ***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 10.1), particularly in intensive rearing systems (Burridge et al 2010)(GESAMP (Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection) 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 3.1: 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 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 is carefully managed, their discharge into the aquatic environment from farms where they have been used 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 (Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection) 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 Environmental Quality Standards (EQS) Directive (2008/105/EC), environmental quality standards have been established for 45 priority substances and 8 other chemical pollutants of high concern across the EU. The amended Priority Substances (PS) Directive 2013/39/EU (due to enter into force on 14 September 2015) will add an additional 12 substances to the list of regulated chemical pollutants. The EQS and PS 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 may also set EQS for those pollutants covered by Annex VIII of the WFD. Achievement of the WFD objective of good chemical 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 WFD standards 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). Biota standards are being introduced, initially only for mercury (Hg), hexachlorobenzene (HCB) and hexachlorobutadiene (HCBD). Nationally, MS can also implement their own separate controls for the discharge of chemicals. In terms of medicines used to treat aquacultured animals, it is a requirement under Directive 2001/82/EC (as amended) to undertake an EIA prior to obtaining a Marketing Authorisation. 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 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, a number of substances covered by Annex VIII of the WFD as river basin specific pollutants are of aquaculture relevance. These include certain heavy metals (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, 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 3.3. 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 RBSP under WFD.

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 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.

3.7 ***River Basin Management Plans (RBMPs) and aquaculture***

3.7.1 Introduction

RBMPs for 20 countries were evaluated from the EU RBMP directory found on the EU website at http://ec.europa.eu/environment/water/participation/map_mc/map.htm (19 Member States [MS] and Norway).

3.7.2 Aquaculture and RBMPs

Aquaculture is recognised as being a major user of water resources within RBMPs (Czech Republic; Estonia; France; Hungary; Italy; Spain) and is identified as exerting pressure with respect to the WFD. Many MS highlight the industry as a point source of pollution (Estonia; France; Germany; Greece; Hungary; Ireland; Lithuania; Netherlands; Norway; Poland; Spain; UK) and note that aquaculture operations are responsible for localised reductions in benthic biodiversity (Greece; Ireland) and for the introduction of alien species (Greece; Hungary; Ireland; UK; Norway) or exotic disease and parasites (Ireland; Netherlands; UK; Norway). Numerous RBMPs also attribute physical modification of land e.g. drainage of river channels, erosion, changes in flow regimes (Ireland, Spain) or significant dredging of water bodies (Czech Republic; Germany; Hungary; Italy) to fish farming operations.
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 of 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 between 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 aquaculture production in the country (many very small scale producers with low profit levels and antiquated equipment) and economic capacity of the country, 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.

3.7.3 Shellfish culture and RBMPs

Since the repeal of Directive 2006/113/EC on the Quality Required of Shellfish Waters in 2013 the WFD has been employed to provide at least the same level of protection to shellfish waters (which the WFD classifies as protected areas) as the previous Shellfish Waters Directive did. The additional measures put in place to achieve this can be of the same nature as those for the WFD (e.g. measures to reduce nitrogen loss from agriculture or measures to improve the hydromorphological status in a river) but must reach a higher level of improvement of status. 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 some MS there is a relationship between Shellfish Protection Areas and Shellfish Production Areas. In these cases, even if the additional measures are not clearly described within the RBMPs, it may be inferred that a level of protection is given. In a number of RBMPs additional objectives and measures have been established above those required to achieve other WFD objectives through the establishment of, for example, pollution reduction programmes (e.g. Ireland). For other MS such as the UK, this information was not clearly stipulated in the RBMPs but could be inferred from other sources of information or established through national regulation (e.g. France, Italy, Germany, or the Netherlands). National regulation for the UK confirmed that measures undertaken within RBMPs will achieve objectives associated with Production Areas. 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 to reach those objectives.

3.7.4 Looking forward to the second round of RBMPs

It is understood that the EU Commission is strongly encouraging Member States to fully include aquaculture within the 2nd round of RBMPs. It is recommended that there should be substantially better integration of aquaculture into the 2nd round of RBMPs if the industry is to prosper.

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

4.1 *Repealed legislation: Shellfish Waters Directive*

The Shellfish Water Directive (SWD) 2006/113/EC (codified version) (EU 2006), adopted in 2006 repealed the original Directive 79/923/EC (CEC 1979) from 1979. 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 molluscs) 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). MSs 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 e.g. the SWD, Urban Waste Water Treatment Directive 91/271/EEC (CEC 1991), and implementation of the WFD will ensure no deterioration of water quality in Shellfish Protected Areas, from water quality pre-SWD repeal levels. Under the first cycle of WFD River Basin Management Planning (RBMPs were due for submission in 2009), 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 may keep or amend/develop their own national legislation transposing the SWD and retain their existing microbiological standards for shellfish flesh. Other standards implemented by the WFD may be **more** stringent and protective of shellfish waters than SWD standards (e.g. Environmental Quality Standard (EQS) for mercury is lower 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 waters covered by the WFD). As with the WFD, the MSFD also implements 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 MSFD and WFD and remain at least as protective of shellfish waters as was the case under SWD.

General aspects of 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 under the polluter pays principle where appropriate; protection of public health by setting environmental quality standards for shellfish protected areas and setting monitoring programs; enabling healthy, diverse and productive waters (including limiting the spread of disease and non-native species).

4.2 ***Guidance Recommendations:***

- During the second cycle of river basin management planning to develop second RBMPs, MS could add in more information on shellfish aquaculture and add detail to the written documents.
- MS could review their national legislation transposing the SWD/WFD requirements for Shellfish Protected Areas and assess its adequacy to protect the life and growth of shellfish and the quality of the shellfish for the consumer.
- MS could continue to 'endeavour to observe' a standard at least equivalent to the SWD guideline faecal coliform standard and other SWD guideline standards rather than just achieve the equivalent mandatory standards, in order to offer at least the same level of protection to shellfish.

- MS to be aware that viral standards are under consideration and may be required for shellfish production areas/protected waters, in the future.
- MS could ensure that implementing the MSFD and WFD allows for the development of sustainable bivalve mollusc aquaculture, where this is seen as appropriate.

The SWD was repealed with effect from 22 December 2013. 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) (EU 2000) prior to the repeal. The MSFD has broadly similar approaches and objectives to WFD, and applies to marine waters which fall under MS jurisdiction (including those coastal waters covered by the WFD). The WFD and MSFD have no microbiological standards for bacterial or viral pathogens. MS should consider reviewing and retaining their national transposition of SWD legislation and standards, or develop new national legislation, to ensure compliance with MSFD and WFD and remain at least as protective of shellfish waters as was the case under SWD.

4.3 ***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 and, although not relevant directly to aquaculture, did cover natural waters supplying land-based systems and in which net-pen systems were used. The quality of waters in such systems were 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).

Obvious concerns are that the WFD will not offer the same level of protection as the FWFD. However, the WFD does include those parameters listed within the FWFD, and also includes additional parameters such as disinfectants and antibiotics. 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 until the 2016 review of RBMPs. This is because within the WFD, the deadlines to achieve Good Ecological Status and Good Chemical Status in all water bodies are 2015, 2021 & 2027; there is a potential window of 12 months in 2014 in which some deterioration is possible theoretically without breaching the legislation.

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

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*." For example, information generated from the implementation of the Strategic Environmental Assessment Directive (CEC 2001b) and Environmental Impacts Assessment Directive (COM 2014a) may (to a greater or lesser extent) may contribute to Member States determination and assessment of Good Environmental Status.

5.1 ***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 2003). Article 1 of the Directive (CEC 2001b) 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 and as such, 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 (www.europarl.europa.eu/sides/getDoc.do?type=TA&language=EN&reference=P7-TA-2014-0449) 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 (CEC 2001b).

5.1.1 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, K., Porter, S., Clark, B.M. and Sink 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.

5.2 ***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 (COM 2012c) as amended by Directive 2014/52/EU (COM 2014a). 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 & 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).

5.2.1 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*."

5.3 ***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 conclusion of SEA and EIA are options and recommendations on the nature and scale of adverse effects and how these may be mitigated which informs the decision on whether or not it is 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 on whether or not it is authorised 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) imperative reasons of overriding public interest can be demonstrated, and compensatory measures are taken.

The EU guidance on Aquaculture & 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).

6 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 recently adopted an ambitious new strategy (COM (2011)244) 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 on reducing the risks from pathways for introductions. The pathways of introduction are numerous, e.g. movement in ballast water, on recreation 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, and explains how alien species fit within WFD and MSFD.

6.1 *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 is expected to be adopted by the end of 2014 and enter into force in January 2015. The forthcoming IAS Regulation is not specific to aquaculture and covers a wider remit, including all IAS and covering all activities and sectors. The Annex IV species listed in Regulation (EC) No708/2007 are excluded from the scope of the new invasive alien species 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 forthcoming IAS Regulation aims to establish 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 forthcoming IAS Regulation are linked to prevention, early detection and rapid eradication of IAS and management of established IAS.

6.2 *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 C. 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 and 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 for the Baltic Sea (HELCOM 2013a) 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 C. 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. 6.1).

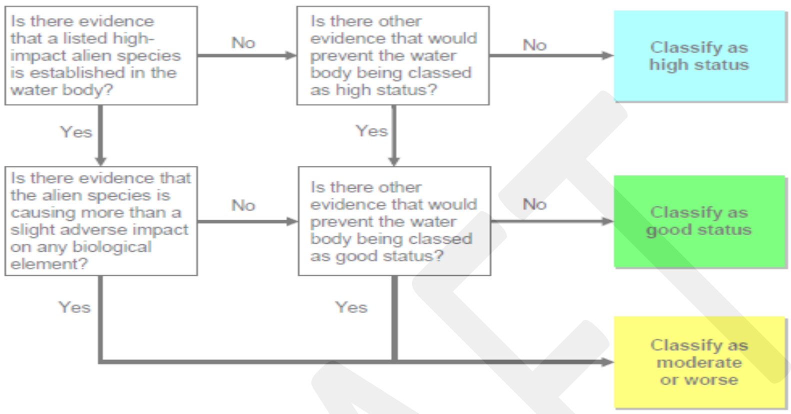

Fig. 6.1: Procedure for using alien species data in assessing ecological status. (UKTAG 2013)

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 where water bodies are classified without explicitly taking account of alien species. A separate 'risk assessment' for alien species is undertaken, by 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 C. 2009; HELCOM 2013a)
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).

6.3 *Alien species in the context of MSFD*

Unlike the WFD, the MSFD (EU 2008) explicitly covers IAS under one of the 11 Good Environmental Status (GES) 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 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-native 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).

7 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 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 major EU aquaculture associations and platforms.

7.1 ***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.

7.2 ***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 in later sections of the report).

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;
- How to implement the Polluter Pays Principle to aquaculture in accordance with a cost recovery approach for regulators;
- 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;
- The issue of when an introduced species becomes naturalised in a particular location (e.g. Pacific oyster), and what this means for regulation and further development of the sector.
- 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?

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;
- Access to freshwater for aquaculture, especially in comparison with other industries such as agriculture;
- Discharge parameters and emission permitting, determination of environmental /ecological flows within a river catchment, and what this means for permitting aquaculture production systems;
- Water use and charging for an industry that produces emissions in the effluent but effectively shows non-consumptive use of water;
- 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.";
- Consistency in approaches taken by regulators to monitoring emissions by the industry.

Areas requiring further R&D and standardisation across MS:

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

Areas where a level playing field is required:

- The aquaculture industry should have the same equal rights to space and water as other users;
- National Administrators and regulators should have common guidelines for environmental licensing;
- 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.

Problem areas 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?
- The apparent misuse and subjective interpretation of WFD monitoring results to the detriment of the industry;
- A variable attitude of regulators between and within MS on aquaculture regulation;
- 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).

7.3 *Conclusion*

The strategic guidelines have outlined the high level needs of the sector such to develop sustainable European aquaculture, i.e. simplification of administrative procedures, co-ordinated spatial planning systems, improving competitiveness, creation of a level playing field. The main European umbrella organisations (FEAP, EATip, EAS, EFARO) broadly agree on sector needs and have identified these in visions and plans for the future. Areas identified by stakeholders as requiring attention and more sector specific guidance for MS include: access to water and charging policies for aquaculture; the application of recognised principles to the aquaculture sector; clarification of application of certain legislative articles to aquaculture; streamlining of approaches to regulation; recognition of ecosystem services provided by some industry sectors.

Good practices for national administrators 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 in guiding, communicating and implementing the Directives requirements.

7.4 *Explanation of the obligations of administrators to provide clear systems and guidelines and an efficient licensing process that delivers decisions within a set time frame*

The WFD and the MSFD 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. 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. However, the 'Strategic guidelines for the sustainable development of EU aquaculture' (COM 2013a) do 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 2007b).

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.

7.5 ***Feedback from Regional Workshops.***

Findings from Breakout Session 2 of the regional workshops (Dublin 10 - 11th April 2014, Athens 5 - 6th May 2014, Vienna 20 - 21st May 2014, Copenhagen 12 - 13th June 2014) are summarised below.

7.5.1 "What constitutes good practice for effective and cost-efficient transposition and implementation of the WFD & MSFD?"

A qualitative analysis was undertaken by the project team on the information received in discussions. Comments received at all the four workshops were reviewed and grouped according to a *post hoc* defined subject area. Scores for each of the subject areas were produced, and are presented (Fig. 9.1) with a descriptive synopsis produced for each subject area.

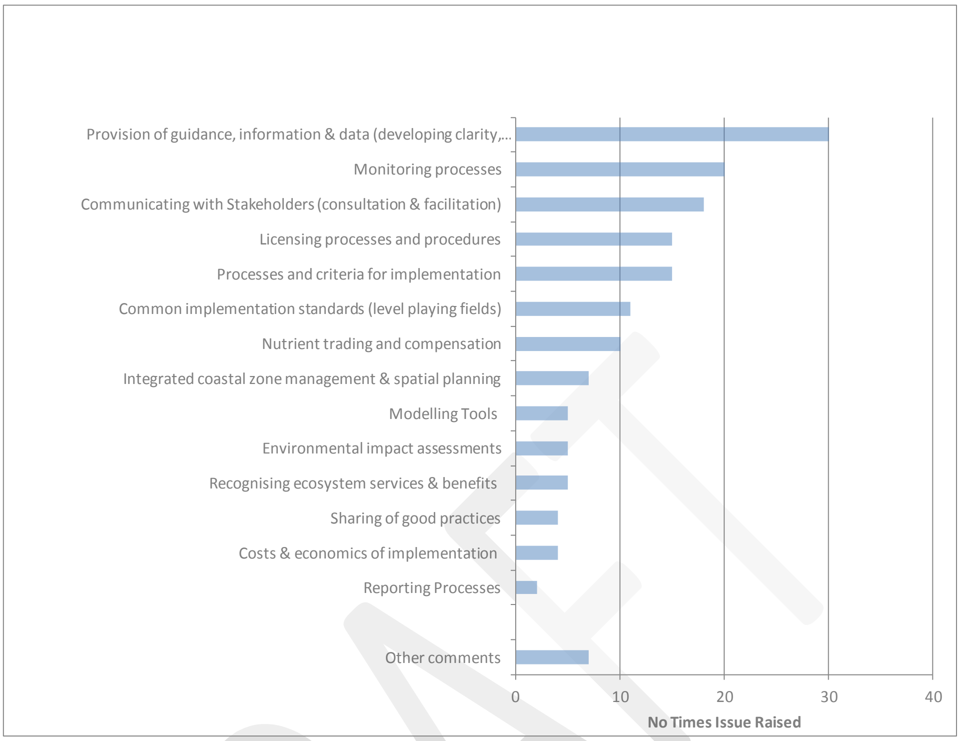

Figure 7.1: Responses to question: "What constitutes good practice for effective and cost-efficient transposition and implementation of the WFD & MSFD?"

7.5.2 Synopsis of comments received

Provision of guidance, information & data (developing clarity, understanding & openness): Provision of clear guidance on WFD & MSFD and other environmental legislation and how they relate to aquaculture is essential. This guidance should provide a common understanding and interpretation of Articles and Directives and provide clarity on what is required leading to a more coherent approach. However, where required the guidance should allow for regional or national needs in relation to implementation without providing barriers to trade or excessive regulatory burdens. Guidance should address the issues that are contentious and causing confusion. To build trust and confidence, data and information from regulators on aquaculture performance should be transparent and readily available for stakeholders. Knowledge and understanding of aquaculture technology needs to be developed within stakeholder groups including regulators.

Monitoring processes: Standardised methodologies and appropriate monitoring of similar aquaculture systems would be beneficial. There is a need to agree EQS for different regions and species. This may require further scientific research and the adoption of risk based monitoring approaches. Such an approach should build on EU project work and work with other MS and European countries as well as organisations such as ICES.   Baseline information is required so that possible effects can be monitored, including at large scales (but taking into account the relative contributions of aquaculture against those of other industries) and should consider the broader picture of what else is happening in the water body.

Communicating with stakeholders (consultation and facilitation): Time should be taken to allow for open consultation across all stakeholders and users. Local communities and authorities should be included. Clarity and understanding is required across boundaries and between ministries. Feedback and review mechanisms should be clear and continual. Translations into local languages must be available. Adaptive strategies and conflict resolution procedures should be considered, and the appropriate amount of time should be taken for consultation.

Licensing processes and procedures: The licensing application should be processed swiftly without undue delay and the conditions should deliver the requirements of WFD and MSFD. The duration for licence applications to be processed should be standardised across EU28. One-stop-shops have been proposed as a means of supporting these aims. Harmonisation of licensing across Member States and sectors would be beneficial. Systems in place need to ensure that the standards applied to currently operating sites are updated to be the same as those applying for new licences when existing licences are renewed. Approaches taken should account for any local variations that may be present under certain conditions. Appeal systems should be available when either applying for, or renewing, licences. The inclusion of aquaculture in RBMPs may be helpful.

Processes and criteria for implementation: Implementation processes should draw from experiences in other fields, e.g. hydropower, and the concept of proportionality needs to be followed. Care should be taken to provide balanced, practical, feasible, simple and streamlined regulations that target the issues concerned without duplicating other regulations.

Common implementation standards (level playing fields): The common implementation of Directives helps provide a level playing field across MS. The implementation should be consistent across different sectors for the same issue e.g. nutrient loads so that some sectors are not disadvantaged. The standardisation of the approach is key. Efforts should be targeted where conflict exists between Directives and to areas of contention such as the application of minimum flow criteria.

Nutrient trading and compensation: This issue was discussed at length in Copenhagen, where there was a real focus on the topic in relation to the Baltic Sea – see section 9.2.2.2 and Annex 4. Compensation methods and nutrient trading schemes should be considered as a permitting option by regulators in areas where good ecological status is compromised or threatened. Further research is required within this area. Technological solutions are likely to become available to help reduce input of N and P.

Integrated coastal zone management and spatial planning: Integrated coastal zone management and spatial planning that incorporate aquaculture and its impacts will help deliver WFD and MSFD objectives and sustainable industry growth. Allocation and sharing of space with other industries are important issues. The marine planning process is important in affording the industry the opportunity to grow.

Modelling tools: The use of approved validated scientific modelling systems based on good baseline data can identify likely impacts and position sites with reduced impacts accordingly. Acceptance and recognition of these models across the EU needs to be achieved. The use of the near field and far-field concept is an option. Models should be validated and improved over time, in order to provide more accurate predictions of impacts.

Environmental Impact Assessments: EIAs should be used to inform decisions before permission is given. The scale of the EIA needs to be appropriate with the size of the operation. Common approaches and standards are needed for EIAs across Member States for equivalent types of aquaculture.

Recognising ecosystem services and benefits: The ecosystem services and benefits provided by some types of aquaculture should be recognised when implementing WFD and MSFD. Workshop contributions highlighted mutual benefits between environmental regulations and the aquaculture industry. For example, sustainable finfish farming can offer environmental services (water quality and purification effects, phosphorous and nitrogen retention), water management and water retention services (e.g. irrigation and flood control, wetland habitats, increased biodiversity) appropriate to WFD objectives. There may also be broader environmental (and social and economic) benefits of some aquaculture systems.

Sharing of good practices: The sharing of good practice and implementation of voluntary schemes such as codes of good practice are cost efficient and effective mechanisms for implementation of WFD and MSFD objectives.

Costs and economics of implementation: The economics and costs of implementing new Directives should be considered and made transparent from administrative levels to producers.

Reporting processes: Reporting requirements should be proportionate, feasible and risk based.

Other comments included: algal toxins and sources should be considered; labelling and benchmarking are important drivers giving consumers choice.

7.6 ***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 communicated. 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.

7.6.1 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. 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).

7.6.2 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 to assist sustainable development in general, as well as providing clarity about the application of the WFD and MSFD. Examples include Hungary in the freshwater environment and also Greece through spatial planning in the marine environment (see section 8.3.4 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 (presentation No. 8). The main actions of the strategy are to simplify administration, enhance competitiveness, spatial planning and a level playing field.

However, the development of strategies is not a guarantee of success as shown by Galicia, where external factors inhibited aquaculture development despite an agreed strategy being in place, as presented at the Dublin workshop. Work began in 2008 on a new Galicia 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 there are many rules that were not framed with aquaculture in mind but nevertheless inhibit its development.

7.6.3 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 guidance documents, handbooks etc. as appropriate. 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/).

Aquaculture can attract negative attention in Ireland. The public perception is influenced by the environmentally damaging image often portrayed in the media. 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.

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 their 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 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.

7.6.4 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, modelling the potential impacts, and the potential to impact on Natura 2000 sites (Anders Vedel presentation at the Copenhagen workshop). Other countries also have their own marine legislation for aquaculture including Greece (Greece 2011) – see below. The Greek legislation sets out the process for aquaculture licences, but also encouraged the creation of Areas for Regulated Aquaculture Development (ARAD) (Greece 2011).

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 systems (EQSs)
- 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 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.

7.6.5 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 Galicia, Spain where evidence was presented that aquaculture was not considered a priority in that it was only ranked as the 5th priority in a list of water uses produced for the WFD, whereas agriculture was ranked 2nd. Potential conflicts between aquaculture operations and projects such as e.g. 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, when 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.

7.6.6 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, i.e. it should look at what is really appropriate to measure. Examples of unnecessary monitoring currently in place cited 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.

7.6.7 Administrative costs

Administrative costs should be proportionate to administrative effort required and should be fairly allocated across different sectors. In discussions, the industry generally felt that no account was taken in the freshwater regimes that their use of water was non-consumptive 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 an additional cost on producers.

7.6.8 Appropriate use of the Precautionary Principle

The Precautionary Principle should be applied in a sensible and pragmatic manner. Some producers believe that some regulators are applying the Precautionary Principle in a very stringent way to aquaculture development proposals that inhibits their development. Consequently, 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 enable further activity to take place, while maintaining the underlying obligation to ensure that the development of the sector is sustainable.

8 Minimising specific environmental impacts through good practices by administrators 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) can indirectly contribute to improvements in environmental performance.

8.1 ***Feedback from regional workshops***

Below is a summary of the findings from Breakout Session 1, of the four regional seas workshops (Dublin 10 - 11th April 2014, Athens 5 - 6th May 2014, Vienna 20 - 21st May 2014, Copenhagen 12 - 13th June 2014).

8.1.1 "What constitutes good practice for ensuring better environmental performance across all types of aquaculture in the context of WFD & MSFD?"

A qualitative analysis was undertaken on the information received in discussion during the breakout groups by the project team at the regional workshops. Comments received at all the four workshops were reviewed, and grouped according to a *post hoc* defined subject area. Scores for each of the subject areas were produced (Fig. 8.1) and a text synopsis produced for each subject area.

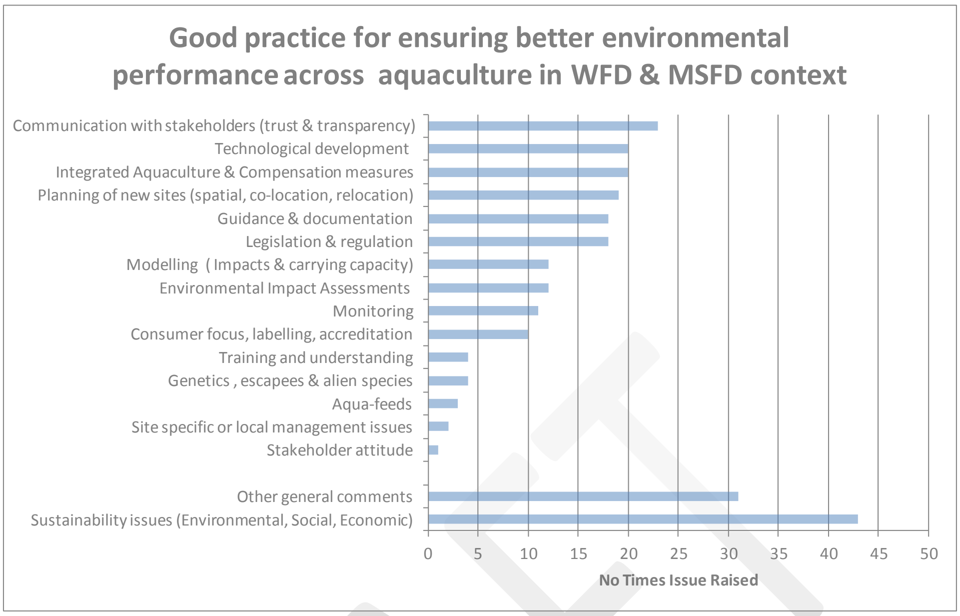

Fig. 8.1: Scores for subject areas discussed in relation to the question "What constitutes good practice for ensuring better environmental performance across all types of aquaculture in the context of WFD & MSFD?"

Communication with stakeholders (trust and transparency): Communication with stakeholders is important in terms of building trust and transparency. Effective consultation, outreaching and inclusion of all stakeholders leads towards improved sustainability. Release of information and communication between administrators and data holders helps develop trust. Sharing of good practice leads to improved environmental performance. Communication should be clear and provided in native languages whenever possible.

Technological development: Further development of new technology such as feeding and farm management systems can help reduce the level of impacts. RAS may play an important role but the commercial viability and competiveness of these systems were questioned and concerns were about technical requirements and issues around disease.

Integrated aquaculture and compensation measures: Integrated aquaculture such as IMTA or aquaponics is seen as having potential to improve environmental performance across aquaculture sectors. Much research, data and sharing of good practices are needed to inform future practices in this area. The nutrient extractive nature of shellfish and seaweed culture may be able to mitigate against potential inputs of N and P.

Planning of new sites (spatial, co-location, relocation): Site selection and location of certain types of aquaculture play an important role in reducing environmental impacts. Spatial planning for aquaculture and integration in RBMPs and MSPs will help achieve aims of WFD and MSFD and deliver space for producers. Integration of aquaculture with other sectors might be an option.

Guidance and documentation: Provision of (regularly updated) guidance documents that help administrators and producers know the requirements for aquaculture would be beneficial. Definitions are needed at a pan-regional level for MSFD and its 11 descriptors. Guidelines should provide for different aquaculture sectors indicating the impact, the measures and the mitigation. Guidelines are required at both a local and regional level.

Legislation and regulation: Greater consistency in interpretation, enforcement and compliance with legislation will help achieve the aims of the environmental legislation. Legislation should be responsive, proportionate to risk and minimise regulatory burden on the producers.

Modelling of impacts and carrying capacity: The use of modelling tools helps to implement an ecosystem approach ensuring that aquaculture impacts can be managed within the system, important habitats are protected and that the carrying capacity is not exceeded.

Environmental Impact Assessments: EIA is already in place and is often stringent. Inconsistency in application needs to be addressed and a fully holistic approach be developed.

Monitoring: Effective monitoring and control of emissions are necessary but this requires clarification and standardisation of parameters to be monitored across sectors and the industry as a whole.

Consumer focus, labelling, accreditation: Labelling and accreditation schemes offer potential consumer choice over the environmental standards of production systems. However, it was questioned whether price overrides labelling and if the producer or the retailer gains. Producers need to benefit from meeting standards whether in the EU or elsewhere.

Training and understanding: Understanding of aquaculture systems, impacts, mitigation and sustainable practices should be developed for training and education at many levels from schoolchildren through to administrators.

Genetics, escapees and alien species: Aquaculture species destined for human consumption need to be separated from stocks that are destined for restocking the wild. Alien species need to be regulated and monitored according to legislation.

Aqua-feeds: Feed quality and its management are important in reducing environmental impact. Consideration should be given to local production of aqua-feeds.

Site specific or local management issues: Local management practices such as operating all –in / all-out year classes with fallowing regimes can provide environmental benefits.

Stakeholder attitude: There needs to be a willingness at all levels of the supply chain and at political levels to improve practices.

Sustainability issues (environmental, social and economic): Comments varied within this section.

- Good practice for environmental performance cannot be separated from social and economic performance. Operational scale may affect good practice.
- An understanding of the laws of nature is important and that sustainability operates over a longer timeframe.
- There is recognition that whilst aquaculture is not the biggest source of nutrient input this must still be managed somehow.
- Producers should operate within the terms of their licence.
- Medicine and treatment usage should be minimised and as prescribed by veterinarians.
- Tax incentives for environmentally friendly aquaculture systems could provide incentives.

Other general comments

- Aquaculture strategies should be in line with MSFD and WFD objectives.
- Positive impacts should be recognised.
- Many producers are already using best practices.
- There is no one-size-fits all approach and best practices need to be specific to the type of aquaculture.
- Better availability and cataloguing of data and use of GIS mapping will contribute to improved environmental performance.

8.2 *Benthic ecology and nutrients*

8.2.1 Benthic impacts and nutrient enrichment

Sustainable aquaculture can make beneficial contributions to environmental status, e.g. water quality and purification, phosphorous and nitrogen retention, irrigation and flood control. However, aquaculture activities also have the potential to impact on biological communities in and on the seabed / riverbed due to organic enrichment and input of nitrogen and phosphorous into the water column. Organic enrichment occurs as a result of deposition of particulate waste (faecal material and uneaten food), for example beneath fish cages or suspended shellfish cultures. Mussels, for example, can produce large quantities of faeces and pseudofaeces, which can accumulate as 'mussel mud' beneath suspended mussel cultures. Particulate waste may result in de-oxygenation of sediments and subsequent changes in the benthic invertebrate assemblage, which typically include reduced biodiversity and an increase in opportunistic species. Input of nutrients to the water column occurs largely as a result of excretory products and decaying particulates releasing ammonia, nitrate and phosphate into the water column, where they may contribute to symptoms of eutrophication. Other diffuse and point sources of nutrient input include urban and industrial waste water, agricultural runoff and erosion. Many of these non-aquaculture sources have important local effects. Input from adjacent coastal water bodies is another factor influencing nutrient loading, indicating the importance of flushing or exchange rates with these water bodies. Impacts on biological communities due to nutrient inputs are further influenced by factors such as physical impacts, disturbance and predator control discussed below.

While aquaculture can impact on the environment, it can also have positive benefits. Workshop contributions highlighted mutual benefits between environmental regulations and the aquaculture industry. For example, sustainable finfish farming can offer environmental services (water quality and purification effects, phosphorous and nitrogen retention), water management and water retention services (e.g. irrigation and flood control, wetland habitats, increased biodiversity) appropriate to WFD objectives. In Eastern Europe for example, carp ponds are in RAMSAR and Natura 2000 areas, and are national parks offering eco-tourism opportunities .

Aquaculture is not specifically mentioned as a pressure in the WFD or in the MSFD. However, indicators for assessments under both the WFD and the MSFD are relevant to benthic impacts and nutrient enrichment due to aquaculture. Under the WFD, indicators for the biological and (physico-) chemical elements are applicable to all water bodies (freshwater and marine) within the 1 nm limit, and 12 nm for chemical elements. Under the MSFD, indicators for Descriptors 1 (biodiversity), 5 (eutrophication) and 6 (sea floor integrity) are of particular importance. A key concern is the potential for enrichment effects which may result in symptoms of eutrophication, such as low concentrations of dissolved oxygen in the sediment and/or water column, increased growth of phytoplankton and macroalgal species, changes in the structure of phytoplankton communities and potential development of harmful algal blooms. While relatively little aquaculture takes place in marine waters relevant to the MSFD, the status of freshwater and coastal water bodies can have an impact on marine waters.

The effect of aquaculture on eutrophication is small relative to the management scales for the MSFD and most are managed under RBMP within the WFD. However, as described at the Baltic workshop (see Annex 4), most of the Baltic Sea is categorised as having poor or bad eutrophication status, so no additional nutrients can be added to the system. As a result, Sweden and Denmark will now only allow new aquaculture sites in the Baltic that are either land-based recirculation units or offset the nutrients released. An example of good practice is that used at Endelave in Denmark that produces around 2,100 tonnes p.a. of marine rainbow trout and adds 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 as the seaweed and mussels do not grow well. A further adaptation is to close the loop on nutrients, so that fishmeal used for feed is from the Baltic, so further nutrients are not introduced from outside the Baltic (see Aquabest 2014).

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 (e.g. AQUAETREAT 2007; Hall et al. 2011; Mckindsey et al. 2011; COM 2012; Price and Morris 2013; SAMS 2002). 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 further develop industry good practice and improve links with regulatory good practice.

8.2.2 Good practice

From the four regional seas workshops, a number of regulatory and industry good practices were identified. Recommendations were put forward for improving and growing the industry while at the same time meeting the requirements of EU environmental legislation.

8.2.2.1 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, Norway; maximum biomass set on site resulting from predictive models of assimilative capacity of receiving environment, Scotland);
- limit discharge (e.g. Sweden) or control discharges (e.g. England, Hungary, Austria, Denmark);
- restrict use of fertilisers such as manure (e.g. Romania, Czech Republic).

<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. Including the use of mitigation tools or practices (e.g. for effluent water quality) in the assessment of consents/licences.

8.2.2.2 Industry good practice and recommendations

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

- Site management , such as fallowing (timing, impacts, area), treatments, exclusion zones (e.g. Greece), 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;
- Nutrient reduction, for example through closed containment, land based/sediment traps, partial recirculation, (e.g. France, Norway), where the release of nutrients into the receiving environment is reduced by processing the effluent to remove dissolved nutrients and solid waste;
- Control of 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;
- Use of efficient feeding systems and feed types to ensure that uneaten (waste) feed is minimised, for example through the use of camera systems or other mechanisms of monitoring feeding response. Camera systems are often used in conunction 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 sufficient feed that led to improvements in the water quality in the ponds and the effluents.
- 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.
- Co-location - 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. See section 10.7 for further details.
- 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 preferred by environmental groups and NGO’s (e.g Baltic Blue Growth Partnership and Coalition Clean Baltic 2014) and is being taken forward in many areas such as the Baltic sea. See section 10.5 for further details of IMTA.

Recommendations include

1. High collaboration at inter-departmental and inter-agency level, to achieve a common level of understanding about the existing situation and measures already in place, and to establish programmes of measures 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. Management of systems by adopting a mass balance approach for nitrogen and phosphorous in any previously impacted locations that may require this e.g. Baltic;
5. Continuing work on the development of sustainable feeds (e.g. Baltic);
6. Further discussion of nutrient trading schemes (including co-location), a flexible regulatory framework (for re-location), and mitigation practices (e.g. Baltic)

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.

8.3 ***Chemicals Good practice***

8.3.1 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 the fish farm is operating within the capacity of the environment. One potential tension between meeting requirements under the WFD to maintain or improve the ecological and chemical status of the aquatic environment and allowing the development of aquaculture can be related to the potential scale of the effects. SEPA differ during their assessments as to what they term 'near field effects' (i.e. in the areas immediately adjacent to an operating or potential aquaculture site, as opposed to 'far field effects'). Essentially, some impacts are tolerated as near field effects 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 basic principles involve the use of local tidal and bathymetric data in computer models to predict impacts with the aim to set 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 (including results of environmental monitoring in and around the sites).

8.3.2 Aquaculture industry good practice examples

There are some aquaculture practices where use of chemicals is negligible. These include examples of extensive freshwater pond culture systems as implemented in Poland and other central European MS, as well as traditional lagoon rearing systems in the Mediterranean, "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.

8.4 ***Disease***

8.4.1 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 received by the local environment during and after treatments.

8.4.2 Good practice

8.4.2.1 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 2006a)(PARCOM 1994), HELCOM (HELCOM 2004a), and GESAMP (GESAMP (Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection) 1997) recommendations as well information provided in the four regional seas 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, potentially as part of river basin management plans. An additional advantage of such schemes is they will likely reduce the overall disease burden on sites, increasing productivity of businesses. These 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 administrators will be to balance the possible environmental effects of the activity (in this case aquaculture) with 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.

8.4.2.2 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.

3. Aquaculture Production Business operators have a duty of care to ensure the seed they import onto their premises are free of diseases that may be transmitted to wild fish and shellfish species.
4. 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.
5. 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.

6. Aquarists 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.

<u>Example from regional workshops: sea lice</u>

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 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). 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. Different MS and EEA countries 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).

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 sealice and other pathogens, limiting their potential for amplification over repeated production cycles;
- Strategic application of chemotherapeutants - Sealice 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 risks 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.

8.5 ***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 native) 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.

8.5.1 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 native organisms. These impacts may shrink spatial distribution of the native species and also reduce native abundance and biomass, resulting in outcompeting of native species (ICES 2009; IUCN 2009b; UNEP/MAP/RAC/SPA 2011). Escaped farmed native species may been have genetically selected for many years causing concern for the fitness and productivity of wild populations (Hindar et al 2006). However, escapees are also equally undesirable for the aquaculture industry as they represent a financial loss. This 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 consequently produced a set of recommendations and guidelines (see: http://preventescape.eu/)to help mitigate both environmental impacts and financial losses (Fredheim et al 2013).

Perhaps the most significant area for reducing escape numbers is marine net-pen culture and improvements have already been taking place 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. 9.2).

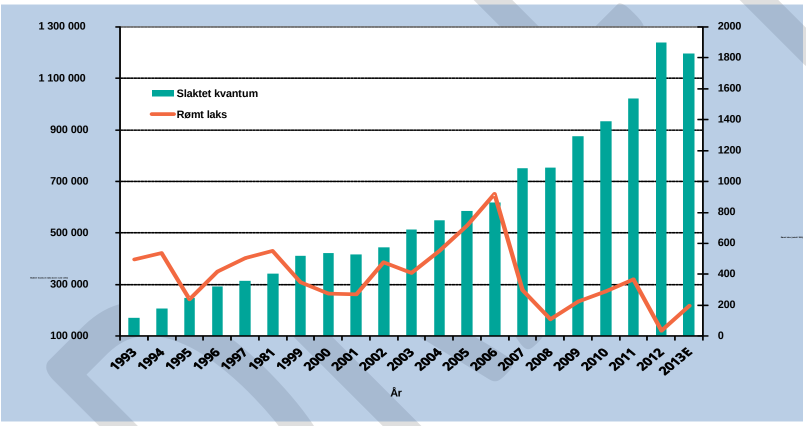

Fig 8.2 : Effect of introduction of technical requirements for farms (NYTEK) reducing annual escapee numbers from Norwegian salmon farms (red line), despite increased production (green bars). (Provided with permission from Norwegian directorate of fisheries/Norwegian seafood federation.)

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 and tear (SSPO 2010).

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 this area 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 consequently reduces risks of interbreeding or genetic interactions with wild stocks should they escape. For example, producers of both rainbow trout and brown trout often benefit from use of triploid and all female stocks. Whilst this might not be currently feasible for all aquaculture species, new technology and techniques are in the latter stages of development which might enable production of sterile stocks by alternative means such as the use of egg dips. REF

Results from the four regional seas 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 project demonstrating this spirit of openness and joined up governance from Scotland was presented at the Dublin workshop (SEPA 2014). This website provides information on numbers of escapees to interested stakeholders.

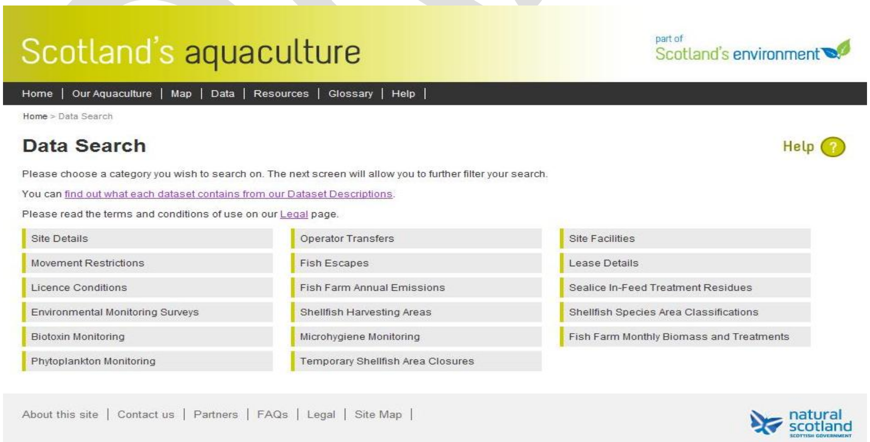

Fig. 8.3: Scotland's aquaculture website, with link to page on fish escape events.

The location of farms close to runs of wild fish often causes conflict between stakeholder groups due to fears of increased sea-lice populations. 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 the narrow river entrances and resolve stakeholder conflicts (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 that these should be kept separate from stocks that have been genetically selected for food production purposes (Reinartz 2014). They further recommend the establishment of non-commercial live gene banks (ecological "hatcheries") with governmental support (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).

Invasive alien species are also 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).

Aquaculture industry reviews and codes of practice recommend that, where possible, the species farmed should be native (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-native (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-native new species. These regulations also provide an option to derogate those species listed in Annex IV from control if MS consider that they do not pose an environmental risk. In order to ensure a coherent legal framework, the forthcoming alien species Regulation (COM(2013) 620 final) 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. The aquaculture industry often needs seed stocks of juveniles to begin cultivation and this can require the 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 native 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.

8.5.2 Regulatory obligations and good practice recommendations

A. Implement Regulations (EC) No708/2007 and (EC) No 304/2011 for alien species in aquaculture
B. Carry out inspections of premises to ensure that they meet conditions of the licence / permit with regard to containment of stock.
C. Ensure licence conditions for open net-pen aquaculture units stipulate that systems comply with technical standards.
D. Consider locating proposed open cage sites away from areas with any potential wild fish interactions, e.g. entrances to rivers or narrow channels.
E. Within the spirit of openness and accountability, publish transparent, easy to access data on escapees.

8.5.3 Industry obligations and good practice recommendations

A. 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 2013a).
B. Risk assess, document and train staff in high risk handling procedures such as transfer, grading and harvest (IUCN 2007).
C. 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).

D. Ensure that fish for mitigation stocking are reared from sustainable caught wild brood-stock and that these are kept separate from domesticated stocks.
E. Use best available technology for the production of sterile fish where possible. Take up new technology when licensed and available.
F. Ensure land based flow-through systems have adequate screening for the size of the fish and that it is maintained regularly.
G. Develop contingency plans for the eventuality of escapee recovery.
H. 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 forthcoming invasive alien species Regulation.

8.5.4 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.

Good practice case study
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 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.

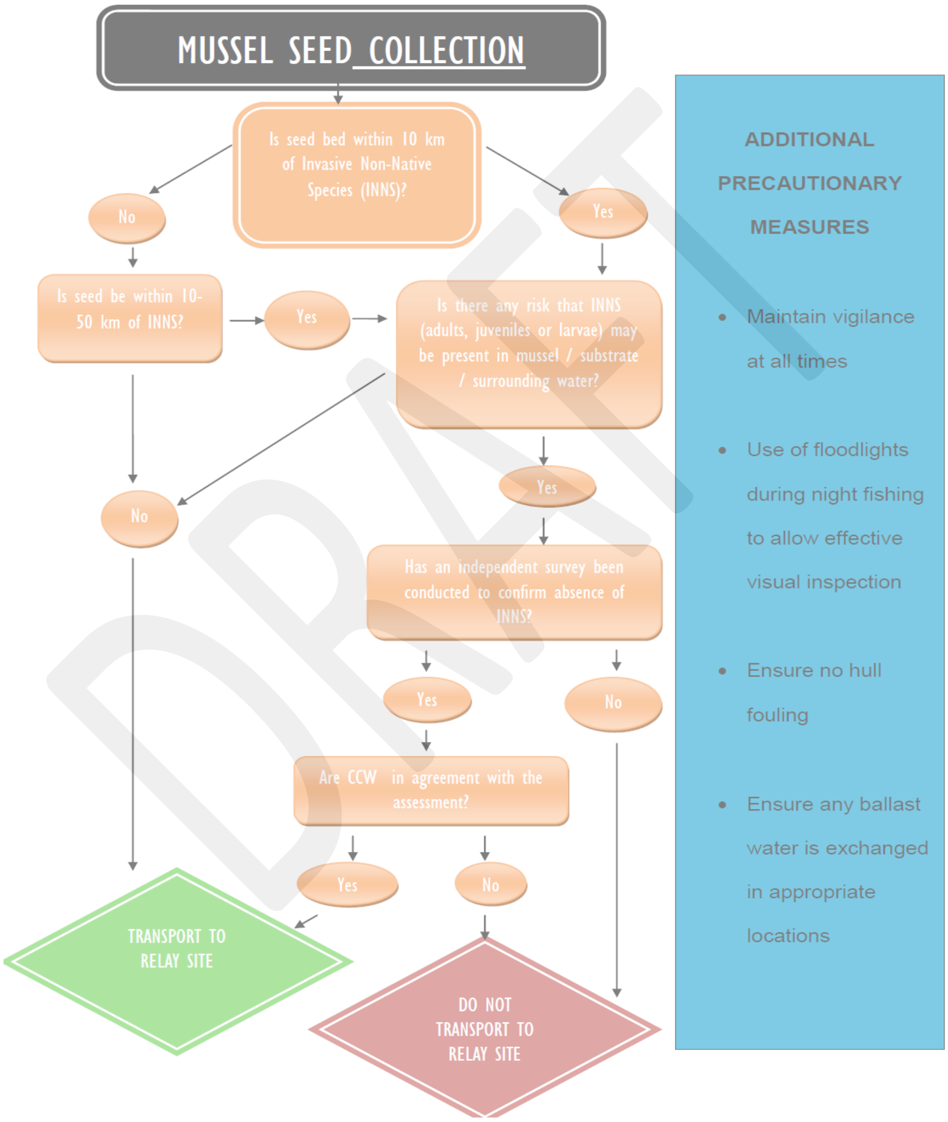

Fig. 8.4: Schematic of code of good practice for mussel seed to prevent transfer of invasive not-native species, produced by Bangor Mussel Producers Association, UK.

8.6 *Physical impacts, disturbance and predator control*

The following definitions 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 10.3). 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 (GEcC) 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).

8.6.1 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 of the structure 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 is required for freshwater aquaculture systems, that takes account of the potential physical, chemical and biological impacts of any new facility, including the impact on delivery of WFD targets.

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 in general 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.

Other countries also have their own marine legislation for aquaculture including Greece (Greece 2011). In Greece, issues were raised about the difficulties for aquaculture producers in identifying 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 done 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 kg 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 is done both within and outside of the AZE at the site to check 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 2012d), so it is important that resource efficient methods are used in aquaculture to mitigate those impacts (COM 2012d). 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). Lake and pond aquaculture generally use lower amounts of water than flow-through systems, but there are some examples of minimising physical impacts such as the use of land-based recirculation systems (see for example Varadi et al.

2009), as well as the Danish model farm approach (partial-recirculation) as discussed at Copenhagen workshop (Annex IV).

The only way to completely remove the physical impacts of aquaculture is to use land-based recirculation systems as these do not provide a barrier to water movement or changes to 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 by aquaculture. Some systems, for example large extensive freshwater ponds, may help to manage the effects of drought or flood within a river catchment, where the systems may act as reservoirs or buffers in reducing extremes of flows.

8.6.2 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 also generally shows a very efficient utilisation of space in comparison to agriculture and other industries, so the net requirement for space for development is low (ADD REF HERE) 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). 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 3.2) 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 around the facility 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).

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).

Good practice examples for marine litter are difficult to find and the relative inputs of aquaculture versus other sources is unknown [NEED REF]. In relatively shallow water, litter on the seabed can be removed by divers but this is often difficult to do and only takes account of litter that is negatively buoyant and remains in the vicinity of the site. The best thing would be not to introduce litter into the environment at all, so voluntary codes of practice could be developed to reduce inputs. The UK also flagged litter as potentially impacting on aquaculture production rather than it being a pressure (HM Government 2012). 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."

Visual impact concerns mostly 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 in three specific regions of Scotland: Mull and Oban, the Outer Hebrides, and Shetland. 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. They may also include siting the cages far from the shore or using submersible cages (IUCN 2009b).

Oyster farming may alter intertidal macrozoobenthic assemblages moderately, and off-bottom cultures generally may cause more disturbance than on-bottom cultures. Hydrodynamics and seasons may interact with regional cultivation practices in smothering/strengthening bio-deposition-mediated effects through dispersal and accumulation of bio-deposits (Bouchet and Sauriau 2008). In the near future, the establishment of offshore oyster production using sub-tidal areas as well as oyster long-lines to decrease stocking biomasses on intertidal leasing grounds may have positive feedback on intertidal benthic communities in some areas; however, the potential deleterious effects of these new culture practices on surrounding sub-tidal areas needs to be further assessed (Bouchet and Sauriau 2008). Shellfish-DEPOMOD, with its capabilities of assessing near-field effects, 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 the tools to efficiently and comprehensively assess the effects associated with shellfish culture activities within an ecosystem-based management framework (Weise et al 2009).

Finally, it is important to consider estuarine changes not simply in terms of departure from baseline, but as they influence resilience, i.e. capacity of the system to withstand or recover from other shocks. Aquaculture as disturbance is generally within the scope of existing “natural” disturbances to the system (e.g. winter storms) and other ecosystem engineers (e.g. eelgrass and burrowing shrimp) are also inherently adapted to this scale of disturbance. Certain anthropogenic disturbances have reduced estuarine resilience, for instance habitat removal via wetland diking and filling, hardening of surfaces in the watershed, nutrient additions, invasive species such as *Spartina*, and possibly food web modifications like removal (sharks, skates and sturgeon) or protection (harbour seals and sea lions) of large predators. In contrast, bivalve aquaculture does not remove area from the estuary or degrade water quality, and thus is less likely to undermine resilience. Though local and short term effects are clearly evident in U.S. West Coast estuaries, bivalve aquaculture has not been implicated in shifts to alternate states or reduced adaptive capacity of the larger ecological system (Dumbauld et al 2009).

8.6.3 Predator control

The fish and shellfish stocks held by aquaculture operations 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). There is also predation of mussels by starfish (*Asterias rubens*), crabs (*Carcinus maenus*) and other predators in the subtidal zone (see e.g. Dankers and Zuidema 1995). Economic performance is another pillar of sustainability and aquaculture businesses need to make a profit in order to continue trading. Protection of stock from a wide range of predators is therefore good husbandry practice. The FAO definition of aquaculture recognises that farming implies interventions in the rearing process and this includes protection from predators (IUCN 2007).

Predator control is dependent on the site and species being cultivated, and 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).

There are many challenges in controlling a diverse range of predators in open aquaculture systems, and this is well illustrated by the situation at 195 aquaculture sites 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 mammals (otters, mink). The most commonly observed predators across sites 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 kills were considered the most effective methods (Marine Scotland 2010). Farmers have used 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 the 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

The ecosystem services provided by extensive freshwater fish farms have become more widely recognised and these systems often accept losses of fish to piscivorous birds including herons and cormorants through provision of wetlands (e.g. carp farms in Hungary). Farms often use combined intensive extensive systems (IES) to mitigate the impact of avian predation. This simple system uses a compartmentalised unit for intensive production placed within in a traditional fishpond system. The concentrated area for fish production reduces impacts from predators (Varadi et al 2009). As an example of mitigation measures, long-term results are usually achieved by using a combination of methods and by frequently alternating the devices used. These include scaring techniques and devices that are regularly moved to different positions, for example using falcons to scare herons away (Behrendt, 1994). Nets positioned above the cages are also regularly used to prevent predation by birds (IUCN 2009b).

Control of protected avian predators may be possible under Article 9 of Council Directive 79/409/EEC. One important factor affecting pond-based aquaculture production in certain regions is related to predators, in particular cormorants. The Birds Directive sets out a derogation system to protect fisheries' and aquacultures' interests. Member States can make full use of the derogation provisions to prevent serious damage by cormorants to fisheries or aquaculture. In order to assist the Member States, the Commission has recently published a guidance document with the aim of clarifying the key concepts in relation to the implementation of the derogation system (COM 2013a). The EU has also developed the EU Cormorant Platform that provides information on cormorant numbers, management, and interactions with aquaculture (http://ec.europa.eu/environment/nature/cormorants/home_en.htm). This 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 including scaring away with audible and visual deterrents, protecting the fish using nets and wires, reducing fish availability (e.g. size of fish), reducing cormorant numbers through culling or reducing reproductive success, and financial compensation (see Table 10.4.2 and Russell et al. 2012). In considering options, it is important to consider protection of cormorants under the European Wild Birds Directive, the complexity of conflicts between cormorants and fisheries, and the efficacy of control measures. There are good examples of deterrents and netting in Greece, shooting in Slovenia, and wires over carp ponds in Germany (Russell et al 2012).

Mussel cultures attract birds bringing these organisms into conflict with the mussel farmers. Of the bird species, eider ducks and scoters seem to cause the most concern. Farmers in Canada 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 birds to move 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

There are a number of mammals that are active predators on fish and are attracted to aquaculture facilities and fishing lakes. These include both indigenous predators like seals, cetaceans and otters, but also non-indigenous predators like the American mink. These predators can have a significant impact on the productivity of an aquaculture facility and need to be managed. However, it is not clear if marine mammal predation is increasing. For example, surveys of salmon farm managers in Scotland indicated that seal predation has declined over the past decade and that less than a quarter of salmon farms reported major problems with seals despite nearly daily sighting of seals 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).

The effects of marine mammals are not limited to predation, but can also have secondary impacts. For example, holes in nets caused by marine mammals were responsible for 26% of escape incidents in Scotland (Taylor and Kelly 2010). However, there are also positive direct benefits of aquaculture for marine mammals. For example, productivity of Mediterranean dolphins is higher in areas with fish farms (Piroddi et al 2011). Control measures for marine mammals are the same as for birds and have the same issues. Some examples of the application in aquaculture are given below.

- Scaring of marine mammals has focussed on using acoustic deterrent devices, but these devices have not been consistently useful against seals (and sea lions) and may have deleterious impacts to non-target marine mammals (Price and Morris 2013).
- Exclusion techniques are commonly used as a deterrent to marine mammals including seal rings and net. Studies on damage to nets caused by marine mammals in Scotland resulted in identification of a number of operational and training issues such as regular inspections which could help reduce the likelihood of escape incidents at cage sites from predators. The use of predator nets on cage sites to prevent seal attacks provides one option, but may cause difficulties for operators and lead to by-catch. The adoption of technical specification so that cages can resist predator attacks provides a solution.
- Farm management strategies including net tensioning, lower stocking densities and seal blinds at the bottom of the nets deterred predation (Price and Morris 2013). These techniques are also commonly used to deter mammals in freshwater like otters where fences are erected (Jay et al 2008). Habitat modification techniques have also been used to deter predators, for example, the removal of mortalities within cages will reduce or prevents attacks (Taylor and Kelly 2010).

- Siting away from known aggregation sites and installing rigid predator exclusion nets are effective at preventing negative impacts to cultured fish, farm structures and marine predators (Price and Morris 2013), again highlighting the importance of a good evidence base feeding into marine planning.
- Culling of predators is often difficult as many mammalian predators are protected. For example, otters are a common freshwater predator and receive full protection under the EC Habitats Directive (CEC 1992). American mink are established throughout the UK following their establishment from 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).

Predatory fish

Aquaculture facilities provide a source of food for predatory fish that can be controlled using the same mechanisms as other predators. However, there are opportunities for co-existence that include the removal of unwanted or sick fish (e.g. pike are often left in freshwater fisheries) and provision of a refuge from exploitation in the sea. There are also opportunities for fishermen and aquaculture infrastructure to work together in order to remove predatory fish aggregations, for example removal of seabream decreases the predation on farmed mussels (Stelzenmüller et al 2013).

Due to the strong aggregative effect of fish farms, possible residence of fishes for periods of weeks to months and the prohibition of fishing within farm leasehold areas, it has been suggested that coastal sea-cage fish farms may act as small (up to 160000 m^2), pelagic marine protected areas (MPAs). Furthermore, at farms where wild fish are abundant, ecological interactions that may influence both wild fish stocks and the impact of farms must be considered (Dempster et al 2006). Negative interactions with wild fishes have also been observed. For example, bluefish are reported to seasonally aggregate around and invade fish cages in the Mediterranean (Sanchez-Jerez et al. 2008). Of the 23 farms surveyed, bluefish aggregations were detected at 16, but only 4 farms reported significant impacts to the cultured fish. In addition to direct predation on the cultured fish, these four farms reported decreased productivity due to stress and additional costs associated with removal of bluefish and net repair (Price and Morris 2013).

9 Future & Emerging Technologies

When planning how aquaculture will develop within Europe over the coming decades in relation to environmental legislation (such as WFD and MSFD) there is a need to consider new and emerging technologies and forms of aquaculture that are either under development, being piloted, or being used in other parts of the world. These include:

9.1 ***Offshore aquaculture***

The development of offshore aquaculture (finfish, shellfish and crustacean) is seen as one of the most promising options for Europe. There are advantages in terms of the availability of space, reduced competition with other sectors, water quality and reduction of environmental impacts. Whilst concerns have been expressed over the unknowns of moving offshore and future research requirements identified (Holmer 2010), it is generally accepted that the carrying capacity and ability of the ecosystem to absorb and assimilate excess nutrients and organic loading will allow licences to be granted for increased production (IUCN 2009b) up to certain limits. Despite significant improvement in technical and engineering standards, challenges still remain in operating in more exposed environments and large areas of the ocean may be too deep for current mooring technology.

9.2 ***Submersible net-pens***

Social and economic factors may restrict development of standard net-pen culture in many near-shore locations. The use of submersible cages may enable finfish farming in more exposed environments which would then reduce the visual impacts , the localised impacts of nutrients and suspended solid inputs as well as offering potential to culture a different range of species (Papandroulakis et al 2013). Sub-surface cages are less exposed to wave damage during storms, and reduce the risks of escapees due to breakages. However, challenges remain regarding mooring in deeper water and areas with strong subsurface currents, operation, and management.

9.3 ***Closed freshwater and marine pens***

In order to reduce the impacts from open net-pens, many closed floating pen projects (at various stages of development) are being trialled. All closed pen systems require water to be pumped in, rather than the free movement through a mesh in open net-pen systems. Potential benefits associated with the closed wall and controlled water supply and 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).

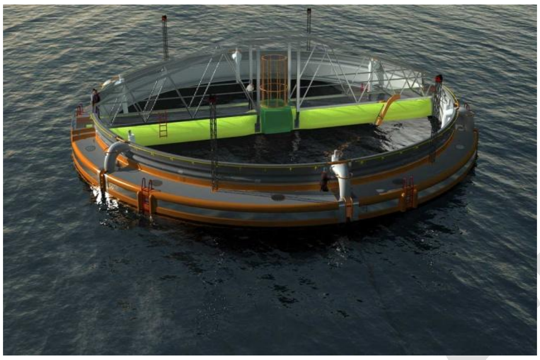

Fig. 9.1 AquaDome project, Norway.

9.4 ***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).

9.5 ***Integrated multi-trophic aquaculture***

Integrated multi-trophic aquaculture (IMTA) uses the waste by-products 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 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 preferred by environmental groups and NGO's (Coalition Clean Baltic 2014) and is being taken forward in many areas such as the Baltic sea.

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). One key goal for integrating aquaculture with the environment is to determine the assimilative capabilities and the environmentally-acceptable critical loading rates of biogenic wastes per volume and per area of sea floor, including the contribution or ecological services of shellfish and macro-algae farmed in aquaculture locations (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). Both EATiP and EFARO have identified these systems as potential options for the future (EATIP 2012)(EFARO 2013). 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).

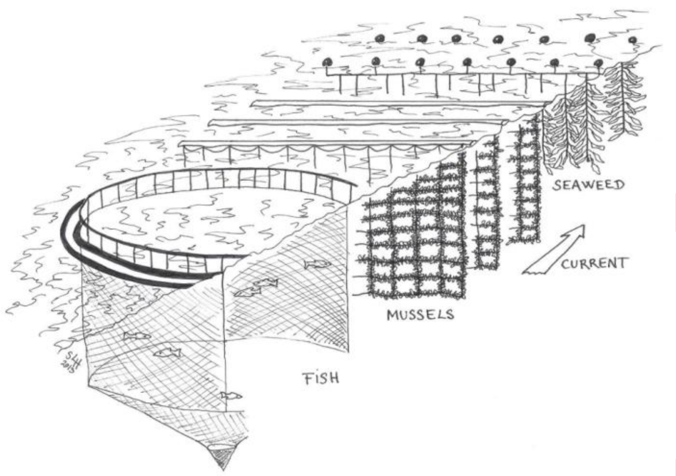

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Fig. 9.2: Illustration of an integrated multi-trophic aquaculture site.

9.6 ***Aquaponics***

Aquaponics 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 with a clean green image 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).

9.7 ***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).

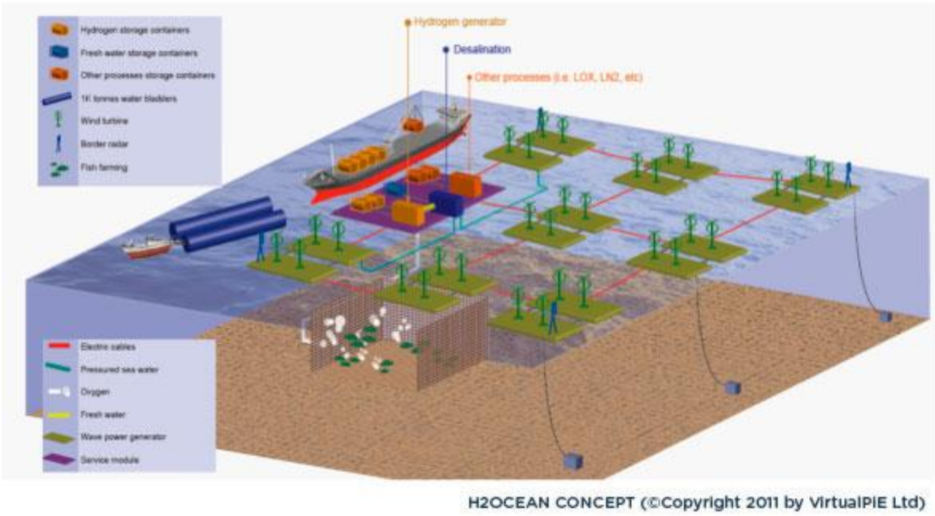

Fig. 12.3: H2OCEAN concept of co-location of aquaculture with other industries

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 environment, 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

For ease of reference, the following list is a summary of the key recommendations that have been highlighted, or come to the fore, in the process of undertaking this project.

10.1 *Recommendations for administrators*

- Consider the "one-stop-shop" approach to improve the efficiency of regulation, where one agency becomes the contact point for industry reducing time for processing applications;
- Provide a vision for aquaculture development within strategies that can also inform the spatial planning processes, linking to and liaising with other marine industry;
- Integrate aquaculture into the 2^{nd} round of RBMPs in a more pronounced fashion;
- Provide Allocated Zones for Aquaculture (AZAs) or similar, that facilitate development in locations that are most suitable for receiving the nutrient emissions from aquaculture businesses;
- Adopt a risk and evidence-based approach to determining monitoring requirements, that is based on good science;
- Improve clarity on which parameters or data the industry should provide for licensing and monitoring;
- The Precautionary Principle should be adopted in a sensible and pragmatic manner;
- Improve monitoring to quantify and allocate proportional nutrient loads from different sources, identifying the contribution from aquaculture within an overall nutrient budget;
- Include an assessment of the use of mitigation tools or practices (e.g. for effluent water quality) and how these may reduce the environmental impact of activities of aquaculture in the review of consents/licence applications;
- Consider the mechanism for, and application of, nutrient trading schemes (including co-location) for aquaculture businesses;
- Provide a regulatory framework that is flexible enough to include mitigation practices or new techniques for managing environmental impacts;
- Ensure administration costs are proportionate to the sector/business regulated;
- National Administrators consider developing simple guidance aimed at helping developers assess whether their planned facilities are likely to comply with the obligations of the WFD and the MSFD;
- National Administrators consider developing specific environmental good practice guidelines for the various main types of aquaculture.

10.2 ***Recommendations for industry***

- Liaise directly with regulators to achieve a common level of understanding about responsible aquaculture operations;
- Adopt holistic management systems that take into account environmental impacts of the business in a broad manner (e.g. includes fish health, welfare, nutrient release, alien species, use of medication, abstraction of water);
- Adopt aquaculture production system types appropriate to the local environment;
- Adopt practices that show continual improvements in sustainability such as feed (e.g. improve feed utilisation efficiency; new sources of raw materials), health management (e.g. use of vaccinated stock), water (e.g. improved water efficiency utilisation through RAS, partial recirculation, filtration);
- Adopt practices of self-monitoring and reporting, such as through Codes of Practice, or sector-specific certification schemes, and especially those that may be independently audited.

10.3 ***Recommendations for areas where either further research or new guidance might be necessary***

- Research to support monitoring and the use of best available technology that 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, whilst at the same time facilitating the growth and development of the sector that is envisaged across EU-28;
- Research that provides more accurate predictive models for the fate of nutrients that originate from aquaculture sites, as well as effective ways of mitigating those impacts (e.g. IMTA);
- Research that supports the development of new and innovative water processing technology for land-based aquaculture systems;
- Development of offshore aquaculture technology that supports the move of the industry beyond the 1nm coastal zone.

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Annex 1: Minutes of the North East Atlantic Workshop (Dublin)

Annex 2: Minutes of the Mediterranean Workshop (Athens)

Annex 3: Minutes of the Black Sea and Danube Workshop (Vienna)

Annex 4: Minutes of the Baltic Workshop (Copenhagen)

Annex 5: Synopsis of Administrators Questionnaires

Annex 6: 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 7.1.

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.

The **Federation of European Aquaculture Producers (FEAP)** presented their views on what was required to boost production in European aquaculture (FEAP 2012) which were broadly in agreement with the new 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).

Table Annex 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 (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.

Annex 7: Activities of the four Regional Seas Conventions (Barcelona, Bucharest Helsinki and OSPAR) and other regional environment/fisheries organisations in relation to aquaculture in EU waters.

Annex 7.1 Barcelona Convention – 'The Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean'

The convention created several protocols which aimed to reduce pollution in the Mediterranean, one of which was the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean. Under this protocol, a Regional Activity Centre for Specially Protected Areas (RAC/SPA) was established to enforce the protocol by creating a network of Specially Protected Areas across the Mediterranean as well as to implement an Action Plan on invasive species. This Action Plan, adopted by the Contracting Parties to the Barcelona Convention in 2003 (UNEP/MAP/RAC/SPA 2003), specifically deals with aquaculture. In 2005 an Action Plan concerning species introductions and invasive species in the Mediterranean Sea was published (UNEP/MAP/RAC/SPA 2005). Guidelines for controlling vectors of species introduction were developed in 2008 (UNEP/MAP/RAC/SPA 2008a) and a guide for risk analysis of the impacts of the introduction of non-indigenous species was also published in 2008 (UNEP/MAP/RAC/SPA 2008b). In 2011 an information document on non-native species in the Mediterranean was published (UNEP/MAP/RAC/SPA 2011).

An assessment of the economic value of sustainable benefits provided by the Mediterranean Sea marine ecosystems was published in 2010 that included aquaculture (Mangos et al 2010). UNEP, in its capacity as Secretariat of the Mediterranean Action Plan, agreed a Memorandum of Understanding with the Food and Agriculture Organisation of the United Nations on behalf of the General Fisheries Council for the Mediterranean in 2012 which includes cooperation in the mitigation of the impact of fisheries and aquaculture on the marine habitats and species.

Annex 7.2 Bucharest Convention – 'The Convention on the Protection of the Black Sea against Pollution'

A Black Sea Strategic Action Plan (BS SAP) was adopted in 1996 and updated in 2009 (BSC 2009). Within the BS SAP there are a number of guiding principles, one of which ensures that environmental and health considerations are included in all relevant policies, sectoral plans and programmes, including those activities relating to aquaculture. The Action Plan also mentions specific challenges to be faced, some of which are relevant to aquaculture, including, eutrophication/nutrient enrichment, commercial marine living resources and alien species introductions. The Action Plan also notes that aquaculture is not strongly developed in the region and there is scope for it to be developed, providing environmental considerations are taken into account.

Annex 7.3 Helsinki Convention – 'The Convention on the Protection of the Marine Environment of the Baltic Sea Area'

The Helsinki Convention has had an involvement in aquaculture for many years going back to at least 1994 when the Helsinki Commission (HELCOM) adopted Decision 15/3 on measures aimed at reducing discharges from marine fish farming. That decision was updated several times with the latest being adopted in 2004 (HELCOM 2004b). Aquaculture was one of the activities assessed as part of the assessment of the ecosystem health of the Baltic published in 2010 (HELCOM 2010a). Aquaculture featured as a pressure for alien species introductions and the introduction of nutrients, organic matter and pathogens. HELCOM published a background report to the methodology and data of the Baltic Sea Pressure Index (BSPI) and the Baltic Sea Impact Index (BSII) used in that assessment (HELCOM 2010b). In a HELCOM implementation report on the status and ecological coherence of the HELCOM BSPA network (HELCOM 2010c), while aquaculture was indicated to be a potential threat to Baltic Sea MPAs, it was ranked 20th in a list of threats.

HELCOM has developed indicators for evaluating whether the targets of the Baltic Sea Action Plan have been met (HELCOM, 2012; 2013b) and these include indicators related to aquaculture . HELCOM has worked on alien species introductions but appears to have been primarily concerned with ballast water from shipping (HELCOM, 2012b, HELCOM, 2013 and Rolke et al., 2013). Aquaculture was responsible for about 13% of the introductions.

The HELCOM Copenhagen Ministerial Declaration made on 3rd October 2013 in Copenhagen, Denmark (HELCOM 2013c) included the following statement on sustainable aquaculture:

> "*22 (B). HIGHLIGHTING the increasing importance of sustainable aquaculture, WE AGREE to develop a new HELCOM Recommendation on sustainable aquaculture by 2014 to substitute the existing HELCOM Recommendation 25/4 aiming at limiting potential environmental impacts of*

aquaculture activities such as the introduction of non-indigenous species, ecological and genetic impacts on wild fish stocks from unintended releases of farmed species, nutrient pollution, as well as introduction of antibiotics and other pharmaceuticals".

Annex 7.4 OSPAR Convention – 'The Convention for the Protection of the Marine Environment of the North-East Atlantic'

The OSPAR Convention and one of its predecessors the Paris Convention 1974 have had a limited involvement with mariculture (as it only covers the marine environment) as detailed below. Under the Paris Convention, 'The Convention for the Prevention of Marine Pollution from Land-Based Sources', PARCOM Recommendation 94/6 covered 'Best Environmental Practice (BEP) for the Reduction of Inputs of Potentially Toxic Chemicals from Aquaculture Use' was adopted in 1994 (PARCOM 1994). This recommendation continued in force under the OSPAR Convention when that Convention came into force in 1998. The Recommendation covered in particular the drawing up by national authorities of Codes of Best Environmental Practice (BEP) and action plans. The Recommendation required reporting of implementation by the Contracting Parties and at the OSPAR Commission meeting in 2006 it was decided that no further implementation reporting was required (OSPAR 2006b). The final implementation report was published by OSPAR in 2006 (OSPAR 2006a).

At that same 2006 meeting, the OSPAR Commission agreed a background paper on mariculture (OSPAR 2006c) that covered hazardous substances, eutrophication and habitats/biodiversity issues. The conclusions of that document were:

> "*The mariculture industry is very diverse. Its impacts are mostly site-specific. Regulation and control will therefore always need to be focused on a case-by-case approach, although the competent authorities need to ensure at the same time that the overall pressure from aquaculture on the marine environment does not compromise the marine environment. A substantial amount of general guidance is available to give the background to these case-by-case decisions. OSPAR has therefore concluded that, in present circumstances, there is no need for the development of additional programmes and measures at the OSPAR level*."

Subsequently, an assessment of the impacts of mariculture was produced in 2009 (OSPAR (2009) that was fed into the OSPAR Quality Status Report (OSPAR 2010). Most recently, the OSPAR Environmental Impacts of Human Activities (EIHA) Committee that met in April 2014 considered a paper on the pressures from mariculture (OSPAR 2014) that included information provided by Norway and Spain and included a work plan on the interaction between wild and caged stocks that the International Council for the Exploration of the Sea (ICES) will report on in 2015. At the meeting, all Contracting Parties were encouraged to report any new information on mariculture to EIHA.

Annex 7.5 International Council for the Exploration of the Sea (ICES)

The ICES Working Group on Aquaculture (WG AQUA) was recently (2013) established as a single working group dealing with science and advice for sustainable aquaculture in the ICES area. The work focuses on aquaculture-environment interactions with the current Terms of Reference (ToR) posted on the ICES website at: www.ices.dk/community/Documents/Science%20EG%20ToRs/SSGHIE/WGAQUA%20multiannual%20ToRs%202013.pdf.

Annex 7.6 General Fisheries Council for the Mediterranean (GFCM)

The GFCM has a significant involvement with aquaculture with a Committee on Aquaculture (CAQ). At its 7th session in 2011 (GFCM 2011a), the CAQ recommended that specific regulations and the simplification of licensing procedures for aquaculture, e.g. "single windows or one-stop shop", should be implemented. It formulated specific management advice on the implementation of Allocated Zones for Aquaculture (AZA) in countries aiming to facilitate and develop aquaculture. It also recommended the implementation of an environmental monitoring programme in the areas surrounding aquaculture activities. The Committee considered some amendments for the Recommendation GFCM/33/2009/4 on Reporting on Aquaculture Data and Information. At its 8th session in March 2013 (GFCM 2013b), the CAQ decided to develop a draft set of guidelines for the use of indicators to monitor the sustainable development of aquaculture in the GFCM area as well as to carry on activities and research on allocated zones for aquaculture (AZA). In light of the increasing role to be played by farmers' organisations in the development of sustainable aquaculture, a proposal to set up an aquaculture multi-stakeholder platform was tabled at the CAQ to increase knowledge capital and improve cooperation in the sector. This was subsequently submitted to the 37th GFCM session. The CAQ welcomed the initiative to undertake a regional review on the current status of aquaculture in the GFCM area.

At its 37th annual session in May 2013 (GFCM 2014), the GFCM renewed its commitment to foster the sustainable development of aquaculture in the Mediterranean and the Black Sea through the establishment of a multi-stakeholder platform involving all players in the sector. The GFCM held a meeting in December 2013 to launch the multi-stakeholder platform to tackle the challenges faced in the sustainable development of aquaculture in the Mediterranean and Black Seas (GFCM 2013c).

The GFCM has published two reports on indicators related to sustainable development of aquaculture (GFCM 2013b; 2013c) and held a 'Regional workshop on the identification of reference points for economic, environmental, social and governance indicators on aquaculture' in 2013 (GFCM 2013d). The GFCM has an 'Information System for the Promotion of Aquaculture in the Mediterranean' on its website at http://www.faosipam.org/index.aspx?pag=_home.

Annex 8: Development of Environmental Indicators for Aquaculture.

The identification of indicators of the environmental impact would support the development of a sustainable aquaculture industry by assessing impacts of operations, the effectiveness of measures to mitigate potential adverse impacts, and changes over time. Sets of common, reliable and easy to measure indicators, to be used as a proxy for potential or actual environmental impact, therefore need to be developed. Unfortunately, this is challenging because they need to account for significant variations, in both production practices and the environment, e.g. the environmental indicators required to monitor intensive marine net-pen salmonid production systems common in Northern Europe will be different to those required for central European extensive freshwater carp farms.

In general, indicators should be developed to monitor the three main envisaged pressures on the environment

- Nutrients (eutrophication) (Section 10.1)
- Contaminants e.g. chemicals (Section 10.2)
- Introduction of alien species (Section 10.3)

The European Environment Agency (EEA) has undertaken some work to develop an indicator that quantifies the development of European aquaculture production by major sea area and country, as well as the contribution of aquaculture discharges of nutrients relative to the total discharges of nutrients into coastal zones (http://www.eea.europa.eu/data-and-maps/indicators/aquaculture-production-1). The EEA recognises that the indicator, although simple and readily available, has limited applicability as a stand-alone indicator, as it takes inadequate account of the widely varying production practices and is restricted to marine production systems. The EEA would like such indicators to be integrated with others related to production practices (e.g. total nutrient production, total chemical discharge) to generate a more specific indicator of pressure. Coupled with information on the assimilative capacity of different habitats, such an indicator would allow estimation of impact and ultimately the proportion of the carrying capacity of the surrounding environment used and the limits to expansion.

The European Pollutant Release and Transfer Register http://prtr.ec.europa.eu/IndustialActivity.aspx does publish information on discharge of 91 pollutants from intensive aquaculture into the environment. However at the present time information is mainly restricted to discharges from large intensive marine aquaculture sites

The JRC has also published guidance on an approach towards general European aquaculture performance indicators (Hofherr et al 2012). They selected, as part of this exercise, Environmental indicators based on parameters specific to production systems which are considered similar across Member States.

Table Annex8.1: Environmental indicators selected by JRC (Hofherr et al 2012)

Indicator	Description
Fishmeal (FM)	Ratio between total quantity of fishmeal used and total aquaculture production
Fish oil (FO)	Ratio between total quantity fish oil used and total aquaculture production
Nitrogen (N)	Ratio between total effluents of nitrogen and total aquaculture production
Phosphorus (P)	Ratio between total effluents of phosphorus and total aquaculture production

There have also been regional efforts to recommend sets of indicators to be used to measure the sustainability of aquaculture which include measures of environmental sustainability. For instance, there has been significant efforts by the GFCM to develop indicators for sustainable aquaculture in the Mediterranean and Black seas regions(GFCM 2011b; 2013c; 2013e). Five indicators for environmental impact were identified (Table 11.2): food conversion ratio, site selection criteria, monitoring for chemical and medicines residues, monitoring for impacts on benthos and reports of escapes.

Table Annex 8.2: Environmental indicators for sustainable aquaculture in the Mediterranean and Black seas Regions (Fezzardi et al 2013)

	Principle	**Criteria**	**Indicator**	**Reference values**
1	Minimize the global impact of aquaculture	Needs of natural resources for food production (pelagic fish and plants)	FCR - feed conversion ratio (kg food/kg fish)*	Seabass (350-400 gr): > 2.2/2.2-1.8/<1.8 Seabream (300-350 gr): >2.1/2.1-1.6/<1.6
2	Maintain the ecological services of ecosystems	Reduction of benthic environmental impact	Existence of criteria for the depth (m) of cage applied to site selection. Related to density. Ratio of depth and density (depth (m)/ density (kg/m^3)	< 1.5 / 1.5 –2 / >2**
3	Minimize the local impact on environmental conditions and biodiversity	Use of chemical products	Existence of a national monitoring programme to monitor antibiotics and other chemical residues	Yes/No
4		Impact on benthic habitats and communities	Implementation of a monitoring system for the evaluation of the level of	Yes/No

			impact on benthos	
5		Biological impact on communities	Reporting of escapees (number of escape events)	Yes/No

Conclusions

There is a need to establish a harmonised approach to the selection and interpretation of indicators for monitor the environmental sustainability of aquaculture operations. The indicators selected by different organisations have varied, relating to the original purpose they have been selected for. Of the sets of indictors referenced, only those proposed by GFCM (2013e) cover all three of the main envisaged environmental pressures. Their general applicability, particularly to EU-wide marine aquaculture operations, should be explored.

Annex 9: Planning for Sustainable Blue Growth.

Annex 9.1. Blue Growth (COM 2013a) is the long term strategy to support sustainable growth in the marine and maritime sector, recognising that the marine environment has great potential for innovation and expansion. While the EU blue economy is already worth just under €500 billion p.a., the strategy highlights where there is the possibility of further sustainable growth. The strategy consists of three components: specific integrated maritime policy measures (e.g. marine spatial planning); sea basin strategies (e.g. in the Baltic); targeted approaches to develop specific activities, one of which is aquaculture.

Comment [EOIN2]: Incorrect ref. 2013a is the Strategic Guidelines according to the existing reference list.

The aims of the environmental legislation are an integral part of the blue growth agenda. The Blue Growth Strategy is all about prioritising the use of ocean resources sustainably as a driver for growth and jobs in Europe (Damanaki 2014).

Annex9.2 Overview of the importance of strategic planning for aquaculture

Given that the output from European aquaculture has been fairly constant since 2000, but global aquaculture production has been growing at nearly 7% p.a., there is a drive from the EC to increase sustainable domestic production as part of the blue growth strategy. The Commission hopes to develop aquaculture through the Common Fisheries Policy reform, together with a set of strategic guidelines (COM 2013c) to aid cooperation and identification of common objectives and indicators. It is clear that there is an important need for strategic planning of aquaculture activities to ensure linkage across Member States, with the guidance identifying four priority areas for development:

Comment [EOIN3]: COM 2013a and COM 2013c both refer to the same document according to the current reference list.

Annex 9.2.1 *Reducing administrative burdens*

Administrative burdens (such as cost and licensing time) could be having an important impact on the current development and competiveness of European aquaculture, and there is a push from the EC to reduce the regulatory burden on producers. Ongoing work includes: determining the different types of administrative burdens for different aquaculture activities, asking MS to compile information concerning costs and timescales of licence determinations, and developing best practice and measures for improvement.

Annex 9.2.2 *Coordinating spatial planning*

Currently, lack of space is often cited as a factor hindering the expansion of EU marine aquaculture. Strategic planning includes the development and application of spatial planning and integrated coastal zone management to identify appropriate sites for aquaculture activities. Spatial planning allows different activities to be examined in an integrated way within a defined region, allowing site planning of each activity within the region to maximise economic and societal benefit, minimise environmental impact and prevent conflict within sectors where possible. (N.B. Such planning will need to take account of the recently-agreed EU Directive on maritime spatial planning.)

Annex 9.2.3 *Increasing competitiveness*

There are plans to improve the structure of aquaculture producer organisations, to reform the Common Market Organisation and implement a new European Maritime and Fisheries Fund in order to increase the competitiveness of EU aquaculture. 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.

Annex 9.2.4 *Exploiting competitive advantages*

Europe has some of the highest standards in environmental, animal health and consumer protection, which potentially gives the EU a competitive advantage over other nations. European consumers are displaying an increased environmental responsibility, with demand for sustainable/certified fish products and organic produce growing.

Annex 9.3 Emerging issues

The Blue Growth agenda provides a clear framework for the further development of economic activities in our oceans, seas and coastal areas. However, this growth can only be developed to its full potential if it operates within the sustainable boundaries of the marine environment. There is strong evidence to suggest these boundaries are under severe pressure, and will be breached unless corrective action is taken. Meeting the 2020 goal of achieving Good Environmental Status, and thereby safeguarding the basis for sustainable blue growth requires commitment, cooperation and above all action (EU Environment Ministers Europe 2014).

Annex 9.4 Horizon 2020

Horizon 2020 is the financial instrument being used to promote research and innovation in Europe, and represents a key implementation tool of Europe 2020, the EU's growth strategy for the next decade. H2020 will provide nearly €80 billion over 7 years (2014 – 2020). It is seen as a means to drive economic growth and create jobs. The overall programme is divided into a number of 'Societal Challenges', one of which is sustainable food provision, in which aquaculture is specifically mentioned. Overlaying this are cross-cutting 'Focal Areas', one of which is Blue Growth. SMEs and industrial partners are strongly encouraged to take part, with a much simplified funding model applying to all potential partners. In addition, there is a specific funding model to encourage individual SMEs to submit funding proposals to take innovative ideas closer to market. It is clear that there excellent opportunities for European aquaculture to benefit from this programme.

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