

Aquaculture site selection and carrying capacity for inland and coastal aquaculture in Northern Europe

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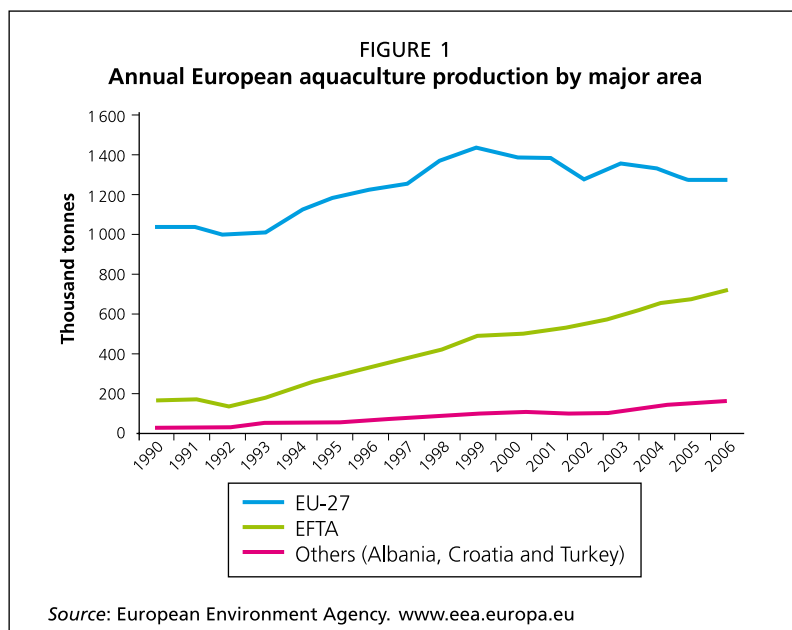
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Abstract

European aquaculture has increased over the past 15 years primarily due to increased production in the Kingdom of Norway and the Republic of Iceland. While mariculture of finfish continues to grow (mainly of Atlantic salmon, sea bass and sea bream), production of molluscs and freshwater fish has shown a steady decline over recent years. Nevertheless Europe has a number of key strengths in aquaculture. There is a strong focus on technology and research, highly trained employees, and appropriate climate for many of the species currently in demand by consumers. Increasing demands on both coastal and inland environments have led to increased competition with other activities for space and water, such as housing and tourism. This paper addresses issues relevant for site selection and carrying capacity for inland and coastal waterbodies in Northern Europe. In Northern Europe the development of aquaculture has focused primarily on intensive farming of carnivorous fish species mainly due to competition for land and water. Many of the factors to be considered depend on the culture system for example cage culture depends on water depth, water quality, water currents whereas land-based systems have to consider factors including water availability and quality, topography, and soil type. The degree of local impact is dependent on production scale and culture system, in addition to local and regional hydrodynamics and chemical characteristics.

Introduction

European aquaculture production has increased over the past 15 years as shown (Figure 1). However, production in the European Union (EU) has been more or less constant since 2000 whereas global aquaculture production has grown by one third. While the farming of sea fish continues to grow (largely due to three species – Atlantic salmon, sea bass and sea bream), production of molluscs and freshwater fish has shown a steady decline over recent years. Aquaculture in the EU contributes about



20 percent of the EU fish production, yet represents only 2 percent of global aquaculture production. The EU aquaculture sector directly employs approximately 65 000 people (EC Factsheet).

Europe has a number of key strengths in aquaculture. There is a strong focus on technology and research, highly trained employees, and appropriate climate for many of the species currently in demand by consumers. The quality standards set in Europe are rigorous to ensure that aquaculture products are

healthy for the consumer, while sustainable with regards to the environment. These strengths also bring with them challenges. High standards inevitably result in higher costs which in turn has a negative impact on the ability to compete in national and international markets. Increasing demands on both coastal and inland environments lead to increased competition with other activities for space and water, such as housing and tourism. The following sections will address issues relevant for site selection and carrying capacity for inland and coastal waterbodies in Northern Europe.

Regional and national factors relevant to site selection for aquaculture

There are several aspects to be considered for the selection of a site for aquaculture depending on the species of interest and a host of other considerations, including socio-economic and political factors which will not be dealt with in detail here. In Northern Europe the development of aquaculture has focused primarily on intensive farming of carnivorous fish species mainly due to competition for land and water. It is widely recognized that this intensive development of the aquaculture industry has been accompanied by an increase in environmental impacts (Ervik *et al.*, 1997). In this context, the sustainability of intensive mariculture has been brought into question (Read, Fernandes and Miller, 2001).

Many of the factors to be considered depend on the culture system for example cage culture depends on water depth, water quality, water currents whereas land-based systems have to consider factors including water availability and quality, topography, and soil type. The degree of local impact is dependent on production scale and culture system, in addition to local and regional hydrodynamics and chemical characteristics.

Inland waterbodies

Site selection and carrying capacity for inland aquaculture has many considerations to take, not least competition for use of water and land. Carp have historically been farmed in freshwater in Europe and Asia for thousands of years. The species appear to have been domesticated independently as the various types of farmed carp are native to different geographic regions, for example the Common Carp (*Cyprinus carpio*) originates in Central Europe. Carp was an important food source in Western Europe in the Middle Ages, however due to the increase availability of other farmed

fish species such as Atlantic salmon (*Salmo salar*) and rainbow trout (*Oncorhynchus mykiss*) in addition to environmental constraints the importance of carp culture has declined. However, pond culture of carp is still a major form of aquaculture in Central and Eastern Europe. In Northern Europe there is limited farming in lakes and this is primarily rainbow trout.

In most European countries there are limited sources of freshwater available for the establishment of new fish farms, and further growth in aquaculture is expected to be in coastal regions and the open sea. The EU Water Framework Directive (WFD) was established in 2002 to protect and restore clean water across Europe and ensure its long-term, sustainable use (further details regarding the WFD are provided below). Site selection criteria are largely determined by the type of aquaculture considered: for example in extensive pond farming, factors include water resource availability, space and geomorphological- and geochemical factors. Water quality management criteria are a major issue defining the type of culture system which is feasible at a given site. Stocking density will be determined by the permit for extractable water volumes per unit time (set by the water authorities). Intensification methods for pond farming, such as is common for trout farming in several European countries, exist within the range of regulated effluent standards by using specifically designed system components such as concrete ponds, raceways, circular tanks, aeration, oxygenation, etc. The requirements to gain a license for aquaculture in freshwater systems varies among countries in Europe, however the WFD plays a central role.

Issues locally specific to species, cultures, and geographies

The Norwegian coastline is 21 000 km long, which is half the length of the equator, and the Kingdom of Norway has a population of approximately 4.9 million, eighty percent of which resides around the coast and up to 10 km inland. Consequently the Kingdom of Norway is greatly influenced by coastal culture, and engaged in marine economic development. There are three principle areas of interest in the coastal zone:

1. protection and conservation
2. recreation
3. usage

Conflicts arise between use and conservation, more specifically, between industry, recreation and nature conservation. The most important legal tool for integrated coastal zone planning is the Planning and Building Act of 1985, which was most recently amended in 2008. The intention of this Act is to harmonize planning of central-, county- and municipal activities. This covers area use and exploitation of natural resources assessed in conjunction with the municipals planning conditions. In the 100-metre belt along the seashore and river systems, special consideration shall be given to the natural and cultural environment, outdoor recreation, landscape and other elements of public interest (which prohibits most building in this zone). However the Act states that this prohibition does not apply where the municipality, in the land-use element of the municipal master plan, has permitted the erection of necessary buildings, small installations and storage facilities for use in agriculture, reindeer husbandry, fishing, aquaculture or sea traffic. There are 280 municipalities in the Kingdom of Norway which have the right to coastal planning of one nautical mile along their share of the coastline in close dialogue with the Norwegian Coastal Administration and the Directorate of Fisheries. The coastline is divided into different zones depending on the activities which are permitted in a particular region: traffic, fishing, aquaculture, nature and/or recreation. An area has to be assigned for aquaculture, or aquaculture and an additional activity in order to be able to establish a fish farm at a particular coastal site.

The Kingdom of Norway is currently the largest aquaculture producing country in Europe. The main aquaculture species in the Kingdom of Norway is Atlantic salmon (860 000 tonnes in 2009), followed by rainbow trout (76 000 tonnes in 2009), other marine fish species, mainly cod (*Gadus morhua*: 23 000 tonnes) and approximately 1 600 tonnes blue mussels (*Mytilus edulis*). Details regarding the integration of aquaculture approaches in the Kingdom of Norway with regulation and governance are provided in detail below.

In the Kingdom of Denmark the main aquaculture species is rainbow trout (approximately 90 percent in 2009, 37 000 tonnes trout production), followed by blue mussels and European eel, *Anguilla anguilla* (total aquaculture production 41 885 tonnes in 2009: Directorate of Fisheries, DK). The set of regulations for farming marine fish or shellfish depend on the type of aquaculture operation. Three categories are defined:

1. Land-based sea water farms taking in or pumping in sea water (including cooling water from for example power plants, the operation of the farm is dependent on the use of feed)
2. Farms with net cages placed in sea water, being defined as farms consisting of net cages/netted boxes or the like placed in marine waters. The operation of the farm is dependent on the use of feed.
3. Farms in seawater without the use of feed i.e. culture of bivalves like mussels and oysters

Before establishing or extending a farm a permit application must be completed according to regulations for polluting industries from the Ministry of Environment. Fish farming applications are submitted to the regional county and the Directorate of Fisheries who are both competent authorities able to issue a permit. The environmental regulation of fish farming in the Kingdom of Denmark started with the Environmental Protection Act of 1974, the Statutory Order of 1985 forbidding wet feed, and the Action Plan on the Aquatic Environment of 1987. In the case of freshwater fish farms, the latter was implemented through the measures stipulated in the 1989 Statutory Order on Fish Farms.

Extensive fish farming has been conducted in Sweden for hundreds of years, primarily pond culture of Common Carp (*Cyprinus carpio*) and Crucian Carp (*Carassius carassius*) In the 20th Century the comprehensive development of hydroelectric power plants was accompanied by the production and release of millions of Atlantic salmon and sea trout (*Salmo trutta trutta*) to compensate for the loss of natural breeding habitats. At the same time there has been an increase in production and release of other naturally occurring or introduced stock such as the signal crayfish (*Pacifastacus leniusculus*) introduced from North America in 1969. In the 1980s there was an increase in the number and an intensification of fish farms primarily producing rainbow trout as well as an increase in blue mussel farms.

The Swedish Board of Fisheries is the government authority responsible for the conservation and exploitation of Sweden's fish resources. Aquaculture is economically a small industry in Sweden, but with a relatively large number of people involved. The licensing system is based on a given production volume per year, but in certain cases there are other requirements such as the maximum amount of feed used per year and maximum cage size. Fish production in freshwater represents approximately half of total Swedish production of farmed fish. There is some cage culture in a few big lakes such as Vänaren, as well as in some large rivers with depths from 15–20 metres.

The yield of Swedish aquaculture in 2009 was 6 130 metric tonnes of fish for consumption and the dominant species was rainbow trout (6 413 tonnes in fresh weight), with 89 percent of the total production of fish for consumption. Furthermore there were 2 125 tonnes of blue mussels cultivated. The production of fish for release to the wild was estimated at 993 tonnes. The dominant species was rainbow trout

(651 tonnes), followed by brown trout (*Salmo trutta*: 212 tonnes) and Arctic char (113 tonnes). For re-stocking approximately 2.9 million fry of Atlantic salmon and sea trout were released in 2009, mainly in rivers running into the Baltic (data source: Swedish Board of Fisheries and Statistics, Sweden, 2010).

As a result of existing strict regulations regarding discharges of nutrients from all activity in the Baltic Region, the potential for Swedish aquaculture is limited. This restricts both the expansion of production at existing locations, and the extension of aquaculture to new locations.

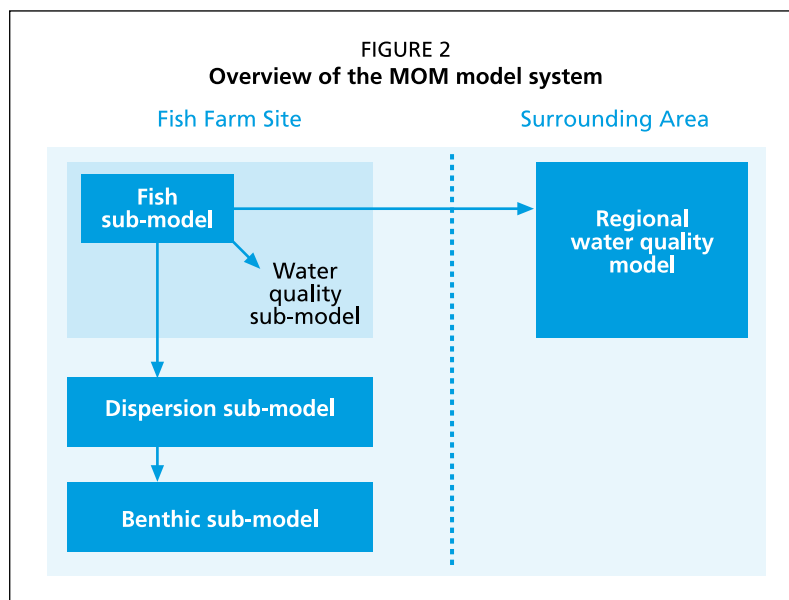
The Baltic Sea is one of the world's largest brackish water areas. It is a semi-enclosed sea with a surface area of 415 000 km² and a volume of 21 700 km³, thereby representing 0.1 percent of the world's oceans in area, but only 0.002 percent of the volume (Ducrottoy and Elliott, 2008). Nearly all fish production in the Baltic Sea is rainbow trout (Finnish Environmental Institute, 2008) which are cultivated in net-pens. Total production of rainbow trout in the Baltic Sea in 2007 was 11 300 tonnes (Finnish Game and Fisheries Research Institute, 2008). Aquaculture causes relatively small-scale nutrient emissions, but local environmental impact may be considerable. Between 2004–2007, the input of nutrients to the system in the form of fish feed was 829 tonnes nitrogen/year and 115 tonnes phosphorous/year. Of the primary input, 70 percent was discharged to the Baltic Sea, directly from aquaculture and indirectly through waste management. The nutrient cycle could be closed partially by using local fish instead of imported fish in rainbow trout feed, thus reducing the net load of N and P to a fraction (Asmala and Saikku, 2010).

Use of models and decision support tools

Several tools exist to evaluate site selection for cage aquaculture, such as the model developed by Halide *et al.* (2009) which includes considerations of site classification, site selection, holding capacity and economic appraisal of farming at a given site. It is based on measurements of water and substrate qualities, hydrometeorology and socio-economic factors and classifies cage culture sites into one of three categories – poor, medium, and good.

In the Kingdom of Norway the Modelling-On growing fish farms-Monitoring (MOM), is the model legally required by the Directorate of Fisheries for site selection for mariculture of salmon and trout. The MOM model has been developed to estimate the holding capacity of sites for cage farming of fish (Stigebrandt *et al.*, 2004). The model comprises four sub-models (Figure 1),

which are input parameters for one or more of the other sub-models. One advantage of a modular model is that the sub-models can be altered individually as new knowledge is acquired or as new managing procedures or fish species are introduced.



Note: The local site model is linked to a regional (inshore) water quality model (Fjord Environment) (Aure and Stigebrandt, 1990). The output parameters from the fish sub-model are used as input parameters to the water quality sub-model, the dispersion sub-model and the regional water quality model. The dispersion sub-model delivers input parameters to the benthic sub-model.

The model management system MOM includes a monitoring program and Environmental Quality Standards (EQS) (Ervik *et al.*, 1997; Hansen *et al.*, 2001). In the MOM system the environmental objective for the management of sites for fish farming is that their impact must not exceed threshold levels that safeguard the well-being of both the fish and the environment. There are three basic environmental requirements which must be fulfilled in order to ensure long-term use of the sites:

1. The accumulation of organic material under and in the vicinity of the farms must not result in extinction of the benthic macro infauna. This condition is met if the flux of organic matter from the farm is adjusted to local dispersion and resuspension conditions so that the decomposition capacity of the benthic system is not exceeded.
2. The water quality in the net pens must meet the needs of the fish. This means that the concentration of oxygen is kept above a threshold level and that the concentration of ammonium and other potentially harmful substances are kept below threshold levels. These conditions can be met if the respiration of, and emissions from, the fish are adjusted to the rate of water renewal in the net pens.
3. The water quality in the areas surrounding the farm must not deteriorate. This requirement is fulfilled if the outlets of nutrients and organic matter from the farm do not contribute to significantly higher algae production in the surrounding surface water or result in low oxygen concentrations in deep water. When the environmental impact is being assessed the contributions of all other sources must also be taken into account, thus considering the total impact.

The holding capacity is determined from the lowest of the three estimates. The fulfilment of the first two requirements depends on local environmental parameters such as water depth, the annual temperature cycle and the vertical distribution of current properties, and concentrations of oxygen and ammonium. It also depends on the maximum fish density per unit area, so the physical configuration of the farm is of importance. These factors as well as feeding rate and feed composition are taken into account in the model. In practice, three different holding capacities are computed; one for each of the basic requirements. The holding capacity of the site is then given by the lowest of the estimates. For the model computations, site-specific environmental conditions such as water depth, current characteristics, concentrations of oxygen and ammonium and the annual temperature cycle must be known. The holding capacity will also depend on the size and the orientation of the net pens, as well as on the maximum fish density per unit area in the farm, the composition of the feed and the feeding rate.

Depending on the input variables the MOM system characterises a given location in terms of how suitable it is for locating a fish farm into the following categories:

- A - Excellent
- B - Very good
- C - Good
- D - Acceptable
- E - Poor
- F - Very poor

The MOM model system is primarily meant to estimate the holding capacity of new sites for fish farming, but it may also be used to assess the environmental consequences of changes in production on farms already in operation. The Ministry of Fisheries and Coastal Affairs is in the process of integrating the MOM system into a cohesive management system – MOLO (MOM–LOkalisering) (environmental monitoring – site selection) for mariculture.

Integration of current approaches with regulation and governance

Fish farming in coastal regions of the Kingdom of Norway is controlled by several laws and regulations administered by Authorities under the Ministry of Fisheries and Coastal Affairs, Ministry of Environment, Ministry of Agriculture and Food, with the Ministry of Fisheries as the main authority responsible for the industry. The Aquaculture Act introduced the licensing system in 1973, and initially imposed limitations on the maximum size of each farm, in addition to the maximum number of permits, which are issued by the Directorate of Fisheries. In 2005, the Aquaculture Act was amended and a new system was introduced for production restrictions with maximum permitted biomass (MTB) instead of a volume restriction of the sizes of fish farms, in addition to environmental monitoring. According to revised legislation, every 1 m³ previously permitted farming volume is considered equal to 65 kg maximum biomass (with the exception of the regions Troms and Finnmark where 1m³ is considered equal to 75 kg biomass). An Act regarding environmental risk assessments of fish farms was enforced from June 2009. The maximum allowable biomass system combined with the requirement for environmental investigations for site selection and environmental monitoring during operation, aim to ensure environmentally sustainable production and protect fish health and welfare. In the event of applications for new farm licenses or expansion of existing facilities, environmental investigations of benthic conditions at the proposed site are mandatory, in addition to hydrographical and topographic surveys. During operation, fish farmers have to perform regular environmental monitoring of the benthic conditions at the site.

There are approximately 1000 permits for mariculture of Atlantic salmon and trout along the Norwegian Coast, one has to purchase a permit (from an existing owner), which has to be approved by the Directorate of Fisheries and then obtain a license to operate at a given site. In order to obtain a license, a form has to be completed, with relevant information regarding the site (water depth, current, water quality etc) and intended biomass, which is submitted to the Directorate of Fisheries, (in accordance with the Aquaculture Act), the Norwegian Food Safety Authority (in accordance with the Food Law), and the Climate and Pollution Agency (in accordance with the Pollution Act). The application is also open for public consultation, and takes considerable time to process. If a license is authorized by the Directorate of Fisheries (from 2011 by the County Authority) the farm has to be established within two year, and there are certain legal requirements which the fish farmer has to follow up. This includes a written operating plan, internal control and monthly reporting to the Directorate of Fisheries (feed use, number of fish, mortalities etc.).

The Directorate of Fisheries is responsible for the inspection of fish farms, which is conducted on a risk-basis. For example there is annual inspection of salmon and trout farms which are located in fjords which have significant wild salmon populations. No new locations for fish farming are being given in fjords with important wild salmon populations, and existing farms are being relocated further off the coast.

Obligatory monitoring of fish farms was introduced from the 1st of January 2005 according to the classification of the standard NS9410 B-survey, and mandatory reporting of the results to the Directorate of Fisheries from summer 2009. The B-survey includes several parameters and distinguishes between four conditions of benthic effect from 1, which represents little effect of the fish farm to 4 which is defined as overloaded. Details regarding the organic loading from different fish farm locations from the North to the South of the Kingdom of Norway are provided (Table 1). From a total of 996 locations, 332 locations were surveyed (Directorate of Fisheries, the Kingdom of Norway). Each fish farm has several locations which are used in rotation in addition to mandatory fallow periods. Consequently many of the locations will be without fish and are thus not surveyed until they are operational.

The recipient may also be monitored according to the more comprehensive C-survey of the NS-EN ISO 1666 standard in certain cases which includes a more detail examination of the benthos and distinguishes between four environmental states where condition 4 represents an overload to the extent that there are no animals present in the sediment.

Salmon hatcheries are freshwater aquaculture operations which mainly use tanks, and which typically have more complex legislative requirements than mariculture in pens or cages. The Norwegian Ministry of Fisheries and Ministry of Agriculture simplified legislation regarding hatcheries in an Act enforced from January 2001 regarding licensing-, establishment-, and management of hatcheries in addition to disease prevention. This Act reduced the number of legislative documents to be followed and facilitated the cooperation between the fisheries- and veterinary government agencies. This Management and Disease Act was adapted to the management- and disease challenges affecting the industry and includes several regulations which the industry have to adhere to.

Water is privately owned in the Kingdom of Norway so an applicant wishing to apply for a fish farm license which requires freshwater first has to obtain permission from the owner to extract the water. Approval of sites for establishing freshwater fish farms requires compliance with many laws and Public Authorities. Central Acts include the Aquaculture Act, Pollution Act, Planning- and Building Act, Food Law, and Water Resource Act, which are all dealt with by separate Authorities. It is essential that the process is coordinated and clarifications dealt with prior to a license being approved by the Directorate of Fisheries in accordance with the Fish farming Act. The Directorate of Fisheries, in collaboration with the Norwegian Food Safety Authority, the Norwegian Coastal Administration, the Climate and Pollution Agency and the Norwegian Water Resources and Energy Directorate has produced a guidance document for applications for freshwater aquaculture. The main type of freshwater aquaculture in the Kingdom of Norway is salmon and trout hatcheries. There are very seldom applications for new hatcheries most applications are to increase the size of existing hatcheries.

TABLE 1
Organic loading at fish farm locations in the Kingdom of Norway between 2008–2010 measured according to the NS 9410 B-survey where condition 1 is best (low impact) and condition 4 is overloaded.

County	Condition				Total no. of surveys	Total no. of locations
	1	2	3	4		
Finnmark	5	2	2	1	10	62
Troms	21	8	0	0	29	107
Nordland	48	19	6	1	74	197
N.-Trøndelag	15	5	2	0	22	71
S.-Trøndelag	8	4	2	0	14	80
Møre and Romsdal	26	3	2	0	31	105
Sogn and Fjordene	23	5	3	0	31	99
Hordaland	50	31	6	0	87	197
Rogaland	14	8	4	0	26	64
Agder	4	4	0	0	8	14
Total	214	89	27	2	332	996

Source: Directorate of Fisheries

There are approximately 220 salmonid hatcheries in the Kingdom of Norway, of which about 75 percent are flow-through systems taking freshwater from rivers, and discharging the water in to the sea or fjord. There are an increasing number of recirculation systems, which rely on partial recirculation of freshwater prior to discharge.

In the European Union, regulation of the aquaculture sector is under the remit of the Common Fisheries Policy (CFP). In 2002 the European Commission addressed the sustainability of this industry. The Common Fisheries Policy, which covers European aquaculture developments, recognizes that the way forward to a sustainable industry is through an ecosystem based approach. Community regulations for fisheries and aquaculture specifically acknowledge that it is necessary to include rules for the monitoring of conservation and resource management, and that Member States shall adopt provisions to comply with the objectives of regular monitoring of activities and technical controls, particularly in development of the aquaculture industry in coastal areas. The submission of statistics on aquaculture products is also a requirement at a European level. This resulted from an acknowledgement of the impact of aquaculture on regional development and on the environment. EU Member States are required to ensure that all aquaculture enterprises operate within the rules on environmental protection. Most of the legislation takes the form of directives adopted by the EU which are translated into detailed national rules and procedures.

The WFD directive provides an approach for water management based on river basins, the natural geographical and hydrological units to protect aquatic ecosystems. The directive addresses inland surface waters, transitional waters, coastal waters and groundwater and has implications for fisheries and aquaculture activities. The WFD has been brought into force nationally in the EU through different Acts, and defined national competent authorities are responsible for implementing the WFD. The Directive prescribes the establishment of ecologically based environmental targets for watercourses and related fjords and coastal waters. In order to meet the environmental target for water that is satisfactory both ecologically and chemically, the countries involved are required to characterize their waterbodies and to establish monitoring strategies etc. Various countries have different time lines for implementation of the WFD, in the Kingdom of Norway the Directive shall be fully implemented by 2015. National regulations based on the WFD define the volume and type of water permitted to be extracted from groundwater and/or surface. These regulations also set water quality criteria for effluent discharge into receiving waters.

Current and future issues and bottlenecks

Many of the drivers for the growth of European aquaculture are found at regional or national levels however the European Commission plays a central role in the potential development of aquaculture in Europe. While there has been consistent growth in salmon culture in Northern Europe (primarily in the Kingdom of Norway), aquaculture production in Mid-Europe has remained fairly constant in the last decade. A major bottleneck for aquaculture in this region is the competition for resources in these countries which have high population densities compared to Northern Europe.

A risk assessment of the environmental effects of fish farming was recently conducted by the Institute of Marine Research, at the request of the Norwegian Ministry of Fisheries and Coastal Affairs (Aure *et al.*, 2010). The main risks to the environment were identified as the spread of salmon lice (*Lepeophtheirus salmonis*) and genetic effects of escaped farmed Atlantic salmon on wild fish. With regards to the discharge of nutrients (nitrogen and phosphorous) and organic matter from sea cages, monitoring of 300 fish farm locations indicated that only two had poor conditions with respect to organic loading and eutrophication according to the classification of the standard NS9410, MOM part B. Most of the phosphorous released from salmon cages is organically bound and sinks out of the euphotic zone. Inorganic phosphorous is seldom a limiting

factor for algal production along the Norwegian coastline. The MOM model was used to calculate the nitrogen and phosphorous release from salmon farms (sea cages). It was estimated that approximately 10.3 kg dissolved nitrogen and 1.7 kg dissolved phosphorous is released per tonne of salmon produced. Most salmonid farming in the Kingdom of Norway is from the coast of Rogaland and northwards and these areas are fairly oligotrophic, and have relatively strong currents and high levels of water exchange. The typical current speed along the coast is 20–50 cm s⁻¹, with a maximum of approximately 100 cm s⁻¹. Water transport in the top 30 metres of the coastal current is about 0.3 million m³ in the South and increases to approximately 1 million m³ in the North. Based on knowledge regarding water transport and typical nitrogen and phosphorous measurements along the coast it is estimated that the contribution of nutrients from fish farming to the background levels of nutrients ranges from 1–1.5 percent in the South to <0.1–0.4 percent in the North. This demonstrates that the release of nutrients from aquaculture has an insignificant effect on the nutrient levels in coastal waters (Aure *et al.*, 2010). Measurements from areas with high densities of fish farms in Chile, Scotland, Mediterranean, and the Kingdom of Norway (Soto and Norambuena, 2004; Gowen and Ezzi, 1994; Pitta *et al.*, 2006; and Husa *et al.*, 2010) show that there is little risk of regional eutrophication of coastal waters in areas with good water exchange.

Several studies have shown that the effect of fish farming on benthic conditions is local, and is limited to a few hundred metres from the cages (Aure *et al.*, 2010). The degree of influence both local and regional depends on whether the input from the fish farm is adapted to the carrying capacity at the site. At a regional level in the Kingdom of Norway it does not appear that the sea bed is overloaded with organic matter from aquaculture.

Recommendations

In order to expand aquaculture in European coastal waterbodies farming techniques should be developed to reduce environmental impact. In Norway this involves combating the problem of salmon lice and reducing the number of escapees from salmon farms. An increased production from inland waterbodies is most likely achievable by intensification at existing sites and further development of recirculation aquaculture systems to reduce water and energy consumption and to reduce nutrient emission to the environment.

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