ECOSYSTEM-BASED APPROACH TO NORWEGIAN AQUACULTURE MANAGEMENT

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Abstract

The Norwegian aquaculture is a growing industry and has become an important industry in Norway. It is one of the most export industries, and contributes to activities throughout the whole country, particularly in many local communities along the cost where the aquaculture industry activity is concentrated. Poor management and unregulated aquaculture industry will lead to many negative effects on the whole ecosystem. The ecosystem has thresholds and limits that can affect the system structure when exceeded. The ecosystem approach for aquaculture is a strategy for the integrated management of land, water, and living resources that it promotes sustainable development, equity, and resilience of interlinked social and ecological systems. Aquaculture development needs to be within the carrying capacity of the water resources, social-based and within other relative sectors so that is sustainable without negative impacts on the environment.

In this paper, I will discuss an applying ecosystem-based approach to Norwegian aquaculture at different scales to ensure a sustainable aquaculture development without negative impacts on the environment.

Keywords: Ecosystem-based management, Norwegian aquaculture, sustainability, aquaculture management, ecosystem approach to aquaculture

Introduction

Aquaculture is about to revolutionize the way we consume fish and other marine food products as agriculture already did on land. During the past few decades' world capture fisheries have stabilized or decreased, whereas aquaculture production has increased massively (FAO[30] 2012). In 2010, aquaculture stood for 47% of global food fish production, and in Norway the export value of farmed seafood now exceeds that of wild caught species (FKD[31] 2013). Today, fish is the third most important export product after oil/gas and metal, and accounts for 5.7 per cent of the total Norwegian export value according to Statistics Norway (SBB[32] 2013). Norway is the largest exporter of aquaculture products in Europe, and number six globally, after Asian nations such as China, India and Indonesia (FAO 2012). This industry is very important for the farmers and the people living along the cost according to the benefits in the form of labour opportunities and financial income. The number of employees who employed directly in the aquaculture production is around 9000, but more than 22,000 are involved in this industry. Most people in Norway (about 80 percent of the population) live in less than 10 km from the sea. It is thus clearly of high importance for Norwegian economy to ensure a sustainable aquaculture development.

The costal/fjord ecosystems receive fresh water inputs; rich in organic and mineral nutrients derived from erosion, urban, agricultural, aquaculture and industrial effluents, and are subject to strong anthropogenic pressures due to the fish farming. The interactions

[30] Food and Agriculture Organization of the United Nations.
[31] The Norwegian Ministry of Fisheries and Coastal Affairs.
[32] Statistics Norway, www.ssb.no

between land environment and sea boundaries reveal high physical, chemical and biological complexities, making the management decisions difficult to take and the consequences of these decisions very hard to predict. Emissions from onshore activities in Norway, from the offshore oil and gas industry and from ships all contribute to inputs of various substances to fjords areas and coastal waters where the aquaculture industry activity is concentrated.

Norwegian government is working with all the stockholders to ensure that the Norwegian aquaculture industry is run on a sustainable basis and eco-friendly as well (*figure 1*). A sustainable aquaculture industry should run with consideration for the environment, and adapted to the surrounding marine environment and biological diversity. It is important to ensure a clean marine environment and good production locations for aquaculture, with minimum impact from transport emissions and pollution from more local sources. Therefore, authorities and industry must cooperate to ensure a sustainable aquaculture development with benefit of its surroundings (ecosystem-based). An environmentally sustainable aquaculture industry, minimizing risks to the marine environment and biological diversity, is a prerequisite for long-term growth and development. The strategy of the Norwegian government identifies five key areas where aquaculture may potentially have a negative impact on the environment (FKD 2009); 1) Escaped fish/genetic interaction; 2) Pollution and discharges; 3) Diseases and parasites; 4) Use of coastal areas; 5) Feed and feed resources. In this paper I will discuss an applying ecosystem-based approach to Norwegian aquaculture at different scales to ensure a sustainable aquaculture development without negative impacts on the environment.

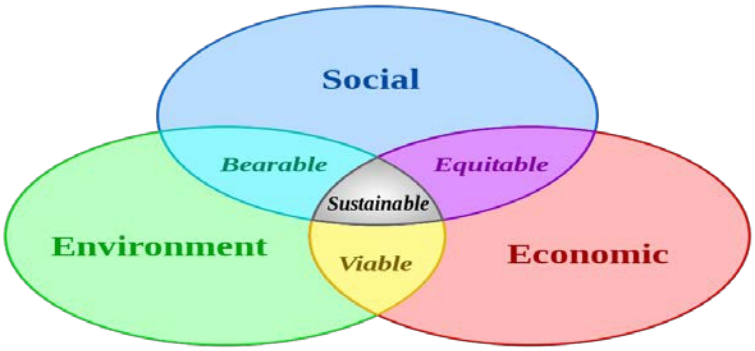

Figure 1: Illustration of sustainable development

Ecosystem approach to aquaculture

Aquaculture growth invariably involves the expansion of cultivated areas, higher density of aquaculture installations and of farmed individuals, and use of feed resources produced outside of the immediate area, thus many negative effects are identified when the sector grows unregulated or under poor management. Norwegian aquaculture operates in the natural environment (mostly in fjords and coastal areas) that we all share, and that imposes obligates on everyone concerned. The authorities, research communities and industry are all should work together to operate the Norwegian aquaculture in a sustainable framework.

Applying an ecosystem approach to aquaculture must involve physical, ecological, social and economics systems in the planning for community development (White et al. 2008). FAO definition of the ecosystem approach to aquaculture is:

An ecosystem approach to aquaculture (EAA) is a strategy for the integration of the activity within the wider ecosystem such that it promotes sustainable development, equity, and resilience of interlinked social-ecological (Soto et al. 2008).

The participation of stakeholders is at the base of the strategy, and EAA is not what is done but rather how it is done. The EAA is based on the principles of sustainable development, where sustainable is not restricted to ecological consideration only, but includes economic and social considerations and their interaction with ecological ones (*figure 1*). Both

the social and biophysical or ecological dimensions of ecosystems are tightly linked, so that disruption in one is likely to cause a disruption or change in the other.

The goal of EAA is to overcome the sectoral and intergovernmental fragmentation of resources management efforts and to develop institutional mechanisms for effective coordination among various sectors active in the ecosystems in which aquaculture operates and between the various levels of government.

Key principles

Reference to (Soto et al. 2008), the EAA should be guided by three main interlinked principles to ensure aquaculture contributes positively to sustainable development and getting the balance between ecological and human well-being:

Principle 1

Aquaculture development and management should take account of the full range of ecosystem functions and services, and should not threaten the sustained delivery of these to society.

Developing aquaculture in the context of ecosystem functions and services is a challenge that involves defining ecosystem boundaries (at least operationally), estimating some assimilative and production carrying capacities, and adapting farming practices accordingly. This requires to consider ecosystem services to be preserved or guaranteed.

Principle 2

Aquaculture should improve human well-being and equity for all relevant stakeholders.

This principle seeks to ensure that aquaculture provides equitable includes opportunities for development and equitable sharing of its benefits. This ensuring that it does not result in any undue detriment for any groups within society, especially the most vulnerable. Both food security and safety are to be promoted as key components of well-being.

Principle 3

Aquaculture should be developed in the context of other sectors, policies and goals.

This principle recognizes the interactions between aquaculture and the larger system, in particular, the influence of the surrounding natural and social environments on aquaculture practices and results. This principle also acknowledges the opportunity of coupling aquaculture activities with other production sectors to promote materials and energy recycling and better use of resources in general. This principle is a call for the development of multi-sectoral or integrated planning and management systems.

Implementations

Because EAA is applied to large, diverse areas encompassing an array of interactions between species, ecosystem components, and humans, it is often perceived as a complex process that is difficult to implement. But in light of significant ecosystem degradation, there is a need for a holistic approach that combines environmental knowledge and co-ordination with governing agencies to initiate, sustain and enforce habitat and species protection, and include public education and involvement.

The EAA requires an appropriate policy framework under which the strategy develops through several steps (FAO 2010):

The definition and scoping of ecosystem boundaries and identifying the stakeholders. Defining clear and concise goals for EAA is one of the most important steps in effective EAA implementation.

Identification of the main issues.

Prioritization of these issues.

Definition of operational objectives.

Elaboration of an implementation plan.

The corresponding implementation process, which includes reinforcing, monitoring and evaluation.

Long-term policy review.

As described by Tallis et al. (2010), some steps of ecosystem-based management in general may include:

Scoping

This step involves the acquisition of data and knowledge from various sources in order to provide a thorough understanding of critical ecosystem components.

Defining indicators

Defining indicators are useful for tracking or monitoring an ecosystem's status and can provide feedback on management progress (Slocombe 1998). Examples may include the population size of a species or the levels of toxin present in a body of water. Social indicators may also be used such as the number or types of jobs within the environmental sector or the livelihood of specific social groups such as indigenous peoples.

Setting thresholds

Tallis et al. (2010) suggest setting thresholds for each indicator and setting targets that would represent a desired level of health for the ecosystem. Thresholds can be used to help guide management, particularly for a species by looking at the conservation status criteria established by either state or federal agencies and using models such as the minimum viable population size.

Risk analysis

A range of threats and disturbances, both natural and human, often can affect indicators. Risk is defined as the sensitivity of an indicator to an ecological disturbance. Several models can be used to assess risk such as population viability analysis.

Monitoring

Evaluating the effectiveness of the implemented management strategies is very important in determining how management actions are affecting the ecosystem indicators. Evaluation involves monitoring and assessing data to see how well the management strategies chosen are performing relative to the initial objectives stated.

The Norwegian Aquaculture Act and The Norwegian Ministry of Fisheries and Coastal Affairs Strategy Plan

The Norwegian Fish Farming Act was adopted almost 30 years ago at a time when the focus was on incorporating the existing enterprises into the licensing system and ensuring that new aquaculture activities were established in a responsible manner. Since 1985, there has been extensive development of the aquaculture industry. The purpose of the Act, which is in use since 2006, is to promote the profitability and competitiveness of the aquaculture industry within the framework of a sustainable development and contribute to the creation of value on the cost (The Norwegian Aquaculture Act, 2005). The establishment of aquaculture is not regulated by the aquaculture Act only, its regulated by several Acts with associated regulations (Legal framework for aquaculture operation, 2010).

The Ministry of Fisheries and Coastal Affairs has worked on the legislation on the basis of four special focus areas:

Growth and innovation in the industry: profitability and innovation in light of Norway's international competitive situation.

Simplification for the industry and public administration: greater efficiency and user friendliness.

The environment: modern and comprehensive environmental regime.

Relationship to other user interests in the coastal zone: efficient land utilization.

The act applies on the Norwegian aquaculture industry. The aquaculture industry includes the production of fish, molluscs, echinoderms, crustaceans and other living aquatic

animals and plants. The organisms are produced primarily for consumption, but they are also used as inputs in other products, including products in the cosmetics and pharmaceutical industries. Increasing the number, weight or quality of these organisms, or preferably a combination of these factors, lies at the core of these activities. This can be accomplished through active feeding and treatment, or by the stocking, collection and storage of these organisms in their natural habitat. The enterprises have developed from small-scale production with local roots to large production units with obvious industrial characteristics.

The Ministry of Fisheries and Coastal Affairs will ensure that the Norwegian aquaculture industry is run on a sustainable basis. A sustainable aquaculture industry is one which is run with consideration for the environment, and adapted to the marine environment and biological diversity. As a food producer, the aquaculture industry depends on good environmental conditions and water quality, which means that in order to protect their own businesses, fish farmers have an obvious interest in maintaining good water quality and avoiding any negative impact on their surroundings. It is important to ensure a clean marine environment and good production locations for aquaculture, with minimum impact from long-distance transport emissions and pollution from more local sources. Similarly, the authorities and industry must cooperate to ensure that aquaculture is run to the benefit of its surroundings, and not to their detriment.

Different spatial scales

EAA involves interactions among different spatial, production and temporal scales, within and among ecological, economical and social systems, and among stakeholder groups and communities interested in the present and future health of aquaculture areas. There is a high need to define the ecosystem boundaries and stakeholders when attempting to implement the EAA and connect it to a strategy plan. The aquaculture industry in Norway is very important for Norwegian economy and for whole the world as well in the context of food security and climate change. *Figure 2* shows the aquaculture activity in Norway. The figure includes all types of licenses for fish, crustaceans, shell and shellfish, its clearly shows the coastal concentration. Inlands marks include licenses for juvenile production for on growing production in sea cages, arctic charr and cultivation farms.

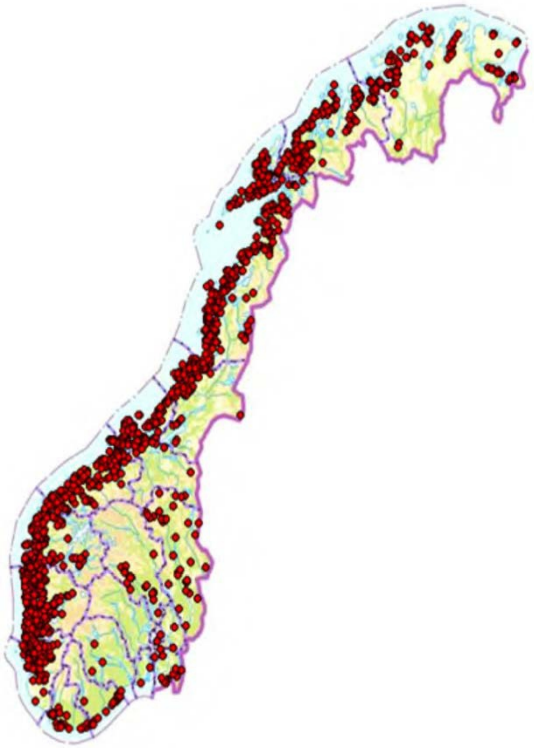

Figure 2: Geographical distribution of aquaculture licenses in Norway (www.fiseridir.no)

The Norwegian government has already lunched three integrated management plans to cover all the Norwegian cost. By following international guidelines for ecosystem-based management, the plans provide an overall framework for managing all human activities (oil, gas, shipping, fishing and aquaculture industry) in these areas to ensure the continued production and function of the ecosystem (*figure 3*). These plans are steered by many authorities, organizations and institutions from different fields. Directorate of Fisheries, Institute of Marine Research, Ministry of Environment and Ministry of Fisheries and Coastal Affaires are directly involved in the aquaculture part.

The Ministry of Fisheries and Coastal Affairs has a strategy plan to have an environmentally sustainable Norwegian aquaculture industry. Help and considerably cooperation of the Directorate of Fisheries, the Norwegian Food Safety Authority, the Institute of Marine Research and the National Veterinary Institute in doing this strategy. *Table 1* shows the five sustainability elements and summaries the goals of each element. In the following of this section, I will connect these elements with the EAA at different spatial scales.

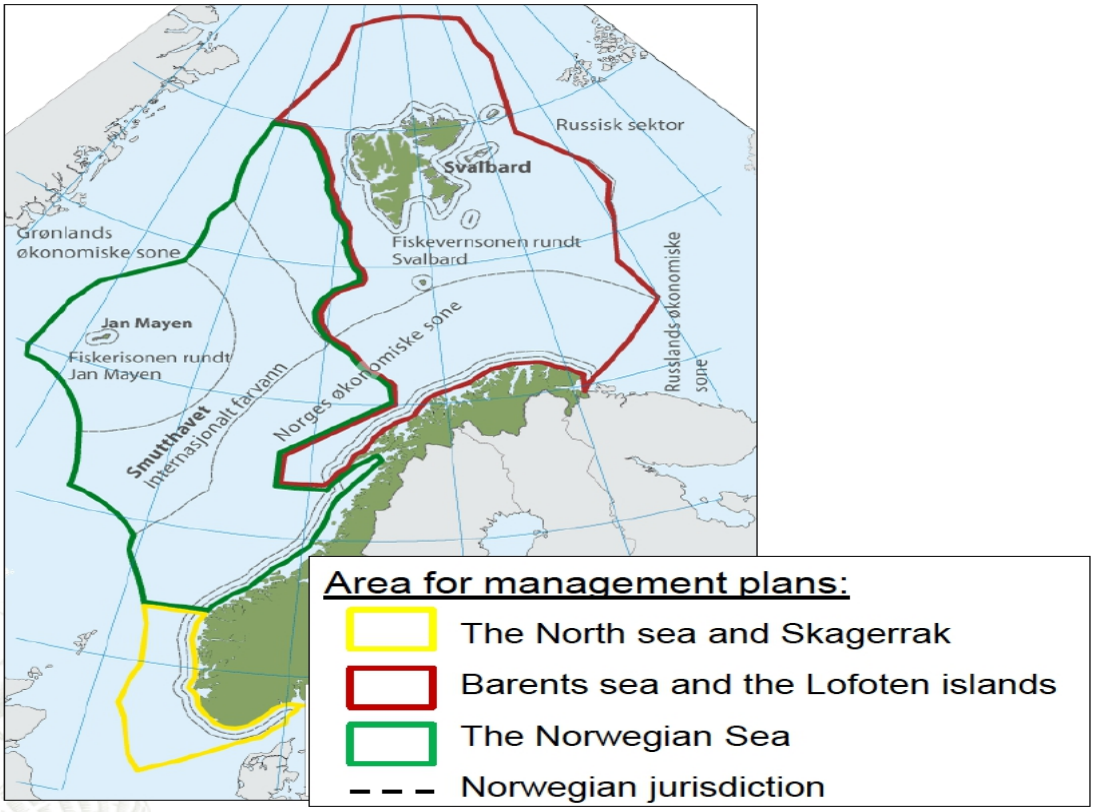

Figure 3: Areas for management plans (www.imr.no)

Number	Element	Goal
1	Genetic influence and escapes	Aquaculture does not cause irreversible genetic changes of the wild fish populations
2	Pollution and discharges	All aquaculture sites in use keep within an acceptable environmental condition and do not have a higher discharge of nutrients or organic material than the recipient can handle.
3	Disease and parasites	Diseases in aquaculture do not have a population effect on wild fish, and as fish much as possible are produced to harvestable size without the use of therapeutics.
4	Use of area	The aquaculture industry has a layout of sites and area use that minimize the environmental effects and exposure hazard
5	Feed resources	The need for feed ingredients /resources are covered with out over exploiting the wild marine fish stocks

Table 1: The five focus elements for a sustainable development of the aquaculture sector set by Norwegian Government.

The farm scale:

In 2012, the total number of licenses in Norway was around 2000 (DOF, 2012). The Norwegian aquaculture is concentrated in the coastal line (around 1300 sites). The individual farm in general is easy to locate and identify, but in cage aquaculture and open ecosystems as in Norwagian coastal areas is challenging to establish the boundary of potential effects (Halwart and Soto et al., 2007). Farm and cage sizes are very related to the environmental impacts such as escape and disease. Preventing genetic interaction and escape controlling start at this scale. Escaped problem is one of the main challenges which threaten the ecosystem in Norway (Jensen et al. 2010), even if the escaped fish total has been reduced recently (FKD 2009). The aquaculture in Norway use very advanced technologies to prevent the escaped fish. The government has a very good inspection program to follow the farming process, and the law is very strict regarding to the escapes.

For the pollution and discharges from fish farming in Norway, this is a minor environmental problem now since Norway has a very long coastline, high level of circulation and a good water quality. But in farm scale we can measure the ecosystem impacts on aquaculture. In Norway, MOM (fish farms – monitoring – modelling) method is mandatory by regulation to monitor the effects on the bottom and on the benthic fauna under and near farming facilities. This method describes how effects on the sea bed are to be monitored, and which environmental thresholds are to be applied (Evik et al. 1997).

Diseases as escapes originate and can be prevented at this scale although their effects usually occur at the watershed scale. Disease including parasites continues to be a major loss factor in Norwegian aquaculture industry. Diseases and parasites can represent a serious threat to wild fish population. Using antibiotics to combating bacterial diseases and having a proper cage size are significant for disease control in Norway.

Use of area and feed recourses are mainly related to the other scales and to the regional plans, but it’s hardly connected to the environmental impacts on the aquaculture sites at this level.

The main stakeholders at this scale are farm owners, the farm workers, family members and local inhabitants who are benefits from the farm.

The watershed/ aquaculture zone scale:

This scale includes a cluster of farms that share a common waterbody and that need a coordinated management. Norway has a long coastline (approximately 101,000 Kilometers in total, mainland including fjords and island coastlines) with around 1200 fjords, thus most of the aquaculture is concentrated in the coast (Statistics Norway for the Ministry of Foreign Affairs, 2013). Norway has more that 200 coastal zoon plans. These plans include research institutions, industry representatives and authorities such as: local authority (municipality), regional authority (county), local communities, research institutions, farmers’ representatives, … etc. (DOF, 2012).

Preventing escapes take place at the farm scale, but relevant impacts on biodiversity often occur throughout entire watersheds. At this scale, the research institutions by cooperating with other stockholders (authorities, communities and companies) run monitoring programs to understand the DNA profiles, genetic stability and understanding of the effects of escaped farmed fish have on wild populations. Considerable work and research is done and still running in Norway on the genetic interaction, particularly on the wild salmon (Geir et al. 2011).

The pollution and discharges are also taken place at this scale. A lot of coastal zoon plans focus on the pollution and discharges level in the fjords or in the aquaculture zones. The Norwegian government prioritizes research into environmental data, water quality and fjord and coast ecology. Protect of environmental sustainability by developing location criteria is

taking place at this level. And conditions related to operation, biomass, location of farming facilities can have negative effects and lead to eutrophication and overexploitation (HRMS, 2013).

Even if disease outbreaks take place at the farm scale, but need control, management and mitigation at this scale. The diseases can spread through currents or transporting process (Stene and Viljugrein et al., 2014). In Norway, there are strict requirements for well boats and transport to prevent disease spreads particularly salmon lice. And there many models that used to figure out and monitor the disease and lice spread in specific aquaculture areas such as SINMOD model which is used to simulate the dynamic of fish viruses between aquaculture sites (MODS 2012).

Effective zoning facilitates maximum production within a limited geographical area and without unacceptable impact on the environment. The Norwegian government cooperates with other stakeholders to have better location criteria to ensure the sustainability in the aquaculture industry in ecosystem-based.

Regards to the growth of the Norwegian aquaculture industry, the need to feed recourses is growing as well. Most of the feed is produced in Norway. The goal is to have the need of raw materials for feed without over exploitation of wild marine resources. To maintain sustainable production of farmed fish, it is important that fishmeal and fish oil used in the production of fish feed come from sustainability-managed stock. Using marine by-products for feed and produce the feed in the same area will strength the sustainability.

The global scale:

EAA at a global scale considers aspects of trans-national and multi-national issues such as climate change, trade of aquaculture products, feed resources and food security. Global issues are normally tackled by international organizations (e.g. FAO) and corporation between the governments. The strategy plan of the Norwegian government is more focusing on the farm and watershed scales, but the environmental impacts has effects at global scale as well.

Climate change has a direct effect on combating the fish diseases and improving the fish quality. Higher temperature and stronger wind (cause to stronger currents) will alter the traditional aquaculture in Norway. Many research institutions developed models to investigate the effects of climate change on the ecosystem as whole and on the aquaculture and fish in particular (Imr.no, 2014).

The pollution and discharges are global issues. The water quality is affected by climate change and other activities, and then has a direct effect on the fish quality. In Norway, there are many research projects on the pollution and discharges issues to investigate fish health and the biochemical consequences (HRMS, 2013).

Regarding to the enormous growth in the Norwegian aquaculture industry, there is enormous growth in feed consumption. Fishmeal and fish oil is the main components in fish feed, but in resent years, using of vegetable oils has growth. On a global basis, the average production of fishmeal and fish oil is generated from around 33 millions tons of fish annually. Norway produces around 200,000 tones of fishmeal and 55,000 tons of fish oil annually, and imports 200,000 tones of fishmeal and 170,000 tons of fish oil (FKD, 2009). The countries (Peru, Denmark, Iceland,...) which export fishmeal and fish oil to Norway have active fishing management and the management of the actual fish species in these countries follows the same principles as in Norway.

Some of the major issues at different scales relating to the key principles:

The EAA should be guided by the three main interlinked principles to ensure the sustainability.

The issues pertaining to principle 1, at the farm scale, usually have to do with the management practices. Best management practices and risk analysis are implemented at this scale in Norway. Farmed fish escapes and diseases / sea lice are controlled at this level. MOM

system is applied at this scale also. Regarding to principle 2, Norwegian aquaculture increase the employment opportunities and improve farmers and their family's condition. Following principle 3 at this scale, Norway has already started research project to utilize discharge and waste for Integrated Multi-Trophic Aquaculture (IMTA) (Wang et al. 2013). Research project (Integrate) from SINTEF[33] focused on IMTA. For small-scale farm system (distance up to 100m from cages), Intensive Integrated Aquaculture (IIA) model has been developed (Sintef.no, 2014).

The issues pertaining to the key principles at the watershed/ aquaculture zone scale: First, regarding to principle 1, potentially cumulative contribution of cluster of farms to the environmental impacts should be investigated at this scale. Norway use MOM system to evaluate and monitor the ecosystem effects of aquaculture (and other sectors) at this scale (Ervik et al. 1997). Regarding to principle 2, Norwegian government by cooperating with local authorities, research institutions and industry has lunched many ecosystem-based management plans in many coastal regions to improve human-well being and social equity to the stakeholders. Following principle 3 at this scale, Research project (Integrate) from SINTEF, that focused on IMTA, for large-scale /fjord system (distance in km), Extensive Integrated Aquaculture (EIA) model has been developed to evaluate IMTA feasibility (Sintef.no, 2014).

The issues pertaining to the key principles at the global scale: Regarding to principle 1, climate change affecting the Norwegian aquaculture development in the ecosystem context. Other relevant concerns are those related to the global environmental costs of aquaculture in terms of energy, water usage, etc. Following principle 2 at this scale is challenging. There is a need to improve the well-being of all relevant stakeholders within the context of trans-national aspects of production, markets, and other decision-making. The global scale offers an opportunity for enforcement of food safety producers to comply with global market demands. Regarding to the principle 3, Fish and aquatic proteins are increasing in world diets, and Norwegian aquaculture is rapidly increasing its relevance. The competition with other sectors for feeds is increasing and the competition for water /area use with other sectors are increasing also.

Conclusion

EAA involves recognizing and addressing interactions among different spatial scales, within and among ecological and social systems, and among stakeholder groups and communities interested in having a sustainable development in health areas. Human use coastal and ocean resources at multiple spatial scales, and recognition of the social and bio geophysical interactions that operate across different spatial scales are vital to effective management.

The Norwegian aquaculture industry is growing rapidly in the recent years, thus the Norwegian government wants to ensure that the Norwegian aquaculture industry is run on a sustainable basis. The Norwegian aquaculture is competing with other industry (gas and oil) in the coast for the resources, and all the industries and the services have their impacts on the environment. The Norwegian government has lunched a strategy plan to have an eco-friendly, sustainable aquaculture industry. The Norwegian aquaculture needs to keep a good knowledge, profitability and sustainability to continue growing and to keep the leading in aquaculture production in Europe and the rest of the world.

The Norwegian government has already lunched three integrated management plans by following international guidelines for ecosystem-based management. These plans are initiated and driven top-down by a coalition of governmental agencies and ministries, thus they need a good coordinating between them. These management plans describes a set of

[33] SINTEF (Norwegian: Stiftelsen for industriell og teknisk forsning) is the largest independent research organisation in Scandinavia.

elements for evaluating the ecological quality, including indicators and action thresholds which will be used to monitor biological diversity, sustainability of fishing, pollution, and the safety of marine foods harvested in the area. Important issues that are related to aquaculture are: 1) Sustainability indicators (Disease (sea lice) and escapes), 2) Siting structure, 3) Instruments in the Aquaculture Act and 4) Farming technology.

The Norwegian aquaculture management must take account of the nature and functioning of ecosystems at a range of spatial scales, from highly local to global. Therefore, there is a need of a "nested approach" with different approaches to management according to scale. Implementation of the EAA will require the development of institutions and associated integrated management systems which can deliver such an approach at realistic and practical scales, taking full account of the needs and impacts of other sectors. The key is to develop institutions capable of integration, especially in terms of shared agreed objectives and standards. EAA planning frameworks are not "top down" but heavily reliant on the dialogue between stakeholders. There is a strong linkage (interdependence) between the ecosystem approach and co-management.

The Norwegian aquaculture development will has better opportunities to run in a sustainable basis if: 1) utilize discharge for IMTA and Bio-FuEel, 2) Do more research on development of sterile fish (salmon), 3) Develop new technologies for removing risk and effect of escaped fish (escape free farms and systems), 4) utilize offshore knowledge for industry building.

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