Market for Water Forecast Services

With Special Attention to Norwegian Aquaculture Operators

REPORT

Rådgivende Biologer AS 926

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TITLE of REPORT:

Market for Water Forecast Services
With Special Attention to Norwegian Aquaculture Operators

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- Water forecast
- Simple market survey

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Front page photo. *A moderately exposed inshore fish farm with single circular netpens. The photo shows the "Gulholmen" location within the county of Hordaland, municipality of Os.*

FOREWORD

DHI Water & Environment has implemented and operated a Water Forecast system for the North Sea and the Baltic Sea, and has now asked Rådgivende Biologer ltd. to make a preliminary survey evaluating the market potential for such water forecast products for the Norwegian Aquaculture Industry.

The preliminary marketing survey gives an overview of the structure and present localization of the Norwegian Aquaculture Industry and focus upon the vicinity of Bergen including interviews with some local and regional aquaculture operators.

Bergen, 7th of September 2006

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DHI Water & Environment has implemented and operated a Water Forecast system for the North Sea and the Baltic Sea, and has now asked Rådgivende Biologer ltd. to make a preliminary survey evaluating the market potential for such water forecast products for the Norwegian Aquaculture Industry.

Norwegian fish farming industry is strongly regulated, based on possession of government assigned licenses, which in turn are connected to governmentally approved farming locations. These in turn have individually adjusted limitations to overall production of fish and also restrictions for dimensioning of the constructions.

Originally, the farming industry consisted of many small companies possessing one or few licences. At present there are few small companies left, and the largest aggregate of companies has nearly 25% of all salmon/trout licenses. In each region there are also a handful of medium sized companies having between approx. 10 to 25 licenses each. The medium and large companies do often have expert employees responsible for the management of all farms within the company. Small operators often combine ownership and management.

Most all of the aquaculture farms are located at quite sheltered sites in between the islands along the coastline or within the fjords. However, the need of good water exchange through the farms, has resulted in relocations towards slightly more exposed sites during the last years. One of the effects of both the increased exposure and also the ageing of the constructions, has been extensive escapements of fish due to breakdown of constructions.

The escapements of fish from fish farms results from the whole range of accidents, from holes in the net pens to complete breakdown of fish farms during extreme weather situations. This has resulted in the need of a certification system for constructions, anchoring and all equipment used, based on the degree of exposures of each individual fish farm.

The Norwegian fish farming industry has until recently mainly focused upon daily outcome, and main efforts have been related to increased production efficiency. Understanding the importance of limiting environmental factors is important to further utilize the biologically significant potential for future increased outcome. The prosperous economic situation at present should be the right moment for investment in future efficiency increases.

Several web sites present various weather and water forecasts, but most of these are on a national or regional scale. Forecasts based on models adjusted to more local conditions are not available. Such models, including tidal currents, current velocity, wave heights and wind exposure, could therefore be of interest. Most farmers, when asked, seem interested and want to follow up the increased focus on physical factors influencing their farms. So, even though most fish farms still are located inshore, being moderately exposed to wind and waves, water forecast designed for distinct areas and adjusted to each individual fish farm, is of interest for the large and growing Norwegian aquaculture industry.

INTRODUCTION

DHI Water & Environment has since July 2001 implemented and operated a Water Forecast system for the North Sea and the Baltic Sea. As an offspring of this development, the ESA co-funded project 'Improved Water Forecast by Integrating EO Products' was initiated in late 2003 under the ESA Earth Observation Envelope Program – Market Development Element Activities. Particularly, the project applies to Line 8 in the Statement of Work (SoW), leaving it to the industry to define target demand sectors and EO services.

In this single-phased contract project, DHI and its partners focused upon integrating EO data and assimilation schemes for two potential customers, -the off-shore fish farm company 'Musholm Lax Ltd.' and the Danish Oil and Natural Gas company (DONG). In wake of the main project, a smaller Contract Change Note (CCN) was accepted in January 2005 addressing mainly accuracy evaluation of wave boundary conditions, validation of integration of AATSR data and general improvements.

However, the main project (Phase 1) foresaw a limited effort of validation and marketing mainly because of focus resting with the technical operation. The service provided, particularly for Musholm Lax Ltd., was satisfactorily and well appreciated by the customer, who provided a very positive value statement. A link to the site where this water forecast is located is provided here: http://www.waterforecast.com/MusholmLax/ (see example on the next page)

Parallel with this service, a small demonstration-type of Water Forecast for, and funded by INTESAL Chile, was set up by DHI Water & Environment in 2004, sparking off interest to expand this forecast. Further, a study made possible through the ESA Earth Observation Program (EOEP) the 'New Earth Observation Markets for Fisheries and Aquaculture' (NEMA) at selected marine fish farmers in Denmark and Norway confirmed a growing interest to apply such water forecast systems.

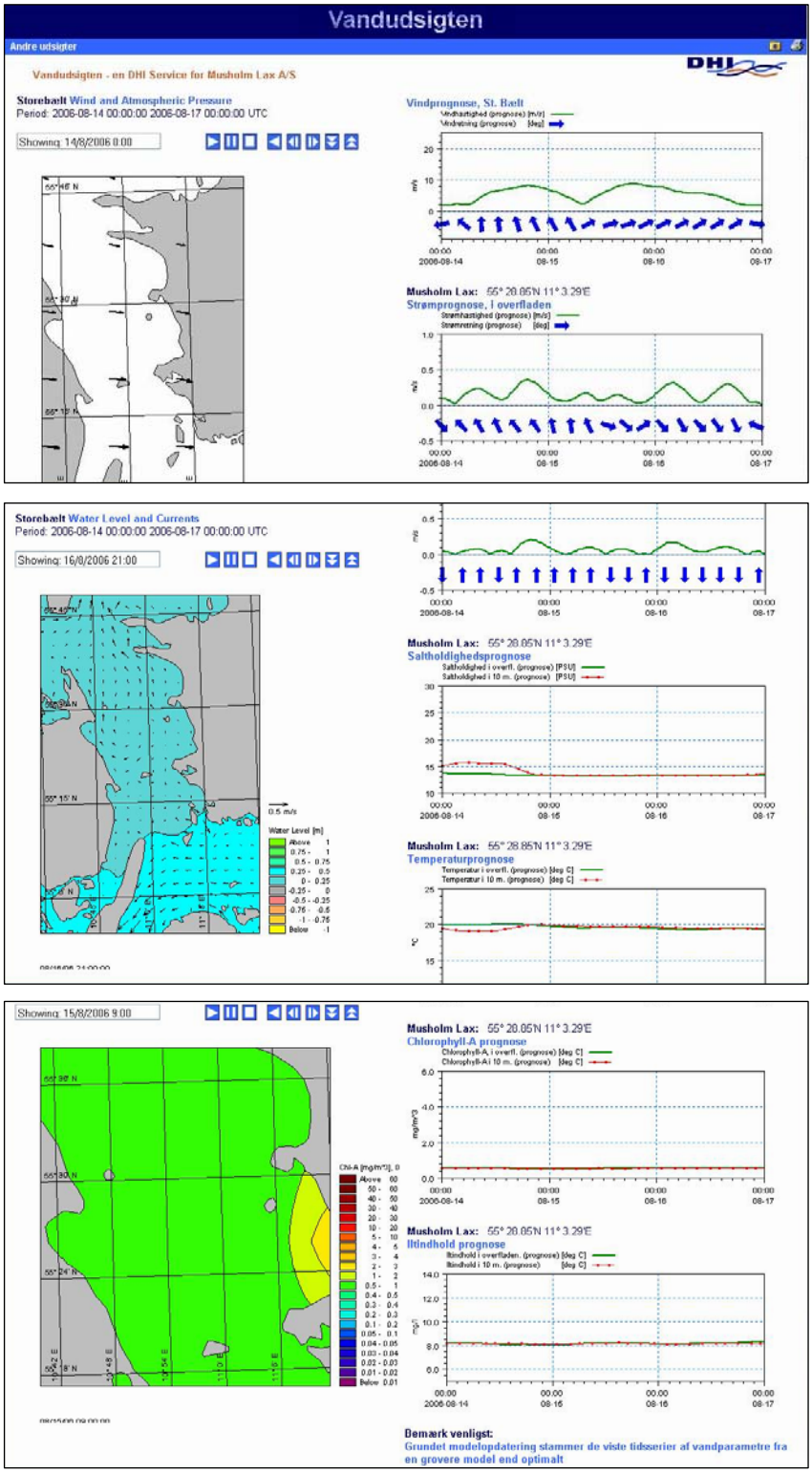
Based on the positive experience with Musholm Lax Ltd., DHI Water & Environment along with its partners therefore would like to extend a similar water forecast service to the fish farming industry in other and larger markets and regions of the world –particularly in Chile along with a probe to the Norwegian market. The program of work described by this CCN covers the tasks outlined for a Phase 2 according to the original SoW and will be focused on the extensive validation and marketing of the service on a larger scale, in a different geographic area, with a potentially large economic impact, to be performed jointly with a large community of fish farmers (INTESAL, Chile, grouping 30.000 different salmon farmers).

To take advantage of an emerging and promising market for EO data services the present project aims to capitalize on the positive past achievements. Essentially, three criteria set off this development:

1. The market for EO based products is bound to increase. The increased ability for large area coverage and forecasting functions make these products superior to conventional data acquisition methods.
2. The integration of EO data in the Water Forecast improving quality and timeliness of algal bloom forecasting.
3. The Water Forecast has proven to be technically achievable and economically viable.

Bearing in mind these criteria the further development of the sector remains with the penetration to markets in other parts of the world, i.e. in this project mainly Chile while at the same time assessing the market in Norway. Norwegian production of salmon grew threefold in the last 10 years, but Chile's jumped nearly 20 times, to 35 percent (620,000 MT) of the world total, compared with Norway's 37 percent share. The extensive off-shore marine fish farming sector in Chile is one example of an obvious market for remote sensing and EO integrated forecasts products.

The aim of this study is to survey the market for water forecast products in Norway particularly in the area within the vicinity of Bergen, where the most densely aggregations of fish farming sites in Norway are located. Information gathered in this survey will come from contacts and the network the Rådgivende Biologer ltd. among fish farmers and organizations. The marketing survey will take place primarily in the vicinity of Bergen, including interviews with the local and regional aquaculture operators.



Figur 1. *Example from the water forecast web site for Musholm Lax Ltd., developed by DHI Water & Environment along with its partners.*

STRUCTURE OF NORWEGIAN AQUACULTURE

Norwegian fish farming industry is strongly regulated, based on possession of government assigned licenses, which in turn is connected to governmentally approved farming locations. These in turn have individually adjusted limitations to overall production of fish.

KEY PLAYERS

Originally, the farming industry consisted of many small companies possessing one or few licences. At present there are few small companies left, and the largest company, Pan Fish, has accumulated nearly 25% of all salmon/trout licenses. Pan Fish thereby is the far dominant key player in Norwegian Aquaculture. The ownership has recently bought four former large Fish farming Companies; Pan Fish, Marine Harvest / Stolt Sea Farm and Fjord Seafood, and gathered all into one great company that now is the dominant Aquaculture key player worldwide. Pan Fish now also have a main part of the salmon and trout licences in both Scotland and Chile after the buying of Marine Harvest.

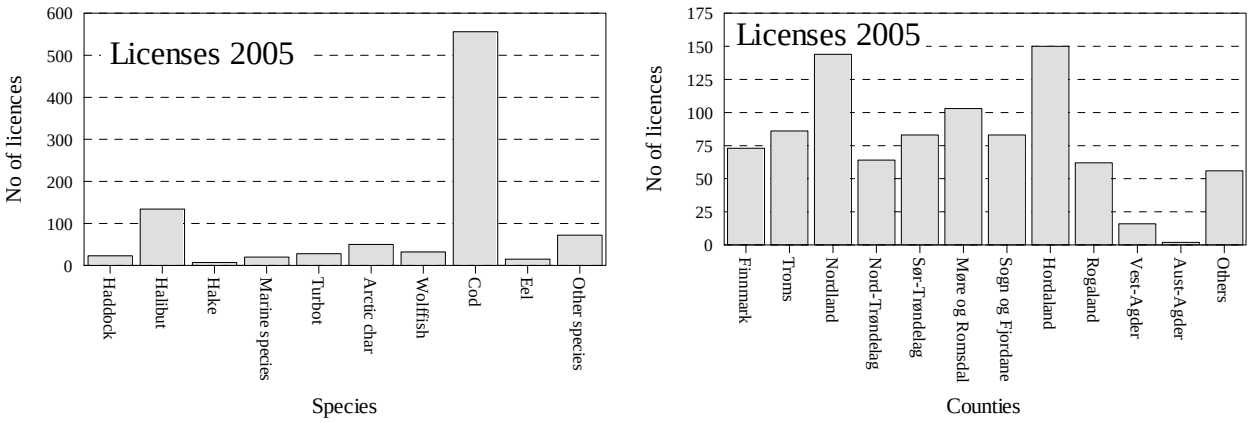


Figure 2. *The distribution of Norwegian licences in 2005 for other species than salmon and trout (**left**) and the distribution of Norwegian salmon and trout licences in 2005 in the different counties (**right**). All information from www.fiskeridir.no*

In the western part of Norway, including the counties Rogaland, Hordaland and Sogn og Fjordane, Pan Fish controls 65 salmon and trout licenses. Besides, there are several other medium sized locally based groups of fish farmers controlling about 10 – 25 salmon and trout licenses each:

- Alsaker Fjordbruk (15 licences)
- Veststar (28 licenses)
- Sjøtroll Havbruk (22 licenses)
- Bremnes Seashore (11 licenses)
- Grieg Seafood Rogaland (14 licenses)
- Firda Sjøfarmer (12 licences)

NORWEGIAN MARINE AQUACULTURE PRODUCTION

The overall and most important part of the Norwegian marine aquaculture farms is the salmon and trout industry. In 2005 there was exported 544 000 tons (round weight) of salmon and 52 000 tons (round weight) of rainbow trout. The value of this export was NOK 13,5 billions last year. Thus, the industry is large and increasing. Still, salmon production makes up approx 90% of the overall industry, and rainbow trout most of the rest, but other species as cod will increase in importance in the near future. The farming of all these three species takes place in similarily constructed farms, having much the same requirements for localization and also when discussing importance of environmental impacts.

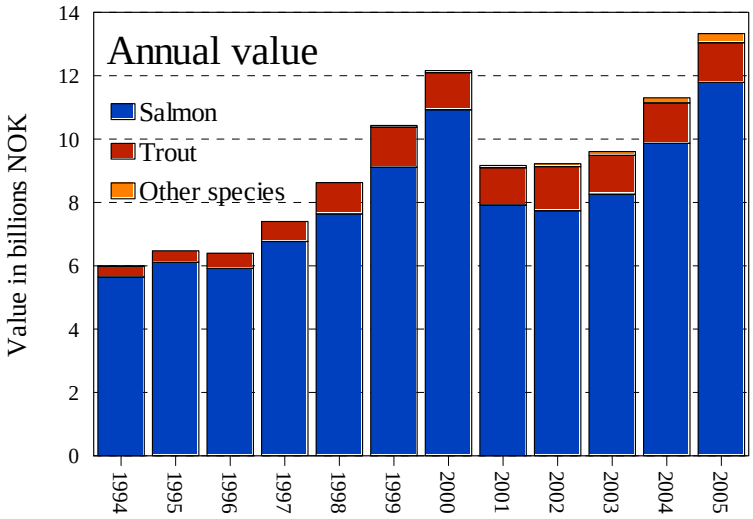


***Figure 3**. The annual value of fish produced in Norwegian fish farming industry, for Salmon, Trout and other species (except shellfish), from www.fiskeridir.no*

DISTRIBUTION ALONG THE NORWEGIAN COAST LINE

The overall number of licenses for farming of salmon and trout is quite well distributed along the Norwegian coast line from the county of Rogaland in south west and all the way up north to Finmark. However, the county of Hordaland is most densely populated with fish farming sites. The coast line between northern part of Rogaland (62 licences) to the county of Nordland (144 licences) makes up the main area for Norwegian aquaculture.

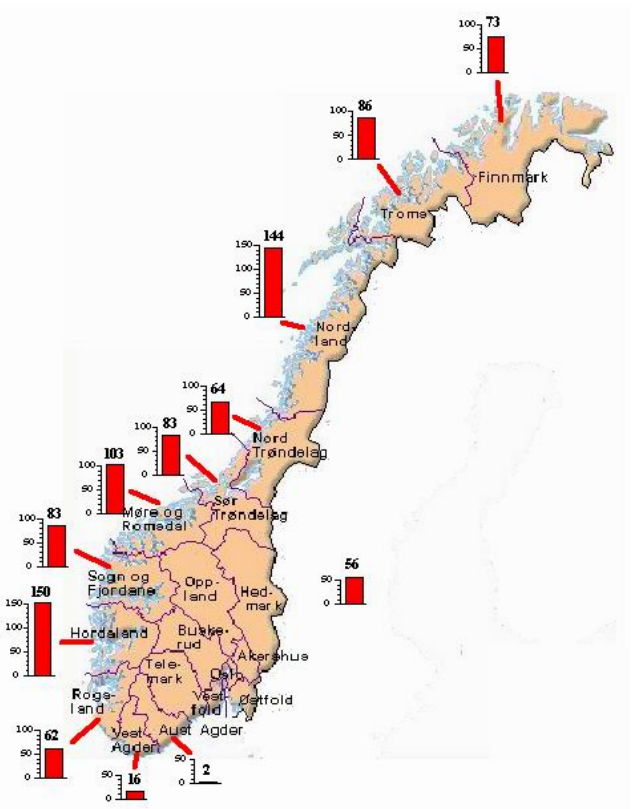


***Figure 4**. Salmon and trout licences distributed among the coastal counties in Norway in 2005). 56 licenses are distributed among the rest of the counties, from www.fiskeridir.no*

LOCALIZATION OF NORWEGIAN FISH FARMS

Most all of the aquaculture farms are located at quite sheltered sites in the Norwegian fjords and current rich straits along the coastline. The geographical landscape of the Norwegian coast line is characterised by a conglomerate of islands that give protection to the inshore fjord areas which often have depths up to 600 and even 1000 meters. Thus, the demand for locating the fish farms offshore in the most exposed areas, has not been large. However, some attempts have been made during the last two decades, but due to very rough conditions at offshore sites during the autumn and winter seasons, the constructions have been breaking down after some time. Today, there are no such sites in the Western part of Norway.

EXPOSURE INDEX AND BREAKDOWN OF FARMS

During the last years, there has been an increased focus on environmental problems due to vast escapements of farmed salmons. Last year an overall certification of all types of equipment in use were introduced to avoid farms collapsing under extreme weather conditions. The annual number of reported escaped salmons has varied between approx 250 000 and 500 000 fish (**figure 5**). The real number of escapees has been suggested to be at least twice these official numbers.

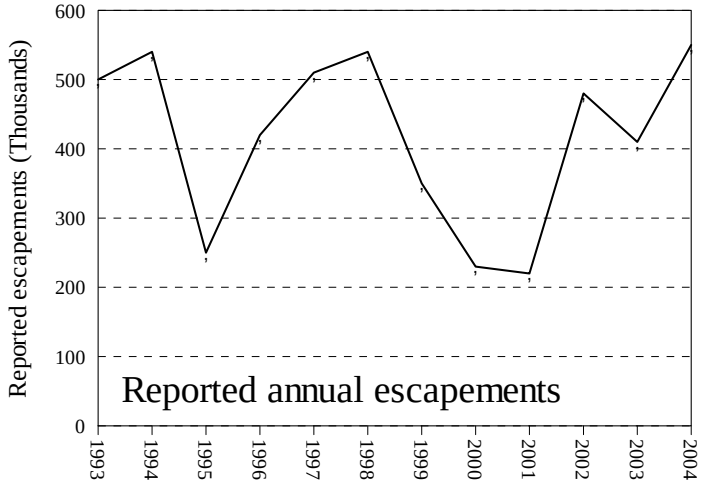


***Figure 5**. The reported annual escapement of salmons from Norwegian fish farms, from www.dirnat.no*

All fish farm sites are now classified according to exposure to wind, waves and all other climatic and physical factors that influence on the constructions, so that each individual farm is designed and suited to its local conditions. The classifications are carried out based on evaluations of the actual parameters according to **table 1**:

Table 1. *Classification of a fish farm site / location is based upon the significant wave height, wave period and current velocity. The exposure on the location is classified along the gradient from A/a = little to E/e = very strong exposure. The colours show categories for dimensioning of net pens, ranging from blue to green, yellow and red categories, corresponding to sheltered towards exposed areas.*

Significant wave height H_s (m)		Wave periode T_p (sec)	Current velocity, V_c (m/sec)				
			a < 0,3	**b** 0,3 - 0,5	**c** 0,5 - 1,0	**d** 1,0 - 1,5	**e** > 1,5
A	< 0,5	< 2,0	Aa	Ab	Ac	Ad	Ae
B	0,5 - 1,0	1,6 - 3,2	Ba	Bb	Bc	Bd	Be
C	1,0 - 2,0	2,5 - 5,1	Ca	Cb	Cc	Cd	Ce
D	2,0 - 3,0	4,0 - 6,7	Da	Db	Dc	Dd	De
E	> 3,0	>5,3	Ea	Eb	Ec	Ed	Ee

An overall summary of the 72 sites we have classified during the last two years, shows that only a minor proportion of the farms are located in areas with high exposure, with respect to both wave heights and water current velocities. Most farms are located at medium exposures to these two factors (**figure 6**). High amplitude of waves combines with larger wave lengths, and represents areas exposed along the coast of the open sea.

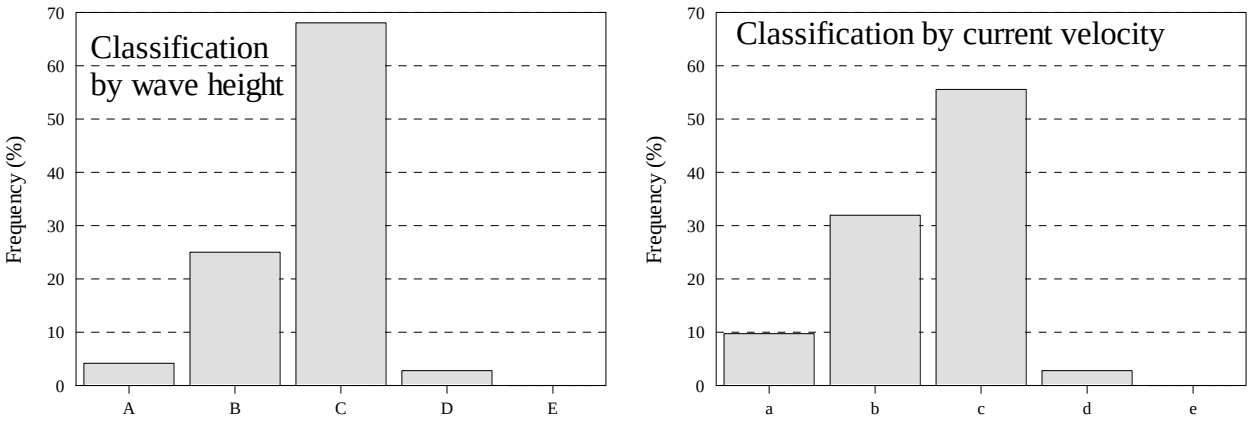
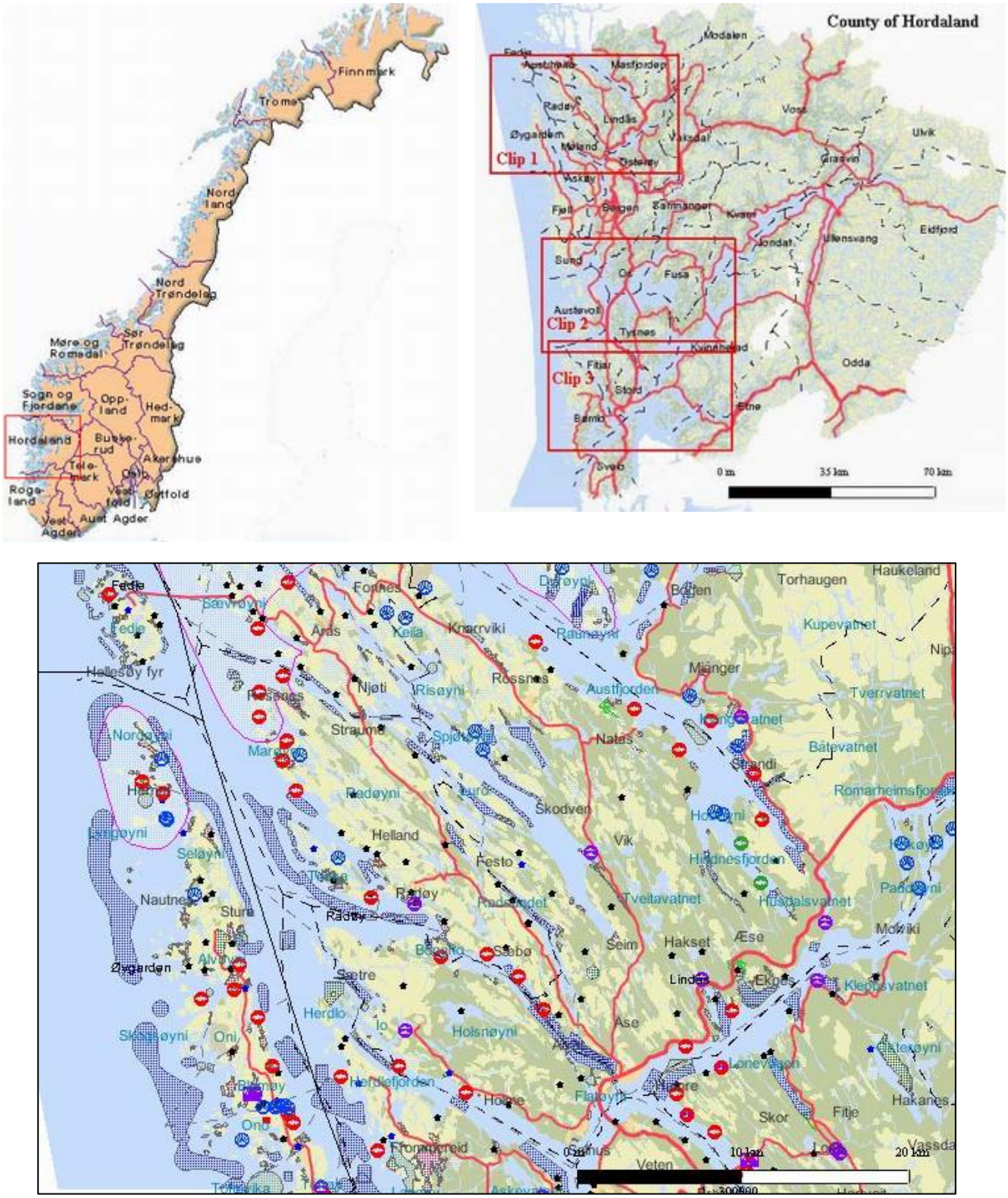


Figure 6. *Summary of the 72 sites classified by Rådgivende Biologer ltd along the coast line of the counties of Rogaland and Hordaland, Western Norway. Shown: distribution of sites classified by estimated wave heights (left) and by measured current velocity (right), according to the classification system in* ***table 1****.*

GEOGRAPHIC EXAMPLE OF SITES IN HORDALAND

Along the coast line of Hordaland county, western Norway, most fish farms are located in quite sheltered areas in between the islands and in the fjords. This area has the densest aggregation of fish farming sites in Norway (**figure 7**).



Three selected parts of the coastline of the county of Hordaland. Legends on the following page.

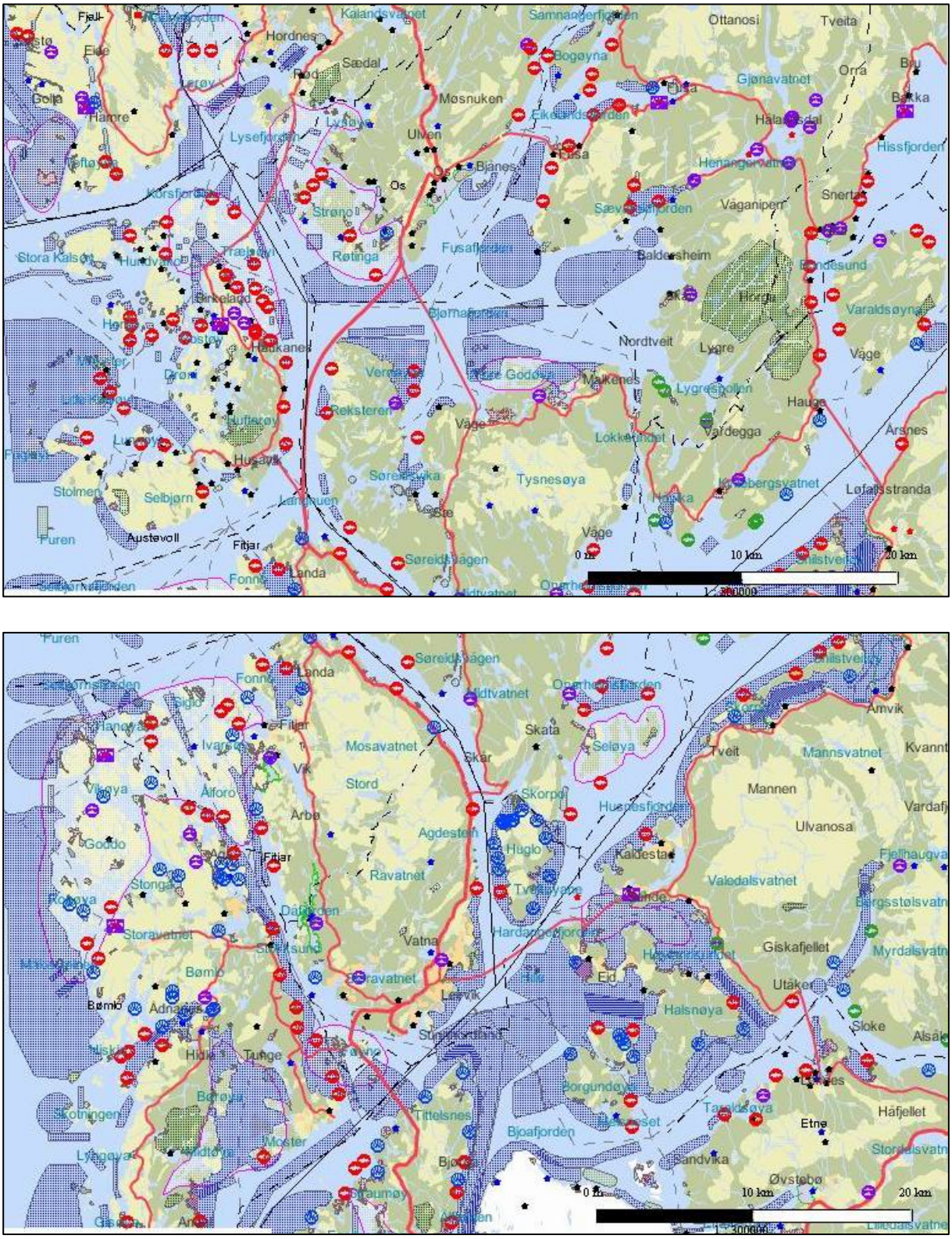


Figure 7. *Three coastal sections of the county of Hordaland, at the western coast of Norway.* ***Red*** *circles show locations for salmon farms,* ***blue*** *represent shellfish locations (not all of these are in active use),* ***purple*** *show freshwater farms for salmon smolt production and* ***green*** *represent broodstock site. Blue shaded areas are fishing grounds.*

During the last years, the aquaculture industry has followed a trend of aggregating more and more fish biomass on restricted areas in compact farms, resulting in an increasing need for better water exchange to ensure oxygen rich water within the farm. As a result of this, the farms can not be located at the most sheltered areas. We therefore see a relocation towards slightly more exposed areas along the coast quite near the North Sea or at sites in large fjords where the weather conditions are quite rough. These sites can therefore be characterized as semi offshore sites.

The development in locating fish farms still goes in a direction of more exposed sites, and therefore this will be the future for some of the Norwegian Fish Farming Companies also. A company called Fusion Marine has delivered solutions based on plastic materials that are able to handle rough weather conditions in Chile, southern Pacific, North-Atlantic and in the Mediterranean. Some of these farms have been exposed to wind strength up to 110-160 km/hour, and waves up to seven meters. The strength of the construction combined with strong pens and good mooring systems have dealt with these rough conditions. The main environmental advantages of these offshore farms are higher oxygen levels for the fish and a better spreading of fish faeces, resulting in reduced environmental impact.

PRESENT ENVIRONMENTAL MONITORING

At most farm sites, there has been little focus on environmental monitoring other than measuring temperature and salinity. Abrupt changes in these parameters can be important to monitor, reflecting large scale changes in water quality and also influencing changes in both fish appetite and possible unknown environmental risks.

Since the start of the aquaculture industry in the early seventies, these parameters were measured by hand at various time intervals. During the last few years, an increasing accumulation of fish in compact farms has resulted in a growing focus on oxygen concentration in the net pens, and therefore this parameter is also monitored at an increasing number of sites.

Most sites, however, have underwater cameras to observe the behaviour of the fish. These make the operators able to adjust feeding rate when environmental conditions changes, causing corresponding changes in the appetite of the fish. Many of these systems are also combined with echo sounders monitoring excess feeding, also enabling the automatic feeding systems to adjust feeding to the actual appetite.

Prior to locating a fish farm at a site, there is an obligatory governmental demand of measuring water current in three layers in the water column in combination with a general description of bottom conditions and recipient capacity of the actual site. These measurements are in turn followed by annual studies of environmental impacts on each site, to ensure that the production corresponds to the environmental capacity of the site. The accumulation of excess feed and faeces on the sea floor also depends on the water current spreading the depositing particles on a wider area below the farm. High water current velocities thus of course results in lesser environmental impacts (**figure 8**). In this way one would expect that the governmental demand of annual monitoring of environmental impact also would result in an increased focus on sites with higher water current speeds.

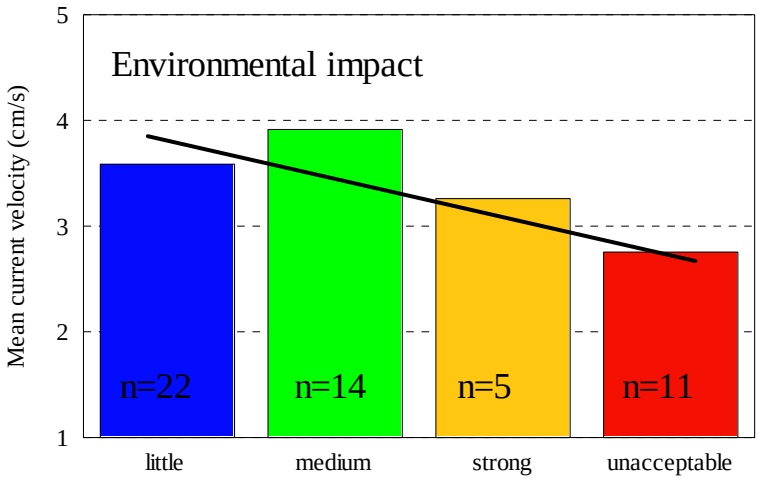


Figure 8. *Results from investigations of environmental impacts on the sea floor below fish farms, expressed as a function of the water current velocity at the site.*

PRESENT METHODS FOR MONITORING

Most environmental monitoring is done by hand-held equipment, measuring temperature, salinity and oxygen manually 3 – 5 times a day. There is, however, a growing focus on continuous 24 hours environmental monitoring of sea farms, where especially oxygen is measured both inside and outside the cages. This requires more sophisticated and expensive equipment, but the advantages of such equipment far exceed the expenses. Oxygen content not only varies inside the cage due to temperature, the activity and the amount of fish in the cages, but also varies diurnally and annually in the sea water passing through the farm.

The fact that most registrations are done by hand and put on paper by pen, has resulted in a corresponding lack of analysis of relations between environmental conditions and fish behaviour and growth. However, most of the automatic feeding systems use temperature data to calculate the feeding rates, so continuous temperature monitoring at several depths is of importance to every fish farm.

The best solution would have been instruments that continuously monitor environmental parameters such as current speed, temperature, salinity, oxygen content and chlorophyll, integrated with feeding behaviour observations and actual feeding. Change in behaviour and appetite would then be more easy to correlate with change in environmental conditions, especially if the observations are continuously stored in a database on a local computer with an analytical tool.

However, due to low salmon prices in the period from summer 2001 to the end of 2004, the industry has been reluctant to invest in new equipment, and expensive instruments for continuous environmental monitoring have been low in priority.

ACTUAL ALARM PARAMETERS

As far as we know, there are very few fish farmers that have instruments that trigger alarms due to sudden unfavourable changes in environmental conditions. Such alarms would normally only be linked vital events as breakdown in the feeding system or the power supply.

Environmental conditions that should trigger an alarm could also be sudden changes in temperature, a fall in oxygen concentration to below 70 % saturation or sudden increase in wave activity. Dramatic changes in either algal concentration or the presence of poisonous jellyfish, would naturally result in dramatic changes in swimming behaviour, which also could be monitored by automatic interpretation and analysis of present video monitoring.

NEED FOR WATER FORECAST SYSTEMS

ELEMENTS OF INTEREST

When discussing the need of any environmental monitoring installations or forecasts, it is important to distinguish between “crucial elements of interest” and “nice to have at the moment elements”. Alarm systems must be related to the possible “crucial elements”, while the accumulating “nice to have” results are of value for future analysis and increases in production efficiency. The alarm functions must in turn be related to actual measures either to avoid the provocation or to reduce the effects of it. Most fish farmers naturally and immediately concentrate on the “crucial elements” and the potential corresponding measures to reduce the potential harm on fish or installations. However, investments in future understanding of the relationships between environmental factors and production should not be underestimated.

Early warning of “red tides” has been focused upon internationally, but is probably of minor importance for Norwegian aquaculture. The only comparable large episode with ”red tides” in Norway relates to the 1988 invasion of the toxic algae *Chrysochromulina polylepis* into the coastal waters of southern Norway, causing extensive fish death along the coast of Sørlandet and creating a vast threat against the fish farms in Rogaland and Hordaland. To avoid this, several fish farms were towed into the brackish waters in the fjords of Rogaland and Hordaland.

Since 1997 various jellyfish invasions have occasionally caused mortality in fish farms. The colonies of *Apolemia uvaria* can be up to 30 m long, but are often broken into smaller pieces when entering the coastal and shallower waters. During 1997, Norwegian Institute of Marine Research received reports of an unknown colonial jellyfish with stinging cells which invaded fish farms and killed fish. A total of 10-12 metric tons of fish were killed in two farms in the county of Hordaland, and afterwards the jellyfish was reported all along the coast from the Swedish west coast of the county of Bohuslän in south east and to the county of Finmark in north. A similar but more intense invasion was observed in late autumn 2001 in mid Norway, where as much as 600 metric tons of salmon were killed mostly in the counties of Trøndelag (Fosså & Asplin 2002).

In august 2002 lots of people were stung by something invisible when bathing in coastal areas in the counties of Rogaland and Hordaland, and fish farmers reported inexplicable fish mortality in the same region. The jellyfish of the species *Muggiaea atlantica* was identified as the cause of these episodes, which resulted in a loss of as much as 1000 metric tons of salmon from fish farms in Rogaland and Hordaland counties. This jellyfish is a relative to the larger *Apolemia uvaria* jellyfish, and can reach sizes of up to 7 mm. It has stinging cells with a strong poisonous substance. It is common in the Atlantic and the Mediterranean. In British waters, the species is known as an indicator of incoming warmer waters, and can occur in high abundances throughout the year. It was concluded that the invasion of these jellyfish was related to the unusually warm coastal waters in august 2002 (Fosså et. al. 2003).

Both these jellyfish species originate in the North Atlantic and are spread with the north flowing Atlantic waters. To forecast invasions of *Apolemia*, the areas between the Faroe Islands and Shetland must be monitored. Start of these jellyfish species invasion can also be monitored locally on the actual sites by registering reduced appetite and changes swimming behaviour of the fish. Experiments with devices upstream fish farms, leading the jellyfish away, have shown to be efficient in reducing effects of such an invasion (Fosså & Asplin 2002).

The most important parameters to measure at a site are temperature and oxygen. Also the current patterns would be of interest because this may give information about a possible algae bloom or change in temperature and oxygen levels. In a more advanced phase of a water forecast system one

could get information about current patterns between different sites in a fjord or current rich straits correlated to the continuous wave tide, surface drifted wind currents and pressure drifted currents (freshwater from rivers to the fjords). In several areas the sites are quite clustered, and each site bear the risk of getting some sort of infection (sea lice larva or a disease) from the sites around it. This could also be an instrument for the veterinarian authorities to better understand how an outbreak of infection may be spread to other sites within a geographical limited area, thus being able to promote locally adjusted and effective disease protection actions.

PRESENT WATER FORECAST SYSTEMS

The company Fugro OCEANOR delivers several types of instruments that can measure the requested type of information in a water forecast (http://www.oceanor.no/index.htm). This company delivers a Weather Monitor that is an Offshore Meteorological, Wave and Current Measurement system. OCEANOR also delivers wave and weather forecasts. At their home page, the company Fugro presents itself as the world's largest and most experienced provider of offshore oceanographic data and services, but they do not deliver water forecast systems. As far as we know, the only service that has previously been carried through, were the algae forecast that OCEANOR delivered in the late eighties and the beginning of the nineties. The growing mussel industry in Norway also have tried to establish an algae forecast service due to the different mussel fish toxins causing sale prohibition.

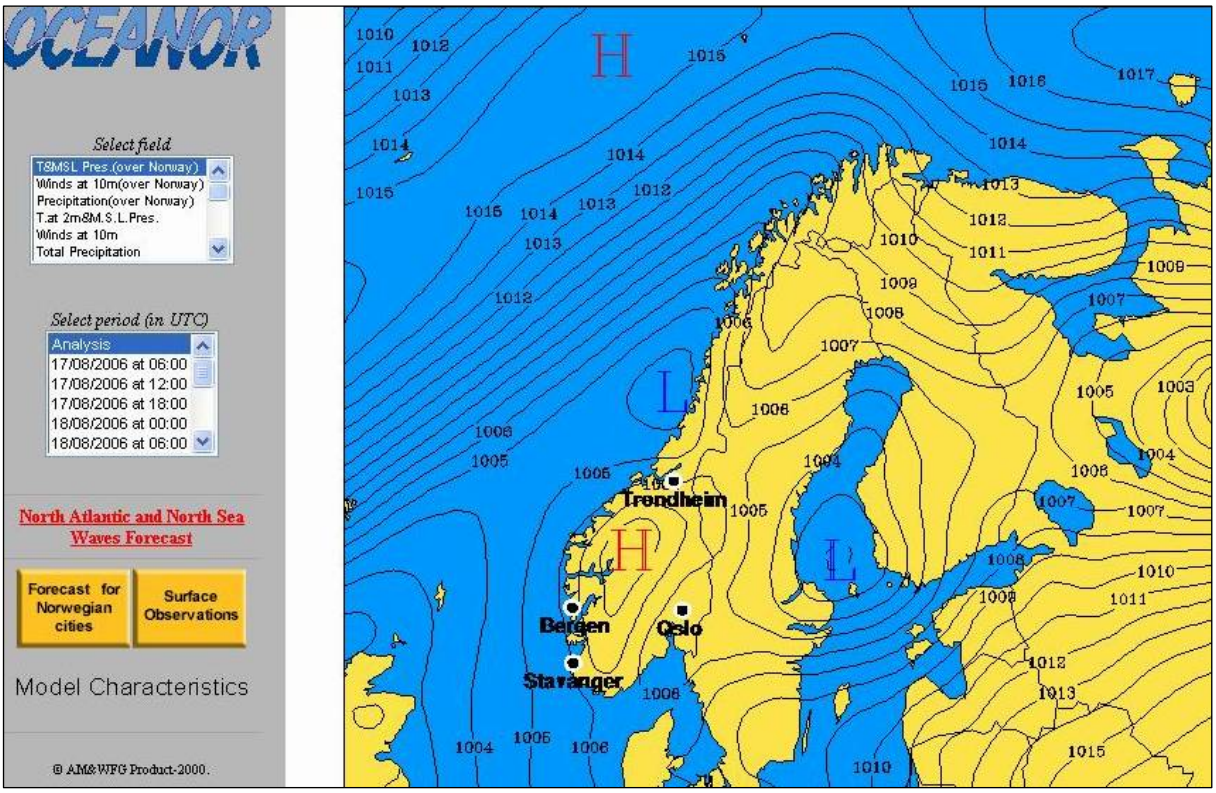


***Figure 9**. Ocean monitoring and mostly weather forecast from OCEANOR. http://oceanor.mg.uoa.gr/*

After the algal invasion along the coast of southern Norway in 1988, the Norwegian Directorate of Fisheries has established a portal of state of readiness where there is given information to the fish farmers about forecasting, counselling and measures by episodes of invasions of harmful algae. From 1997 also jellyfish plagues have been on the list of warning. They cooperate with Nansensenteret (satellite photos), OCEANOR (water samples, algae information), NIVA Division Western Norway (water samples, algae information) Marine Research Institute (water samples, algae information), FHL havbruk (exchange of information), Norwegian Veterinary University (testing of toxins), etc (**figure 10**).

***Figure 10**. The emergency portal of Norwegian Directorate of Fisheries, with links to status and forecasts for water quality, jellyfis, nuclear accidents and radioactivity, algal information and sudden instances of pollution or contamination*
http://www.fiskeridir.no/fiskeridir/fiskeridirektoratets_beredskapsportal

The Norwegian Meteorological Institute presents animated water forecasts, with sea temperature, ice cover and wave height and direction on their net site www.dnmi.no. These maps can be animated much the same as DHI's forecast for Musholm lax, and detailed maps for separate regions of the coast are available (**figure 11**).

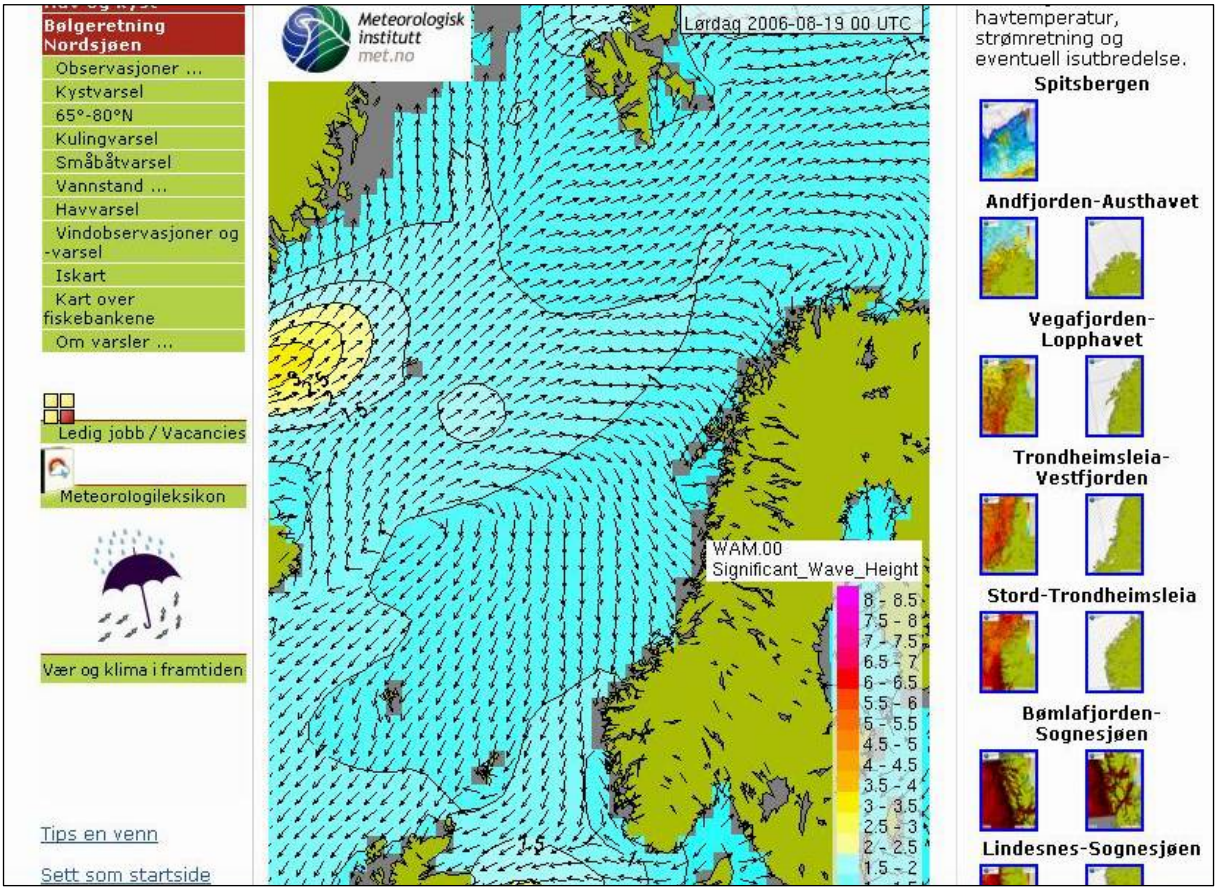


Figure 11. *Example of the ocean monitoring and water forecast from Norwegian Meteorological Institute, http://met.no/kyst_og_hav/havvarsel.html*

The fish farmers in the region of Hardangerfjorden have established a Fish Health Network, running a web based information system, where both general information on environmental monitoring and special information on salmon lice registrations on farmed fish can be found. Here salinity, temperature and secchi-depth are also presented (**figure 11**).

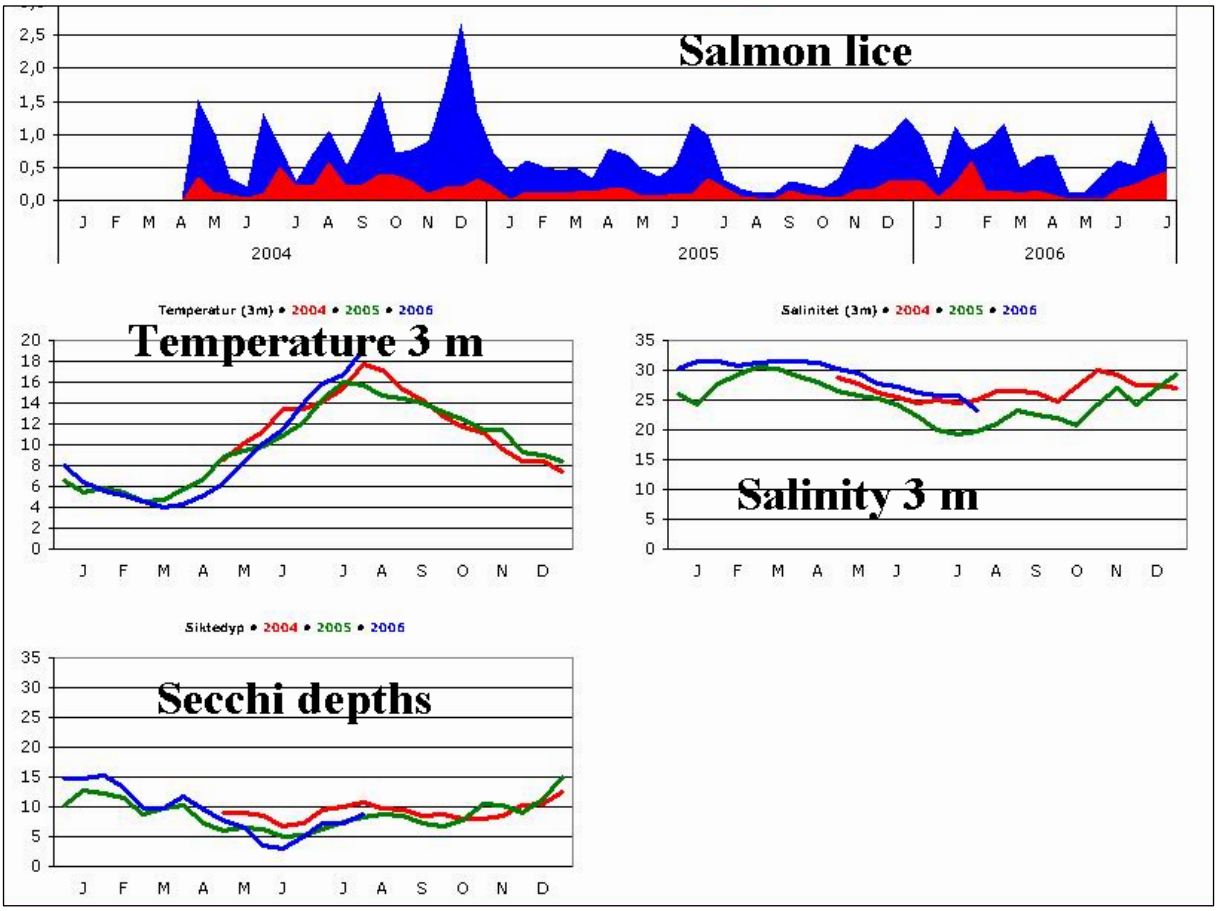


Figure 11. *Example from the registrations monitored and presented at the site of Hardanger Fiskehelsenettverk (Fish Health Network)* at http://www.lusedata.no/Lists/FS1/Display.aspx?ID=1

REQUIRED ACCURACY OF WATER FORECAST

The most important parameters to measure at a site is the temperature, salinity and oxygen levels inside every fish cage and in the water column outside the farm. Also the wave activity, current speed and direction at different depths are of importance since available oxygen for the fish is depending on the current conditions at every site.

At most sites in Norway episodes of algal blooms that kill fish are rare events because most of the sites are quite open and exposed. But measures of algae concentrations are still important because high concentrations of these may not kill the fish but reduce their appetite considerably. In the western part of Norway there have also been episodes with fish mortality at sites due to invasions of small colonial jellyfishes (*Apolemia uvaria*).

The water forecast should be a combination of both hydrological and meteorological data, as well as actual field observations:

- In situ measurements of temperature and oxygen levels at different depths, algae concentrations, current speed and –direction, etc.
- There should be located different standard observation points where environmental parameters are registered and water sampling done for algae analyses.
- In addition it also would be natural to include tide flow heights, waves and swells, wind and air pressure, as done by the DHI water forecast service

Of special interest would be forecasts that estimate future temperatures, algal blooms and oxygen levels at different depths based upon the current pattern around a fish farm.

Some companies e.g. Anderaa Instruments, already have in situ measurements of both weather and water parameters (The Automatic Weather Station and the Recording Doppler Current Profiler 600 in Vatlestraumen). See www.aanderaa.com for further information. The company Fugro OCEANOR also have a Wavescan buoy for offshore measurements and Seawatch Mini buoy for coastal and inshore measurements. These instruments can measure wave height and direction, temperature and salinity profiles, ocean current speed and direction. The instruments may be supplied with sensors that measure oxygen and an optical sensor of algae detection. The fish farmer should be able to log on a site at his PC and get information from a grid of observation points near his farm.

MARKET POTENTIAL

Until recently, aquaculture operators had no tradition with respect to automatic monitoring apart from the feeding system and the cameras that observe the feeding activity of the fish. However, there is a growing understanding of the need for continuous monitoring of environmental parameters, and it should also be expected that the farmers recognize the value of a simple and useful water forecast system.

A simple survey among some of the medium sized companies in Hordaland showed variable enthusiasm towards this type of forecast. Some were quite eager and would also be interested in a potential second phase of applying and testing the water forecast system. Only one out of six contacted operators was negative. Those farmers located in sheltered sites within the fjords were less enthusiastic than those operating on more open and exposed sites closer to the open coast line of the North Sea. The farmers who were asked make up approx 50% of the licences in the county of Hordaland (**table 2**).

Table 2. *Fish farmers that received an informal request regarding their view of a water forecast of the DHI type.*

Reguested	Contacted	No of licences
Veststar	Sebjørn Madsen	28
Sjøtroll Havbruk	Nils Arve Eidsheim	22
Alsaker Fjordbruk	Torgun Gjefsen	15
Bremnes Seashore	Geir Magne Knudsen	11
EWOS Innovation	Aage Melstveit	3
Eide Fjordbruk	Knut Frode Eide	3

The acceptable level of costs will depend on the actual need and the value the results have for the operators, and they will soon recognize if a product is just another “nice to have” among all the other things they are offered all the time. A standard farm, housing fish for three licenses within one site, produces fish for more than 50 mill NOK annually. The investment needed in equipment should in this framework be rather minor in relation to the possible benefits.

It would possibly be more interesting for the farmers if the developing costs of local models adjusting the forecasts to the actual sites, were divided among several operators within a restricted region

STRUCTURE OF INDUSTRY AND MARKET POTENTIAL

The Norwegian aquaculture industry consists of a few really large operators, some medium sized operators and also an underwood of smaller companies with few or one licence. The overall production of salmon and rainbow trout is increasing year by year, and at present the production of others species as cod is also taking off. The number of sites in use for aquaculture purposes (growing fish) is large and unknown, but in 2005 a total of 922 licences produced salmon and trout and 937 licences were assigned for producing other fish species. More than half of these are planned for producing cod, but not all of these are in operation yet.

The need for water forecast should be present for most of the fish farms, but we suppose that the interest for such systems would be highest among the large and medium sized companies. These operators have skilled and educated middle managers being responsible for the production. However, many of the smallest companies are also very well operated, but without this middle level of leaders, the busy daily tasks dominate the leadership and focus corresponds to this. However, these smallest operators often have combined ownership and leadership, and therefore very dedicated leaders with long term perspectives. The interest for water forecast systems inevitably depends on the individual persons and their focus.

LOCALIZATION AND MARKET POTENTIAL

Most all of the aquaculture farms are located at quite sheltered sites in between the islands along the coastline or within the fjords. However, the need for high water exchange through the farms, has resulted in relocations towards slightly more exposed sites during the last years. One of the effects of both the increased exposure and also the ageing of the constructions, has been extensive escapements of fish due to breakdown of constructions.

The escapements of fish from fish farms are a result of the whole range of accidents from holes in the netpens to complete breakdown of fish farms during extreme weather situations. This has resulted in a certification system for constructions, anchoring and all equipment used, based on the degree of exposures each individual fish farm is exposed to.

The need for a combined weather and water forecast, including current velocity, wave heights end wind exposure, could therefore complete this increased focus on physical factors influencing the farms. So, even though most fish farms are still located inshore and moderately exposed to wind and waves, a water forecast at least on a regional scale, but possibly also for each individual fish farm should be of interest.

PRESENT SYSTEMS AND FURTHER MARKET POTENTIAL

Today simple weather stations are available for household purposes, and wind gauges automatically regulate window shades. Simple and similar weather and water monitoring stations, directly logging environmental conditions directly to a local computer, would be of interest to all fish farmers. If these measurements are easily connected to the registrations of the feeding system and also monitoring of fish activity, it could be efficiently connected to most useful alarm functions.

The Norwegian fish farming industry has until recently mainly focused upon daily outcome, and main efforts have been related to increased production efficiency. Understanding the importance of limiting environmental factors is important to further utilize the biologically significant potential for future increased outcome. The prosperous economic situation at present should be the right moment for investment in future efficiency increases.

FURTHER DEVELOPMENT AND LOCAL PARTNERS

If DHI should pursue the idea of setting up water forecast systems in Norway, some of the following institutions might be interested to serve as the local cooperation partners. These represent both actual suppliers of information to a water forecast system such as Anderaa Instruments, Directorate of Fisheries, Nansensenteret in Bergen, Institute of Marine Research, as well the actual users represented by some major farming companies requested.

There might also be other potential markets for water forecast system in Norway apart from the offshore aquaculture industry. National environmental authorities as well as private operators like towing companies, professional diver companies, offshore oil industry, ferry companies, offshore engineering companies, fishing industry and tourism sector could be of interest. However, these weather forecasts would be needed on a more regional scale than would be optimal for each fish farming site. The insurance companies for fish and aquaculture farms, will also have great interests in foreseeing extreme situations.

If DHI Water & Environment is going to pursuing the task of setting up water forecast systems for the Norwegian market, we suggest that it is necessary to find a collaborating fish farming company that is genuinely interested in such a system. The best advertisement for future development of such a system is an operator who embraces and appreciates it, and he will be the best ambassador to other fish farming companies. After doing some tests and having found a satisfied and pleased operator, then it is time to participate with a stand at the world's greatest aquaculture exhibition in the world, the Aqua Nor in Trondheim, Norway. The next exhibition is set for 2007, and is held every second year.

CONCLUSIONS

Several web sites present various weather and water forecasts, but most of these are on a national or regional scale. Forecasts based on models adjusted to more local conditions are not available. Such models, including tidal currents, current velocity, wave heights and wind exposure, could therefore complete the market. Most asked farmers seem interested and want to follow up the increased focus upon physical factors influencing their farms. So, even though most fish farms still are located inshore being moderately exposed to wind and waves, water forecast designed for distinct areas and adjusted to each individual fish farm, is of interest for the Norwegian aquaculture industry.

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