

ECASA Study Site Report

Åbornes, Karlsøy Kommune

Norway

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Akvaplan-niva

Final Version

Non Technical Summary

1. Åbornes farm owned and operated by Lerøy Aurora produces salmon for the Norwegian and European markets. The site has been used for aquaculture site since the early 1990s.
2. The farm is situated in an enclosed sound subject to low wave exposure but with good water exchange due to moderate tidal currents. The depth of water below the farm cages is between 50-60 m.
3. The site was surveyed in July 2006 as part of the ECASA project and previously in 1994 by Akvaplan-niva AS as part of a study evaluating the methods and development of procedures for environmental monitoring of fish farms.
4. Water and sediment samples were taken during the ECASA survey although only the sediment samples collected for benthic organisms were analysed due to lack of resources. Supplementary data on the water column (currents, oxygen concentration, salinity and temperature were kindly supplied by Fiskeriforskning following a study they completed for Lerøy Aurora.
5. A total of 218 species or higher taxa were recorded from the 4 stations from 17 phyla. The most frequently recorded taxa were Annelid polychaetes which were also the most numerically abundant taxa. Crustaceans and molluscs were the next most dominant taxa both in terms of the number of species or higher taxa and number of individuals. Both the number of individuals and number of taxa increased at stations away from the fish farm. Of the indices applied to the data only Margalefs diversity index showed a similar trend.
6. The benthic indicators used suggest that there is some change in the environmental state between the station under the cage and those further away. These changes could be attributed to the presence of the farm. There would appear to be no effect of the farm at the reference station and no effects would be envisaged further away from the farm. As such the effects of the fish farm appear to be localised, although not excessively detrimental to the environment. This is most likely attributable to the environmental conditions at the site and to the way the aquaculture operation is managed at this location

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1 Introduction and scope of studies

The aim of the ECASA field studies was to provide 'real' data to test the "toolpack" of indicators and predictive models developed in the project that capture process understanding for the purposes of site selection and Environmental Impact Assessments (EIA). The studies were undertaken at sites representing the range of European marine environments, in the Adriatic, Eastern Mediterranean, Western Mediterranean, Atlantic Coast of mainland Europe and the West coast of Scotland and covering the range of species and culture types predominant in European aquaculture.

Prior to field studies a workshop was held in SAMS, Oban to identify the suite of measurements and samples to be collected at each of the ECASA sites. It was recognised that not all measurements and samples could be collected at each station due to the environmental conditions, type of farm and resource constraints (equipment, expertise and finances held by the ECASA partners) and a prioritised suite of parameters was identified. Where possible expertise and resources was share between ECASA partners to allow for the most work to be completed.

Following the start of the project Akvaplan-niva were asked to contribute to the field site studies in order to provide additional data (operational and environmental) on a large salmon farm in European arctic waters. The aim, in theory, to optimise the resources available, was for Akvaplan-niva to carry out the fieldwork, whilst other ECASA partners would carry out the analysis of samples. In practise the scope of the fieldwork was reduced compared to other ECASA study sites and the analysis of samples was also limited and carried out by Akvaplan-niva. In addition not all the samples were analysed.

This report details the studies that were made and provides a summary of the results collected. A detailed comparison with models and indicators was not possible due to the reduced scope.

2 Introduction to the aquaculture operation

1.1 Introductory background statement

The Åbornes farm is run by Lerøy Aurora AS and produces salmon for the Norwegian and European markets. The site, located in Langsund, Karlsøy Kommune, Norway, has been in

operation since the early 1990 and is one of several locations utilised by Lerøy Aurora in the Langsund/Dåfjord area.

This survey of Åbornes was carried out by researchers from Akvaplan-niva AS (ECASA partner 6) and the University of Kiel, Germany, (IFMGEOMAR) (ECASA partner 5).

The survey was carried out during the period 13-18 July 2006. Prior to fieldwork the farm manager, Roy-Tore Rikardsen, was contacted. He was a major source of information, both when conducting site visits and for providing background information.

Fieldwork, *in situ* sample processing and laboratory analysis were carried out according to the appropriate methodologies described in the Book of Protocols. The methods used in the survey are can be found in the ECASA Book of Protocols available from the ECASA website (www.ecasa.org.uk).

In addition to the field survey, data was supplied on water currents and temperature, salinity and oxygen profiles from studies carried out between August and November 2006 by Bjørn Steinar Sæther, Fiskeriforskning for Lerøy Aurora.

A previous study carried out by Akvaplan-niva AS on the same site in 1993 'Evaluation of methods and development of procedures for environmental monitoring of fish farms' (Cochrane *et al.* 1993) also provided valuable information and historical data.

This field study data is intended to present a snapshot of the environmental conditions prevalent at the time of sampling, undertaken towards the end of a production cycle.

1.2 Summary statement of key site specific environmental issues

The site has been in use since the early 1990s however it has not been stocked constantly. The site is located in Langsund and enclosed sound protected from strong wave action but subject to strong tidal flows and subsequently good water exchange. The farm site is located in approximately 50-60 m of water. The site is located in a rural area and provides local employment opportunities.

As such there are no site specific environmental issues related to the aquaculture activity at this site.

1.3 Information of farmer's environmental strategy:

Lerøy Aurora has an environmental objective to use no antibiotics on its sites, to have zero escapees and to achieve low Food Conversion Ratios. The latter is controlled through the use of underwater cameras to control and maintain optimum feeding with zero food waste.

At the time of writing these objectives have been achieved and maintained.

1.3.1 Current regulatory status

In Norway, a license is required to engage in aquaculture and sea ranching activities. This means that activities without a license are illegal. A license represents an individual exemption from a general ban. All activity in aquaculture is regulated by The Norwegian Aquaculture Act (Norwegian Ministry of Fisheries and Coastal Affairs 2005) which entered into force on 1st January 2006. Before this comprehensive revision The Norwegian Fish Farming Act was in force for almost 20 years. The Norwegian system for aquaculture licensing and the federal aquaculture register are the major tools for the enforcement of environmental considerations.

In the introductory chapter of The Aquaculture Act it says:

“There has been extensive development of the aquaculture industry since 1985. The industry has exhibited strong growth, and the ownership/structure, size, production technology, localisation and operating patterns have changed. Certain problems have become less relevant over the years, while new problems have arisen. The outlook for the potential of the marine sector also indicates a high rate of change for the industry in the years to come. Aquaculture will become a more diversified concept through the establishment of activities based on unexploited production opportunities. In addition, environmentally friendly production considerations, the weighing of land use interests in the coastal zone, market access, as well as food safety, health and fish welfare issues will be topics that one will be expected to take into consideration to an increasing extent.”

Two of the focus areas of this new act are the environment and relationship to other user interests in the coastal zone. The environmental conservation provisions provide an opportunity for the development of new requirements and measures to protect the environment. It is also proposed that the establishment of aquaculture activities shall take

place based on an assessment of how the coastal area can best be utilised for various forms of aquaculture and other land use and user interests. The environmental and land use provisions shall contribute to a good coexistence between the aquaculture industry and other social interests.

In the Act it is stated that:

“Aquaculture will of course affect the surrounding environment through the discharge of nutrient salts, etc., and the production will be affected at the same time by the surrounding environment. For development of the aquaculture industry it is therefore important that the production is environment friendly and does not pollute to any significant extent or otherwise damage the ecosystems where the production takes place. In addition, the industry must be ensured a good production environment with respect to other environmental impacts.

The discharge of nutrient salts and organic material from aquaculture does in general not represent any environmental problem at the individual enterprises at present. This is due to development of the localisation of such enterprises so that aquaculture is carried out in more exposed localities than earlier and in areas with better biological recipient conditions, high bearing capacity and generally good self-cleaning properties. It is, nevertheless, well-known that intensive aquaculture may affect the seabed below installations as a result of the sedimentation of waste and the dispersion and decomposition rate not being high enough. The localisation of aquaculture at sites that are adapted to the environmental conditions is therefore important. In light of the continued growth of the aquaculture industry, challenges related to the regional environmental impact from the discharge of nutrient salts and organic material must be dealt with by the industry and administration to a greater extent than before.

In addition, the aquaculture industry currently faces several specific environmental challenges. In salmon farming, the challenges associated with the reduction of escapes and the fight against salmon lice will be given high priority by the authorities and industry. The industry players have invested substantial funds in measures to reduce the number of escapes and combat salmon lice.

The fisheries authorities have issued regulations and requirements for the technical standard of fish farming installations. The regulations apply to new and existing installations, and they require product certification for new installations and so-called capability certificates for existing installations. The primary purpose of the scheme is to limit the number of escapes from fish farming installations. Special competence requirements have also been introduced as measures to reduce escapes. In addition, internal control regulations have been introduced effective as of 2005 to ensure observance of the relevant regulations and thus reduce the risk of escape or other accidents. The salmon lice problem is combated, for example, by special

operating requirements as a follow-up to the national action plan against salmon lice and by testing more effective treatment regimes.”

Other measures to reduce the aforementioned environmental impacts is the implementation of the Norwegian Parliament’s resolution on the establishment of the first 37 national salmon watercourses and 21 national salmon fjords. To help safeguard the wild salmon stocks rules are established for management of aquaculture in such areas.

In conclusion, environmental considerations are mentioned in a broader sense and are safeguarded through requirements for a maximum biomass and fish density at the individual sites, minimum distance between installations, fallowing of sites after slaughtering or disease outbreaks, etc. With regard to sea ranching, the authorities have issued special requirements for documentation of the environmental condition at the sites. In addition, there is a requirement that sea ranching can only be carried out with indigenous stationary species.

An aquaculture license is a set of rights and obligations for the holder of the license. The main components of the license consist of the right to produce specific species, in a specific quantity, at specific sites. The reason for the license requirement for aquaculture activities is the fact that important overall social considerations should be safeguarded. Environmental considerations and optimal use of the coastal zone are considerations that should be safeguarded during the establishment, operation and discontinuation of aquaculture facilities. Advance approval of the activities with respect to the environmental and area issues is therefore a key reason for the license requirement.

In Chapter III The Aquaculture Act defines rules with regard to environmental considerations. Requirements for environmental standards, environmental monitoring, installations, equipment, restoration, recapture and protection of specific areas are given, however methods for environmental monitoring of aquaculture sites are not provided in detail. The Norwegian Ministry of Fisheries and Coastal Affairs provides rules for monitoring by administrative decision or regulation.

For all new sites these rules require that the farmer provides information on:

- currents (minimum two weeks measurement with current meters),
- recipient capacity (either MOM B or MOM C survey as defined in Norwegian standard NS 9410 (Standard Norge 2007)
- hydrographical data such as salinity, temperature, and oxygen,
- chart of bottom topography (by echo sounding),
- detailed drawings and information about positioning of the farm in sea charts, economical and geographical charts,
- agreements with land owners,

- coastal plan from municipality,
- classification with regard to natural forces such as wind, waves, ice at the site (defined in Norwegian standard NS 9415).

In general, rules are provided by administrative decision or regulation from The Norwegian Ministry of Fisheries and Coastal Affairs or the Norwegian Fisheries Directorate, while details about methodology are given by standards such as NS 9410 (Environmental monitoring of marine fish farms) (Standard Norge 2007), NS 9415 (Marine fish farms - Requirements for design, dimensioning, production, installation and operation) (Standard Norge 2007), NS-EN ISO 16665:2005 (Guidelines for quantitative investigations of sublittoral-soft bottom benthic fauna in the marine environment), and NS-EN ISO 19493:2007 (Water quality - Guidance on marine biological surveys of hard-substrate communities (ISO 19493:2007)).

3 Site specific regulatory and management background

1.4 The regulatory status of proposed location with respect to fish farming developments

Currently there is no management plan for the area with respect to aquaculture development. The site and surrounding area is not designated in anyway and there is no local Marine Framework although there is a local Spatial Plan. This primarily addresses land-use within Karlsøy Kommune including zoning areas for industrial, residential and amenity use. The implications for the aquaculture industry are likely to be limited although as the Spatial Plan proceeds this may change.

1.5 Site description

Åbornes is located in Langsund a marine sound between the islands of Ringvassøya and Reinøya in Karlsøy Kommune, North Troms, Norway (Figure 1, Figure 2 and Figure 3). The farm lies approximately 500 m off the coast of Ringvassøya at Åbornes. At this point Langsund is approximately 2 km wide and runs in a south-south-east to north-north-west direction. The coastal environment is complex with numerous islands and enclosed and semi-enclosed water bodies and as such Langsund extends for approximately 20 km and opens at either end into larger sounds which extend to the open coast after some distance.

The seabed surrounding the farm is mixed substratum of bedrock, boulders, cobbles, gravel and shell sand (Cochrane *et al.* 1993). No information is available on the seabed type in the outer areas of the sound.

The tidal range is moderate 2 -2.5 m.



Figure 1 Location study site in Norway.

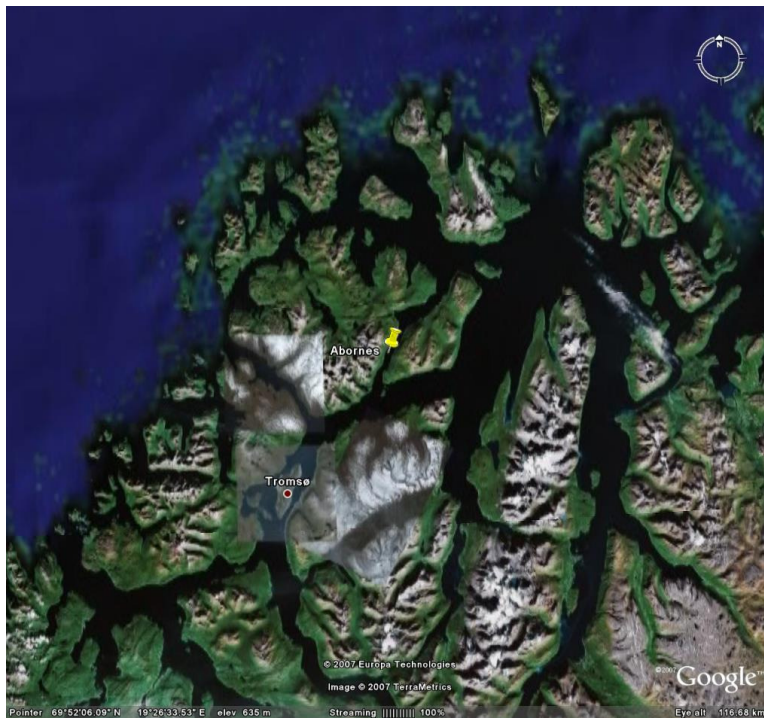


Figure 2 Location of study site in relation to Tromsø.



Figure 3 Aerial imagery of Langsund showing location of study site

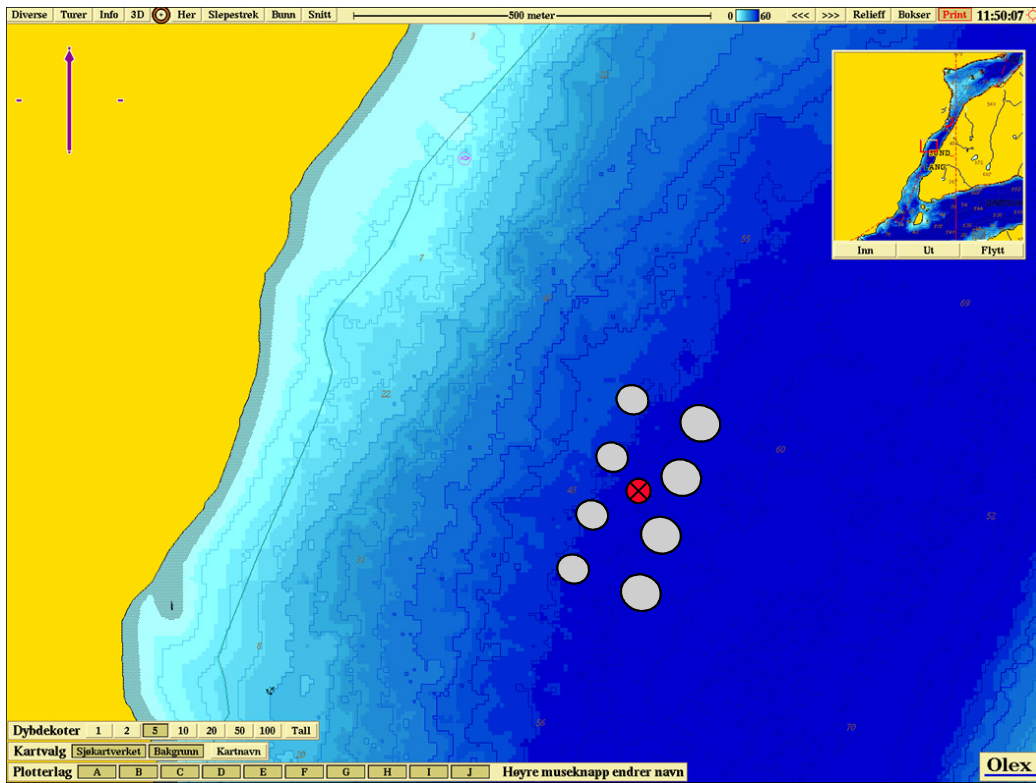


Figure 4 Detailed location and arrangement of Åbornes salmon farm. The red circle indicates the location of the water current sampler. Figure courtesy of Fiskeriforskning 2007.

1.6 Detailed description of the farm

The site has been licensed and in operation since the early 1990s but has changed ownership since it was established.

At the time of survey the fish farm consisted of 8 circular NOFI cages (4x130 m circumference and 4 x 90m circumference). The arrangement is shown in Figure 4. Staff facilities were available on a feeding barge moored along side the cages, and at onshore office and storage buildings adjacent to the site on Ringvassøya. Automatic feeding through high pressure air hoses was also carried out from this barge. Since May 2007 the barge has been removed and feeding is carried out from a tender boat. From July 2007 all cages were removed from the site leaving only mooring buoys in place.

The site provides employment for 4 full time staff and 1 part-time. In total 15 people are employed at Lerøy Aurora facilities within the Langsund/Dåfjord area.

1.7 Proposed management strategy: biomass, medicines, chemicals, cycle, feed inputs, growth measurements.

The production cycle of the farm is 2 years and the highest biomass is 2000 t for which 3420 t of feed are used. At the time of sampling the farm contained 1516 t of salmon. These had been on site since June 2006. Prior to June 2006 the site had remained empty from 2004.

The expected Food Conversion Ration (FCR) is estimated at 1.15. The stocking density range is 7.6 kg/m³.

Lerøy Aurora has an objective to raise salmon with zero medication and treatment which was achieved during the course of the last production cycle.

1.8 Physical farm logistics, including type of gear used (cages, long lines, rafts...), moorings, access, lighting and anti-predator measures (use maps and diagrams).

The configuration of the site consisted of eight circular NOKI cages (4x130 m circumference and 45 m deep nets and 4 x 90m circumference 27.5 m deep nets. At the time of sampling all cages were in operation (Figure 4).

The barge and cage are lit during the winter months when there are extended periods of darkness during the Arctic winter. During the summer months the use of continuous lighting is not necessary.

No anti-predator measures are deployed on the farm.

1.9 Production and processing

Salmon are removed from the site prior to slaughtering. Fish are transported in well-boats to the processing plant at Djupvik, Kåfjord commune approximately 65 km from the site by sea where slaughtering and processing takes place.

Airborne emissions from the farm are minimal. The only smoke arises from the diesel generator on board the feed barge and from the exhausts of work boats.

4 Description of the site and quantification of effects on the environment – existing information only, not collected by ECASA

1.10 Land use, landscape and visual quality (use maps and photographs)

There are no major settlements within the immediate vicinity; the village of Gamnes is approximately 3-4 km north although scattered houses occur along the road which follows the coastline.

The surrounding land is primarily mountain wilderness and the main use is recreational (skiing, hiking, hunting and freshwater fishing) and residential with some small agricultural farms (goats) to the north of the site.

The nearest other fish farm is at Glimma approximately 6 km south west of the site near the entrance to Langsund. This site is also owned by Lerøy Aurora. Other fish farm sites do occur within broader area however environmental interactions between them would be negligible or non existent due to the distance between them and the coastal topography and hydrography.

Sea fishing in the area is primarily recreational.

The coastal area has high visual amenity, although the fish farms are generally considered visually unobtrusive.

1.11 Hydrography and water quality

The area is sheltered from the wind by the surrounding mountains and coastal topography and is not subject to high wave exposure. Small rivers and streams enter the sea at several locations along the coast although freshwater runoff is highly seasonal. There is little input during the winter months when the temperatures are below freezing for most of the time and are high during the spring thaw. The river and stream catchments are small and therefore subject to spate following heavy rain. Periodic but short lived stratification can therefore occur with reduced salinity waters forming a surface layer.

The farm location is subject to water movement primarily driven by tides although there is a certain amount of wind influence on the surface waters. Data collected between August and December 2006 indicates that the predominant water flow varies with depth (Figure 5). For near surface waters (2-4 m BSL), predominantly driven by wind and tide the main flow is north east whilst for water between 8-10 m, the flow is south. For deeper waters (> 18 m) the net flow is south-east (unpublished data from Fiskeriforskning 2007).

The current speed generally increases with depth with a maximum greater than 100 cm/s (Figure 6).

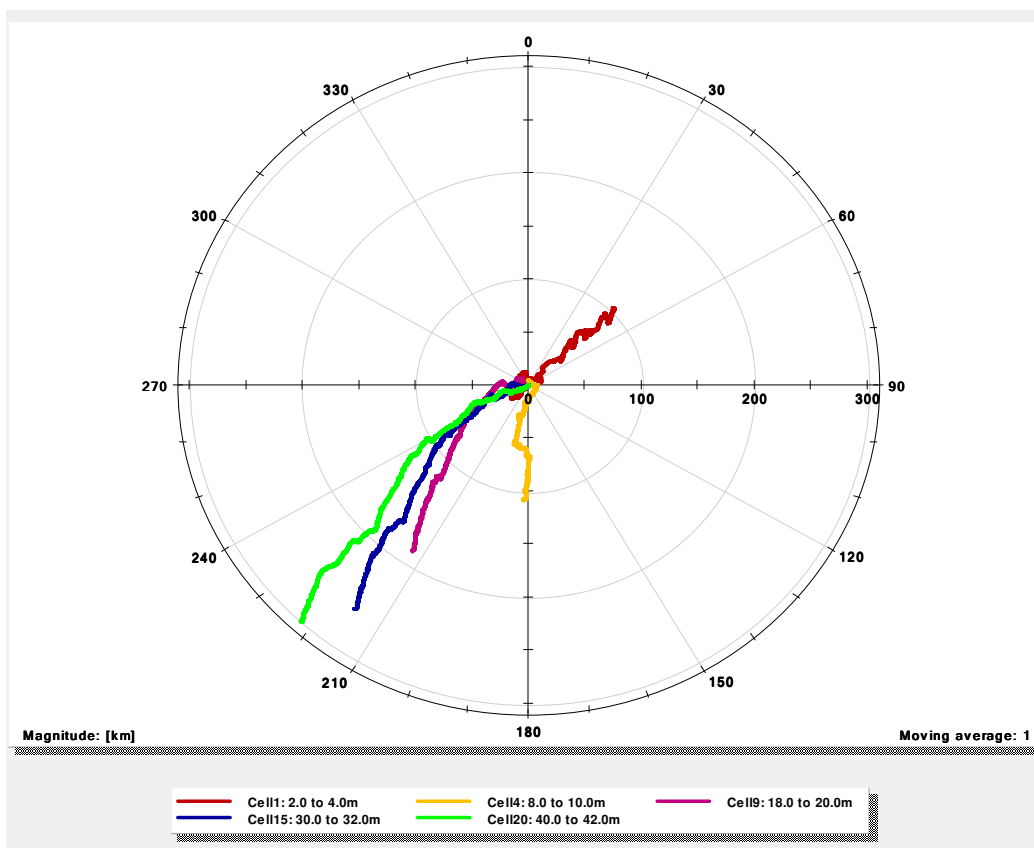


Figure 5 Summary current data for Åbornes collected from August – November 2007 at 5 depth cells. Unpublished data courtesy of Fiskeriforskning 2007.

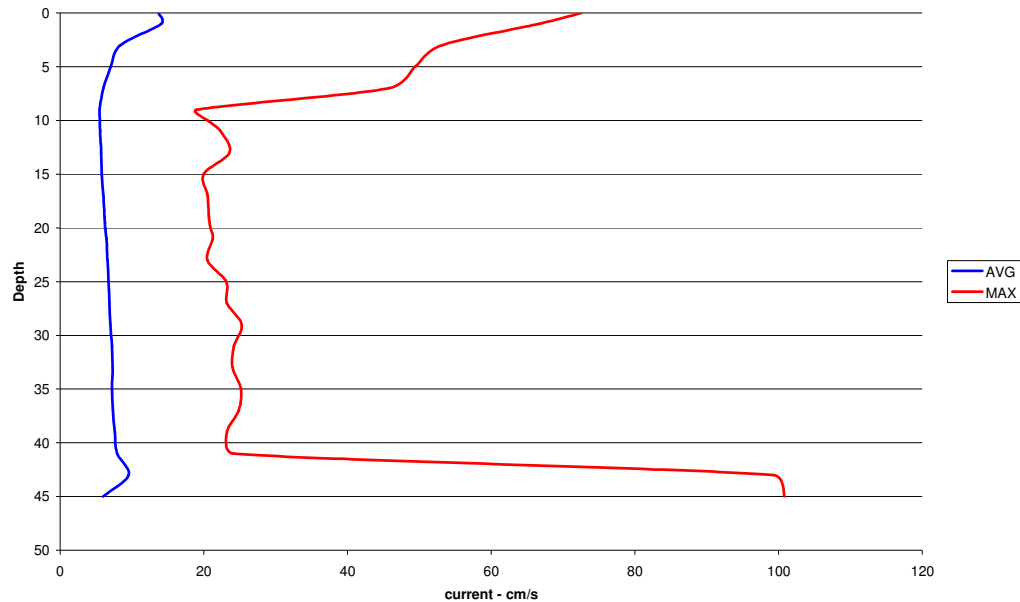


Figure 6 Summary of water current velocities from August – November 2006. Unpublished data courtesy of Fiskeriforskning 2007.

Water temperature ranges from approximately 5-6 °C in the winter to 10-11 °C in the summer months.

The quality of water over the area is high with low levels of nutrients and generally good oxygenation (unpublished data from Fiskeriforskning 2007). There is good water exchange through Langsund and very few nutrient discharges from land sources, mostly from single dwellings. It appears that there is no risk of eutrophication resulting from fish farm activities.

No studies have been carried out on the dispersion of dissolved medicines. Due to the farmers policy of no medication there is no perceived risk to the environment.

No information is available on zooplankton or phytoplankton within Langsund and no studies have been carried out on the wild fish population.

1.12 Bathymetry, geology and habitats

The site is located over approximately 50–60 m of water and the seabed is generally a mixture of poorly sorted cobbles, pebbles, gravel, coarse and fine sand and mud (current study and Cochrane *et al.* 1994). No substratum map is available for the site.

1.13 Benthos and sediments

1.13.1 Previous studies

Benthic community data was collected by Akvaplan-niva at the same farm site in 1993 as part of a study evaluating the methods and development of procedures for environmental monitoring of fish farms (Cochrane *et al* 1994). Four stations were sampled, one located at the edge of the cage group (station 1), one 50 m (station 2) and one 100 m away (station 3) and a reference station (Reference) 500-600 m from the farm. The fauna at station 1 were dominated by the polychaetes *Malacocoeros fuliginosus* and *Capitella capitata* and to a lesser extent the amphipod *Caprella* sp. At stations 2 and 3 the scale worm *Pholoe minuta* and bivalve *Thyasira sarsi* occurred in relatively high abundances. The echinoderms *Ophiura robusta* and *Strongyloscentrotus drobachiensis* also occurred in high numbers at station 2. The Reference station also had a high abundance of the polychaetes *Chaetozone setosa* and *Scoloplos armiger* and the amphipod *Caprella* sp. The general conclusions were that the area of seabed strongly impacted by nutrient output from the farm was extremely localised however there was some indication of nutrient enrichment up to 500 m away at the Reference site.

No protected species were recorded from this study.

1.13.2 Current study

Benthic community data collected from the current study provided quantitative data from a different set of stations than those from Cochrane *et al.* 1994 and details of the results are presented in section 4 of this report.

1.14 Marine mammals; seals, cetaceans, otters

Langsund is not considered important for the marine mammals although periodic sightings of porpoises (*Phocoena phocoena*), dolphins and whales do occur.

There are no seals present within the area.

Otters occur along most of the coastline although there would be little or no interaction with the fish farm.

No anti-predator devices are employed on the site.

1.15 Birds

There are significant numbers of eider duck (*Somateria mollissima*) in the area as well as numerous gull species (blackback and herring gull). Arctic terns (*Sterna paradisaea*) also occur in large numbers during the daylight months. Geese also occur during spring and autumn. Sea eagles occur along much of the coastline.

The current aquaculture activities do not impact on the resident or migratory bird populations within the area and wild birds are not considered a problem to the fish farming activities.

1.16 Fisheries and wild fish populations

The sea area around the fish farm is not considered as important for commercial fisheries. There is a local recreational fishery for cod, saithe, haddock and occasionally halibut, through most of the area although the farm would not be seen to restrict it. Fishing and angling is permitted near the farm.

There is no record of any escaped fish from the study site.

Periodically the farm attracts large numbers of wild fish, particularly saithe (*Pollachius virens*) and to a lesser extent cod (*Gadhus morhua*). During the course of the current survey large numbers of saithe were observed immediately outside of the cages near the water surface.

1.17 Noise

The noise emitted from the site is limited to the sound of the generator on the barge, boat traffic and feed travelling through plastic pipes running from the barge to the cages.

All work is carried out between normal working hours, although the farm is manned 24 hours (accommodation on the barge) when the farm is stocked.

The closest main settlement is greater than 4 km away although several residential properties are adjacent to onshore site facility. Noise from the site is minimised to ensure operations are as unobtrusive as possible.

1.18 Transport

The onshore site facilities are accessible by road and the site is generally accessed by boat from this facility. Feed is delivered by boat directly to the barge whilst all other deliveries are by road. The road is a rural two lane highway.

1.19 Socio-economic impact

The farm provides employment for 5 people (4 full-time, 1 part-time) some from the local community and others from the wider area. Fourteen people are employed on other Lerøy Aurora facilities in the Langsund/Dåfjord area.

5 Results of ECASA field studies: Indicators and Models applied and evaluated.

1.20 Background to field programme: dates, staff, boats, stations sampled

Field sampling and experimental work was undertaken between 13 and 18 July 2006. All fieldwork was carried out by Chris Emblow from Akvaplan-niva AS and Helmut Thetmeyer from IFM – GEOMAR. All sampling and experimental work was carried out from boats supplied by the fish farmer.

Five stations were sampled at various distances along a transect in the direction of the predominant current away from the farm (Table 1 and Figure 7). Not all parameters were measured at each location (Table 2).

Table 1 Summary of benthic sampling stations

Station	Distance from farm -		Date	Time	Latitude	Longitude	Depth - m
	m						
1	0		18/07/2006	15:31	69.882N	19.438E	56.0
2	58		18/07/2006	14:38	69.883N	19.438E	54.0
3	100		18/07/2006	11:32	69.884N	19.438E	54.6
4	200		18/07/2006	11:11	69.884N	19.440E	56.1
Ref	1909		18/07/2006	13:20	69.896N	19.468E	58.0

Table 2 Summary of data and number of replicates collected at each station

Station	Macrofauna		Meiofauna	Sediment	Water	CTD	Secchi		Bioassay
	0.5 mm	1 mm					depth		
1	4	4	2	6	3	yes	yes	yes	
2	4	4	2	6	3	yes	yes	no	
3	4	4	2	6	3	yes	yes	yes	
4	-	-	-	-	3	yes	yes	yes	
Ref	4	4	2	6	3	yes	yes	yes	

Table 3 Summary of bioassay sampling stations

Station	Latitude	Longitude	distance from farm (station 0) - m
B1	69°52.971'N	019°26.239'E	0
B2	69°52.984'N	019°26.222'E	26
B2	69°53.007'N	019°26.287'E	73
B3	69°53.056'N	019°26.359'E	175
BRef	69°53.781'N	019°28.037'E	1887



Figure 7 Sample site locations in Langsund. Station 1 is the location of the farm cages.

The following activities were undertaken:

1.20.1 Sediment sampling

Four replicate samples for benthic fauna were collected using a 0.1 m² van Veen grab and sieved onboard into 1 mm and 0.5 mm fractions. Each infaunal replicate grab sample was sieved, stored and labelled separately. The residue was also stored separately in durable plastic buckets and samples were preserved in buffered 4% formaldehyde solution and returned to the laboratory for sorting and identification.

Due to resource constraints only the first three replicates sieved on the 1 mm mesh from each station were sorted and identified following Akvaplan-niva standard protocols. The remaining

1 mm replicate and 4 x 0.5 mm replicates have been stored for future analysis if funding permits.

Taxonomic data were entered into Akvaplan-niva's database and taxon names cross checked against the online version of the European Register of Marine Species (ERMS 2007).

One additional grab sample was collected and sub sampled using a 25 mm Perspex core from the undisturbed sediment surface through the inspection ports on the grab. The tube was inserted into the sediment to a depth of 20 cm ensuring the sediment layering remained intact. For meiofaunal samples the contents of the tube were transferred to a plastic tub before relaxing and fixing of samples in formaldehyde. Sediment samples were transferred to durable plastic bags and labelled. Sub samples of sediment were also taken for TOC, TON, TOP, LOI, chlorophyll and granulometric analyses.

Sediment and meiofaunal samples were not analysed further.

Details of the sampling procedures can be found in the ECASA book of protocols.

1.20.2 Water column sampling.

Water samples were collected using Niskin bottle for measuring concentrations of dissolved nutrients (ammonia, nitrate, phosphate, and silicate), POC, PON and chlorophylls. Samples were decanted into durable plastic bottles, labelled and frozen prior to analysis being completed.

Water samples were not analysed due to resource constraints.

Secchi depth measurement was made for estimating the water turbidity

CTD deployment for estimating the vertical profile of water temperature and salinity at different distances from the cages although the data gathered was not used as a more complete dataset was made available by the Lerøy Aurora and Fiskeriforskning.

A bioassay experiment set up for assessing nutrients level around the fish farm at 4 stations over a 5 day period.

1.21 Sampling methods and materials, analytical methods

Details of the sampling procedures can be found in the ECASA book of protocols.

1.22 Models used and their parameterisation

No models have been used at present.

1.23 Results (Give tables of bulk data/model outputs electronically and/or in appendices. Here only give highlights and summary information).

1.23.1 Water

CTD measurements at each station indicate that there was little stratification in the water column at the time of the survey. There was no marked change in salinity or oxygen saturation with depth at any of the stations. Temperature decreased from 8.9 °C on the surface to 8.4 °C at 45 m BSL.

Salinity, sea water temperature was measured at two cages, from two depths (9 and 19 m) between August and early November 2006 by Fiskeriforskning. Oxygen concentration was measured from four cages at the same depths over the same time period.

The average daily salinity ranged from 34 in September at 19 m BSL to 30.1 in November at 9 m BSL. A general decrease in salinity was noted for the winter months (Figure 8) with slightly higher values at occurring in the upper water column (9 m) compared to deeper waters (19 m). This difference was more marked in the winter months.

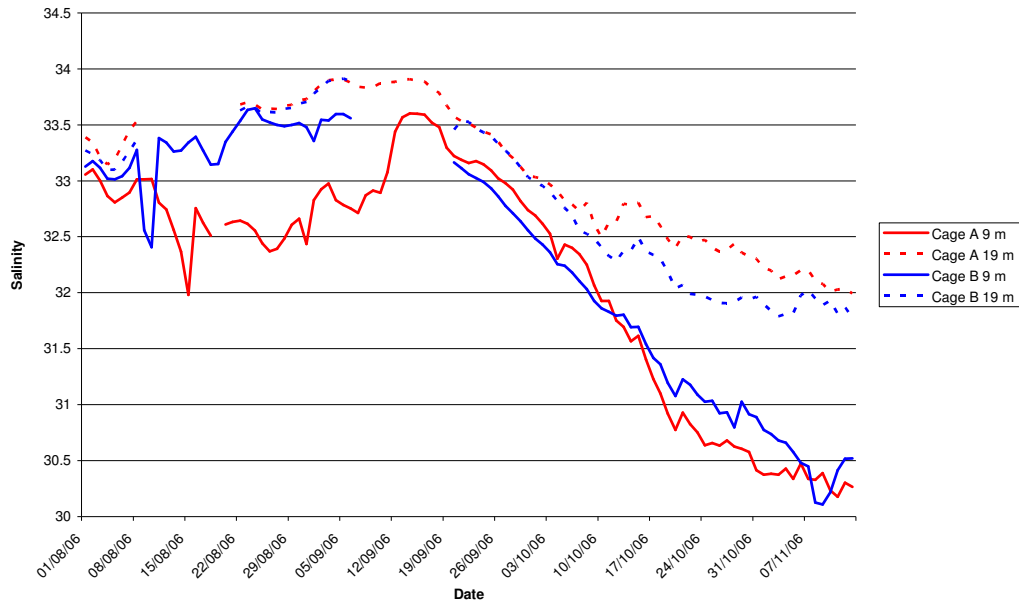


Figure 8 Average daily salinity measurements from two of the cages between August and early November 2006. Recordings were taken at a water depth of 9 m and 19 m. Unpublished data courtesy of Fiskeriforskning 2007.

The temperature reached an average daily maximum of 10.2 deg. C in early September and a minimum of 6.4 deg. C in November. The temperature in the upper layers of water (9 m) was slightly higher than at 19 m during August and early September (Figure 9). During the second half of September, October and November no real temperature differences occurred.

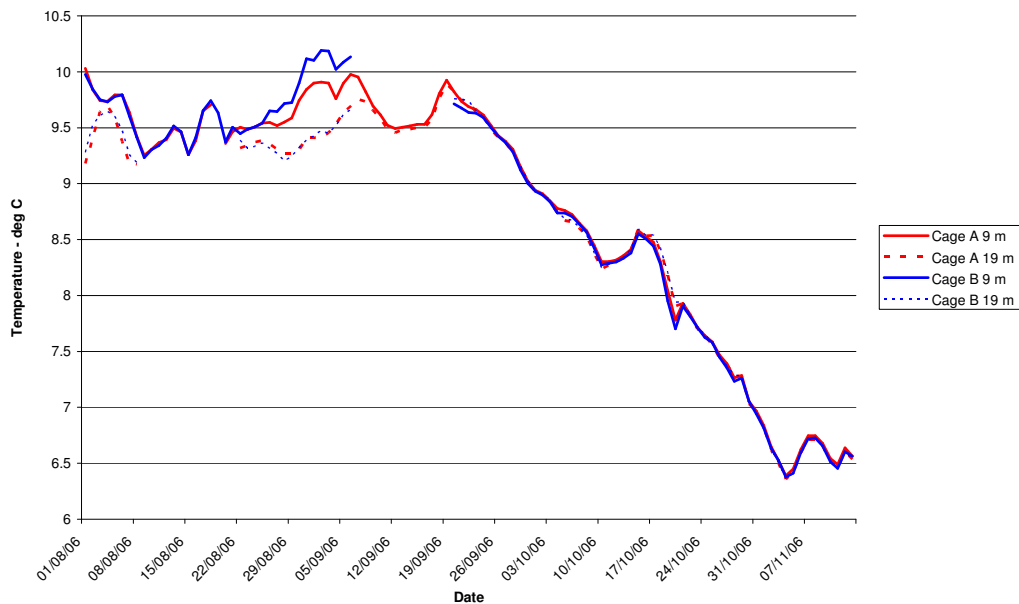


Figure 9 Average daily temperature measurements from two of the cages between August and early November 2006. Recordings were taken at a water depth of 9 m and 19 m. Unpublished data courtesy of Fiskeriforskning 2007.

Oxygen concentrations reached an average daily maximum in August and then decreased to November. Generally there was no noticeable difference between oxygen concentrations in the deeper and shallower waters although in October and November the oxygen concentration at 19 m at cage 4 were consistently lower than values at 9 m.

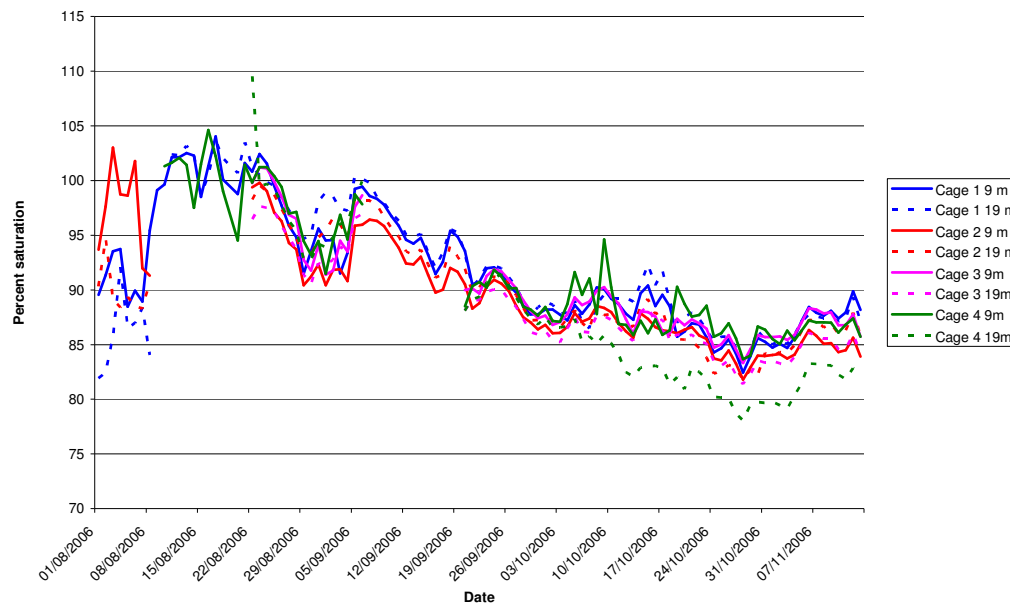


Figure 10 Average daily percent oxygen saturation from four of the cages between August and early November 2006. Recordings were taken at a water depth of 9 m. Unpublished data courtesy of Fiskeriforskning 2007.

No analyses were made of the water samples collected due to resource constraints.

1.23.2 Bioassay results

Full analysis of the bioassay results is being carried out by other ECASA partners as part of a review of the applicability of the technique to fish farm assessments. This study will take into account results from all the ECASA sites where the bioassay experiment was carried out and as such was not available at the time of writing this report.

In summary the bioassay experiment showed that concentrations of Chlorophyll a were higher at the stations closer to the fish farm but were much reduced at station B4, 175 metres and at the Reference station, 1887 metres from the fish farm (Figure 11).

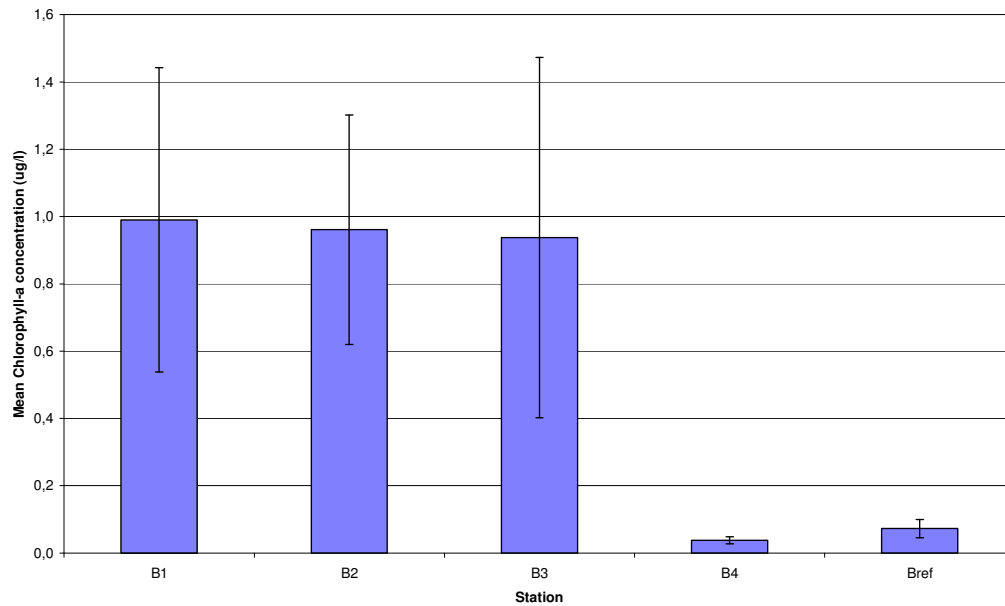


Figure 11 Mean Chlorophyll a concentrations at each station following bioassay experiment showing standard deviation.

1.23.3 Sediment

No analysis was made of the sediment samples collected.

1.23.4 Benthic communities

Consideration is given to both the current survey and that carried out on the same farm by Cochrane *et. al* in 1994. Analysis was not carried out on the dataset as a whole due to differences in data collection methodologies but some broad comparisons can be made.

A total of 218 species or higher taxa were recorded from the 4 stations from 17 phyla. The most frequently recorded taxa were Annelida polychaetes which were also the most numerically abundant taxa. Crustaceans and molluscs were the next most dominant taxa both in terms of the number of species or higher taxa and number of individuals. In contrast Cochrane *et. al* 1994 recorded 176 taxa from 4 stations (2 replicates only).

Table 4 Density (ind. /m²) and number of taxa recorded for each phyla by station

[negative numbers relate to colonial taxa]

Station distance from farm – m	0	58	100	1909	Total no. of individuals	No. of taxa
Annelida	556.67	716.67	1743.33	2266.67	1585	109
Brachiopoda	16.67	36.67	60.00	6.67	36	1
Bryozoa	-3.33	0.00	-3.33	-10.00	-5	1
Cnidaria	6.67	30.00	20.00	43.33	30	4
Crustacea	83.33	393.33	426.67	370.00	382	31
Echinodermata	6.67	56.67	136.67	86.67	86	15
Echiurida	0.00	0.00	3.33	0.00	1	1
Foraminifera	0.00	-3.33	-3.33	-10.00	-5	1
Hemichordata	3.33	0.00	3.33	0.00	2	1
Mollusca	83.33	170.00	273.33	726.67	376	41
Nematoda	6.67	0.00	10.00	10.00	8	1
Nemertini	10.00	20.00	33.33	30.00	28	1
Platyhelminthes	0.00	3.33	0.00	0.00	1	1
Porifera	0.00	0.00	-3.33	-10.00	-4	1
Priapulida	0.00	0.00	0.00	3.33	1	1
Sipunculida	40.00	46.67	76.67	170.00	100	3
Tunicata	6.67	13.33	33.33	66.67	36	5

The number of taxa per station ranged from 65 to 140 whilst density of individuals ranged between 823 and 3780 individuals m² (Figure 12). The highest number of taxa and the highest density of individuals were recorded from the reference station (5) and the lowest number of taxa and density of individuals immediately under the farm.

The number of taxa per station recorded by Cochrane *et. al* (1994) ranged from 76 at the station under the cages to 126 at station 2 50 m from the cages. The reference station, 600 m from the cages, had 81 taxa and station 3 100 m from the site had 108 taxa. The highest faunal densities occurred at 50 m from the farm with a total of 2048 individuals recorded whilst the lowest was the reference station with 873 individuals. A total of 1202 individuals were recorded at the station under the cages whilst at station 3.

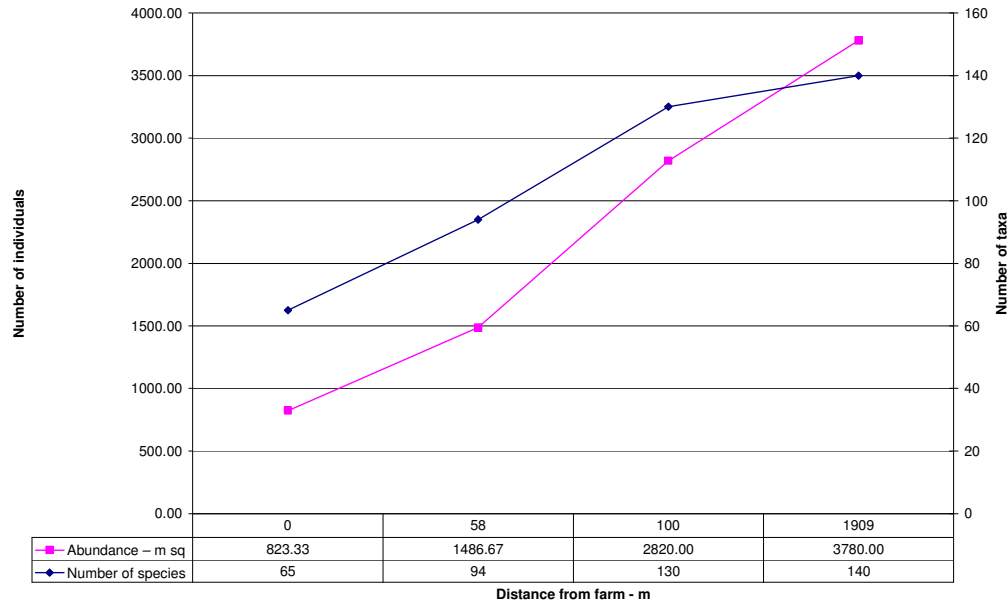


Figure 12 Species richness and abundance

The most dominant species and their density changes across the transect (Figure 13). At the station located under the farm the most abundant species were the annelid worms *Nothria hyperborea*, *Scoloplos acutus* and *Typosyllis cornuta*. These three species were also recorded at the two intermediate stations. At the 100 m station all three taxa dominated the fauna whilst at the 58 m station only *Nothria hyperborea* and *Typosyllis cornuta* were dominant. At the reference station the taxa was dominated by the mussel *Modiolus modiolus*, with the annelids worms *Chaetopterus variopedatus* and *Typosyllis armillaris* although densities of *Typosyllis cornuta* still exceeded those present at the stations closer to the farm.

The dominant taxa recorded by Cochrane *et. al* (1994) were different from those recorded from the current survey. The fauna at station 1 were dominated by the polychaetes *Malacocoeros fuliginosus* and *Capitella capitata* and to a lesser extent the amphipod *Caprella* sp. At stations 2 and 3 the scale worm *Pholoe minuta* and bivalve *Thyasira sarsi* occurred in relatively high abundances. The echinoderms *Ophiura robusta* and *Strongyloscentrotus drobachiensis* also occurred in high numbers at station 2. The reference station also had a high abundance of the polychaetes *Chaetozone setosa* and *Scoloplos armiger* and the amphipod *Caprella* sp.

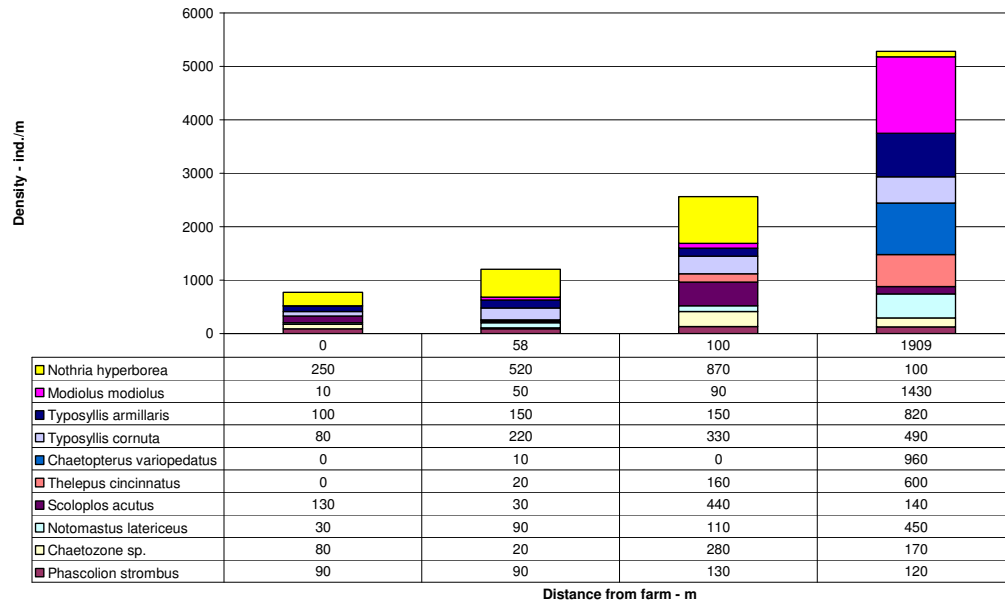


Figure 13 Number of individuals for the 10 most abundant species from current study

Of the diversity indices that were calculated for the current study only Margalef showed a trend from the farm station to the reference station (Figure 14). Brillouins, Shannon-Wiener and Simpsons indices, and Pielou's evenness co-efficient showed no real trend across the transect.

Values for Pielou's co-efficient (J') varied from 0.77 58 m from the farm to 0.89 at the farm site. Higher values of J indicate a higher degree of co-dominance by many species although in general there was little difference between stations.

Shannon-Wiener index (H') ranged from 3.49 58 m away from the farm to 4.09 100 m from the farm. In general a value greater than 5 are considered to represent high diversity however none of the stations reached this value.

Simpson's index (D) ranged from 0.93 58 m away from the cages to 0.97 at the farm station and 100 m away. Simpson's index indicates the degree of dominance in a population. Low values, (less than 0.8) indicate low diversity however none of the stations reached this value.

Margalef's index ranged from 11.62 at the farm station to 19.76 at the reference station indicating an increase in diversity away from the farm.

Brillouin's index ranged from 3.21 58 m from the farm to 3.86 100 m from the farm.

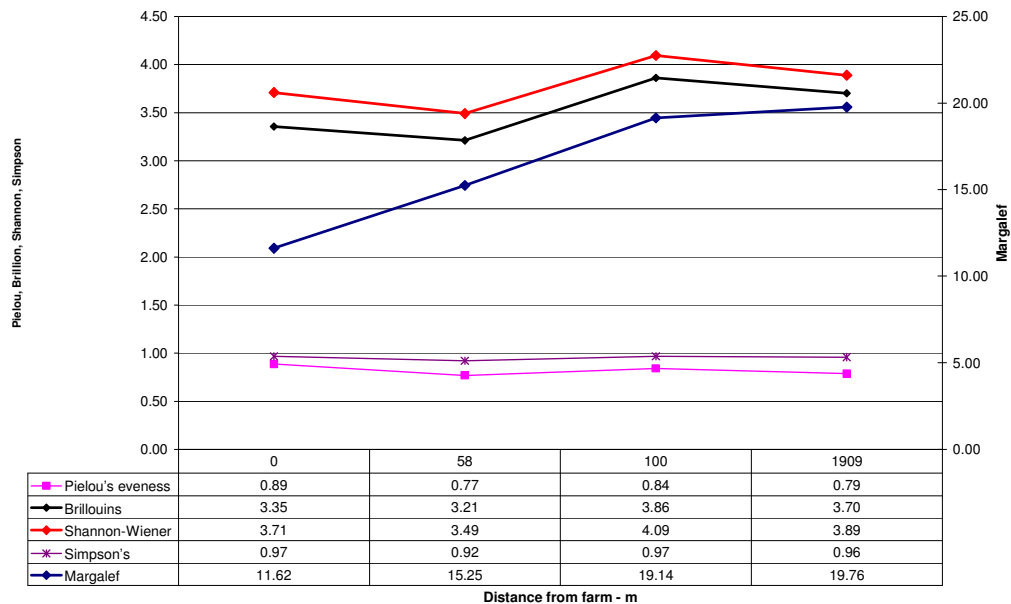


Figure 14 Margalef, Pielou's evenness, Brillouins, Shannon and Simpson indices

Shannon-Wiener, and Simpson's indices and Pielou's evenness co-efficient were also calculated by Cochrane *et. al* (1994). Values for Shannon-Wiener were highest at stations 2 and 3 (>5) indicating high diversity and lowest at station 1 closest to the farm. Values of Simpson's index indicated the degree of dominance was greatest at station 2 and 3 and the reference station. For Pielou's co-efficient the lowest value (low co-dominance) also occurred at the farm station.

Cochrane *et. al* (1994) concluded that the fauna at station 1 were severely disturbed due to the aquaculture activities however the area impacted is much localised to the area directly below the cages. Stations 2 and 3 can be considered to be indicative of moderate to intermediate levels of organic enrichment (due to the aquaculture facilities) whilst the reference station showed some, albeit low, level of environmental disturbance.

1.24 Evaluation of Indicator Performance

Water column indicators

No sediment indicators were applied although full details of the bioassay studies will be reported separately by other ECASA partners.

Sediment indicators

No sediment indicators were applied

Benthic indicators

The benthic indicators used in this study were useful for detecting differences in the benthic communities between different stations. Species abundance and density showed clear increases at stations further away from the farm. Likewise there was a general increase in values for Margalefs index however Brillouins, Shannons and Simpsons indices, and Pielou's evenness co-efficient showed no real trend across the transect. It is however difficult to draw conclusions as to the reasons for these differences and most of the indicators used did not detect a gradient of environmental impact.

1.25 Evaluation of Model Performance

No models were evaluated during this study.

1.26 Site specific conclusions

The benthic indicators used suggest that there is some change in the environmental state between the station under the cage and those further away. These changes could be attributed to the presence of the farm. There would appear to be no effect of the farm at the reference station and no effects would be envisaged further away from the farm. As such the effects of the fish farm appear to be localised, although not excessively detrimental to the environment. This is most likely attributable to the environmental conditions at the site and to the way the aquaculture operation is managed at this location. Prior to 2006 the site had been fallow since 2004 and following the survey in late 2006 the farm was emptied of fish. In late 2007 the site is once again fallow. Efficient feeding to obtain high Food Conversion Ratios and consequently minimise waste products from the fish also contribute.

There are no conflicts with other human activities in the area and in general the value of aquaculture as an employer in rural areas is seen by local stakeholders as more important than any perceived negative impacts on the environment.

The site location and environmental conditions along with the good management practises and environmental aims of the company suggest that the long term sustainability of the site for aquaculture is viable.

1.27 Culture type and environment type conclusions

Without the full suite of data available it was not possible to fully assess the effectiveness on different types of indicators on the effects of salmon farming within this location. What we have learnt however is that in addition to the scientific effort required to carry out all the sampling and analysis proposed by ECASA there is also a very important financial requirement. A cost benefit analysis needs to be made to recommend indicators and tools based on their scientific merit and value for money.

The traditional sampling of benthic fauna and flora at this station revealed some changes in biodiversity between the farm station and the reference station along a gradient away from the farm. The level at which environmental change had occurred would however be considered acceptable following Norwegian standards.

6 Acknowledgements

We are grateful to Roy-Tore Rikardsen from Lerøy Aurora for facilitating the ECASA field survey particularly in providing data information on the company, current data and allowing us to use the company boats.

We would also like to thank Bjørn Steinar Sæther from Fiskeriforskning for supplying, at short notice, current and water column data.

7 References

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Standard Norge 2007 NS-EN ISO standard, Water quality - Guidance on marine biological surveys of hard-substrate communities (ISO 19493:2007) edition 1.

Standard Norge 2007. Norwegian standard *Environmental monitoring of marine fish farms*. NS 9410:2007 edition 2 (in Norwegian).

Appendices

Appendix 1

Produce a metadata table with references to electronic files (e.g. spread sheets etc) containing the data collected and analyzed. Separate data clearly into water column, sediments and benthos.

Metadata table

Study environment: Benthos
File type: Excel
Parameter: Macrofaunal data
File name: ECASA 2006 Artsliste til punchekontroll.xls

Study environment: Water
File type: ASCII data
Parameter: Current data
File name: environmental data.xls (not available for circulation)

Study environment: Water
File type: excel
Parameter: Salinity, temperature, oxygen
File name: ascii data.txt (not available for circulation)