Faglig rapport til NFR fra prosjekt 149791/S40:

Sea Lice as a population regulating factor in Norwegian salmon: status, effects of measures taken and future management.

1 Norsk sammendrag 3

2 English abstract 3

3 Introduction 4

3.1 General introduction....4

3.2 Introduction to hydrography....4

4 Material and methods 5

4.1 Estimates of sea lice infection in farms....5

4.2 Estimates of lice infection in seaward migrating postsmolts....9

4.3 Estimates of salmon lice infection in adult salmon....10

4.4 Estimates of sea lice on stationary sea trout and artic char....12

4.5 Hydrographic observations....12

4.6 Freshwater runoff and precipitation....12

4.7 Wind model....12

4.8 Coastal ocean model....12

4.9 Fjord model....13

4.10 Particle advection model....13

5 Results 14

5.1 Estimates of sea lice infection in farms....14

5.2 Estimates of lice infection in seaward migrating postsmolts....17

5.3 Estimates of salmon lice infection in adult salmon....20

5.4 Estimates of sea lice on stationary sea trout and artic char....22

5.5 Hydrography....25

5.6 Runoff and precipitation....27

5.7 Wind....28

5.8 Currents....30

5.9 Particle advection....33

5.10 Hydrographic classification....43

5.11 Concluding remarks modeling section....44

6 Discussion 44

6.1 North-south gradient in sea lice infection. 44

6.2 Sea lice infections in seaward migrating postsmolts of salmon....45

6.3 Sea lice infections in stationary sea trout stocks....46

7 Management advice 46

1 Norsk sammendrag

Forskningsresultater som fremkom utover 1990-tallet pekte på lakslus som en potensielt alvorlig populasjonregulerende faktor for norske laksebestander. Tiltak ble satt i verk, for eksempel i form av en veterinærforskrift i 1997 som regulerte hvor mange lus som var lovlig pr individ i oppdrettsanlegg. I dette prosjektet er det gjennomført en sammenlignende studie av interaksjoner mellom lakslus, oppdretts- og villaks i to norske fjordsystemer; Altafjorden og Sognefjorden. I Alta er prosjektets konklusjon at lakselus med stor sannsynlighet aldri har vært et problem for utvandrende villaks, mens i Sogn er situasjonen gått fra alvorlig i årene før 2002 til meget gode i 2002-2004. For sjøørret synes situasjonen mer uklar. I Altafjorden er det ikke observert bedring i luspåslag hos sjøørret mens det i Sogn synes å være en generell bedring parallelt med oppdrettsnæringens innsats for å senke lusproduksjonspotensialet i sine anlegg. Hydrografisk-biologisk modellering viser at forholdene i Sogn nå har vært tilfredsstillende over en treårs periode med både gunstige og ugunstige forhold for luspåslag. Det konkluderes med at vill- og oppdrettslaks kan sameksistere i norske fjorder gitt at totalutslippet av luslarver tilpasses de lokale hydrografiske forhold og de ville laksefisk-populasjonenes karakteristikker. For å sikre en langsiktig bærekraftig lakselussituasjon vil en i mange fjordområder trenge vesentlig bedre kunnskaper om disse forhold enn det som er tilgjengelig i dag, spesielt der det er aktuelt å øke oppdrettsproduksjonen.

2 English abstract

Research carried out during the 1990ies identified salmon lice as a potentially serious population-regulating factor in Norwegian salmonid stocks. Various management measures were imposed, amongst them a veterinarian act in 1997 regulating the numbers and stages of salmon lice allowed per individual fish in farms. Through a comparative study between two major salmon fjords, Altafjord and Sognefjord, this project has focused on interactions between salmon lice, wild- and farmed salmon. In Altafjord the results indicate that salmon lice never was a problem for migrating postsmolts of salmon while in the Sognefjord the conditions have gone from negative before 2002 to good during 2002-2004. In sea trout the situation seems less clear. There is no apparent improvement in the Altafjord while in the Sognefjord there seems to be a positive trend also for this species in parallel with the fish farming industry’s efforts to reduce the salmon lice production potential in the farms. Hydrographic-biologic modelling in Sogn shows that the conditions has been satisfactory over a three year period characterized both by positive and negative conditions for salmon lice infections. The project concludes that wild- and farmed salmon can coexist in Norwegian fjords given the total release of salmon lice larvae isaadapted to the local hydrographic conditions and the population characteristics of the wild salmonids. To secure a long term precautionary salmon lice status in Norwegian fjords there is a large need for increasing the present state of knowledge, in particular where there are plans for increaseing the farmed tonnage.

3 Introduction

3.1 General introduction

The Norwegian fish farming industry showed a strong growth during the 1990's, and in 2000 over 500 000 tonnes of farmed salmonids were produced. At that time, sea lice (*Lepeophtheirus salmonis* Krøyer) represented an important economical loss factor in Norwegian and international salmon farming industry. Given the frequently high numbers of gravid salmon lice carried by the large numbers of cultured fish throughout the year, it was likely that the development of the aquaculture industry had led to changes in the natural host-parasite relationship, and made possible the production of large amounts of infective dispersal lice stages. As plankton, these larvae drift and are dispersed over long distances, but apparently concentrate near the surface by day, and probably also near pycnoclines in stratified waters. The density of infective salmon lice stages are, therefore, likely to be greatest in inshore coastal areas and fjords that are subject to constrained tidal flushing. These locations are exploited by the farming industry as well as seaward migrating postsmolts salmonids. In particular during the latter half of the 1990ies more and more alarming reports on premature return migration of sea trout and mortal sea lice infections in postsmolt emerged from different parts of the Norwegian coast. Parallel with these reports different measures were imposed to counteract the effects of sea lice to wild salmonid populations, amongst them a veterinary act regulating the numbers of sea lice allowed per fish in fish farms.

In the present project we have carried out a comparative study between the sea lice conditions in a northern Norwegian fjord, the Altafjord, and a southern one, the Sognefjord. The project has been a carried out as a combination of field studies and modelling activities aiming at exploring and explaining the trends observed in sea lice infections in wild and farmed salmonids on the Norwegian coast.

The present report gives a brief overview of the project and results. Significant results are currently being processed for publication in international journals.

3.2 Introduction to hydrography

The physical oceanographical conditions include the state of the water masses and its motion and variability. Thus the salinity, temperature and water circulation are investigated. Central in this investigation is the assessment of the different forcing, given by the wind, the tides, the freshwater runoff, radiation from the sun and the exchange between the fjord and the coastal ocean.

The study gives an overwiev of the physical oceanographical conditions in the spring period for the years 1999 to 2004 for the Sognefjord area. In Altafjord, the variability on shorter time scales are compared as the amount of historical observations are less.

The natural conditions for the currents in these fjords are characterized by temporarily strong currents and high variability. This makes the analysing of the conditions demanding, having almost always to consider an undersampled system. The aid of numerical hydrodynamical modelling helps, but the present state of the art in fjord models is still not good enough to answer all questions from model results only. This is also due to lacks in the prescription of the forcing, especially winds on sufficient high resolution and the amount of freshwater discharged to the fjord. Despite these shortcomings, the numerical simulated currents seems to be of a good standard making us able to explain features of the upper water mass distribution.

To investigate the distribution of salmon lice in the fjord, artificial “model lice” are transported with the simulated currents. This gives a much more intuitive picture of the conditions in the fjord than looking at the hourly shifting currents, and the salmon lice as a threat for the smolt is easier to asses

4 Material and methods

To obtain the largest possible dataset a large number of data-sources has been used. The data collected within the project thus constitutes only parts of the total database available. It is only to a limited distinguished between the different projects contributing to the total database.

The data series can be divided in the following coarse groups:

1. Estimates of sea lice infection in farms
2. Estimates of sea lice infection in seaward migrating postsmolts
3. Estimates of sea lice infection in adult salmon
4. Estimates of sea lice on stationary sea trout and artic char
5. Hydrographic observations
6. Freshwater runoff and precipitation

The modeling activity can be divided in these sections:

7. Wind model
8. Coastal ocean model
9. Fjord model
10. Particle advection model
11. Hydrographic-biologic interaction model

The following sections describe the different dataseries and modeling activities

4.1 Estimates of sea lice infection in farms

The collection of this dataset was carried out and paid within the frames of the project. The goal was a satisfactory number and stage resolution counting of salmon lice at appropriate times with regard to salmon by trained personnel in *all* operating salmon and rainbow trout farms in both fjords in 2003 and 2004 (Fig. 1,2,3,4). This was achieved by operating two teams of two-three students or researchers at a time in each fjord (Table 1). In Sognefjorden, the teams counted in weeks 13, 16-17 and 20 in 2003 and 2004. In Altafjorden, counts were similarly arranged in weeks 21, 24 and 27 in 2003 and in weeks 22, 25 and 28 in 2004. Additional counting was performed by veterinarians and farmers after the last of these weeks. In Hyllestadfjorden and in certain sites in

Sollund in Sognefjorden, lice counting was carried out by the veterinarian Trude Lien in arrangement with the local veterinary authorities due to lack of cooperation by the farmers. However, in general the project was met with great enthusiasm and cooperation by the farmers.

At least twenty fish from at least two pens in each farm were taken out, anaesthetised and examined for lice. Counts were recorded on forms designed especially for the project. Care was taken to include at least one pen of the oldest and largest fish on the site, and to examine both salmon and rainbow trout if both species were being farmed at the same site. With the exception of the farmers from Hyllestad, the counting teams were well received on all sites. The researchers responsible for this part of the project visited approximately half of the farm sites during the 2003 field season to communicate goals and relevance to farmers, and to inspect counting procedures. In the period between team countings and after these the farmers were encouraged to send their own counting records to the project, but this was rarely done.

Data were collected on paper forms, but were later entered in a custom built MS Access data base. In total, 90 sites were visited by the counting teams and included in the project.

Table 1 Inspection periods for farms in Altafjord and Sognefjord in 2003 and 2004 with number of days work put into collection of data.

		Period			Number of
Fjord	**Year**	**1**	**2**	**3**	**day's work**
Alta	**2003**	19.5 - 23.5	9.6 - 13.6	30.6 - 4.7	75
	2004	24.5 - 28.5	14.6 - 18.5	5.7 - 9.7	60
Sogn	**2003**	24.3 - 28.3	14.4 - 25.4	12.5 - 16.5	75
	2004	24.3 - 28.3	14.4 - 25.4	12.5 - 16.5	60
					Total: 270

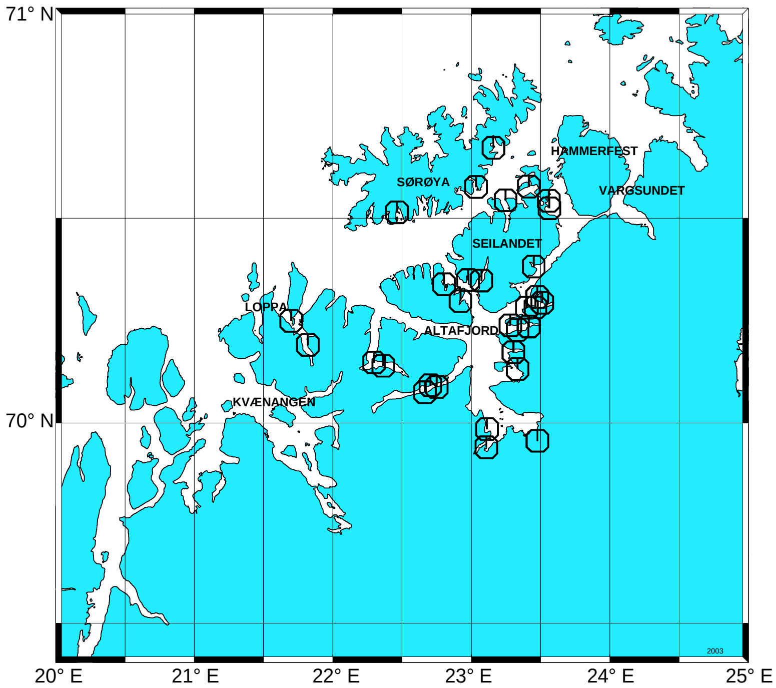

Figure 1 Farms counted in the Alta area in 2003.

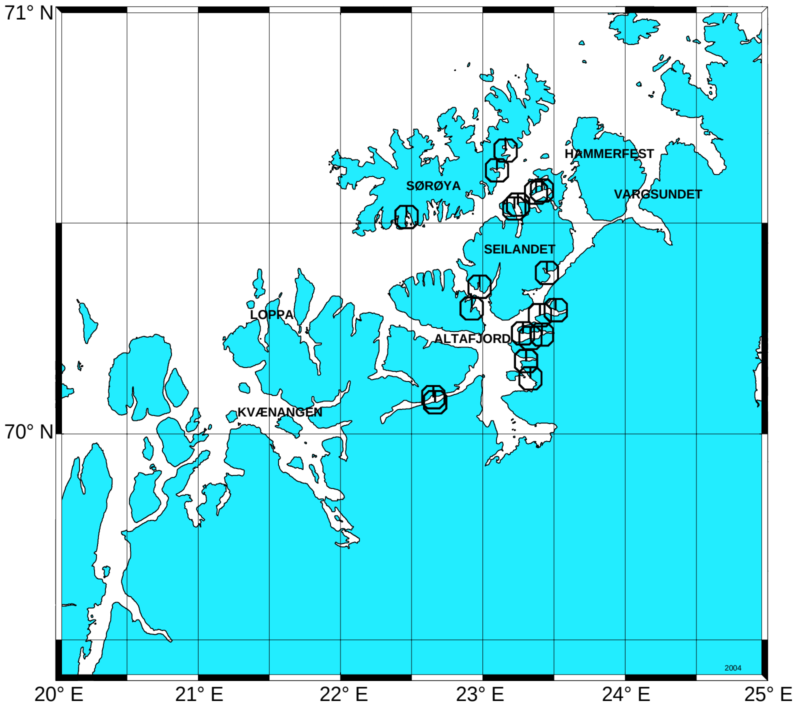

Figure 2 Farms counted in the Alta area in 2004.

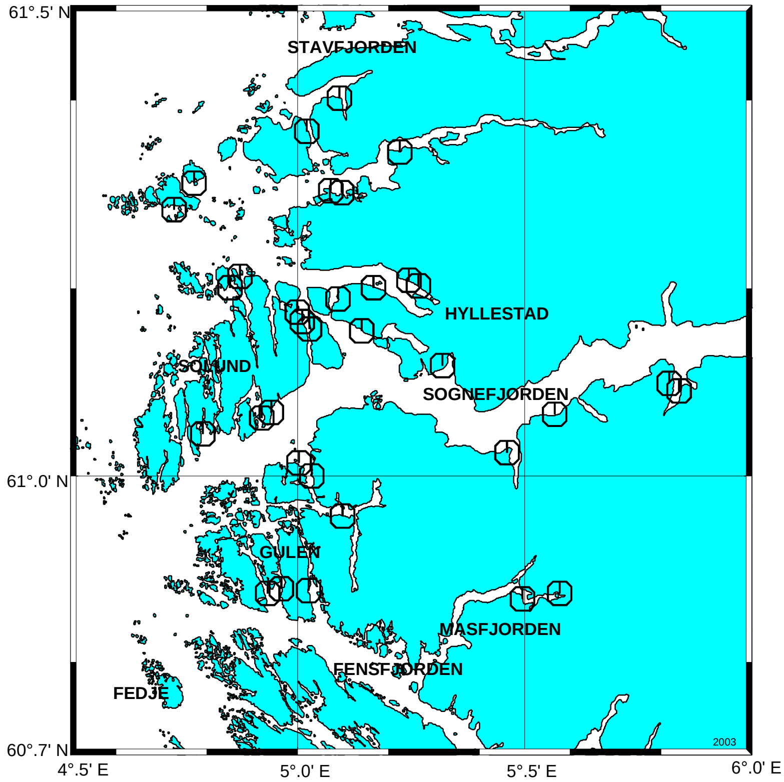

Figure 3 Farms counted in the Sogn area in 2003.

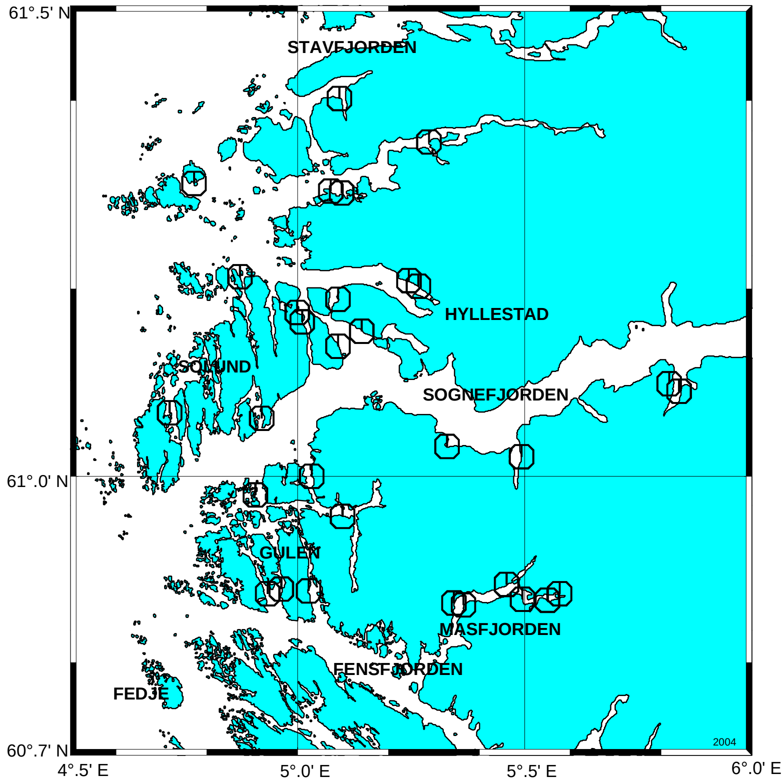

Figure 4 Farms counted in the Sogn area in 2004.

4.2 Estimates of lice infection in seaward migrating postsmolts

Systematic trawling for seaward migrating postsmolts of salmon, sea trout using the Fish-Lift live capturing device (Holst and McDonald, 2000) was started in 1998 in Norway. Results from a number of different projects have been included in the project reported in order to get the best possible overall picture of the spatial and temporal trends in Norwegian fjords since these investigations started. A varying number of fjords have been trawled every year (Figure 5, table 2).

A common procedure for obtaining trawl samples of migrating postsmolts in fjords has been applied in the various projects. Trawling was either carried out with smaller research vessels from 150 hp up to 450 hp or with the 1200 hp IMR RV "Michael Sars". Trawls specially designed for surface trawling was hauled with 300-400 meters of wire, sweeps at 50-90 meters and aluminium doors at 2-3 sq. meter (5 on MS). The horizontal openings of the trawls were 20-40 meters and vertical opening 8-12 meters. The trawls were hauled at 2-3 knots speed and hauls lasted from 30 min to 2 hours. In general there is a temporal shift northwards, coordinated with smolt migration, with the southernmost trawling carried out during May and the northernmost trawling carried out in July.

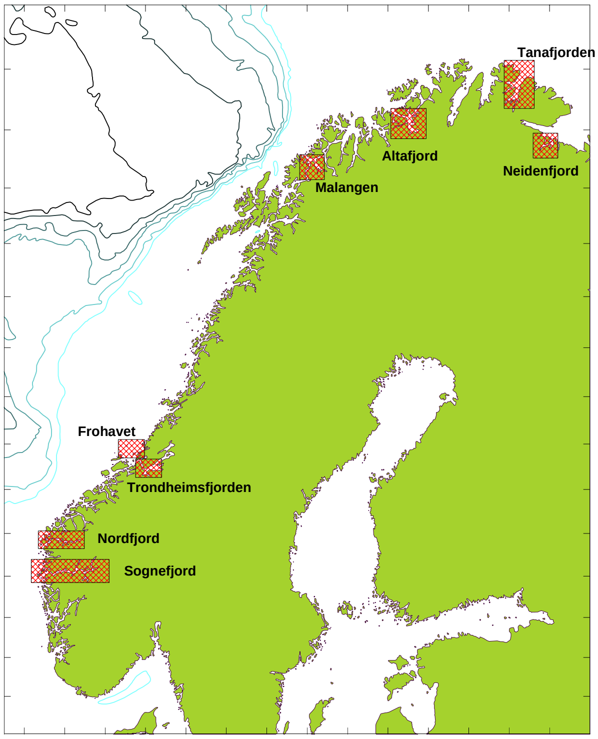

Figure 5 Fjords and coastal areas trawled for seaward migrating postsmolts of salmon during the period 1998-2004.

Table 2. Sampling years by fjord with number of postsmolts inspected for salmon lice. Vessel size indicated.

Fjord	Year	Number of postsmolts	Large vessel
Neiden	2000	30	*
Tana	2000	161	*
	2000	156	
Alta	2001	64	
	2002	37	
	2000	93	
Malangen	2001	17	
	2002	3	
	1999	86	*
Frohavet	2000	41	*
	2001	33	*
	1998	62	
Nordfj	1999	115	
	2000	15	
	1999	22	*
Trondheimfj.	2001	1	*
	2002	68	*
	1998	52	
	1999	374	
	2000	95	
Sogn	2001	161	
	2002	268	
	2003	88	
	2004	316	

At retrieval the Fish-Lift live aquarium was hoisted onboard the vessel and the mix of fish and water poured into a larger basin onboard the vessel. The salmon, sea trout and artic char was sorted from bycatch like jellyfish, sprats, herring and other fishes soon as possible and put directly into individually marked plastic bags. The fishes were measured and weighed while in the plastic bag, then frozen for later counting of salmon lice infection. The fishes were thawed in the lab and numbers and stages of salmon lice counted under a binocular. Plastic bags were screened for lice detached from the fish.

4.3 Estimates of salmon lice infection in adult salmon

Riverwards migrating adult salmon were caught in bagnets in both fjords both years (Figure 6,7). In addition bycatches of sea trout, artic char (Alta), escaped salmon and escaped rainbowtrout (Sogn) were caught. The fishes were killed and put in plastic bags onboard the fishing vessel. Care was taken in handling the fishes not to remove attached salmon lice accidentally. Later in a lab salmon lice were peeled of the fish skin and stages decided.

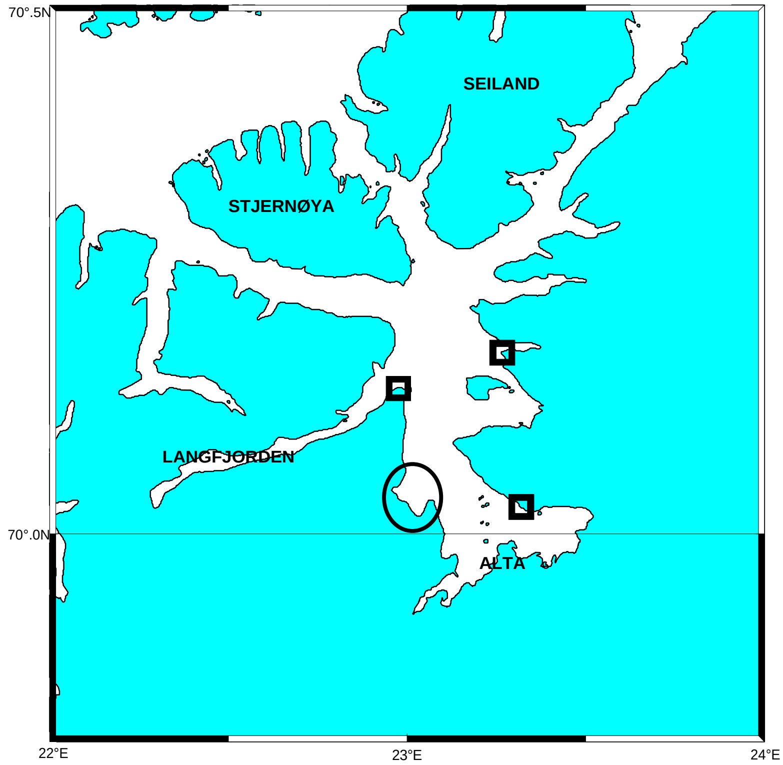

Figure 6 Salmon bagnet positions (squares) and area for sea trout floating gillnet fishing in Altafjord in 2003 and 2004.

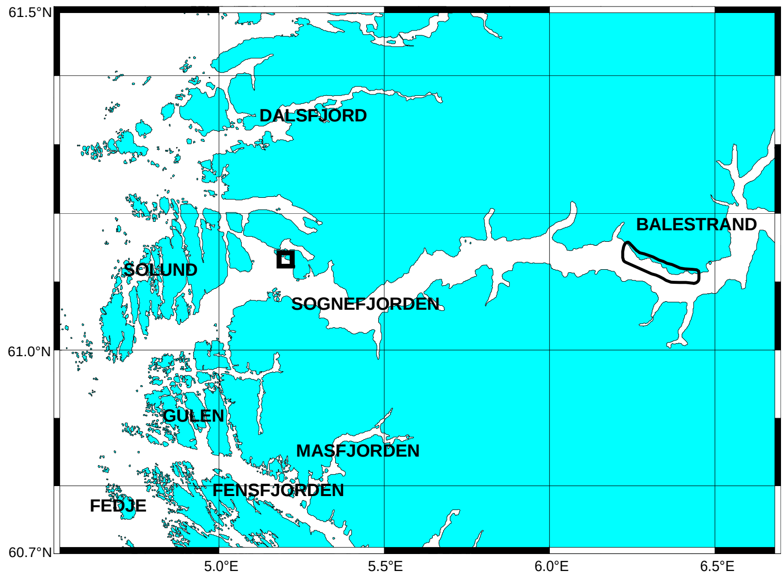

Figure 7 Salmon bagnet position (square) and area for sea trout floating gillnet fishing in Sognefjord in 2003 and 2004.

4.4 Estimates of sea lice on stationary sea trout and artic char

Sea trout were caught by standardized sets of floating gill nets of 1 x 16.5, 1 x 18.0, 3 x 19.5, 3 x 21.0, 1 x 24.0, 1 x 26.0, 1 x 29.0 and 1 x 35 mm mesh size in both fjords in both years (Figure 6,7). The fishing was done throughout a tidal cycle. We anchored the nets above high tide level, and put out single or randomly selected nets in series, with an angle of approximately 90 ° to the shore, and across the littoral zone where most of the sea trout seemed to forage. The nets were left over night and fish taken out of the nets in the morning. To further minimize the possible loss of lice, the fish were cut out of the nets, put in individually tagged plastic bags and frozen after weight and total length had been measured. Sea lice infection was counted at a later stage.

4.5 Hydrographic observations

The hydrographic observations in Sognefjorden are collected from two sources: 1. The coastal monitoring station Sognesjøen (green circle in Figure 32a) operated by the IMR about every second week, 2. Scientific surveys by IMR vessels during 2002-2004.

In Altafjorden, the observations are less frequent as the closest IMR coastal monitoring station Ingøy is located outside the fjord to the north and with less representative observations. A full coverage of the fjord with hydrographical observations was made in mid July 2004, and temperature records from a few locations exists for the period 1999-2004.

All combine salinity and temperature observations are made with the SAIV ctd-profiler.

4.6 Freshwater runoff and precipitation

Data for daily freshwater runoff from eleven rivers in Sognefjorden are obtained from the Norwegian Water Resources and Energy Directorate (NVE). Monthly mean precipitation for several locations in the fjord surroundings is taken from the “eklima”-service by the Norwegian Meteorological Institute (met.no). Together, these data are used as a basis to specify runoff from 35 rivers. No information from hydro electric power plants exists.

In Altafjorden, runoff data from Altaelva is provided for the period 1996-2003.

4.7 Wind model

In a cooperation with Anne D. Sandvik at the Bjerknes Centre for Climate Research, the meso-scale numerical atmospheric model MM5 was implemented for the western part of Norway and for Altafjorden. Wind fields with a horizontal resolution of 3km were provided for April 15 to June 16 in the years 1999-2004. In Altafjorden, this period is prolonged to July 31 for 2003 and 2004.

4.8 Coastal ocean model

Boundary conditions towards the coast were calculated by a separate numerical model simulation. The IMR ecological model system

NORWECOM implemented for the North Sea was used, giving boundary values for currents, water elevation (tides) and hydrography with a horizontal resolution of 4km.

4.9 Fjord model

The fjord model is the Bergen Ocean Model made by professor Jarle Berntsen at the University of Bergen. This is a three-dimensional model solving the primitive hydrodynamical equations for an Arakawa C-grid and with a terrain-following sigma-coordinate system in the vertical. The forcing of the model consists of wind (6 hourly), tides/open boundary conditions (every 30 minute) at the coastal ocean outside the fjord and freshwater runoff (daily values). Radiation from the sun is parameterized from the open boundary condition at the coast, i.e. representative for the coastal waters.

The set-up for both fjords has 800m horizontal resolution and 21 sigma-layers vertically (with fine resolution, 0.25-1m, in the upper 5m and gradually coarser vertical grid below).

The results from the model includes sea-surface elevation, 3D currents, density, salinity and temperature. To include the tidal current, the results are stored every hour. One 60 days simulation needs ~16Gb disk storage.

4.10 Particle advection model

The advection of horizontally passive particles are modelled based on the results of currents and hydrography from the fjord model. The currents with hourly time resolution will advect particles in three-dimensions. The effect of turbulence is parameterized by a random walk diffusion, where each particle is given an induvidual axi-symmetric Gaussian random velocit every time step. This corresponds to a diffusion coefficient of 1 m^2/s.

Since these model particles are to adopt certain behavior from natural salmon lice, some restrictions on the vertical movement are implemented. These are: 1. A diurnal migration with upward movement during day and downward movement during night, 2. Particles reaching the surface are given a weak downward movement, 3. Particles reaching 10m depth are given a weak upward movement, 4. Particles in water with salinity less than 24 are given a downward movement.

5 Results

5.1 Estimates of sea lice infection in farms

In Sognefjord, the farmed fish had an average of c. 0.6 adult female lice in the first sampling week in both 2003 (n=1164 fish) and 2004 (n=867). This was the highest number recorded during the sampling weeks both years. Four sites had more than the legal limit of 0.5 lice, and one of these had an average of 7 adult females on 40 fish. Later counts gave lower abundances (Figure 8c & d). Initially in 2003 chalimus numbers ranged from 0 to 7, with an average abundance around one (Figure 9). Higher intensities occurred around week 13 than later. Chalimus abundance remained below 2 in week 16-20, with a few exceptions. In 2004 the chalimus infection pattern was similar, but the highest intensities of chalimus infection were found later, around week 16. There were significant differences in the abundance of adult female lice between the geographical regions within Sognefjorden. In 2003 the farms in Sollund and Værlandet had on average 1.5 adult females (SD 3.1) in week 13, falling to 1.16 (SD 1.77) by week 17, whereas the other regions on average had 0.4 (SD 0.9) adult females in the same period. Except for Gulen, at 1.5 lice (SD 2.3), Sollund and Værlandet also had more adult female lice in the first sampling week of 2004, 0.8 lice (SD 1.8), than the other regions.

In Altafjord lice numbers were generally lower than in Sognefjorden (Figure 8a, b; 9). The farmed fish carried on average 0.13 adult female lice in week 21 in 2003 (n=625) and 0.06 lice in week 22 (n=621) in 2004. Only four farms exceeded the limit of 0.5 adult females in 2003, and none did in 2004. There were also much fewer chalimus larvae: no average abundance higher than 0.3 was recorded (Figure 9). No clear pattern of infection with respect to time was apparent. With few exceptions, chalimus abundance stayed between zero and 0.2 at all sampling times. In 2003, there were significant differences in the abundance of adult female lice between the geographical regions within Altafjorden. The farm sites in the region Rognsundet had an average of 0.33 lice (SD 0.077), whereas the other sites had less than 0.07 lice on average (SD 0.044, all samplings pooled). In 2004 there were no significant differences in adult female lice abundance between the regions.

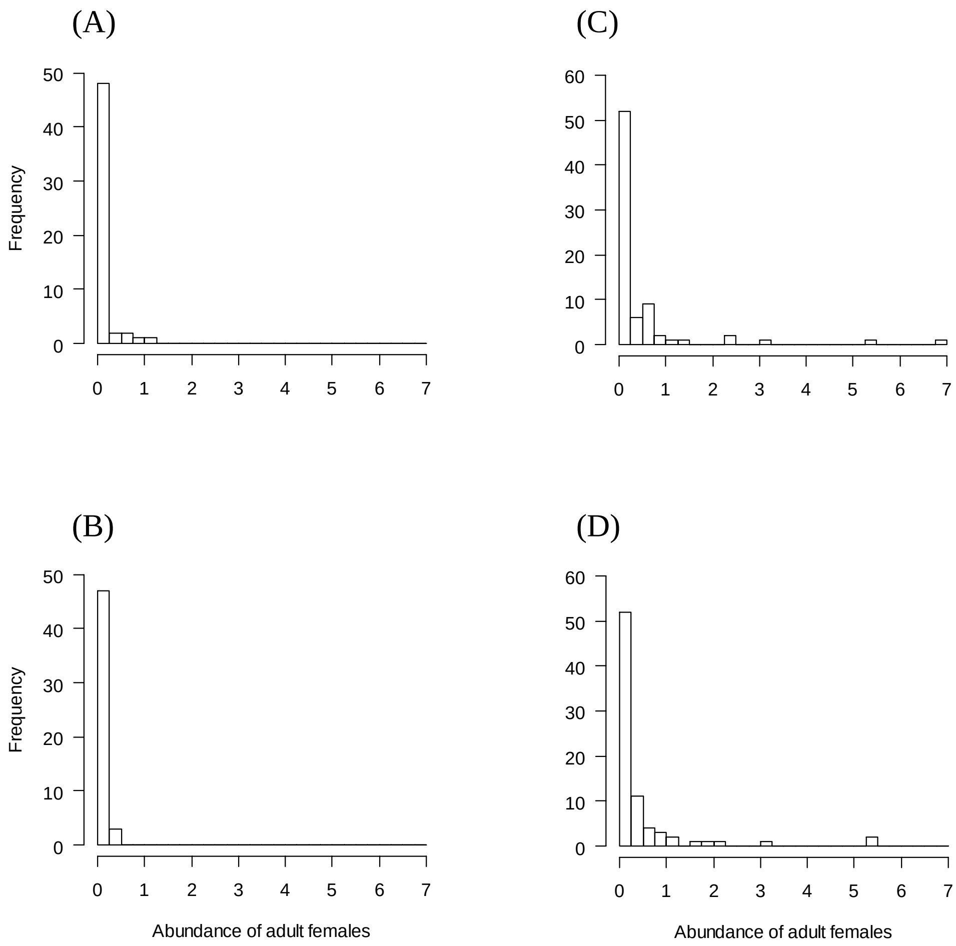

Figure 8 Frequency of farm adult female salmon lice *Lepeophtheirus salmonis* averages in Altafjorden in 2003 (A) and 2004 (B), and Sognefjorden in 2003 (C) and 2004 (D).

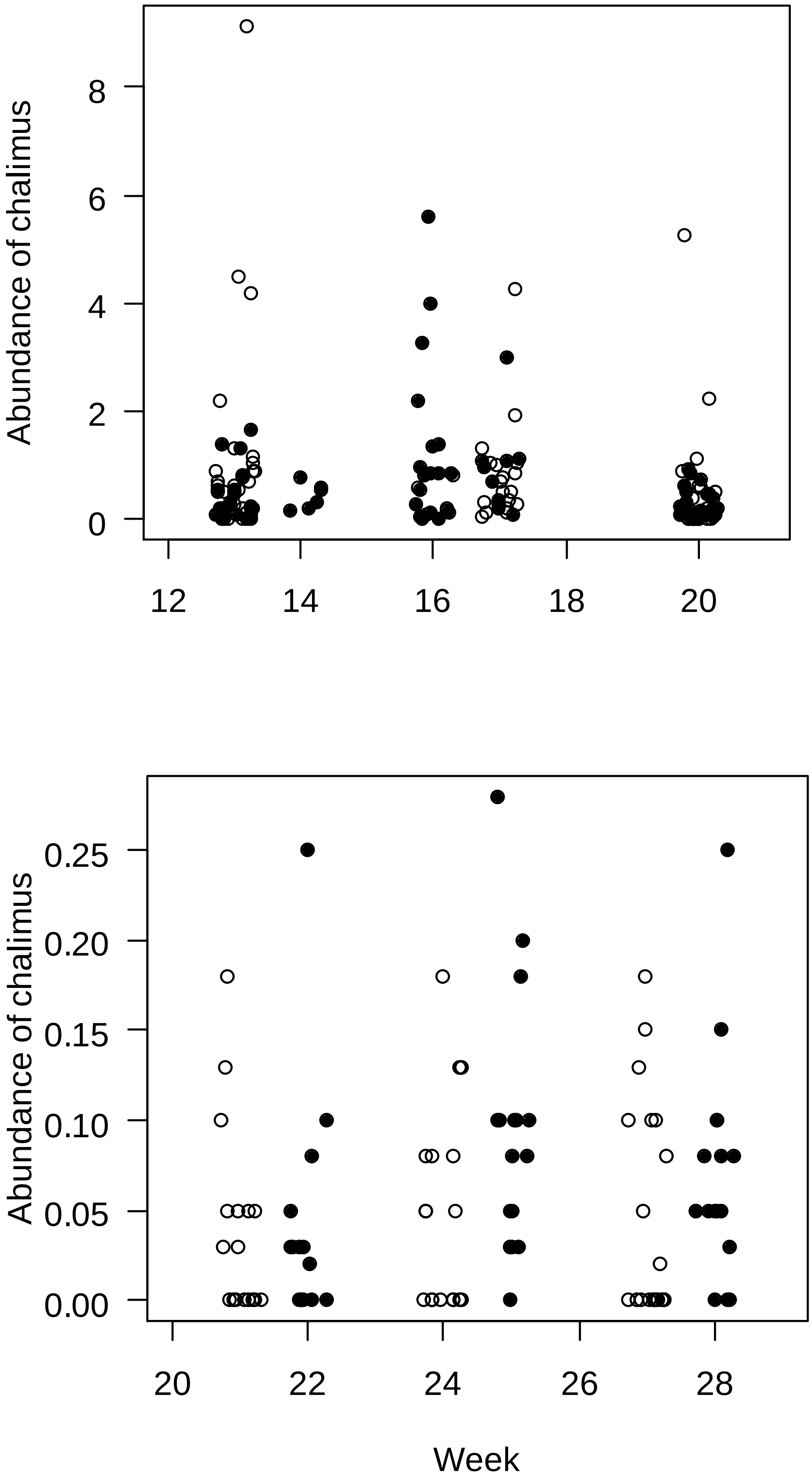

Figure 9 Mean abundance of sessile salmon lice (*Lepeophtheirus salmonis*) in farm counts in 2003 (circles) and 2004 (filled circles) in Sognefjorden (top panel) and Altafjorden (bottom panel). Note different axis scales.

5.2 Estimates of lice infection in seaward migrating postsmolts

In general sea lice infections were absent or in one occasion at a very low level in all areas sampled in northern Norway (Figures 10-14, Table 3). The only observations of infections in postsmolts of salmon appeared in Altafjord in 2004, but at a very low level. In western Norway infection levels were higher but with a decreasing tendency in the later years sampled. There was consequently a distinct spatial south-north gradient in infection level and also a clear temporal gradient going toward lower levels at the end of the studied period.

Table 3. Sampling areas by year, catch of postsmolt salmon and mean infection intensity.

Location	Year	Number of salmons	Mean infection	St. dev
Neiden	2000	30	0	0
Tana	2000	161	0	0
	2000	156	0	0
Alta	2001	64	0	0
	2002	37	0.1	0
	2003	80	0	0
	2004	165	0.1	0.4
	2000	93	0	0.8
Malangen	2001	17	0	0
	2002	3	0	0
	1999	86	2	1.6
Frohavet	2000	41	1.1	1.3
	2001	33	2.3	5.2
	1999	22	11.6	8
Trondheimfj.	2001	1	1.4	2
	2002	68	1.5	2.1
	1998	62	17.2	39.6
Nordfj	1999	115	14.5	16
	2000	15	0.1	0.3
	1998	52	2.1	3.8
	1999	374	36.6	48.9
	2000	95	74.8	26.5
Sogn	2001	161	64.7	43.8
	2002	268	2.3	2.6
	2003	88	1	1.5
	2004	316	2.1	3.2

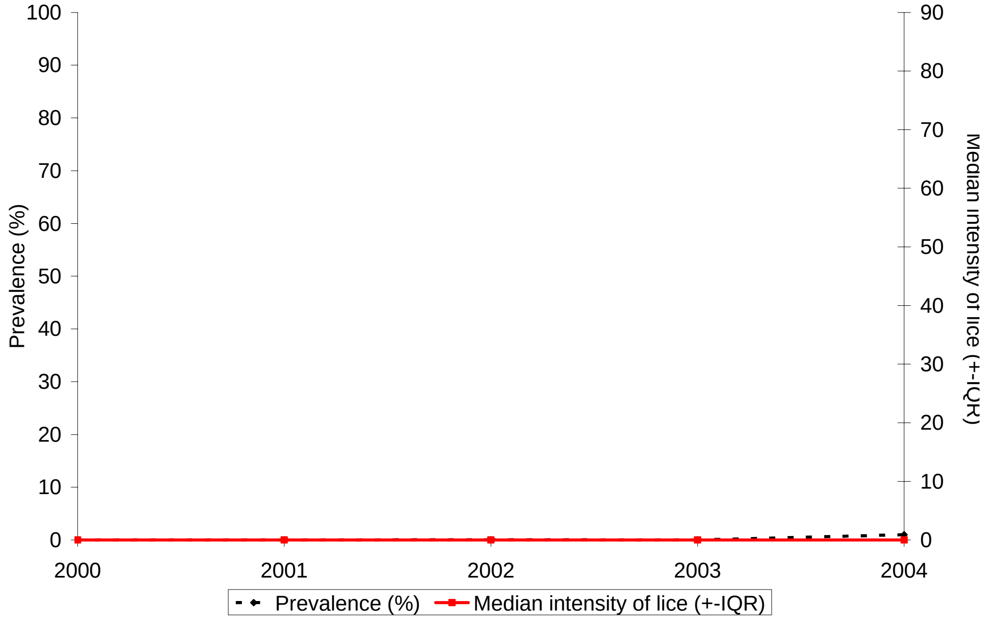

Figure 10 Prevalence and median intensity of sealice on postsmolts of salmon taken in the Altafjord during 2000-2004. Note that values are 0 in all years except 2004.

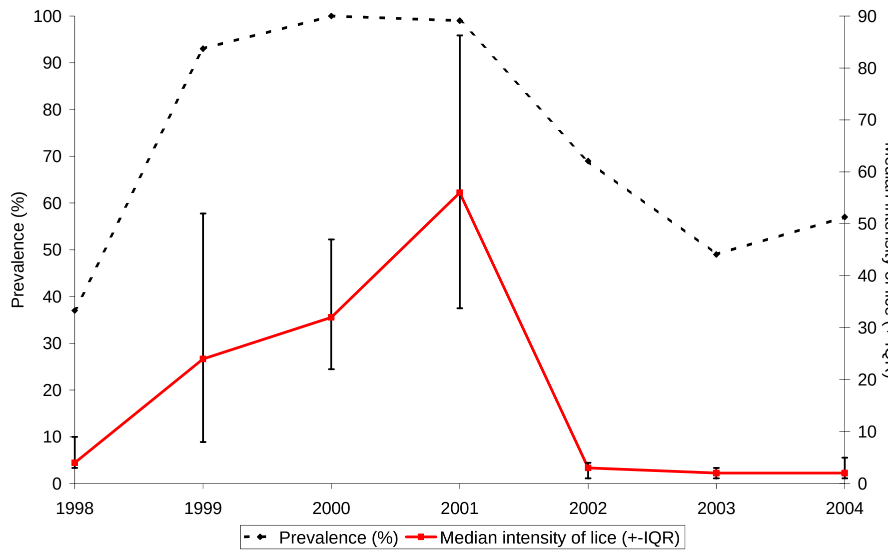

Figure 11 Prevalence and median intensity of sealice on postsmolts of salmon taken in the Sognefjord during 1998-2004.

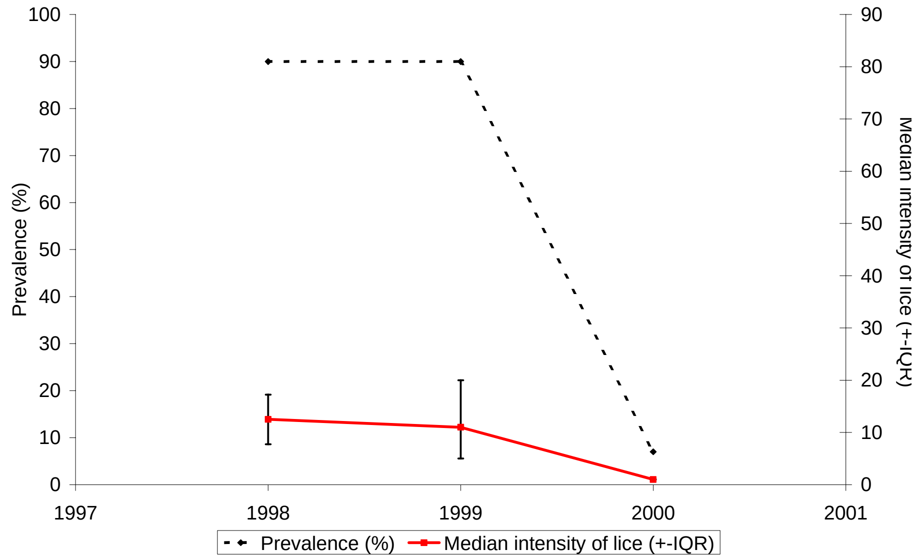

Figure 12 Prevalence and median intensity of sealice on postsmolts of salmon taken in the Nordfjord during 1998-2000.

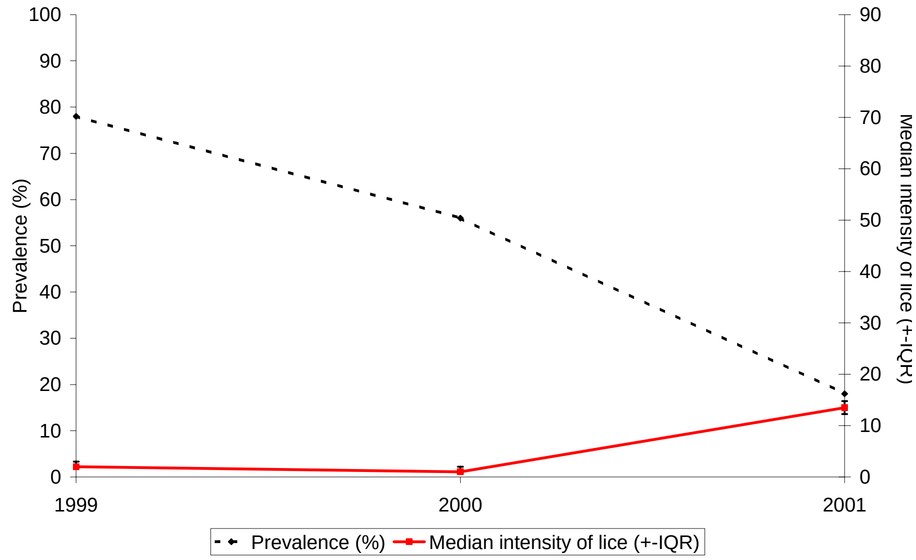

Figure 13 Prevalence and median intensity of sealice on postsmolts of salmon taken in the Frohavet area during 1998-2004.

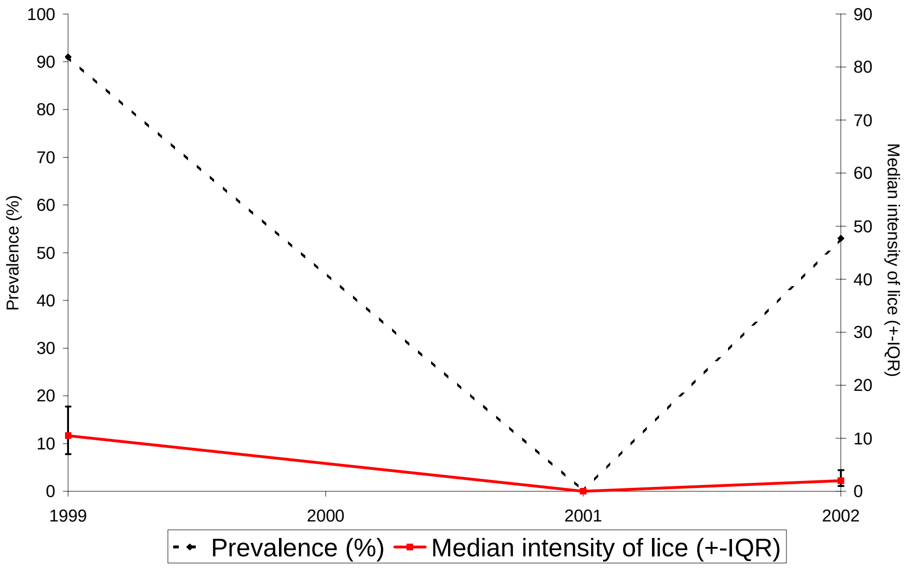

Figure 14 Prevalence and median intensity of sealice on postsmolts of salmon taken in the Trondheimsfjord during 1998-2004. No data in 2000.

5.3 Estimates of salmon lice infection in adult salmon

A total of 625 adult maturing salmon were caught in the bagnets and inspected for sea lice infections (Table 4,5). In Sognefjord the catch rates were almost double in 2004 compared to 2003 (Figure 15), in Altafjord the catch rates were more comparable between years. The mean infection rates varied relatively little between years and fjords (Table 5, Figure 16). In the Sognefjord a relatively small fraction of the catches were done before the main run of smolt had left the fjord system (estimated 15. June).

Table 4. Fishing periods and catches in numbers in bagnets in Sognefjord and Altafjord in 2003 and 2004.

	Location		Week	Wild salmon	Farmed salmon	Salmon total	Sea trout	Rainbow trout
Sogn	Sognes	2003	20-28	106	15		7	10
	Sognes	2004	20-28	197	28	225	23	5
Alta	Inner	2003	26-30	61	-	-	-	-
	Inner and outer	2004	26-31	216	-	-	-	-

Table 5. Catch of adult salmon and sea trout in bagnets in Altafjord and Sognefjord in 2003 and 2004 with prevalence, mean infection intensity and median infection.

	Year	n	Weight	sd	Prev	Mean	sd	Median	Min	Max
Alta	2003	61	9929.5	2784	100	18.6	14.9	14	2	73
	2004	216	5800	4002	99	15.9	11.8	13	0	65
Sogn	2003	106	-		53	6	7.9	4	0	33
	2003 (Trout)	7	-		29	1.9	3.5	0	0	9
	2004	197	5800	2218	95	14.7	12.2	12	0	70
	2004 (Trout)	23	3317	1600	78	7.7	8.5	5	0	32

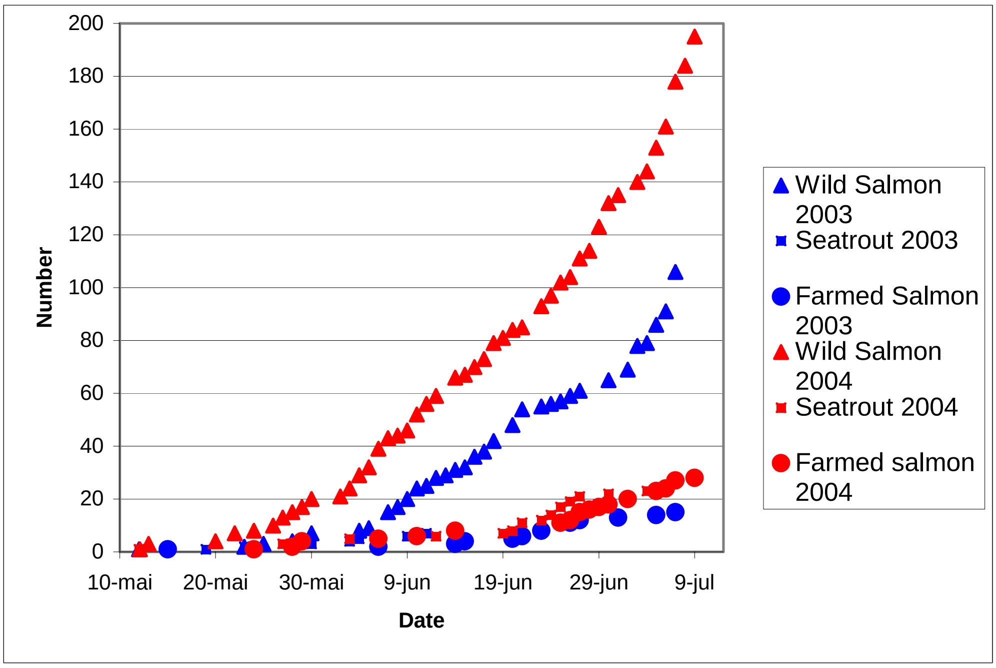

Figure 15 Accumulated catch in number of wild salmon, farmed salmon and sea trout in bagnet in Sognefjord by date in 2003 and 2004.

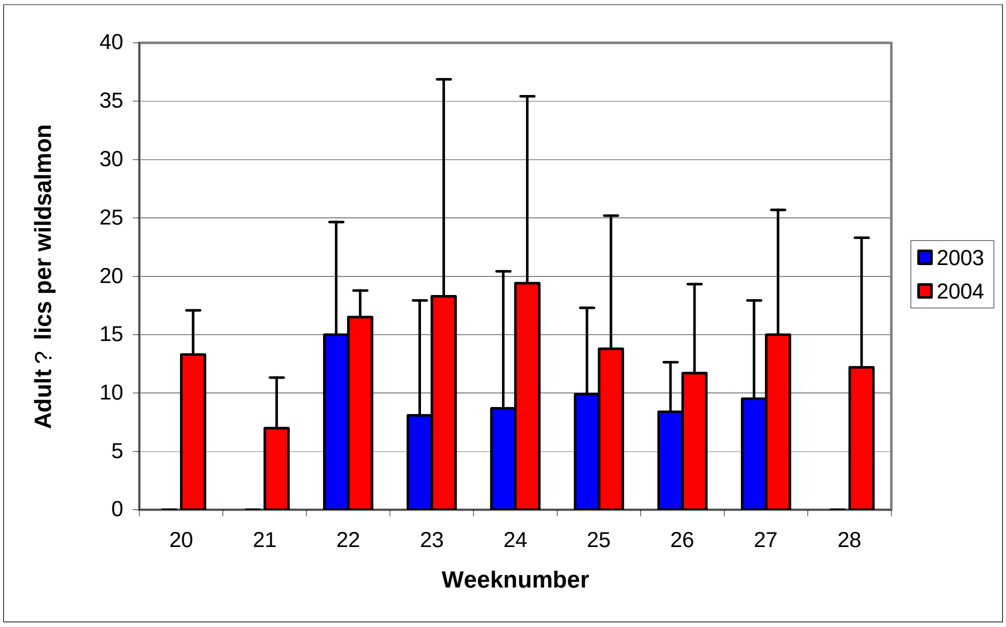

Figure 16 Mean numbers of adult female sea lice + st.dev. per adult salmon caught in the Sognefjord during the period 10th May - 10th July 2003 and 2004.

5.4 Estimates of sea lice on stationary sea trout and artic char

Larvae dominated the sea lice structure on sea trout and artic charr in Altafjord in early in summer 2003 while older stages as well as a continuous reinfection occurred later in the season (results not shown). In general observed infection levels were low in week 24-25 and increased towards week 30-33 both in the fishes caught in the littoral (Fig.17) and the pelagic caught fishes (Fig. 18).

Also in 2004, littoral captured sea trout and Arctic charr was moderately high infected with salmon lice (Fig 19). In late June (week 27), the fish was uninfected with lice. Lice abundance increased in July (week 30) and highest median value was found in September (week 36). Lice larvae dominated the structure in week 30, and a continuous reinfection as well as older stages were observed on the fish in August and September (results not shown).

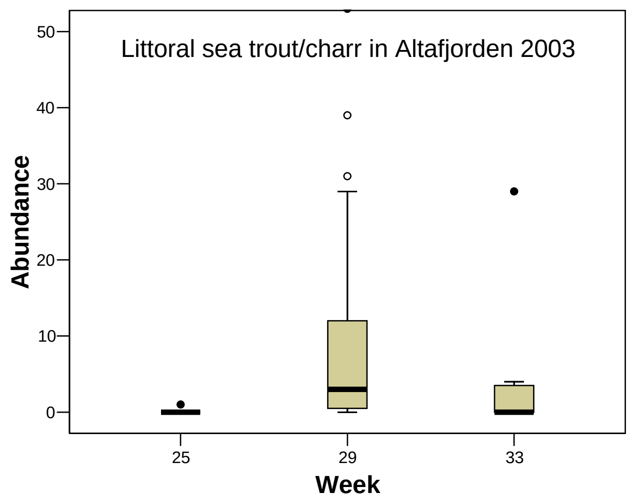

Figure 17 Abundance of salmon lice on gil-nettet wild sea trout in Altafjorden during the summer of 2003. 10-40 sea trout were captured in each week in the fjord.

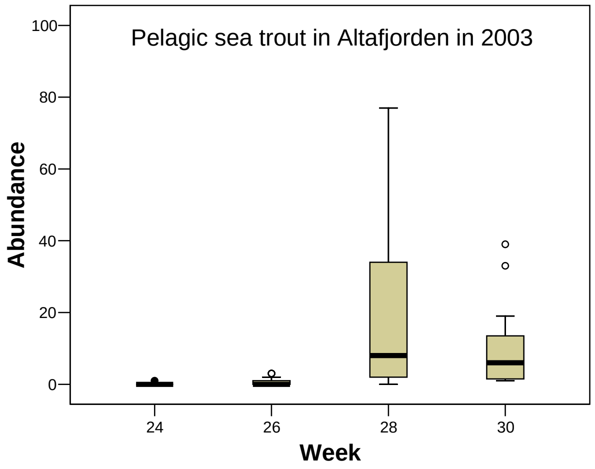

Figure 18 Abundance of salmon lice in sea trout from the 2003 trawling survey in the Altafjord.

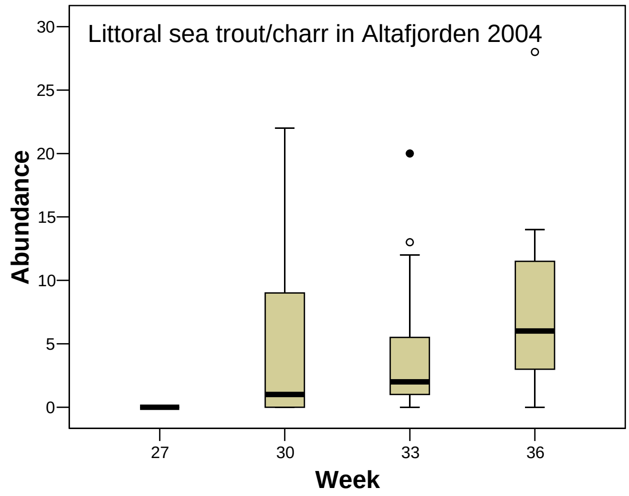

Figure 19 Abundance of salmon lice on gil-nettet wild sea trout in Altafjorden during the summer of 2004. 10-40 sea trout were captured in each week in the fjord.

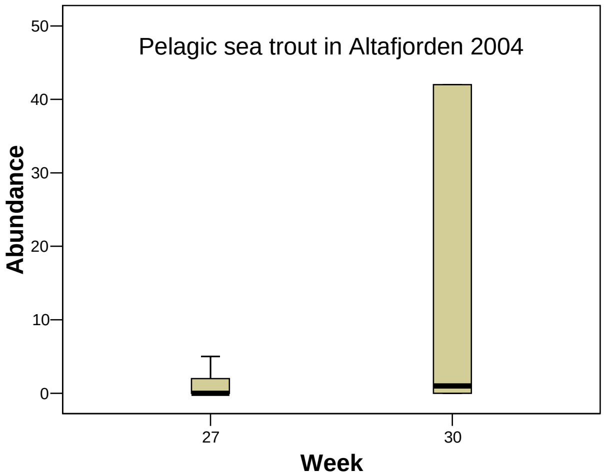

Figure 20 Abundance of salmon lice on pelagic captured sea trout in Altafjord in 2004.

The sea trout in the Sognefjord had high infections early in the summer 2003 (Table 6). In June/July there was a 100% prevalence with mean intensity over 80 per fish. Max value were about 200 per fish. A population structure dominated by larvae indicateing a substantial infection pressure at that time. The small size of the fishes makes the situation even worse with high relative infections. With relative infections in the range over 1.6 most of these fishes would experience osmoregulatory problems as the sea lice grows older. Unless the fishes would migrate back to freshwater an estimated 50% would die as a direct consequence of the infection.

In 2004 sea trout was only sampled in the littoral zone in week 23. At this time the infection level is relatively low (Table 7). The numbers and temporal spread is too low to compare these values with those of 2003. The population structure was towards older stages this year as compared to the same period in 2003, maybe indicating a lower infection level in 2004.

Table 6. Sea lice intensity and median intensity in sea trout caught in the littoral zone in the Sognefjord in 2003. Relative intensity is lice/gram fish.

Week	Hab	n	Weight (g) ± SD	Prev (%)	Average ± SD	Median	IQR	Min	Max	v/x	Relative Intensity Median (n)	IQR	Min	Max
23	SV	26	186,3 ± 252,2	92,3	16,5 ± 14,3	12,0	15,0	1	59	12,4	0,269 (24)	0,51	0,010	2,252
24	SV	8	62,2 ± 20,4	100	83,0 ± 79,3	48,0	154,3	13	204	75,7	0,794 (8)	3,23	0,187	4,146
27	SV	30	63,3 ± 106,1	100	80,8 ± 55,4	70,0	94,7	4	189	38,0	1,604 (30)	1,87	0,062	4,970

Week	Hab	n	Weight (g) ± SD	Prev (%)	Average ± SD	Median	IQR	Min	Max	v/x	Relativ Intenscity Median (n)	IQR	Min	Max
23	SV	11	209,6 ± 208,1	50,0	18,8 ± 18,3	15,0	32,0	1	48	17,8	0,118 (5)	0,17	0,013	0,194

Table 7. Sea lice intensity and median intensity in sea trout caught in the littoral zone in the Sognefjord in 2004. Relative intensity is lice/gram fish. Fishing was only carried out in week 23.

5.5 Hydrography

In short, the hydrographical conditions in the upper 10-20m of the outer part of Sognefjorden for the spring in the years 1999-2004 can be characterized as the following:

1999, 2000 and 2002 – relatively fresh and warm,

2001, 2003 and 2004 – relatively saline and cold.

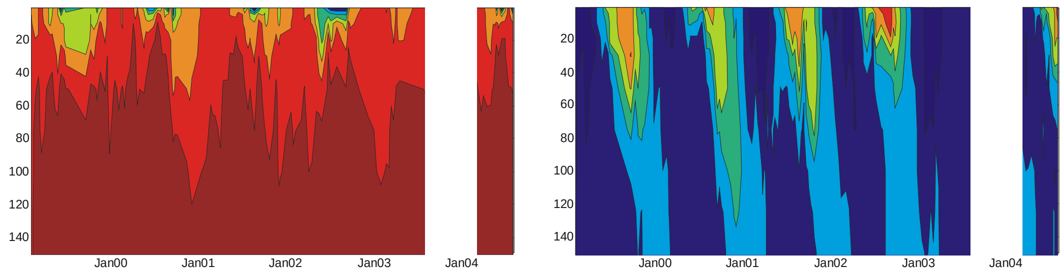

Figure 21 Vertical sections of salinity (left panel) and temperature (right panel) from the outer part of Sognefjorden (the IMR coastal station Sognesjøen) from 1999-2004. Note the gap in observations from May to December 2003.

The seasonal signal of hydrography is clear from the observations in the outer part of Sognefjorden (Figure 21). The upper water masses are fresher and warmer in the summer than the winter due to frehwater discharge and sun radiation. There are marked differences from year to year.

Most prominent from the inter-annual variations are the relatively fresh and warm waters in 2000, 2001 and especially 2002 in the upper ~10m, and that 2001 differs with saline and cold waters (Figure 22).

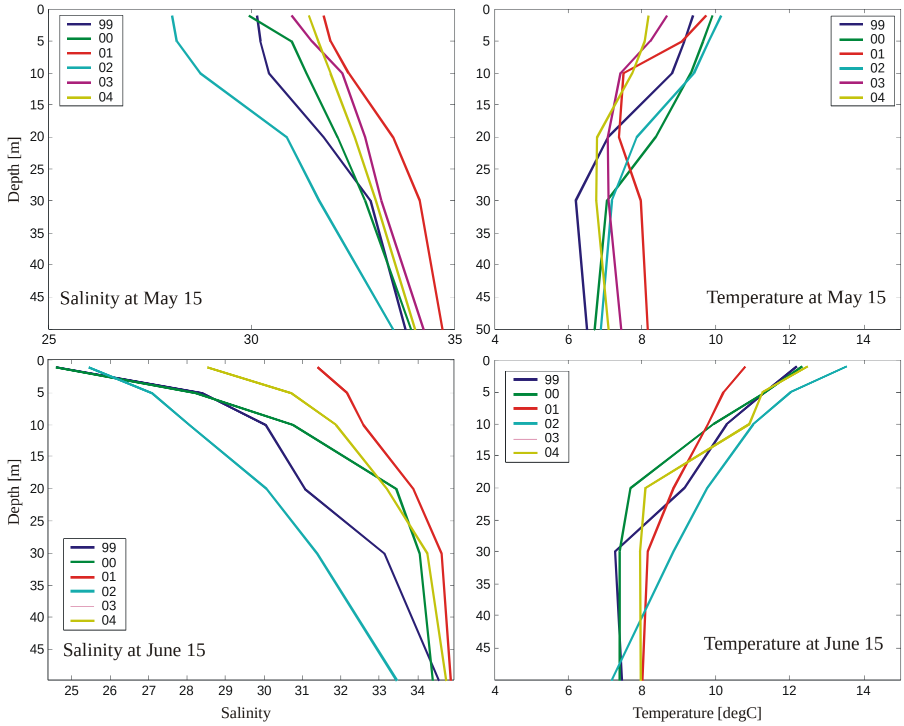

Figure 22 Vertical profiles of salinity (left panels) and temperature (right panels) from the outer part of Sognefjorden for May and June 15, 1999-2004.

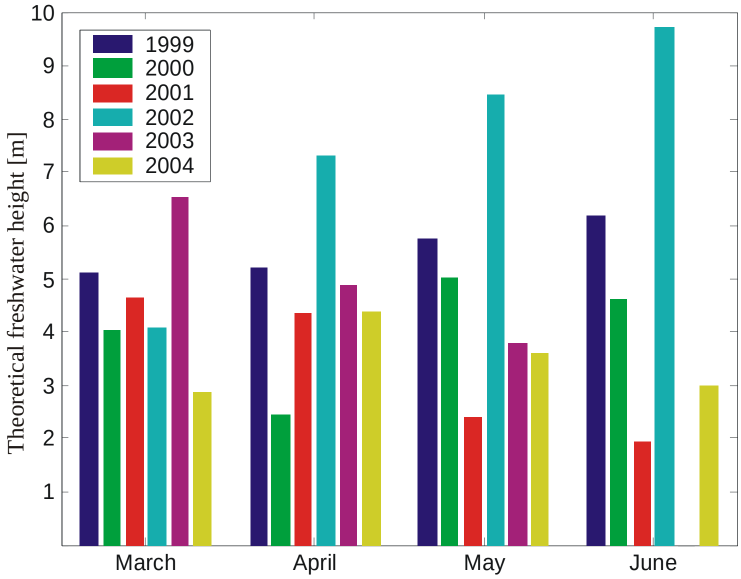

Figure 23 Theoretical freshwater height in the outer part of Sognefjorden.

Theoretically the amount of freshwater can be extracted from the observed water columns, as a construction with a layer of pure fresh water above homogeneous water with salinity of 35. The height of such a freshwater layer, based on the salt profiles at the Sognesjøen station, will vary considerably between the years (Figure 23). In May, the "fresh" years 1999, 2000 and 2002 have more than double the height than in 2001.

At Ingøy in the northern Norway, the seasonal amplitude and absolute inter-annual variability of salinity and temperature is less than at Sognesjøen (Figure 24). Temperature recordings from the surface inside Altafjorden, however, has a seasonal variation of ~10 ^{o}C.

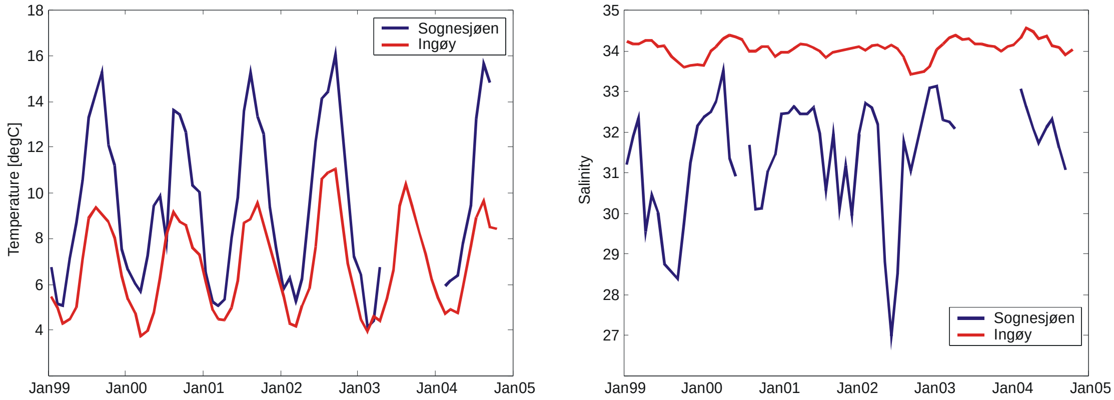

Figure 24 Monthly mean values at 10m depth of temperature (left panel) and salinity (right panel) observed at the IMR coastal stations Ingøy (red line) and Sognesjøen (blue line).

5.6 Runoff and precipitation

The runoff is found to correspond well with the winter NAO index (e.g http://www.cgd.ucar.edu/~jhurrell/nao.html) which is the strength of the atmospheric pressure field between Iceland and Portugal in the period December to March. At the western coast of Norway the NAO indexs is typically a measure of the strength of the SW winds, and indirectly a measure of the precipitation (Figure 25).

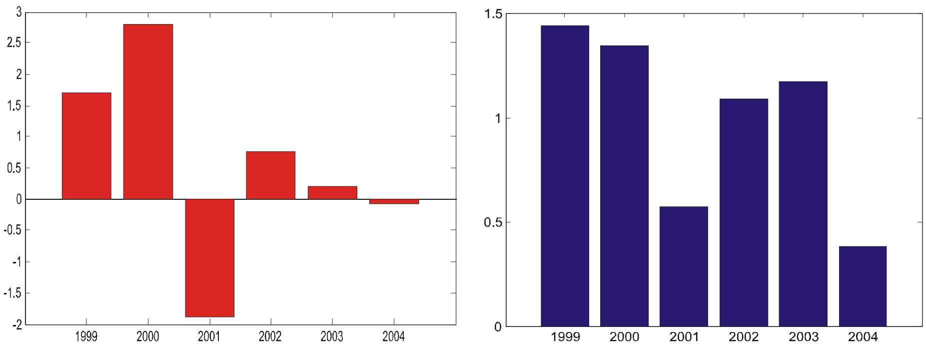

Figure 25 The relative precipitation from Årdal in the inner part og Sognefjorden (right panel) and the winter NAO index (left panel) for 1999-2004.

It is anticipated that the NAO index and the runoff to Sognefjorden will be correlated. Indeed, this is true (Figure 26), however this accounts only for the unregulated runoff, as the regulated runoff (from hydro electric power plants) more follow economical indexes rather than natural ones. Thus, the total freshwater runoff to the fjord might not be correlated with the precipitation at all.

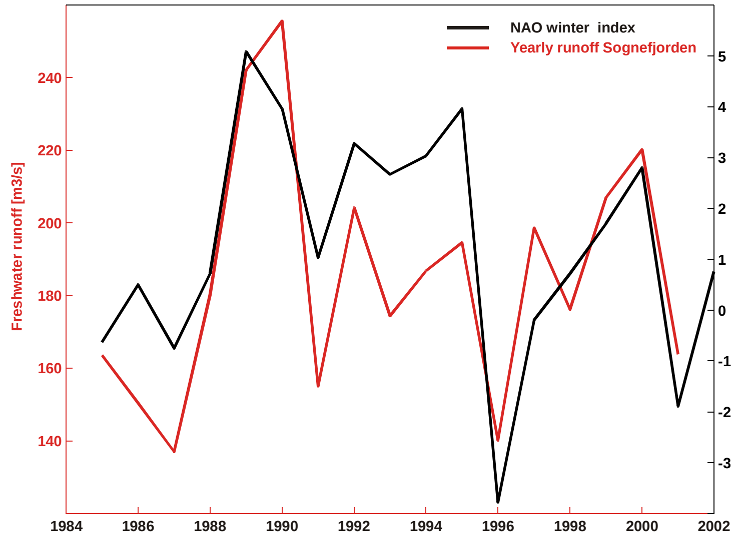

Figure 26 The winter NAO index (black line) and the yearly mean runoff to Sognefjorden (red line).

5.7 Wind

The winds in the fjord will be significantly influenced by the steep land topography. Typically the wind directions will be along the fjord axis. The general wind fields are also determined by the storm-track (atmospheric Polar front) positioned across Norway, leding to usually strong and shifting conditions.

The winter NAO index is a good measure of the strength of the SW-winds along the western Norwegian coast (Figure 26), and the years from 1999 to 2004 includes two extreme years: 2000 with high and 2001 with low NAO index. Since the winter NAO index only is a measure of the winds until March, the actual winds for the spring might not be represented by this index.

Extracted from the MM5 wind-model results, mean wind vectors at the location in the outer part of Sognefjorden (red circle I in Figure 1) show large differences for the period April 15 to June 16 (Figure 27). The fjord axis at this location is directed approximately in the direction of the mean wind vectors from 1999 and 2000. The mean wind for the low-NAO year 2001 is rotated ~45 degrees to the right while the mean wind from 2002 is rotated ~45 degrees to the left compared to 1999 and 2000 (Figure 27). The mean wind strength also differs, with 1999, 2000 and 2002 being strong and 2001, 2003 and 2004 being weaker. The mean wind in 2003 is even directed almost perpendicular to the fjord.

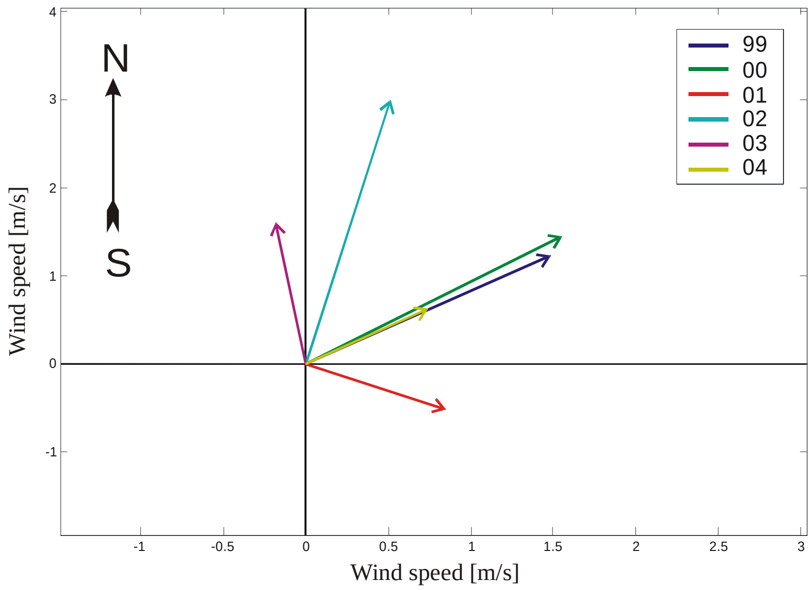

Figure 27 Mean wind vectors from the MM5 wind model results for the period April 15 to June 16 at a position representing the outer part of Sognefjorden.

The mean wind has no information on the episodes that characteristically can be many and long lasting (~days). To investigate if wind episodes differ between the years, the number of events in three speed ranges were summarized. These speed ranges were: 0-5 m/s, 5-10 m/s and above 10 m/s. We find that in 2001 the amount of wind episodes from south were more frequent than the other years and that the episodes with northerly winds were less (Figure 28).

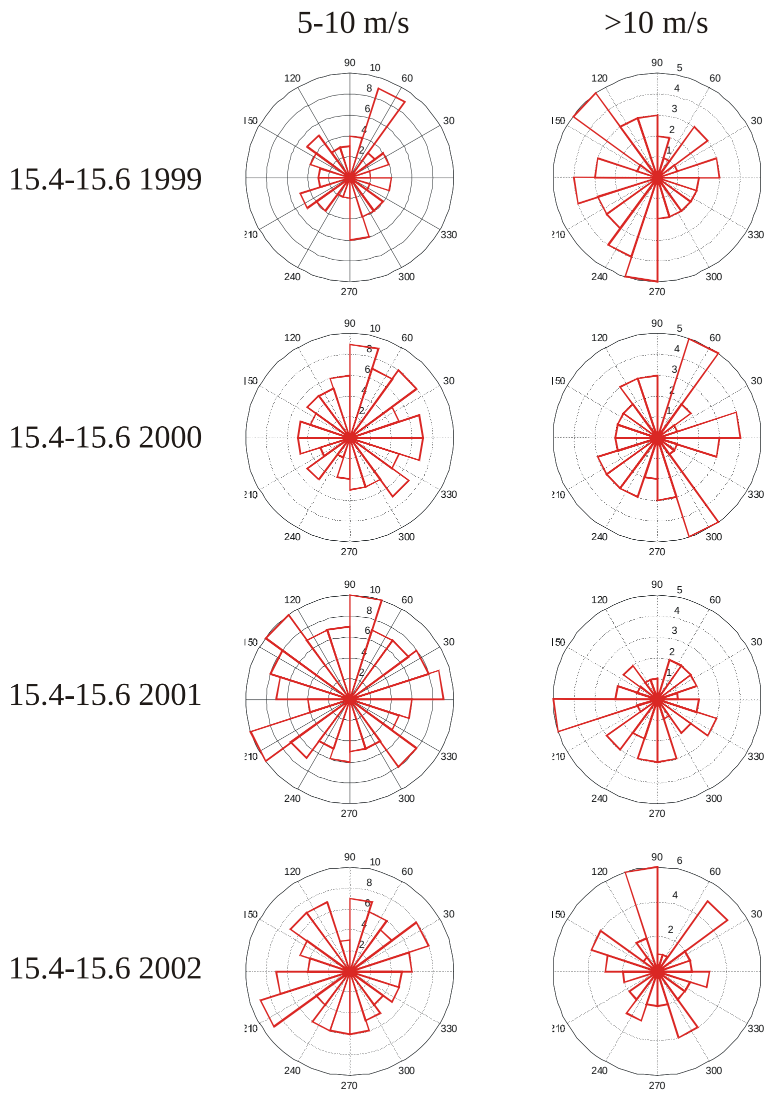

Figure 28 Wind roses showing number (length along the radial axis) and direction (compass direction where the wind comes from) of wind episodes from the MM5 results at the location in the outer part of Sognefjorden for the periods April 15 to June 16, 1999-2002. The episodes are divided into speeds between 5 and 10 m/s and above 10 m/s.

5.8 Currents

The currents in the fjord will typically be a linear composition of several contributions: 1. The tidal current, which is vertically indifferent, is a regular feature with a period of slightly more than 12 hours. Maximum flow, in either direction, happens 3 hours before or after high or low water. In Sognefjorden the current speed is typically 0.1-0.2 m/s and in Altafjorden the speed is higher. 2. The freshwater current is confined to a shallow surface layer (1-4m) and most prominent closer to the freshwater sources. The freshwater driven flow usually have speeds of 0.1-0.3 m/s. The rotation of the earth will steer the freshwater driven flow and the brackish surface layers towards the coastlines to the right of the flow direction. Often horizontal surface fronts, visible as streaks of foam etc., will identify the freshwater flow. The maximum flow will be in these fronts (parallel to the front) and water from each side will be transported towards it. 3. The wind driven flow is strongest at the surface and has an exponential reduction towards the interior. The vertical extention of this flow component is typically not more than 10-20m. The rotation of the earth will usually deviate the wind driven flow towards the right of the wind direction. Stratification in the water can influence the vertical structure of the flow. 4. Internal wave flow, typically originating from upwelling or downwelling episodes or tidal flow across sills. These currents can both be strong (0.1-0.5 m/s) and long lasting (~days), and depends on the vertical stratification. They are usually complicated to assess.

A numerical model is ideal for producing currents with high resolution in time and space. However, the possible error sources for model simulations are numerous, and an ongoing validation of the model results is necessary. Usually a comparison between observations (expensive to collect) and the (relatively cheap) model will give an idea of the usefulness of the model results. All the different data collected during the project, although not always presented separately, have been used for model validation and improvement. The present model results compare favorably with observations from the outer part of Sognefjorden giving confidence that these results can be used for a description of the current system in the fjord (Figure 29).

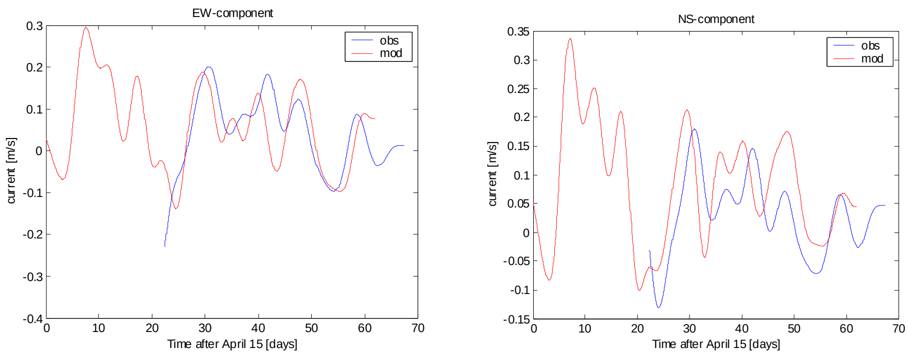

Figure 29 Time series of east-west and north-south current components, 5 days low-pass filtered, at 10 m depth from the current meter position in the sill area of Sognefjorden (red circle I in Figure 1) for the model (red line) and the Aanderaa RCM7 current meter (blue line).

Similarly as for the winds, the surface currents (in periods totally dominated by the winds) vary a lot (Figure 30). Maximum speed can exceed 1 m/s, and episodes with strong currents can exist for several days.

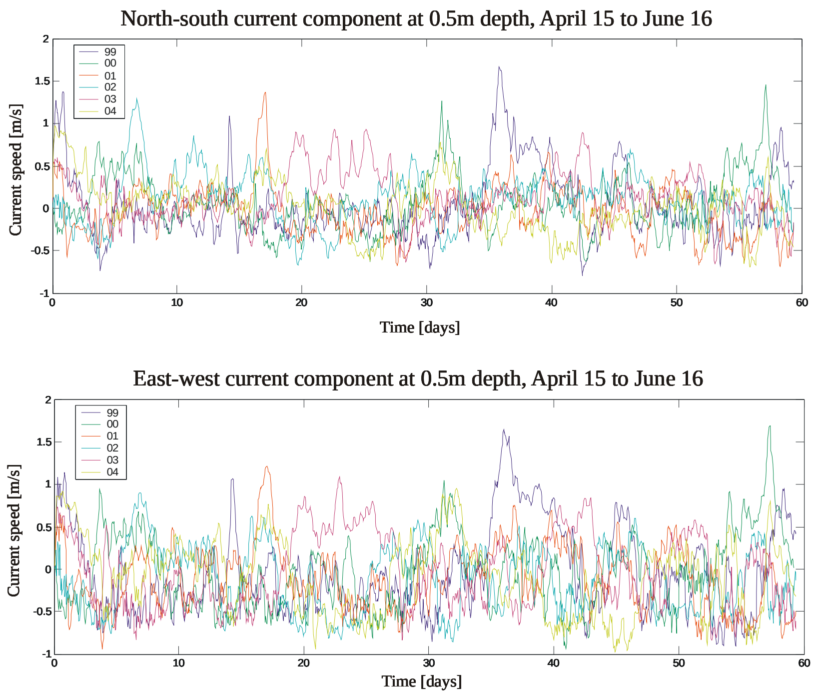

Figure 30 Hourly values of north-south and east-west current components from the outer part of Sognefjorden (red circle I from Figure 1) at 0.5 m depth from the fjord model results.

It is quite complicated to estimate the differences between years from these records, although differences are obvious. The mean currents for the period, though, illustrate differences better. At the position in the outer part of Sognefjorden (red circle I from Figure 1), all currents from April 15 to June 16 is directed towards west-north west (Figure 31). The strongest current is for 2002, and the mean current for 2001 differs from the other years by having a south-westerly direction.

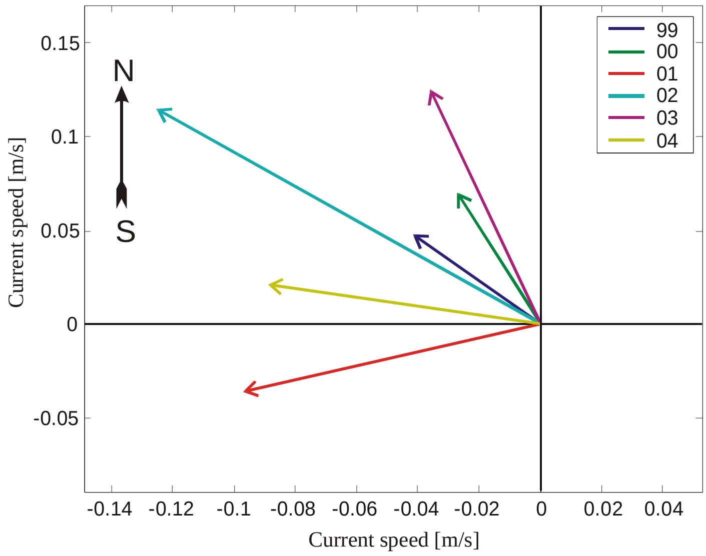

Figure 31 Mean current vectors from the fjord model results for the period April 15 to June 16 at a position representing the outer part of Sognefjorden.

5.9 Particle advection

The purpose of the present investigation is to find the distribution patterns of pelagic salmon lice. Driven by the modelled currents, the advection of particles will illustrate variability in both time and space, on short scale as well as inter-annualy. Thus, it will give a more intuitive and quantitative visualization of the current conditions.

A series of different simulations were run in order to assess different hydrography-sea lice scenarios. Only a limited situations are reported here for demonstrating the potential outcome of the simulations. Two particle advection simulations were performed for each of the years 1999-2004 in Sognefjorden, where the difference between the two were the release positions only (marked in Figure 1 with red circles I and II). Two particles were released every hour at 1 m depth from May 1 and this went on for 40 days. The distribution at May 25 for the simulation with release in the outer fjord show significant differences between the years (Figure 32), where the particles released in the 2001 and 2004 current fields have a distribution more into the fjord.

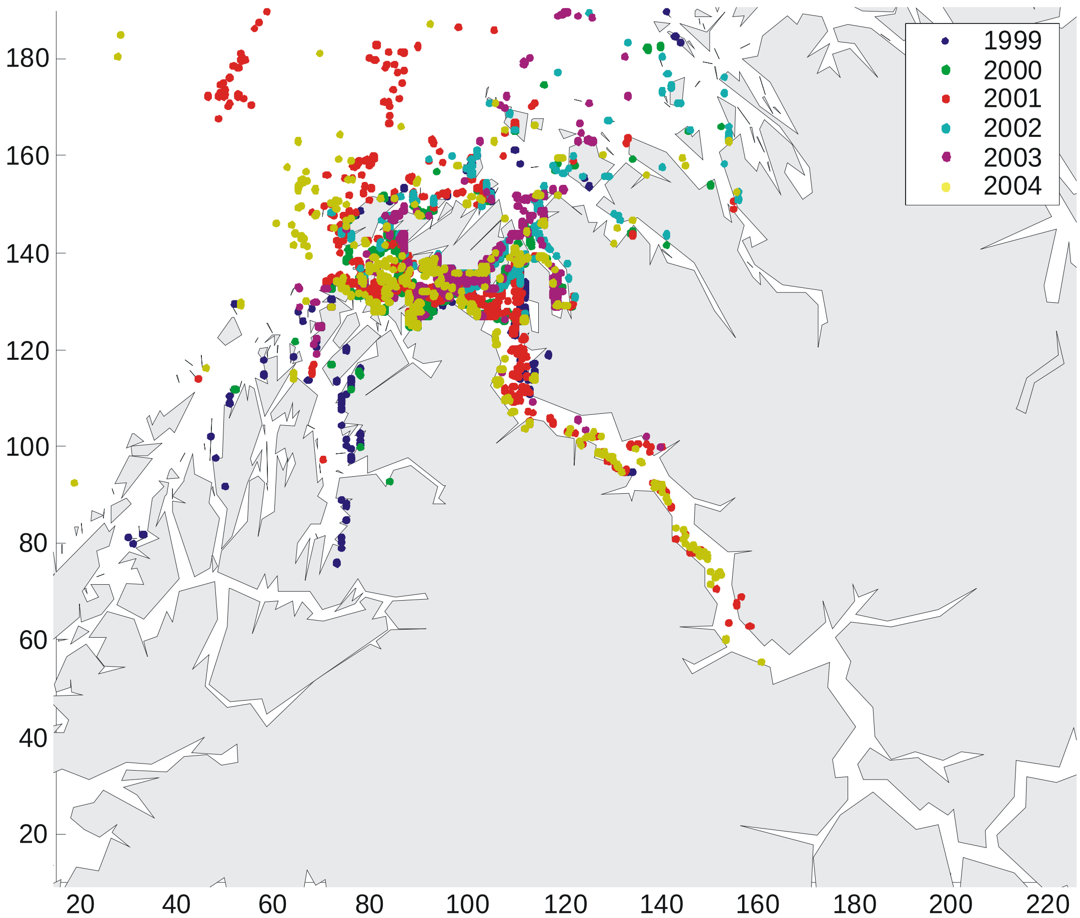

Figure 32 Particle distribution at May 25 for the simulation with the particle release in the outer fjord (I).

To illustrate this more quantitatively, the number of particles being infectious and in the upper 2 m of the water column were summarized within the three regions given in Figure 32a.

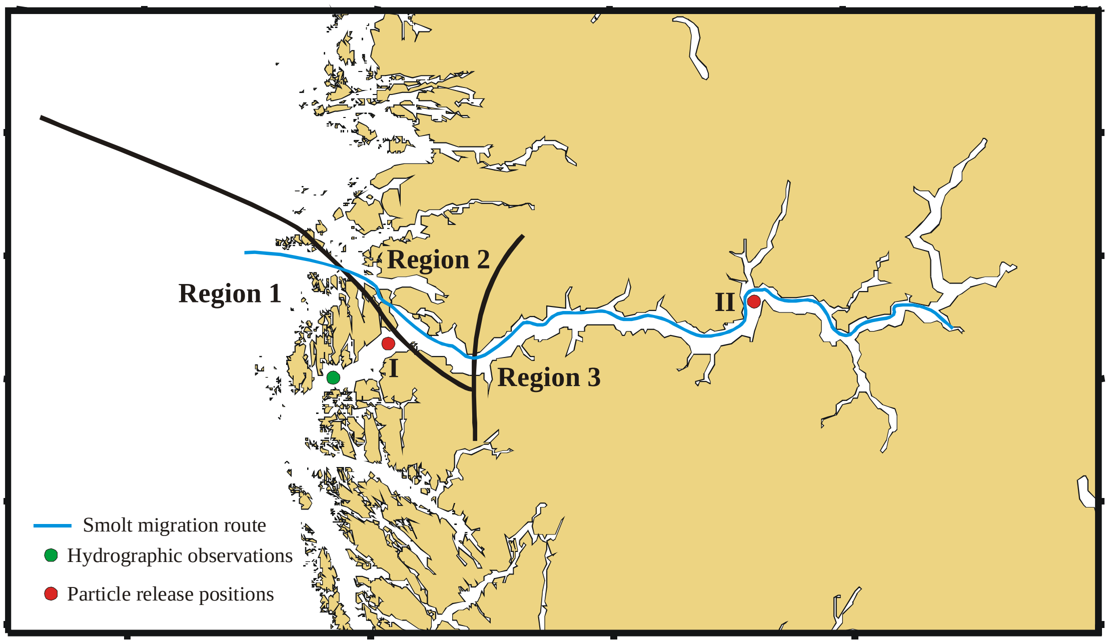

Figure 32a. Regions defined for the Sognefjord.

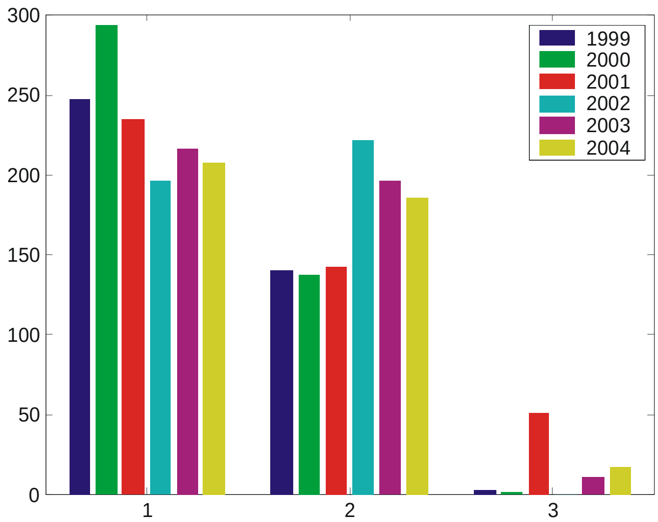

Figure 33 Mean number of particles in the three regions for the simulation with release position in the outer fjord (I).

The mean number of particles within each region for the simulation show that in Region 1 there were small differences between the years (Figure 33). In Region 2, there is a tendency that particles from the years 2002-2004 aggregate. The most pronounced result, however, is the clear tendency for an inward drift (Region 3) of particles in 2001 compared to the other years. An illustration of the time evolution of this accumulation, show the massive excess in 2001 of particles in Region 3 compared to the other years (Figure 34). The short time variations in the number of particles are due to the tidal current pushing particles back and forth across the region border.

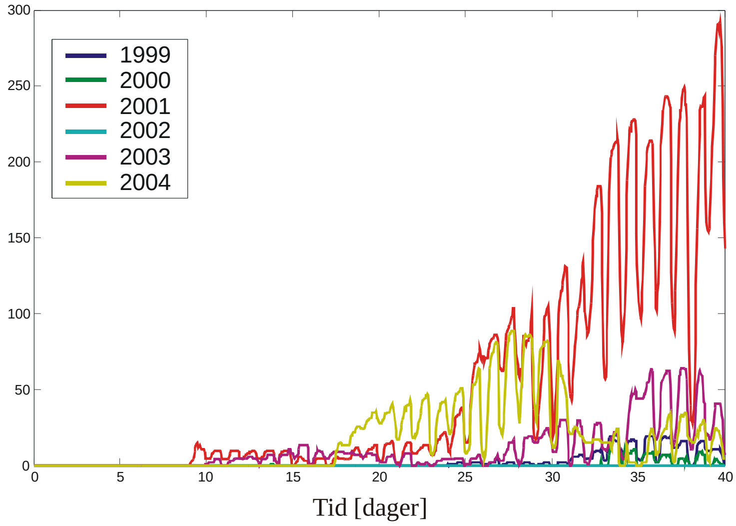

Figure 34 Time series of the number of particles inside Region 3 during the simulation with release position in the outer fjord (I).

For the simulation with particle release in the inner part of the fjord, the same tendency of an inward drift of particles in 2001 and 2004 occur. At May 25, also particles released in 2002 can be seen to be distributed far out in the fjord (Figure 35). Also noticeable is the distribution along different fjord sides between years, most likely due to the differences in the winds between the years (however, the horizontal resolution of the fjord model is not fine enough, and together with the limited details of the model forcing, these results will have uncertainties on the order of km).

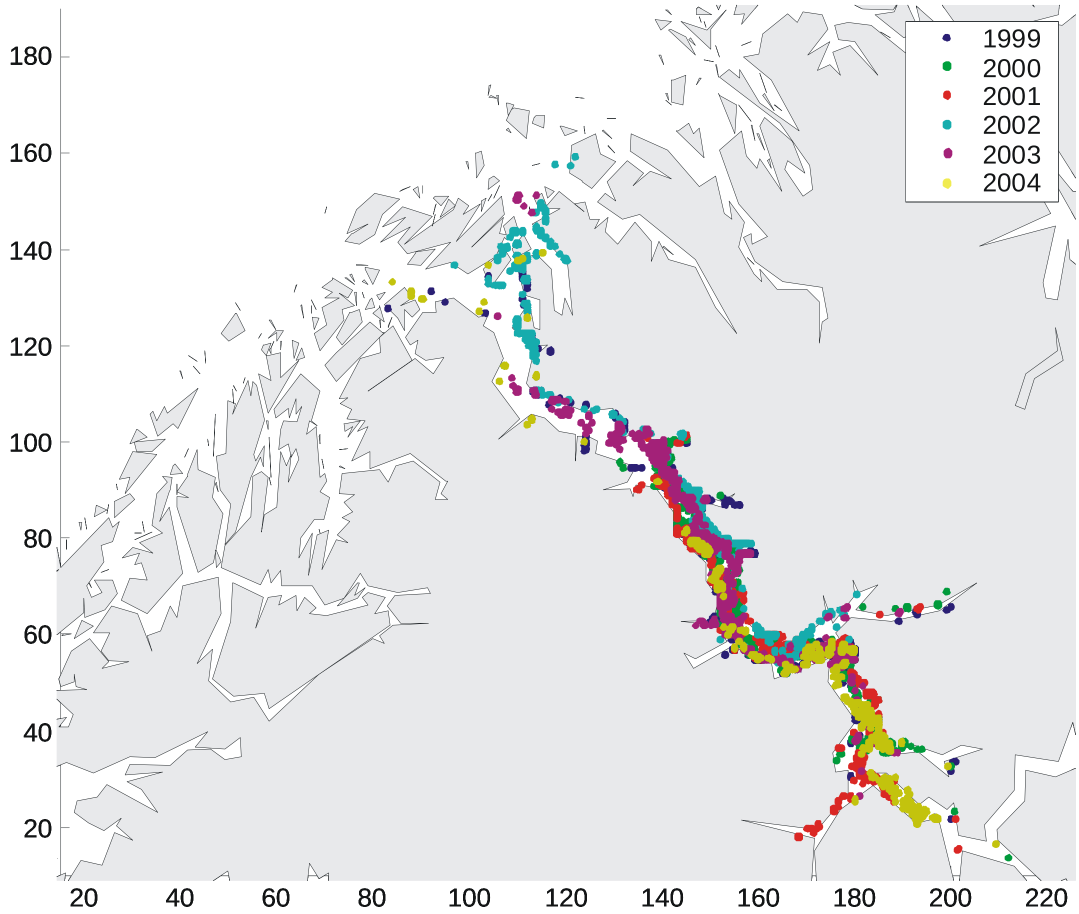

Figure 35 Particle distribution at May 25 for the simulation with the particle release in the inner fjord (II).

The mean number of particles within the three regions for the simulation with particle release in the inner part of the fjord show of course that most particles remain in region 3 most of the time (Figure 17). However, the distribution in 2002 stand out with more particles towards the fjord mouth (Region 2).

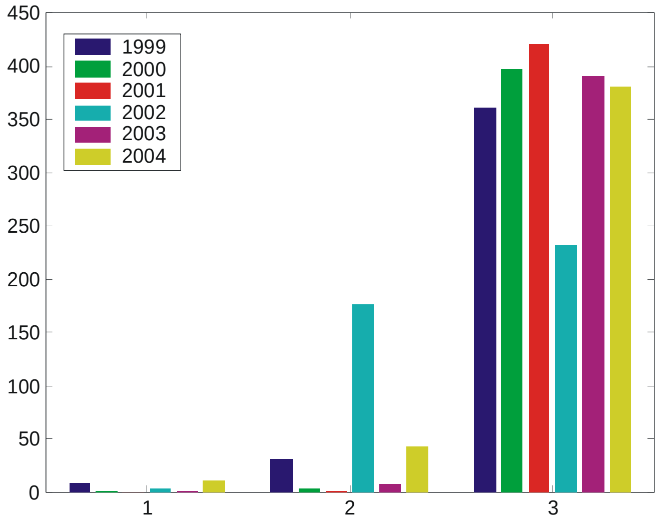

Figure 36 17Mean number of particles in the three regions for the simulation with release position in the inner fjord (II).

Finally, to try a more sophisticated sampling of the “model salmon lice”-distribution within Sognefjorden, a “model smolt” is allowed to migrate through the particle fields and encounters between this smolt and a particle is recorded. The smolt has a simplified behavior, with swimming speed of 20 km/day and a fixed swimming route (obviously a more advanced model for smolt swimming should be developed, but that will in turn require an even better model for particle distribution). The migration starts in the inner part of the fjord and ends at the coastal ocean. The smolt basically follows the northern fjord side, and exits the fjord through the narrow sound Loksundet (following roughly the border between Region 1 and 2, Figure 32a).

With the relatively low precision level of the numerical model currents, and with the uncertainty of how a real encounter between a smolt and a salmon louse actually occur, a “hit” between a louse and the smolt is recorded if the louse appear within 3 grid nodes (~2km) on each side of the smolt in both x and y directions of the grid. This represents a major uncertainty of such models, but can probably be used for a crude comparison between the years. It is also illustrative with respect to show how the conditions changes on shorter time scales within the period May 1 to June 10. For the six simulations performed, with a 10 day swim of the smolt starting at May 5 to May 30, there were significant differences. For the simulation with particle release in the outer fjord, the number of smolt-salmon lice encounters were highest for the years 2003 and 2004 (Figure 37). In 2001 the number of encounters at the end of the period (after May 20) were twice as many as in 1999, 2000 and 2002.

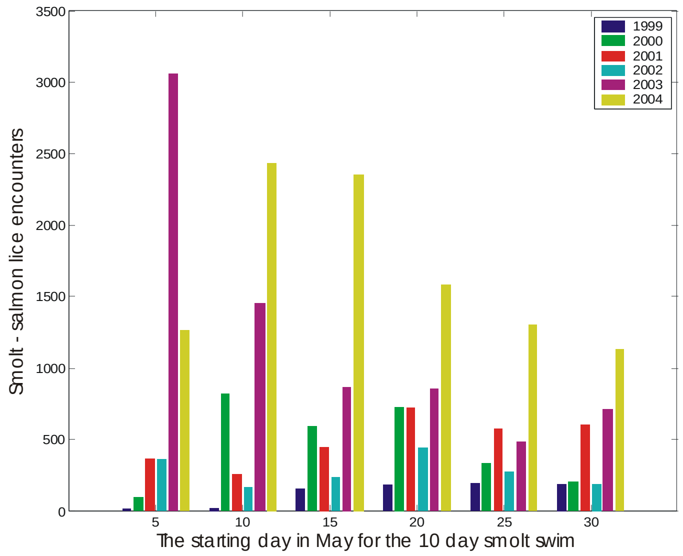

Figure 37 Number of smolt-salmon lice encounters for each of the 10 days smolt migration experiments with start every 5th day from May 5 and with salmon lice release in the outer fjord.

When the particle release is in the inner part of the fjord (Figure 38), the number of smolt-salmon lice encounters is 2-3 times higher than for particle release in the outer part of the fjord. Variations both between years and within the year can be large.

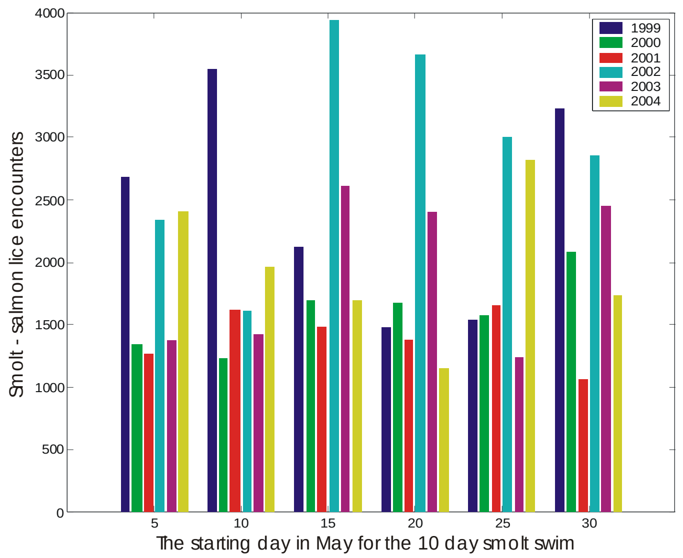

Figure 38 Number of smolt-salmon lice encounters for each of the 10 days smolt migration experiments with start every 5th day from May 5 and with salmon lice release in the inner fjord.

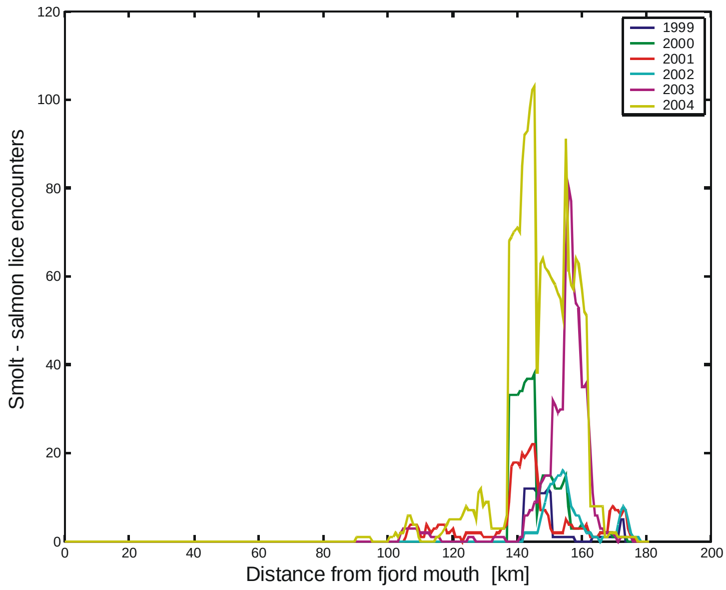

Figure 39 Number of smolt-salmon lice encounters along the smolt migration route with particle release in the outer fjord and for the smolt starting its swim at May 15.

To look more in detail where the encounters takes place for the particle releases in the outer fjord, we find that the area prior to the narrow sound Loksundet (140-160km) is critical (Figure 39), and the results for the smolt starting its swim at May 15 are used as example although similar pictures could be presented for the other starting dates.

With the particle release in the inner fjord, the encounters along the migration route are not as localized (Figure 40) and the differences between the years are larger.

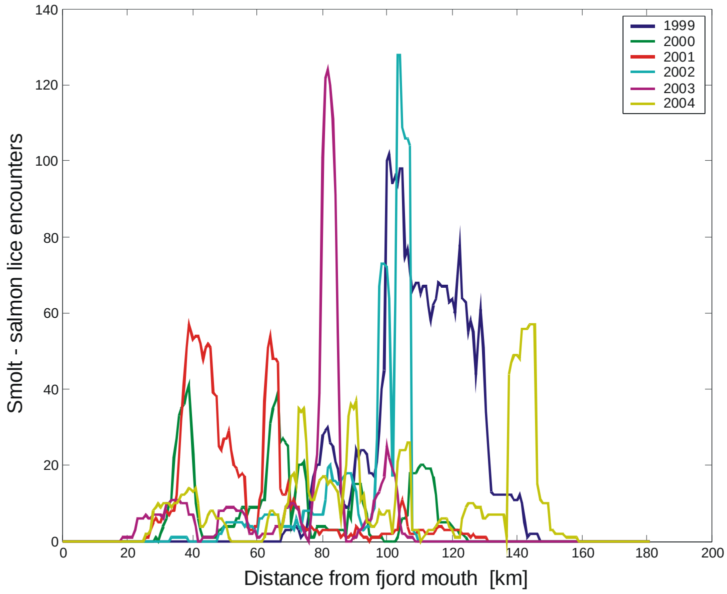

Figure 40 Number of smolt-salmon lice encounters along the smolt migration route with particle release in the inner fjord and for the smolt starting its swim at May 15.

To illustrate the potential spreading of salmon lice in Altafjorden, results of advection of tracers from a numerical simulation of July 10-17, 2004 were used (Figure 41). Two release positions with a continuous saturation of the tracers were used (red arrows) and the situations after 4, 6 and 8 days at the surface are shown. Without making any detailed analysis of these results, it can be concluded that rapid distribution can occur (as well as periods with less spreading as until day 4 when the dominating winds were northerly, i.e. from right to left on the figures). Similarly as for Sognefjorden, and probably in a even higher degree, the wind has a dominating effect on the variability of the upper layer flow.

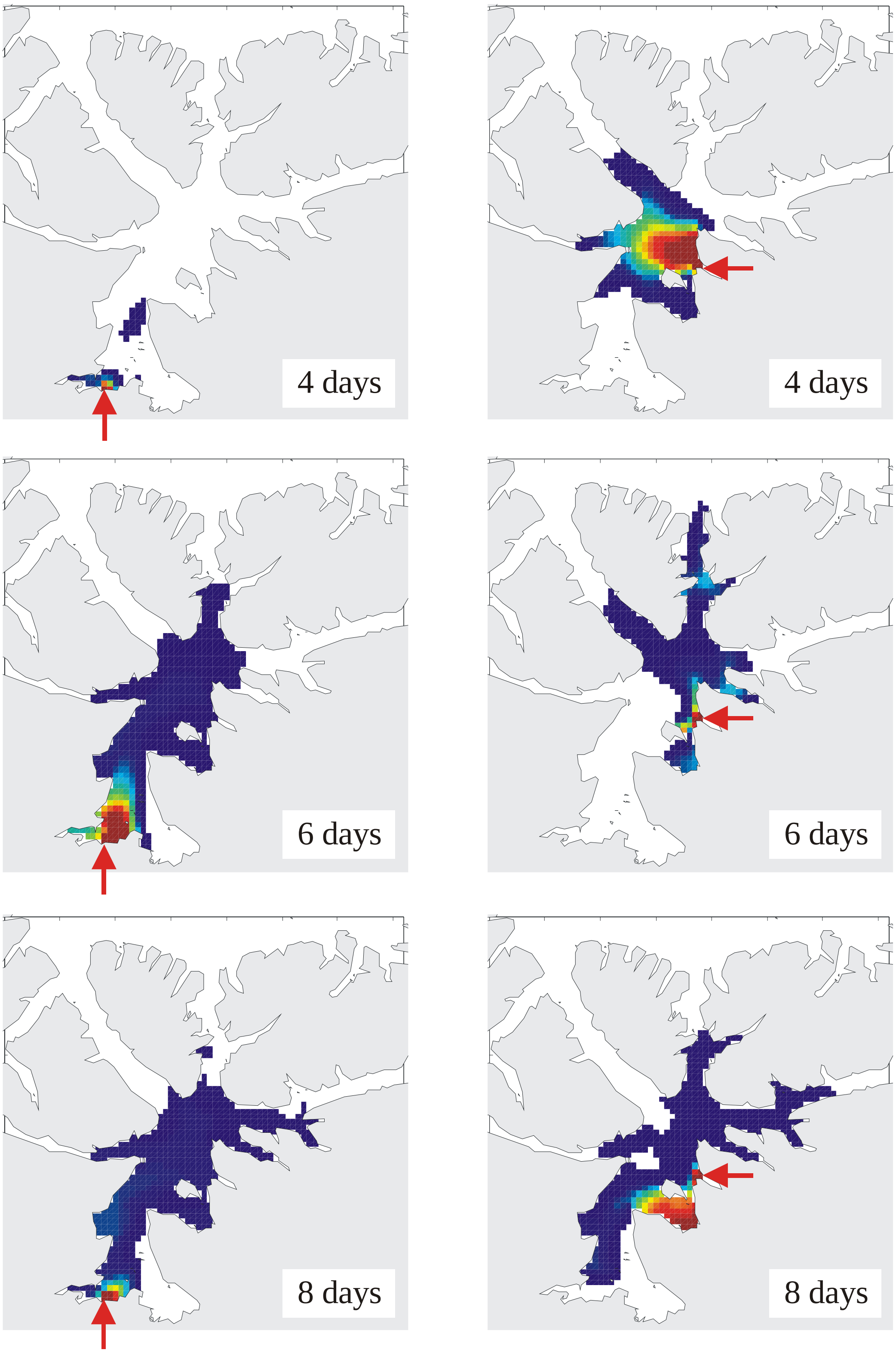

Figure 41 Distribution of tracer water masses in the surface layer of Altafjorden from two sources (marked by red arrows) after 4, 6 and 8 days using numerically simulated currents. Red color is > 50% saturation and dark blue < 1 % saturation. White areas are waters without the tracer completely.

5.10 Hydrographic classification

In 1999, 2000 and 2002, the physical oceanographical conditions in the inner part of Sognefjorden were favorable for the salmon and the sea trout regarding salmon lice since

1. the salinity of the upper layer water mass were low
2. the currents in May-June transported salmon lice out the fjord

In 2001, 2003 and 2004, the physical oceanographical conditions were opposite those above, and the conditions in the inner part of Sognefjorden were unfavourable for the salmon and sea trout (Table 8).

In the outer part of Sognefjorden, the physical oceanographical conditions between the years regarding the salinity of the water masses were as described above. However, the currents will not significantly transport salmon lice away in any of the years, and the conditions for salmon and sea trout is indifferent regarding advective transport (Table 9).

Table 8. Physical oceanographical conditions for salmon and sea trout versus salmon lice in the inner part of Sognefjorden (Region 3)

	1999	2000	2001	2002	2003	2004
hydrography	good	good	very bad	very good	bad	bad
currents	very good	very good	very bad	very good	bad	bad

Table 9.Physical oceanographical conditions for salmon and sea trout versus salmon lice in the outer part of Sognefjorden (Region 1&2)

	1999	2000	2001	2002	2003	2004
hydrography	good	good	very bad	very good	bad	bad
currents	bad	bad	bad	bad	bad	bad

5.11 Concluding remarks modeling section

The numerical model results give a good description of the currents in the wind driven upper layers of the fjord. This can be utilized to study distribution of salmon lice, as these usually are confined in these upper water masses. The numerical model reproduces the hydrography of the fjord in a less good way, mainly due to insufficient forcing. The model lacks a direct radiation model for warming of the water, which can account for the reduced temperature increase in the model results compared with observations. Furthermore, despite having all available runoff data from the NVE as well as precipitation data from met.no, the model does not reproduce sufficiently the observed salinity changes in the outer fjord system. This can mean two things: 1. More freshwater sources are necessary or more likely 2. The contribution from the hydroelectric power plants are vital for the salinity of the fjord. Especially in the spring of 2002 (preceeding the “power crisis” in the fall of 2002 - winter of 2003) the extremely high amount of freshwater observed in the outer part of Sognefjorden can possibly be explained by an exessive runoff from the power plants during April-June. In the model, the runoff from these plants are estimated based on nearby natural rivers and the actual precipitation, and the efforts to establish contact with the hydro electrical companies operating in this region have been in vain.

One motivation for using the numerical fjord model was to investigate if these results could be used for questions regarding localization of fish farms etc. The present grid size (800 m) will probably be too coarse to be necessarily detailed (the accuracy will be 2-3km). It is possible to refine the gridsize and run sub-models within the fjord model. However, the demands of the forcing of such a model will increase. Especially the resolution of the prescribed wind fields will be a challenge. Furthermore, detailed topography needs to be achieved. More details in the model also needs more details in the initial fields of salinity and temperature. All in all, it is possible to produce numerical simulations with higher spatial resolution, and the present day computer speed makes it possible to run a sufficiently sized model domain with ~100m grid size, but this is not a trivial task and the compilation of the nescessary forcing fields (in order to make a non-trivial exercise) will be demanding as well as the necessary man power needed exceeds what was available for the present project.

6 Discussion

6.1 North-south gradient in sea lice infection.

With one exception sea lice infections in the different groups of salmonids studied appears to be at lower levels in the northern areas investigated as compared to the southern ones. The infections and infection pressure are lower in the northern farms, the infection level is lower in northern seaward migrating postsmolt of salmon and it is lower in northern stationary sea trout. Only in riverward migrating adult salmon the difference is small between the northern and southern area. One possible explanation for this could be the fact that much of these infections originate from high seas infections and have generally not been obtained in the fjords. The conditions for high seas infections may be more comparable for northern and southern stocks as they are known to winter in common areas with presumably more comparable infection regimes. There may also be density dependent infection mechanisms regulating these high seas infections processes, leading to less variance in such infection.

According to the farmers from the Alta area the sea lice newer was a major problem in the fish farms in the area and they had always experienced low infection levels. For 2003 and 2004 the counting data from farms collected by the project confirm very low infection levels in the farms in the Alta area. While the farms in the Sognefjord area had infection levels close to the limit set in the Veterinary act of 1997 the levels in the Alta area were far below in both years. The implementation of the veterinary act of 1997 probably had a higher effect in the southern areas as the initial levels of sea lice were further away from the allowed levels here than in the northern areas. The lower sea temperatures in the northern areas are a negative factor for sea lice population growth and probably an important factor in explaining the general differences observed between the northern and southern area.

6.2 Sea lice infections in seaward migrating postsmolts of salmon

In the period up to 2001, characterised by serious sea lice infections in postsmolt of southern Norwegian salmon stocks, none of the northern stocks studies appears to have experienced these problems.

While sea lice never seems to have been a major problem for postsmolts of salmon in northern stocks it was probably an important population regulating factor in many southern Norwegian stocks during the latter part of the 1990ies and up to 2001. The situation for the postsmolts of salmon improved strongly from 2002 in the Sognefjord when the observed infection levels dropped dramatically. These results are further confirmed by other times series not included in this study, but to be included in publications. We can so far only explain this improvement by changes in farming practices since the hydrographic conditions have been both negative and beneficial for sea lice infections during the period 2002-2004. The stocks of wild fish have improved during this period which would lead to an expected higher contribution from this group. Potential changes in farming practices can be lowered total standing fish stocks in farms and/or lowered mean lice infections in farms. Our data are not at a satisfactory detailed level to assess this but lowered mean lice infections in farms seems the stronger candidate in most cases.

While infection pressure for wild postsmolts of salmon and sea trout appeared to be high already during early May in the first half of the studied period it now appears to increase first in late May during the last years. With a lower initial sea lice population in the fjords in spring the sea lice population growth has been delayed. This change may partly explain the improvement in conditions for southern postsmolts of salmon which in general runs during May. Given the lowered levels of sea lice in the pens the maximum infection level during summer is also expected to be of lower intensity (ie lower larvae concentration in the free water masses).

6.3 Sea lice infections in stationary sea trout stocks

The situation for sea trout is less encouraging than that of salmon. While the young salmon is a highly migratory species which leaves the fjord relatively quickly, the sea trout is a resident species which has its main habitat in the major infection zone of fish farms during the summer. Various studies have described an improvement in the conditions for western Norwegian sea trout stocks since 1997, which was the year of most extreme infections in sea trout. In the northern areas the infections appears to be at lower levels than in the southern ones, but the positive trend has not been observed in the northern areas.

Given the good conditions for wild salmon in many fjords today, the main potential for improved habitat is for the sea trout stocks. We recommend strongly to evaluate whether the limit for sea lice in farmed fishes in summer should be lowered to the same level as during spring. This is probably not far off with current practice in many farms. The farmers and their organisations could consider implementing this as a voluntary act. Such a step would benefit the wild sea trout stocks, it would also probably benefit the farmers in terms of increased growth and better disease control in their own fish and could be used in positive image building towards the public.

7 Management advice

- Conditions are generally good for seaward migrating postsmolts of salmon under the current sea lice regime in Norway. A continuation of this situation requires that the total sea lice production potential within any area not to be significantly increased without prior assessment of consequences.

- There are negative population effects of sea lice in wild sea trout populations in Norway. These problems have in general been larger in southern Norway than in northern Norway. In particular in the southern area there has been an improvement in conditions for sea trout in parallel with the general decrease in sea lice output from salmon farms.

- In particular for the sake of sea trout it is recommended to consider reducing the allowed level of sea lice in farms in summer (2 adult females) down to that allowed in spring (0.5 adult females) according to the veterinary act of 1997.

- Given the production of farmed fish is planned to increase significantly in any area, investigations should be initiated to assess the effect of the increased production to the sea lice situation in the area.

- It is recommended that quality controlled counting of sea lice levels in farms be carried out twice during spring. Although most farms keep to the limits set by the veterinary act some few farms were observed to break the rules more than tenfold, seriously reducing the effect of the work carried out by the other farms.