Extracts from "Fisken og havet, særnummer 3-2010"
printed August 2011

Risk assessment –

environmental impacts of Norwegian aquaculture

INSTITUTE OF MARINE RESEARCH
HAVFORSKNINGSINSTITUTTET

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Risk assessment – environmental impacts of Norwegian aquaculture

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Preface

The current report presents translated extracts from ”Fisken og havet, særnummer 3-2010” that was published in Norwegian by the Institute of Marine Research, Norway, in January 2011. The current translation contains the Summary, and Chapters 1, 2, 3, 5 and 6 of the original publication. The original Norwegian version “Risikovurdering – miljøvirkninger av norsk fiskeoppdrett” and the current report are available at www.imr.no.

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Summary

The Institute of Marine Research has conducted an initial risk assessment of the environmental effects of Norwegian Aquaculture for the Ministry of Fisheries and Coastal Affairs. The assessment builds on goals specified in the Ministry's "Strategy for an Environmentally Sustainable Norwegian Aquaculture Industry" from 2009. We have focused on the environmental goals for disease dispersal, genetic impact of escapees and the release of nutrient salts, organic waste and drugs.

Infection pressure from salmon lice and genetic impact of escapees came out as the most problematic factors in this analysis. We consider that there is a moderate to high probability for these effects to be in conflict with the goals specified in the sustainability strategy along large parts of the Norwegian coast. This builds on proposed threshold values for effect indicators described in this report. The development of resistance towards several drugs used against salmon lice may exacerbate the situation.

We do not have enough data on disease dispersal from fish farming to wild fish of other pathogens than salmon lice to do a regionalized analysis. However, several other pathogens are recognized as potential threats against the wild stocks.

There is low probability of negative effects of nutrient salts and organic load on a regional scale. The legislated monitoring programme on the local impact of organic load shows an overall good situation. Drugs used against salmon lice can potentially be environmentally problematic, but we lack the data for a precise assessment.

There seems to be a connection between the scale of salmon farming within a county and the probability of unwanted environmental effects in the same area. Given the biological, operational and technological limitations of salmon farming today, we assess that a further increase in biomass in the counties from Rogaland to Troms can exacerbate the situation in terms of negative environmental impact.

On the basis of this initial risk assessment, we have identified a need for a strengthening of the monitoring and research, especially on impact of salmon lice on wild stocks, dispersal of other pathogens and the genetic impact of escapees. It is essential to get a better scientific basis for the suggested thresholds for the environmental effect indicators used in this analysis. It is also important to improve the geographical coverage in the national monitoring programmes. There are also knowledge gaps on potential environmental effects of drugs, local effects of nutrient salts and the impact of organic waste on hard bottoms.

Chapter 1

Introduction

Photo: Kjartan Mæstad

Mandate from the Ministry of Fisheries and Coastal Affairs

The governmental letter from the Ministry of Fisheries and Coastal Affairs to the Institute of Marine Research (IMR) in 2009 states: "It is important for the regulators of the aquaculture industry to take a risk-based approach to their regulatory activities. The priority for IMR is to evaluate risk factors in the Norwegian aquaculture industry, in order to enable the Directorate of Fisheries and Norwegian Food Safety Authority to take a risk-based approach to their tasks". A similar wording was repeated in 2010.

We have limited the scope of the risk assessment to negative environmental impacts of fish farming, and have focussed on issues where the authorities are in need of advice, such as infectious pressure on wild fish stocks, genetic impact on wild populations, eutrophication and organic load, as well as the use and release of drugs to combat diseases and parasites. This is based on prioritised areas as stated in the "Strategy for an environmentally sustainable Norwegian aquaculture industry" published by the Norwegian Ministry of Fisheries and Coastal Affairs in 2009. The strategy sets out five main goals (Table 1.1), of which the the first three are dealt with in this report.

Area use and site selection (Goal 4) in the Norwegian aquaculture industry have been addressed by another committee (the "Gullestad committee") – and is therefore not covered in the present report. Feed and feed resources (Goal 5) is also not covered in the current report, but will be considered in the proposed annual audits of the risk assessment. At this stage we have also refrained from assessing various measures to reduce risk, but we consider this to be an important area for future risk assessments. Animal welfare is a topic that also will be considered to be covered by later versions of this risk assessment.

Table 1.1

Goals specified in the Ministry of Fisheries and Coastal Affairs' report "Strategy for an environmentally sustainable Norwegian Aquaculture Industry" from 2009.

Goal 1: Disease	Disease in fish farming will not have a regulating effect on stocks of wild fish, and as many farmed fish as possible will grow to slaughter age with minimal use of medicines.
Goal 2: Genetic interaction	Aquaculture will not contribute to permanent changes in the genetic characteristics of wild fish stocks.
Goal 3: Pollution and discharge	All fish farming locations in use will maintain an acceptable environmental state, and will not have higher emissions of nutrient salts and organic materials than the receiving waters can tolerate.
Goal 4: Zoning	The aquaculture industry will have a location structure and zoning which reduces impact on the environment and the risk of infection.
Goal 5: Feed and feed resources	The aquaculture industry's needs for raw materials for feed will be met without over-exploitation of wild marine resources.

Chapter 2

Methods for risk assessment

2.1 ABOUT RISK ASSESSMENT

Risk is usually defined as the product of the probability of something happening and its impact (consequence). A risk analysis is an analysis of both of these components, and is therefore more than just an impact assessment. Several conditions must be in place in order to perform a comprehensive risk analysis. First, the potential impacts must be identified; second, it must be possible to measure or estimate the severeness of the impacts; and third, it must be possible to quantify the probability of an event and its impacts, preferably in such a way that one can compare different risks in order to determine where it is most important to take mitigating action. A risk analysis looks at things that may happen in the future, and the decisions you take on the basis of your analysis depend on your goals.

Risk analyses are normally carried out as part of a larger process in which you start by identifying risks, and continue with a preliminary risk analysis, before finally working with key stakeholders on a more detailed risk analysis. In this process it will also be necessary to define what you consider to be an acceptable level of risk.

A comparison between a risk analysis and the acceptable risk is called a risk assessment. This is what provides the basis for risk management. We envisage establishing an initial risk management system, and then regularly updating and improving it in order to achieve the overall goals.

It is important to bear in mind that risk assessment and management is a multi-stage process, and for risk management to be successful, several of those stages must be in place. You must start by having or defining overall goals, which then need to be operationalized. This involves evaluating the most pressing threats, carrying out a risk analysis, implementing any necessary risk-reduction measures, monitoring the current status and the impact of regulatory requirements, and finally monitoring and enforcing compliance with regulatory standards.

Lack of quantification in the risk analysis can be solved by introducing categories, or if an impact cannot be measured directly, it can be measured through a proxy indicator. If there is a great deal of uncertainty on the probabilities and impacts, you need to consider whether it is appropriate to carry out a full risk analysis.

One alternative to a risk analysis is a current status analysis, which in reality involves studying the impacts retrospectively, as opposed to a risk analysis, which looks at the probabilities in advance. The difference between them is that a risk analysis allows you to implement measures in order to prevent an impact, whereas a current status analysis only enables you to implement measures after an impact (or one level of an impact) has occurred. A current status analysis can provide the basis for a subsequent and more comprehensive risk analysis.

2.2 RISK ASSESSMENT APPROACHES IN THIS REPORT

2.2.1 Topics included

Below we have reviewed the relevant risk factors, and have carried out a preliminary assessment of the current status of the Norwegian aquaculture industry, and of the risks that it faces. We started by considering five potential problem areas: 1) ecological impacts of the Norwegian aquaculture industry on ecosystems; 2) environmental impacts on the aquaculture industry that affect the health and welfare of farmed organisms; 3) food safety (the quality of the farmed organisms) and unwanted impacts on consumers; 4) potential HSE (health, security and environment) impacts on the people working at, and around, fish farms; and 5) social and economic impacts on the wider society. However, the current report is limited to risks relating to negative environmental impacts of fish farming. In other words, we have looked at neither profitability, nor risks that only affect the fish farmer, nor any benefits of fish farming (for example, economic benefits).

2.2.2 Implementing consensus and quality control

We have drawn on the expertise of leading researchers on each topic and sub-topic when establishing current knowledge, preparing the current status evaluation and finally carrying out the risk assessment. Moreover, the leaders of the relevant research groups have been responsible for ensuring a transparent process in which various people have been involved in reviewing and quality assuring the work done. Hege Iren Svensen has produced the graphical material.

2.2.3 Defining the problem and scientific implementation

Based on a preliminary analysis of current knowledge, on the uncertainty levels associated with the indicators and on the general lack of quantifiable probabilities and impacts, we have chosen to carry out a qualitative evaluation of what we consider as the most important risk. The risk assessment is based on the environmental goals defined in the sustainability strategy, as well as proposed threshold values for the effect indicators for each individual environmental threat (see Chapter 5).

Based on current knowledge about each topic, as well as the regional situation, we have performed a risk assessment on negative environmental impacts of salmon farming, broken down by county, from Rogaland in the south to Finnmark in the north. This is based on data from recent years, with main emphasis on 2009–2010. Based on the selected environmental effect indicators and the proposed threshold values, we have qualitatively assessed the likelihood that the situation is in conflict with the environmental goals set out in the sustainability strategy, assigning one of three probabilities for each county: low (green), moderate (yellow) and high (red).

The degree to which the risk assessment can be broken down by geographic areas varies from topic to topic, but we do have monitoring data for some of the environmental threats such as sea lice, escaped salmon and impact of nutrient and organic load on local and regional scale . We have therefore chosen to define the risk level by county, but for some counties we have also broken it down into smaller areas. For some of the topics and risk factors we have only done a case study; this applies to cod, for example.

We propose this report as being the first step in a process to further develop risk assessment and risk management practices in co-operation with the key stakeholders.

Chapter 3

Current status of fish farming in Norway

The Norwegian aquaculture industry predominantly produces Atlantic salmon, with over 233 million salmon smolts put into sea cages in 2009, and total biomass reaching over 610,000 tonnes in October and November 2009. A significant amount of rainbow trout is also produced, with 17 million trout put into sea cages in 2009, and total biomass peaking at almost 40,000 tonnes. In addition, cod farming has seen significant growth over the past ten years, with 10 million cod put into sea cages in 2009. Up to 606 cage sites were used for salmon and rainbow trout farming in 2009, at which time there were 207 sites available for cod farming. Salmon, rainbow trout and cod are mainly farmed from Rogaland in the south to Finnmark in the north, but there are also some salmon farms in the Agder county. The number of salmon and rainbow trout in the sea varies over the course of the year, in response to when they are set into sea cages and subsequently harvested. For Norway as a whole the maximum number of individuals and the highest biomass is normally reached during the period October to December.

Table 3.1
Number (in 1000), weight (kg) and biomass (metric tonnes) of salmon (A) and rainbow trout (B) per county in the end of December 2009 distributed over several transfer points to sea. Source: Directorate of Fisheries.

A. Salmon	Earlier transfer		2008 transfer		2009 transfer		Total	
County	Number	Av. weight	Number	Av. weight	Number	Av. weight	Number	Biomass
Finnmark	96	5.63	8 249	3.78	11 414	0.89	19 759	41 831
Troms	0	6.55	9 980	3.54	24 007	0.95	33 987	58 014
Nordland	0	-	17 289	4.17	37 346	1.11	54 634	113 339
Nord-Trøndelag	272	3.65	9 063	3.97	12 498	0.99	21 833	49 416
Sør-Trøndelag	0	-	8 610	4.89	31 366	0.86	39 975	69 010
Møre og Romsdal	0	-	10 969	3.85	24 581	1.01	35 550	67 154
Sogn og Fjordane	0	-	7 905	3.93	18 416	1.13	26 322	51 795
Hordaland	0	-	15 097	3.83	34 959	1.12	50 056	97 008
Rogaland and Agder	2	10.39	11 124	3.88	18 945	0.84	30 071	59 153
Total	**370**	**4.20**	**98 285**	**3.98**	**213 532**	**1.00**	**312 187**	**606 720**

B. Rainbow trout	Earlier transfer		2008 transfer		2009 transfer		Total	
County	Number	Av. weight	Number	Av. weight	Number	Av. weight	Number	Biomass
Finnmark	688	3.90	1 352	2.75	0	-	2 039	6 398
Troms	0	-	413	3.50	402	1.59	815	2 085
Nordland	0	-	117	3.61	544	-	661	422
Nord-Trøndelag	0	-	0	0	0	-	0	0
Sør-Trøndelag	0	-	46	3.48	22	0.60	68	173
Møre og Romsdal	2	10.70	986	2.85	2 381	0.66	3 369	4 398
Sogn og Fjordane	1	5.02	860	3.34	2 584	0.58	3 446	4 376
Hordaland	0	-	1 562	3.76	8 007	1.32	9 569	16 478
Rogaland and Agder	0	-	0	0	4	0.65	4	3
Total	**691**	**3.92**	**5 336**	**3.24**	**13 945**	**1.03**	**19 972**	**34 333**

Table 3.2
Production intensity for salmon for each county in December 2009 in proportion to the sea area as calculated within the coastal straight baseline. Production numbers from the Directorate of Fisheries and the sea area from the Institute of Marine Research.

	Salmon December 2009			Farming intensity	
County	Sea area (km^2)	No of fish (in 1000)	Biomass (metric tonnes)	No of fish/km^2 kg	biomass/km^2
Finnmark	14 604	19 759	41 831	1 353	2 864
Troms	11 354	33 987	58 014	2 993	5 110
Nordland	19 906	54 634	113 339	2 745	5 694
Nord-Trøndelag	4 996	21 833	49 416	4 370	9 891
Sør-Trøndelag	7 262	39 975	69 010	5 505	9 503
Møre og Romsdal	6 271	35 550	67 154	5 669	10 709
Sogn og Fjordane	4 532	26 322	51 795	5 808	11 429
Hordaland	3 959	50 056	97 008	12 644	24 503
Rogaland and Agder	3 526	30 071	59 153	8 528	16 776
Total	**76 410**	**312 187**	**606 720**	**4 086**	**7 940**

Table 3.3
Number of fish sites in use within each county, October 2009. Source: Directorate of Fisheries.

County	October
Finnmark	34
Troms	52
Nordland	113
Nord-Trøndelag	32
Sør-Trøndelag	51
Møre og Romsdal	66
Sogn og Fjordane	59
Hordaland	137
Rogaland and Agder	62
Total	**606**

The density of salmon farms varies from county to county. We have presented data showing the distribution of sites in operation, as well as the number of individuals and the total biomass in the sea cages at the end of the year, and have compared it with the total available sea area by county within Norwegian internal waters. For practical reasons, Rogaland and Vest-Agder are combined in the statistics of the Directorate of Fisheries. Table 3.1 (A: salmon; B: rainbow trout) shows the distribution of salmon and rainbow trout in the sea by county, as well as the total biomass at fish farms at the end of the year. For salmon and rainbow trout, the highest number of individual fish and the largest biomass are in the counties of Nordland and Hordaland, respectively.

If we look more specifically at the density of farmed salmon by county, we can see that the highest density per km^2 within Norwegian internal waters exists in Hordaland, which has over eight times the biomass per km^2 and around ten times as many individuals per km^2 as Finnmark (Table 3.2).

Salmon and rainbow trout are held in around 600 sites along the Norwegian coast. The number of sites in use varies from month to month as smolts are set into the sea cages and fish are harvested from the farms. In 2009 the number of sites in use varied between 509 in February and 606 in October. Table 3.3 shows the breakdown of sites in operation by county in October 2009.

Meanwhile, there were just over 18 million farmed cod in sea cages at the end of 2009, with Nordland being home to the largest number of them.

Table 3.4
Distribution of operative farms and number of cod in sea for each county by end of 2009. Source: Directorate of Fisheries.

	Number of companies and licenses in use		No. of cod to sea during the year (in 1000)	Standing stock of cod by the end of the year (in 1000)		
County	**Company**	**Licenses**	**Number**	**No hatched**	**Wild caught**	**Total**
Finnmark and Troms	8	20	1 154	792	2	794
Nordland	19	88	3 388	7 930	0	7 931
Trøndelag	5	15	1 898	2 634	0	2 634
Møre og Romsdal	5	39	2 715	3 922	0	3 922
Sogn og Fjordane	9	22	1 172	2 285	0	2 285
Hordaland	10	16	29	429	1	430
Rogaland and remaining counties	7	7	156	149	0	149
Total	**63**	**207**	**10 512**	**18 141**	**3**	**18 145**

Chapter 5

Environmental impact and risk assessment

Foto: H. I. Svensen

5.1 DISEASE AND DISPERSAL OF INFECTION

5.1.1 Salmon lice

Photo: J.A. Knutsen

In recent decades, salmon lice have been a major disease problem in the Norwegian salmon farming industry, and can also be a serious problem for wild salmonids. It is highly likely that infective salmon lice at different stages are being transmitted from farmed salmon to salmon in the wild (Heuch and Mo 2001, Heuch et al. 2005, Finstad et al. 2011). High levels of infection can inflict extensive physiological problems on wild salmon (see Wagner et al. 2008) and, in a worst-case scenario, death. We have data indicating that approximately 0.1 lice per gram of fish weight results in physiological problems for wild salmon (Nolan et al. 1999, Wagner et al. 2003, 2004, 2008, Tveiten et al. 2010). This is equal to just a few (2–3) lice on migrating wild salmon smolt, about 10 lice on a 100 gram sea trout and some 70–100 lice on a larger sea trout or Arctic charr. We also know that historical levels of lice, and also the levels in areas where fish farming is not practiced, were often characterised by high prevalence but low intensity. This means that relatively many fish had salmon lice (50–100%), but that the infected fish most often had only a few lice each (under 10) (Schram et al. 1998, Mo and Heuch 1998, Rikardsen 2004, Bjørn et al. 2001a). We therefore assume that a low likelihood of this having an effect sufficient to regulate stocks in relation to the long term targets set out in the strategy for sustainable fish farming (Ministry of Fisheries and Coastal Affairs), can be set at < 10% of stocks within a given area should have > 0.1 lice per gram of fish weight.

Regional production of salmon lice eggs from fish farm facilities along the coast of Norway in 2010

The quantity of salmon lice that wild salmon are exposed to is considered to be correlated to the number of farmed salmon in the sea and the number of mature lice on each farmed salmon (Heuch and Mo 2001). This is because the number of farmed salmon x the number of mature lice x the number of eggs per mature louse gives an estimate of the number of infectious stages that are released into the sea. These infectious stages can be spread by ocean currents and wind (Asplin et al. 2004), and consequently infect both farmed and wild salmon.

A preliminary estimate of the impact of salmon lice in different regions can therefore be calculated by taking the number of farmed salmon and the number of lice eggs produced within each county in the most important months for wild salmonids (Table 5.1.1.1). This is during the April–September period, when the vulnerable wild salmon smolt migrate from the rivers and when the majority of sea trout and Arctic charr make their feeding migration in the fjords and along the coast. The table gives an overview of production in terms of the number of individuals (data provided by the Norwegian Directorate of Fisheries) in each county during these months. If we then collate the average number of mature female lice per farmed salmon (data available at www.lusedata.no) and the number of eggs per mature female lice (data from Heuch and Mo 2001). Using actual lice statistics and

Table 5.1.1.1
Production of salmon lice eggs per county in the period April–September 2010. Number is number of farmed salmon in the sea, salmon lice is the calculated total number adult females and egg is the calculated total number of eggs produced within the county.

	April 2010			May 2010		
County	**Number**	**Salmon lice**	**Egg**	**Number**	**Salmon lice**	**Egg**
Finnmark	17 311 000	0	0	19 904 000	0	0
Troms	30 495 000	1 219 800	609 900 000	37 239 000	744 780	372 390 000
Nordland	49 338 000	5 920 560	5 920 560 000	56 470 000	564 700	564 700 000
Nord-Trøndelag	18 276 000	3 472 440	3 472 440 000	24 018 000	720 540	720 540 000
Sør-Trøndelag	36 400 000	1 820 000	1 820 000 000	44 671 000	1 340 130	1 340 130 000
Møre og Romsdal	33 518 000	4 357 340	4 357 340 000	37 147 000	1 114 410	1 114 410 000
Sogn og Fjordane	25 156 000	1 509 360	1 509 360 000	28 619 000	1 144 760	1 144 760 000
Hordaland	48 059 000	12 975 930	12 975 930 000	54 331 000	5 976 410	5 976 410 000
Rogaland/Agder	25 043 000	751 290	751 290 000	29 291 000	585 820	585 820 000
Totalt	**283 596 000**	**32 026 720**	**31 416 820 000**	**331 690 000**	**12 191 550**	**11 819 160 000**
	June 2010			**July 2010**		
County	**Number**	**Salmon lice**	**Egg**	**Number**	**Salmon lice**	**Egg**
Finnmark	23 584 775	471 696	471 695 500	24 819 949	248 199	248 199 490
Troms	37 781 577	377 816	377 815 770	37 067 471	1 482 699	1 482 698 840
Nordland	58 140 524	2 907 026	2 907 026 200	57 629 648	4 034 075	4 034 075 360
Nord-Trøndelag	22 024 616	2 202 462	2 202 461 600	20 944 879	2 722 834	2 722 834 270
Sør-Trøndelag	43 584 145	4 794 256	4 794 255 950	44 808 800	10 306 024	10 306 024 000
Møre og Romsdal	36 503 477	6 205 591	6 205 591 090	35 719 680	7 501 133	7 501 132 800
Sogn og Fjordane	28 236 722	1 976 571	1 976 570 540	26 581 168	4 784 610	4 784 610 240
Hordaland	48 364 824	12 091 206	12 091 206 000	43 100 366	24 998 212	24 998 212 280
Rogaland/Agder	25 624 997	768 750	768 749 910	25 277 083	4 549 875	4 549 874 940
Total	**323 845 657**	**31 795 373**	**31 795 372 560**	**315 949 044**	**60 627 662**	**60 627 662 220**
	August 2010			**September 2010**		
County	**Number**	**Salmon lice**	**Egg**	**Number**	**Salmon lice**	**Egg**
Finnmark	25 454 682	3 563 655	3 563 655 480	24 545 419	2 699 996	2 699 996 090
Troms	38 948 532	2 336 912	2 336 911 920	37 975 821	5 696 373	5 696 373 150
Nordland	57 299 454	12 605 880	12 605 879 880	61 747 540	14 201 934	14 201 934 200
Nord-Trøndelag	24 512 065	14 462 118	14 462 118 350	27 528 804	16 792 570	16 792 570 440
Sør-Trøndelag	44 989 771	32 842 533	32 842 532 830	45 713 768	42 513 804	42 513 804 240
Møre og Romsdal	35 113 854	14 045 542	14 045 541 600	35 389 480	31 850 532	31 850 532 000
Sogn og Fjordane	24 436 512	11 973 891	11 973 890 880	24 899 299	30 128 152	30 128 151 790
Hordaland	41 823 394	28 021 674	28 021 673 980	46 259 265	43 483 709	43 483 709 100
Rogaland/Agder	25 493 247	6 628 244	6 628 244 220	31 589 443	6 949 677	6 949 677 460
Total	**318 071 511**	**126 480 449**	**126 480 449 140**	**335 648 839**	**194 316 748**	**194 316 748 470**

assuming that each female louse reproduces once a month in the counties of Troms and Finnmark in April and May and twice a month in all other counties and months, one can make a rough estimate on the number of salmon lice eggs produced each month in each county. Based on this method, Hordaland has the highest egg production, while Finnmark and Troms have the lowest. In general, egg production is low in May, probably as a consequence of the synchronised spring delousing carried out along the coast of Norway. The egg production shows a strong increase throughout the summer months and into autumn. In the north there is a tendency for the increase to come somewhat later and to be significantly lower, despite the fact that the numbers of farmed salmon can be high.

However, the production of farmed salmon and number of salmon lice eggs alone do not give a comprehensive picture of how salmon lice impact stocks of wild salmon. There is not necessarily any direct association between the biomass being farmed in a given area and the extent of infection pressure that stocks in the wild are exposed to in the same area (Bjørn et al. 2007a). To date, we have not developed sufficiently accurate sustainability models (how much farmed salmon we can allow in a fjord before salmon lice dispersion reach a critical level for stocks of wild salmon) for salmon lice in fjords containing fish farms along the coast of Norway. The effect of the initiatives to counter salmon lice infection from fish farm facilities that the administrative authorities and the industry have implemented, must therefore primarily be measured in terms of direct reductions in infection levels among wild salmon (Heuch et al. 2005, Finstad et al. 2011).

Monitoring of salmon lice infection on wild salmonids

Since the early 1990s, when the continuous national monitoring of salmon lice on wild salmon was first started, it has mostly been carried out under the auspices of the Norwegian Directorate for Nature Management. Since 2005, the Norwegian Food Safety Authority has been responsible for financing this monitoring, particularly in relation to assessments of the effect of national salmon fjords. In addition, the Norwegian Ministry of Fisheries and Coastal Affairs through the Institute of Marine Research have projects to establish a comprehensive database of basic knowledge of salmon lice and the impact on national salmon fjords.

Since 2010, IMR has taken over coordination responsibility for the national salmon lice monitoring on wild salmonids, particularly in relation to national salmon fjords, in cooperation with the Norwegian Institute for Nature Research and consultant biologist company Rådgivende Biologer AS. In 2010 this comprised of the systems shown in Figure 5.1.1.1 (see Bjørn et al. 2010a for a more detailed description of localities and methodology for catching and processing wild salmon).

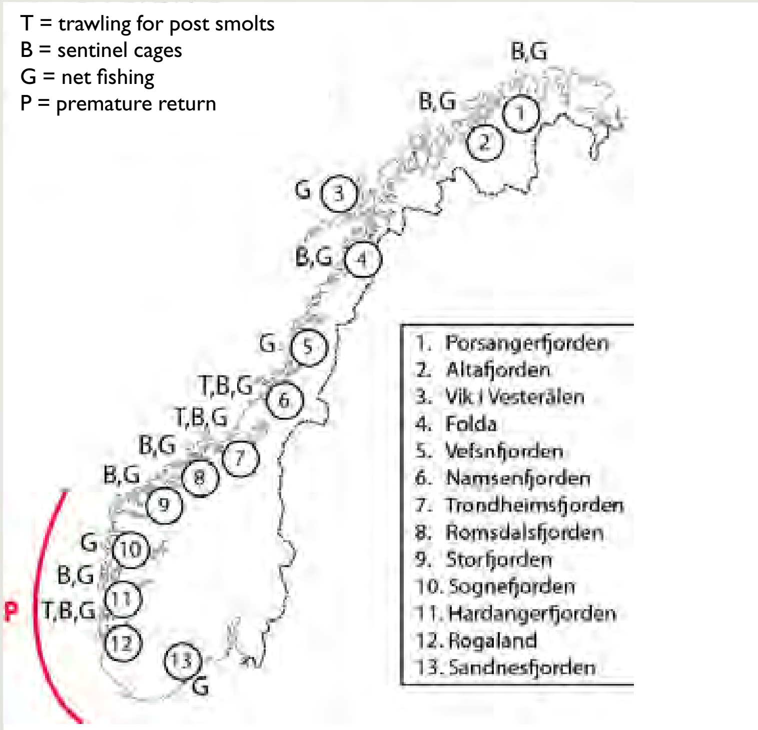


Figure 5.1.1.1
Map of survey areas during summer of 2010. Sea trout (and some Arctic charr) were captured in sea (G) during two to three periods and in two to three stations in each survey area. All fish were examined for degree of salmon lice infection. The first survey was done during the migrating wild salmon smolt run (May/June from south to north), while the second (and third) survey was done later in the summer. In some fjords sentinel cages were deployed (B) and trawling for wild salmonids undertaken (T). On the western coast the degree of premature sea trout returns were monitored (P). A survey was done within the national salmon fjords and one to two in reference areas outside the national salmon fjords in addition some fjords with no protection status (see Bjørn et al. 2010a for details).

The survey enable us to compare and analyse national salmon fjords with fish farms against national salmon fjords where there are no fish farms within the different counties (e.g. Altafjord with fish farms and Porsanger without fish farms). Comparisons can also be made between national salmon fjords (e.g. Vefsnfjord) and non-national salmon fjords (e.g. Follafjord) and large national salmon fjords with small national salmon fjords (e.g. Sognefjord and Etnefjord). Gradient surveys are being carried out in all fjords, from areas with little or no fish farming within salmon fjords to areas with large-scale fish farming outside salmon fjords (e.g. Trondheimfjord without fish farming and Hitra with large-scale fish farming), as well as inner salmon fjords without fish farming and inner fish farm fjords with intensive fish farming (e.g. Sognefjord and Ålesundfjord). We also have two references enabling comparison between a northern point (Porsangerfjord) and a southern point (Sandnesfjord) without any fish farming activity whatsoever. We will also enhance our understanding of the system through coordination with the Institute of Marine Research's basic R&D activities in a number of important fjords (Hardanger, Sogn, Romsdal, Namsen, Folla, Alta and Porsanger). The impact of salmon lice from the Norwegian fish farming industry on wild salmonids, directly measured on wild salmonids in 2010, is therefore presented not only by county, but also directly by the various localities inspected. We have no monitoring data for Troms county from 2010. Here, the assessment of conditions is based on monitoring data from 1998–2000 (Bjørn et al. 1999, 2000, 2001b, 2005b, 2007b) (Table 5.1.1.3).

Assessment of condition of wild salmonids infected with salmon lice along the coast of Norway summer 2010

Rogaland and Agder
For Rogaland and Agder, we have collected infection data from sea trout prematurely returning to fresh water (see Kålås et al. 2010) and from sea trout in the sea (see Bjørn et al. 2010a). In the southern part of Rogaland, where fish farming is intensive, a small number of fish started migrating back to fresh water at the end of May and beginning of June 2010. By mid-June, large numbers of sea trout were migrating back to fresh water in. These fish had in part high levels of salmon lice infection (average intensity over 60 lice). Based on the stage of development of the salmon lice, these fish were most likely infected during the first half of June. At the end of June, even greater numbers of prematurely returning sea trout were observed in southern parts of the county. Some of these had been waiting a long time in the river to be deloused, while others had only just migrated back to fresh water and were in part heavily infected with lice. In the central and northern parts of Rogaland, only a few prematurely returning sea trout were observed between the end of May and the middle of June. At the end of June, larger numbers of fish were observed migrating back to central and northern parts of the county, though still not as many as in the southern part of the area. The average infection intensity here was approximately 40 lice per fish.

In the last survey, carried out in mid-July, there were fewer lice on the prematurely returning fish in the southern part of Rogaland. There remained a large number of fish in the river mouths. These were mostly deloused, and it appears that no newly infected fish came in during the last two weeks. The northern part of Rogaland also saw large numbers of deloused fish in the river mouths, although some newly infected fish had also come in for delousing. In the monitored areas of Jæren and Dalane, no returning fish were registered for the entire inspection period. Our survey areas lie far to the south of Jæren, in a national salmon fjord and far away from the nearest fish farm facility. An amount of salmon lice has also been registered on sea trout in the sea (fishing net) off five rivers in Rogaland, as well as at an survey area with no fish farming southwest of Risør in Aust-Agder. In Rogaland, sea trout off all rivers were highly infected. Most localities had prevalence of between 75% and 100%, and average infection intensity was between 20 and 60 lice. The relative intensity (lice per gram of fish weight) was also high. Most localities had relative intensity of between 0.5 and 1.6. At the survey area in Aust-Agder, there were virtually no instances of lice on sea trout throughout the entire survey period. The relative intensity was also extremely low and none of the sea trout had more than 0.1 lice per gram fish.

Hordaland
The amount of salmon lice was registered in sentinel cages with salmon smolt, on

migrating salmon smolt (trawl), on sea trout (net and trawl) and on sea trout that have prematurely returned to the river mouths. We also have data for settlement of salmon lice on fish caught in a newly developed sea trout trap.

All methods showed very low infection pressure for the whole of May, although they also showed a significant increase in settlement of salmon lice, initially in the outer part of the fjord and subsequently in the central part of the fjord during June. We found relatively little salmon lice among sea trout caught using nets at the end of May, with approximately a 50% prevalence rate and on average less than 10 salmon lice per fish for the outer parts of the fjord and very little further into the fjord. The same tendency was found in the data from the sea cages and trawl-caught smolt, with overall relatively low infection pressure and lessening further into the fjord. There was also no premature returning to fresh water.

In the beginning of June, significant increased infection was detected in the outermost parts of Hardangerfjord, while there continued to be fewer lice further in. The salmon smolt in the sea cages in the outermost parts of the fjord had on average near to 4 lice, while over 70% of trawl-caught sea trout were infected with on average 23 lice. There was also increasing infection among trawl-caught salmon smolt, although relatively few salmon smolts were caught in June. In total, 1.7% of the trawl-caught salmon smolt had more than 10 lice and 8.3% had more than 0.1 lice per gram fish. Towards the end of June, results from fish caught by net in the national salmon fjord in Etne showed over 90% prevalence and on average more than 100 salmon lice on sea trout. 54% of the sea trout had more than 0.1 lice per gram of fish weight. The same tendency was noted in data from the sea cages, with a significant increase in the outer stretches of the fjord and in the Etnefjord area, where the average settlement of lice was over 20.

An increase was also found in the central part of the fjord, with almost 100% prevalence and an average of 60 lice (net and cage) on the fish. 65% of the fish had more than 0.1 lice per gram fish. Results from the sentinel cages also showed an increase, although the data is more variable. Prematurely returning fish were also observed in the outer parts of Hardangerfjord in week 26, with an average of just over 80 salmon lice per infected fish. In Varaldsøy, very low infection pressure was found regardless of method (net, sea cages, premature returning to fresh water).

In the middle of July, a relatively high number of sea trout prematurely returned to the rivers in the central part of Hardangerfjord. On average, these were infected with 46 lice per fish. In the outer parts of Hardanger, only deloused fish were found in week 28, while in the rivers in inner Hardanger no fish have been found.

Sogn and Fjordane

Here we have data from the Sognefjord system (including a few survey areas for premature return between Sotra and Nordfjord). The results showed little lice around end of May/beginning of June on fish caught by net. At the same time, there was only a little or no premature returning to fresh water. By the end of June there was a significant increase among sea trout caught by net in the outer parts of Sognefjord, with a prevalence of 100% and an average of more than 40 lice per fish. 35% of the sea trout had a relative intensity of more than 0.1 lice per gram fish. Premature returning to fresh water was also observed in the outer parts of Sognefjord, and the infected fish had on average more than 40 lice. In the central parts of the fjord, within the national salmon fjord, the infection pressure remains low and no sea trout had more than 0.1 lice per gram fish.

In the middle of July, settlement of salmon lice on sea trout was found in most of the river mouths in the outer parts of Sotra, Masfjord, Sognefjord, Sunnfjord and Nordfjord. These fish were infected with a few adult lice, slightly more pre-adult lice and large amounts of larvae. It may be that these fish had become slightly infected in June, but not sufficient to force them back to fresh water. By late June/early July the infection pressure had apparently increased considerably, giving an average infection level of about 50 lice, despite having returned to fresh water for delousing.

Møre and Romsdal

From Møre and Romdsal we have data from the Storfjord system near Ålesund and the Romsdalsfjord system. At the end of May there were very few lice on the fish, mostly adult stages, in all survey areas in the Storfjord system. By the end of June there was a significant increase in the outer parts of the fjord system (in the national salmon fjord in Ørstafjord). Here it was found that 90% of the fish were infected with on average 24 lice per fish, and 35% had more than 0.1 lice per gram of fish weight. In the central part of the Storfjord system (Sykkylven), where there is intensive fish farming, some 70% of the fish were infected with about 3 lice on average (intensity), while the fish in the inner fjord (Sylte) had a prevalence of 7% and an intensity of only one louse.

Towards the end of July, infection was lower in all localities including Ørstafjord. Prevalence for the two outer localities (Sykkylven and Ørstadfjord) was 67% and 75%, with average intensity of about 9 lice. In the inner part of the fjord, 13.4% of the fish were infected with an average of 1.5 lice per fish.

In the Romsdalsfjord system there was also few lice in all survey areas in the first part of June, mostly adult stages. At the end of June there were still only very little lice on the fish in the inner part of the fjord system (Eresfjord). Only 5% of the fish were infected with lice and no fish had more than 2 lice. In the central part of the Romsdalsfjord system (Bolsøya) the prevalence was 86% and infected fish had on average 7 lice. In the national salmon fjord (Isfjord), 33% of the fish were infected with on average 12 lice per fish.

At the end of July the level of infection was still low in all localities in the fjord system, although there had been a slight increase. Prevalence was between 77% and 88%, with an average intensity of approximately 7 for all localities and between 12% and 24% of the fish had more than 0.1 lice per gram fish.

Sør-Trøndelag

In the beginning of June there was few lice on the fish, and mostly adult stages, in all survey areas. At the end of June there were still only very few lice on the fish in the inner part of the national salmon fjord in the Trondheimfjord system (Stjørdalsfjord). Immediately outside the national salmon fjord in the Trondheimfjord system (Agdenes), a number of fish were infected (100% prevalence) and had on average 14 lice. Almost 60% of the fish had relative intensities of more than 0.1 lice per gram fish.

In the area around Hitra where fish farming is intensive, 64% of the fish were infected with on average 9 lice per infected fish. Post-smolt trawling was carried out in the outer part of Trondheimfjord and out towards Frohavet in the period from 18 May to 16 June. We found very low settlement of salmon lice in the first weeks of the smolt migration in May (weeks 20 and 21, prevalence about 10% and roughly 2 lice per infected fish). No smolt had more than 10 lice, and about 10% had more than 0.1 lice per gram fish. Throughout June infection increased slightly, but the prevalence (between 13% and 33%) and the intensity (average approximately 3) remained low. No smolt had more than 10 lice, although the percentage of fish with relative intensity increased to between about 10% and 30%. In the last weeks (weeks 22 and 24) only a few fish were caught.

Nord-Trøndelag

In the beginning of June, moderately high amounts of lice were found on sea trout in areas outside Namsenfjord (Sitter), where fish farming is intensive. 88% of the fish caught in nets outside Namsenfjord were infected with lice. Infected sea trout had on average about 17 lice per fish and 27% of the fish had more than 0.1 lice per gram fish. In the national salmon fjord (Tøtdal), no lice were found in June.

In the beginning of July (week 27), 96% of the sea trout caught in nets outside the Namsenfjord system were infected with on average over 30 lice, and 60% had relative intensity over 0.1 lice per gram fish. In the inner Namsenfjord, prevalence was 30% and with on average approximately 6 lice per infected fish. None had more than 0.1 lice per gram fish.

In the outer parts of Namsenfjord, migrating salmon smolt was trawled in the period from 15 May to 5 June. Of the 106 post-smolt caught, lice were found on only 2 (Finstad et al 2010). This indicates that the salmon smolt from Namsenfjord avoided the settlement of lice that was later found on sea trout at Sitter in week 27.

Nordland

At the end of June, very few lice were found on sea trout outside Vefsnfjord. In the middle of July, the amount of lice both in (Leirfjord) and outside (Dønna) the national salmon fjord in Vefsn was still small. In Leirfjord, 13% of the fish were infected with on average 8 lice per fish. Around Dønna, 83% of the fish were infected with on average 11 lice.

On fish caught in nets at the end of June and beginning of July, in Nordfold we found approximately 50% prevalence and intensity of less than 3 lice per fish. In Sørfold, prevalence was about 70% with on average approximately 6 lice per infected fish.

In the last half of July, infection pressure increased significantly in areas with fish farming in Nordfold, while in areas with fish farming in Sørfold there continued to be only very few lice. In Nordfold, almost 90% of sea trout caught with nets were infected with lice. The infected fish had on average about 30 lice, and 52% had relative intensity of more than 0.1. In Sørfold, too, over 90% of the fish were infected, but here average intensity was less than 7 lice per infected fish and none had more than 0.1 lice per gram fish.

In Vik in Vesterålen, fish caught with nets at the end of June in areas with intensive fish farming showed approximately 70% prevalence with on average less than 3 lice per infected fish, primarily in the larval stages. At the end of July, 95% of the fish were infected with on average 26 lice, and 40% had relative intensity of more than 0.1 lice per gram fish. Among smaller sea trout, premature return to the lower part of Vik watercourse was observed.

Troms

Monitoring data for 2010 is not available from Troms county. The assessment of stock conditions here is based on older monitoring data from 1998–2000 (Bjørn et al. 1999, 2000, 2001b, 2002, 2007b) combined with hydrographical observations and data on presumed production of lice and dispersal. This is supported by an earlier model showing the spread of salmon lice in Sør-Troms (Bjørn et al 2005a). Between 1998 and 2000, salmon lice infection among wild sea trout and Arctic charr was inspected three times in the summer period (June, July and August) at the principal areas at Løksebotten in Salangen, Laksefjord on Senja in Sør-Troms and at Jægervatn in Ullsfjord in North Troms. In addition, a further ten secondary areas, from Kvænangen in Nord-Troms to Ofotfjord in northern Nordland, were inspected once at the end of July/beginning of August. Salmon lice infection was also studied on migrating salmon smolt in Malangen in Central Troms in 1999, 2000 and 2001 (Bjørn et al. 2007b). The results showed that infection pressure on sea trout and Arctic char was low in Ullsfjord in all the survey areas. Taking all survey weeks/years together, prevalence was between 30% and 100% and median intensity between 3–7 lice. Relative intensity was also low and only a few fish (a small percentage) had more than 0.1 lice per gram fish. We also found small amounts of lice on sea trout at the secondary areas in north and central Troms. No lice were found on migrating salmon smolt in the Malangsfjord system in central Troms in any of the survey years (Bjørn et al 2007b). In Løksebotten and the salmon fjord in Sør-Troms, in isolated instances some years we found moderately higher salmon lice infection among wild sea trout. For example, in 2000 it was found that 80% of sea trout in Løksebotten were infected with an average of 24 lice, and in individual cases up to 60 lice. Premature returning to fresh water was also observed. In 1999, too, 80–90% of the fish in Sør-Troms (the salmon fjord and Løksebotten) were infected with up to 20 lice and it is likely that more than 10% of stocks had more than 0.1 lice per gram fish weight. There was also a tendency for secondary areas here had moderately increased levels of salmon lice infection (Bjørn et al. 1999, 2000, 2001b).

Finnmark

Here we have data from the Altafjord and Porsangerfjord systems. This data shows that in the beginning of July, fish caught in nets in the outer parts of the Altafjord system, where fish farming is intensive, 84% of the fish were infected with on average less than 8 lice per infected fish, primarily in the larval stages. In the inner part of Altafjord (national salmon fjord), 70% of the fish catch was infected with an average intensity of 4 lice per fish, primarily salmon lice larvae. In the beginning of August, infection pressure was still low in both the outer (prevalence 60% and intensity approximately 5 lice) and inner (prevalence 68% and intensity approximately 6 lice) Altafjord.

On fish caught in nets in the outer parts of the Porsangerfjord system (outside the national salmon fjord) in the beginning of July, approximately 7% of the fish were infected on average with only one louse per infected fish, and these were only in the early larval stages. In the inner part of Porsangerfjord (in the national salmon fjord), about 24% of the fish catch was infected with approximately one louse in average intensity per fish. In the beginning of August, infection pressure was still low in both the outer (prevalence 11% and intensity approximately one louse) and inner (prevalence 55% and intensity approximately one louse) Porsangerfjord. No fish in this system had more than 0.1 lice per gram fish.

Summary of salmon lice infection in wild salmon along the coast of Norway summer 2010

In May and the beginning of June, salmon lice infection in wild salmon smolt and sea trout appears to have been low in the majority of survey areas. There is clearly increasing infection in the Hardangerfjord system in early June compared to May, and in particular sea trout in the outer fjord were relatively highly infected. The same has been observed in Herdlefjord in the outermost part of the Osterfjord system. In the other survey areas along the coast, infection is considered to have been low at the end of May and beginning of June.

Between roughly the second week of June and the middle of July we find a significant increase in infection pressure from salmon lice, in part very high infection levels among sea trout, and prematurely returning fish in large numbers to south-

Table 5.1.1.2
Prevalence (% infected sea trout), intensity (no of lice per infected sea trout) and % sea trout (included uninfected fish) with more than 0.1 salmon lice per gram fish given for each county and each area within the county early (period I) and late (period 2) the summer of 2010. Registered incidence of premature return is indicated.

	Periode 1				Periode 2			
	Prevalence	Intensity	% > 0,1 rel int.		Prevalence	Intensity	% > 0,1 rel int.	Premature return
Finnmark	**38.5**	**4.9**	**1.9**		**42.1**	**4**	**0**	**-**
Alta inner	70	4.4	0		68.2	6.4	0	-
Alta outer parts	84.2	7.6	10.5		60	4.8	0	-
Porsanger inner	23.5	1.3	0		54.5	1.5	0	-
Porsanger outer parts	6.5	1	0		11.1	1	0	-
Nordland	**65**	**4.3**	**0**		**65.8**	**17.7**	**18.3**	**-**
Vesterålen	68.4	2.6	0		95	24.5	40	-
Nordfold	52.9	2.9	0		89.5	30	52.6	-
Sørfold	70.8	6.3	0		92.9	6.5	0	-
Leirfjord	-	-	-		13.5	8.2	2.7	-
Dønna	-	-	-		83.3	11.0	10	-
Nord-Trøndelag	**48.9**	**16.7**	**14.9**		**69.2**	**27.3**	**35.9**	**-**
Namsen inner	0	0	0		31.3	6.2	0	-
Namsen outer parts	88.5	16.7	26.9		95.7	32.1	60.9	-
Sør-Trøndelag	**-**	**-**	**-**		**73.6**	**11.7**	**28.6**	**-**
Trondheim inner	-	-	-		33.4	12	11.1	-
Trondheim outer parts	-	-	-		100	14.4	58.6	-
Hitra og Frohavet	21.4	2.7	0		64.3	8.8	11.9	-
Møre og Romsdal	**32.7**	**4.5**	**0**		**41**	**8**	**3.6**	**-**
Romsdal inner	11.8	5	0		5	2	0	-
Romsdal outer parts	55.6	4.5	0		88.9	6.6	5	-
Isfjorden	30	4.3	0		33.4	12.5	5.6	-
Ålesund inner	8	1	0		7.4	1	0	-
Ålesund central parts	31.3	2.4	0		69.2	3.16	3.8	-
Ålesund outer parts	50	2	0		90	24.1	35	-
Sogn og Fjordane	**26.5**	**2.7**	**0**		**75.7**	**29.5**	**18.9**	**-**
Sognefjord inner	31.6	2.5	0		47.1	2.6	0	-
Sognefjord outer parts	20	3	0		100	40.2	35	Yes
Hordaland	**-**	**-**	**-**		**75.4**	**79.7**	**36**	**-**
Hardanger inner	11.8	1	0		7.7	1	0	No
Hardanger central parts	-	-	-		95.5	43.3	36.3	Yes
Hardanger outer parts	57.1	9.1	-		92.3	114.8	53.8	Yes
Rogaland	**-**	**-**	**-**		**-**	**-**	**-**	**-**
Ryfylke south	-	-	-		-	-	-	Yes
Ryfylke midh	-	-	-		-	-	-	Yes
Ryfylke north	-	-	-		-	-	-	Yes
Jæren	-	-	-		-	-	-	No
Agder	**-**	**-**	**-**		**-**	**-**	**-**	**-**

ern areas of Ryfylke and also parts of central and northern Ryfylke, as well as the outer and stretches nearer the middle of Hardangerfjord. There was also relatively high infection among sea trout outside the Namsenfjord system in the second week of June. Infection levels appeared low at all the other survey areasalong the coast of Norway in the first half of June.

From the second half of June to the middle of July, there was an increase in infection pressure, in part high infection levels and premature return in the outer Osterfjord system, Masfjord, outer parts of the Sognefjord, Sunnfjord and Nordfjord systems and as far as the outer parts of Storfjord system near Ålesund. The increase apparently came somewhat later and was of rather less intensity than in Hardanger and Ryfylke. There was also still relatively high infection of sea trout outside the Namsenfjord system at the end of June and beginning of July. Further north, lower infection pressure was found at the Porsangerfjord system. The same largely applied in the inner parts of the fjord areas of Vestlandet, as well as for the major national salmon fjords of Sognefjord, Trondheimfjord and Namsenfjord.

For the period from mid-July to mid-August we only have data from a few areas in Nordvestland and northwards to Porsangerfjord. Infections were low in the majority of localities in Storfjord and the Romsdalsfjord system at the end of July and beginning of August. In areas in Folda and Vesterålen where there is intensive fish farming, as July progressed there was increasing infection, while in Altafjord, where there is also intensive fish farming, there was a little lice in the beginning of August. This was also the case in Porsangerfjord, which does not have fish farming.

The development of salmon lice infection in wild fish is very similar to the situation in 2009, with only few lice in the spring and early summer (May and early June), increasing during the summer and autumn.

Photo: Lars Hamre

Assuming that the migration of salmon smolt occurred at the usual time in spring and early summer (May and beginning of June in western and central Norway, and June and early July in northern Norway), this indicates relatively low infection in the majority of the migrating smolt in the fjords where inspections were carried out along much of the coast in 2010. This is most likely the result of the synchronised winter and spring delousing, which tends to keep the infection pressure lower during the salmon smolt migration in May (see Table 5.1.1.1). In addition, the cold winter and spring and the low temperatures in Vestlandet appear to have delayed the time when the infection pressure increases, so that the majority of the salmon smolt has probably managed to leave the fjords before the infection pressure increased. This fits with data from the salmon trawling in the Hardangerfjord system, outer Trondheimfjord and Frohavet, and from outside Namsenfjord (Finstad et al. 2010). However, we find rather more lice on the salmon smolt at the end of the trawling period in Hardangerfjord, Trondheimfjord and Frohavet. The increase in infection also came a little earlier in the survey areas in Hordaland and Rogaland. The main migration of salmon smolt appears to have occurred in mid-May in these areas in 2010 (provisional data from the Norwegian Institute for Nature Research, the Institute of Marine Research and environmental research organisation UNI Miljø 2010). Late migrating salmon smolt may have been exposed to increased salmon lice infection in the outermost parts of the fjord. Some rivers in these areas also have later migrations than others, such as Eidfjord watercourse in Hardanger (50% smolt migration on 7 June 2010, provisional data from UNI Miljø), and may have been highly infected. Also, we have no post-smolt data on salmon in the outer coastal areas.

The maximum salmon lice infection pressure that we have registered in certain areas in June and July is substantially higher than we have registered in recent years, especially in Ryfylke and Hardanger, but also the stretch from Sogn to and including Ålesund. In the case of Ryfylke, we have to go back to 1997/1998 to find years with a greater incidence of salmon lice infection. For the outer and inner parts of the Hardangerfjord system, salmon lice infection in 2010 has probably also been higher in summer 2010 than in most years since 2004, with the possible exception of 2008. The increase in infection has come a bit later than in 2008, with the consequence that migrating salmon smolt have probably been infected to a lesser extent.

Sea trout, which are on their feeding migration in the outer fjord and coastal areas of Vestlandet throughout the summer, have periodically been exposed to very high infection and a high proportion of catches (30% to 65% in a number of localities) have extensive infection (more than 0.1 lice per gram of fish weight). We have also found relatively large quantities of lice on sea trout in certain areas outside the Namsenfjord system, in Folda and Vesterålen.

Further north, the infection pressure from salmon lice in summer 2010 is considered to be relatively low. The same applies to more or less all the inner parts of the fjord areas of Vestlandet, and for the inner parts of the large national salmon fjords of Sognefjord, Trondheimfjord and Namsenfjord. However, we found relatively high to very high infection in the small salmon fjords (Etnefjord, Isfjord, Ørstafjord) in the outer fjord stretches.

Specific risk assessment of impact of salmon lice on wild stocks

We take as our starting point that < 10% of stocks of wild salmon with > 0.1 lice per gram of fish weight gives a low probability of having a stock regulating effect, as defined in the sustainability strategy, of salmon lice on wild stocks of salmon (green). If between 10% and 30% of stocks in an area have more than 0.1 lice per gram fish, we consider the probability of a stock regulating effect to be moderate (yellow). If 30% or more of the fish in our inspection material have > 0.1 lice per gram fish, we consider the probability of a negative effect on stocks in the area to be high (red).

In Finnmark, the monitoring data we have collated indicates a low likelihood of population regulating effects resulting from salmon lice. Only a few sea trout and Arctic charr have more than 0.1 lice per gram of fish weight. At the same time, the time of the increase in infection indicates that the salmon smolt had very probably migrated from the fjords in Finnmark with few lice (Finstad et al. 2010).

Monitoring data for 2010 is not available from Troms county. We have therefore opted to use older data from 1998–2000 in our assessment (Bjørn et al. 1999, 2000, 2001b, 2002, 2007b). This data indicates that infection pressure was low in Nord-Troms (from Ullsfjord northwards to the boundary with Finnmark) and that only a few per cent (significantly less than 10%) of the fish had more than 0.1 lice per gram fish. The same applies to salmon smolt migrating from the Malangsfjord system. No salmon smolt had lice in the period 1998–2000, mirroring the situation in West Finnmark (Bjørn et al. 2007b). However, in a few areas in South Troms we find higher infection and premature returning in some years. There is a likelihood that > 10% of sea trout here have had > 0.1 lice per gram fish. In addition, a survey of salmon lice infection from fish farms in the Lofoten–vest-Finnmark area showed a higher infection index south of Ullsfjord/Lyngen (Bjørn et al. 2005a). In combination with lice data from farmed fish, we consider that as a whole there is a moderate likelihood of salmon lice having a population regulating effect in Troms, with Nord-Troms relatively like Finnmark and Sør-Troms more like Nordland.

For Nordland as a whole, 34% of sea trout had more than 0.1 lice per gram fish. However, there are substantial variations in the data from the different localities: in Vesterålen, more than 40% were over the limit in August and in Nordfold the figure was 50%, while Sørfold and Vefsn were under the threshold value in 2010. Most of the fish farming activities in Nordland are in the coastal areas. With the exception of a number of inner fjords, we believe that that lice limit for sea trout in Nordland was exceeded in 2010, i.e. there was a high likelihood of a population regulating effect. However, the increase in infection came late enough – at least in central Nordland and northwards – that the salmon smolt from most of the county had very likely migrated from fjords with low salmon lice infection.

In Nord-Trøndelag, we only have data from Namsen. Lice limits have not been exceeded in the national salmon fjord, although in the outer coastal areas they were exceeded by 60%. Taking these outer coastal areas as the basis for assessment, we believe that the lice limits have been exceeded for Nord-Trøndelag as a whole. However, salmon smolt caught by trawling indicated that the salmon smolt migrated from Namsenfjord with no marked salmon lice infections (Finstad et al. 2010), despite the fact that we found lice on sea trout at the same time.

Table 5.1.1.3

Risk assessment for salmon lice for counties based on the likelihood of a population regulating effect on wild salmonids (low = green, moderate = yellow, high = red). For all counties with exception of Troms the risk assessment is based on surveillance data for wild salmonids in 2010, but the standing biomass of farmed salmon and calculated salmon egg production thereof have been taken into consideration. Percentage of wild caught sea trout with more than 0.1 salmon lice per gram fish is listed were data is available (see also Table 5.1.1.2).

Risk assessment per county	May/June (indicator for effect on salmon smolts)	July/ August (indicator for effect on sea trout)
Finnmark	2	0
Troms	-	-
Nordland	0	18
Nord-Trøndelag	15	36
Sør-Trøndelag	2	29
Møre og Romsdal	0	4
Sogn og Fjordane	0	19
Hordaland	0	36
Rogaland	Premature	Premature
Agder	0	0

In Sør-Trøndelag, 28% of fish had more than 0.1 lice per gram fish, although there are sizeable variations between inner Trondheimfjord and Hitra (around the limit) and outer Trondheimfjord (58% > 0.1 lice). We found only few lice on migrating salmon smolt in outer Trondheimfjord and Frohavet. Therefore we postulate that there is a moderate likelihood that salmon lice infection in Sør-Trøndelag, particularly for sea trout during the summer, has a population regulating effect.

In Møre og Romsdal we found very few lice on fish in 2010. With the exception of an outer locality (Ørstadfjord), the majority of sea trout were within the lower limit. Some areas are periodically over the limit and the resulting uncertainty is taken into account in our assessment, i.e. moderate likelihood of population regulating effect.

In Sogn og Fjordane (including individual fjords between Masfjord and Nordfjord), we found a lot of premature returning with partly high levels in the outer stretches of fjords. In addition, 35% of sea trout in outer Sognefjord had more than 0.1 lice per gram fish. With the exception of a number of inner fjords, we consider that there is a high likelihood that salmon lice have a population regulating effect on sea trout in Sogn and Fjordane. However, the time of the increase in infection indicates that the salmon smolt migrate from the fjords before the infection pressure increases, with the possible exception of the last of the smolt.

In Hordaland, we found significant numbers of prematurely returning sea trout with high levels of salmon lice infection. We also found a lot of lice on sea trout caught by net in outer and smaller stretches of fjords, with 54% and 65% of fish respectively having more than 0.1 lice per gram fish. Therefore we consider that there is a high likelihood that salmon lice have a population regulating effect on sea trout in Hordaland. In Hardangerfjord, trawl catches of salmon indicated that much of the salmon smolt migrated out before the infection pressure increased in 2010, with the possible exception of the later migration of smolt from the inner fjord areas.

In Rogaland, there was heavy number of premature returns in 2010. These fish also had a high number of lice, and we have assumed that large parts of the fish stocks have more than 0.1 lice per gram fish. We consider that there is a high likelihood that salmon lice have a population regulating effect in Rogaland, particularly on sea trout. Also, the infection came a little earlier at the survey areas in Ryfylke, so that the last of the migrating salmon smolt may have been infected.

In Agder, we found no premature returning and very few lice on fish in the sea. Here we consider that there is a low likelihood of salmon lice having a population regulating effect.

Which criteria/indicators form the basis of and uncertainty over threshold values?

Experimental trials indicate that approximately 0.1 lice per gram of fish is the level at which the fish start to encounter physiological problems (Nolan et al. 1999, Wagner et al. 2003, 2004, 2008, Tveiten et al. 2010). This limit also appears reasonably consistent between small, first-time migrating salmon smolt (most uncertain) and sea trout and larger (700–1000 g) salmon and Arctic charr, even though the transference

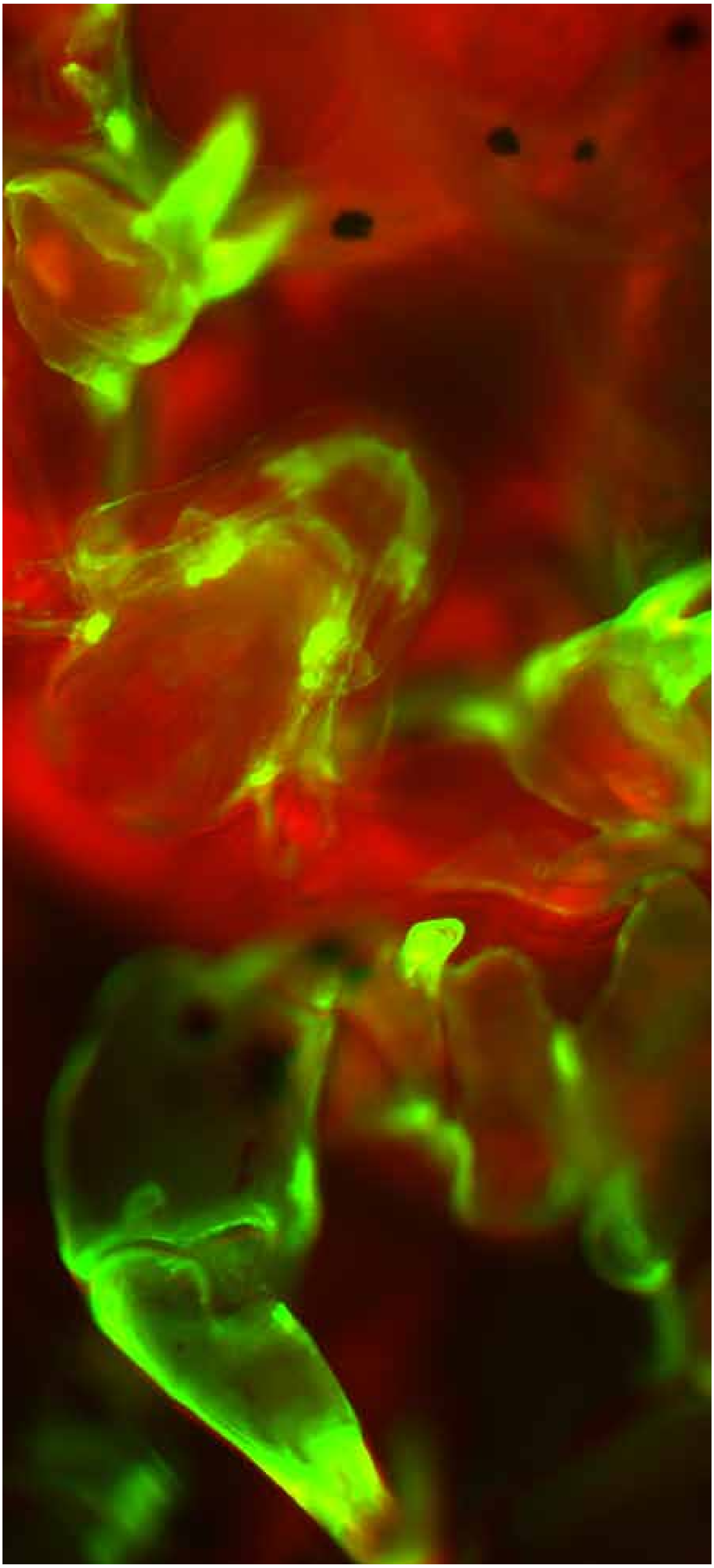


Photo: Sussie Dalvin

of dose-response studies from large to small fish based on weight can be problematic (see Wagner 2008). As a conservative limit for a physiological effect on individual wild salmon, we have chosen to apply 0.1 lice per gram of fish weight, or more than 10 lice on a 100 gram sea trout.

As mentioned above, we have taken as our starting point that < 10% of stocks of wild salmon with > 0.1 lice per gram of fish gives a low likelihood of a stock regulating effect on wild stocks of salmonids. This is founded on the long time goal formulation in the Norwegian Ministry of Fisheries and Coastal Affairs' Strategy for a sustainable Norwegian aquaculture industry, which states that disease (including lice) will not have a population regulating effect on wild stocks. The transference of dose-response influence on individuals to dose-response influence on stocks is, however, problematic, and we have no experimental or fieldwork results that document such a limit value. Although we know that, in a historical context and in areas without fish farming, salmon lice usually occur with relatively high prevalence but low intensity. This means that the majority of fish are infected, but with only a few lice per fish (most likely well under 10). We also know that in areas without fish farming, salmon lice do not have a normal spread among the host population. This means that even though the majority of fish have few or no lice, there will always be some individuals (as is the case with most parasites) that have many lice (probably a few per cent). However, the results from the national salmon lice monitoring 2010 survey areas where there is no fish farming activity, Sandnesfjord and Porsangerfjord, show that none of the sea trout here had > 0.1 lice per gram of fish.

Our lowest limit value of < 10% with > 0.1 lice per gram of fish weight takes into account the fact that some individuals can naturally be more highly infected, but is otherwise presumed to be higher in relation to assumed historical levels and areas without fish farming (see Finstad et al. 2011). This means that the limit value set for salmon lice infection will likely have some influence on wild stocks, but that over time most populations would be able to absorb up to 10% of individuals in a population being affected to some extent. In practice, this means it is "accepted" that one out of ten smaller sea trout (about 100 g) will have more than 10 lice and that one out of 10 larger sea trout veterans (about 1000 g) will have up to 100 lice. In all probability this could affect these individuals negatively in terms of physiological homeostasis and in worst instances also reproduction (see Finstad et al. 2011, Tveiten et al. 2010). Therefore it is likely, although not documented, that this could also have a regulating effect on stocks.

In the absence of more precise knowledge, we have decided to assume a relatively conservative limit value of < 10% with > 0.1 lice per gram fish as having a low likelihood (green) of affecting stock levels. Similarly, as a result of uncertainty concerning the master data, particularly the effect on populations over time, we have decided to include additional assessment criteria. Where between 10% and 30% of wild salmon in a given area have > 0.1 lice per gram, we have assessed the likelihood of it having a regulating effect on stocks as moderate (yellow), and where > 30% of fish have more than 0.1 lice per gram fish we have assessed the likelihood of it having a regulating effect on stocks as high (red).

This is weighted against salmon production and the total number of salmon escapes within a region, other environmental factors and the status of stocks of wild salmon. Thus the specific risk assessment in each county is based on a wide-ranging general assessment.

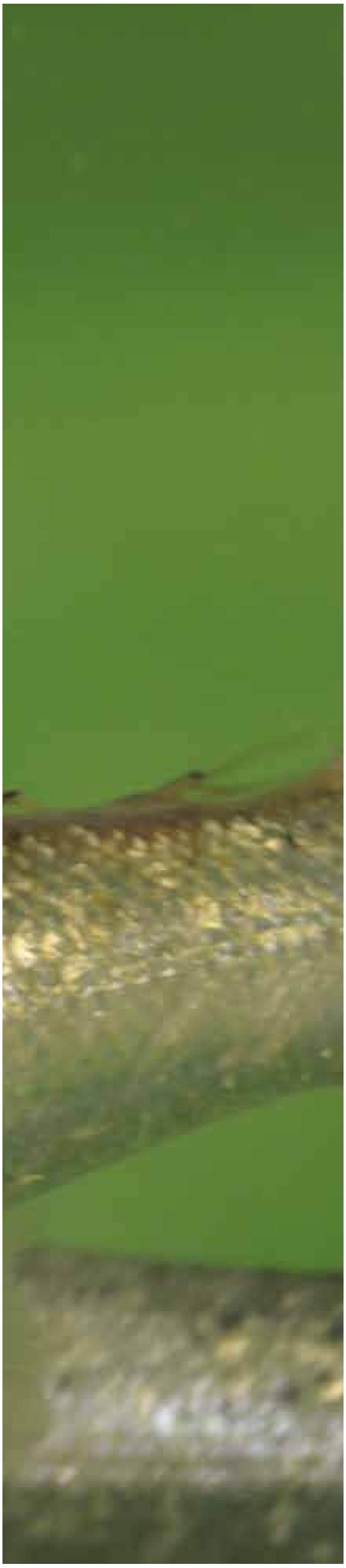
In Hordaland, for instance, we can see that there is a large number of farmed salmon in the sea, that the average number of lice per salmon is relatively high and that therefore the total egg production is also high (Table 5.1.1.1). At the same time, we can see that infection of wild sea trout is very high and we also know that stocks of sea trout and salmon are dangerously low (Bjørn et al. 2010b). All these factors are taken into account in our general assessment of how high likelihood there is of salmon lice in, for instance, Hordaland having a regulating effect on stocks, particularly sea trout, but also certain stocks of salmon.

In Finnmark, we find only little lice on sea trout throughout the summer and in the majority of areas, despite the relatively sizeable fish farm production established there, particularly in Altafjord. We also know that egg production in the spring is relatively low (Table 5.1.1.1) and that stocks of sea trout and salmon are relatively strong (Anon. 2010). Our assessment is therefore that the likelihood of salmon lice having a regulating effect on stocks in Finnmark is low.

In Sør-Trøndelag and Møre and Romsdal the assessment is more complex. In 2010, we found few lice on sea trout in the areas around Hitra where fish farming is intensive. We also found few lice on migrating salmon smolt. However, the level of lice on sea trout in the outer part of Trondheimfjord has increased, where 58% had more than the limit value of 0.1 in July and 45% in August. At the same time, we can see that lice egg production on farmed salmon is significant during the summer (Table 5.1.1.1) and that individual stocks of wild salmon have become weakened (Anon. 2010). In Møre and Romsdal we also find relatively few lice on the majority of sea trout, although in some areas there is a clear increase in infection pressure. Here, we can also see that egg production is relatively high (Table 5.1.1.1). We also know that individual stocks of wild salmon have become weakened (Anon. 2010). Our overall assessment is therefore that the likelihood of salmon lice having a regulating effect on stocks, particularly sea trout, is moderate in both of these counties.

For Troms, the assessment is also more complex. We have only older data available from Troms. This indicates a low level of infection among sea trout/Arctic char and salmon smolt in the northern parts of the county. However, in southern parts of Troms we found significantly higher infection pressure in some years. Fish farmers and the Norwegian Food Safety Authority have reported that also in 2010, farmed salmon in Troms and Finnmark had the lowest levels of salmon lice of all regions, and we can also see that egg production is low (Table 5.1.1.1). In addition, fish farm intensity remains relatively low, particularly in Nord-Troms, and stocks of wild salmon continue to be relatively strong (Anon. 2010). As a whole, our assessment is that the likelihood of salmon lice – also in 2010 – having a stock regulating effect in Troms county is moderate, but that there are differences between the northern and southern parts of Troms. We have also stated that the lack of recent data makes an assessment for Troms difficult.

Generalising for an entire county based on only a few monitoring points can be challenging. Looking ahead, it is absolutely necessary to develop precision models that can predict how large lice pressure (partly on the individual, but particularly on the population level) wild stocks in different regions/fjords can tolerate over time without it having a population regulating effect.



Data material and data uncertainty – base data assessment by county

In this assessment, we have principally used infection data for wild salmon in 2010, mainly sea trout, as the basis for our county and area assessments. Given the situation with regard to failure of treatment and increasing lice levels in fish farms from autumn 2009, we do not consider it very relevant to use older data.

Instances of lice and their effect on wild stocks are conditional on a number of variables that create a complex situation for assessing the lice situation. These variables can range from number of lice in fish farms and delousing strategies to the significance of current direction and strength for dispersal of sea lice, salinity, temperature, instances of escaped farmed fish and wild fish as possible carriers of mature lice. An evaluation of initiatives implemented by the administrative authorities and the industry along the length of the Norwegian coast and the effect of the national salmon fjords with regard to lice as an influencing factor would require a large degree of detail in the inspection programme. Without monitoring of many areas, it would be difficult to arrive at any satisfactory conclusions. For the time being, monitoring of wild salmon will be central because the effect of countermeasure initiatives can at present only be measured in terms of a reduction in infection levels among wild salmon (Heuch et al. 2005, Finstad et al. 2011).

The resolution for pointing out national salmon fjords, which both the Norwegian Food Safety Authority and the Institute of Marine Research have surveillance activities in, is an initiative that covers a vast geographical area, from Tønsberg in the south to Neiden in the north. It is also extremely varied in scope. The design of a monitoring and assessment programme that takes into account variations in seasons and between years, geographical areas and sizes of fish is therefore a massive undertaking. The grant from the Norwegian Food Safety Authority set 2007 as the start-up year. Therefore we opted to concentrate on some of the national salmon fjords that, to the fullest extent possible, cover the entire coast of Norway such that all regions would be included (from Finnmark to Vestlandet) and variations in the different types of national salmon fjords would be covered. It was also important to select areas where we have available historic data and/or a good systemic understanding as a basis for extended analyses (for example, the institute's more general activity with modelling of current and disease dispersal).

We also decided to divide the salmon fjords into several zones so that ideally we could cover the gradient both in and outside the national salmon fjord, as well as areas on the outer coast with intensive fish farming. We can examine and compare the infection pressure using a number of established methods (smolt cage, trawling, net fishing, premature returning) (Bjørn et al. 2001a, Asplin et al. 2004, Heuch et al. 2005, Bjørn et al. 2007a, Finstad et al. 2011) in these zones within the same fjord. With a methodical approach, we consider that we can representatively determine the infection level on wild salmonids in the surveillance period and area, although more frequent surveillance in time would have been preferable (see Bjørn et al. 2001a). With a partial escalation of activities by the Norwegian Food Safety Authority and the Norwegian Ministry of Fisheries and Coastal Affairs in 2008, 2009 and 2010, we could also include fjords without fish farming as areas of reference (Sandnesfjord in the south and Porsangerfjord in the north). We have also increased our efforts in areas where we have geographically insufficient coverage (Nordland), as well as in several reference fjords without national salmon fjords and where fish farming is intensive throughout the fjord.

Taken together this gives usable, methodical monitoring of salmon lice infection in wild stocks of salmonids along the coast of Norway, including evaluation of the national salmon fjord scheme. An assessment of the entire coast, however, is based only on data from 13 fjord systems and our coverage remains insufficient in some regions/counties (Troms, parts of Nordland, Sogn og Fjordane, Rogaland) and in general in outer coastal areas. Also, we have no data on migrating salmon smolt off Trondheimfjord, Namsenfjord and Hardangerfjord. County level assessments are therefore necessarily rough and based mainly on sea trout, even though we indirectly assess infection levels for salmon smolt based on the infection dynamic we find among sea trout during the salmon smolt migration period. Therefore there is a relatively high degree of uncertainty in assessments of the entire coast of Norway and it is not necessarily the case that the selected areas are representative. Making generalised assessments for an entire county based on only a few monitoring points presents us with major challenges. In the longer term, it is absolutely essential that we develop methods and models which in an indirect, simple and cost effective way can provide us with information on sustainability in individual fjords or fjord systems (see Chapter 6.2.1).

5.1.2 Spread of other infectious agents

There is very little data on the prevalence of pathogens in stocks of wild fish in Norway. At present, there is no systematic surveying of pathogen prevalence in salmon and other marine species from the Norwegian coast or rivers, with the exception of sporadic screening work. Our knowledge of various pathogens suggests, however, that transmission of pathogens from farmed to wild fish may occur. However, we do not know with certainty if outbreaks of disease in today's fish farms represents a source of infection/disease in wild fish. Therefore the main questions are if such infection occurs, the frequency with which it occurs and if it may lead to disease that has a stock reducing effect.

Proving disease in wild fish or the effects of disease on wild populations may be very difficult. Diseased fish in their natural habitat often disappear quickly (are eaten). Epizootic outbreaks can occur, but are usually caused by agents introduced to naive host populations or at extreme environmental factors (e.g. high temperatures), high infection pressure and immune suppression. Infection with enzootic agents under normal environmental conditions certainly causes disease development among some individuals in a population, and therefore affecting their survival (i.e. predator avoidance) or investment in reproduction. Subclinically infected fish (carriers) may represent individuals that have been through such an episode, but can also represent fish that have contracted a pathogen without developing disease or that have been infected vertically. There is limited available data on carriers of viral and bacterial infections in wild salmon populations. It is particularly important to establish genotyping methods for the detection and tracing of highly virulent pathogen strains that can be generated by aquaculture.

There is a clear need to improve our knowledge about infections in wild fish and pathogen transmission between farmed and wild fish and vice versa. Infections and disease must be seen in an ecological context and implemented in ecosystem-based management.

Data from outbreaks of disease among farmed fish is important information that must be used in risk assessments. The Norwegian Veterinary Institute is primarily responsible for monitoring disease among farmed fish and collects data on outbreaks. In order to assess the impact of disease in aquaculture on wild fish, it is important that the Institute of Marine Research has full access to updated and complete data on disease outbreaks in farmed fish.

The management of diseases among fish is based on the fact that the most serious diseases should be reported to a system developed by the World Organisation for Animal Health (OIE), which in Europe is managed in compliance with applicable EU regulations (as directive 88/2006 EC). Given the lack of data from wild fish population, we decided to present the disease status among farmed fish as important information that may reflect the infection pressure along the coast of Norway.

Viral diseases

Viral diseases and diseases with likely viral causes represented a major problem in the aquaculture industry in Norway. Trends show that IPN, PD, HSMB and CMS are the most prevalent viral or likely viral diseases among farmed fish in recent years.

The risk of transmission of ISAV to wild fish is generally considered to be small, although in Troms it is considered to be moderate. Based on the knowledge currently available, the likelihood of a negative impact of ISA outbreaks on wild salmon as a result of infection from farmed fish is considered to be low.

IPN was a significant problem in fish farming. The risk of transmission of IPNV to wild fish is generally considered to be moderate, based on the fact that IPNV has been detected in a number of different host-species. The likelihood of IPN outbreaks in aquaculture faming to have negative effect on the populations of wild salmon and other wild fish is considered to be low to moderate.

The majority of PD outbreaks were registered in Hordaland county. The risk of transmission of SAV to wild fish is generally considered to be low, although in Hordaland it is considered to be moderate. The likelihood of negative effects of PD outbreaks in fish farms on wild salmon cannot be assessed from the knowledge currently available.

Only rainbow trout farms has been affected by VHS in Norway. However, fish farms in Norway are considerd to be VHS-free today. It is considered possible that VHSV

from outbreaks fish farms may spread to wild fish. The probability of the negative effects of VHS impacting wild salmon and other wild fish as a result of infection from farmed fish is considered to be low.

Nodavirus has been found in a number of species; in Norway in farmed cod, halibut and turbot. The virus does not infect salmon. During outbreaks of VNN the risk of transmission of NNV to wild fish is considered possible.

HSMB has been reported for 43 farms in 2009. The disease is associated with areovirus (PRV). The risk of infection spreading to wild fish is considered to be moderate in Møre County and northwards. Negative effects of HSMB on wild salmon and other wild fish as a consequence of infection cannot be neglected.

CMS has been shown to be viral disease (totivirus). The risk of the disease spreading to wild salmon cannot be determined-due to the limitid available knowledge.

Bacterial diseases

Vibriosis problems are primarily associated with farming of cod and up until the fry stage among other marine fish. Vibrio anguillarum occurs naturally in the environment. Vaccines for cod are under development. The risk of infection spreading to wild fish is considered to exist. The likelihood of the negative effects of vibriosis impacting wild fish as a result of infection from farmed fish is considered to be low.

Furunkulosis (typical and atypical): Typical furunkulosis has been practically eradicated from Norwegian fish farms. Atypical furunkulosis is however a growing problem in cod farming. A decline in cod production in 2010 is expected to cause a decline in the prevalence of this disease. The risk of infection spreading to wild fish is therefore considered to be low. Consequently, the likelihood of the negative effects of furunkulosis impacting wild fish as a result of infection from farmed fish is considered to be low. However, there is also a likelihood that an increase in cod farming without access to an effective vaccine could bring with it infection of significance for local cod populations and possibly also for other marine fish species.

The risk of infection of wild fish in the sea phase from *Renibacterium salmoninarum* (which causes BKD) is considered to be low. The likelihood of the negative effects of BKD impacting wild salmon in the sea phase as a result of infection from farmed fish is considered to be low.

The risk of infection of wild fish from *Piscirickettsia salmonis* (piscirickettsiosis) is considered to be low. The likelihood of the negative effects of piscirickettsiosis impacting wild salmon in the sea phase as a result of infection from farmed fish is considered to be low.

In Norway, francisellosis is a problem in cod farming. A decline in cod farming in 2010 is expected to cause a decline in the prevalence of this disease. The risk of infection spreading to wild cod is therefore considered to be low. The risk of it spreading to wild salmon is considered unlikely in the current situation. Consequently, the likelihood of the negative effects of francisellosis impacting wild fish as a result of infection from farmed fish is considered to be low. However, there is also a likelihood that an increase in cod farming without access to an effective vaccine could bring with it infection of significance for local cod populations.

The risk of infection of wild fish in the sea phase from *Flavobacterium psychrophilum* is generally considered to be low, with the exception of the Osterfjord area (Hordaland), where salinity stays low for long periods. The likelihood of the negative effects of flavobacteriosis impacting wild salmon in the sea phase as a result of infection from farmed fish is generally considered to be low, as the bacteria is absent from seawater with salinity of over 2%.

Parasitic diseases

The infection pressure of *Paranucleospora theridion* is apparently dependent on the abundance of lice, as the parasite does not appear to spread from fish to fish. The development and proliferation of the parasite depends on ambient temperature, and it is not common in the north. The risk of infection of wild fish with contagion propagated in lice from fish farms is considered high in southern Norway. The significance cannot be assessed, as very little is known about the effect of the parasite on salmon.

The risk of infection of wild fish from *Parvicapsula pseudobranchicola* is considered to be low. The likelihood of the negative effects of infection impacting wild salmon in the sea phase as a result of increased infection pressure due to salmon farming is considered to be low.

It is difficult to make a lastingly valid risk assessment of the effects of fish farming today on the disease status among wild fish based on currently accessible data. The few reports that are available indicate that pathogen transmission from farmed fish to wild fish occurs. Therefore the possibility that pathogens in the sea phase (in addition to salmon lice) can be of significance for stocks of wild salmon through causing disease cannot be excluded. To what extent this occur is not known at present. Data from the salmon farming sector shows that viral diseases (or likely viral diseases) represent the greatest risk in terms of infection from the fish/salmon farming industry today. IPN, PD, HSMB and CMS have dominated the disease picture in fish farming in recent years. It appears that fallowing, separating generations, zoning and other hygienic measures have not brought these diseases or their spread under control. The lack of effective vaccines renders control of these diseases difficult.

5.2 GENETIC EFFECTS

5.2.1 Genetic effects – salmon

What serves as the basic criteria/indicators?
The strategy for sustainable aquaculture expressly states the goal that fish farming activities must not cause lasting genetic changes to wild populations. Such impactive changes could lead to a loss of biodiversity in Norwegian wild salmon and reduced production abilities in individual populations. In this assessment of current conditions, we have sought to identify the basic data that can contribute to spotlighting the issues and enabling accessible knowledge in regionalised form.

In assessing the condition of stocks in the different counties, we wish primarily to determine the impact that escaped farmed salmon have or could potentially have on the genetic composition of individual populations and on the natural differentiation that has been shown to exist between populations. Direct observations of genetic changes in populations over time are easy to carry out with the DNA tools that have been developed in recent years. Proving that such changes are a consequence of interbreeding with farmed fish have been more difficult, although new SNP markers currently under development can potentially resolve this particular problem. It is difficult to demonstrate the effects of interbreeding on population productivity and there are few published studies that put a figure on such effects. The effect on the individual population will depend on a number of factors, such as the proportion of escaped fish in the spawning population, the population's state of reproduction, the extent to which escaped farmed fish can successfully spawn, genetic differences between the escaped fish and the local population etc. Also, different populations could be affected in different ways because different gene complexes can be involved in local adaptation to local environmental conditions in different watercourses.

We have attempted to map which sets of data are available and relevant for quantification and risk assessment of the effect of escaped salmon on wild populations. These sets of data are shown in Table 5.2.1.1 and commented on below.

Changes in the productive abilities of populations
Direct estimates of the effect of escaped salmon on the productive abilities of wild populations are to our knowledge only available from two studies carried out in Imsa in Rogaland (Fleming et al. 2000) and in Burrishoole in Ireland (McGinnity et al. 2003). These studies each give a clear indication of the production reducing effect of interbreeding between wild populations and escaped farmed salmon, although it is difficult to generalise and determine general quantitative effects or establish direct connections with other measurement parameters, such as the proportion of escaped salmon in spawning stocks.

Changes in genetic structure and biodiversity
Data showing changes in genetic structure among wild salmon populations over time are available for a few Norwegian wild salmon populations (Skaala et al. 2006). This

Table 5.2.1.1
Available data for risk assessment linked to genetic effects of escaped farmed salmon.

Parameters/data series	Available data
Change in the populations productive ability.	Two published experiments (Rogaland, Norway and Ireland). No data series.
Change in genetic structure, biodiversity.	Early studies from Ireland, one published study from Norway over several populations. No data series.
Number of escapees in the spawning populations.	Time series: analysis of scales taken from sport fishing catches and autumn fisheries on spawning stock combined with registration of spawners.
Level of escapees in the region.	Reports from fish farmers on number of escapees. Statistics by the Directorate of Fisheries.
Population status of wild salmon.	Directorate of Nature Reserve's category status for salmon producing rivers are under revision and not available at present.
Harvest status in salmon rivers.	Harvest status for approx 200 rivers is published by The Scientific Advisory Board for Salmon Advice.

study gave indications that the changes observed in smaller populations could be attributable to the high proportion of farmed salmon in spawning stocks over time, although the genetic indicators that were used were not suitable for the purpose of quantifying interbreeding with escaped farmed salmon. A more comprehensive set of data on genetic changes/stability over time is currently under development at the Institute of Marine Research. This project will involve analysis of historic and present-day data from 22 salmon rivers for stability on neutral genetic indicators, and also for variation in so-called SNP indicators to enable a quantification of the degree of interbreeding with escaped farmed salmon in wild populations.

Proportion of escaped salmon in spawning populations

Several sets of data are available for escaped farmed salmon in rivers. This consists in part of analyses and classification of fish scale samples taken from fish caught by anglers, and in autumn the proportion of escaped salmon in the spawning population are estimated by several methods, including rod fishing and netting, in a number of rivers. Research indicates that escaped farmed salmon have a tendency to migrate upriver later than wild salmon. Estimates of escaped farmed fish in the rivers vary between the two data series, and the proportion of escaped farmed salmon is consistently higher in the autumn (Anon 2010). There are also indications that the proportion of farmed salmon that have escaped at an early stage is somewhat higher among salmon caught in the recreational rod fishery, while there are more immature adult salmon among the autumn catch (Harald Sægrov, personal comment.). It is unclear to what extent the data collation method is standardised between years and localities. Lack of standardisation will give rise to numerous sources of error in the data material. Given that the focus in the autumn investigations are primarily directed towards removing escaped farmed salmon, this can result in over-estimates of the proportion of escaped farmed salmon. Similarly, collection of broodstock fish for supplemental breeding in hatcheries can give an over-estimation of the proportion of wild fish. Classification of wild salmon and escaped farmed salmon based on morphology and fish scale analyses has reportedly become increasingly difficult in recent years. This may be due to the fact that farmed salmon that escape early assume a growth pattern resembling that of wild salmon, possibly because growth among wild salmon in the sea in recent years has apparently been reduced. In addition, classification based on morphology and growth patterns does not identify salmon that are the offspring of interbreeding between wild salmon and escaped farmed salmon.

Extent of escapes in different regions

All escape episodes must be reported to the Norwegian Directorate of Fisheries, where figures are available showing the number of escapes in different regions over the years. However, these figures include only registered escapes from fish farms. There are reasons to believe that the numbers of escaped farmed fish are higher than indicated by these figures and that there are more escapes of salmon in the smolt phase, which are not included in these statistics. Fiske et al. (2006) showed that fish farming activities in a region and escaped farmed salmon in nearby rivers are correlated to a certain degree. Because escapes range from smaller, often undetected and unreported "drip escapes" to larger episodic events involving mass escapes of farmed salmon, it is difficult to use the reported escape figures as a direct parameter for estimates of the effect on wild salmon populations.

Status of stocks in wild salmon populations

The effect of escaped farmed salmon on wild salmon populations depends not only on the proportion of escaped farmed salmon in the spawning population, but also in the condition of the wild population. Numerous populations with sufficiently large spawning populations to achieve the spawning target can seem less vulnerable to receiving large numbers of escaped farmed salmon than small populations that fall short of the spawning target (Skaala et al. 2006). However, these results must be interpreted with some caution, given that the survey was based on variations in neutral genetic indicators and changes can occur in genes or gene complexes that are of significance to growth and survival, even though no changes are observed in the neutral indicators. In a risk assessment, an assessment of the condition of the watercourses in each county would have been a great help. The Norwegian Directorate for Nature Management has previously issued a stock characterisation, but this has not been updated in recent years and has a number of weaknesses, and as a result the Norwegian Directorate for Nature Management has advised against using it. A new stock characterisation report is currently under preparation, but will not completed in 2010.

Status of stock decline in salmon watercourses

A first generation conservation limit (CL), defining the number of spawning females to achieve full utilization of the river habitat, has been drawn up for most of the salmon watercourses in Norway. In report no. 2 from the Scientific Advisory Committee for Atlantic Salmon Management in Norway (Anon. 2010), catch reports from watercourses (compared with catch rates and other information) are used to assess the extent to which CL was attained in approximately 200 watercourses. The proportion of rivers in a region that attain CL gives an indication of the status of stocks of wild salmon in the region. And while there can be many reasons why CL is not attained (stock decline, low sea survival, intervention in rivers etc.), this overview still provides useful additional information that can be used in a risk assessment.

Of the different types of measurement parameters discussed here, we have chosen to use the proportion of farmed fish found in rivers during the autumn investigations, as in practice this is the best data series that is available for this purpose. The proportion of escaped farmed fish in autumn investigations gives an indication of both the numerousness of the population (and thus to a certain degree the condition) and the amount of escaped farmed fish. In our work, we have categorised the impact of escaped farmed fish in the spawning stocks as follows: low impact (0%–5%), moderate impact (6%–20%) and high impact (>20%). However, we are of the opinion that this base data is far from sufficient for the purpose and that precision in the risk assessment ought to be improved by improving the existing set of data and developing new smonitoring data sets that more closely approximates the issues on which we wish to cast light. In ongoing monitoring activity of the Institute of Marine Research, the DNA profiles of over 20 Norwegian salmon populations are being monitored. From 2011, this work will provide an overview of the degree of impact on these monitores, and will provide a basis for a repeatable and quantitative measurement series that will be of great use in the years to come.

Data material and data uncertainty

In this overview, we have taken as our main starting point the registration of escaped farmed salmon in rivers in the autumn and which have been reported to the Norwegian Directorate of Fisheries in connection with the programme for assessment of national salmon watercourses. Material is available for the period 2006–2009. However, the data is so limited in number that we found it served our purpose better to summarise the figures from all four years for all rivers in each county, in order to give an indication of the numbers of escaped farmed fish found in them. More in-depth analyses are only possible in exceptional cases with the existing material. In addition, we have drawn on data provided by the Scientific Advisory Committee for Atlantic Salmon Management in Norway and reports from consultant biologist company Rådgivende Biologer AS.

When we have categorised the counties into the three categories – low, moderate and high – the numbers of escaped farmed salmon present in the spawning populations will be used to approximately determine their impact. It should be pointed out that there are significant variations within areas categorised as ”moderate” and that many watercourses can have exceeded the high impact limit. According to current knowledge, it remains unclarified, though likely, that many rivers in such areas will be significantly affected if current levels of escaped farmed salmon continue in the years to come.

An overview of the proportion of escaped farmed salmon on a per county basis is an oversimplification and by no means constitutes a natural physical or biological regionalisation. In a number of counties, such as Rogaland and Sør-Trøndelag, there are regions that are affected to extremely varying degrees, which appears to mirror the density of aquaculture activity. From a risk assessment perspective, neither the base data that is available nor the knowledge status about mechanisms of action are good enough to forecast future developments in the regions. Simulations are available showing that, with the proportion of escaped farmed salmon in the rivers at the level we have seen over the last ten years, we will see a gradual change in the genetic structure of stocks in all counties (Hindar et al. 2006). In a further development of the model, calculations have been made of the degree of interbreeding between escaped farmed salmon and stocks of wild salmon in different regions in Norway in 2009, based on the average proportion of escaped farmed salmon in these regions. The results from the simulations show that in several regions the proportion of original wild salmon in stocks has already been reduced and that the proportion of escaped farmed fish in spawning stocks needs to be reduced to an extremely low level, if not to zero, if the stocks are to return through selection to having pure wild salmon (Diserud et al. 2010). Even though these models are based on relatively uncertain data in terms of the real proportion of escaped farmed salmon in spawning stocks, successful spawning among escaped farmed salmon and marine survival of the offspring of farmed salmon that spawn in the rivers, the results indicate that in a precautionary approach

Table 5.2.1.2
Status of wild populations of salmon divided by county (source:Anon 2010) and amount of escaped salmon – Autumn. (Source: Directorate of Fisheries)

		Assessment of harvesting					Escapees – survey 2009				Escapees – survey 2006-2009			
County	**# Rivers**	**# Rivers examined**	**Sustainable**	**Possibly not sustainable**	**Likely not sustainable**	**Far from sustainable**	**# rivers examined**	**# scale samples**	**# escapees**	**% farming per county**	**# scale samples**	**# escapees**	**% farmed fish**	**Assessment**
Østfold	2	2	1	1	0	0	1	73	37	50,7	311	148	47,6	Moderate. One large river (Glomma) seems to draw the escapees
Oslo og Akershus	1	1	1	0	0	0	0							No data
Buskerud	3	1	0	1	0	0	0							No data
Vestfold	3	1	0	0	1	0	1	68	2	2,9	207	5	2,4	Low abundance of farmed fish in a small river examined
Telemark	2	2	0	1	1	0	1	122	17	13,9	448	50	11,2	Moderate abundance of farmed fish in one river examined
Aust-Agder	3	2	0	0	0	2	2	158	17	10,8	606	79	13,0	Moderate abundance of farmed fish
Vest-Agder	8	7	1	1	1	4	2	94	0	0,0	437	5	1,1	Low abundance of farmed fish
Rogaland	30	22	12	6	4	0	6	174	16	9,2	772	56	7,3	Low abundance of farmed fish in Rivers on Jæren, moderate to high abundance of farmed fish in Ryfylke
Hordaland	24	6	2	2	1	10	1	90	50	55,6	781	314	40,2	High abundance of farmed fish
Sogn og Fjordane	32	20	14	1	3	5	6	324	81	27,1	893	209	23,4	High abundance of farmed fish
Møre og Romsdal	63	28	1	7	5	15	4	146	11	7,5	561	150	26,7	High abundance of farmed fish
Sør-Trøndelag	58	15	4	3	2	6	4	194	17	8,8	700	68	9,7	Moderate abundance of farmed fish, but lower within the Trondheim fjord
Nord-Trøndelag	28	10	2	0	3	5	2	293	40	13,7	1239	155	12,5	Moderate abundance of farmed fish
Nordland	103	33	6	2	10	17	2	76	12	15,8	989	31	3,1	Variability in the data set and many rivers with reduced population status, estimated to moderate.
Troms	34	20	6	3	2	10	2	72	6	8,3	183	30	16,4	Very few data, estimated to moderate impact on basis of other data
Finnmark	37	27	8	8	3	8	4	203	9	4,4	727	50	6,9	Low abundance of farmed fish

and until more precise knowledge is available, strict limitations should be set for the proportion of escaped farmed salmon in spawning stocks. In this context, data from ongoing studies with SNP indicators will be extremely important in determining the present condition of the stocks and any initiatives that may be required. A complete risk assessment in relation to the present increased or reduced aquaculture production will have to be based on better monitoring data and mapping of mechanisms that can help quantify the models to a greater degree. The development of aquaculture technology, regulations and other circumstances that may influence the strength of the stocks must also be taken into consideration.

Assessment of escaped farmed salmon by county

In the following, we have given an assessment and categorisation of each county based on available knowledge.

Østfold: The data is from the autumn catch in a large river (Glomma) with relatively weak stock that clearly attracts a large proportion of escaped farmed fish (approx. 50%). The proportion of escaped farmed fish in the recreational rod fishery in the county's other watercourses indicates that they contain a low proportion of escaped farmed fish. Assessment: Moderate proportion of escaped farmed salmon.

Oslo and Akershus: No data.

Buskerud: No data.

Vestfold: One of three rivers has been inspected. Assessment: Low proportion of escaped farmed fish.

Telemark: One of two rivers has been inspected. Assessment: Moderate proportion.

Aust-Agder: Two of three rivers have been inspected. Assessment: Moderate proportion.

Vest-Agder: Two of three watercourses have been inspected. Assessment: Low proportion.

Rogaland: Moderate proportion if we take the county as a whole (6 of 30 watercourses inspected in total, 4 in 2009), but there are significant differences within the county. While the rivers along the coast of Jæren have a low proportion of escaped farmed salmon, proportions are higher in rivers in Ryfylke. Scale samples from recreational rod fisheries confirm this polarisation within the county. Assessment: Low/high.

Hordaland: Just one river inspected in 2009 (up to 4 previously). This is in part because fishing has been stopped in a number of weak stocks in the county. But consistently high proportion both there and in registrations in a number of rivers throughout the sportsfishing season. Assessment: High proportion of escaped farmed salmon.

Sogn og Fjordane: Data from 6 of 32 watercourses in 2009, and a further 2 have previously been included. Although the proportion in the recreational rod fisheries in a number of watercourses is lower than in autumn, all regionalised data shows that the proportion is high. However, there are large variations between rivers in the county, and a high number of watercourses have fairly sized spawning stocks. Assessment: High proportion.

Møre og Romsdal: 5 of 63 watercourses have been inspected (4 in 2009). Few good stocks in the county and relatively few scale samples have been investigated. Consistently high proportion of escaped farmed fish when the data sets covering the period 2006–2009 are collated. Assessment: High proportion.

Sør-Trøndelag: 4 of 58 rivers have been inspected. Stocks in Trondheimfjord are generally in better condition than those along the coast, with periodically low proportion of escaped farmed fish. Assessment: Moderate proportion.

Nord-Trøndelag: Moderate proportion in the 2 watercourses inspected out of 28 in the county in 2007–2009. The data is dominated by a lot of material from Namsen. Assessment: Moderate proportion.

Nordland: Low proportion in samples from 5 of 103 registered salmon rivers over a four-year period. However, most of the rivers in the county have very weak stocks and there are substantial differences between samples from different years and between rivers. The proportion was low in the two rivers reported from in 2009. Assessment: Moderate proportion.

Troms: Moderate proportion in 2 out of 34 watercourses inspected. The material reported to the Norwegian Directorate of Fisheries comprises only 183 scale samples in total from four investigations over a four-year period, and is therefore extremely sparse. Other registrations reported by the Scientific Advisory Committee for Atlantic Salmon Management in Norway confirm that proportions range from moderate to high in a number of stocks. Assessment: Moderate proportion.

Finnmark: Low proportion in 2009 in the 4 rivers that were inspected (out of a total of 37). The summarised figures for the last four years show a moderate proportion, although the average is inflated by Vestre Jakobselv, where the proportion is higher and was one of only 2-3 rivers inspected in previous years. Assessment: Low proportion of escaped farmed salmon.

Uncertainty of threshold values

In a risk perspective, it is difficult to define absolute threshold values for what can be considered an acceptable degree of impact. This applies especially where there are no methods for measuring the impact directly and instead estimates must be given based on other measurement parameters where the relation with the degree of impact is not unequivocally formulated. In this case, for example, the proportion of escaped farmed fish in the rivers could serve as an indicator or proxy of the impact on genetic structure, biodiversity and the productive capability of the wild salmon population. However, there is uncertainty in the estimates of the proportion of escaped farmed salmon and also the relation between this proportion and its impact. This makes the risk assessment much more uncertain than it ought to be, given that it is for use in an management context. In addition, there are local and regional variations in vulnerability for this type of impact. Different wild salmon populations with variable stock status and exposed to different environmental conditions will respond differently to a given proportion of escaped farmed salmon in the spawning population. Another key factor is the degree of success in spawning among escaped farmed salmon in the rivers. Here, too, the base data is limited. The extent to which the proportion of escaped farmed salmon comprises in general early escapes of salmon that have had a natural lifecycle, or in part immature salmon that have escaped as adults, will also give significant variations in relation to the impact that a given proportion of escaped farmed salmon will have on the wild salmon population.

In making these assessments, we have decided to define a proportion of escaped farmed fish of fewer than 5% as low. This is roughly at the level of average natural straying between populations of wild salmon. Of course, it can be claimed that even such a low level could still influence the condition if the population, as it is additional to natural straying. Thus it represents an ”additional load” that puts local adaptation under further pressure.

We have defined a proportion of escaped farmed salmon of between 6% and 20% as moderate. While there is not really much solid basis in research for defining 20% as an upper limit for moderate impact, a model study by Hindar et al. (2006) simulated the effect of different proportions of escaped farmed salmon on populations of wild salmon and found that a proportion of over 20% would over time result in significant genetic changes in the populations. Based on the results from this study, we have decided to define 20% as an upper limit for moderate impact. However, we would again emphasise that the impact of a given level of escaped farmed fish has depends on the condition and then genetic complexities that are key to local adaptation in the individual population. It is important to take into consideration the present condition of the stocks in assessing what proportion of escaped farmed salmon in spawning stocks can be characterised as low, moderate or high. When new data becomes available on the degree of past interbreeding of escaped farmed salmon in wild salmon stocks, these limit values may require adjusting and adapting to the individual stock/region so that the goal of preserving the genetic integrity of wild salmon stocks is maintained.

5.2.2 Genetic effects – cod

In order to make a risk assessment, extensive knowledge is essential, as discussed in Chapter 4.2. As far as coastal cod is concerned, there is a lack of data for important parameters such as stock structure, population size and migratory patterns. Also, any interbreeding with foreign genetic material will be related to how many escaped farmed cod are to be found in a given area. To date, no systematic monitoring or registration along the coast has been carried out. There is also insufficient data on survival rate, dispersal and spawning success among escaped farmed cod. To assess the risk of any genetic effects, we have therefore had to rely on the official statistics from the Norwegian Directorate of Fisheries supplemented with data and registrations from our own surveys in selected areas (Hordaland, Sogn og Fjordane; Chapter 4.2.2).

In Table 5.2.2.1 we have summarised the number of released cod in the sea over the last three years and compare this with reported number of escapes. The figures are given per county and clearly show which areas are dominant in terms of both production and reported escapes (Møre og Romsdal; Nordland). Troms has the biggest percentage of registered escapes and the counties in the western part of Norway the lowest. In recent years there has been a strong focus on escaped farmed cod in the counties in the north of Norway, although there are no systematic field registrations of the proportion of escaped farmed cod in these areas nor instances of escaped farmed cod in, for example, important spawning fields for coastal cod. In some cases, the Institute of Marine Research together with the Norwegian Directorate of Fisheries have collected samples in order to identify sources of escapes (Storfjord in Troms; Skjerstadfjord in Nordland). In other cases, samples have been taken in areas with a special farmed cod (Tresfjord in Møre og Romsdal) or following escape episodes (Masfjord in Hordaland). The proportion of farmed cod based on external morphological characteristics is given in Table 5.2.2.2. The proportion in Skjerstadfjord was over 23%, while it was close to 5% in Tresfjord. However, our samples are so small that it is not possible to make assessments in the counties from Møre and Romsdal northwards. Skjerstadfjord stands out as a specific area for follow-up, while in the other areas inspections need to be carried out in order to acquire the necessary baseline data. There has not been any systematic registration of farmed cod in Rogaland. Escaped farmed cod was also registered in 2007 through other surveys (Table 5.2.2.2), but also here there is a lack of baseline data.

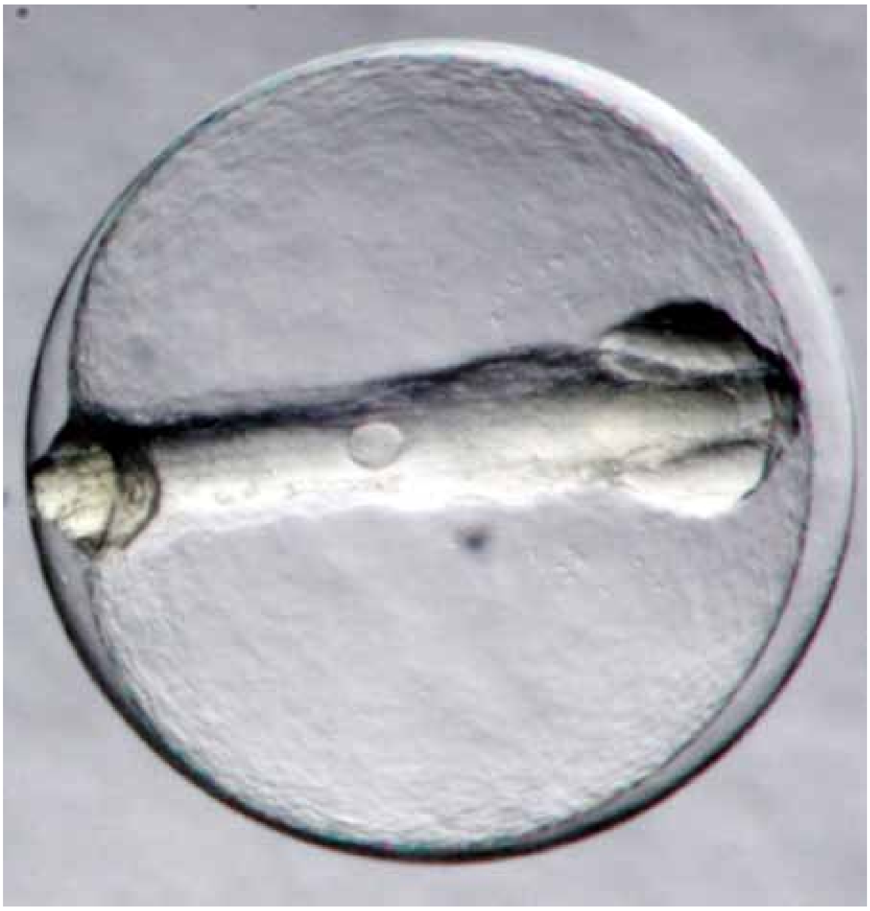


Table 5.2.2.1
Number of cod fingerlings transferred to sea cages and number of cod escaped in the period 2007–2009.

Counties	Transfer* 2007–2009	Loss (escapees)* No	in %
Finnmark og Troms	3 691	135	3,7
Nordland	18 358	145	0,8
Trøndelag	3 368	43	1,3
Møre og Romsdal	13 513	231	1,7
Sogn og Fjordane	4 997	9	0,2
Hordaland	1 840	0	0,0
Rogaland/other counties	2 104	38	1,8
Total	**47 871**	**601**	**1,3**

*Source: Directorate of Fisheries

In Hordaland and Sogn and Fjordane, the Institute of Marine Research has ongoing projects that are registering escaped farmed cod in selected areas. This applies particularly to Austevoll, Hosteland in Masfjord, Gulen and the Florø area (Table 5.2.2.2). Therefore our own registrations form the basis for the assessments given below, although we would emphasise that these data do not give a complete picture per county.

There is a great deal of uncertainty associated with the threshold values used in the assessments below. The low risk assessment applies where the proportion of escaped farmed cod in total during the inspection period for a given locality comprises under 10% of the total number sam-

Table 5.2.2.2

Locality	Date of sampling	Number of cod examined	Escapees (n)	% escapees
Nordland:				
Fauske and Bodø: Skjerstadfjorden	04.11.–05.11.09	60	14	23,3
Møre og Romsdal:				
Vestnes: Tresfjorden	29.04.09	110	5	4,5
Sogn og Fjordane:				
Flora: Nærøysund	21.02.07	109	19	17,4
Flora: Nærøysund–Seljestokken	03.04.–04.04.08	59	5	8,5
Flora: Florøområdet	08.06.–12.06.08	78	51	65,4
Florø: Norddalsøya	24.10.–26.10.08	119	16	13,4
Florø: Årebrotsfjorden	28.10.–29.10.08	138	109	79,0
Florø: Brandsøysund and Klavfjorden	29.10.–30.10.08	47	12	25,5
Flora: Årebrotsfjorden	12.06.09	62	23	37,1
Flora: Brandsøysund and Klavfjorden	14.06. og 17.06.09	34	0	
Flora: Norddalsøya	15.06.–16.06.09	53	1	1,9
Flora: Årebrotsfjorden	25.10.–29.10.09	60	8	13,3
Flora: Kvalvika	27.10.–30.10.09	48	16	33,3
Flora: Brandsøysund and Klavfjorden	29.10.–02.11.09	84	7	8,3
Flora: Norddalsøya	31.10.–02.11.09	83	1	1,2
Flora: Uravågen	02.03.10	38	1	2,6
Flora: Årebrotsfjorden	02.03.10	46	5	10,9
Flora: Haukå i Norddalsfjorden	03.03.–04.03.10	37	5	13,5
Askvoll: Flokenes in Førdefjorden	02.03.–03.03.09	96	6	6,3
Askvoll: Flokenes in Førdefjorden	05.03.–06.03.10	43	2	4,7
Askvoll: Gjelsvika in Førdefjorden	06.03.10	3	0	
Naustdal: Engebø in Førdefjorden	07.03.10	5	1	20,0
Gulen: Byrknesøy	16.02.07	28	0	
Gulen: Ånnelandsundet	06.03.09	27	0	
Gulen: Ånnelandssundet north	07.06.–08.06.09	57	7	12,3
Gulen: Ånnelandsundet north	16.10.–24.10.09	115	7	6,1
Gulen: West of Mjømna	19.10.–21.10.09	84	3	3,6
Gulen: Ånnelandsundet south	22.10.09	19	0	
Gulen: Vassvik	23.10.–24.10.09	30	3	10,0
Gulen: Lesdalsvåg Byrknesøy	01.03.–08.03.10	98	3	3,1
SUM Sogn og Fjordane:		**1700**	**311**	**18,3**
Hordaland:				
Masfjord: Hostelandsundet	10.03.09	108	80	74,1
Masfjord: Hostelandsundet	16.10.09	83	32	38,6
Masfjord: Solheim	25.02.10	90	61	67,8
Masfjord: Hostelandsundet	26.02.10	96	31	32,3
Øygarden	23.02.–24.02.06	11	0	
Austevoll: Heimarkspollen	08.11.–07.12.07	42	0	
Austevoll: Heimarkspollen	01.02.–20.10.08	98	0	
Austevoll: Heimarkspollen and Osen	18.12.08.–04.06.09	406	0	
Austevoll: Heimarkspollen and Osen	22.12.09–26.05.10	318	2	0,6
Austevoll: Drønspollen and Busepollen	26.02.–19.05.09	73	0	
Austevoll: Drønspollen, Busepollen	17.12.09–11.05.10	140	0	
Austevoll: Huftarøy east, Storebøvågen east	26.02.–04.06.09	23	0	
Austevoll: Huftarøy east, Storebøvågen east	19.01.–11.05.10	9	2	22,2
North of Bømlo	01.12.–20.02.06	64	0	
Tysnes: Færevåg	01.03. og 24.03.09	97	1	1,0
Tysnes: Færevåg	24.02.10	96	0	
Fusa: Vinnes	28.09. og 13.10.–14.10.09	134	1	0,7
Fusa: Ådlandsfjorden	22.02.10	23	0	
Kvinnherad: Halsnøy	01.12.–20.02.06	96	0	
SUM Hordaland:		**2007**	**210**	**10,5**
Rogaland and other counties:				
Strand: Tau, Boknafjorden	16.02.07	28	0	
Suldal: Stokkavåg, Sandsfjorden	21.02.07	58	2	3,4
Suldal: Sand, Sandsfjorden	26.02.07	16	0	
Nordvest for Finnøy, Boknafjorden	21.02.07	36	0	
Boknafjorden	19.02.–20.02.06	59	10	16,9
Sokndal: Siragrunnen, Åna Sira	01.03.07	83	0	
Farsund: Lista northwest	28.02.07	39	0	
Farsund: Lista south	2.03.07	52	0	
Lillesand: Brekkestad and Blikkøy	16.02.07	91	1	1,1
SUM Rogaland and other counties:		**462**	**13**	**2,8**

◀ ***Table 5.2.2.2***
Escaped cod presented at different localities. The sampling was undertaken by the Institute of marine research in the period 2006–2010 and the assessment is based on several methods, but in most instances on outer morphological traits. In some instances genetic markers have been used.

pled, while the moderate risk assessment applies where the proportion of escaped farmed cod is between 10% and 30%. The high risk assessment is used where the proportion of escaped farmed cod is over 30%.

Hordaland

In the official statistics (Table 5.2.2.1), there is not much production of cod in the sea and no reported escapes. In our inspections, a total of 2007 cod were checked and of these 210 (10.5%) were classified as escaped farmed cod based on external morphology. A large proportion of the escaped farmed fish were found in Masfjord municipality. In this area the proportion of escaped farmed cod was found to be between 30% and 70%, and the reason for this can only be unreported escapes. Disregarding the registration from the Masfjord area, the figures for the rest of the county are low, which was expected based on the official figures from the Norwegian Directorate of Fisheries. Based on our registrations, established and unreported escapes, and given that we lack data from the southern areas, we assess the general risk in this county to be moderate. However, based on the collated data (Table 5.2.2.2), it is clear that the risk assessment for Hordaland does not fully reflect the prevailing situation. The high figures shown for Masfjord are alarming. No escapes are reported in the official statistics, but the proportion of farmed cod among the samples from the area is extremely high. In this area, we consider that there is a high risk of genetic changes, while the other inspected areas are considered to be low risk (Figure 5.2.2.1). It should be noted that in 2010 farmed fish were observed in Austevoll, where they have not previously been seen.

Sogn og Fjordane

Official statistics for this county also show very low reported number of escapes from fish farms (Table 5.2.2.1). Through our registrations in the Florø area in connection with the surveys referred to above- and based on genetic indicators, we have detected that a total of three unreported escape incidents have occurred from the farm in question. In addition, escapes of farmed cod have been registered based on morphology. The actual figures are given in Table 5.2.2.2. A total of 1700 fish have been registered, of which 311 fish (18.3%) were farmed cod. The material is, of course, dominated by the samples from the Florø area, although farmed cod have also been found in other areas: Førdefjord and Gulen. Based on existing data, we consider the risk of genetic changes in stocks of wild fish generally in the county to be moderate.

The Florø area is an interesting case in terms of escaped farmed cod, with high proportions of escaped farmed cod (25%–79%, Table 5.2.2.2). In this area, offspring from escaped, genetically marked farmed cod (see above) have been identified. The actual farm in question has been closed down and we can see a clear downward trend in the proportion of escaped farmed cod in the area. To what extent this is attributable to dispersal or an inability to survive is unclear. In this connection, we have found genetically marked cod near Engebø in Førdefjord, approximately 30 km away from the farm in Florø. If we focus on the Florø area, we consider the risk of genetic changes here to be moderate, but with a decreasing risk if the observed downward trend in the incidence of escaped farmed cod continues. For Førdefjord, the risk is considered to be low. For Gulen, there have been some samples that show a significant proportion of escaped farmed cod, although the general picture is that this area represents a low risk of genetic effects.

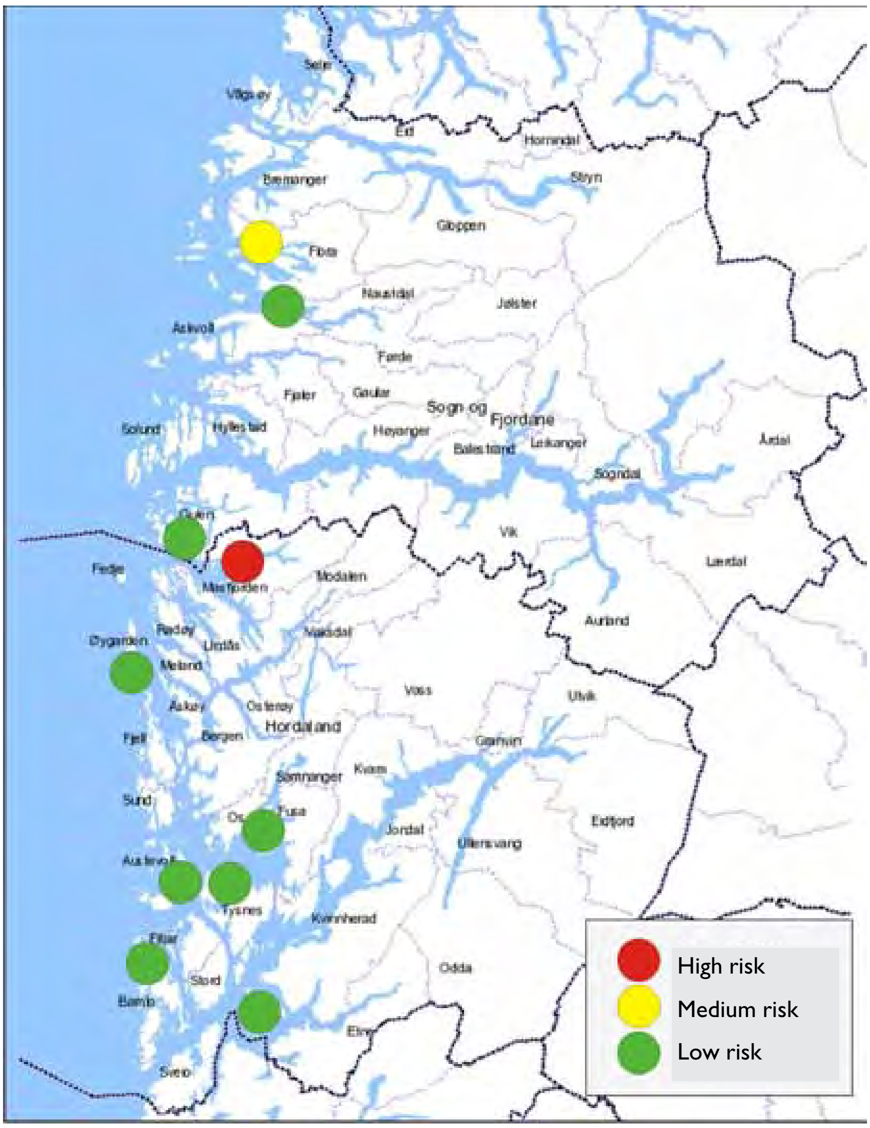


Figure 5.2.2.1
Assessment of risk for genetic change in wild populations of cod in selected areas in the counties of Hordaland and Sogn og Fjordane for the period 2006–2010. The assessment is based on the level of cod escapees as classified in Table 5.2.2.2.

5.3 NUTRIENT SALTS

Assessment of current conditions and risk of eutrophication at county level
In 2009, the total production of farmed fish (salmon, rainbow trout and cod) in Norway was about 950,000 tonnes distributed along the coast from Rogaland to Finnmark. The counties of Trøndelag have the highest production with approximately 190,000 tonnes per year, while Rogaland has the smallest production with 64,000 tonnes per year. Discharges of dissolved nutrients are directly related to the production level of fish, with the highest emissions in the counties of Trøndelag and the lowest in Rogaland. The total discharges of dissolved nutrients along the Norwegian coast are estimated to be approximately 9,800 tonnes of nitrogen and 1600 tonnes of phosphorous each year (2009: calculated by the Ancylus/MOM model). The discharges of dissolved nutrients from fish farms in 2009 calculated by each county can be seen in Table 5.3.1.

Discharges of nutrients from fish farms may have different consequences for phytoplankton production in the pelagic zone and for benthic macrophytes close to fish farms. In the following we will therefore distinguish between these.

Phytoplanktonin the pelagic zone
The effect of nutrient emissions will depend on the sea surface area the residence time and the current regime in the area where the nutrients are released. The sea area within the baseline in each county and the total sea area from Vest-Agder to Finnmark are calculated as the sum of the segments in the “Fjord catalogue” (Table 5.3.2). The total sea area is approximately 76,000 km^2 (not including the open areas of Vestfjorden).

Tables 5.3.1 and 5.3.2 show that there is high variation in the sea area in different counties and also in the emission of nutrients per year and km^2 . The highest discharge of nutrients per unit area is in Hordaland (0.46 tonnes nitrogen/year/km^2) and the lowest is in Troms/Finnmark (0.06 tonnes nitrogen/year/km^2). Mean phytoplankton production in Norwegian coastal and fjord areas, are approximately 130 g carbon/year/m^2 (Wassmann 1990 a, b). In order to assess a potential increase in phytoplankton production due to fish farming, an assumption based on 100% conversion of dissolved nitrogen to phytoplankton biomass during the growth season was made. Figure 5.3.1 shows that the highest increase in the natural levels of plant plankton biomass might be expected in Hordaland (4.8%) and the lowest in Troms/Finnmark (0.6%).

Natural chlorophyll-*a* values for the west coast of Norway are approximately 1.5–1.85 µg/l (Erga 1989 a, b, Wassmann 1990 a, b). With an increase of 4.8% as estimated for Hordaland, the elevated value will still be within the threshold for very good water quality (SFT 1997). Unfortunately there is a scarcity in basic data in the form of regular measurements of nutrients and chlorophyll along the coast from Rogaland to Finnmark. Based on estimates and models and given the current fish production levels, we consider the risk of regional eutrophication in all counties to be low. This is based on knowledge of the amount of discharges compared to water exchange and natural nutrient thresholds. Experience gained from the Hardangerfjord, Norway’s most intensive fish farming area, supports this assumption, although we cannot entirely rule out local impact when fish farms are located in areas with poor water exchange. As environmental conditions in the different water areas in Norway are assessed as part of the implementation of the Norwegian Water Regulation, we will attain more nuanced knowledge of which areas may be at risk of local eutrophication.

Macroalgae and eelgrass beds
The effect of dissolved nutrients from fish farms on benthic vegetation on the shore will likely vary according to the distance from source, the volume of discharge and the water exchange (currents, wave exposure etc.). Today, most fish farms are located close to land in the archipelago and the fjords. Dissolved waste from fish farms will result in continuous pulse of ammonium in the vicinity of the facility, which may impact benthic vegetation. At present, we are studying the possible local impact on seaweeds and assessing the size of the influence area. A few studies show increased values of ammonium around fishfarms that indicate an influence area of 500–1200 metres around farms. In areas with high production the farms are often situated less than 2 km apart, which could result in a continual stretch of coastline being impacted. Today we lack criteria for assessing the effect on benthic vegetation and therefore this will issued closer in the next risk assessment.

Table 5.3.1
Calculated release of dissolved nutrients (N & P) from fish farms in 2009 tabulated per county, year and km^2. The calculations are based on the Ancylus/MOM model (see text).

	Nitrogen (1000 kg/year)	Phosphorous (1000 kg/year)	Nitrogen (1000 kg/year/km^2)	Phosphorous (1000 kg/year/km^2)
Rogaland	670	110	0,25	0,040
Hordaland	1 813	300	0,46	0,076
Sogn og Fjordane	845	140	0,19	0,031
Møre og Romsdal	1 270	210	0,20	0,033
Trøndelag (S and N)	1 957	320	0,16	0,026
Nordland	1 800	300	0,09	0,015
Troms and Finnmark	1 500	250	0,06	0,010
Total	**9 855**	**1 630**		

Figure 5.3.1
Total sea area within the baseline for the counties on the coastal stretch from Rogaland to Finnmark. The open areas of Vestfjorden are not included. Source: Fjordkatalogen (the Fjord catalogue).

Tabell 5.3.2
Sea area within the baseline and total sea area in the coastal counties from Rogaland to Finnmark (open stretches of Vestfjord not included (Source:The Fjord catalouge).

County	Sea area (km^2)
Rogaland	2 723
Hordaland	3 959
Sogn og Fjordane	4 532
Møre og Romsdal	6 271
Sør-Trøndelag	7 262
Nord-Trøndelag	4 996
Nordland	19 906
Troms	11 354
Finnmark	14 604
Total	**75 601**

5.4 ORGANIC IMPACT

Organic particles from fish farms can be divided into two groups: those that sink quickly (>5 cm/s^{-1}) and settle on the seabed in the vicinity of the facility, and floating particles that can be carried with the current and impact areas further away. The impact of organic waste is highest in the vicinity of the facilities, although the area further away is normally less affected by waste from the farm and may also be influenced by other sources.

Mandatory monitoring of areas in close proximity to fish farm facilities with MOM-B inspections due to the standard NS 9410 was introduced in January 2005, and mandatory reporting of the results to the Norwegian Directorate of Fisheries started in summer 2009.

The MOM-B inspection includes a number of parameters and categorizes the impact on the seabed of the site in one of four conditions: Condition one denotes little impact and condition four is defined as severe overloading.

The recipient may also be monitored with MOM-C inspections, but is today only used under certain circumstances rather than in accordance with a fixed routine. MOM-C inspections are a modification of the more comprehensive seabed inspection following the standard NS-EN ISO 1666 and differentiate between four environmental conditions, of which no. 4 is defined as severe overloading and arises when the sediment is without animal life. To date, a public database for the results of the MOM-C inspections is lacking, but in the future such results will provide a valuable contribution in assessing the condition of the recipients.

Table 5.4.1 is based on information from the Norwegian Directorate of Fisheries regarding results from MOM-B inspections and shows the environmental condition at locality level in the period 2008 to 2010.

According to the results from the MOM-B inspections, the environmental condition under fish farms varies from average to good. Over 90% of the facilities have an environmental condition of one or two, i.e. little or no impact. 8% of the facilities are classified to condition 3, which is defined as on a critical limit to overloading. Two of the facilities have an environmental condition four, which is defined as overloaded. Of a total of Norwegian 996 localities, 332 have been inspected (source: Norwegian Directorate of Fisheries). Each aquaculture unit has several localities that are used in rotation, in addition to the mandatory fallow period. Therefore a large number of these localities will at any given time be without fish and therefore not inspected before being taken into use. Considering that mandatory reporting of monitoring results was first introduced in summer 2009, and since facilities with an environmental condition one are inspected every two years, the total number of facilities inspected can be considered reasonable. The inspections have their strength in the fact that they are regularly repeated, and future inspections will increase the strength of the monitoring.

A number of studies show that the impact on the seabed from food fish facilities is local and limited to a few hundred metres of the fish farms. However, currently the trend is fewer and larger facilities. There have also been suggestions to group facilities into clusters separated by infection prevention zones. It is possible that the cumulative effect from clusters of fishfarms may result in regional seabed impacts; however, these will probably be limited to the vicinity of the clusters.

The degree of impact, both locally and regionally, depends on the carrying capacity of the recipient and is a matter of the right localisation of the farms. At county level, there is no indication of a general overloading of the seabed caused by organic waste from aquaculture, based on the reported inspections.

Table 5.4.1
Organic impact on fish farms in Norway in the period 2008–2010 measured using National Standard 9410, B-survey. Condition 1 is best (low impact) and condition 4 is worst (high impact). *These data are based on statistics from Directorate of Fisheries.*

County	Condition 1	Condition 2	Condition 3	Condition 4	Total no of farms checked	Total no of farms within the county
Finnmark	5	2	2	1	10	62
Troms	21	8	0	0	29	107
Nordland	48	19	6	1	74	197
Nord-Trøndelag	15	5	2	0	22	71
Sør-Trøndelag	8	4	2	0	14	80
Møre og Romsdal	26	3	2	0	31	105
Sogn og Fjordane	23	5	3	0	31	99
Hordaland	50	31	6	0	87	197
Rogaland	14	8	4	0	26	64
Agder	4	4	0	0	8	14
Total	**214**	**89**	**27**	**2**	**332**	**996**

5.5 MEDICATION

There are at present no statistics available of consumption of medications at regional or county level, although the Norwegian Foods Safety Authority has the possibility to compile such statistics.

Antibacterial agents

Consumption of antibacterial agents has for many years been at a low, stable level and at the present time is not considered to have a serious impact on the environment. The development of resistant bacteria constitutes the most serious threat, and it has been proven that there is a connection between increased consumption and an increase in instances of resistance. An increased level of resistance will lead to diminishing treatment effectiveness. The transference of resistance from marine bacteria to human pathogens can occur, although the risk of this happening is considered to be small. The development of resistance can be countered by avoiding the consistent use of only one antibacterial agent. Therefore it is important to have several agents available with different action mechanisms. Sensitivity testing of pathogens prior to starting treatment with antibacterial medications ought to be mandatory. New species in aquaculture and new pathogens can again lead to increased consumption, and we must work to ensure continued low use by enabling the opportunity to develop new vaccines as needed. The environmental effect of medication should in principle be limited to the immediate proximity of the facility in question.

Antiparasitic agents

The antiparasitic agents can have a large effect on"non-target" organisms such as crustaceans, i.e. potentially sensitive species in the environment. The effect of antiparasitic agentsss used as bath treatment is considered to be limited due to rapid thinning. The orally administered agents used today are associated to a great degree with organic material such as faeces, waste feed and floating particles. These gather largely as sediment on the seabed under and to a limited extent around the facility. Today's fish farm facilities are bigger and sited in greater depths than in the past, and little is known about the actual concentrations of medications found in the sediment after medication. The content of antiparasitic agents in faeces and floating particles is also not known.

In order to assess the effect these agents have on "non-target" organisms, the level of sensitivity must be determined experimentally for each species and at different stages of life. This value is called the "No Observable Effect Level" (NOEL) or "No Observed Adverse Effect Level" (NOAEL). By comparing these values with measurements of the concentrations of agents in the sediment, water phase, floating particles and faeces, the effect on "non-target" organisms can be determined. At present, insufficient data is available on NOEL/NOAEL values for actual species such as deepwater prawns, crabs, lobsters and copepods (Calanus sp). Therefore it is difficult to comment on the effect that the use of orally administered antiparasitic agents have on these organisms. The effect is largely limited to the area around the facility, although we know little about how the agents may spread over a larger area when it binds to floating particles.

5.6 SUMMARY AND CONCLUSION OF RISK ASSESSMENT

The risk assessment is based on the goals specified in the ”Strategy for an environmentally sustainable Norwegian aquaculture industry” from 2009.

Goal 1 is associated with disease and infection, and reads: ”Disease among farmed fish shall not have a stock regulating effect on wild fish, and as much farmed fish as possible shall grow to slaughter with minimal use of medication”.

Goal 2 is associated with genetic interaction and escapes, and is defined as: ”Aquaculture shall not contribute to lasting changes in the genetic characteristics of stocks of wild fish”.

Goal 3 is associated with contamination and (other) discharges: ”All fish farm localities that are in use shall maintain acceptable environmental standard and shall not discharge nutrients and particulate organic material in excess of what can be tolerated by the recipient”.

For each of the three objectives, we have suggested and implemented effect indicators and threshold values for these for salmon lice, genetic effects of escaped farmed salmon, discharges of nutrients and organic load.

On the basis of these threshold values, we have assessed the national monitoring data (for each county or with higher geographical resolution). The risk assessment is based on whether the situation in each county (or area) exceeds these threshold values.

The assessment was graded into three levels, indicating the likelihood of being in conflict with the environmental goals in the sustainability strategy: low (green), moderate (yellow) and high (red).

By linking the risk assessment to the goals in the sustainability strategy, we can to a certain extent compare across different risk factors and counties.

The conclusion of the risk assessment is shown in Table 5.6.1, showing that there is a high likelihood that we are in conflict with the goals concerning salmon lice and/or genetic impact in all counties from Rogaland to Nordland. In Troms, this likelihood is considered to be moderate. However, the situation in Troms regarding salmon lice appears to be twofold, with a high likelihood in the south and a low likelihood in the north. Only Finnmark shows a low likelihood for all the factors assessed.

We have insufficient data to do a regionalised assessment on other infections than salmon lice.

The likelihood for negative environmental impact is considered to be low for nutrient salts and organic load on a regional scale in all counties examined. However, there can be local effects associated with nutrients.

Table 5.6.1
Summary of probability of negative environmental effects of salmon farming at a county level from Rogaland to Finnmark (based mainly on data from 2009–2010). Colour code (green = low, yellow = moderate, red = high, blue = lack of data) indicates our assessment of the probability of being in conflict with goals defined in "Strategy for an environmentally sustainable aquaculture industry".

	Goal 1	Goal 1	Goal 2	Goal 3	Goal 3	Goal 3	Goal 3
				Nutrients			
	Salmon lice	Other diseases*	Genetic impact	Euthropication in the free water masses	Local effect on vegetation*	Organic load	Drugs*
Finnmark							
Troms	**						
Nordland							
Nord-Trøndelag							
Sør-Trøndelag							
Møre og Romsdal							
Sogn og Fjordane							
Hordaland							
Rogaland							

*For the effect of other diseases, local effect on vegetation and drugs there is not enough data to do a regional assessment.
**For salmon lice there is not enough data for Troms in 2009–2010. The analysis is based on older data and modelling as described in the text.

Table 5.6.2
Probability score used in the county based assessment.
Where lack of data appears, see text.

High probability
Moderate probability
Low probability
Lack of data

To summarise, infection from salmon lice and genetic impact emerge as the most problematic factors in this analysis. All counties from Rogaland to Troms are considered to be problematic in terms of environmental sustainability, i.e. there is a high to moderate likelihood that the situation in these counties are in conflict with the goals stated in the sustainability strategy.

There are indications for a connection between the scale of salmon farming in a county and the likelihood of undesirable environmental effects in the same region. Given the biological, operational and technological limitations in today's salmon farming, we consider that a further increase in biomass in the counties from Rogaland to Troms can worsen the sustainability situation.

There is still limited regional data on both salmon lice infections and effects of escaped farmed salmon. In Chapter 6, we have suggested ways of obtaining better data for these factors and also for the other factors that are considered important. We would also point out the uncertainty in both the use of indicators and the threshold values for the likelihood of undesirable environmental effects. Proposals regarding further clarification and improvements in environmental indicators and threshold values (environmental standards) for sustainability are briefly outlined in Chapter 6.

Chapter 6

Recommendations for the work ahead

Foto: H.I. Svensen

6.1 FURTHER WORK ON RISK ASSESSMENTS IN NORWEGIAN AQUACULTURE

Photo: Lars Asplin

The current risk assessment of the Norwegian aquaculture industry have documented several problem areas in relation to the environmental objectives set out in the ”Strategy for an environmentally sustainable aquaculture industry” published by the Norwegian Ministry of Fisheries and Coastal Affairs in 2009.

In the current report, we have focused on goals 1–3 from this strategy that deal with the spread of infection to wild stocks, genetic effects, and local and regional effects of nutrient salts, organic load and use of medicines in Norwegian salmon sea farming systems. The current risk assessment has identified regional differences in sustainability status related to these three main objectives, and concluded that salmon lice and the genetic effects of escaped farmed salmon constitute the most significant environmental threats from Norwegian salmon farming .

The Institute of Marine Research would like to see this risk assessment carried out annually and to collate new monitoring data and take into consideration newly acquired knowledge of the effects. We would also like to see the analysis expanded to cover all five objectives in the sustainability strategy by also taking into account factors such as coastal area use, siting and site structuring and feed resources.

Based on interaction with the most important stakeholders, consideration could be given to increasing the scope of information, both on geographical and time resolution, and include more details in the annual risk assessment updates.

A critical factor in improving precision in the risk assessment is to have better knowledge, and more monitoring data in connection with the most critical influence factors. This includes having more precise indicators for environmental effect, a better knowledge base for threshold values for acceptable environmental effects and better knowledge on the dose-response effects of the different influencing factors.

In addition, we need more knowledge of the importance of geographical proximity in relation to such dose-response considerations, as well as detailed knowledge of coastal hydrography.

In this version of the risk assessment, we have not touched on risk-reducing measures. We recommend that this should be considered in future risk assessments. This consideration is based on the current risk assessment, which has identified a number of major challenges in terms of sustainability for the salmon farming activity for all counties from Rogaland to Troms. In particular, the situation regarding salmon lice infestasions on wild sea trout populations and the potential genetic impact on wild salmon stocks implicated by high incidence of escaped farmed salmon in salmon rivers urgently requires mitigating measures. Better measures and initiatives should also be considered in relation to other types of infections, such as viruses that can cause outbreaks of PD, as these pose a potential risk of infection among wild fish.

Animal welfare is not included in the ”Strategy for an environmentally sustainable aquaculture industry”. In our opinion, this is an element that goes together with the risk assessment for the aquaculture industry. This is also related to the fact that a number of initiatives under consideration in order to achieve environmental sustainability may also represent challenges from an animal welfare point of view, such as the implementation of new aquaculture technology, new operational models or new methods of fish farming. Therefore we recommend that animal welfare should also be integrated into future risk assessments.

Risk management falls within the sphere of the administrative authorities. Here, the research environments will play a central role in relation to proposals and assessments of new regulatory measures, better monitoring of conditions, assistance with tools for enforcement and inspection, and in ascertaining the achievement of stated objectives.

6.2 NEED FOR MONITORING, EFFECT INDICATORS AND THRESHOLD VALUES

6.2.1 Salmon lice

The programme for monitoring the effect of lice on wild salmonid stocks is extensive and demanding. The programme requires good geographical coverage of the Norwegian coast and a significant degree of detail in connection with assessments of national salmon fjords.

There are three areas of particular importance to take a closer look at:

1. *The threat of salmon lice:* We have to know with higher certainty to what degree salmon lice are a significant population regulating factor for wild salmonids in given areas. It is important to know this so as to determine if initiatives taken by the administrative authorities are adequate to tackle the problem, and also to convince the fish farming industry to accept the initiatives.
2. *Method validation:* We have to know with greater certainty that the methods we use to monitor and count lice on wild salmonids are sufficiently good and precise. In the future we must also strive to develop standardised, indirect methods (without the need to catch wild salmon).
3. *Sustainability model:* A regionalised sustainability model for salmon lice needs to be developed for use by the industry and the administrative authorities with the aim of having an operative system capable of assessing sustainability in each fish farming region along the entire length of the coast of Norway.

Most important is that we have good, standardised methods for registering the lice pressure on wild salmonids. Next, we must have good models for evaluating the effect of lice as population regulating factors. Also, using the ”coast model” in years to come will enable us to acquire detailed information about the dispersal of infection between localities, fjords and regions. In addition, a system must be developed for standard inspections that can be carried out by the industry and/or the administrative authorities. Based on the knowledge thus acquired and a detailed national monitoring programme, an operative administration system can be developed and implemented for regulating production of salmon lice within a sustainable framework.

6.2.2 Spread of other infectious agents

Indicators
To estimate infection preasure from farmed salmon in wild fish stocks, it will be relevant to establish indicators that – with measurements over time – will be able to identify changes in disease prevalence and the risk of infections from farmed to wild salmonids. Possible indicators of the influence of fish farming on the infection status in wild salmonid populations include:

- Changes in prevalence of agents in wild fish associated with outbreaks of disease among farmed fish.
- Pathogen prevalence in roe, fry and escaped smolt.
- Pathogens in the water in close proximity of fish farms and in rivers with high numbers of escaped farmed salmon.
- Prevalence of pathogens in escaped salmon in rivers.
- Pathogens carried in salmon lice (acting as possible transmission vector for certain pathogens).

Similar indicators can be established for wild marine fish.

Threshold values:
Due to the current lack of data it is not yet possible to establish threshold values for indicators related to the risk of transfer of infectious diseases from farmed salmon to wild fish stocks.

Specific recommendations:
Mapping of infection status among wild fish
There is a need for a monitoring programme for pathogens in wild fish in order to evaluate the influence of the aquaculture industry on the disease status among wild fish. It is also important to isolate and characterise naturally occurring genotypes of pathogens in wild salmonid populations, and use genotyping on pathogens to monitor potential spread of infectious agents from farmed to wild fish.

Mapping of pathogens in salmon in rivers
A sampling programme should be developed to identify pathogens in adult salmon in rivers, based on either non-lethal sampling on wild fish or sacrificed salmon (e.g. on escapes farmed salmon that are removed from rivers). Screening of egg and parr can also be a possibility. It is important to determine a baseline situation by monitoring the pathogen presence in salmon in selected rivers with no or very little influence from fish farms. This work can be carried out in connection with monitoring programme for escaped farmed salmon

in rivers. In watercourses where there is monitoring of spawning, water samples could be collected and analysed during spawning periods.

Mapping of pathogens in marine fish and invertebrates from aquaculture environments in connection with disease outbreaks

Few data are available on the spread of pathogens in connection with outbreaks of diseases in fish farms (i.e. precence of pathogens from farmed salmon in marine fish, mussels, other filterers, plankton etc.). At selected fish farms, specific sampling regimes can be activated under and after disease outbreaks on marine fish and other fauna in close proximity of the fish farm and compare with the pathogens found in the fish farm.

Establishment of biobank

The samples should also be used to establish a biobank. This will enable retrospective testing of samples for new agents or when new and better methods are available.

Use of model organisms

Data from the monitoring programmes can be used to model transmission routes. In this context, it is important to study pathogens under experimental conditions to ascertain their survival under different conditions.

6.2.3 Genetic effects – salmon

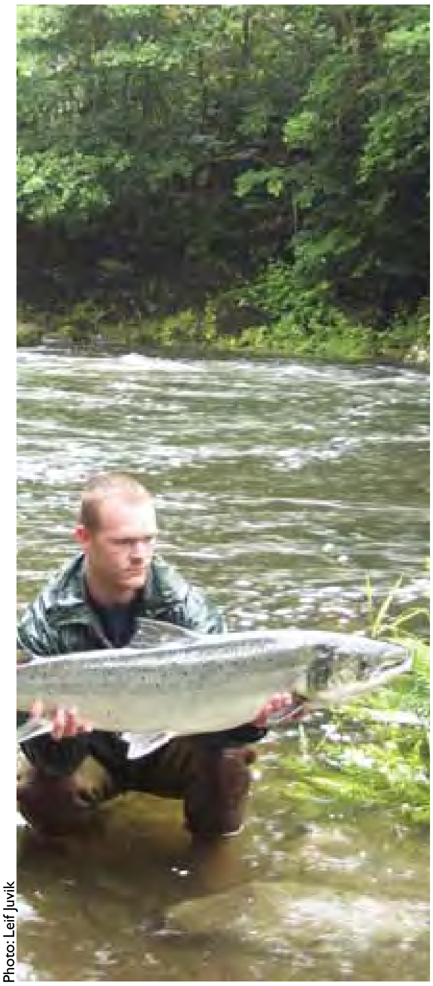


Photo: Leif Juvik

The most precise indicator we have on the genetic effects of escaped farmed salmon is registration of the proportion of farmed salmon found in spawning stocks. The survey system was initiated at the end of the 1980s and has been financed through various schemes. Since 2006, monitoring has been financed by the Norwegian Directorate of Fisheries. However, there are significant limitations to this indicator. There is no simple relation between the proportion of escaped farmed fish observed in a watercourse and the genetic changes that can occur in the population (Chapter 5.2.1), and the effect of interbreeding on the production ability of the stock is unpredictable. There is a need for more knowledge in this field, and direct measurements of interbreeding in the future, as well as experimental studies, can help increase understanding of the connection between the proportion of escaped farmed salmon in different stocks and interbreeding.

This is partly because the spawning success of the escaped farmed fish depends on a number of factors including sexual maturity, distribution by gender, density of wild spawning fish, genetic source and size of the escaped fish, time of escape, competition in the spawning area, and very probably also topography and water flow speed. Consequently, spawning success will vary from case to case, between years within a given watercourse and between localities. Survival of any offspring will also vary depending on genetic background and the degree of competition for growing space in the river. Farmed salmon that have escaped at an early stage can in some cases be difficult to distinguish from wild fish, and hybrids also cannot be distinguished from wild salmon by visual observation or by analysis of growth patterns on the scales. Consideration must also be given as to whether the wild and farmed salmon sampled are representative.

A number of these issues are addressed in the follow-up to the government's strategy for an environmentally sustainable aquaculture industry. In 2010, the Norwegian Ministry of Fisheries and Coastal Affairs requested clarification and further research in order to address the issues associated with:

- suitable administrative indicators
- assessment of proportion of escaped salmon in spawning grounds in selected salmon rivers
- assessment of how good a correlation there is between the surveys done on spawning grounds one year and the measured genetic effects of offspring (spawn) the following year.

Further, several major R&D projects and the monitoring program have been established by the Norwegian Institute of Marine Research to fill important gaps in our knowledge. This includes Interact, a five year strategic institute project (SIP) with the aim of mapping and quantifying genetic differences between farmed and wild salmon and cod, and the underlying mechanisms. The project includes biological tests supplemented with molecular methods of casting light on these issues, in addition to modelling of the long-term consequences of the exchange of genetic traits.

The Institute of Marine Research has also established a salmon monitoring programme to map genetic stability in selected salmon stocks that show varying degrees of escaped farmed fish in spawning grounds. Historical and new samples of salmon from more than 20 stocks along the Norwegian coast are to be analysed for both neutral selected microsatellite indicators and SNP indicators. The project aims to answer the question of whether there have been genetic changes in wild stocks as a result of interbreeding with escaped farmed salmon.

In another project (Mentor), which follows on from a ten-year programme of placing planting wild and farmed salmon in the Guddal river, the objective is to study selection and fitness in a natural environment. The project involved the placement of over 300,000 eggs combined with recapture in a fish trap and DNA analyses to assign the surviving individuals to families and groups (wild, farmed, hybrid). We are currently in the process of analysing the material for a large number of DNA SNP indicators in order to identify genes under selection, which can be important for survival in nature. To date, such studies have not been carried out on Atlantic salmon or other fish that are found in both domesticated and wild groups.There is a fast-moving research development, and the risk assessments made will be continually subject to change as the research front pushes the bounds and new knowledge is acquired.

Proposed follow-up 2011

Monitoring escaped farmed salmon and the effects on stocks of wild salmon is today typified in part by short-term research project and a high degree of fragmentation, and with a lack of organisation and coordination of the monitoring side at national level. We consider it especially important that the work of strengthening national monitoring is prioritised for 2011. Existing surveys of the proportion of escaped salmon in selected stocks with the help of scale samples has significant limitations. Present day monitoring of escaped fish will be assessed in accordance with the new efforts related to follow-up of the government's strategy for an environmentally sustainable aquaculture industry (see above).

For 2011, we will follow up on monitoring in the more than 20 selected salmon rivers being monitored today. During 2011 we will also have the basis to formulate a more comprehensive and scaled-up monitoring programme to ensure the data that is gathered gives a representative picture of the status of genetic influence from escaped farmed salmon.

6.2.4 *Genetic effects – cod*

The risk of negative genetic effects will be associated with the incidence of sexually mature, escaped farmed cod in natural spawning grounds, and the degree to which they are capable of reproducing and interbreeding with wild cod. The chances of survival (fitness) of offspring are fundamental in assessing potential genetic changes over a longer period of time. Stocks of coastal cod in the fjords and along the coast are generally weak and consequently more vulnerable to changes in relation to more vigorous and robust stocks. In 2002, the Norwegian Institute of Marine Research embarked on a comprehensive work project to biologically and genetically map coastal cod. This has covered the spawning grounds Finnmark in the north to Hvaler in the south (approx. 10,000 fish; depending if Lofoten is included). The purpose of this project (Codbiobank) was to establish a "baseline" for wild coastal cod before the industry really takes off. This material is fundamental to being able to assess the future effects of escaped farmed cod. During the latter part of the period (2006–2007), some farmed cod were registered in individual areas where there are fish farm facilities. In the last 2–3 years there has been a strong focus on escaped farmed cod, based on reports from fishermen of "monster cod" with deformed appearances. Apart from inspections carried out in Austevoll, Gulen and Florø (Chapter 5.2.2), no systematic registrations have been made of farmed cod in spawning grounds or in fjords with fish farm facilities for cod where escape episodes have been reported.

These issues are also addressed in the follow-up of the government's strategy for an environmentally sustainable aquaculture industry. In 2010, the Norwegian Ministry of Fisheries and Coastal Affairs requested comprehensive clarification of the influence of farmed cod on wild cod, together with a scientific inspection – primarily in Skjerstadfjord – with the objective of arriving at potential effect indicators.

Proposed follow-up 2011
As detailed in Chapter 5.2.2, a number of inspections are currently under way that focus on escaped farmed cod and genetic effects. There is a lack of knowledge and method development in a number of fields that would form the basis for good management indicators. The most important are commented on below.

Monitoring programme – mapping of escaped farmed cod in spawning grounds
Apart from selected areas in Hordaland and Sogn and Fjordane, we are lacking reliable figures for escaped farmed cod in the spawning grounds along the coast. We need to develop our own monitoring programme with the inclusion of important aquaculture and reference areas.

Development of methods for future identification of escaped farmed cod
This work has been initiated and must be prioritised in the coming years. Both genetic and morphological methods must be tested and assessed as identification tools. Otholitic characterisation and analyses must be adapted to farmed cod and incorporated into the institute's routine monitoring work.

Spawning in aquafarms – interbreeding with wild fish
The experiment in Heimarkspollen started in 2006 and we have now begun to register adult fish from this spawning ground. In the years ahead, we will be able to determine if these fish are capable of reproducing and to what degree it will interbreed with wild cod in the area. This will provide us with unique knowledge with which to assess the genetic effects as a consequence of spawning in aquafarms.

Escaped farmed cod and interbreeding with wild cod
The experiments in Gulen and Florø give us the opportunity to both register any escapes (using gene indicators) and demonstrate potential interbreeding with wild cod. The latter applies especially in Florø, where a total of three escape episodes occurred involving our farmed cod. In Florø there is no longer a cod farming facility, so here we can follow developments in the fjord with the focus on interbreeding and genetic changes in the stock without it receiving any further farmed material. This is also the case in two other areas: in both Masfjord and Skjerstadfjord there has been a high frequency of farmed cod in the test material inspected. We have from both locations samples and data from cod before cod farming took off. Thus we have the possibility to monitor the stock in the future with the focus on interbreeding and genetic changes over time. In these two cases, we must use an expanded set of DNA indicators (SNPs, microsatellites). This represents a unique opportunity to study genetic changes and other effects as a consequence of escaped farmed cod.

6.2.5 Nutrient salts

Previously, only measurements of nutrients at small farms have been performed, while the trend today is a constant increase in facility size. Therefore we need better knowledge of concentrations of dissolved nutrient and small particles around large facilities and clusters of farms. We also need better knowledge of how extensive the influence area is and to what degree there may be an impact on seaweeds and eelgrass, microalgae and zooplankton in the area around the facilities.

6.2.6 Organic impact

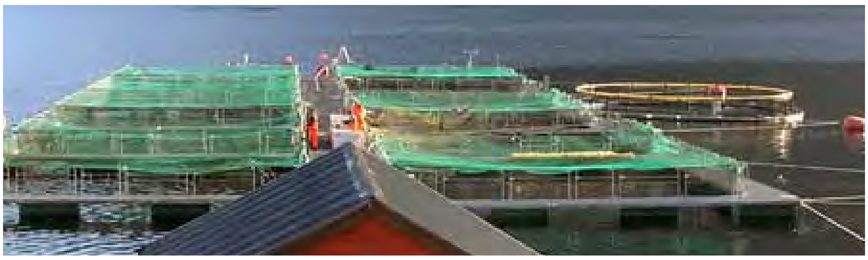
It is important to clarify how particulate organic discharges impact rocky shores, and which monitoring methods and environmental standards is applicable in this habitat. The impact on vulnerable habitats, such as corals, sponges, and areas of high ecological value, must be clarified. To assess such impact, studies of dose-response mechanisms and tolerance limits of such habitats must be performed. Moreover large farming facilities represent a challenge for monitoring of particulate waste, due to difficulties in sampling directly under such large net pens where the impact is highest. The impact on the seabed at deep sites is different from that is experienced in shallower sites and the research on these differences should be continued. Cumulative impact on a regional level in areas with high production is an important issue to address in the future. The recovery of the ecosystem at fallowed or permanently abandoned sites should be studied to better assess the long term carrying capacity of the sites.

6.2.7 Medication

The prioritised areas in regard to possible environmental impact of medications are to acquire data on concentrations and distribution of orally administered antiparasitic drugs in the environment and their toxicity on e.g. prawns, lobster larvae, dogfish and crabs. Availability of statistics by county showing consumption of medications will also be a prerequisite, as well as a more detailed overview of resistance levels in salmon lice.

6.2.8 Other undesirable substances

Data collation and threshold values for the effect of environmentally hazardous substances in feed,should be prioritised. This should be implemented to be able to include these substances and their groupings in next year's risk assessment. In addition, we recommend having a complete overview of use of copper in the aquaculture industry.



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