THE HARDANGERFJORD SALMON LICE PROJECT

Applicant:
The Norwegian Institute for Nature Research (NINA)

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Scott McKinley and Kevin Butterworth (University of British Columbia, UBC)

SUMMARY

This three-year research effort will focus on the interactions of salmon lice between farmed and wild salmonids in the Hardangerfjord and will be a continuum of the project which was initiated in 2004 (see: http://www.nina.no and the attachment to the present application; NFRProgressReportHardanger2005). The applied project consists of four closely linked workpackages: 1) Salmon lice abundance on wild and escaped salmonids; 2) Optimised salmon lice monitoring and control strategies in farms; 3) Understanding the physical oceanographical factors on salmon lice abundance and distribution in the Hardangerfjord and 4) Development of a mathematical population model for the Hardangerfjord system.

The Hardangerfjord has the largest density of fish farms in Norway. However, even though strategies for lice treatment in fish farms have been greatly improved during the present project, we still experience episodes of high lice infestation on wild salmonids in this fjord. Therefore, there is a great need to extend the time series to cover and understand more of the different combinations of environmental and managemental factors which influence salmon lice levels on the different salmonid populations.

By using and combining the long-time results from the project our overall goal is to develop a mathematical population model for the Hardangerfjord system which can be used in management schemes aimed at minimising the risk of salmon lice infestation on wild and farmed fish stocks. Epidemiological models in combination with lice dispersal models is vital to understand the complex relationship between hosts, parasites, environment and measures taken in fish farms. Modelling will also give advice to the industry for optimal placement of fish farms within a fjord system. The degree of international collaboration also shows that results obtained in this project can be used for other fjord systems globally in management schemes aimed at minimising the risk of salmon lice infestation on wild and farmed fish stocks.

1. BACKGROUND

The Norwegian fish farming industry has shown a strong growth during the last years and in 2004, 627000 tonnes of farmed salmonids were produced (Anon. 2006, Fiskeridirektoratets statistikk). Salmon lice (*Lepeophtheirus salmonis* Krøyer) represent an important economical loss factor in Norwegian and international salmon farming industry (Pike & Wadsworth 1999; Johnson et al. 2005) and a constant threat to sustainable production if not controlled. Given the frequently high numbers of gravid salmon lice carried by the large numbers of cultured fish throughout the year, it is likely that the development of an aquaculture industry has lead to changes in the natural host-parasite relationship, and made possible the production of large quantities of the infective dispersal lice stages (Tully et al. 1993; Heuch & Mo 2001ab; Gargan et al. 2003; McKibben & Hay 2004; Penston et al. 2004; Heuch et al. 2005). As plankton, these larvae will drift and be dispersed over long distances, but apparently concentrate near the surface by day (Heuch et al. 1995), and probably also near pycnoclines in stratified waters (Heuch 1995). The density of infective salmon lice stages are, therefore, likely to be greatest in inshore coastal areas and fjords that are subject to constrained tidal flushing. These locations are exploited by the farming industry as well as seaward migrating postsmolts.

Salmon lice epidemics have also been described as a problem for wild salmonids (e.g. Tully et al. 1993; Finstad et al. 2000; Holst et al. 2001; Bjørn et al. 2001a; Gargan et al. 2003; Heuch et al. 2005). Based on crude estimates of how many lice a smolt can tolerate (Bjørn & Finstad 1997; Finstad et al. 2000), direct parasite-induced mortality of wild postsmolt sea trout has been estimated to 30-50 % in an area with intensive fish farming activity (Bjørn et al. 2001b). Recent results also shows that a load of 12-13 lice•fish^{-1} is found to be a consistent breakpoint across a range of physiological measures (Wells et al. 2006). The salmon lice problem on wild salmonids has increased during the last decade, and while no direct link has yet been established, increasing evidence suggests that the problem has a connection with the rapidly growing salmon farming industry (Tully et al. 1993; Pike & Wadsworth 1999; Heuch & Mo 2001a; Bjørn et al. 2001ab; Gargan et al. 2003; Heuch et al. 2005). Measures have, therefore, been taken by the fish farming industry and Norwegian management authorities to reduce salmon lice levels in the fjords and coastal current.

It is indicated that the relative contribution of lice may vary between host species, geographic area, levels of farming activity and management practises (e.g. Jakobsen & Gaard 1997; Bjørn et al. 2001b; Heuch & Mo 2001a; Heuch et al. 2003). Furthermore, hydrographic conditions (Heuch 1995) and current systems seem to be crucial in the dispersal of infective lice, and will determine the risks of re-infection of hosts (Heuch & Mo 2001b; Revie et al. 2003; Holst et al. 2005). Currently such models are being tailored to model drift of infective lice stages (Boxaspen et al. 2001; Asplin et al. 2004; Holst et al. 2005). Epidemiological models (Stien et al. 2005; Revie et al. 2005b) combining lice population dynamics and dispersal potential is needed to understand the complex relationship between hosts and parasites. This can be done by using multi-factorial regression techniques to analyze data sets collected associated with varying lice infection pressure on farmed and wild fish. This model is the basis for investigating sea lice control at national and site level through veterinary interventions (Revie et al. 2005b). This component requires extensive modelling and programming effort, and could also form the basis for exploring in more detail the 'sources' and 'sinks' of lice as a means of better understanding the interaction between wild and farmed salmonids.

The Hardangerfjord which is the study area has the highest density of fish farms in Norway (approx. 45 fish farms in 2005), is 150 kms long and approx. 60 000 tonnes salmon is produced here. This system is an ideal study area because it is mainly affected by inner fjord dynamics, has important wild salmon and sea trout stocks affected by salmon lice, and nearly all salmon farms are cooperating through a fish health network. The applied project will be a continuum of the project in Hardangerfjorden which was initiated in 2004 (see http://www.nina.no and the attachment to the present application; NFRProgressReportHardanger2005). The project has consisted of analyses of salmon lice abundance on wild and escaped salmonids, optimised salmon lice monitoring and control strategies in farms, quality of farmed and wild smolts, migration speeds and routes of Atlantic salmon smolts, spread of salmon lice larvae, and physical oceanographical factors on salmon lice distribution.

During the project period we have gained much experience and information. However, althogh strategies for lice treatment in fish farms have been greatly improved through syncronized delousing in all farms in the fjord, we still experience episodes of too high lice infestation on wild salmonids in this fjord system. The reason for this may be the greater biomass of farmed fish in the Hardangerfjord system compared to other fjord systems still makes the prevailing lice levels in farms too high or that the prevailing environmental conditions (eg. salinity, temperature, currents) have led to favourable environmental conditions for the spread of lice from farms to wild salmonids despite the greatly improved measures taken. Therefore, it is vital to extend the time series to cover more of the different combinations of environmental and management factors which influence salmon lice levels on the different salmonid populations. This will enable us to reach a better understanding of interactions of salmon lice between wild and farmed fish in this fjord system and merge this into an epidemiological model combining data of lice population, environment and measures taken in the farming industry.

The project consists of four closely linked workpackages: 1) Analyses of salmon lice abundance on wild and escaped salmonids; 2) Optimised salmon lice monitoring and control strategies in farms; 3) To understand physical oceanographical factors on salmon lice abundance and distribution in the Hardangerfjord and 4) Development of a mathematical population model for the Hardangerfjord system. The project will be closely coordinated with another ongoing internal supported project in the Hardangerfjord (Institute of Marine Research, see http://www.imr.no).

Through broad cooperation among the leading Norwegian research institutes, industry, international partners and experiences from adjoining projects, we aim to further develop a model system for the Hardangerfjord and for other fjord systems globally, which can be used in management schemes aimed at minimising the risk of salmon lice infestation on wild and farmed fish stocks.

2. OBJECTIVES

Even though strategies for lice treatment in fish farms have been greatly improved during recent years there still remain episodes of high lice infestation on wild salmonids in the Hardangerfjord system. Therefore, there is a need to extend the time series to cover more combinations of environmental and management factors which influence salmon lice levels on the different salmonid populations. This will enable us to obtain a better understanding of the fjord system by:

1. Improving sea lice monitoring and management on individual farms and the region in general by fjord integrated pest management and synchronized delousing processes.
2. Evaluating the success of sea lice management strategies in the Hardangerfjord through investigation of the infection level on farmed and wild fish.
3. Quantifying the abundance and distribution of salmon lice in the Hardangerfjord area based on the physical oceanographical and meteorological conditions for a given salmon lice production.
4. Analyzing data sets being collected at the Hardangerjord for possible risk factors associated with varying lice infection pressure with the aim of developing a mathematical population model for the Hardangerfjord system.

Results obtained in this project can also be used for other fjord systems globally in management schemes aimed at minimising the risk of salmon lice infestation on wild and farmed fish stocks.

3. PROJECT DESCRIPTION

The applied project will be a continuum of the project in Hardangerfjorden which was initiated in 2004 (see http://www.nina.no

The different parts of the project will be achieved through four closely linked workpackages (WPs):

- WP 1 – Salmon lice abundance on wild and escaped salmonids
- WP 2 - Optimised salmon lice monitoring and control strategies in farms
- WP 3 - Understand physical oceanographical factors on salmon lice abundance and distribution in the Hardangerfjord
- WP 4 - Development of a mathematical population model for the Hardangerfjord system

WP 1 is necessary in order to verify the effects of measures taken in fish farms (WP 2) and as a further supply of data to WPs 3 and 4. WPs 3 and 4 will use already sampled data (see project description on

http://www.nina.no, the attachment to the present application (NFRProgressReportHardanger2005) and http://www.imr.no) and data which will be further sampled in the applied project. Presentations of the four WPs are given below:

WP 1: Salmon lice abundance on wild and escaped salmonids

Introduction

As the national action plan against lice on salmonids (NA) has been formed by the farming industry and management authorities, fish farmers have put more effort into reducing the number of lice on farmed fish using medicines. Therefore, the untreated wild and escaped hosts may become increasingly important in the epidemiology of the parasite-host system. New results indicate that the relative contribution of lice may vary between host species, geographic area, levels of farming activity and management practises and emphasize the need for local salmon lice management models.

However, a prerequisite for the development of local salmon lice management models is intimate knowledge of the abundance of salmon lice on the different hosts as well as their population size. Furthermore, the extent to which a local salmon lice management model reduces the abundance and prevalence of infective salmon lice stages, the infection level of the wild salmonid population remains the ultimate measure of success. From the ongoing Hardangerfjord project, lice levels on wild salmonids are still too high even if lice numbers in fish farm have been significantly reduced. Therefore, several questions regarding this problem still remain unanswered.

Objectives

1. We will gather data of salmon lice abundance on all free swimming hosts in the fjord system: wild salmon and sea trout and escaped farmed salmon
2. We will evaluate the success of the local salmon lice management model in Hardangerfjorden through the infection level on wild salmonids

Methods

Gillnet test fishing for sea trout using standardized methods (Bjørn et al. 2001b) will be conducted to assess infection levels of salmon louse. The consequences of the infection both in fresh and seawater will be evaluated according to Bjørn et al. (2001b), Wagner et al. (2003) and Wells et al. (2006) and the effect of the management measures taken will be estimated during annual sea trout smolt surveys in the project period. Test fishing will be performed through the season (May-August) by the Norwegian Institute of Fisheries and Aquaculture Research (FF), the Institute of Marine Research (IMR) and the Norwegian Institute for Nature Research (NINA). This test fishing will be coordinated with test fishing for prematurely returning sea trout in the region performed by Rådgivende Biologer. The location of the fishing stations are selected according to geographic distribution, hydrographic conditions, distribution of fish farms, and distribution of wild salmonid populations. The following areas will be used: 1) Utne/Granvin, 2) Tørvikebygd, 3) Kvinnherad, 4) Etne and 5) Bømlo.

A further test fishing after escaped farmed fish will be continued during late winter and spring by FF, NINA and IMR. We will capture escapees through net-fishing following the methods previously used with success in the Hardangerfjord.

Wild fish migration and population estimates will be monitored at the facilities in River Guddal which consists of a permanent Wolf downstream trap produced in concrete and aluminium, and an adjacent upstream trap. Along with the monitoring (e.g. lice) in the upstream trap, the Sahølen pool below the traps is monitored during summer and autumn. This is the only part of the river where some angling for salmon and sea trout is permitted, and scales from all catches, wild and escaped fish, are collected and submitted over to the field station manager for further processing. Thus, in this river, the absolute number and lice level of ascending wild and escaped fish are recorded at a regular basis.

The sampling programme proposed will give us detailed information on the infection level in all free swimming salmonid hosts in the Hardangerfjord system. These data will also be calibrated against the lice treatment strategies performed in WP 2. This will make it possible to target an infection level shown

to have minimum effects on wild hosts and populations, and to develop a sustainable interaction between salmon lice on farmed and wild salmonids in the Hardangerfjord system

WP 2 – Optimised salmon lice monitoring and control strategies on farms

Introduction

Since 1987 the monitoring of lice on salmon farm sites has carried out routinely according to regulatory requirements. A sample of at least 20 fish must be taken from the two presumably most infected pens, and lice averages in these reported. In addition to estimating the average lice number on the site, monitoring allows the farmer to determine whether the farm exceeds legal threshold limits above which chemotherapeutic control is required. Counting is carried out in an attempt to ensure that farmed fish do not carry lice burdens which could increase the infection pressure on wild salmonids. Although procedures are well established, there is a need to improve estimation of lice abundance and prevalence in farms, particularly at low lice prevalence. In addition, by quality controlling counting procedures the data collected can be analyzed to determine overall trends and relations to factors influencing these trends (WP 4).

Objectives

1. Improve sea lice monitoring and management on individual farms and the region in general by fjord integrated pest management and synchronized delousing processes
2. Evaluate the success of sea lice management strategies in Hardangerfjord through investigation of the infection level on farmed fish (and wild fish – WP1)

Methods

Quality controlled sea lice counting on farms or adjacent to the model fjords will be fully organized, performed and coordinated by the Hardanger Fiskehelse Nettverk (HFN). Scientists from the National Veterinary Institute (NVI), Marine Harvest and University of Strathclyde will also participate in this workpackage. Methods developed by Revie et al. (2005a) will be used, and statistical properties of estimates will be analysed (see workpackage 4). Counting teams and farm personnel/local veterinarians will perform standardized lice counting procedure, and will subsequently report lice numbers using modified procedures and standard forms. Sub-samples from selected farms will also be counted at the lab to evaluate the quality of the fieldwork. Farm stocking data, environment and treatment history will be obtained from the farmers, the Directorate of Fisheries or/and the Animal Health Authorities. Numbers of escaped salmon and rainbow trout will be obtained from the same groups. The counting will be performed from April to July. HFN will be the link to the fish farms (see http://www.fom-as.no) and through this give support with respect to equipment/labour needed in the field work in this and other WPs.

WP 3 – Understand physical oceanographical factors on salmon lice abundance and distribution in the Hardangerfjord.

Introduction

Salmon lice have a total free-living pelagic period of 2-3 weeks at 10°C (Johnson & Albright 1991). During this period the larvae can potentially be carried more than 100 km, or as little as 0. However, there still remains insufficient information of the development of the parasitic stages at low (T < 7ºC) and high (T < 15 ºC) temperatures (Stien et al. 2005) and the effects of changes in environmental conditions on survival and spreading potential for the infective lice stages. The dispersal would depend on fjordic and coastal circulation patterns (Asplin et al. 2004). Driven by rapidly changing forcing, like winds and tides, this circulation varies a lot, and the complex topography complicates the picture (Farmer & Freeland 1983; Asplin et al. 1999). Since salmon lice avoid water of low salinity (Heuch 1995), the freshwater discharge to the fjord and coastal area is another factor influencing the distribution of the lice. In particular two physical oceanographical factors in the Hardangerfjord area are important for the distribution of salmon lice in the fjord system, i.e. transport of water masses and the temperature and salinity of the water masses. The water mass transport inside the Hardangerfjord depends on the local winds, tides, freshwater runoff and the density distribution of the coastal water masses outside the fjord mouth. Salmon lice will horizontally to a large degree drift passively with the flow. Vertically each lice will probably move actively based especially on the salinity values and stratification. Previous results show that there is a huge potential for spreading of salmon lice in western Norwegian fjords due to the

dynamic flow fields particularly as a result of the shifting wind conditions (Holst et al. 2005). Due to the environmental conditions, important variations of the conditions for the planktonic salmon lice can occur. First, annual variations in the freshwater runoff will lead to a larger or less brackish water layer sheltering the salmon from the salmon lice. Second, variations in the wind patterns, which acts on a daily time scale but seems to have an annual cycle as well (Holst et al. 2005), will distribute the salmon lice differently in the fjord system, from a distribution far into the fjord to a distribution out of the fjord. This obviously will influence the salmon lice as a threat for the fish.

Objective
To quantify the abundance and distribution of salmon lice in the Hardangerfjord area based on the physical oceanographical and meteorological conditions for a given salmon lice production (number of lice and origin).

Sub-goals
1. To estimate the time variations (seasonal/annual) of the sheltering brackish fjord water
2. To estimate the total fjord distribution of salmon lice from different fish farming locations (farming strategies)

Methods
The work package will mostly use numerical ocean models as scientific method. The numerical model is a generic ocean model producing time series of sea-surface elevation, currents, salinity and temperature for a 3D numerical grid. At present the grid resolution is 800m by 800m in the horizontal, thus the model results will be mean values within this grid. The model is forced by realistic winds, tides, freshwater runoff and inflow from the coastal ocean. Realistic topography and the rotation of the earth are important steering agents.

Detailed wind fields are important for a realistic forcing of the model, and cooperation with the Meteorological Institute (see http://www.met.no) is established for producing high resolution winds from a mesoscale atmospheric model. From the currents produced by the ocean model, a lagrangian particle tracking model will simulate the spreading of the salmon lice. This model can be run both forward and backwards in time, estimating both the destination of lice from a specified source as well as the origin of lice from e.g. an observation.

A collaborating project at IMR funded by the Norwegian Research Council for 2003-2005 (LEIF) with the aim of investigating primary production in the Hardangerfjord, is heavily contributing on the numerical model part. The Institute of Marine Research (IMR) will continue to develop the methodology of fine scale fjord models, including particle tracking models, which the present project both will benefit from as well being a part of.

WP 4 – Development of a mathematical population model for the Hardangerfjord system
Introduction
Existing epidemiological modelling, supported by the UK's Department for Environment Food and Rural Affairs (DEFRA), Marine Harvest (MH) and Scottish Quality Salmon between 1999 and 2005, on sea lice populations on farmed salmon using large scale industrial data sets, has demonstrated that modern informatics and statistical modelling methods can advance our knowledge of infestations and how best to control them using veterinary medicines (e.g. Revie et al. 2002, 2003, 2005b, McKenzie et al. 2004). Such work could be of value within the Hardangerfjord research programme; and initial interactions have already contributed to thinking on sampling protocols within the initial phase of the work.

Objectives
1. To analyze data sets being collected at the Hardangerjord for possible risk factors associated with varying lice infection pressure
2. Develop a mathematical population model for the Hardangerfjord system to enable the exploration of optimal lice control strategies

Methods
We will use multiple regression techniques to analyze data sets collected in the Hardangerfjord for possible risk factors associated with varying lice infection pressure on farmed and wild fish. Further, research and development of a mathematical population model which simulates lice development in space and time in Scottish lochs and the transfer of this model to the Hardangerfjord setting. The basis for this work was initiated as a part of a DEFRA research programme and represented the first time a mathematical model had been developed that described salmon lice populations on farmed salmon during the production cycle (Revie et al. 2005b). This model is the basis for investigating salmon lice control at national and site levels, as well as exploring the impacts of various veterinary treatment interventions. This component requires extensive modelling and programming effort, and would only be possible if adequate funding were available to engage suitable expertise. The model could also form the basis for exploring in more detail the 'sources' and 'sinks' of lice as a means of better understanding the interaction between wild and farmed salmonids. Access to such a model would provide an unique management tool for comparing the effects of varying treatment strategies which can never be investigated empirically due to prohibitive cost and resource requirements.

Outcome from WPs 1 thru 4
By combining results from WPs 1, 2, 3 and 4 we aim to further develop an ecological model system for the Hardangerfjord which can be used in management schemes aimed at minimising the risk of salmon lice infestation on wild and farmed fish stocks. Modelling may also give advice to the industry for optimal placement of fish farms within a fjord system. Results obtained in this project can be used for other fjord systems globally in management schemes aimed at minimising the risk of salmon lice infestation on wild and farmed fish stocks.

4. INSTITUTES AND STAFF QUALIFICATIONS

Collaborating institutes
The project will be an operational cooperation between the Norwegian Institute for Nature Research (NINA), Institute of Marine Research (IMR), Norwegian Institute of Fisheries and Aquaculture Research (FF), Hardanger Fiskehelse Nettverk (HFN), National Veterinary Institute (NVI), Marine Harvest (MH), University of Strathclyde (UoS) and the University of British Columbia (UBC). All these partners are collaboration through the ongoing Hardangerfjord project (2004-2006). The applied project will be coordinated by NINA. NINA's work is directed towards environmental research, with emphasis on interactions between human societies, natural resources and biodiversity. Aquatic ecology and sustainable use of aquatic resources are central topics in NINA's activity. Thus NINA possesses expertise within the field that encompass most aspects from social sciences to marine ecology. Marine ecology is also an area of high priority at the Institute of Marine Research and at the Norwegian Institute of Fisheries and Aquaculture Research. Both NINA and FF are collaborating with the University of British Columbia (UBC) through AquaNet (see http://www.aquanet.ca) and this collaboration have been of great scientific value. The National Veterinary Institute is working with topics regarding fish health and diseases and has had an extensive collaboration with all involved partners. Our industry partners, Hardanger Fiskehelse Nettverk and Marine Harvest will cover the fish farming perspective in this project. Hence, the proposed project falls naturally into the core expertise and activities at all institutions.

Researchers
Dr. Bengt Finstad (Senior research scientist, NINA) has 19 years of research experience and is a specialist in fish physiology and ecology, particularly the effect and impacts of salmon lice infestations. Dr. Finstad is currently leading several projects related to the problematic associated with sea lice and aquaculture e.g. NFR-project 149796/720 (The importance of early marine feeding on the growth and survival of Atlantic salmon post-smolt in Norwegian fjords – 2002-2006); NFR-project 163869/120 (Salmon lice project in the Hardangerfjord, 2004-2006). Dr Finstad has published 49 peer-reviewed scientific publications and 11 are within the field of salmon lice-wild fish interactions. **Dr. Ingebrigt Uglem** (Research scientist, NINA) has 14 years of research experience, encompassing crustacean biology, behavioural ecology in marine fishes, aquaculture of cod and lobsters, stereovideography and fish telemetry. **Cand. scient Finn Økland** (Research scientist, NINA) has a broad experience in fish telemetry and since 1991 has been working with development and use of telemetry techniques in more

than 20 different fish species. He has been involved in several projects at NINA within the field salmon lice and fjord ecology. **Dr. Karin Boxaspen** (Research scientist, IMR) is an expert in sea-lice biology and sea-lice behaviour related to the physical environment. She is the coordinator of the sea-lice research at the Institute of Marine Research. **Dr. Øystein Skaala** (Senior scientist, IMR) has 21 years of research experience. Main research area is population genetics and environmental effects of salmon farming, with focus on genetical and ecological effects of escaped salmon, and salmon lice on wild fish. **Dr. Lars Asplin** (Research scientist, IMR) is a physical oceanographer with special expertise in fjord and coastal ocean dynamics. He uses both high resolution numerical model results and field observations for his investigations of water mass distribution in the Hardangerfjord. **Dr. Pål Arne Bjørn** (Senior research scientist, Norwegian Institute of Fisheries and Aquaculture Research, FF) has in particular focused on aspects related to salmon lice infestations, both on farmed and wild fish. Dr. Bjørn is currently involved in several projects dealing with the interaction between fish farming (salmon and cod) and the environment. **Cand.scient. Rune Stigum Olsen** (Hardanger Fiskehelse Nettverk, HFN) is the head of this network. His MSc. thesis was on host specificity in salmon lice and he has been organizing the lice countings in Hardangerfjorden for the current Hardangerfjord project. Presently he is production coordinator for some fish farms in this fjord system. **Dr. Peter Andreas Heuch** works as a researcher in the section for parasitology at the NVI. He has worked on parasitic copepods since 1990, and has published 17 peer-reviewed scientific papers on different aspects of their biology. At the NVI he has cooperated with Norwegian and foreign research groups on epidemiological aspects of salmon lice *Lepeophtheirus salmonis*. **Dr. Gordon Ritchie** (Fish Health Technical Manager, Marine Harvest Technical Centre) has 17 years of research and industry experience, particularly in the field of sea lice control, treatment strategies, medicine development, industry management and husbandry practises and Integrated Pest/Disease Management. Dr. Ritchie is currently involved in several international projects and industry programmes on disease management and control. **Dr. Crawford Revie** is a Senior Lecturer in the Department of Computer and Information Sciences at the University of Strathclyde in Glasgow. He also works extensively with colleagues from the Department of Statistics and Modelling Science where he has recently completed a PhD in modelling sea lice epidemiology. His main focus of research over the past 5 years has been the application of data-based models to problems in the domain of veterinary epidemiology. During 2000-2005 he worked on a DEFRA funded project with industrial partners Marine Harvest Scotland which focused on the epidemiology of sea lice on Scottish salmon farms. The initial research established descriptive overviews of the Scottish situation and has now extended into formal mathematical models to predict sea lice dynamics on salmon farms. **Prof. George Gettinby** is a professor in the Department of Statistics and Modelling Science at the University of Strathclyde in Glasgow. Professor Gettinby's contributions to the published literature have centred around the use of statistical approaches and mathematical models for the control of human and animal diseases. He has published two mathematical and statistical textbooks, over 150 peer-reviewed scientific publications and supervised over 40 Ph D students. Since 1999 his research interests have been in food borne pathogens, infectious diseases and aquaculture. **Dr. Kevin Butterworth** (Research Associate, CAER, University of British Columbia and AquaNet). Has conducted systematic investigations on the distribution, efficacy and control of sea lice epizootics on wild and farmed salmonid stocks. Assisted in the development of sea lice management strategies for the aquaculture industry. Managing BCARD and AquaNet sea lice projects in Canada. Managing a work package in the Hardangerfjord sea lice project in Norway. Partner on a NFR project in Norway and Canada. **Prof. Robert Scott McKinley** (University of British Columbia, UBC) has profound skills within fish ecology and telemetry, and will have a consultative role in the project. During the last years, he has been involved in several projects, both in Canada and internationally, aimed at examining the effects of salmon lice in aquaculture. Prof. McKinley is currently holding a Canadian Research Chair in Aquaculture at the UBC and is director of the Canadian centre of Excellence "AquaNet".

5. ACTIVITIES, TIME SCHEDULE AND BUDGET

Relevance of research

The project fits into the theme 4.1.2 Strategic basic research and sub-programme 4.1.2.2. – Health in the programme plan for AQUACULTURE – An industry in growth. This covers basic research associated with topics and species relevant to further development of the aquaculture industry. The project may also have a link into the theme 4.1.3 – Sustainability and sub-programme 4.1.3.1 – Environmental and ecological aspects. The outcome of the present project is to give advice to the

industry where placement of fish farms at "safe" sites within a fjord system may reduce the interaction between farmed- and wild fish. The rising level of activity in the coastal zone means that the availability of suitable areas is in the process of becoming a limiting factor in marine value creation. Therefore, these studies may also give advice to further placement of fish farms in order to increase industrial development in the coastal zone and also to expend this production to other marine resources. The degree of international collaboration also covers the fact that results gained from this project can be used for other fjord systems globally in management schemes aimed at minimising the risk of salmon lice infestation on wild and farmed fish stocks.

Reporting and communication

The results from the proposed project will be communicated to the management authorities, to fisheries associations and to local users of the study area. Other important target groups for the results are national and international R&D groups. Results will be published both in peer-reviewed journals, and in Norwegian national journals. Information will be disseminated through talks on national and international meetings and symposia as well.

Time schedule

A summary of the activity plan and milestones are given in the table.

Project period, From date:	**1/1-2007**	**To date:**	**31/12-2009**	**2007**				**2008**				**2009**			
Main activities during the project				**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
WP 1 - Analysis of salmon lice abundance on wild and escaped salmonids					X	X			X	X			X	X	
WP 2 – Optimised salmon lice monitoring and control strategies in farms					X	X			X	X			X	X	
WP 3 – Understand physical oceanographical factors on salmon lice abundance and distribution in the Hardangerfjord					X	X			X	X			X	X	
WP 4 - Development of a mathematical population model for the Hardangerfjord system					X	X	X	X	X	X	X	X	X	X	
Yearly project meetings							X				X				X
Reporting							X				X				X

Cost and financing (numbers in 1000 NOK)

Specification	**2007**	**2008**	**2009**	**Total**
Salary				
NINA	300	300	300	900
FF	150	200	200	550
IMR	200	225	225	650
NVI	80	80	80	240
HFN/MH	250	250	250	750
Total	*980*	*1055*	*1055*	*3090*
Travel				
Fieldwork	70	70	70	210
Annual meetings (all partners)	40	40	40	120
Total	*110*	*110*	*110*	*330*
Other costs				
Fishing nets	20	20	20	60
Laboratory supplies – instruments for measurements	40	40	20	100
Boat - hire	40	40	40	120
Total	*100*	*100*	*80*	*280*
International collaboration				
Travel costs/annual meetings (UBC)	25	25	25	75
Travel costs/annual meetings/invoiced services (Univ. of Strathclyde)	250	250	250	750
Total	*275*	*275*	*275*	*825*
Sum - Norwegian Research Council	**1465**	**1540**	**1520**	**4525**
Own funding (salary and running costs)				
NINA	75	75	75	225
FF	50	50	50	150
IMR	70	70	70	210
NVI	20	20	20	60
MH	79	79	64	222
SUM - Total own funding	**294**	**294**	**279**	**867**
Total for the project	**1759**	**1834**	**1799**	**5392**
Applied from the Norwegian Research Council	**1465**	**1540**	**1520**	**4525**

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