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A review of the factual basis of interactions between farmed and wild salmon as it applies to salmon lice

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Summary:

The report entails a critical review of the factual basis(*) concerning interactions between farmed and wild salmonids as it applies to salmon lice, with specific relevance to Norway.

The summary is in accordance with the report roughly divided into three main areas:

- i) Population dynamics; various factors that affect stocks of wild (anadromous) salmonids
- ii) Evaluation of the current knowledge concerning salmon lice; about occurrence of salmon lice, vectors and dispersion models
- iii) Evaluation of the current knowledge concerning status reporting that forms the basis for decision makers / the management of wild salmonid stocks

* This report is a translation of the report published in Norwegian in April 2011. Hence, studies performed and published after April 2011 are not included in this review.

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1 Summary and conclusions

This report entails a critical review of the factual basis concerning interactions between farmed and wild salmonids as it applies to salmon lice.

The report is roughly divided into three main areas/chapters. The current knowledge is summarised below along with separate conclusions for each area.

Population dynamics; various factors that affect stocks of wild (anadromous) salmonids:

The development on both sides of the North Atlantic Ocean show the same population trends from a geographical perspective: In recent decades the stocks of wild salmon are described as stable in northern areas and decreasing towards the south in both Europe and North America (on both sides of the North Atlantic Ocean). In large parts of the southern area of distribution, the salmon population in river systems is regarded as threatened and/or extinct.

This relatively clear north-south gradient and correlation in the size of the populations of wild salmonids on such a large geographic scale suggests a common response by populations to large, global or sectorial environmental conditions (changes or variations that have an effect on population regulation of wild fish which are common and/or function the same over a large geographical area). There is increasing documentary evidence that the environmental conditions necessary for survival of anadromous salmonids during their marine life stage could explain such a correlation: Plausible explanations for population regulatory effects on such a large scale include climate changes and natural fluctuations in sea temperature that may cause fluctuations in the food availability and, consequently, of the marine survival for salmon.

Moreover, common denominators for all areas in the south where local populations have become extinct or threatened (international level) are: High human population density, intensive dam construction on major waterways, pollution and total dewatering of streams.

The probability that the potential negative effects resulting from an increased occurrence of salmon lice in fish farms may have an effect on such a large geographical scale is virtually nonexistent. This is based on the following facts:

- Salmon stocks are influenced throughout their entire distributional range, including in areas where aquaculture does not occur.
- The decline is greatest in the south, where aquaculture occurs only on a small scale.
- The decline is least or nonexistent in northern parts of the distribution area, where the existence of aquaculture is greatest (exception – Tana River – refer to the text).

No documented evidence exists on the causal relationship between increased salmon lice and a decline in salmon stocks, over such a large scale

Evaluation of the current knowledge concerning salmon lice; about occurrences of salmon lice, vectors and dispersion models

Few descriptions exist of lice abundance in a more historic perspective. In the past, salmon lice infection was often registered on returning spawners, where as today registration of salmon lice infection is registered on outwardly migrating salmon smolts. To our knowledge there is no documentation that points to the fact that the level of infection of wild salmon at sea has changed in a historical perspective. However, it is also well documented that salmon lice infestations in coastal areas (immediately adjacent to fish farms) are more severe during times of the year, which in turn exposes migrating Atlantic salmon smolts to greater infection pressure than would normally have been the case without the presence of fish farms.

We have reviewed the literature that points out variation in salmon stocks in areas with and without aquaculture, and see that:

- The extent of salmon lice/infestation by salmon lice can be more severe periodically during the year in areas with aquaculture activity given the higher number of hosts (=correlation in occurrences of salmon lice and farmed fish).
- Local salmon lice abundance correlates and, in other instances, varies independent of the presence of aquaculture.
- Correlation has been detected in the amount of returning infested wild salmon and infestations of salmon lice in farms the following spring (infection can occur from wild fish to farmed fish).
- Correlation has been detected in the abundance of salmon lice infection on wild smolts and increased levels of salmon lice in fish farms (infection can occur from farmed fish to wild fish).
- It is documented that high levels of salmon lice can be deadly for salmon smolts.

On the contrary, we cannot see that there is documented evidence of a cause-effect relationship between the population size and the occurrence of salmon lice (as a separate factor). There are no instances to document that salmon lice are the <u>main reason</u> for change to the population dynamics. However, a lack of documented evidence does not have to mean a lack of connection; it can also mean that it is difficult to document whether there is a connection or not. There is, without doubt, a need for more knowledge on this area.

It has been established that brown trout, sea char and other species such as stickleback can be carriers and reservoirs for salmon lice. The brown trout lives in fjords and coastal waters year-round and can, therefore, sustain production of salmon lice year-round. It has been established as probable that wild brown trout makes a significant contribution to the maintenance of local salmon lice abundance.

It has been established as probable that infection by salmon lice resulting in osmo-regulatory problems can lead to behaviour such as premature returns. In spite of the fact that the description of this phenomenon is relatively new, we cannot see that there is documented evidence that this is a new phenomenon.

Weaker fish are possibly more susceptible to infestation by salmon lice than “robust”/non-weakened fish, but it remains uncertain how it can influence or contribute to the maintenance of the local abundance of salmon lice. However, it is known that acidification can indirectly affect survival of smolts in the marine phase as smolts that are exposed to an acidified environment (containing aluminium) have higher mortality resulting from infestation of salmon lice when compared with smolts from “healthy” freshwater environments.

To what extent Atlantic salmon might have developed resistance (in other words the degree to which natural selection for resistance against lice has taken place) remains uncertain. A possible effect of natural selection would be expected to increase with increasing salmon lice-related mortality. However, in populations where mortality is connected to (increased) infestation by salmon lice only at a low degree (low salmon-lice related mortality), natural selection for resistance against lice will not be of special significance.

Based on the available knowledge, we cannot find any existing scientific evidence documenting a simple/direct connection between the number of sexually mature female lice, essentially a product of the number of farmed salmon and the number of female lice per fish, and marine survival of wild salmonids, and the calculation/estimates of a sustainable level of lice is, therefore, not sufficiently knowledge-based.

The dispersion dynamics of salmon lice is extremely complex and parallel with the complexity in the fjord systems and along the coast generally. Variations in topography, climate, geographical location, flow conditions and local weather conditions can make a significant contribution to the dispersal pattern in terms of both time and space. Consequently, assumptions about “ideal localisation of fish farms” will involve a significant element of speculation. However, if speculation is permitted, it is possible on a general basis to mention that some areas in the fjord system appear to be more exposed than others.

In an ideal situation (where the goal is the most effective management of wild salmon stocks) it would be desirable that modelling of dispersal patterns is implemented more specifically, possibly separately for each fjord system, in order to be able to offer better advice about when delousing would be more effective.

Evaluation of the current knowledge concerning status reporting that forms the basis for decision makers / the management of wild salmonid stocks

Working parties and councils appointed to undertake assessments that will form the basis for management carry a major responsibility and, according to the regulations, have an obligation to ensure such evaluations are “objective and (scientifically-)knowledge-based”. Following a review of a large amount of material in connection with the compilation of this report, included reports that evaluate the threats to and status of wild salmonids, we believe we have revealed several instances where

i) assertions are expressed without scientific basis,

ii) there are instances of under-reporting of other probable contributing factors to negative development of salmon stocks, and

iii) there are instances of over-reporting of negative effects of salmon lice (which is attributed to aquaculture).

If the goal is to protect/preserve wild stocks of anadromous salmonids, we recommend documentation of actual causes of stock size regulation and that an attempt is made to do something about these.

We are calling for more objective, scientific and integrated (in other words multifactorial) assessments to form the basis for decision making relating to the management of wild anadromous salmonids.

Excerpt from the (Norwegian) Nature Diversity Act:

§ 10: Ecosystem approach and cumulative environmental effects
Any pressure on an ecosystem shall be assessed on the basis of the ***cumulative environmental effects*** *on the ecosystem now or in the future.*

2 Introduction – background and tender

2.1 Background

The industry, represented by the Fishery and Aquaculture Industry Research Fund (FHF), has identified a requirement for a neutral and professional review of the factual basis (reports and publications) concerning salmon lice and the interaction between wild Atlantic salmon and farmed Atlantic salmon.

Under the auspices of FHL (The Norwegian Seafood Federation), an external expert has examined a series of publications concerning the interaction between farmed salmon and wild salmon and summarised this in a preliminary report entitled “Prosjekt lakselus” (“Project salmon lice”). The report mainly evaluates research, statements and conclusions dealing with the relationship between salmon lice on farmed fish, infection pressure on the wild fish and the marine survival of the wild fish. This report includes some different evaluations than what has to date been the benchmark for the official communication concerning salmon lice. The preliminary assessment in this report is that there are a series of indications that one may not conclude with a simple connection between sexually mature salmon lice females, production of louse eggs, infestation level of sessile lice and the marine survival of wild fish.

Consequently, FHF is inviting the academic environments to perform a critical, professional and objective review of the assertions in the expert report “Project salmon lice” as well as the literature on which it was based.

The interaction between salmon lice on populations of farmed salmon and wild salmon is a complex and large field. There will in several cases not be a clear and/or simple causal connection and subsequent conclusion. However, the importance of gaining greater clarity is undisputed and great.

2.2 Goals

2.2.1 Main goals

Undertake a critical review of the factual basis (referenced publications) and the evaluations outlined in the preliminary expert report “Project salmon lice” with focus on research that supports or contradicts the assertions in the report.

Where appropriate and/or possible, Nofima will refer to other and more relevant references that support our assessment, and that can shed further light on the assertions in the report.

In order to shed light: Quote: “If it may be documented, or at least shown to be probable, that the spreading of salmon lice from farmed fish to wild fish has affected, and/or is continuing to affect, the population trends of wild salmon and brown trout in a negative manner on the four levels, internationally, nationally, regionally and locally”.

2.2.2 Subsidiary goals: Specific questions to be considered / evaluated

Evaluate the literature referred to in the preliminary expert report that deals with the causal relationship between the occurrence of salmon lice and decline of wild fish stocks

- Are any of the articles of a misleading / tendentious nature?
- Are a lot of circular references used?
- Is further literature available that supports or rejects conclusions/assertions in the reference?

Discuss / evaluate questions raised in the report

We would like to point out that simple and/or unambiguous answers do not exist for all the questions raised in the memorandum, and that several of these questions are the basis of discussion in the research environments. Where possible Nofima will find references/literature that supports or invalidates and/or answers these questions in part or in full. This applies in particular to the following points (These points were defined by FHF in their tender as points to be considered / evaluated):

- Reasons for synchronous decline of wild salmon
- Low abundance of lice in Finnmark – but nonetheless the same population trends for wild salmon
- Do observations/data exist concerning lice abundance prior to the establishment of aquaculture activity?
- Premature returns – connection with high infection pressure?
- The importance of dispersion surveys with respect to the ideal location of fish farms
- Is the result available of the temporary geographical zones established in 1991 for wild fish protection?
- Reports 1/2009 and 2/2010 from the Scientific Advisory Committee for Atlantic Salmon Management in Norway
- Transmission direction (from aquaculture to wild fish and *vice* versa) and weaker fish as a possible source
- The role of brown trout as a vector
- Suitability of Heuch & Mo's model for modelling of the sustainability level for salmon lice
- Possible causal relationship between negative growth and condition during the marine life stage and feeding conditions / salmon lice

Evaluate assertions/quotes from the expert report/statistical appendix:

In the report's statistical appendix, the external expert presents some assertions.

Quote:

> *After a review of a number of data sources, the preliminary conclusion is that the official catch statistics do not show that the salmon population in Norway is in critical decline.*
>
> *It is most unlikely that the synchronised decline for the wild salmon is related to salmon lice, the escape of farmed fish or other effects of salmon farming.*

Neither does it seem likely that the aquaculture activity can have had a significant influence on the development for the wild salmon in Norway, since Norway has had the largest growth in salmon farming and at the same time the smallest decline for wild salmon.

A negative development trend cannot be demonstrated for the nominal catch after 1990 and consequently neither can it be demonstrated that salmon farming has had a negative effect on the wild salmon, either on a national or regional level.

End quote.

These assertions will be commented on during the review work.

3 Variations in wild populations of anadromous salmonids; briefly about stock size regulating factors.

3.1 Variations in wild populations – seen in a larger perspective

In the ongoing discussion about potential negative factors that may influence the Norwegian wild stock of salmon, there is considerable focus on a very short time perspective (”the time after increased aquaculture activity”) and preferably on a geographical scale that is as small as down to individual populations.

In order to have a knowledge-based discussion concerning stock size regulating factors of wild salmon populations, and about whether salmon lice may have such a regulating effect in the rest of this report, it will be necessary to set the population trends of salmon in a larger perspective, both geographically and temporally.

Population dynamics is a large and complex field of knowledge, particularly with respect to anadromous salmonids that have a complicated life cycle involving phases in both freshwater and marine environments. Consequently, in this chapter we will summarise only the aspects of the population trends that describe variations in the salmon population that are of relevance in answering the issues raised in this report.

The factual basis in this chapter will, therefore, not be evaluated but summarised in order to provide an overview as basis for further discussion in the rest of this report.

3.1.1 Population dynamics on a variable geographic scale

Correlation in abundance of wild salmonids on a large geographic scale suggests a common response by populations to large / global environmental conditions.

Correlation in abundance over time on a local level suggests a common response to local factors.

<u>Example of stock size regulating factors; International, sectorial and local, Europe</u>

Vøllestad et al. (2009) perform analyses of long-term catch data from a broad geographic range and establish trends in population variations across a range of spatial subscales over a longer time perspective with the aim of identifying the significance of various factors that influence the population size of wild anadromous salmonids. The catch data that is used are two of the most robust groups of time series available for European populations: Rod catch data from 84 Norwegian rivers over a period of 125 years (1876-2000) as well as 48 rivers in Scotland over a period of 51 years (1952-2002).

Taking into account patterns across the Scottish and Norwegian data (wild populations in the East Atlantic, the largest geographic scale in this study), the catch data shows an increasing trend in the north and a decreasing trend over the southern end of the Scotland-Norway transect. Vøllestad et al. (2009) suggest that geographical and temporal variations in feeding conditions/access to food in the marine environment is a probable stock size regulating factor that may have caused a trend of increased marine mortality of salmonids since 1980 on such a large scale.

This indirect trend involving increased marine mortality since the 1980s over the southern end of the Scotland-Norway transect is supported by finds/results using direct estimates of marine mortality from catches registered in traps in the rivers North Esk in Scotland and Imsa in Southern Norway (for references see Vøllestad et al., 2009).

Probable factors that affect populations on a sectorial level in Norway from south to north are summarised by Vøllestad et al. (2009) as follows:

Skagerrak: long-term, dramatic decline in rivers that drain into the Skagerrak sector up to 1980, followed by a significant increase, which in all probability may be attributed to the effects of acidification of freshwater in this region, and with subsequent habitat improvement resulting from the large reduction in discharge of SO_2 and liming, and consequently increased recruitment and re-establishment.

In both Central and Western Norway there has been a strong increase in human activity since the 1940s (although, a general trend in salmon populations since the 1990s is an increase in central parts of Norway and a decrease in Western Norway). Hydropower development has resulted in loss of habitat, the parasite Gyrodactylus has been introduced, and increased occurrence of potentially harmful salmon lice from aquaculture activities as well as losses of fitness due to interbreeding of escaped farmed salmon with wild salmon has been implicated. The majority of these consequences have arisen after the 1980s, and as a result of its strong local dimension the effect will not be uniformly clear between rivers.

Northern Norway: Catches have increased gradually since the 1940s. Human influence on rivers has been less in this area, and there is no indication that an increase in the number of fishermen or increased reporting may explain the increase in salmon fishing since the 1970s.

Example of effects on population regulation; International and sectorial,

Friedland et al. (2009) have studied correlations in

i) the recruitment of salmon smolts
ii) the growth of salmon smolts
iii) sea surface temperature and
iv) variation in plankton stocks and the food availability for the salmon smolts.

This analysis is based on the release of approximately 6000 salmon smolts per year in the period 1965-2005. In the same period the average weight of returning 1 SW/2SW salmon was recorded. Data from the registrations of the monthly average of plankton abundance in the same period (Continuous Plankton Recorder Database) was used to analyse patterns in correlation.

Variations in plankton levels over 10-year periods correlated with marine survival of salmon.

There was a positive correlation between the post-smolt growth in the summer, in other words growth of recently migrated salmon smolts, and survival and recruitment.

Example of stock size regulating factors; International and sectorial, North America and Europe

Parrish et al. (1998) summarise the status of Atlantic salmon in 1998 based on developments in catch data from Northern American and European river systems from 1960 – 1998. The various river systems are classed as i) stable, ii) declining, iii) extirpated with restoration, and iv) extirpated. The geographic trend is clear and in accordance with that reported by Vøllestad et al. (2009): When viewed on a large scale, the population of Atlantic salmon in the north is stable. Moreover, there is an increasing negative trend towards southern parts in both Europe and North America.

Parrish et al. (1998) explain this by the fact that areas with the largest number of extirpated salmon populations in river systems in the southern area of distribution of Atlantic wild salmon concur with areas with the highest human population density, which consequently have been influenced most by manmade environmental changes.

It is pointed out in this study that many causal factors work in concert, which makes it difficult to differentiate between the effects of the individual factors/components. However, the study refers to some individual factors:

River regulation (construction of dams/building of reservoirs) is identified as the main cause of extirpation. The study refers to many specific examples of the expiration of populations in southern parts of Europe as a direct result of such regulation and in some instances the total dewatering of streams. The density/number of dams concurs with the human population density.

Further, pollution (sewage, industry, agriculture) is mentioned as a factor that is concurrent with areas with intensive dam construction and high human population density.

Acid rain is referred to as a complex factor that may have an impact on areas far from the point of discharge. The strength and diffusion vary according to weather and wind conditions. This non-constant influence is concurrent with the variable population sizes of Atlantic salmon in centrally located geographic areas in comparison with populations in the north and south.

Potential stock size regulating effects from global climate changes and the increase of aquaculture activities are mentioned as too subtle and unspecific to have contributed to the clear pattern of declining and extirpated populations in the south.

Commercial marine fishing is referred to as to variable and unpredictable, and there is a lack of information in order to be able to address the effect.

In summary, areas with extirpated or threatened salmon populations are concurrent with areas with high human population density and pollution and areas with a high level of river regulation.

Example of stock size regulating factors; national; north-south gradient in Norway

Rikardsen et al (2004) have performed a field study in a total of eight fjords; four in Northern Norway (Neidenfjord, Tanafjord, Altafjord and Malangen), two in Central (Trondheimsfjord and Namsfjord) and two in the south-Western part of Norway (Nordfjord and Sognefjord).

This study sheds light on how critical the period immediately after transition to the marine environment is for recently outwardly migrated post-smolts:

Recently outwardly migrated post-smolts had a higher feed intake in fjords in the northern and middle parts of Norway as compared with more southerly fjords, possibly owing to more available feed/greater productivity in the northern fjords. Consequently, northern populations also had larger post-smolts (greater feed intake-greater growth) which in turn may reduce the risk of predation during migration to the sea, as well as makes larger prey available (feeding on larger prey gives more food).

A high feeding intensity and increased growth may also improve the migration and resistance to possible parasites, and may influence behaviour (avoiding predators) and physiological processes. Consequently, a high feed intake immediately after migration to seawater is decisive for the survival rate of juvenile salmon in the marine environment.

Another north-south difference that may influence migration and be decisive for the survival rate is the fjord morphology: Many fjords in Southern Norway are long and narrow threshold fjords with up to several river mouths which may result in a brackish layer. Fjords in Northern Norway are often shorter and wider, and with just one main river running into them. Northern fjords are also more productive, influenced to a greater extent by current conditions (coastal and tidal) and have less bounded thresholds (Rikardsen et al., 2004).

As there is a high density of potential predators in a fjord system (compared with in the open sea?), a long fjord may increase the predation risk.

Example of stock size regulating factors; local; the Tana River

Even though the population of wild salmon generally appears to be more stable in the north (see introduction), the Tana River is one of the exceptions. The proportion the Tana salmon represents of the total catch of wild salmon has shown a dropping trend over the past 30-40 years.

The Tana River is one of the rivers in Norway with the least impact from escaped farmed salmon, and demonstrates that a negative stock size regulating factor in this instance does not embrace effects from aquaculture (or lice from aquaculture).

The factual basis that describes possible stock size regulating factors in the Tana River demonstrates that exploitation stands out;

On the Finnish side of the river the number of fishing days has tripled over the past 30-40 years. In Troms and Finnmark the estimated catch has been from 70-90 % of the returning salmon over the past 30 years (www.intrafish.no 01.02.2010)

In addition, there is an effect of accumulated exploitation: The salmon that shall to the upper reaches of the Tana River are exploited along the entire outer coast of Finnmark (and Troms), in the Tanafjord and up the main river. The accumulated exploitation is estimated to be nearly 90 %, in other words just one in 10 salmon survive to spawning (Johansen, 2010).

3.1.2 Factors that have a stock size regulating effect – brief discussion

The literature generally divides the factors that have a negative impact on wild populations of salmonids in two:

1) Factors that influence the production of salmon smolts
2) Factors that influence growth and sea survival

Factors that influence the production/recruitment of salmon smolts

In Norway the main documented/known causes of mortality in freshwater are as follows:

- intervention in the river: river regulation and other physical interventions
- pollution: mainly acidification, also pollution from agriculture
- effects of the parasite *Gyrodactylus salaris*
- river fishing / exploitation of spawners (hindrance to sustainable production of spawners)

Other factors that may influence the population in the freshwater phase (but of which the direct effect of or the extent of the effect are more difficult to document):

- escaped farmed salmon / genetic interaction
- predation
- disease (e.g. polycystic kidney disease – PKD)

These factors, and their possible stock size regulating effect, are discussed in greater detail in Chapter 5.

Factors that influence growth and survival in the marine life phase

Probable effects that may be expected to have a common influence on populations on large geographic scales are those which exist in the open sea where salmon from very distinct populations in freshwater may periodically feed together in the course of their most important growth phase.

The factual basis/documentation that has shown as possible that conditions in the marine environment contribute to variations in the population of wild salmon is significant and growing (Beaugrand and Reid, 2003; Friedland et al., 2003; Friedland et al. 2009; Vøllestad et al 2009).

Factors that influence survival during the marine life phase:

- Food availability and growth
- Food availability/feeding conditions are in turn influenced by climate changes / sea surface temperature / ocean currents
- Harvesting / marine fishing
- Disease (e.g. salmon lice, red vent syndrome - RVS)

Prominent scientists believe the environmental conditions in the marine environment are without doubt the most important factor in explaining the increase and decrease in the wild stocks and that this is also reflected in the composition of the returns from feeding migration.

Salmon lice is discussed further in Chapters 4 and 5.

Connection between food availability, early growth and survival

Marine mortality among salmon is often associated with the first phase after migrating to the marine environment; this is summarised, for instance, in the report commissioned for DN (Hansen et al., 2008) which reports several observations with high correlation between the average weight of grilse (one sea winter salmon) and marine survival in 20 rivers in the period 1989-2007. This report also refers to a similar connection between survival and growth in Scotland, Ireland and Norway (for references see Hansen et al., 2008) where the results also indicate that poor growth of salmon during the first year in the marine environment leads to higher mortality. Long series of monitoring in the Drammen, Ims, Figgjo and Halsa rivers have indicated that the survival rate today is just a quarter of what it has been previously, which suggests that we are in a period in which food availability for the salmon is poor, and the salmon struggles to survive in the marine environment (Eggereide, 2010).

Connection between negative growth and condition during the marine life phase and feeding conditions

It has been proven over recent years that there is a negative development in growth and condition during the marine life phase, and that a greater proportion of the returns now comprises salmon that have been on feeding migration for two or multiple years (2SW or MSW), and fewer grilse returning after a single sea winter (1SW) (Europharma fokus 1/2011 page 11-14, www.atlanticsalmonlostatsea.net).

Provisional results from the major Salsea-project indicate that there is limited food availability for outwardly migrating salmon smolts. The plankton stocks in the Labrador Sea, Irminger Sea and Atlantic Ocean have been gazed down by large populations of pelagic fish. This correlates with lower individual growth, higher mortality and less fish returning to the rivers. Signs of this include:

1) Shift from one sea winter salmon / 1SW (grilse) to two sea winter salmon / 2 SW (large salmon)
2) The average weight of grilse has dropped from 2.6 kg in 2003 to 1.9 kg in 2008. The fish are starving and are thin when they return to the river
3) The 2 SW salmon are becoming larger (large enough to feed on fish)

The decrease in growth in recent years has also been observed for salmon in Sweden and Scotland. There may be several explanations for this, and in all probability it may be attributed to a combination of several factors.

Todd et al. (2008) suggested that warmer water in areas where the salmon stays during grow-out may be one reason for reduced growth.

It has also been proposed that salmon lice may influence condition. A Scottish study of condition factors and level of salmon lice infection on returning 1 SW salmon in Scotland, which was implemented over eight seasons (same sampling location each season) (Todd et al., 2006), showed that condition factor was not influenced by the number of sea lice on the fish or vice versa: In seasons with a low condition factor infestation levels by salmon lice was not registered that varied from the infestation by salmon lice in seasons with a higher condition factor. Individuals with a low condition factor did not have a higher (or lower) level of infestation by salmon lice than fish with a high condition factor. Variation in annual condition factor was linked to feeding and growing conditions out in the marine environment and not to annual variations in infestation levels by salmon lice. In other words, a connection was not found between low condition factor and infestation by salmon lice (refer also to Chapter 4 of this report).

Connection between food availability and climate changes; natural and man-made

Much of the warming that has been measured from 1995 may be attributed to natural variations (e.g. the Atlantic Multidecadal Oscillation, AMO). The sea temperatures have a direct influence on many processes. The brief period from 1995 and onwards, with a strong warming of the Norwegian Sea, has led to a solid recruitment in the pelagic populations of herring and blue whiting, and possibly also mackerel. In the same period plankton measurements have shown a strong decrease that corresponds to the growth in the pelagic population. This establishes as probable that the pelagic populations have grazed down the plankton (Europharma fokus 1/2011, page 11-14, www.atlanticsalmonlostatsea.net).

The temperature increase from approx. 1995 was most unfavourable for the salmon in the southernmost part of the European area of distribution, such that the potential area of distribution was pressed northwards. Further warming of the sea as a result of anticipated climate changes is likely to have the most harmful effects on the more southern populations (see Todd et al., 2008), but to a lower degree on the northern populations, and particularly little effect in Northern Norway.

North Norwegian populations of salmon are closest to the cold ocean areas, which with a high level of probability will be extremely productive (Gross et al. 1988). In order to reach these productive northerly feeding areas, the fish from southerly populations must undertake far more extensive migrations through larger areas of sea, where they will be vulnerable to human exploitation, predation, energy shortage and other deadly factors.

3.2 Summary of Chapter 3

The development on both sides of the North Atlantic Ocean show the same population trends from a geographical perspective: In recent decades the stocks of wild salmon are described as stable in northern areas and decreasing towards the south in both Europe and North America (on both sides of the North Atlantic Ocean). In large parts of the southern area of distribution, the salmon population in river systems is regarded as threatened and/or extinct.

This relatively clear north-south gradient and correlation in the size of the populations of wild salmonids on such a large geographic scale suggests a common response by populations to large, global or sectorial environmental conditions (changes or variations that have an effect on population regulation of wild fish which are common and/or function the same over a large geographical area). There is increasing documentary evidence that the environmental conditions necessary for survival of anadromous salmonids during their marine life stage could explain such a correlation: Plausible explanations for population regulatory effects on such a large scale include climate changes and natural fluctuations in sea temperature that may cause fluctuations in the food availability and, consequently, of the marine survival for salmon.

Moreover, the common denominators for all areas in the south where local populations have become extinct or threatened (international level) are: High human population density, intensive dam construction on major waterways, pollution (including acid rain) and total dewatering of streams.

The probability that the potential negative effects resulting from an increased occurrence of salmon lice in fish farms may have an effect on such a large geographical scale is virtually nonexistent. This is based on the following facts:

- Salmon stocks are influenced throughout their entire distributional range, including in areas where aquaculture does not occur.
- The decline is greatest in the south, where aquaculture occurs only on a small scale.
- The decline is least or nonexistent in northern parts of the distribution area, where the existence of aquaculture is greatest (exception – Tana River – refer to the text).
- No documented evidence exists on the causal relationship between increased salmon lice and a decline in salmon stocks, over such a large scale.

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4 Evaluation of the factual basis concerning salmon lice – and interactions between salmon lice, wild fish and farmed fish

4.1 Salmon lice – a brief retrospective glance

Few descriptions exist concerning lice abundance in a more historic perspective. Berland and Margolis (1983) have reviewed historic literature concerning salmon lice, where it is shown that infection by salmon lice was reported as early as around the year 1600. They quote, among others, from PC Friis (published/written approx. 1600) in which returning salmon are described as follows;

> ”…*søge strax op i Elffuen oc Fosser at de kunde afftoe i Fosser oc paa Steen affscraabe store Lus aff sig, som sider i hans Nache*". (...seek immediately up in the river and waterfalls so in the waterfalls and on stones they can scrape large lice of them, which are attached to his neck”.) Moreover, Berland and Margolis quote from a work published by E. Pontoppidan in 1753: “… *da den i store Flokke kommer fra Havet og søger op i Elverne, deels for at forfriske sig i det ferske Vand, deels for at afgnie og afskylle, ved skarpe Strømmes og Fossers Fald, et Slags grønaktig Utøy, kaldet Laxe-Luus, som sette sig imellem Finnerne og plage den i Foraars Varme.*” (“...big schools of fish come from the sea and seek up in the rivers, partly to refresh themselves in the freshwater, partly to rub off and rinse off in the rapidly flowing streams and waterfalls, a type of green-like vermin called salmon lice, which attaches itself between the fins and torments them in the spring warmth”).

They also quote from a description by H. Strøm in 1762, in which Strøm describes salmon lice in the following manner;

> “*Den Luus, som plager Laxen om Sommeren, og driver dem til at søge de stridige Elve-Fosse, for der at skylle dette Utøi af sig* …” (“The lice that plagues the salmon during the summer, and drives them to seek the defiant waterfalls in the river, in order to rinse this off itself...”.

There is no doubt that salmon lice have been in existence and catching the eye long before the introduction of aquaculture. Salmon lice were previously regarded as the reason why wild salmon returned to freshwater – high salmon lice abundance gave notice of a good year for salmon fishing in the river. Traditionally one has had a positive view of salmon lice infection of salmon in rivers as there has been an assumption that the salmon had just returned from the sea.

An interesting comparison (and the only one we could find) of the level of abundance of salmon lice on wild salmon “before and after the introduction of significant aquaculture” was carried out by Berland (1991). The last year drift net fishing was permitted (1988), he registered the existence of salmon lice on wild salmon caught with drift nets at Sotra outside Bergen in weeks 24 and 25 (the second half of June). In his article, he compares the infection level with a study carried out at the same time in 1973 (Johannessen 1975.) In brief: The fish size was 50-109cm. The prevalence of salmon lice was 85-100 % in 1988 compared with 100 % in 1973, and the average number of lice (only figures for *L. salmonis* are summarised here) per fish was 7.44 in 1988 compared with 12.2 in 1973. Berland (1991) sums up his finds as such (quote):

> *"Despite the fact that my values for infection in 1988 were somewhat lower than Johannesen's in 1973, we must be able to draw the conclusion that the infection with the two lice species was reasonably similar in 1973 and 1988. In 1973 salmon farming had barely started, while in 1988 we had a significant aquaculture industry. What is interesting is that despite the mass appearance of salmon lice on farmed salmon, and consequently enormous quantities of nauplii/copepodites in the coastal water, this has not led to increased lice infection of wild salmon."* (end quote)

The wild salmon referred to in the above text is adult salmon, while today most registrations occur at the juvenile stage, and then of outwardly migrating post-smolts. This makes it difficult to compare the "historical" infection values mentioned here with today's values.

4.2 Today's situation: Evaluation of the factual basis that deals with the level of salmon lice, wild fish and farmed fish

A selection of the latest reviews that deal with the interaction between salmon lice, farmed and wild fish (Revie et al, 2009, Raynard et al, 2006, Costello et al, 2009) provide a good overview of the literature in the field. However, one is reliant on going to the original works in order to assess whether the results and conclusions are "watertight". Even though the reviews are of limited value in relation to critical evaluation of the literature, it is nonetheless interesting to see which conclusions have been drawn. All aim to summarise the knowledge concerning salmon lice and take a stand about some central questions in this context, but interestingly the conclusions are somewhat different. In Costello (2009), the conclusion, based on the works that are referred to in the review, is that there is evidence that aquaculture is the main source of salmon lice infections of wild juvenile salmonids. One of the arguments to support this is the enormous reservoir of lice found on escaped salmonids, here with reference to Heuch & Mo (2001). However, the number of escapes has dropped significantly since this article came out. Revie *et al.* (2009) appears to be the most balanced review in this field. This review concludes, among other points, that lice from farmed salmon is of significance for infestation of wild fish, but there are also many other factors that need to be taken into consideration and the significance of these is not known.

Some factors that influence the results and consequently the conclusion of the published works:

- Variation in fishing method and handling of the fish that are examined
- Direct comparison of different geographical areas with different environmental conditions
- Annual variations/seasonal variations that need to be taken into consideration
- Low or extremely varying numbers of fish included in the studies and which form the basis for statistical calculations and strongly held conclusions
- Variation in how lice registration, determination of species etc. is carried out. This is also complicated at early stages, as it is difficult to distinguish between different parasites, e.g. *C. elongatus and L. salmonis*.

In the NINA reports (Bjørn et al., 2008; 2009 and 2010) that describe the situation for wild salmonids in Norway in relation to infestation by salmon lice over the past three years, there are many references to Heuch & Mo (2001) and Heuch *et al.* (2005). In some instances, the interpretation in the reports is difficult to understand. Take for instance an example from the 2008 report (see figure 18, p. 32): It is stated on p. 31 that there was a major increase in salmon lice in 2007 in some areas compared with the previous year. However, if you look at the median values you will find that this is incorrect. The reports include some opinions and assumptions, including the main conclusion that there is an "increase in the number of lice compared with historical data" also with reference to Heuch *et al.* (2005). Historical data is not based on actual counting of lice, but on the conveying of oral observations made by individuals and by assumptions in relation to the number of wild salmonids, farmed fish and infestation by salmon lice of these. The reports also state that the number of lice in fjords including the Hardangerfjord have an effect on population regulation of wild salmonids. However, no concrete evidence is presented, and the authors admit that several more years of studies are necessary in order to draw safe conclusions.

Low lice abundance on wild fish in a number of fjords with high aquaculture activity suggests that many other factors need to be taken into consideration when assessing the risk of infestation by salmon lice of wild fish, such as variations in environmental conditions including flow conditions, the amount of freshwater/salinity, temperature etc. There is a relatively high proportion of fish caught in the outer fjord areas classified in the reports as farmed fish. This proportion is higher than the registered escape figures indicate as probable.

For an expanded discussion of Heuch & Mo (2001), see Chapter 4.6 of this report.

4.2.1 Evaluation of some mentioned articles that suggest a correlation between an increased level of salmon lice from aquaculture and a decline for wild fish

Ford & Meyers (2008) carried out analyses in which they compared existing data of marine survival (returning spawners) of wild populations of brown trout, Atlantic salmon and three species of Pacific salmon (coho, pink and chum salmon) that during their migration to the marine environment as post-smolts either migrated through areas with or without intensive aquaculture activity.

It is reported that the decline in wild populations of salmonids in Ireland (1985-2001), Atlantic Canada (1987-2004) and British Colombia (1970-2004) concurs with populations that have migrated through areas with intensive aquaculture activity. The results from Scotland (1971-2004) were unclear, and reliant on which data was included.

Based on the results, Ford & Meyers (2008) conclude that the global decline for salmon and brown trout correlates with the growth and increased production of farmed salmon, and that a causal relationship exists between increased aquaculture activity and decline for the wild fish.

Comments:

Without having gone in detail into the use of the data set and statistics, some weaknesses immediately appear in the summary by Ford & Meyers (2008). Although they report a correlation between decline in salmon populations and the occurrence of salmon farms, no causal relationship is documented (no causal factors are isolated). In all analysed instances, control areas (areas without fish farms) are located to the north of areas of intensive aquaculture activity. This is not sound from a statistical perspective (systematic error) as the control and experimental areas should have been located to both the north and south of each other. Not only is this unsound from a statistical perspective, where the choice of controls in the north concurs with the areas that show the lowest declines in wild populations on a global scale, the effect of the location of the areas can in itself have a major effect on the result of the analyses.

A curiosity is the absence of statistical significance in the data set for Scotland, where the authors admit that the decline in the salmon population had begun before the presence of intensive aquaculture activity. Nonetheless, they find an “increased” decline on the west coast of Scotland compared to the east coast, which is free of aquaculture activity. This is also an interesting observation given that Urquhart et al. (2010) (mentioned further down) report on higher infection pressure from parasites on the east coast of Scotland.

Krkošek et al., (2007) make a similar comparison to Ford & Meyers (2008). A large collection of data of population dynamics of wild pink salmon from areas without aquaculture activity was compared with population dynamics of wild populations of pink salmon from areas with intensive aquaculture activity. The study includes estimates of mortality as a result of infection with salmon lice.

The data set covers the period 1970-2006, and describes the population dynamics of wild pink salmon along Canada’s Pacific Coast.

The article reports a significant increase in mortality from 2002 to 2006, with salmon lice infection from aquaculture stated as the reason. The authors conclude that there is a 99 % probability of a total collapse of wild populations within four generations unless immediate changes are made to the level of abundance of salmon lice.

Comments:

The relevance of the study by Krkošek et al., (2007) in this report is somewhat unclear since it deals with a wild population of Pacific salmon and moreover in a geographical area far removed from the eastern part of the North Atlantic. However, the study is included as it should be included in a discussion concerning possible connection between salmon lice and population dynamics. **Brooks & Jones (2008)** on the other hand point out several flaws in the study carried out by Krkošek et al., (2007). They describe, among other points, that the natural variations in the number of returning salmon in the Northeast Pacific are unpredictable and large. This was also confirmed recently by the record high spawning migration of another type of Pacific salmon (Sockeye) in British Columbia in 2010, when 25 million salmon returned to the Fraser River compared with 1.7 million the previous year. (http://www.cbc.ca/news/canada/british-columbia/story/2010/08/25/bc-sockeye-salmon-fraser-river.html).

Brooks & Jones (2008) also shed light on flaws in the statistical analysis of data, including the fact that one of the most important salmon producing rivers in the Broughton Archipelago was excluded in the analysis. Neither does the conclusion take into consideration the natural reservoir of salmon lice (such as stickleback and wintering juvenile wild salmon), and they consider the mortality as a result of salmon lice infection is overestimated. Marty et al (2010) use partly the same data set as Krkošek et al., (2007) base their conclusions on. However, Marty et al (2010) include significantly more information. Based on the new extensive analyses, no connection was found between the total number of lice on farmed Atlantic salmon and recapture of pink salmon (see the comment and discussion in Chapter 4.2.2)

4.2.2 Evaluation of articles that report <u>lacking/improbable</u> correlation between an increased level of salmon lice, aquaculture and population variations

Marty et al., (2010) point out in conformity with Vøllestad et al. (2009) the importance of including several factors in an analysis of variations in wild salmon abundance. The article appears to be well considered and solidly conducted. The studies use data from the Broughton Archipelago (Canada's west coast) that included 10-20 years of lice data and figures for farmed fish in 17 different fish farms with Atlantic salmon as well as 60 years of data on variations in abundance of wild pink salmon (*Onchorhynchus gorbuscha*, Pacific salmon). The study shows that there is a connection between the number of returning wild salmon in the autumn, and the number of lice females on farmed fish the following spring (i.e. that the returning spawners are vectors of lice and the number of spawners predicts the level of lice/infection of farmed fish), which in turn has a high correlation with the annual variation in lice abundance on outwardly migrating smolts of wild fish (i.e. that there is high probability that farmed salmon are the source of salmon lice infection of outwardly migrating smolts of pink salmon in the Broughton Archipelago).

Despite the last-mentioned correlation, there is no correlation between the number of lice at fish farms and the survival rate of wild fish. The article further concludes that the productivity of wild salmon (the size of the wild salmon population) is neither connected with the number of lice at fish farms nor the size of production (biomass/number of fish) at the fish farms. The analysed data set supports the fact that there are factors other than salmon lice that caused the decline in the population of pink salmon in 2002. Marty et al. (2010) call for studies that include the entire pathological picture, as mortality is not proven as a result of lice infection. Moreover, many instances of symptoms of ill/weakened juvenile salmon (bleeding around the fins/red fins) were detected that do not correspond with the symptoms resulting from infestation by salmon lice, but rather as symptoms of negative environmental impact or bacterial or viral infections.

Strong arguments that support the conclusions of Marty et al. (2010) include the following:

Data from 17 fish farms in the period 2000 to 2009 shows that relative variation in the number of salmon lice is significantly higher than relative variation in the number of farmed fish during the same period. The highest estimated number of salmon lice at fish farms during this period was 180 times higher than the lowest estimate during the same period, but the highest number of fish during the same period was only 2.3 times higher than the lowest number. Consequently, the number of salmon lice per farmed fish varies independently from the number of farmed fish, which indicates/establishes as probable that variations in the number of salmon lice are caused by other factors.

Farmed salmon are free of salmon lice when they are transferred to the marine environment, and are infested with salmon lice within a couple of months.

The highest total number of lice females in the period was registered in May 2004; when two fish farms alone accounted for 18.7 million lice females compared with a total of 7.9 million lice females one month earlier in all 17 fish farms combined. This sudden increase in the number of lice females at these two fish farms can only be explained by an unusual source, possibly wild fish, that year in the northern part of the Broughton Archipelago.

The correlation between the number of returning wild salmon in the autumn and the number of salmon lice that infest farmed salmon the following spring is statistically significant.

Urquhart et al. (2010) carried out a field study in Scotland in which 300 sea trout from wild populations were analysed for bacterial and viral infections, ectoparasites and endoparasites over a three-year period (2005-2007). The samplings were carried out at two localities on the west coast with aquaculture activity and three localities on the east coast without aquaculture activity. Thorough examinations were carried out on the sampled fish:

- Registration of pathogen virus and bacteria; detailed tissue samples
- Registration of ectoparasites; immediately in the field (visual) and storage of parasites in ethanol for determination of the species, thorough analysis of the skin, gills and fins under the microscope/magnifying glass
- Registration of endoparasites; studies of the side of the mouth and stomach as well as the inside/dissection of the organs

In total the following were registered and the species determined; no bacterial infections, five viral infections, ectoparasites on 49 % of the fish, a total of 9182 endoparasites and > 2000 cysts. The statistical analysis was carried out at two localities in the east and two in the west with data from 2006-2007 (most comparable). Occurrences of lice of the type *L.salmonis* was significantly higher at both locations on the east coast (aquaculture-free zone) as compared to the west coast (p=0.0001 in all cases).

In general there was a higher level of parasite infection on the east coast than on the west coast.

The article concludes that the generally higher occurrences of parasites on the east coast indicates the existence of a larger reservoir of parasitic fauna there than on the west coast. The level of lice infection found on the east coast in this study is comparable with the level of lice infection described for brown trout in aquaculture-free zones in East Anglia and England. This establishes as probable that salmon lice in these areas cannot be from fish farms but instead from another source of infection.

Weaknesses/some points of uncertainty:

The localities that were sampled on the west coast, River Carron and River Annan, appear to lie in a fjord system and possibly at a river mouth(s) in contrast to, for instance, North Esk on the east coast, which has a completely exposed location facing the open sea. Even though the article explains that all fish are caught in the estuarine and/or tidal zone, it is possible that there are differences in salinity and flow conditions. Nevertheless, the location Upper Forth

Estuary on the east coast also appears to lie in a fjord system (therefore with similar conditions to the two localities on the west coast), and this locality also had significantly higher lice abundance than both locations on the west coast. However, various salinity and exposure conditions cannot explain the entire difference in the infection level between east and west.

Moreover, the sampling of fish on the west coast was undertaken later in the year (July-December) compared with fish on the east coast (May-August), so that the data sets are not entirely overlapping in season.

Consequently, there are some seasonal differences as well as possible differences in salinity/exposure between the various localities that may explain some of the significantly higher occurrence of salmon lice on the east coast. There were also large differences in year class / size of the fish between east and west. Statistical analysis would have been stronger if it has been corrected/sorted for this.

Hvidsten et al. (2007) describe trawl data over a 12-year period (1992-2004) from a population in the Trondheimsfjord, which is a fjord without any aquaculture activity. The authors wanted to investigate whether there is a detectable correlation between the lice infection levels on outwardly migrating wild smolts and the number of returning 1 SW in river fishing in the River Orkla the following year (as an indirect measurement/estimate of the possible effect of lice infection on marine survival).

The article reports that no significant connection was found between the infection levels on outwardly migrating smolts and the number of returning 1SW. Thus, there was no detectable effect of salmon lice on marine survival in wild populations in the Trondheimsfjord. The large variation in the number of returning salmon may therefore probably be attributed to other factors (e.g. sea temperature).

A tagging trial conducted in 1996-1998 involving treated and untreated salmon smolts (approx. 3000 smolts per group per year) on the other hand led to a larger number of returning fish from the group that was treated against infection in 1998. This suggests a possible connection between the level of lice infection and marine mortality of post-smolts in 1998. However, the results are based on low recapture.

Comments:

The composition of lice data and catch data over a 12-year period is a good study. The figures have been adjusted for variation in catch statistics that may be attributed to ”natural” marine mortality (based on catch statistics in the River Namsen.

The tagging trial was carried out with a large number of smolts per group. But the tag return percentage was relatively low, and varied from 0.51 – 2.20 % (is equivalent to mortality or lacking tag return (=lacking registration) of 99.5-98 %. This is an extremely low number from which to draw conclusions? Further, the data from the two other years of tagging trials did not result in differences between the treated and untreated groups.

Sources of infection in the Trondheimsfjord; It is speculated in the introduction of this study that lice may be transported from south-west Norway to the Trondheimsfjord. It also refers to the fact that brown trout with high levels of infection of salmon lice have been reported at Hitra, which lies to the west of the Trondheimsfjord. We perceive therefore that wild brown trout may be a source of salmon lice in the Trondheimsfjord?

Marshall, S. (2003) concludes on the basis of a field study of several years duration that the abundance of lice on wild fish is not directly related to the abundance of lice at nearby fish farms. Correlations that were registered in the data material in the study were not significant factors that influence infestation by salmon lice of wild fish. However, treatment against lice at fish farms seemed to have a positive effect on wild fish to a certain extent, and fallowing periods were recommended. Without assessing the statistical calculation carried out in this work, the article deals with some interesting relevant issues. The author problematises the comparisons that are made of infestation by salmon lice of wild fish in areas with and without aquaculture activity, where these areas are geographically different and where the studies have been carried out at different times (season and year). This may, according to the author, have a major affect on the results that are attained. This study was conducted in a limited geographic area where the fallowing period at the fish farms is used as a control zone.

There are large variations in the number of fish examined (from five up to 50-60 per time), which creates greater uncertainty about the data material at some points. As such, the variation in registration of the amount of lice may be attributed to that fact that different numbers of fish were examined each time. The sampling of wild fish and farmed fish was carried out during the same week in order to achieve the best possible basis for comparison. The trend was that seasons of fallowing gave low/declining infestation by lice of wild fish, while an increase in the number of lice on wild fish was registered when the biomass at the fish farms increased. Due to variations in the registrations this difference/trend is not significant. There was a correlation between the abundance of lice on wild fish and lice on farmed fish, but the amount of gravid lice and chalimus on the farmed fish did not correlate with the total number of lice on the wild fish.

Schram *et al* (1998) studied brown trout in an area without aquaculture activity (Tromøy, Arendal) in the period March-December in the years 1992-1995. A total of 502 trout were examined for lice, showing 20-35 % prevalence in April and 100 % prevalence in July-October. Low numbers of lice were found with 1 (minimum) to 8 (maximum) as the median figures. Mostly adult lice females with egg strings were found, and the maximum proportion of chalimus registered was 15 %. The infestations by salmon lice were not correlated to condition factor or age. The fish were in good condition and no injuries were detected. The authors conclude that the large variations from month to month found in this study on wild fish cannot be related to treatment regimes at the fish farm, but that the seasonal variations may be attributed to other factors (environment, geography etc.).

Gottesfeld *et al.* (2009) studied the risk of dispersion between juvenile pink salmon and returning Coho and Chinook salmon in coastal waters of Canada in an area without aquaculture activity in the period 2004-2006. The examined juveniles comprised more than

20 000 individuals collected during several sampling periods. The returning salmon were examined only in 2006 (69 individuals). The conclusions were that the most important reservoir of salmon lice in areas without salmon farms is returning salmon. All the returning salmon had lice when they reached the coast (on average 18 per fish, mostly adult lice females). Motile stages comprised more than 80 %, of which nearly 80 % had egg strings. The study concludes that much of the reproduction of *L. salmonis* must occur in the sea before it reaches the coast. Experimental studies have shown that adult lice can move between hosts (Hull *et al.,* 1998), but this only occurs in the sea if the louse has the ability to survive a period of time without the host. Experimental studies have also shown that adult lice females can survive 49 days without food intake (Hogans *et al.,* 1995). A 100 times increase in lice abundance was found on salmon juveniles during the grazing period in coastal waters. However, the level of infestation by salmon lice was still more than 10 times lower than on wild juveniles in areas with aquaculture activity. These comparisons involve other studies carried out in completely different geographic areas and in different periods of time.

4.3 Weaker wild fish as possible vectors

Little research has been conducted in this area, and recent reviews and other articles express a need for more knowledge concerning infestation by lice of wild salmon and trout in the marine environment. There is also little knowledge concerning the ecology of lice in the sea. A number of studies have been carried out on premature freshwater return as a result of infestation by salmon lice. This appears to be a reasonably well studied field by several and with the same conclusion: Lice infestation of outwardly migrating trout and char that occurs a short time after ocean entry leads to early returns (ref. Birkeland, 1996, and Birkeland & Jacobsen, 1997, among others).

A few works have been published on condition factor and risk of infestation by salmon lice. One study is published on wild salmon in Scotland returning after one winter in the sea (Todd et al, 2006). The study was carried out over eight seasons with the same sampling locality each season. The fish were caught out by the coast while returning from the sea and some distance from larger river areas. The condition factor was calculated (two calculation methods; Fulton's index and the relative mass index (W_R)), and lice counts were conducted. Both *L. salmonis* and *C. elongatus* were registered, and a multitude of statistical analyses were performed. The work appears on the whole to be thorough and considered and with conclusions that match the results that were actually achieved. The condition factor of fish examined within a season had extremely little variation, while the variation from year to year was significant. This conclusion is also supported by earlier studies that went over 13 seasons.

The abundance of salmon lice per fish varied from year to year, but 100 % of the fish were infested by salmon lice in all seasons. This is also described in Raynard et al (2006) who summed up that 95 % prevalence on wild trout and salmon is also common in areas without fish farms. Others have concluded that wild salmon which are naturally infested with lice and graze in the fjords for a time before they migrate up the rivers are a local source of infectious lice stages (see Heuch *et al*, 2005). The fish length was positively correlated with infestation level: the longer the fish, the more lice. This is explained by the fact that longer fish have a larger body surface area (BSA). A low number of larvae (chalimus) was registered on fish in this study, pre-adult and adult lice females dominated. The condition factor was not influenced by the number of lice on the fish; in seasons where fish had low condition factor infestation by salmon lice was not registered that deviated from infestation by salmon lice in seasons with higher condition factor. Individuals with low condition factor did not have higher (or lower) infestation by salmon lice than fish with high condition factor. The same conclusions have been drawn for brown trout in Schram *et al* (1998). It is established as probable that the presence of pre-adult lice stages indicates that the fish were infected at least 3-4 weeks prior to catching, i.e. before it reached the coast. The speed at which salmon lice develop further suggests that finds of adult lice are not survivors of infestation by salmon lice that occurred when the fish migrated from the rivers and into the marine environment. The authors conclude that a continual re-infection occurs out in the open sea in connection with feeding activity. The variation in condition factor from year to year is linked to marine feeding and growing conditions and not to annual variations in infestation by salmon lice. Consequently, there is no clear evidence that poor condition factor in brown trout makes them more susceptible to infestation by salmon lice or that poor condition factor may be attributed to infestation by salmon lice (cf. references in Todd *et al.*, 2006).

To what extent "weakened" salmon may be more susceptible to infection is described by Hindar et al., 2010, among others. In acidified environments the salmon is extremely sensitive to aluminium. Too much aluminium will in turn reduce the seawater tolerance of the smolts. When smolts from various environmental treatments were exposed for salmon lice, higher mortality was found in smolts that had been "aluminium strained" than smolts that had only been exposed to low aluminium environments.

How this can influence the salmon as a vector will only be speculative. We cannot see how such weakened smolts can constitute an extra infection pressure, particularly not in the event of increased mortality.

What is very interesting on the other hand is the indirect effect of pollution on survival of smolts early in the marine life phase (more about this in Chapter 5 – concerning pollution).

4.4 Brown trout as a possible vector and/or reservoir for salmon lice

In Norwegian waters, salmon, brown trout, rainbow trout and Arctic char can have salmon lice. Fjords and coastal waters are year-round habitats for the brown trout, which can sustain production of salmon lice throughout the year. The significance of the brown trout to salmon lice production along the coast means that according to Jonsson et al. (2006) one can perceive salmon lice more as brown trout lice than as salmon lice.

The anadromous form of brown trout resides in fjords and coastal waters during the summer period, and mostly within 100 km of the source rivers/river systems. For "northerly populations" of brown trout, the grazing activity of the brown trout is more intense during increasing sea temperatures in spring and early summer (Klemetsen et al., 2003). In Norwegian waters, this corresponds with the period in which salmon smolts migrate, which confirms what Jonsson et al. (2006) describe concerning the significance of the brown trout to salmon lice production.

As a curiosity, it is also worth mentioning that in addition to salmonids there is increasing mention of sticklebacks as vectors (Jones et al 2006 a, Jones et al 2006b).

4.5 Premature freshwater return – correlation with high infection pressure

Birkeland (1996) seems to be the first publication on premature freshwater return due to infestation by salmon lice detected in Norway. The author studied one river in Western Norway (Lønningsdalselva) in a fjord system with aquaculture activity. The fish were collected using trapping sites (two collections per day) throughout one season. The returns occurred in June for post-smolts (too early) and July for more mature fish (normal). The article states that returns normally occur in July-August and it is normally the oldest fish that migrate up the river first. A high abundance of lice was found on the fish, which were in poor condition (mostly skin damage). The highest number of lice were found on post-smolts (98 fish examined, median figure for lice was 206), and the lowest on larger fish (74 fish examined, median figure was 43.5 with a total of 90 % prevalence). The post-smolts had approx. 87 % copepodites and chalimus and approx. 13 % pre-adult lice, while the older fish had approx. 70 % copepodites and chalimus and approx. 30 % pre-adult and adult lice. A mortality rate of approx. 20 % was registered for the older fish in the first week they resided in the river, but the lice count did not differ from the fish that survived. Only three post-smolts were observed dead, but the figures have elements of uncertainty due to insufficient registration (difficult to conduct mortality registrations, particularly for post-smolts). What is normal mortality in a river for returning fish? Approx. 40 % of the post-smolts migrated back to the sea after an average of 37.5 days in the river. This was size-dependent; small fish returned to the sea (due to better growth conditions in the marine environment), while larger fish remained in the river. The fish that returned to the sea again were free of lice, but had lost 23.5 % bodyweight and showed no length increase. Pre-adult and adult stages are regarded as the most harmful, and several estimate 30 pre-adult/adult lice as the threshold for whether the fish is inflicted considerable damage. The fish, therefore, must get rid of the lice before it reaches these stages to prevent major damage, and this is suggested as the reason why premature freshwater return occurs. Moreover, it is concluded that premature freshwater return is detrimental to growth and consequently also to reproduction.

As mentioned previously, around 90 % prevalence is also common for trout and salmon returning from the sea and caught in coastal waters and also in areas without aquaculture activity. It is possible that there is a difference in the abundance of chalimus found in this study compared with other studies of fish out in the fjords. A high abundance of chalimus should indicate that the fish was infested relatively recently, while pre-adult and adult stages indicate that they were infected several weeks ago.

In an experimental study (Birkeland and Jakobsen, 1998) in which infected and uninfected brown trout were released in the same river (Lønningsdalselva), the infected fish migrated back to the river, many within the first week, and this study supported the findings from Birkeland (1996).

Overall, it is established as probable in the literature that infection with salmon lice resulting in osmo-regulatory problems may lead to behaviour such as premature freshwater return, although the infection threshold for such premature return is uncertain. With respect to potential consequences of such premature freshwater return, are local conditions such as the food availability and the condition of the fish of major importance for how the fish is physiologically in a position to tackle the infestation by salmon lice.

Despite the fact that the description of this phenomenon is relatively “new”, we cannot see that it is documented that this is a new phenomenon.

4.6 Natural resistance

Significant genetic variation against salmon lice has been documented in Norwegian farmed salmon (Kolstad et al. 2005, Gjerde & Saltkjelvik 2009, Gjerde et al., 2011). In these studies, resistance against salmon lice is defined as the number or density of lice on the fish. Consequently, the grade of resistance reflects the ability of the fish to limit the number of parasites on its body surface (either by preventing the parasite from attaching to the fish and/or by getting rid of the parasites after they have become attached). Fish with a low density of lice (regardless of the reason) will naturally be less exposed to lice-related injuries and disease. As the farmed salmon is developed from wild salmon from many Norwegian salmon rivers, there is probably also a significant genetic variation in resistance against salmon lice in wild salmon, which indicates that Atlantic salmon in all likelihood has a genetic potential to develop greater resistance against salmon lice through natural selection. However, there may also be genetic variation in tolerance, i.e. the ability to live with a significant number of parasites, a topic that has to date not be studied (as far as I know). To the extent that there is genetic variation in tolerance, this will also be of significance for the survival of the salmon in a natural environment with a significant infection pressure, and consequently could be relevant for natural selection.

However, natural selection for increased resistance/tolerance against salmon lice presupposes that any increased infection of wild populations with salmon lice results in increased mortality (and/or reduced reproductive success) in the population. The effect of natural selection will increase with increased salmon lice-related mortality. In populations where mortality is related to (increased) salmon lice infestation only to a low extent, natural selection for resistance against salmon lice will not be of particular significance. The degree to which natural selection has been of significance to the wild salmon is therefore uncertain, all the time that significantly increased mortality due to increased infection pressure with salmon lice from aquaculture may only be documented to a small extent.

4.7 Adequacy of Heuch & Mo’s model for estimation of a sustainable level of salmon lice

It has been demonstrated in laboratory trials that salmonids are inflicted physiological stress when they are infected with a sufficient level of salmon lice (Wagner et al., 2008) and this may produce increased mortality in smolts (Heuch et al., 2005; Bjørn et al., 2009). But knowledge concerning the critical threshold from the number of lice of various stages (parasitic, chalimus, pre-adult and adult) on, for instance, a salmon smolt in the wild is insufficient. However, it is intuitive to imagine that an increase in the number of salmon lice produced will lead to an increase in infection pressure and consequently an increased number of lice per wild salmonid, and reduced survival given that this tolerance limit is exceeded.

Heuch & Mo (2001) have developed a simple model for this relationship: Marine mortality of wild salmonids = Infection pressure by salmon lice = Number of louse eggs at a given time = Number of salmonids x Number of sexually mature salmon lice females/salmonid x Number of louse eggs/sexually mature salmon lice females/brood.

Based on this model Heuch & Mo (2001) calculated a critical treshold for the number of lice per salmonid as a function of the number of farmed salmonids for a total of 50 and 5.2 billion louse eggs. The highest level was set at the estimated number of louse eggs in 1986 and 1987, therefore before the first reports concerning a negative effect of lice on brown trout came (NINA, 2009, letter to the Ministry of Fisheries and Coastal Affairs), while the lowest level was an estimated number of 2.6 million louse eggs from wild salmonids plus an equivalent number from farmed salmonids.

The number of eggs per louse female per brood from farmed salmon in the model was set at 500 compared to 1000 per louse female from wild salmonids (Tully and Weland, 1993). Heuch et al. (2000) report a lower average number of eggs per louse per brood for both wild (356) and farmed (472) salmon. For lice from farmed salmon in the laboratory, the report is of an equivalent number (444) of eggs per louse per brood (Hamre et al., 2010). An estimate of 500 eggs per louse female per brood from farmed salmon may therefore appear to be a realistic estimate, and 1000 eggs per louse female from wild salmon maybe a high estimate, and that this therefore will underestimate the total number of louse eggs from farmed salmon as pointed out by Heuch & Mo (2001).

At any given time there are far more farmed salmonids than wild salmonids along the coast (probably >> x 500 during the summer months when the number of wild salmonids peaks). Therefore, the number of louse eggs produced at any given time will essentially be determined by the number of farmed salmonids and the number of sexually mature lice females per fish. As a consequence of this, an upper limit for the permitted number of lice per farmed salmon has been set in order to hold the infection pressure by lice on wild salmon (and farmed salmon) at an acceptable level (from the year 2000 0.5 adult lice females per fish in the period January 1 to August 31, § 5 of *Luseforskriften*, the official regulations relating to salmon lice).

According to Heuch & Mo (2001) the model shows that if the number of louse eggs produced shall not exceed this lowest level (5.2 million eggs), the number of lice per farmed salmonid must be 0.1 louse in 1988, 0.05 louse in 1999, and today substantially lower than 0.05 lice per fish due to the substantial production increase in farmed salmon in recent years.

Heuch & Mo (2001) estimated louse eggs at 88 billion in 1988 and 111 billion in 1999, or 32 and 43 times larger respectively than the desirable natural (sustainable) level of 2.6 billion louse eggs. If this multiplied infection pressure actually has a negative effect on the survival of wild salmonids as the model suggests, it is reasonable to assume that this should lead to reduced catches of wild salmon in the following years of the 21st century.

However, the catch statistics do not indicate such a negative effect. On the contrary, the statistics show that the number of salmon caught in 2000 and 2001 were the best years after 1988, and that 2002 and 2003 were also above average, and that for brown trout the years 2000-2005 were better than 1995, 1998 and 1999, but with a declining trend in the period 2006-2009 (SSB, official catch statistics). Therefore, the more probable conclusion is that the sustainable level in 1999 has not been exceeded, even with a multiplication of the estimated infection pressure (the number of louse eggs produced). Moreover, the lice counts per fish are to a large extent registered on net-caught and returning brown trout, and to an extremely low extent on outwardly migrating smolts, as also pointed out in the report concerning risk assessment (Institute of Marine Research, 2010; Chapter 5.1, page 77).

With respect to Arctic char, the Norwegian Scientific Advisory Committee for Atlantic Salmon Management (Anon, 2009) reported that “It can appear that the Arctic char has had a negative development in several river systems throughout Northern Norway in recent years. In Finnmark, for instance, the catch of Arctic char has dropped from 8 tonnes per annum in the 1980s to 2.5 tonnes in 2007”. But this probably has nothing to do with lice as lice is less of a problem in Finnmark compared with fjords further south (Anon, 2009).

In addition, the decline in catches of wild salmonids in recent years has been less in Norway than in other countries (see Chapter 3 of this report), on the assumption that the catch statistics are accurate enough to capture the actual changes from year to year. But at the same time, it is impossible to know what the catch would have been given a natural infection pressure of lice just from wild salmon.

Another example is that in the period 1999-2001 Bøe observed 36-104 lice per outwardly migrating smolt and 100-130 lice per brown trout in the Sognefjord (State of the Environment in Sogn og Fjordane) and also high infection levels of brown trout (40-150) in Nordfjord and Sunnfjord, but far less lice on salmon (0-30) in the same fjords. In 2002 and the following years lice for some reason were virtually not registered on wild salmonids in the Sognefjord. For the year 1999 it was estimated that salmon lice killed 90 % of the outwardly migrating smolts in the Sognefjord, which one would imagine would be reflected in the catch statistics in the subsequent years. But the catch statistics for Sogn og Fjordene for the period 2002-2010 which roughly covers the three fjords studied (SSB, official catch statistics) does not reflect any such collapse in the catch of brown trout and salmon. This indicates a lack of logical correlation between estimated critical threshold, observed infection level and registered catches of brown trout and salmon, which raises questions about the degree to which the present low critical threshold is correctly calculated. For example, such a discussion lacks in what we must presume are the most updated reviews of physiological effects of lice infections (Finstad et al., 2011; HI, 2010). Moreover, an interesting observation exists from Nordfjord in 1998, where more than 90 % of the outwardly migrating smolts had empty stomachs (Rickardsen et al., 2004).

The major weakness of the model of Heuch & Moe (2001) is that infection pressure is set equivalent to the number of louse eggs produced and as such does not take into consideration how large the proportion is of eggs produced that become copepodites (the infective stage of the lice), the large the proportion of the copepodites is that become attached to the wild salmon and remain attached and for how long, and its fate if it detaches from, the host, and also if these proportions may be different for the offspring of lice from wild as compared to farmed salmon. The latter is not improbable since the production of louse eggs from farmed salmon occurs from localities with an extremely large number of fish per locality and that the dispersion of eggs, nauplii and copepodites therefore may be significantly different for offspring of lice on farmed salmonids compared with offspring of lice from wild salmonids. On the whole, we know very little about the ecology of the louse in the ocean.

Even though there has without doubt been documented lice on outwardly migrating salmon smolts and on other salmonids that in all likelihood is related to offspring of lice from farmed salmon (Bjørn et al., 2010a), no good field data exist concerning critical levels for mortality and levels with negligible effect. Consequently, the conclusions that are drawn and may be drawn from the national surveillance of salmon lice to a large extent characterised by expressions like probably and indicia (Bjørn et al., 2010a), rather than results one may attach scientific confidence to.

The model of Heuch & Moe (2001) is also very simple in the sense that it models the production of louse eggs on a given day of the year (May 1) and as such does not take into consideration the variation in the number of lice on wild and farmed salmonids during the year as well as geographical variations (Gillibrand & Willis, 2007). For instance, at a sea temperature of 4º C it takes approx. 43 days from hatching to develop into the first copepodite stage and the copepodite is infective for 30 days (Heuch et al., 2005), while at 10-12º C it is infective one week after hatching and stays infective in the subsequent week (Heuch, personal communication). In addition, the model is linear, which means that an extra egg produced has the same effect regardless of the number produced, which is probably not the case in reality. These factors are probably highly important for determining the proportion of the louse eggs produced at any given time that may constitute a real infection pressure on wild salmonids.

In the report concerning risk assessment (HI, 2010) the model of Heuch & Mo (2001) is for instance applied to calculate the number of louse eggs produced for each county and each month during the summer of 2010 (table 5.1.1.2). The total for all counties was 31 billion in April, 12 billion in May, 32 billion in June, 61 billion in July, 126 billion in August and 194 billion in September; a total of 456 million louse eggs. Not surprisingly, the counties with the largest production of farmed salmon have the largest production of louse eggs.

The report concludes that there is not necessarily a direct correlation between biomass in aquaculture within an area and the level of infection pressure the wild populations are exposed to within the same area (Chapter 5.1, page 69). However, the question that is not reflected on is if it constitutes a particular difference for wild salmonids whether 500, 50, 5 or 2.5 billion louse eggs are produced, i.e. whether there is a simple/direct correlation between the number of louse eggs produced, the number of copepodites and the number of lice stages of various stages per fish. We cannot find any field data of relevance to this.

Based on the available knowledge, we cannot find any existing scientific evidence documenting a simple/direct connection between the number of sexually mature lice females, essentially a product of the number of farmed salmon and the number of female lice per fish, and marine survival of wild salmon, and the calculation/estimates of a sustainable level of lice is, therefore, not sufficiently knowledge-based.

Marty et al. (2009) could not document such a correlation between the number of lice on farmed Atlantic salmon and recapture of wild pink salmon (*Oncorhynchus gorbusha*) based on many years of data from the Broughton Archipelago, British Columbia. On the other hand, they did find a positive correlation between the number of returning pink salmon in the autumn and the number of lice females on farmed salmon in April the following spring and the number of lice on outwardly migrating pink salmon in May, a month later. However, despite this clear connection, they could not document any correlation between the number of lice on outwardly migrating pink salmon and recapture the following year. For example, there were more lice on farmed salmon in March 2000 (9.1 million) than in March 2001 (7.5 million), but a record high recapture in 2001 and record low recapture in 2002. And contrary to predictions of Krkosek et al. (2007) that the pink salmon would be extirpated as a result of lice infection from farmed Atlantic salmon by 2010, the recapture of pink salmon from 2004 and onwards has shown a steady increase (Brooks and Jones, 2008). Further, they found that the variation in the number of lice per farmed salmon varied significantly over years and independent of the number of farmed salmon. Their conclusion, therefore, is that there must be factors other than the number of farmed fish and the number of lice per fish that caused the collapse of the pink salmon population in 2002

4.8 Summary of Chapter 4

Few descriptions exist of lice abundance in a more historic perspective. In the past, salmon lice infection was often registered on returning spawners, where as today registration of salmon lice infection is registered on outwardly migrating salmon smolts. To our knowledge there is no documentation that points to the fact that the level of infection of wild salmon at sea has changed in a historical perspective. However, it is also well documented that salmon lice infestations in coastal areas (immediately adjacent to fish farms) are more severe during times of the year, which in turn exposes migrating Atlantic salmon smolts to greater infection pressure than would normally have been the case without the presence of fish farms.

We have reviewed the literature that points out variation in salmon stocks in areas with and without aquaculture, and see that:

- The extent of salmon lice/infestation by salmon lice can be more severe periodically during the year in areas with aquaculture activity given the higher number of hosts (=correlation in occurrences of salmon lice and farmed fish).
- Local salmon lice abundance correlates and, in other instances, varies independent of the presence of aquaculture.
- Correlation has been detected in the amount of returning infested wild salmon and infestations of salmon lice in farms the following spring (infection can occur from wild fish to farmed fish).

- Correlation has been detected in the abundance of salmon lice infection on wild smolts and increased levels of salmon lice in fish farms (infection can occur from farmed to fish wild fish).
- It is documented that high levels of salmon lice can be deadly for salmon smolts.

On the contrary, we cannot see that there is documented evidence of a cause-effect relationship between the population size and the occurrence of salmon lice (as a separate factor). There are no instances to document that salmon lice are the main reason for change to the population dynamics. However, a lack of documented evidence does not have to mean a lack of connection; it can also mean that it is difficult to document whether there is a connection or not. There is, without doubt, a need for more knowledge on this area.

It has been established that brown trout, sea char and other species such as stickleback can be carriers and reservoirs for salmon lice. The sea trout lives in fjords and coastal waters year-round and can, therefore, sustain production of salmon lice year-round. It has been established as probable that wild brown trout makes a significant contribution to the maintenance of local salmon lice abundance.

It has been established as probable that infection by salmon lice resulting in osmo-regulatory problems can lead to behaviour such as premature returns. In spite of the fact that the description of this phenomenon is relatively new, we cannot see that there is documented evidence that this is a new phenomenon.

Weaker fish are possibly more susceptible to infestation by salmon lice than "robust"/non-weakened fish, but it remains uncertain how it can influence or contribute to the maintenance of the local abundance of salmon lice. However, it is known that acidification can indirectly affect survival of smolts in the marine phase as smolts that are exposed to an acidified environment (containing aluminium) have higher mortality resulting from infestation of salmon lice when compared with smolts from "healthy" freshwater environments.

To what extent Atlantic salmon might have developed resistance (in other words the degree to which natural selection for resistance against lice has taken place) remains uncertain. A possible effect of natural selection would be expected to increase with increasing salmon lice-related mortality. However, in populations where mortality is connected to (increased) infestation by salmon lice only at a low degree (low salmon-lice related mortality), natural selection for resistance against lice will not be of special significance.

Based on the available knowledge, we cannot find any existing scientific evidence documenting a simple/direct connection between the number of sexually mature female lice, essentially a product of the number of farmed salmon and the number of female lice per fish, and marine survival of wild salmonids, and the calculation/estimates of a sustainable level of lice is, therefore, not sufficiently knowledge-based.

The dispersion dynamics of salmon lice is extremely complex and parallel with the complexity in the fjord systems and along the coast generally. Variations in topography, climate, geographical location, flow conditions and local weather conditions can make a significant contribution to the dispersal pattern in terms of both time and space. Consequently, assumptions about "ideal localisation of fish farms" will involve a significant element of speculation. However, if speculation is permitted, it is possible on a general basis to mention that some areas in the fjord system appear to be more exposed than others.

In an ideal situation (where the goal is the most effective management of wild salmon stocks) it would be desirable that modelling of dispersal patterns is implemented more specifically, possibly separately for each fjord system, in order to be able to offer better advice about when delousing would be more effective.

4.9 References for Chapter 4

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5 Evaluation of status reporting / various assessments relating to the status of wild salmon and brown trout

Working parties and councils appointed to undertake assessments that will form the basis for management carry a major responsibility and, according to the regulations, have an obligation to ensure such evaluations are "objective and (scientifically-)knowledge-based". Following a review of a large amount of material in connection with the compilation of this report, including reports that evaluate the threats to and status of wild salmonids, we believe we have revealed several instances where i) assertions are expressed without scientific basis, ii) there are instances of under-reporting of probable contributing factors to negative development of salmon stocks, and iii) there are instances of over-reporting of negative effects of salmon lice (which is attributed to aquaculture).

If the goal is to protect/preserve wild stocks of anadromous salmonids, we recommend documentation of actual causes of stock size regulation and that an attempt is made to do something about these.

Therefore, in this chapter we have reviewed and discussed some assertions and conclusions that may be found in the reports that form the basis for the management of wild salmonid stocks in Norway, and which we believe do not fulfil the standard as "objective and (scientifically-)knowledge-based".

5.1 Status reports of population status of salmon and brown trout

The Norwegian Directorate for Nature Management (DN) has appointed two working parties that will report on various conditions that are of importance for the survival and production of wild populations at a national level. For the salmon stock, there have been annual reports since 2000. This information forms the basis of Norway's reporting to the International Council for the Exploration of the Sea (ICES). The status reports prepared by Hansen et al. (2008) (salmon) and the Norwegian Directorate for Nature Management, report (2009-1)(brown trout) are discussed in this chapter.

Table 1 Overview of the population status of Norwegian salmon and brown trout river systems. Summarised, based on the figures reported by the working parties appointed by the Norwegian Directorate for Nature Management (Hansen et al., 2008 (salmon); DN report 2009-1(brown trout).

	SALMON RIVER SYSTEMS		BROWN TROUT RIVER SYSTEMS	
	# river systems	% of total	# river systems	% of total
Extinct	45	10	28	2.4
Threatened	32	7.1	18	1.6
Reduced or vulnerable	116	25.7	324	27.9
Moderately or barely affected	246	54.4	658	56.7
Uncertain	13	2.9	133	11.5
TOTAL # river systems	**452**	100	**1161**	100

Hansen et al. (2008) have estimated the relative impact of the various conditions of decisive importance for the categorisation of salmon and trout river systems in Norway. The figures/values from the report are shown in table 2 below; absolute values = column #; relative values according to Hansen et al = columns %.

Table 2 Condition/impact factor of decisive importance for the categorisation of river systems. Figures are shown from Hansen et al., 2008 (salmon) and DN report 2009-1 (brown trout). Blue columns= corrected relative values

	Condition/impact factor	**SALMON**			**BROWN TROUT**		
	(Descending order)	#	% Hansen	% Corr	#	% DN report	% Corr
1	Watercourse regulation	84	18.6	29.7	146	12.6	22.4
2	Acidification	41	9.1	14.5	51	4.4	7.8
3	Other physical interventions	37	8.2	13.1	185	15.9	28.4
4	Gyrodactylus	28	6.2	9.9	0	0.0	0.0
5	Salmon lice	22	**7 (4.9)**	7.8	78	6.7	12.0
6	Pollution from agriculture	20	4.4	7.1	78	6.7	12.0
7	Other pollution	19	4.2	6.7	43	3.7	6.6
8	Other conditions	17	3.8	6.0	58	5.0	8.9
9	Overexploitation (overfishing)	11	2.4	3.9	8	0.7	1.2
10	Unknown impact	2	0.4	0.7	1	0.1	0.2
11	Other fish diseases	2	0.4	0.7	4	0.3	0.6
	# cases of impact assessed	283	**62.6**	**100**	652	**56.2**	**100**

A recalculation of the impact factors immediately demonstrates two errors:

1) If one calculates the relative degree of impact in the same manner as Hansen et al., salmon lice is over-reported/described with an incorrect/too high impact in proportion to the other factors:

Take for instance how Hansen et al have calculated the relative degree of impact of pollution from agriculture:

20 registered cases of impact by agriculture / 452 rivers * 100 = 4.4 %.

In that case, the correct degree of impact of salmon lice in proportion to the other factors would be: 22 registered cases of impact by salmon lice / 452 rivers * 100 = 4.9 %.

2) The calculation of relative (percentage) impact factor performed by Hansen et al is incorrect: They take as a starting point the total number of river systems (i.e. 452) and calculate "relative impact" based on this. But it is incorrect to relativise the number of registered cases of impact factor to the number of rivers. This is also revealed by totalling up the percentage in the row relative impact as is done in table 2 (red columns). The total of relative impact as calculated by Hansen et al 2008 is 62.6 rather than 100. The relative impact should obviously be calculated based on the total number of assessed/registered cases of degree of impact, i.e. 283. (It is true that 452 salmon rivers are described in the report. But if one total up the number of registered cases of impact factor, this total is 283. In other words: a total of 283 cases of impact condition have been assessed. However, in

several cases several river systems are impacted by several conditions/factors simultaneously, and in other cases no impact is reported (the impact factor that brings about the category placement is indecisive or unknown). The corrected values/correct calculation of the impact factors are shown in the blue columns in table 2.

This means that if one arranges the impact factors in descending order (as is done in this report, table 2, figure 1), salmon lice will come in close proximity to a shared fifth place with pollution from agriculture, which has an equally large degree of impact as salmon lice in both salmon and brown trout river systems.

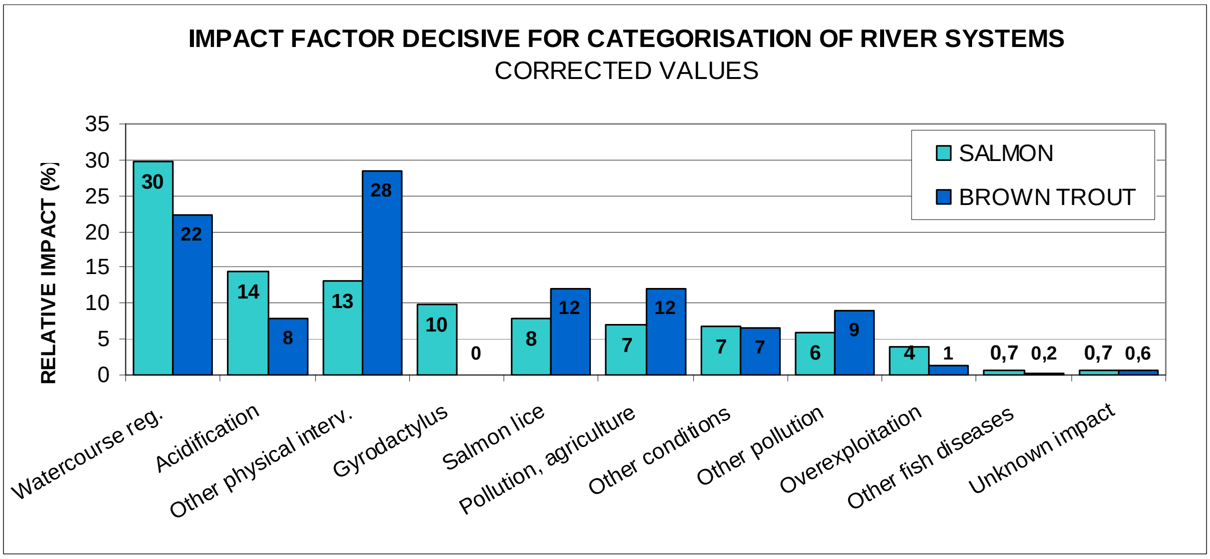

Figure 1 *Overview of impact factor/condition of decisive importance for the status of river systems with populations of salmon and brown trout on the national level (Norway as a whole). Based on figures reported by working parties appointed by the Norwegian Directorate for Nature Management (Hansen et al., 2008 (salmon); DN report 2009-1 (brown trout). The degree of impact is corrected/relativised in proportion to the total number of registered cases of impact.*

If one totals up the largest factors watercourse regulation, acidification and other physical interventions, these collectively account for nearly 60 % (57.2 % for salmon and 58.6 % for brown trout) of the impact factors (reason / fault that the river systems are placed in the categories) in comparison to salmon lice, which has a reported degree of impact of 4.9 and 6.7 % for salmon rivers and brown trout rivers respectively.

The corrected relative degree of impact of decisive importance for the category placement of salmon rivers is also shown in figure 2.

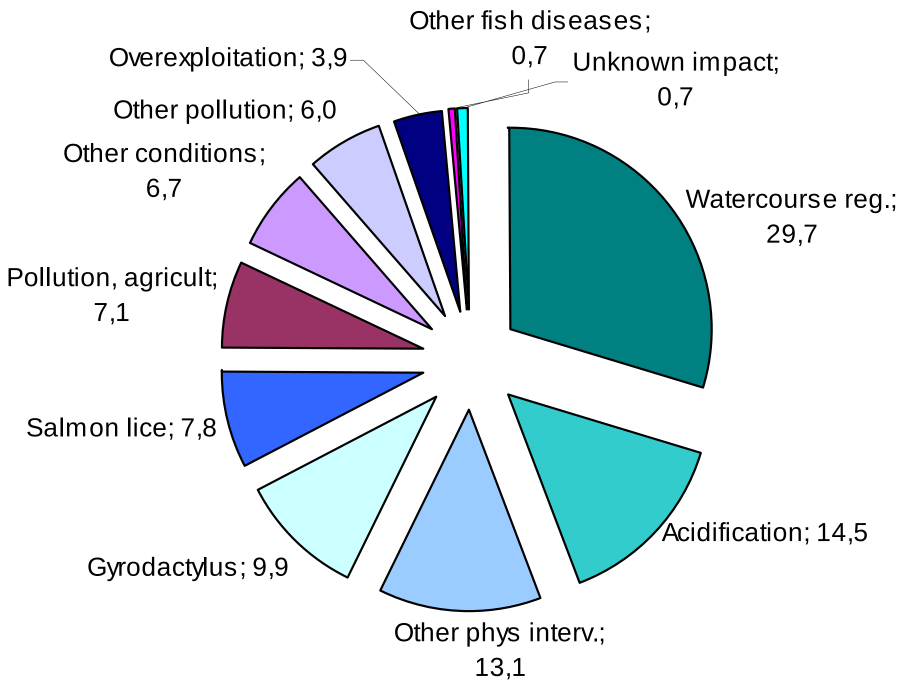

Figure 2 Overview of impact factor/condition of decisive importance for the status of river systems with populations of salmon on the national level (corrected values in relation to the text of this report).

Consequently, the following applies for salmon rivers: Of the total number of registered cases where the impact factor is decisive for the salmon river system, watercourse regulation is of decisive importance for category placement in nearly 1/3 of the cases. In comparison salmon lice is decisive for category placement in less than 1/10 of the cases (7.8 %). Further, it appears that of the total number of registered cases of impact conditions, watercourse regulation, acidification and other physical interventions constitute well over half of the impact (57.2 %). Other physical interventions (13.1 %) and acidification (14.5 %) each have approximately twice the impact as compared to salmon lice. Other pollution (6.0 %) and other conditions (6.7 %, which are not explained?) have approximately the same degree of impact as salmon lice. Overexploitation is decisive for the category placement in 3.9 % of the cases, and in that case constitutes approximately half the effect of salmon lice.

The summary of the report of Hansen et al., 2008 (which is the only part translated to English, and for many the only part that they read) concludes as follows (quote):

> *"Acid rain, the parasite Gyrodactylus salaris, watercourse regulation and hybridisation between wild and escaped farmed salmon are the main threats to salmon in freshwater, whereas sea lice is a problem in several marine areas."* (end quote).

It is by no means correctly stated in the summary how large the presumed/estimated degree of impact the various factors/conditions have in the cases where impact has been registered in river systems (e.g. it does not emerge that watercourse regulation is the decisive impact factor in 29.7% of the registered cases, or in other words, approximately four times higher than the impact factor of salmon lice).

However, the information appears somewhat different if one reads in the actual report the section dealing with categorisation of salmon populations (p. 33-35). This reports as follows (quote):

> *"Acidification of river systems and mortality as a result of the parasite Gyrodactylus salaris are the two most important reasons that populations are extinct or threatened with extinction. Watercourse regulation also strongly affects some populations. In addition, the effect of salmon farming on wild salmon, such as the dispersion of salmon lice and diseases, and genetic interaction between wild and farmed salmon is worrying*" (end quote).

A third version of a summary is included in the introduction. Excerpt of introduction, Hansen et al., (2008) (quote):

> "*In Norway the most important reasons for the decline in individual populations are local problems such as pollution (particularly acidification), but liming programmes and reduced sulphur in the precipitation in recent years has contributed to the salmon being re-established in many river systems where it was previously extinct. Moreover, the effects of the parasite Gyrodactylus salaris, as well as different interventions in river systems led to reduced smolt production. It has also been pointed out that inter-breeding with escaped farmed salmon may result in changes in the genetics of the wild salmon and as a result of this reduce the salmon's capability of survival in nature (fitness). Some salmon populations may have been overfished, to the extent that there have been insufficient spawners to give a sustainable reproduction."* (end quote)

There is not a single word in the introduction about salmon lice. Further, the introductory text states that populations may have been overfished. Therefore, there is no conformity between the summary and the introduction.

In parts of the report, Hansen et al. (2008) describe a completely different picture than that concluded in the summary. Seen as a whole, this demonstrates that the summary of the report gives an incorrect and misleading picture to the reader. The summary is written in such a way that it attributes a larger negative impact to salmon lice than there is evidence for in the report and other decisive factors are under-reported to the reader.

The same applies for the reporting of population trends of the brown trout. By plotting the figures that describe relative impact of the various factors at county level (figure 3) it appears there is poor conformity between what is stated in the summary and what is stated when one reads the full report in detail.

The summary sums it up as follows (quote):

> *"The brown trout catches in Western and Central Norway have halved over the past five years. There are strong indications that the population trends over recent years may be attributed to reduced sea survival. The main reasons appear to be discharge of salmon lice from fish farms combined with poor feeding conditions and climate changes."* (end quote)

But on page 4 of the same DN report, there is an overview of the various impact factors of decisive importance for category placement of river systems with populations of brown trout at county level. Poor feeding conditions and climate change do not even appear in the table. If one combine the registered cases of impact in the counties of Hordaland, Sogn og Fjordane, Møre og Romsdal, South Trøndelag and North Trøndelag (figure 3) and calculate the relative values for the three largest factors, it will in descending order of impact be 1. watercourse regulation (33.9 %), 2. salmon lice (25.3 %) and 3. acidification (22.9 %) which are decisive for the category placement of trout river systems in Western and Central Norway. Watercourse regulation, which thus impacts to a greater degree than salmon lice, as well as acidification, which impacts to almost the same degree as salmon lice, are not mentioned for Western and Central Norway in the summary.

However, if one reads through the report, the impact factors on a national basis are summarised in the chapter concerning categorisation as follows (quote):

> *Of impact factors, interventions in the river systems have had the greatest impact, but acidification, pollution and salmon lice are also strongly in the picture.* (End quote)

This is not the same as what is stated in the summary, and is yet another example that the summary of the report gives an incorrect and misleading picture to the reader. The effect of salmon lice is over-reported in the summary, while other decisive factors are under-reported.

We find it documented that the summary of the reports in Chapter 5.2 gives an incorrect and misleading picture to the reader. The effect of salmon lice as an individual factor is over-reported in the summary, while other decisive factors are under-reported. Only the summary (abstract) is translated to English. The importance of synergy of factors is pointed out in the literature (see also earlier mention).

5.2 Report from the Norwegian Scientific Advisory Committee for Atlantic Salmon Management Anon 2010

The Norwegian Scientific Advisory Committee for Atlantic Salmon Management is a committee appointed by the Norwegian Directorate for Nature Management (DN) in 2009. The committee shall function as an independent committee, and report/describe the population status of Atlantic salmon and provide advice concerning the management of wild salmon based on existing scientific knowledge. The report shall be the public administration's central document and compiled knowledge basis for the management of wild salmon. This chapter discusses the report "Anon. 2010. The status of Norwegian salmon stocks in 2010. Report from the Norwegian Scientific Advisory Committee for Atlantic Salmon Management no. 2".

Below is a discussion of the reporting form and aspects of the reference base of Anon 2010/2.

<u>Anon 2010/2 Excerpts from the summary (quote):</u>

(…) the general infestation pressure from several infective agents against wild salmonids has increased during the last 20-30 years. This is mainly due to infective agents that proliferate in farmed salmon.

(…) There reported river catches of sea trout in Western and Central Norway and for anadromous Arctic char in Northern Norway are rapidly declining. Most likely this reflects declining population sizes. The most likely causes for this decline in sea trout populations are related to marine conditions, including ecosystem changes, salmon lice infestations and other infective diseases. Knowledge on the causal relationships is far from satisfactory…". (End quote)

Questions are raised about whether it is misleading to sum up in this manner in the summary:

In the DN report concerning population trends of brown trout (mentioned in Chapter 5.2), it states that a total of 277 cases of impact factor of decisive importance for category placement of river systems with brown trout populations have been registered in Hordaland, Sogn og Fjordane, Møre og Romsdal, South Trøndelag and North Trøndelag (see DN report 2009-1 for detailed data).

In the DN report, other fish diseases (infectious diseases) are not registered as any impact factor in any of the above-mentioned counties in Western Norway or Trøndelag. Therefore, the fact that the Advisory Committee for Atlantic Salmon attributes infectious diseases "that proliferate in farmed salmon" as one of the most likely causes of the decline in population is not in accordance with the DN report 2009-1, and is an unfounded/subjective statement.

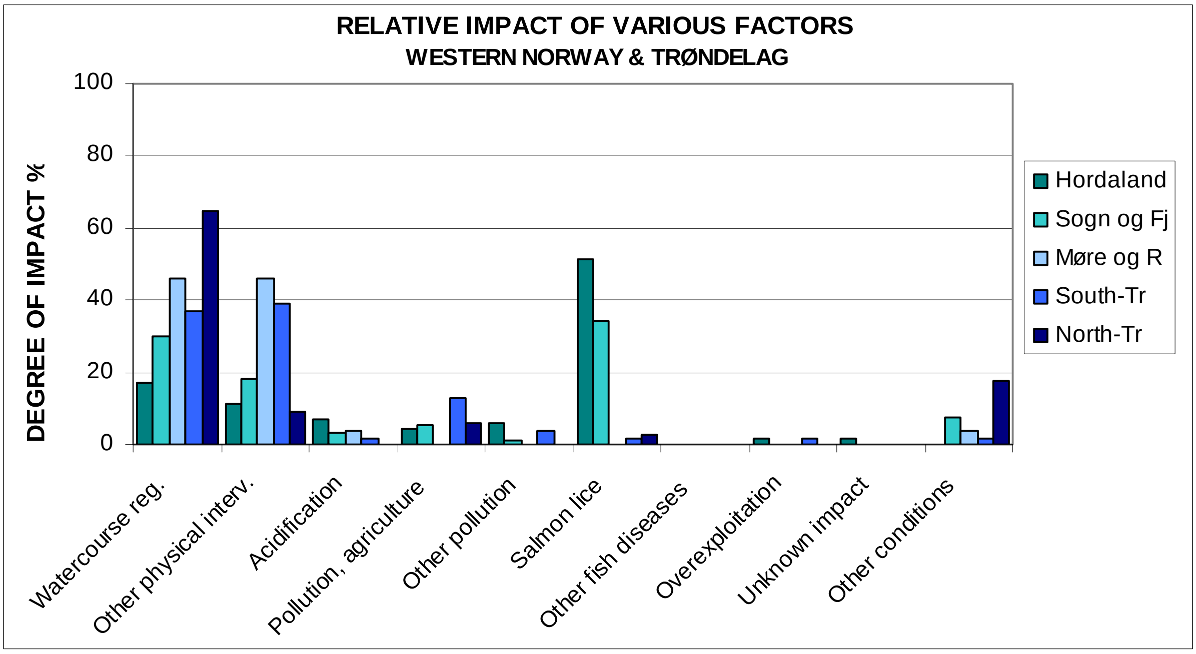

Figure 3 Overview of the relative degree of impact of various factors/conditions of decisive importance for the status of river systems with brown trout populations; divided by county. Relative impact is calculated based on the figures from the DN report 2009-1.

As mentioned previously (Chapter 5.1), the relative impact of various factors in Western Norway and Trøndelag in descending order are 1. watercourse regulation (33.9 %), 2. salmon lice (25.3 %) and 3. acidification (22.9 %).

If one looks at the various counties separately, it appears that in just one of the counties (Hordaland) salmon lice is the factor that is registered as decisive in most of the cases.

In Sogn og Fjordane a total of 93 cases of impact are registered, of which salmon lice on the same level as hydropower development constitutes approx. 1/3 of the degree of impact. Further, in Sogn it is registered that in almost 1/4 of the cases (18.3 %) other physical interventions have decisive importance for the category placement along with pollution from agriculture (5.4 %) and acidification (3.2 %).

In Møre og Romsdal no cases are registered in which salmon lice is decisive for the category placement of river systems with brown trout populations. On the contrary it is registered in a total of 24 of 26 cases that watercourse regulation and/or other physical interventions are the reason for category placement of the river systems.

In South and North Trøndelag, a total of 88 cases of the degree of impact that is decisive for category placement have been registered. Of these watercourse regulation and other physical interventions constitute approx. 3/4 of the degree of impact (75.9 and 73.5 % for South and North Trøndelag respectively), and pollution from agriculture 13 and 5.9 %, and salmon lice 1.9 and 2.9 % respectively.

The fact that the Advisory Committee for Atlantic Salmon Management concludes that salmon lice is one of the most likely causes for the decline in the wild salmon population in Western Norway and Trøndelag is, therefore, inconsistent/in conflict with the DN report. It appears that the Advisory Committee attributes too much weight to salmon lice and at the same time under-reports major impact factors that actually have a documented effect.

The cause for this over-reporting of the impact of salmon lice is substantiated in the conclusion of Anon 2010/2 by that the other factors are stabilised (acid rain, hydropower development and physical interventions) or relatively stabilised (*Gyrodactylus salaris*). Salmon lice and escaped farmed salmon were considered as clearly not stabilised as well as existential threats against wild salmon.

Whether these factors are stabilised or do not constitute any existential threat against wild salmon is a subject of dispute/discussion both within own ranks and in other research environments:

(Stabile may also imply a constant/stable negative effect – which does not mean that the negative effect does not exist). An assessment of the interaction of the various factors seems underestimated or may appear to be missing.

Updated arguments from specialists concerning the various factors as threats are presented here:

Watercourse regulation

In his presentation "Effects of watercourse regulation", Bjørn Ove Johnsen indicates several points where watercourse regulation still constitutes a significant threat, and it is evident that such regulations are still stated as a threat factor against salmon in 106 river systems and as an important reason why the salmon is extinct or considered as threatened or vulnerable in 43 river systems (Johnsen, 2010).

Gyrodactylus

On average, mortality among salmon juveniles caused by *Gyrodactylus* is in Norwegian rivers estimated at 86 %. In some rivers the mortality rate may be as high as 90-95%.

Even though the number of Gyro-infested rivers in Norway has approximately halved, the majority of the rivers reported to no longer be infested is relatively small. The majority of the large and complex river systems and regions remain. Consequently, *Gyrodactylus salaris must still be assessed as a threat for Norwegian wild salmon populations.* For a long time to come, large resources will be needed for the monitoring and controlling (Mo, 2010). Also, in this context, concern is expressed about the unknown impact of other diseases, such as proliferative kidney disease (PKD) and red vent syndrome (RVS), which may result in high mortality at smolt and post-smolt level.

Statement from Rieber Moen, Excerpt from "*Villaksutvalget-10 år etter;* compilation of presentations from meeting held in 2010 by The Wild Salmon Committee *(appointed by Royal Decree of 18th July 1997),*(Quote):

> *"I will now make some comments about the wild salmon committee's report of one of the most dangerous threats salmon are exposed to, at least in the freshwater phase, namely the parasite Gyrodactylus salaris. This little salmon killer has been a nightmare for the management of salmon stocks for nearly three decades. The committee's main conclusion is clear: Continued control of the parasite with rotenone is necessary" (…) "But this remedy is out of the question in the largest of the infested river systems, such as for example the Drammen River and maybe also with limited impact in rivers such as the Driva and Vefsna."* (End quote)

Hence, it may be interpreted that watercourse regulation and Gyrodactylus (as well as the effect of other diseases) still constitute a threat, which is not completely controllable.

Acidification

Excerpt from Hindar et al. (2010), page 38 (Quote):

> *Based on this positive development, some people have drawn the conclusion that the problems with acid rain are over. This is incorrect. The salmon is extremely susceptible to even low concentrations of aluminium in acidic water and even though the reduction over time has been great, aluminium is still present, which causes injuries to salmon. (…) The level of aluminium in the river may be so low that it does not affect the salmon to any great extent when it resides there. But as a smolt the*

salmon adjusts physiologically to life in the saltwater, and it is during this phase that the salmon is particularly vulnerable. Too much aluminium in the river may reduce the saltwater tolerance of the smolt and in this way damage the population. It has also been demonstrated that such exposure combined with salmon lice weakens the smolts more than the two effects separately. (End quote)

The way we see it, there is therefore reason to assume that acidification, both directly (in the freshwater phase) and indirectly (affects survival during the marine phase), may contribute to reduced survival of recently outwardly migrated salmon.

Under-reporting of exploitation as a threat

Exploitation is not classified as a threat factor in this report by the Advisory Committee (exploitation is not described in the chapter concerning threat factors), but is described in a separate chapter. Nevertheless, the following quote is included in the summary of the same report (Anon 2010, p.4) (Quote):

> *"Despite reductions in harvest rates, both in the river fisheries but particularly in the sea fisheries, management targets (for spawning populations) were not met for populations in 70% of the river systems."*

In other words, this is actually reporting overexploitation – i.e. fishing above the critical threshold – in 70 % of the river systems.

Concern about exploitation is expressed by several

Excerpt from the compilation of presentations from meeting held in 2010 by The Wild Salmon Committee. Where are we today, and where is the path ahead leading?

Quote from Rieber-Mohn, p. 9:

> *…"the national fjords and rivers shall in principle give the wild salmon better protection than the salmon's other natural habitats in our country. It is stated in this manner in the recommendation to the Storting, the Norwegian Parliament (Innst. S. nr. 183 (2006-2007), and with the approval of the Parliament, the plan concerning national salmon rivers and fjords was established:*
>
> *"The main intention with the national salmon watercourses and fjords is to provide so much as possible of the Norwegian wild salmon resource special protection within the scope of a limited number of salmon populations." It is stated explicitly in the same recommendation that one of the general measures that shall provide such special protection is "regulations in salmon fishing". But up to day there is little to indicate that the authorities responsible for managing wild salmon stocks have taken these directions from the Storting seriously. Take for instance the national salmon river Numedalslågen – possibly the most important river system in Southern Norway. It is managed today worse than virtually all the other river systems supporting a wild salmon population. Almost without exception, it is not permitted to fish with seine, nets or other fixed fishing gear in rivers. However, in Numedalslågen raft fishing and*

fishing with pots and some nets is permitted for those with historical rights to this. Even though the salmon population in the river has shown decline over several years, it is exploited harder than the stocks in almost all the other river systems, the vast majority of which are not national salmon rivers. It may be argued against this that despite the broader range of fishing gear, the exploitation rate in the river is not excessively high. But there is no weighty objection. The river should be managed in the same manner as other river systems, and if the limitation of fishing gear in the river had been the same as other rivers, the exploitation rate in the river would have been substantially lower. And more salmon would have had the opportunity to spawn. It is sad to find that the river far from has the protection regime that should result from …"

Refer also to Chapter 3 concerning the stock size regulating effect of exploitation.

It may appear that the effect of overexploitation is under-reported in the report by the Advisory Committee for Atlantic Salmon Management.

<u>Evaluation of references used concerning infection pressure on wild fish; chapter 3.2.2 in Anon 2010/2</u>

Anon 2010 bases its discussion concerning infection pressure on wild fish (chapter 3.2.2, page 80) on registrations/reports by NINA (Bjørn et al. 2010a) and Kålås et al. 2010).

The chapter concerning infection pressure begins as follows (quote/translated):

"So far, the surveillance programme shows that the salmon lice infection pressure is chronically elevated along the majority of the Norwegian coast. Infection levels are probably above a sustainable level, both on brown trout and probably also for Atlantic salmon smolts in some areas along the Norwegian coast. This was especially the case in the most intensively farmed areas of Hordaland, Trøndelag (outer Trondheimsfjord, Hitra and Flatanger) and partly Nordland County. Other areas only had a moderate infection pressure (outer part of Sognefjorden and Romsdalsfjorden),..." (End quote).

We cannot see that any of the studies Anon 2010/2 refers to describes or has performed analyses of salmon lice abundance in Nordland in 2009. In that case, there is no evidence to assert that the infection pressure was in all likelihood higher than sustainable on brown trout and salmon in Nordland.

One may also question whether this assertion concerning high infection pressure on brown trout and salmon in the other areas is supported/reported in the reports by Bjørn et al (2010a) and Kålås et al. (2010).

The two references referred to in Anon 2010/2 are discussed further below:

Norwegian national salmon lice surveillance 2009. NINA report 547

(=Reference Bjørn et al 2010a in Anon 2010)

This study describes the occurrence of salmon lice/infection level on brown trout (net caught in fjords/sea water) and salmon (trawl studies on outwardly migrating wild smolts and smolt in cages) along parts of the Norwegian coast.

Nevertheless, it is pointed out on page 13 of the report referred to that owing to the lack of necessary resources some localities needed to be cut, so that large parts of Norway are not covered in this report. According to the author's own description, this applies to large parts of Nordland, but by studying the map in the material and method we cannot see that registrations/localities appear in the counties of Aust Agder, Rogaland, the coastal part of North Trøndelag (just the inner part of the Trondheimsfjord), Troms or Nordland. (Compared with Bjørn et al. 2010c, report to the Norwegian Food Safety Authority, the localities of the Sandnesfjord, Rogaland, the Storfjord, the Namsenfjord, the Vefsnfjord, Folda and Vik in Vesterålen are all missing).

The authors point out that as a result of this it is more difficult to assess the effect of national salmon fjords in a scientifically sound manner.

Concerning the reporting of the infection intensity in the various areas

The introduction that is quoted further up on this page is copied/quoted from the abstract on page 3 of the NINA report 547 (Bjørn et al. 2010a), which is discussed further below.

A thorough review of the registered data on salmon lice infection on salmon and trout in the various areas indicates that the summary (which is quoted above) gives an incorrect picture to the reader and that the summary is based on insufficient grounds.

The infection intensity in the various areas is discussed below, based on the precautionary principle and a conservative maximum limit for *no negative effect* of salmon lice described in Risk assessment of IMR/HI 2010: Precautionary principle: Limit for "no negative effect"; relative infection intensity= 0,1 lice/gram fish.

Hardanger:

Brown trout - net

A total of nine registrations were conducted: 3 zones/localities x 3 different periods.

Lice were found (prevalence) on 31-100 % of the captured individuals.

In seven of nine cases, the median of relative intensity was under 0,1 louse per fish weight, and varied between 0,0121 and 0,0692, i.e. well under the limit for no negative effect. (80.57 % of the brown trout with infestation by lice have in all likelihood no negative effect from lice).

In one of nine cases, the median of relative intensity was 0.1117, i.e. the median of 22 of 175 registered cases was approximately equal to the limit for no negative effect. (Nevertheless, it must be pointed out that it varied between 0.005 and 0.901, so that in some cases there was a high relative infection).

In one of nine cases, the median of relative intensity was 0.1740, i.e. 0.074 over the limit for zero negative effect. In other words, the median for 12 of 175 registered brown trout was 0.074 over the limit for no negative effect; 6.85 % may have had <u>some</u> negative effect from lice. But no sound documentation exists concerning these limit values (threshold values)/effect of such low values (IMR/HI 2010 – risk assessment).

Cage investigation, <u>salmon smolts</u>

Relative intensity is not calculated/estimated. Prevalence of 0-88 % is reported. That sounds much, but it is further reported that the average varied around 1 (and none over 3). With a starting point of an average weight of approx. 50-60 gram (see table 2 in the same report) – it demonstrates an average relative infection intensity of 0.017 – 0.02. This is a factor five times lower than the limit for <u>no</u> negative effect.

<u>Infection level of outwardly migrating wild salmon smolts:</u>

Quote: The prevalence was only 20 %. (…) nearly 75 % of the infested salmon smolts had more than 0.1 lice per gram of fish weight, and half (median) had more than 0.2 lice per gram of fish weight. Around three of four infested salmon smolts may therefore be expected to develop physiological disturbances as a direct result of the infection. A total of 5.2 % of all salmon smolts in addition had more than 11 lice larvae and will in all likelihood die as a direct result of the infection. End quote.

As in the quote above, it is asserted throughout the entire report that "negative effects of intensity over 0.1 louse per gram may be assumed". *This is a misleading assertion, which is not supported by any evidence.*

In the Risk assessment recently performed by HI/IMR (Rapport 3-2010), there is a discussion about the physiological effect/critical threshold for infection of salmonids. The report refers to, among others, laboratory studies that demonstrate that 30 larvae be mortal for farmed salmon smolt of 40 g, which is equivalent to a relative intensity of 0.75 lice per g fish weight, or approx. 11 larvae can kill a recently outwardly migrated smolt of approx. 15 g, but that it is possible that just 1-3 lice can have a negative impact on a recently outwardly migrated wild salmon smolt (10-15 g). As mentioned introductorily, 0.1 louse per gram of fish is a conservative maximum limit for *<u>no</u> negative effect* of salmon lice described in the Risk assessment by IMR/HI 2010 based on the precautionary principle. It is, therefore, incorrect to conclude that values close to or just over 0.1 have negative effect.

Based on the relative intensities reported for Hordaland, questions may also be raised concerning whether it is correct to report this infection level in the abstract as "probably above a sustainable level".

Trøndelag

Brown trout - net:

Of a total of 110 captured brown trout: The relative infection intensity for the whole material (3 zones x 2 periods = 6 medians for relative intensity) demonstrates that the median for infested individuals varies between 0.0171 and 0.0863, i.e. across all the figures, the median for relative infection intensity is within 0.1 (no negative effect).

However, the authors round up 0.0863 to "almost 0.1 lice per gram" and incorrectly conclude that "well over half of the smallest brown trout will then experience physiological disturbances as a direct result of lice". This is an ungrounded assertion, this is not documented, and neither do the authors refer to any references to support this assertion.

Further in the report the authors report/operate with separate values for "the smallest" brown trout (<200 g). The median values are higher than the figures should indicate; but the basis of calculation is not visible, so it is impossible to recheck the calculation.

Cage investigation, salmon smolts:

The use of six cages, each with 25-30 salmon smolts, divided between three localities is reported.

The relative infection intensity is not calculated, but the following is a rough estimate based on the stated values for the average weight of smolts and intensity of lice infection: 56 g / 1 – 2 lice; 0.018 – 0.036, i.e. << 0.01.

Salmon smolts - trawl:

A total of 177 salmon smolts were captured over five weeks (five registered medians).

- In three out of five cases, the median for relative infection intensity was under 0.1 (0.0387 – 0.0898).
- In one case, the median was approximately at the level of the limit for no negative effect; 0.1068. In this case there was a low prevalence; 6.9 % of 29 salmon smolts had a median intensity of 0.1068, the remaining 93 % were not infected.

In one case, the median was 0.1266, i.e. somewhat over the limit for no negative effect. In this case the prevalence was 35 %. In other words, 65 % of the captured smolts were not infected by salmon lice.

In conformity with the description of Hordaland, the question is therefore raised concerning whether it is correct to report the infection level in Trøndelag in the abstract as "probably above a sustainable level".

In the report, concerning the Romsdalsfjord:

By using the values states in the text and tables, the following is evident:

Brown trout

With registrations of 119 brown trout, the median for relative infection intensity for all the figures (3 zones x 2 periods) varies from 0.0072 – 0.0449 lice per gram fish, i.e. a factor 2 – 13.8 times lower than the level for no effect (0.1 lice/gram fish).

Salmon smolt in cages;

Relative intensity is not calculated. But based on the stated values from registrations in 10 cages x 24-26 salmon smolts one may estimate/roughly calculate; intensity: 1.2 – 2.1 lice per fish and average weight per smolt 65 g:

The estimated relative intensity of salmon smolts in cages will then be: 0.018 – 0.032, which again is under << 0.1.

It is, therefore, considered misleading to describe the infection pressure in the abstract as "moderate".

Nordland (Sørfold)

We cannot see that registrations have been performed in Nordland / Sørfold in this report, and can therefore not see how conclusions may be drawn in the abstract concerning this area.

Returning brown trout summer 2009 Rådgivende biologer report 1275

(= Reference Kålås et al. 2010 in Anon 2010/2)

The study performed by Rådgivende biologer (a Norwegian consultancy agency) was a field study in which salmon lice was registered on premature returns of brown trout in eight regions in the counties of Rogaland, Hordaland and Sogn og Fjordane.

Salmon lice were not registered on salmon smolts in this study – only on brown trout.

Basically, the registration of prematurely returning brown trout with salmon lice is not an adequate measure of infection pressure, since it is not related to the total number of brown trout or the number of uninfected trout:

1) It does not, therefore, provide a measurement of the extent of the stock/population that is infected
2) An increase in the stocks of prematurely returning brown trout may just as easily be an indication of / a result of an increase in the local brown trout population per se.

But if in this context it shall be regarded as an indirect indication of infection pressure, the report by Kålås et al. suggests a positive development over time:

The total number of prematurely returning brown trout registered in 2009 was 269, i.e. 0.3 – 25 individuals per river mouth. In comparison with the median for 2000-2008, the registrations in 2009 show a decline in seven of the regions.

Kålås et al. summarise in the following manner on page 28, (Quote, translated):

> *Our measurements demonstrated that salmon lice affected brown trout less in 2008 and 2009 than in the period 2000-2007 in the majority of the regions we studied in Western Norway. This is clear in the regions of Nordfjord, Sunnfjord, Sognefjord, Masfjord and Sotra. In these regions the returns of salmon lice infested trout in 2009 were so few in number that it is difficult to date the timing of the first return and measure the strength of the salmon lice infections using our method. This is a clear distinction from what has been common. In Ryfylke the brown trout was affected to a relatively little extent by salmon lice in 2008, but in 2009 the condition returned to the levels of the years 2000-07.*
>
> *In the Hardangerfjord there is no change. Large amounts of trout have been greatly affected by salmon lice. This has been the case as far back as the early 1990s. The condition in the control area Jæren and Dalane is as previously. Here, we find only a small number of salmon lice infested trout that return to the fresh water relatively late in the summer. Owing to the generally low infections, we also expect that the salmon smolts were less affected by salmon lice in the spring of 2009 than in the majority of past years in the majority of regions in Western Norway.* (End quote)

The results in Kålås et al., therefore, do not correspond with that reported in Anon 2010/2 (We cannot see that this supports the assertions concerning infection levels that are chronically high or above a sustainable level).

In general about the reference base in Anon 2010/2

In scientific-based documentation, one should aim to present a factual basis that is as holistic as possible. Where assertions/hypotheses are not proven/documented, one should therefore include studies/articles that shed light on several sides of the case (thus include articles that both contradict and support the case that shall be presented). Only in this manner is it possible to have a rational and scientific discussion concerning the subject of matter.

It may appear that the reference material used by the Norwegian Scientific Advisory Committee for Atlantic Salmon Management only supports their own assertions, and there is considerable references to their own reports (many of which have not undergone peer review, i.e. they have not undergone critical/objective assessment). We are calling for references that shed light on several sides of the case and that may give a complete/holistic presentation of the case (example from the list of references on page 179: Out of the 20 references, 10 refer to their own reports/publications (6xAnon, 4x Barlaup (member of the Norwegian Scientific Advisory Committee for Atlantic Salmon Management), and out of the same 20, only seven have undergone peer-review (external quality control).

Moreover, as mentioned previously, this report demonstrates that the reference base (used by the Advisory Committee) may be unsound; assertions are followed by references that do not correspond with the assertion.

If the goal is to protect/preserve wild stocks of anadromous salmonids, we recommend documentation of actual causes of stock size regulation and that an attempt is made to do something about these. We are calling for more objective, scientific and integrated (in other words multifactorial) assessments to form the basis for decision making relating to the management of wild anadromous salmonids.

In summary, concerning the report from the Norwegian Scientific Advisory Committee for Atlantic Salmon Management, Anon 2010/2:

We find that it is documented that the abstract of the report gives an incorrect and misleading picture to the reader. The effect of salmon lice as an individual factor (threat factor) is over-reported, and other factors such as exploitation, watercourse regulation, acidification and Gyrodactylus (factors that have documented effects on stock size reduction) are under-reported. Moreover, we find that assertions are put forward concerning salmon lice in Anon 2010/2 that are not supported by the references that are referred to. Further, the reference base may appear biased.

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