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MUTUAL IMPACT OF WILD AND CULTURED ATLANTIC SALMON IN NORWAY

By

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ABSTRACT

The development and current status of the fish farming industry, enhancement and sea ranching of salmon in Norway are briefly described, and an account is given of the natural salmon river populations in different parts of the country.

Record of cultured salmon in the open sea, coastal waters and rivers are briefly reviewed, and so are also migration studies on liberated farmed salmon. Diseases common to wild and cultured populations are described and discussed in relation to mutual impact.

The current situation is discussed in relation to actual and potential effects on natural gene pools and spreading of disease agents. Initiatives to protect natural gene pools are discussed, and experiments to gain additional knowledge of the genetic ressources are outlined.

INTRODUCTION

Farming of Atlantic salmon in Norway commenced around 1970, and since then the production has increased steadily. In 1987 the annual production amounted to 47.417 metric tons, and the predictions for 1988 are around 75.000 tons. The production takes place along larger parts of the coast, but is low in southeastern parts and in the northernmost county Finnmark.

Wild Atlantic salmon is found in rivers all along Norway, and despite damage of stocks in southern Norway due to acid precipitation and in mid- and northern Norway due to the parasitic monogean fluke Gyrodactylus salaris, the total reported catch of salmon has varied between 1050 and 2147 metric tons over the last 27 years. The annual variation in the production of the different rivers is considerable. All rivers seem to have their own stock with specific life histories and productive traits. Investigations of the population structure of Norwegian salmon using gene markers have been conducted by Ståhl and Hindar (1987).

Atlantic salmon has been released in Norwegian rivers for many years to enhance local stocks. They have mostly been released as unfed fry (10-15 millions a year), but also as underyearlings or smolt. Smolts (4-500 000 a year) are released primarily to compensate for damages to recruitment caused by river regulations (Hansen et al. 1987). Most fish released are from local stocks (Ståhl & Hindar 1988). Ocean ranching has so far been carried out on an experimental basis only, although the results have been most encouraging (Hansen and Jonsson 1988).

It is a reasonable assumption that the fish farming industry in Norway will continue to increase, and we therefore need to take good care of our several hundred local populations of wild salmon. Moreover the possibilities to augment the stock enhancement work and to develop ocean ranching of salmon should be assessed.

Many questions have been raised about the impact of the growing fish farming industry on the natural salmon populations. This concern has mainly been focused on two aspects; the transfer of disease from farmed to wild fish and the danger of eradicating salmon gene pools by breaking down isolation mechanisms between stocks, and decreased fitness of the wild salmon due to introduction of nonindigenous gene or gene combinations. Transfer of diseases from wild to farmed fish is also a matter of concern, and for the fish farming industry strong and healthy wild populations with a high degree of genetic variation is a good insurance if the cultured populations should be subject to massive disease infections or unexpected genetic alterations.

The aim of the present case study is to give an overview of the relationship between wild and cultured salmon in Norway, including initiatives to protect the natural gene pools. The greater part of the study is based on published papers and reports, and in addition some discussion on validity of concern is included.

DESCRIPTION OF THE SITUATION

Recent development in farming and ocean ranching of Atlantic salmon has led to an increased proportion of reared fish in nature. Based on fin morphology and scale analysis the proportion of reared fish (ranched and farm escapees) has increased from about 10% in 1986 to about 20% in 1988 in commercial fisheries in Norwegian home waters (Hansen et al. 1987a, Lund and Hansen 1988, Lund et al. in prep.). If not caught in the fisheries, the adult salmon enter rivers to spawn (Hansen et al. 1987b). Using direct observations of body morphology, brood stock surveys in rivers in southern Norway in 1987 revealed that 23 (43%) out of 54 rivers examined contained reared salmon (Gausen 1988). In total of 615 salmon examined 83 (13%) were determined to be of reared origin.

These escaped fish spawn in the streams. For instance, in the small river Imsa there is an annual run of between 100 and 200 mature rainbow trout which have escaped from fish farms. They spawn and they leave the river system as kelts (Jonsson and Hansen, in prep.). The number of viable offspring is extremely low. Because Atlantic salmon is a species native to Norway it is likely that reared salmon can yield viable offspring in nature. However, the reproduction success of reared salmon in nature is still unknown (Ståhl and Hindar 1988).

Experimental releases of farmed Atlantic salmon show that there is a seasonal variation in survival. Survival of escaped salmon during their first sea year is much higher for those escaping in spring than for those escaping during the rest of the year (Hansen & Jonsson 1986, 1989). Adults escaping during summer seem to enter rivers at random and behave like homeless fish (Hansen et al. 1987b). When escaping from sea cages at the smolt stage the fish return to the same area from which they escaped and enter rivers in this area to spawn (Hansen et. al. 1989).

Reared salmon might affect natural populations in several ways. For example the fluke Gyrodactylus salaris is at present spread to 32 rivers by stocking fish from infected hatcheries. This parasite attacks salmon parr and causes heavy mortality. In 1984 the estimated loss of salmon to Norway was around 250-500 tonnes (Johansen & Jensen 1986), and now the damage is still higher as the fish in more rivers have been infested by the fluke. Salmon smolts are still imported to Norwegian fish farms from other countries, which imposes a continuous risk of importing disease and parasites to which Norwegian salmon stocks are not adapted.

Extinction of local, indigenous fish stocks and erosion of genetic resources are subjects of growing concern to salmon management in Norway. The primary causes of exess salmon mortality in the present century are acid precipitation (Hesthagen & Mejdell-Larsen 1987), and the parasite Gyrodactylus salaris (Johnson & Jensen 1986, 1988). Effects of escapees from salmon farms on natural stocks also is a matter of concern among biologists. For these reasons the Directorate of Nature Management has established a gene bank for salmon based on deep frozen sperm. In 1986 and 1987 sperm collected from a number of salmon rivers throughout the whole country were stored (Gausen 1986 and pers comm.). In total sperm from 69 stocks are by now stored in the sperm bank.

DISEASES

Of the interaction problems between wild and farmed salmonids, diseases is possibly the largest and most serious one. Disease in fresh water farmed fish has been known for considerable time. Sea water farming started more recently, and it was believed that conditions in seawater would be much better, with cleaner water and less disease problems.

Very little was known about diseases and parasites in free-living marine fishes when the fish farming industry started, and still there are immense gaps of knowledge. It has also appeared that diseases expected to occur only in fresh water, thrive very well in seawater.

The case of the salmon lice, Lepeophtheirus salmonis, is maybe the one giving the best illustration of an interaction between wild and farmed fish. This parasite was well known, it was described by Krøyer as early as in 1838. It is a copepod with a life cycle of 10 stages, 3 pelagic stages and 7 attached to or living on the host. It is found circumpolarly in the northern hemisphere and is host specific for salmonids; the lice disappears from the fish in fresh water within a short time. When and where the free-living fish is infected is not known. The chance for a pelagic-living larvae to encounter its specific host in the open sea, does not seem very large. When wild salmon still were abundant in the rivers, the saying of experienced fishermen was that a high density of lice on the upward migrating fish, was indicative of a good salmon run. Only once, in Canada in 1940, lessions and death probably due to salmon lice were reported (White 1940). Actually, it should have been foreseen that salmon lice could become a potential problem in salmon farming. Under the intensive conditions found in farms, it is no longer a problem for the pelagic larvae to find their spesific host and complete their life cycle producing new larvae easily finding new hosts and so on. It soon became evident that the lice, if present in large numbers, were harmful to salmon. They live on mucus, skin and blood and in the most advanced cases fish are seen with large open lessions especially in the head region. Even if wild-living salmonids arround fish farms have been observed carrying large numbers of lice (Djupvik, pers. com.) lessions or mortality in such fish are not reported.

We still know little about diseases in free-living marine fish, clearly it is among the farmed fish we really encounter the problems. The largest problems are seen in connection with bacterial infections. Vibriosis due to the bacterium Vibrio anguillarum is probably the most well known of such diseases. Vibriosis was one of the economically most important diseases in marine fish farming, but can now be controlled efficiently through vaccination. Vibriosis is known from a large amount of freeliving marine fish, but epidemics are rarely seen. Along the Norwegian west coast local outbreaks of vibriosis in young saithe are found annually, reaching epidemics proportions in certain years (Egidius et al. 1983). Experiments have shown (Egidius and Andersen 1978) that there is some host specificity amongst V. anguillarum strains isolated from for example rainbow trout and saithe, and more recent investigations have shown that there at least at the DNA level is a slight difference between strains from different hosts (Wiik et al., in press). Mass mortality due to vibriosis is reported in homeward migrating salmonids when entering the rivers, but it does not seem to occur very frequently. Coldwater vibriosis due to V.salmonicida has not yet been reported in wild salmon.

Furunculosis due to the bacterium Aeromonas salmonicida var. salmonicida is another of the important bacterial diseases that must be considered. Furuncoulosis is endemic in the wild salmonid populations in Scotland, Ireland and Canada, but free-living affected fish are not frequently seen. In fish farms on the other hand the disease can be disastrous and in general of great economic importance. With furunculosis it seems clear that the free-living fish is the reservoir for the disease in farmed fish. In farmed fish the disease outbreaks seem linked with fish density in tanks and cages and other stress inducing factors.

The bacterium Yersinia ruckeri is a newcomer in European fish farms. Even if the disease was believed to be a fresh water one, it has spread to salmon farms all along the Norwegian coast. Possible effects on free-living salmonids are not known. Although the bacterium has been isolated from marine scavenger fish like saithe around affected sea cages, it is not known if the saithe just harbours the bacterium for a short time or if it can be pathogenic also for this and other marine species.

Bacterial kidney disease (BKD) due to Renibacterium salmoninarum is probably the most dreaded of the salmonid diseases mainly because its development is slow and because the diagnostication is difficult and time consuming. BKD was first thought to be purely a disease of farmed fish, but with improved diagnostic methods the bacterium was also found in wild stocks though its impact there is unknown. We most probably have the same situation as with furunculosis: that the infection reservoir is in the wild stocks, but the disease problems break out under farming conditions. The disease in farms can lead to higher infection rates of wild stocks in the vicinity.

Of fungal disease agents Ichtyophonus hoferi is common and often harmful in several species of marine fish. It has been found in farmed salmon, but until now without showing much effect.

Of parasites the monogean fluke Gyrodactylus salaris has done great harm in Norwegian salmonid rivers. The fluke is believed to have been imported with smolts for farming from Sweden to Norway in the early seventies. This fluke is now spread to about 30 salmon rivers, many of which are nearly emptied of Atlantic salmon. In the fish farming industry Gyrodactylus is no problem. Infected fish are easily treated and the parasite disappears when the smolts are put into sea water. This is the only disease mentioned here where apparently wild stocks are the loosers.

Examples have been given of disease interactions between free living and farmed salmonids, mostly to our knowledge in the disfavour of the farmed fish. Our general knowledge on disease in free living marine populations including salmonids, is still far too restricted, but there clearly is reason for great consideration and carefullness in movements of fish from different regions.

GENETIC VARIATION AND GENETIC STRUCTURE OF SALMON IN NORWAY

Population structure of salmon in Norway

Ståhl and Hindar (1988) have made a comprehensive monograph of the Norwegian salmon stocks with reference to the population structure, number of spawners (population size) and differences within and between wild and farmed salmon stocks. From studies on biochemical genetics they concluded that the natural salmon is divided into genetically distinct populations; sometimes more than one within the same river system. Farmed salmon (commercial stocks for intensive farming and culture aimed stocks) is not a homogeneos group and it is not possible to distinguish between wild and cultured salmon on the individual level by use of biochemical gene markers.

Potential genetic impact

Skjervold (1988) gave an overview of the types of genetic impact the fish farming could have on natural salmon stocks. In spite of the difficulties in estimating the numbers of escapees from fish farms, and of the magnitude of their contribution to the recruitment of salmon, evidently a great potentiality excists of significant gene transfer risk from farmed salmon to occasional rivers.

The farmed salmon has been subjected to intensive selection for improvement of productive traits, especially improved growth rate and late maturation. Genetic selection is performed systematically through a large scale program on improvement for fish farming conducted by the Fish Farmers Assosiation and the Fish Farmers Sales Organization in Norway. In addition most egg producers make phenotypic selection of broodstock, and probably also seminatural selection as an adaptation to life under farming condition (domestication) has taken place for 4-5 generations. The genotypes of the farmed fish may differ in several respects from the genotype of the population from which they originated several generations ago. It is difficult to predict how this change will affect their adaptation with respect to survival in the natural environment, but escapees which reproduce in rivers chosen by random will always decrease the differentiations between the wild salmon populations.

The origin of the salmon used for fish farming is important. Ståhl (1987) has shown that especially the Baltic salmon differs in genetic composition from the salmon in the north-east Atlantic, and east-Atlantic salmon differs in several aspects from the west-Atlantic stocks. As far as we know there has been no import of west-Atlantic live salmon to Norway (except for scientific purpose), but for several years we have had importations of smolts from Iceland, Scotland and especially from Sweden and Finland (Baltic salmon).

Gjedrem and Aulstad (1974) observed that a strain of Baltic salmon showed much lower resistence to vibrio disease than the Norwegian strains, indicating that genetically differences in resistence to certain diseases exist between geographically distant groups. Escapement of fish with other adaptations to diseases and parasites in the environment will represent a risk for transferring such disease agents to natural population. Thus newly established or potential hybride populations may be eradicated due to spontanous or accidental disease outbreaks.

Hybridization, hybride vigor and short term adaptation

Crossbreedings of natural and escaped salmon in the rivers are expected to cause increased heterozygosity, which may lead to hybrid vigor for some traits. Hybride vigor most often is found for traits with low heritability (Skjervold 1988), and survival traits have low heritabilities as far as they have been studied (Gjerde 1986). Thus, hybridizating with natural salmon in a river may give the impression of very well adapted fish; an adaptation which may oust nonhybride natural salmon, but last only for the first generation. Altukhov (1981) described a similar case with chum salmon where liberation of non-indigenous fish resulted in very low production both of the introduced fish and of the indigenous fish in the same river.

Genetic drift, reduced genetic variability and low numbers of spawners

Low numbers of spawners (effective population size) will always increase genetic drift, decrease heterozygosity and consequently increase the risk of loss of genes. A number of 100 speciemens of each sex is recommended by Allendorf and Ryman (1987) but in several cases of artificial reproduction for enhancement work and intensive fish farming, the spawning populations are considerably less than recommended based on theoretical considerations. However, judged from the results of Ståhl and Hindar (1988) the heterozygosity is higher in artificial than in most natural populations, and the genetic variability within populations is not reduced due to culture activities. This may be due to the fact that cultured populations usually represent different natural populations and contain more genetic variation than any single population. Therefore the risk of reducing the fitness of salmon through reduced genetic variability does not seem to be serious for the moment, although it should be kept in mind by monitoring both cultured and natural populations through several generations.

In conclusion the escapement of farmed salmon, and liberation of non-indigenous salmon for enhancement work represents a risk of decreasing the genetic variability between populations, possibly also reducing the long time fitness by first generation hybrid vigor in adaptive traits through hybridization between indigenous and non-indigenous fish. For the moment, however, loss of genetic variability through low numbers of broodstock for culture purpose does not seem to represent a risk.

INITIATIVES

To avoid impact of cultured salmon on wild stocks a series of initiatives have been taken or are being planned in Norway. These initiatives are listed below with a statement of the status of each of them.

Technical improvement

In addition to representing a risk for wild salmon, salmon escaping from fish farms always represent a loss for the fish farmer. Improvement of technical facilities to prevent escapement therefore is an immediate initiative to prevent contact between wild and cultured salmon. Usually, the security of a fish farming facility is a compromise between the chance of loss and the cost of investment. Landbased facilities are more safe than ordinary net pens, and closed or semiclosed pens are also an alternative. For the moment, landbased facilities for marine culture are not much used in Norway, but closed or semiclosed systems are under development. No specific demand is required for fish farming devices, but it has been proposed to establish protective areas for salmon where no farming activities will be allowed unless they are secured with respect to escapement. Within the zones technical improvements may prevent contact between natural and farmed salmon.

Gene banks (sperm banks)

Salmon from Gyrodactylus-treated streams are taken care of by artificial breeding and liberation, partly also in intensive culture (Ståhl and Hindar 1988). A sampling program for deep-freezing of sperm is undertaken (Gausen 1986). In 1986 sperm from 48 strains were preserved, while in 1987 the sperm bank increased to contain sperms from 69 populations. By using such sperms, populations which have been eradicated may at least partly be reconstructed. By use of androgenetic techniques more complete natural populations may be reconstructed from sperm banks (Scheerer et al. 1986).

Restriction on transfer of live material

For many years there has been a lack of smolts for the fish farming industry in Norway, as the smolt production did not increase as fast as the development of food fish production. For this reason, some imports have been legislated, in some cases with disastrous results concerning cultured salmon (i.e. import of furunculosis from Scotland) and natural populations (possible import of Gyrodactylus salaris from Baltic countries). In 1988 there was a surplus of smolts in Norway. This situation is expected to persist, and there is no longer any reason for import of live salmon, although even this year (1988) there has been an import of salmon eggs from Iceland. Transport of live material within the country probably also has contributed to the spread of Gyrodactylus. This seems to be a problem especially in cases where salmon farms are situated in fresh water systems also supporting anadromous salmonids, or in brackish water with a salinity lower than 14 to 18 o/oo. For this reason restrictions of transfer within Norway are also proposed, but not yet decided upon.

Use of indegenous fish for enhancement work

Enhancement has been conducted for several years by releasing offspring from occasional salmon of unknown origin, also farmed fish. To protect the between strain variation, in principle now only endemic fish are allowed to be used for enhancement of natural stocks. Only when such fish is unavailable, non-indegenous fish are allowed used.

Areas protected from fish farming

Hatcheries for commercial production of smolts for intensive fish farming are usually not located in or close to rivers with anadromous salmonid populations. However, some excisting hatcheries are located close to rivers with sea-run fish, and inland in Norway plants for rainbow trout productions (mostly small) are sometimes located in lakes draining to salmon rivers. Such fish farms have probably spread Gyrodactylus salaris. Hereafter no new installation for intensive production or for enhancement work for other than indigenous populations, will be allowed in rivers supporting anadromous populations.

To protect larger areas, a plan has been formulated for time restricted protective areas for wild salmonids. This plan is now subjected to consideration by involved official agencies and private organizations, and the fate of the proposal is yet uncertain. The aim of the proposal is to protect larger areas and secure references for observation of gene introgression and spread of disease agencies. To prevent further spread of Gyrodactylus salaris no new culture activities will be allowed where this parasite has been found. This include the river drainage and a defined area usually within about 20 km of the river mouths. Usually, rivers having a mean annual catch of more than 500 kgs anadromous salmonids will be protected. A few larger fjord areas (Sognefjorden, Trondheimsfjorden) are also proposed to be held free from new aquaculture installations. Such protective areas are proposed for five years as it is desirable to gain experience about the effect of such restrains before long-lasting decisions are made. If escapement free facilities are constructed, limited farming activities may be allowed, and existing farms within the areas will be allowed to continue.

MONITORING AND RESEARCH

The establishment and increase of the intensive fish farming industry represent a new and possibly serious threat to the natural populations of Atlantic salmon in Norway as well as in several other countries. From a management point of view actions are taken or will be taken to conserve the natural population in coexcistence with the developing fish farming industry, and possible commercial sea ranching activities. A first approximation to such management is to monitor the changes that really take place, and then to develop new methods for interaction studies. Further studies on quantities of escaped reared salmon in coastal areas and in the rivers, studies on infection sources for disease agents, occurrence of disease agents in natural populations and development of methods for defence against parasites (i.e. Gyrodactylus) in natural environment are required. Reconstruction of eradicated (or strongly decreased) natural populations from live gene banks or sperm banks by androgenesis is another area of research and development. Concerning genetic impact, the discussion is often loose and concentrates more on potential impact than on actual facts. To base this discussion on observed or experimental data will be a great challenge for scientific activites in the near future. Further studies on genetic differentiation of natural populations is important. To study hybridization and gene introgression, use of gene markers is a promising method. For other species (cod, brown trout) broodstocks homozygous for specific gene markers (biochemical or morphological are developed (Skaala et al. 1988). No suitable markers are yet found for salmon, but this will be further investigated for application in field studies on interaction between populations. If such studies are difficult or impossible to perform with salmon, they will be performed with brown trout as a model species.

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