Agenda item 7
For decision

Council

CNL(04)25

Predator-Related Mortality

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Predator-Related Mortality

Introduction

1. Many predators of Atlantic salmon have been identified but their impact is hard to quantify, particularly in the marine environment. Salmon abundance is presently low while at the same time some populations of predators of the Atlantic salmon are increasing, and in some cases the species concerned are protected. This has led to calls to restore the balance to ecosystems through the introduction of measures, both lethal and non-lethal, to reduce the impact of some species of predators. There are likely to be strong reactions to such measures.

NASCO's Actions to Date

2. At the Council's Annual Meeting in 1996, a Special Session was held entitled 'The Atlantic Salmon as Predator and Prey'. The issue remained on the Council's agenda in 1997 when a summary of the session was presented and the need for additional research on this topic was noted by several Parties. At the Seventeenth Annual Meeting in 2000, Canada made a presentation and tabled a paper, CNL(00)48, on the effects of predators on Atlantic salmon. In 2001, the representative of the European Union tabled a paper, CNL(01)61, on control of seals as predators of salmon in the European Union and verbal reports on the management of seal populations were given by the other Parties. In 2002, a further paper, CNL(02)46, was presented by the EU in relation to predation of salmon by seals and birds, summarizing ongoing research initiatives and outlining management options. The Council was advised that some EU Member States have management programmes in place and others are considering them for the future. Iceland had indicated that increased predation by cod on salmon smolts in Icelandic waters was a concern. Denmark (in respect of the Faroe Islands and Greenland) referred to the importance of predator-related mortality for wild salmon conservation and for salmon aquaculture, and noted that the issue should be considered in relation to application of the Precautionary Approach. At the Council's 2003 Annual Meeting, information on research and management activities in relation to predator-related mortality was provided by the EU (Denmark, Finland, Sweden and UK (Scotland)), CNL(03)24. A paper entitled 'The Effects of Marine Predation on US Stocks of Atlantic Salmon' was tabled by the US, CNL(03)39. Written statements on predator-related mortality have also been distributed to delegates by one of NASCO's NGOs at a number of recent Annual Meetings (CNL(97)72, CNL(98)71, CNL(01)70, CNL(02)44) and the issue has been referred to in a number of joint NGO Opening Statements.

Returns

3. Last year the Council agreed to gather together all available information on this subject and each Party was asked to appoint a coordinator for this work. These coordinators were asked by the Secretary to provide the following:

- information on the impact on salmon populations of predation by piscivorous birds, fish and mammals;
- details of measures implemented in relation to management of these predators of salmon and any assessment of the effectiveness of these measures;
- details of on-going research in relation to predator-related mortality.

4. The returns are presented in Annex 1. At the time of preparation of this document, no information had been provided by Greenland, a number of EU Member States with salmon stocks (France, Portugal and Spain) and the USA.

Canada has provided information on a three-year management plan introduced in 2003. This plan established a harp seal quota of 975,000 over the three-year period 2003-2005. For the same period, the TAC for hooded seals is 10,000 animals per annum and a small harvest of grey seals is permitted. The seals hunted must be independent, self-reliant animals. Actual harvest levels are highly variable and dependent on environmental and market conditions. 289,000 harp seals were harvested in 2003. Less than 200 hooded seals and a small number of grey seals are hunted annually. An active seal research programme has been maintained for many years and in April 2003 a two-year Atlantic Seal Research Programme with funding of CAN$ 6 million was announced to expand research activities in relation to abundance and distribution of seals and their impact on fish stocks. The programme will also evaluate seal management tools to aid recovery of cod stocks including exclusion zones and reproduction control. The results of this scientific programme will inform future management. A recent study suggests that seal predation of smolts leaving the Miramichi River is unlikely to be significant and no evidence was found of consumption of adult salmon, although this may be because the heads of salmon were not consumed or the head parts used for identification had been digested. Information on a river observation programme in Newfoundland rivers is also presented. Recent warm winters have altered coastal ice coverage and allowed seals access to estuaries and rivers.

Denmark (in respect of the Faroe Islands and Greenland) has indicated that there is no ongoing research on predator-related mortality of salmon in the Faroe Islands.

The European Union has reported that the Atlantic salmon is preyed upon by a number of species of fish, birds and mammals throughout the European Union and there has been much conjecture about the impact of this predation on salmon stocks and fisheries. Many of the species that predate on salmon are themselves subject to protection although for some species this protection has been relaxed in response to concerns from fishery interests. Pike, brown trout, burbot and a number of gadoid species are among the fish species listed as predators of salmon. Red-breasted merganser, goosander and great cormorant are considered by managers to be particularly serious predators, with predation by grey heron significant in some areas. Of the mammalian predators, seals have received the greatest attention by managers and scientists. Details of potential interactions between predators and salmon and of the measures taken to reduce damage to salmon stocks and fisheries, are provided for a number of EU Member States.

In Finland, research suggests that the main prey of medium and large burbot in the river Teno in winter months is juvenile salmon but the impact of this predation has not been quantified.

In Germany, studies of the impact of hydro-electric schemes on migrating salmon smolts indicated that smolts weakened by their passage through turbines were easy prey for predatory fish gathered downstream. Harvesting of these predators has been recommended during the migration period of smolts. Both cormorant and grey heron populations have increased substantially since the 1970s. Increasing awareness that continuing high levels of protection for cormorants could jeopardize the salmon restoration programme in the Rhine may lead to the authorities allowing scaring-off or shooting of cormorants.

In Denmark, in response to an increase in the cormorant population and the number of complaints from fishermen a variety of control measures, both lethal and non-lethal, have been introduced. They include changes to fishing gear and the mode of fishing, scaring of birds (e.g. from release sites used for stocking salmon), removal of nests, shooting, spraying of eggs with paraffin oil and the illegal release of predators such as mink, a practice that can lead to predation on other species of birds. The mink may also prey on Atlantic salmon.

For Great Britain, information has been provided on the number of licences issued and the numbers of cormorants, herons, mergansers and goosanders shot under these licences. In England and Wales, the general view is that predation on salmon by seals is probably limited to a small number of seals that target fish in nets and in river mouths and estuaries. In Scotland, there are increasing reports of seals moving upstream into rivers and lochs and it is assumed that they are feeding on salmon. Although some seals are known to eat salmon, evidence of salmon in the diet of seals is limited. Details of the number of licences issued to shoot seals and the numbers shot under these licences is provided. Collaborative research projects are on-going in Scotland to assess the diet of seals and the use of scaring devices and to identify interactions and damage "hotspots".

In Sweden, damage to salmon stocks and fisheries from seals has been recorded.

In Ireland, salmon smolts are frequently recorded in the stomachs of pike in large lakes and some large rivers, although many large rivers lack suitable pike habitat, so predation in these rivers is low. Ferox trout may also prey on salmon smolts. The cormorant population in Ireland has increased following reduction in persecution by humans and stocking of game and coarse fish of a size suitable for consumption by cormorants. Disturbance of cormorants and, in exceptional circumstances, shooting are used to protect migrating smolts. Although salmon fishermen have reported that seals are major predators of salmon, studies on the diet of seals have failed to produce evidence to substantiate this. A report on a meeting held in Londonderry, Northern Ireland, entitled "Seals/Atlantic Salmon Interaction Workshop – a recent Irish review of the evidence" is referred to. One recommendation from the Workshop was that further seal control measures should be tested in Ireland with a view to replacing the lethal control methods currently available.

Iceland has provided a list of potential predators of Atlantic salmon in both fresh and marine waters. Information from an ocean ranching site suggests predation losses in the first 24 hours following release to be in the range of 0.2 – 1.1% of smolts released. It includes 15 species of birds, 8 species of fish and 3 species of mammal (including mink, a species introduced to Iceland), although no information is available on the impact on salmon of a particular predator. The urgent need for an extensive study on the impact of predation on salmon stocks in Iceland is noted. Details of predator control programmes are provided. For most potential predators these are implemented during short periods of time considered to be critical for the salmon. They include activities to control seal populations and to keep them away from river estuaries during the peak salmon migration period.

Norway has also indicated that information on the impact of predation on salmon stocks is limited, but has listed those fish, birds and mammals which are potential or confirmed predators of salmon at the different stages of its life-cycle. A study of the diet of goosanders and red-breasted mergansers showed that salmon was the dominant prey species but it was concluded that this predation did not significantly affect smolt production. Salmonids made up to 70-80% of the diet of otters but only 10% of the fish eaten were juvenile salmon. Predation is presumed to be the most important cause of natural mortality of salmon at sea and mortality is highest in the first few months at sea. Cormorants, grey seals and harbour seals are thought to be capable of exerting heavy predation pressure during the post-smolt migration period. Avian predation probably declines as the salmon grow while seal predation can occur throughout the marine phase. Elevated sea lice levels on migrating post-smolts may lead to increased predation. No specific management measures to control predators of salmon have been implemented. It is noted that a review of the literature suggests that predation pressure at certain stages in the salmon's life-cycle may be high although there is no empirical evidence that the total predation pressure or any individual predator is having a significant negative impact on salmon stock level. In several Norwegian rivers catches and pre-fishery abundance of salmon have increased significantly since 1997 despite the presence of stable or slightly increasing populations of predators. It is believed, therefore, that the decline in abundance in other areas is the result of environmental pressures other than predation.

The **Russian Federation** has provided information from observations at in-river barrier fences on a number of rivers with regard to seal damage and from studies on piscivorous fish. The percentage of salmon examined which showed signs of seal damage ranged from <1% to 5.3%. Analysis of the diet of pike in the Umba River during the smolt migration period indicated that 19% of the fish examined contained juvenile salmon. Management of predatory fish populations is undertaken in rivers in the Murmansk region. Pike, perch and burbot are harvested.

Further actions

4. NASCO has agreed guidelines and agreements on a wide range of threats to wild Atlantic salmon stocks but has not yet done so in relation to predator-related mortality although the Habitat Plan of Action states that habitat protection and restoration plans should take into account biological factors affecting the productive capacity of Atlantic salmon populations including predator-prey interactions. This is undoubtedly a complicated area. There are difficulties in assessing the impact of predation because

of the complexity of predator-prey interactions, and there are certain political overtones. Nevertheless, it would be difficult to argue that it should not be undertaken because of the political complexities. One approach which a Party has proposed is that the SCPA be asked to make recommendations on this issue consistent with the Precautionary Approach. Alternatively, a workshop might be held to assemble more detailed data on predator-related mortality, and to list options for future actions. When this has been done, another Special Session might be held, perhaps in 2005. It is, of course, also an issue of concern to the salmon farming industry so it may be useful to discuss it in the Liaison Group The Council is asked to consider the information provided by the Parties and decide what further action it wishes to take in relation to predator-related mortality of wild Atlantic salmon.

Secretary
Edinburgh
2 June, 2004

CANADA

Summary of 2004 - 2005 Seal Management Measures

The Canadian seal hunt is a sustainable, economically viable fishery based on sound conservation principles. Fisheries and Oceans Canada (DFO), the federal department responsible for managing the seal hunt, introduced a three-year management plan in 2003.

DFO sets the total allowable catch at levels that ensure the health and abundance of seal herds. Many factors are considered in establishing quotas. The full Atlantic seal hunt management plan is available at: http://www.dfo-mpo.gc.ca/seal-phoque/reports-rapports/mgtplan-plangest2003/mgtplan-plangest2003_e.htm

Key Management Measures:

- The seals that are hunted must be independent, self-reliant animals. The hunting of harp seal pups (whitecoats) and hooded seals (bluebacks) is prohibited.

- Persons may not hunt adult seals in breeding or whelping patches.

Harp Seals:

- The Northwest Atlantic harp seal is the most abundant of all seal species in Atlantic Canada and accounts for most of the commercial harvest. The harp seal herd is healthy and abundant, nearly triple what it was in the 1970s.

- The harp seal quota is set at 975,000 over a three-year period, from 2003-2005 inclusive.

- Although this size of harvest will reduce the population if the full quota is achieved, the population will remain above a level where there are any conservation concerns.

Hooded and Grey Seals:

- For the 2003-2005 sealing seasons, the annual total allowable catch (TAC) for hooded seals remains at 10,000 animals. As in previous years, there will be no hunt of hooded seals in the Gulf of St. Lawrence.

- A small harvest of grey seals is permitted in areas other than Sable Island, Nova Scotia (NS).

Recent Canadian Harvest Levels

Harvest levels are highly variable, dependent on environmental and market conditions.

Harp Seals:

- The harp seal quota was set at 275,000 from 1997 to 2002. Given the low harvest in 2000 (92,000), and because there were no conservation concerns, sealers were

permitted to exceed the pre-season quota and harvested 312,000 seals in 2002. By comparison, 289,500 harp seals were harvested during the 2003 season.

Hooded Seals:

- Less than 200 hooded seals have been harvested annually in Canada since 1998.

Grey Seals:

- Only small numbers of grey seals are hunted each year and a TAC has not been established. At present, they are harvested in Atlantic Canada, mostly in the Magdalen Islands and Cape Breton. No commercial hunting is permitted on Sable Island, NS.

Scientific Initiatives

- The multi-year management plan is based on sound conservation principles and a commitment to strong, peer-reviewed scientific advice.

- Fisheries and Oceans Canada has maintained an active seal research program for many years. This programme is aimed at understanding population dynamics, trends in reproductive performance and survival, migration, diving behaviour and diet analysis. These studies provide a better understanding of predation on fish stocks by seals and how seals interact within the marine ecosystem.

- In April 2003, the Government of Canada announced a two-year, $6 million Atlantic Seal Research Programme (ASRP) to expand on current research activities for the purposes of understanding of abundance, distribution and potential impact of seals on fish stocks.

- The ASRP is divided into three key components: 1) population assessments on harp, hooded and grey seals; 2) seal impact on cod (seal distribution and diet analysis); and 3) evaluation and implementation of seal management tools to aid in the recovery of Atlantic cod stocks (seal exclusion zones and reproductive control).

- Population surveys on grey seals and harp seals are scheduled for January and March 2004 respectively. A hooded seal population study is scheduled for March 2005.

- When results of population assessments and other research become available, DFO will rely on this scientific advice during the development of the next multi-year seal management plan, beginning in 2006.

- Satellite tagging is also being conducted to assist scientists determine migratory habits. The results of this work will give the department a better understanding of seal-fish interaction within the marine ecosystem. Approximately 65 seals will be tagged in this study.

- Part of the funding will also focus on seal exclusion zone research and how they may contribute to the recovery of cod stocks. A pilot seal exclusion zone (SEZ) will assist in the collection of scientific information pertaining to the evaluation and

effectiveness of establishing these zones for the protection of cod. A pilot SEZ began in Smith Sound, Newfoundland in January 2004.

Seal Predation on Cod

- Studies of predation by seals on fish in Atlantic Canada have focused on harp seals and grey seals. Predation by harbour and hooded seals has also been estimated. Harp seals accounted for the largest amount of consumption, followed by hooded and grey seals. However, recent data on diets of hooded seals suggest that they may also be important fish predators.

- The commercial seal quota is established based on sound conservation principles, not an attempt to assist in the recovery of groundfish stocks.

- Seals eat cod, but seals also eat other fish that prey on cod. There are several factors contributing to the lack of recovery of Atlantic cod stocks such as fishing effort, the poor physical condition of the fish, poor growth, unfavourable ocean conditions and low stock productivity at current levels.

- It is widely accepted in the scientific community that there are many uncertainties in the estimates of the amount of fish consumed by seals. Seals and cod exist in a complex ecosystem, which mitigates against easy analysis or simple solutions to problems such as the lack of recovery of cod stocks.

- Canada also provided copies of two recent working papers on seals and salmon which are available from the Secretariat. A summary of each of these papers is presented below:

Halichoerus grypus **and** ***Salmo salar***: **Is the Grey Seal predating on Atlantic salmon in Miramichi Bay?** Claire Williams - Biology Intern 2002 Miramichi Salmon Association Inc. With funding assistance from Fisheries and Oceans Canada – Youth Internship Programme.

The purpose of this study was to determine if the grey seals of Miramichi Bay were eating outgoing salmon smolts and incoming adult salmon. This was accomplished by collecting a sample of forty seals from early June to late August 2002, removing, rinsing, sieving, and sorting their digestive tract contents by organ. Once this was completed, fish otoliths were removed and identified. There were very few seals in the bay before late June, so they could not be eating many of the salmon smolts as they went out to sea. Also, there was no evidence of salmon otoliths in any of the samples, meaning none of the seals collected for this study were eating salmon, or more particularly, salmon heads.

Seals and Salmon: Comments on the Results of a River Observation Programme in Newfoundland and Labrador. B Sjare and D Reddin, Science and Oceans Environment, Northwest Atlantic Fisheries Center, St John's, Newfoundland. Working Paper – Marine Mammal Peer Review Committee, February 2003.

There are six species of seals present in Newfoundland and Labrador waters including harp, hooded, harbour, grey, ringed and bearded seals. All are known to opportunistically feed on salmon; however, only two incidences of salmon have been documented in the stomachs of harp seals and nothing for any other species (n=7,000 stomachs). Presently there is growing

concern from resource users and the general public that seals may be responsible for the declining returns of salmon in many Newfoundland and Labrador rivers. To address this issue a River Observation Programme was implemented in 1999 to identify which rivers have seal/salmon interactions and to document the frequency of occurrence and nature of the interactions. Also a questionnaire dealing with a wide range of seal/salmon concerns related to the commercial fishery in Labrador was conducted in 1997 (n=89 participants). The occurrence of schooling bait fish (i.e. capelin, smelt or juvenile herring) in a river estuary during the smolt or adult salmon run appears to be an important factor in determining when and where seal/salmon interactions will occur (particularly in the case of harp seals). Whether the seal predator is a migratory or a more resident species also appears to influence the nature and frequency of occurrence of a predation incident. There is also evidence that recent warm winter temperatures have altered coastal ice coverage enough to allow seals access to river and estuarine habitats that were traditionally protected by ice during the early winter and spring. These findings emphasize the importance of having a good understanding of the ecological factors influencing the distribution, seasonal migration patterns and feeding behavior of the seal predator in question and its preferred prey.

DENMARK (IN RESPECT OF THE FAROE ISLANDS AND GREENLAND)

Faroe Islands

There is no ongoing research conducted in relation to predator-related mortality of Atlantic salmon.

EUROPEAN UNION

Introduction

Throughout the European Union - from Finland in the north to Portugal in the south - the Atlantic salmon is preyed upon by a number of species of fish, birds and mammals. There has been much conjecture over the impact of such predation on stocks and fisheries, and NASCO has returned to this issue several times in recent years.

Many of the species that predate on salmon are native to the European Union, and are subject to protection themselves. The EC Birds Directive and Habitats and Species Directive have been introduced in domestic legislation in member states throughout the EU. As well as the designation of Special Areas of Conservation and Special Protection Areas under Natura 2000, the legislation has led to the effective protection of species, including piscivorous birds, otters and seals, and habitat types throughout Europe. Currently, there are almost 19,000 Natura 2000 sites within the EU, covering some 230,000 km^2 , approximately 14% of the EU landmass. Many of the sites have been designated for plants and animals that have little or no effect on salmon.

NASCO Council Paper CNL(03)24 provided information from Finland, Denmark, Sweden and UK(Scotland). This paper updates the material presented in 2003, and describes further information on predation on salmon from a number of countries throughout the European Union.

Predators

A number of species that predate on salmon throughout the EU have been described.

Among the fish listed are pike (*Esox lucius*), brown trout (*Salmo trutta*), burbot (*Lota lota*), and a number of gadoid species which prey on smolts as they emigrate into coastal waters.

A number of piscivorous birds are known to predate on juvenile salmon. However, those considered by managers to be potentially serious predators are the Red-breasted Merganser (*Mergus serrator*), Goosander (*Mergus merganser*), and the Great Cormorant (*Phalacrocorax carbo*). The Grey Heron (*Ardea cinerea*) is considered to be a potentially significant predator in some areas.

Salmon are also preyed upon by a number of mammals, including otters (*Lutra lutra*), mink (*Mustela vison*) and seals (common seal, *Phoca vitulina* and grey seal, *Halichoerus grypus*). These two species receive the greatest attention by managers and scientists in the EU, as they can be observed along most shorelines. However, several other seal species may interact with European Atlantic salmon during their long oceanic migration to Greenland, including the harp seal (*Phoca groenlandica*) and the hooded seal (*Cystopha cristata*).

Predation by fish species

Finland: Information has been gathered on predation on juvenile Atlantic salmon in the River Teno during the winter by burbot. Stomach samples of burbot have been collected over some winter periods in the 1980s and 1990s, and information on winter activity and diel movements have been collected using under-ice video monitoring in 2003. These data

suggest that the main prey of large- and medium-size burbot during winter in the River Teno system is juvenile salmon. However, the impact of this predation is not yet quantified as no information on the size of the burbot population is available, nor information on consumption rates of burbot during winter. There are plans to intensify the burbot predation studies, probably in cooperation with the Norwegian counterparts. Detailed analyses of the recently collected video material are underway.

Germany: *Nordrhein-Westfalen* In 1996, an experiment to study the impact of turbine plants on migrating smolts was conducted at the Unkelmühle weir. For this purpose, two-year-old salmon, marked with VI-tags and telemetric transmitters, were released above a dam with a turbine plant. Suitable measures were taken to control the downward movement of the fish.

Observers noted that salmon were being predated by large fish in the tailrace of the power plant. One pike (98 cm long) had two marked salmon in its stomach. Another young salmon which had been fitted with a telemetric transmitter was eaten by a pike-perch (*Stizostedion lucioperca*) of approx. 70 cm in length, also in the tailrace of the power plant.

It was noted that an injury-free passage through the turbines was possible, but that fish in the tailrace, which might have been weakened during their passage through the turbine, constitute easy prey for predatory fish gathering downstream. It must also be assumed that dams and weirs form structures in the river that present excellent settlement and feeding places for large predatory fish. These are slack water areas upstream of the weir crests, and on the edge of the turbulence zones downstream of the turbines. After the experiment, repeated harvesting of predatory fish was recommended during the main migrating period of smolts. The predatory fish were removed alive to other locations.

Ireland: Pike (*Esox lucius* L.) are known to prey on salmon smolts during the spring period. Salmon smolts passing through large lakes on their downward migration are frequently recorded in pike stomachs in Lough Corrib on the Corrib system and Lough Conn and Cullin on the Moy system. Pike have been recorded accumulating in significant numbers where inflowing streams enter lakes in spring. Predation on salmon smolts also takes place on large rivers like the Boyne and Barrow, where salmon smolts have been recorded in significant numbers in pike stomachs in spring. Pike population size is low on many large salmon rivers, such as the Nore, Suir, Slaney and Blackwater, most likely due to lack of spawning areas, and thus predation on smolts is low.

There have been rare incidences of large pike preying on adult salmon in both Lough Corrib and Lough Conn, and two grilse of 4lb and 5lb were recorded in one large pike on one occasion. Little is known of the significance of trout predation on salmon smolts in rivers or lakes but it is believed to be less than that of pike. Salmon smolts have been recorded in the stomachs of ferox trout in Lough Corrib.

United Kingdom: During the late 1950s and early 1960s, it was estimated that 10% of the smolt run on the River Bran, a tributary of the River Conon in Ross-shire in Scotland, was eaten by pike (Mills, 1964). Research is currently underway by Fisheries Research Services in Scotland, using PIT and radio tags, to estimate the impact of predation by pike on juvenile salmon.

Predation by birds

Finland: In the lower reaches of the River Teno, some data on predation of mergansers on seaward-migrating salmon smolts have been collected in recent years. This collection and the analyses have been carried out by Norwegian research agencies.

Denmark: Cormorants have been protected since 1979, and no killing, disturbance or harassment has been allowed. Figure 1 below shows the increase in the number of colonies recorded since 1979.

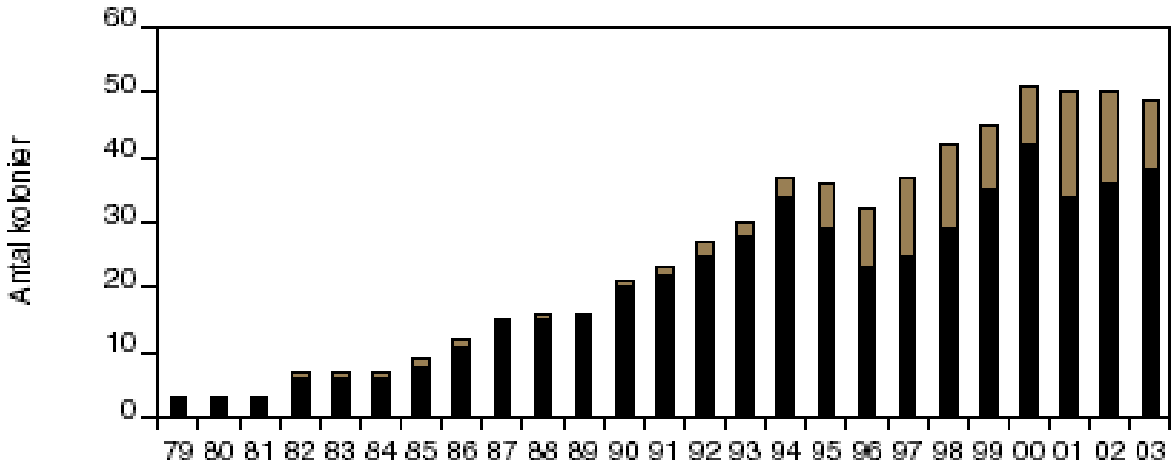

Figure 1. Number of Danish cormorant colonies 1979 – 2003.
Lighter shading shows the regulated proportion.

In 1992, the high number of birds in combination with increasing number of complaints from fishermen, led to the creation of a National Cormorant Management Plan. This plan made it possible to shoot at cormorants, foraging at or in fishing nets and at fish farms. The revised plan also allows for shooting at cormorants not only in the vicinity of nets, but within a distance of 1,000 metres of fishing gear. To assess the effect of shooting as a management tool, permits were issued to hunters in the Ringkøbing Fjord area to shoot cormorants in the hunting season. The management plan includes extensive monitoring of the birds through the first 4 years, to evaluate the effects of the new measures.

The continuing growth in population and number of conflicts led to a revision of the plan in the spring of 2002. This new plan allowed for a more intensive use of a new type of management measure, the spraying of eggs. This method aims to reduce significantly the breeding success of cormorants at selected (ground-based) colonies by preventing the eggs from hatching. This method has also been used to prevent establishment of new colonies on publicly owned land.

Conflicts that arise are generally between recreational and commercial fishermen and cormorants. The issues raised in relation to fish farms are different, but here effective protection against most birds is achieved by using cover-nets, combined with shooting intruding birds.

No economic compensation has been given to fish-farmers, fishers or forest owners for damage caused by cormorants.

Control Measures

Non lethal measures:

Cover-nets combined with "otter guards" to keep birds from hunting in pound-nets: When Danish pound net fishermen began to report severe losses to catches as a result of cormorant foraging in their nets during the late 1980s, attempts were made to try to keep the cormorants away from the nets. Initial attempts to reduce damage to catches involved the fishermen trying to empty their nets as early in the day as possible, because it was known that cormorants left their colonies around sunrise. There was some initial success, but then the birds changed behaviour and began to arrive at the nets even earlier. Thus, unless a fisherman could empty all his nets before daybreak, significant losses were recorded. Fishermen operating only a few nets in a restricted area could avoid severe loss by fishing early in the day, but for most fishermen, who have many nets in a large area and whose times of fishing are dependent on the right tide conditions (slack-tide), this approach was not successful. Fishermen tried various modifications of their gear to prevent cormorants getting access. One method was to hammer spikes in the top of each of the poles to prevent cormorants from landing and roosting. Another was to hang dead (drowned in nets) birds on the nets to scare others away. Neither of these measures had any significant effect.

In 1994, a more focused research programme was started to evaluate the value of cover-nets. The proposed method was to exclude the birds from the nets. Field experiments, including thousand hours of video surveillance, were carried out in 1994, 1995 and 1997. Initial results showed that cover nets alone had little or no effect, because cormorants simply dived through the trap entrance into the nets and were able to find their way out again. Additionally, cover nets are difficult to mount and include extra cost and labour. Another approach assessed involved installing cormorant barriers in the pound nets, so called barrel-nets, that allow fish to pass, but not the birds. Experiments with barrel-nets showed a positive effect because it was much more difficult for the cormorants to hunt in the nets, but the results were not really conclusive. Finally, experiments were carried out with a combination of cover-nets and barrel-nets covering the entrance. This method effectively keeps the birds out, but it is rather costly, labour-demanding and some fish species are much harder to catch in these net types than in regular nets. The information about these tests was disseminated to all fishermen, and today a few regularly use these methods, but most do not.

In the new management plan initiated in 2002, it is stated that: "It is planned to conduct new experiments with covered pound nets in the plan-period. This will be initiated in cooperation with DIFRES and University of Copenhagen and will aim at testing if it is possible to construct a net-type that will solve the problems caused by cormorants in a practical and economical way".

Commercial trout farmers traditionally use cover-nets to prevent predation from fish-eating birds. However, several birds walk or fly into the farms under the nets (mounted 3-4 metres above the ground). The most common birds are grey heron, cormorant and mergansers. Most fish farmers simply shoot intruding birds. It is likely that a rather high number of birds are killed annually this way, but this has not been quantified.

Scaring of birds: Generally, scaring away birds that are believed to be causing damage is the first and most obvious action to take and thus, cormorants are being harassed in a number of

ways all the time. However, in Denmark no co-ordinated research or monitoring of efforts of scaring cormorants away from sensitive areas has been carried out. The only exception is that a growing number of angling associations are attempting to scare away cormorants from release sites at the time just after fish have been stocked. In the special cases where large number of juvenile (trout, salmon, eel, pike) are released it may be very efficient to keep the birds away for just a few days until the stocked fish disperse or migrate. However, no evaluation of this method has been done.

Prevention of establishment of new colonies by removing nests: When cormorants attempt to establish a new colony, the owner or the authorities can decide to simply remove or destroy the nests. This is easily done when the birds attempt to nest on the ground, but more difficult where they nest in trees. In some places, trees with nests have been cut down, both legally and illegally. The method is very effective, but requires good access and usually takes several removals to prohibit the establishment of a new colony. When cormorants nest on private land, the nests can only be removed if the owner gives permission. Several large colonies in Denmark are situated on privately owned land, where the owners accept the presence of many cormorants.

Lethal measures:

Shooting: Shooting (and killing) of cormorants is generally forbidden, but some exceptions exist. It is legal for owners of fixed nets to shoot cormorants at the nets from 1 August until 31 March. In 1992 this was in effect for birds within 100m of nets. In 1995 the distance allowed was increased to 500m from a net, and since 2002 it has been legal to shoot birds within 1,000m of fixed nets. An owner of nets can also issue permission to another person(s) to shoot birds, and one pound-net fisherman claims to have up to 1,000 birds shot every year in the area where his nets are located. There are no estimates of the total number of birds shot in the proximity of nets, but it could be up to 10,000 annually. During the last two years, hunters have been given permission to shoot cormorants in Ringkøbing and Nissum Fjords from 1 September to 31 January. A total of 410 permits were issued, but only a few birds were actually shot (300 – 400). The conclusion from the first two years of testing the effect of opening a hunting season for cormorants is that this approach has had little effect.

Spraying of eggs: The management plan gives recommendations for each existing colony, regarding whether it may be regulated or not. Some colonies are protected and cannot be touched at all, others can be regulated only in special circumstances, and the remaining are open for regulation if the management authorities judge it to be necessary. The regulation method employed is to spray all or a proportion of the eggs with paraffin oil, which seals the eggs so that they do not hatch. The birds stay with the eggs and do not lay new eggs, so the method effectively reduces the reproductive success (to zero) of the birds. The method has been used since 1995 (before that a few colonies were physically removed) and the experience from 7 years of regulation is that the establishment of new large colonies has been prevented. However, it cannot be concluded that the regulatory methods introduced have diminished the conflicts with fisheries.

Illegal releases of predators: This illegal measure seems to be a rather common response of local people (fishers?) to the growing number of cormorants. The annual report of the status of all colonies, give several examples of such releases every year. In particular, mink are easy to obtain (from fur farms) and they can do significant damage in ground-nesting

colonies. However, a major problem is that other nesting birds (terns, swans, gulls) also suffer from such illegal releases.

Germany: Juvenile stocking to reintroduce salmon in Baden-Württemberg is currently conducted in the Rhine tributaries (Alb, Murg, Rench and Kinzig) coming from the Black Forest, as well as in the remaining Rhine area at Breisach (from the French and Swiss sides). The programme is to be extended to other Rhine tributaries.

Until about 1970, only very few cormorants had lived in the entire region and only as over-wintering birds. From the early 1970s onwards, the number of winter visitors increased steeply (currently >1,000 specimen). Over-summering birds and breeding birds have also been increasing visibly for some years now. In Baden-Württemberg alone, there are currently 200 pairs. Other breeding colonies, very large in some cases, can be found in the adjoining Bundesländer of Rheinland-Pfalz, and Hessen.

The grey heron population in the region has also increased substantially since it had been placed under full protection in 1974. Today, numerous colonies consisting of 50 or 100 breeding pairs respectively live in the Upper Rhine area.

Other fish-eating bird species have not been important in this context to date.

Areas of conflict

The lower courses of the Rhine tributaries and the main Rhine area are heavily populated with cormorants. There is also likely to be heavy predation pressure by the large number of grey herons in some parts. While cormorants are rarer in the smaller tributaries than in the main water bodies, grey herons occur frequently everywhere.

Impact on the salmon stocks

Many good nursery areas for salmon smolts are located in the middle and lower courses of the waters included in the re-introduction schemes, and in the remaining Rhine. These nursery areas are frequently visited by cormorants. Salmon parr and smolts fit excellently into the prey spectrum of these birds, and a considerable predation pressure can therefore be assumed. However, quantitative data are not available on this issue.

Fishery experts consider the impact of fish-eating birds on the juvenile salmon population as potentially heavy enough to jeopardize the salmon and sea trout restoration project to a great extent. This assessment is, *inter alia*, based on studies on salmonid rivers where a large influx of cormorants reduced stocks by over 90%.

Protective measures

Birds are protected under both Federal law (*Bundesnaturschutzgesetz*) and at the *Bundesläder* level (*Landesnaturschutzgesetze*). Under these provisions, regulations can be made addressing when measures may be taken, what those measures may be, and whether financial compensation could be granted. The regulations made may be quite different in different *Länder*. However, most of them will allow measures to be taken only under specific conditions.

Until recently, protective measures could only be taken to a very limited degree in the reintroduction waters. Bird protection has been a frequent reason for non-approval of proposed measures. However, the state of Baden-Württemberg has issued a regulation in

relation to control of cormorant populations. An increasing awareness that a continuing high level of protection for cormorants could jeopardize all efforts to reintroduce salmon may lead to an increased willingness of the authorities concerned to allow the scaring-off or shooting of cormorants.

Impact of cormorants on migrating fish stocks (salmon, sea trout)
The river catchment formed by the Sieg, Agger, and Bröl comes within the scope of application of the so-called Cormorant Decree of Nordrhein-Westfalen. Parts of the rivers Wupper and Rur have also been included in this programme. An application has been filed to enlarge the scope by the Rur. This is adequate proof of the fact that rivers where salmon is being reintroduced by the Land in cooperation with the fishing associations, serve as feeding territory for cormorants. Even though the data evaluation only concerns grayling stocks, it can be assumed that cormorants feed on all other fishes of a suitable size that migrate in shoals. However, precise data and assessments on this are not currently available.

Literature shows that sawbill ducks, cormorants and other birds feed, to some extent, on migrating young salmon. Comparable studies have not yet been carried out in Germany. Hence, no statements on the transferability of the statements made in the literature can be made.

Ireland: Cormorants (*Phalacrocorax carbo carbo)* in Ireland breed primarily in coastal regions although some breeding also occurs inland. As in other European countries cormorants are considered by some to have an adverse effect on fish stocks. During the 1900s some fishery managers offered rewards for the killing of cormorants in their fisheries. This was later followed by a National bounty system introduced by the Department of Fisheries and between 1973 and 1976, 3,527 cormorants were reported killed under the scheme. With the implementation of the Wildlife Act 1976 cormorants were given full protection and can now only be disturbed or shot by licence in exceptional circumstances under Section 42 of the Act. Licences are issued by the National Parks and Wildlife Division of Duchas who are responsible for natural heritage conservation in Ireland.

The protection of cormorants led to concern among fishery interests that any population increase or change in distribution would have an adverse effect on fish stocks, particularly due to the apparent increase in use of inland waters for feeding. During the mid 1980s the Forest and Wildlife Service carried out a cormorant breeding census to monitor changes in population size since the previous census in 1969/70. The results of this census showed the population had increased from 1,865 pairs in 1969-70 (Operation Seafarer) to 4,455 pairs in 1986-87 (Macdonald 1987). The reasons given for the increase in population size were reduction in human persecution and the increased availability of winter food in inland waters as a result of pike predation control and a stocking programme run by the Central Fisheries Board. Examination of cormorant diet during the non-breeding season showed a high incidence of coarse fish, particularly roach and perch, with roach providing over 80% of the diet in late winter (Mcdonald 1987). Mcdonald 1987 also showed that systems with high populations of roach coincided with the highest concentrations of wintering cormorants. Sellers (1991) estimated that roughly half the wintering population of cormorants is found inland. Doherty and McCarthy (1997) found that cormorants in the lower reaches of the Shannon fed predominantly on perch in winter and eels in summer and concluded that the ‘greatest potential for impact on economically important fish stocks seems to involve eels’.

A study carried out on the Erne to assess the impact of cormorants on salmonid stocks suggest that cormorants did not pose a serious threat to salmon smolts,)Crowley, Mathers and O' Teangana 2001). This was similar to the findings of Doherty and McCarthy (1997) who suggested that it was unlikely that salmon smolts were extensively predated by cormorants in the lower river Shannon system.

To gauge the present level of conflict in Ireland between cormorants and fisheries, information was gathered from stakeholders in the aquaculture sector (freshwater and marine), salmonid game fisheries, coarse fisheries and conservation groups. In the case of the aquaculture industry, damage control activities, primarily predator netting, were shown to be effective on most sites and resulted in minimal losses due to direct consumption of fish. Some sites did report indirect damage by cormorants stabbing fish but in general cormorants were not considered a major problem to the aquaculture industry.

The continued stocking of inland waters with coarse and game fish, which are a suitable size for cormorants, continues to act as an attractant to the cormorants as they are opportunistic feeders. The presence of cormorants at these fisheries is considered by many anglers to have a significant impact. However, due to the limited resources of the Fisheries Boards it is not possible to assess the actual impact of cormorants on these stocked fisheries. Resources are also limited in relation to providing damage control activities.

In relation to salmonid fisheries the main periods of potential conflict with cormorants occurs during smolt migration and stocking. Damage control activities, when used, are generally human disturbance and, in exceptional circumstances, shooting. However, the number of licences applied for nationally to shoot cormorants in recent years was low and the majority of these were required during smolt migration.

Overall, in comparison to other European countries the interaction between cormorants and fisheries in Ireland does not appear as great. In most cases there is a lack of scientific data on the actual impact of cormorants on fish stocks and what their impact is in relation to other mortality factors. However, whereas the cormorant is not seen as a major problem to the aquaculture industry it is still perceived as a problem to the angling sector, particularly on larger water bodies. Despite the perceived problem the number of applications to shoot cormorants under Section 42 of the Wildlife Act 1976 has been low. In the last three years the number of cormorants permitted to be shot has not exceeded 150 birds in any one year.

United Kingdom: In England and Wales, and in Scotland, birds are protected under the provisions of the Wildlife and Countryside Act 1981. Special provision is made, however, to allow for the killing of birds *inter alia* "for the purposes of preventing serious damage to livestock, foodstuffs for livestock, crops, vegetable, fruit, growing timber and fisheries". In Northern Ireland, similar provisions are available under the Wildlife (NI) Order 1985.

England and Wales

Cormorants

Overview and level of potential interaction with salmon

The population of cormorants wintering in Britain has increased around four-fold over the last 25 years. Cormorants in England and Wales have extended their range from coastal areas

and now over-winter and feed in many inland areas, taking advantage of new wetland habitats, many created as a result of mineral extraction and water-supply reservoirs. In addition, over the last 18 years cormorants have started to develop inland breeding colonies. The increase in inland colonies has meant that some birds are present at inland sites throughout the year, although peak numbers occur over winter with many birds returning to coastal breeding sites in the spring. The range extension and increase in numbers of birds has increasingly brought cormorants into conflict with inland fisheries.

There is marked variation in the diversity of fish species in river systems in England and Wales, with the number of species increasing with decreasing latitude and decreasing altitude. Fish communities are dominated by relatively small numbers of species (primarily salmonids) in many of the rivers in northern England and in those draining more upland areas on the west coast and in Wales. In contrast, more diverse fish communities (predominantly cyprinids) are present in most of the rivers towards the south and east of England and in the lower reaches of some rivers elsewhere.

Cormorants are perceived to be a fairly widespread 'problem' on river systems throughout England and Wales, particularly in central and southern England. However, relatively few licences to shoot cormorants have been issued over recent years for river systems, and these have mostly been in southern England. The relatively small number of licences on rivers may, in part, reflect the difficulties of demonstrating serious impact at such sites. The limited data available from cormorant stomach analysis for birds shot on these river systems are consistent with the variable distribution of fish species and the fact that cormorants are opportunist predators which consume locally abundant species. Very few salmon have been recorded in these birds, shot mostly in the lower reaches of rivers over the winter months. The limited available data suggest that the proportion of salmon in the diet would be greater in more northerly and upland catchments (consistent with the latitudinal trends reported in Scotland – Marquiss *et al*., 1998). A brief summary of the diet differences between different river 'types' in England and Wales is included in Russell *et al* (2003).

There have been a number of reports in England and Wales of birds aggregating on estuaries and the lower reaches of rivers in spring and thus concerns about predation on smolts. These reports have not been quantified and there are no published estimates of losses of salmon to cormorants for river systems in England and Wales. However, this remains a potential concern given that the majority of salmon stocks in England and Wales remain in a depleted state.

R&D and other reports

As a result of growing concerns about the problem of fish-eating birds at inland fisheries in England and Wales, a programme of research was commissioned in 1995. Much of this work focussed on cormorants. The R&D investigations (5 separate projects) reported in the late 1990s (see references). The overall aim of the research was to improve the level of information on the behaviour of fish-eating birds, the populations of these birds, the extent of the problem they cause to fisheries and to develop effective management strategies. However, as noted above, this did not include estimating cormorant impact on salmon stocks, since this was not perceived as the main 'conflict issue' in England and Wales. The Department for Environment, Food and Rural Affairs (Defra) is continuing to fund research that might reduce cormorant impact, but this work is directed at the potential benefits of fish refuges and is

mainly applicable to stillwater coarse fisheries. This work is being undertaken by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS).

Apart from the scientific advances resulting from the R&D programme, there has also been recent emphasis on consensus building and conflict resolution. This has done much to break down the polarised and entrenched views that have tended to characterise the issue in the past. Different groups have been set up to bring together stakeholders (i.e. fisheries and conservation organisations, ornithologists, fishery scientists) and other interest groups. An EU Concerted Action programme ('REDCAFE' – Reducing the conflict between cormorants and fisheries on a pan-European scale) was recently completed (final report available at http://banchory.ceh.ac.uk/REDCAFE/REDCAFEdocs.htm). Within the UK, a group was set up as part of the Moran Committee to address the concerns about cormorants. The Moran Committee (Chairman Lord Moran) represents 13 of the major fisheries and angling organisations in England and Wales; the Committee's Joint Bird Group also comprises representatives from RSPB, Environment Agency and English Nature. The group has recently produced a leaflet 'Cormorants – The Facts' and an advisory booklet 'Protecting your fishery from cormorants'. Details are available on a dedicated website (www.cormorants.info).

Legal status

As stated above, in England and Wales, cormorants are protected under the Wildlife and Countryside Act (WCA) 1981, which implements the 1979 European Community Directive on the Conservation of Wild Birds (EEC/79/409). In its capacity as a licensing authority under the 1981 Act, Defra issues licences (Welsh Assembly Government (WAG) in Wales) to shoot cormorants at specific sites. Licences only allow limited numbers of birds to be killed to reinforce the effects of other scaring measures, and are only issued where Defra is satisfied that:

- birds are causing sufficiently serious damage to justify shooting;
- other methods of non-lethal scaring have been shown to be ineffective or impracticable;
- shooting will be successful in reducing the damage; and
- there is no other satisfactory solution.

There are no powers to undertake a general cull. The numbers of birds for which licences to shoot have been issued in England over recent years and the numbers of birds shot are provided in the Table 1 below.

	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02
Cormorants						
Licensed	366	443	517	485	506	545
Shot	180	139	167	205	199	225
Herons						
Licensed	22	32	45	67	62	68
Shot	5	10	15	31	33	28
Goosanders						
Licensed	5	11	11	9	5	5
Shot	3	6	3	0	0	1

Table 1. Numbers of birds for which licences were issued, and the numbers reported shot in 1996-2002

Sawbill Ducks

Overview and level of potential interaction with salmon

Goosanders and red-breasted mergansers breed on rivers and lakes in northern and western Britain. Goosanders have extended their range into many parts of England and Wales over recent decades and are much more widespread in winter than at other seasons. In view of their favoured foraging habitat on upland rivers, these birds are seen as a problem for salmon fisheries in many parts of the country. In contrast, there are relatively few red-breasted mergansers in England and Wales and this species is not generally perceived to be a problem.

R&D and other reports

The recent Government-funded R&D programme (noted above) includes case studies of goosander impact on the Rivers Wye and Ribble. The goosander case study on the Wye estimated that the diet of goosander broods comprised between 16 and 97% salmon (by weight). However, the level of impact remained unclear (the study found that estimates of annual depredation exceeded the estimated standing crop of salmon by between 1 and 7 times). The difficulties were believed to lie in providing reliable estimates of the standing crop biomass of juvenile salmon. Notwithstanding the uncertainties, the results are seen as a cause for ongoing concern (particularly given the current depleted status of salmon on the Wye). Estimates for the Ribble/Hodder system found that salmon comprised a much smaller part of the diet (7 to 14% by weight), but with estimated annual standing crop reduction still ranging from 6 to 60%, although these again are likely to be over-estimates. Full details of these studies are provided in Feltham *et al*. (1999) and Wilson *et al*. (2003).

Only small numbers of goosanders have been shot under licence in England and Wales in recent years (e.g. see Table 1 above for England). The limited available data from these birds have confirmed the presence of some salmon in the diet, but have been insufficient to provide reliable estimates of percentage composition of diet for these birds.

Recent R&D (M^{c}Kay *et al*., 1999) indicated that shooting may increase the sensitivity of goosanders to human disturbance, and that disturbance by anglers reduced goosander numbers on rivers. Gas cannons were found to be ineffective.

The Moran Committee have recently completed an advisory leaflet ‘Goosanders and Mergansers – The Facts’, this is available on the Moran Committee website (see above).

Legal status

As with cormorants, goosanders and red-breasted mergansers are protected under the Wildlife and Countryside Act (WCA) 1981. The same provisions also apply for killing or taking birds under licence for the purpose of preventing serious damage to fisheries. However, relatively few licences have been issued in England and Wales for goosanders (e.g. see table above for England) and no licences have been issued over recent years to shoot red-breasted mergansers.

Scotland

Atlantic salmon may be preyed upon by a number of bird species, but those of principal interest in Scotland are the sawbill ducks (goosander, and red-breasted merganser), and the great cormorant.

Marquiss *et al* (1998) reported that the most recent estimates indicated that there were 2,600 pairs of breeding goosanders and 800 breeding pairs of red-breasted mergansers on Scottish rivers. The most recent estimate of cormorant numbers is 11,700 pairs in Britain and Ireland.

Fishery managers may apply for a licence to shoot piscivorous birds under the provisions of section 16 of the WCA to prevent serious damage to fisheries.

The Scottish Executive Environment and Rural Affairs Department (SEERAD) may issue licences where appropriate application has been made.

Licences are issued as an aid to scaring and to provide point protection to salmon, not as an exercise to reduce bird populations. No licences are issued during the periods of mating, nesting and fledging. Licences to protect salmon fisheries are issued generally only to District Salmon Fishery Boards, or to proprietors of salmon fisheries where there are no Boards in place. Each applicant has to provide estimates of the amount of damage sustained, counts of the numbers of birds involved, and details of any non-lethal methods of control that have been tried. Bird counts must be made in accordance with specified techniques. Before a decision on whether to issue a licence is made, SEERAD consults Fisheries Research Services Freshwater Laboratory (FRSFL), Scottish Natural Heritage (SNH), and the Wildlife Management section at the Scottish Agricultural Science Agency (SASA).

If a licence is issued, it stipulates where, when, how and how many birds may be shot. It makes clear that shooting must be used as an aid to scaring.

Table 2 shows the numbers of cormorants and sawbill ducks for which licences were issued, and the numbers reported as being shot for the period 1997-2003.

	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03
Cormorants						
Licensed	308	191	204	165	118	125
Shot	193	138	154	95	106	108
Mergansers						
Licensed	210	136	105	85	68	64
Shot	148	89	88	48	68	64
Goosanders						
Licensed	529	417	417	400	357	320
Shot	410	345	352	285	357	312

Table 2. Numbers of cormorants and sawbill ducks for which licences were issued, and the numbers reported shot in 1997-2003

Concern has been expressed by some about the shooting of piscivorous birds. It has been argued that there is no evidence that shooting sawbill ducks and cormorants has resulted in

any increase in salmon numbers. The advice from fishery scientists is that as predation is being controlled at a stage in the life-cycle of the fish when density-dependent mortality has ceased to have an effect, then the avoidance of losses can be expected to provide a real gain, even if subsequent density-independent mortality acts on the fish populations. Research continues at FRSFL into the population dynamics of Atlantic salmon and other species of freshwater fish in relation to predation and other impacts.

Northern Ireland

There has been little work undertaken to assess the impacts of predation on salmon by birds in recent years. Kennedy and Greer reported in 1988 on predation by cormorants on the salmonid populations of the River Bush, Northern Ireland. They concluded that birds feeding in the upper reaches of the river fed on wild smolts and brown trout, whereas those feeding downstream of the salmon hatchery at Bushmills fed exclusively on hatchery-reared smolts.

Predation by mammals

Ireland: The most recent information available is presented at a workshop convened by the Loughs Agency of the Foyle, Carlingford and the Irish Lights Commission (a joint Ireland/UK N. Ireland agency) at the request of the North-South Ministerial Council. The ensuing report is entitled "Seals/Atlantic Salmon Interaction Workshop. A Recent Irish Review of the Evidence" (Boylan, Crozier, McGinnity and Ó Maoiléidigh, 2003).

The most recent estimates of seal abundance indicate a minimum population of 1,000 common seals and 4,000 grey seals. Although salmon fishermen have reported that seals are major predators of salmon, studies on the diet of grey seals failed to produce evidence of salmon in either faecal or stomach content analyses. However, salmon were noted to be relatively scarce in the areas where samples for dietary analysis were taken, and the difficulties with identifying salmonid remains reported from studies in Scotland apply equally to the Irish investigations.

The Workshop also noted that there was a distinct lack of information relating to the behaviour of seals encountering free-swimming salmon and particularly on the diet of seals in the high seas.

Recommendations from the Workshop included:

- seal census should be co-ordinated on an all island basis with appropriate standardisation to avoid conflict of observations from fishermen and official observers.
- studies should target specific areas (e.g. the Foyle estuary and river) to examine the impact on salmon at the population level.
- modelling techniques should be developed to allow extrapolation of survey results to wider geographic areas and populations.
- further seal control measures should be tested in Ireland with a view to replacing the lethal control methods which are currently available.
- information of seal census and scientific research should be more widely and routinely available.

Sweden: Damage to salmon and salmon fisheries by seals has been recorded in Sweden. Until recently, Sweden used the same method to estimate the level of damage as that used in Finland, UK, and Ireland. However, this method takes account only of the visible remains of fish, whereas whole fish are known to be taken from fishing gear without leaving a trace. In 2003 (CNL(03)24), Sweden presented a document describing methods to estimate hidden losses to salmon fisheries as a result of seal activity.

United Kingdom:

Otters

The Otter is given full protection under the Wildlife and Countryside Act 1981 and is listed on both Schedules 5 and 6 of the Act. Among other things, it is an offence for any person to intentionally kill, injure or take an otter, or damage, destroy, or obstruct access to, any structure or place which it uses for shelter or protection. Otters are also protected by the EC Habitats Directive 1992, being listed on Annexes II and IV, which is implemented in the UK through the Conservation (Natural Habitats, &c.) Regulations 1994. The Directive makes it illegal to intentionally kill, capture, injure or disturb otters, or to damage or destroy breeding or resting site. In England and Wales, under the Countryside And Rights of Way Act 2000, it is also an offence to recklessly disturb an otter or to damage, destroy or obstruct their place of shelter. The Wild Mammals (Protection) Act 1996, also protects, in England and Wales, wild mammals from cruel acts. The Protection of Wild Mammals (Scotland) Act 2002 prohibits, with certain exceptions, the hunting of wild mammals, including otters, with dogs.

Derogation from the protection afforded to otters under the 1994 Regulations (e.g. to provide fencing that restricts or excludes otters from their habitat) requires a licence from Defra in England, WAG in Wales, and SEERAD in Scotland. Before a licence can be granted, three tests specified in regulation 44 of the 1994 Regulations, must be satisfied:

- That the project or plan will prevent 'serious damage to livestock, foodstuffs for livestock, crops, vegetables, fruit, growing timber or any other form of property or to fisheries';
- That there is 'no satisfactory alternative';
- That the derogation is 'not detrimental to the maintenance of the populations of the species concerned at a favourable conservation status in their natural range'.

Otters were seriously affected by organic pesticide residues in the 1960s and 1970s and were lost from many rivers. Nevertheless, Scotland is regarded as having one of the best otter populations in Europe. Numbers throughout the UK have increased considerably in recent years, but populations have still not reached previous sizes in many areas. Throughout the UK, various agencies, including the Environment Agency and the Wildlife Trusts, have taken the lead in producing a Biodiversity Action Plan for otters and have been involved in the Otters and Rivers Project designed to encourage the return of otters to river systems where otters used to live, mainly by improving habitats. The return of the otter has generally proved popular, since it is a charismatic species. Some 80 local biodiversity action plans across the UK include specific proposals to benefit otters.

The main current concerns in England and Wales relating to otter impacts on fisheries are among coarse-fishery owners and anglers, who claim that otters are killing large, highly-

prized carp. There do not appear to any major current concerns about the impact of otters on salmon fisheries in the UK.

The review of Salmon & Freshwater Fisheries in England and Wales, completed in 2000, recommended that: *Research is required to investigate the potential effects of reintroduced populations of otters in areas where the native fish populations are under particular pressure. Any programme designed to encourage the re-establishment of otters should take account of the impact of the resulting predation on vulnerable fish stocks.*

Seals

Two species of seals predate on salmon in UK waters, the grey seal (*Halichoerus grypus*), and the common or harbour seal (*Phoca vitulina*). The most recent estimates of seal population sizes in UK (2002) were 109,500 grey seals (99,100 in Scotland) and 35,000 common seals (minimum estimate), of which 29,700 are in Scottish waters (Report of the Special Committee on Seals - http://smub.st-and.ac.uk/pdfs/SCOS%2003_v7.pdf). The estimated population of grey seals is lower than in 2001, not because of a decrease in seal numbers but because of the introduction of a new and more robust population estimation model. The new model reflects strong indications that the rate of increase in pup production is slowing due to limits on the carrying capacity of the main breeding sites. In the late 1980s, pup production increased at over 6% per annum, whereas in the past 5 years, it has been less than 2% per annum. If conditions persist as they are, the total population size is predicted to increase by no more than about 1% over the next ten years.

Seals are protected in Scotland and in England and Wales under the provisions of the Conservation of Seals Act 1970. The 1970 Act provides a close season for grey seals during the period 1 September to 31 December, and for common seals in the period 1 June to 31 August. During the remainder of the year, seals may be shot providing an appropriate, licensed firearm is used. This firearm must be a rifle using ammunition with a muzzle velocity of not less than 600 footpounds (813.5 joules) and a bullet of not less than 45 grains (15.4 g). Under the provisions of section 10 of the 1970 Act, fishermen may shoot seals during the annual close times only if serious damage is being caused to catches or gear, and if the seal in question is in the vicinity of the fishing gear. Seals may also be shot under licence during the close times if there is evidence that they are causing serious damage to fisheries or gear. In practice, fishermen apply for licences to shoot seals, rather than depending on the defence section of the 1970 Act. In Northern Ireland, seals are protected under provisions in the Wildlife (NI) Order 1985, which allows for the issue of licences where fishermen can demonstrate damage to catches and fishing gear.

Under the Habitats Directive, both common and grey seals are identified as protected species for which SACs must be designated, and for which UK has special responsibility. The UK has about 40% of the world population of grey seals, and about 45% of the EU population of common seals. Of the UK population of both species, around 90% are found in Scottish waters.

Designation of sites as SACs does not preclude control of seals within the sites, but it does place restrictions on the scale of control, including taking appropriate steps to avoid "significant disturbance". More generally, the EC Habitats Directive imposes a requirement to maintain the "favourable conservation status" of grey and common seals. This would

certainly prevent any significant cull being undertaken within an SAC, and may even restrict shooting on sites or in the wider environment.

In 1988, an outbreak of Phocine Distemper Virus (PDV) was recorded in the UK, and an Order effectively making a year-round close time for seals was introduced under provisions in the 1970 Act. This Order remains in force in England and Wales. In Scotland, where the PDV outbreak affected fewer animals, the Order lapsed in 1990, except for around the Shetland Islands where it remained in force until 1998. Another outbreak of PDV occurred in 2002, and a Conservation Order was made under the 1970 Act to prevent shooting of common seals anywhere in Scottish waters, except under licence, and grey seals in the Moray Firth. That Order is due to lapse in September 2004.

England and Wales Salmon are known to feature in the diet of seals, but are not considered to form a major part of the diet (although there are well-publicised concerns about how representative the available diet data are). The general view is that predation on salmon is probably limited to a small number of seals that target fish in nets and in river mouths and estuaries. However, it is recognised that this could be significant for salmon populations in local areas.

There are no recent data available on the extent of seal predation on salmon stocks in England and Wales. However, 'seal problems' are often reported by salmon netsmen; Potter and Swain (1979) estimated seals removed about 5% of the fish caught by netsmen in the north east coast fishery in 1977. Seals are also often seen taking fish in rivers and estuaries, and around barrages.

Scotland There is considerable debate about the level of impact on salmon of predation by seals. There are increasing numbers of reports of seals moving upstream into rivers and lochs, and the assumption is that they are likely to be predating on salmon in these areas. Investigations are underway to determine whether a small number of seals specialise in this activity, or whether seals in general will enter freshwater if the opportunity presents itself.

A Seals Forum has been established, chaired by the Scottish Executive and comprising representatives of Sea Mammal Research Unit, Scottish Natural Heritage, Fisheries Research Services, Joint Nature Conservation Committee, University Marine Biological Station Millport, University of Aberdeen, Highlands & Islands Fishermen's Association, Scottish White Fish Producers Association, Spey Fishery Board (on behalf of ASFB and the Atlantic Salmon Trust), Salmon Net Fishing Association of Scotland, Tourism and Environment Forum, the Scottish SPCA, and Countryside Council for Wales. This Forum provides an opportunity for sectors with interests in seals and their potential impacts to disseminate information, and consider current and proposed research.

Licences to shoot seals may be issued by SEERAD under provisions in the 1970 Act. Each applicant must provide evidence of damage to catches and/or gear, provide details of the location where shooting would take place, and provide counts of the numbers of seals present. Before any licence is issued, advice is sought from FRSFL, SNH, and the Sea Mammals Research Unit (SMRU). Table 3 shows the numbers of seals for which licences were issued and the numbers reported shot during the period 1997-2003.

Year	Scientific Issued	Seals Shot	DSFB Issued	Seals Shot
1997	0 Common	0	25 Common	20
	0 Grey	0	25 Grey	14
1998	14 Common		25 Common	25
	77 Grey		20 Grey	10
1999	0 Common	0	30 Common	25
	0 Grey	0	30 Grey	30
2000	0 Common	0	53 Common	22
	0 Grey	0	53 Grey	33
2001	0 Common	0	50 Common	40
	0 Grey	0	52 Grey	25
2002	Common	0	50 Common	0
	Grey	0	61 Grey	8
2003	Common	0	26 Common	17
	Grey	0	52 Grey	42

Table 3. Numbers of licences issued to shoot seals in 1997-2003, and the numbers of seals shot.

Although some seals are known to eat salmon, evidence of salmon in the diet of seals, except where the seals have been taken from salmon nets, or shot in the immediate vicinity of salmon fisheries, is lacking. It is not clear whether this indicates that salmon form a small proportion of the diet of seals, or whether salmonid hard parts, such as bones, scales and otoliths, are less robust and thus more likely to be destroyed during digestion. Collaborative research projects involving SMRU, FRS and DSFBs are currently underway. These programmes include assessments of diets of seals, seal/salmon interactions, the use of scaring devices, and identification of seal damage "hotspots".

Northern Ireland The most recent information available is presented in the report "Seals/Atlantic Salmon Interaction Workshop. A Recent Irish Review of the Evidence". The Workshop was convened by the Loughs Agency of the Foyle, Carlingford and the Irish Lights Commission, at the request of the North-South Ministerial Council.

Mean counts of seals indicate that around 194 adult grey seals and 551 adult common seals frequent the Northern Ireland coast. Distribution is not uniform, with seals being concentrated in a small number of well populated sites. No data are available on the level of damage to catches.

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ICELAND

Predator overview

The anadromous life-cycle of the Atlantic salmon is divided into the freshwater phase, during the juvenile stage, and the marine phase, which lasts from smolt to adult stage. The freshwater phase in Icelandic rivers is 2-6 years (Antonsson and Gudjonsson 2002). The survival from fry to smolt is commonly close to 1% (Mills 1989). The mortality is also high in the ocean and sea survival in Icelandic rivers has been estimated to be 4.4-12% in rivers in southwestern Iceland and 1-4.9% in northeastern Iceland (Antonsson and Gudjonsson 2002).

Predation is one of the factors causing mortality of salmon both as a primary and secondary cause. The predators and competitors of hatchery smolts of Atlantic salmon after their release from an ocean ranching site have been studied by Thorisson and Sturlaugsson (1995). The estimated total predation in the first 24 hours after release was 0.2-1.1%.

The potential predators of Atlantic salmon in Iceland are listed in Table 1. The list includes 15 species of birds, 8 species of fish, 2 mammalian species in the sea and 1 in fresh water. All of the species in Table 1 are native to Iceland with the exception of mink (*Mustela vision*), which originates from North America and was imported to Iceland in 1931 for culture on mink farms (Skírnisson 1993). The first mink escaped in 1932 and subsequently naturalised mink were caught in 1937. By 1975 mink were distributed throughout Iceland. Mink usually live close to rivers and lakes and are known predators on Atlantic salmon, mainly of the parr to smolt stages, although there have been no investigations into the effects of this predation on population size in rivers. Predation activity by mink at fish farms is, however, well known and this predator's effects on the Icelandic bird fauna in general have been extensive.

Table 1 includes species observed as predators on hatchery smolts as reported by Thorisson and Sturlaugsson (1995). No information is available to quantify predation or to rank the risk from potential predators.

It is generally believed that the salmon is especially vulnerable to predation during the smolt run. The migrating salmon smolts are the index of the salmon production of the rivers. During their migration down rivers and through estuaries, which are often shallow, especially at low tide, the smolts tend to be highly vulnerable to avian predation.

It can be concluded that there is an urgent need for an extensive study of predators and their impacts on Atlantic salmon in Iceland.

Predator control

The population size of many of the species that are regarded as potential predators of Atlantic salmon is shown in Table 2. The source of the information is the Icelandic Environment and Food Agency (www.ust.is). The table includes both species that are hunted for game as well as those targeted for extermination. The extermination activity is, in most cases, supported both by the government as well as relevant communities where the extermination is either conducted by official employees or facilitated by paying a bounty for each animal killed.

The annual catch for some of the species, e.g. the mink, is much higher than the population size in spring. That means that the catch is not likely to influence the population size of the

predator and the populations is likely to be determined by other factors. However, it is possible that the population size of predators, especially in the case of the mink, could be higher or have different distribution patterns if control measures were not in place.

It can be concluded that for most potential predators of Atlantic salmon in Iceland, predator control can only be used in management during short periods determined as critical for salmon. The period when salmon are regarded as being most vulnerable is during the smolt run in spring when smolts are travelling downstream and through shallow waters in estuaries. It is during this period that some river associations try to control avian predators in the estuaries.

Although not shown in Table 2, there is some ongoing activity to control seal populations and to keep seals away from river estuaries during the peak period of salmon migration.

Table 1. Potential predators of Atlantic salmon in Iceland

Freshwater phase

	Species		Life stages
Mammals	Mink	*Mustela vision*	juveniles - smolts, adults
Birds	Goosander	*Mergus merganser*	juveniles - smolts
	Red-breasted merganser	*Mergus serrator*	juveniles - smolts
	Cormorant	*Phalacrocorax carbo*	juveniles - smolts
	Red-throated Diver	*Gavia stellata*	juveniles - smolts
	Arctic Tern	*Sterna paradisaea*	juveniles - smolts
	Black-headed Gull	*Larus ridibundus*	juveniles - smolts
	Lesser Black-backed Gull	*Larus fuscus*	juveniles - smolts
	Great Black-backed Gull	*Larus marinus*	juveniles - smolts
Fish	Brown trout	*Salmo trutta*	juveniles - smolts

Marine phase

Mammals	[1] Common seal	*Phoca vitulina*	smolt post-smolt, adults
	[1] Grey seal	*Halichoerus grypus*	smolt post-smolt, adults
Birds			
	[1] Cormorant	*Phalacrocorax carbo*	smolt post-smolt
	[1] Fulmar	*Fulmarus glacialis*	smolt post-smolt
	[1] Gannets	*Sula bassana*	smolt post-smolt
	[1] Puffin	*Fratercula arctica*	smolt post-smolt
	[1] Kittiwake	*Rissa tridactyla*	smolt post-smolt
	[1] Black guillemot	*Cepphus grylle*	smolt post-smolt
	[1] Glaucous gull	*Larus hyperboreus*	smolt post-smolt
	[1] Black-headed Gull	*Larus ridibundus*	juveniles - smolts
	[1] Arctic Tern	*Sterna paradisaea*	juveniles - smolts
	[1] Arctic skua	*Stercorarius parasiticus*	smolt post-smolt
	[1] Lesser Black-backed Gull	*Larus fuscus*	juveniles - smolts
	[1] Great Black-backed Gull	*Larus marinus*	juveniles - smolts
Fish			
	[1] Salmon	*Salmo salar*	smolt post-smolt
	[1] Cod	*Gadus morrhua*	smolt post-smolt
	[1] Sea scorpion	*Myoxochephalus scorpius*	smolt post-smolt
	[1] Pollock	*Pollachius virens*	smolt, post-smolt
	Eel	*Anguilla anguilla*	smolt
	Spiny dogfish	*Squalusn acanthias*	smolt, post-smolt, adult
	Greenland shark	*Somniosus microcephalus*	post-smolt, adult

[1] From Thorisson and Sturlaugsson 1995

Table 2. Estimated population size* and average catch in game shooting or extermination operations 1995-2001.
***The population size is the number of animals in spring or the number of nesting**

Freshwater

	Species		Population size [1]	Yearly catch 1995-2001 [1]	Control activity	STDEV of mean
Mammals	Mink	*Mustela vision*	3,500	7,627	Extermination	853
Birds						
	Goosander	*Mergus merganser*	2,000-4,000	630	Game shooting	100
	Cormorant	*Phalacrocorax carbo*	2,000-3,000	2,459	Game shooting	510
	Black-headed Gull	*Larus ridibundus*	25,000-30,000	2,374	Extermination	393
	Lesser Black-backed Gull	*Larus fuscus*	25,000	24,314	Extermination	5,075
	Great Black-backed Gull	*Larus marinus*	50,000	27,646	Extermination	5,752
	Gannets	*Sula bassana*	23,000	827	Game shooting	129
	Puffin	*Fratercula arctica*	2-3 million	169,202	Shot, netted	44,248
	Kittiwake	*Rissa tridactyla*	900,000	1,717	Shot	353
	Black guillemot	*Cepphus grylle*	20,000-30,000	4,227	Shot	552
	Glaucous gull	*Larus hyperboreus*	8,000	4,041	Extermination	785
	Arctic skua	*Stercorarius parasiticus*	5,000-10,000	1,773	Extermination	533

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NORWAY

The issue of predator-related mortality in fresh- and saltwater was reviewed in connection with the work of the Wild Salmon Committee, that was appointed by Royal Decree of 18th of July 1997. The background for the Committee's work was the marked decline in the stocks of wild Atlantic salmon (henceforth: salmon) in Norway since the 1970s. NOU 1999:9[1] was received by the Ministry of the Environment (MD) on the 12th of March 1999.

The report is based on NOU 1999:9, but we have also considered recent changes in the status of the salmon stocks in Norway in relation to the predator populations.

The salmon catches in Norway declined markedly during the 1980s and the first half of the 1990s. The decline continued despite extensive measures and restrictions in the fisheries. Catches in the period 1997-2002 have increased significantly compared with the situation in the early 1990s, but it is far too early to conclude that the declining trend in Norwegian salmon stocks that occurred in the 1990s has been reversed (Hansen *et al* 2003[2]).

Predators on salmon

The knowledge base concerning the significance of predation on salmon stocks is limited, but a number of species of fresh- and saltwater marine fish, birds and mammals are potential and/or documented predators on salmon at different stages of their life-cycle.

Freshwater

The most significant/important predators in fresh water in Norway are probably: pike *(Esox lucius),* goosander *(Mergus merganser),* red-breasted merganser *(Mergus serrator),* dipper *(Cinclus cinclus),* mink *(Mustela vison)* and otter *(Lutra lutra).* The harbour seal *(Phoca vitulina)* is occasionally observed in estuaries and rivers, where it probably forages on salmonids.

Estuaries and coastal waters

Potential predators in the estuaries and along the coast are: coastal populations of cod *(Gadhus morhua),* saithe *(Pollachius virens)* and pollack *(Pollachius pollachius),* cormorant *(Phalacrocorax carbo),* shag *(Phalacrocorax aristotelis),* common tern *(Sterna hirundo),* arctic tern *(Sterna paradisaea),* gulls *(Larus spp),* mink *(Mustelo vison),* otter *(Lutra lutra),* grey seal *(Halichoerus grypus)* and harbour seal *(Phoca vitulina).* Killer whale *(Orcinus orca)* has been observed foraging on salmon in the outlet of the Trondheimsfjord in Central Norway (Røv *et al* 1999[3]). The harp seal *(Phoca groenlandica)* is observed regularly in estuaries and in coastal waters in Finnmark, but was also observed in coastal waters in Middle/Southern Norway on several occasions during the "seal-invasion-years" in the latter half of the l980s.

[1] NOU 1999:9 Til laks åt alle kan ingen gjera?

[2] Hansen, L.P, Fiske, P., Holm, M., Jensen, A.J., og Sægrov, H. 2003. Bestandsstatus for laks i Norge 2002. Rapport fra arbeidsgruppe. Utredning for DN 2003-2, 1-56.

[3] Røv, N., Folkow, L., Øien, N., og Hvidsten, N.A. 1999. Predasjon på atlantisk laks med hovedvekt på sel. I: NOU 1999:9 Til laks åt alle kan ingen gjera?

Open ocean

The number and "density" of potential predators in the Norwegian Sea and the Barents Sea is considerably lower than the number of potential predators in coastal waters. Harp seal *(Phoca groenlandica)* is distributed within parts of the salmon's feeding areas in the southern parts of the Barents sea. The distribution of the hooded seal *(Cystophora cristata)* overlaps the distribution of salmon, both in the feeding and wintering areas in the Norwegian Sea and in the feeding areas in the Barents Sea. The gannet *(Sula bassana)* is a possible predator on post-smolt salmon in the open sea (Holm *et al* 1999[4]).

Table 1. List of some of the species identified as potential predators on Atlantic salmon *(Salmo salar)* in the Norwegian Sea, the Barents Sea and in Norwegian rivers.

Species	**Scientific name**	**Population size**	**Pop. trend**	**Exploitation/ protection**	**Predation documented**	**Comments**
Cod	*Gadhus morhua*		-	commercial fishing	Hvidsten & Møkkelgjerd 1987[5], Hvidsten & Lund 1988[6]	Coastal populations
Northeast Atlantic cod	*Gadus morhua*		-	commercial fishing		
Saithe	*Pollachius virens*		0	commercial *fishing*	Hvidsten & Møkkelgjerd 1987, Holm *et al* 1999	
Haddock	*Pollachius pollachius*		-	commercial fishing	Skilbrei *et al* 1998[7]	
Gannet	*Sula basana*	4,000 pairs	+	protected		
Cormorant	*Phalocrocorax carbo*	24,000 pairs		open season		Responsibility species
Shag	*Phalacrocorax aristotelis*	15,000 pairs		open season		Responsibility species
Grey heron	*Ardea cinerea*	5,000-10,000 pairs	0/?	protected		
Red-breasted merganser	*Mergus serrator*	25 – 30,000 ind	0/?	protected		Responsibility species
Goosander	*Mergus merganser*	2,000 pairs	0/+	protected		
Dipper	*Cinclus cinclus*	5 – 25,000 pairs	0/?	protected		
Mink	*Mustela vison*	?		open season		
European otter	*Lutra lutra*	10 – 20,000 ind	+	protected		Responsibility species
Harbour seal	*Phoca vitulina*	6,700 ind	0/ (+)	open season/quotas	Røv *et al* 1999	Data from Scotland

[4] Holm, M., Hansen, L.P. & Holst, J.C. 1999. Laks i havet — kunnskapsstatus, forskningsbehov og flaskehalser. I: NOU 1999:9 Til laks åt alle kan ingen gjera?

[5] Hvidsten. N.A., & Møkkelgjerd, P.I. 1987. Predation on salmon smolts, *Salmo salar,* in the estuary of the river Surna, Norway. J. Fish. Biol. 30:273-280.

[6] Hvidsten N.A., & Lund, R.A. 1988. Predation on hatchery-reared and wild smolts of Atlantic salmon, *Salmo salar*, in the estuary of the river Orkla, Norway. J. Fish. Biol. 33:121-126.

[7] Skilbrei, O.T., Johnsen, B.O., Heggberget, T.G., Krokan, P.S., Aarset, B., Sagen, T., & Holm, M. 1998. Havbeite med laks - artsrapport. Norges forskningsråd.

[Table 1 continued]

Species	Scientific name	Population size	Pop. trend	Exploitation/ protection	Predation documented	Comments
Harp seal	*Phoca groenlandica*	2 mill +	+	quotas		Responsibility species. Breeding grounds (Jan Mayen/White Sea (1.7 mill ind.)
Grey seal	*Halichoerus grypus*	4,400 ind	0	open season/ quotas	Røv *et al* 1999	Data from Scotland
Hooded seal	*Cystophora cristata*	100-150,000 ind	0	quotas	Røv *et al* 1999	Data from 1907. Responsibility species
Killer whale	*Orcinus orca*	3,000 ind	0	protected	Røv *et al* 1999	
Harbour porpoise	*Phocena phocena*	95,000 ind	+	protected		Responsibility species

*Population size and trend data on birds are collected from Norsk Fugleatlas (Gjershaug *et al* 1994[8]**)**. **Similar data on marine fish are from Michalsen (2003[9]**)**. ***Status related to the national red list and international responsibility are from the Norwegian Red List 1998 (DN 1999[10]).

Predation pressure in relation to the life-cycle of salmon

Juvenile salmon

The importance/effect of predation on juvenile salmon in fresh-water is unknown. Predation pressure is dependent upon, and varies with, factors like distribution/density of predators, water clarity, season, "river size", availability of alternative prey, etc.

The pike is probably among the most effective predators on juvenile salmonids in general, but the species has a rather limited distribution in Norway (south-eastern parts of the country and in Finnmark). The number of salmon rivers in the south-eastern parts of Norway is limited. Pike predation on juvenile salmon has not been investigated.

The dipper is widely distributed in Norway. The dipper has been observed eating salmon fry.

The heron is widely distributed along the coast between Vest-Agder and Helgeland, and more sparsely distributed along the coast in the south-east. The species is rare in Troms and Finnmark. Heron predation on salmon fry/parr is documented, but the predation pressure from heron is probably relatively low because of the species' preference for sub-optimal habitats for juvenile salmon.

The red-breasted merganser is widely distributed along the coast, while the goosander is more common in inland areas. The influence of predation from red-breasted merganser and goosander on smolt production in the Alta River in Finnmark was investigated by Moen

[8] Gjershaug, J.O., Thingstad, P.G., Eldøy, S. & Byrkjeland, S. (red.). 1994. Norsk fugleatlas. Norsk Ornitologisk Forening. Klæbu. *552* s.
[9] Michalsen, K. (red) 2003. Havets ressurser 2003. Fisken og havet, særnr. 1-2003.
[10] Direktoratet for naturforvaltning. 1999. Nasjonal rødliste for truete arter i Norge 1998. Norwegian Red List 1998. DN-rapport 3:1-161.

(1983[11]), who examined the stomach contents of 160 goosanders and 40 red-breasted mergansers. He concluded that although salmon was the dominant prey species, predation did not significantly influence smolt production.

The mink is widely distributed along the coast. The otter is widely distributed and common from Sogn og Fjordane to Finnmark. The otter population is expanding southwards. The diet composition of mink and otter in Gråelva was investigated by Heggberget *et al* (2001[12]). Gråelva is a small tributary to Stjørdalselva. The proportion of salmonids in the otter diet was 70-80%. 10% of the fish were juvenile salmon. The diet composition of mink was more varied. The magnitude of mink and otter predation on juvenile salmon in general is unknown, but the results from Gråelva indicate that mink and otter can be effective predators on juvenile salmon.

Smolt/post-smolt and mature salmon

Smolt age in Norwegian rivers varies between 1-5 years. Age at smoltification increases with latitude and in glacier-fed rivers, i.e. the youngest smolts are produced mainly in the rivers in Southern Norway. Smolt migration from Norwegian salmon rivers takes place between the end of April in the rivers in southern Norway and the beginning of September in the rivers in the north. Smolt migration is dependent on the temperature in the rivers and in the sea.

Migrating post-smolt actively utilise the outward bound currents in the fjords and the north-bound current along the Norwegian coastline. The feeding area covers the northern parts of the Norwegian Sea and parts of the Barents Sea. The wintering areas lie north of the Faroe Islands in the Norwegian sea (Holm *et al* 1999).

Predation is presumed to be the most important cause of natural mortality from the marine environment (Wheeler & Gardner 1974[13]). It is generally accepted that mortality is highest at the post-smolt stage, i.e. in the first few months in the marine environment.

According to Holm *et al* (1999), the presence and concentration of migrating post-smolts in the estuaries attracts predators. The predation pressure will depend upon factors such as turbidity, the depth of the freshwater layer and the speed of the outward bound currents in the fjords. Seaward migration at night (Hansen & Jonsson 1986[14]) and the timing of the smolt migration from individual rivers (Greenstreet *et al* 1993[15]) are strategies to reduce predation. Smolt/post-smolts are most vulnerable to predation during the fresh-water to sea-water transition period.

The predation pressure from marine fish and avian predators decreases with increasing distance to the coastline (Holm *et al* 1999). Coastal cod are described as predators on post-

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[15] Greenstreet, S.P.R., Morgan, R.I.G., Barnett. S. & Redhead, P. 1993. Variation in the number of shags *(Phalacrocorax aristotelis)* and common seals *(Phoca vitulina)* near the mouth of an Atlantic salmon *(Salmo salar)* river at the time of the smolt run. Journal of Animal Ecology, 62 (3):565-576.

smolts in estuaries and in the fjords (Hvidsten & Møkkelgjerd 1987, Hvidsten & Lund 1988). Saithe (Hvidsten & Møkkelgjerd 1987) and haddock (Skilbrei et at 1998) are also documented predators on post-smolts. Northeast Arctic cod is a potential predator on post-smolts, but the salmon was not found in the stomach contents of 80,000 stomach samples from Northeast Arctic cod (Holm *et al* 1999).

The abundance of coastal cod, saithe and haddock in most areas along the Norwegian coastline is lower than in the 1980s. Haddock has a limited distribution along the coast, but can be abundant locally. The stock of Northeast Arctic saithe is considered to be within safe biological limits. The spawning stock biomass of coastal cod north of 62°N is presently at its lowest observed level. The recruitment has been well below average since 1995. The spawning stock biomass of coastal cod south of 62°N has been below safe biological limits since 1984 (Michalsen 2003). It is, therefore, unlikely that the general decline in the salmon stocks during the 1990s can be attributed to predation by coastal cod, saithe or haddock.

Predation pressure from mink and otter in salt water is probably negligible, compared to fresh water. Predation from terns and gulls is also negligible, due to the species' limited ability to catch the smolt/post-smolts. The importance of cormorant and coastal seal predation on post-smolts is unresolved. Several authors (Holm *et al* 1999, Røv *et al* 1999) have concluded that cormorant, grey seal and harbour seal are probably capable of exerting a heavy predation pressure during the post-smolt migration period. Coastal seal predation on mature salmon has been documented from Scotland (Røv *et al* 1999).

Man-induced threats, for example an elevated infection level of salmon lice *(Lepeophtheirus salmonis)* on migrating post-smolts in areas with high fish-farming intensity, may also increase marine mortality through behavioural changes that expose the post-smolts to an elevated risk of predation.

The knowledge base concerning predation in the open sea is restricted, but the potential for predation can be estimated by considering the overlap between the distribution of salmon and their potential predators. Avian predation decreases during the first sea-winter as the size of salmon increases (Holm *et al* 1999). Hooded seal and harp seal clearly have the greatest potential for predation at sea, both in the feeding/overwintering areas and again on the return to spawn.

Management regimes

Freshwater fish, including anadromous salmonids, and birds are managed by the environmental authorities with the Directorate for Nature Management as the central advisory and executive agency. The County Governor has regional responsibility. Marine fish and marine mammals are managed by the fisheries authorities, with the Directorate for Fisheries as the central advisory and executive agency. Specific management measures to control the populations of potential salmon predators have not been implemented.

Conclusion

Review of the available literature on predation of salmon indicates that there might be a relatively high predation pressure at certain stages in the life-cycle of the salmon. Only a small number of the potential predators of salmon have been documented as such, through stomach content samples and/or direct observation. Juveniles and smolt/post-smolts, during the freshwater to seawater transition period and in coastal waters, seem to be more vulnerable to predation than adult salmon.

In Norway, there is at present no empirical evidence that either the total predation pressure or any individual predator species have a significant negative impact on the stock level.

Catches and pre-fishery abundance in several rivers in, e.g., Central Norway have increased significantly since 1997, despite the presence of stable/slightly increasing populations of otter, grey seal, harbour seal and cormorants within the same area. The continued negative development in several other regions of Norway must, therefore, most probably be attributed to environmental pressures other than predation.

RUSSIAN FEDERATION

No targeted research was conducted in Russia to assess the predator-related mortality of Atlantic salmon. There is only evidence available from observations at in-river barrier fences where adult counts are derived and biological sampling is done, as well as evidence relating to the impact of predatory fish in juvenile salmon habitat and on their migration routes.

1. The impact of marine mammals on salmon populations

We have evidence available on damage caused to salmon by seals, which was derived on rivers where biological sampling and counts of returning adult salmon were conducted.

For instance, for the Severnaya Dvina (White Sea basin) damaged fish accounted, on the average, for 1.7% of all salmon examined in the period from 1994 to 2002 (variation range was 0.7 to 2.6%).

In the Pechora river (Barents Sea basin) no records of damage to salmon by seals were available after the closure of the commercial fishery in 1989. However, there are data available for the period 1975-1980 when salmon damaged by seals accounted for 3.6%, on average, of all salmon examined (variation range 2.8-5.3).

For rivers on the Kola Peninsula the following records of damage by seals were made during biological sampling of salmon at in-river barrier fences in 2003:

B.Z.Litsa river (Barents Sea basin): 205 salmon sampled, 6 of which had damage caused by seals (2.9%);
Ura river (Barents Sea basin): 278 salmon sampled – 2 of which had damage (0.7%);
Tuloma river (Barents Sea basin): 422 salmon sampled – 5 of which had damage (1.2%);
Varzuga river (White Sea basin): 1,784 salmon sampled, – 5 of which had damage (0.3%);
Kitsa river (White Sea basin): 232 salmon sampled: 4 of which had damage (1.7%).

2. The impact of piscivorous fish on juvenile salmon populations

In its freshwater period of life the survival of salmon is affected by predation by piscivorous fish found in the habitat of juvenile salmon and on their migration routes (during smolt migration). For instance, 19% of the stomachs of pike caught in the Umba river at the end of July 2003 contained juvenile salmon.

A complex of measures designed to enhance the production of salmon helps reduce the pressure from predatory fish. In the Murmansk region, fishing for management purposes (regulation of the species composition) is carried out on all salmon rivers and non-stagnant lakes. In the winter season, ice fishing by rods and nets in non-stagnant lakes. In spring, during the pike and perch spawning season, directed net fishery in flooded areas and pools in salmon rivers. For instance, in 2003 a total of 2.98 t of pike, 7.43 t of perch and 6.41 t of burbot were harvested.