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Agenda item 5.9
For decision

Council

CNL(03)24

Predator-Related Mortality

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CNL(03)24

Predator-Related Mortality

Background

1. At its 1996 meeting, at the request of NASCO's accredited NGOs, the Council held a Special Session entitled "The Atlantic salmon as predator and prey". Two papers were presented during this Special Session on predation; one paper summarised information on the numerous predators of salmon, their impact on salmon stocks and possible management measures, while the second paper considered the public perception of predator control programmes. In 1997 the Council considered a review of the management implications arising from this Special Session, CNL(97)44. The issue was not included on the Council's agenda in 1998 or 1999, but in 2000 Canada made a presentation and tabled a document, CNL(00)48, on the effects of predators on Atlantic salmon. The Council noted that there is ongoing research on, and increasing understanding of, predator-related mortality. At the Council's 2001 Annual Meeting, the European Union tabled a paper, CNL(01)61, on control of seals as predators of salmon. Verbal reports were given by the other Parties on the management of seal populations and there was a contribution, CNL(01)70, from the Salmon Net Fishing Association of Scotland, one of NASCO's accredited NGOs. The Council agreed to consider holding a Special Session on predator-related mortality of salmon at a future meeting.

2. Last year the representative of the European Union presented a document, CNL(02)46, providing information on predation of salmon by seals and piscivorous birds and the management of these predator populations. It was noted that some EU Member States have management programmes in place and others are considering them for the future. Reference was also made to a workshop which had been held in Northern Ireland to review information on seal numbers and on interactions between seals and salmon. Denmark (in respect of the Faroe Islands and Greenland) referred to the importance of predator-related mortality of salmon for the conservation of the wild salmon stocks and for salmon aquaculture, and suggested that the issue should be considered in relation to application of the Precautionary Approach. Iceland indicated that there is considerable concern about increased predation by cod on salmon smolts in Icelandic waters in recent years. The President asked that the Parties provide to the Secretariat an update on research and management in relation to predation on salmon, covering the period since the Special Session held in 1996. He suggested that the next steps might include another Special Session, asking the International Cooperative Salmon Research Board if it might consider allocating new funds to this matter and consideration of this issue under the Precautionary Approach.

Returns

3. Accordingly, the Parties were requested to provide this information to the Secretary by 28 February 2003. To date, information has only been provided by the European Union (Denmark, Finland, Sweden and UK (Scotland)) and this is attached (Annex 1). No returns have been received from Canada, Denmark (in respect of the Faroe Islands and Greenland), Norway, Russia or the United States, or other Member

States of the European Union with salmon interests. In summary the information provided indicates that:

- in Denmark, tagging studies indicated heavy predation by cormorants and gulls on smolts migrating through estuaries. The major cormorant nesting colony is regulated through controlling the number of offspring. Predation by piscivorous birds and pike and pike-perch around dams and weirs has been identified as the main mortality factor during downstream migration of smolts. Stocking above dams has been reduced in some areas;
- in Finland, juvenile salmon are the main prey of burbot during the winter but no assessment has been made of the significance of this predation;
- in Scotland, although it is recognised that losses occur due to predation there is debate as to the significance of this mortality. The approach taken to regulating predation-related mortality is to provide point protection at vulnerable locations and stages of the life-cycle rather than controlling population sizes of predators. Licences to shoot piscivorous birds and seals are issued to prevent serious damage to fisheries. Since the arrival of phocine distemper virus (PDV) in the UK additional protection has been provided to seals. Furthermore, under the EC Habitats Directive both common and grey seals are identified as protected species for which Special Areas of Conservation must be designated although such designation does not preclude control of seals within sites;
- Sweden has provided details of approaches being used to estimate hidden losses to salmon fisheries from seals. It is concluded that the traditional method of assessing seal damage to fisheries in the Baltic, based on counts of fish remains in gear, underestimates the losses and that there are negative after-effects of seal visits to salmon traps possibly as a result of structural damage to the gear.

Additional Information

4. Two recent publications which have come to the attention of the Secretariat on this subject might also be of interest to delegates. In April 2000, the Atlantic Salmon Trust, one of NASCO's accredited NGOs, held a Workshop entitled "Predation of Migratory Salmonids". While no proceedings of the Workshop have been published, an assessment of the Workshop has been prepared by its Chairman and is available from the Trust. Secondly, the International Fisheries Institute at the University of Hull, the European Inland Fisheries Advisory Committee (EIFAC) and the European Union REDCAFE project held a symposium and workshop in April 2001 entitled "Interactions between Fish and Birds: Implications for Management". The proceedings of the Symposium have now been published by Fishing News Books.

Future Action

5. The Council is asked to consider what further action, if any, it wishes to take in relation to predator-related mortality.

Secretary
Edinburgh
29 May, 2003

EUROPEAN UNION

Denmark

by Gorm Rasmussen, Danish Institute for Fisheries Research

In the beginning of the 1990s Carlin tagging experiments (on salmon and sea trout smolts) provided indications of large estuarine bird predation (cormorants and sea gulls). Later, experiments designed to quantify the smolt mortality caused by birds also demonstrated that the pound-net fishery caused extensive smolt mortality in Danish estuaries. Consequently, in some local areas regulations imply lowering of the top of the net during spring (i.e. March to May) and the major cormorant nesting colony in the most important salmon estuary is regulated by reducing the number of offspring.

Studies in fresh water (i.e. tagging, radio tagging and prey fish stomach examination) have demonstrated that hydro-electro dams and weirs in connection with fish farms have a large adverse effect on down-migrating salmon and sea trout smolts. Predation by birds (e.g. cormorant, mergansers and grey heron), pike and pikeperch was identified as the main factor. Action has been taken to reduce stockings above dams in some areas. In the period 2003 - 2006 a large-scale project was initiated to evaluate measures to prevent smolts being captured within the fish farms, i.e. grid size, grid construction, allocation of water (absolute and relative) to fish passage.

At present and in future years, more effort to identify problems in the post-smolt phase is being initiated in some important salmon estuaries by acoustic telemetry.

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Finland

There has been no systematic monitoring of the predation of salmon in the Finnish Atlantic salmon rivers (Rivers Teno and Näätämöjoki). However, in the early 1990s, the winter-time feeding of burbot (*Lota lota*) was studied in the River Teno system. The results showed clearly that the main prey for burbot during the winter was juvenile salmon, but no quantitative assessment of the significance of this predation, e.g. the population size of burbot, is available.

Sweden

Estimation of hidden seal-inflicted losses in salmon fisheries
by

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Introduction

The interaction between marine mammals and fisheries has many facets and works at several levels. The effects are usually divided into two main groups: operational effects and biological effects (Northridge 1984; Wickens 1995), Table 1, modified after (Westerberg *et al.* 2000). This paper will focus on one of the operational effects, lost catch.

Table 1. Interactions between marine mammals and fisheries.

	Impact on fisheries	Impact on marine mammals
Operational	Damaged fishing gear Lost catch Altered fishing strategies	By-catch of marine mammals
Biological	Competition for the resource Spreading of parasites	Competition for the resource Disturbance Protective hunting

From the fisheries point of view, the most widespread and serious conflict is with seals. Set fishing gear (gillnets, traps) are most commonly attacked and salmonids are top of the list for targeted fish species (Rae and Shearer 1965). This, together with a rapidly growing grey seal population, explains the severe problems presently experienced in the set trap fisheries for salmonids in the Baltic Sea (Anon 1998; Lunneryd 2001; Westerberg 2000; Westerberg *et al.* 2000), the area from which data for this paper are taken. The most obvious effect at the operational level of interaction is a reduction in catches. In several reports on the seals-fisheries conflict, the percentage of damaged fish found in the catch is given as a measure of loss (Wickens 1995). These figures are used to derive estimates of overall impact on large-scale fisheries as in Wickens *et* al. 1992. In salmon fisheries, estimation of the total damage is often made via the mean weight of the fish caught, or a more thorough calculation is made whereby remains of individual fish are measured and individual weights are back-calculated. This method was earlier used in Sweden and is still used in Finland, Great Britain and Ireland among other countries. It is straightforward but might underestimate the losses to seals since it only accounts for the visible remains of fish, whereas in fact whole fish are known to be taken from fishing gear without leaving traces (Greenwood 1981; Mountford and Smith 1963; Wickens 1993), all referred in (Wickens 1995). This can take place in several ways. Small fish can be eaten whole by seals; alternatively they may simply fall off the gear or may be taken by other predators such as seagulls. In addition, live fish contained in the fish chamber of a trap can be chased out by a seal or can escape through holes torn in the net. The catch can also be lowered by a reduced fishing efficiency due to the nets being tangled. Yet another possibility is that fish are taken at the entrance of the gear or chased away. For these and other non-evident seal-inflicted causes of lowered catch, the term "hidden damage" is used in this paper. Attempts to estimate parts of this effect were made by (Potter and Swain 1979), referred to in Beddington *et al.* 1985 and some were suggested, Anon 2001). No attempt has, however, been made before to explore the details of this issue.

Quantitative data from seals' interference with fisheries are needed as a basis for strategic decisions at the political level. These may concern the launching and financing of investigations and research or administrative decisions concerning, for example, hunting regulations. Likewise, a sound data basis is required when designing schemes for economic compensation to fishermen or financial support to change over to other lines of work. Therefore, new methods are needed which allow more precise estimates of losses to seal predation in fisheries, including hidden damage. A deeper insight into the processes involved in seal-fisheries interactions is also much needed. In this paper three models or tools intended to help fill these needs are presented.

Materials and Methods

For Model 1, a database that holds detailed facts from a number of contracted commercial fishermen along the Swedish Baltic coast was used (about 20 informants during 2002). Each time the traps or nets were checked and emptied (usually once per day), defined as a lifting event, data were noted on the fishing operation (number of gear, gear type, position), catch (species, number, weight), damage to gear (size and position of holes in mesh) and damage to catch (species and number of fish damaged by seals or by birds, respectively). As of 2002, the database holds about 12,000 entries for the years 1993 – 2001. The bulk of these data concern set traps (mainly for salmonids and eels) and gillnets (mainly for salmonids, herring, cod, perch and pike-perch). From this material a selection was made of all 7,290 lifting events (representing 7,944 fishing days) for the main group of set traps for salmonids (salmon trap, combi trap and combiD trap), encompassing total catches of 127,401 kg (salmon, sea-trout and whitefish). The number of liftings with some seal damage noted was 4,071. The basic design of all three traps mentioned is that of a Scottish salmon trap (Brandt 1984). They differ in that the two combi traps are of small mesh net in order to catch whitefish in addition to salmon and the combiD is partially made from a very strong material, Dynema. Since species composition varies with mesh size, catches were summed to give a total figure for salmonids. Catch data were not normally distributed; the Wilcoxon two-sample rank test was used for paired comparisons. The seal species mainly found in the study areas is the grey seal; occasionally ringed seals may occur.

For Model 2, data used came from a pilot trial at Skärså during 2002 with small bottom-set nets (length 30m, depth 150 meshes, mesh size knot to knot 18.4 mm) for herring. The nets were set one by one over even sedimentary bottom within an area of 2km by 4km. Depth was 8 – 15m. Some of the nets were pre-baited with fish evenly spread out over the surface of the net panel. Most of these fish were caught during the preceding fishing round and left gilled in the net; some were added manually. The head of a fish was then pushed into the mesh until the twine cut in behind the opercula in the same manner as these fish usually gill. All fish were marked by having their eyes punctured. At the shooting of the net, the position, water depth and number of the marked fish were noted. At lifting, all signs of a seal visit were noted as well as the number of marked fish (whole and bitten) and the number of unmarked fish (whole and bitten). Some nets were set and then immediately retrieved in order to supply data for an analysis of short-term spontaneous fall-off of fish. The spontaneous fall-off for longer set times was determined from nets that remained undisturbed by seals. The total number of nets set was 73, of which 44 showed signs of seal visits. The location where nets were set was observed during several of the fishing bouts. Seals were observed in the immediate vicinity of the nets on an almost daily basis. No predatory diving birds were observed.

For Model 3, data used came from a trial with a new seal-safe fish chamber for set traps (Fjälling *et al.* 2003) that was added to the final section of a conventional combi trap in order to house and protect the accumulated catch. The combi trap itself was not modified. During the trials the trap was lifted daily and the catch recorded (species, number, weight). The summed catch of salmonids was used as in Model 1. All holes in the net that were found during handling of the gear were noted and mended as soon as possible. Each week the trap was lifted to the surface section by section and net panels were carefully inspected and mended, and the size and positions of all holes were noted. The fishing trial took place at a river mouth where seal activity was extremely high. Seal behaviour was studied and recorded as a part of another project (Lunneryd *et al.* 2002).

Results and Discussion

Model 1: Day pairs

Catch and other data for days when seals visited traps were compared with days when they did not. Summed over season catch was significantly lower for days with seal visits than days without ($p<0.001$).

Table 2. Average catch for all days with and without seal visits in database for salmonid set trap fisheries in the Baltic Sea

	lifting occasions	Salmonids, kg per unit effort	Catch %
liftings without signs of seal visits	3,849	22.1	100%
liftings with signs of seal visits	4,071	10.4	47%

Catches peak during a short period in the early summer whereas seal-inflicted damage to the fishery gradually increases in extent and intensity as the season progresses. For this reason it is unclear whether average seasonal figures from days with and without seal visits reflect the immediate effects of a seal visit or not. Catches vary with biological factors (over a time-scale of months) and on a shorter time-scale (weeks or days) with weather, wind and currents. However, if catches vary less over a short time-scale than over a longer one, it may be possible to estimate the expected catch for a certain day from that on a preceding day at the same site. To test this all day-pairs were selected where seals did not visit the trap on either of two consecutive days and where fish was caught on at least one of the two days.

Table 3. Catch for successive day-pairs without seal visits either day.

	Lifting occasions	Salmonids, kg per effort	%
day-pairs, liftings without signs of seal visits, first day	3,504	18.1	100%
day-pairs, liftings without signs of seal visits, second day	3,504	18.3	101%

The catch for day 1 and day 2 did not differ ($p=0.19$). It was concluded that in the absence of seals, the catch one day can, as a rule, be expected to be the same as the day before. Then the catch for days with seal visits was compared with the expected catch had there been no seal visits. This was done by selecting all day-pairs where one day without a seal visit was followed by one with such a visit.

Table 4. Catch for successive day-pairs where the first day did not have a seal visit and the second day did

	Lifting occasions	Salmonids, kg per effort	%
day-pairs, liftings without seal visit day –1	1,054	24.7	100%
day-pairs, liftings with seal visit day 0	1,054	10.8	44%

The catch the second day (with a seal visit) was significantly lower than expected, i.e. than the catch for the first day ($p<0.001$). The catch was then compared for occasions where seal visited traps two days in a row. This was done by selecting all day-trios where the first day did not have a seal visit and the second and third day did.

Table 5. Catch for successive day-trios where the first day did not have a seal visit and the second and third did.

	Lifting occasions	Salmonids kg per effort	%
Day-trios, liftings without seal visit day –1	446	25.9	100%
Day-trios, liftings with seal visit day 0	446	11.6	45%
Day-trios, lifitngs with seal visit day 00	446	11.0	42%

The catch for the two consecutive days with a seal visit did not differ ($p=0.24$). Since the relative level of catches varies strongly with location, such that a fishing site near a river may yield catches one size of magnitude higher than one from far from a river, a relative measure of damage to catch is likely to be more useful than the absolute figures. It might seem straightforward to calculate from the above a factor by which the undamaged proportion of the catch for days with seal visits should be multiplied to estimate the theoretical total catch prior to seal damage. This may, however, be unwise, at least for smaller sets of data (high frequency of zero catches, small catches with high variance). Instead, the effect of seal visits may rather be calculated from the catch for undisturbed days and a loss factor S_a.

$$F_{d-1} * S_a = F_{d-1} - F_{d0} \quad \text{i.e.} \quad S_a = \frac{F_{d-1} - F_{d0}}{F_{d-1}}$$

where

F_{d-1} = undisturbed catch the day before a seal visit
$F_{d\,0}$ = catch the day with a seal visit

The factor S_a can then be determined and used for calculations of the total damage in a specified fishery (gear, species, area) using data from undisturbed fisheries and knowing the rate of seal attacks. There may, however, be some adjustments called for. Fishermen often claim that "when a salmon run begins, seals show up". If this is so and catches generally tend to be increasing when seals are arriving on the scene, there is a risk of underestimating the amount of damage they cause. To test this day-trios were selected where a day with seal damage was preceded by two consecutive days without damage.

Table 6. Catch for two successive days, both without seal visits, preceding a day with a seal visit

	Lifting occasions	Salmonids, kg per effort	%
day-trios, liftings without seal visit day –2	683	20.1	100%
day-trios, liftings without seal visit day –1	683	22.1	110%

There was indeed a positive trend in catch with time ($p<0.05$). This means that a trend factor, T_f is justified to correct for this. It was defined:

$$T_f = \frac{F_{dd\text{-}1} - F_{dd\text{-}2}}{F_{dd\text{-}2}}$$

where

$F_{dd\text{-}2}$ = undisturbed catch the first of two consecutive days preceding a day with a seal visit
$F_{dd\text{-}1}$ = undisturbed catch the second of two consecutive days preceding a day with a seal visit

The trend-adjusted loss factor S_{af} can then be expressed in a general form as:

$$S_{af} = \frac{T_f * F_{d\text{-}1} - F_{d0}}{F_{d\text{-}1}}$$

T_f was, in the specific case above, determined to be 0.10 (i.e. a 10% positive trend). With two points to plot it is only possible to determine a linear trend ($y = kx + l$), whereas in biology it is not uncommon that trends are actually described by higher order functions. For this reason another test was made by selecting day-quartets, where three consecutive days without seal visits were followed by a day with a seal visit.

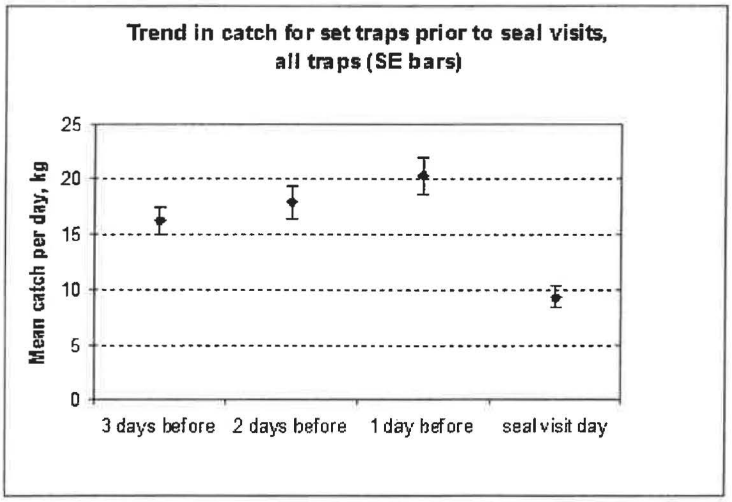

Figure 1. Catch of salmonids in set traps during periods of four days where three days without seal visits precede a day with a seal visit.

Then the second order polynomial that best fits the data for the first three days was determined. In this specific case it was found to be $Y = 0.3056x^2 + 0.8387x + 15.108$ and T_f 0.145 (i.e. a positive trend of 14.5%) which was higher than for a linear model based on the same data (0.096), R^2 was 0.003 in both. Further analyses may decide which model is the better.

Then it should be considered if there may be any delayed or persistent negative effects of seal visits as fishermen sometimes suggest (Bonner 1994). If there are no such effects the catch the day after a seal visit should be the same as the calculated expected catch for the day with the seal visit and somewhat larger than the day before this due to the trend factor. To test this day-trios were selected where an undisturbed day was followed by a day with a seal visit and then again by an undisturbed day.

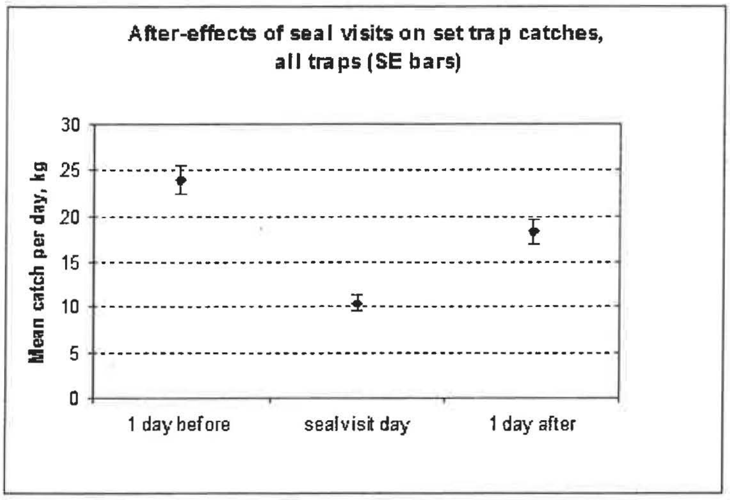

Figure 2. After-effect of seal visits on set trap catches, all traps.

The mean catch for the undisturbed day after the seal visit was significantly lower than expected ($p<0.001$), there were indeed negative after-effects of seal visits. These may conceivably be related to tangled gear, holes in net panels, scent from damaged fish, scent from seals, seals still present in the area, or possibly to fish having been chased away from the area. There were differences between the different types of traps. Two of them (salmon trap and combi trap) did comply with the picture above ($p<0.05$, $p<0.001$ respectively), while the third (combiD) did not, the catch for the undisturbed day after the day with a seal visit in this trap was no lower than expected ($p=0.70$).

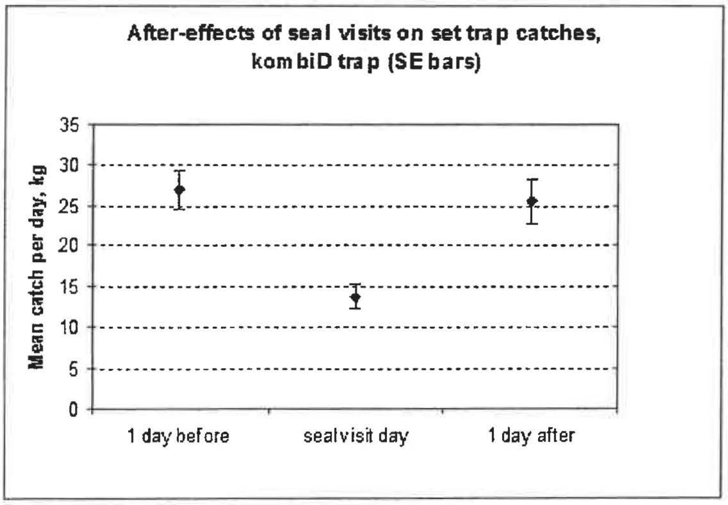

Figure 3. Mean catch in combiD set trap the day of a seal visit and adjoining days.

The difference between the traps is not the design but the material. The salmon trap and the combi trap are both made from terylene twine whereas the central parts (mainly the net panels in the fish chamber) of the combiD trap are made of Dynema, a material of great strength. This was reflected in the average rate of seal damage to nets per day with seal visits, highest (0.68) for the salmon trap that is most vulnerable, intermediate (0.55) for the combi trap and lowest (0.52) for the strongest combed trap. Furthermore, the severity of damage (size of holes) normally differ greatly; damage to a salmon trap or a combi trap is often serious whereas for a combiD trap it is usually small. The most obvious interpretation of these data should be that the negative after-effects of a seal visit in this case were mainly a result of the gear being physically damaged (holes in net panels).

It may be possible to work out a general correction factor for the persistent effects of a seal visit. There are, however, complications: it is, for example, possible that a few days after a seal attack, most fishermen have made the necessary repairs to their gear, whereas others do not care to do so, or are less proficient in this work. Holes in the bottom sections of traps often go undetected until the gear is lifted.

A prerequisite for this model is that days without seal visits occur regularly. A comparison of catch for day-pairs according to this model should be possible to perform in several fisheries, both for passive and active gear.

Model 2: Pre-baited gear

A different way of quantifying seal-inflicted impact on the catch in fishing gear (i.e. gillnets, longlines) may be to attach a number of marked fish to the gear prior to shooting the gear. Starting from the number of fish attached and the number of remaining marked fish after hauling, the fraction of seal-taken fish can then be calculated. This figure can in turn be used for an estimate of the expected total catch from the actual catch of unmarked fish. The basic formulas are:

$$F_e = F_f * (1 - K) \quad \text{or} \quad F_f = \frac{F_e}{(1 - K)}$$

where

F_e = actual catch
F_f = expected catch
K = fraction of marked fish taken by seals

An adjustment needs to be made for an expected spontaneous fall-off during shooting, immersion or hauling the gear.

$$K = \frac{A * (1 - L) - B}{A * (1 - L)}$$

where

A = the number of marked fish
B = the number of recaptured fish
L = fraction of marked fish that fall off spontaneously

are combined to

$$F_f = \frac{F_e * A * (1 - L)}{B}$$

Data from a pilot trial with herring nets were collected and used for a test. The fraction of marked fish that fell off spontaneously did not differ for a short set time (0.077 during 6 hours) compared to a long set time (0,080 during 22 hours) ($p=0,9$) (mean 0.078). One conclusion was that in this fishery (bottom set gillnets) baits mainly fell off during shooting and/or hauling the gear, not during soaking. The expected catch F_f was then estimated to be 3,497 fish from the actual catch F_e of 655 and the loss to seals 81%. The described trial was on a small scale and performed with experimental gear, so it does not permit a more comprehensive analysis. A somewhat larger trial is, therefore, suggested where the theoretical total catches for individual damaged nets are compared with figures from adjacent nets not visited by seals. This might serve to test and possibly confirm the validity of the suggested model. Another angle worth pursuing would be to include partially consumed fish, both marked and unmarked, in the analysis. Model 2 does not demand occasions of undisturbed fishing as Model 1 does. The proportion of fish (marked and unmarked) that seals take must, however, not be too high. A zero or a very small catch cannot be multiplied to form the theoretical catch, and if all, or nearly all, marked fish are taken the same problem occurs.

Model 3: "hole in the net + fish remains found"

The two first models attempt to estimate the major part of the hidden damage to fish catches. In this third model a certain defined type of non-evident damage was estimated and set in relation to catch size, namely the use by seals of fine mesh net panels or the leading net of a set trap (combi trap) as a hunting aid. The way this happens is that fish are first chased into the sides of the net and become entangled. As the seal catches up it grabs the fish and force-fully pulls it out again, creating a small or sometimes even a large hole. Alternatively, the seal consumes the fish in situ, in which case remains are usually visible.

Table D. Undamaged catch of salmon and sea-trout, fish remains tangled in net panels and estimated hidden damage in a set trap for salmonids (combi trap).

	Period 1 **24/06 – 9/7**	**Period 2** **10/7-3/8**	**Period 3** **6/8 – 31/8**	**All periods**
Catch, number	63	100	62	225
Catch, weight (kg)	486	633	296	1,407
N fish remains	15	12	11	38
N holes in trap side	26	75	86	187
Total number of lost fish assumed	41	87	97	225
% lost fish of theoretical total catch	39%	47%	61%	50%

The number of holes found in the net was added to the number of fish remains found to estimate the minimum figure of fish taken by seals. It was estimated that the overall loss to seals was about half of the predicted total catch. Since the trap was mended on a continual basis, the loss due to fish escaping through holes was kept to a minimum. The accumulated catch was also not affected by seals since a seal-safe fish chamber was connected to the trap.

There were, however, other factors that may have influenced catch negatively. It was observed that individual seals repeatedly took up positions in the entrance of the trap for hours at a time, just surfacing to breathe every ten minutes or so. Another observation was that seals frequently entered the first compartments of the trap, on average twice per hour (Lunneryd et al. 2002). These factors are likely to have affected catches negatively.

Comparisons between models

The assumption underlying the traditional method of counting fish remains is that each fish lost to seals is later found as remains. The validity of this was tested in a simulation with data from the database used for Model 1. The comparison was made separately for all three types of set traps for salmonids discussed. Day-pairs of data where a day without seal disturbance was followed by a day with evident seal damage were selected as before. The loss of fish was calculated as before, only that this time not the weight but the number of fish was estimated. Then the number of fish remains actually found was summed. From these data the estimated number of fish lost per fish remains found was calculated.

Table E. The number of lost fish per fish remains found was calculated using Model 1.

		Estimated hidden seal damage calculated from day-pair selection								
		lost number of fish per effort			**fish remains found per effort**			**lost number of fish per fish remains found**		
	Day-Pairs	**salmon**	**sea-trout**	**whitefish**	**salmon**	**sea-trout**	**whitefish**	**salmon**	**sea-trout**	**whitefish**
combi trap	293	1.5	0.6	15.6	1.2	0.5	3.0	1.3	1.2	5.3
combiD trap	416	1.5	1.0	11.2	1.3	0.6	2.2	1.2	1.5	5.2
salmon trap	345	1.7	0.4	-	1.1	0.1	-	1.6	4.1	-
all traps	1,054	1.6	0.7	12.9*	1.2	0.5	2.4*	1.3	1.5	5.1*

* The zero catch of whitefish in salmon traps was expected as this gear has large meshes which whitefish normally pass through, average figures were calculated for combi and combiD traps only.

If Model 1 is accepted as giving a reasonably good measure of the hidden damage, it is evident that the traditional method underestimates the number of fish taken by seals. In the present case this was especially pronounced for whitefish but clearly also true for sea-trout caught in salmon traps. For a fisherman receiving compensation for seal damage, calculations based on the traditional estimation method (number of fish remains found) can mean a substantial financial loss.

An attempt was made in Table F to condense the characteristics of the different methods discussed for estimating loss to seals in fisheries.

Table F. Rough comparison of which direct negative effects on catch from seals are estimated by traditional and newly described models.

Seals direct interference with fishing operation	Traditional, counting remains	Model 1, day pairs w/w-o damage	Model 2, pre-baited gear	Model 3, counting remains + holes in net
	Estimation of damage:			
caught fish damaged	x	x	x	X
caught fish eaten whole	-	x	x	-
caught fish fallen out of gear	-	x	x	X
caught fish escaped (i.e. holes)	-	x	-	-
fish chased out of / away from gear	-	(x)	(x)	-
reduced fishing efficiency (tangles)	-	x	(x)	-
fish diverted from vicinity of gear	-	-	-	-

The traditional measure of seal damage, i.e. the number of fish remains, is simple and straightforward. It may still be useful in the day-to-day practical fisheries management work, but should be calibrated for hidden damage. This adjustment could be made on the basis of either method 1 or method 2, depending on gear type. In the example presented in Table E (salmon traps in the Baltic Sea) this would mean that for each salmon remains found, the fisherman should be paid compensation for 1.2 to 1.6 fish, depending on trap type, or 1.3 as an average over all traps.

Models 1 and 2 allows for a deeper analysis of the damage process. For example, seals' preferences as to fish species, size, sex, condition factor etc can be studied. In employing Model 1, their preferences will be seen by which fish are missing from the expected catch. Using Model 2 their preferences will be seen by which marked fish are taken from the gear and which are not. Individual marks may be used to increase precision. Fishermen say that seals prefer female fish with roe to males or immature fish; this could easily be tested. Such information could deepen our knowledge and be used to refine models further.

Models 1 and 2 may be further improved by documenting the observations of seals in the vicinity of fishing gear during trials. The diversion effects of seals' presence near to the gear could then be evaluated by comparing catch for days with observations of seals (without signs of damage to gear or catch) with days without observations of seals (also without signs of damage to gear or catch).

Some improvements to traditional methods for estimation of seal damage can be discerned. When counting fish remains, a parallel documentation of holes in net is advocated. Generally, damages to net panels require immediate repairs but foul weather conditions and lack of time is likely to prevent a satisfactory record keeping in the daily commercial fishing operation. It may then be possible to integrate over time, at least for the first season for a new gear, by mending holes with a twine of a different colour compared to the net material. After the season ends, the net panels can be hung high and mendings optically classified to type, size and position. This may give additional information on the damage process.

The estimates presented here of the effects on fisheries of seal visits to set gear for salmonids constitute minimum figures. This is because some days which were classified as "seal-free", simply because there were no clear indications of a seal visit, will in fact have suffered from the attentions of seals. These occasions will tend to reduce figures for expected catch. The magnitude of this source of error is likely to vary with gear type but also among gear of the same type but made of different materials or operated in different ways. Another source of underestimation may be the after-effect of seal visits.

In general, losses to seals and our other calculated figures (i.e. correction factors) are likely to be dependent on gear type, fish species and other elements. Therefore they need to be calculated for each new fishery separately and tried under varying conditions.

Lighter gear such as gill nets and fyke nets are usually distributed relatively randomly over even bottoms where fish are also fairly evenly distributed. This increased randomness enhances the validity of statistical evaluation. Set traps, on the other hand, are usually placed at carefully selected spots where conditions such as depth, currents, etc. are specific. In theory this makes analysis more difficult, but the use of paired data is a powerful tool, which could be used more extensively.

In the Baltic, fisheries for salmonids there are several examples of extreme effects of seal interference. One is the cessation in the 1980s of a late-season fishery for sea-trout. This fishery was closed when damage gradually grew to impossible levels along with an increasing grey seal population. Generally, the fall closure of the set trap fishery for salmonids is determined nowadays by when the seal attacks become too severe, not by fish being too few. There are several reports of seal damage, especially for traps of older designs or traps not closely watched, which amount to 100%. At the end of the season, fishermen often watch each other carefully. When one of them starts hauling his traps the other fishermen in the area rapidly do the same. If one of them is caught off-guard and leaves his traps in the water a few days or a week longer than the others, seals rapidly concentrate there, and traps may then be permanently destroyed in the course of a day or two.

Apart from the factors already discussed in this paper there are several further non-evident effects of seals' activities that ultimately lead to reduced catches and/or income for the fisherman. Most of them belong under the Direct Effects heading and can as a group be labelled "Altered fishing strategies" (alternatively "Indirect effects"). Among them are the effects of changing to stronger but less efficient materials, relocation to safer but less productive areas, increased lifting frequency, earlier closing of season etc. Some other effects belong under the Biological Effects heading and could be labelled "Predator Interaction". Among these are of course the competition for the fish resource, but there are also others such as fish temporarily being scared away from the area, fish stocks being reduced locally by predation, fish behaviour being altered and reduced growth in fish exposed to predators, Foster referred to in Pemberton and Shaughnessy (1993). Under the heading of Biological Effects, a group could be discerned which might be labeled as reduced quality of fish. This should include the well studied transmission of parasites to commercial fish and the occurrence of fish carrying fresh or healed scars from close encounters with seals. Both of these effects entail losses for the processing industries. As a whole, the classification of seal-inflicted damages to fisheries may gain from a revision and elaboration of categories.

Conclusions

- The methods described can be used to estimate hidden damage due to seals for traps and nets.

- The method described under "Model 1" may possibly be used in connection with a variety of other types of fishing gear.

- The methods described may be used for a deeper analysis of the damage process.
- The traditional method of assessing seal damage by counting remains of fish underestimates losses.
- There were negative after-effects of seal visits to salmon traps, probably as a result of structural damage to gear.
- The commonly used definitions of seals-fisheries interaction in literature would gain from a revision.

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United Kingdom (Scotland)

Control of Predator-Related Mortality of Atlantic Salmon

Introduction

There is a long history of regulation of fishing mortality on Atlantic salmon (Salmo salar) in Scotland, with laws dating back with certainty to 1424, and indications that legislation was in place as early as the 12th Century. It has long been recognised that losses also occur as a result of predation. There has been, and there continues to be, debate as to the extent to which such mortality has an effect on the numbers of salmon returning to Scottish rivers.

The approach to regulating predation-related mortality on salmon taken in Scotland is not one of controlling population sizes of predators, but rather to provide point protection to salmon at particular locations and at stages in the life cycle when salmon are particularly vulnerable and predation is likely to result in a direct reduction in the stock of adult fish.

The predators considered here are piscivorous birds and seals

Piscivorous birds

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

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.

These species are afforded protection under provisions in the EC Birds Directive and the Wildlife and Countryside Act 1981. However, fishery managers may apply for a licence to shoot these birds under the provisions of section 16 of the 1981 Act to prevent serious damage to fisheries.

The Freshwater Fisheries Branch (FFA2) of the Freshwater Fisheries and Aquaculture Division in the Scottish Executive Environment and Rural Affairs Department (SEERAD) acts as licensing authority.

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 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, FFA2 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 I shows the numbers of cormorants and sawbill ducks for which licences were issued, and the numbers reported as being shot for the period 1997-2002.

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.

Seals

Two species of seals predate on salmon in Scottish waters, the grey seal (Halichoerus grypus), and the common or harbour seal (Phoca vitulina). The most recent estimates of seal population sizes in Scotland (2001) were 119,000 grey seals and 30,000 common seals (minimum estimate).

Seals are afforded protection 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 9 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.

Licences to shoot seals may be issued by FFA2. 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 II shows the numbers of seals for which licences were issued and the numbers reported shot during the period 1997-2002.

Phocine Distemper Virus (PDV)

In response to the arrival of PDV in the UK, the Scottish Executive introduced The Conservation of Seals (Scotland) Order 2002 on 4 September 2002 to provide additional protection for seals vulnerable to PDV. The Order extends the close season to 12 months for the period to September 2004 (subject to review) and covers common seals throughout Scotland and grey seals in the Moray Firth. The Scottish Executive will review the Order in the light of the actual impact of PDV in Scotland. The virus was confirmed in Scottish seal populations in September 2002.

Since the start of the PDV outbreak in Scotland, a total of 917 dead seals has been reported. Post-mortem examinations have been carried out on 93 animals, and 17 have tested positive for PDV (10 common, and 7 grey seals). The PDV outbreak is now considered to be over in the UK, although it is possible that there may be a secondary outbreak in Scotland in the spring of 2003.

EC Habitats Directive and Special Areas of Conservation (SAC)

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.

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".

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Table I Numbers of cormorants and sawbill ducks for which licences issued, and numbers reported shot 1997-2002

11,700 800 prs 2600 pairs

	Cormorants	Mergansers	Goosanders
Sept 1997-April 1998			
Number Licensed Number shot	**308** **193**	**210** **148**	**529** **410**
Sept 1998-April 1999			
Number Licensed Number Shot	**191** **138**	**136** **89**	**417** **345**
Sept 1999-May 2000			
Number Licensed Number Shot	**204** **154**	**105** **88**	**417** **352**
Sept 2000-April 2001			
Number Licensed Number shot	**165** **95**	**85** **48**	**400** **285**
Sept 2001-April 2002			
Number Licensed Number shot	**118** **106**	**68** **68**	**357** **357**

Table II Numbers of seals for which licences issued and numbers reported shot 1997-2002.

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