Freshwater Fisheries Laboratory

ATLANTIC SALMON TRUST

PROBLEMS WITH SEA TROUT AND SALMON IN THE WESTERN HIGHLANDS

A report of a one-day conference organised by

The Freshwater Fisheries Laboratory,

The Atlantic Salmon Trust

and

The Association of Scottish District Salmon Fishery Boards

held near Inverness on 24th November, 1993

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2. THE PROBLEMS (Opening remarks by Dr R G J Shelton, Freshwater Fisheries Laboratory)

As Admiral Mackenzie has said, this meeting is a response to the increasing concern about the current well-being of salmon and sea trout stocks in the western highlands.

My scientific colleagues' task this morning is to put us all in the picture about the results of the intensive investigations they have undertaken over recent field seasons.

The amount of interest in this meeting is testimony in itself that all is not well. What my colleagues have set out to do is to look coolly and analytically at the problems the stocks appear to be facing; and to proceed from this analysis to the identification of what precisely has gone wrong. An important issue from the start was the extent to which the problems of the western highlands were local to the area. We knew, for instance, that the ocean survival of salmon smolts in 1989, 1990 and to a lesser extent 1991, had been unusually low over much of the North Atlantic. We therefore had to ask ourselves whether west highland salmon worries were merely a local expression of a much more widespread phenomenon.

One local problem we **did** know about, and have examined in detail, is the problem of escaped farmed salmon. Today **John Webb** of the Atlantic Salmon Trust, whose research programme is fully integrated with our own, will tell us how widespread the problem is and the extent to which escaped fish interbreed with wild salmon and, indeed, trout.

When we turn to sea trout we also see evidence of widespread **moderate** reductions in their availability to the fisheries. However, so far as the west highland scene is concerned, we are on much surer ground in seeing sudden unprecedented declines, **way beyond any national trends** in sea trout catches.

Now what does all this mean in terms of the size and structure of the populations from which the reduced sea trout catches are derived? What are the consequences for future spawning stocks and are they already so depleted that smolt production is now limited by the few relatively small hen fish left? I know that my Faskally colleague **Andy Walker** has given much thought to these and related questions and I look forward to hearing his talk.

My Marine Laboratory colleagues, **Bill Turrell and Peter Wright**, are world authorities on the oceanography of the North Atlantic and on the ecology of sandeels. They will undoubtedly have much to tell us about the feeding environment to which our post smolt salmon and sea trout have recently been exposed, especially to the west of Scotland.

The comparatively sudden and more localised collapse of north west sea trout populations, beside which the still healthy Hope system sea trout stand in marked contrast, poses far more challenging questions than can possibly be answered by feeding opportunity considerations alone. Although a dramatic reduction has taken place in the survival of sea trout post smolts and kelts at sea, the majority of survivors have normal condition factors. Although there is some evidence for reduced size at age, the change is **much** too small to account for such a large reduction in marine survival.

Predators are, of course, prime candidates for the role of villain and it **is** true that populations of grey seals and cormorants are larger than they were. However, the rates of increase have been gradual and, on their own, could in **no** way account for the changes we have seen.

Finally, we come to parasites and disease and the joint presentation by my Marine Laboratory colleague, **Alasdair McVicar and Miss Laura Sharp** of the University of Aberdeen. Both are renowned in their respective fields and I look forward to hearing the results of their work with the greatest interest.

May I conclude by saying that I hope that by the beginning of the afternoon, and in the light of what I expect to be **Geoff Tingley's** admirable summing up, we will have the basis for a stimulating discussion. We will **not** leave Inverness with **all** the answers but we **will**, I am sure, have a much clearer idea of where they may be found.

Figure 2

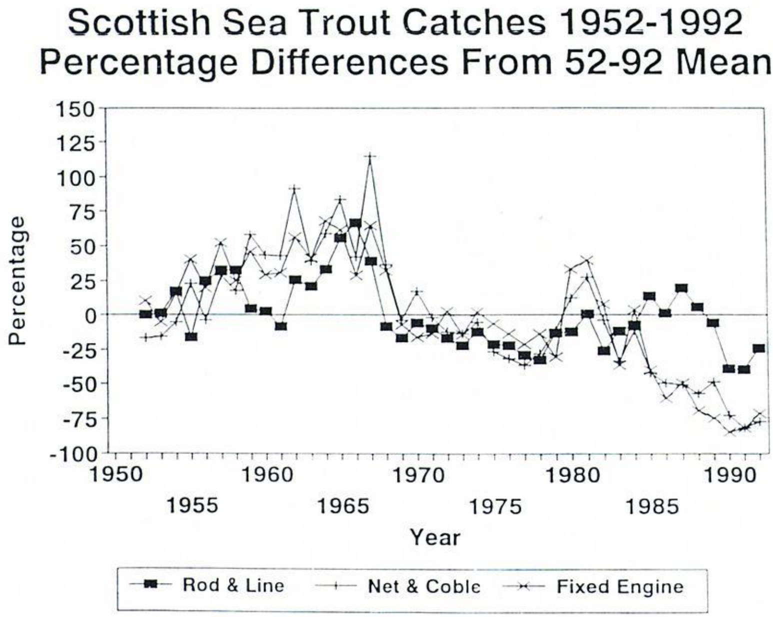
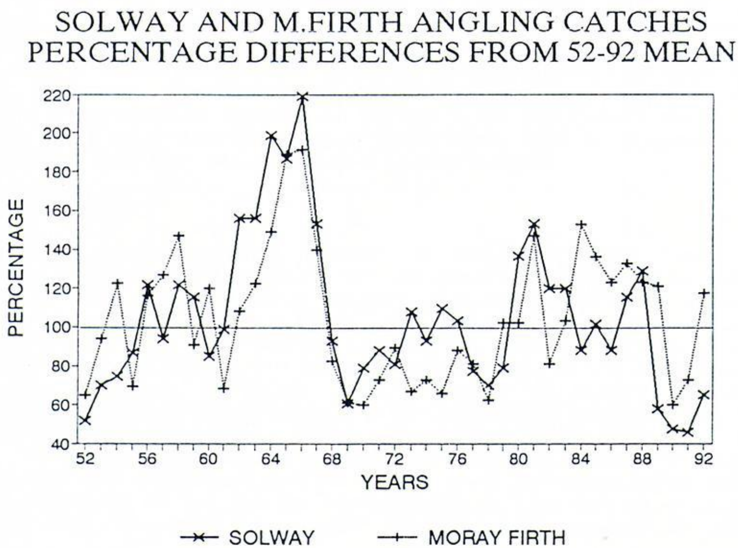


Figure 3



Simultaneous fluctuations in river flows during the main sea trout angling months are likely to be one cause of similarities in catch trends between regions and between fishing methods. This is because flow can directly affect both the local availability and catchability of sea trout (Walker, 1984). Taking the country as a whole, wet summers are associated with better catches and dry summers with poorer catches of sea trout by angling (Figure 4). Prolonged summer droughts also reduce survival of juvenile trout (eg. Egglishaw and Shackley, 1977; Elliott, 1984; 1985). The severity of the decline in sea trout in north western rivers cannot, however, be accounted for by summer droughts. For example, recent summer river flows (June-August) in the River Ewe were similar to, or higher than, average (Figure 5).

Figure 4

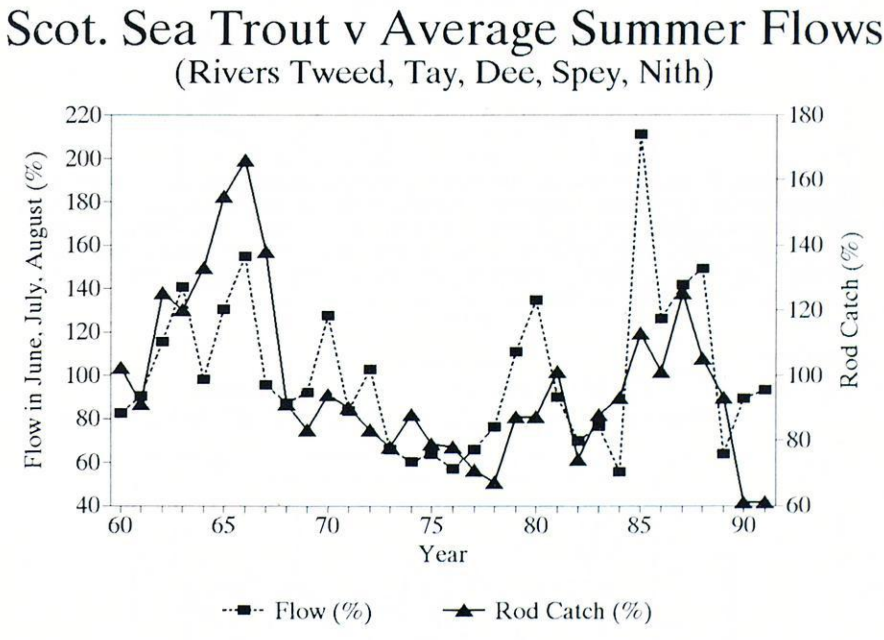
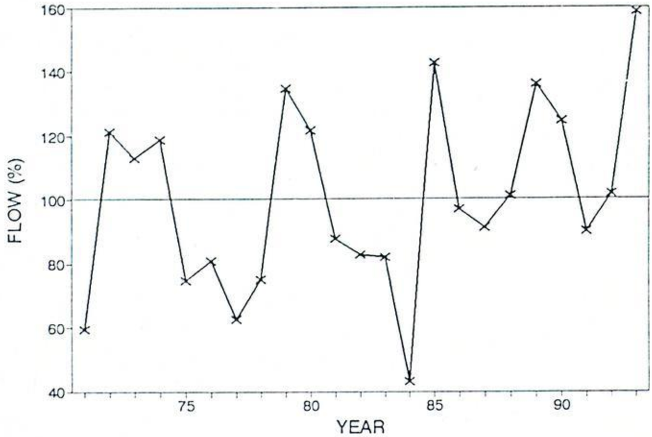


Figure 5

RIVER EWE MEAN SUMMER FLOWS
JUNE TO AUGUST

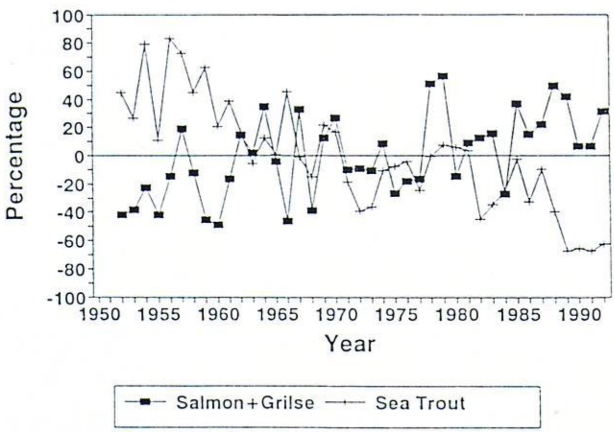


Data from the Highland River Purification Board

In contrast to the decline in sea trout, salmon angling catches have been increasing in most west highland rivers (Figure 6), perhaps because of the presence of escaped farmed salmon in more recent years (Webb, 1994). However, this pattern is not universal, both sea trout and salmon catches having declined sharply in some rivers (eg. Fyne, Aray, Torridon, Carron and Lochy).

Figure 6

North West: Rod & Line Catches
Percentage Difference From 52-92 Mean



3.3 Sea Trout Growth and Egg Production

An additional feature of the recent decline in sea trout catches in north western rivers has been a fall in their mean weight (Figure 7). The mean weight of sea trout reported from rod and line fisheries in the North West Region fell sharply in 1986, recovered in 1987 and 1988 and then fell again to consistently low levels from 1989 to 1992. Attempts to gain a full understanding of the underlying causes are inhibited by the small numbers of fish currently available for scale analysis. However, it is apparent from studies on the River Ewe System that there has been a marked reduction in the proportion of older and larger fish in the catch (Figure 8) and there is some evidence for a reduction in marine growth within individual year classes (Walker et al, 1992). It is not possible to say whether this reduced growth performance is because of a lower marine growth rate or a shorter period of marine feeding.

Figure 7

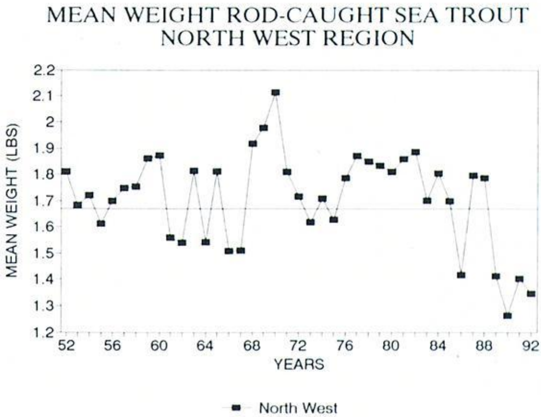
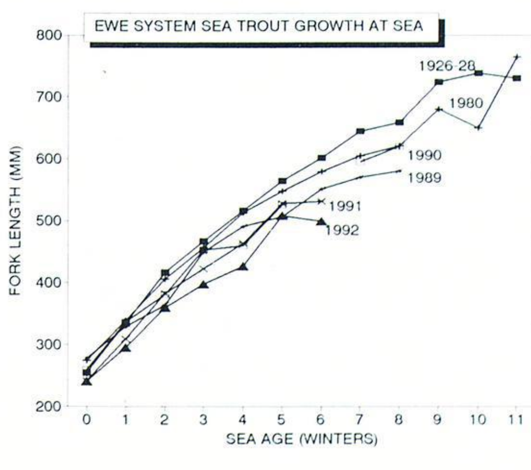


Figure 8



3

The overall mean length of the sea trout sampled in the Ewe System fell from 432 mm in 1980, to 404 mm in 1989, 366 mm in 1990, 349 mm in 1991 and to 341 mm in 1992. Fecundity data obtained from Ewe sea trout suggest that a decline in mean length of this magnitude for the population as a whole would approximately halve the overall number of eggs available for deposition (Table I), even if the numbers of sea trout had remained constant. The true extent of the decline in egg deposition cannot be estimated since data on adult abundance are unavailable.

Table I

Estimated Egg Numbers per Annual Mean Lengths of Ewe System Sea Trout Samples (1980-92)

Year	Numbers of fish	Mean length ± Standard error (mm)	Egg Number
1980	1089	435 ± 3	1143
1989	136	404 ± 7	945
1990	171	366 ± 5	713
1991	232	349 ± 4	623
1992	135	341 ± 5	583

The relationship between fecundity and body length was of the form:-

$$y = 2.84246\ x - 0.174958\ (N = 54,\ R^2 = 84\%,\ P < 0.001)$$

Where y = egg number
and x = body length (mm)

3.4 Juvenile Surveys

During 1992 and 1993, surveys of juvenile trout and salmon were undertaken in selected north western river systems to see whether there was evidence that spawning stocks had declined to the point at which egg deposition was inadequate to make full use of the available rearing habitat. Quantitative electrofishing was undertaken in the Hope, Ewe, Gruinard, Shieldaig, Shiel, Ailort, Aray, Shira and Eachaig Systems. By Scottish national standards, the densities of both species were low, but this was not surprising since many of the burns are in steep, rugged terrain and are particularly prone to spates and droughts. Table II compares the densities of fish recorded during 1990-93 with data from north western rivers visited during 1984-1986 (W.R. Gardiner pers. comm.). The results are very similar, indicating no major change in overall juvenile abundance in burns. These results should be interpreted with caution in the absence of long time-series data from the same sites and given the lack of information concerning the production of juvenile trout in lochs.

Table II

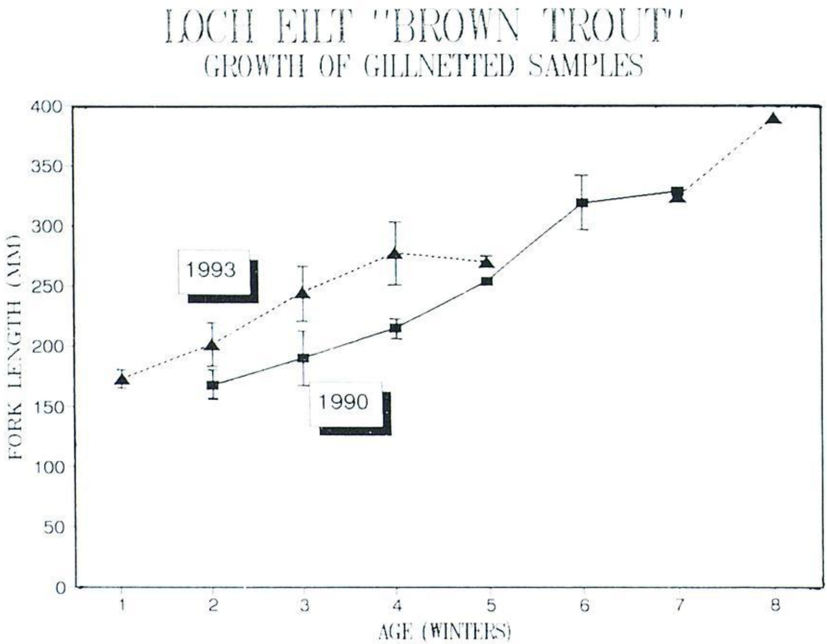
Mean Densities of Juvenile Trout and Salmon in North Western River Systems

		Densities/100 m^2			
		TROUT		SALMON	
Years	No. of Sites	Fry (0+)	Parr (1+ etc)	Fry (0+)	Parr (1+ etc)
1984-86	27	12 ± 24 (0 - 103)	3 ± 4 (0 - 16)	40 ± 44 (0 - 203)	18 ± 19 (1 - 80)
1990-93	114	18 ± 27 (0 - 130)	7 ± 11 (0 - 80)	26 ± 50 (0 - 289)	12 ± 20 (0 - 144)

Means ± standard deviation

Range in brackets

Figure 9



LOCH EILT "BROWN TROUT"
GROWTH OF GILLNETTED SAMPLES
FORK LENGTH (MM)
400
350
300
250
200
150
100
50
0
1993
1990
1
2
3
4
5
6
7
8
AGE (WINTERS)

3.6 Survival of Post-smolts in Sea Water

Post-smolt sea trout were sampled for condition factor, parasites and diseases (McVicar et al, 1994). Most of these fish were sampled on their return to the rivers and few were obtained during experimental beach seining and inshore gill-netting in north western sea lochs, perhaps because of their scarcity and their patchy distribution.

In the absence of good samples of trout from marine sites, the performance of trout smolts was studied under captive conditions. Details of the sites at which these experiments were conducted are given by McVicar et al (1994). The possibility that the marine survival of the wild sea trout smolts might be compromised because of poor adaptation to sea water was investigated in experiments carried out at the Gatty Marine Laboratory of the University of St Andrews by Drs N Hason and M Tierney. Subsamples of the wild smolts captured at each of the cage locations were transported to the Gatty Laboratory and acclimatised to laboratory conditions. Samples of the smolts were transferred directly to full-strength sea water and monitored at intervals for three days. While in fresh water, the ionic concentrations of the body fluids of salmonid fishes are regulated within narrow limits but, on transfer to sea water, this balance is upset. Water is lost from the body fluids and, to compensate for this, the fish drink sea water and excrete unwanted ions. A stable pattern of sustained drinking indicates that the fish are adapting to their new sea water environment. The drinking rate of smolts from all sites stabilised within three days, although smolts from the Holy Loch were slower to respond. Other indicators (plasma chloride and plasma osmolality) confirmed that smolts from all sites adapted equally well and that there was no indication that their marine survival would be compromised by any inability to tolerate sea water.

3.7 Marine Mortality of Sea Trout

In the absence of full scale assessments of the abundance and structure of successive generations of specific stocks of sea trout, a direct evaluation of recent changes in the dynamics of west highland populations is not possible. However, the evidence presented in the preceding paragraphs indicates that, in a number of key fisheries, there has been a marked reduction in the abundance of sea trout which is not explicable in terms of a shift in life history pattern toward freshwater residence. There is no general evidence of a recent decline in the quantity or quality of freshwater habitats. Furthermore, at some of the sites surveyed, juvenile trout numbers were high given the estimated reduction in eggs deposited. It therefore seems unlikely that the primary cause of the shortage of sea trout was reduced production of smolts. The alternative explanations are reduced viability of the smolts because of problems arising in fresh water or a sharp increase in the mortality of smolts at sea. There is no evidence for the former and, where smolts have been examined and or challenged with sea water, their condition and viability have been normal. On present evidence it would seem that increased mortality during the marine phase lies at the heart of the current sea trout crisis.

3.8 Conclusions

North western Scottish sea trout rod and line catches (Durness to South Argyll and much of the Hebrides) have been in decline over an extended period (1952-1992) and have been especially low in the years 1989-1992. During the same recent period, catches also were low in several other areas of the UK and Ireland.

- A decline in the mean size of adult sea trout has been observed in a number of north west highland fisheries. Studies in the River Ewe System have shown that both a reduction in the proportion of older fish and a decline in size at age are responsible.

- Fecundity studies show that the recorded decline in the proportion of larger sea trout would be expected to result in a substantial drop in egg production even without a fall in the numbers of fish in the spawning stocks.

- There is no evidence of any major shift in life history pattern from sea trout to brown trout ie. an increase in the proportion of trout that mature before smolting.

- Sea trout smolts obtained from rivers in North West Sutherland, Wester Ross and the Inner Clyde Estuary were found to be competent to transfer directly into full-strength sea water.

- On the evidence presented in this preliminary analysis, the primary cause of the current shortage of sea trout in some west highland rivers would appear to be an increase in total marine mortality levels.

3.9 Acknowledgements

I wish to thank the many individuals and organisations, too numerous to name, who have helped with this study. Special thanks are due to several colleagues and summer students, but in particular, to Alistair Thorne, Ron Greer and, more recently, Dr Sally Northcott. A number of colleagues also provided helpful comments on the manuscript.

4. PREVALENCE AND BEHAVIOUR OF ESCAPED FARMED SALMON IN COASTAL WATERS AND RIVERS: WESTERN SCOTLAND

(J H Webb, Atlantic Salmon Trust)

4.1 Introduction

The last decade has seen a rapid increase in the production of farm-reared Atlantic Salmon in Scottish coastal waters. In the ten years from 1983 the industry has grown from a production of 2,500 tonnes to a predicted harvest of 45,000 tonnes by the end of 1993.

Salmon are now reared in cages in several hundred sea-cage sites distributed along the western coastal zone and throughout the western and northern islands. Some fish escape due to human error or equipment failure. Small numbers of fish escape intermittently, and sometimes frequently from most farms. Occasionally however, major losses of many thousands of fish may occur, usually as a result of storm damage at sea (Youngson, 1991; Webb and Youngson, 1992).

In the late 1980s, it became clear that increasing numbers of putative escapes from cage rearing units were being captured by the various commercial and sport salmon fisheries for wild salmon around Scotland. No totally discriminatory method exists to identify positively all members of either group. Estimates of the proportion of escaped farmed salmon in catches will therefore tend to be less than the true levels. However, over the last four years a range of field and laboratory methods has been developed in Norway and Scotland to enable researchers to identify escapes among catches of putatively wild fish. Many reared salmon can be identified by using a combination of discriminating characters. The characters most commonly used include external morphology, flesh pigmentation and scale growth patterns.

It is important that the numbers of escaped farmed salmon be determined in the various fisheries for two reasons:

- To enable biologists and managers monitoring the abundance and structure of wild salmon stocks and the various fisheries that exploit them to take full account of biases caused by the presence of escaped farmed fish in catches.
- To provide numerical data as a basis for assessing the potential effects of escaped farmed salmon on wild salmon populations.

4.2 The Prevalence of Escaped Farmed Salmon in Coastal Fishery Catches

Commercial catches of salmon made at a number of netting stations on the west and northwest of Scotland have been routinely sampled since 1990. However, the most concentrated programme of research has been carried out at a coastal netting station near Gairloch, Ross-shire.

At Gairloch escaped farmed salmon have been found to be present in catches over the full duration of the netting season (May-August, inclusive). Levels have ranged from 15-15% (mean, 22%) of total daily catches (Webb and Youngson, 1992). In June of 1993 however, levels rose to ca. 66% of the total monthly catch - despite there being relatively good catches of wild fish. Over the same period, catches at other fishing stations on the west and north-west regions levels have ranged between 1-20% of daily catches. Levels of escapes among catches made at netting

4

stations on the east coast of Scotland ranged from <1-6% (Webb and Youngson, in prep).

4.3 Prevalence of Escaped Farmed Salmon in Angling catches

The most extensive angling catch sampling programme has been carried out on the River Lochy by scientists from the Freshwater Fisheries Laboratory, Pitlochry. Over the period 1988-1990 catches within the five principal beats between Mucomir dam and Loch Linnhe at Fort William were routinely monitored. In the years 1988, 1989 and 1990, the incidence of escaped farmed salmon in the total annual catches was 18.5%, 0% and 61.5% respectively (Struthers, et al., 1991).

4.4 The Behaviour of Escaped Farmed Salmon in Rivers

Most of the research into the detailed behaviour of escaped farmed salmon in Scotland has been carried out on the River Polla (NW Sutherland) 1989 and 1990.

Escaped farmed salmon entered the Polla over the summer months among the run of wild salmon. Spawning took place during the following November - typically a little later than the wild indigenous stock. In contrast to the wild females, escaped farmed females tend to restrict their distribution to the lower and middle reaches of the river. Male escapes tended to distribute themselves more widely - penetrating most of the accessible areas of the river system. At the completion of spawning, all of the female escapes subsequently captured during electrofishing surveys were fully spent.

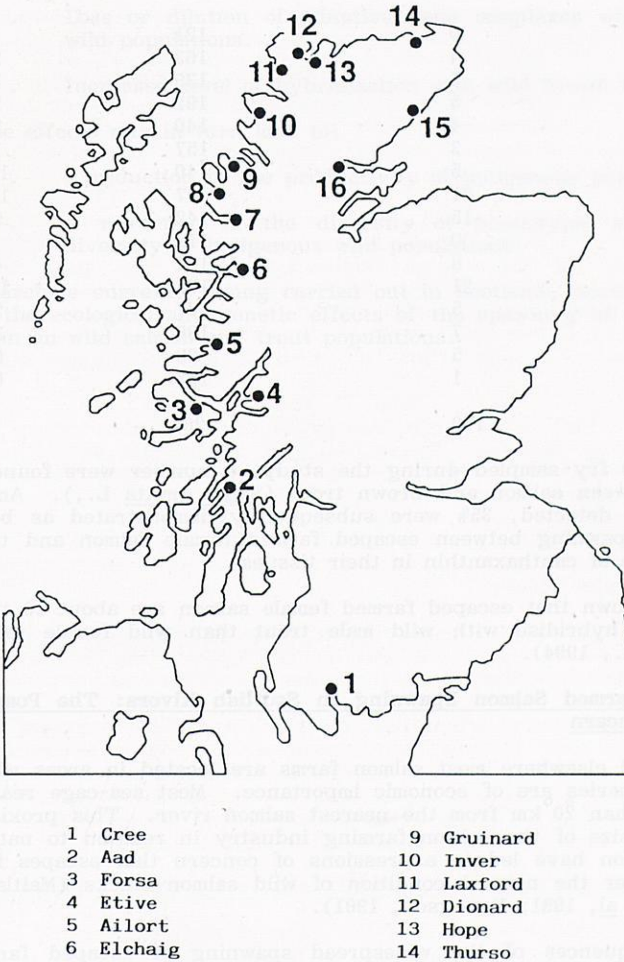
While in culture, most of the female escapes entering the Polla had been fed with a pelleted diet containing the artificial flesh colorant, canthaxanthin. Wild salmon contain a different pigment called astaxanthin. In female salmon the flesh pigments are passed to the developing eggs. Canthaxanthin can be detected in ova by a simple laboratory test; eggs derived from the spawning by escaped farmed female salmon were detected from samples of ova removed from spawning redds.

Redds containing fertilised eggs bearing canthaxanthin (and therefore spawned by farmed female salmon) were found in the middle and lower reaches of the Polla in both years of the study. In contrast, redds containing eggs bearing astaxanthin and therefore spawned by wild salmon were found throughout the stream (Webb, et al., 1991; Webb et al., 1992).

After the completion of the Polla investigation, the next step was to establish how extensive spawning by escaped farmed female salmon was in Scottish rivers as a whole. For the purposes of the investigations, the presence of the 'labelling' pigment (canthaxanthin) in alevins and fry was used as the means to identify the progeny of escaped farmed females.

In the spring of 1991, alevins and emerging salmon fry were electrofished from the lower reaches of 16 rivers from the Solway to Dornoch Firths (Figure. 1). Fry that were spawned by escaped farmed females were detected in 14 of the rivers surveyed (Table I). The mean incidence of fry of this kind was ca.5%. This level however would have been an underestimate of the true levels of spawning by escapes because only 65% of escaped farmed salmon were found to contain the canthaxanthin pigment. Furthermore, the spawning input by escaped farmed males cannot be detected (Webb et al., 1992).

Figure 1



1 Cree
2 Aad
3 Forsa
4 Etive
5 Ailort
6 Elchaig
7 Torridon
8 Kerry
9 Gruinard
10 Inver
11 Laxford
12 Dionard
13 Hope
14 Thurso
15 Helmsdale
16 Carron

Figure 1

Map showing the locations of the 16 rivers used in the study of canthaxanthin in salmon alevins and fry

Table I
The frequency of occurrence of alevins or fry bearing canthaxanthin among samples obtained from 16 rivers in northern and western Scotland.

River	Canthaxanthin Present	Absent	%
Cree	0	121	0
Aad	4	163	2.4
Forsa	5	139	3.5
Etive	5	192	2.5
Ailort	4	140	2.8
Eachaig	3	157	1.9
Torridon	5	40	11.0
Kerry	21	97	17.8
Gruinard	15	142	9.6
Inver	0	118	0
Laxford	8	162	4.7
Dionard	21	165	11.3
Hope	5	177	2.7
Thurso	7	186	3.6
Helmsdale	5	68	6.8
Carron	1	197	0.5
Totals	109	2264	

Among the 2500 fry sampled during the study, a number were found to be hybrids between salmon and brown trout (Salmo trutta L.,). Among the hybrid fry detected, 35% were subsequently demonstrated as being the result of spawning between escaped farmed female salmon and trout by the presence of canthaxanthin in their tissues.

Analysis has shown that escaped farmed female salmon are about 10 times more likely to hybridise with wild male trout than wild female salmon (Youngson et al., 1994).

4.5 Escaped Farmed Salmon Spawning In Scottish Rivers: The Possible Reasons for Concern

In Scotland and elsewhere most salmon farms are located in areas where wild salmon fisheries are of economic importance. Most sea-cage rearing sites are less than 20 km from the nearest salmon river. This proximity and the large size of the salmon farming industry in relation to natural salmon production have led to expressions of concern that escapes from culture may alter the natural condition of wild salmon stocks (Maitland, 1989; Hinder et al, 1991; Youngson, 1991).

Negative consequences of the widespread spawning of escaped farmed salmon in rivers with native populations can be envisaged on two main levels:

4.4.1 Ecological

- Competition for spawning habitat among adults.
- Competition for freshwater habitat and resources among resultant juveniles.

4.4.2 Genetic

Widespread spawning by escaped farmed salmon may lead to:

- Homogenisation of genetic base of wild indigenous populations.
- Loss or dilution of **adaptive gene complexes** within indigenous wild populations.
- Increased level of hybridisation with wild brown trout.

These effects may in turn lead to:

- A reduction in the productivity of indigenous populations.
- A reduction in the diversity of phenotypic and behavioural diversity of indigenous wild populations.

Research is currently being carried out in Scotland, Norway and Ireland into the ecological and genetic effects of the spawning of escaped farmed salmon on wild salmon and trout populations.

5. OCEANOGRAPHIC INFLUENCES ON SCOTTISH WEST COAST SALMON AND SEA TROUT

(Dr W R Turrell, Marine Laboratory, Aberdeen)

5.1 Introduction

There has been recent concern over the fall in the numbers of salmon and sea trout in rivers on the west coast of Scotland. The precise nature of this decline and of the associated changes in the populations of salmon and sea trout have been described previously in this volume. This paper concentrates on describing climatic changes that have occurred over the past decades, on different space and time scales, which may have influenced changes to marine survival and the marine habitat of Scottish west coast salmon and sea trout.

Commencing at the largest scale, while relatively little is actually known of the movements of salmon at sea, it is believed that fish which spend several winters in the ocean before returning to their rivers (multi-sea-winter or MSW fish) may migrate across the full extent of the North Atlantic (Turrell and Shelton, 1993). Certainly Scottish fish have been recovered from the fishery which occurs to the west of Greenland. Hence environmental change within the North Atlantic as a whole must be considered.

More common to west coast rivers are grilse (salmon which return after just one winter in the sea. These fish may not migrate as far as the MSW fish and most likely remain in the northeast Atlantic. A directed fishery for European salmon north of the Faroe Islands confirmed that grilse may migrate at least as far north as this point (Turrell and Shelton, 1993). Changes in the marine environment of the northeast Atlantic are hence of most relevance to Scottish salmon which return as grilse to their home rivers.

Remaining with salmon, a further spatial scale must be considered, as post-smolts are clearly influenced first by conditions in the coastal waters surrounding the rivers from which they emerge into the sea.

Considering environmental effects on sea trout, even less is known about their movements after leaving their native rivers. It is believed that they are restricted to the coastal waters around the west coast of Scotland, feeding in the sea lochs and close coastal waters. Hence, environmental change in the coastal waters around Scotland may be of more relevance when examining changes in these populations.

5.2 Climatic Change in the Northern Hemisphere and North Atlantic

Much has been written recently in the general press concerning 'global warming'. Figure 1a demonstrates a general rise in sea surface temperature (SST) which is commonly imagined as typical of changes in the ocean during the present century. The approximate rise of 0.8°C in the mean sea surface temperature since 1900 (Figure 1a) was restricted, however, to the southern hemisphere only. A rather different pattern of change was observed in the northern hemisphere (Figure 1b), with warming from the start of the century until the 1950s followed by a cooling until the late 1970s and a subsequent rise to present conditions.

Figure 1

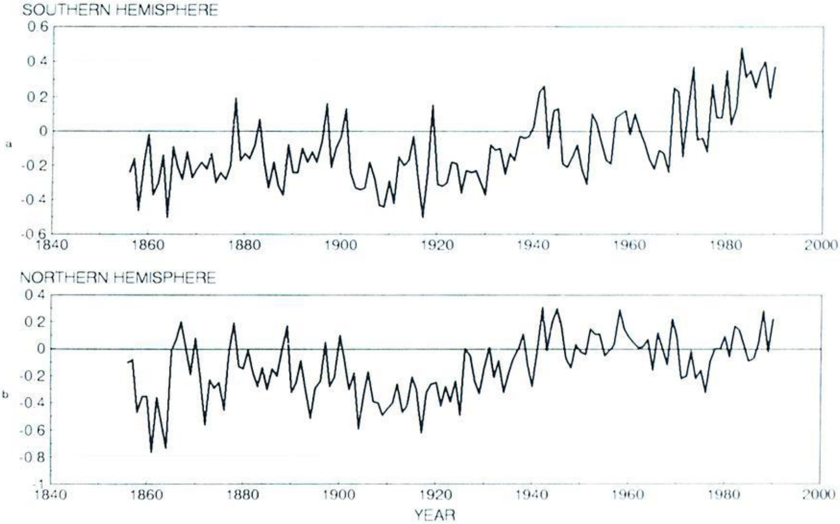


Figure 1 - Annual mean sea surface temperature anomalies for the period 1856 to 1990. The anomaly is the difference of each individual year from the 1951 to 1980 mean value. a) Southern Hemisphere, b) Northern Hemisphere.

Figure 2

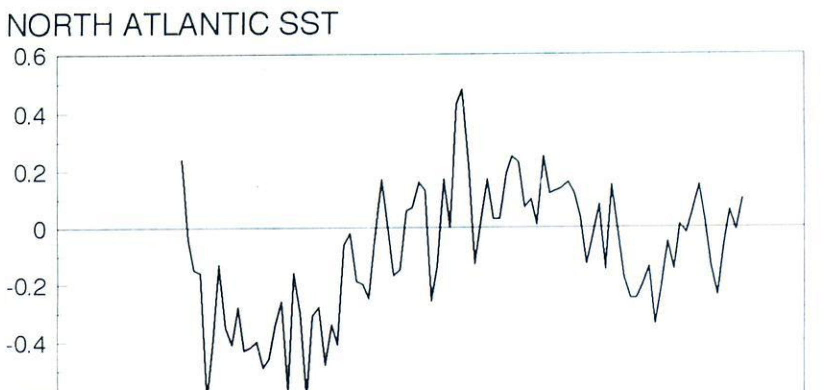


Figure 2 - Annual mean sea surface temperature anomalies for the period 1900 to 1990 in the North Atlantic (Relative to 1951-1980 mean).

This pattern of change was also observed in the North Atlantic (Figure 2), which on average has shown a 0.8°C rise from 1900 until 1950, a cooling of about 0.4°C until 1980 followed by the subsequent warming.

Figure 3

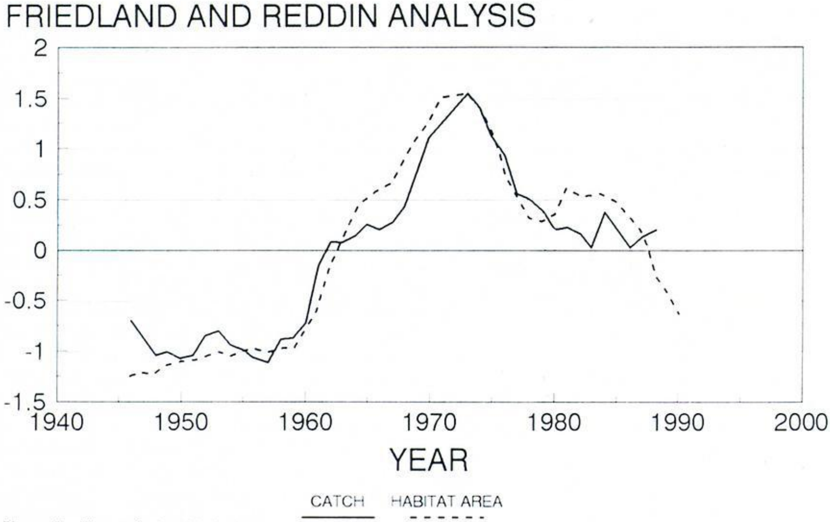


Figure 3 - The analysis of Friedland and Reddin (1993) relating the area of the spring ocean habitat for European salmon to an index of total catch derived from a variety of sources. Solid line - index of total European salmon catch for the period 1946 - 1990. Broken line - Index of change in habitat area for the same period. (Derived from their Figure 6.6). The actual values plotted are the Z-score resulting from several derived time series. These are the first principal component of the time series, with the mean removed and normalised using the standard deviation. The indices are also smoothed.

5.3 The Analysis of Friedland and Reddin

The environmental change described above has been related to changes in the size of European salmon stocks by researchers in the United States and Canada (Friedland and Reddin, 1993). They found a close correlation between total catch of European salmon and an index which they referred to as the "European spring habitat area" (Figure 3). This was described as the area of the northeast Atlantic which was suitable for salmon to live in during the critical months of March to May, when post-smolts first enter the sea. The area of the habitat was defined to the north and south by temperatures below and above which it was believed that conditions were unsuitable for salmon (7°C to the north and 13°C to the south). The east and west limits were set by an assumption of how far European salmon might migrate after first entering the sea (0°W to 20°W).

A closer examination of their index reveals that the variation in habitat area was closely related to the inverse of the mean sea surface temperature (Figure 4). Hence in years when the spring sea temperatures were warmer than average, the habitat area available to post-smolts was smaller than normal, and by implication the catch was reduced. Conversely in cold years the area was larger and, according to the analysis' catches were higher.

Figure 4

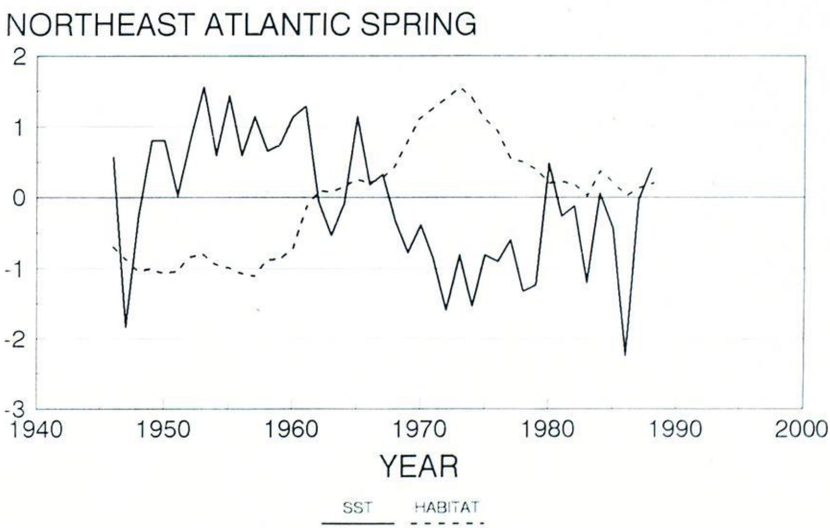


Figure 4 - Plot demonstrating the inverse relationship between variations in the sea surface temperature of the northeast Atlantic and the index of ocean habitat area derived by Friedland and Reddin (1993). Solid line - spring northeast Atlantic SST anomaly (Bottomley et al 1990). Broken line - index of spring habitat area for European salmon.

5

The reasons for the inverse relation between SST and habitat area are related to the circulation of the North Atlantic, and are described in a following section.

The simple correlation between the inverse of mean spring SST in the northeast Atlantic and the variation of the "spring habitat area", and hence catch size, is clearly seen in Figure 5 where the inverse of SST is plotted. Once this relationship is established it is possible to extend the predictions of habitat area both backwards in time from Friedland and Reddin's limit of the late 1940s, and forward in time to the present day.

Figure 5

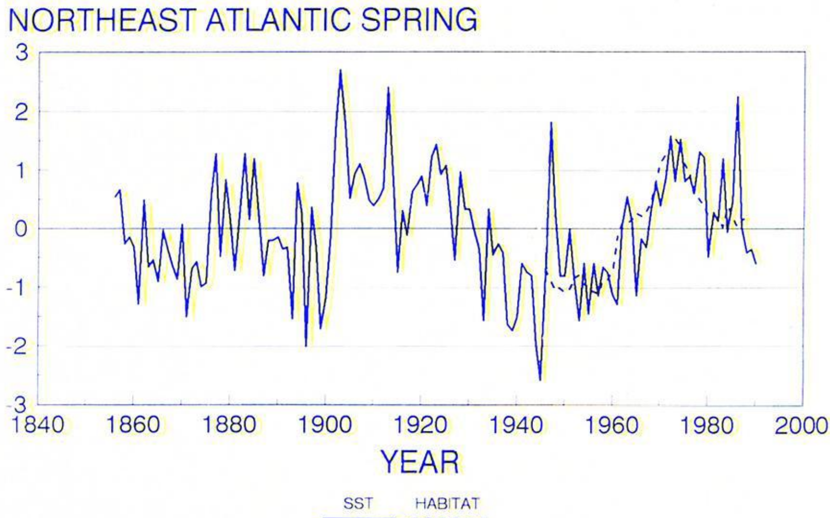


Figure 5 - The inverted time-series of the spring sea surface temperature anomaly for the northeast Atlantic used as an approximate extension of the Friedland and Reddin (1993) index of habitat area. The close correlation between the two time-series may be observed for the period 1946 to 1990 for which their computed index is available (broken line).

The results of this analysis demonstrate that during the latter half of the last century habitat area, and hence catches, were roughly stable about a mean value. Habitat area increased after 1900 until about 1920, then began to decline again as the northeast Atlantic warmed up. The habitat area, and hence catches, reached a minimum in the 1950s, and then increased towards the late 1970s coinciding with the temporary cooling of the northeast Atlantic described above. Finally after 1980 habitat area and total catch again began to decline.

The recent data show that this trend is continuing and there is little likelihood of a quick recovery to 1970s conditions. Examination of the past SST records shows that, although there was quite large variability between individual years, there were long term trends which lasted for periods typically of the order of decades. For example the cool period at the start of the century lasted 20 years, the warmer period in the 1950s lasted 30 years and the cool period in the 1970s 10 years.

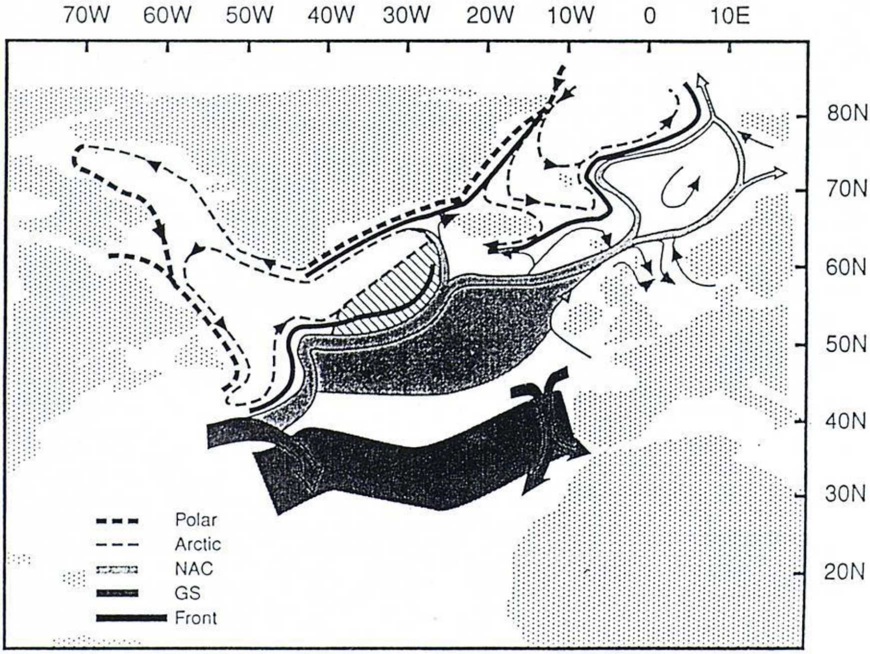
Hence there can be no expectation that present conditions may suddenly alter for the better. Indeed if predictions regarding "global warming" are correct the present warming is certainly set to continue for some time (Houghton et al, 1990). If the Friedland and Reddin hypothesis is correct, and warm sea temperatures in the northeast Atlantic equate with small habitat areas and small catches, then the outlook for increased catches in the near future is indeed gloomy.

5.4 Variation of Spring Habitat Area

The variation of the spring habitat area may be explained by examining the circulation of the North Atlantic (Figure 6). Commencing at the eastern seaboard of the United States, very warm (18°C) water leaves the coast to flow east as the extension of the well known Gulf Stream. Contrary to popular belief this does not cross the North Atlantic, but in fact turns south to eventually complete a clockwise gyre around the Sargasso Sea.

Figure 6

Summary of the main features of the circulation of the North Atlantic (modified from Krauss, 1986). Principal water types are those of polar origin (cold, fresh - heavy broken lines), arctic origin (intermediate cool, fresh - light broken lines), North Atlantic Current origin (warm, saline - lighter shading) and Gulf Stream origin (warmer, saline - heavy shading). Cold waters are separated from warm waters by fronts (heavy solid line).



A broad and diffuse drift of eddying water does, however, cross the North Atlantic towards Europe; the North Atlantic Current. The water making up this current is partly derived from the Gulf Stream water found in the extension area, and hence is relatively warm. While branches of this current turn north to inundate the waters south of Iceland (the Irminger Current), most of the North Atlantic Current enters the Norwegian Sea through the channel between Scotland and Faroe.

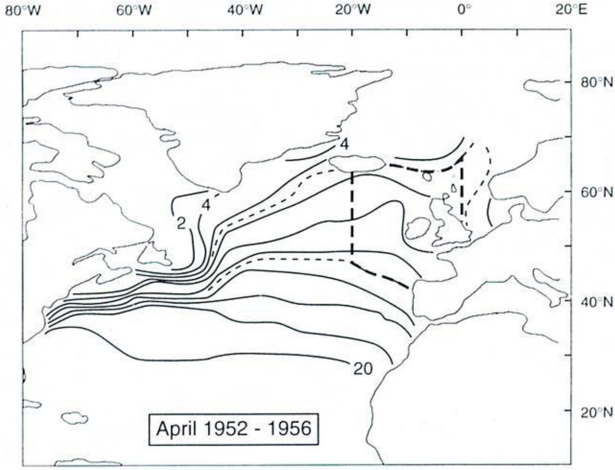
A second important source of warm water entering the Norwegian Sea occurs along the edge of the European continental shelf; the Slope Current. This current is of particular importance to changes in the coastal waters around Scotland, and will be described more fully in later sections.

Once the water has entered the northern oceans it undergoes significant changes. Eventually very cold and less saline water leaves the Arctic ocean to flow south along the coast of Greenland as the East Greenland Current. Some of the cooled water also recirculates in the Greenland and Iceland Seas to form a cool anti-clockwise gyre.

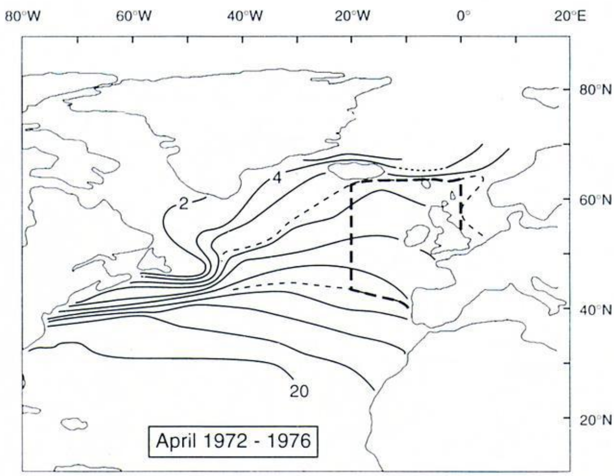
Hence at several locations in the North Atlantic cold arctic water lies adjacent to warm Atlantic water (Figure 6). These areas, known as fronts, are extremely productive biologically. It is worthy of note that both of the known ocean fishing grounds for salmon lie close to Arctic Fronts, to the north of Faroe and to the west of Greenland.

There is some evidence that these fronts are fixed in position by the shape of the ocean floor (Turrell and Shelton, 1993). Certainly the location of the front north of Faroe has not been observed to vary a great deal. Hence the change in "habitat area" may now be understood. While the northern extent of the area is fixed in space owing to physical mechanisms, the southern boundary may alter with climatic conditions. During the warm period (1950s) the southern boundary, defined by the 13°C isotherm, moved further north and hence the habitat area was reduced in size (Figure 7a). Conversely during the cooler 1970s 13°C water lay further south and hence the habitat area was enlarged (Figure 7b).

Figure 7



a



b

Figure 7 - Diagram demonstrating the actual areas of the spring habitat area for European salmon as defined by Friedland and Reddin (1993). a) The relatively warm period 1952 - 1956. b) The cool period 1972 - 1976.

5.5 The Spring Habitat Hypothesis

The poor outlook for a recovery of the marine survival of Atlantic salmon catches is based upon the hypothesis of Friedland and Reddin. This hypothesis linking habitat area to total catch may not, however, be wholly correct. In the past several studies which have resulted in significant correlations between the size of a fish stock or catch to a particular environmental variable have derived these correlations over the relatively short period for which figures are available. Subsequent analyses have shown these correlations to collapse over more extended periods. Hence these types of correlations must be viewed with some caution.

They are certainly useful in suggesting mechanisms which link environmental change to fish biology and hence stock size. Hence the actual mechanisms linking habitat area to salmon survival must be more closely examined.

In the present case the implication is that salmon leaving European rivers distribute themselves over the northeast Atlantic within an area set by environmental limits. Any change in the area available affects their marine survival. However, this almost implies a territorial behaviour for salmon in the sea.

An alternative view of salmon migratory behaviour is that they move north from coastal waters to the biologically productive areas around Arctic Fronts in the North Atlantic. This hypothesis is compatible with the location of the high seas fishing areas, and with the westerly movement of multi-sea-winter fish. An examination of Figure 6 shows that westerly currents prevail along the southern boundaries of the Arctic Fronts.

If this alternative view is correct, changes in the southern extent of the "habitat area" are irrelevant to the survival of European salmon.

Finally, Figure 7 shows that the changes to the "spring habitat area" are relatively small compared with the size of the area itself. Considering the small numbers of salmon that are actually utilising this habitat, and hence the low densities of fish in the sea, it may be surprising that small changes in the area would have significant effects upon salmon survival.

5.6 Oceanic Circulation around Scotland

Of more relevance to sea trout and salmon smolts are changes in the coastal waters around Scotland. Figure 8 shows the mean circulation patterns around the British Isles. A dominating feature is the persistent current of warm and saline water that flows along the edge of the continental shelf towards the north. Water leaving this current and crossing onto the shelf forms the source water for much of the seas around the United Kingdom. It is diluted in coastal waters by freshwater runoff from the land. This results in the formation of secondary water masses which themselves mix with the source water to result in a range of water characteristics around Britain.

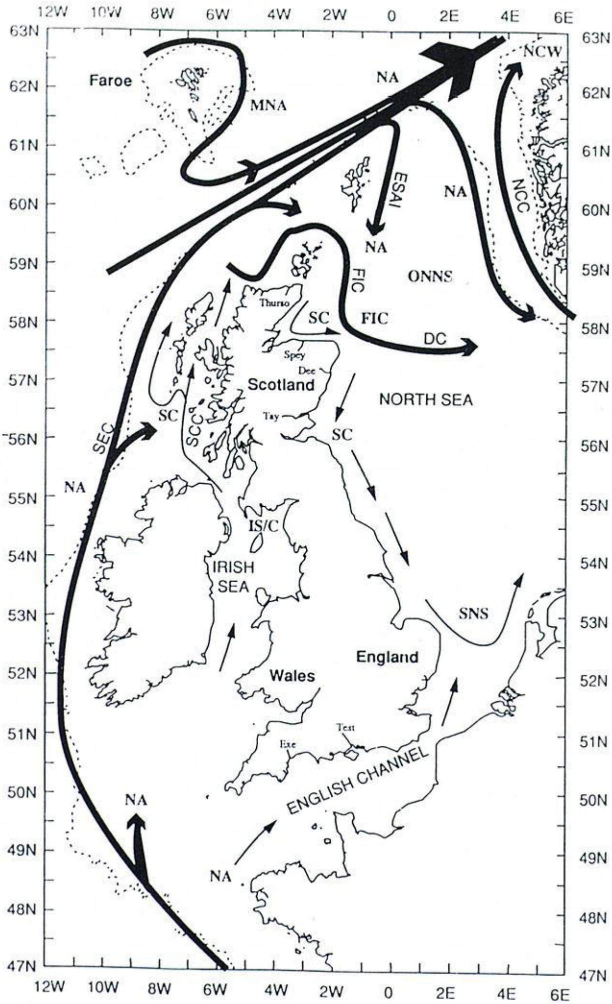


Figure 8

Summary of the main features of the circulation around the United Kingdom. The main residual currents are shown, along with principal water types; NA - North Atlantic, IS/C - Irish Sea/Clyde, SC - Scottish Coastal, FIC - Fair Isle Current, NCW - Norwegian Coastal Water, SNS - Southern North Sea, MNA - Modified North Atlantic, DC - Dooley Current, SEC - Shelf Edge Current, ESAI - East Shetland Atlantic Inflow, NCC - Norwegian Coastal Current.

North Atlantic water entering the Irish Sea predominantly from the south is significantly modified by freshwater runoff. Water leaving the Irish Sea and Clyde Sea is therefore of reduced salinity, and hence density, and flows north along the west coast of Scotland forming the Scottish Coastal Current (Turrell and Shelton, 1993). While some of this water hugs the coast around the north of Scotland, much of it moves offshore and mixes with fresh North Atlantic water. This mixed coastal and oceanic water flows into the North Sea between Orkney and Shetland as the Fair Isle Current. Within the North Sea this current is forced to flow south and then east across the northern North sea by the shape of the sea bed. Further south a general anti-clockwise circulation is evident around the Southern North Sea.

5.7 The 1989/1991 Salinity Anomaly

While the climatic trends described above have been observed in the oceanic waters of the northeast Atlantic, the same trends are not evident in the coastal waters around Scotland. It would appear that other more local processes are dominant in these inshore waters.

Figure 9 shows the monthly mean sea surface temperature anomalies in three coastal areas around the United Kingdom from 1952 to 1991. While the trends described above are not present, it is clear that certain events affected all areas simultaneously. One such event was the warming in 1960 followed by the subsequent cooling in 1964. A more recent event was the sudden warming in coastal waters after 1989. This event caused considerable interest at the time. It was first noted by a change in the mean salinity of the water at several places within the northwestern European shelf seas.

Figure 9

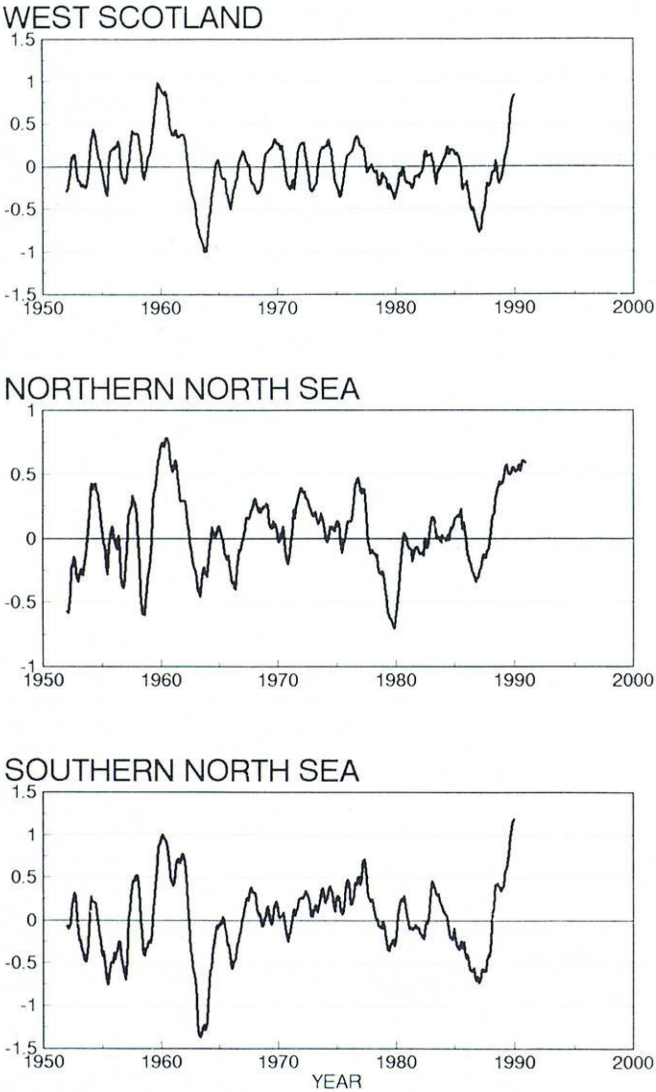


Figure 9 - Monthly sea surface temperature anomalies in three areas around the United Kingdom; West Scotland, northern North Sea and southern North Sea.

Figure 10 shows the mean salinity of North Atlantic water at the shelf edge at locations to the west of Scotland, in the Rockall Channel, and to the north of Scotland in the Faroe-Shetland Channel. The two records demonstrate that changes to the salinity of North Atlantic Water have generally followed that of temperature. The 1950s was a period of higher than normal salinity, with a dramatic decline in the late 1970s. The gradual recovery from the minimum values in 1976 was greatly accelerated in 1989 by a sudden increase. Salinity values observed in the northern North Sea in January 1990 were the highest since records began (Heath et al, 1991).

Figure 10

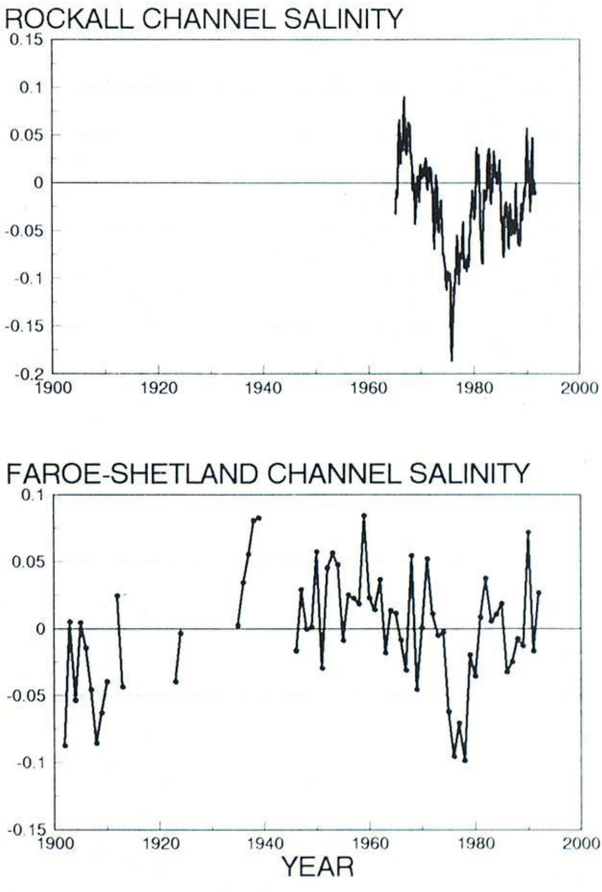


Figure 10 - Observed salinities of North Atlantic water observed at the shelf edge at two locations around Scotland; to the west at the edge of the Rockall Channel and to the North in the Faroe-Shetland Channel

The high salinity event has been analysed by several studies since it occurred. One explanation is that the Slope Current, flowing along the edge of the continental shelf, was particularly strong in 1989 and 1990, bringing warmer and saltier water from areas further south in the North Atlantic. This resulted in waters around Scotland being inundated by this water of more southerly origin. it is possible that, not only did mean temperatures rise by about 1°C and salinities by 0.05 units, but the biological nature of the source water may have altered, with the importation of exotic plankton species not normally found in Scottish waters.

Evidence that this event affected the waters within enclosed sea areas and lochs on the west coast of Scotland is given by observations at the Marine Biological Station at Millport in the Firth of Clyde (Figure 11). The warmer conditions following 1989 were clearly evident there.

Figure 11

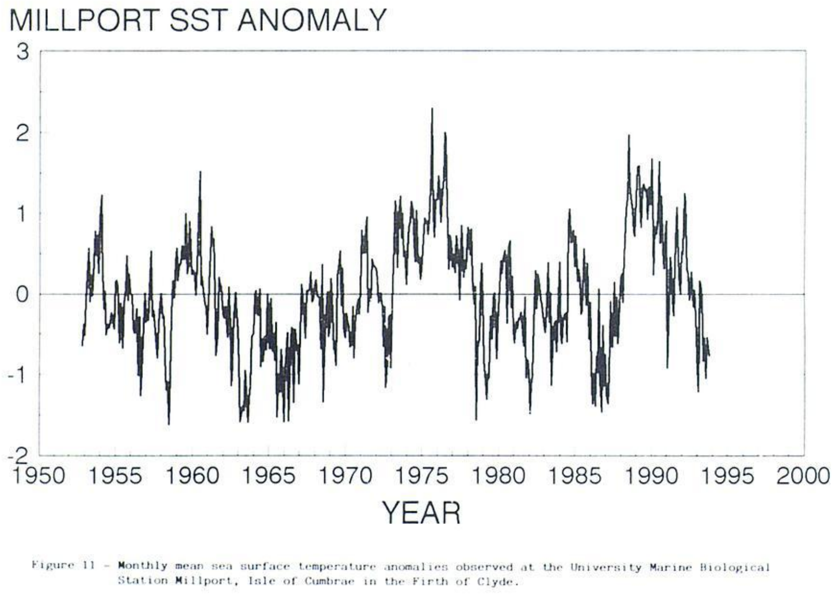


Figure 11 - Monthly mean sea surface temperature anomalies observed at the University Marine Biological Station Millport, Isle of Cumbrae in the Firth of Clyde.

5.8 Changes in Production in Scottish Coastal Waters

Finally, one last piece of evidence may also suggest significant environmental change within the coastal waters around Scotland during 1989 and 1990. Production in the sea by plant life, as on land, commences in the spring following the cold conditions of winter. Unlike terrestrial plants, the simple cellular plants in the ocean, called phytoplankton, are not fixed to the sea bed, but are free to float around in the water column and are moved by the action of the tides, waves and wind.

Following winter conditions there are sufficient nutrients in the sea to support plant growth. As the sea temperature and the available light increases with day length in the spring, conditions are suitable to permit sustained plant growth. However the plant cells must remain in the surface waters, where sunlight can penetrate the water, for sufficient periods of time. Windy conditions mix the water column and plankton up, between the sea surface and sea bed, with the result that the cells cannot get sufficient light to grow. However, calm periods allow the surface waters to heat, forming a stable layer at the sea surface in which plant life can rapidly flourish.

Depending on the weather experienced in any one year there is normally a sudden increase in growth in the sea, corresponding to one of these calm periods, known as the spring bloom. Once the phytoplankton increase in numbers, so the populations of small animals, or zooplankton, which graze on the phytoplankton may also begin to increase. It is these small animals which support the food chain providing post-smolts and sea trout with their first food source.

The time which smolts enter the sea is relatively fixed. Hence a change in the timing of the spring bloom may result in an unavailability of the necessary food species required by the young fish.

The calm weather conditions associated with the onset of the spring bloom are typically those associated with anti-cyclonic conditions over the British Isles. An analysis of past weather patterns (Figure 12) reveals that the spring periods of 1989 and 1990 were particularly stormy, with very few calm periods. In fact these two years had the latest inferred onset of the spring bloom during the period 1967 to 1993, both commencing at the start of May, whereas the more typical start was mid-April. The development of the food chain in the coastal waters around Scotland could be expected to have been delayed significantly during these two years.

Figure 12

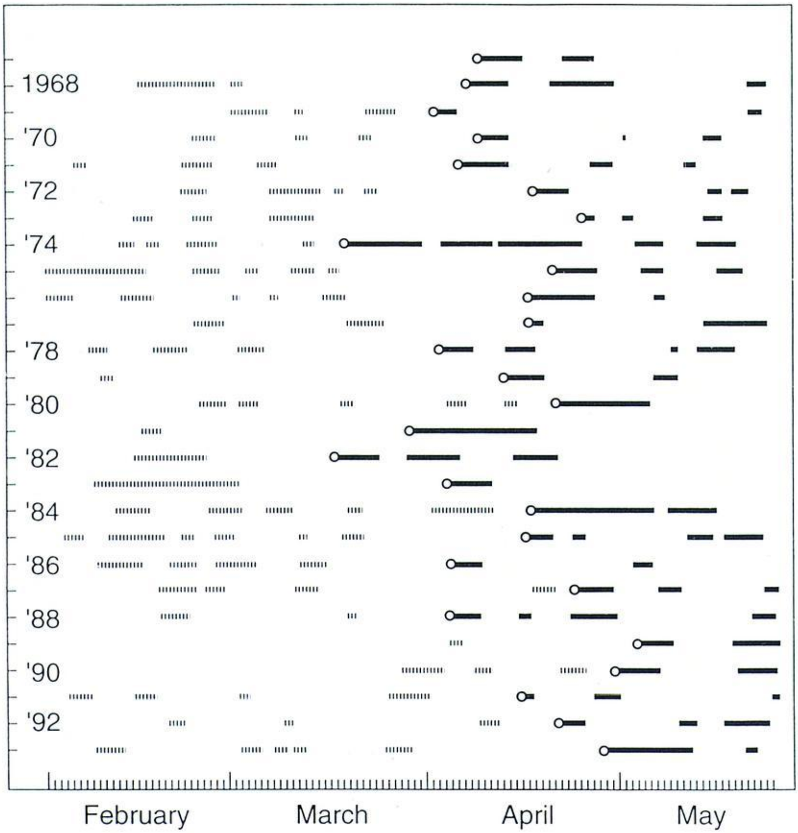


Figure 12 - Summary of the occurrence and duration of anti-cyclonic weather conditions experienced over western Scotland between 1967 and 1993. The inferred date of the onset of the spring bloom is indicated by the circles. (The period 1967 - 1983 is from Dooley 1984).

5.9 Conclusions

From the above analysis of climatic trends within the northeastern Atlantic, it is clear that a warm period is commencing which may last for a period of 10 to 20 years. Indeed if some of the predictions of global warming prove to be correct then this warming may be sustained for some time. In the period 1940 to 1980 it was evident that warm periods were associated with poor catches of European salmon and hence, it is inferred, reduced salmon populations. Hence there may be no likelihood of a rapid recovery of salmon numbers, if marine environmental factors dominate marine survival.

In addition to the long term trends, the period 1989 to 1991 appears to have been additionally extreme. The observed high salinity anomaly altered the temperature and salinity of coastal waters around Scotland, and may have resulted in changes to the local plankton communities. Certainly this period appears to have been associated with a rapid decline in the numbers of sea trout in some west coast rivers, and hence these changes may have been of importance.

Additionally the local weather experienced by the British Isles may have reinforced the situation in 1989 and 1990, resulting in a delayed spring bloom and hence again changes to the food webs which support sea trout and salmon smolt marine growth and survival.

5.10 Suggestions for Future Research

The examination presented here of marine climatic factors affecting west coast salmon and sea trout populations suggests some further lines for research.

The suggestion of changes in plankton populations owing to the increased importation of water from southern origins might be examined using data from the Continuous Plankton Recorder program run by the Sir Alister Hardy Foundation for Ocean Science. These records might also be used to quantify the delay to the spring bloom in 1989 and 1990, and the resulting effects on the development of zooplankton populations in coastal areas around Scotland. The food required by salmon and sea trout smolts during the first few days at sea should also be examined.

Finally, the conflicting hypotheses of the migratory behaviour of salmon in the sea could be tested. The actual distribution of fish in the sea with respect to sea temperatures might be investigated using systematic research vessel fishing surveys. A promising new development is that of data tags which may allow the return of a record of the sea temperatures a fish has experienced during its marine life. As the cost and size of these recording tags reduce with time, so their use may become more practical.

5.11 Acknowledgements

The author would like to thank Dr John Davies for suggesting the extension of the weather analysis of Dooley (1984). The Millport temperature data were kindly supplied by the University Marine Biological Station Millport, Isle of Cumbrae. The salinity data from the Rockall Channel was kindly supplied by Mr David Ellett of the Dunstaffnage Marine Laboratory, Oban.

6. SANDEEL AVAILABILITY TO SALMONIDS IN SCOTTISH WATERS

(P J Wright and S A Reeves, Marine Laboratory, Aberdeen)

6.1 Introduction

Sandeels (Ammodytidae) are one of the principal prey of sea trout and salmon during their marine phase. Based on the size of fish generally found in stomachs (<10 cm in length; see Hislop and Shelton, 1993), salmonids appear to feed mainly on young of the year (0-group) sandeels. Although the extent to which salmonids are dependent on sandeels is not known, recent concern over sea trout stocks has led to questions regarding the availability of this prey. In particular, it has been argued that sea trout post smolt survival is related to 0-group sandeel abundance and that the west coast sandeel fishery may, in some years, affect sandeel availability (Tingley et al., 1992). In this paper, we describe the factors affecting sandeel availability in Scottish waters, and consider the potential impact of the west coast sandeel fishery. Only one species of sandeel, Ammodytes marinus, is considered since this is the major sandeel species landed by industrial fisheries (Anon., 1994). It is also the only species whose young of the year are of a suitable size by the time of salmonid smolt migration in April/May.

Previous attempts to consider sandeel availability to sea trout have only examined abundance, as indicated from fishery assessments of the west coast sandeel stock (see Tingley et al., 1992). However, since the range and period of foraging in sea trout and salmon may differ from the area and period over which fisheries data are collected, fishery assessments may not provide a representative index of prey availability to salmonids. In the following three sections consideration is given to sandeel distribution, abundance, and the west coast sandeel fishery. Finally the possible impact of the west coast sandeel fishery on sandeel availability to sea trout smolts is discussed.

6.2 Distribution

There are no published accounts of the distribution of Ammodytes marinus in Scottish waters and so information has been extracted from unpublished sources including the Scottish demersal trawl surveys (1922-1990), Marine Laboratory exploratory sandeel surveys (1967-1974), International Young gadoid surveys (1971-1988) and acoustic surveys around Shetland and Orkney (1990-1993). Sites where 1 year old and older (1+) A. marinus have regularly been caught are shown in Figure 1. As would be expected from the sandeels, requirement to bury, all these sites are characterised by sandy sediments (median particle diameter 250-1000 μm) and high current velocities (see Reay, 1970). Around the Scottish mainland coast, many grounds occur close to estuaries and rivers, as well as near west coast sea lochs, such as Loch Ewe.

Figure 1

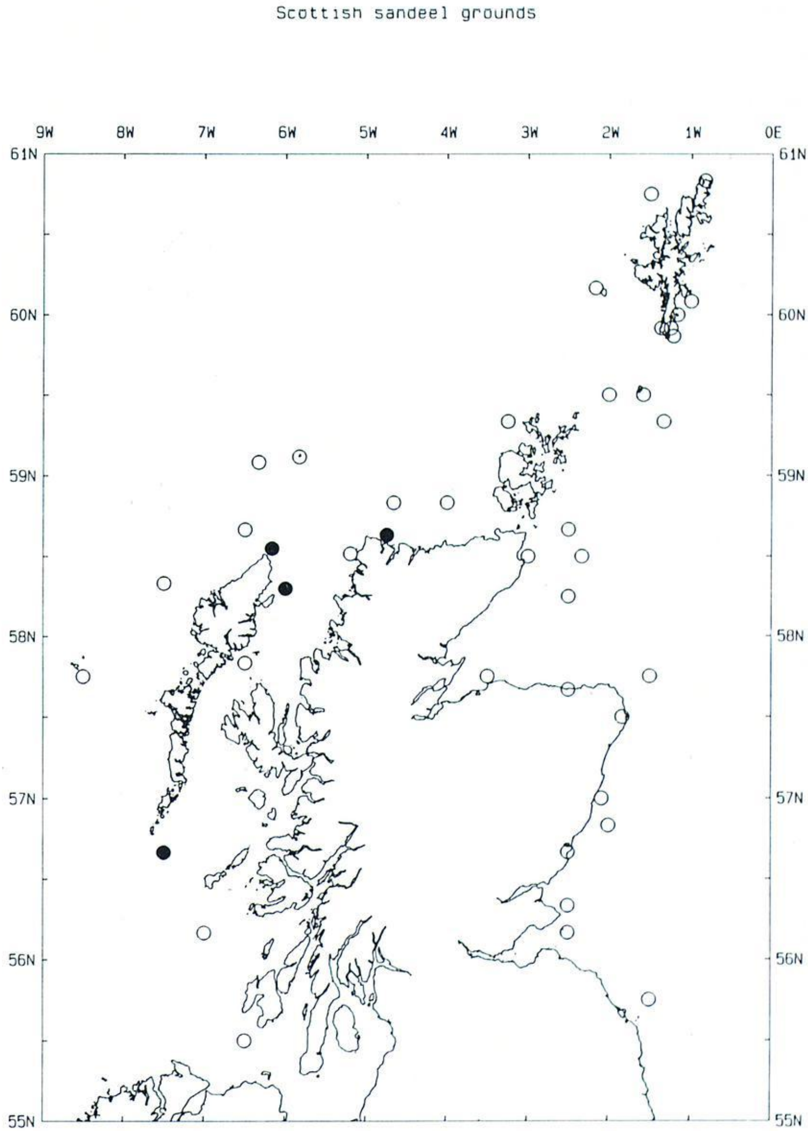


Figure 1 - Distribution of adult Ammodytes marinus in Scottish waters, determined from trawl surveys since 1922. Only sites where sandeels have been caught on more than one occasion are shown. Solid circles show the main west coast sandeel fishing grounds.

Although the distribution of all age-classes of sandeels overlaps, juvenile 0-group sandeels often have a far more extensive geographic range than older age-classes, as shown in Figure 2. The occurrence of 0-group far from areas of adult concentrations can be explained by larval and juvenile movements. A. marinus often spawn in areas where the larvae are subject to dispersal by water currents and the late larvae and juveniles must make a return migration in order to settle in areas of suitable habitat (Macer, 1965; Wright & Bailey, 1993). Inter-annual differences in the geographic range of juvenile 0-group sandeels are positively related to abundance with expansions and contractions in distribution being centred around the most suitable habitat (Wright & Bailey, 1993; Wright in prep). Such changes in geographical distribution may influence where sandeels settle and hence their availability to predators, particularly in more marginal habitats, ie. areas other than sandeel grounds.

Figure 2

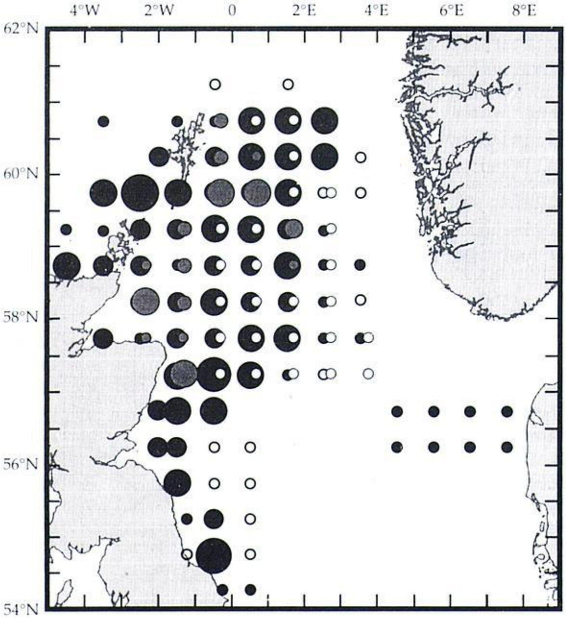


Figure 2 - Changes in the density distribution of 0-group sandeels in the northern North Sea in July 1971 (grey circles) (open circles = no sandeels present) and 1977 (solid circles). Data derived from the international young gadoid survey (IOGS).

6.3 Trends in abundance

According to Thurow (1968), the transition from an invertebrate to fish diet in salmon smolts is also associated with rapid growth. As this transition appears dependent on prey availability (Thurow, 1968), the time when sandeels begin schooling and appear in coastal waters may be critical to the early growth of smolts (Morgan et al., 1986).

Based on information from Langham (1971) sandeel larvae are likely to begin schooling between April and May. However, studies on the appearance of 0-group sandeels around Shetland suggest that the time when 0-group sandeels appear in coastal waters can vary (Wright & Bailey, 1993). Unfortunately, there is no information on 0-group abundance in the west coast region between April and June, because 0-group sandeels do not generally become accessible to the west coast fishery until they settle on the substrate in June and July.

Sandeel abundance on the west coast has been assessed from an age-based analysis of fishery catches (virtual population analysis: VPA) since the fishery began in 1980. An index of 0-group abundance has also been determined from research vessel surveys in 1992 and 1993. It is important to note that both sources of information are only from the fishable grounds, which comprise just a part of the sandeels, geographic range (See Figure 1). Further, as can be inferred from density-related distributional changes in 0-group distribution in the Northern North Sea (See Figure 2), changes in 0-group abundance at fished grounds may not be representative of changes in sandeel abundance throughout the Scottish west coastal region. For reasons discussed elsewhere (see Anon., 1994; Tingley et al., 1992), estimates of the most recent year-classes can be unreliable and so in this paper we use the latest VPA runs (Anon., 1994). Changes in spawning stock biomass (- the total weight of the adult stock) and 0-group abundance since 1983 are presented in Figure 3. This analysis suggests that the size of the west coast spawning stock has generally increased since the fishery began, with changes in this trend being related to the size of the year-class entering the spawning stock. For example, small year-classes in 1984, 1987 and 1988 were followed by low spawning stock size in 1988 and 1990 whilst the large 1988 spawning stock coincided with the entry of the large 1986 year-class. The 1993 VPA run suggests that the 1991 year-class was far larger than any previous year-class and that the 1992 year-class may also be very large., As with other sandeel stocks, there is no evidence of any significant relationship between year-class size and spawning stock biomass in the west coast stock (Anon., 1994). Recent studies of sandeel concentrations around Shetland suggest that the varying year-class size for a given spawning stock size can be explained from differences in the survival rates of early life-history stages and the occasional entry of 0-group sandeels from spawning areas that are not fished. With respect to the latter it is now clear from studies of larval distribution that there is a very large spawning area near Orkney (Figure 4) and that in 1991 large concentrations of 0-group sandeels extended from this area up into Shetland. This observation suggests that the coincidence between the large 1991 year-classes around Shetland and the west coast may reflect larger scale changes in 0-group sandeel abundance in Scottish waters.

Figure 3

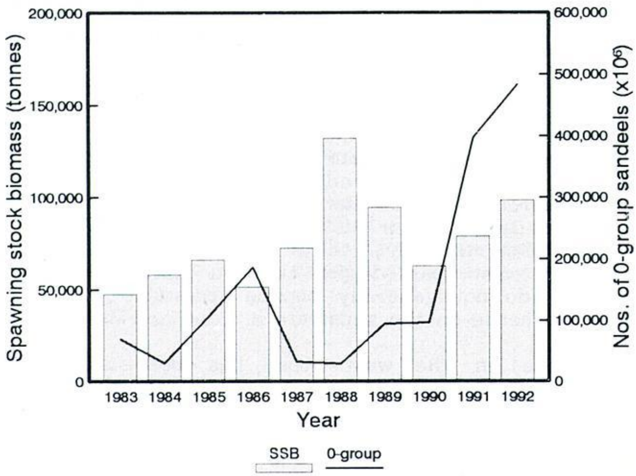


Figure 3 - Changes in 0-group abundance and spawning stock biomass in the Scottish west coast stock, based on VPA.

Figure 4

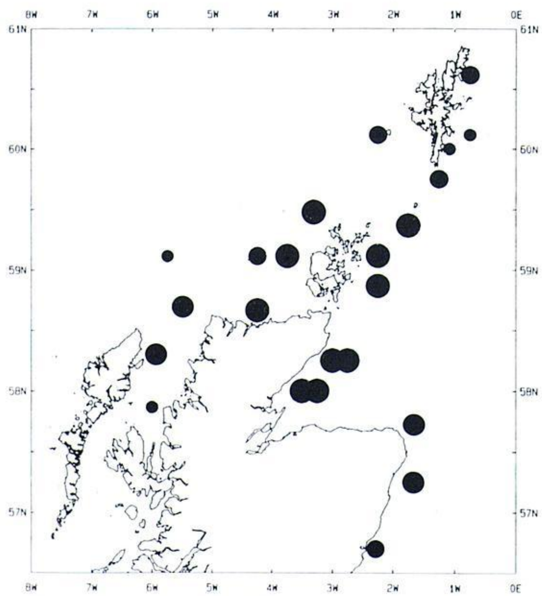


Figure 4 - Spawning areas of *A. marinus* in Scottish waters. Circles indicate densities of recently spawned larvae per m^{-2}. 11-100, 101-250, 251-500. Data based on cumulative data from 1961-1974.

6.4 West coast sandeel fishery

Landings from the west coast sandeel fishery reached a peak of 24,469 t in 1986 and both catches and fishing effort have since declined. Economic constraints, including the closure of a local fishmeal processing plant, have been the main cause of the decline in fishing effort. Fisheries scientists from both The Scottish Office Marine Laboratory and the ICES Advisory Committee on fisheries management currently regard the west coast sandeel stock to be virtually unexploited at present.

Estimates of the mortality caused by fishing (F) suggest that the fishery has never accounted for a high proportion of total mortality ($Z = F +$ natural mortality) in the west coast sandeel 'stock' ($F/Z < 0.2$). Moreover, fishing has accounted for a far smaller proportion of mortality in 0-group sandeels than in older age-classes (0-group $F/Z < 0.05$).

6.5 Competition between the west coast fishery and sea trout smolts

Based on the previous sections there appears to be little evidence to suspect that the west coast sandeel fishery has affected prey availability to sea trout. As 0-group sandeels only become accessible to the fishery in June-July, the fishery clearly cannot compete with post-smolts during the initial few weeks following the smolts departure from rivers. Once 0-group do become available to the fishery, levels of fishing mortality appear to be very low. Further, there is no reason to expect that the fishery has significantly affected 0-group production, as the abundance of juvenile 0-group sandeels is largely unrelated to the size of the spawning stock and the spawning stock has tended to increase since the fishery began. The last estimate of the 1991 year-class size (Anon. 1994) also sheds doubt on the Tingley et al. (1992) relationship between post-smolt survival in sea trout and 0-group abundance, since the 1991 year-class appears to have been particularly large. This does not necessarily mean that sandeel availability is not important to sea trout smolts because we do not know whether there is a significant overlap between sandeel fishing grounds and the foraging range of sea trout.

6.6 Summary

- The lesser sandeel, <u>Ammodytes</u> <u>marimus</u> is widely distributed throughout Scottish waters.
- 0-group density distribution can fluctuate markedly between years and such changes are often unrelated to the size of the fished spawning stock.
- The 1991 year-class was very large both around the Scottish west coast and the Northern Isles, suggesting that prey availability to salmonids should have been high.
- The west coast sandeel fishery has never accounted for a high proportion of 0-group mortality and 0-group sandeels only become accessible to the fishery some time after salmonid smolt migration.

7 INFECTIOUS DISEASES OF SCOTTISH SEA TROUT AND SALMON

(A H McVicar, L A Sharp, A W Pike, Marine Laboratory and Aberdeen University)

The abundance of the stocks of wild salmonids may be affected by a wide range of environmental and biological factors, including disease caused by infective agents. This paper considers whether there is evidence that the health status, especially of sea trout in Scottish waters, has changed in recent years and whether a particular disease or diseases has contributed to the observed decline in the level of stocks in the west.

7.1 Disease Epidemiology

Parasites, bacteria and viruses occur naturally on or in all living things and salmonid fish are no exception. Seventy-four different infective agents have been listed from wild and farmed Atlantic salmon in Scotland (Working Group on Pathology and Diseases of Marine Organisms (WGPDMO, 1992). The occurrence of an infective agent in a fish population does not necessarily mean that the fish are sick or unhealthy and, as a general rule, naturally occurring infections usually do little harm to their hosts.

The study of diseases in wild fish populations is not a well defined subject partly because of sampling difficulties. In their natural environment fish are preyed on by a variety of predators and when a fish can no longer behave normally and take the necessary actions to avoid predation, it is likely to be eaten. The time between when the behaviour of a fish becomes abnormal due to sickness and it is consumed by a predator, or dies, is the time available to a scientist to assess the number of sick fish in the population. Some acute disease can kill quickly, perhaps within 1-3 days of clinical signs appearing, with other (chronic) diseases taking longer. Although the time to death after infection can be assessed in captive fish, it is self evident that as soon as behaviour is compromised in wild fish, predation may remove evidence of disease. So a survey sample from a river is likely to show only clinically healthy fish. it is therefore possible that the finding of isolated incidents of disease could have great significance, particularly if there is accompanying evidence that the observed disease is highly pathogenic.

Changes in disease from naturally occurring background levels are thus often difficult to detect. When spectacular incidents occur, with associated high mortalities, such as happened during outbreaks of furunculosis earlier this century and with Ulcerative Dermal Necrosis (UDN) (Roberts, Shearer, Munro and Elson, 1970), the occurrence and impact of the disease is obvious. However, such incidents are rare. Since the major outbreaks of UDN in the 1960s and 1970s, river owners/fishermen have been encouraged to assist in disease studies by providing samples of sick fish for analysis in the Marine Laboratory, Aberdeen. However, the number of sick fish reported has been very low. Most data on salmonid disease is therefore obtained from fish farms.

7.1.1 Introduced infections

When an infective agent is introduced for the first time or spreads into a new area there are serious risks that it will meet hosts which have little or no resistance. This is thought to have happened in Britain with the bacterial disease furunculosis around the turn of this century and led to the major epidemic of this disease particularly during the 1920s and 1930s

(Furunculosis Committee, Report, 1935). Legislative control on the import of salmonid fish through the Diseases of Fish Acts 1937, 1983 has prevented the introduction of some other serious diseases currently present in continental Europe and Scandinavia, such as the viral diseases VHS and IHN and the skin parasite Gyrodactylus salaris. Experiments have shown the latter to be highly pathogenic to Scottish salmon and trout and its introduction would probably lead to a similar devastation of Scottish wild salmonid populations as occurs in some Norwegian rivers (Bakke and MacKenzie, 1993). Currently, there is no indication that this or any other new disease has been recently introduced into Scotland which could account for declining native stocks of salmonids.

7.1.2 Enhancement or amplification of existing diseases

The development of salmon farming to reach a peak in 1988, represents one of the more obvious changes to the aquatic environment in Scotland in recent years. As the recent population decline in wild salmonids is thought to have occurred over approximately the same period, it is naturally tempting to make a correlation between the two events. However, further investigation is needed before it can be concluded that the apparent relationship is a real one, or that the two factors are not independently reacting to a common stimulus. Evidence is needed for an abnormal change in disease level in the wild fish population, and if this is suspected, information is then needed for the cause of this change and on whether or not it is significant to the survival of the fish.

Fish farming necessarily means rearing fish at densities significantly greater than exist in the wild. Reservoirs of infection in wild fish are often transmitted via water into farms where the natural barriers to infection may be reduced with resulting disease. A consequence is that when farm disease outbreaks occur, disease agents are shed back into the water course, often at detectable levels. However, it is not always evident, at the population level, that wild fish are at risk from these outbreaks in farms. The reasons for disease outbreaks in fish were summarised by Snieszko (1972) as:

- increased pathogen virulence or densities such as may exist in fish farms during outbreaks of disease.
- decreased resistance/increased susceptibility of the fish eg. due to stress;
- environmental degradation such as reduced oxygen levels in farm water or lower food availability.

Any one of these factors could have a major role in influencing disease levels but experience has shown that fish disease outbreaks typically depend on a combination of several variables and the combination of conditions necessary for disease to occur in wild fish as a consequence of disease on a farm may seldom exist. Tully et al (1993b) discussed the possibility of changes in host susceptibility to sea lice infection in western Ireland but did not reach any conclusions and some environmental aspects were considered by Turrell and Wright (this symposium) without specific reference to disease.

There have been no instances of large numbers of diseased dead fish in Scotland in recent years which could signal an epidemic of an acute disease. However, there are several endemic infections which can cause significant disease problems in fish farms and which may occur in wild fish eg sea lice, the bacterial agents causing furunculosis and BKD and the virus causing IPN. It is known that bacteria, such as Aeromonas salmonicida (the cause of furunculosis), do change and develop resistance when antibiotics are regularly used in fish farms and the question may be asked if these changes could have implications for wild fish. Antibiotic-resistant strains of bacteria have not been normally isolated from the wild salmonids submitted for disease analysis in Scotland perhaps because resistant bacteria survive less well in the wild.

7.2 Diseases in Wild Sea Trout

A cooperative study between the Marine Laboratory and Aberdeen University, linking closely with the Freshwater Fisheries Laboratory, Pitlochry has been undertaken to investigate whether diseases are having a significant impact on wild salmonids. Most of the research has been done on sea trout. Early results, presented at the Symposium on Pathological Conditions of Wild Salmonids in Aberdeen in 1992, did not identify any disease which was having a significant detrimental effect (McVicar et al, 1993). Since then these studies have continued with sampling concentrating on finnock and adult sea trout in 1991 and being extended to include parr and smolts in fresh water in 1992. In addition, earlier samples have been more fully analysed.

7.2.1 Virus and bacterial diseases and diseases of unknown aetiology

Since the start of the sea trout disease survey in 1990, a total of almost 500 wild sea trout have been analysed for the presence of viral agents (totals 1990 = 162; 1991 = 220; 1992 = 107). Infectious Pancreatic Necrosis (IPN) virus was detected in 16 fish in June 1991, taken from two different rivers within the north western fishery district. Since then no other virus has been found. IPN has shown an increased prevalence in fish farms in Scotland over the last few years, particularly in sea water. However, in the early 1970s, extensive studies assessing the spread of IPN virus from a highly infected rainbow trout farm in Loch Awe into local wild stocks of salmon and trout, indicated that the disease did not become established in the wild populations (Munro et al, 1976). Similarly, although it is known that furunculosis is widespread in Scotland in both farmed and wild salmonids and that there can be a cross transmission between both, evidence is lacking of a detrimental effect on wild fish since the last major outbreaks occurred during the 1930s. Neither furunculosis nor other serious bacterial disease has been detected in 245 sea trout examined (totals 1991 = 160; 1992 = 85). The effect of furunculosis and IPN on sea trout is currently being examined under experimental conditions but data so far do not give reason to suspect them as a significant cause for concern. However, an open mind is still being kept on their potential to cause problems, particularly in sea water stocks, as it is in this area that they cause most problems in farmed salmon.

Other conditions with unknown causes have given reason for concern in farmed and wild salmon stocks; their role, if any, in the sea trout population decline has not been determined but they have sufficiently serious consequences for them not to be excluded from consideration at present. For example the failed/failing smolt syndrome reported in salmon farms (Davidson, 1993) can seriously affect post-smolts in the first two to three months after entry into sea water. M74 disease has been reported in Sweden to cause 90-97% mortalities in salmon fry (hatchery and wild).

This condition is currently under intensive study in Sweden and will be assessed by the ICES WGPDMO at its next meeting (Resolution 2.25 (h) of ICES Statutory Meeting, Dublin, 1993). Also the thin state of sea trout prematurely returning to fresh water after smolting, as reported from Ireland (Tully et al., 1993a, b), is reminiscent of the effect of Pancreas Disease on some farmed salmon (McVicar, 1987). This infectious disease (probably caused by a virus) is widespread in Scottish farmed salmon but there has been no pathological evidence of its presence in any of the sea trout samples examined to date.

7.2.2 Parasites

As indicated by McVicar et al. (1993) no internal parasite has been found in sea trout samples either at high levels or associated with any significant pathology.

However, there has been widespread comment, particularly from Ireland (Tully and Whelan, 1993; Tully et al., 1993a, b) and more recently from Norway (Berland, 1993), that there is increased infestation with sea lice associated with the decline of stocks and in the premature return of fish in poor condition to rivers. Although there are apparent differences in the state of the sea trout stocks and in the behaviour of finnock in Scotland (Walker, this symposium), considerable research emphasis was placed on these parasites in Scotland (Sharp, Pike and McVicar, in press).

Two species, Lepeophtheirus salmonis and Caligus elongatus, were present on sea trout sampled (total number = 81) from nine different locations around the Scottish coast representing east, north and west coast river estuaries (Table 1). Lepeophtheirus was present in all areas sampled but Caligus was only found in one east coast river estuary, the Ythan.

Table 1

Occurrence of *Lepeophtheirus salmonis* and *Caligus elongatus* (in parenthesis) on wild sea trout caught in the estuaries of different Scottish rivers

Area	River	No Fish	% Infected with lice	Mean number of lice/fish	Maximum number of lice/fish
			1991		
East	Don	4	100	4.5	9
	Ythan	13	100	5.0	11
	(Ythan)	(13)	(85)	(10.6)	(49)
North	Hope	8	25	1.4	10
N West	Ewe	4	75	20.5	38
	Squod	2	100	7.0	12
	Morar	19	100	23.8	83
West	Euchar/Creran	3	100	5.0	9
Clyde	Eachaig	20	75	10.7	46
			1992		
N West	Ewe	8	100	63.9	216

There have been problems in obtaining an accurate assessment of lice levels on sea trout in this study. With low sea trout population numbers prevailing in the sampling areas and the dependence on rod-caught fish from estuaries, the numbers of samples available were low (also high variation in infestation levels between fish from the same area made statistical analysis difficult), the capture of a finnock in an estuary did not necessarily indicate that it had returned directly from sea (any which had returned from extended periods in fresh water would have lost lice burdens leading to an underestimation of lice burdens) and, in the absence of knowledge of the habits of sea trout smolts on leaving the rivers, it was impossible to determine whether or not the fish caught were representative of the local population of sea trout.

In 1991, the greatest mean numbers and maximum numbers of Lepeophtheirus per sea trout were from River Morar with the lowest maximum number from River Hope. Sea trout from River Ewe had major differences in the mean number of lice per fish 1991 and in 1992. Each of the sea trout populations investigated showed some fish with parasite numbers well above the average number per fish in that sample (in statistical terms, an overdispersed distribution) (Sharp et al., in press). The consequence was that the majority of the lice population was carried by a small part of the sea trout population. This was greatest on River Ythan with Caligus and on River Echaig in 1992 with Lepeophtheirus. In 1993, River Ewe fish also showed a very high overdispersion. Thus, the numbers of lice on sea trout caught on the same area, even at the same time, can vary greatly, indicating a different acquisition or survival of parasites on different individual hosts.

When samples are grouped within areas, it is clear that higher numbers of lice per sea trout were found in the north western district than in other parts of Scotland (Figure 1) (Sharp et al., in press). These higher burdens of lice are generally correlated with the area where most fish farms are found and the question has to be asked whether the farms have caused, or contributed to these infestation levels. It is generally accepted that salmon smolts held on the same fish farm as older year groups infested with lice are liable to infestation, indicating that a focus of infestation exists at fish farms when these have lice problems. However, it is not known whether sea trout smolts naturally come into close association with salmon farms as there is little information available on their behaviour on leaving their rivers. Also, there is a naturally occurring background level of Lepeophtheirus in the sea in areas clear of fish farming activity; a mean number of 10 lice was found in 20 fish from River Echaig estuary (Holy Loch) with a maximum of 46 on one fish, while mean numbers of approximately five Lepeophtheirus, with a maximum of 11, were found in River Don and River Ythan sea trout. It is not possible to show whether there has been a change in lice levels in sea trout since the development of salmon farming as there is little historic data on lice available in Scotland; an indication of the natural occurrence of Lepeophtheirus infection of sea trout was indicated by the studies by Pemberton (1976) in the Loch Etive area, but the numbers of lice found were not given. In Norway, Berland (1993) could not establish an association between lice levels and the development of salmon farming, but again data were limited. Also, it has been demonstrated that the levels of the lice Caligus elongatus and Lepeophtheirus pectoralis (and other diseases) on common dab can vary considerably, even over short distances in sea areas, in response to natural causes (Begg and McVicar, 1991 and 1993) and until similar studies have been undertaken with lice on sea trout, the extent of similar natural regional variability in sea trout lice levels cannot be determined.

Figure 1

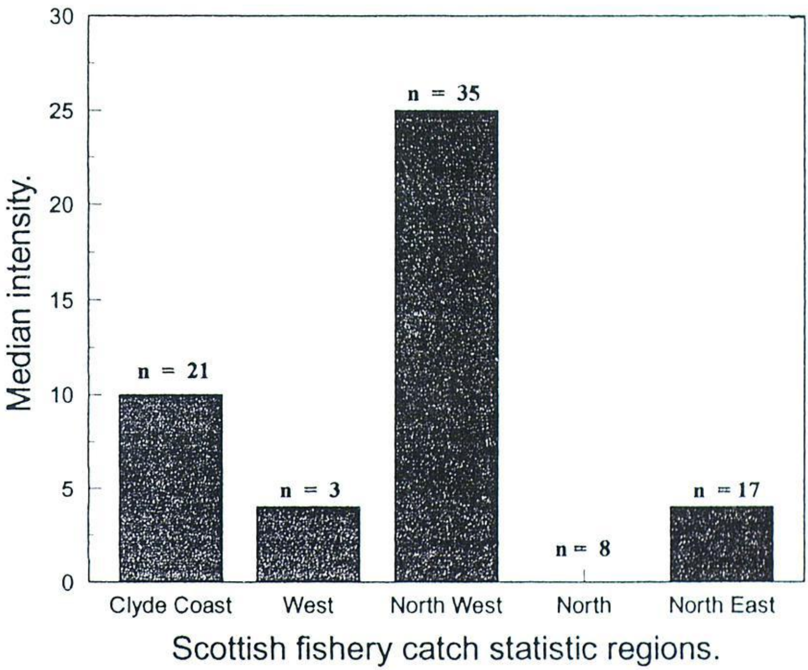


Figure 1 - Median intensity of infection of sea trout with lice, Lepeophtheirus salmonis caught in different areas of Scottish estuarine and coastal waters. n = number of sea trout available for examination. Data from Sharp et al. (in press).

Lepeophtheirus salmonis has a series of life cycle developmental stages from free swimming larva (nauplius and copepodid) through stages firmly attached to the fish host (chalimus) to pre-adult and adult stages (Figure 2). It develops from juvenile to pre-adult stage in 20 to 25 days at temperatures of approximately 9 to 10°C (Johnston, 1993). When the age composition of the Lepeophtheirus population on sea trout is analysed, it is evident that the highest proportion of juvenile stages is found in west coast areas (Sharp et al., in press). This suggests a more recent acquisition of infestation in that area (assuming that parasites are not lost in a different pattern in different areas). How this can be related to the areas where such infestation is obtained is difficult to evaluate, as little is known of the behaviour of sea trout in the period immediately after entry into sea water. Interpretation is made even more difficult because of the variation in patterns found in different samples. In two samples taken within approximately a day of each other in June 1991 from the vicinity of the River Ewe (four fish) and Squod burn (two fish), both draining into Loch Ewe, totally different patterns of maturity of parasites were found; adult female lice represented 35.4 and 71.4% respectively of the total lice population. These fish caught on different days had been exposed to a different pattern of lice infestation. The use of morphometric measurements of lice to distinguish between populations and origins of lice around the Scottish coast has been investigated and significant differences found between east and west samples (Sharp et al; in press). Such variations may be associated with the migration of sea trout to different feeding grounds.

Figure 2

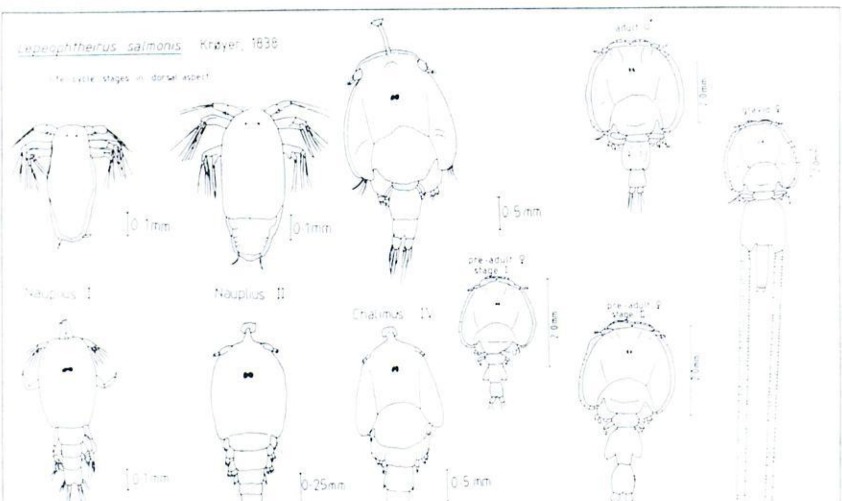


Figure 2 – Developmental stages of Lepeophtheirus salmonis. (By courtesy of Dr D Bruno, Marine Laboratory, Aberdeen).

There was no apparent relationship between the condition of fish and the numbers of sea lice on them (Figure 3). Lice-associated damage to fins and heads was noted by McVicar et al. (1983) on some sea trout sampled in 1991 and 1992, particularly up to early June, with fish taken later showing evidence of recovery. There is also anecdotal information that fishery managers and anglers have observed a hooded grey appearance on early returning finnock, particularly in 1991 with the occurrence of this condition decreasing since then (A Walker, personal communication). Data from Scottish sea trout differ from that from Ireland (Tully et al., 1993a) in that thin early returning smolts were not readily found and skin lesions were uncommon.

Figure 3

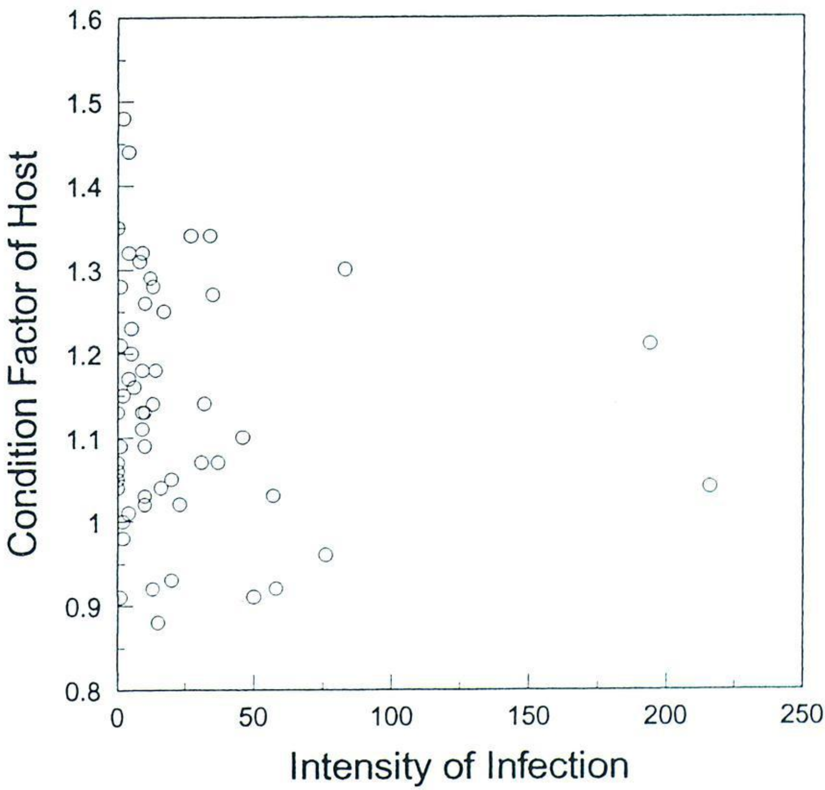


Figure 3 - Condition factor of wild caught sea trout in relation to the level of infection with lice, Lepeophtheirus salmonis (all stages). Data from Sharp et al. (in press).

There are difficulties in interpreting the significance of lice numbers on a sea trout for three reasons:

- Lice survival. It has been demonstrated (Wootten and Sommerville, Institute of Aquaculture, Stirling University, personal communication) that at least 97% of Lepeophtheirus copepodids which settle on a salmon do not survive to become adults (the remaining 3% includes both males and females and only a proportion of the females will produce eggs). Very high numbers of juveniles are thus required to produce an adult population of lice on a fish. A high proportion of the lice found on sea trout by Sharp et al. (in press) were juvenile (non mobile) stages and Tully et al. (1993a) also showed a high proportion of the same stages in their data from Ireland.

- Effect of lice on sea trout. In salmon farming, juvenile stages of sea lice cause little pathology to post-smolt and adult fish. However, relatively low numbers of pre-adult and adult lice can cause significant damage. Salmon farmers usually start to treat post-smolts whenever there are more than five pre-adult or adult lice per fish and when there are above about 10 on adult fish; in both cases treatment is designed to start before female parasites begin producing eggs. How sea trout smolts may similarly react to juvenile and adult lice infestation is unknown. The finding of all but three (of 44) Lepeophtheirus to be pre-adult or adult on seven adult fish (maximum infection 11) taken in July 1991 from the Ythan estuary, indicates a parasite loading which could occur without evidence of associated pathology in older fish.

- Secondary lice infestation. It should be noted that the occurrence of high levels of lice on a fish may indicate the presence of other problems with sea trout. It is clearly evident in fish farms that salmon suffering smolt transfer problems or which are sick with other diseases, such as Pancreas Disease (PD), are highly susceptible to sea lice infestation. Individual fish which are slow to recover selectively accumulate high lice burdens in comparison to healthy or PD-recovered fish in the same cage. Thus, the possibility should be kept open that the lice burden on early returning finnock is a secondary attack on weakened or abnormally behaving fish which have suffered another debilitating problem. The lice may, of course, contribute to the ultimate death of the fish, although in the absence of lice these fish may still die from the other causes.

7.3 Cage Experiments

The period immediately after movement of a smolt from fresh water to sea water is critical and traumatic to the fish. Data from farmed salmon smolts indicate that over a period of approximately two weeks there is significant weight loss, depletion of fat reserves, (even in feeding populations), and physiological upset, as indicated by depression of digestive enzyme levels (unpublished results). To evaluate some of the aspects of the survival of sea trout during this period, a cage trial was set up, using smolts from the local river and disease tested farmed sea trout smolts as control fish. Three different areas were chosen to reflect differences in the local status of sea trout stocks and the proximity of fish farms:

- Loch Eriboll, representing an area with adjacent fish farms (nearest approximately two miles distant) but no serious problem with local sea trout stocks;

- Little Loch Broom, representing an area with adjacent fish farms (nearest approximately 200 metres distant) but with decline in the local sea trout population;

- Holy Loch, representing an area without adjacent fish farms (nearest approximately 12 miles distant) and no serious decline in the local sea trout population.

The main disease objectives, results and conclusions were:

- To determine if the condition of smolts leaving rivers differed from area to area.

- Mortality levels were low and no disease (viral, bacterial) was found when river-caught fish (number = 24) were transferred to Aberdeen and held in fresh water tanks for two to three weeks. Low numbers of internal parasites such as previously noted by McVicar et al. (1993) were again observed but no pathology has been associated with these. Thus there was no indication that the health of the smolts leaving the rivers was contributing to decreased survival.

- To determine if the environment in the vicinity of the river of origin of smolts influenced their survival and if any disease showed itself in the immediate post-smolt period.

  As noted by A Walker, the survival of caged fish did not differ in the different test sites demonstrating that the sea water quality near the different rivers did not cause mortality. A low level of mortality found probably represented some handling and transfer problems. No significant bacterial or viral diseases were found in any of the samples (number of fish = 143) and other than sea lice, no parasitic infections of marine origin were found.

- To determine if there was a differential lice loading on post smolts in the different areas and if this could be associated with the size and condition of fish and appearance of lesions.

- This aspect of the trial formed the major part of the disease studies in 1993 and full results were not available at the time of the Inverness meeting. Fish were sampled for disease on three occasions up to two months after transfer to sea water, but emphasis was placed on the analysis of samples from the critical two to three week period after transfer to sea water and the results presented here are from this period only. Sea trout in all sites became infested with Lepeophtheirus but the infestation levels differed in each of the areas (Table 2). Fish in the Little Loch Broom cage showed a range of lice age stages, indicating continual infestation with lice over the entire period. Fish in the cages in the other lochs showed a narrow band of maturity stages indicating that there were episodes of infection which were limited in duration. Caligus infestation was found in fish in Little Loch Broom and a wave of infestation with this species was found in the Holy Long cage around the end of May. Also, within 11 days of transfer to sea water a single adult Lepeophtheirus was found at the latter location. As this greatly exceeds the normal rate of development of this parasite it can be concluded that infestation was gained through migration of the parasite from another wild salmonid outside the cage.

Table 2

Accumulation of sea lice *Lepeophtheirus salmonis* and *Caligus elongatus* (in parenthesis) on sea trout of farmed and wild origin within the first 20 days of being caged in different localities

Area	Miles to fish farms	Stock	Sea days	*L. salmonis* Fish No inf/uninf	(*Caligus*) Fish No inf/uninf	Lice *L.s* (C) Average No/fish	Lice *L.s* (C) Max No/fish
Loch Eriboll	1		14				
		Wild		1/9	(0)	1.2 (0)	6 (0)
		Farmed		5/10	(0)	1.5 (0)	2 (0)
L. Loch Broom	<0.5		18				
		Wild		10/10	(4/10)	14.2 (0.5)	25 (2)
		Farmed			(2/10)	19.7 (0.2)	36 (1)
Holy Loch	12		17				
		Wild		5/10	(0)	0.1 (0)	1 (0)
		Farmed		8/10	(0)	0.7 (0)	2 (0)

The main results obtained and conclusions which can be reached from the data so far available on the cage experiments are:

- there were no marked differences in the prevalence of infestation (number of fish infested in relation to the number examined) between fish and wild and farmed origin at any individual site.

- the proportion of fish infested and the number of parasites per fish in the Little Loch Broom cage, which was closest to fish farm cages, was significantly higher than the other two sites ($p = 0.0001$ for L Loch Broom/Holy Loch; $p = 0.003$ for L Loch Broom/Loch Eriboll) and the Loch Eriboll cage fish had significantly higher parasites per caged wild fish than the wild fish in the Holy Loch cage ($p = 0.0365$). There is some evidence of overdispersion in the infestation in caged sea trout of wild origin indicating that some fish were more susceptible to infestation than others. In those of farmed origin in the same cages, infestation was more homogeneous and this may reflect a genetically closely related reared stock.

- there was no relationship between the size of fish and the level of parasitism within the cages.

- there were no lice-related lesions observed in any of the fish in the cages and no differences in the mortality of fish caged in the different lochs. Experimental trials in tanks are being carried out to attempt to define what range of infestation with lice and what age of lice may have a significant effect on the survival of sea trout post smolts.

The higher level of lice in the Little Loch Broom site than in the other two areas may be related to the fact that experimental cage was located more closely to a salmon farm with lice present than either of the other two cages; it is already well known in salmon farming that the stocking of cages in the close vicinity of a population of lice-infested fish will lead to accumulation of lice in the introduced fish. However, the relevance of these data to the question of interaction between lice infestation in fish farms and wild sea trout is not clear at present as it is not possible to state that the pattern of lice infestation found in the experimental cages reflects the situation which sea trout migrating from local rivers would experience. Wild fish would not necessarily remain in the vicinity of the river where the cages were situated or, as in the case of the Little Loch Broom cage, in the immediate vicinity of a fish farm. Also the holding conditions and unnatural behaviour of fish in the cages may have led to abnormal exposure to infestation; this possibility is indicated by the appearance of Caligus in caged sea trout in Little Loch Broom (and also later in Holy Loch) when this parasite has not been recorded in any wild caught trout in the west of Scotland.

Principally, for control of disease, including lice, fish farmers attempt wherever possible to stock one year class of fish on a site, operate an all-in all-out policy and are entering area management plans where complete sea lochs are fallowed simultaneously with any treatments for disease being synchronised between sites. The effectiveness of this policy is reflected in the increased survival of salmon in sea cages during the last two years (report of the SOAFD Annual Survey of Fish Farms for 1992). During the next few years it will be useful to evaluate if there will be a corresponding improvement in returns of wild sea trout, either within areas subject to such fish farm disease control strategies, or more generally throughout the west of Scotland.

7.4 General Conclusions

There is not sufficient evidence to conclude that infectious disease is the cause of the decline in salmonid stocks on the west of Scotland. Some bacterial and viral infections causing disease at fish farms may occur in wild fish, but parallel epidemics in wild fish have not been recognised. No internal parasite has been implicated as potentially causing problems, no newly introduced disease was detected and there was no evidence of a change in the pathogenicity of an already existing disease.

In the absence of signs of a major disease epidemic, the possibility of a chronic diseases such as IPN, furunculosis and lice infestation causing debilitation of individual fish at sea and increased predation or death should not be ignored. Higher levels of infestation with the sea louse, Lepeophtheirus have been shown to occur in west Scottish stocks of sea trout compared to east/north stocks, both in natural populations and caged fish. As in western Ireland, this pattern of infestation coincides with the main distribution of salmon fish farms, most of which are infested with lice and are known to release infective stages. This correlation has led to the linking in Ireland of lice infestations of fish farms with the sea trout population decline. However, it is difficult to determine whether farmed lice infestation has contributed to the infestation in wild sea trout in Scotland. In areas distant from fish farms there is a background level of this parasite which may naturally vary and it has not been possible to establish what constitutes a "normal" level of infestation. Moreover, the significance of different levels of lice burdens, especially of juvenile stages, to the survival of the fish is not yet known. Lice are known to secondarily attack weak salmon and it is important not to discount the possibility of a similar situation in sea trout. The lower numbers of lice levels recorded, the scarcity of early returning sea trout smolts and lesser severity of lesions in Scotland compared with Ireland does not correlate with the relative sizes of the salmon farming industries (several times larger in Scotland) or with the severity of lice problems in each area; a significant proportion of the Irish farmed salmon production is from offshore cages with less lice problems.

More research is needed on the biology of sea trout in the period immediately after they enter sea water, on the pattern of accumulation of sea lice infection and on the effect of different levels of lice infestation on the survival and behaviour of individual fish before definitive answers can be obtained to these complex questions.

7.5 Acknowledgements

We would like to thank Mr A F Walker, Dr S J Northcott and other staff at FFL Pitlochry for considerable cooperation during sampling and many other different aspects of this study. We would also like to thank Dr A D Hawkins and Dr A Munro for critical reviews of the manuscript.

8 SUMMING UP THE EVIDENCE

(Dr Geoffrey A Tingley, Imperial College, London)

The formal presentations covered a very wide range of subject areas and in a great deal of depth. It is crucial, if successful action is to be forthcoming, that those areas of most immediate importance be addressed, not to the exclusion of other areas of concern but as priority.

A brief examination of the rod and line catch returns for salmon and sea trout was shown for the Northwest region (as defined by the Scottish Office) by Mr Walker. This showed that the catches of salmon were not declining, but rising slightly, even allowing for the effect of fish farm escapes and decreased netting. This was also very clearly not the case for sea trout. The decline of sea trout catches in the Northwest region from an average of around 9,000 fish in the early 1950s to about 2,000 now can only be described as extremely worrying. The pattern of catches over the last few years shows a further marked drop, in addition to the general decline, to very low levels. Although this pattern will have been affected by changes in the pattern of fishing effort in the last year or so (ie declining effort, the taking of smaller fish - as indicated by Mr Walker and as can be seen in reported catch weight data) there can be little doubt that the position for sea trout is very serious and probably the prime motivation in the arrangement of the meeting.

Mr Walker gave a very thorough and, unfortunately, rather depressing overview of the status of the sea trout in the North and West of Scotland that effectively speaks for itself. Water quality in freshwater is not implicated in most areas as good stocks of brown trout can be found and based on sex ratios, there were no indications that sea trout were becoming less migratory. Mr Walker reported on evidence for poor marine survival of post-smolts in Eire, with an effective lack of equivalent Scottish data.

Probably the most important of the findings reported by Mr Walker is the apparent lack of any major, regional problem in the freshwater part of the sea trout life-cycle. Coupled with some evidence for good smolt transfer to sea water, the inevitable conclusion has to be that any problems are occurring during the marine phase.

It is, therefore, my conclusion that we should, as a matter of some urgency, concentrate our efforts towards an understanding of the reasons for the rather dramatic decline in the sea trout of the Northwest and attempt to identify ways of reversing the trend if at all possible.

This is not to assume that all is well with the salmon in this area. As was shown with clarity by Mr Webb, fish farm escapes pose some significant threat to the salmon stocks on a number of fronts, particularly by genetic dilution, competition for limited resources (spawning redds, juvenile habitat) and, by my inference, possible disease transmission as well. In this context, efforts to reduce the numbers of fish that escape and to use fish that will have a minimal effect if and when they do escape, such as sterile individuals, should be encouraged. The efforts of NASCO (as reported to the meeting by Dr Windsor) in this direction are to be applauded, as are plans by The Scottish Office to introduce separate reporting for the capture of escaped salmon from farms in the net and rod fisheries. It is also of note that, during the discussion, it was made clear from the floor that in some areas salmon have also undergone some alarming local declines which need to be addressed, albeit, at a local level in the first instance.

Significantly, the pattern of sea trout catches from other areas of Scotland do not show the same recent downward trend. For example, the patterns for the Northwest, West and Outer Hebrides regions all show significant declines, whilst those for the East and Northeast show recent increases. Given this evidence, it would appear that the cause or causes are local to the North and West rather than more general and wide spread.

Dr Turrell showed us that there were long term climatic factors that appeared to be correlated with the overall pattern of catches of salmon. This was a particularly compelling presentation with regard to salmon and has the potential to aid our understanding of the long term fluctuations in salmon abundance. It was, however, not apparent that the oceanographic patterns presented showed any fit to the pattern of sea trout catches for Scotland in general or those of the Northwest in particular.

In his very interesting description of sandeel biology Dr Wright provided a sound basis for our understanding of the interaction of salmonid populations and one of their major coastal prey species. The most important point brought out in this paper was the very local nature of some of the major events in sandeel population dynamics. No data were presented to suggest that the hypothesis that in years of strong recruitment to the sandeel population, smolt survival would tend to be enhanced and in years of poor sandeel recruitment, smolt survival may be poorer as a consequence, was in error.

Data reported and analysed by ICES working groups does, I believe, show that 'O' group sandeels are present and form part of the catch of the industrial fleet during the months where post-smolts are likely to be feeding on them. What is also important, is that the numbers of '0' group sandeels actually available at this time, in a local area, may be relatively low and thus a fishery for sandeels has at least the potential to interact with post-smolts.

Disease has always to be a concern when animal populations show rapid declines. Dr McVicar described in some detail the lengths to which he and his colleagues have gone in looking for a range of diseases in the migratory salmonids in Scotland and in the North and West coast sea trout in particular. There are many sampling problems in finding parasites in affected stocks and there are additional problems in identifying the causative organism and such studies certainly require more time. However, it is important that no disease has been implicated as the cause of the current problem as yet. In considering sea lice, Dr McVicar indicated that no relationship between the intensity of infestation and fish condition had been found but that, based on limited data, intensity in the Northwest tended to be higher than elsewhere (also reported by Mr Walker). Demonstrating such effects in the field is, however, notoriously difficult.

The finding from the cage experiments that more sea lice occurred on the caged animals when the cage was closer to a salmon farm is obviously a preliminary result but may be of considerable importance and further experiments of this type would be welcomed.

In the context of disease, one question would be, are newly descended smolts being attracted to sea cages (as are other marine fish) for a 'free' meal and there exposing themselves to infection?

Finally, Mr Semple, in a brief unscheduled presentation, raised the question of possible interactions between salmon farming activities and the decline of the sea trout. Such questions have and are being examined in Eire and Norway with respect to some diseases but have only recently really begun to have been examined in Scotland. Although the principal suspect would appear to be diseases, other effects, such as interference in homing, should not be excluded from study at this stage.

In conclusion, the available evidence all points to a problem for sea trout at sea, probably as post-smolts and, therefore, relatively coastal. A number of key questions that need to be addressed emerge naturally, firstly for the immediate future and then for the longer term.

There are four questions concerning immediate remedial measures that could be taken with respect to the sea trout, particularly given the reduction in the probable egg output by sea trout populations as reported by Mr Walker. These are (a) what is the impact of angling on sea trout populations at low population levels and what would be the effects of implementing (b) bag limits on all catches and (c) catch and release policies. Different types of bag limits (area, catchment, angler and time based) may have different implications for the stock and for proprietors. Finally, is there likely to be any benefit, short or long term, of further enhancement using local brood stock?

A number of maps showing the main salmon farming sites in Scotland are available. It is obvious that the general area where there have been sea trout problems coincides with the general geographical distribution of marine salmon farm sites. This does not necessarily imply cause and effect but a study to examine the possibility that salmon farming activities could be having a detrimental effort on wild migratory stocks appears essential at this time.

One of the problems that was apparent in a number of the analyses prepared for this meeting was that estimates of the size of the stocks of salmonids had to be based upon catch data only. As far back as 1985 a detailed statistical appraisal of the Scottish salmonid catch statistics found them inadequate for the purpose of stock assessment (Lakhani, 1986). Surely, it is time that data that would enable better estimates to be made of the size of the stocks of salmon and migratory trout in north west Scottish rivers were collected?

9 STATEMENT BY JAMES E SEMPLE
CHAIRMAN, RIVER SHIEL (Loch Shiel District Salmon Fishery Board)

I have listened with great interest to the careful presentations made today. I believe that they contribute much to the advancement of the subject which concerns us all.

I believe that today's conference presents us with a special opportunity to agree what might be done to protect our stocks of wild sea trout and salmon to benefit not only the environment but also the livelihood of thousands of Scots whose living depends on the sport of angling for these magnificent fish.

I have two proposals to make:

The first is that this conference should request the authorities to conduct detailed research into the reasons for the long term and short term decline in the sea trout population and rod and line catches in a number of parts of Scotland and to take steps intended to repair the damage which has taken place and to monitor the position in the future.

The second is to request the authorities to enforce controls on those who operate salmon farms requiring them to rear stocks in conditions which are disease-free from the perspective of wild sea trout and salmon as well as reared fish.

I wish to make it quite clear that what I am not proposing is any kind of war against those who operate salmon farms. I believe that they make a very great and very welcome contribution to the country's economy. I have no wish to inflict damage on that industry, but what I do say is that there are legitimate interests competing for the same environment, in this case, parts of sea.

Not everyone who is here may know that in 1989 the Scottish Tourist Board surveyed the economic importance of salmon fishing and netting in Scotland. That report estimated that approximately 3360 jobs on a full time equivalent basis were generated in Scotland by salmon and sea trout angling. The total expenditure estimated to be generated from the same source was approximately £50.4 million.

It is necessary for these different interests to respect each other's needs and to conduct their activities in a way which inflicts the least possible harm on the others. I believe that at present this is not being recognised nor achieved between those who depend on wild salmon and sea trout and those who depend on farmed salmon for their living. I believe a great deal can and should be done, now.

9.1 What is the evidence for the decline in sea trout?

The Scottish Office Statistical Bulletin is the official source of information. The tables in the editions for 1992 and 1993 catches are as follow:

	Rod & Line	All methods
5 year average 86/90	43.7 k.	94.2 k.
5 year average 87/91	40.0	83.3
1990	27.8	57.4
1991	27.5	50.1
1992	34.3	64.5

Regrettably the commentary compares the 1992 figures with the 1991 figures which allows it to report an increase. If the comparison is with the previous 5 year average the figures show a substantial fall.

This is confirmed by my own experience in the River Shiel and my neighbours in the Lochy and Morar where the sea trout fishing has all but disappeared. In the 1960s these rivers were producing many hundreds of sea trout of good size.

I believe that many other West Coast rivers have shared the same fate.

It also appears from the Statistics that the East coast rivers have suffered much less than some of the West coast rivers.

9.2 What do we know about why this problem has come to pass?

Regrettably very little research on sea trout in Scotland has been published.

On the other hand, in Ireland considerable work has been done and been published. In May of this year a number of papers were given on the subject to a conference in Galway on Aquaculture in Ireland.

Dr Ken Whelan (a Director of the Salmon Research Agency of Ireland) gave a paper on a "Historic Overview of the Sea Trout Collapse in West of Ireland". He observed that the affected areas closely parallel areas where salmon farms are present and the survival of sea trout appears to follow the presence or absence of salmon farms in specific bays.

The same conference heard the results of The Sea Trout Working Group 1992 reporting to the Minister for The Marine. This showed the large amount of work done on the subject there. The studies confirmed the serious collapse which had taken place in stocks and which was continuing.

It reported that significant numbers of prematurely-returning sea lice-infested sea trout were obtained from the south west in the area of sea cages and that this must be considered a serious new development.

It is evident that there may be many reasons for the fall in numbers of sea trout and that the salmon farms may be one of them.

To the best of my knowledge the published research into sea trout in Scotland is minimal.

I would propose to you that it is not acceptable that we in Scotland should have to rely on research carried out in Ireland to help us to decide what action should be taken.

The issue is one of significant commercial importance to Scotland. It is here that research on a matter of such importance to us should be done and published.

For this reason I request support for my first proposal.

9.3 What is the threat posed by the salmon farms to the wild fish stocks?

I have already cited the results of research carried out in Ireland. The Norwegian experience seems to confirm the Irish experience. At the conference in Galway in May of this year which I previously mentioned, Dr Per Jakobsen of the University of Bergen, presented a paper on "Lice Infestation of Wild Salmonid Populations in Norway". His work shows that wild salmonids suffer high mortalities and reduced growth due to lice infestations. He said that when compared with the Irish registrations (of lice) the sea trout in Norwegian waters had more than three times as high infestation rates as the Irish smolts. In the same way as in Ireland the nearer the fish were to the fish farms the greater were the infestations.

In Scotland the lack of published research makes it hard to draw conclusions. However the statistics published by the Scottish Office show that the coastal areas which have suffered worst from falls in sea trout are those areas where the fish cages are mainly situated namely in the North West, West and Outer Hebrides.

I do not, of course, suggest that there are no other reasons for falls in the fish stocks. However the evidence from elsewhere suggests that fish cages are an important factor.

The Irish have been working on a system intended to reduce the problem. It is called the Single Bay Management System. This includes three strategies:

- Fallowing (which they claim originated in Scotland).
- Single generation per site management.
- Coordination of treatments amongst salmon farmers.

Such a system has important implications for the management and organisation of the farms. If it is successful it may be one way in which the farmers could be required to accommodate the needs of those whose livings depend on the wild fish.

Such a proposal also may require new law to be made. It is reasonable that the government should be asked to invest in the regulation of an industry from which they receive tax benefits.

The comments of the chairman, Professor Palmer Newbould, at the Galway conference are an apt conclusion.

He said, "We need an awareness of the needs of the different uses of the aquatic environment and of the need to seek a strategy which will allow each to survive in a sustainable way".

The view of the National Trust for Ireland is that unless these matters are addressed and dealt with immediately, the famed wild sea trout runs, and the viable industry which they support, will become only a memory.

I suggest that the situation in the West and North West of Scotland is the same.

I ask you, therefore, to support my second proposal.

10 GENERAL DISCUSSION - A SUMMARY BY LT COL G D B KEELAN

10.1 Introduction

The discussion opened with a statement by Mr James Semple, a transcript of which is included above. He made two proposals which were that:

- There should be detailed research into the reasons for the decline in the sea trout population and rod and line catches in parts of Scotland so remedial measures could be taken.
- Controls should be enforced on salmon fish farmers requiring them to rear stocks in disease free conditions.

10.2 Mr Malcolm Windsor, Secretary to NASCO, made a statement about a meeting held very recently at which the wild and farmed fish interaction had been discussed. NASCO felt that the evidence was strong enough to conclude that there was a linkage between the wild stock collapse, the subject of this conference, and the activities of fish farms. He felt strongly that action should be taken now before it was too late and that the precautionary principle should apply. The genetic resource was finite and the issue was so immediate that it was inappropriate to wait for conclusive scientific proof. He was optimistic that progress was being made and reported that an international dialogue was underway. There was to be another meeting in January 1994 at which the questions of sterilised fish in fish farms and aquaculture free zones would be addressed.

10.3 Q. Mr Fred Lang asked about the pheromone trail and whether farmed stocks would cause dislocation to the scenting systems of returning wild stocks.

A. Mr Alan Youngson explained the workings of pheromones and the theory developed in Norway that returning fish follow a trail left by smolts at the start of the marine phase of their life cycle. He thought that such action was most unlikely in the light of Scottish evidence but it could not be discounted. It was more probable, in his view, that there was a process of sequential imprinting on the smolt memory.

10.4 Q. Mr John Douglas-Menzies referred to the talk in the morning by Dr W R Turrell on oceanographic factors. Mr Orri Vigfusson was able to predict likely salmon catches based on sea temperature and white fish catches. Perhaps these should be measured more generally and then correlated in respect of Scottish salmon. He went on to say that the Lochy DSFB, of which he was Chairman, was experiencing catches of which 69% were 'foreign' that is from different rivers of origin. He asked if stocking with fish from a different river - such as Conon fish in the Lochy - would cause harm. He had observed that Conon fish introduced into the Helmsdale had a distinct and different look to them.

A. Mr Alan Youngson answered that local adaptations were possible but that the genetic balance might be altered. He talked of the balance between the mortality rates of introduced and native fish. He, too, agreed that time was of the essence if these declining stocks were to be saved.

A. Dr Dick Shelton made the further point that the late 1960s and 70s were periods of exceptional abundance for a number of species of sub-arctic fishes including Atlantic salmon, cod and haddock.

10.5 Q. Mr Malcolm Spence supported Mr Semple in his earlier statement and proposed that Boards should come together to form larger geographical groupings, probably under the broad guidance of the Association of DSFBs, with a view to identifying mutual interests and perhaps raising funds for research. **Mrs Penny Murch** subsequently explained the problems she faced with sea trout when she took over as Chairman of the Hope and Polla DSFB. She greatly regretted the decline of these exciting fish. The size of sea trout caught on the Hope had increased but the numbers were half what they were. She was grateful for the help already given by the Freshwater Fisheries Laboratory and asked to join any grouping that might emerge in the North West.

A. Mr Andy Walker confirmed that matters in the Hope and Polla District were improving.

A. Dr Alistair Stephen spoke of the West Galloway Trust and described some of its work and how it was set up. It had gained charitable status because it existed to enhance the natural resource rather than to improve the fishings. Here was clearly an example for others to follow if they so chose.

A. Admiral Mackenzie reported that The SO(AFD) had limited resources with which to fund further research and Government budgets were in any case being reduced. DSFBs may well have to resource research more fully and that groupings of which the West Galloway Trust was an excellent example, should be formed to help spread the financial burden. He went on to say that not all Districts had formed Boards. This should happen and they should join the Association of DSFBs.

A. Colonel Keelan advised that it was very much on the Association's agenda to encourage smaller Boards to form larger groupings and expand the membership. The more we were all of one company the firmer our base would be and the stronger our hand. The matter was being addressed at the Association's AGM in April 1994 and members were encouraged to start gathering ideas.

A. Mr Robert Williamson, Inspector of Fisheries, said that such moves should come from within.

10.6 Q. Mr Colin Carnie asked, in the light of the morning's scientific presentations and the discussions, what was actually going to happen next. The Salmon Advisory Committee had already looked at some of the issues that had been raised and the time had most certainly come for the exercise of the precautionary principle. There was an urgent problem and assumptions should be made now albeit based on partially complete information. It might well be necessary to exercise a catch and return policy, regardless of the commercial imperative, until such times as stocks had recovered.

A. Dr Dick Shelton felt that, in the light of present stock levels, finnock should not be killed. A reduction in exploitation was necessary. He reported that the quality of research in Scotland was every bit as good as that in Ireland.

A. **Mr Andy Walker** felt that Ireland had a greater problem with sea lice and had been able to devote more resources to the problem.

A. **Mr Read** from Ireland confirmed that he did not think that sea lice were solely to blame for the Irish decline. He felt that scientists in Scotland were looking at the problem from a much broader base and that this was healthy.

10.7 Q. Mr John Noble reported that his District, Loch Fyne, had seen a total stock collapse of salmon as well as sea trout. He asked if this was so elsewhere and whether it was right to look at the problem purely in terms of sea trout. He felt strongly that matters had deteriorated so badly particularly as, in his own case, he had spent considerable sums of money on research programmes and other management measures to no obvious benefit. He asked for guidance on how Districts could help themselves.

A. **Mr David Dunkley** said that it was not possible to give specific answers on salmon catch returns as they were compiled on a more general basis.

A. **Dr Dick Shelton** said that, in his view, where there was a stock collapse, the fishery should be closed. If the problem was at sea, there was less that could be done in the short term. Stocking was not necessarily the answer.

A. **Mr Fred Lang** reported that there was a stock collapse on the Carron.

10.8 Q. Mr Ian McDonald felt that grilse were more aggressive than sea trout and might be destroying the redds and spawning grounds of sea trout. He asked if managers should be doing more to protect sea trout redds. He went on to say that in British Columbia, Canada, school children were brought in to help with elementary research and data collection. Perhaps the same could be done in Scotland.

A. **Mr Andy Walker** reported that from his own observations, trout burns were for trout and salmon burns or rivers were for salmon. There was some overlap but, generally speaking, each had different requirements and he was not aware of a problem in this respect.

A. **Dr Dick Shelton** mentioned the riverine buffer zone set aside plan set up by The Scottish Office, albeit limited to only a few rivers. The nursery habitat was an area of greater risk than the redds. He went on to say that schools were often approached and contributed periodically to the research effort. This was confirmed by **Dr Alistair Stephen** from the West Galloway Trust.

10.9 Mr John Webster sought to reassure those present that the SSGA took the sea lice problem very seriously. The use of marine medicines was carefully monitored. He explained that funding arrangements within the SSGA were limited and monies raised came only from the growers themselves.

10.10 <u>Conclusion</u>

This discussion concluded with a proposal by Mr James Semple and seconded by Mr Malcolm Spence, that the meeting accept the proposals tabled at the beginning of the afternoon (paragraph 1). The Chairman felt that it was inappropriate to vote because the purpose of the meeting was exploratory and in any case it had no established constituency. Nor was it known whether the Scottish Office would be able to provide funding of the sort this research would require. The conference had been successful in bringing to notice the major salmonid stock problems that existed in many Districts of the Western Highlands and would lead to carefully considered and achievable action plans. On that note the meeting was closed.

11 REMEDIAL ACTION FOLLOWING THE DEPLETION OF SEA TROUT POPULATIONS - ADVICE TO DISTRICT SALMON FISHERY BOARDS

11.1 Introduction

Following the (30 November 1993) meeting at the Drumossie Hotel, Inverness on "Problems with sea trout and salmon in the western highlands", the following notes have been prepared by The Freshwater Fisheries Laboratory on remedial conservation measures for sea trout.

11.2 Restrictions on fishing

In a number of west highland catchments, the availability of sea trout to the fisheries has reached the point where there is real concern about the adequacy of spawning stocks. In the worst affected areas there is a case for restricting fishing to make the most productive use of the depleted runs.

It could be argued that directed fishing for sea trout should be banned altogether until stocks recover and any caught as a by-catch when fishing for salmon should be released.

If this option is not possible for economic or social reasons, the next best thing would be a total catch and release policy for sea trout. Ideally, this policy would specify the use of barbless hooks and non-removal of the fish from the water to avoid scale-loss and handling stress.

A variety of less effective restrictions are possible, including the compulsory return of all finnock and the banning of all capture methods other than fly fishing. Although better than nothing, these partial measures have much less conservation value than the first two options specified.

11.3 Freshwater habitat conservation

The weight of scientific evidence suggests that the immediate cause for recent stock collapses is a sharp reduction in the survival of sea trout at sea. Intensive efforts are being made to address this problem. In the meantime it is very important to ensure that freshwater conditions for sea trout adults and juveniles are as good as they can be.

Everything possible should be done to ensure the free access of spawners and any polluting inputs, including less obvious effects such as siltation from forest drainage and the erosion of unfenced banks by livestock, should be reduced to a minimum. The prompt reporting of polluting incidents to River Purification Boards is essential.

Where possible, the natural regeneration of bankside vegetation should be encouraged to increase holding and parr rearing capacity and to help consolidate banks. New forest planting and the clear-felling of mature trees should take proper account of the Forest and Water Guidelines published by the Forestry Commission.

11.4 Stocking

Stocking depleted tributaries should not be undertaken without the advice of the Scottish Office Freshwater Fisheries Laboratory at Pitlochry (Mr A F Walker, Tel. 0796 472060).

In general, the planting out of ova and juvenile salmonid fishes is effective only when the wild stocks are inadequate to make full use of the spawning and nursery habitat available. It is not possible to make this judgement without a direct investigation of the distribution and abundance of the juvenile population. Normally this requires an electro-fishing survey. If it is clear that there is cope for stocking, local broodstock should be used wherever possible. Stocking options include the planting out of green or eyed ova, unfed or fed fry, parr and smolts. There is no one correct method. The preferred option will depend upon local circumstances. Advice is available from the Scottish Office Freshwater Fisheries Laboratory.

11.5 Reporting of diseased fish

Where diseased or heavily-parasitised fish are seen, the affected fish should either be retained alive, or, if dead, kept chilled (rather than frozen). Contact should be made immediately with the Scottish Office Marine Laboratory, Aberdeen (Dr Alasdair McVicar, Tel. 0224 876544) so that arrangements can be made for the specimens to be collected.

FORMATION OF WEST HIGHLAND SEA TROUT AND SALMON GROUP

Rear Admiral John Mackenzie, Director of The Atlantic Salmon Trust announced today the formation of the "West Highland Sea Trout and Salmon Group" to tackle the problem of declining sea trout and salmon in the West Highlands including the Outer Isles.

The remit of the group is to work together with local and other interests to rehabilitate - through coordination, cooperation, appropriate resourcing and other means - the sea trout and wild salmon fisheries in the West Highlands including the Outer Islands.

John Mackenzie has agreed to chair the group consisting of :

The Atlantic Salmon Trust
The Association of Scottish District Salmon Fishery Boards
The local proprietors, represented by Jim Semple
The Salmon & Trout Association
The Crown Estate Commissioners
The Scottish Salmon Growers' Association
The Scottish Office Agriculture and Fisheries Department

He is very encouraged by the immediate and enthusiastic response from the organisations involved.

Commenting on the formation of the West Highland Sea Trout and Salmon Group, Sir Hector Monro, Minister for Agriculture and the Environment said

"I commend this cooperative action aimed at tackling the problems affecting some sea trout and salmon stocks in the West Highlands. Rear Admiral John Mackenzie, the Chairman of the Group, can be assured of my, and my Department's full support for the Group's work".

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