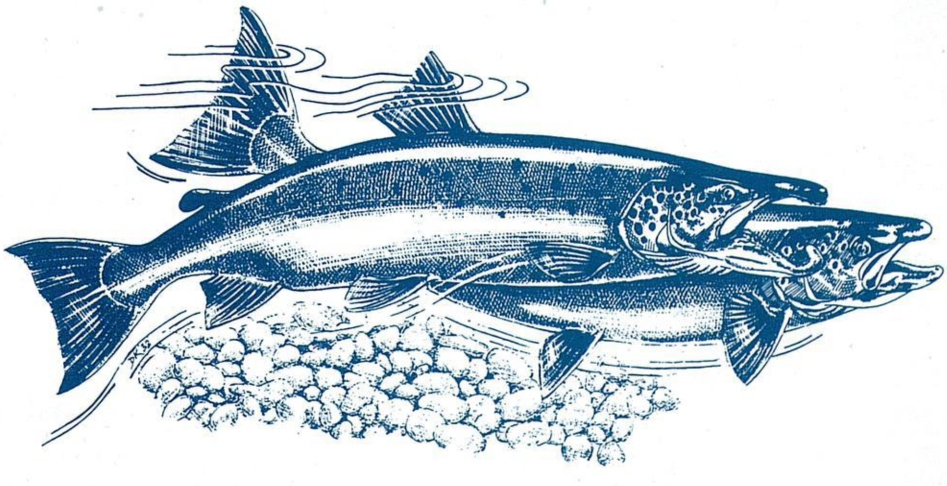
FACTORS AFFECTING SALMON IN THE SEA

Report of the Salmon Advisory Committee



Ministry of Agriculture, Fisheries and Food
Scottish Office Agriculture, Environment and Fisheries Department
Welsh Office Agriculture Department

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1. INTRODUCTION

The Salmon Advisory Committee was established by Fisheries Ministers in October 1986. Its membership is shown at Appendix A.

The terms of reference of the Committee are:

> 'To examine and report on those matters relating to the conservation and development of salmon fisheries in Great Britain which are referred to it by Fisheries Ministers.'

1.1 AIMS AND OBJECTIVES

Ministers have asked the Salmon Advisory Committee to examine the various influences on wild salmon stocks. These are numerous and varied, both in their nature and extent. We recognised that this subject was therefore too large to be addressed in a single report, and that a convenient and logical way to proceed was to consider human activities in terms of their impact on distinct phases of the life-cycle. With this in mind we have already produced two reports on the effects of these activities on the Atlantic salmon. We have identified those activities which may have significant and widespread effects on salmon and their environment. We have also made constructive and practical recommendations where there is a reasonable expectation that undesirable effects can be alleviated.

The first of these reports, *Factors Affecting Natural Smolt Production*, was published in May 1991 and dealt with human activities that affect the survival of juvenile salmon prior to their migrating as smolts. The report contained a number of recommendations and also pointed to the need for a more integrated approach to all aspects of stream management, including the creation of buffer zones between agricultural activity and the water course. The second report, *Factors Affecting Emigrating Smolts and Returning Adults*, published in May 1993, considered the activities which can affect emigrating smolts and returning adults in fresh water and estuaries. It highlighted the importance of minimising adverse impacts upon the fish by explaining the possible consequences of various forms of human activity which can affect survival and seriously disrupt the natural movements of fish to and from the sea.

This, the third report in the series, concentrates on the remaining stages of the life-cycle, and those factors affecting growth, survival and distribution of salmon in the sea. In it we have reviewed the effects of both natural factors and human activities, including fishing; we have also attempted to highlight data deficiencies and research requirements and have recommended a number of possible management actions.

Two of our other reports also refer to salmon in the sea. The report entitled *Run Timing of Salmon* examined the influence of the marine environment, and the effects, both direct and indirect, that long-term changes in environmental conditions may have on salmon in the sea. It also highlighted the importance of developing long-term monitoring of oceanographic processes.

Predation occurs at all stages in the life-cycle of the Atlantic salmon and is yet another factor that can affect salmon populations in the sea. This subject was covered in greater detail in our report on *The Effects of Predation on Salmon Fisheries*.

The superscript numbers used throughout this report refer to the publications listed in numerical order at Appendix B.

2. NATURAL FACTORS AFFECTING SALMON IN THE SEA

2.1 INTRODUCTION

Natural features and variations in environmental conditions can have a major impact upon the survival and growth of salmon in the sea, and any human interference is superimposed on these already powerful influences. We therefore present in this section a description and discussion of the influence of the natural environment on salmon in the sea, as a forerunner to the consideration of human activities in Section 3.

Migration to sea is advantageous to salmon because of the greater opportunities it provides for rich feeding, rapid growth and larger ultimate size, and thus reproductive potential, than would be possible in fresh water. When they leave the river, smolts generally weigh less than 50 g. Those returning in the following year as grilse usually weigh 2–5 kg. Fish returning after two sea-winters generally weigh from 3–7 kg, while those remaining a further year may weigh 8–16 kg. Thus over 95% of the growth in weight of salmon occurs at sea.

Below we present a brief synopsis of the life-history and biology of salmon in the sea.

In Britain, salmon migrate to sea in the spring, typically at an age of one to three years and a length of 10–18 cm. They usually descend the river in shoals, but the extent to which these shoals persist in the sea is not known. For the purposes of this report, the fish are termed smolts until they leave coastal waters and post-smolts until the beginning of their first sea winter.

As salmon smolts are seldom caught in coastal waters, it is assumed that they leave the area promptly and actively, in contrast to the more coastally distributed sea trout. They migrate to and feed in a wide area of sea to the north and north-west of Britain, extending from the Norwegian Sea to West Greenland, particularly areas of nutrient upwelling and high productivity, which provide rich feeding. Salmon are carnivorous, feeding on a wide range of animals. Prey species found in salmon stomachs include crustaceans, squid and a wide variety of fish.

Salmon are caught in a number of fisheries, both as target species and as by-catch. Directed fisheries on feeding salmon occur in Faroese and West Greenlandic waters and in the international waters of the Norwegian Sea. Salmon are also exploited by coastal and estuarial net fisheries in home waters on their return journey. They may come into coastal waters a considerable distance from their home rivers, and then follow the coastline. They may thus be exploited by coastal fisheries a long way from their home river.

Salmon acquire a range of parasites during their life in the sea, but most are not considered to be a serious cause of mortality. However, on occasions heavy infestations of ectoparasitic sea lice cause extensive damage to the skin which may lead to mortality in the sea or on return to fresh water. Some diseases, such as fungal infestations, are killed by salt water but others like infectious pancreatic necrosis (IPN) can persist in salmon in the sea. However, the presence and impact of such diseases may be difficult to detect in the sea because affected fish are not seen.

Estimates of survival rates for salmon from their emigration as smolts to their return to coastal waters as adults vary geographically and between years; values for wild smolts typically lie between 10% and 30% but higher and lower values have been observed. In the early stages, fish are small and vulnerable to a wide range of predators, and it is likely that much of the mortality occurs soon after migration to sea. However, some of the factors responsible for year-to-year variations in marine mortality operate far from Britain. Several investigations have correlated changes and trends in oceanographic conditions with survival rates and changes in the age composition of populations of returning fish.

Much of the remainder of this section deals with oceanographic features and these are related to three phases of the salmon's migration at sea: the emigration of smolts through coastal waters; the distribution of larger salmon in the open ocean; and the return of maturing fish to their home river. Two other subsections address the factors affecting salmon as a predator and as prey to other species.

2.2 OCEANOGRAPHY

2.2.1 Emigration through coastal waters

The early weeks and months spent by young salmon in the sea are believed to be critical to their survival. Changes in natural environmental conditions are thought to have a major impact upon mortality at this stage. However, little information is available on how the fish behave in relation to currents, water temperature and other environmental factors, or on the migration routes they take.

Small numbers of smolts have been caught in coastal waters and a few post-smolts further offshore. These have generally been caught in surface waters. During their passage across the continental shelf towards deeper oceanic waters, smolts and post-smolts will be influenced by various tidal and residual (non-tidal) currents around the coast of Great Britain (Figure 1). Smolts entering the sea on the west coast will meet a strong northerly current (3–10 cm per second). As the speed of this current is of a similar order of magnitude to the normal swimming speed of the fish (about 10 cm per second), it will tend to transport them in a northerly direction.

Smolts that enter the North Sea will tend to encounter weaker (up to 5 cm per second) southerly currents which will have less effect on their movements. Around the north of Scotland, the Fair Isle Current flows into the North Sea at a speed of about 10 cm per second but the smolts can probably swim across it fairly quickly.

As the young salmon leave the waters of the European continental shelf, they must cross the well-defined and persistent Shelf Edge Current (Figure 1). This current is strong all year round, and around the north of Scotland flows at speeds of up to 30 cm per second towards the north-east. The current is known to be a migration route for mackerel when moving north from their spawning grounds south-west of Ireland and may be used by salmon from Ireland and the west coast of Great Britain to move rapidly north towards the Norwegian Sea. Indeed, surveys undertaken in 1995 by a Norwegian research vessel using a large surface trawl caught some small salmon along the Shelf Edge to the west of Scotland (June) and to the west of Norway (July/early August).

The temperature and salinity of the water encountered by smolts on entering the sea are determined by a number of local and more general climatic factors. Run-off from the land after heavy precipitation may have significant effects on the temperature of coastal waters. In addition, shallow coastal areas, as well as the surface waters in the open ocean, are significantly heated and cooled by short-

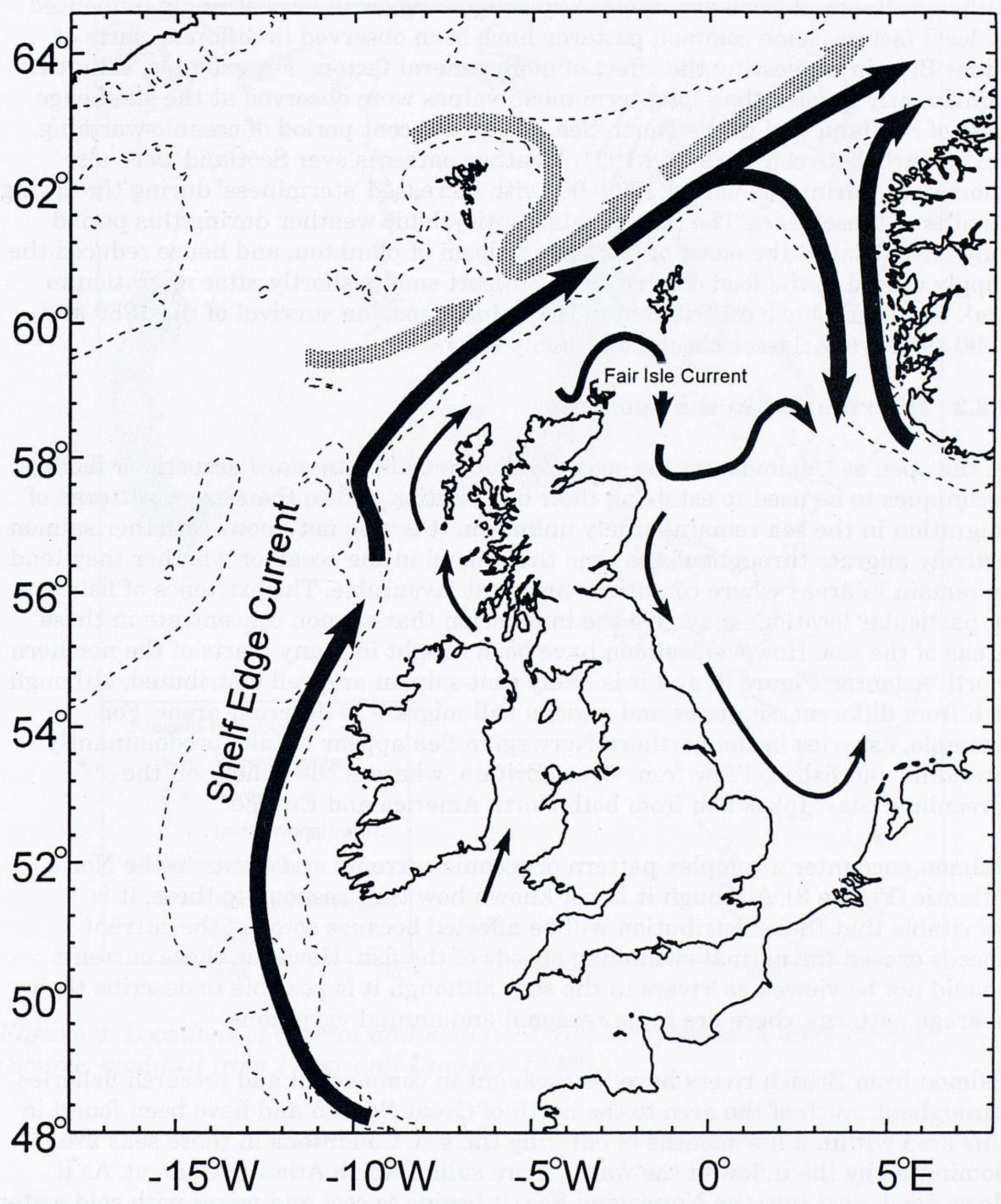

Figure 1: *Schematic summary of the typical mean long-term residual circulation around Great Britain. The main currents affecting emigrating salmon smolts are shown. (Source: modified from Turrell, 1994[1])*

period local weather events such as solar warming during calm spells. The waters further offshore are influenced by the relative proportions in the mixture of Atlantic and coastal waters, which in turn are determined by the magnitude of the various wind-driven movements of oceanic water onto the continental shelf. The temperature and salinity of the Atlantic water itself vary seasonally and annually.

Although the conditions experienced by emigrating smolts are strongly influenced by local factors, some common patterns have been observed in different parts of Great Britain suggesting the effect of more general factors. For example, salinities significantly greater than long-term mean values were observed at the shelf edge west of Scotland and in the North Sea during a recent period of oceanic warming, particularly between 1989 and 1991. Weather patterns over Scotland were also anomalous during the period 1989–90, with increased 'storminess' during the spring months of those years. The lack of calm, anticyclonic weather during this period may have delayed the onset of the spring bloom of plankton, and hence reduced the supply of food to the food chains which support smolts shortly after migration to sea[1]. This could have contributed to the reduced marine survival of the 1989 and 1990 smolt year classes observed in many rivers.

2.2.2 Distribution in the open sea

In the open sea, salmon are too sparsely dispersed for standard acoustic or fishing techniques to be used to establish their distribution and so their exact patterns of migration in the sea remain largely unknown. It is also not known whether salmon actively migrate throughout the time they spend in the ocean or whether they tend to remain in areas where conditions are most favourable. The existence of fisheries in particular locations may give the impression that salmon concentrate in those areas of the sea. However, salmon have been caught in many parts of the northern North Atlantic (Figure 2) and it is likely that salmon are well distributed, although fish from different countries and regions will migrate to different areas. For example, fisheries in the northern Norwegian Sea appear to take predominantly Scandinavian fish and few from Great Britain, whereas the fishery off the Greenland coast takes fish from both North America and Europe.

Salmon encounter a complex pattern of oceanic currents and fronts in the North Atlantic (Figure 3). Although it is not known how they respond to these, it is inevitable that their distribution will be affected because some of the current speeds exceed the normal swimming speeds of the fish. However, these currents should not be viewed as 'rivers in the sea'; although it is possible to describe their average patterns, there are large seasonal and annual variations.

Salmon from British rivers have been caught in commercial and research fisheries throughout much of the area to the north of Great Britain and have been found in this area within a few months of entering the sea. Conditions in these seas are dominated by the inflow of the warm, more saline North Atlantic Current. As it flows north-east into the Norwegian Sea, it begins to cool and mixes with cold water of low salinity originating in the Arctic Ocean. The complex nature and interaction of these currents (Figure 3) results in the formation of distinct oceanographic zones separated by fronts[3]. These fronts are areas with high levels of planktonic production[4] and a mixture of Arctic and sub-Arctic plankton species[5]. As a result, they may be important feeding areas for salmon.

Some salmon may migrate no further than the Norwegian Sea before returning to their home river as one-sea-winter fish (1SW), but those that remain in the sea for one or more additional years may travel as far as Greenland before returning. In this area, cold Arctic water (the East Greenland Current) flows southward along the east coast of Greenland, where it meets warmer saline water (the Irminger Current) which is an offshoot of the North Atlantic Current[6]. These currents

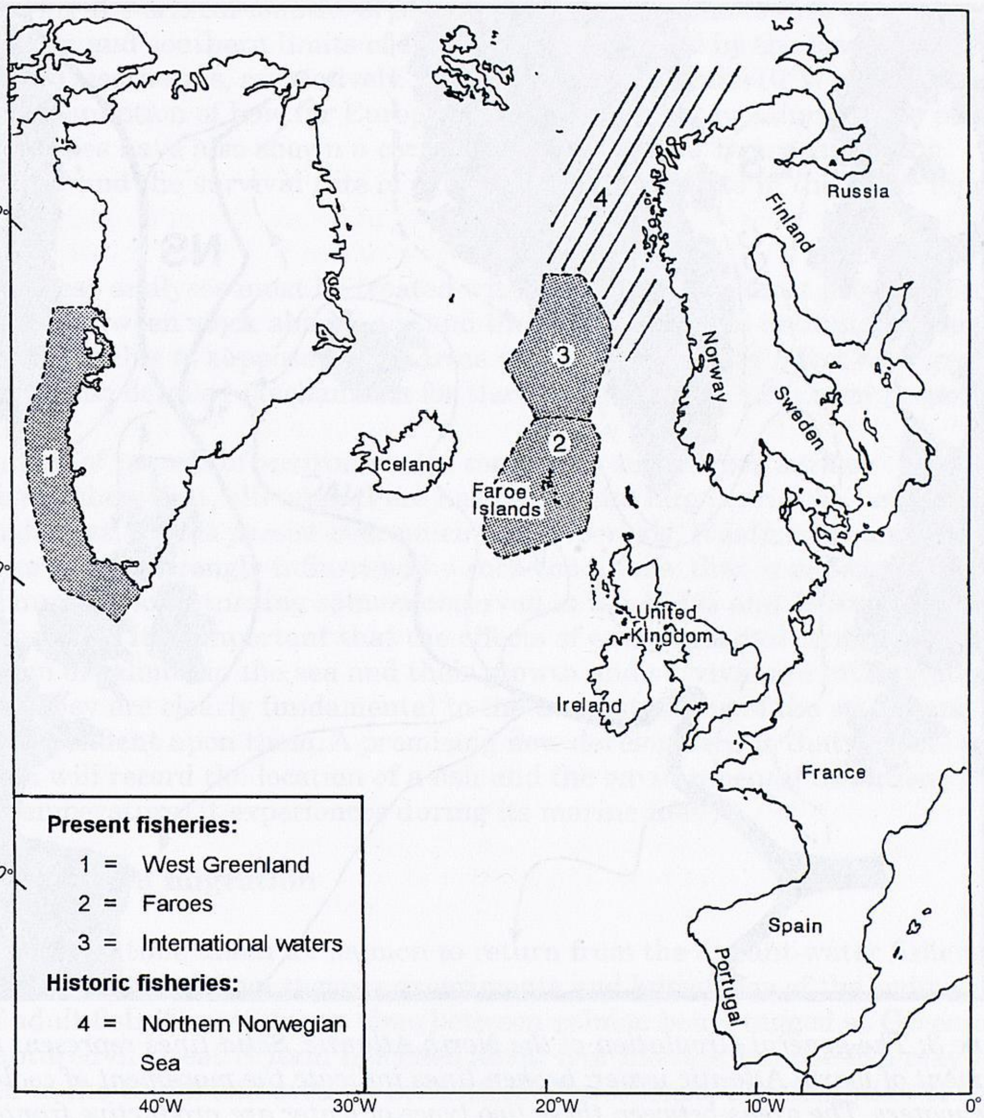

Figure 2: *Locations of current and historical salmon fisheries in distant water. (Source: modified from Potter and Dunkley, 1993[2])*

combine to pass around the south of Greenland and flow northwards along its west coast (West Greenland Current)[7]. It is here that the second major distant-water fishery for European salmon occurs.

In our earlier report, *Run Timing of Salmon*, we looked in some detail at changes in marine environmental conditions over the past century and their possible influence on the age of maturity of salmon. We noted that there have been periods of warming and cooling in the areas of the North Atlantic which are frequented by salmon from Great Britain. These and other variations in the marine environment have been associated with a number of biological effects, such as changes in the timing of the spring bloom of plankton and in the abundance of different fish species. We observed that changes in the age composition of catches and timing of returns in several rivers in Great Britain had shown patterns of change similar to the variation in sea temperatures.

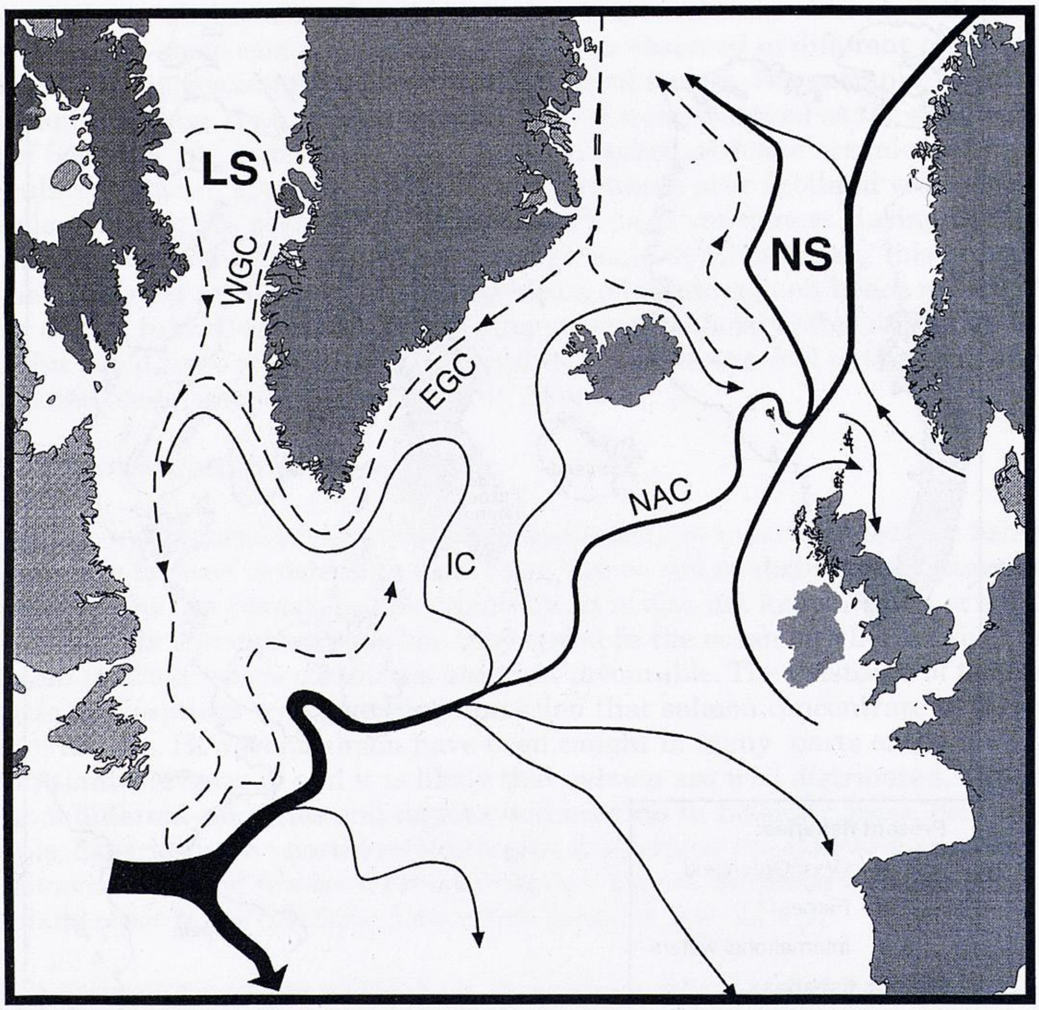

Figure 3: The general circulation of the North Atlantic. Solid lines represent the movement of warm Atlantic water; broken lines indicate the movement of cooler Arctic waters. The areas between these two types of water are productive frontal areas. NS, Norwegian Sea; LS, Labrador Sea; NAC, North Atlantic Current; IC, Irminger Current; EGC, East Greenland Current; WGC, West Greenland Current. (Source: modified from Turrell 1994[1])

Salmon abundance and marine survival are also affected by marine conditions. Salmon cannot grow in very cold water; in the Labrador Sea they are most abundant in areas where the sea temperature is between 4°C and 10°C[8]. For North American stocks, the estimated numbers of non-maturing 1SW salmon in the sea have been shown to be correlated with an index of 'available habitat' based upon sea temperatures in this area[9]. This relationship has been used to forecast the numbers of fish that should be available in the subsequent season[10] and thus to set the quota for the West Greenland commercial salmon fishery. However, it is important to note that the mechanisms behind this apparent relationship are not understood and the correlation between these data does not necessarily demonstrate any causal link.

Analysis of European catch statistics and indices of environmental change has also shown a correlation between total catch of European salmon and an index which was referred to as the 'European spring habitat area'[11]. This was described as the 'area of the north-east Atlantic which was considered most suitable for salmon to live in during the critical months of March to May, when smolts first enter the sea'. The northern and southern limits of this area were defined by the location of the 7°C and 13°C isotherms, respectively. The east and west limits (0°W to 20°W) were set by an assumption of how far European salmon might travel during this period. Further studies have also shown a correlation between the 'European spring habitat area' and the survival rate of salmon tagged as smolts in the River Figgio, Norway[10].

However, these analyses must be treated with caution. They do not prove direct causal links between stock abundance and the area of suitable habitat. Although it is not unreasonable to suppose that marine temperatures could affect both growth and survival, no detailed mechanisms for these relationships have been proposed.

Examination of records of environmental conditions such as sea surface temperature show that, although there has been quite large variation between individual years, trends persist over much longer periods. If salmon abundance or marine survival is strongly influenced by such conditions, then it appears unlikely that the numbers of returning salmon observed in the 1960s and 1970s will be rapidly restored. It is important that the effects of environmental conditions on the distribution of salmon in the sea and their growth and survival are investigated further as they are clearly fundamental to the understanding of the stocks and the fisheries dependent upon them. A promising new development is that of archival tags which will record the location of a fish and the environmental conditions (e.g. sea temperature) it experiences during its marine life[12].

2.2.3 The return migration

Estimates of the time taken for salmon to return from the distant-water fishery areas may be obtained from tagging experiments and knowledge of the swimming speed of adult fish. The minimum time between salmon being tagged at Greenland and recaptured in Great Britain has been about four months, but the fish may have remained in the Greenland area for some time after release. Consideration of the typical swimming speed of salmon (40 km per day) as derived from tracking and tagging studies suggests that a fish could return within three months. It also suggests that they could return to the north of Scotland from the southern edge of the Faroes area in about a week. Travel from the northern part of the Faroes 200-mile limit to the south of England would take much longer, perhaps ten weeks.

As with the outward migration, the influence of ocean currents on the return journey of adult salmon to their river of origin is not understood. While surface flows in the northern Atlantic Ocean are predominantly to the west, the North Atlantic Current to the south provides a return flow. This current is a broad (1,000–1,500 km) wind-driven easterly drift of 2–3 cm per second, upon which are superimposed large eddies (with diameters of 200–300 km and circulating speeds of 20–50 cm per second) which may last for many months[13, 14]. Particles within these eddies remain there for some time. As a result the return migration of salmon is unlikely to occur by passive drift and is probably active and directed.

Once the returning adult salmon reach the continental shelf they will again experience the residual and tidal currents in the shelf seas through which they must pass. Tracking studies have shown that they maintain steady compass headings and constant swimming speeds through the water[15, 16]. They may, therefore, be carried back and forth over the ground by the tide, while maintaining a constant heading through the water. They may then follow the coast and use coastal currents to detect home river odours in the final stages of their marine migration[16].

2.3 FOOD AND FEEDING

The food of salmon in the sea has been a matter of debate for many years. In the early 19th century it was recorded that on their return to British coastal waters adult salmon ate small fish (particularly sandeels), 'worms' and 'insects'[17]. Almost all early records were from inshore fisheries, but more information has been acquired since the advent of fisheries off West Greenland and in the Norwegian Sea[18, 19]. Data are now available from several widely separated areas in the northern North Atlantic, but the number of stomachs of salmon that have been examined is small.

Observations in Iceland[20], Canada[21] and Scotland[22] indicate that when smolts begin to feed in estuaries and in the sea their main prey are invertebrates. A considerable proportion of the stomach contents of the smaller individuals often consists of winged insects. This suggests that these fish are feeding at the surface, which may reflect their behaviour in fresh water. However, fish prey have been found in smolts in inshore waters from Scotland[22]. As the salmon grow larger, their diet includes a greater proportion of crustaceans (particularly amphipods and euphausiids) and fish, indicating an increase in vertical foraging range. Fish recorded from the stomachs of salmon in the sea include sandeels, capelin, herring, sprat, lantern fish, barracudinas and three-spined stickleback. It seems, therefore, that small salmon have a varied diet but that most of their fish prey consists of pelagic, shoaling species.

Salmon diet has been described in terms of the species eaten and the frequency of occurrence of each prey species in a sample of stomachs. Such data give little indication of the relative amount, in terms of bulk, of each prey species eaten; for this we need information on numbers, weights or volumes[23]. Further, the proportions of each prey species in stomach contents, however measured, do not necessarily reflect the relative quantities consumed: small, quickly digested food items may be more important components of the diet than their representation suggests. Data are presented in Table 1 for stomach contents of salmon caught in a range of sea areas[24]. Fish were consistently the largest component of the diet, although salmon caught on the west coast of Greenland and to north of the Faroe Islands also contained significant quantities of crustaceans. However, fish predominate to such an extent that it is reasonable to consider them to be the principal prey of salmon.

It is known that salmon feed over a very extensive area of sea, and that the kinds of fish eaten vary with locality (Table 1) and possibly from year to year. Capelin are the main prey on the Canadian Shelf and off the west coast of Greenland, whereas clupeids (herring and sprat) predominate in the Baltic. Both clupeids and sandeels are important in the waters around the British Isles. Salmon sampled over oceanic depths in the Labrador Sea and near the Faroe Islands fed mainly on lantern fish, barracudinas and blue whiting, all relatively small shoaling species.

Although salmon tend to eat small fish [25, 26], it is known that they will eat fish more than 20 cm in length [19, 27–29]. In some species of piscivorous marine fish there is a pronounced tendency for bigger individuals to eat larger prey, but no such trend has been demonstrated for salmon.

Table 1: Percentage composition by weight of stomach contents of adult Atlantic salmon in the sea in each major geographic area. (Source: modified from Hislop and Shelton, 1993[24])

	Area					
Prey item	British Isles	Faroes	Canada	Labrador Sea/Davis Strait	Greenland	Baltic
Total stomach contents						
Fish	98.9	69.0	97.9	82.7	82.3	98.0
Crustacea	0.5	28.0	0.7	14.3	15.8	2.0
Molluscs	0	1.5	0.5	3.0	0	0
Annelids	0.6	0	0.2	+	0.1	0
Insects	0	0	+	0	0	0
Unidentified	0	1.5	0.7	+	1.8	0
Principal fish prey						
Clupeids	57.4	0	13.5	0.6	0.1	90.4
Capelin	0	14.0	73.7	0.2	71.8	0
Sandeels	29.6	0.8	11.2	0.3	17.4	2.6
Lantern fish	0	47.2	+	15.9	0	0
Barracudinas	0	2.3	0.1	59.0	2.0	0
Others	13.0	35.7	1.5	24.0	8.7	7.0
Principal crustacean prey						
Euphausiids	0	8.7	1.5	0.4	40.2	+
Amphipods	+	88.6	87.3	97.3	59.8	2.0
Others	+	2.7	11.2	2.3	0	98.0

+ = present

The change in diet from invertebrates to fish is an important feature in the life-cycle of salmon[30], because they only begin to grow rapidly once they have become mainly piscivorous, at a length of about 25 cm. It should be appreciated, however, that fish are not necessarily more nutritious than other foods. There are considerable differences between both the calorific value and the total energy content of similarly-sized individuals of different fish species. Also, fat content and calorific value may vary markedly within a species, in relation to factors such as season, size, sex and state of maturity. Some fish, such as juvenile sandeels, are eaten in quantity by many species of birds and fish but are a low-quality food, in terms of energy content[31]. On the other hand, some planktonic crustaceans, including euphausiids, may have very high calorific value[32].

Overall, crustaceans are a much less important food than fish. However, salmon sometimes feed very heavily on crustaceans and their stomachs may contain many hundreds of individuals. The principal crustaceans are hyperiid amphipods and euphausiids (shrimp-like organisms) which may occur in dense swarms. Other types may occasionally be eaten in quantity; for example, 340 common shrimps were found in the stomach of an adult salmon caught off the north-east coast of England in May 1976[33].

The observation made earlier that salmon appear to feed mainly on fish may seem surprising as they owe the characteristically pink colour of their flesh to carotenoid pigments found in crustaceans. Only a very small amount of the carotenoid pigment appears to be necessary to give the salmon its colouring.

2.4 PREDATION

Smolts are eaten by a wide range of predators in the sea. Gadoid fishes, including cod, saithe, pollack and whiting are known to feed on young salmon [34–38] and all four species may be locally abundant in inshore and estuarine waters. Other fish known to take smolts include sea trout[37], bass[39] and garfish[40]. In addition, several species of birds eat smolts, including cormorants, goosanders and mergansers[41, 42]. These examples are certainly not exhaustive; most species of seabirds and marine fish have varied diets and are likely to eat young salmon when the opportunity arises. In addition, seals, toothed whales and dolphins take some young salmon.

It is highly likely that predation levels vary from year to year, in response to changes in the number and variety of predators and of alternative prey. Heavy predation may occur at specific localities and at particular times of the year. For example, in the late 1960s, the stomachs of more than a thousand cod caught near the mouth of the Aberdeenshire Dee were examined during the main smolt run and no smolt remains were found[43]. However, Norwegian observations have shown that predation by cod on wild and reared smolts in the mouths of two Norwegian rivers is sometimes as high as 20%[37, 38]. Similarly, saithe have sometimes been netted at the mouth of the River Spey during the smolt run, and these fish have been full of smolts[43, 44], whereas in other years saithe have apparently been absent from this area at this time of year. In sampling throughout the North Sea, no salmonid was found in an examination of many thousands of stomachs of cod, whiting and saithe during the International Council for the Exploration of the Sea (ICES) Stomach Sampling Project in 1981[45].

Salmon grow very rapidly in salt water and by the end of the calendar year in which they enter the sea they may measure 30 to 45 cm in length[21, 29]. Fast growth rapidly reduces vulnerability to predation, because comparatively few predators are capable of catching and eating large fish. Thus it is unlikely that seabirds, with the possible exception of gannets and cormorants, could prey upon 1SW or older salmon.

There have been some instances of adult salmon being found in the stomachs of other fish[35, 46–51]. In many of the well-documented cases, the predators are believed to feed mainly near the bottom (benthic feeders), such as Greenland shark, skate, ling and cod. This may support the hypothesis that salmon are not restricted to surface waters, but equally might indicate that the species believed to be primarily benthic feeders may forage vertically. Virtually all of the records are from shelf seas and there is no information from the open ocean. Assessment of the level of predation on salmon by fish in the open ocean is impracticable as this could only be investigated by means of very extensive sampling programmes targeted at likely predators such as sharks.

Marine mammals are known to eat adult salmon and they may be the only significant predators of returning fish in home waters. There is good evidence for predation by grey and common seals[52–56]. Much concern has been expressed about the problem of predation by seals and this subject will undoubtedly attract more attention as the North Atlantic populations of grey seals and harp seals continue to increase. Seals frequently take salmon from nets, from long-line hooks and from around nets and traps. In addition, they are often seen eating kelts and fresh-run salmon in estuaries and rivers, far from fishing stations and at times when the commercial fishery is closed. The scale of these losses is unknown. The populations of many seal species have increased substantially in recent years and are now at levels at which they could have a major impact on salmon populations, even if only a small proportion of their diet consisted of salmon.

Bottlenose dolphins have been observed taking salmon in the Moray Firth[57] and it is likely that salmon are also occasionally eaten by other species of dolphins and porpoises.

3. HUMAN ACTIVITIES AFFECTING SALMON IN THE SEA

3.1 INTRODUCTION

In this section we consider the human activities which affect salmon while they are in the sea. The activities discussed are not placed in order of importance, but are grouped by topics. We begin by discussing the impacts of fisheries on salmon at different stages in their marine migration. Salmon originating in British rivers are exploited first by fisheries in the waters of the Faroe Islands and Greenland and in international waters to the north of the Faroes 200-mile limit. On their return migration, some pass through the coastal waters of Ireland and Northern Ireland where they are exploited by drift nets operating within the 12-mile limit. Finally, on their return to British inshore waters they are exploited by fisheries within the six-mile limit of England & Wales and along the coast of Scotland. There are differences in the effects of these fisheries and in the possibilities and mechanisms for controlling them and they are therefore considered separately below. However, they are all discussed in the context of the need to control exploitation in order to ensure that adequate numbers of salmon return to provide for fisheries in the rivers and sufficient spawning fish to achieve the optimum level of juvenile production. Salmon are also exploited in the sea by illegal fisheries, usually by means of gill nets operated in coastal waters.

We also consider the effects on salmon populations of fisheries for marine species. The main concern about these fisheries is that they may take salmon as a by-catch. As salmon stocks are numerically very much smaller than most stocks of marine species, even a small by-catch may represent a significant threat to salmon stocks. In the case of industrial fisheries, we consider whether the survival of young salmon may also be affected by the depletion of food supplies.

Although some aspects of fish farming have been considered in our earlier report on *Factors Affecting Natural Smolt Production*, we consider here those aspects of this practice which may have a direct effect on salmon in the sea. Changes in water quality are considered in some detail, and reference is also made to possible effects of changes in the physical environment. Finally we summarise some of the impacts from predators which may have arisen as a result of changes in management practices.

3.2 SALMON FISHERIES AT FAROES AND WEST GREENLAND

3.2.1 Description

Salmon from rivers in Great Britain are distributed throughout much of the North Atlantic. Some fish move into the Northern Norwegian Sea, where they mix with other stocks, principally from Scandinavia, Finland and Russia, and may be caught in the fishery operating within the Faroes 200-mile limit. Those fish that remain at sea for more than one year may also migrate to the north-west Atlantic, where along with other European salmon they mix with salmon from North America and may be taken in the fishery operated on the west coast of Greenland.

The UN Convention on the Law of the Sea (Article 65) states that where a stock of salmon migrates through the waters of a State other than the State of Origin of the stock, such State shall co-operate with the State of Origin with regard to the conservation and management of the stock. Concern about exploitation of salmon beyond the 12-mile limits led to the Convention for the Conservation of Salmon in the North Atlantic Ocean, under which the North Atlantic Salmon Conservation Organisation (NASCO) was established, expressly recognising Article 65 of the then draft UN Convention. The parties to the NASCO Convention agreed that there should be no fishing for salmon beyond the 12-mile limit except in specified areas at Faroes and West Greenland. The Organisation has powers to make regulations relating to the Faroes and Greenland fisheries.

Faroes

There have been significant long-line fisheries for salmon in the Northern Norwegian Sea since the 1960s. Until the 1970s, most of the fishing was concentrated off the Norwegian coast, between the 12-mile limit and about 200 miles offshore. However, a series of measures was introduced in the early 1970s, and by 1977 these resulted in the fishery being restricted to the waters within the Faroes 200-mile limit and beyond national 200-mile limits to the north (Figure 2).

A small fishery developed in the Faroese area in the late 1960s, with catches building up to 40 tonnes in 1977. In the following years catches rose rapidly, peaking at 1,027 tonnes in 1981 (Figure 4). Since 1982 catches have been controlled by quotas and programmes to limit effort which were negotiated between the Faroese and the EC (1981/82 to 1986/87 fishing seasons) or through NASCO (1987–95 calendar years). The fishery has involved up to 44 vessels in some years, but by the 1990/91 season (the last season before the suspension of commercial fishing) the number had reduced to 13, of which only eight actually fished. The fishery operates from October to April and vessels use long-lines up to 30 km in length with about 100 hooks per kilometre. The fishery takes predominately 2SW fish, most of which would have returned to their home river within a few months. Some 1SW fish are caught during their first winter in the sea, but the majority of these are small and have to be discarded because of the minimum landing size of 60 cm total length. Although efforts may be made to avoid catching these small fish, they have sometimes comprised as much as 70% of the catch on a single set of a long-line and up to 16% of the total seasonal catch in numbers. About 80% of them are thought to be dead when they are removed from the line or die after their release[58].

The quota agreement for 1996 restricts catches in the Faroes area to 470 tonnes (Figure 4), which would be expected to represent about 140,000 fish. This would include both wild fish and fish farm escapees, which have comprised 17–44% of the catch in recent years. In addition, fishing effort is restricted through limits on the number of boats that may be licensed (13), the season length (150 days between 1 January and 30 April and 1 November and 31 December) and the total number of boat-days that may be fished (1,200).

In March 1991, an agreement was reached between the Faroes fishermen and the North Atlantic Salmon Fund (NASF) under which the fishermen agreed not to fish for salmon in exchange for annual compensation payments. One vessel was not included in the agreement and continues to fish under the direction of the Faroes Fisheries Laboratory. The NASF has been financed by contributions from various organisations, individuals and some governments in salmon-producing countries. The current agreement expires in 1996, but there is provision to negotiate a renewal.

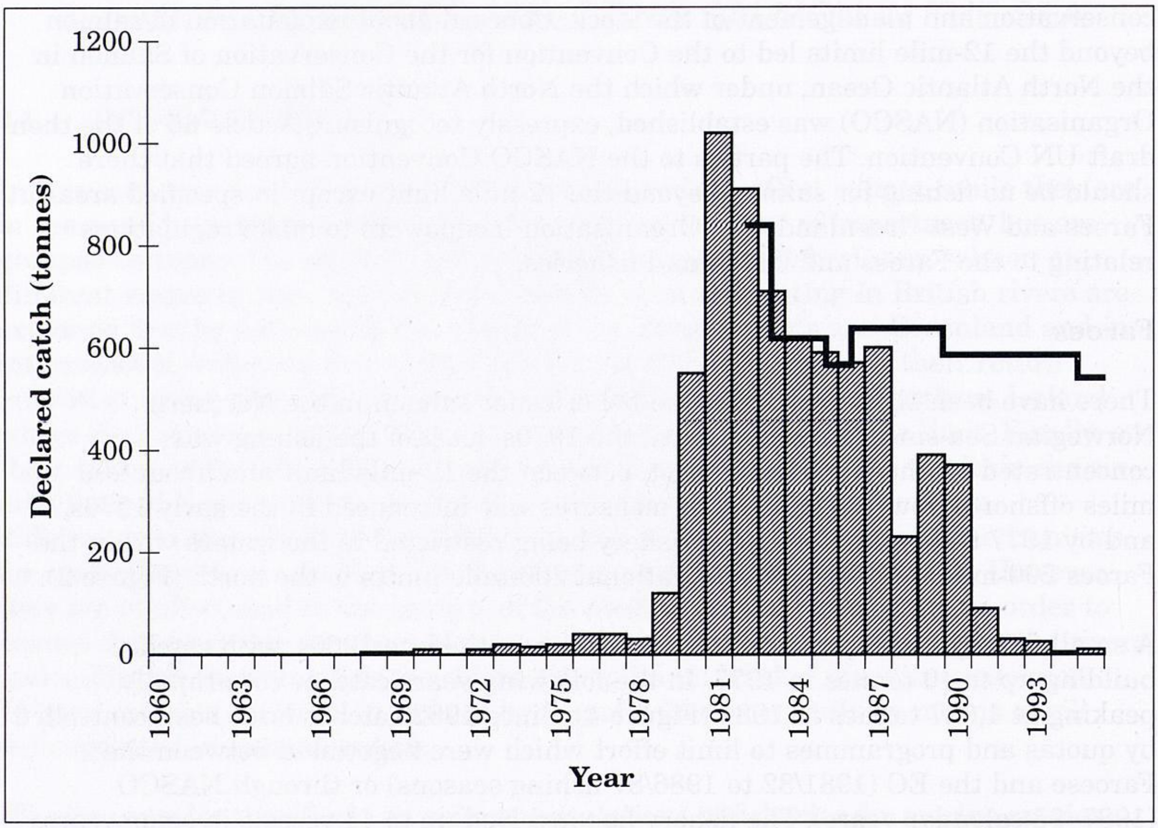

Figure 4: *Catches of salmon in the Faroes fishery between 1970 and 1994* ***(bars)*** *and the quotas* ***(line)*** *from the 1981/82 fishing season to the 1996 calendar year. (Source: data kindly supplied by ICES)*

Estimates have been made of the level of exploitation of salmon from the North Esk, Scotland, in the Faroes fishery for each season from 1981 (Table 2). This indicates that the fishery took significant numbers of fish in the early 1980s, but that the exploitation rate declined to 1% or less on each sea-age group in the four fishing seasons prior to the suspension of commercial fishing. Microtagging experiments conducted in England & Wales show that the exploitation rate on stocks from these countries is less than 1% for each sea-age group.

Table 2: Estimated levels of exploitation of North Esk salmon in the Faroes fishery in the periods 1981/82 to 1986/87 and 1987/88 to 1990/91. (Source: data kindly supplied by ICES)

Sea-age group	Estimated exploitation levels		
	Mean level (%) 1981/82–1986/87	**Mean level (%) 1987/88–1990/91**	**Range (%) 1981/82–1990/91**
One sea-winter	<1	1	0–4
Two sea-winter	8	<1	0–10
Three sea-winter	6	0	0–18

In comparison, the mean levels of exploitation of 2SW fish from four stocks in Norway and Sweden in the four years prior to the suspension of commercial fishing were 7–25 %. Thus, it appears that a greater proportion of Norwegian fish must be available to the Faroes fishery than fish from rivers in Great Britain. Preliminary recapture data from tagging of adult salmon in the fishery are consistent with these results. These tagging studies have indicated that some fish from North American rivers are also caught[10].

Greenland

The present fishery on the west coast of Greenland began in the early 1960s and has been conducted by small boats operating fixed or drifting gill nets close inshore and larger vessels using drift nets up to 40 miles offshore. Since 1976, only Greenlandic vessels have been allowed to take part in the fishery and fishing has moved closer inshore with the majority of the catch being taken by small vessels, some as small as 16 feet. Most of these operate drift nets but some use fixed gill nets. The fishery operates in the summer and early autumn, but much of the catch is usually taken in a short period in August or early September.

The reported catches in the Greenland fishery from 1960 to 1995 are shown in Figure 5 along with the annual quotas which were introduced from 1976. Additional fish are landed for local consumption; these fish do not pass through the processing plants and are not counted against the quota. Since 1993, the quota has been calculated using a formula developed by ICES[59] and agreed by NASCO. The calculation is based on the number of potential multi-sea-winter (MSW) North American salmon predicted to be alive prior to the start of the fishery and the target number of fish which must be allowed to survive to spawn (currently thought

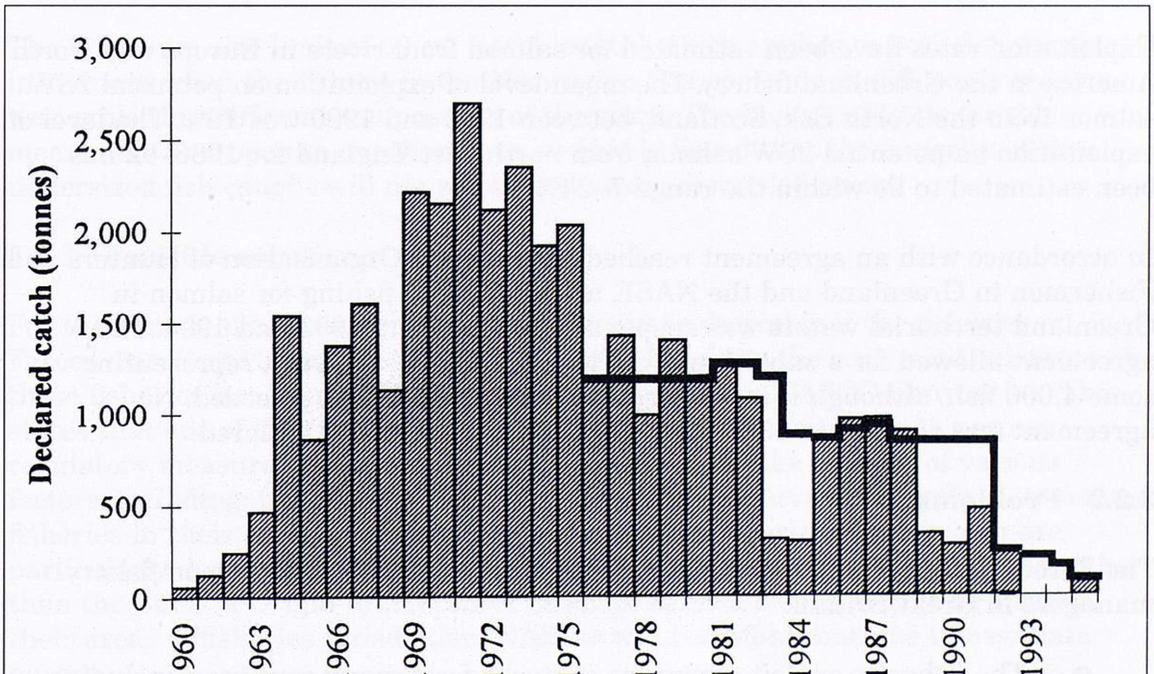

***Figure 5:** Declared catch of salmon at West Greenland between 1960 and 1995 **(bars)** and the quotas **(line)** from 1976 to 1995. (Source: data kindly supplied by ICES)*

to be about 180,000 salmon). The difference between these two numbers (with some minor adjustment to take account of natural losses and the migrations of the fish) provides an estimate of the number of fish that can be caught without reducing the total spawning stock below the target level. A proportion of this surplus has been allocated to Greenland (in recent years this has been set at 40% based upon historical catch levels). The quota has been calculated by estimating the total weight of these fish and adding the weight of the European fish that would be expected to be caught with them. The quota agreement in 1995 restricted the catches to 77 tonnes, representing approximately 13,000 salmon from Europe and 15,000 from North America.

Almost all of the salmon caught at Greenland (about 95%) have been in the sea for about 15 months and would have returned to home waters as 2SW fish[10]. The remainder of the catch are older fish (about 4%) and previous spawners (about 1%). In most years, the catch has been fairly equally split between North American and European fish. The average size of the European salmon is larger than the North American fish, although there has been a gradual decrease in the size of all the salmon caught, with the mean weight of the European fish declining more rapidly than the North American fish. Because gill nets tend to be selective for fish of a particular size, salmon from the two continents could be exploited at different rates. In response to a recommendation from ICES, an increased mesh size of 140 mm was introduced in the early 1980s in an attempt to equalise the levels of exploitation on North American and European fish in the Greenland fishery.

Total estimates of the spawning requirements for European stocks have not been derived and predictive models of stock abundance have not been developed. This limits the ability of ICES to provide NASCO with separate catch advice in relation to European salmon exploited at Greenland.

Exploitation rates have been estimated for salmon from rivers in Europe and North America in the Greenland fishery. The mean level of exploitation on potential 2SW salmon from the North Esk, Scotland, between 1982 and 1990 was 10%. The level of exploitation on potential 2SW salmon from north-east England for 1986–92 has been estimated to lie within the range 7–24%.

In accordance with an agreement reached between the Organisation of Hunters and Fishermen in Greenland and the NASF, all commercial fishing for salmon in Greenland territorial waters was suspended for the years 1993 and 1994. The agreement allowed for a subsistence catch of 12 tonnes each year, representing some 4,000 fish, although it is believed that this number was exceeded. No agreement was reached in 1995 and a catch of 83 tonnes was declared.

3.2.2 Problems

The Faroes and Greenland fisheries pose particular problems for salmon fishery managers in Great Britain.

- The fisheries exploit a mixture of stocks from many countries, including Great Britain.

- The West Greenland quota is based upon the state of North American stocks only.

- The Faroes quota is not based on biological criteria.
- The purchase of the annual quotas is fragile and depends on continued financing.
- The losses of fish through discarding and local consumption are poorly estimated and are not counted against the quota.

The Greenland fishery takes salmon from many European salmon rivers and from North America. The Faroes fishery exploits salmon from many, predominantly European, rivers. However, there is considerable variation in the level of exploitation of salmon from different regions or different rivers in both fisheries. This makes it very difficult to determine the numbers of fish taken from individual river populations.

As already discussed, the West Greenland quota is based upon a scientific assessment of the state of North American MSW salmon stocks and the number of these fish required for spawning. Currently, this is also believed to provide adequate protection for European stocks, but should the relative status of North American and European stocks change this may no longer be the case. The Faroes quota is based largely on historical catch levels and political negotiations, and limited consideration is given to the state of the stocks being exploited.

The NASF, by paying compensation, secured a suspension of both the Faroes and West Greenland fisheries for several years. However, these arrangements have to be renegotiated at regular intervals and may fail. Indeed in 1995, the NASF failed to reach an agreement for an appropriate compensation payment for the Greenland fishermen to continue the suspension of the fishery.

The minimum size limit of 60 cm (total length) which applies to both fisheries was introduced when the fishery in the Norwegian Sea operated in different areas and was exploiting different components of the stock. The biological basis for this measure is now open to question because it is believed that the majority of the undersized fish caught will die whether they are discarded or not.

3.2.3 Possible solutions

For the benefit of homewater fisheries, it would be desirable if the fisheries at Faroes and West Greenland ceased to operate. However, the continued existence of these fisheries has been expressly acknowledged by the NASCO Convention. This states that one of the functions of the appropriate Commissions is to propose regulatory measures for these fisheries. These should take account of various factors, including: the efforts of States of Origin to conserve and regulate stocks and fisheries in their areas of jurisdiction; the interests of communities which are particularly dependent upon salmon fisheries; and the contribution of Parties other than the State of Origin to the conservation of salmon stocks migrating through their areas of fisheries jurisdiction. NASCO will therefore continue to negotiate quotas.

We recommend that continued efforts be made to negotiate a permanent closure of these fisheries. In the meantime, the suspension of fishing can justifiably be viewed as a cost-effective and immediate stock enhancement technique for some homewater fisheries.

In the absence of a permanent closure of these fisheries, we consider that the quotas negotiated by NASCO should, wherever possible, be based on biological principles and should be related to the current state of the individual stocks being exploited and the fisheries in homewaters. This will depend upon the development of methods to assess the state of European stocks similar to those currently used in North America, and will require the cooperation of all European salmon-producing countries.

Further research should be carried out in order to gain information on the stocks exploited by the fisheries and the levels of exploitation upon them. In addition, we recognise the importance of continued research on the salmon occurring in these areas even if the commercial fishery has been suspended. This may require some fishing to continue on a strictly limited scale. Better estimates should be obtained of the undeclared catch that is sold locally in Greenland.

The basis of the requirement to discard salmon under 60 cm is questionable because few of the discarded fish survive. It might be preferable that these fish are landed and counted against the quota and we therefore suggest that NASCO be asked to review this regulation.

3.3 SALMON FISHERIES IN INTERNATIONAL WATERS

3.3.1 Description

Fishing has taken place throughout much of the Norwegian Sea in the past. However, since 1983, the NASCO Convention has forbidden fishing for salmon in international waters (Figure 2), although this does not bind vessels registered in countries that are not Parties to the Convention. A small number of such vessels fish for salmon in international waters to the north of the Faroes 200-mile limit.

The vessels that have been observed participating in the fishery in this area originate from countries that are Parties to the NASCO Convention but have reflagged in other States such as Poland and Panama in order to avoid the regulations. They are ex-Danish long-liners which spend about four weeks at sea to catch up to 20 or 30 tonnes of salmon and they may make up to four trips a year. Because of the nature of this fishery, it is difficult to estimate the numbers of fish caught. The fishery occurs over a similar period to the Faroes fishery (October–May). Six named vessels were identified as operating in 1989–91, although there may have been others. Since then the numbers are thought to have declined.

ICES has suggested that if seven vessels were involved in the fishery in 1989–90, the potential catch could have amounted to about 630 tonnes. However, this catch was probably not realised because of adverse weather conditions and, on the basis of limited information, ICES suggested that the catch may have been 180–350 tonnes in 1989/90 and 25–100 tonnes in each season since[10, 60]. It is known that salmon from rivers in Great Britain occur this far north, but the effects of this fishery on national stocks cannot be estimated.

Stories of other salmon fisheries involving trawling or seining on the high seas also abound. None of these reports can be substantiated and some have been shown to be based on erroneous information. There is no evidence that Atlantic salmon ever occur in sufficient concentrations in the open ocean for it to be practicable to target them with such methods, but some by-catches probably occur.

3.3.2 Problems

Although fishing for salmon in international waters is legal for some vessels, it is clearly contrary to the spirit of the NASCO Convention and it poses a number of specific problems for salmon fishery managers.

- The fishery exploits a mixture of stocks from many countries.
- The fishery is uncontrolled.
- Catches are landed through many different ports and are not reported or recorded.
- The existence of the fishery may undermine efforts to limit and control other distant-water fisheries or to arrange compensation agreements.

The fishery is believed to take salmon originating from, and which might otherwise have returned to, most European countries, although the relative contributions are not known. It is believed that relatively few salmon originating in British rivers are taken in this area, but tags are not generally returned from fish that are caught and it is not usually possible to examine catches. As a result, this assumption is based upon historical data and knowledge of the Faroes fishery.

The lack of control over the fishery means that it might be possible for it to expand rapidly. However, because of its covert nature, little information can be obtained on fishing activities and catches. Furthermore because much of this fishing takes place during the winter months in areas where there may be few, if any, hours of daylight, surveillance is extremely difficult.

3.3.3 Possible solutions

We recommend that all efforts should be made to eradicate this fishery. However, the fishery operates in waters outside national 200-mile limits and is therefore very difficult to control. In 1992, NASCO developed a Protocol under which countries which were not Parties to the Organisation could formally adhere to its principles and prohibit fishing for salmon beyond national 12-mile limits. The Protocol has been brought to the attention of Poland and Panama, although neither has signed it. NASCO has agreed on the need for further diplomatic efforts in order to eliminate this fishery, and we consider that efforts should continue to encourage the countries in which the vessels are registered to stop this practice. We recommend that the Government lends its support to these efforts.

The *UN Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks* has specifically excluded salmon from its discussion. However, the conclusions relating to other species may provide some parallels for the management of salmon fisheries. The Food and Agriculture Organisation (FAO) Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas addresses the problems associated with the reflagging of vessels in order to avoid international agreements and Conventions. We recommend that their conclusions are examined closely with a view to finding a means to prevent fishing for salmon in international waters.

Methods of improving cooperation on the surveillance of the international waters to the north of the Faroes 200-mile limit have also been agreed within NASCO but have been slow to be implemented. We believe that this fishery should be monitored more closely to obtain better information on salmon fishing activity and catches, despite the practical difficulties mentioned above.

3.4 IRISH SALMON FISHERIES

3.4.1 Description

Salmon from many rivers in Great Britain pass through the coastal waters of Ireland and Northern Ireland on their homeward migration and are caught in licensed drift net fisheries which operate up to 12 miles from the shore. An increase in catches in these fisheries in the 1960s (Figure 6) was associated with the introduction of nets made from synthetic twines which resulted in an increase in the inshore drift net fleet. In the early 1970s, over 1,000 drift net licences were issued in Ireland but this has declined to around 700 in the 1990s, despite the fact that the limit is still 1,090. No drift netting is permitted before 15 March, although there are later opening dates (up to 1 June) in some regions. The drift netting season closes on 25 July on the west and south coast, on 1 August in the Southern Fisheries Region and on 13 August on the east coast, where little drift netting takes place. The majority of the fishing occurs in June and July and so the fishery exploits mainly grilse.

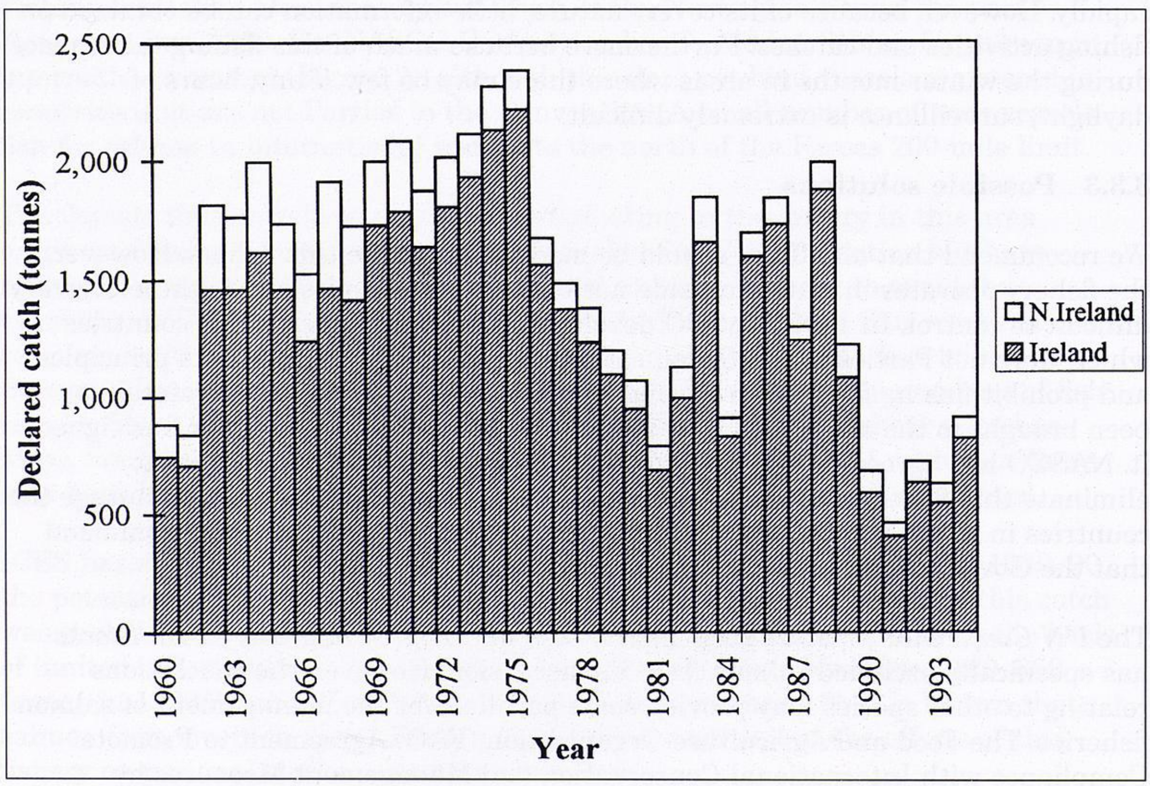

__Figure 6:__ Catches of salmon in the drift net fishery in Ireland and all net fisheries in Northern Ireland between 1960 and 1994. (Source: data kindly supplied by the Department of the Marine, Dublin and Department of Agriculture for Northern Ireland)

In Northern Ireland, a small number of drift nets (10 in 1995) are licensed by the Fisheries Conservancy Board and are operated mainly on the County Antrim coast. The season in this area is 17 March to 15 September. In addition, the Foyle Fisheries Commission issues licences (112 in 1995) for drift netting in the Foyle estuary and the adjacent coastal waters. This fishery operates from 20 June to 31 July, and 50% of the catch is recorded in Irish statistics and 50% in the Northern Ireland data.

3.4.2 Problems

We recognise that as the majority of the salmon caught in the sea off Ireland and Northern Ireland are probably returning to rivers in those countries, the management implications for these fisheries are different from those for the Faroes and Greenland fisheries. However, the fisheries pose the following problems for the salmon managers in Great Britain.

- The fisheries exploit a mixture of stocks from many rivers, including substantial numbers from rivers in Great Britain.
- A substantial part of the exploitation of some British stocks takes place in these fisheries, over which British managers have no control.
- There appears to be limited control on the level of exploitation on either local stocks or those from other countries.

Salmon tagged as smolts in most parts of Great Britain have been caught in the drift net fisheries in Ireland and Northern Ireland, although the levels of exploitation vary. For example, relatively few tagged fish from east coast stocks have been reported from the Irish fishery, but some salmon returning to some rivers in Wales and southern England may be exploited as heavily in these fisheries as they are in Great Britain. Reliable estimates are few, but the exploitation rate on 1SW hatchery-reared salmon returning to the River Test between 1991 and 1993 was estimated to be 23%[61]. Thus, these fisheries may be responsible for a significant part of the exploitation of some British stocks and may present particular management problems for stocks that are seriously depressed.

Serious problems with illegal fishing have been reported in the fishery, for example fishing taking place outside the 12-mile limit[62]. This has been difficult to quantify because the illegal catches are thought to be disposed of other than through the normal channels and are, thus, not recorded[63]. However, with the introduction of fast patrol vessels in the 1990s and other measures to curb illegal fishing, the Irish authorities believe that these catches have been significantly reduced.

3.4.3 Possible solutions

While the problems posed by the fisheries in Ireland and Northern Ireland may be similar, the possible solutions in terms of the regulations which might be applied may well be different because of the different legislative framework in the two countries. Within England & Wales, there is now a stated aim of phasing out fisheries that do not exploit predominantly a single stock. We recommend that Ministers continue to apply pressure on the Irish Government and on the Department of Agriculture, Northern Ireland (DANI) to phase out fisheries, particularly the offshore drift net fisheries, which exploit fish returning to Great

Britain. We understand that a review of the Irish salmon fisheries is currently in hand and we fully support any action taken to improve their management.

We acknowledge the good work undertaken by the Department of the Marine and DANI in conducting their own tagging studies and assisting those in Great Britain to provide a greater understanding of these fisheries. We recommend that these studies should continue in order to monitor the effects of the fisheries, particularly on stocks that are under pressure.

3.5 BRITISH SALMON FISHERIES

3.5.1 Description

In Great Britain, fishing for salmon by nets is prohibited beyond the six-mile limit of England & Wales and beyond 1,300 metres of the coast of Scotland. In theory, it is permitted to fish for salmon by rod and line out to the 12-mile limit, but in practice very few salmon are caught by rod and line in the sea and this method is not considered further in this report. There are important differences between the operation and management of salmon fisheries in Scotland and those in England & Wales. In Scotland, the lawful nets are so defined that they may only be operated from the shore or be set within 1,300 metres of it and must not be designed or constructed to enmesh fish: in England & Wales, fishing may be licensed by the Environment Agency (EA) in the area out to the six-mile limit but is prohibited by Order beyond that. In Scotland, the fishing right is privately owned and can be sold or let, the owner or occupier having the exclusive right to fish for salmon at the site of his fishery: in England & Wales, with few exceptions fishing in tidal waters is a public right. However, in practice many of the private rights in Scotland are not used and access to the public fishery in England & Wales is limited by Net Limitation Orders (NLOs) which restrict the number of licences issued by the EA.

The basic differences influence both the effects of the fisheries and the range of management mechanisms that are available to control them. The various national regulations have a number of common features (e.g. weekly and annual close times, prohibition on the use of poisons, explosives etc.), but there are also many differences.

In Scotland, the lawful salmon netting methods are net and coble (a sort of beach seine net) and fixed engines (bag nets and stake nets). Fixed engines may only be used on the open coast (i.e. beyond estuaries); the beach seines are mainly used in estuaries. Fishing for salmon with drift nets was banned in Scotland in 1962.

In England & Wales, the methods most widely used in coastal waters are drift nets, fixed traps (T or J nets) and types of seine nets. Most estuary fisheries also employ seine nets, although a number of other methods, including drift nets and traps, are also used. In both jurisdictions, large hand nets are operated at particular sites (e.g. haaf nets in the Solway, and lave nets in the Kent and Severn estuaries). The statutory regulations are described in detail and compared in Annex 2 of our report *The Anti-poaching Measures Contained in the Salmon Act 1986*.

In addition to the legal fishing activity, illegal netting takes place in many parts of Great Britain. Gill netting is the method most frequently used, and is usually associated with relatively short lengths of fixed or drifting net operated at sea from boats or beaches and in estuaries and rivers.

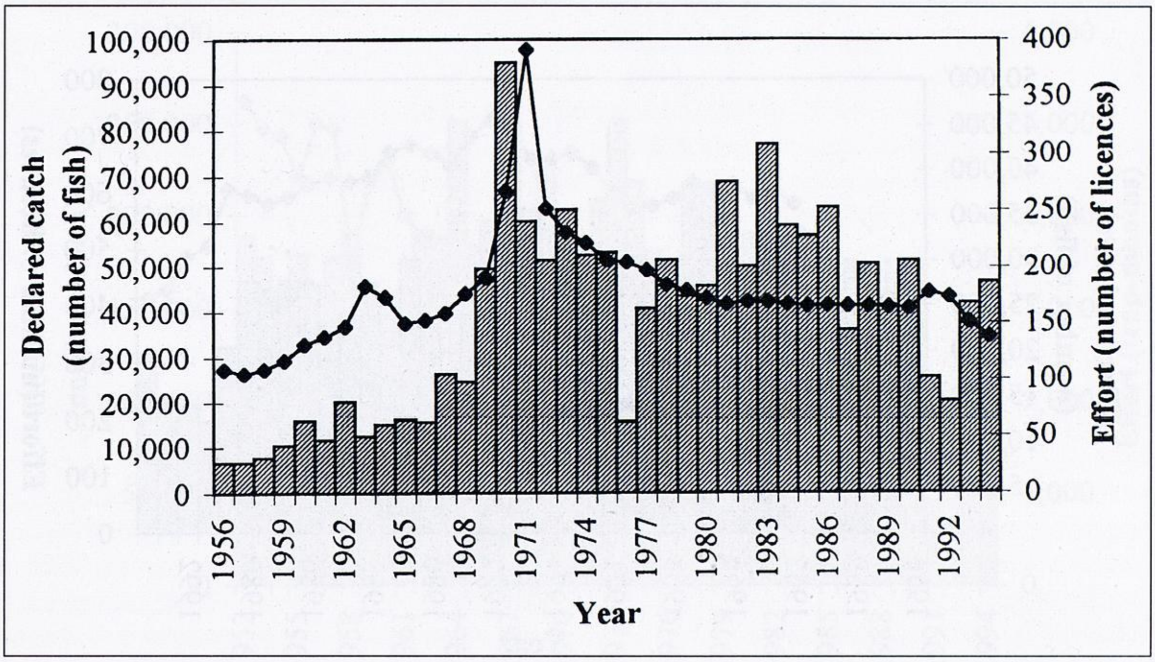

***Figure 7:** Catches of salmon and grilse in net and fixed engine fisheries **(bars)** and total number of salmon netting licences issued **(diamonds)** on the north-east coast of England (North East Region of EA) between 1956 and 1994. (Sources of data: Russell et al. 1996[64] and National Rivers Authority, (NRA)[65])*

The number of net licences issued and the declared net catches are shown for the north-east of England (North East Region of EA) in Figure 7 and for the remainder of England & Wales in Figure 8. The majority of the catches in the North East Region (up to about 90%) have been taken by drift nets. The number of licences issued provides an indication of the changes in fishing effort between years. Fishing effort, along with the catches, increased steadily in the 1960s following the introduction of nets made from synthetic twines, with more dramatic increases resulting from the introduction of monofilament drift nets at the end of the 1960s. Subsequently, NLOs were approved to bring the number of licences under control and, since 1993, a reducing NLO has been in force to phase out the drift nets as fishermen leave the fishery.

The total annual catch taken by a wide variety of nets and fixed engines in other EA regions in England & Wales has fallen fairly steadily since the mid-1960s (Figure 8). The number of licences for these fisheries is also shown in the figure, although because this includes a large number of different fisheries it provides only a very rough guide to the changes in effort. (Data for the Solway haaf net have been excluded because the large number of licences issued and low catch per unit of effort in this fishery distort the overall picture). The number of licences issued has fallen by over a third from a peak of 892 in 1977 to 578 in 1994.

The annual reported catches and measures of the fishing effort for net and coble and for fixed engine fisheries in Scotland from 1952 to 1994 are shown in Figures 9 and 10. (As above, data for the Solway haaf nets have been excluded.) There has been a steady decrease in catches by both net and coble and fixed engines since the mid-1960s, but to a large extent this reflects the marked reduction in fishing effort. The figures do not include catches taken by drift nets which were operated on the east coast of Scotland from 1960 until their use was banned with effect from September 1962. In 1962, these nets took an estimated 115,000 salmon.

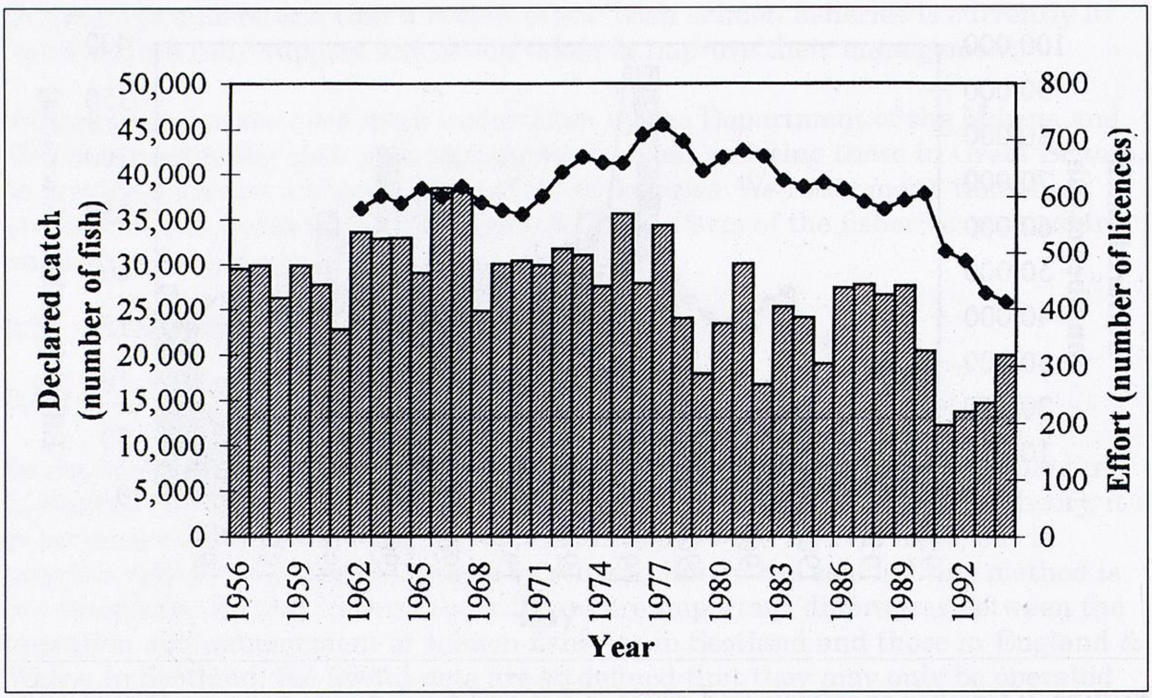

*Figure 8: Catches of salmon and grilse in net and fixed engine fisheries **(bars)** and the number of salmon netting licences issued **(diamonds)** in England & Wales (excluding North East Region of EA) between 1956 and 1994. (Sources of data: Russell et al. 1996[64] and NRA[65])*

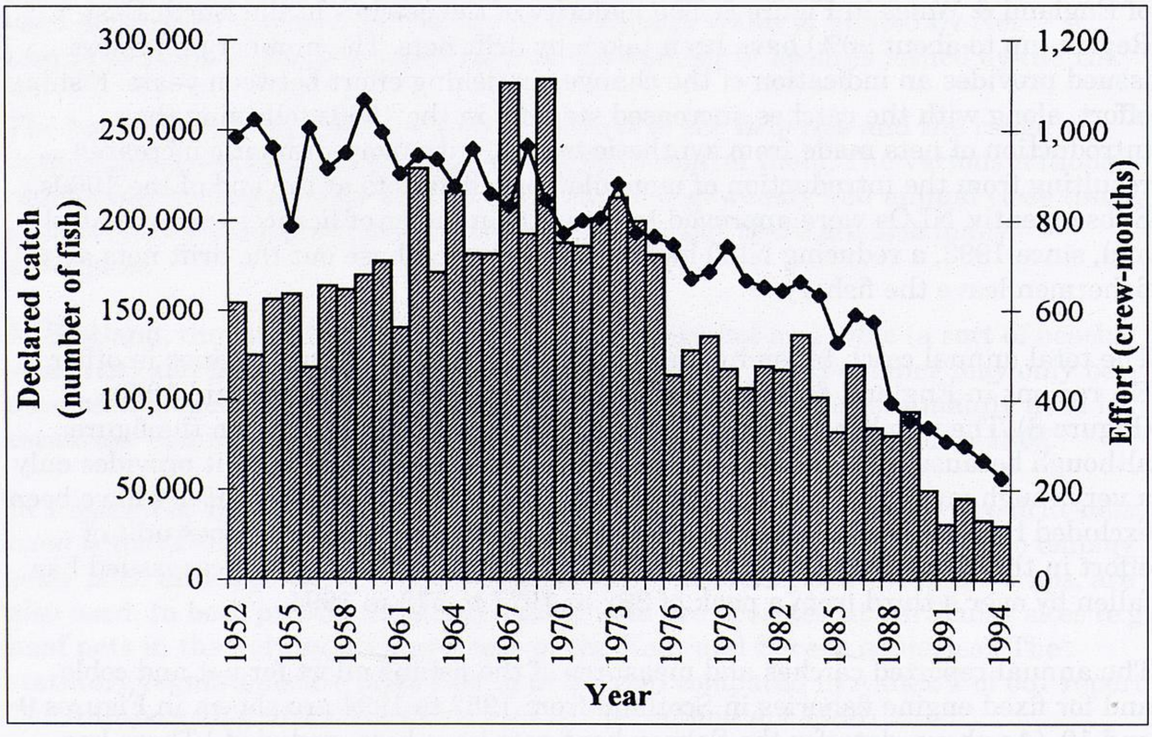

*Figure 9: Catches of salmon and grilse **(bars)**, and fishing effort (crew-months) **(diamonds)** in net and coble fisheries in Scotland between 1952 and 1994. (Sources of data: Scottish Office Agriculture, Environment and Fisheries Department (SOAEFD)[66,67])*

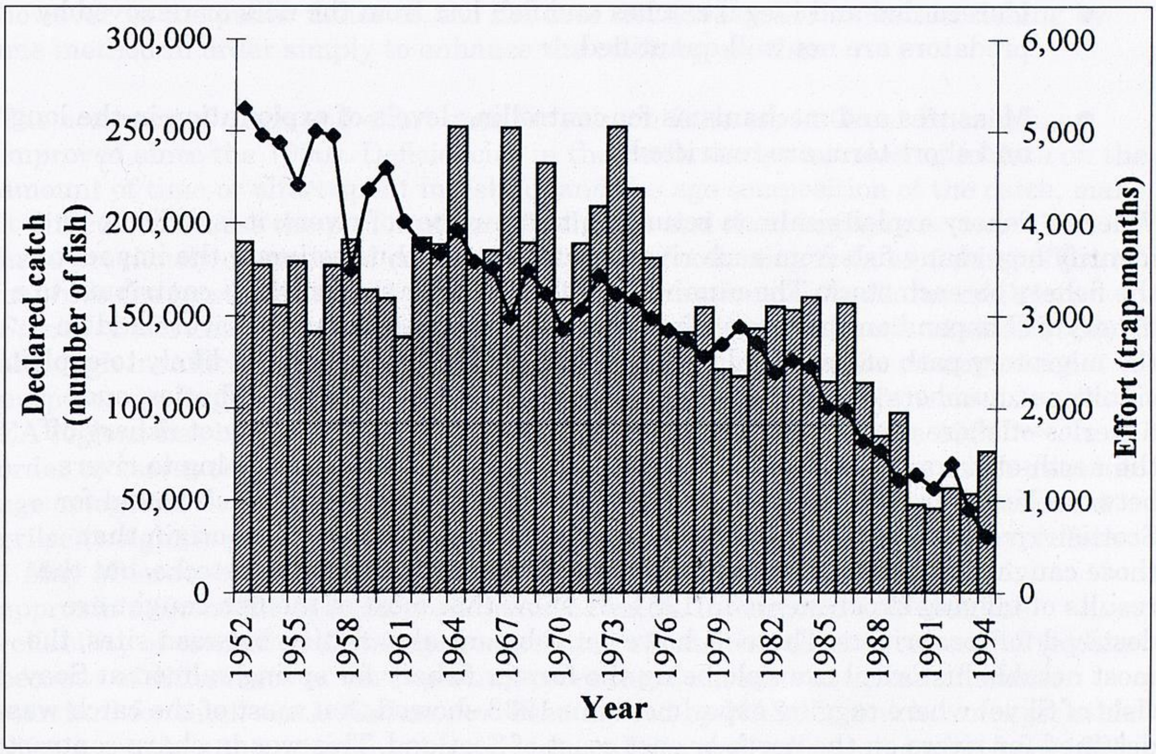

Figure 10: *Catches of salmon and grilse* ***(bars)*** *and fishing effort (trap-months)* ***(diamonds)*** *in fixed engine fisheries in Scotland between 1952 and 1994. (Sources of data: SOAEFD[66,67])*

These homewater fisheries exploit salmon on their return migration to their river of origin. Although some fish are taken in the estuary of their home river, others may be caught in fisheries operating in coastal waters many miles away. Thus, while some fisheries take fish mainly returning to one river, others exploit fish from a number of rivers.

3.5.2 Problems

Fishing for salmon in British coastal waters and estuaries reduces the numbers of fish that will return to their river of origin and consequently the numbers available to fisheries in the rivers and the numbers available to spawn. The significance of the reductions and whether they present a problem depends upon the absolute and relative sizes of the catches in the sea and in the river; the number of fish required to support river fisheries; and, most important of all, the number of spawning fish needed to ensure full juvenile recruitment.

A number of management problems are identified.

- Many fisheries exploit significant numbers of salmon returning to more than one river.
- It is difficult to establish the level of exploitation that stocks can sustain.
- It is difficult to establish an appropriate balance between net and rod fisheries and spawning escapement.
- Information on catches and fishing effort is often inadequate.

- Unrecorded and illegal catches and fish lost from the nets or removed by predators are not well quantified.

- Measures and mechanisms for controlling levels of exploitation in the long and short-term are restricted.

Where a fishery exploits salmon returning to a number of rivers, it is difficult to identify how many fish from each river are taken and thus estimate the impact of the fishery on each stock. The number of different river stocks which contribute to a fishery will depend on the site of the fishery relative to the various rivers and on the migratory path of the fish. In general, coastal fisheries are more likely to exploit significant numbers of fish from several rivers than are estuarial fisheries, and fisheries offshore more so than nets set close to the shore. The drift net fishery off the north-east coast of England, for example, exploits salmon returning to rivers between Yorkshire to Aberdeenshire, about 80% of the catch being fish bound for Scottish rivers[68]; fish taken in beach nets tended to be of more local origin than those caught in drift nets. The Scottish bag nets also exploit mixed stocks, but the results of tagging experiments in 1954–81 show that most of the fish caught are destined for local rivers. There is, however, substantial variation between sites, the most notable historical example being the former fishery for spring salmon at Soay (Isle of Skye) where tagging experiments in 1938 showed that most of the catch was destined for rivers on the north or east coast of Scotland. This was in sharp contrast to the results from contemporary tagging on the east and north coasts, where at a grilse fishery only 25 miles from Soay most of the recaptures were local.

It has also been shown that some estuarial fisheries exploit mixed stocks. For example, on the Fowey (Cornwall), 27% of the fish caught in the estuarial fishery are estimated to be returning to other rivers[69], while on the Avon (Hampshire) the proportion is about 10%[70]. The management difficulties created by mixed stock fisheries are exacerbated when the rivers of origin are under different jurisdictions, as they are on either side of the border between England and Scotland.

Catch and effort statistics provide only an approximate picture of changes in the size of a stock. Estimates of the proportion of the salmon population taken by nets are also required. However, additional information is also required on the size of the population from which the catch is made and such information is available for very few fisheries. Where counters are operated, catches can be related to the numbers of fish entering the river.

The balance of exploitation between rod and net fisheries is a matter of concern in some areas. The value of each rod-caught fish to the economy far exceeds that of fish taken by nets, but this oversimplifies the relationship between catches and the value of different fisheries. In particular, most studies of the value of fisheries have not been able to evaluate the benefit of changing the balance of exploitation between rod and net interests. In Scotland, the fully marketable nature of the salmon fishing rights, and the effect of market forces, provides a means by which the balance between net fishing and angling may be adjusted as relative values change. There is a long history of angling interests buying-up cruives or net fisheries with the purpose of limiting their operation. The recent large increase in the value of rod fisheries and the decline in value of net fishings has led to a reduction in net fishing effort over the past ten years. In England & Wales, many private net fishing rights in estuaries have been bought and are not operated;

however, in the public fisheries, the EA does not have power to restrict fishing by one method in order simply to enhance the catch by another.

The accuracy of catch and effort data for salmon fisheries in Great Britain has improved since the 1950s. Deficiencies in the catch statistics, relating to data on the amount of time or effort spent in fishing and the age composition of the catch, make it difficult to assess the performance of fisheries and their impact on stocks. We have previously commented on the importance of collecting data on fishing effort to improve the interpretation of catch figures *(Information on the Status of Salmon Stocks)*. Such data have been collected for all net fisheries in Scotland since 1952, although insufficient detail is provided to use the information for management purposes. In England & Wales, the catch per licence-day for net fisheries in some EA regions has been reported in the published catch statistics since 1988[71, 65]. In order to assess the impact of the fisheries, it is necessary to split the catch data into age categories. In Scotland, catches have been reported separately as salmon and grilse (weight is generally used to separate salmon from grilse after 1 May; before 1 May all are recorded as salmon), but these categories provide only an approximation of the age composition of the catch. In England & Wales, the reliability of estimates of the age composition of catches varies between EA regions because of differences in the reporting procedures. An international minimum standard for catch statistics has now been agreed by NASCO, which, amongst other things, requires the returns to be split into salmon and grilse categories from 1995.

There are still many fisheries for which a significant proportion of the fish killed is not reported in the catch statistics. Unrecorded catches may include catches made by people who are not authorised to fish (illegal fishing) and fish that are legally caught but are not reported in the catch statistics (unreported catches). Attempts have been made to estimate the unrecorded catches in some areas, but these figures are generally very imprecise. Additional fish may also be killed as a result of fishing activities but not landed. This will include fish which die in a net and then fall out, fish removed from fishing gear by predators and fish which escape but die later as a result of their encounter with the net. These losses are all part of the fishing mortality on the stock and, where possible, should be taken into account when considering the level of exploitation on stocks and planning future management strategies.

The differences between the regulatory systems of Scotland and England & Wales do not in themselves cause problems except in fisheries close to the border. In England & Wales, the number of participants in most fisheries is restricted by NLO and fishing activities are controlled through byelaws, which define the allowable dimensions of the gear and when and where it may be used. These regulations are designed to be applied in such a way as to limit fishing effort and thus the level of exploitation. In Scotland, the mechanisms which control fishing effort by nets, and thus exploitation levels, are conditioned by the fact that the right to fish for salmon at any particular site, on the coast or in an estuary, is privately owned and exclusive; salmon fishing in the sea around Scotland is not a 'common property' resource. Consequently, there has been no licensing or direct control on the number of fishing nets, with the exception of some fixed nets in the Solway, but there are regulations on netting methods and times. In neither jurisdiction does the system allow for precise control of catch nor, usually, for the rapid imposition of regulations. Nevertheless, *ad hoc* short-term controls have been achieved by providing financial compensation, such as the scheme that operated on the River Camel for three years following a major pollution incident. In Scotland, in a number of fishery Districts, netsmen have accepted voluntary restrictions which delay the start of the season or extend the weekly close time.

3.5.3 Possible solutions

The continued operation of fisheries exploiting mixed stocks makes proper conservation of salmon much more difficult. We commend the decision by Ministers to retain the ban on drift nets in Scotland and recommend that mixed stock fisheries should be phased out throughout Great Britain as soon as possible, due consideration being given to the financial consequences for the fishermen concerned.

We consider that the appropriate authorities should have powers to make changes in the relative levels of exploitation between rods and nets, taking account of social and economic factors. More detailed consideration of the allocation of the resource is beyond the scope of this report but requires attention at the national level. In Scotland, because fisheries are saleable, there is a mechanism which allows for some changes in the balance of exploitation.

We wish to reinforce what was said in our first report, *Information on the Status of Salmon Stocks*, about the importance of obtaining comprehensive catch statistics and effort data as indices of the performance of salmon fisheries. Although data collection procedures have improved recently, there is still a requirement for more comprehensive catch and effort data. Our earlier report emphasised the difficulty of evaluating exploitation rates even for single stock fisheries, in the absence of data on population sizes.

We consider it important to obtain estimates of unrecorded and illegal catches and that these should be considered alongside catch statistics, even though these are difficult by nature to establish.

In England & Wales and in Scotland, a range of measures is available to control levels of exploitation by nets, but procedures for introducing measures can be slow and often do not permit a rapid response to problems. We reiterate the recommendation made in our report, *The Regulation of Salmon Angling in Great Britain*, that procedures for introducing byelaws and Orders should be processed more rapidly. Ministers have some powers to introduce emergency measures to regulate fisheries if stocks are perceived to be under threat under the Sea Fisheries (Conservation) Act 1967 and the Inshore Fisheries (Scotland) Act 1984. However, legislation in this area is complex and we recommend that the adequacy of the provisions to allow a prompt and effective response is reviewed.

3.6 INDUSTRIAL FISHERIES

3.6.1 Description

Industrial fisheries are defined as those directed at catching fish for reduction purposes (fishmeal and oil) and not for human consumption. Typically, they are conducted using small mesh nets. Bottom trawls are the main gear used, purse seines only being used in industrial fisheries in Arctic waters. Preliminary figures for total international landings from the North Sea industrial fisheries in 1994, as reported to ICES, amount to 1.307 million tonnes[72]. This represents an increase on the 1993 catch (1.083 million tonnes), but is still below the long-term average (1974–93) of 1.439 million tonnes. The 1994 catches comprised mainly sandeel (59%), Norway pout (21%) and sprat (13%). Landings from the small industrial fisheries to the west of Scotland in 1994 amounted to 14,800 tonnes of Norway pout and 10,600 tonnes of sandeel. Annual catches of capelin from the Iceland, Greenland and Jan Mayen areas for 1964–94 are shown in Figure 11. The directed fishery was closed from December 1981 to November 1983 in response to the low stock abundance.

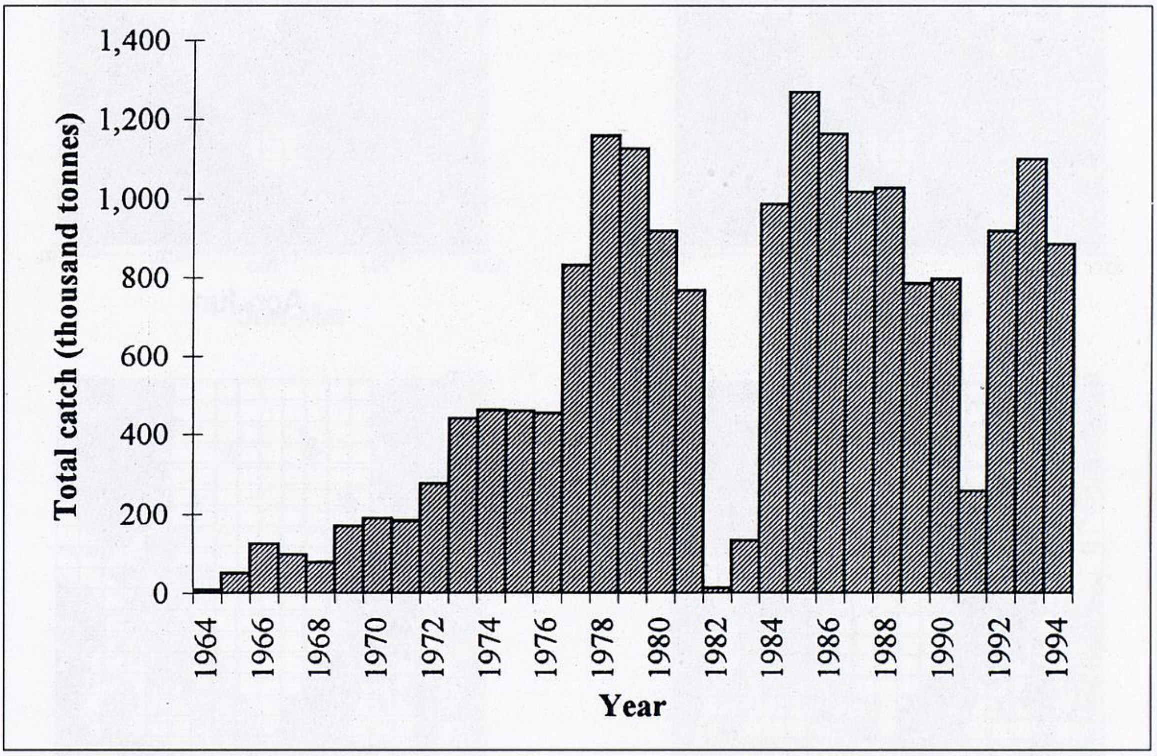

Figure 11: *Annual catches of capelin from the Iceland, Greenland and Jan Mayen area, 1964–94. (Source: data kindly supplied by ICES)*

The other target species include blue whiting and horse mackerel. There is a ban on directed fisheries for herring for industrial disposal, but many are caught as a by-catch in sprat and mixed clupeid fisheries. Figures 12, 13 and 14 show the distribution and timing of the major industrial fisheries around the UK in 1992–94. Areas of substrate suitable for sandeels in the North Sea are relatively small and fishing operations may be concentrated in banks of only a few hundred metres in width.

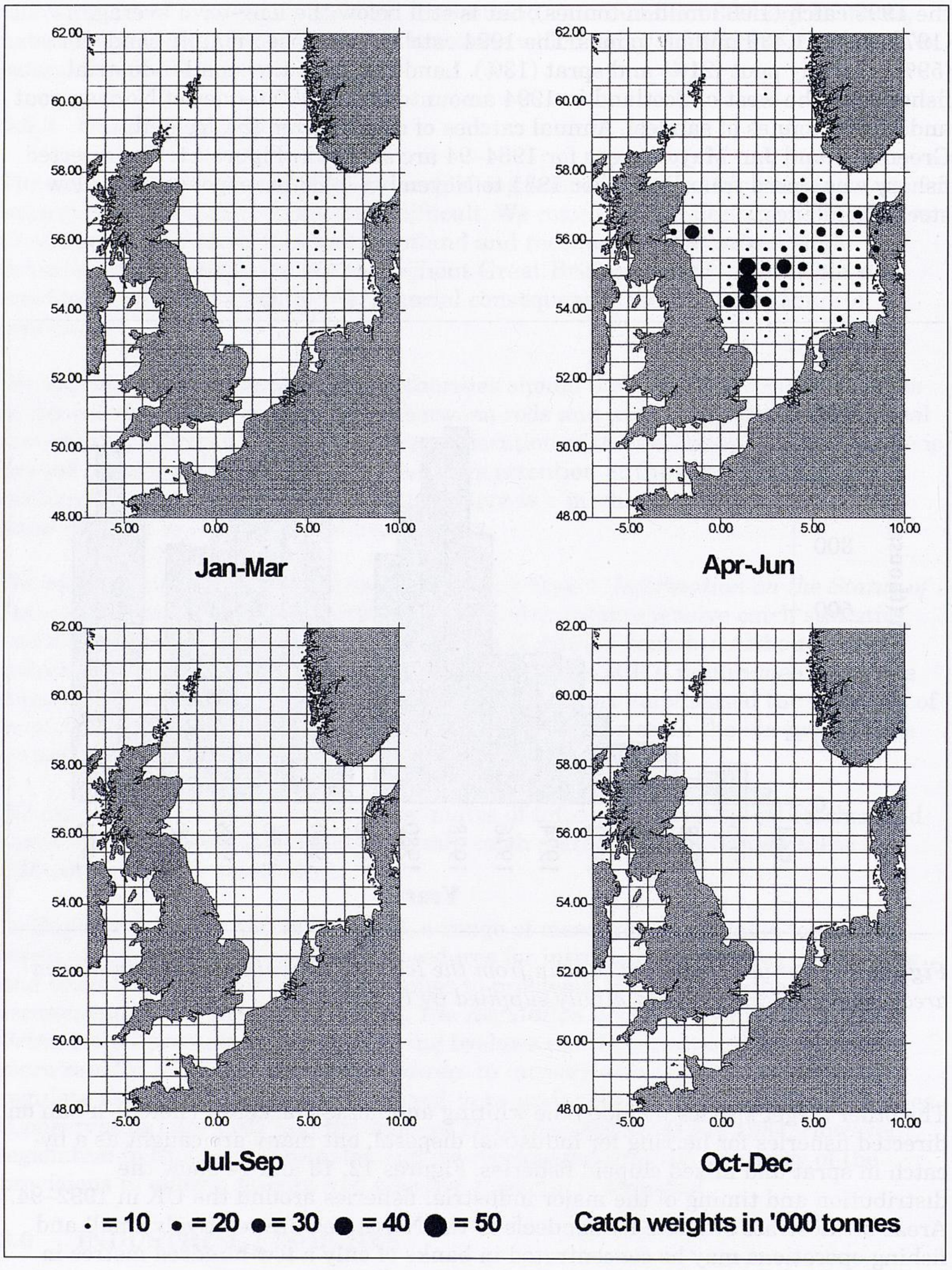

Figure 12: *The quarterly distribution of Danish and Norwegian sandeel catches in the North Sea, 1992. The diameter of the black circles is proportional to the catch taken in that statistical rectangle. For comparison, the circles in the key above represent a range of catch sizes between 10,000 and 50,000 tonnes. (Source: data kindly supplied by ICES)*

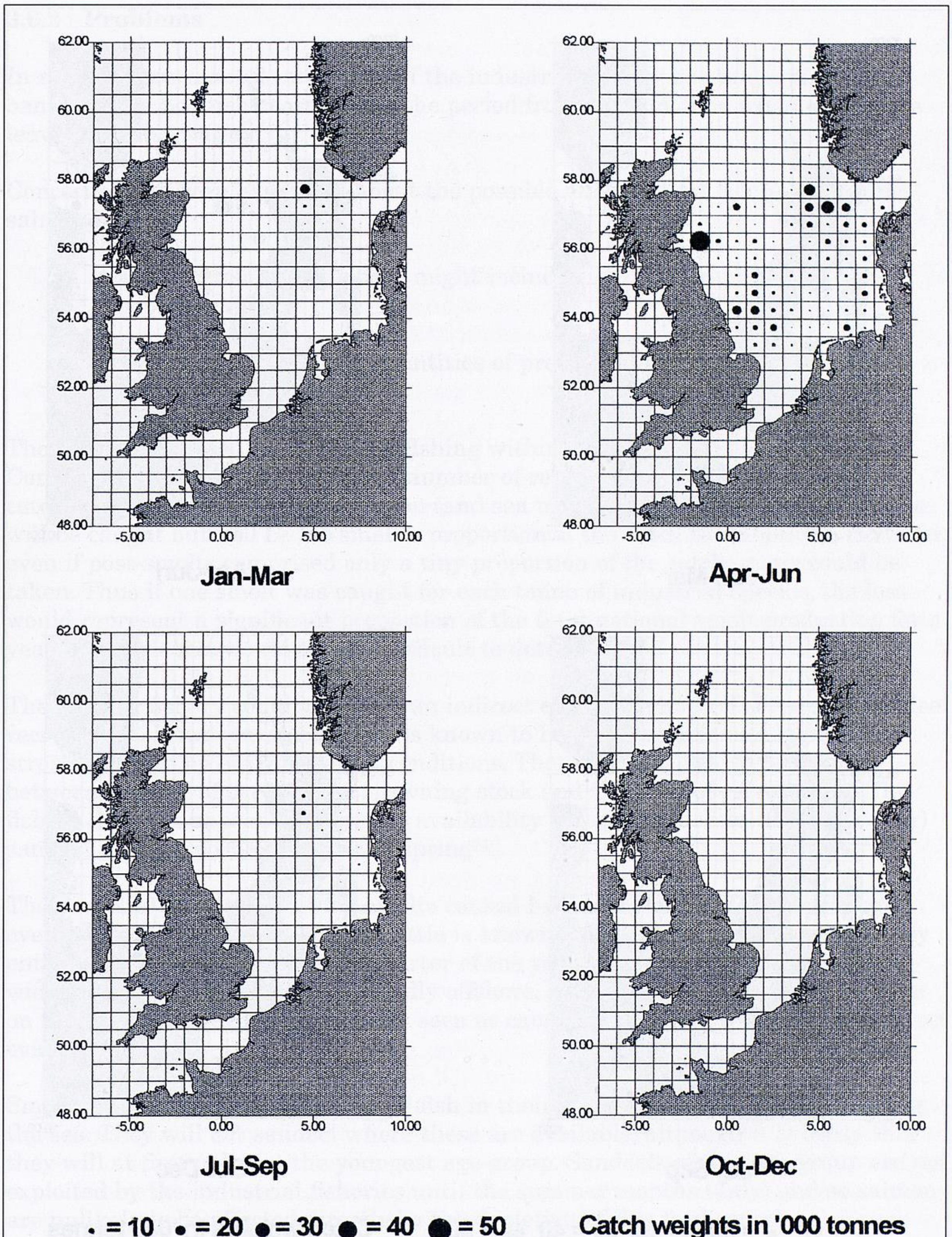

Figure 13: *The quarterly distribution of Danish and Norwegian sandeel catches in the North Sea, 1993. The diameter of the black circles is proportional to the catch taken in that statistical rectangle. For comparison, the circles in the key above represent a range of catch sizes between 10,000 and 50,000 tonnes. (Source: data kindly supplied by ICES)*

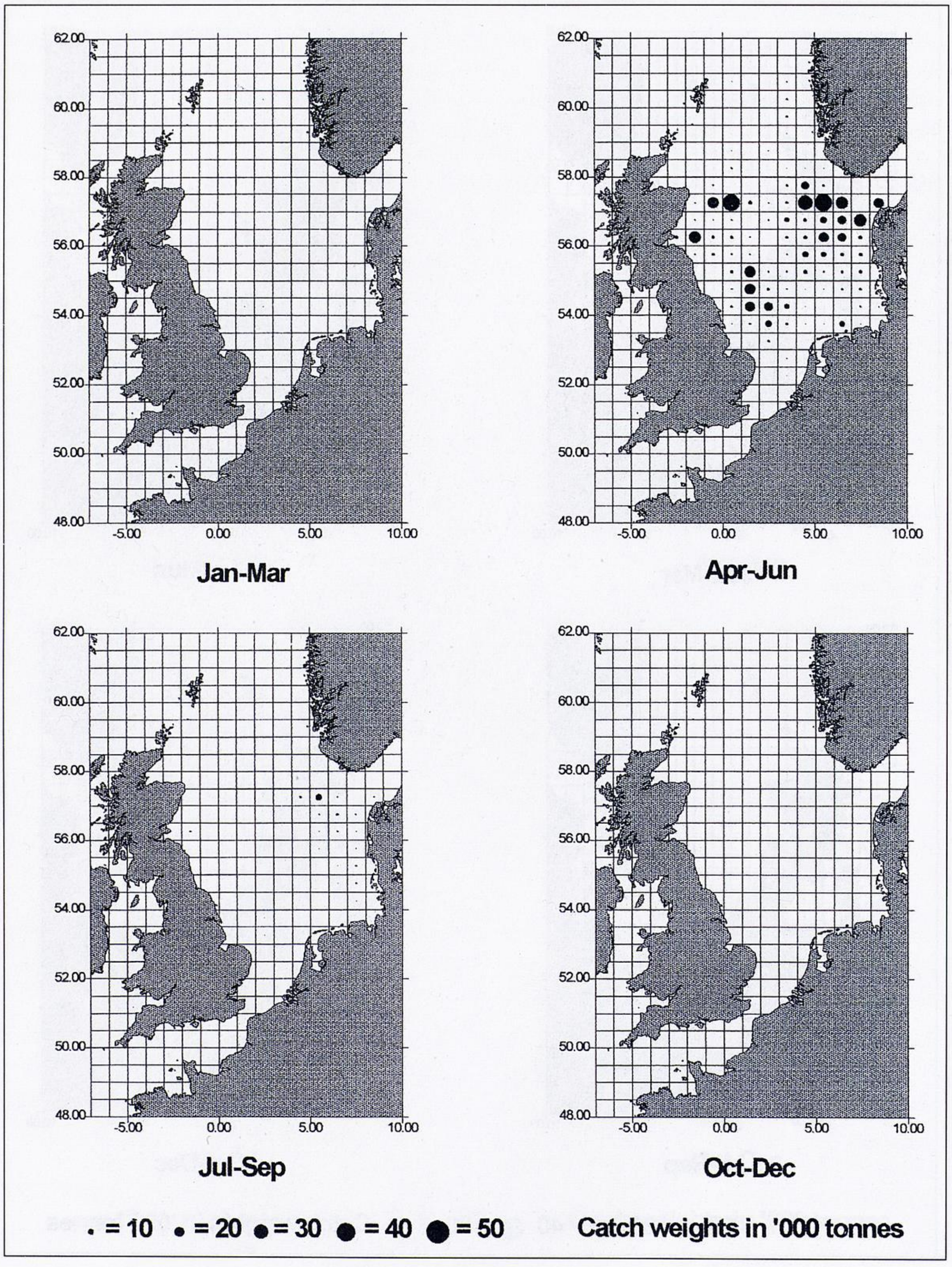

Figure 14: *The quarterly distribution of Danish and Norwegian sandeel catches in the North Sea, 1994. The diameter of the black circles is proportional to the catch taken in that statistical rectangle. For comparison, the circles in the key above represent a range of catch sizes between 10,000 and 50,000 tonnes. (Source: data kindly supplied by ICES)*

3.6.2 Problems

In recent years, a substantial part of the industrial fishery has taken place on banks off the Scottish coast during the period from April to June when smolts are leaving coastal waters.

Concerns have been expressed about the possible effects of industrial fishing on salmon because:

- the by-catch in the fishery might include significant numbers of post-smolts; and
- the fishery takes large quantities of prey species and may deprive post-smolts of food.

The controls imposed on industrial fishing within the European Union by the Common Fisheries Policy include a number of restrictions on the levels of by-catches. The main concern for salmon (and sea trout) is that smolts or post-smolts will be caught but will be too small a proportion of the catch to be noticed. However, even if post-smolts comprised only a tiny proportion of the catch, many could be taken. Thus if one smolt was caught for each tonne of industrial species, the loss would represent a significant proportion of the total national smolt production for a year, although this would be very difficult to detect.

The sandeel fishery could also have an indirect effect on smolts if it reduced sandeel recruitment. However, recruitment is known to be very variable and is probably strongly driven by environmental conditions. There is not a clear relationship between the size of the sandeel spawning stock and the level of recruitment. The fishery does not appear to affect the availability of 0-group (fish in their first year) sandeel prey for post-smolts in the spring[71].

The potential effects on salmon smolts caused by the depletion of their prey are even more difficult to assess. Very little is known about where smolts go after they enter the sea during the second quarter of the year, or about what they eat. It is widely thought that they move rapidly offshore, although this belief is based more on the fact that they are very rarely seen or caught close inshore than it is on direct evidence.

Smolts have been caught with small fish in their stomachs not long after entering the sea. They will eat sandeel where these are available, although it is likely that they will at first only eat the youngest age-group. Sandeels of this age-group are not exploited by the industrial fisheries until the summer months (July) and so salmon are unlikely to be affected directly by the depletion of this food source.

A study has been carried out to investigate possible relationships between rod and line catches of salmon and sea trout and the relatively small sandeel fishery off north-west Scotland[73]. Although the statistical treatment of the data was limited, the authors concluded that there was no indication that catches of salmon or grilse were affected by any by-catch of smolts. The study suggested that catches of MSW salmon, but not grilse, in the north-west were correlated with the abundance of sandeels available to the emigrating smolts. These correlations have been lost with the addition of more recent data.

Although there is no direct evidence that the current levels of industrial fishing are having an adverse impact upon UK salmon stocks, the Committee is concerned about the sandeel fishery in the North Sea, and the apparent lack of regulation of catches. This lack of evidence may indeed reflect a true absence of impact, but any impact on salmon stocks would have to be very considerable for it to be apparent in catch statistics in the short-term.

3.6.3 Possible solutions

Much more information is required on the movements, behaviour and food of smolts in their first few months in the sea in order to assess the factors which influence early survival and thus whether the industrial fisheries present a real threat to stocks. The EC has been asked to press ahead with a thorough study of industrial fishing including its possible effects on the marine ecosystems and marine animals and birds.

We urge Ministers to promote investigation of the impact of industrial fisheries, both upon salmon and upon the marine ecosystem as a whole. We note and welcome the initiative of the Atlantic Salmon Trust to finance an investigation of potential by-catch problems, but are concerned that such an important investigation had to be proposed and funded by a charitable organisation. We recommend that action is taken to ensure the proper management of industrial fisheries, taking account of the scientific findings of these investigations. We consider that further studies are required on the distribution and behaviour of smolts and post-smolts, including vertical movements, in the waters around Great Britain in order to assess the potential for interactions with industrial fisheries. We also recommend that some investigations of by-catches are targeted at areas where salmon smolts are most likely to occur.

3.7 BY-CATCHES IN MARINE FISHERIES

3.7.1 Description

Adult salmon may be caught as a by-catch in a range of fisheries for marine species. Catches in active gear such as trawls are probably infrequent because adult salmon can swim fast enough to avoid the net, although there is now good evidence from research fishing off north-west Scotland and in the Norwegian Sea that post-smolts may be caught in surface trawls. However, gill nets set for whitefish may take significant numbers of salmonids, particularly where they are set in shallow water and can thus catch salmon swimming close to the surface. Prior to the provision made in the Salmon Act 1986, salmon and sea trout were caught in large numbers around the coast and in the estuaries of England & Wales by fishermen using anchored gill and trammel nets. Although the Salmon Act has alleviated some of these problems, spring salmon are still thought to be particularly vulnerable to static trammel nets because these nets can retain large fish. In the north-east of England, salmonids are known to be caught in drift nets ostensibly set for mackerel. The number of mackerel drift nets is not restricted, although the catch is limited by quotas.

3.7.2 Problems

By-catches in marine fisheries represent additional fishing mortality over and above that caused by directed salmon fishing. If it occurs at a significant level, it poses the following additional problems to directed legal fisheries.

- The fishing activity may be diffuse in nature and thus difficult to control.
- It may be difficult to obtain information on catches.
- The river of origin of fish caught at sea will usually be unknown.

The fact that retaining any salmon caught as a by-catch is generally illegal means that records are rarely kept of such by-catches. However, even if the fish are discarded as required by law, they are likely to die and this will not be recorded. This increases the difficulties of estimating the impacts of these activities on individual river populations. This problem is also addressed in our recent report *The Anti-poaching Measures Contained in the Salmon Act 1986*.

3.7.3 Possible solutions

We believe that the recent results of Norwegian sampling with large surface trawls now justify a directed investigation into the occurrence of post-smolts as a by-catch in fisheries using surface trawls for other species. In the first instance, we suggest that this issue should be considered by ICES.

Regulations have now been introduced in much of England & Wales to restrict the use of fixed nets in areas where they are most likely to catch migratory salmonids. We recommend that such measures should be introduced in all areas and should be carefully monitored to ensure that they are effective in limiting the by-catch of salmon.

We consider that policing of fisheries responsible for by-catches of salmon could be improved by greater cooperation between all EA and Sea Fishery Committee Enforcement Officers, especially when vehicle searches and vessel inspections are undertaken. English and Welsh Sea Fisheries Committee Fishery Officers are empowered under the Sea Fisheries Regulation Act 1966 to enforce byelaws made to protect salmon under Section 37 of the Salmon Act 1986. We recommend that every effort is made to utilise this power.

3.8 SALMON FARMING

3.8.1 Description

Salmon farming involves the captive rearing of salmon to produce fish for the table. Eggs from farmed broodstock are incubated in hatcheries often capable of producing several million young fish. Smolts are produced in freshwater tanks or cages and then transferred to sea water to grow to marketable size. The majority of sea water salmon farming takes place in Britain in floating cages in sea lochs or sheltered coastal sites around the west coast of Scotland and the Scottish Islands (Figure 15). Developments in the manipulation of the life-cycle and improvements in husbandry and feeds have shortened both the freshwater and the seawater stages in the production. Most smolts are transferred to sea water after one year in fresh water but, increasingly, younger smolts (less than one year old) are being put to sea at times of year other than spring. Many salmon are now harvested after only a year in sea water at weights of 3–4 kg.

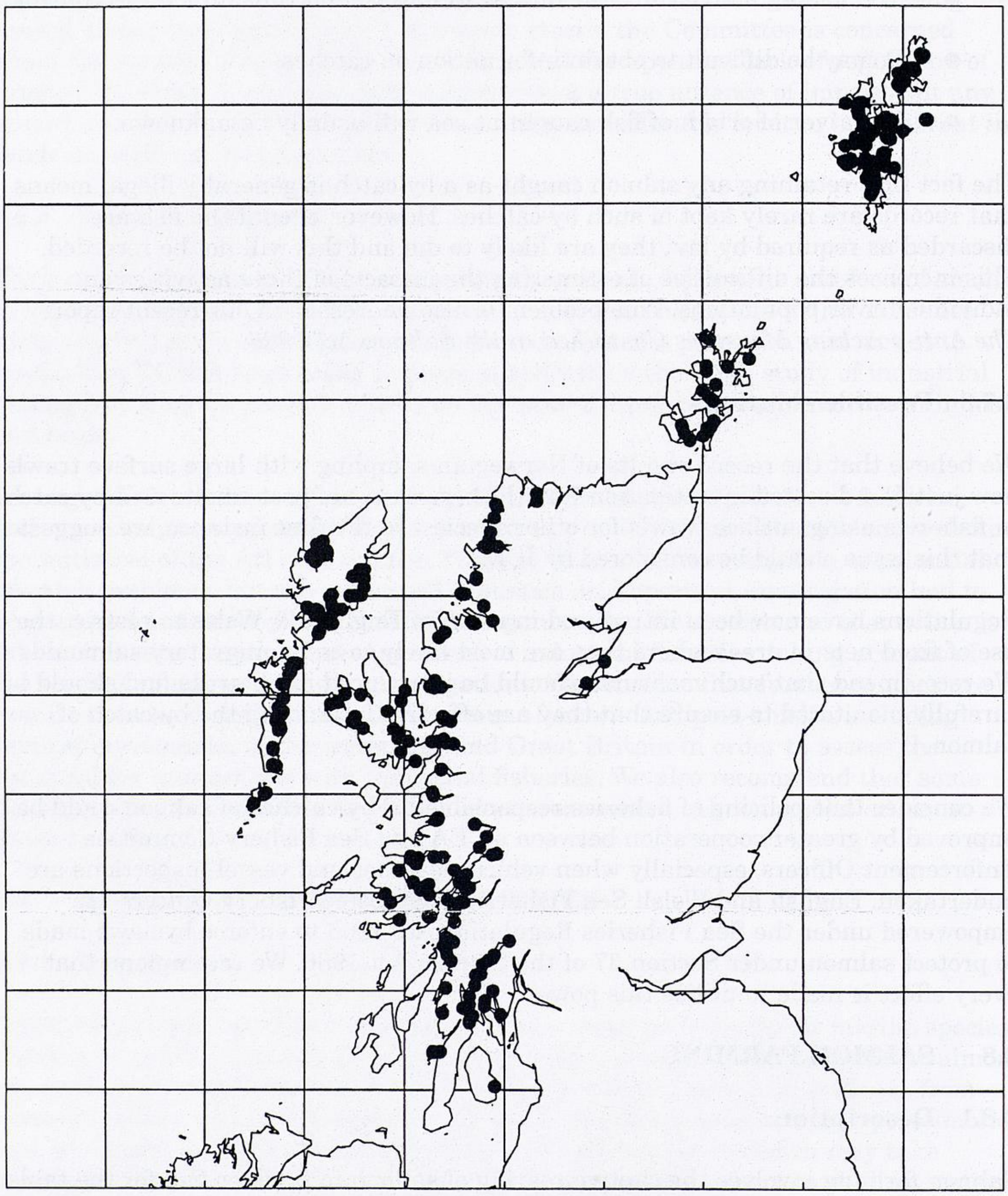

Figure 15: *Distribution of seawater salmon farms in Scotland in production in December 1995. (Source: SOAEFD[74])*

Salmon farming began in the 1960s in Norway and Scotland. It was carried out on a relatively small scale through the 1970s while many problems including those of breeding and rearing, nutrition, health and the design and management of cages were addressed. From the early 1980s, the industry expanded rapidly with the total production from farms in the North Atlantic increasing from less than 5,000 tonnes in 1980 to over 400,000 tonnes in 1995 (Figure 16). In 1995, the total output from Scottish farms was just over 70,000 tonnes.

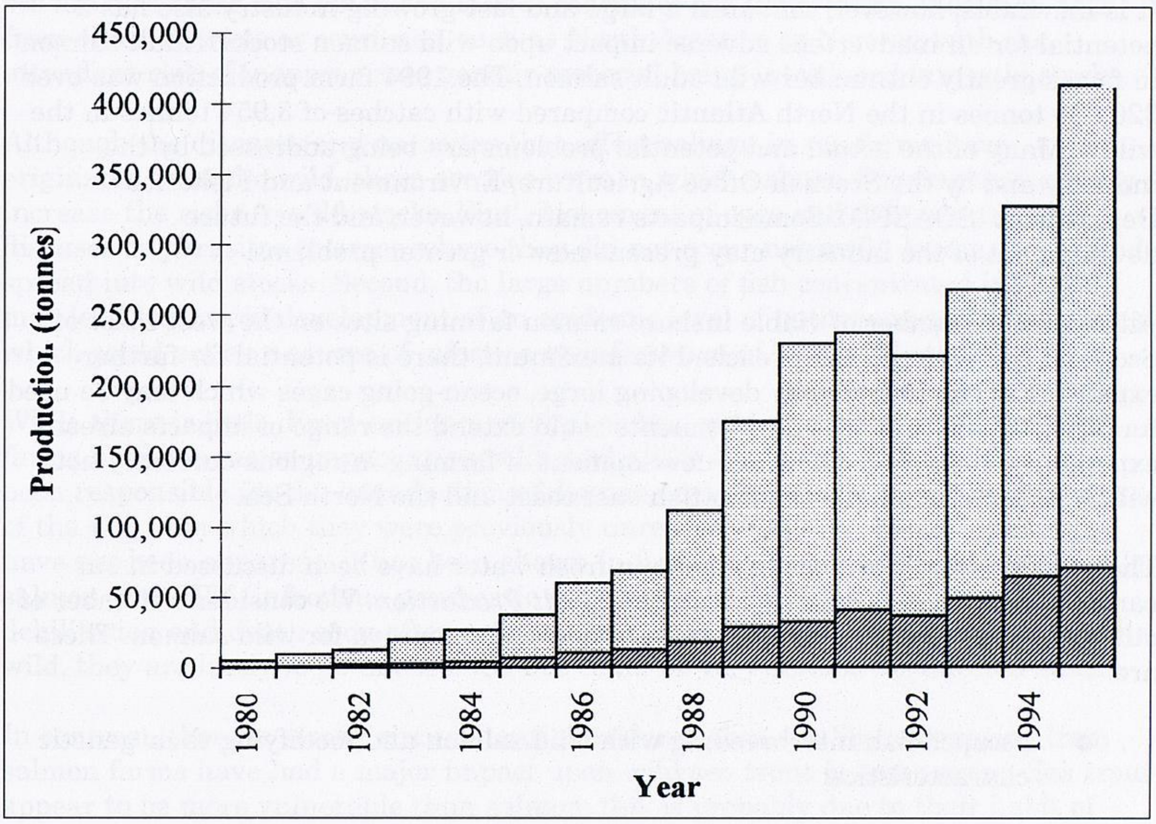

***Figure 16:** Weight of farmed salmon (tonnes) harvested annually in the North Atlantic, 1980–95. Darker area denotes Scottish production. (Source: figures kindly provided by ICES)*

The earliest cages to be used were small (125 cubic metres and 5 metres deep) with a wooden frame and polystyrene flotation and their use was confined to sheltered inner loch areas. Now most production is in robust galvanised steel-framed cages with flexible rubber or plastic flotation collars which can be moored on more exposed sites. The largest cages enclose over 1,000 cubic metres of water and can hold over 100 tonnes of fish. Production from individual sites, which may have an array of cages, varies from less than 50 tonnes to more than 1,000 tonnes of salmon per annum. The largest groups of cages may house 500,000 or more salmon.

In the Scottish industry, the percentage of smolts put in cages which was subsequently harvested has increased from 58% to 90% between 1989 and 1995. Losses have been mainly due to diseases, husbandry problems and escapes from cages caused by accident, human error or damage by storms or predators. In recent years, harvest rates have been in the upper part of the range quoted above.

3.8.2 Problems

The short history of salmon farming represents a remarkable success, providing wide-ranging benefits for the community. It has brought employment and associated benefits to many remote rural areas and also produces a valuable food commodity. Salmon farming has also provided extensive benefits for the management of wild salmon stocks in terms of advances in hatchery and rearing technology and a greater understanding of the physiology and genetics of the species. Farmed fish now dominate the market for salmon for human consumption. This has reduced the sale price of salmon and has eased the pressure of exploitation on wild stocks.

It is inevitable, however, that such a large and fast-growing industry also has a potential for an inadvertent adverse impact upon wild salmon stocks. Adult salmon in farms greatly outnumber wild adult salmon. The 1994 farm production was over 326,630 tonnes in the North Atlantic compared with catches of 3,954 tonnes in the wild[10]. Many of the actual and potential problems are being addressed by the industry and by the Scottish Office Agriculture, Environment and Fisheries Department (SOAEFD). Some impacts remain, however, and the future development of the industry may present new or greater problems.

Although the number of viable inshore salmon farming sites on the west coast of Scotland has now probably reached its maximum, there is potential for further expansion of the industry by developing large, ocean-going cages which may be used further from shore. These developments could extend the range of impacts already experienced and could allow the development of farming in regions currently not widely used, for example the Scottish east coast and the North Sea.

The possible effects of rearing smolts in fresh water have been discussed in our earlier report *Factors Affecting Natural Smolt Production*. We consider a number of other aspects of salmon farming to be of particular concern for wild salmon. These are:

- escaped fish interbreeding with wild salmon and modifying their genetic characteristics;
- spread of viral and bacterial diseases from fish in cages to wild fish;
- production of large numbers of larval sea lice which infest wild fish; and
- pollution of sea lochs and the sea bed with waste food, faeces and chemicals.

It has been demonstrated that salmon which have escaped from farms can breed successfully with wild fish[75]. While this would clearly take place in fresh water, we consider the consequences in this report. Concerns have been expressed that the viability of wild salmon stocks may be reduced if these fish breed with those that have escaped from fish farms where in-breeding or selection for particular characteristics may have reduced their genetic variability. Of particular concern is the current experimentation with genetically modified salmon. If the use of such fish were to be developed by the salmon farming industry, and they were to be reared in sea cages, the escape of genetically modified fish could be ultimately expected to occur with unknown consequences for the future of wild salmon stocks.

Commercial catches of salmon at some fishing stations on the west coast of Scotland have, in some years, contained as many fish of farmed origin as wild salmon. Although the reliability of cage frames and flotation, moorings and nets has improved, it must still be assumed that farmed salmon will escape from sea cages from time to time, occasionally in large numbers or as large individuals. Where salmon farms are located close to small rivers supporting stocks of wild salmon and sea trout, the potential exists for the number of wild fish in such rivers to be greatly exceeded by fish farm escapees.

We are also concerned about the lack of control of the importation of salmon eggs from other districts or countries, such as North America or Norway, with the attendant risk of inappropriate genetic material being introduced into wild stocks.

Although the diseases and parasites that affect salmon in sea farms have originated from the wild, there are two ways in which salmon farming may greatly increase the risks to wild stocks. First, movement of eggs and fish may transfer diseases or parasites to areas where they did not occur naturally, leading to a rapid spread into wild stocks. Second, the large numbers of fish concentrated in farms may lead to a rapid development of an epidemic level of pathogens and/or parasites which could act as a source of infection or infestation of local wild stocks.

While there is little direct evidence of viral or bacterial disease agents from fish farms having a major impact upon wild stocks, it is likely that fish farming has been responsible for the introduction of disease organisms into the UK and to parts of the UK from which they were previously unrecorded. While obvious epidemics have not been apparent, it has been shown in fish farming that infection of juvenile salmon with IPN (infectious pancreatic necrosis) in fresh water may cause debilitation and death soon after entry to salt water. If such mortalities occur in the wild, they are likely to go unobserved but could be very serious for affected stocks.

In contrast, there is strong circumstantial evidence that sea lice originating from salmon farms have had a major impact upon wild sea trout in some areas. Sea trout appear to be more vulnerable than salmon; this is probably due to their habit of remaining close inshore in coastal waters after leaving the river whereas salmon smolts generally leave the coastal area promptly. However, salmon smolts may also be vulnerable in situations where they have to travel significant distances in coastal waters to reach the open sea, for example in long sea lochs. If salmon smolts do die as a result of heavy sea lice infestation, it seems likely that this would occur unnoticed at sea.

Significant levels of disease or parasitic infestation represent a problem for fish in cages as well as for wild stocks. Considerable progress has been made, for example in the control of the bacterial disease furunculosis which was a major cause of mortalities on farms in the 1980s. However, outbreaks of diseases and parasites are still likely to occur from time to time. Further, levels of sea lice infestation that cause few problems for adult salmon in cages may nonetheless generate numbers of larvae that could cause major problems for local wild stocks.

The build up of uneaten food and faeces beneath salmon cages is known to have significant but localised effects upon the local environment. While passing wild salmon are less likely to be affected, it is possible that the decomposition products could interfere with the sensitive chemosensory system that salmon use in homing to their native stream. It is also possible that some of the therapeutic chemicals used in the salmon farming industry could have an impact on wild fish. However as a result of the stricter regulation of the use of these chemicals this risk is now considerably diminished.

3.8.3 Possible solutions

Having recognised the wide-ranging benefits arising from salmon farming, the Committee wishes to see an assured and prosperous future for the industry developing within an appropriate framework of management of the coastal zone as a whole. We are concerned that the development of large ocean-going cages could lead to the establishment of salmon farming on a large scale in new areas, particularly on the Scottish east coast and in the North Sea. We recommend that there should be a presumption against any such development because of the risks posed to local, wild salmonid stocks.

We believe that many of the present and potential impacts could best be addressed by a new authority with responsibility for developing and managing a strategic policy covering all aspects of salmon farming, working in concert with the industry itself. Such an authority would impose regulations, taking a balanced view of the reasonable requirements and aspirations of the industry on the one hand, and of the real and potential impact of salmon farming in local, regional and national terms on the other.

The new authority should incorporate a salmon farming inspectorate with powers to ensure compliance with these regulations. We recognise the good work being undertaken by the existing SOAEFD Fish Health Inspectorate and suggest that the new authority should incorporate this body.

Below we detail specific actions and recommendations addressing the problems already discussed. While ideally these would be the responsibility of the new authority, they should be addressed even in the event of a delay in establishing such a body.

We consider that ideally fish farmers should only rear sterile salmon so that any fish that escape cannot breed in the wild. However, current techniques for producing sterile fish, such as triploidisation and chemical or immunological castration, have not yet been successfully incorporated into the farming process. While triploid salmon are sterile, they may be more susceptible to stress and disease than the normal diploids. We therefore welcome the research being conducted into the production of sterile salmon.

Given that escapes will continue to occur from sea cages, we believe that all major escapes from fish farms should be notified immediately upon discovery, and that approved contingency plans should be in place for containing and recovering as many escaped fish as possible. Such plans should provide for speedy but temporary licensing of netting by methods that might otherwise be illegal. We recognise however that many escapes occur in stormy weather which may restrict attempts to recapture fish.

Experimentation with genetically modified salmon is already controlled by licence. Even if there is perceived to be any commercial advantage in rearing such fish in fish farms, this practice should not be permitted in sea cages. If authorised, any genetically modified fish should be held only in secure land-based tanks, which are independently monitored. Even in such circumstances, the possibility of escape into the wild should not be ignored, either as a result of accident or by deliberate design.

The solution and avoidance of disease and parasite problems for salmon farms must continue to lie in the regulation of the industry and adoption of good husbandry practices. When enforced, the notifiable diseases legislation is generally effective within farms, but it is far less effective outside the farm and greater stringency is required to reduce the introduction and spread of pathogens to wild stocks. Farms should continue to make efforts to reduce the incidence of diseases such as IPN and pancreatic disease (PD) through use of certified disease-free eggs, careful control of stock distribution, good husbandry, site fallowing, etc.

In Ireland, the problems caused by sea lice from fish farms have been addressed by setting advisory maximum levels of egg-bearing sea lice backed-up by regular statutory inspection of cages on each site. Development of a similar system is recommended for Great Britain, although careful consideration of the definition of 'acceptable' levels of lice on an area-by-area basis will be required. This must reflect a total bay-by-bay loading and not just the average level of infestation of individual fish. Methods potentially available for management of levels of sea lice include chemical treatments by immersion or food additives, fallowing or other stock management to limit infestation between year classes, and use of wrasse as 'cleaner fish'.

3.9 ACTIVITIES AFFECTING WATER QUALITY

3.9.1 Description

Good water quality is an essential requirement for the well-being of the salmon population. The various stages of a salmon's life-cycle have the same basic water quality requirements including well oxygenated water, appropriate water temperatures and pH, and an absence of chemicals in concentrations which are acutely or chronically toxic. These requirements are described in our earlier reports, *Factors Affecting Natural Smolt Production* and *Factors Affecting Emigrating Smolts and Returning Adults*. Both reports describe those human activities which affect water quality in rivers and estuaries and consequently smolt production and migration, and returning adults.

Most pollutants are produced as a consequence of human activities and, for persistent chemicals (i.e. those which are not readily degradable), the seas and oceans are the ultimate sinks in which they accumulate in the water, the sediments and in organisms. The sources of marine pollutants can be summarised as follows.

A. From land:
- river discharges (sewage and industrial wastes);
- direct discharges through coastal outfalls (sewage and industrial wastes including food processing wastes); and
- agricultural run-off (pesticides and fertilisers).

B. From activities at sea:
- licensed dumping from ships (sewage sludges, food processing wastes, industrial wastes and dredged material);
- deliberate unauthorised dumping from ships (tank washings, e.g. oil);
- accidental discharge from ships and installations as a consequence of spillages, collisions, ship-wreck, blow-outs or other incidents at off-shore platforms and from ruptures of underwater pipelines (oils and other noxious chemicals);

- mariculture (nutrients and particulate matter); and
- exploitation of the seabed (oils, gases, minerals including potentially toxic chemicals and gravel).

C. Atmospheric deposition of volatile compounds and particulate matter (emissions from industry, energy production and use, combustion processes and agricultural activities).

3.9.2 Problems

A detailed review of water quality in the seas and oceans can be found in the report of the Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP)[76]. This review concluded that the open sea beyond the continental shelf was still relatively clean and that although low levels of lead and synthetic organic compounds, particularly chlorinated hydrocarbons, were widely detectable, the concentrations found were biologically insignificant. It also states that although contaminants arising from land-based sources are transported to the seas and oceans, only a small proportion of these contaminants has spread beyond the limits of the continental shelf.

About 98% of the lead which eventually dissolves in sea water enters from the atmosphere, as does most of the dissolved cadmium, iron and zinc. Inputs of arsenic and nickel derived from the atmosphere are also significant. Atmospheric inputs account for 80–99% of polychlorinated biphenyls (PCBs), dichlorodiphenyl–trichloroethane (DDT), hexachlorobenzene (HCB) and hexachlorocyclohexanes (HCH). Concentrations of contaminants derived from the atmosphere decrease with increasing distance from their land-based sources[77]

In general terms, therefore, although contaminants are found, salmon appear to face few water quality problems in the open sea or the ocean. It is in coastal waters and enclosed seas such as the North and Irish seas that water quality problems for salmon are most likely to occur.

The Irish Sea generally has higher concentrations of dissolved trace metals than the North Sea[77]. The highest concentrations have been observed in estuarine waters and have been attributed to human activities. The concentrations have been found to decrease rapidly with distance from the shore. In 1992, none of the concentrations measured exceeded the established Environmental Quality Standards (EQSs). The level of HCHs and triazine herbicides present have also been measured and all were found to be below the established EQS values[77].

For the Irish Sea, it has been reported that although effects and influences of human activities could be detected, they were, by and large, of relatively minor importance, or if serious then the effects were either localised and or temporary[78]. There were no clear indications of adverse impacts in the coastal waters of the Western Irish Sea due to such contaminants. However, two issues of concern were identified in Liverpool Bay. First, multiple-loading by individually 'harmless' contaminants may still result in what is described as an 'environment under stress', and second, concentrations of mercury in fish which were close to the prescribed EQS.

The NRA report[79] that 'the levels of contaminant inputs monitored over the period 1990 to 1993 varied around the England & Wales coastline, the North Sea and the

Irish Sea receiving the highest loads of many substances. Loads of copper, zinc, nitrogen and phosphorus were highest into the North Sea, whereas cadmium and mercury inputs were greatest into the Irish Sea'. Between 1985 and 1993 the loads of cadmium, mercury, copper, zinc, lead and lindane discharged to the coastal waters around England & Wales have been reduced by 65, 80, 60, 21, 27 and 63%, respectively. We welcome these reductions in the amounts of pollutants discharged to the sea and would wish to see this trend continue.

The GESAMP Report[76] considered that the rate of introduction of nutrients, especially nitrates but sometimes also phosphorus, was increasing and areas of eutrophication were expanding along with enhanced frequency and scale of unusual plankton blooms.

Consideration of the evidence presented in these reports suggests that, at present, returning salmon are not likely to be affected adversely by water quality conditions in the seas around the UK coastline. We are concerned, however, about the possibility of long-term or chronic effects arising from the additive effect of individually harmless contaminants and would wish to see this investigated. We are also concerned by potential problems arising from the eutrophication of coastal waters. The consequent blooms of algae, if large enough, could lead in some circumstances, particularly in sheltered areas, to deoxygenation of the water and deaths of fish.

3.9.3 Possible solutions

In 1992, member states of the Paris Convention, the Oslo Convention and the EC agreed the *Convention for the Protection of the Marine Environment in the NE Atlantic*. It included proposals to establish a quality assessment programme for the marine environment; to reduce discharges or emissions of substances which are toxic, persistent or liable to bioaccumulation; to reduce, by the year 2000, concentrations of these substances to levels which are not harmful to man or nature; to prevent and eliminate pollution caused by dumping of wastes; to reduce discharges or emissions of nutrients in those situations where they are the likely cause of eutrophication; and to collect quantitative data about land-based discharges and diffuse sources of hazardous substances and nutrients reaching the sea. We welcome these initiatives and would like to see the Convention ratified.

We welcome the continued efforts being made as a consequence of the North Sea Conference Declarations to reduce the input of loads of dangerous substances discharged from rivers and estuaries to the North Sea, and particularly the requirement to reduce inputs by the year 2000 to such an extent that inputs of hazardous substances no longer represent a danger to man or nature. Efforts to comply with the requirements of the *EC Directive on Pollution Caused by Dangerous Substances Discharged to the Aquatic Environment* and its various subsidiary directives, which prescribe the standards for such substances, are also contributing to the reductions in the amounts of hazardous substances reaching the sea. Similarly, compliance with the *EC Directive on Urban Waste Water Treatment* will reduce the quantities of untreated sewage discharged to the sea and also, in some circumstances, the quantities of nutrients.

Effective implementation and enforcement of these measures will reduce the potential risks to salmon in coastal waters around Great Britain. However, there will continue to be threats from accidental or deliberate discharges of hazardous materials, the sublethal effects of certain contaminants and the additive or synergistic effects of concentrations of chemicals which are in themselves harmless. We recommend that these threats are investigated further.

We recommend that appropriate programmes are maintained or implemented to monitor the atmospheric inputs of contaminants to the oceans, and that the biological significance of such inputs is assessed.

3.10 ACTIVITIES AFFECTING THE PHYSICAL ENVIRONMENT

3.10.1 Description

There are two levels of potential impact on the physical environment of salmon in the sea. First, on a global scale, the burning of fossil fuels is contributing to climatic change, generally described as global warming. Second, there are activities that may have an impact at a local level. These include seismic surveys and shipping that generate acoustic disturbance, and power stations and other industrial activities with effluents of warmed water discharged into estuaries and coastal waters.

3.10.2 Problems

Global warming has been discussed for many years, but there is still great uncertainty about its extent and impact. In Section 3, the apparent sensitivity of salmon to changes in water temperature in its oceanic habitat has been described. Many of the oceanographic processes likely to influence salmon, including currents, fronts and upwelling are largely driven by atmospheric conditions, especially wind. We are concerned that many of the critical processes may be highly sensitive to even minor climatic change. However, it is not at present possible to say whether any of the recent oceanographic variation associated with poor marine survival of salmon is in any way connected with global warming.

Generally, local physical impacts appear to have little effect upon salmon. Many important salmon rivers have estuaries with busy harbours and considerable industrial activity, e.g. Dee (Aberdeen), Tay (Dundee), Tyne (Newcastle), Test and Itchen (Southampton) and Tamar (Plymouth). Although water quality associated with such activities has often had a major impact, there is little evidence of impacts of physical effects. Heated water from power stations may cause local disruptive effects upon salmon passage (as described in our report *Factors Affecting Emigrating Smolts and Returning Adults*), but any more general impact upon their migration appears unlikely.

3.10.3 Possible solutions

Any action in relation to global warming will stem from much wider concern than the well-being of salmon stocks. However, salmon are sensitive to changes in marine environmental conditions and may therefore be particularly vulnerable to climatic change. We recommend that Ministers should take account of this when considering the development of policies in relation to global warming.

3.11 PREDATOR CONTROL

A great variety of species may prey on salmon in the open sea. Given the wide dispersion and mobility of salmon and their predators, it is almost impossible to measure the quantities of salmon taken as prey by each species of predator and to relate these to salmon stocks from particular river systems, or indeed countries. In general, the possibility of effective management of predators in the open sea, even if desirable, is remote. When returning salmon are channelled and concentrated by coastal features, they are more likely to attract the attention of predators such as seals. Predation by seals is more fully discussed in our report on *The Effects of Predation on Salmon Fisheries*.

3.12 SPECIFIC RECOMMENDATIONS CONTAINED IN SECTION 3

3.12.1 Salmon fisheries at Faroes and West Greenland (Section 3.2.3)

(a) Efforts should be made to negotiate a permanent closure of the fisheries in Faroes and Greenland waters. In the meantime, the suspension of fishing can justifiably be viewed as a cost-effective and immediate stock enhancement technique for homewater fisheries.

(b) In the absence of a permanent closure of these fisheries, the quotas negotiated by NASCO should be based on biological principles and should be related to the current state of the individual stocks being exploited and the fisheries in homewaters.

(c) Better estimates should be obtained of the undeclared catch that is sold locally in Greenland.

(d) NASCO should be asked to review the requirement to discard salmon under 60 cm in length. The justification for this measure is questionable because few of the discarded fish survive. It might therefore be preferable that these fish are landed and counted against the quota.

3.12.2 Salmon fisheries in international waters (Section 3.3.3)

(a) All efforts should be made to prevent any fishing for salmon in international waters.

(b) The conclusions of the UN *Conference on Straddling Fish Stocks and Highly Migratory Fish Stocks* and the FAO *Agreement to Promote Compliance with International Conservation and Management Measures by Fishing Vessels on the High Seas* should be closely examined with a view to finding a means to prevent the reflagging of vessels used for fishing for salmon in international waters.

(c) Until permanent closure is achieved, any salmon fishery in international waters should be closely monitored to obtain better information on fishing activity and catches.

3.12.3 Irish salmon fisheries (Section 3.4.3)

(a) Continued pressure should be applied by Ministers on the Irish Government and DANI to phase out fisheries, particularly the offshore drift net fishery, which exploit fish returning to Great Britain. We fully support any action to improve the management of these fisheries.

3.12.4 British salmon fisheries (Section 3.5.3)

(a) Mixed stock fisheries should be phased out throughout Great Britain as soon as possible, due consideration being given to the financial consequences for the fishermen concerned.

(b) The appropriate authorities should have powers to make changes in the relative levels of exploitation between rods and nets, taking account of social and economic factors.

(c) The introduction of new byelaws and Orders should be processed more rapidly. Ministers have some powers to introduce emergency measures to regulate fisheries if stocks are perceived to be under threat. However, the legislation is complex, and the adequacy of the provisions to allow a prompt and effective response should be reviewed.

3.12.5 Industrial fisheries (Section 3.6.3)

(a) Ministers should promote investigation of the impact of industrial fisheries upon salmon and upon the marine ecosystem as a whole. Action should be taken to ensure the proper management of industrial fisheries, taking account of the scientific findings of these investigations.

(b) Investigations of by-catches in industrial fisheries should be conducted in areas where salmon smolts are likely to occur.

(c) Further studies are required on the distribution and behaviour, including vertical movements, of post-smolts in waters around Great Britain in order to assess the potential for interactions with industrial fisheries.

3.12.6 By-catches in marine fisheries (Section 3.7.3)

(a) Directed investigations should be conducted into the occurrence of post-smolts as a by-catch in fisheries using surface trawls for other species. In the first instance, we suggest that this issue should be considered by ICES.

(b) Measures to further restrict the use of fixed nets in areas where they are most likely to catch migratory salmonids should be introduced in all regions of England & Wales. These should be carefully monitored to ensure that they are effective in limiting the by-catch of salmon.

(c) Policing of fisheries in England & Wales responsible for by-catches of salmon should be improved by greater cooperation between all EA and Sea Fishery Committee Enforcement Officers.

(d) Fishery Officers from English and Welsh Sea Fisheries Committees should utilise their powers under the Sea Fisheries Regulation Act 1966 to enforce byelaws made to protect salmon.

3.12.7 Salmon farming (Section 3.8.3)

(a) A new authority should be established with responsibility for developing and managing a strategic policy covering all aspects of salmon farming, working in concert with the industry itself.

(b) There should be a presumption against the establishment of salmon farming on a large scale in new areas, particularly on the Scottish east coast and in the North Sea.

(c) Further research should be conducted on techniques for production of sterile salmon, so that all cage production can be of sterile fish.

(d) All major escapes from salmon farms should be notified immediately, and contingency plans should be developed to allow prompt and effective response to such events.

(e) Authorisation for rearing of genetically modified salmon should be granted only for secure independently monitored land-based premises and not for cages in the sea.

(f) A system for managing and monitoring sea lice levels should be developed for the UK along the lines of that currently operated in Ireland, with careful consideration of the concept of 'acceptable levels'.

3.12.8 Activities affecting water quality (Section 3.9.3)

(a) We welcome the initiatives of the *Convention for the Protection of the Marine Environment in the NE Atlantic* and recommend that this Convention be ratified.

(b) Appropriate programmes should be maintained or implemented to monitor the atmospheric inputs of contaminants to the oceans and the biological significance of such inputs should be assessed.

(c) Investigations are required into the threats associated with discharges of hazardous materials, the sublethal effects of certain contaminants and the additive or synergistic effects of concentrations of chemicals which are in themselves harmless.

3.12.9 Activities affecting the physical environment (Section 3.10.3)

(a) Salmon are sensitive to changes in marine environmental conditions and may therefore be particularly vulnerable to climatic change. We recommend that Ministers should take account of this when considering the development of policies in relation to global warming.

4. GENERAL RECOMMENDATIONS

4.1 INTRODUCTION

In Section 3, we have made a number of specific recommendations concerning the individual activities discussed and their effects on salmon in the sea. We hope that all these will be considered by the relevant bodies and taken up as appropriate. However, there are a number of areas where we wish to make more general recommendations. These concern issues such as mixed stock fisheries which relate to several of the activities discussed above, and activities such as fish farming and industrial fishing, where the impacts may extend far wider than on salmon in the sea.

4.2 MIXED STOCK FISHERIES

Nearly all salmon fisheries operating in the sea catch fish originating from more than one river system. It is only possible to evaluate the numbers of fish from each river that are killed in such mixed stock fisheries through detailed scientific investigations. Unless such studies are conducted on a continuous basis, increases in the level of exploitation on certain stocks may go unnoticed. Mixed stock fisheries, therefore, make the task of conservation and management of the salmon populations of individual rivers very difficult.

As a result every effort should be made to close salmon fisheries operating in the sea, except where they exploit predominantly salmon from a single river. In this context, we welcome the decision of Ministers to retain the ban on drift nets in Scotland and the action to phase out mixed stock fisheries in England & Wales. We believe that Ministers should continue to urge the Irish Government and DANI to phase out those fisheries, particularly the offshore drift net fisheries, which exploit fish returning to Great Britain. Efforts should continue to secure a permanent closure of the salmon fisheries in Faroes and Greenland waters.

Pending the closure of these mixed stock fisheries, research should be conducted to identify the stocks exploited by them and to find methods to discriminate fish from different stocks in the catches. Tagging studies have been particularly useful in providing data on the levels of exploitation of salmon in mixed stock fisheries, and should continue in Great Britain in order to assess the impacts of these fisheries, particularly on stocks that are under pressure. Studies should also be conducted to assess changes in the biological characteristics (e.g. length and weight) of the fish caught in mixed stock fisheries in order to monitor changes in the stocks that they exploit. These studies should continue even if the commercial fisheries have been temporally suspended. In England & Wales, the phase out of mixed stock fisheries should be kept under careful review to ensure that it is having the desired effects on the level of exploitation of affected stocks.

4.3 INFORMATION ON CATCH AND EFFORT

It is important to obtain information on all salmon directly or indirectly killed by fisheries in order to manage stocks. We reinforce the recommendations of our first report, *Information on the Status of Salmon Stocks*, concerning the need to collect comprehensive catch statistics and effort data as indices of the performance of all salmon fisheries. In addition, efforts should be made to obtain best estimates of unrecorded and illegal catches in all areas, and these data should be analysed alongside the catch statistics.

4.4 INDUSTRIAL FISHERIES

There is widespread concern about the potential effect of industrial fisheries on salmon and sea trout stocks in several parts of Great Britain. In addition, concerns have been expressed by environmental groups that these fisheries could also affect seabird populations and the marine ecosystem as a whole. We are concerned that the industrial fisheries currently operate with very few controls and that there is no restriction of catches in the industrial fisheries in the North Sea. We recommend that action should be taken to ensure the proper management of industrial fisheries.

It is clear that it will be difficult to demonstrate whether salmon stocks are really being adversely affected, and research is required to investigate the problem. We note and welcome the initiative of the Atlantic Salmon Trust to finance an investigation of possible by-catch of salmon in industrial fisheries, but we are concerned that such an important investigation had to be proposed and funded by a charitable organisation. We consider that Ministers should promote investigation of the impacts of these fisheries, not only upon salmon but on the whole marine ecosystem.

4.5 FISH FARMING

The salmon farming industry has expanded very rapidly in the last 20 years. This has brought advantages for wild salmon and has provided socio-economic benefits to remote areas. This report has mainly considered issues relating to salmon in the sea, but we have previously reported on the effects of the industry on salmon in fresh water. The salmon farming industry has also had more widespread effects on the environment. However, we are concerned here about the potential adverse impacts of the industry on wild salmon.

There is potential for the industry to continue to expand. We believe that the strategy for this development should be carefully considered and that there should be a presumption against the establishment of salmon farming on a large-scale in new areas, particularly on the Scottish east coast and in the North Sea.

We recommend that an appropriate regulatory authority should be established at a national level to develop and manage a strategic policy for the regulation of the industry, and to develop more stringent planning for salmon farms. The new authority should also establish a salmon farming inspectorate with legal powers to enter farm premises in order to ensure compliance with planning and operating regulations and to monitor the performance of individual farms. The available protocols promoting good husbandry and reduction of environmental impacts should be reviewed and a single code of practice should be developed with, where appropriate, the status of legal controls.

4.6 REQUIREMENTS FOR FURTHER INFORMATION ON SALMON IN THE SEA

Information provided in this and previous Salmon Advisory Committee reports indicates that both natural and man-made factors operating in the sea may have significant effects on salmon populations. However, we have also highlighted the general paucity of knowledge about salmon in the sea. This greatly limits our ability to predict the effects of any changes in these factors on salmon populations and thus to conserve and manage stocks.

Further information is therefore required on the distribution and behaviour of salmon in the sea. Particular attention should be paid to the emigration of smolts through coastal waters where they are particularly vulnerable to predation and changes in environmental conditions. Information is also required on the effects of environmental factors on salmon in the open ocean; in particular on growth, survival, maturation and migratory behaviour.

APPENDIX A

MEMBERSHIP OF THE SALMON ADVISORY COMMITTEE

Chairman: Mr R M Clerk

Mr G H Bielby

Mr C G Carnie

Mr J H Ferguson

Mr D Heselton

Dr L M Laird

Mr I Mitchell

Mr M Owens

Mr D R Paton

Dr D J Solomon

PREVIOUS REPORTS BY THE SALMON ADVISORY COMMITTEE

- *Information on the Status of Salmon Stocks* published in September 1988. Ref. No. PB 2021, price £3.
- *The Effects of Fishing at Low Water Levels* published in March 1989. Ref. No. PB 0176, price £3.
- *Factors Affecting Natural Smolt Production* published in May 1991. Ref. No. PB 0535, price £3.95.
- *Assessment of Stocking as a Salmon Management Strategy* published in September 1991. Ref. No. PB 0641, price £1.50.
- *Factors Affecting Emigrating Smolts and Returning Adults* published in May 1993. Ref. No. PB 1270, price £4.
- *Run Timing of Salmon* published in June 1994. Ref. No. PB 1797, price £4.95.
- *The Effects of Predation on Salmon Fisheries* published in July 1996. Ref. No. PB 2514, price £4.
- *The Anti-poaching Measures Contained in the Salmon Act 1986* published in July 1996. Ref. No. PB 2515, price £4.
- *The Regulation of Salmon Angling in Great Britain* published in March 1997. Ref. No. PB 2993, price £3.
- *Fish Passes and Screens for Salmon* published in March 1997. Ref. No. PB 3001, price £5.

Copies of these reports may be obtained from:
MAFF Publications, London, SE99 7TP

APPENDIX B

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APPENDIX C

GLOSSARY OF SCIENTIFIC NAMES

Fish:	Atlantic salmon	*Salmo salar*
	bass	*Dicentrarchus labrax*
	blue whiting	*Micromesistius poutassou*
	cod	*Gadus morhua*
	capelin	*Mallotus villosus*
	garfish	*Belone bellone*
	Greenland shark	*Somniosus microcephalus*
	herring	*Clupea harengus*
	lantern fish	*Myctophidae*
	ling	*Molva molva*
	migratory/sea trout	*Salmo trutta*
	saithe	*Pollachius virens*
	sandeels	*Ammodytes* spp.
	skate	*Raja batis*
	sprat	*Sprattus sprattus*
	three-spined stickleback	*Gasterosteus aculeatus*
	whiting	*Merlangius merlangus*
Birds:	cormorant	*Phalacrocorax carbo*
	gannet	*Sula bassana*
	goosander	*Mergus merganser*
	merganser	*Mergus serrator*
Mammals:	bottlenose dolphin	*Tursiops truncatus*
	common seal	*Phoca vitulina*
	grey seal	*Halichoerus grypus*
	harp seal	*Pagophilus groenlandicus*

APPENDIX C

GLOSSARY OF SCIENTIFIC NAMES

Fish	Atlantic salmon	*Salmo salar*
	bass	*Dicentrarchus labrax*
	halibut	*Hippoglossus hippoglossus*
	cod	*Gadus morhua*
	eel	*Anguilla anguilla*
	garfish	*Belone belone*
	Greenland shark	*Somniosus microcephalus*
	herring	*Clupea harengus*
	lantern fish	*Myctophidae*
	ling	*Molva molva*
	migratory/sea trout	*Salmo trutta*
	saithe	*Pollachius virens*
	sand eel	*Ammodytes* spp.
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	sprat	*Sprattus sprattus*
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