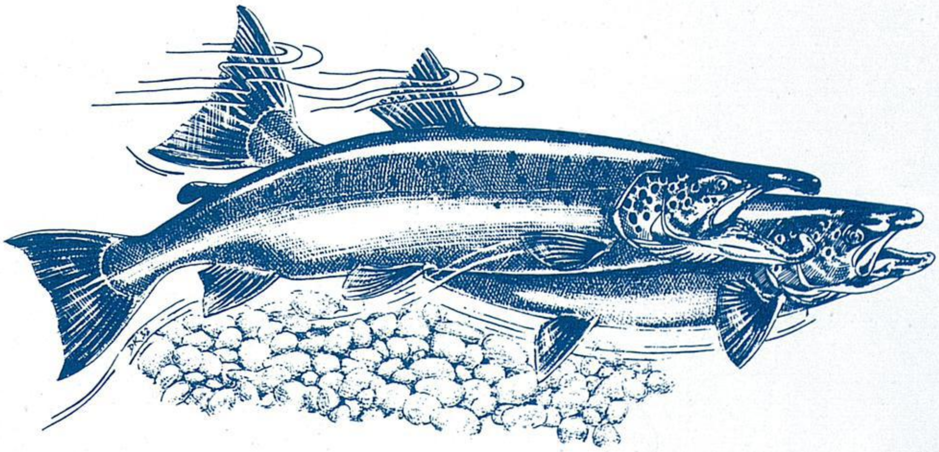
RUN TIMING OF SALMON

Report of the Salmon Advisory Committee



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

CONTENTS

APPENDICES

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".

This report deals with one area of particular concern in relation to the conservation of salmon stocks, the decline in spring runs of salmon. In preparing this report the Committee has considered the main factors which have been identified as likely to influence the season of return to the river of salmon. Using the most reliable data available this report aims to:

- summarise current knowledge of run timing;
- analyse the possible mechanisms and causes of changes in run timing;
- consider the extent to which recovery of spring runs might occur naturally;
- identify any research and development and pilot scale investigations which may be desirable; and
- provide guidance on any specific measures which fishery managers might find appropriate for individual rivers.

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

1.1 BACKGROUND

There has been a general reduction in numbers of salmon reported caught in home waters over the past thirty years. This may largely be a reflection of an earlier period of high abundance and probably high marine survival during the peak years of the 1960s. In recent years, the closing down of a number of net fisheries has further reduced the overall reported catch. However, there has also been a significant reduction in the proportion of fish taken early in the year. This is a matter of concern and sadness to those involved in salmon fisheries for the following reasons:

- fish caught between January and, say, the end of April, generally described as spring fish, may be large and in excellent condition;
- they are highly prized by both anglers and netsmen; and
- existence of good early runs may lengthen the fishing season considerably; at present fishing in the spring months is not economical for netsmen and is of reduced interest to anglers, with adverse economic consequences in many rural areas.

The terms *run* and *run timing* are used in this report to indicate the act and timing of the return of adult fish to the river, rather than the progress of fish moving up river. Much of the evidence for changes in run timing comes from analysis of the monthly distribution of net and rod catches. As is discussed later in the report, we are satisfied that timing of catches is a reasonable indicator of run timing. In particular, there is ample evidence that the decline in rod catches of spring fish is due predominantly to a decline in runs of such fish.

2. THE BASIS OF RUN TIMING

2.1 SALMON LIFE-HISTORY AND SEASON OF RETURN TO THE RIVER

Salmon spawn in the autumn and winter throughout the river system where suitable spawning and nursery habitat exists. Fish generally spawn earliest in northern areas and in upper headwaters where the water is cooler and the development of eggs is slower, and later in warmer streams in southern Britain and in the lower reaches of rivers.

Although the spawning season may last only a few weeks in any area, fish may enter the river at any time of the year and some spend as long as fourteen months in fresh water before spawning. Presumably this aspect of life-history offers some advantage in terms of reproductive success.

Possibilities include:

- survival rates could be greater in the river than in the sea;
- by ascending the river before the gonads are fully developed, upstream migration may be facilitated especially if there are falls and rapids;
- entering up to a year early maximises the number of opportunities when the ascending salmon will encounter the specific river conditions which will facilitate continued upstream movement past any given point in the river system; and
- estuaries and lower reaches of rivers may be less readily negotiated in summer and early autumn because of low flows, high water temperatures or poor water quality.

Certainly in many river systems, the earliest running fish in each sea-age class tend to penetrate furthest into the river system. In examining this behaviour, it is difficult to separate cause and effect; do the fish penetrate furthest because they happened to come in first, or do they come in early because they had furthest to go within the river system?

Some rivers have a predominance of late summer and autumn fish, even when spring runs predominate elsewhere. On many smaller rivers dry summers with low flows could make spring entry a distinctly disadvantageous strategy. In general, rivers with a strong early-season run are well endowed with good holding water by virtue of large size, good pools, or lakes within the system.

Salmon that have spent one, two or three years at sea tend to enter the river at a particular time of year and this alone is responsible for much of the apparent difference in run timing between rivers and between years. However, there are differences between the run timing of individual sea-age classes between rivers, and on occasions the timing of entry of age groups in one river may change over a period of years. This is discussed further in Section 5.

2.2 SEA-AGE CLASSES AND RUN TIMING

2.2.1 Definition of sea-age classes

At this point it is desirable to define the limits of sea-age classes. Smolts enter the sea in the spring. The first fish to reappear as adults in the river do so a little over a year later, as one-sea-winter (1SW) fish. Fish returning the following year for the first time are termed two-sea-winter (2SW) fish, and so on. Two-sea-winter and older fish are often collectively termed multi-sea-winter (MSW) fish.

Most 1SW fish return to fresh water after one winter in the sea and spawn during the second winter after leaving the river. However, a few may not return to fresh water until as late as January in their second adult winter, spawning within a week or two; these are still classified as 1SW fish. A few fish return to fresh water more than twelve months before they spawn. Although these fish will not remain at sea for their last winter prior to spawning, this winter is added to their adult sea-age. Thus, as shown in Figure 2.1, some fish that spawn as 2SW salmon return to fresh water after a shorter time at sea than a late running 1SW fish.

Fish returning to fresh water after 1SW are generally termed *grilse*, and MSW fish *salmon*. However, these terms are also used by custom to distinguish fish smaller and larger than some specified weight, generally 7 lbs or 8 lbs, when taken after mid-May.

In the following sub-sections, the characteristics of different sea-age classes in terms of weight and season of entry to the river are discussed. Two long-term studies of population age-structures based on scale-reading are drawn upon. A study by the Scottish Office Agriculture and Fisheries Department (SOAFD) fisheries laboratory has involved collection and interpretation of over 53,000 sets of scales collected from fish caught in the net fishery (February to August) on the North Esk between 1963 and 1991. The second study was that by J Arthur Hutton, who analysed over 36,000 scale samples from fish on the Wye (January to September) between 1908 and 1939[1]. About 60 per cent of the sets of scales were from netted fish, the remainder being taken by angling; altogether, the scale sets represented about 20 per cent of the fish caught during these years. While a fish may be caught by rod at any time after it has entered the river, it is much more vulnerable to capture during the first few weeks in fresh water. In some rivers fish become vulnerable to capture again as spawning time approaches, but the lack of a secondary peak in the graphs showing monthly distribution of catches (Figure 2.2) suggests that this was not a marked phenomenon on the Wye. We therefore consider that analysis of catches by month provides in practice a useful though imperfect indicator of the runs of fish entering the river at that time.

2.2.2 One-sea-winter fish

Generally, a few 1SW fish are caught in coastal waters as early as March but they do not appear in numbers until June, peaking in about July in most areas. They average 5–7 lbs in weight. In many rivers numbers of new arrivals decline sharply in August and September, but in others there is a strong autumn run of 1SW fish. This is particularly so in some of the small rivers of south-west England, where there are good runs of such fish which are fished for by rods into December. On the River Plym, for example, over 90 per cent of the rod catch (1972–88) was taken in November and December, and comprised mainly 1SW fish. However, with the extra

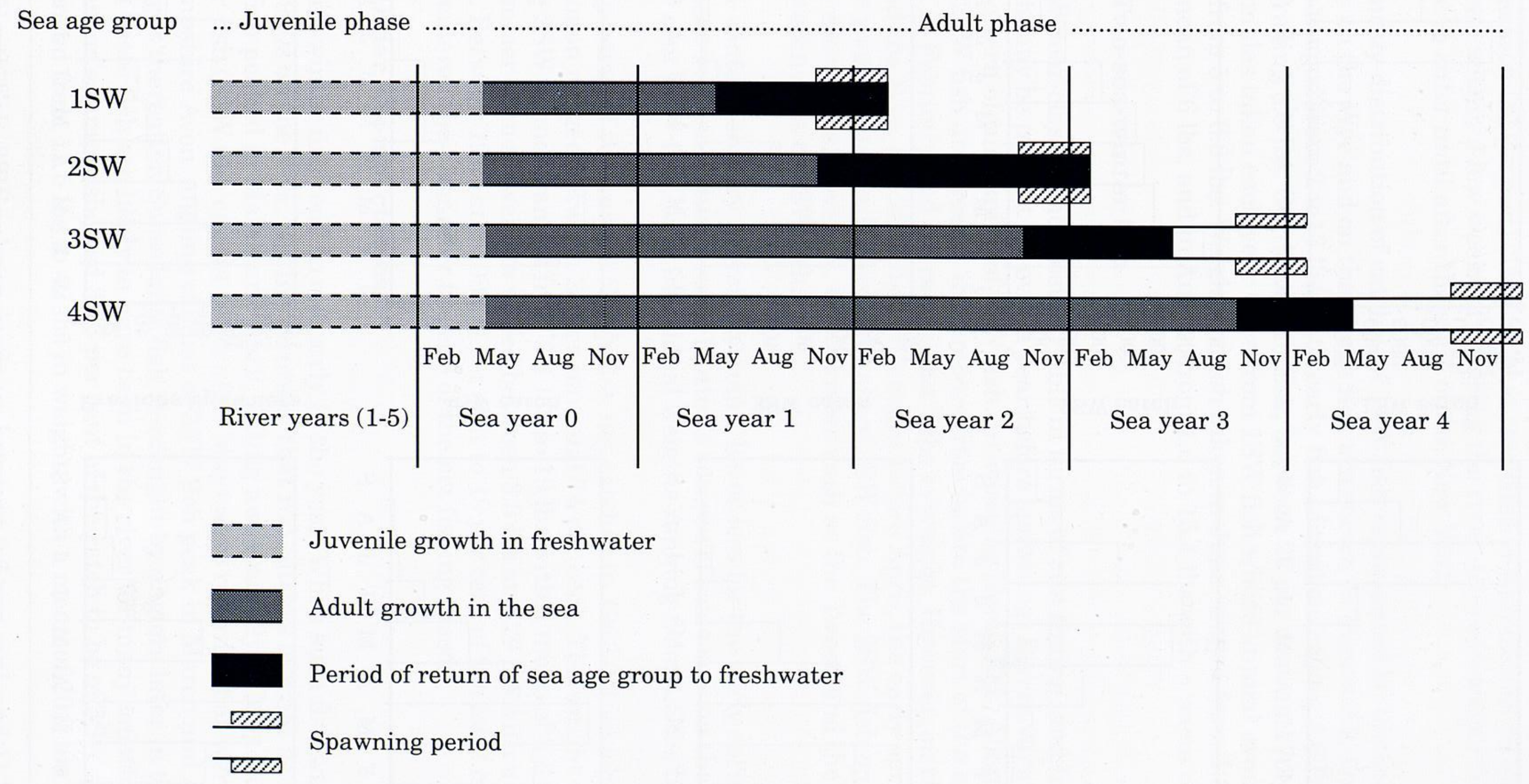


Figure 2.1: *The range of possible times of return of salmon of different sea-age classes.*

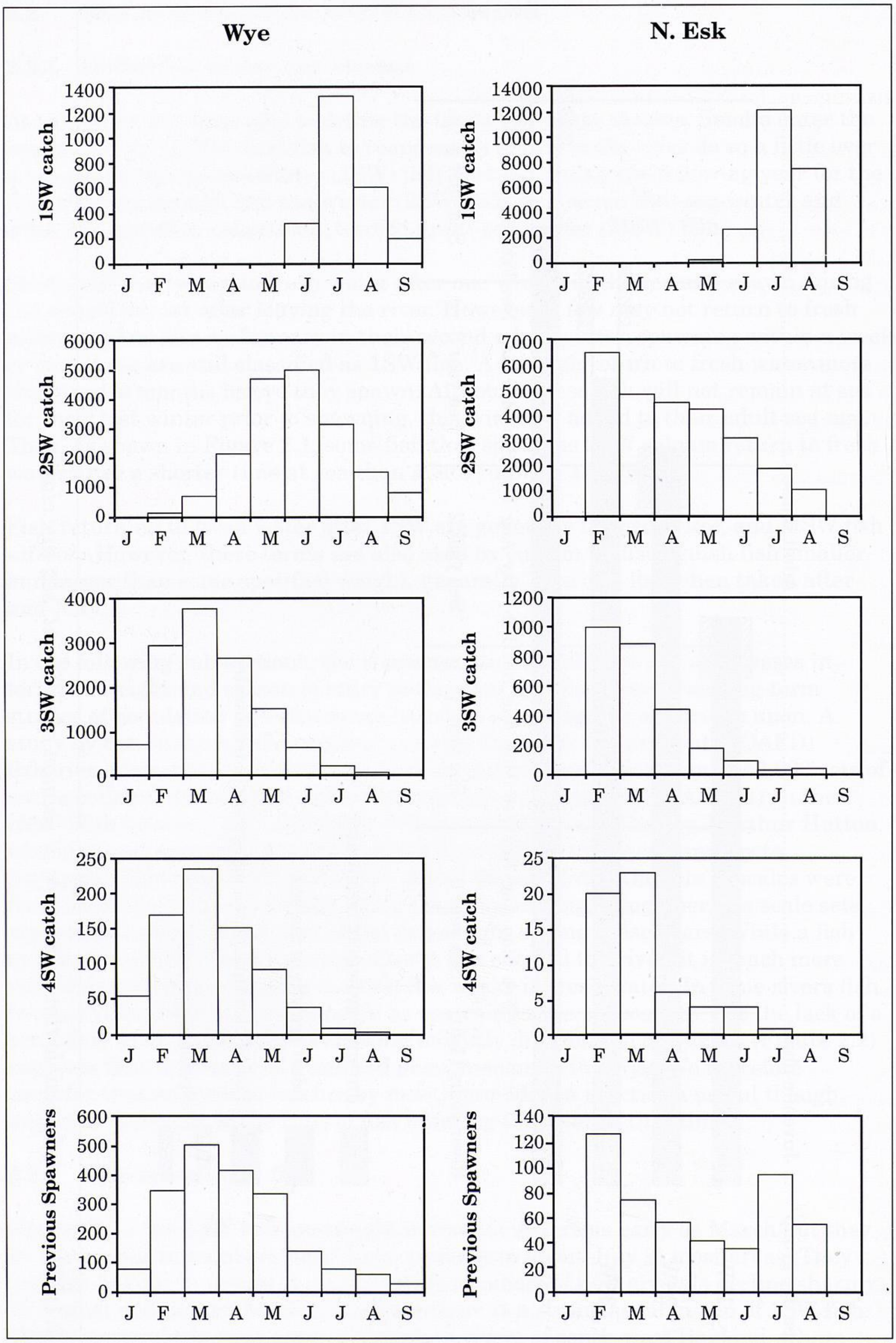


Figure 2.2: *Monthly distribution of salmon catches by sea-age classes in the River Wye rod fishery (1963-91) and the North Esk net fishery (1908-39).*

months of feeding in the sea these fish were much larger than those returning in summer, averaging close to 10 lbs. In the North Esk between 28 per cent and 66 per cent of the annual total run of 1SW fish enter the river after the end of the net fishing season (31 August). They may at this time of year exceed 16 lbs in weight and spawn within a few weeks of entering the river. One-sea-winter fish may continue to enter until after the start of the New Year.

The monthly distribution of catches of 1SW fish represented by the scale sample analysis on the Wye and on the North Esk are shown in Figure 2.2. On the Wye the weights ranged from 2 to13 lbs, with early fish (June) averaging 4.6 lbs and October fish averaging 8.5 lbs. On the North Esk, between 22 per cent and 70 per cent of the scale samples taken each year were from 1SW fish whose annual average weight ranged from 5 to 6.8 lbs. Weights of fish taken in June ranged from 1.8 to 9.8 lbs with a mean of 6 lbs, and in August from 1.6 to 15.4 lbs with a mean of 7.5 lbs.

2.2.3 Two-sea-winter fish

The 2SW year-class is the most variable in terms of run timing, and in some rivers such fish may be present for over a year before spawning. Rivers vary considerably in the pattern of run timing of 2SW fish. In some (eg North Esk, Aberdeen Dee, Tweed) 2SW fish are present in numbers from before the start of the angling seasons in February and average about 7 lbs in weight. However, on the Hampshire Avon and the Wye, few 2SW fish are caught before April, the early spring catches on these rivers historically being mainly of 3SW fish. The 2SW fish on these rivers average over 10 lbs in weight. Other rivers such as the Tweed and the Annan have good autumn runs of 2SW fish.

Two-sea-winter fish vary in weight, from 7 lbs or less for the early spring fish, to 20 lbs or more in some autumn runs. Hutton's sample of scale sets on the Wye included 47.6 per cent 2SW fish, with individual weights ranging from 4.5 lbs to 27.5 lbs.

The proportion of the annual North Esk net catches in 1963–91 which comprised 2SW salmon ranged between 23 per cent and 74 per cent. The weight of spring running 2SW salmon ranged from 3.1 lbs to 19 lbs with a mean of 9.8 lbs, while for 2SW summer salmon, weights varied between 3.3 lbs and 29 lbs with a mean of 12.6 lbs. Between 1981 and 1991, 6 per cent to 19 per cent of the total run of 2SW salmon entered the river after the end of the net fishing season.

2.2.4 Older sea-age classes

Three-sea-winter fish tend to run early in the year. When such fish were numerous in the 1920s on the Wye, Hutton recorded that rod catches of what he called large spring fish peaked in March and April, falling away rapidly in May. Some large summer fish (3SW fish caught fresh after May) were recorded but were scarce. On the Hampshire Avon, angling catches of 3SW fish peak in March and April, with few caught thereafter. Some large fish are caught by anglers later in the year, but many of these fish are likely to have been in the river for many months. On the Wye, Hutton's sample showed 37.3 per cent of the catch to be of 3SW spring fish. They ranged from 11.5 lbs to 42 lbs in weight, with a mean of 20.7 lbs.

On the North Esk, 3SW salmon made up between 0.5 per cent and 11.7 per cent of the annual net catch. They ranged from 6.5 lbs to 35.6 lbs in weight, with a mean of 16.4 lbs. Catches of 3SW fish are rare after April.

Four-sea-winter fish are now very rare indeed. Hutton's scale samples included 2.2 per cent of this class, ranging from 19.5 lbs to 59.5 lbs with a mean weight of 34.4 lbs. The 40 lbs-plus fish that were once regularly caught on the Hampshire Avon were 4SW, but there have been no confirmed captures for at least ten years. As with the 3SW fish, runs on the Wye peaked in March and April; the same was true on the Avon. On the North Esk 4SW salmon comprised between 0 per cent and 0.7 per cent of the net catch. Annual mean weights varied between 15.8 lbs and 26.9 lbs. As with the 3SW salmon, very few 4SW salmon are caught after April.

2.2.5 Previous spawners

The last class of salmon requiring consideration is previous spawners. Among Hutton's scale samples were 6.9 per cent such fish, but previous spawners nowadays normally represent a lower proportion of catches than was the case in former years. There is less information on run timing of previously spawned fish than for the first time spawners. Generally it appears that a fish returning to the river for a second time exhibits a similar pattern of run timing to the first time. Thus in Figure 2.2 the histograms for second time spawners tend to reflect those of the dominant year classes of first time spawners, ie 1 and 2SW fish on the North Esk, and 2 and 3SW fish on the Wye.

2.2.6 Conclusions

Differences in the patterns of run timing between rivers may reflect:

- a different composition of age-classes in the stock; or
- differences in run timing within sea-age classes.

Changes in run timing within a river over a period of years may arise through changes in either or both of these factors. Analysis of the situation in a number of fisheries is described in Section 3.

3. ANALYSIS OF SOME EXAMPLES OF CHANGES IN RUN TIMING

3.1 INTRODUCTION

Changes in the seasonal timing of catches of salmon and the relative contributions of different sea-age classes have been apparent since reliable records were first collected. Cyclical variations and long-term trends in both numbers and proportions become apparent only when long time series of data are available. An example of this may be seen in the salmon catch records for the fisheries operated by the Berwick Salmon Fisheries Company on the River Tweed from 1857 to 1983, which have been kindly provided to us by the River Tweed Commissioners. These data show considerable year to year variability along with a long-term cycle in the relative proportions of MSW fish (salmon) and grilse in the catch (Figure 3.1.1). The proportion of salmon appears to have been low in the latter part of the last century but increased between 1900 and 1920 and remained high until the 1950s. Since then it has fallen back to the levels recorded at the beginning of the time series. Similar cycles in the seasonal composition of the catches have been observed in other Scottish salmon fisheries going back to the late eighteenth century[2].

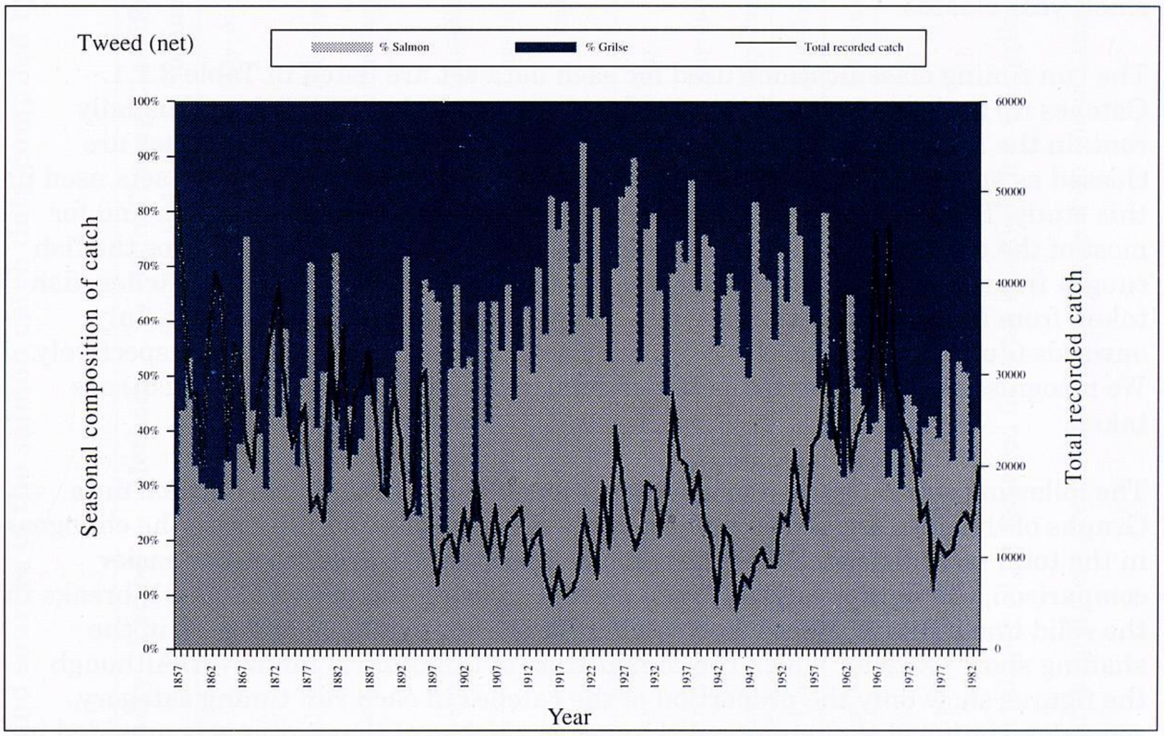


Figure 3.1.1: *Annual net catches recorded by the Berwick Salmon Fisheries Company on the River Tweed from 1857 to 1983 and the proportions recorded as grilse (fish caught after May 1 and weighing less than 8 lbs) and salmon (all other catches).*

The purpose of this section is to examine long-term changes in the pattern of catches of a range of stocks. We have gathered data from a number of salmon fisheries in Great Britain and from one in Ireland for which detailed catch records are available for at least fifty years (Table 3.1.1).

Only limited data are available on fishing effort in most areas, but in some net fisheries, the changes observed partly reflect variations in the pattern of fishing through the season, particularly in the last forty years. In this period, netting effort in the spring has tended to be reduced while that in the summer has remained more constant. Although this must have contributed to the decline in the early-running component of the catches, these changes themselves occurred in response to perceived decreases in spring runs. There is also likely to have been an increase in fishing effort in most rod fisheries since the early part of the century, but little information is available on changes within the season.

The different sea-age groups returning in one year are derived from smolts leaving the river in different years. Variations in smolt production between years may also therefore account for some of the fluctuations in age composition of catches. However, freshwater and sea-age readings are not available for the long-term catch records, and the annual age composition can only be approximated from the seasonal distribution of the catch as has been described in Section 2. This does not give a sufficiently precise measure of sea-age to permit analysis of the data by smolt year classes.

The run timing classifications used for each data set are listed in Table 3.1.1. Catches up to the end of April tend to be almost entirely MSW fish and usually contain the majority of the catches of 3SW and 4SW returns; these catches are classed as spring salmon and have been separated out from all the data sets used in this study. The second group, summer salmon, comprise mainly 2SW fish and for most of the data sets are defined either as the catches in May and June or the fish caught from May onwards that are greater than 8 lbs. The remaining catches, fish taken from May onwards that are less than 8 lbs, or all those taken from July onwards (June onwards on the Exe), are classed as grilse or later fish respectively. We recognise that in some rod fisheries relatively few true grilse (1SW fish) are taken.

The following section gives a brief description of each of these sets of catch data. Graphs of the data are shown alongside the descriptions and illustrate the changes in the total recorded catch and the catch composition. In order to allow easier comparison, the figures have all been plotted showing the period 1900–91; breaks in the solid line indicate years when catch data are not available and gaps in the shading show years for which the composition of the catch is unknown. Although the figures show only the proportion of the catches in each run timing category, some description of the numerical changes in catches of these groups is provided in the text.

TABLE 3.1.1: Details and sources of the salmon catch data compiled by the Committee to examine changes in run timing

Country	River	Fishery	Period	Method	Run Timing Classification			Source
					Spring Salmon	Summer Salmon	Grilse/Later fish	
Scotland	Spey	Rake	1900–1991	net & coble	Feb–April	May–Aug>8lb	May–Aug<8lb*	Crown Estate Commissioners
	NE coast	coastal nets	1900–1991	fixed engine	Feb–April	May–Sept>8lb	May–Sept<8lb*	Mr P Sellar
	Tay	TSF Co Ltd	1910–1991	net & coble	Feb–April	May–Aug>8lb	May–Aug<8lb*	Tay Salmon Fisheries Co Ltd
	Thurso	whole river	1900–1991	rod	Jan–April	May–Oct>8lb	May–Oct<8lb*	Lord Thurso
	Tweed	Floors	1900–1991	rod	Feb–April	May–June	July–Nov#	Roxburghe Estates
	Tweed	Birgham	1900–1991	rod	Feb–mid–Aug+	mid August to November		Douglas and Angus Estates
England	Exe	estuary	1910–1991	seine net	Feb–April	May	June–Aug#	Authority reports•
	Eden	whole river	1936–1991	rod	Jan–April	May–June	July–Oct#	Authority reports •
	Test	Nursling	1920–1991	rod	Jan–April	May–June	July–Oct#	Mr John Potter
Wales	Usk	whole river	1910–1991	rod	Feb–April	May–June	July–Oct#	Authority reports•
Ireland	Blackwater	Careysville	1927–1991	rod	Feb–April	May–June	July–Sept#	Christopher Moriaty

*Grilse classification used in current Scottish catch statistics.

Includes all fish caught in this period; in some rod fisheries relatively few true grilse (1SW fish) are caught.

+ Catches for the Tweed, Birgham fishery are divided into spring salmon and autumn salmon categories.

• Mr P Ecroyd

3.2 DATA INDICATING CHANGES IN AGE COMPOSITION OF CATCHES

3.2.1 River Tay, net and coble catches

The overall pattern of catches in the River Tay net and coble fishery (Figure 3.2.1) shows an increase in the proportions of spring and summer salmon between 1910 and about 1920 followed by a steady decline in these components and a corresponding increase in the proportion of grilse from the mid 1920s to the present. These trends are quite stable despite fluctuations in total catches and a period of particularly high catches between about 1960 and 1975.

Looking at the data in more detail we see that the changes from 1910 to 1920 reflect a decrease in the catch of grilse while salmon catches remained fairly stable. Catches of all stock components then increased in the 1920s, and the best catches of spring salmon in the whole time series were recorded in this period. Between the late 1920s and 1945 the pattern of change mainly reflects the general decline in the spring catch, despite a small secondary peak in the late 1930s. There was a marked dip in catches in the mid 1940s.

Both the summer salmon and grilse catches increased rapidly from the mid 1950s to about 1970 but quickly fell back again and have remained fairly stable since. Throughout this period there was a steady decline in the spring salmon catch, which has now declined to very low levels.

3.2.2 River Spey, net and coble catches

From 1900 to about 1950, total catches in the River Spey net and coble fishery (Figure 3.2.2) varied considerably from year to year without showing any clear trend; they then increased to the mid 1960s before returning to their earlier level in the 1980s. The composition of the catch remained fairly stable from 1900 to about 1915, but the spring and summer salmon proportion then rose sharply. This peak lasted until the late 1930s, since when there has been a fairly steady decline in these components and a corresponding increase in the grilse.

Looking at the separate components of the catch, it is clear that the change around 1915 occurred as a result of the collapse in the grilse catch. Catches of spring and summer salmon remained relatively stable until the 1930s and then rose to a peak before falling to lower levels in the 1940s. Spring salmon catches increased from the late 1940s to the mid 1950s but fell rapidly to the mid 1960s and continued to decline subsequently. Catches of summer salmon increased until the late 1950s but then declined and, despite a short recovery, have now also fallen to very low levels. Grilse catches also increased through the 1950s but then fluctuated very widely in the 1960s. There was a clearer peak in grilse catches in the mid 1970s, since when they have fallen to the levels recorded earlier in the time series.

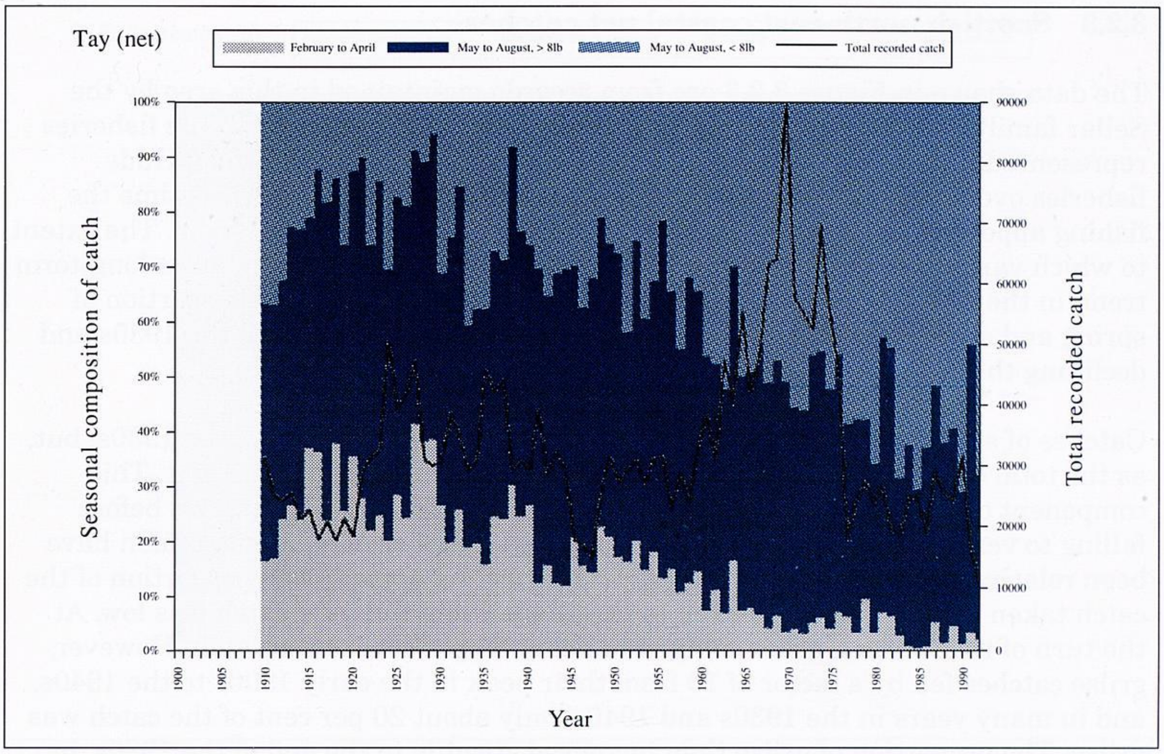


Figure 3.2.1: *Annual net catches recorded by the The Tay Salmon Fisheries Company in the River Tay net and coble fishery from 1910 to 1991 and the proportions of spring salmon (fish taken between February and April), summer salmon (fish over 8 lbs taken between May and August) and grilse (fish under 8 lbs taken between May and August).*

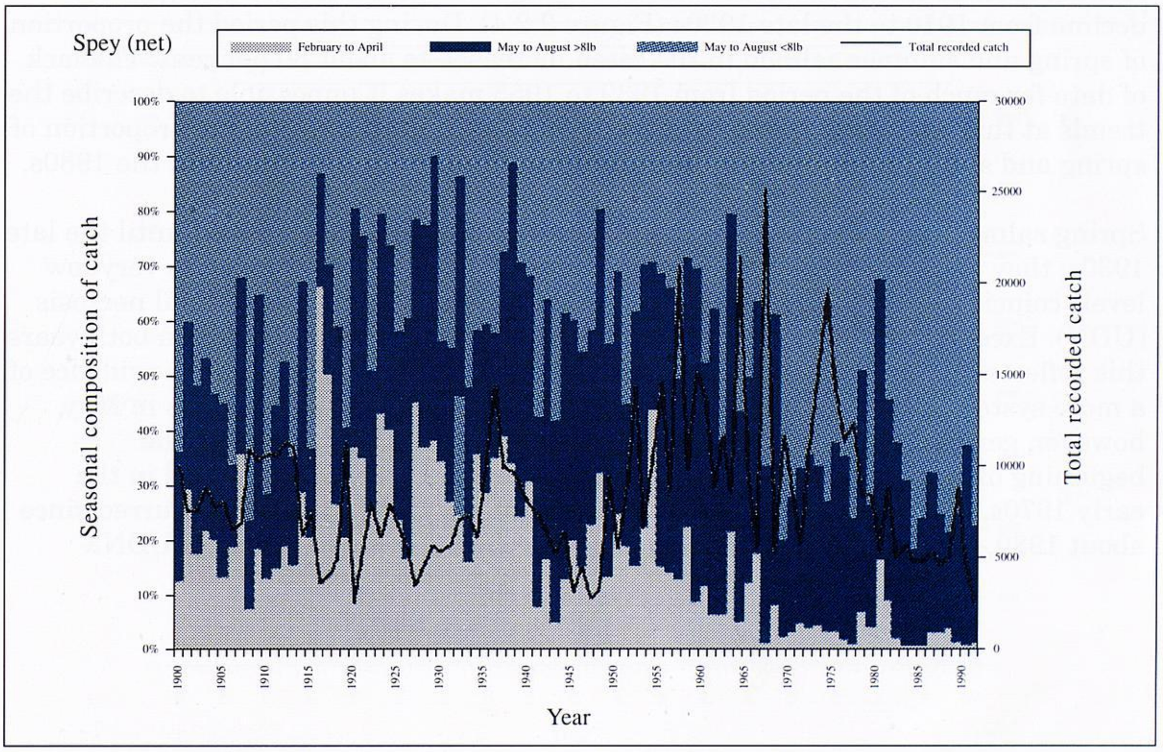


Figure 3.2.2: *Annual net catches recorded in the River Spey net and coble fishery from 1900 to 1991 and the proportions of spring salmon (fish taken between February and April), summer salmon (fish over 8 lbs taken between May and August) and grilse (fish under 8 lbs taken between May and August).*

3.2.3 Scottish north-east coastal net catches

The data shown in Figure 3.2.3 are from records maintained in this area by the Sellar family over many years, and there has been some variation in the fisheries represented in the past 90 years. From 1900 to the 1940s the records include fisheries over a considerable part of north-east Scotland, but since this time the fishing appears to have been confined to the Deveron and Spey districts. The extent to which variations in the catch reflect these changes is not known, but a long-term trend in the seasonal composition of the catch is evident, with the proportion of spring and summer salmon in the catch increasing from 1900 until the 1930s and declining thereafter.

Catches of spring salmon increased only slightly between 1900 and the 1930s, but, as the total catch declined, they comprised an increasing proportion of it. This component of the catch then decreased rapidly, levelling off in the 1950s before falling to very low numbers from the late 1960s. Catches of summer salmon have been relatively stable throughout the data series. As a result, the proportion of the catch taken in the summer peaked in the 1940s when the total catch was low. At the turn of the century, grilse comprised about 80 per cent of the catch. However, grilse catches fell by a factor of 10 from their peak in the early 1900s to the 1940s, and in many years in the 1930s and 1940s, only about 20 per cent of the catch was grilse. The proportion of grilse then increased steadily to the end of the 1980s, by which time it had returned to the levels recorded at the turn of the century.

3.2.4 River Exe, seine net catches

Annual catches on the River Exe have been very variable but showed a general decline from 1910 to the late 1930s (Figure 3.2.4). During this period the proportion of spring and summer salmon in the catch increased to about 80 per cent. The lack of data for much of the period from 1939 to 1955 makes it impossible to describe the trends at this time. Since 1955, catches have been more stable but the proportion of spring and summer salmon has declined steadily to about 20 per cent in the 1980s.

Spring salmon and summer salmon catches were highest in the period until the late 1930s; they were at a lower level from 1955 to 1973 and then dropped to very low levels coinciding with the advent of the salmon disease ulcerative dermal necrosis (UDN). Exceptional total catches were reported in 1922 and 1932, and in both years this reflected particularly good salmon catches. Apart from this, there is evidence of a more systematic increase in the spring catch in the late 1920s; catches in May, however, generally declined from 1910 to the late 1930s. Catches after the beginning of June have shown small peaks around 1912, 1922, 1935 and in the early 1970s, but the main change in this component of the catch has occurred since about 1980, when it has been the only one to recover from the effects of UDN.

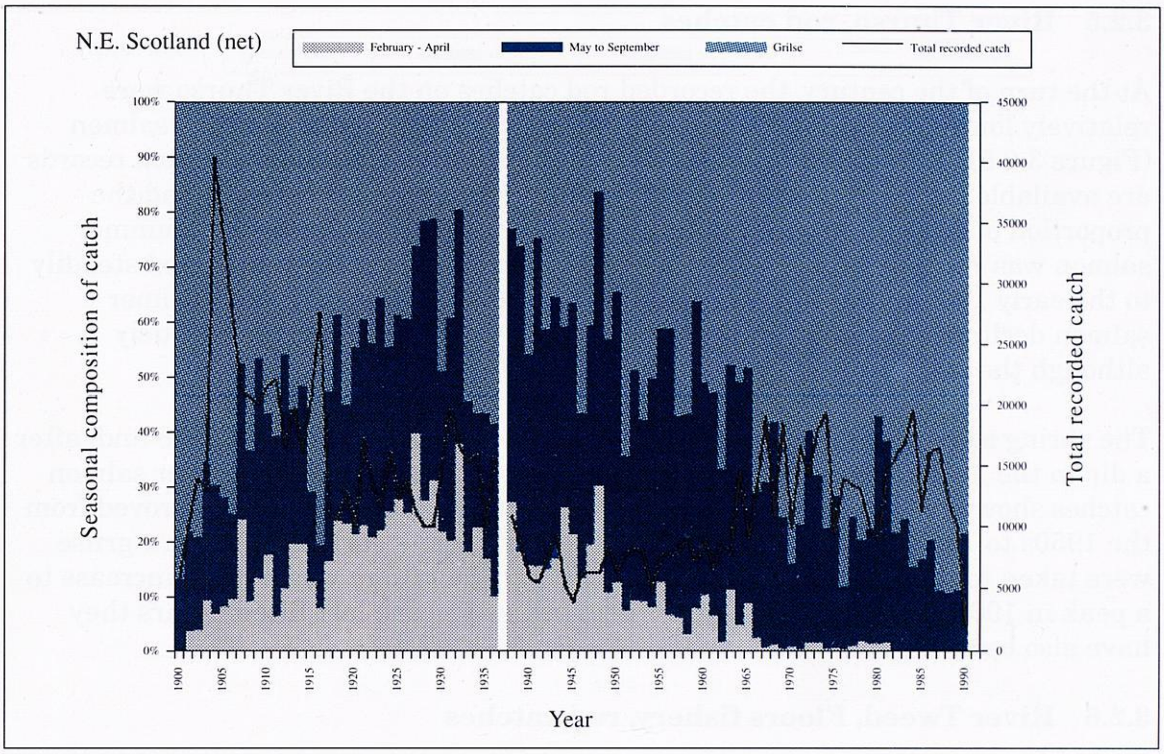


Figure 3.2.3: *Annual catches recorded by the Sellar family in fixed net fisheries operated in north-east Scotland from 1900 to 1991 and the proportions of spring salmon (fish taken between February and April), summer salmon (fish over 8 lbs taken between May and September) and grilse (fish under 8 lbs taken between May and September) in the catches.*

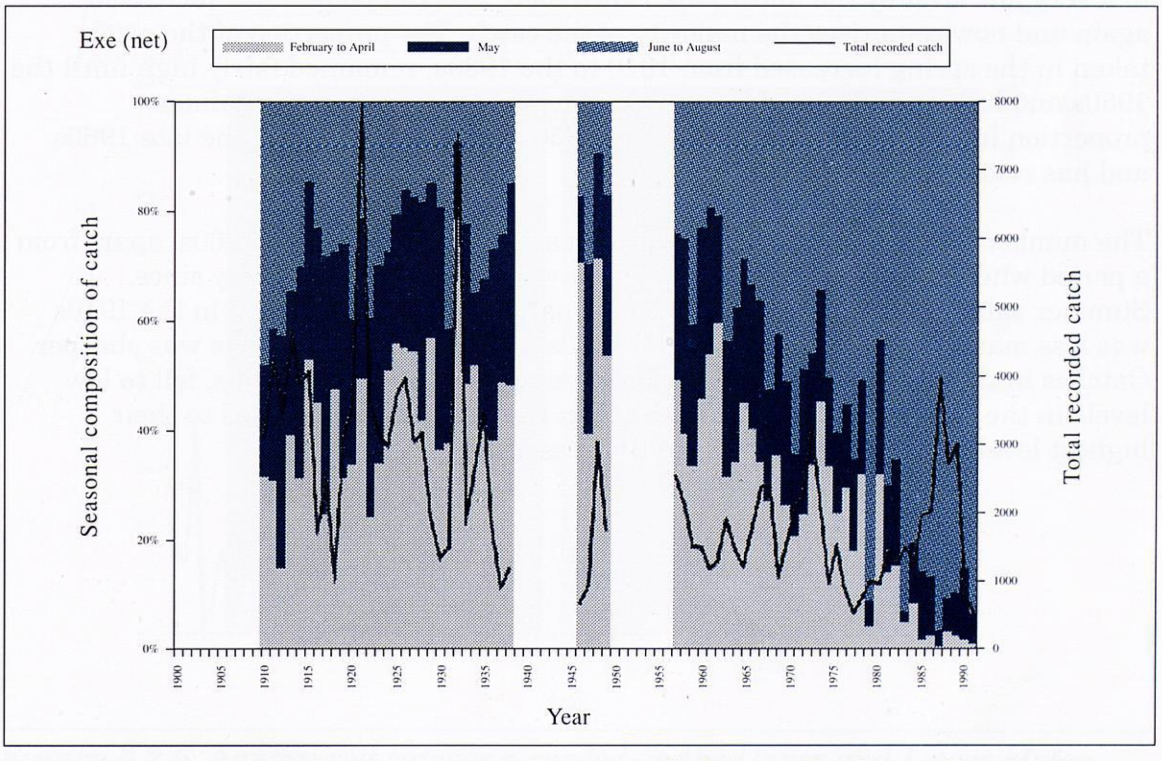


Figure 3.2.4: *Annual seine net catches recorded from the River Exe from 1910 to 1991 and the proportions of spring salmon (fish taken between February and April), summer salmon (fish taken in May) and later fish (fish taken between June and August) in the catches.*

3.2.5 River Thurso, rod catches

At the turn of the century, the recorded rod catches on the River Thurso were relatively low and nearly all of the fish caught were spring and summer salmon (Figure 3.2.5). This is unlike most other fisheries for which such long catch records are available. In the 1920s and 1930s the total catch had increased as had the proportion of summer salmon. An exceptional catch of both spring and summer salmon was reported in 1927. Catches fell in the 1940s but then increased steadily to the early 1960s, during which period the proportion of spring and summer salmon declined. Since the early 1970s, catches have fluctuated quite widely although the composition has remained relatively stable.

The spring salmon catch was at its highest between about 1923 and 1938 and, after a dip in the 1940s, rose in the 1950s but declined thereafter. The summer salmon catches showed a similar pattern between the 1920s and 1940s, but improved from the 1950s to 1965. Since then they have been extremely variable. Very few grilse were taken in the fishery until the early 1950s, when there was a rapid increase to a peak in 1965. Subsequently catches declined and in the last fifteen years they have also been very variable.

3.2.6 River Tweed, Floors fishery, rod catches

The total catch of salmon and grilse on the Upper and Lower Floors rod fisheries of the River Tweed increased fairly steadily from 1900 to the mid 1930s (Figure 3.2.6). There were then two sharp falls followed by gradual recoveries, first between 1938 and the early 1960s and then again between 1968 and the early 1980s. Around 1910, the majority of the catch was taken from July onwards but this proportion fell to a very low level by the mid 1940s. Since then, this component has increased again and now comprises the majority of the catch. The proportion of the catch taken in the spring increased from 1910 to the 1930s, remained fairly high until the 1950s and has since declined steadily to the present. The summer salmon proportion increased from 1910 to about 1950 but then declined to the late 1960s and has remained low since.

The numbers of spring salmon caught increased from 1910 to the 1960s, apart from a period when they fell in the 1940s, but have declined fairly steadily since. Summer salmon catches showed a similar pattern, although the fall in the 1940s was less marked while the drop in the 1960s to the current low levels was sharper. Catches in the latter part of the season were variable until the 1930s, fell to low levels in the 1940s and 1950s but peaked in the 1960s and increased to their highest levels from the mid 1970s to the present.

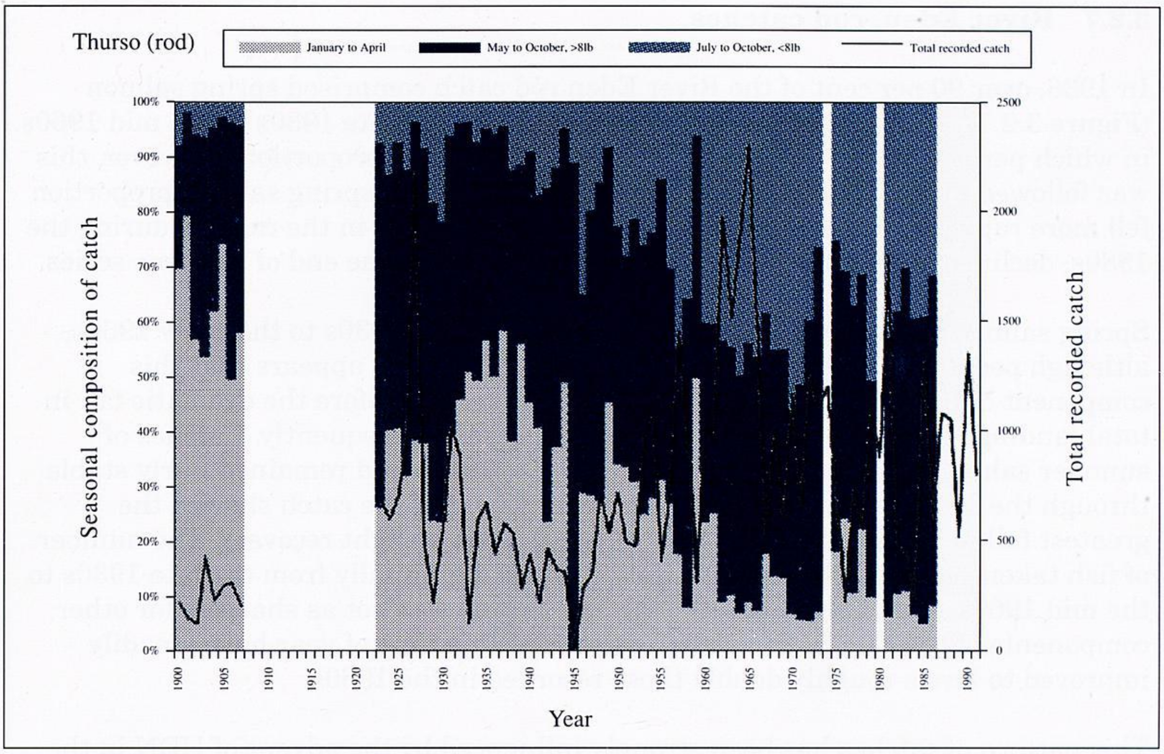


Figure 3.2.5: *Annual rod catches recorded on the River Thurso from 1900 to 1907 and 1923 to 1991 and the proportions of spring salmon (fish taken between January and April), summer salmon (fish over 8 lbs taken between May and October) and grilse (fish under 8 lbs taken between May and October) in the catches.*

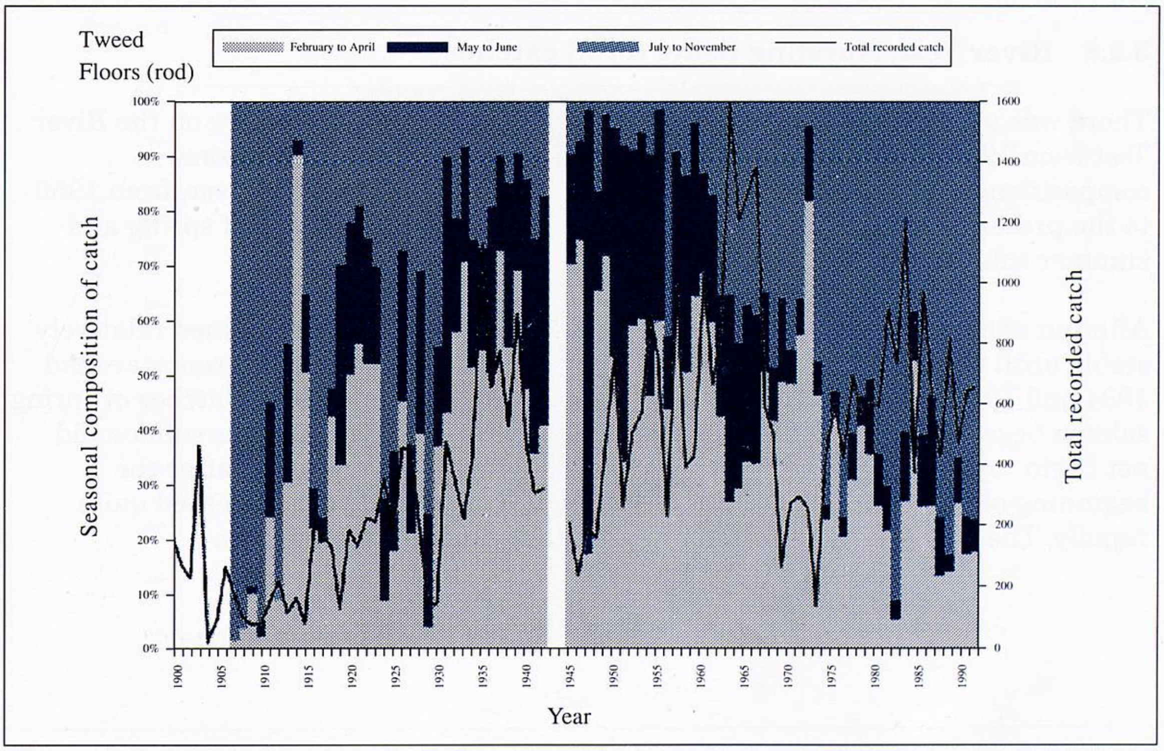


Figure 3.2.6*. Annual rod catches recorded on the Upper and Lower Floors fisheries of the River Tweed from 1900 to 1991 and the proportions of fish taken between January and April, in May and June and between July and November in the catches.*

3.2.7 River Eden, rod catches

In 1936, over 90 per cent of the River Eden rod catch comprised spring salmon (Figure 3.2.7). The total annual catch doubled from the late 1930s to the mid 1960s, in which period there was a slight decline in the salmon proportion. However, this was followed by a dramatic fall in the catch in 1967. The spring salmon proportion fell more rapidly from 1970 and, despite an improvement in the catches during the 1980s, declined to its lowest level (about 10 per cent) at the end of the time series.

Spring salmon catches increased slightly from the late 1930s to the early 1960s, although poor catches were recorded in 1945 and 1946. It appears that this component of the catch had probably started to decline before the dramatic fall in total landings in 1967, and catches continued to fall subsequently. Catches of summer salmon increased from 1936 to the late 1940s and remained fairly stable through the 1950s and early 1960s. This component of the catch showed the greatest fall in 1967 but, since then, there has been a slight recovery. The number of fish taken after the beginning of July increased gradually from the late 1930s to the mid 1960s. They then fell, although the decline was not as sharp as for other components of the catch. Since 1970, catches at this time of year have steadily improved to levels roughly double those recorded in the 1960s.

This pattern of catches has been strongly influenced by the advent of UDN in the river in 1967. This had its greatest effect on the early summer catches. As on the River Exe, it appears that the early-running components of the stock have never recovered from this, and their place has been taken by later-running fish. It is likely that angling effort has changed to take account of this shift in run timing, but the extent to which this has occurred is not known.

3.2.8 River Test, Nursling fishery, rod catches

There was a general increase in the rod catch on the Nursling fishery on the River Test from 1920 to the late 1950s, although until about 1950 the seasonal composition of the catch remained fairly stable (Figure 3.2.8). However, from 1950 to the present there has been a steady decrease in the proportions of spring and summer salmon in the catch.

After an early increase, catches of spring and summer salmon remained relatively stable until the 1950s, although there were marked peaks for both groups around 1934 and 1943 and dips around 1930 and between 1945 and 1947. Catches of spring salmon began to decline from the early 1950s, while those of summer salmon did not begin to fall until around 1960. Until 1950, few fish were taken after the beginning of July, but subsequently catches at this time of year increased quite rapidly. They peaked in 1962 and have declined a little subsequently.

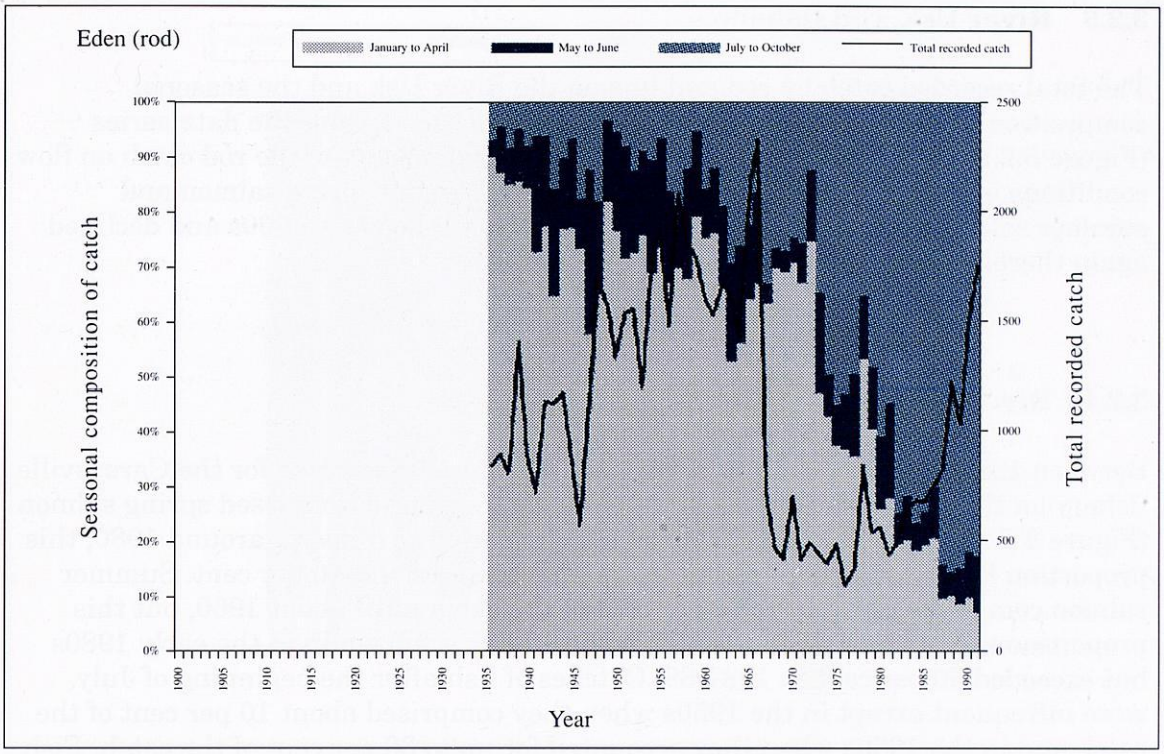


***Figure 3.2.7:** Annual rod catches recorded on the River Eden, Cumbria from 1936 to 1991 and the proportions of spring salmon (fish taken between January and April), summer salmon (fish taken in May and June) and later fish (fish taken between July and October) in the catches.*

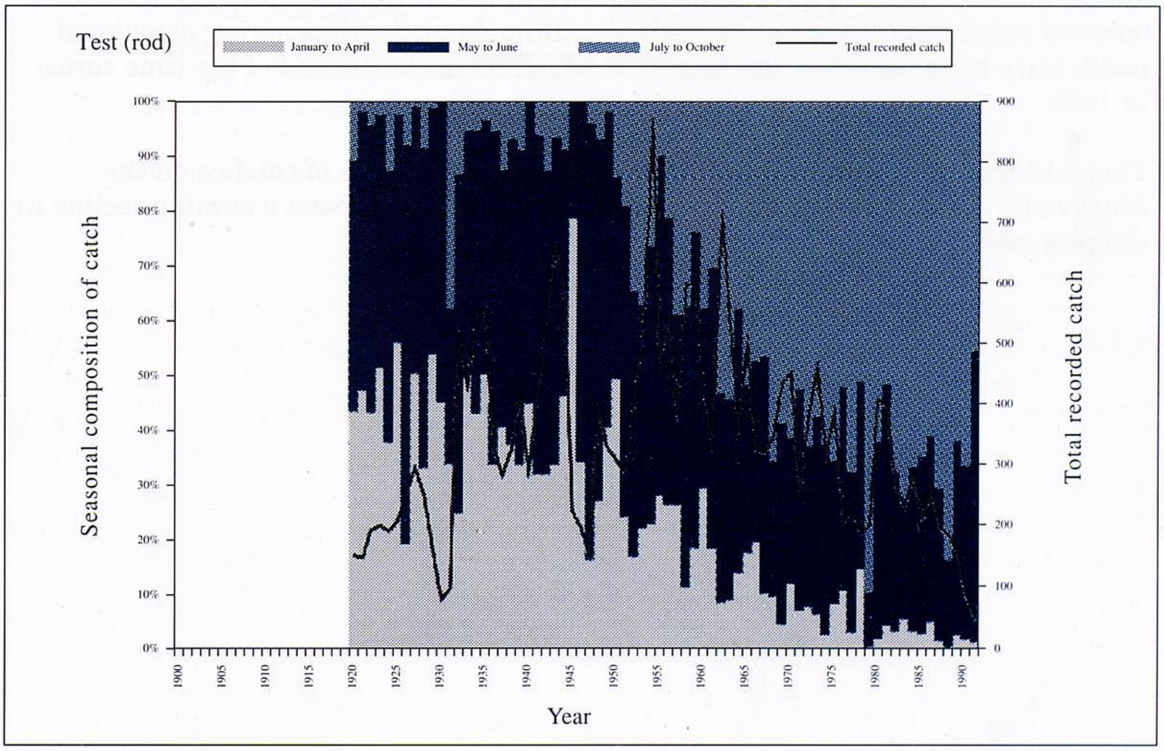


***Figure 3.2.8:** Annual rod catches recorded on the Nursling fishery of the River Test, Hampshire from 1920 to 1991 and the proportions of spring salmon (fish taken between January and April), summer salmon (fish taken in May and June) and later fish (fish taken between July and October) in the catches.*

3.2.9 River Usk, rod fishery

The total recorded catch by rod and line on the River Usk and the seasonal composition of the catches have been very variable throughout the data series (Figure 3.2.9). This probably reflects the strong dependence of the rod catch on flow conditions in such spate rivers. Overall the proportion of spring salmon and summer salmon in the catch increased from 1910 to the early 1960s and declined again thereafter.

3.2.10 River Blackwater, Ireland, rod fishery

Between 1927 and 1960 over 70 per cent of the annual rod catch for the Careysville fishery on the River Blackwater in Co. Waterford, Ireland comprised spring salmon (Figure 3.2.10). Since then, apart from a short period of recovery around 1980, this proportion has fallen and in recent years, has been around 40 per cent. Summer salmon comprised only about 10 per cent of the catch until about 1960, but this proportion then increased in the 1960s and 1970s; it fell again in the early 1980s but exceeded 50 per cent in 1987-89. Catches of fish after the beginning of July were infrequent except in the 1950s when they comprised about 10 per cent of the catch and in the 1980s when they accounted for up to 30 per cent of the catch. Fish effort for grilse was not constant during the period and was probably very low until the 1950s.

The numbers of spring salmon taken increased slightly from 1927 to the early 1960s, but then fell and have since remained at a relatively low level. Catches of summer salmon have increased gradually throughout the time series; occasional peaks have been recorded, the largest of which comes at the end of the time series in 1989.

Thus although there are marked differences in the patterns of catches on the Blackwater compared to rivers in Great Britain, there has been a similar decline in the proportion of spring salmon in the catch.

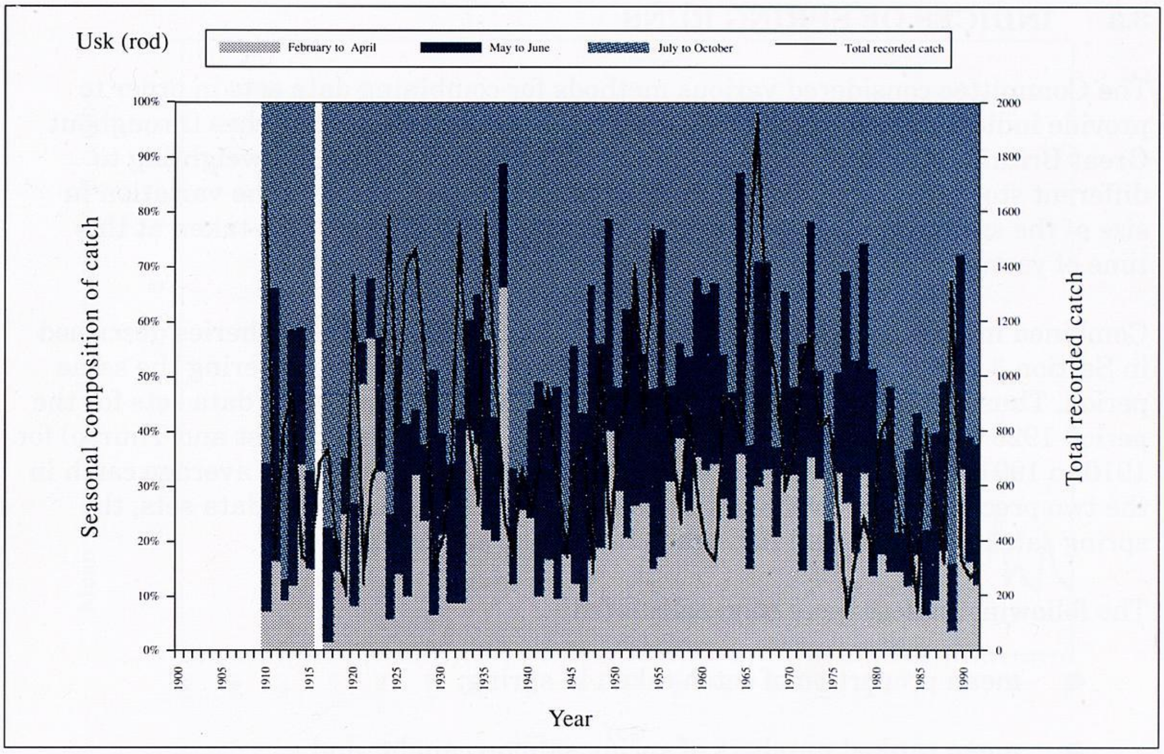


Figure 3.2.9: *Annual rod catches recorded on the River Usk, from 1910 to 1991 and the proportions of spring salmon (fish taken between February and April), summer salmon (fish taken in May and June) and later fish (fish taken between July and October) in the catches.*

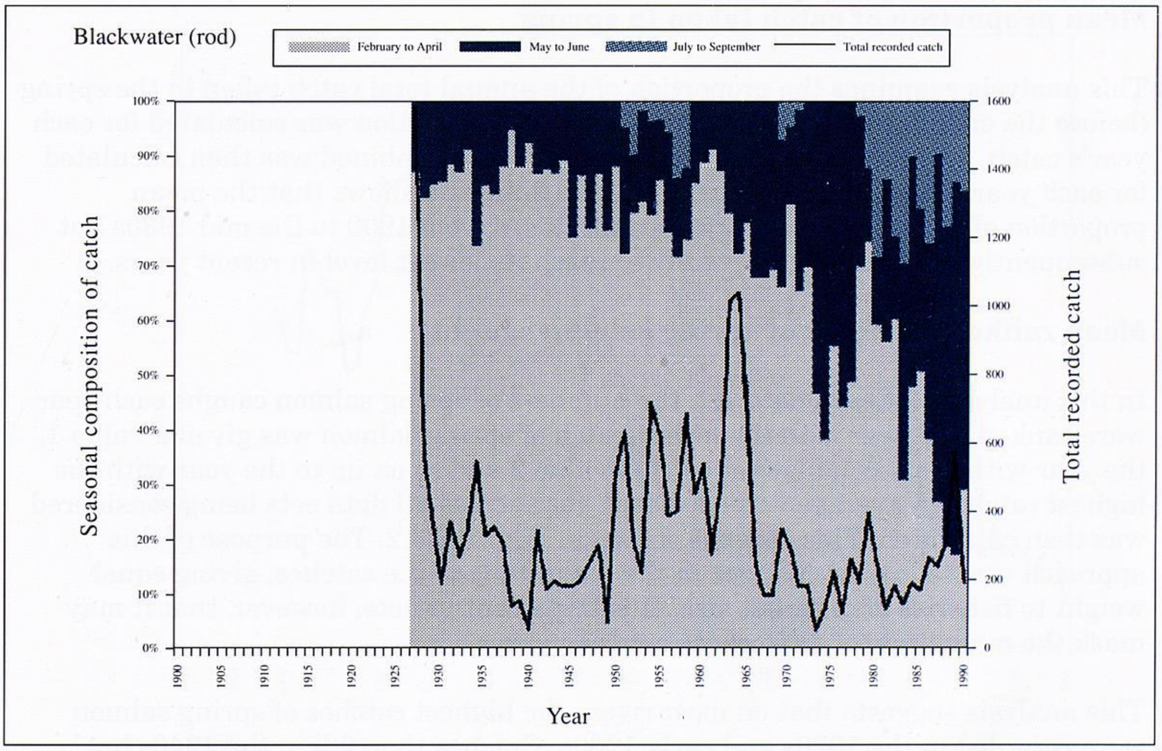


Figure 3.2.10: *Annual rod catches recorded for the Careysville fishery on the River Blackwater, Co.Waterford, Ireland, from 1927 to 1989 and the proportions of spring salmon (fish taken between February and April), summer salmon (fish taken in May and June) and later fish (fish taken between July and September) in the catches.*

3.3 INDICES OF SPRING RUNS

The Committee considered various methods for combining data sets in order to provide indices of changes in the spring component of salmon catches throughout Great Britain. It is intended that these indices should give equal weighting to different stocks and that they should attempt to take account of the variation in size of the spring catch as well as the proportion of the total catch taken at this time of year.

Combined indices have therefore been prepared for the British fisheries described in Section 3.2. Such indices can only be prepared for data sets covering the same period. Thus one set of indices has been calculated using all eight data sets for the period 1923 to 1991 and another using six data sets (all except Test and Thurso) for 1910 to 1991. Where there were short breaks in the data sets, the average catch in the two preceding and two following years has been used. For all data sets, the spring catches included all fish taken before the end of April.

The following indices have been calculated:

- mean proportion of catch taken in spring;
- mean ranked numbers of spring salmon caught; and
- mean logit of proportion of catch taken in spring.

These are now considered in turn.

Mean proportion of catch taken in spring

This analysis examines the proportion of the annual total catch taken in the spring (before the end of April). For each data set, this proportion was calculated for each year's catch. The mean proportion for the data sets combined was then calculated for each year. This index is shown in Figure 3.3.1 and shows that the mean proportion of spring salmon in catches increased from 1900 to the mid 1930s but subsequently declined fairly steadily to reach its lowest level in recent years.

Mean ranked numbers of spring salmon caught

In this analysis, for each data set, the numbers of spring salmon caught each year were ranked; the year with the lowest catch of spring salmon was given a value 1, the year with the second lowest catch a value 2 and so on up to the year with the highest catch. An average value for each year across all data sets being considered was then calculated. This index is shown in Figure 3.3.2. The purpose of this approach was to look at changes in the magnitude of the catches, giving equal weight to fisheries of different size. It is important to note, however, that it may mask the magnitude of differences between years.

This analysis suggests that on most rivers the highest catches of spring salmon were recorded in the 1920s and early 1930s. Catches then fell in the 1940s but recovered somewhat in the early 1950s before declining to their lowest level in the most recent years.

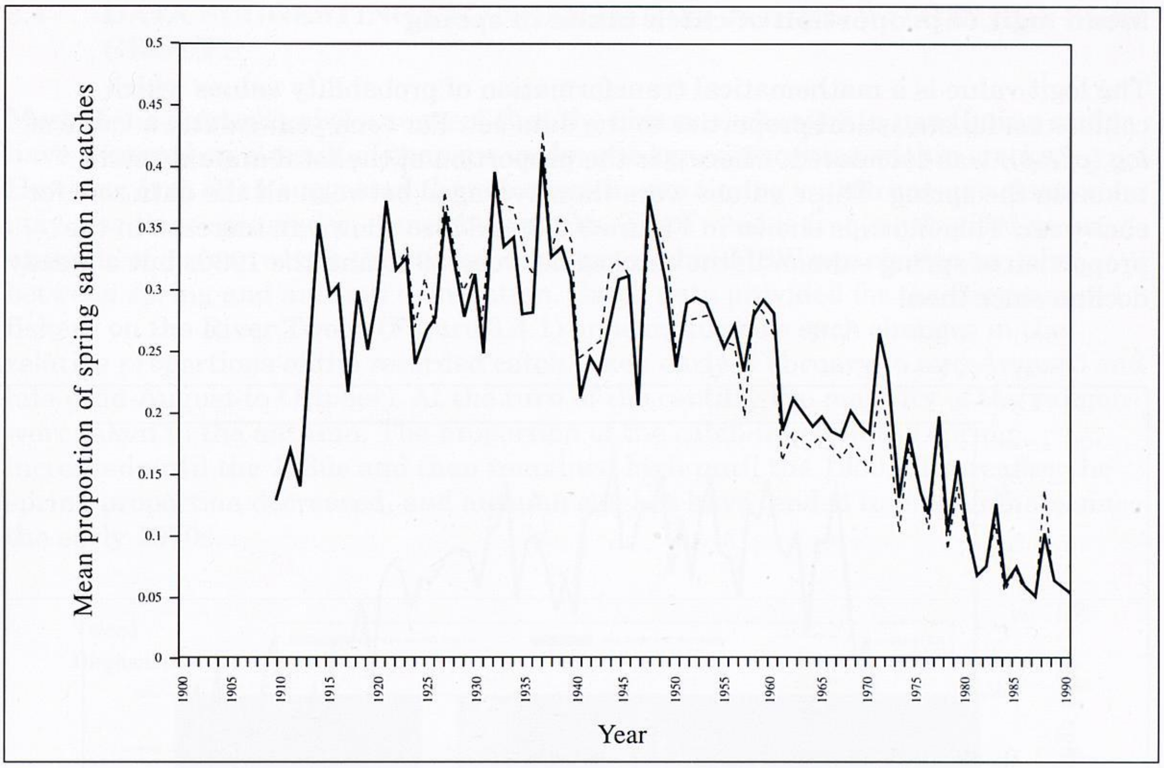


Figure 3.3.1: *Mean proportion of spring salmon in the annual catches in two sets of fisheries. Set A (______) shows means for six fisheries, 1910-91. Set B (......) shows means for eight fisheries, 1923-91. Details of fisheries given in Section 3.3.*

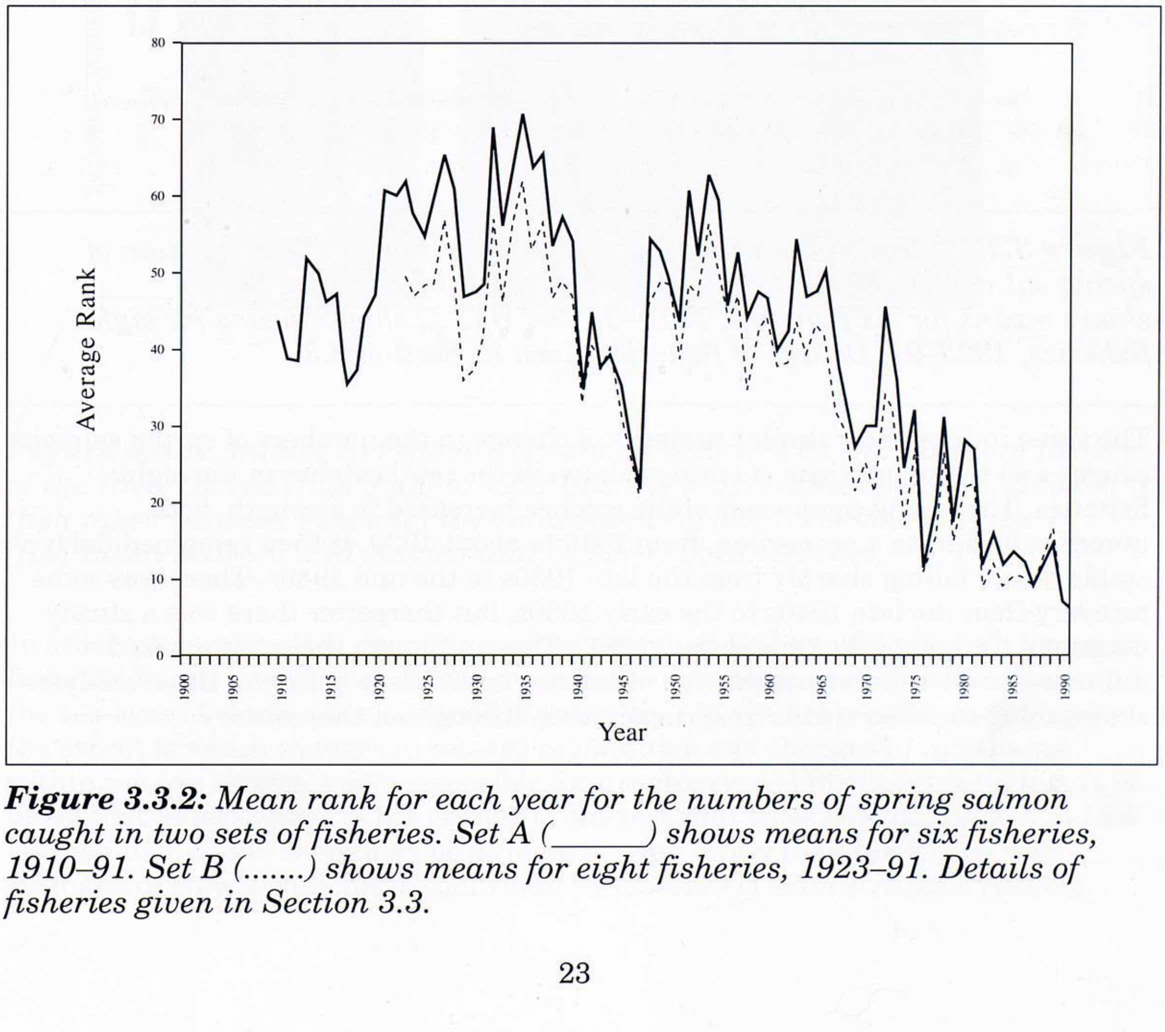


Figure 3.3.2: *Mean rank for each year for the numbers of spring salmon caught in two sets of fisheries. Set A (______) shows means for six fisheries, 1910–91. Set B (.......) shows means for eight fisheries, 1923–91. Details of fisheries given in Section 3.3.*

Mean logit of proportion of catch taken in spring

The logit value is a mathematical transformation of probability values which confers useful statistical properties to the data set. For each year's data, a value of *log (p/(1-p))* was calculated, where *p* is the proportion of the total annual catch taken in the spring. These values were then averaged between all the data sets for each year. This index is shown in Figure 3.3.3 and also shows an increase in the proportion of spring salmon in the catches between 1910 and the 1930s but a steady decline since then.

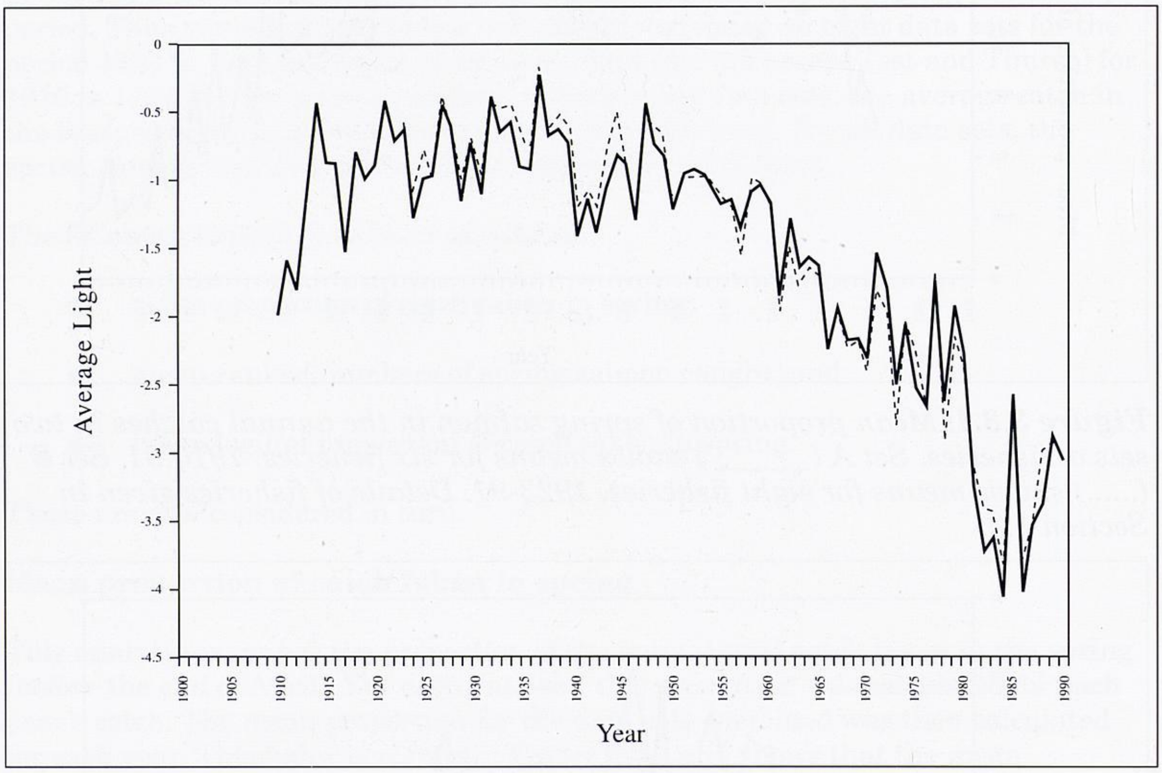


Figure 3.3.3: *Mean value of the logit transformation of the proportion of spring salmon in the annual catches in two sets of fisheries. Set A (______) shows means for six fisheries, 1910–91. Set B (.....) shows means for eight fisheries, 1923–91. Details of fisheries given in Section 3.3.*

The three indices show similar patterns of change in the numbers of spring salmon caught and the proportions of spring salmon in the total catches in the eight fisheries. The spring component of the catches increased in strength, both numerically and as a proportion, from 1910 to about 1930. It then remained fairly stable before falling sharply from the late 1930s to the mid 1940s. There was some recovery from the late 1940s to the early 1950s, but thereafter there was a steady decline to the end of the time series (1991). Thus, although there are marked differences between the composition of catches in different fisheries, these analyses show strong common trends in spring catches throughout this century.

3.4 DATA SUGGESTING CHANGES IN RUN TIMING WITHIN SEA-AGE GROUPS

Most of the data sets above suggest that the observed changes in run timing could have occurred as a result of changes in the sea-age composition within stocks. However, it is often suggested that changes in run timing within sea-age classes may also have occurred in some river stocks. The Tweed is frequently cited as an example of a river where the season of return within MSW age classes switches between spring and autumn domination. Catch data provided for the Birgham rod fishery on the River Tweed (Figure 3.4.1) appears to show such changes in the relative proportions of the recorded catch taken early (February to mid-August) and late (mid-August to October). At the turn of the century the majority of the salmon were taken in the autumn. The proportion of the catch taken in the spring increased until the 1930s and then remained high until the 1950s. Thereafter the spring proportion decreased, and autumn catches have tended to predominate since the early 1970s.

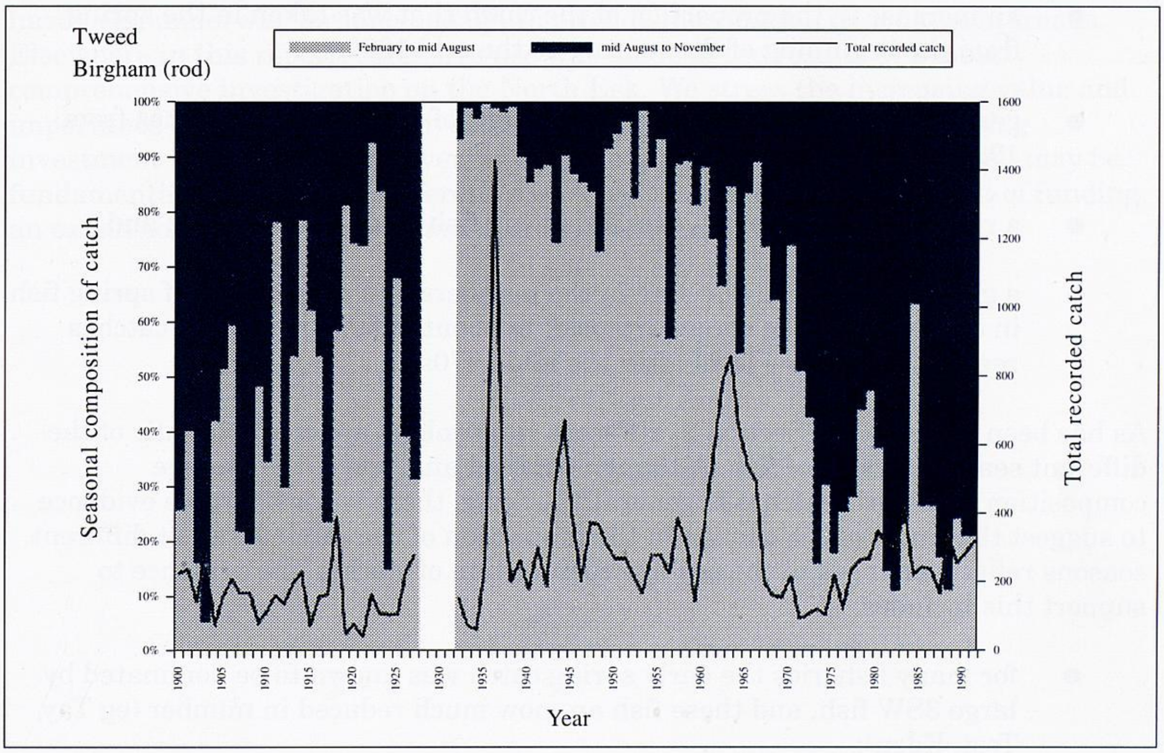


Figure 3.4.1: *Annual rod catches of salmon recorded on the Birgham fishery of the River Tweed from 1900 to 1991 and the proportions of early salmon (fish taken between February and mid-August), late salmon and grilse (fish taken between mid-August and October) in the catches.*

In order to elucidate this phenomenon, we consulted Dr Ronald Campbell, biologist from the Tweed Foundation. It was concluded, in the absence of detailed data on the sea-ages of catches over a period of years, that it was not possible to determine the extent to which changes in sea-age composition and changes in run timing within sea-age classes were responsible for the observed shifts in catch timing. It is likely that at least some of the change is due to a shift from 2SW spring fish to 1SW autumn fish; as the latter may be as large or even larger than the former, this mechanism may be difficult to confirm in the absence of extensive scale reading.

Extensive sampling of the commercial catch on the North Esk by SOAFD since 1963 has indicated a change in the times by which 25 per cent and 50 per cent of the catches of 3SW and 2SW fish have been taken each year. For example, the time by which 25 per cent of the catch of both age classes was taken was about six weeks later in the 1980s than it was during the 1960s. While it is likely that this reflects a true shift in run timing, there has also been a change in the distribution of netting effort, especially early in the season, which could account for at least part of the change in timing of catches. Once again, conclusive evidence of a shift in run timing within sea-age classes is elusive.

3.5 CONCLUSIONS

It is apparent from the graphs described in Section 3.2 that coincident changes in the seasonal timing of catches have been taking place in most of the salmon fisheries for which adequate data are available. These changes include:

- an increase in the proportion of the catch that was taken in the spring from the beginning of the century to the mid 1920s;
- generally large numbers and proportions of spring fish in catches from 1920 to the 1950s;
- a run of slightly poorer years for spring fish from 1941 to 1947; and
- a gradual but steady decline in the numbers and proportions of spring fish in catches from the secondary peak in about 1950, with spring catches remaining at a low level after the mid 1970s.

As has been described in Section 2, different run timings are characteristic of the different sea-age classes of fish. Although detailed analysis of the sea-age composition of historic catches is generally lacking, there is considerable evidence to suggest that most of the change in the proportion of the catch taken at different seasons reflects changes in the sea-age composition of stocks. The evidence to support this includes:

- for many fisheries the early spring catch was known to be dominated by large 3SW fish, and these fish are now much reduced in number (eg Tay, Test, Eden);
- in almost all fisheries there has been a downward shift in overall mean weight of fish caught coincident with the trend to later catches; if a shift in run timing occurred due to later return of fish within sea-age classes an increase in mean weight might be expected; and
- it is generally apparent that grilse (1SW fish) numbers have increased during the period associated with later timing of catches.

While shifts in the run timing within sea-age classes are believed to occur, we were unable to identify any situation where this mechanism was dominant in an observed shift in the timing of catches.

The analyses undertaken in this section were made possible by the existence and availability of a number of reliable, detailed long-term data sets of catch statistics. In some cases the sets had not been analysed before, and access to them was made possible by the wide range of experience and contacts of Committee members. It is concluded that many other data sets are likely to exist. In view of the value of such long-term catch records, we recommend that efforts are made to identify, access and collate such records for use in such analyses as this.

In order to maximise the value of future catch statistics it is important that the figures are as complete and as accurate as possible, and that they are gathered in a consistent manner. We therefore recommend that catch statistics are gathered for all salmon fisheries in a rigorous manner. Some of the most valuable data sets used by us are for individual estates rather than for whole rivers. This recommendation is therefore directed towards fishery proprietors as well as to statutory authorities.

Very much more reliable information on runs of fish can be obtained from direct observation using traps or electronic counters, although at present no such studies have been underway for long enough to provide information on long-term trends. Elsewhere in this report, extensive use was made of the results of a most comprehensive investigation on the North Esk. We stress the increasing value and importance of the North Esk investigation and strongly endorse continuing investment in this area. However, as stocks and the factors affecting them may be fundamentally different in different rivers, we recommend consideration of funding an expansion of the concept of *index* or *monitored* rivers.

4. FACTORS THAT MAY AFFECT THE SEA-AGE OF RETURNING SALMON

4.1 INTRODUCTION

This section reviews the information available on what factors influence the sea-age at which salmon return to freshwater.

The problem can essentially be reduced to a series of straightforward questions; unfortunately the answers are not so straightforward! The questions are:

To what extent is the sea-age of salmon determined by:

- the genetic make-up of the fish?
- juvenile phase of the lifecycle in freshwater?
- the marine environment?

4.2 GENETIC CONSIDERATIONS

Various hatchery-based studies have shown that the genetic make-up of the fish influences its sea-age at maturation to some extent. For example, in breeding experiments carried out at the Salmon Research Trust for Ireland (SRTI)[3], the following results (returns) shown in Table 4.2.1 were obtained from reared smolts between 1966 and 1982:

TABLE 4.2.1: Sea-Age at Return (Numbers of Fish)

Parentage	1SW	2SW
2SW x 2SW	187 (87%)	27 (13%)
1SW x 1SW	4283 (98.4%)	70 (1.6%)
2SW x 1SW	147 (96.1%)	6 (3.9%)

Thus, although 1SW returns predominated in all crosses, there was a greater tendency for the progeny of 2SW parentage to return as 2SW fish than for other crosses.

More evidence of genetic influence on sea-age comes from the experiences of the salmon farming industry. Some stocks of Norwegian origin show grilsing rates as low as 1 per cent compared to 35 per cent for Scottish stocks reared under identical conditions[4]. Experiments in Norway involved breeding 2SW x 2SW, 3SW x 3SW and their crosses, and showed a high level of heritability of sea-age at maturity[5]. In breeding experiments in New Brunswick, involving the release and evaluation of smolts produced from a number of river stocks and their crosses, one stock (and its hybrids with other stocks) consistently produced the highest proportion of grilse[6].

Wilkins (1985)[7] provides an instructive discussion of the possible genetic basis of salmon sea-age determination. As like does not invariably breed like, he suggests that sea-age may be determined by a combination of several or many gene loci, each of which has a tendency towards or away from a particular pattern of maturation. He points out that if age of maturation is influenced by six genes, over 700 different genetic combinations are possible. This situation could explain the predominance of grilse in all crosses in the SRTI results described above; the grilse parents were derived from a line selected for a grilse habit, and which would therefore contain a high proportion of genes for a grilse tendency. The 2SW parents were derived from wild stock, and in a population where grilse predominated most 2SW fish would possess, in Wilkins' model, only a slight excess of 2SW genetic material over grilse material.

There is a tendency for males to mature and return at a younger age than females. In many stocks the 1SW component of the run is predominantly male while the 2SW fish are predominantly female. The catch of salmon at West Greenland, where most fish are approaching their second sea-winter, and represent a wide range of stocks, shows a predominance of females. Some studies have shown that sex ratios of 3SW fish are more even while others have indicated a bias towards females in some stocks and males in others.

4.3 INFLUENCE OF THE JUVENILE PHASE OF THE LIFECYCLE IN FRESHWATER

There is a range of rather inconclusive and often contradictory observations which suggest that the freshwater environment, to the extent that it influences growth rate of parr, might play a role in determining the sea-age of salmon. The data presented in Table 4.3.1 have been used to support an inverse ratio theory of river and sea life[1]. This hypothesis proposes that slow-growing parr which become smolts at an older river-age return as younger sea-age salmon than parr which become smolts at a younger river-age. There is an inference that salmon may have a tendency towards a particular total age which is attained by a combination of low river and high sea-age or high river and low sea-age.

TABLE 4.3.1: Sea-age distribution (%) of smolt-age classes of salmon caught on the River Wye 1908 to 1939

	Sea-age at return (SW)			
	1	2	3	4
One-year smolts	0.3	35.9	60.4	3.4
Two-year smolts	6.9	53.9	27.0	2.2
Three-year smolts	17.0	57.7	23.9	1.4

The inverse ratio hypothesis is supported by the results from two controlled breeding programmes releasing smolts in Ireland[8] and Canada[9] which indicated a relationship between smolt-age and sea-age; in both cases, one-year-old smolts produced relatively more 2SW fish and relatively fewer 1SW fish than two-year-old smolts from the same parentage. The Canadian study also showed that the smallest one-year-old smolts returned the lowest percentage of 1SW fish and the larger two-year-old smolts returned the largest proportion of 1SW fish. A review of the results from experimental releases of two groups of wild smolts in the Miramichi River, Canada found no clear relationship between smolt size and age at first maturity[10]. Examination of results from three groups of two-year-old hatchery smolts in the same river, however, showed that the slower growing (smaller) juveniles tended to return at a lower sea-age than the faster growing fish. These findings were later contradicted by results from releases in the Miramichi and the LaHave Rivers where it was found that large smolts produced proportionately more 1SW fish than small smolts[11]. It was concluded that the relationship observed in the earlier experiment was anomalous and could be attributed to variations in the sex ratio among the smolt size classes, the incidence of precocious male parr in the smaller smolt size classes increasing the proportion of 1SW returns from these smaller smolt groups.

From an examination of samples from seven rivers in Canada, it was found that large smolts tended to return as younger sea-age adults and that the age at first maturity in female salmon appeared to be associated with the ovarian development of smolts before they enter the sea[12]. It was also found that ovarian development was greater in smolts derived from low sea-age parents than in smolts derived from older sea-age parents. The sea-age structures of the parental groups from these rivers differed, some being all 1SW salmon, some with more than 70 per cent as 2SW salmon and some with all parents being 3SW salmon. Samples from thirty-four rivers in Newfoundland indicated a relationship between smolt size and the sea-age of their parents.

A review published in 1976 of the available literature described contradictory evidence regarding the inverse ratio hypothesis and it was suggested that there was no dominant causal relationship between growth (river or sea) and the time of return to fresh water[13]. It was suggested that the differences in smolt characteristics of different sea-age or seasonal runs may be a reflection of different genetic make-up or reproductive isolation in different tributaries and have no direct causal relationship.

Data from rod catches in twenty Quebec North Shore rivers showed no evidence of any relationship between river-age and sea-age and, in fact, it was concluded that "future studies should not focus on river-age *per se* as a determinant of sea-age"[14].

In the North Esk, adult returns are divided almost equally between 1SW and MSW salmon. Of the MSW salmon, more than 90 per cent are 2SW fish. Table 4.3.2 shows the percentage sea-age distribution at return of each of the four smolt-age classes. Comparisons with the results from the Wye in Table 4.3.1 indicate a quite different relationship with younger smolts tending to return at a lower sea-age.

TABLE 4.3.2: Sea-age distribution (%) of smolt-age classes of salmon caught on the North Esk between 1963 to 1992

	Sea-age at return (SW)	
	1SW	MSW
One-year smolts	55.3	44.7
Two-year smolts	49.7	50.3
Three-year smolts	43.6	56.4
Four-year smolts	33.0	67.0

Smaller samples from the Rivers Tweed, Tay, Dee and Spey show similar patterns to those observed for the North Esk. Thus, the inverse ratio hypothesis does not hold in the case of North Esk salmon, and probably salmon populations in other major Scottish rivers, nor can it be shown that river-age and sea-age are completely independent in fish from these rivers. It would appear that fish which develop quickly in fresh water tend to continue to develop quickly once they go to sea. Thus, we conclude that there is no fundamental causal mechanism linking freshwater growth and sea-age.

4.4 INFLUENCE OF THE MARINE ENVIRONMENT

Relatively little is known about where salmon go or how they behave during the marine phase of the lifecycle. Although salmon are caught around The Faroes and off West Greenland, these fisheries provide only limited information on the spatial and temporal distribution of the fish. Thus it is difficult to investigate the effects of natural environmental conditions upon salmon in the sea. Direct evidence of natural changes in the survival of salmon (smolt to returning adult) is available from observations made by SOAFD scientists on the North Esk salmon stock. Marking and catch sampling studies during the past thirty years have suggested that survival has varied considerably from about 15 per cent to over 50 per cent, and recent values have been lower than those during the 1960s. However, in these studies it is possible that factors affecting the fish during the freshwater phase could also account for some of the variation in survival at sea.

Further evidence of the scope for conditions experienced by the fish during the marine phase of the lifecycle to influence the sea-age at maturity has been provided by experiments carried out in Canada[15]. A group of two-year-old hatchery fish was divided into two groups; one of which was released into the river and the other transferred to sea cages. Only 1 per cent of the fish held in the cages matured as 1SW fish, but 63 per cent of the adults returning from the released group did so after 1SW. While conditions in the cages were of course far from natural, the results show that the different conditions experienced by these fish during the marine phase resulted in them maturing at different ages. Thus marine environmental factors may dominate effects of hereditary characteristics and factors in the freshwater phase in determining the sea-age at return.

Several studies have shown that there are various changes taking place in the marine environment over similar time-scales to the long-term trends in salmon catches. Globally, surface temperatures have been increasing during the past century[16]. However, in the Northern hemisphere during the same period there have been areas of warming and of cooling; areas of cooling have occurred over much of the north and north-east Atlantic. The most marked long-term trends are in waters around The Faroes, Rockall and south Iceland, all areas that may be frequented by salmon during their first year in the sea. These waters are fed by currents originating to the west and south-west and cooling occurred from 1900 to 1920 followed by warming which reached a maximum from 1950 to 1960. There was then a period of cooling, possibly reaching a minimum in 1985, followed by further warming. The pattern of these temperature changes are of a similar time scale to the trends in the composition of salmon catches reported in Section 3.

Similar, though less marked changes have been observed in sea surface temperatures around Greenland. A period of warming from 1915 to 1940 has been associated with increased cod and halibut catches west of Greenland, while the subsequent cooling period has been related to a disappearance of cod and the increase in abundance of salmon, which resulted in the high seas fishery there[17].

Attempts have been made in the past to correlate changes in the sea-age structure of salmon catches with records of marine conditions. The most comprehensive of these studies[18] examined net catches in the Aberdeenshire Dee from 1877 to 1972 and compared these with the mean annual sea surface temperatures at Grimsey Island, off northern Iceland, which were taken as representative temperature values for the sub-arctic (Figure 4.4.1). An increase in sea temperature was shown to be associated with larger numbers of fish returning as MSW salmon and fewer as grilse. We attempted to extend this analysis to see whether the relationships still held over the last twenty years. The Dee fishery continued until 1986, but unfortunately the Grimsey Island recording station was abandoned in 1973. However, an overlapping time-series of sea surface temperature data is available for Siglunes, in north-west Iceland. For the overlapping period, the two temperature data sets were found to be well correlated ($p<0.001$), and so the Siglunes data were used to extend the Grimsey temperature data (Figure 4.4.1). The correlations between temperature and salmon and grilse numbers were found to be maintained although their statistical significance was somewhat reduced. This is consistent with the observation that the marine environmental conditions have been particularly variable since 1972, while the proportion of MSW salmon in the Dee catch generally remained low from 1972 until the closure of the net fishery[19].

We are aware that such statistical analyses are complex and great care must be taken in the interpretation of the results. The fact that both the annual catches and sea temperatures are strongly auto-correlated (values in one year tending to be similar to values in neighbouring years) may reduce the significance of the observed relationships. This means that caution might be exercised in attributing causal links between sea temperature and age at maturity.

A long time series of hydrographic measurements across The Faroes-Shetland Channel derived from surveys conducted by the Marine Laboratory, Aberdeen has also revealed major environmental changes this century. Two periods of low salinity and water temperature have been observed between 1906 and 1912 and 1974 and 1978[20]. These are believed to have been the results of similar events;[21,22] the latter period has been termed the Great Salinity Anomaly (GSA) and occurred as a result of a complex series of meteorological changes. In brief, anomalously high atmospheric pressure over Greenland in the 1950s and 1960s resulted in increased northerly winds around northern Iceland and east Greenland. This resulted in cooler, less saline water entering the east Greenland and east Icelandic currents. This salinity and temperature anomaly reached its peak in around 1968 and could subsequently be tracked around the North Atlantic circulation system[22]. Thus water of low salinity and temperature was recorded on the West Greenland Banks between 1969 and 1970; off Newfoundland between 1971 and 1972; at Rockall in 1975; south of Iceland and in The Faroes-Shetland Channel in 1976; and in the North Sea and English Channel between 1977 and 1978. The anomaly then proceeded along the Norwegian coast and arrived at the entrance to the Barents Sea between 1978 and 1979 and west of Spitzbergen in 1979. Finally, after circulating around the northern seas it returned to the east of Greenland between 1981 and 1982, thirteen to fifteen years after its inception there. The end of the atmospheric conditions that created the low salinity and temperature conditions

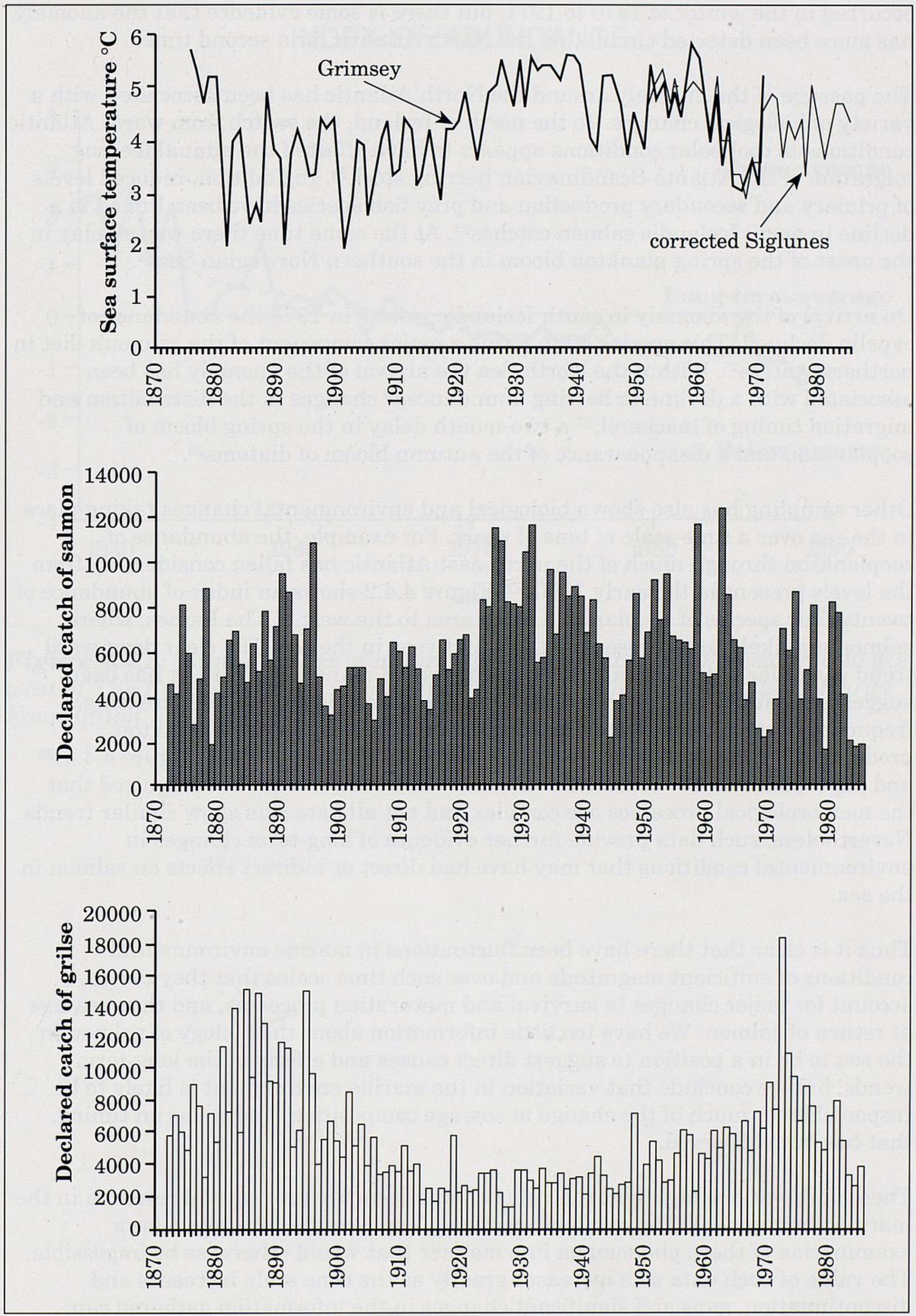


Figure 4.4.1: *Mean annual sea surface temperature measured at Grimsey Island (1876-1972) and Siglunes (corrected data) (1952-1986) and declared catches of salmon and grilse in the Dee net and coble and fixed engine fisheries (1872-1986).*

occurred in the winter of 1970 to 1971, but there is some evidence that the anomaly has since been detected circulating the North Atlantic for a second time.

The passage of the anomaly around the North Atlantic has been associated with a variety of biological changes. To the north of Iceland, the switch from warm Atlantic conditions to cool polar conditions appears to have affected the annual feeding migration of the Atlanto-Scandinavian herring stock[23]. In addition, reduced levels of primary and secondary production and prey fish species have been linked to a decline in north Icelandic salmon catches[24]. At the same time there was a delay in the onset of the spring plankton bloom in the southern Norwegian Sea[23].

On arrival of the anomaly in south Icelandic waters in 1976 the abundance of capelin declined. This species often forms a major component of the salmon's diet in northern waters[25]. Within the North Sea the arrival of the anomaly has been associated with a decline in herring abundance;[26] changes in the distribution and migration timing of mackerel;[27] a two-month delay in the spring bloom of zooplankton and a disappearance of the autumn bloom of diatoms[26].

Other sampling has also shown biological and environmental changes taking place in the sea over a time-scale of tens of years. For example, the abundance of zooplankton through much of the north-east Atlantic has fallen considerably from the levels present in the early 1950s[22]. Figure 4.4.2 shows an index of abundance of twenty-four species of zooplankton in an area to the west of The Faroes, where salmon are likely to be present in their first year in the sea. The clear downward trend is similar to that of catches of spring fish in many UK rivers. It has been suggested that the change in zooplankton abundance is a result of increasing frequency of strong winds causing a reduction and delay in phytoplankton production;[22] records of wind speeds (Figure 4.4.3)[28] wave heights (Figure 4.4.4)[29] and phytoplankton are consistent with this. However, it must be recognised that the meteorological processes are complex and not all data sets show similar trends. Nevertheless, such data provide further evidence of long-term changes in environmental conditions that may have had direct or indirect effects on salmon in the sea.

Thus it is clear that there have been fluctuations in marine environmental conditions of sufficient magnitude and over such time scales that they could account for major changes in survival and maturation processes, and thus sea-age at return of salmon. We have too little information about the biology of salmon in the sea to be in a position to suggest direct causes and effects of the long-term trends, but we conclude that variation in the marine environment is likely to be responsible for much of the change in sea-age composition, and thus run timing, that has been observed.

These observations highlight the value of long-term monitoring and research in the marine environment. The availability of long, comparable data sets allows examination of these phenomena in a manner that would otherwise be impossible. The value of such data sets increases greatly as the time scale increases and discontinuation, gaps and significant changes in the information gathered can greatly reduce the value. We strongly support the continued funding and development of long-term monitoring of oceanographic processes.

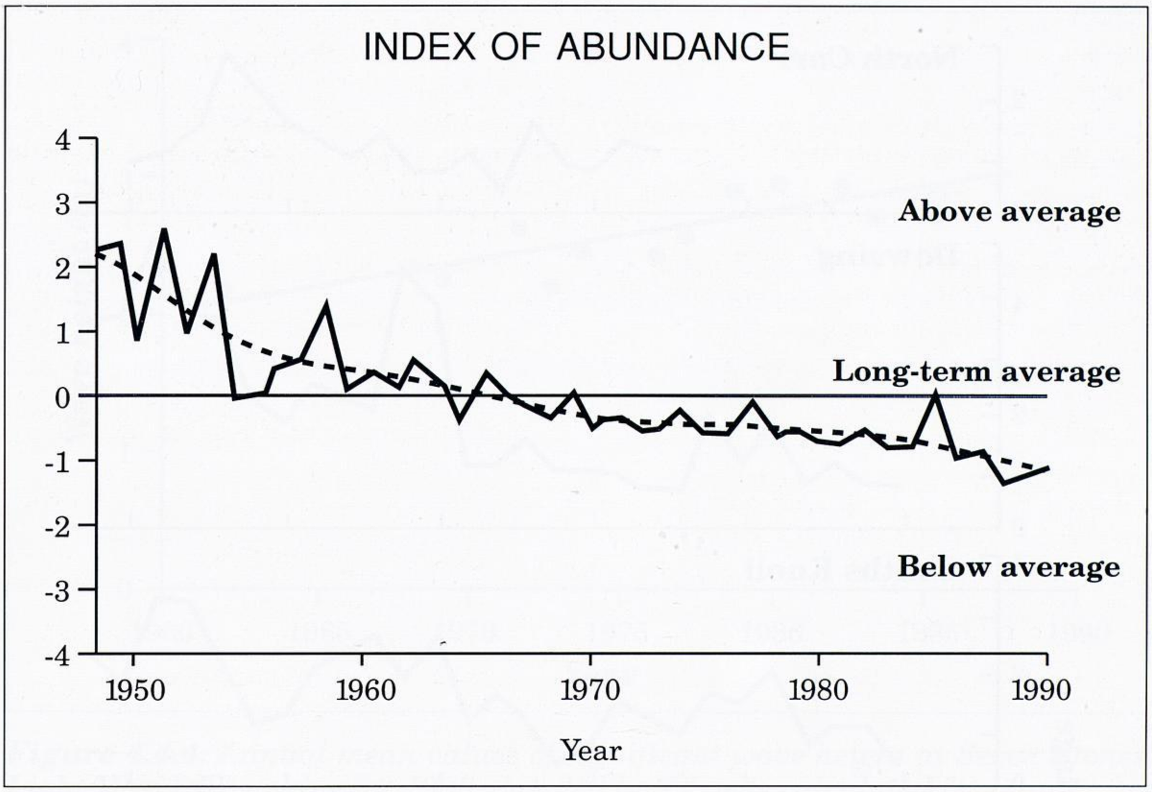


Figure 4.4.2: *Annual index of abundance of zooplankton in a sea area to the west of The Faroes. (Data provided by Dr John C Gamble, Sir Alister Hardy Foundation for Ocean Science Plymouth.)*

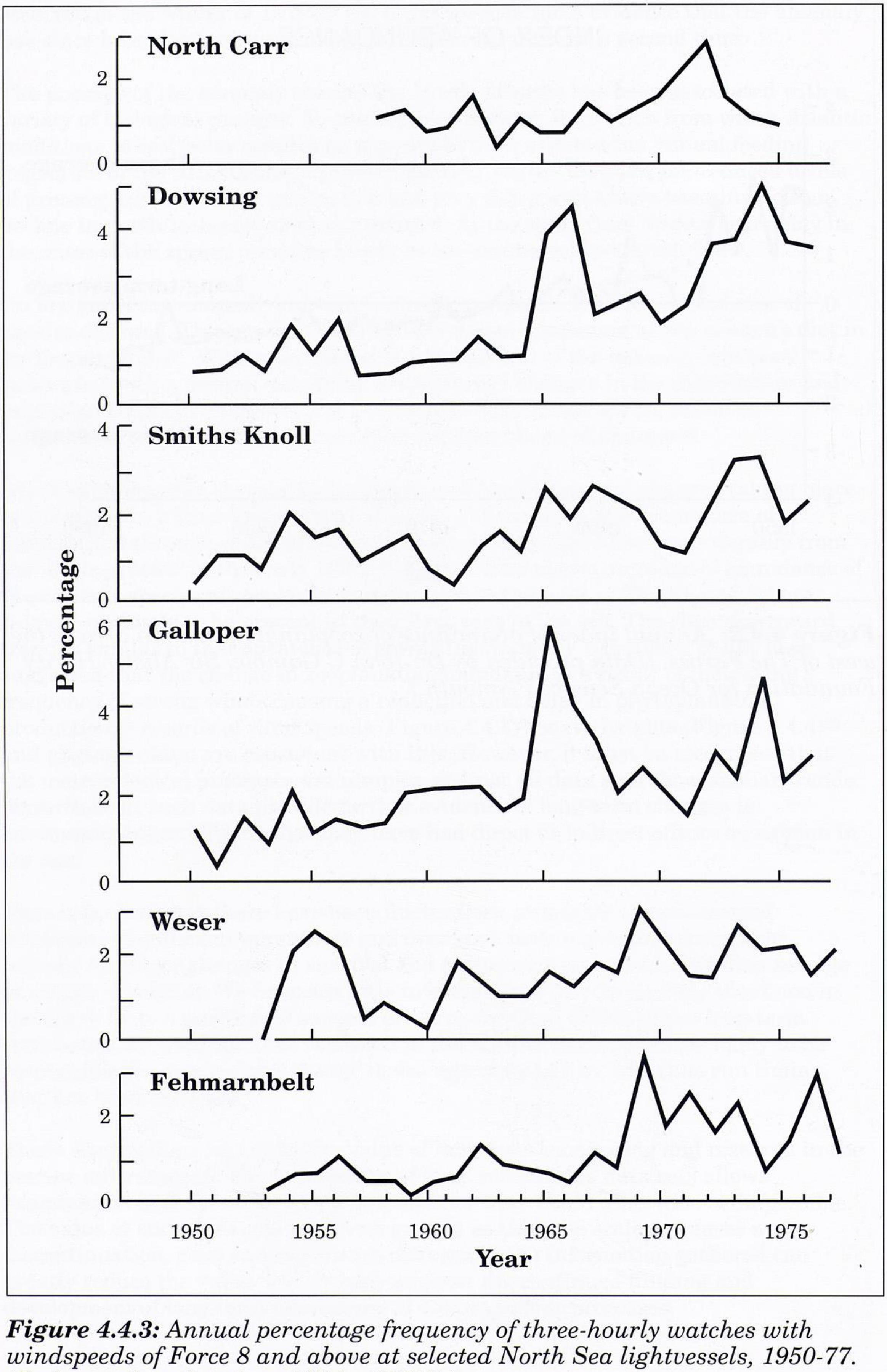


Figure 4.4.3: *Annual percentage frequency of three-hourly watches with windspeeds of Force 8 and above at selected North Sea lightvessels, 1950-77. (Redrawn from Lamb and Weiss (1979).)*

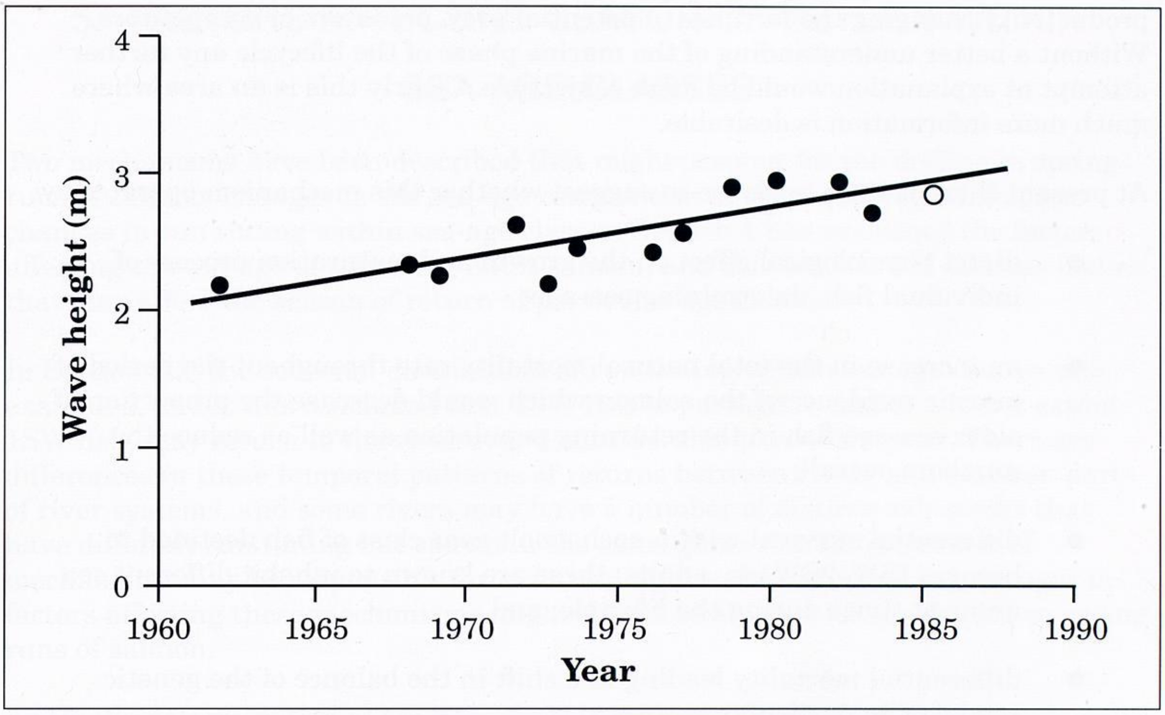


Figure 4.4.4: *Annual mean values of significant wave height at Seven Stones Light Vessel. The value for 1985, denoted by 'O', was calculated from an incomplete data set. (Redrawn from Carter and Draper (1988).)*

4.5 FACTORS CONTRIBUTING TO THE CURRENT TENDENCY TO LOWER SEA-AGE

As discussed in Section 3.5, we conclude that a shift to lower sea-age is predominantly responsible for the current lower catches in the early months of the year. Which mechanisms are likely to be responsible? The obvious contenders are:

- widespread changes in the freshwater environment that influence the development of the juveniles, and in turn the development of the adults;
- changes in natural marine conditions that affect a wide range of stocks; and
- exploitation exerting selective pressure against particular parts of the stock hardest hit, in this case the early-running component, reducing runs of such fish in later generations.

There is no evidence that the first mechanism has operated in recent years, with no evidence of a shift in growth rates or smolt-age on a similar timescale to that of the observed changes in sea-age composition.

As described in Section 4.4, there have been major changes in marine conditions and productivity of both plankton and fish populations over a similar timescale to the changes in the pattern of salmon maturation. Although no obvious direct causal mechanism is apparent, given the poor state of our knowledge of the marine life of the salmon it is perhaps unrealistic to expect that it should be so. Many possible mechanisms can be suggested for example, temperature affecting growth rate, distribution or physiological development, changes in primary and secondary productivity changing the fortunes of potential prey, predators or competitors. Without a better understanding of the marine phase of the lifecycle any further attempt at explanation would be mere conjecture. Clearly this is an area where much more information is desirable.

At present there is little evidence to suggest whether this mechanism operates by:

- direct physiological effect on the growth and maturation process of individual fish, determining sea-age;
- an increase in the total natural mortality rate throughout the period of marine residence of the salmon which would decrease the proportion of older sea-age fish in the returning population as well as reduce the numbers overall;
- differential survival within each smolt year class of fish destined to become 1SW, 2SW etc. adults; these are known to inhabit different sea areas at times during the lifecycle; and
- differential mortality leading to a shift in the balance of the genetic tendency to particular sea-age.

Thus although we believe we can identify the likely cause (changing marine conditions) and the effect (changes in sea-age structure), we cannot identify the exact mechanism at present. We recommend that more research should be funded on the interrelationship between the biological and environmental factors that are responsible for determination of sea-age.

Heavy selective exploitation is also likely to be implicated in changes in sea-age composition, at least to the extent of accelerating and deepening the decline in MSW numbers which may already be occurring as a result of changes in marine conditions. It is known that exploitation by rod and line of MSW fish, and 3SW fish in particular, may be considerably higher than for 1SW fish in the same fishery[30]. All the salmon caught in the West Greenland fishery and most of those taken at The Faroes are potential MSW returners. Mathematical models have been developed to estimate exploitation rates in the fisheries of West Greenland and The Faroes. However, these models can only be applied where smolts are tagged and the numbers of returning tagged adults can be monitored. Nevertheless, this suggests that the exploitation rate in these fisheries on potential 2SW fish from rivers in Great Britain has probably been between about 5 and 15 per cent in recent years. It is difficult to estimate the exploitation rate on potential 3SW fish because of their low abundance. However, the exploitation rate at West Greenland on potential 3SW fish from the USA is higher than on potential 2SW fish. If this is also the case for European stocks then the level of exploitation on the early-running fish is likely to represent a significant additional loss to an already depleted fraction of the stock.

5. FACTORS AFFECTING SEASON OF RETURN WITHIN SEA-AGE CLASSES

Two mechanisms have been described that might account for the decline in spring runs of salmon: changes in the sea-age composition of the returning adults; and changes in run timing within sea-age classes. Section 4 has examined the factors affecting the sea-age of returning adult salmon, and this section will address factors that may affect the season of return of particular age classes.

In Section 2.2, the seasonal distribution of run timing within sea-age classes was examined, and it was concluded that 2SW fish in particular, and to a lesser extent 1SW fish, may return to the river over a considerable part of the year. There are differences in these temporal patterns of returns between rivers and between parts of river systems, and some rivers may have a number of distinct sub-stocks that have different run timing but spawn in the same general area. A number of mechanisms may be responsible for maintaining these differences and changes in factors affecting these mechanisms might therefore account for the decline in spring runs of salmon.

As for the determination of sea-age, there is evidence that a number of genetic and environmental factors have an influence on run timing within sea-age classes. Clear evidence of a genetic involvement comes from an experiment in Norway[31] where eggs were taken from two river stocks with different season of return of 2SW fish. When reared together under identical conditions and released as smolts into several rivers, they retained their ancestral run timing habits upon return.

There is also evidence that the environment in which the juveniles are reared can affect run timing, though care is needed in deciphering cause and effect. Sampling investigations in the North Esk[32,33] showed that within any sea-age class, fish derived from the older smolts returned to the river earlier in the year than those derived from younger smolts. For example, in the 2SW age class, the mean smolt-age of fish entering the North Esk in February was significantly greater than that of fish entering in March which was in turn significantly greater than that of fish entering in April and so on throughout the year[32]. Late in the year however, early-running spring salmon which would spawn the following year start to appear and are found to have high smolt ages, with four-year-old and three-year-old smolts much more in evidence than was the case in the same sea-age class of fish entering during the following fishing season. These results were not fully supported by the findings in other experiments carried out on the Girnock Burn and in the Tay system but in these cases, the time of entry to the tributaries was investigated whereas in the North Esk, the fish being sampled came from the entire system and were being sampled virtually at the head of tide. It would appear, therefore, that in whole river systems at least, the month of return to the river is linked to both sea-age and river-age.

In the Miramichi, a large Atlantic salmon river system in Canada, smolts derived from the headwaters tended to return to the river as grilse as a distinct run some months earlier than grilse derived from smolts originating from lower down the system[34].

In the North Esk, parr surveys have shown that the populations present in the upper tributaries tend to include more older fish than the populations in the lower tributaries. Thus, it is probable that the older smolts are derived from stock components reared in the upper parts of the catchment. Investigations at spawning time suggest that the stocks spawning in the upper tributaries comprise small 2SW and small 1SW fish of high smolt-age, and thus, probably fish which entered the North Esk early in the run of each sea-age class.

The likely explanation for the situation described is that the slow growth rate achieved by fish in upper tributaries, due to limited food supplies and a short growing season, influences the development of the fish at sea and leads to return early in the run. However, definitive experiments with, for example, fish derived from lower tributaries being reared in upper tributaries, have not been conducted and the possibility remains of a genetic developmental difference between fish spawning in different parts of the river.

Environmental conditions in the river and estuary can have a major impact upon the time of entry of fish to freshwater. Although timing of return to coastal waters is likely to be unaffected by river conditions, entry to the estuary and river may be delayed considerably by low river discharge levels. The timing of entry of the grilse run to the North Esk, as indicated by the Logie counter situated some 3.5 km upstream of the tidal limit, varies considerably between years depending upon river flow conditions. In most years, large runs of grilse are counted during July but numbers decrease markedly in August when river levels are usually at their lowest. Large numbers of fish may then be recorded during September and October when the river level rises during autumn spates. However, in 1988, river levels were unusually low in June and July but rose during August and the number of fish recorded in this month was unusually large. In 1989, low river levels and low counts were recorded throughout the summer months and it was not until September and October when the river rose in spate that large numbers of fish were counted.

There are thus several factors that can affect the time at which fish of a particular sea-age enter and ascend the river. However, in the absence of convincing evidence of significant long-term changes in run timing within sea-age classes (Section 3.4), discussion of potential mechanisms for such changes is inappropriate.

6. OPTIONS FOR MANAGEMENT ACTION

6.1 THE BASIS FOR ACTION

There are two quite separate sets of processes that may be amenable to fisheries management action to conserve and possibly restore early runs of fish. These are:

- the mechanisms that are responsible for the current low level of spring runs; and
- the mechanisms that generate some early-running fish even when spring runs are generally poor.

In the first category come the natural marine conditions that we conclude are a dominant influence on changes in run timing, although there is little if anything that can be done in this case. Also in this category is the heavy exploitation whenever it occurs on early-running and MSW fish.

In the second category are the physical, chemical and biological characteristics and well-being of the spawning and nursery areas historically used by spring fish, often the upper reaches and tributaries of large river systems. Also in this category is the genetic material that confers a tendency to early-running in some stocks.

While there may be little that can be done about what is assumed to be the dominant factor, that of marine conditions, we believe that this should not be taken to suggest that no action is appropriate. In some extreme cases early-running fractions of the stock, once a major proportion, may be reduced to a very few individuals. Protection and perhaps enhancement of such depressed components of the stock may be justified, to preserve the variability and adaptability of the stock so that it is able to respond when marine conditions allow.

The four approaches that may be appropriate for fishery management action in respect of early runs are therefore:

- protection, rehabilitation and development of habitat in areas of catchment believed to be associated with the production of potential early-running and MSW fish;
- development of rearing programmes to maintain and develop early-running and MSW components of the stock, possibly involving selective line-breeding, and preserving genetic material in gene banks;
- management of exploitation to reduce, or at least prevent an increase in, fishing mortality on early-running and MSW fish; and
- protection of spawning stock from illegal fishing, in particular in the upper reaches where early-running fish tend to spawn.

We concluded that as patterns of exploitation, other factors affecting stocks and, indeed, even the stocks themselves, are often quite different in different rivers, development of appropriate plans of action must be undertaken on a river by river basis. Thus while possible approaches can be discussed in general, it is not feasible to produce a set of detailed recommendations which would be applicable to all situations. We recommend that the appropriate authorities produce an action plan for each catchment based on river-specific analysis.

6.2 HABITAT PROTECTION, REHABILITATION AND DEVELOPMENT

As described in Section 5, spawning and rearing of the early-running component of the stock may be associated with particular parts of the upper reaches of the catchment, which for that reason should be carefully protected. Good salmon fishery management of course involves protection of all spawning and nursery areas, but as most agencies have limited resources it may be possible to give priority to areas associated with early-running fish. Possible management actions include:

- ensuring good access for spawners, removal of obstructions, provision of fish passes (SAC 1992);
- improvement in channel topography to optimise habitat for juveniles;
- checking that spawning gravel is abundant and clean, and taking appropriate remedial action (SAC 1991);
- careful management of riparian vegetation and the near-river catchment (the buffer zone concept) (SAC 1991a); and
- restocking with eggs or fry from early-run parents above impassable obstructions in upper catchments (SAC 1991b).

Aspects of the above approaches have been covered by earlier SAC reports as indicated.

6.3 REARING PROGRAMMES

Taking account of the evidence that both the tendency towards high sea-age and the tendency to early-running within sea-ages are both at least partly under genetic control (Section 5), a selective breeding programme is a valid concept. However, numerous attempts to introduce or boost spring runs in the past have failed or have been of questionable success. Even where success has been claimed there has been no conclusive demonstration that a perceived increase or recovery of spring runs was due to the initiative and not just coincidental.

We are therefore unable to recommend that selective breeding programmes are implemented on a general basis at present. However, we feel that a thorough investigation of the approach is an urgent requirement for the following reasons:

- it is possible that the approach is potentially effective and powerful: if so, the sooner it is evaluated the better;
- by definition a selective breeding programme that influences the characteristics of a wild stock involves genetic manipulation. In dealing with depleted stocks or sub-stocks there is a potential danger of inbreeding or reduction in effective numbers of spawners. There is

therefore a clear need for authoritative genetic guidelines for this approach; and

- ill-conceived and potentially damaging programmes are likely to continue until and unless an authoritative assessment is undertaken.

We therefore recommend that the potential for selective breeding programmes to enhance spring runs be examined by the establishment of one or more authoritative pilot scale investigations as a matter of urgency.

6.4 REDUCING EXPLOITATION OF EARLY-RUNNING STOCKS

Four categories of fisheries exploit British salmon stocks. These are:

- high seas fisheries and other countries coastal fisheries (The Faroes, Greenland, Eire);
- home water net fisheries;
- rod and line fisheries; and
- illegal fisheries.

As discussed in Section 4.5, the loss of potential 2SW fish from British rivers in the fisheries at West Greenland and The Faroes is thought to lie between 5 and 15 per cent. It is likely that losses of potential 3SW fish are higher. We endorse initiatives to limit and reduce the catch in these fisheries.

The drift net fishery off north-west Ireland, while taking a number of fish returning to British waters, catches predominantly grilse and summer salmon, and minimal numbers of early-running fish.

Average catches of salmon and grilse by season in Great Britain between 1986–90 by nets and rods are shown in the following figures:

TABLE: 6.4.1

Scotland

	Salmon		Grilse	Total
	Jan-April	May-Dec		
Net	4,165	48,747	137,827	190,739
Rod	8,524	49,837	22,129	80,490

England and Wales

	Salmon and Grilse		Total
	Jan-April	May-Dec	
Net	1,248	73,453	74,701
Rod	1,631	18,865	20,496

A number of points are apparent. First, catches in the spring are low, being only 4.4 per cent of the total. Second, although net catches dominate overall (73.9 per cent of the total), rod catches dominate up to the end of April (65.2 per cent). If a reduction or restriction in overall exploitation of spring fish is perceived as necessary it must clearly include all fisheries if it is to be effective.

Options for reduction of exploitation of early-running fish include delaying the start of the season by an increase in close time. The effectiveness of this measure relies on the fact that early-running fish are less likely to be caught by legal angling once they have been in the river for a few weeks. They again become vulnerable in the weeks preceding spawning, and an earlier closing date for all or part of the catchment might also be considered.

Other options include the application of catch limits, restrictions on methods of angling and of the baits and lures which may be used. Such restrictions may be varied by fishery managers, according to seasons and flow conditions.

The practice of catch-and-release is now widespread in North America and is gaining in popularity in the UK. There is no doubt that carefully handled, undamaged fish can be released after capture by rod and line and may survive to spawn. However, we have some reservations about the application of this approach for the protection of spring fish. Our uncertainty arises because of:

- the potentially long period of time between capture/release and spawning;
- the possibility that large spring fish may be exhausted in order to land and release them; and
- with high exploitation rates, the likelihood that each fish might be caught more than once.

We do not wish to discourage catch-and-release as a voluntary restraint. However, we believe that its validity as a first line approach to protection of early-running fish needs further examination. We recommend that an investigation be commissioned to examine all aspects of catch-and-release as a stock management technique, including the preparation of guidelines for its implementation.

Adjustment of legal exploitation could be achieved by voluntary restraint (with or without compensation) by fishery managers, proprietors and fishermen, or by orders and byelaws under fishery legislation. The Game Angling Code subscribed to and accepted by all UK angling and fishery management organisations provides a basis for programmes of voluntary restraint.

6.5 PROTECTION OF SPAWNING STOCK FROM ILLEGAL FISHING

Early-running fish are at greater risk of being taken illegally than are components of a stock that enter a river system later in the year. This is because:

- salmon are generally more easily caught in a river than at sea. Early-running fish spend a longer period in the river than their counterparts that enter fresh water later in the year;

- large numbers of early-running fish often congregate and spend many months together prior to spawning in deep holding pools well known to poachers where they may be subject to repeated illegal fishing activity; and
- as spawning approaches, early-running fish which have penetrated to the upper part of a catchment may be found in very small tributaries of main river systems where, for a limited period of time, they may be extremely vulnerable to the activities of poachers.

Recognising the value of early-running fish in terms of their genetic potential to breed early-running and MSW progeny, protection of this component of the stock from illegal fishing should form an important part of fishery management strategy.

We appreciate that adequate resources may often be unavailable to fishery managers to protect stocks fully from illegal fishing, especially when fish move to their spawning grounds. However, where possible, emphasis should be placed upon protection of spawning stocks in those upper parts of river systems so as to ensure maximum egg deposition within these parts of a catchment from which early-running components of each stock are thought to derive.

7. SUMMARY OF CONCLUSIONS

1. The task addressed in this report is to review the decline in spring runs of salmon in rivers in Great Britain. In doing so it has been necessary to consider the main factors influencing run timing, with the following specific aims:

- summarise current knowledge of run timing;
- analyse the possible mechanisms and causes of changes in run timing;
- consider the extent to which recovery of spring runs might occur naturally; and
- provide guidance on any specific measures which fishery managers might find appropriate for individual rivers (Section 1).

2. The main evidence for changes in run timing comes from examination of long-term records of seasonal distribution of catches. We are satisfied that the timing of both rod and net catches are reasonable indicators of the timing of entry to the river (run timing), and that significant changes in run timing have taken place (Section 2).

3. Different sea-age classes of salmon have different patterns of run timing, and these vary between stocks. One-sea-winter (1SW) fish (grilse) mainly enter rivers from June to August, though some rivers have strong autumn runs. Two-sea-winter (2SW) fish may enter rivers at any time of the year. Three-sea-winter (3SW) fish generally enter rivers early in the year, with few running after about May in most stocks. There is evidence that fish spawning for a second time adopt similar run timing to that of their first spawning migration (Section 2.2).

4. A change in the pattern of run timing of a stock could therefore be a reflection of a change in balance of the sea-age classes, a change in run timing within sea-age classes, or both (Section 2.2).

5. We examined the monthly catch records for twelve fisheries for which records could be obtained covering a period in excess of fifty years; for eight, the records spanned over eighty years. Similar changes in the monthly pattern of catches and, where data are available, the contribution of different sea-age classes were apparent in all cases. The spring component of the catches increased both numerically and as a proportion of total catch from 1910 to about 1930. There were then fluctuations until the early 1950s, but thereafter there was a steady decline to the current low levels (Section 3).

6. We have concluded that the main mechanism in these shifts in timing of catches and runs has been a change in the sea-age composition of stocks. While there is evidence of shifts in run timing within sea-age classes, we were unable to identify any situation where this mechanism was dominant in an observed shift in the timing of catches (Section 3.5).

7. A review of available evidence indicated that the genetic make-up of the fish, the freshwater environment of the juveniles, and the marine environment may all influence the timing of maturation and thus the sea-age at return. Examination of the results of long-term studies of marine processes indicated the existence of major fluctuations of fundamental biological significance which were occurring on a timescale of a similar order to that in the shifts of salmon run timing. The parameters involved include temperature, salinity, and productivity of zooplankton in certain areas. Although no direct causal link could be identified, we concluded that variation in the marine environment is likely to be responsible for much of the change in sea-age composition, and thus run timing, that has been observed (Section 4).

8. We were unable to determine the mechanism through which changing marine conditions influenced sea-age composition of stocks. Possibilities are:

- direct physiological effect on the growth and maturation process of individual fish, determining sea-age;
- an increase in the total natural mortality rate throughout the period of marine residence of the salmon which would decrease the proportion of older sea-age fish in the returning population as well as reduce the numbers overall;
- differential survival within each smolt year-class of fish destined to become 1SW, 2SW, etc. adults; these are known to inhabit different sea areas at times during the lifecycle; and
- differential mortality leading to a shift in the genetic balance of the genetic tendency to particular sea-age (Section 4.5).

9. Heavy selective exploitation of older sea-age classes and early-running fish is also likely to be implicated in changes in sea-age composition of stocks. Rod fisheries may be responsible for a much higher level of exploitation of spring fish than of grilse in the same stock. The fisheries at The Faroes and Greenland are taking overwhelmingly potential 2SW and older returnees (Section 4.5).

10. There are distinct differences in the pattern of run timing within sea-age classes between different river stocks and sub-stocks, and also changes between years even though evidence for long-term trends is lacking. There is clearly a genetic element involved in maintaining these differences, and also evidence that the growth opportunity in freshwater may have an influence. River conditions upon return to coastal waters can also affect timing of entry to the river, with low flows often causing a considerable delay (Section 5).

11. We concluded that fishery management action may be appropriate to protect and perhaps restore early runs of fish by the following approaches:

- protection, rehabilitation and improvement of habitat in areas of catchment believed to be associated with the production of potential early-running and MSW fish;
- development of artificial rearing programmes to maintain and develop early-running and MSW components of the stock, possibly involving line-breeding, and preserving genetic material in gene banks;
- management of exploitation to reduce, or at least prevent an increase in, fishing mortality on early-running and MSW fish; and

- protection of spawning stock from illegal fishing, in particular in the upper reaches where early-running fish tend to spawn (Section 6).

Recommendations for specific action are made under each of these headings. A summary of recommendations will be found in Section 8.

8. SUMMARY OF RECOMMENDATIONS

Summarised below are the main recommendations made in the body of the report. The summaries are kept very brief here, and greater detail and background can be found by reference back to the appropriate part of the main text.

Recommendation 1. We consider that the poor catches of spring fish in recent years is predominantly due to a shift in sea-age class composition of returning runs of fish, and is one of the most important issues in salmon fishery management. We therefore recommend that research into the factors that control the proportions of the stock that return after one or more sea winters be actively pursued (Section 4.5).

Recommendation 2. We stress the value of long-term investigations of the characteristics and performance of individual river stocks, such as those that comprise trapping, fish counting, scale reading, juvenile surveys etc. While detailed monitoring of all stocks is unrealistic, we recommend development of an increased coverage of monitored river stocks (Section 3.4).

Recommendation 3. We consider that reliable long-term catch data have been of great value in our deliberations. We located and collated data sets a number of which had not before been analysed, and conclude that many other sets of potentially valuable data exist in the UK. We recommend that steps be taken to identify, access and collate such sets of catch statistics so that they are available for future studies on this and other aspects of fisheries management (Section 3.4).

Recommendation 4. In order to maximise the value in future of current catch statistics, we recommend that all efforts are used to ensure that accurate and comprehensive catch statistics be rigorously collected and maintained for all salmon fisheries (Section 3.4).

Recommendation 5. In order to analyse the role of changes in the marine environment in determining aspects of salmon lifecycles, long-term records of marine environmental conditions and investigations of the factors influencing these are essential. We therefore strongly support the continued funding and development of long-term monitoring of oceanographic processes (Section 4.4).

Recommendation 6. We conclude that conditions in the sea are likely to be a major factor in the current low abundance of spring fish (Section 4.4). However, it is also likely that heavy and selective exploitation is implicated in some rivers (Section 4.5). We recommend that consideration be given to protection and perhaps enhancement of early-running fish, particularly in stocks where spring runs have suffered the most acute decline, in order to preserve the variability and adaptability of a stock so that it is able to respond when marine conditions once again become conducive to spring runs (Section 6.1).

Recommendation 7. We conclude that different river stocks varied considerably in terms of stock characteristics including sea-age composition and run timing, patterns and levels of exploitation, and that a variety of different problems face the stocks. We recommend that analysis of status and performance of stocks and consideration of fishery management action in reference to run timing be undertaken on a river by river basis (Section 6.1).

Recommendation 8. Actions which we recommend for consideration for protection of early-running fish are protection, rehabilitation and development of habitat (Section 6.2) and control of exploitation in both commercial and sport fisheries (Section 6.4). Protection of stocks from illegal fisheries is also appropriate (Section 6.5).

Recommendation 9. We endorse the limitation and reduction of the catch of salmon in the fisheries at West Greenland and The Faroes (Section 6.4).

Recommendation 10. We recommend that the effectiveness of returning undamaged rod-caught fish to the water (catch-and-release) as a means of protecting early-running fish should be investigated further (Section 6.4).

Recommendation 11. We recommend that the potential for selective breeding programmes to enhance spring runs should be examined by the establishment of one or more pilot-scale investigations as a matter of urgency (Section 6.3).

APPENDICES

A: MEMBERSHIP OF THE SALMON ADVISORY COMMITTEE

Chairman: Professor G M Dunnet

Mr G H Bielby

Mr C G Carnie

Mr R M Clerk

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 UR 145, 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).

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

B: ACKNOWLEDGEMENTS

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The Hon Caroline Douglas-Home

Peter Ecroyd Esq

The Duke of Roxburghe

The Sellar Family

The Tay Salmon Fisheries Company Limited

The River Tweed Commissioners

The Late John Potter Esq

The Viscount Thurso of Ulbster

The Crown Estate Commissioners

Christopher Moriarty, Fisheries Research Centre, Dublin for supply of data from the River Blackwater, Ireland originally made available to him by the Proprietors of the Careysville Fishery.

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