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Effects of the English north-east coast salmon fisheries on Scottish salmon catches

E.C.E. POTTER and A. SWAIN

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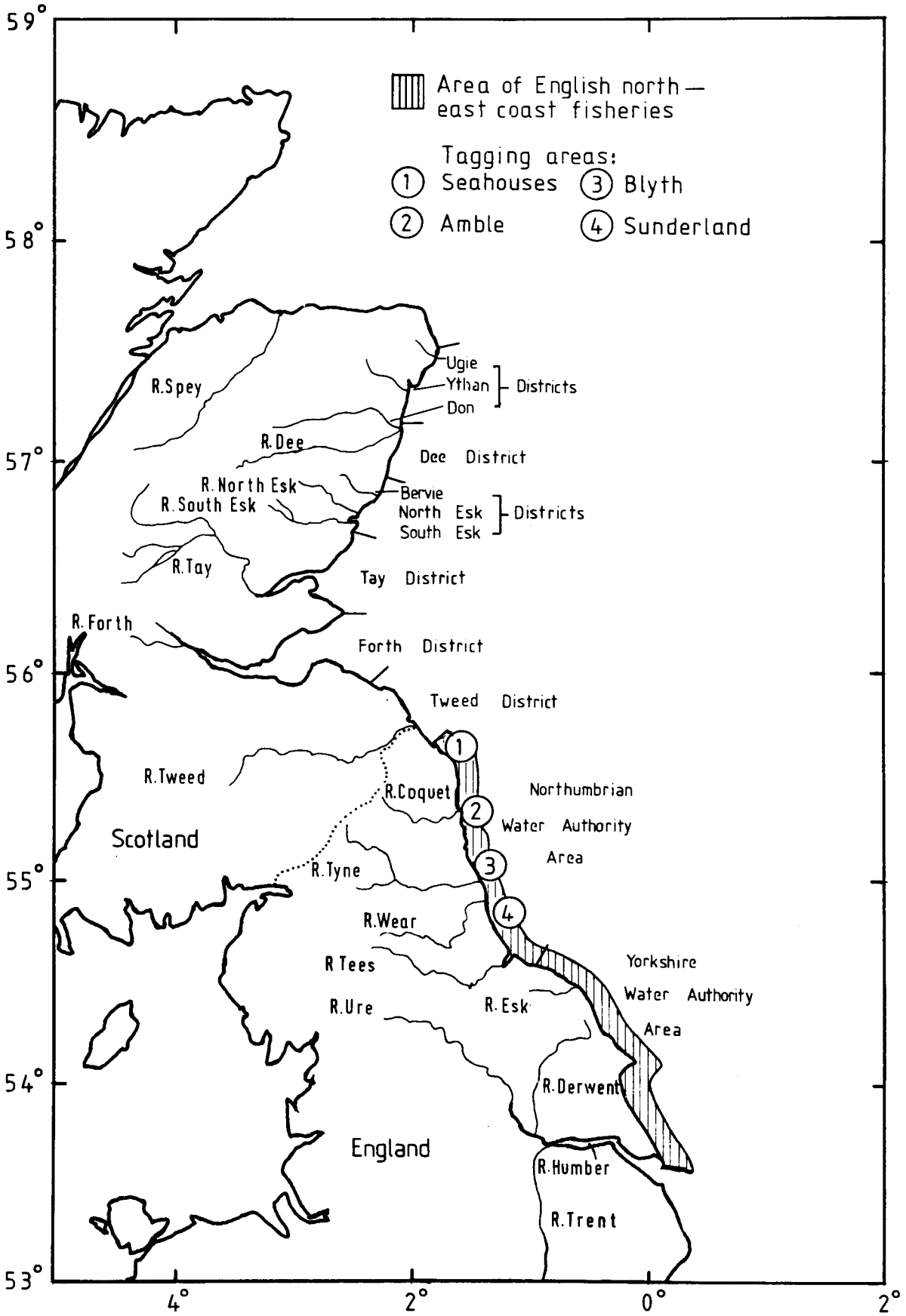

Figure 1. Map showing salmon fishery areas and major salmon rivers on the English north-east coast and Scottish east coast.

1. Introduction

Between 1970 and 1976 the mean annual declared catch of salmon (*Salmo salar* L.) in the commercial fisheries on the north-east coast of England was 55 945 fish. Over 90% of these salmon were caught in drift nets up to 6 miles from the shore between Holy Island and the River Humber (Figure 1). There are several salmon rivers in this area but they are thought to support annual runs totalling no more than 5 000–10 000 returning adults; there are no other salmon rivers to the south between the River Humber and the River Itchen on the south coast. To the north of this area, however, there are a number of Scottish rivers with very large stocks of salmon. There could therefore be little doubt that the majority of the salmon taken by the English nets were returning to Scottish waters. The purpose of the present study was to discover to which individual rivers the fish were returning and what effect the English fisheries might be having on the stocks and catches in these rivers.

2. The sea fisheries

Drift or hang nets have been used for catching Atlantic salmon and sea trout (*Salmo trutta* L.) along the north-east coast of England for at least one hundred years. Reference is made to their operation around the mouth of the River Tyne in the Seventh Annual Report of the Inspectors of Salmon Fisheries, for the year 1867 (Anon., 1868) and there is considerable discussion of the technique in the Report of the Select Committee on Salmon Fisheries (Anon., 1870). Grimble (1913) refers to 'vast numbers of hang nets' being used off the River Tyne in the early 1870s, some of which were 'nearly 2 miles in length'. 'Most of them', he says, 'were fished five to six miles from the shore, but some (boats) went as far as thirty miles out to sea .....'. By 1890 drift nets were licensed in all the Fishery Districts from the River Esk (Yorkshire) to the River Coquet, with the Boards of Conservators enforcing restrictions on lengths of nets and weekly and seasonal closed periods similar to those operating today.

The early drift nets could only be operated effectively at night or in rough weather, presumably because of the visibility of the natural fibre twines in the water. However, the same nets were also used in daylight to form a type of trap net on the beach. Except for the introduction of nets made from synthetic fibres which have allowed the move from dark to daylight drift netting, the gear and methods used have changed little over the years. Catches increased markedly following the introduction of monofilament nylon nets in 1967, and, as a result, efforts have had to be made to reduce the number of licences by applying net limitation orders.

The fisheries are now controlled by the Northumbrian and Yorkshire Water Authorities (NWA and YWA) who limit the issue of licences to about 200 each year. In the Northumbrian area, which stretches from Goswick Sands in the north to Boulby Craggs in the south (Figure 1), all licence holders (128 in 1977) may fish with up to 550 m of drift net, but several crews (18 in 1977) use T-nets, a type of trap net, for all or part of the time. The majority of these T-nets are fished within a few miles of the River Coquet. In the Yorkshire fishery, which extends south from Boulby Craggs to the River Humber, only two-thirds of the licences issued are for the use of drift nets (53 in 1977), which in this area must not exceed 370 m in length. As in the Northumbrian area, the drift nets may be operated up to 6 miles from the shore. However, between 10 and 20 of the Yorkshire drift-net licensees choose to work their nets from the beach. The other 29 Yorkshire licences are issued for the use of beach nets only.

No salmon netting is permitted in the river estuaries along the north-east coast of England and there are closed areas for netting around the mouths of the Rivers Tyne, Coquet, Wansbeck and Esk. Fixed nets, of the types used on the Scottish coast, are also forbidden in English waters.

The salmon netting season runs from 26 March to 31 August in the Northumbrian area and from 1 February to 31 August in Yorkshire. However, many of the fishermen in the Northumbrian area and nearly all in Yorkshire wait until June before they begin netting. The netsmen must also observe a 42-60 h (depending on the area) weekend closed time for each week of the season.

Between 77% and 95% (mean 90%) of each year's catch on the north-east coast from 1970 to 1976 was taken in the Northumbrian area. Over 95% of the salmon landed in the Northumbrian area and about 90% in the Yorkshire area are taken by drift nets. Thus, of the total north-east England net catch, approximately 85% and 9% are taken in Northumbrian and Yorkshire drift nets respectively and 5% and 1% in Northumbrian and Yorkshire beach nets respectively.

Scottish salmon fisheries and fishery regulations are different from those in England. North of Goswick Sands to the Scottish border and along the east coast of Scotland commercial salmon fishing is controlled by District Fishery Boards (except the River Tweed area which is controlled by the River Tweed Commissioners). The principal salmon fishing methods are seine nets operated within the river estuaries and fixed trap nets (fly or bag nets) set along certain parts of the shore. Drift net fisheries began to develop on the Scottish east coast in the early 1960s, and in 1962 the catch is estimated to have reached 110 000 fish, but drift netting for salmon was banned in Scottish waters from 1963. However, in the mid-1970s illegal netting became a problem, reaching a peak in 1977, but declining thereafter.

3. MAFF tagging experiment

3.1 Method

In 1977 the Ministry of Agriculture, Fisheries and Food carried out tagging experiments as part of a general investigation of the Northumbrian salmon fishery. In order to assess the effects of this fishery on salmon fisheries and stocks elsewhere, it was necessary to tag and release a sample of the commercial catch. Attempts were made to ensure that the fish marked were broadly representative of the catch, by tagging throughout the season and in several areas of the fishery. (It should be noted that, because of the migratory movements of the salmon and the selective action of the drift nets, the tagging sample was not representative of all the salmon passing through the fishery area). Arrangements were made to tag viable salmon caught by the commercial netsmen fishing normally with monofilament drift nets. Observers sailed with netsmen in four areas along the Northumbrian and Durham coast (Figure 1):

1. Seahouses (Holy Island to Newton-by-the-sea);
2. Amble (Boulmer to Newbiggin-by-the-sea);
3. Blyth (Blyth to South Shields);
4. Sunderland (Souter Point to Saltburn).

In the Amble area salmon from T-nets were also tagged.

Detailed records were kept of netting procedures and of the prevailing sea and weather conditions. All salmon caught were weighed and measured (length and girth) and a scale sample was taken for age determination. Other data collected included the depth and direction in which the fish were held in the net, the percentage scale loss caused by the nets, and fish liveliness. All live salmon brought aboard the boat were placed in a tank (85 x 65 x 65 cm) of sea water, which was continually refreshed. Those fish that showed no signs of damage to the gills and were actively swimming after a few minutes were marked with yellow anchor tags beneath the dorsal fin on the left side of the fish. Tagged fish were released about 200 m beyond the end of the net.

3.2 Returns

The boats taking part in the experiment in 1977 caught 1 604 salmon and, of these, 670 (41.8%) were tagged and released. By the end of 1977, 158 recaptures had been reported, with a further two following in 1978, a total recapture rate of 23.9% (Table 1). The majority (78%) of the recaptures from all tagging areas were made within two weeks of the date of tagging.

Tagged salmon from the drift net fishery returned to all the large east coast salmon rivers from the River Wear in England to the River Dee in Scotland, with the majority moving northwards. The river stocks were fairly well mixed throughout the drift netting area although the concentration of River Tweed fish increased towards the north. The fish tagged from the Amble T-nets appear to have been more local; two-thirds of their recaptures came from the River Coquet or within a few miles of its mouth, and none were reported from north of the River Tweed.

Table 1 1977 Northumbrian salmon tagging

Tagging area	Number tagged	Recaptures												
		YWA area (nets)	NWA area				Tweed District	Forth District	Tay District	South Esk to Bervie Districts	Dee to Ugie Districts	Illegal drift nets	Other	Total
			Blyth to south		Newbiggin to north									
			Rods (Tyne & Wear)	Nets	Rods (Coquet)	Nets								
Seahouses	113	0	0	3	0	1	18	0	4	3	0	1	0	30
Amble	131	0	1	2	0	3	10	1	8	6	1	1	2[b]	35
Blyth	300	2	0	3	0	12	17	1	17	8	2	2	2[de]	66
Sunderland	87	1	0	2	0	2	3	0	3	0	0	1	1[d]	13
T-nets	39	1	0	0	2	7	4	0	0	0	0	0	1[c]	15
Total	670	4	2[a]	10	2	25	52	2	32	17	3	5	6	160[a]

[a] One recapture in River Wear, tagging location unknown.

[b] Both fish found dead in River Coquet.

[c] One fish passed through Warkworth counting station, River Coquet.

[d] One recapture in 1978.

[e] One recapture in Scotland, exact location unknown.

Table 2 Tagging mortality correction

Scale loss (%)	Experienced taggers				Inexperienced taggers			
	Number tagged	Number recaptured	Percentage recaptured	Grouped percentage recaptured	Number tagged	Number recaptured	Percentage recaptured	Grouped percentage recaptured
0–4	86	31	36.0	36	48	10	20.8	18
5–9	89	32	36.0		127	23	18.1	
10–14	57	14	24.6	22	120	22	18.3	
15–19	47	10	21.3		51	8	15.7	
20–24	8	0	0		22	5	22.7	
> 25	5	2	40.0		10	0	0	
Total	292	89	30.5		378	68	18.0	

Good tagging = Experienced taggers, < 10% scale loss = 36% recapture rate

Poor tagging = the remainder = 19% recapture rate

Correction factor for poor tagging $= \frac{19}{36} = 0.528$

3.3 Tagging mortality

Although the total recapture rates were higher than expected, it was clear that three experienced taggers tended to have more of their tagged fish recaptured than three inexperienced workers taken on for the project. This suggested that there was some form of differential tagging mortality. Fish liveliness proved to be an unreliable statistic, but an interesting relationship appeared when the tagging/recapture data were grouped by 'percentage scale loss' for the two sets of taggers. The inexperienced taggers achieved an overall recapture rate of 18% with no apparent relationship between percentage scale loss and the number of returns. However, the experienced taggers achieved a higher return rate (36%) from fish with less than 10% scale loss, whereas that from their fish with more than 10% scale loss (22%) was similar to the inexperienced tagger rate (Table 2). The 36% recapture rate, for fish with few scales lost and tagged by experienced workers, was taken as the norm, and it was assumed that there was negligible tagging mortality in this group. The other tagged fish ('poor tagging') gave a total return rate of 19% so it was assumed that approximately half of them had died as a result of handling and tagging, and this proportion was deducted from the 'poor tagging' samples. Thus about 20% of all the fish tagged by experienced workers and 50% of those tagged by inexperienced workers are estimated to have died as a result of injuries sustained during capture and tagging. This gives an overall mean tagging mortality rate of about 35%. The numbers of salmon tagged in each area, corrected for tagging mortality, are shown in Table 3.

Table 3 Correction of tagging data

Tagging area	Number tagged	'Number tagged' corrected for mortality	Number of recaptures in English commercial fisheries	Number of tagged fish assumed to have left the English fishery area
Seahouses	113	82	4	78
Amble	131	103	5	98
Blyth	300	165	17	148
Sunderland	87	46	5	41
T-nets	39	39	8	31
Total	670	435	39	396

It was anticipated that, because many of the tagged fish were quite badly descaled by the nets, mortality rates might increase once they entered freshwater. This would have resulted in fewer tagged fish than expected being caught by anglers and hence in a bias to the tag return data.

Separate rod and net catch figures cannot be made available for Scottish rivers, but it is possible to assess the extent of this problem as follows. Over 98% of the Scottish east

Table 4 The numbers of salmon caught in five areas of the Northumbrian fishery that would have been taken in various district fisheries if the English fishery had not been operating

Tagging area	Commercial catch in tagging area	Rivers and District fisheries						
		Rivers Tyne and Coquet	Tweed District	Forth District	Tay District	South Esk to Bervie Districts	Dee to Ugie Districts	Total Tweed to Ugie Districts
Seahouses	6 288	0	1 451 ± 300	0	322 ± 157	242 ± 137	0	2 015 ± 332
Amble	15 086	154 a	1 539 ± 461	154 a	1 232 ± 417	924 ± 365	154 a	4 002 ± 673
Blyth	6 458	0	732 ± 167	43 a	732 ± 167	344 ± 118	86 ± 60	1 937 ± 242
Sunderland	10 581	0	774 ± 430	0	774 ± 430	0	0	1 548 ± 584
T-nets	980	68 ± 46	135 ± 63	0	0	0	0	135 ± 63
Total 'extra catch' lost from each district[b]		222 ± 148	4 631 ± 638	197 ± 140	3 060 ± 530	1 510 ± 380	240 ± 154	9 637 ± 851

[a] Standard errors have not been calculated for estimates based on single tag recaptures.

[b] Standard errors calculated as $\pm C\sqrt{((L_f/C)(1-L_f/C))/T}$, where C and T are the total catch and total tag sample in the English fishery, and L_f is the number of salmon caught in the Northumbrian fishery that would have been taken in the District fishery if the English fishery had not been operating.

coast grilse catch is taken by the commercial nets and only 2% on rods. Thus, as 87 tagged grilse were recaptured by the net fisheries, only 2 tagged grilse* could be expected to be taken by anglers. Similarly, as the commercial nets take about two thirds of the total declared catch of multi-sea-winter salmon, and 16 tagged multi-sea-winter fish were recaptured by the nets, the anglers might have been expected to catch 8+ tagged multi-sea-winter salmon.

Scottish anglers reported recaptures of 3 tagged grilse and 2 multi-sea-winter salmon. The rod catch of tagged grilse was thus within the expected range, but for multi-sea-winter fish the rate was significantly lower than expected. This deficit may be accounted for by the different timings of the rod and net fisheries. The rod fisheries tend to be concentrated on the multi-sea-winter salmon runs early in the year, while the peak of the commercial net fishing, in both England and Scotland, occurs during the grilse runs between June and August. At the time that the tagging experiment was carried out in the English net fishery the Scottish anglers were probably accounting for less than one third of the catch of multi-sea-winter fish. The 'true' number of multi-sea-winter salmon expected to be taken by anglers would thus have been less than 8 and is probably no more than the two recaptures recorded.

3.4 Analysis of tag recapture data

In 1977 the total declared catch in the Northumbrian fishery was 39 393 salmon. The distribution of this catch between the five areas (the T-nets are here treated as though they were a separate area) in which fish were tagged is shown in Table 4. The aim of the following calculations is to estimate the numbers of these fish that would have been caught in other fisheries if the English commercial fishery had not been operating. Those tagged fish that were recaptured in the English fishery are therefore not relevant to the calculations and must be deducted from the tagging samples (Table 3).

In addition to the 39 reported recaptures in English commercial fisheries, various unrecorded losses of tagged fish, termed non-catch fishing mortalities by Ricker (1976), may also have occurred in the English fishery. Seal predation on fish held in the nets is estimated to be of the order of 5% of the landed catch (Potter and Swain, 1979) but no reliable estimates are available for mortalities of fish escaping or falling from the nets. It is possible that the unrecorded losses may have been as much as 20% of the reported landings, and this would mean that a further 8 fish should be deducted from the total tagging sample. However, this would only change the final estimates of effects on catches elsewhere by a factor of 0.02 (i.e., 8 out of 396). Since this is clearly insignificant, the very approximate estimate of non-catch fishing mortality is not included in the calculations and no adjustment is made to the tagging data. Similarly, the declared English and Scottish catch figures are used without any correction for unrecorded losses, although, in this case, the errors may be significant: they are discussed in a later section.

The remainder of the tagging sample (the total sample minus the recaptures in the English commercial fisheries) from area 'a' (T_a) may still be regarded as representative of the commercial catch in that area (C_a). The probability of a fish tagged in area 'a' being recaptured in river or District fishery 'f' (P_{af}) is estimated as

$$P_{af} = \frac{R_{af}}{T_a}, \text{ with standard error } \pm\sqrt{\left(\frac{P_{af}(1-P_{af})}{T_a}\right)},$$

* 95% confidence limits 0–5

\+ 95% confidence limits 3–13

where R_{af} is the number of recaptures in district 'f' from the tagging sample in area 'a'.

If the number of fish from the total commercial catch in area 'a' that would have been taken in district 'f' had there been no English fishery is denoted by L_{af}, then

$$L_{af} = (P_{af})(C_a) \text{ with standard error } \pm C_a\sqrt{\left(\frac{P_{af}(1-P_{af})}{T_a}\right)}.$$

For example, the number of fish tagged at Seahouses, assumed to have left the English fishery area was 78 (Table 3), and 18 of these were recaptured on the River Tweed (Table 1). Thus, the probability estimate of a fish tagged at Seahouses being recaptured in the Tweed District is 18/78 = 0.23 ± 0.048. So, out of the 6 288 fish caught in the Seahouse area, 6 288 x (0.23 ± 0.048) = 1 451 ± 300 would have been taken in the Tweed District. Table 4 gives the values of 'L' for the five areas against the various districts. This shows where salmon caught in each of the five parts of the Northumbrian fishery would have been taken if the English fishery had not been operating and also the total 'extra catch' that would have been recorded in each Scottish District. The 'extra catch' added to the actual declared catch gives a 'potential catch'. In Table 5 the 'extra catch' is expressed as a percentage loss from the 'potential catch' (with 95% confidence limits) for each District fishery.

3.5 The proportion of salmon in the Northumbrian area returning to Scottish waters.

The exploitation rate for all Scottish east coast salmon fisheries from the River Tweed to the River Ugie during the netting season is thought to lie between 20% and 60% (W M Shearer, personal communication) and the overall exploitation rate by salmon anglers in the rivers in the north-east of England between 10% and 30%. Table 5 shows that, based on the results of the MAFF tagging experiments, if the Northumbrian commercial fishery had not been operating in 1977 about 9 637 extra salmon would have been caught in Scottish district fisheries and 222 in English rivers. It therefore appears that between 16 000 and 48 000 extra fish might have entered Scottish rivers and between 740 and 2 220 the English rivers. Manipulating these figures within the limits of the declared landings of 39 393 suggests that between 94% and 98% of the fish are returning to Scottish waters:

(39 393 – 2 220) x 100/39 393 = 94;
(39 393 – 740) x 100/39 393 = 98.

4. The effects of the Northumbrian Fishery on salmon numbers and fisheries elsewhere.

4.1 Effects on catches

The estimates of percentage losses shown in Table 5 suggest that in 1977 the combined rod and net catches, by numbers, on the Scottish east coast rivers were reduced by 5.8% as a result of the declared landings in the Northumbrian fishery. A very much greater proportion of the catches on these rivers than of the English commercial catch is of large multi-sea-winter salmon. Thus the losses by weight experienced by the Scottish fisheries will have been less than the 5.8% estimated by numbers.

It appears that the Tweed district and the local English rivers were affected most by this fishery and that the 'losses' became smaller in more northerly rivers. It is therefore probable that a smaller proportion of the stocks of more northerly rivers passes through the Northumbrian

Table 5 Total effect of Northumbrian salmon fishery on catches elsewhere

Fisheries	Recorded catch in 1977[a]	'Extra catch' lost to Northumbrian fishery	Estimate of percentage loss of potential catch to Northumbrian fishery		
			Lower 95% cl	Estimate	Upper 95% cl
Rivers Tyne and Coquet	426	222 ± 148	0	34.3	54.6
Tweed District	32 883	4 631 ± 638	9.3	12.3	15.2
Forth District	1 887	197 ± 140	0	9.5	20.0
Tay District	36 486	3 060 ± 530	5.2	7.7	10.1
South Esk to Bervie Districts	42 376	1 510 ± 380	1.8	3.4	5.1
Dee to Ugie Districts	42 302	240 ± 154	0	0.6	1.3
Total, River Tweed to River Ugie	155 934	9 637 ± 851	4.9	5.8	6.8

[a] The recorded catches for the Scottish Districts are based on returns made by the owners or occupiers of salmon fishings. The catch data 1952 to 1978 are being prepared for publication and, in that context, the summaries are being checked against the original forms. It is however not expected that the final figures will differ significantly from the interim ones used here.

fishery area. The tagging and recapture data are not sensitive enough to reveal detailed patterns of movement. However, a significantly greater proportion of the fish tagged at Seahouses than from other areas was recaptured in the Tweed District ($P < 0.05$). This suggests that the northern part of the Northumbrian fishery may have a disproportionate effect on the River Tweed stock.

4.2 Effects on spawning stocks

The foregoing calculations account for approximately 10 000 salmon out of the total 1977 Northumbrian catch of 39 393. The rest of the catch (almost 30 000 fish) represents the lost spawning escapement, i.e., fish not caught which can migrate upstream to spawn, to both English and Scottish rivers, although this figure will be an overestimate if there is significant natural morality (e.g., seal predation or disease) or illegal netting between the Northumbrian fishery and the legal Scottish fisheries. The problem of illegal netting is discussed in more detail below. Assessment of the lost spawning escapement is also complicated by the relative levels of non-catch fishing mortality in the English and Scottish fisheries. The spawning escapement cannot be apportioned to different rivers or districts because the relative exploitation rates are not known. From the catch and escapement figures the overall exploitation rate by the legal Scottish fisheries is approximately 25%. This is not an estimate of the total Scottish east coast exploitation rate, since it is heavily biased towards the more southerly rivers. The effect of the Northumbrian fishery on the total spawning escapement of the Scottish east coast rivers would, of course, be less than the 5.8% loss to the potential catch since many salmon must pass through the commercial fishery areas outside the netting season.

4.3 Additional effects of the Yorkshire fishery.

The Yorkshire fishery catches have not been included in these calculations. More recent investigations suggest that the salmon off the Yorkshire coast behave similarly to those off Northumberland.

Thus, as the Yorkshire catches are generally about 10% of the Northumbrian catches, the estimates of percentage loss may be increased by one-tenth giving the total effect of English north-east coast fisheries on Scottish catches as a reduction by about 6.4%.

4.4 Errors caused by non-catch fishing mortality.

The 'extra catches' calculated above are based on the declared landings in the Northumbrian fishery and do not take account of possible non-catch fishing mortalities. No reliable figures are available for these unrecorded losses; even the estimate of seal predation quoted earlier is not directly applicable since it is not possible to predict how many fish would be taken by seals if the fishery was not operating. However, if, for example, the non-catch fishing mortality in the Northumbrian fishery was 20% of the declared catch, then the estimates of the 'extra catches' lost to Scottish fisheries would have to be increased by 20%. The alteration to the 'percentage loss' estimates will be somewhat less than 20%, and the total effect of the English fisheries on Scottish catches would be 7.5% instead of 6.4%. Non-catch fishing mortality in the Scottish fisheries will not influence the estimates of effects on declared landings but will alter the estimated lost spawning escapement.

The effects of the English fisheries on both catches and stocks in Scottish waters may be underestimated if the tagging mortality was greater than the 35% calculated. However, injuries caused by the nets and by tagging could also have the opposite effect on the calculations if they result in less fit fish spending longer in the river estuaries and thus being more susceptible to capture.

4.5 Errors caused by the Scottish drift net fishery.

The calculations were further complicated by the illegal drift net fishery operating on the Scottish east coast, which is thought to have been exploiting the same stock between the Northumbrian fishery and the legal Scottish fisheries. The Scottish traditional salmon fishermen fishing along the east coast and in the adjacent rivers have suggested that in 1977, over the period when both the legal and illegal fisheries were operating simultaneously, the illegal catch may have equalled the number of salmon landed legally (W M Shearer, personal communication). However, it is not known during exactly which periods the illegal fisheries were operating. Nevertheless, it has been suggested that in 1976 about 300 tonnes of salmon may have been taken in drift nets off the Scottish east coast (Anon, 1977). From the mean weight of salmon caught in the English drift net fishery, it appears that this represents a total of about 90 000 fish. Since all U.K. salmon fisheries experienced poor catches in 1976 and the Scottish poaching is widely thought to have reached its peak in 1977, the 1976 figure may probably be regarded as a conservative estimate of the illegal landings in 1977.

Assuming the illegal catch was of this order of magnitude we can identify two significant errors in the deductions from our experimental results: (a) some tagged fish (60) will have been taken by poachers, leaving fewer (340) to reach the legal Scottish fisheries; (b) the mean Scottish legal exploitation rate on this stock will have been greater than the 25% estimated (about 30%). We can then predict roughly what would have happened if this poaching had been prevented:

1. more tagged fish (120) would have been recaptured in the legal Scottish fisheries;
2. the higher tag returns would have indicated that a greater number of salmon (approximately 12 000) taken by the Northumbrian netsmen were lost to the legal Scottish fisheries;
3. the legal Scottish catches would have been increased probably by between one quarter and one-third of the illegal catch (27 000);
4. the percentage loss of the potential Scottish east

coast catch would remain at 6.4%;

5. the estimate of the numbers of salmon taken by Northumbrian netsmen lost to English and Scottish spawning escapement would be reduced (to about 27 000);
6. the spawning escapement to Scottish rivers would be increased probably by between two-thirds and three-quarters of the illegal catch (63 000).

It should be noted that improved patrolling of the Scottish fisheries has greatly reduced the illegal landings in more recent years.

4.6 Department of Agriculture and Fisheries for Scotland (DAFS) smolt tagging experiments.

The calculations from the MAFF tagging results depend on a number of assumptions and do not include certain unquantifiable variables. There may thus be a tendency to question the accuracy of the estimates or to assume that they are minimum values. However, an entirely independent assessment of the effect of the English fisheries on certain Scottish rivers may be made by examining returns from smolt tagging experiments.

Salmon smolts were tagged by DAFS scientists on the River Almond, a tributary of the River Tay, from 1968 to 1974 (Struthers, 1975, and personal communication). The majority of the reported recaptures (80%) came from the River Tay system, but tags were also returned from the salmon fisheries off West Greenland (6%), off the south-east and north-west coasts of Ireland (1%), off north-east England (3%) and at various points around the Scottish coast (8%). These data can be used to indicate the relative levels of exploitation of River Almond salmon in different fisheries.

Over the eight years in which recaptures were recorded there is a significant correlation between the number of returns from Scottish waters and the number from the north-east of England ($r = 0.95, P < 0.001$). The regression of the number of Scottish recaptures (Y) on the number of English recaptures (X) by the year of recapture is shown (in Figure 2) to be $Y = 25.98X + 1.07$, which suggests that consistently over this period the salmon fisheries in England were taking only one River Almond fish for every 26 caught in Scottish waters. The ratio of recaptures between England and the River Tay system alone is 25:625 (1:25). If this ratio is applied to the total River Tay catch (36 486) it means that only 1 459 (± 280) Tay fish were taken in English waters in 1977. Using the exploitation rates for Scottish east coast rivers of 20% – 60%, we can estimate that between 182 and 1 205 extra fish would have been caught in the Tay if the English fishery had not been operating. This represents a 0.5% – 3.2% loss in potential catch in the Tay district.

The MAFF tagging experiment gives an estimate of the effect of the English fishery on catches in the Tay district of 7.7% (with 95% confidence limits 5.2% and 10.1%). The estimate from the DAFS smolt tagging is thus significantly

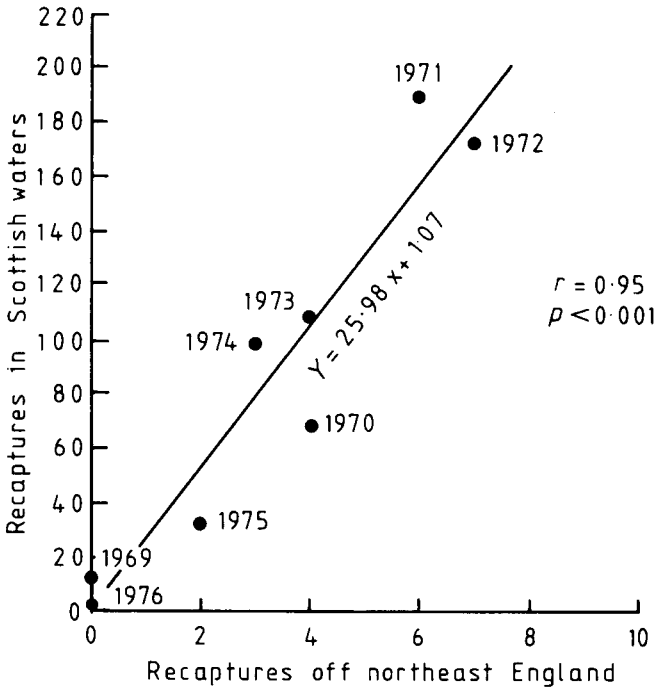

Figure 2. River Almond smolt tagging 1968-74. Regression of recaptures in Scottish waters on recaptures off the English north-east coast by year of recapture.

lower but it may be biased by a number of factors. Firstly, the age structure of the River Almond stock may not be the same as that of the total River Tay stock. In fact the River Almond appears to support a higher proportion of grilse than the remainder of the Tay system, and this should tend to exaggerate the effect on the Tay fisheries of the English fishery which is selective towards grilse. This is confirmed by the results of smolt tagging on the River Tummel, also a Tay tributary, which has more multi-sea-winter salmon and thus gave only 3 English recaptures to 149 recaptures in the Tay. Secondly, the smolt tagging gives an estimate based on returns between 1969 and 1976, whereas the MAFF tagging experiment was carried out in 1977. The difference in the results might therefore reflect a real increase in effort or efficiency in the English fishery. However, although no figures are available for efficiency, the number of licenses issued, which is the only measure of effort available, was lower in 1977 than at any time between 1969 and 1976. A third possibility is that the reporting rate of tag recaptures may be lower in the English fisheries than in the legal Scottish fisheries. Non-reporting of tags in the English fisheries would have a much greater effect on the estimate based on the smolt tagging results than on the estimate from the MAFF salmon tagging experiment. Thus, although examination of the pattern of recaptures has revealed no evidence of extensive non-reporting, this could account for some of the difference between the estimates.

The smolt tagging results confirm that the Northumbrian and Yorkshire fisheries take only a small proportion of the salmon returning to Scottish rivers. However, since these results appear to be more sensitive to the types of errors discussed above, it seems likely that the MAFF tagging data give the more reliable estimates of the Scottish losses.

5. Conclusions

1. Salmon caught in the English north-east coast fishery are returning to all east coast salmon rivers from Yorkshire to the River Dee in Scotland.
2. Probably more than 94% of these fish are returning to Scottish waters.
3. The Northumbrian rivers and the River Tweed are those most affected by the fishery, which has a decreasing effect on more northerly rivers.
4. The most northerly part of the Northumbrian fishery may have a disproportionately large effect on the River Tweed stocks.
5. The total effect on all catches on the Scottish east coast rivers between the Rivers Tweed and Ugie in 1977 was approximately 6.4%.
6. The effect on total stocks of these rivers would have been less than 6.4%.
7. These results do not take account of possible non-catch fishing mortality. With 20% non-catch fishing mortality the total effect of the English fishery would have been about 7.5%.
8. If the Northumbrian fishery had not operated in 1977 the lost catch of 39 393 salmon would have been replaced by an increased legal catch in Scotland of approximately 10 000 fish.
9. Absence of both the Northumbrian and Yorkshire commercial fisheries would have resulted in a net loss in landings of at least 30 000 fish.
10. It seems likely that in 1977 illegal netting had a greater effect than the English fisheries on legal Scottish salmon catches. The illegal netting is thought to have been greatly reduced since 1977.

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