RESTRICTED

INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES

Serial No. 1770
(B.g. 14)

ICNAF Res. Doc. 67/5

ANNUAL MEETING - JUNE 1967

Final Report of First Meeting of ICES/ICNAF Joint Working Party on North Atlantic Salmon [1]

Madrid, 25-26 May 1966

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1 This is the final version of the Report of the First Meeting of the ICES/ICNAF Joint Working Party on North Atlantic Salmon (first produced as ICNAF Res. Doc.66/79). It contains amendments and suggestions approved by the Second Meeting of the Joint Working Party. Copenhagen, 4 October 1966 (ICNAF Res. Doc. 67/6)

I Introduction

Following the rapid development of a fishery for salmon at Greenland, and the recovery in that fishery of fish tagged in several countries on both sides of the Atlantic, and discussion of the problem at the 1965 ICNAF meeting, ICES at its 1965 Annual Meeting recommended that a working group should be set up to study the state of stocks of Atlantic Salmon, and the effects of the Greenland fishery. ICNAF agreed that this should be a joint working group with ICES and the first meeting of the joint group was held in Madrid on 25th and 26th May, 1966. The members of the group present were as follows:

J.A. Gulland (Chairman)	
K.R. Allen	Canada (Rapporteur)
P.M. Hansen	Denmark
A.E.J. Went	Ireland
L. Rosseland	Norway
B. Carlin	Sweden
I.R.H. Allan	England and Wales
K.A. Pyefinch	Scotland
B. Skud	U.S.A.

The following also took part in the discussions:

W. Templeman	Canada
S. Horsted	Denmark
B.B. Parrish	Scotland
L.R. Day	ICNAF

II History of the Fishery

The Greenland fishery first developed to any extent in 1961, and the output, in tons (gutted), in subsequent years was as follows:

1961	115
1962	220
1963	420
1964	1,400
1965	716

The decrease in 1965 was due primarily to a decreased amount of fishing caused by better cod fishing and also increased prices of cod and decreased prices for salmon in 1965 compared with 1964. The catches at Greenland are taken in the autumn between late August and December: the great bulk of the catches are one-sea-winter fish with a few two-sea-winter fish and previous spawners, including some fish tagged in countries on both sides of the Atlantic. The bulk of the tag returns have been of fish tagged as smolts leaving their parent streams some 18 months before being caught at Greenland. The average size is around 65 cm fork length, with very few less than 55 cm. Thus it is reasonably certain that the present Greenland catches do not include any fish that would return to the home rivers as grilse, and the Greenland fishery can only affect the abundance and catches of fish which have spent at least two winters in the sea by the time they return to home rivers (such fish will be referred to in this report as "large salmon"). However the possibility cannot be excluded that a fishery may develop on small salmon, only a few months in the sea, and the effect of such a fishery might be quite different from the effects of the present Greenland fishery as considered in this report.

It is not known whether salmon from the Greenland west coast return to their home rivers or not. The following sections of this report have been based on the assumption that they do. There is, however, no evidence to support any suppositic th the salmon visiting Greenland are abnormal in their behaviour, and there is abundanc evidence both that the Pacific species of salmon do return to the rivers in which they were bred from distances as great or greater than from Greenland to Europe and that those Atlantic salmon which return to rivers to spawn do return to their native streams. In this paper, therefore, it has been assumed that the salmon visiting Greenland are part of the normal population and that, if they survive, they will normally return to their native rivers. It is hoped that continuation of the tagging experiments, begun in Greenland in 1965, will soon provide evidence on this vital point.

The methods of mathematical analysis used in Sections IX to XI are largely based on those developed in ICES/ICNAF Salmon Document 66-9 by Allen and Saunders. As the authors point out, the main purpose of that report was the development of methods and the examination of the availability of data, and its conclusions as to the effects of the Greenland fishery were highly tentative. The present report examines, in addition, data provided by other countries besides Canada; it will be apparent, however, that the total data now available are very incomplete on many points, and therefore the Working Party also is only in a position to reach tentative conclusions at this stage.

III General Considerations of the Effect of the Greenland Fishery

The effect of the Greenland fishery can be considered in two parts; first the effect on the numbers and weight of fish returning to, and caught in home waters, and secondly the effect on the numbers and composition of the spawning stock and hence on the subsequent production of smolts.

The effect on the numbers and weight of fish returning to home waters and the catches there will depend on

(a) the proportion of the original population that visits Greenland
(b) the proportion of those that are caught at Greenland
(c) the proportion of those fish which avoid capture at Greenland which survive to return to home waters
(d) the growth of the fish between the times of the Greenland and home fisheries
(e) the proportion of the returning fish caught in home waters.

IV Separation of Races

A. Objects and Lines of Approach

Full assessment of the effects of a fishery in an area, such as Greenland, where salmon originating in various countries are found together, must involve the ability to determine separately the factors determining the impact on the stocks and fisheries of the different countries. Study of the population dynamics of the various stocks, and of tagging results, will be useful for this purpose, but valuable advances should be possible if means of identifying the region of origin of individual salmon, or groups of fish, can be found.

The principal means which seem available for this purpose are studies of blood characteristics, parasites, scale characteristics and meristic characters. The Party was pleased to note that active work on the first two of these was already being organised and supported the principle that individual research organisations should concentrate their efforts on a limited number of such fields and that they should, as far as possible, assist organisations specialising in other fields by the supply of material. It felt that the study of scale characteristics, using critical methods like those which had proved successful with Pacific salmon, merited further study, and that members of the Group would welcome further information on these techniques. The possibility of recording meristic data for marked salmon caught in Greenland was discussed as a basis for a later study if one should develop, but it was felt that the value of such material would not be sufficient to justify the special effort the collection would require.

B. Work in Preparation

Both English and Scottish workers are planning to commence blood studies in 1966, using different techniques, and preliminary trials have, in both cases, shown promising results. Both groups are planning to collect material in Greenland, and to compare it with material both from their own countries, and from other areas. Arrangements for the collection of this material are in hand.

Canada is planning a study of the parasites as a means of race separation, and hopes to use techniques which have been successful with Pacific salmon. Initially effort will be concentrated on the examination of smolts and large parr from as many areas as possible to establish the main geographical patterns of parasite distribution. It is also hoped to visit Greenland during 1966 to examine material there, Scotland may also contribute to the parasite programme and its effort will be coordinated with Canada's.

No proposals have yet been made for the examination of the possibilities of scale and meristic characters for this purpose.

V Tagging Data

The data on tagging results which were available to the Working Party have been summarised on Table 1. The returns of smolts to countries of origin have been sub-divided into grilse and large salmon, since it is only the latter which can be affected by Greenland catches.

In addition four tags were recovered from fish tagged in Sweden and also two from fish tagged in Maine, U.S.A. The striking feature of the results is that no tags have been recovered in Greenland from the extensive taggings in Norway. There are many returns in other areas of large fish from the Norwegian experiments, so that the lack of returns from Greenland cannot be due to tag shedding etc.; the numbers involved are so high that it is most unlikely to be a chance effect. The most likely explanation is that the Norwegian fish move to some more easterly feeding area. Most Norwegian experiments have been on the West Coast, and it may be that fish from southern Norway may go to Greenland. However, for the present it will be assumed that no Norwegian fish go to Greenland.

VI Growth between Greenland and Home Waters

Measurements of samples of commercial catches of salmon at Greenland during the 1963, 1964 and 1965 seasons showed a pronounced mode at around 65 cm (fork length). The catches taken by Scottish workers during the 1965 tagging experiments at Greenland were similar, with a mean length of 65 cm. Though length sampling could not cover the whole season, nor all the fishing area, the data on the composition of the total catches by broad weight categories confirmed that most of the catches were fish of almost the same size, mainly 3 to 5 kg. The exception was the fishery in the northern part of ICNAF Div. 1B, which in the later part of the 1965 season caught larger fish, many over 5 kg and some over 9 kg. This average size (say 65 cm, or 3-5 kg) should be compared with the size that would be achieved by the same group of fish if they had survived to reach home waters; this cannot be known precisely because of the uncertainty about which home waters are concerned. A more reliable comparison has been made between the size of fish tagged as smolts in the Miramichi River in Canada when caught at Greenland, and the size of large fish when returning to the same river. The average length of the 14 tagged Miramichi fish caught at Greenland was 65.9 cm (total length, i.e., about 62 cm fork length), while the length of returning two-sea-winter fish from the same smolt classes was 74.2 cm. The relation between length and weight ("condition factor") at Greenland and Canada is very nearly the same. Thus, assuming that the average size on return to the home area as two-sea-year fish is the same for fish which have been to Greenland as for all two-sea-year fish of the same smolt class, then the increase in weight is given by the ratio of the cube of the lengths, i.e., 1: 1.46.

Table 1. Returns of tagged salmon from Greenland and in home waters

Country	Year	No. tagged	Greenland recaptures	Home recaptures Grilse	Large salmon
Tagged as smolts					
CANADA	1959	3,442	1	25	41
	1960	882	1	18	7
	1961	9,555	0	22	22
	1962	13,213	3	158	54
	1963	12,865	12	203	34
	1964	34,550	7	223	-
	Total	74,507	24	649	158
ENGLAND and WALES	1960	13,579	2	7	28
	1961	13,395	2	41	86
	1962	19,763	2	64	165
	1963	9,485	6	16	28
	1964	17,129	8	33	-
	Total	73,351	20	161	307
SCOTLAND	1960	11,644	0	6	3
	1961	13,168	2	252	92
	1962	15,934	1	99	123
	1963	17,748	10	305	148
	1964	12,180	0	304	-
	Total	70,674	13	966	366
Tagged as adults					
CANADA	1960	676	2	-	412
	1961	581	0	-	225
	1962	651	2	-	281
	1963	1,519	0	-	655
	1964	1,267	1	-	253
	Total	4,694	5	-	1,826
ENGLAND and WALES	1960	313	0	-	10
	1961	141	0	-	5
	1962	157	1	-	6
	1963	185	2	-	9
	Total	796	3	-	30
SCOTLAND	1960	490	0	-	11
	1961	161	0	-	1
	1962	683	1	-	17
	1963	270	0	-	7
	1964	753	0	-	2
	Total	2,357	1	-	38
IRELAND	1960	2,070	0	-	81
	1961	2,095	0	-	73
	1962	2,218	0	-	79
	1963	2,207	2	-	31
	1964	2,351	2	-	70
	1965	2,695	2	-	34
	Total	13,636	6	-	368

For Canadian fish the average interval between the Greenland fishery and the time of capture in home waters of fish of the same group is about 10 months. The observed increase in weight thus corresponds to an average instantaneous monthly growth rate of 0.04 (i.e., 4% per month). The tagged Canadian fish caught at Greenland were only slightly smaller than the average Greenland fish, and the average weight of large fish caught in Canada is similar to that in European rivers (about 10 lbs). Thus the proportional increase in weight found for Canadian fish (about 50%) may be taken as generally applicable for a preliminary estimate. In many European waters (e.g., in Great Britain and Ireland), however, the large fish tend to return earlier in the year than they do in Canada, so that the interval between the Greenland fishery and the home water fishery is correspondingly less. If it is taken to be about 6 months, the monthly instantaneous growth rate is increased to 0.065 (6.5% per month).

VII Natural Mortality between Greenland and Home Waters

The proportion of fish present at Greenland which return to home waters will depend on the natural mortality rate during the interval, which may for convenience be taken to include any failure to navigate the 1, - 2,000 miles back to the home waters. This is very difficult to determine but the apparent average mortality rate during the whole period of sea life can be estimated from the proportion of smolts that return. For the Miramichi River in Canada the best return of tagged smolts is 5%, three-quarters as grilse after 14 months, and one-quarter as large fish after 26 months; this corresponds to an average monthly mortality rate of 0.19. The proportion of tagged fish reported will be less than the true proportion of smolts returning as adults, due to such causes as loss of tags, abnormally high mortality in tagged fish, and failure to return tags. The figure 0.19 is therefore almost certainly an over-estimate of the true mortality rate. It is very likely that the mortality rate in early sea-life is higher than the average rate for the whole sea-life, due to the initial stress of changing from fresh water to salt water, and to the fish being smaller and more exposed to predation; the mortality during later sea life is then correspondingly lower. The figure of 0.19 is likely to be very much an upper limit.

Another estimate is provided by the return of second-time spawners. Tagging of kelts often gives low returns (10% or less) but some quite high rates of return have occurred; of 162 kelts tagged in the Indian River in Newfoundland in 1964, 82 were recaptured in 1965. This corresponds to a monthly mortality rate of 0.06.

Similar difficulties have occurred in studying the effects of the offshore fishery on Pacific salmon, for which, despite considerable research few good estimates have been obtained. Published monthly values range from 0.02 (Ricker, 1964) to 0.08 (Doi, 1962).

On this evidence it seems probable that the monthly natural mortality rate during the later part of ocean life lies within the range from 0.02 to rather less than 0.19. This would include the period between Greenland and the return to home waters unless the assumption is incorrect that fish visiting Greenland behave normally as regards their return to home waters. If they do not return normally their mortality rate will be correspondingly higher. For the present analysis it has been assumed that the mortality rate between Greenland and home waters lies between 0.02 and 0.15 and is probably less than 0.10.

VIII Exploitation Rates in Home Waters

The estimates developed in this section ignore natural mortality during the period of coastal and river life. The exploitation rates as estimated therefore represent the proportion of the fish, surviving natural deaths on the coast or in the rivers during their return, that are caught either in the commercial fishery or by angling. This rate will tend to be higher than the exploitation rate expressed as the proportion caught from all the fish reaching the coastal area during their return. There is little evidence that much natural mortality usually occurs during the river phase prior to spawning, and therefore the differences between the rates as estimated here, and those based on the total returning population are likely to be usually small. During coastal life, however, substantial natural mortality may occur at times (e.g., due to predation by seals) and in these circumstances the differences would be correspondingly large..

When better estimates of the natural mortality rates during sea life become available, it will be necessary to consider closely the corrections which should be made to the exploitation rates obtained by the methods used in this section. If the most reliable estimates of natural mortality include that occurring while the fish are inshore and exposed to the coastal fisheries, then estimates of exploitation rate of the type developed in this report will require relatively little adjustment. If, on the other hand, the estimates of ocean mortality do not include coastal effects then the exploitation rates must be based on the total population of fish reaching the coast. The natural mortality in coastal waters must not however be brought in twice..

In order to clarify these relationships there is need for further study of the extent and causes of natural mortalities during the coastal and river phases of adult life.

A. Canadian Data

Data were presented in ICES/ICNAF Salmon Doc. 66-9 on the rates of exploitation (i.e., the proportion of the initial population caught during the fishing season) in 1964 and 1965 of large salmon in the coastal commercial fishery and the river angling fishery respectively in the Northwest Miramichi River. Estimates of these rates (Table 2) were derived from data on

(a) The numbers of salmon caught by anglers in the river
(b) Census counts of salmon entering the main river
(c) The relative recapture rates of tagged salmon in the commercial and angling fisheries respectively.

Table2. Exploitation rates on large salmon in the Miramichi River.

	Rate of exploitation		
	Commercial fishery	Angling	Both fisheries combined
1964	0.84	0.53	0.92
1965	0.84	0.51	0.92

These high estimates for this river system are supported by data on the rate of recapture of salmon tagged as smolts in the Miramichi River since 1961. It appears to the Working Group, therefore, that they provide a reasonably accurate index of the rate of exploitation of adult salmon in this river system, in which both the commercial and angling fisheries are intensive. The limited amount of available data for other river systems suggest that the rates of exploitation of salmon in the Miramichi system may be higher than in some other rivers of the Canadian east coast. The overall rate for the Canadian river systems as a whole is tentatively estimated to lie between 0.85-0.90.

Data for the Miramichi and other rivers also indicate that the rate of exploitation of grilse is substantially smaller than for the older salmon considered here.

B. European Data

Data on the catches of large salmon by anglers and census counts of spawners in the Laerdal river in Norway in the years 1960-64 allow similar estimates to be made of their rates of exploitation by the angling fishery there (Table 3).

The available data on the rate of recapture of tagged salmon in this and other rivers in Norway suggest that these estimates for the Laerdal river are lower than the average for all Norwegian river systems combined.

Table 3. Estimated exploitation rates of salmon in the Laerdal River.

Year	Catch of salmon in rivers (nos)	No. of spawners (from redd counts)	Estimated no. of salmon entering river	Proportion caught = rate of exploitation
1960	833	1,059	1,892	0.44
1961	879	1,320	2,199	0.39
1962	1,434	1,888	3,322	0.43
1963	946	1,196	2,142	0.41
1964	1,343	981	2,324	0.58

Although accurate data of the catches of salmon destined for the Laerdal river in the commercial coastal fishery are not available, estimates of them can be made, as with the Canadian material, from the river catch data and the relative numbers of tagged salmon recaptured in the coastal and river fisheries respectively. The tagging data indicate that over the period 1960-1964, the coastal catch each year in the Laerdal district was about 6 times the river catch. Estimates of the coastal catch, the initial population entering the coastal fishery (natural mortality assumed negligible during the coastal fishery season) and the proportion caught in this fishery, are given in Table 4.

Table 4. Estimated exploitation of Laerdal River salmon in coastal areas.

Year	Catch (nos) of Laerdal river salmon	Initial population (nos) in coastal fishing area	Proportion caught = rate of exploitation
1960	4,998	6,890	0.73
1961	5,274	7,473	0.71
1962	8,604	11,926	0.72
1963	5,676	7,818	0.72
1964	8,058	10,382	0.80

The estimate for the coastal and river fisheries combined, obtained from these two sets of data, averages approximately 0.84 per year over the period. Thus, the total rate of exploitation of salmon in the Norwegian river system is similar to or somewhat lower than that in Canada.

The available data for Norway indicate that the rate of exploitation of grilse is substantially lower than of the older salmon.

Although no detailed data on the rate of exploitation in the river systems of other European countries were available to the group, UK and Irish representatives indicated verbally that the rates of exploitation of large salmon in the rivers (excluding exploitation on the coast and in the estuaries) in most of the English, Scottish and Irish river systems are believed to be much smaller than those reported above for the Canadian and Norwegian rivers respectively.

IX Exploitation Rate at Greenland

The quantity of fish caught in Greenland depends on the exploitation rate, and thus on the fishing effort, in Greenland waters. As judged by the recent catches this varies greatly from year to year so that any assessment of the effects must be definitely referred to a particular amount of fishing. There are no data available which can provide any reasonable quantitative estimate of the fishing effort on salmon at Greenland, the best available being the numbers of nets sold. In analysing the tag returns a standard catch of 1,000 tons has been used but catches can only be used as a measure of effort if the stock does not vary. Thus, though in the following sections the standard effort has been taken as a catch of 1,000 tons with the effect of different catches being in proportion, if there should be changes in the total stocks, then the percentage effect of a given Greenland catch would be different - less if the stock is greater, more if the stock decreases.

From the data at present available it is not possible to estimate separately the proportion of the stock that goes to Greenland, and the proportion of the fish at Greenland that are caught there, and it is only possible, even tentatively, to estimate the proportion of the total stock that are caught at Greenland. That is, it would be at present impossible to distinguish directly between a situation where the Greenland fishery takes 20% of the fish there, but only half the fish go to Greenland, and a situation where all the fish go to Greenland, and the Greenland fishery takes 10%. However an attempt can be made to estimate the combined effect, i.e., the proportion of the total number of the fish taken at Greenland.

Thus, if E_g = proportion of all fish alive caught at Greenland (effective exploitation rate)

E = proportion of the fish returning to home waters caught there.

M = instantaneous natural mortality rate between Greenland and home waters.

t = average time between presence in the Greenland fishery and presence in the home fishery.

N = number of fish alive at the time of the Greenland fishery.

Then number caught at Greenland $= NE_g$

number returning to home waters $= N(1-E_g)e^{-Mt}$

number caught in home waters $= NE(1-E_g)e^{-Mt}$

and let $R = \dfrac{\text{number caught at Greenland}}{\text{number caught in home waters}} = \dfrac{E_g}{E(1-E_g)e^{-Mt}}$

then $E_g = \dfrac{REe^{-Mt}}{1+REe^{-Mt}}$

Because the Greenland catch cannot as yet be split into fish of different origin, an estimate of R based on total catches would only be obtained for the North Atlantic as a whole, using some average figure of the exploitation rate in home waters. At present there are very few reliable data on efficiency of exploitation in any home waters, although it probably varies widely from river to river. It is therefore not possible to obtain an average value for the exploitation rate which would be reliable for use in the estimation of E_g. Useful estimates of E_g can however be made from tagging data where the number of recaptures in Greenland and in home waters from the same group of fish are known. This approach has the further advantage that, since it generally involves fish from only a few stocks, more reliable estimates of home exploitation rates also become possible.

The exploitation rate for Greenland as estimated in this way is the proportion of the Greenland catch in the entire group of fish from which they are drawn whether or not they visit Greenland waters. This rate, which may be called the overall rate, will therefore be determined both by the local exploitation rate in the Greenland area (i.e., the proportion caught from the fish which actually visit Greenland) and by the proportion of the group which go to Greenland. The local Greenland exploitation rate may be expected to be generally similar for all fish, whatever the region of origin, although it could be modified if fish from different areas visited different parts of the coast or spent different lengths of time on it, but there could be great differences in the proportion of fish from different areas visiting Greenland. The overall exploitation rates on fish from different areas may therefore vary significantly. The ratio of tags returned from Greenland and from large fish in the home fishery (R) gives, in effect, a measure of the relation between the overall exploitation rate and the exploitation rate in home waters. These ratios are available for Canada and the United Kingdom; adjusted to a standard Greenland catch of 1,000 tons they are given in Table 5.

Table 5. Ratios of the number of tags returned from Greenland, and from large fish in home waters.

Canada	.29
England (Axe)	.07
England (other rivers)	.23
Scotland	.05

The method of adjustment employed here is slightly different from that used in Salmon Document 66-10.

The English data for the Axe refer to a river where most of the run passes through a counting fence so that E is effectively 1.0. For this river, the range of values of E_g, for a range of M of .02 to .10, is .025 to .054. The corresponding values of E_g for Canada are .095 to .192, which are about 3.5 to 4 times those for the Axe. Assuming that both groups are subject to the same local Greenland exploitation rate, this suggests that the proportion of Axe fish in the sea which visit the Greenland area is only about a quarter of the Canadian proportion. The other English rivers from which tagging data are available are, like the Axe, in the south-west of England. For these no direct estimates of the home water exploitation rate (E) are available, but one can be obtained by assuming that E_g is the same for them as for the Axe. The equation relating E, R, E_g and M can then be solved for E. Doing this yields an estimate of E for the rivers of south-west England of .30, and this is virtually independent of the value of M. This is in agreement with verbal estimates made by the U.K. representatives to the Group.

For the Scottish rivers no direct estimates of E are available and thus E_g cannot be estimated. It is possible however to define the relation between E_g and E on the basis of the value of R obtained from the data. Table 6 shows the values of E_g which would correspond to a range of values of E and M on this basis.

Table 6. Exploitation rates at Greenland (E_g) corresponding to possible values of home water exploitation rate and natural mortality (from Scottish data).

	M	
E	.02	.10
.2	.003	.008
.4	.007	.014
.6	.010	.020
.8	.013	.025

Thus, even at a high home exploitation rate of .8, and the actual average exploitation rate for Scotland is believed by Scottish fishery workers to be much less than this, the estimate of E_g for Scottish rivers is only about half that for south-west England, and for a lower exploitation rate it would be correspondingly still less. Assuming again a similar local Greenland exploitation rate for fish from all areas, this would imply that the proportion of Scottish fish visiting Greenland is lower than that for England and much lower than that for Canada. This is of interest in view of the fact that fish from the west and north coasts of Norway are not known to visit Greenland at all, so that in the east Atlantic there appears to be a decreasing proportion of fish visiting Greenland from south to north within Europe.

X National Contributions to Greenland Catches

A. From Tagging Data

The ratios of captures of marked fish in Greenland and home waters should, when adjusted to the appropriate size of the total Greenland catch be equal to the ratio of Greenland to total home water catches. In Table 7 estimates are made of the quantity of fish from each country caught in Greenland in 1964 by applying the adjusted ratios to the 1964 national catches as listed in the FAO Bulletin of Fisheries Statistics. For this purpose the ratios have been adjusted from the values given in the previous section, which were for a Greenland catch of 1,000 tons, to those corresponding to the actual catch for 1964. A number of assumptions and approximations have had to be made in compiling the table, but they generally only influence the smaller totals. These are that the ratio for Ireland is rather higher than that for Scotland; that the ratio for Baltic countries is 0 except for Sweden where it is known that some fish reach Greenland and a low value has been inserted in the table; and that, except where otherwise known, half the catch consists of large salmon. Since the estimates are for the weight of catch it has also been necessary to adjust the figures to allow for growth between Greenland and home waters.

The estimated Greenland catch obtained in this way is rather less than half the actual value. This level of agreement cannot be regarded as unsatisfactory in view of the sampling errors and assumptions involved. The fact that the estimate is low implies that the contributions from at least some countries must be underestimated. This could apply to any country as a result of sampling errors or the use of too low a value for an assumed figure. Even in the case of Canada, for which the most complete data were available, this possibility still exists, particularly because practically all the data were drawn from the Maritimes area, and few data were available from Newfoundland (including Labrador), which is the nearest major salmon producing area to Greenland.

On these estimates the probable values of the percentage contributions by the various countries involved are:

Canada	31-76
Ireland	4 - 10
U.K. (Scotland)	4 - 9
U.K. (England and Wales)	1
Iceland	1
Sweden	1

Table 7. Estimates from tagging data of the contribution of various countries to the 1964 Greenland catch.

Country	Total catch (tons)	Large salmon (tons)	Ratio (numbers)	Est.. catch in Greenland (tons)
Canada (Maritimes and Quebec)	855)		.41)	
Canada	)	1,700	)	480
(Newfoundland)	1,263)		.41)	
U.S.	No data	(very small catch)		
Denmark	1,745	(872)	0	0
Finland	465	(232)	0	0
Iceland	200	(100)	.10?	7?
Ireland	1,364	300	.32	66

Continued...

Table 7 - (continued)

Country	Total catch (tons)	Large salmon (tons)	Ratio (numbers)	Est.. catch in Greenland (tons)
Norway	1,600	-	0	0
Poland	357	-	0	0
Sweden	647	(320)	.05	11?
U.S.S.R.	880	(440)	0	0
U.K. (England and Wales)	61	40	.32	9
U.K. (Scotland)	1,913	1,107	.07	57
			Total	630
Greenland (actual catch) *				1,539

*This figure differs from that in the introduction because one is gutted weight and one round fresh weight.

Where a range is given, the lower value is obtained on the estimated contribution in the actual Greenland catch, and the higher value on the estimated contribution in the total of these estimates.

A slightly different method of estimating directly the proportion of fish from different nations in the Greenland catches is to use the ratio between tags per 1,000 salmon caught in Greenland and tags per 1,000 large salmon caught in home waters. This is a direct estimate of the proportion desired, but it can be influenced by differences in the efficiency of return of tags between the Greenland and home water fisheries, as well as by any difference in the home water exploitation rate for the waters in which fish are being tagged and the rate for the area as a whole.

Table 8 summarises the results for the countries for which data are available.

Table 8. Proportions of tagged salmon in the catches at Greenland and elsewhere.

		Home waters		Greenland		
	Years of tagging	Tags returned	Tags/1000 salmon	Tags returned	Tags/1000 salmon	Ratio
Canada	1959-63	159	.096	17	.034	.35
U.K. (Scot)	1960-63	371	.376	13	.037	.10
U.K. (England and Wales)	1960-63	170	1.030	12	.032	.03

The total of these ratios is much less than 1.0. This is due at least in part to the lack of estimated ratios for these countries for which suitable data are not available. The estimate obtained earlier by another method indicated that these countries of which Ireland seems the most important, are unlikely in total to account fully for the deficiency. In this case at least some of the estimated proportions given above are too low; this would occur in cases where the particular stocks which were tagged had a higher exploitation rate than that for the country as a whole. An efficiency of tag recovery in Greenland which was lower than that generally existing in home waters would also cause the total of the ratios to tend to be less than 1.0.

B. From Smolt Ages

Data from the scales of salmon caught during the Scottish tagging experiments at Greenland in 1965 showed that there were fish with a wide range of smolt ages, from 1 year in freshwater to 7 years. This is a much wider range than is found in any individual spawning river. Since the smolt ages vary from country to country the observed distribution among the Greenland catches provides, at least in principle, a method of determining the quantitative contribution of each country to the Greenland catches.

Templeman (ICES/ICNAF Salmon Doc. 66-12) has tabulated available data of smolt ages in different Atlantic rivers. Grouping the rivers on the basis of area and smolt age, his data are summarised in Table 9 below. Also included are additional data for R. Axe in south-west England provided by the U.K. members of the Working Party. (The figures are simply the average of his percentage figures, with no attempt to weight the figures for the size of the sample, or for the abundance of the stock in the different rivers within each area).

Table 9. Percentage of different smolt ages in salmon from various **areas**.

	Smolt age (years in fresh water)						
Area	1	2	3	4	5	6	7
Maine and Bay of Fundy		76	22	2			
Rest of Maritimes		13	52	30	5		
Newfoundland		8	46	38	7	1	
Labrador			8	44	37	10	0.5
Kapisigdlit R Greenland*			43	52	5		
South England (Test and Itchen)*	91	9					
" " (Axe)	23	72	5				
England and S. Scotland	5	89	6				
North Scotland	1	65	33	1			
South west Norway*		16	69	14	1		
Ireland	13	83	4				
Mean (excluding *)	5	51	22	14	6	1	0.1
Greenland catches	3	49	32	11	4	1	0.25

The table also gives, in the bottom line, the smolt ages of the fish caught at Greenland. Clearly these are very different from the fish in the River Kapisigdlit, the main salmon river at Greenland. Omitting this river and also the rivers in southern England (with a low smolt age, and a comparatively low total stock), and Norway, the mean of the 7 areas, given in the last but one line, agrees quite well with the Greenland sample. This average figure was obtained as the unweighted mean of the percentage compositions in the different areas: this gives a weighting of 4:3 for North American: European waters.

Detailed comparison of the last two lines in the table shows an appreciable difference only in three-year smolt age: the Greenland sample having somewhat more three-year fish. Thus presumably the Greenland fishery contains a greater proportion of fish from rivers producing a high proportion of three-year smolts than is assumed in the sample weighting used.

It is also possible to calculate what the smolt age composition would be in Greenland if the fish were drawn from the different areas in the relative amounts estimated previously in Table 7, using the same proportions as before in each of the home areas. The composition obtained in this way is compared with the actual Greenland composition in Table 10.

Table 10. Distribution of smolt ages at Greenland estimated from the mixing rates of Table 7 and observed in samples at Greenland.

Smolt age	1	2	3	4	5	6	7
Estimated	1	27	35	25	8	2	0.5
Greenland catches	3	49	32	11	4	1	0.25

In this case estimated proportion is deficient in 1 and 2 years and has an excess of four-year smolts and older. This indicates either that the proportion of the Greenland catch derived from areas producing salmon of high smolt age has been overestimated, or that in some areas where a diversity of smolt age patterns occur in different rivers the mean derived from the data available is not representative of the salmon from that area as a whole.

Mathematically, denoting the proportion of say three-year fish among the fish in the ith area = ${}_iP_3$ and the proportion of those that go to Greenland = ${}_iQ_3$ = ${}_iQ$ if it is assumed that there is no differential movement of fish of different smolt ages total numbers of fish in the ith area = N_i and total numbers of fish in whole North Atlantic = N = sum (N_i) then if the proportion of three-year fish at Greenland = ${}_GP_3$

$$N \times {}_GP_3 = \text{Sum} (N_i \times {}_iP_3 \times {}_iQ_3)$$

and similarly for other smolt ages. Taking smolt ages from 1 to 7 years gives 7 equations for the 7 unknown Q's; these have an infinite range of solutions, but probably only a limited range if they are assumed to have a reasonable pattern of change from north to south on each side of the Atlantic.

Another method, at least to determine the contribution from each side of the Atlantic, is to use the mean smolt age as follows:

Mean smolt age of 4 North American areas = 3.37
Mean smolt age of 4 European areas = 2.02
Mean smolt age of Greenland sample = 2.78

then, if proportion of north American fish at Greenland = P

$$3.37\,P + 2.02\,(1-P) = 2.78$$
$$P = 0.76/1.35 = 0.56$$

Again a better estimate would be obtained by using a mean smolt age for each side of the Atlantic based on weighting the age in each area by the population abundance in that area. The method actually assumes that, on either side of the Atlantic, the number of fish visiting Greenland is the same for each of the constituent areas.

XI. EFFECT OF THE GREENLAND FISHERY ON THE COMBINED SALMON CATCHES AT WEST GREENLAND AND IN HOME-WATERS

Consider 100 salmon in Greenland waters of average weight W_1, if they are all caught they will yield a catch weighing 100 W_1. - If they are not caught and start their return to home rivers, some will die naturally, some will survive, and spawn, and some will be caught in the fisheries, by which time they will have an average weight W_2. If the percentage of the original 100 which is caught in the home fisheries is P, then the weight of the home catch will be PW_2.

If the two catches are exactly balanced, so that the same total weight of fish will be caught from the original 100 fish, whether they are caught in Greenland or left with the subsequent chance of capture in the home fisheries, then

$$100\,W_1 = PW_2$$

or

$$P = 100\,\frac{W_1}{W_2}$$

From Section VI we have an estimate of W_2/W_1 as 1.46, therefore

$$P = \frac{100 \times 1}{1.46} = 69{,}0 \text{ or } 70\% \text{ approximately.}$$

If the actual percentage caught in home waters, of the fish escaping in Greenland is greater than this amount, then, and only then, will the combination of a Greenland and a home-water fishery give a lower total yield than the home-water fishery alone.

XII Reduction of Home Water Catches due to the Greenland Fishery

Two approaches to the estimation of the reduction in the home water catch as a result of the West Greenland fishery have been used, one considering the effect on all home waters together, the other the separate effect for each country.

The overall effect on total home water catches can be estimated as follows:

Using the same notation as before,

Number of fish caught in Greenland $= N$

Number of these which would reach home waters if not caught $= Ne^{-Mt}$

Number of these which would be caught in home waters $= NEe^{-Mt}$

∴ Reduction in home water catch as a result of unit catch by number in Greenland $= Ee^{-Mt}$

Similarly, in terms of weight

Reduction in home water catch for unit weight caught in Greenland $= Ee^{(K-M)\,t}$

This reduction therefore depends only on the home water exploitation rate, and the difference between the growth and natural mortality rates, and though these are not known precisely, the likely reductions in catch can be determined by calculation for a range of values. The results are set out in Table 11, assuming t = 10 months, K = 0.04 (i.e., 4% growth in weight per month). This shows the reduction in the home water catch, and the change (increase or decrease) in total catch. Included in the table are the values for a home water exploitation rate of 1.00; at this value the "reduction in home catch" is the reduction in the weight of fish reaching home waters. This would be the actual reduction of home catch if the salmon fishing in home waters was managed so as to leave the same number and weight of salmon reaching the spawning grounds.

Table 11 shows that while there will always be some loss to the home water catch, it is only at combinations of rather low natural mortality rates and high exploitation rates that the total catch is decreased. Although the Greenland fishery would increase the total catch for the greater part of the range of M that has been examined, it is still possible that the true value of M lies in the part of the range where the total catch can be decreased. It will therefore not be possible to assess definitely the effect on the total catch until M has been more reliably determined.

Taking a value for the average exploitation rate in home waters of 0.75 the actual reduction in home water catches at the limiting values of M taken - 0.02 and 0.10 - are 915 and 411 tons from a Greenland fishery of 1,000 tons. The actual catch in 1964 of large fish from the countries likely to be concerned (see Table 7) was 3,237 tons, i.e., the reduction is between 28 and 13% in total catches of large salmon. The difference (increase) in weight between Greenland and home waters has been examined in a previous section and shown to be of the order of 50%, and the range of natural mortalities used is probably wide enough to include the true value; the most likely source of error is therefore in the value of E used since this is the result of combining the exploitation rates of many areas and these are rarely known with any accuracy. The value used here, 0.75, seems more likely to be an overestimate than an underestimate because of a possibly very low exploitation rate for some home rivers. This would suggest that the reduction in the home water catch given above is overestimated.

These values are estimates for home waters as a whole. Separate estimates for individual countries can be obtained from the estimates of Greenland catches for each country developed in an earlier section from tagging experiments.

These estimates were set out in Table 7. By the above methods the corresponding reductions in the home water catches can be calculated and are set out in Table 12.

These reductions have been calculated for the likely limits of the value of M and it appears that in this example, which is based on the fishing rate which gave a catch of the 1964 level in Greenland (the highest on record), would bring about a reduction in home water catches of an amount between, at one extreme, about 5% more than the Greenland catch or, at the other, about half the Greenland catch.

From these estimates of the reduction in home water catch, estimates of the exploitation rate at Greenland can be obtained which may be compared with those obtained in Section IX from tagging data. The latter was based on a standard Greenland catch of 1,000 tons, for which the reduction of home water catches, estimated in this Section, would be from 500 to 1,050 tons. Expressed as a percentage of the total home water catch of large salmon from

Table 11. Reduction, in tons, of home catch and increase of total catch for catch of 1,000 tons in Greenland for a series of values of M and E, taking K = .04 per month and t = 10.

		Reduction in home catch					Change in total catch				
M	E	.50	.75	.85	.90	1.00	.50	.75	.85	.90	1.00
.02		610	915	1,037	1,098	1,220	390	85	-37	-98	-220
.03		552	828	939	994	1,104	448	172	61	6	-104
.04		500	750	850	900	1,000	500	250	150	100	0
.05		452	678	769	814	904	548	322	231	186	96
.06		409	614	696	737	818	591	386	304	263	182
.07		370	555	629	666	740	630	445	371	334	260
.08		335	502	569	603	670	665	498	431	397	330
.09		303	455	515	546	606	697	545	485	454	394
.10		274	411	466	494	548	726	589	534	506	452
.11		248	372	422	447	496	752	628	578	553	504
.12		224	336	381	404	448	776	664	619	596	552
.13		203	305	345	366	366	797	695	655	534	594
.14		184	276	312	331	368	816	724	688	669	632
.15		166	248	282	294	332	834	752	718	706	668

the countries known to contibute fish to the Greenland fishery (Canada, Ireland, Sweden, U.K., see table 7), this reduction is from 15 to 30%. This percentage reduction is equivalent to the overall exploitation rate of the Greenland fishery. Since in Section X it appears that the Greenland catches contain relatively more North American than European salmon, the Greenland exploitation rate on North American fish will be in the upper part of the 15 to 30% range or rather above it, and on European in the lower part or rather below. These are rather above the estimates obtained from tagging in Section X of 9.5 to 19.2% for Canadian fish, and 2.5 to 5.4% for English fish, though considering the rather crude nature of some of the data employed the agreement is not unsatisfactory. A subjective impression of the nature of the Greenland fishery which is carried out by small boats along a very long coastline, suggests that the local exploitation rate is not likely to be very high. This is the upper limit possible for the overall exploitation rate, even for a stock which visits Greenland waters in its entirety. Section IX has produced data suggesting that at least for some European stocks the proportion visiting Greenland may be relatively small, and for these the overall exploitation rate must be correspondingly lower. The estimates in Section X are there fore probably nearer to the true values than the exploitation rates of up to 30% estimated here.

Table 12. Estimated reduction of catches of large fish in home waters.

Country of origin	Estimated Greenland catch (tons, gutted)	E	Reduction in home catch for M = .02	.10
Canada	480	.875	547	246
Iceland	7	.5	6	1
Ireland	66	.5	55	13
Sweden	11	.5	6	3
England and Wales	9	.5	3	1
Scotland	57	.5	32	14
	630		649	278

Since the proportional reduction in the home water catch in any area due to the Greenland fishery will be equal to the overall exploitation rate at Greenland on that stock, assuming that fish visiting Greenland will return to home waters if they survive, then local differences in the overall exploitation rate will produce corresponding differences in the proportional reduction in catch. In Section IX it has been suggested that differences in overall exploitation rate may be due to differences in the proportion of fish which visit the Greenland area, and the evidence considered in that Section indicates that this proportion may be higher for Canda than for the European area, and that within Europe the proportion tends to diminish from south to north. It is probable therefore that similar differences exist in the proportional reduction in the home water catch in different areas due to the Greenland fishery.

XIII Reduction in Spawning Stock

The numbers of large fish returning to home waters have been estimated to be reduced by between 5% and 30% by a Greenland fishery of 1,000 tons depending on the country and the precise values of the mortality and exploitation rates. The spawning stock would therefore be expected to be similarly affected, i.e., a reduction of 5% to 30% in large fish, but there would be no change in the grilse. There is virtually no information on what effect this reduction in the spawning stock will have on subsequent smolt production and hence on future catches at both Greenland and in home waters. However, the following points should be noted.

Firstly, while the degree to which the distinction between grilse and large fish is genetically determined is unknown, the existence of unchanged numbers of spawning grilse means that, even with the increased exploitation on large fish, the continued production of smolts is assured, though, if grilse tend to breed grilse, the number of large fish might be progressively reduced in the future.

Secondly, the reduction in spawning due to the Greenland fishery is in no way different to the reduction that would occur following an increase in the exploitation rate for large fish in homewaters by an equivalent amount. If the exploitation rate is high, quite small changes in it can cause big changes in the spawning escapement. For instance a reduction in 10% in spawning stock (of the order of the effect of the Greenland fishery) would be caused by a change in home exploitation rate from 80% to 82% (a reduction in escapement from 20% to 18%).

Thirdly, and most important, evidence from other salmonids and other fish strongly support the supposition that the production of smolts will only be proportional to the spawning stock at very low stocks. With large stocks the increase in smolts will be progressively less than the increase in spawners, and it is probable that beyond some level further increase in spawners will give no increase in smolts, and may even give a decrease. The position on the curve relating spawning stock to smolt production for Atlantic salmon is not definitely known for any rivers at present but it is believed that except where the total exploitation rate (Greenland plus home waters) is very high, a moderate reduction of spawning stock would generally cause at most only a small reduction in smolt production.

XIV Sources of Error

The methods used in this report, being often dependent on tagging data, are subject to a variety of potential errors, although they have been devised to minimise the errors as far as possible. Many of these errors have been discussed at appropriate points, but a general statement may be desirable. The principal sources of error are: (A) Sampling error. Most of the calculations are based on the numbers of tags returned, and these are often small, particularly from Greenland. The ranges of probable error, which have not been examined by the Working Party will therefore tend to be high. (B) Tag losses and tagging mortalities. The methods used are based generally on comparison of Greenland recaptures and recapture in home waters nearly a year later. Since the fish were originally tagged as smolts, losses of tags, as well as deaths due to tagging, in the first year after tagging do not affect the results and this is the period in which they are likely to be highest. There is probably some small tag loss between Greenland and return, and this will tend to make the estimates of Greenland exploitation rates, which have ignored it, rather too high. The errors from this source are likely to be small compared to the others involved. (C) Non-recognition and non-return of tags. Since the methods are comparative, the results will be affected by differences in the efficiency of tag recovery in the various areas. The results would still be unbiased from this source even if there was only a low and unknown level of efficiency in tag return, provided it was the same in all areas. In general the efficiency of the Greenland recoveries will affect estimates for all countries equally, but the efficiency in a particular country will only affect the estimates for that country. (D) Non- representativeness of tagging operations. While not a source of error due to tagging in the usual sense, this can have a considerable effect on the results in the present study. Tagging operations in most countries have to be limited to a very few rivers, and it is often impossible to be sure how the exploitation rates for these, and therefore the chance of recapturing tags, would compare with that for the country as a whole. The effect of errors of this kind has been discussed above.

XV Future Work in Greenland

Work in 1966 will be a continuation and extension of that in 1965. Danish scientists will continue to sample catches and take part in tagging operations. The research ship "DANA" will visit Greenland for this purpose. United Kingdom workers will undertake both tagging and blood sampling. They will work both on shore and off-shore from the research vessel "ERNEST HOLT" which will spend 3 weeks in Greenland waters in October. During the off-shore operations it is hoped to experiment with as many methods of catching salmon as possible.

The Group regretted that Canda would not be able to carry out the off-shore studies which had been planned for 1966, and hoped that it would be able to do so in 1967.

It was felt that sampling, and tagging, salmon in oceanic waters between Greenland and the main salmon producing areas, both during the Greenland fishing season and at other times of year, would constitute an additional and valuable method of studying directly the problems of the Greenland exploitation rate and of salmon movements at sea.

XVI Recommendations for Future Work

1. The Working Group reaffirms the recommendations made by the ICNAF Assessment Sub-Committee at the 1965 ICNAF Meeting, and repeated by the ICES Salmon and Trout Committee, concerning the need for regular collection of statistics of catches, (divided between grilse and salmon), estimates of stock abundance, data on length, weight and age composition, tagging of smolts, and examination of possible racial characteristics, such as growth characteristics, scale types, parasites and serological and biochemical characters.

2. In order to ensure the completeness of the information from tagged fish caught in Greenland, including scales and parasite samples, these fish should, if possible, be purchased.

3. An effort should be made to introduce tagged fish into the catches of the Greenland fishery at an early stage of the handling processes in order to check the efficiency of tag recovery.

4. To define more precisely the area from which salmon travel to the Greenland area the Norwegian Government should be urged to arrange for the liberation of tagged smolts from the south coast of Norway.

5. Since, in some home river systems, the very high exploitation rates which exist for salmon of two or more sea years may be approaching levels which can affect escapement, it is important to obtain precise data regarding the sex composition of catches, both at Greenland, and in home waters.

6. To obtain more direct estimates of the rate of exploitation in the Greenland fishery, and to study movements of salmon in the oceanic areas, further experimental fishing operations, including the tagging of as many fish as possible should be undertaken in the area. Such fishing should be carried out with a wide range of mesh sizes of nets.

7. In view of the critical importance of knowledge of the natural mortality rate during sea life in assessing the effects of the various fisheries, and of the absolute lack of such knowledge at present, every effort should be made to assemble data bearing on this problem. This should include data on the smolt-age distribution at the time of the smolt migration and in the fish returning from the sea after various times, and the proportion returning after each of these periods. Where complete sets of such data for a series of years are available it may be possible to estimate directly the mortality rate during the later years of sea-life. The studies of adult mortality rates should extend over the coastal and river phases of the return journey.

8. Better understanding is required on the nature of the stock-recruitment relationships for Atlantic salmon stocks, and the present position of the stocks in them. Data should be assembled as widely as possible on observations recording the numbers of smolts produced from known numbers of spawners in a series of years for individual rivers. Such data can probably be obtained from counting fence experiments.

9. To obtain additional data on the movements and growth of salmon in the sea, information should be collected as widely as possible on salmon caught at sea in commercial fishing directed at other species. To assist this, all countries engaged in sea-fishing in the area occupied by the Atlantic salmon, whether having salmon stocks themselves or not, should be asked to encourage the reporting and handing in of salmon caught incidentally at sea by their nationals.

10. To enable the results of different workers to be comparable, efforts to obtain uniformity in the method of measuring length (e.g., fork-length, total length with caudal fin in relaxed position, total length with caudal fin extended to give maximum possible length) should be continued. Until this is actually achieved in practice all workers should ensure that their reports and publications state clearly, in each document in which such data are presented, the exact method of measuring length which was used.

11. Application of critical methods of scale examination as a means of separating salmon originating in different areas will require the use of scales taken from a standardised region on the body of the fish. In order that material for such a study shall be available when required from as many areas as possible, steps should be taken to promote uniformity among all workers concerned in the region from which scales are taken. At present at least two distinct regions, the "shoulder", and the vicinity of the lateral line between the dorsal and adipose fins are in common use.

XVII Election of Chairman

Following the resignation of Mr. Gulland, the Working Party elected Mr. K R. Allen as chairman.

XVIII Summary and Discussion

The fishery for salmon at Greenland developed from an output of 115 tons in 1961 to 1,400 tons in 1964 with a drop due to decreased effort to 716 tons in 1965. Tagging has shown that these catches include fish from the United States, Canada, Ireland, England, Scotland and Sweden. The fish in the catches have a modal length of 65 cm and have spent one winter in the sea, so that, even on the assumption that they would return home if not caught, they would return to home waters as large fish (two or more winters in the sea) rather than as grilse. Analysis of the available biological and statistical data was carried out by the working group. In many respects these data are much less complete than is desirable, and in particular there is no direct information on whether the salmon at Greenland do return to home waters. For these reasons some of the calculations are presented in the report rather as examples of the techniques that could be used as further data are collected than for the value of the precise estimates obtained.

However, on the basis of the working assumption which was applied throughout the report that the salmon in the stocks fished in West Greenland behave like salmon visiting other ocean areas, and if they survive will return to their native rivers, certain deductions can be made:

(a) The West Greenland Salmon fishery as operated at present almost certainly has no direct influence on the abundance of grilse returning to home waters.

(b) The proportion of salmon appearing in the stocks exploited at West Greenland varies widely for different countries; probably the proportion from Canada is greater than that from the United Kingdom, while few, if any, of the fish in the stocks exploited at West Greenland come from the north or west coasts of Norway.

(c) Between the time of the West Greenland fishery and assumed return to home waters the fish of the sizes caught in the present West Greenland fishery increase in weight by about 50%. Therefore, if more than about 70% of the fish present in West Greenland waters were, in the absence of the Greenland fishery, caught in home waters, then a West Greenland fishery would reduce the total world catch (W. Greenland plus home waters). If less than 70% were caught, then a West Greenland fishery would increase the total catch. The percentage which would be caught in home waters depends on the exploitation rate in home waters, and on the losses (mortality, including any failure to navigate) between West Greenland and home waters. At present no good estimate of the rate of loss is possible, and the home rate of exploitation, which can only be estimated very approximately, seems to vary greatly between countries.

(d) If the assumption concerning the return of fish from West Greenland to home waters is correct, and if there are no compensatory changes in growth or in natural mortality rate as a direct consequence of the West Greenland fishery, the West Greenland fishery will reduce the total catches of large salmon in home waters.

(e) Because of probable differences in the proportion of fish visiting West Greenland, the proportional reduction in North American catches Will probably be greater than in European catches. The weight of salmon caught in Greenland which originated in each of the European countries individually is at present estimated in all cases to be less than 100 tons annually.

(f) There is no direct evidence on the probable effect of increased exploitation on subsequent natural production of smolts. The West Greenland fishery may reduce spawning stocks but if this reduction is small, the effect on smolt production will be negligible.

The reduction in home waters must be considered in relation to the contribution of grilse to the total salmon catch, and the natural variability of catches. The proportion of grilse in the catches varies widely in different fisheries, but, except in parts of the Canadian commercial fishery where the taking of grilse is forbidden, they usually make up a significant part of the total (e.g., 50% by weight in some fisheries). These grilse catches will probably be unaffected by the Greenland fishery, so that the proportional reduction in total catch will be less than the reduction in large fish (in the example half the reduction).

Catch statistics show that there is great year-to-year variability; within any five-year period the biggest annual catch is likely to be anything from 30% to 100% greater than the smallest catch, so that a reduction due to the Greenland fishery may not be immediately noticeable. In particular the catches for the last two or three years on both sides of the Atlantic have been better than usual. Therefore, it is not unlikely that the catches of salmon in home waters in 1966 and 1967 will be less than in 1964 and 1965, and this reduction, if it occurs, should not be taken as an immediate measure of the effect of the Greenland fishery.

K.R. Allen
Chairman

Appendix I

ICES/ICNAF Joint Working Party on North Atlantic Salmon

Agenda for First Meeting

Madrid, Spain

25-26 May, 1966

1. Review 1965 catches at Greenland
2. Questions to be answered (vide Annex I)
   - A. Movements and origins
   - B. Immediate effects
   - C. Long-term effects
3. Future work
   - A. At Greenland in 1966
   - B. At Greenland after 1966
   - C. Elsewhere
4. Preparation and approval of report of the meeting
5. Other business
   - A. Future meetings
   - B. Election of Chairman

Annex I

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD

Fisheries Laboratory, Lowestoft
Suffolk, England

Our ref: 1/B/6

12th January 1966

Dear Colleague: ICES/ICNAF Salmon Working Group

Though not all countries have nominated members of the group, we should be getting on with preparations both for the meeting in Madrid, and for other work during the year. Regarding the Madrid meeting, I have suggested that the dates proposed in the draft programme circulated by ICNAF (23rd-26th) give more time than we are likely to need, and have suggested that it would be better to arrange to meet definitely only on the Wednesday and Thursday (25th and 26th), with the possibility of continuing on the Friday, during the ICNAF Assessment Subcommittee meeting, if this should prove essential.

I have attached a list of questions which I think it will be our task to try and answer; could you let me know whether you agree with the list, or have any amendments or additions. The questions have been, for convenience, grouped into three groups - on movements etc., and immediate and long-term effects. Of the questions the most important are probably B4 and C3 and 4, as the answers provide the data to determine whether or not the Greenland fishery is a "bad thing", and what it is worth to the fisheries in home waters to reduce or restrict the Greenland fishery. Some of the A questions can, in part, be answered already from the results of the tagging work already available. In the table below I have tried to express the results of the smolt tagging in quantitative terms, using the returns given in Paul Hansen's ICNAF paper, and the liberation data circulated by Arthur Went. (If these figures should be revised I would be grateful if you would let me know.)

Country	Year tagged Year recapture	1959 1960	1960 1961	1961 1962	1962 1963	1963 1964	1964 1965
Canada	No. tagged	32,942	45,882	68,868	27,817	22,953	42,190
	No. returned	1	2	-	3	6	
	Returns/100,000 tags	3	5	-	11	26	
Scotland	No. tagged	13,051	11,644	13,109	15,713	17,748	12,180
	No. returned	-	-	2	1	11	
	Returns/100,000 tags	-	-	15	7	62	
Ireland	No. tagged	150	1,440	2,630	4,000	1,700	0
	No. returned	-	-	-	-	-	-
	Returns/100,000 tags	-	-	-	-	-	-
England	No. tagged	2,565	13,579	11,393	19,763	19,485	17,129
	No. returned	-	2	3	2	7	
	Returns/100,000 tags	-	15	27	10	74	
Norway	No. tagged	2,848	4,120	10,034	11,429	11,097	10,849
	No. returned	-	-	-	-	-	
	Returns/100,000 tags	-	-	-	-	-	
Sweden	No. tagged	2,643	2,640	3,249	0	0	0
	No. returned	-	1	1	?	?	
	Returns/100,000 tags	-	40	30			

The important figures are the numbers returned per 100,000 smolts released; these tend to increase from year to year, following the increase in the Greenland fishery. A better index would be the numbers returned per 100,000 released per unit weight caught at Greenland, but these figures tend to decrease in time, probably because in the earlier years especially, the available statistics of exported salmon are underestimates of the actual catch. From the table the rate of returns from England and Scotland are very similar; although the numbers are small the Swedish returns are also similar. The returns from Candian experiments are rather lower, perhaps half the British figures. No returns have been reported from Irish or Norwegian smolt tagging; few smolts have been tagged in Ireland, so that the expected number of returns, at the English or Scottish return rate, would be only one or two fish: the lack of returns can therefore reasonably be ascribed to the small numbers tagged, particularly in view of the returns from Greenland of big fish tagged at Ireland. However, the expected numbers of Norwegian tagged smolts is ten or a dozen fish, and it seems very probable that a considerably smaller proportion of Norwegian smolts go to Greenland (but is there any difference between north and south Norway: where were these tagged?). Presumably the results of the smolt tagging in 1964 and 1965 (Particularly the substantial Canadian work) will enable these results to be refined, but I doubt whether further work on a practicable scale will make a great improvement (except that it would be useful to have some further smolt tagging from Sweden and Ireland, say 20,000 fish, to check whether the return rate was in fact similar to British or Canadian smolt tagging). Provisionally therefore the answers to questions A1 and A3 are:

1. Salmon at Greenland, apart from the local stock, come from North America, and most of Europe, but probably excluding Norway.

3. A group of 100 salmon contain fish from the above countries possibly in proportion to the size of the stocks in these countries, though possibly proportionately fewer fish from Canada. There are indications that these proportions vary, depending on the position at Greenland, with rather more Canadian salmon occurring in the north. Again, any practicable scale of tagging is unlikely to improve these indications much; biological characteristics, e.g. blood types may help here, and I gather that plans are being made by the United Kingdom to try to work along these lines. Presumably the essential first step is to examine samples from European and American rivers to see if there are differences between them which might be detectable in later samples taken at Greenland.

Judging by the time available it seems unlikely that fish can go to Greenland and get back to their home waters as grilse; I do not see how this can be proved, but it seems a reasonable assumption. The conclusion must be that in considering the effect on the stocks and catches in home waters grilse and salmon must be treated separately, and the catch statistics treated accordingly.

The most difficult of the A questions is the last. As a first attempt it seems that perhaps 1% of tagged smolts are returned from home waters. As not all the run are caught perhaps 2% of the tagged smolts return successfully. Taking the average sea life as 2 years, an estimate of the mean <u>monthly</u> loss rate Z may be given as

$$e^{-24Z} = .02$$

or $$24Z = 4.0 \quad Z = 0.16$$

i.e. the total loss over the 2 years is equivalent to a steady loss of about 15% per month. If the average period between the time the fish are exposed to the Greenland fishery and entering the home river is nine months, then the survivors during this period may be estimated as

$$e^{-9 \times .16} = e^{-1.44} = .25$$

Clearly as the fish are bigger than during the first few months in the sea, the mortality rate may be less than the overall average; against this there are the added risks in the long migration involved, and the possibility of some navigational errors causing extra losses. I think therefore that the figure of 75% may at least be a reasonable one to base our thoughts on. As a start it can be improved by making the above calculations more accurate as regards both the times involved, and the loss between smolts leaving the river, and adults re-entering it. More direct estimates are clearly required; ideally this would be solved by tagging. Any percentage return from tagging experiments will give a lower limit to the percentage of all fish returning from Greenland, but it seems that it may well be so low a limit as not to be worth much. Thus from the Scottish-Danish releases of 200 fish forecasts of 0 to 5 returns have been made. This, averaging say 1%, is very much less than the 25% guessed above, but, assuming it turns out to be right, it can still be argued whether the causes are real and applicable to all fish, i.e. mortality or movement to areas where there is no salmon fishery, or applicable only to tagged fish - failure to detect tags, shedding of tags, or mortality due to handling or tagging. The returns from the 1965 experiment will presumably tell us whether the returns are around 1%, or 10- 20% (or even more). If the latter we have a useful lower limit, and should do more tagging to make it more precise. If the former, I doubt whether the actual values can mean very much, and further tagging would be much less useful.

Regarding the B questions, on immediate effects, it will probably be very difficult to get at all precise answers, but it may be relatively easy to set useful limits to the effects. Thus, while it is impossible to say what percentage of the stock at Greenland is taken locally, the great length of coast in relation to the numbers of fishermen involved suggests that the percentage cannot be high. Two ways of getting quantitative estimates suggest themselves:

(1) from cod tagging data (most cod survive tagging, and the Greenlanders are good at returning tags), find the percentage returned by the Greenland inshore cod fishing and compare the numbers of fishermen fishing for cod and salmon (Dr. Hansen's laboratory has extensive cod tagging data); and

(2) by comparison with any inshore salmon fishery where the fishing rate is known (is there such, particularly on a similar coast using similar gear?).

Once the fishing rate at Greenland is known, the effect on stocks and catches in home rivers can be directly estimated provided the proportion of the stock that comes from Greenland is known, i.e. if the Greenlanders catch 10% of the salmon and 50% of the salmon at Scotland come from Greenland then the reduction in Scottish catches is .1 x .5 = .05.

Alternatively, accepting the earlier estimates that 25% of salmon at Greenland get back to home waters, then each 100 salmon caught at Greenland will reduce the numbers reaching home waters by 25, and therefore the catch by 12 fish, and the number of spawners by 10 (can better estimates of the relation between stock and catch, and of other non-fishing losses between reaching home waters and spawning be made?).

Taking the average weight of salmon caught at Greenland as 2kg, and of salmon in home waters as 5 kg, then the catch of 100 salmon at Greeenland is 200 kg, and the loss of catch in home waters is 5 x 12 = 60 kg, i.e. only 30% of the Greenland catch. These figures could definitely do with refining, but I doubt whether any changes in them will alter the conclusion that, to take the greatest weight of salmon from a given number of fish reaching commercial size, they should be harvested at Greenland. This of course does not solve the problem: it is likely to add greatly to the political problem, and as precise a figure as possible may be required to help in any bargaining.

Finally the effect might be estimated directly from changes in the catches, though these may fluctuate too much to be sure of any change in a short period. Certainly we should look at catches for a long period, say 10-20 years; these must be seperated into grilse and salmon, both because only the salmon catches should be affected, and also because it might be possible to estimate an "expected" salmon run from the previous year's grilse run (is this so?).

The real problem is the long-term one - what affects the number of smolts produced. This can be separated into the effect of the number (and size) of spawners (the stock and recruitment problem), and effect of other measures such as the reduction of pollution, removal of obstructions etc. I would suggest that we should not be involved much with the latter, except to note that such actions are very relevant to the practical political problems of who harvests Atlantic salmon where. The problem of stock and recruitment seems to be an increasingly urgent one in many fisheries without any easy solution coming any closer. For Madrid the best we can do probably is to think about it; and also look at any available pairs of calves of spawning stock and smolt production (or size of later run of adult fish) to see whether any pattern emerges.

This letter has turned out rather longer than I meant, but I hope it will serve as a start to our discussions in Madrid. I look forward to meeting you there.

Yours sincerely,

(signed) J.A. Gulland

Questions to be answered

A. Movements and origins

B. Immediate effects

C. Long-term effects

A.1. Where do the salmon caught at Greenland come from?

2. Do fish destined to be grilse go to Greenland, or only those destined to be salmon?

3. Of every 100 salmon at Greenland, how many come from each country?

4. Do all salmon from e.g. Scotland go to Greenland?

5. Neglecting the Greenland fishing, not including natural deaths what proportion of the fish at Greenland return to home waters?

B.1. What proportion of the fish at Greenland is taken by the Greenland fishery?

2. What proportion of the potential run to each country's home waters, of grilse and salmon separately, is taken at Greenland?

3. Of every 100 salmon caught at Greenland, how many would otherwise

(a) return to home waters?

(b) be caught in home waters?

(c) spawn?

4. For every ton of salmon caught at Greenland what is the reduction, other things being equal, of the catch in home waters in the seasons immediately following?

C.1. Is the number of adult fish returning to home waters proportional, on the average, to the number of smolts?

2. If the Greenland fishery reduces the number of spawners by x%, or n fish, what will be the changes in the number of smolts produced?

3. What will be the long-term effect on the fisheries both at Greenland and in home waters of the changes in the number of spawners?

4. What pattern of fish, at Greenland, at sea in home waters, and in the rivers, is likely to give the maximum sustained yield of salmon?

Appendix II

ICES/ICNAF Joint Working Party on North Atlantic Salmon

Working Papers for First Meeting

Madrid, Spain

25-26 May, 1966

1. Summary of 1965 Program Activities of the Atlantic Sea Run Salmon Commission, Maine, USA
2. Preliminary Report of Recaptures in ICNAF Convention Area of Atlantic Salmon tagged in Narraguagus River, Maine, USA
3. UK Research Program for the Greenland Salmon Fishery, 1966
4. Scottish Salmon Catch Statistics
5. Canadian data on salmon catch, age and size
6. Canadian Salmon Tagging Data
7. ICES/ICNAF Working Group on North Atlantic Salmon - Canadian salmon research plans for 1966
8. Atlantic salmon tagging data for England and Wales
9. A Preliminary Study of the Influence of the Greenland Salmon Fishery on the Salmon Stocks and Fishery of the Miramichi River, New Brunswick, Canada
10. Supplement to ICES/ICNAF Salmon Doc. 66/6
11. Preliminary note on distribution of Atlantic salmon off the Newfoundland bank and shelf areas 21 March-1 May 1966. by W. Templeman
12. Atlantic salmon from the Labrador Sea and off West Greenland, taken during A.T. Cameron cruise, July-August 1965. by W. Templeman
13. Recaptures of tagged Atlantic salmon in Greenland waters in 1965 and some remarks about the Greenland salmon fishery. by Sv. Aa. Horsted
14. Information on Salmon in the Blackwater, Moy and Shannon Rivers of Eire
15. Salmon Catches for England and Wales 1945-1964
16. Notes on Salmon caught in Greenland 1965
17. Scottish Salmon Tagging Data
18. Immunological and Biochemical Studies on Atlantic Salmon (*Salmo salar* L.) (Progress Report). by N.P. Wilkins, Marine Laboratory, Aberdeen