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The Greenland Fishery for Atlantic Salmon and Canadian Catches

by

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Introduction

A new evaluation of effects of the high seas fishery on Canadian catches, present and future, is offered in this paper. It involves analysis of more detailed data on Canadian fisheries and stocks than have been available to the ICES/ICNAF Joint Working Party on North Atlantic Salmon (ICES/ICNAF, 1967; 1969; 1971a,b, 1972).

Effects of the Greenland fishery (Table 2) on home salmon catches (Table 1) are assessed by examining the changes in Canadian catches since the beginning of that fishery. The analysis indicates that the most important effect of the Greenland fishery is not the immediate loss to home-water fisheries (Figs 1 and 2) but the reduction of spawning stocks and the future long-term production of salmon in Canada.

Tagging studies

Data for the 1950's are used to provide a base with which to compare that for the 1960's when salmon were, besides the traditional fisheries, also subject to fishing in the West Greenland area. A continuing program of marking and/or tagging the seabound smolts has been carried out by the Fisheries Research Board of Canada in tributaries of the Miramichi River system since 1950. Emphasis is placed on the FRB studies because they are the only long-term series available and the taggings in different years are relatively comparable.

From 1950 to 1961 a total of 174,509 salmon smolts were marked by finclipping as they descended Miramichi tributaries (Kerswill, 1971). Some of these data are summarized in Table 3.

In the 1960's a comparable program was continued by placing serially numbered tags on the smolts. Early FRB tagging in the Miramichi system was reported by Saunders (1969). A compendium of all of the taggings carried out was given by Elson (1970) and brought up to date by May (1971). Table 4 summarizes the FRB tagging data from the Miramichi system and Table 5 the results of some Resource Development Branch tagging in the same system

Data for finclipped smolts (1950 to 1960) are given in Table 3. Data for later taggings are grouped for 1960 to 1963, 1964 and 1965, and 1966 to 1968 in Table 4.

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Table 6 summarizes the percentage escapements (passed through counting fence and not subsequently caught by anglers) and the percentage recoveries (counting fence plus angling) in home river for native and hatchery-reared fish in the Northwest Miramichi. The percentages are based on total recaptures for salmon or grilse.

The total percentage recovered in the home river should be a more sensitive index of effects of the Greenland fishery on home water stocks than the percentage escapement. In the early years, 1950-60, about 22% of salmon were caught or counted in their home river. In the early 1960's when the Greenland fishery was just starting, the percentage dropped to 18% and then later on to 9-12% in 1964 to 1968 (Table 6). Correlating the percentage returns in home river with the average catches in Greenland one year earlier gives as coefficient of correlation r = -0.94, significant at 95% level.

A number of tagging experiments have been carried out in Nova Scotia by both the Fisheries Research Board and the Resource Development Branch. Table 7 summarizes the results of those taggings involving substantial numbers of fish over several years. The rivers include the Margaree, the River Philip and the Medway. The rate of recovery ranges between 0.5% to 0.9%. These figures compare with 0.5% reported by Tétreault and Carter (1972) for taggings in two Quebec rivers.

The data on Newfoundland taggings of wild smolts up to 1968 are summarized in Table 8. Only about 2 thousand fish were tagged in 1963 or before, but some 17 thousand were tagged between 1964 and 1968. Returns from West Greenland are conspicuously absent. These results may, however, be peculiar to the particular rivers where the experiments were carried out. Table 8 shows that only about 5% of the returns were salmon and 95% were grilse. These data contrast with the breakdown of Newfoundland landings where salmon account for about 53 to 65% of total (May and Lear, 1972). Hence these tagging experiments reflect poorly the Newfoundland fisheries as a whole. Later tagging studies on smolts (14,755) of the Sandhill River of Labrador showed about 67% returns as grilse in home waters and 33% as 1+ fish in Greenland and 2-sea-winter fish in home waters. About 51% of the non-grilse were taken in Greenland, 44% in home-water commercial fisheries and 5% were registered as escapement (Peet and Pratt, 1972).

Tétreault and Carter (1972) give information on the effect of Greenland catches on Quebec salmon. A total of 20,456 hatchery-reared smolts were released in 1968. Only 105 were recaptured including 44 fish in Greenland, 44 in Newfoundland and 17 in home waters. The percentage captured in Greenland (42%) is higher than for any other taggings except those for large salmon of the Sandhill River (51%). A high rate of utilization of Quebec fish by the Greenland fishery may explain negative correlation between increased catches in Greenland and decreased catches in Quebec (r = -0.74) or between catches in Greenland and decreased catch per rod hour in Quebec rivers (r = -0.35).

In 1969, 36 recaptures were reported from Greenland, only 3 of these from the offshore fishery. Yet, as Tétreault and Carter point out, the inshore fishery took only 2.15 million lb and the offshore fishery 2.72 million lb. The discrepancy between number of recoveries reported and landings suggests that a much higher number of tagged fish were actually caught but not reported. By correcting the reported recoveries from the offshore fishery for non-reporting, Tétreault and Carter estimate that 80 fish were in fact captured as opposed to the 44 reported.

Rate of utilization of salmon

Table 9 gives percentages of salmon caught both in Greenland and Newfoundland for the previously reported taggings in New Brunswick and in Nova Scotia. Percentages do not incorporate any correction for non-reporting.

Of particular interest are percentage returns for salmon and the trends exhibited. Data for grilse have been entered for completeness. Only the data for native salmon, Part A (and native grilse, Part A) are assumed to give reliable information on trends. Numbers of hatchery-reared fish for the early 1960's are rather small to base conclusions on.

The important fact that emerges from Table 9 is that while the Greenland fishery has been increasing its share, the other distant fisheries, e.g., the Newfoundland fishery, have not. Recent depression of the New Brunswick stocks appears not to be related to increased exploitation in Newfoundland.

Inspection of the actual percentages shows that the Greenland fishery takes 16-24% of all salmon originating in New Brunswick and 20-52% of those originating in Nova Scotia. If we were to correct for the non-reporting of tags in the manner earlier applied by Elson (1970) and Tétreault and Carter (1972), the actual number of returns would almost double and the estimated share of the Greenland fishery would range from 27-38% for New Brunswick salmon stocks and from 32-68% for Nova Scotia stocks. In a paper analysing returns from smolt taggings in 1968-70 in the Miramichi, Turner (1972) estimates that the relative exploitation by the high seas fishery of Miramichi salmon stocks is around 39%. For their four Quebec rivers Tétreault and Carter estimated a 30% exploitation rate of Quebec grilse plus salmon by the offshore Greenland fishery and 27% by the inshore fishery based on total recaptures of Quebec fish (i.e., both grilse and salmon combined).

Stock and recruitment

The Fisheries Research Board of Canada has maintained a counting fence on the Northwest Miramichi at Curventon since 1950 (Kerswill, 1971). Counts of salmon and grilse ascending the river past the fence have been tabulated in Table 10, columns 1 and 2. The abundance of young has been followed by annual electrofishing surveys in 10-14 sampling sections of the river. Estimated populations converted to 100 yd^2 indices are tabulated in Table 10, columns 3, 4 and 5. Column 3 gives the numbers of underyearlings, column 4 the numbers of small parr and column 5 the numbers of large, pre-smolt parr. By and large these correspond to 0+, 1+, and 2+ year olds.

Numbers of smolts counted descending the rivers are given in column 6. For most years the counts are not complete, installation of the fence being delayed by log drives and/or high water. But, except 1952, 1957, 1960, 1961 and possibly 1963, they probably provide some indication of levels of smolt production.

Estimates of the smolt run for the whole Miramichi system are given in Table 11. It lists the numbers of smolts tagged or fin-clipped at Curventon, number caught in research-operated estuarial traps at Millbank, number of recaptures at Millbank of smolts marked up river and Petersen estimates of total smolt runs for all years except 1952 when no estimate was feasible and 1963 when the Petersen estimate appeared totally unreasonable. Estimates for those two years have been obtained by regressing estimated smolt production for the remaining years on the numbers descending at Curventon and subsequent total salmon landings and obtaining substitute estimates from a regression equation as indicated in Table 12. E 4

To determine the relationship between the number of potential spawners and the resultant progeny, multiple regression analysis has been carried out by regressing the estimated density of underyearlings above Curventon on the numbers of grilse and salmon ascending the year before. The results are presented in Table 13. To counteract sampling errors and fluctuations in the environment a three-year running average of the data has been used in the regression.

The regression of the numbers of underyearlings on the numbers of salmon is significant while that on the numbers of grilse is not (Table 13). Graphically, this can be verified by plotting the numbers of underyearlings against the numbers of salmon (Fig. 4) and against the numbers of grilse (Fig. 3).

The results from the multiple regression suggest that the numbers of salmon are more important in determining the spawning success than the numbers of grilse. To ensure adequate recruitment in this stream spawning stocks must include adequate numbers of salmon and not grilse alone.

We have also estimated the number of eggs deposited and correlated that with the number of underyearlings. The potential egg deposition has been calculated by assuming 800 eggs per pound of female fish. The sex ratios of male:female have been set at 1:1 for salmon and 2:1 for grilse and the average weights at 9.2 lb and at 3.2 lb respectively. The resultant figures are given in Table 10, column 7. Correlation between the potential egg deposition in the previous fall and density of underyearling gives $r^2 = 0.69$, Table 13, Part B. While this is significant, it is not as high as the multiple correlation coefficient, $R^2 = 0.82$, when the numbers of grilse and salmon are entered separately. The discrepancy is consistent with our earlier conclusion that salmon are more important than grilse in determining the spawning success.

Further regression analysis carried out in Table 14 shows a significant relationship between density of small parr and that of underyearlings the year before, while the relationship between density of large parr and preceding small parr is not significant.

Correlation between large parr and the numbers of smolts counted is, however, significant despite the incompleteness of counts in many years (Table 14, Part C). Since the relationships between abundances at successive stages from the spawners through to smolt run are all significant, except for the relationship between the small parr and large parr, it is concluded that the transitional phase from the small to large parr is a most critical, or at least a most variable phase in the freshwater life of Northwest Miramichi salmon. This particular relationship is probably also weakened by the fact that the small parr group includes, in addition to 1+ fish, some small 2-year-olds. But large parr, regardless of age, are likely to become smolts the following spring (Elson, 1957).

Smolt production and subsequent landings

Miramichi smolt production as estimated in Table 11 is variable. The annual estimates are sometimes based on small samples of marked fish in the estuarial traps. Part of the apparent variability is probably due to sampling error. That a significant correlation exists between estimated parr populations and subsequent smolts suggests that some of the observed variability is real.

The commercial fishery in New Brunswick is based on salmon, i.e., on fish that have spent two or more years at sea (Allen, 1967). Table 15 gives the summary of sea ages of commercially caught fish in New Brunswick from 1949 to 1964 and, for comparison, also those landed in Nova Scotia and Newfound-

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land. Over 80% of the reported landings in New Brunswick were salmon which had spent 2 years at sea. Although some grilse are taken (see Table 4) they are, for the most part, not reported in commercial landings because their sale in New Brunswick is illegal.

Through the 1950's and earlier the Miramichi system produced about 60% of the salmon landed in New Brunswick. A significant relationship between Miramichi smolt production and New Brunswick landings two years later might be expected if distant fisheries do not have a significant effect on the stock. Our analysis of tag returns indicates the only distant fishery whose take from New Brunswick stocks has appreciably changed is that in the Greenland area. Hence if the Greenland fishery has had a noticeable effect on New Brunswick stocks, any relationship which may exist between smolt production of the Miramichi and subsequent home commercial landings should improve noticeably when the Greenland landings are taken into account. Such is the case.

Total landings of salmon that originate in New Brunswick include those caught in West Greenland. A reasonable estimate might be that 50% of the Greenland caught salmon come from Canadian waters and that about 22% of Canadian catches in the past ten years are landed in New Brunswick. Thus about 11% (= .50 x .22) of Greenland catches should be New Brunswick fish. The 11% may be too low since more fish originating in New Brunswick than fish originating in Newfoundland appear to be caught in Greenland. Lacking information on the actual percentage, we have made our calculations using both 11% and 20%. The 20% figure which agrees with the tag returns tabulated in Table 4 is derived as follows. In 1964-65 there were 82 tag returns reported from Greenland out of a total of 704 returns. Assuming about 50% losses for non-reporting[1], there should have been 164 Greenland captures out of a total of 786 (= 704 + 82) giving a 20% rate of exploitation in Greenland (164/786 = .20). The latter figure, in fact, will give us slightly better results although the conclusions are essentially unaltered.

The coefficient (r) for simple correlation between smolt production and New Brunswick landings based on three-year running averages for both sets of data is represented by $r^2 = 0.79$ (Table 16). When the 11% of the Greenland landings are included with the New Brunswick landings this is increased to $r^2 = 0.93$. Adding 20% instead of 11% gives $r^2 = 0.94$, a slight improvement but not significant. If the calculations are done without smoothing the data, the same picture emerges but the correlations are not as high.

The fact that correlation between smolt production and subsequent home landings is appreciably improved by including an allowance for New Brunswick fish taken in Greenland indicates that the Greenland fishery exploits a noticeable share of New Brunswick smolt production. The close relationship between smolt production and subsequent landings is shown in Fig. 5.

Landings per million smolts (Table 17) have, on the average, been somewhat higher since 1963 than prior to that. The rate of exploitation is higher now than at any time since 1950, at least in part because of the Greenland fishery. That this has had an adverse effect on escapement, egg deposition and hence subsequent recruitment to stocks already heavily exploited in home waters is understandable.

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[1] This degree of non-reporting cannot be substantiated for 1964 but is increasingly valid as the high seas component of the fishery increased.

Table 18 lists the number of salmon and grilse caught in the estuary at Millbank in research traps while ascending the Miramichi system. These are the best available indicators of escapement of salmon and grilse from the commercial fishery. Potential egg deposition represented by these catches is also set out in Table 18, column 3. The figures do not represent the total escapement or egg deposition in the Miramichi system, but egg deposition thus calculated should be an indication of the total for the system and hence an index of expected level of progeny.

If recruitment to young stocks is a limiting factor, then egg deposition, or some index of it, should correlate with consequent smolt production.

If the survival at sea and the take by the fishery were constant from year to year, egg deposition per smolt production should also be constant. But both natural and fishing mortality doubtless vary. With all other factors constant, inverse correlation between egg deposition per smolt production and landings per smolt production would be expected, i.e., high landings from a smolt run would imply fewer salmon remaining for spawning. But if landings are dependent on variable natural mortality, then high landings per smolt production would tend to be an index of good survival of a year-class. This would tend to counteract any inverse correlation with egg deposition.

Since grilse escapement results from smolt production one year before and salmon escapement from smolt production two years before, egg deposition arises from production both one and two years earlier. The two-year component is a very important one because salmon, due to higher fecundity and female:male sex ratio, frequently make the larger contribution to egg deposition. There are now, moreover, indications of genetic polymorphism in Atlantic salmon stocks which involves a tendency for progeny to mature at the same sea age as their parents, i.e., large salmon spawners appear necessary for recruitment of a good stock of large salmon (Elson, 1973a). In addition, the analysis presented in Table 13 suggests that salmon eggs, usually larger than grilse eggs, are also more viable. To avoid the difficulties of smolt production contributing to egg deposition one and two years later, three-year running averages have been used for calculations.

The problem of two smolt classes contributing to one year's egg deposition can be approached in another way. It has already been shown (Table 16) that home commercial landings, consisting of over 90% 2-sea-winter salmon, are correlated with smolt production 2 years before. Escapement of salmon (an index of egg deposition) might, then, also be expected to correlate with smolt runs two years before, i.e., salmon escapement (and egg depositfon) per smolt production should be constant if other factors such as natural and fishing mortality, etc., are constant.

Multiple regression analyses of both egg deposition (Table 19, Part A) and salmon escapement (Part B) on Greenland and home commercial landings are summarized in Table 19. The analyses show significant and positive correlation with New Brunswick landings and significant and negative correlation with Greenland landings in both cases.

It is concluded on the basis of these results that landings in New Brunswick have acted more as an indicator of the year-class strength and subsequent escapement, but that Greenland landings have contributed to the depressed escapement reported by Elson (1973b). The escalated Greenland landings supply the best available explanation for the recent and continuing deficiency in numbers of salmon returning to the Miramichi River to spawn. E 7

Summary

Recaptures of Atlantic salmon tagged as smolts show that substantial numbers of those produced in the Maritimes are caught in Greenland waters. Percentage recoveries in the home river system show a significant inverse correlation with levels of catches in Greenland. Analyses of detailed data collected since 1950 indicate that the onset of the Greenland fishery is one of the major, if not the most significant, recent changes in salmon fisheries affecting Miramichi stocks of 2-sea-winter salmon.

Total landings have risen higher per million smolts produced in the Miramichi system since the Greenland fishery began. The escapement from fisheries and the potential spawning stock per given numbers of smolts has dropped correspondingly.

Lowered escapement has been followed by lowered abundance of progeny as reflected by density of young in nursery stream areas. Significantly, the recruitment as measured in the numbers of underyearlings depends more crucially on the numbers of salmon escaping the fishery than on numbers of grilse. As shown by this statistical analysis, the Greenland fishery has had a direct adverse effect on the numbers of salmon surviving to enter their spawning river. Consequently, the abundant smolt runs in 1964, 1965, and 1968 produced by good escapement some four years earlier failed to maintain adequate levels of recruitment and have instead been followed by all-time low commercial catches and recruitment of young in rivers.

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Table 1. Commercial salmon landings by provinces and angling catches for the provinces of New Brunswick and Nova Scotia from 1950 - 1971. Data from May & Lear (1971) till 1970, for 1971 from the Wykes & Dunfield (1972). Landings and catches are in thousands of pounds.

	Commercial Landings				Angling Catches	
Year	N.B.	N.S.	P.Q.	Nfld. and Labr.	N.B.	N.S.
50	980	294	829	3676		
51	740	262	799	3351		
52	717	214	793	3415	315	38
53	698	271	672	3087	302	50
54	879	228	520	2355	292	30
55	349	128	443	1751	226	21
56	422	136	466	1645	290	21
57	500	146	445	1965	230	10
58	613	204	510	2154	380	38
59	786	210	651	2345	191	34
60	642	240	632	2089	158	13
61	604	279	509	2093	141	24
62	735	312	501	2239	178	33
63	663	302	432	2677	354	21
64	1063	252	449	2792	269	28
65	1233	294	572	2561	309	16
66	1246	281	590	3078	401	21
67	1448	346	501	4007	349	32
68	798	232	424	3180	155	19
69	586	171	381	3176	210	18
70	574	155	383	3842	174	28
71	273	69			98	19

Table 2. **Commercial salmon catches off the West Coast of** Greenland from 1960 - 1971 in thousands of pounds. Data from ICES/ICNAF Joint Working Party Report (1972).

Year	Commercial Landings West Greenland
1960	132.3
1961	280.0
1962	537.9
1963	1027.3
1964	3392.9
1965	1898.2
1966	3020.3
1967	3529.5
1968	2484.6
1969	4872.2
1970	4731.1
1971	5765.0

Table 3. **Numbers of marked Northwest Miramichi smolts returned as grilse and salmon. Smolts marked by finclipping from 1950 to 1961. Data from Kerswill (1971).**

Total Number Finclipped from 1950 - 1961 = 174,509

Method of Capture	Recaptured as Grilse	Salmon
Commercial		
Home	278	1753
Distant	315	607
Angling	339	126
Escapement	796	531
Total	1728	3017

Percentage escapement from total returns
for grilse = 46.1 %
for salmon = 17.6 %

Rate of Recovery = 2.71 %

<u>Table 4.</u> Numbers of tagged smolts returned as grilse or salmon. All smolts marked and liberated in Northwest Miramichi by the Fisheries Research Board of Canada between 1960 to 1968. Data from May (1971).

<u>Years 1960 - 1963</u>

	Native fish Total No. = 12313		Hatchery fish Total No. = 11227	
	Recaptured as			
Fishery Caught in	Grilse	Salmon	Grilse	Salmon
W. Greenland		12		3
Commercial				
Home	35	46	30	14
Distant	9	15	14	17
Angling	50	13	10	7
Escapement	159	3	51	2
Total	253	89	105	43
Rate of Recovery	2.78%		1.32%	

<u>Years 1964 - 1965</u>

	Native fish Total No. = 28327		Hatchery fish Total No. = 26356	
	Recaptured as			
Fishery Caught in	Grilse	Salmon	Grilse	Salmon
W. Greenland		82		48
Commercial				
Home	61	196	66	85
Distant	23	34	73	54
Angling	120	20	87	17
Escapement	158	10	59	4
Total	362	342	285	208
Rate of Recovery	2.49%		1.87%	

Table 4 continued.

Years 1966 - 1968

Fishery Caught in	Native fish Total No. = 48500 Grilse	Native fish Recaptured as Salmon	Hatchery fish Total No. = 70147 Grilse	Hatchery fish Salmon
W. Greenland		145		86
Commercial				
Home	301	344	120	269
Distant	89	104	119	142
Angling	433	52	170	38
Escapement	386	29	62	9
Total	1209	674	471	544
Rate of Recovery	3.88%		1.45%	

Table 5. Numbers of tagged smolts returned as grilse or salmon. All smolts marked and liberated in the Miramichi system mostly by the Resource Development Branch between 1960 to 1968. Data from May (1971).

Years 1960 - 1963

Fishery Caught in	Native fish Total No. = 1474		Hatchery fish Total No. = 7658	
	Recaptured as			
	Grilse	Salmon	Grilse	Salmon
W. Greenland		0		2
Commercial				
Home	1	0	0	2
Distant	4	0	9	3
Angling	0	0	31	4
Escapement	0	0	4	2
Total	5	0	44	13
Rate of Recovery	0.34%		0.74%	

Years 1964 - 1965

Fishery Caught in	Native fish Total No. = 921		Hatchery fish Total No. = 54696	
	Recaptured as			
	Grilse	Salmon	Grilse	Salmon
W. Greenland		0		22
Commercial				
Home	0	1	20	25
Distant	0	0	13	19
Angling	0	0	51	18
Escapement	0	0	65	21
Total	0	1	149	105
Rate of Recovery	0.11%		0.46%	

Table 5 continued.

Years 1966 - 1968

Fishery Caught in	Native fish Total No. = 13242 Grilse	Salmon	Hatchery fish Total No. = 105423 Grilse	Salmon
	Recaptured as			
W. Greenland		12		86
Commercial				
Home	19	47	36	109
Distant	8	9	111	79
Angling	26	30	58	21
Escapement	20	11	19	3
Total	73	109	224	298

Rate of Recovery 1.37% 0.49%

Table 6. The percentage escapement and the percentage recovered in home rivers for the Northwest Miramichi taggings. Data from Tables 3 and 4.

The percentage escapement

	Native fish		Hatchery fish	
		Recaptured as		
Years	Grilse	Salmon	Grilse	Salmon
1950 - 1960	46.1	17.6	-	-
1960 - 1963	62.8	3.4	48.6	4.6
1964 - 1965	43.6	2.9	20.7	1.9
1966 - 1968	31.9	4.3	13.2	1.7

The percentage recovery in home river

	Native fish		Hatchery fish	
		Recaptured as		
Years	Grilse	Salmon	Grilse	Salmon
1950 - 1960	65.6	21.7	-	-
1960 - 1963	82.6	18.0	58.1	20.9
1964 - 1965	76.8	8.8	51.2	10.1
1966 - 1968	67.7	12.0	49.3	8.6

The correlation coefficient between the percentage recovery and the Greenland catches, $r^2 = -0.94$

Table 7. Numbers of returns of smolts tagged in Nova Scotia rivers of Margaree, Medway and Philip from 1960 to 1968. Data from May (1971).

Years 1960 - 1963

Fishery Caught in	Hatchery fish Total No. = 7658 Recaptured as Grilse	Salmon
W. Greenland		2
Commercial		
Home	0	2
Distant	9	3
Angling	31	4
Escapement	4	2
Total	44	13
Rate of Recovery	0.74%	

Years 1964 - 1965

Fishery Caught in	Hatchery fish Total No. = 25195 Recaptured as Grilse	Salmon
W. Greenland		26
Commercial		
Home	1	25
Distant	12	41
Angling	27	10
Escapement	46	34
Total	86	136
Rate of Recovery	0.88%	

Table 7 continued.

Years 1966 - 1968

Fishery Caught in	Hatchery fish Total No. = 69195 Recaptured as Grilse	Salmon
W. Greenland		117
Commercial		
Home	3	29
Distant	49	.54
Angling	18	7
Escapement	41	18
Total	111	225
Rate of Recovery	0.485%	

Years 1960 - 1968

Fishery Caught in	Native fish Total No. = 7614 Recaptured as Grilse	Salmon
W. Greenland		7
Commercial		
Home	1	5
Distant	1	15
Angling	13	1
Escapement	16	3
Total	31	31
Rate of Recovery	0.8%	

Table 8. Numbers of returns of smolts tagged in Newfoundland rivers from 1960 to 1968. Data from May (1971).

Years 1960 - 1968

Native fish
Total No. = 19868

Fishery Caught in	Recaptured as Grilse	Salmon
W. Greenland		0
Commercial		
Home	19	5
Distant	49	1
Angling	22	1
Escapement	30	1
Total	120	8

Rate of Recovery 0.64%

Table 9. The percentage utilization of salmon and grilse in Greenland and other distant (mostly Newfoundland) waters. Data from Table 3 and 4 for Northwest Miramichi, Part A, and from Table 7 for Nova Scotia, Part B.

Part A, New Brunswick

Place of Capture	Percentages by years 1950 - 1960	1960 - 1963	1964 - 1965	1966 - 1968
Native Salmon				
Distant	20	17	10	15
Greenland	0	13	24	22
Hatchery Salmon				
Distant		40*	26	26
Greenland	0	7*	23	16
Native Grilse				
Distant	18	4	6	7
Hatchery Grilse				
Distant	0	13	25	25
Part B, Nova Scotia				
Hatchery Salmon				
Distant		23*	30	24
Greenland	0	15*	19	52
Hatchery Grilse				
Distant		20*	14	41

* based on total returns which number less than 50 fish.

Table 10. Numbers of grilse and salmon ascending at the Curventon Counting Fence and the subsequent production of young and eggs.

Year	No. ascending the year before Salmon	Grilse	No. of under-yearlings	No. of Small Parr	No. of Large Parr	Smolt Run	Egg Deposition in millions
	1	2	3	4	5	6	7
1950			5.6	3.5	0.5		
1951	720	1931	24.9	15.7	8.9	33451	4.31
1952	387	2113	19.8	19.3	11.6	849[1]	3.24
1953	1302	2148	22.1	27.8	12.2	25269	6.64
1954	1030	2165	1.0	4.8	7.0	25429	5.65
1955	1055	2601	53.3	1.0	2.6	25728	6.12
1956	783	2756	11.2	37.6	1.4	13251	5.25
1957	561	762	14.7	20.6	13.0	831[1]	2.72
1958	706	875	20.7	12.6	6.1	18327	3.35
1959	580	2420	33.9	18.6	9.8	19241	4.21
1960	1002	7357	12.5	14.2	10.4	32[1]	10.00
1961	377	2712	6.7	14.2	8.9	402[1]	3.72
1962	879	952	26.3	2.8	9.2	18559	4.05
1963	223	2285	13.1	19.3	5.9	6716	2.78
1964	311	6085	17.6	11.3	13.2	28929	6.37
1965	146	5125	13.9	11.0	10.3	32504	4.93
1966	120	1689	5.9	14.8	12.4	22749	1.89
1967	111	2990	10.6	4.5	11.3	30892	2.97
1968	171	1809	16.7	4.9	6.8	51161	2.18
1969	74	971	1.2	6.8	6.3	12878	1.11
1970	129	2453	34.2	4.9	4.5	17675	2.58
1971	105	731	4.4	5.9	8.6	15322	1.01

Columns 1 and 2: Data from Henderson et al (1965) for 1950 to 1963, for the later years from Elson (unpublished manuscript F.R.B., St. Andrews).

Columns 3 to 5: Data from Elson (unpublished manuscript, F.R.B. St. Andrews). The figures are average numbers per 100 square yards with lower and upper sections of the Northwest Miramichi weighted equally.

Column 6: Data from the same source as for columns 1 and 2.

Column 7: Egg deposition = 800{9.21 x .5(no. of salmon ascending) + 3.22 x .333(no. of grilse ascending)}

[1] Not used in regression analysis in Table 12.

Table 11. Estimated smolt production of Miramichi from 1951 to 1971.

Column	(1)	(2)	(3)	(4)	(5)
Year	No. finclipped	No. tagged	No. of smolts at Millbank	No. recap. at Millbank	Estimated smolt prod. in millions
	M	M	n	m	
1951	48373		1671	48	1.7
1952	1309		3998	0	2.3[2]
1953	45214		17615	989	0.8
1954	45914		35592	1068	1.5
1955	38792		76818	2265	1.3
1956	21863		58215	679	1.9
1957	779		25118	17	1.2
1958	28853		69855	776	2.6
1959	26426		4937	209	0.6
1960	3429		40823	47	3.0
1961	597		18906	20	0.6
1962	16737[1]		44826	237	3.2
1963		8958	49723	49	2.2[3]
1964		24499	16472	79	5.1
1965		30184	31930	194	5.0
1966		40566	9085	366	1.0
1967		41720	20555	313	2.7
1968		55093	6414	65	5.4
1969		63214	4927	793	0.4
1970		47665	8698	346	1.2
1971		18950	2431	36	1.3

Column (1): Data from Kerswill (1971).

Column (2): Data from Elson (unpublished manuscript, FRB, St. Andrews), cf. May (1971). Figures include both native and hatchery-reared smolts.

<u>Table 11 continued.</u>

Column (3) & (4): Data from Elson (unpublished manuscript, FRB., St. Andrews), some of the earlier data given in Kerswill (1971).

Column (5): Petersen estimate = Mn/m

[1] Not included in Kerswill's article because of the 1961 cut-off date.

[2] No Petersen estimate available. The value given is calculated from the regression of smolt run at Miramichi on landings in New Brunswick and Greenland, Table 12, Part A.

[3] The Petersen estimate comes to 9.9 million smolts. This was judged totally unreasonable in the light of subsequent landings (Table 1) or of numbers of smolts descending at Curventon. Instead two estimates, one based on the regression of smolt run on landings, and the other based on the regression of smolt run on numbers descending at Curventon were used; the two regressions gave the estimates 3.6 and 0.8, the average 2.2 being the one used in the Table.

Table 12. The regression of estimated smolt run (Table 11) on the New Brunswick commercial landings two years later (Table 1) and on the numbers descending at Curventon. The regressions are used only to estimate the smolt run at Millbank for 1952 and 1963.

Part A Y = smolt run from Table 11, X = New Brunswick commercial landings two years later. The years 1952 and 1963 have been excluded.

Regression Analysis

Variable	Regr. Coeff.	Std. Dev.	t-ratio
Const.	-0.2696		
X	0.0035	0.00104	3.39**

$r^2 = 0.812$

Part B Y = smolt run from Table 11, X = numbers descending at Curventon. The years 1952, 1957, 1960 and 1961 have been excluded.

Regression Analysis

Variable	Regr. Coeff.	Std. Dev.	t-ratio
Const.	0.061		
X	0.000088	0.000031	2.92**

$r^2 = 0.611$

** Significant at 1% level.

Table 13. **Regression analysis of the density of underyearlings on the numbers of grilse and salmon the year before (Part A) and the density of underyearlings on the estimated egg deposition (Part B).**

Part A Y = the number of underyearlings (Table 10), X_1 = numbers of salmon ascending, X_2 = numbers of grilse ascending at Curventon. Data smoothed by taking three-year running averages.

Regression Analysis

Variable	Regr. Coeff.	Std. Dev.	t-ratio
Const.	8.17		
X_1	0.014	0.0024	5.92**
X_2	0.0003	0.0008	0.405

$R^2 = 0.818$

Part B X = the estimated egg deposition, Y = numbers of underyearlings.

Regression Analysis

Variable	Regr. Coeff.	Std. Dev.	t-ratio
Const.	5.06		
X	2.73	0.694	3.94**

$r^2 = 0.691$
(0.619)[a]

** Significant at 1% level.

[a] The second correlation coefficient is based on a differently calculated three-year running average. In the first instance the successive years are grouped in the second the data is arranged in ascending order in X prior to calculating the three-year running average.

Table 14. Regression analysis of the abundance of young salmon on their abundance in the previous year. Data from Table 10 and Table 11. Figures based on three-year running averages.

Part A Y = number of small parr, X = number of underyearlings a year before.

Regression Analysis

Variable	Regr. Coeff.	Std. Dev.	t-ratio
Const.	-0.128		
X	0.779	0.15	5.37**
			r^2 = 0.793 (0.846)[a]

Part B Y = number of large parr, X = number of small parr a year before.

Regression Analysis

Variable	Regr. Coeff.	Std. Dev.	t-ratio
Const.	7.000		
X	0.118	0.104	1.13
			r^2 = 0.265 (0.693)[a]

Part C Y = smolt production, X = number of large parr a year later.

Regression Analysis

Variable	Regr. Coeff.	Std. Dev.	t-ratio
Const.	0.585		
X	0.187	0.092	2.05*
			r^2 = 0.445 (0.397)[a]

** Significant at 1% level.

* Significant at 5% level, one-sided test.

[a] See footnote *a* for Table 13.

Table 15. Sea ages of commercially caught salmon in New Brunswick, Nova Scotia and Newfoundland.[1]

New Brunswick

Years grouped	No. of salmon at sea age 1 yr	2 yrs	3 yrs	4 yrs	Ave. age
1949 - 54	52	1686	228	1	2.09
1955 - 60	245	5287	363	8	2.04
1961 - 64	631	2127	262	7	2.00
Total	928	9100	853	16	

Nova Scotia

1949 - 64	38	40	9	0	2.00

Newfoundland

1949 - 54	102	427	35	0	1.99
1955 - 60	309	985	44	0	1.97
1961 - 64	102	223	11	0	1.96
Total	513	1635	90	0	

[1] Data source same as used in Allen (1967).

Table 16. Regression analysis of total landings from New Brunswick salmon stock on the estimated total smolt production of the Miramichi. A three-year running average has been used in all cases.

Part A Y = total New Brunswick commercial landings in 1000 pounds two years later, X = smolt production at Miramichi in millions of fish.

Regression Analysis

Variable	Regr. Coeff.	Std. Dev.	t-ratio
Const.	249.11		
X	226.96	46.47	4.88**

$r^2 = 0.784$

Part B Y = total New Brunswick commercial landings two years later + 0.11(Greenland catches a year later) in 1000 pounds, X = smolt production.

Regression Analysis

Variable	Regr. Coeff.	Std. Dev.	t-ratio
Const.	45.85		
X	376.95	38.68	9.75**

$r^2 = 0.929$

Part C Y = total New Brunswick commercial landings two years later + 0.2 (Greenland catches a year later) in 1000 pounds, X = smolt production.

Regression Analysis

Variable	Regr. Coeff.	Std. Dev.	t-ratio
Const.	-120.45		
X	499.66	44.32	11.27**

$r^2 = 0.946$

** Significant at 1% level.

Table 17. Landings per smolt production. Data from Table 11 and Table 1.

Year	Commercial[1] Landings	Total Commercial Landings 1954-1963	Smolt Production two years earlier	Total Smolt Production two years earlier	Landings[2] Per Smolt Production
1954	879.0		2.3		
1955	349.0		0.8		
1956	422.0		1.5		
1957	500.0		1.3		
1958	613.0		1.9		
1959	786.0		1.2		
1960	642.0		2.6		
1961	630.5		0.6		
1962	791.0		3.0		
1963	770.6		0.6		
		6383.1		15.8	404.0
		1963-1971			
1964	1268.5		3.2		
1965	1911.6		2.2		
1966	1625.6		5.1		
1967	2052.1		5.0		
1968	1503.9		1.0		
1969	1082.9		2.7		
1970	1548.4		5.4		
1971	1219.2		0.4		
		12212.2		25.0	488.5

[1] N.B. landings + 0.2* Greenland landings one year earlier.

[2] Calculated by dividing total landings by estimated total smolt production for 1954 to 1963 and for 1964 to 1971.

Table 18. Number of salmon and grilse caught at Millbank in research operated estuarial traps from 1954 to 1971 and the estimated egg deposition represented by these catches. Data from the Fisheries Research Board of Canada, St. Andrews, and the Resource Development Branch, Halifax. Sex ratios used - salmon 1:1; grilse 2M:1F.

Year	No. of Salmon	No. of Grilse	Potential Egg[1] Deposition
1954	2130	1833	9.42
1955	2882	1818	12.18
1956	3361	3434	15.33
1957	4187	4159	18.99
1958	4625	8581	24.40
1959	2872	1931	12.24
1960	5123	4708	22.91
1961	3073	6944	17.28
1962	1992	3293	10.09
1963	1834	14455	19.15
1964	1008	8945	11.38
1965	1818	15791	20.24
1966	1793	9818	15.03
1967	1014	7693	10.33
1968	1415	3218	7.97
1969	659	4325	6.14
1970	213	2427	2.87
1971	382	1960	3.09

[1] Calculated as in Table 10.

Table 19. Regression analysis of potential egg deposition per smolt production on New Brunswick commercial landings per smolt production 2 years earlier and on Greenland landings one year earlier per smolt production 2 years earlier.

Part A

Y = egg deposition/smolt production two years earlier,
X_1 = New Brunswick landings/smolt production two years earlier,
X_2 = Greenland landings one year earlier/smolt production two years earlier.

Variable	Regression Analysis Regr. Coeff.	Std. Dev.	t-ratio
Const.	0.425		
X_1	0.025	0.00578	4.32**
X_2	-0.002	0.00065	-3.28**

R^2 = 0.859

Part B

Y = salmon escapement/smolt production two years earlier,
X_1 and X_2 as in Part A.

Variable	Regression Analysis Regr. Coeff.	Std. Dev.	t-ratio
Const.	1442.56		
X_1	1.63	1.56	1.04
X_2	-0.59	0.18	-3.32**

R^2 = 0.730

** Significant at 1% level.

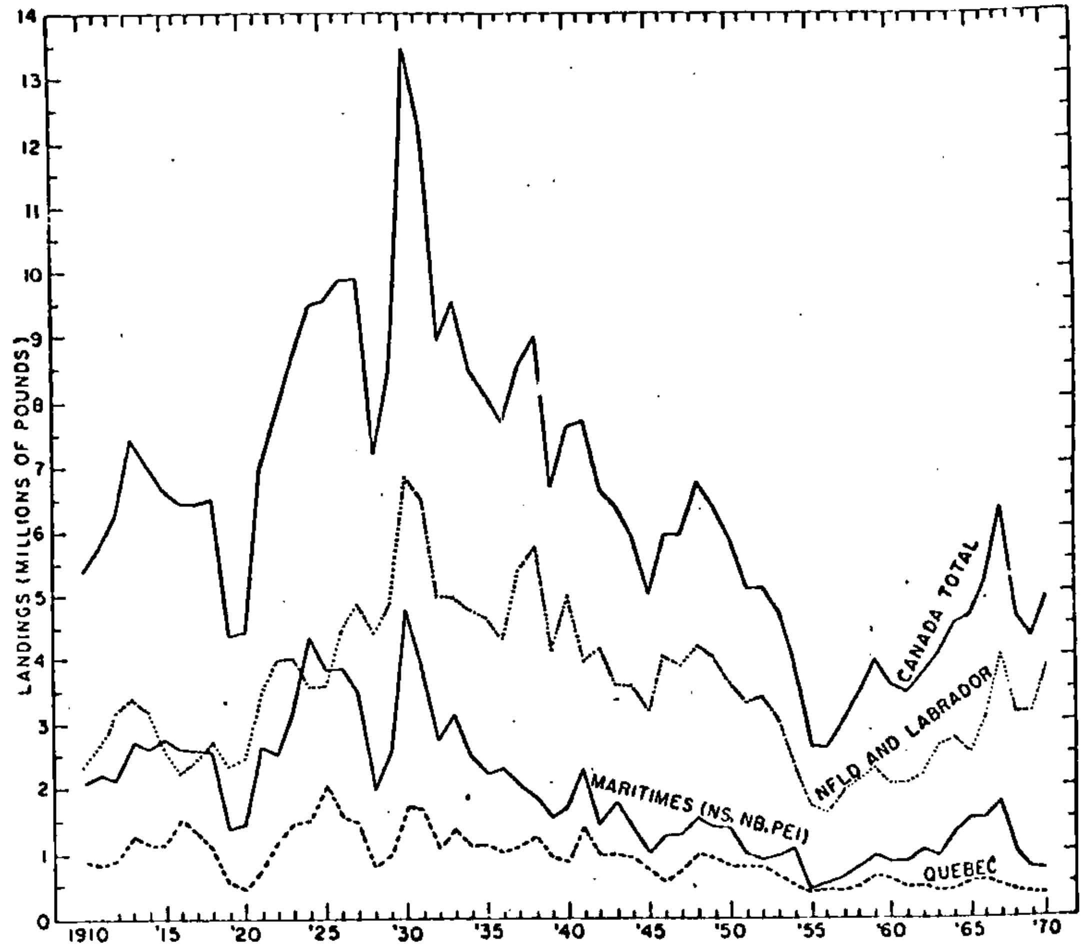

Fig. 1 Commercial salmon landings on the Canadian East Coast since 1910. Figure from May & Lear (1971)

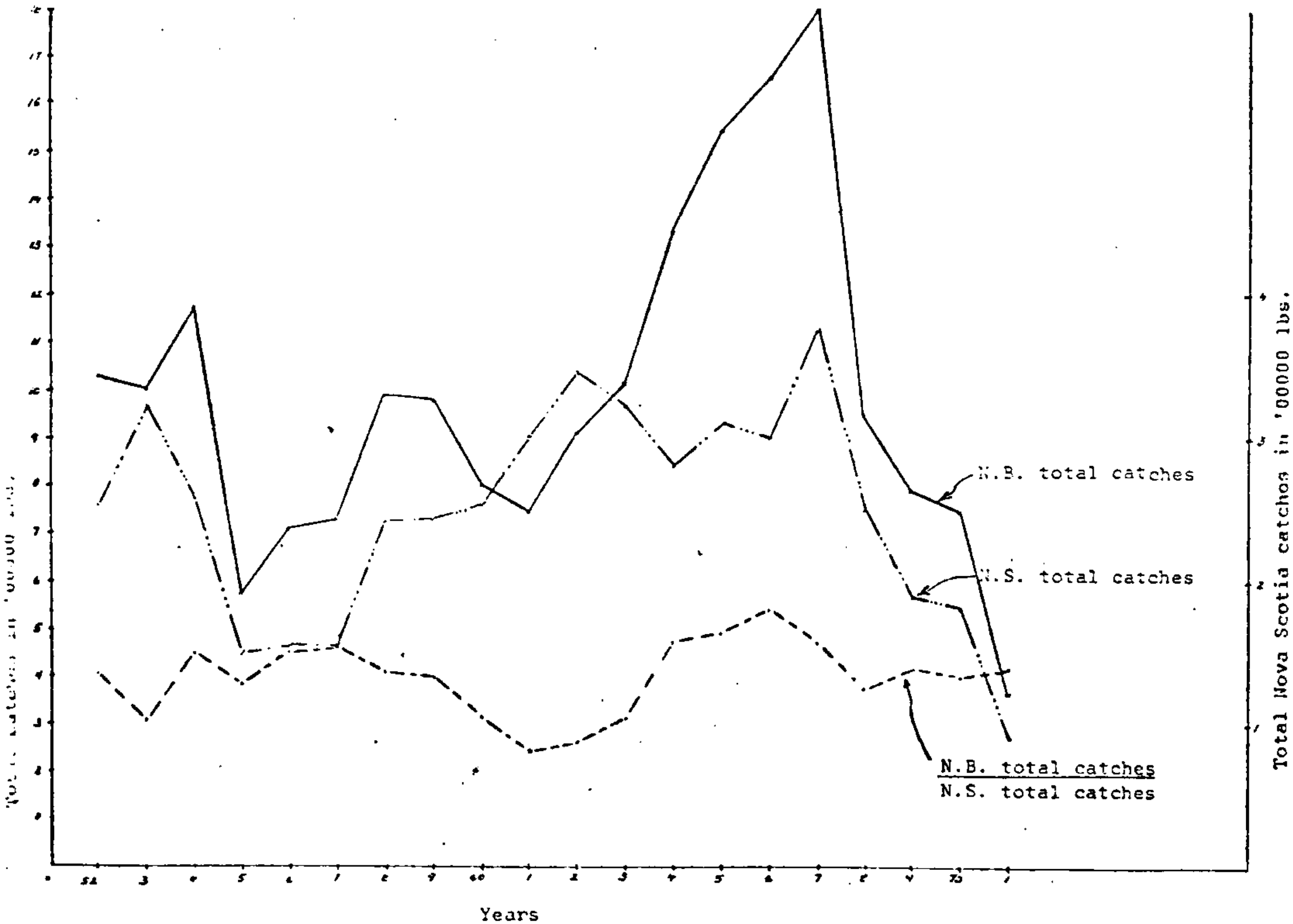

Fig. 2 Total landings in New Brunswick and Nova Scotia from 1952 to 1971.

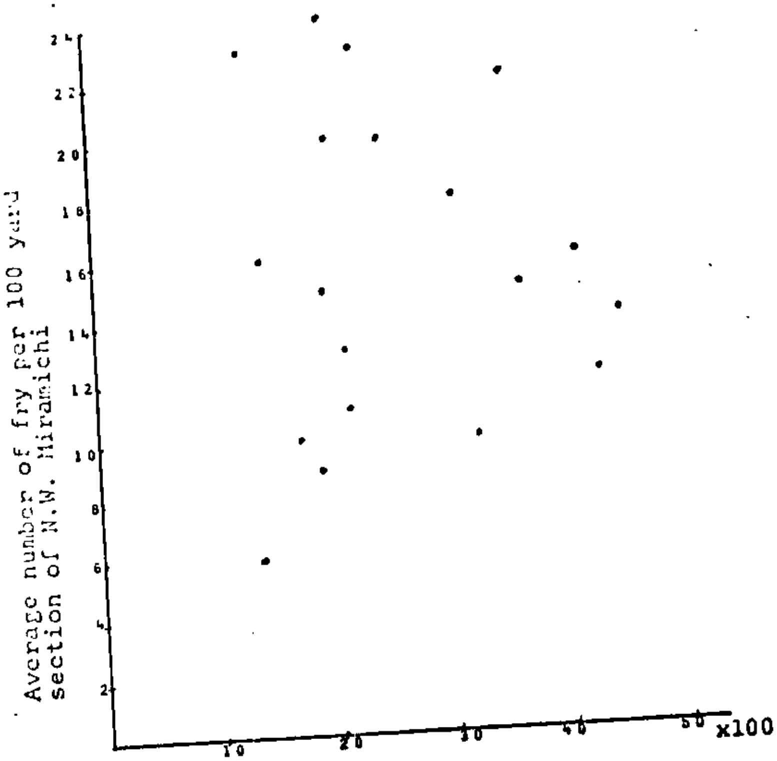

Fig. 3. Correlation between númbers of fry and numbers of grilse.

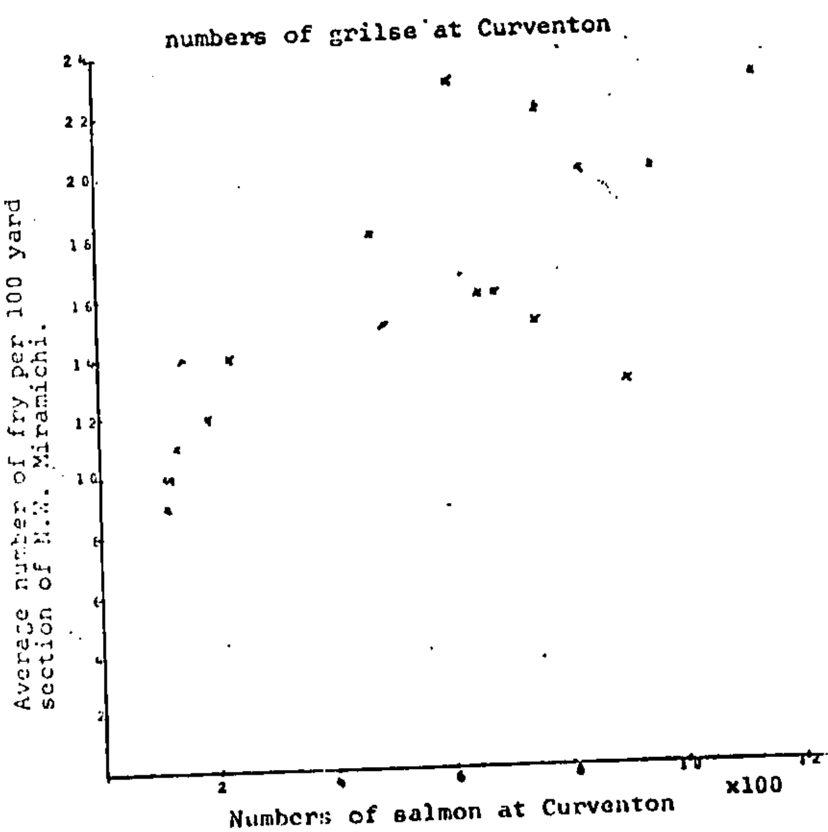

Fig. 4. Correlation between numbers of fry and numbers of salmon.

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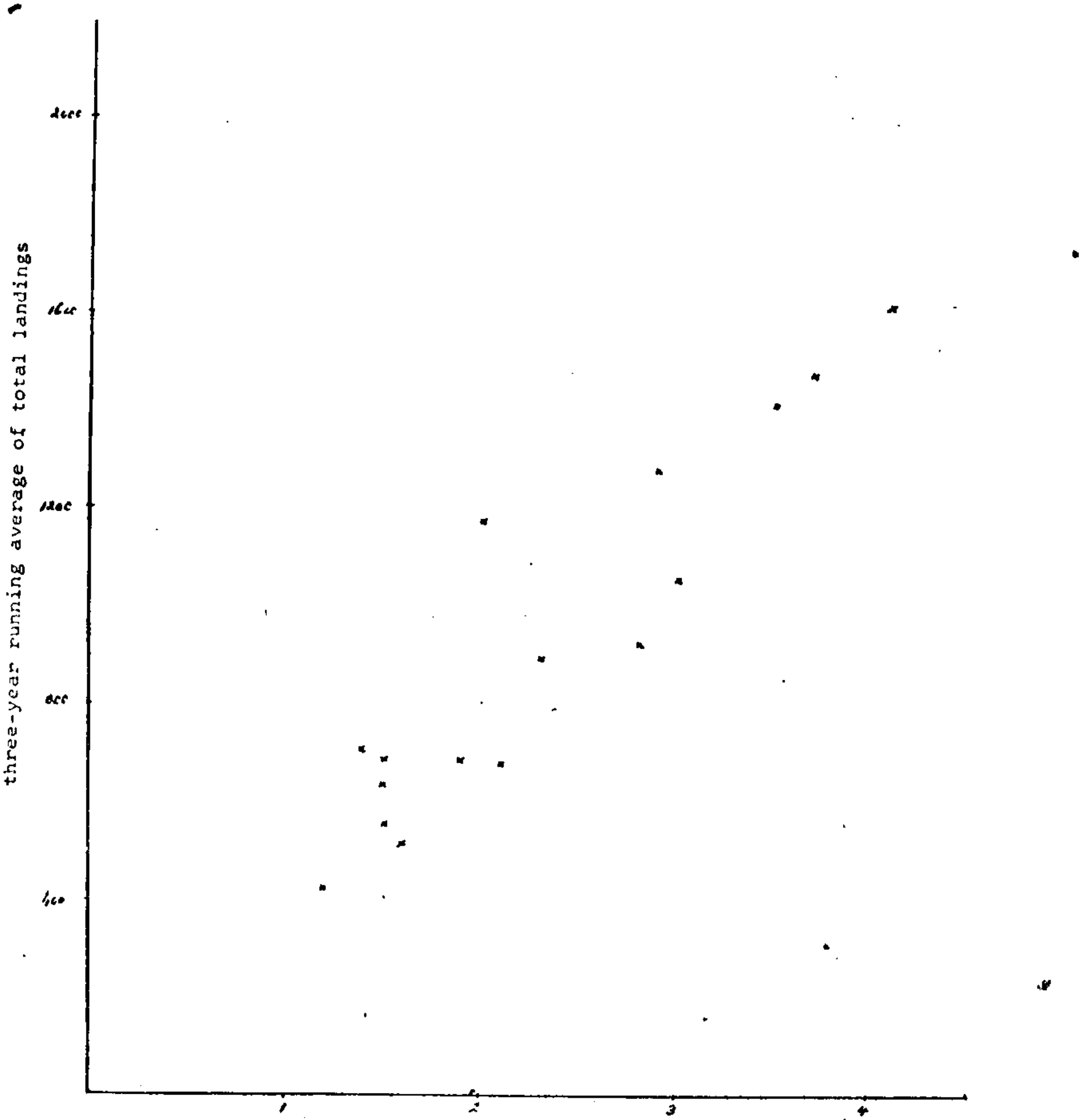

Fig. 5. The relationship between estimated smolt production and subsequent commercial landings. The landings plotted are the total New Brunswick landings two years later plus 0.2 times the Greenland landings one year later.