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Application of a stock-recruitment model to assess the Labrador Atlantic salmon fishery

by

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Abstract

The Labrador salmon fishery was in a general increasing phase. Grilse catches by the recreational fishery were highly correlated with large salmon escapement the following year. A stock-recruitment model indicated that at present low levels of recreational harvesting, a sustainable commercial yield of 619 MT was possible.

Page 2, Methods Section, 4th paragraph

The equation should read: $R = P\, e^{a(1-P/Pr)}$

Page 2, 7th line from bottom should read:

a represents the ratio of spawners required . . . . .

Page 4, 2nd paragraph, 2nd line should read:

. . . . . The parameters $a(4.92400)$

Page 7, last line should read:

a = 4.92400 Pr = 16,397

International Council for
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Introduction

This paper summarizes catch and effort statistics for the Labrador commercial and recreational fisheries, then evaluates the status of the Labrador component using the stock-recruitment model of Ricker (1954, 1975).

Catch and Effort Statistics

Catch statistics from the Labrador commercial and recreational fisheries have been available since 1952 and 1954 respectively (Appendix 1). The commercial landings from 1952 to 1970 show little change during this period, averaging 358 metric tons per year. From 1971 to 1977 catches generally increased, averaging 673 MT with a peak of 756 MT in 1976 (Fig. 2a). Landings have subsequently decreased to a low of 326 MT in 1979. Landings by statistical section (Fig. 1) have been available since 1969 (Table 1). Apart from year-to-year fluctuations and a decline in the last two years, no trends are apparent (Table 1).

Coincident with the increase in total landings was a progressive increase in effort. Gear available to the fishery during the period 1971-79 has increased an average of 45% from 1959-70 (Fig. 2b). However, catch per unit effort, as tested by ANOVA, was not significantly different between the respective periods ($F_{1,19} = 1.19$, $P = 0.29$). It should be noted, that prior to 1971 effort statistics for Labrador are questionable (G. Rendell pers. comm.).

The Labrador recreational salmon fishery has developed in three stages. During the first period, 1954-62, effort averaged 668 rod-days per year (Moores et al. 1978). From 1963 to 1970 effort increased substantially to an average of 3560 rod-days per year, while during the most recent stage, 1971-79, effort averaged 6000 rod-days per season (Appendix 1).

Recreational catches have similarily increased to an average of 4946 fish per year during the latter period (Fig 3a). Catch per unit of effort has declined from the initial years, however, it has remained relatively constant since 1964 (Fig. 3b). In general, the Labrador recreational fishery plays a minor role in the overall provincial fishery contributing less than 13% and 6% of the catch and effort resepectively.

Stock Composition

Data pertaining to the proportion of grilse and large salmon in the Labrador commercial catch have been available since 1969. The large salmon component represented approximately 80% of the catch by weight. There were no significant differences (ANOVA) in the proportion of large salmon in the landings when the two periods 1969-73 and 1975-79 were compared for individual areas or the combined Labrador catch ($F_{1,8} = 2.17$, $P = 0.18$).

With respect to the recreational fishery, similarly no significant differences were found in the grilse:salmon ratio when comparing individual statistical sections or the total Labrador recreational harvest between the period 1954-63 and 1970-79 ($F_{1,18} = 1.32$, $P = 0.27$). The proportion of grilse ranges from 67% by number in section 53 to 94% in section 51. The combined recreational harvest was approximately 85% grilse by number.

Methods

In order to establish the relationship between the commercial and recreational fishery a least squares regression was fitted to angling catch on commercial harvest for the years 1954-79. A six year running average of the data removed year to year fluctuations and provided the best fit to the regression.

Following this the relationships between the grilse run in one year, in terms of angling catch, and the large salmon run in the succeeding year were examined by linear regression. Six-year running averages were also used in clarifying these associations for individual statistical sections and the combined Labrador angling harvest for the years 1954-79. These correlations of year-class strength were used as an index in predicting the large salmon run for the 1980 season based upon the 1979 grilse catches.

Mean weight for grilse and salmon derived from 1975-77 commercial fishery data were used in estimating number of grilse and salmon in the commercial catches. Prior to 1969 only total catch information was available thus the grilse:salmon ratio for 1969-73 was applied to previous years data in order to back-calculate numbers of grilse and large salmon in the commercial fishery.

The stock recruitment model of Ricker (1954, 1975) employed to determine maximum sustainable yield for the commercial fishery was of the form:

$$R = P\, e^{(1-P/Pr)}$$

where R represents the number of recruits; P is the size of the parent stock; represents the ratio of spawners required for replacement to those required for maximum reproduction, and Pr is the replacement abundance of stock (Ricker 1977).

For the Labrador assessment, recreational salmon catches were used as an index of parental stock. Mean age calculated for Labrador salmon smolts was 4.3 years (unpublished data) and assumed constant, thus recruitment from the parent stock was the number of grilse in the commercal catch six years later plus

the number of large salmon caught after seven years. In order to use the grilse catch for the 1979 fishery, an estimate of the 1980 large salmon catch was calculated based upon the mean proportion of grilse in the landings during the past 5 years. Similarily, the MSY derived from the model was converted into respective numbers of grilse and salmon using this relationship.

An estimate of the rate of exploitation by the angling fishery was derived from recreational fishing statistics and counting fence runs from the Sand Hill River, 1970-74 (Pratt et al. 1974), and was used for sections 51, 52, and 53. No significant differences were found between years and therefore data were pooled to obtain an average exploitation rate ($F_{1,6} = 0.0415$, $P = 0.85$). As a result of the greater angling pressure on rivers in section 50, an exploitaton rate derived for insular Newfoundland was chosen for this area. These two rates were 0.0624 and 0.28 respectively, and were employed to convert index of necessary spawners, Ps, into total river escapement subdivided by statistical section.

An independent estimate of salmon production and available harvest was derived from exploitation rates in the commercial and recreational fisheries. Exploitation rates for grilse and large salmon in the home fishery were $\mu = 0.45$ and $\mu = 0.92$ respectively, and for the Greenland fishery $\mu = 0.22$ (Reddin, pers. comm). Predictions of large salmon catches by the recreational fishery for 1980 were employed to determine Ps values, and subsequently an estimate of the spawning escapement for 1980. Thus by employing the same exploitation rates, predictions of the salmon stock size and available harvest to the 1980 commercial and recreational fisheries were derived. Appendix 3 outlines calculations used to derive available production and harvest.

Results and Discussion

Fig. 4 illustrates the relationship between the commercial and recreational salmon fishery along the Labrador coast. Even when data are not averaged to remove year to year fluctuations the correlation ($r = 0.71$) is still significant ($P < 0.01$). Thus the relationship substantiates the use of these data in the stock-recruitment model and provides a simple index of abundance of the available spawning stock. In years where commercial catch is large, river escapement is similari y high as evidenced by the recreational catch.

Grilse catches by the recreational fishery appear promising as a method of estimating large salmon escapement for the following year. The relationships between grilse catch in one year and the large salmon catch the succeeding year are outlined in Fig. 5. As indicated very significant relationships were found for each statistical section as well as the combined Labrador stock. Correlation coefficients ranged from 0.62 to 0.95, the former for section 51, least important in terms of the recreational fishery with catches contributing less than 5% of the Labrador total during the past five years. If this relationship holds, grilse catches for 1979 suggest an improvement in the large salmon catches and subsequently escapement for the 1980 season.

Mean weight derived for grilse and salmon was 1.95 and 4.7 kg (round condition) respectively. Estimated number of grilse and large salmon in the commercial catches for the years 1952-79, along with the stock and recruitment data used for the Ricker model are listed in Table 2.

The regression of log R/P against parent stock, P, was significant ($P < 0.001$) and $r = 0.87$ for the relationship (Fig. 6). The parameters (4.92400) and Pr (16,397) were derived from the slope and intercept following the method of Ricker (1975). Fig. 7 illustrates the arithmetic mean transformation recruitment curve with recruitment plotted against parental stock. The index of the spawners required is 3265. From this the maximum sustainable yield was calculated to be 174,142 salmon.

The proportion of grilse in the commercial catch for the past five years was 41.7% by number. By converting the MSY into respective numbers of grilse and salmon, a total harvest of 618,771 kg results. This would represent a substantial increase in the commercial landings over the previous two years, however, 15% lower than the peak landings of 1974-77. Although this figure represents a catch primarily derived from Labrador stocks, a proportion of it is comprised of stocks produced in other areas.

The mean exploitation rate by the recreational fishery is 0.0624 except for section 50, where 0.280 was employed. Table 3 summarizes the index of required number of spawners, Ps, and estimated spawning escapements by statistical section. Results from this assessment indicate a total escapement of 35,907 is required to produce the MSY of 174,142 salmon. At present this represents an average production to the commercial fishery of 4.85 salmon per spawning fish.

Appendices 2a and 2b summarize the predicted stock size of salmon and available harvest for the 1980 season as estimated using the commercial and recreational exploitation rates.

Conclusion

Apart from the decreased landings of the commercial fishery during the last two years, the Labrador salmon fishery is in a general increasing phase. The high proportion of large salmon in the commerical catch may be of some concern and should be monitored in order to detect significant changes in the present grilse:salmon ratio. The stock-recruitment model indicates that at present low levels of recreational harvesting, a sustainable commercial yield of 619 MT is possible. This figure represents a harvest primarily of Labrador origin fish and corresponds particularly well to the average commercial catch for the years 1970 to 1978 (623 MT). In addition, the value also falls within the 95% confidence limit of the available commercial harvest as calculated using exploitation rates. This alternative method of predicting stock size for 1980 suggests a commercial harvest of 578 ± 56 MT, and a total recreational harvest of 13 ± 1 MT. It should be noted, however, that the former value represents an available harvest to both the Labrador and east coast Newfoundland fisheries.

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Table 1. Summary of Labrador Atlantic salmon commercial catch (kg x 1000) and effort (gear units) data by statistical section, 1969-79.

	Statistical section									
	50		51		52		53		Total	
Year	catch	effort	catch	effort	catch	effort	catch	efffort	catch	effort
1969	30	356	154	-	232	-	46	367	461	2208
1970	73	492	255	-	95	-	36	507	458	3052
1971	76	438	250	-	245	-	71	452	641	2720
1972	71	450	268	-	145	-	55	465	537	2795
1973	67	241	211	1320	217	821	149	594	653	2976
1974	96	240	452	-	119	-	47	415	714	2741
1975	100	434	303	1493	184	671	118	556	705	3154
1976	96	503	297	1595	195	823	169	549	756	3558
1977	114	543	279	1344	197	909	123	612	712	3408
1978	63	557	189	1492	90	675	93	1001	435	3725
1979	32	613	92	1541	113	761	88	960	326	3875

Table 2. Stock and recruitment data with estimated number of grilse and salmon in the Labrador commercial landings, 1952-79.

Year	Parental stock P	Number of recruits R	Commercial landings Number of grilse	Number of salmon	kg x 1000
1952	-	-	30176	57267	328
1953	-	-	28244	53601	307
1954	754	99553	38180	72457	415
1955	532	99448	24180	46443	266
1956	374	89649	27968	53077	304
1957	1587	112458	28980	54998	315
1958	1445	103108	28152	53426	306
1959	1452	91452	30176	57267	328
1960	1034	111603	21160	40157	230
1961	1418	102987	41308	78393	449
1962	1373	112505	30636	58140	333
1963	1990	110601	31096	59013	338
1964	3206	158127	42872	81362	466
1965	2972	158402	31740	60236	345
1966	4021	161164	31454	59712	342
1967	2795	190408	42228	80139	459
1968	4441	160753	32016	60759	348
1969	3270	235562	33104	74665	461
1970	4575	205549	48194	77497	458
1971	4420	151991	63903	109934	641
1972	3371	76485	47850	94499	537
1973	8501	118342	61693	113314	653
1974			56104	128715	714
1975			109261	104647	705
1976			83412	126302	756
1977			70965	122137	712
1978			27829	81026	435
1979			49526	48656	326

= 4.92400 Pr = 16,397

Table 3. Summary of required number of spawners, Ps, estimated river and spawning escapement.

Section	Index of required spawners, Ps	Exploitation rate	Estimated river escapement	Estimated spawning escapement
50	1056	0.280	3771	2715
51	142	0.0624	2276	2134
52	1385	0.0624	22196	20811
53	682	0.0624	10929	10247
Labrador total	3265		39172	35907

Appendix 1. Summary of catch statistiacs for Labrador commercial and recreational fisheries.

	Commercial					Recreational				
Year	1	2	3	4	5	6	7	8	9	10
1952	328			30176	57267					
1953	307			28244	53601					
1954	415			38180	72457	754	167	4.51	476	278
1955	266			24472	46443	532	654	.81	280	252
1956	304			27968	53077	374	407	.92	177	197
1957	315			28980	54998	1587	686	2.31	1250	337
1958	306			28152	53462	1445	641	2.25	1375	70
1959	328	2165	152	30176	57267	1452	761	1.91	1320	132
1960	230	2184	105	21160	40157	1034	643	1.61	943	91
1961	449	2015	223	41308	78393	1418	1105	1.28	1180	238
1962	333	2062	162	30636	58140	1373	947	1.45	1250	123
1963	338	1457	232	31096	59013	1990	1303	1.53	1793	197
1964	466	2435	191	42872	81362	3206	2789	1.15	2570	456
1965	345	2367	146	31740	60236	2972	3422	.87	2345	627
1966	342	1798	190	31454	59712	4021	4619	.87	3315	706
1967	459	2262	203	42228	80139	2795	3337	.84	2206	589
1968	348	2430	143	32016	60759	4441	4054	1.10	3776	665
1969	461	2208	209	33104	74665	3270	3646	.90	2877	393
1970	458	3052	150	48191	77497	4575	5308	.86	4013	562
1971	641	2720	236	63903	109934	4420	4898	.90	3934	486
1972	537	2795	192	47850	94499	3371	5165	.65	2947	424
1973	653	2976	219	61693	113314	8501	8271	1.03	7492	1009
1974	714	2741	261	56104	128715	3304	5492	.60	2501	803
1975	705	3154	224	109261	104647	4299	4209	1.02	3972	327
1976	756	3558	213	83412	126302	6556	7155	.92	5726	830
1977	712	3408	209	70965	122137	5880	7234	.81	4594	1286
1978	435	3725	117	27829	81206	3458	6248	.55	2691	767
1979	326	3875	84	49526	48656	4727	5333	.89	4118	609

1. Commercial landings (kg x 1000)
2. Effort in gear units (1 unit = 50 fathoms of net)
3. Catch per unit effort (kg)
*4. Estimated no. of grilse in commercial landings
*5. Estimated no. of salmon in commercial landings
6. Recreational catch in number of fish
7. Effort in rod days
8. Catch per unit effort
9. Estimated number of grilse in recreational catch
10. Estimated number of salmon in recreational catch

* Prior to 1969 number of grilse and salmon were estimated by applying the grilse:salmon ratio for 1969-73.

Appendix 2a. Prediction of salmon production available to the 1980 recreational and commercial fisheries in numbers of fish.

Section	1	2	3	4	5	6	7
50	3783	5254	0.83	6814	11163	14312	21126
51	3005	3205	0.90	4508	4000	5128	9636
52	43319	46202	0.94	67859	34650	44423	112282
53	15071	16074	0.66	16577	68313	87581	104158
Labrador	65178	70735		95758	118126	151444	247202

1. Predicted spawning escapement.
2. Predicted river escapement.
3. Mean proporton of grilse as derived from recreatonal fishery 1975-79.
4. Estimated grilse stock size prior to home fishery, where $\mu = 0.36$.
5. Two-sea-winter salmon stock size prior to home fishery, where $\mu = 0.92$.
6. Stock size of two-sea-winter salmon prior to home fishery assuming no Greenland exploitation ($\mu = 0.22$).
7. Predicted total salmon production for 1980 (Col. 4 + Col. 6).

Appendix 2b. Predicted harvest available to 1980 recreational and commercial fisheries assuming present allocation and a Greenland exploitation of $\mu = 0.22$.

Section	Grilse				Salmon			
	Stock size	Availble harvest			Stock size	Available harvest		
		Recreational	Commercial	Total		Recreational	Commercial	Total
50	6814	1221	2453	3674	11163	250	10270	10520
51	4508	180	1623	1803	4000	20	3680	3700
52	67859	2710	24429	27139	34650	173	31878	32051
53	16577	662	5968	6630	68313	341	62848	63189
Labrador	95758	4773	34473	39246	118126	784	108676	109460

Appendix 3. Example of calculations used to derive avalable production and harvest.

Section	Ps	1	2	3	4	5	6
50	1056	2715	3771	0.83	4891	8013	10273

1056 ÷ 0.28 = 3771 = river escapement (2)
- 1056
2715 = spawning escapement (1)

3771 x 83% = 3130 grilse
3771 - 3130 = 641 salmon
3130 ÷ (1-0.36) = 4891 (4)
641 ÷ (1-0.92) = 8013 (5)
8013 ÷ (1-0.22) = 10273 (6)

Section	Grilse				Salmon			
	Stock size	Available harvest			Stock size	Available harvest		
		Recreational	Commercal	Total		Recreational	Commercial	Total
50	4891	876	1761	2637	8013	180	7372	7552

Stock size from Col. 4 and 5.
Available recreational harvest: 3771 - 2715 = 1056
1056 x 83% = 876 grilse
1056 - 876= 180 salmon
4891 x 0.36 = 1761; 1761 + 876 = 2637 Total available grilse harvest
8013 x 0.92 = 7372; 7372 + 180 = 7552 Total available salmon harvest
(4891 - 2637) + (8013 - 7552) = 2715 Spawning escapement

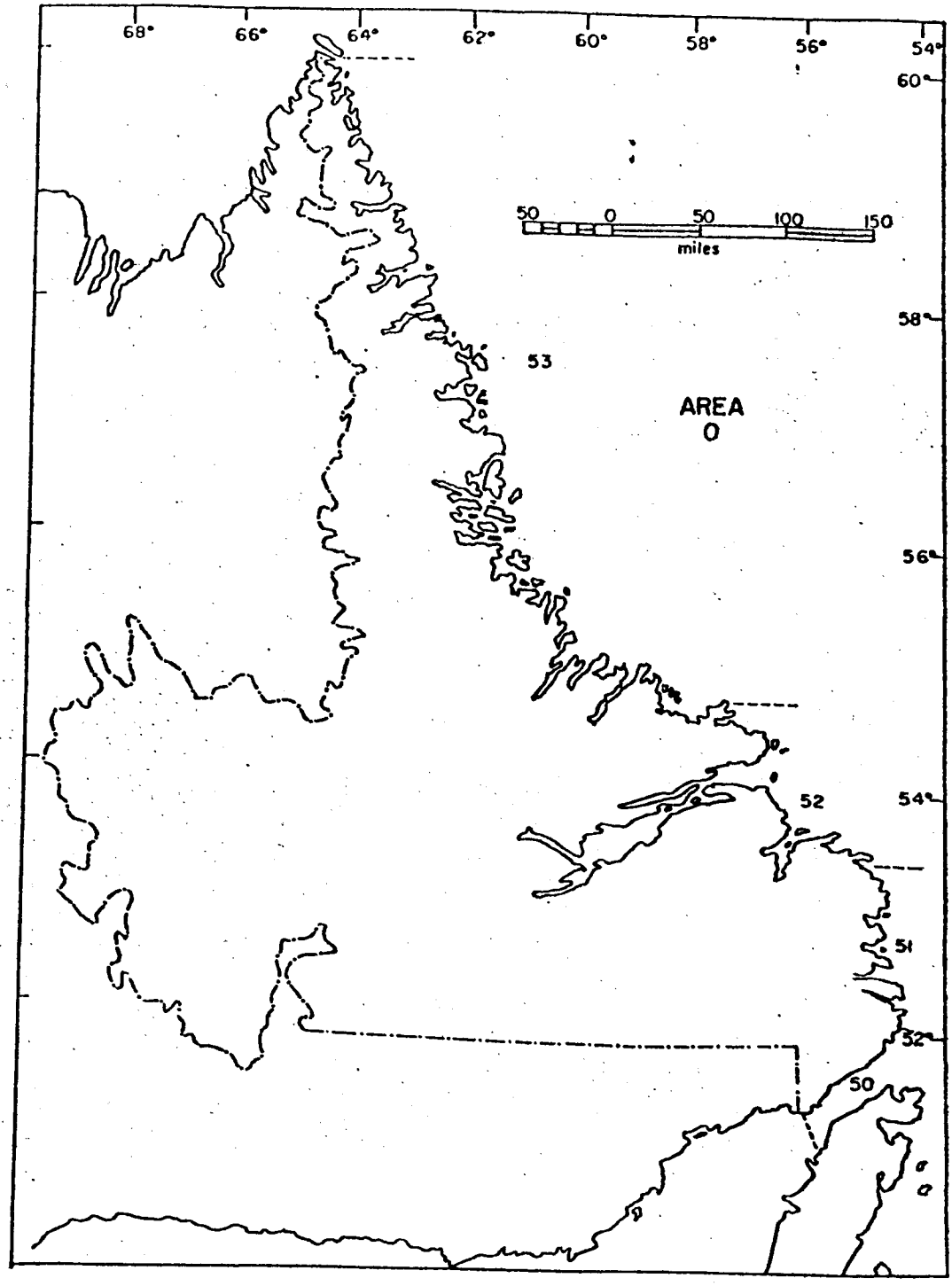

Fig. 1. Labrador with breakdown of statistical fishing sections.

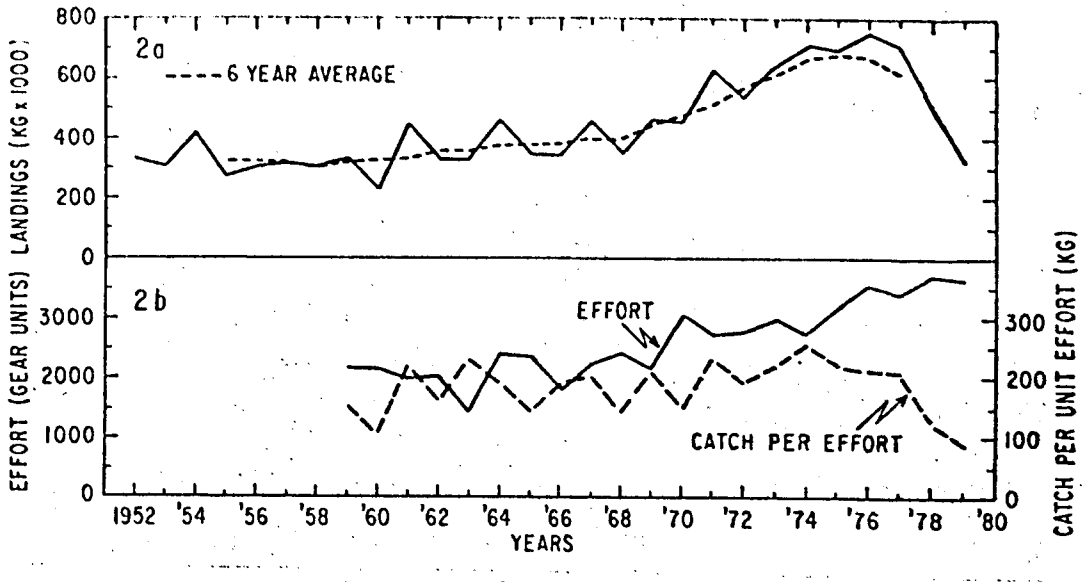

Fig. 2a. Commercial landings (kg x 1000) of Atlantic salmon in Labrador, 1952-1979.
2b. Effort (gear units) and catch per unit effort (kg) for the Labrador salmon fishery, 1959-1979.

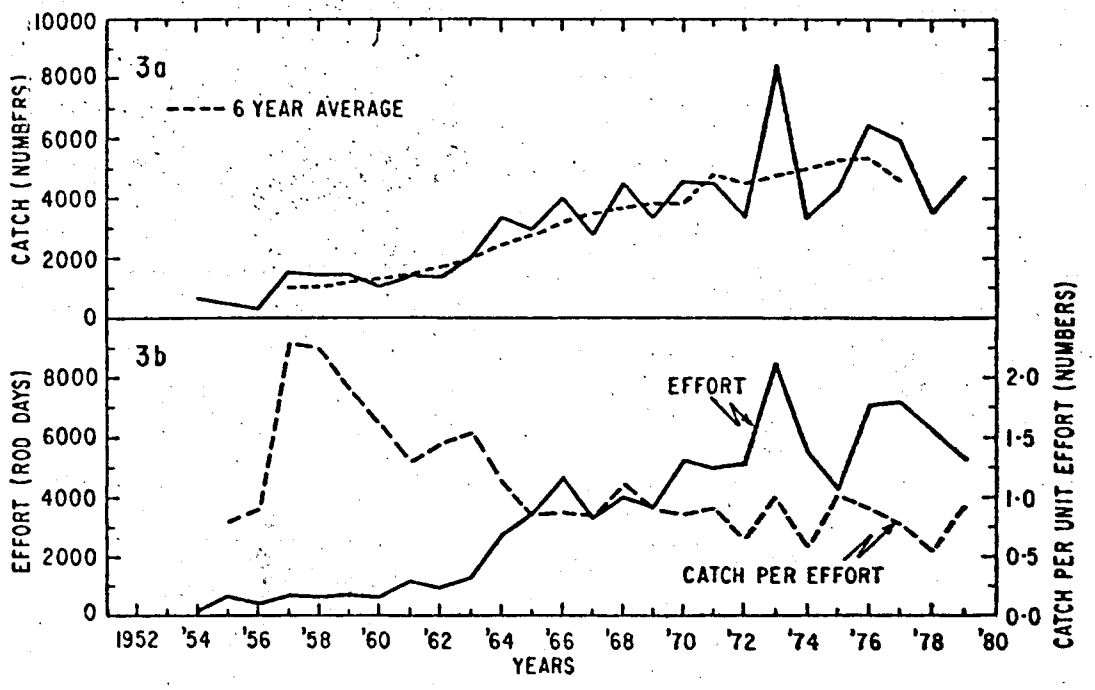

Fig. 3a. Recreational catch of Labrador Atlantic salmon, 1954-1979.
3b. Effort (rod days) and catch per unit of effort for the recreational fishery.

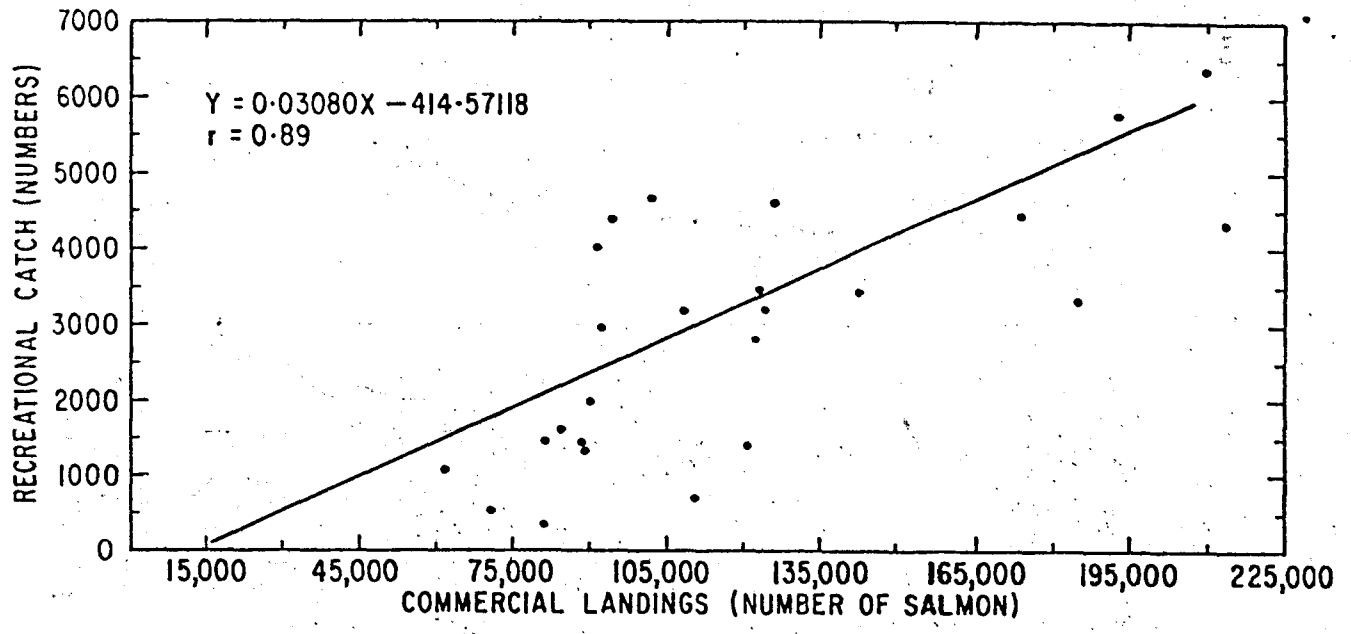

Fig. 4. Regression of recreational catch on commercial landings by six-year running average, 1954-1979.

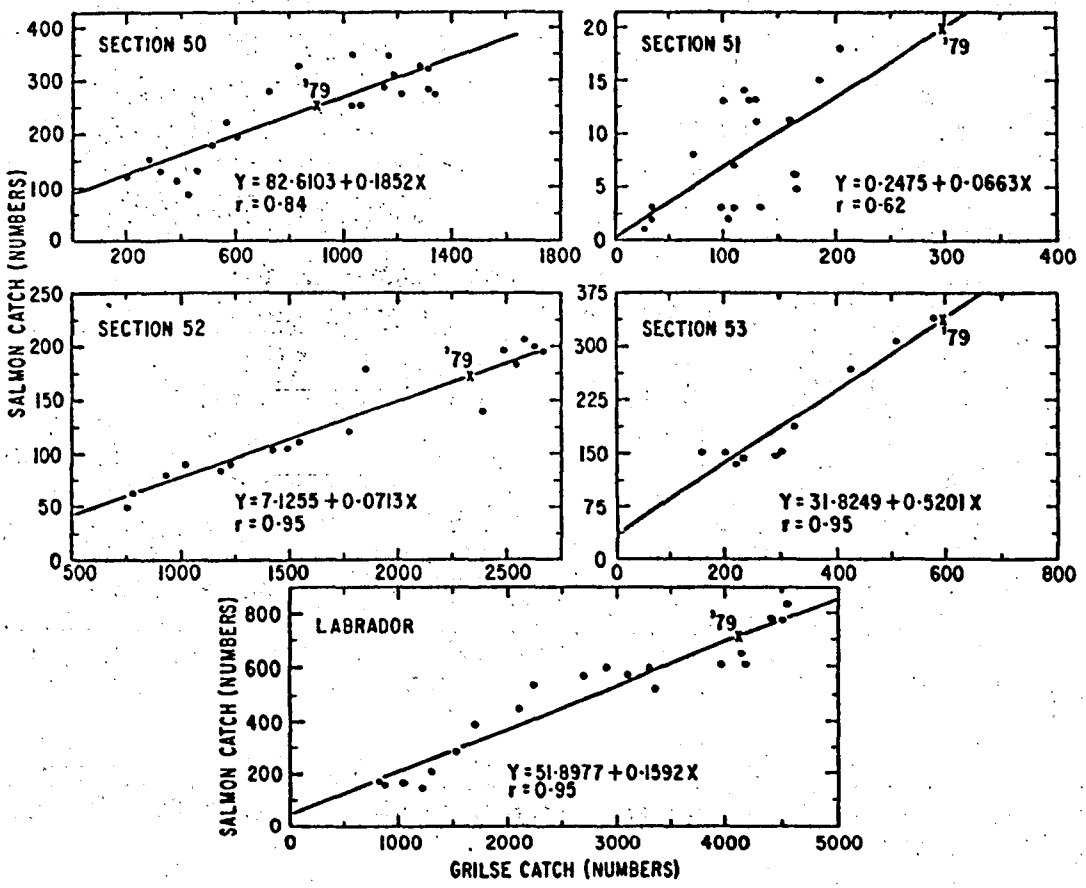

Fig. 5. Relationship between salmon angling catch in year i+1 with grilse catch in year i.

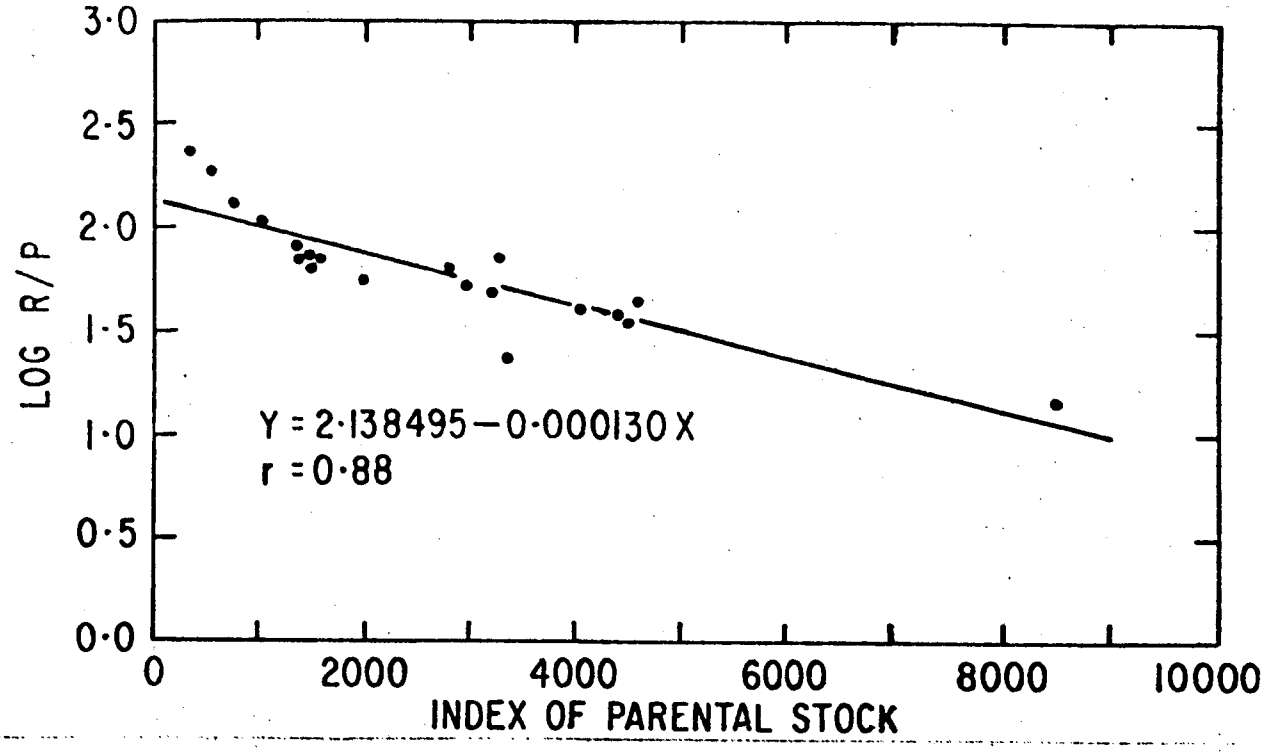

Fig. 6. Regression of log R/P against P.

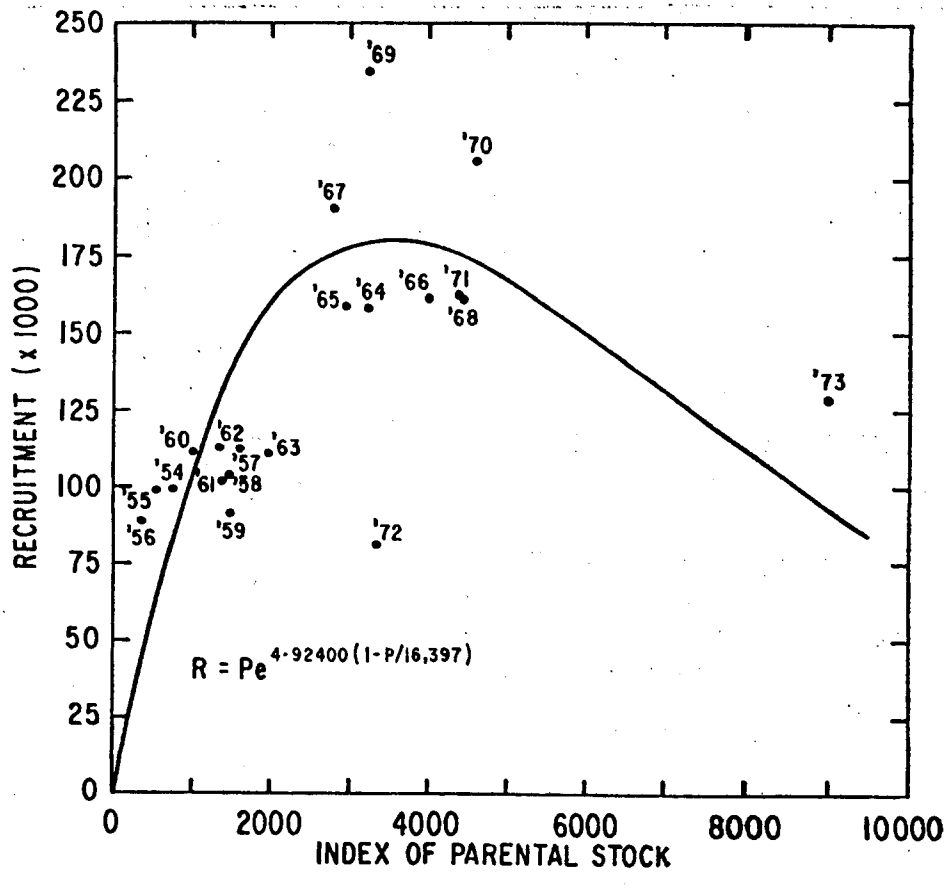

Fig. 7. Reproduction curve for Labrador Atlantic salmon using recreational salmon catch as an index of parental stock for brood years indicated.