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Evaluation of the impacts of major management changes in the Atlantic salmon (*Salmo salar* L.) fisheries of Newfoundland and Labrador, Canada, 1984–1988

M. F. O'Connell, J. B. Dempson, and D. G. Reddin

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A management plan was introduced in 1984 to rebuild depressed Atlantic salmon (*Salmo salar* L.) stocks in mainland Canada and southwestern Newfoundland. The focus of the plan was a reduction in the interception and exploitation of large salmon, primarily virgin multi-sea-winter salmon, in the commercial fisheries of Newfoundland and Labrador. The plan was evaluated based on analyses of the timing of commercial catches, proportions of large salmon in commercial catches, and levels of catch. Analyses of the impacts of changes in the commercial fisheries in river escapements in Newfoundland and Labrador were based on changes in recreational catches and counts at fishways. With respect to commerical fisheries, the timing of catches of large salmon was later, and the percentages and levels of catches of this component tended to be lower in plan years (1984–1988) than in pre-plan years (1974–1983). However, declines in percentages and catches of large salmon began prior to the initiation of the plan in 1984. Timing and levels of catches of small salmon did not change appreciably in most areas. These results were consistent with plan objectives. While the delayed season appears to have achieved results consistent with plan expectations for large salmon, it is not possible to determine the contribution of reductions in licensed gear in this regard. Although not an objective of the plan, restrictions imposed in the commercial fisheries did not result in increased escapements of grilse in either Newfoundland (except for two areas) or Labrador. No changes in escapements and in catches suggests that the overall abundance of grilse did not change between pre-plan and plan years and that reductions in licensed effort had little effect on reducing commercial catches. No increases were noted for escapements of large salmon (except for one area). Overall observations pertaining to river escapements were not consistent with plan expectations.

M. F. O'Connell, J. B. Dempson, and D. G. Reddin: Science Branch, Department of Fisheries and Oceans, P.O. Box 5667, St. John's, Newfoundland, Canada A1C 5X1.

Introduction

In Canada, Atlantic salmon (*Salmo salar* L.) are still harvested in mixed-stock coastal gillnet fisheries in the provinces of Newfoundland and Quebec. The largest fishery occurs in the Newfoundland Region, represented by Salmon Fishing Areas (SFAs) 1–11 (Fig. 1), where catches averaged 478 metric tonnes of small salmon and 755 metric tonnes of large salmon for the period 1974–1988. In addition to salmon of Newfoundland and Labrador origin, salmon originating in rivers of mainland Canada (Gulf of St Lawrence) and the eastern United States are also caught in this fishery (Pippy, 1982; Reddin and Misra, 1985; Reddin and Dempson, 1986). A 5-year Management Plan (hereafter referred to as the plan) based on a knowledge of the historical performance of the fisheries and migration routes as determined from tagging studies (Pippy, 1982), and biological stock characteristics (Porter *et al.*, 1986), was implemented in 1984. The major elements of the plan involved season changes in the commercial fishery and catch restrictions in the recreational fishery (Table 1) as well as reductions in the numbers of commercial fishermen and amount of licensed commercial gear (Fig. 2). The main objective of the plan was to rebuild depressed stocks in rivers in mainland Canada and southwestern Newfoundland through a reduction in the interception of large salmon (mainly virgin multi-sea-winter salmon) in the commercial fishery of Newfoundland and Labrador. It was also expected that the restrictions in the commercial fishery would result in increased escapements of grilse and large salmon (mainly repeat spawning grilse) into rivers in Newfoundland in general.

Before modifying existing management plans or implementing new strategies, it is important to evaluate the success of previous management measures. This paper examines the impacts of the plan on the commercial fishery and on river escapements in the Newfoundland

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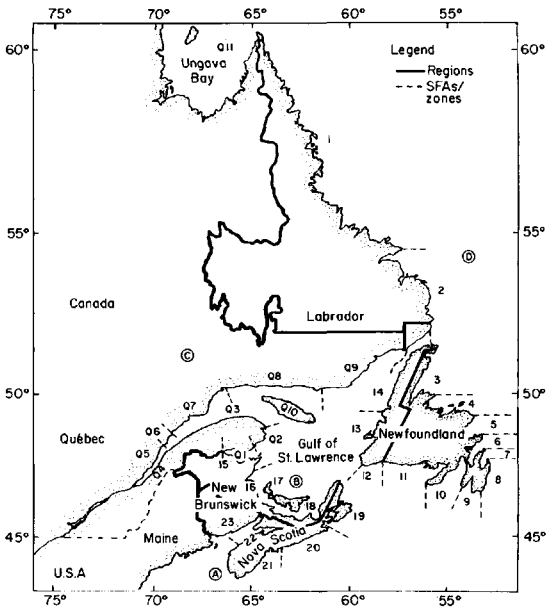

Figure 1. Map of Atlantic Provinces of Canada showing Salmon Fishing Areas (SFAs) 1–23, Salmon Management Zones of Quebec (Qs) 1–11, and regional boundaries. The Newfoundland Region comprises SFAs 1–11. Regions: A, Scotia Fundy; B, Gulf; C, Quebec; D, Newfoundland–Labrador.

Table 1. Summary of key factors associated with the Atlantic Salmon Management Plan of 1984.

COMMERCIAL FISHERY
Opening date of fishery delayed until 5 June (standard week 23) from 15 May (standard week 20) prior to 1981, and 18 May 1981–1983.
Retention of Atlantic salmon caught as by-catch in other fisheries became illegal in 1984.
Voluntary buy-back of full-time and part-time licensed salmon fishermen. In 1985 there was a mandatory buy-back of all part-time salmon licences.
A mandatory programme to tag all commercially caught salmon began in 1986.
RECREATIONAL FISHERY
Mandatory release of all large salmon caught in recreational fisheries in Newfoundland (Labrador exempt) in 1984. These fish were also considered part of the daily bag limit of two fish per day with a limit of four per day including hooked-and-released fish.
Hook-and-release regulation extended to grilse in 1985. Released fish were not considered part of the bag limit. Once the daily bag limit (two fish) was attained (grilse in Newfoundland, grilse and/or large salmon in Labrador), angling ceased for the day.
A limit of four was placed on the number of fish an angler could hook and release per day in 1986; angling ceased for the day when either two fish were retained or four fish were hooked and released. A seasonal bag limit of 15 fish was also imposed.
Mandatory tagging programme was introduced in 1988.

Region using catch data and counts of fish at fishways. Differences in timing of commercial catches, changes in the proportion of large salmon caught, and variations in the magnitude of catches of large and small salmon are compared within and among SFAs for pre-plan and plan years. Counts at fishways and recreational catches are used as indices of escapement (Chadwick, 1982, 1985). Potential savings for each SFA as a result of foregone commercial catches during plan years are discussed based on the performance of the commercial fisheries in pre-plan years.

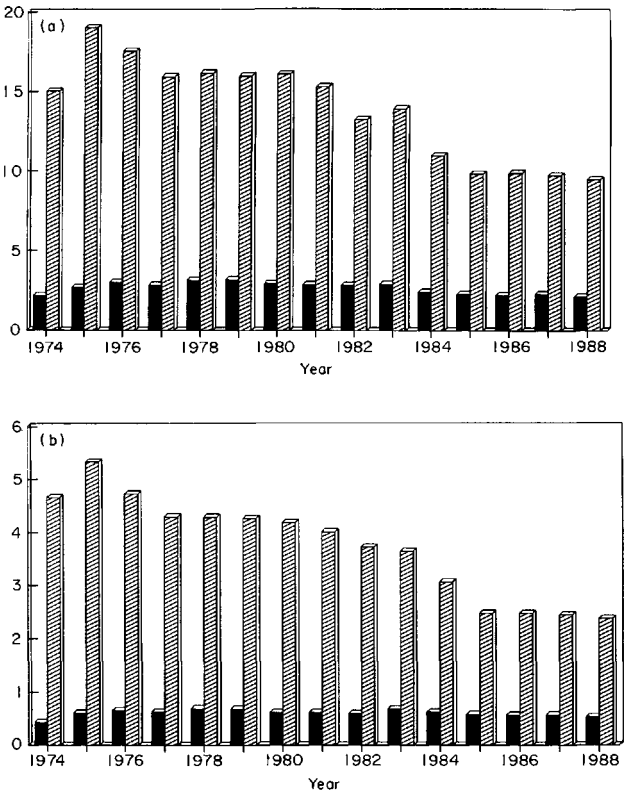

Figure 2. The amount of licensed gear (a unit of gear = 91.5 m of running length of gillnet) and number of commercial fishermen for the Newfoundland and Labrador portions of the Newfoundland Region, 1974–1988. (a) Number of gear units (thousands). (b) Number of fishermen (thousands). ■ = Labrador, ▨ = Newfoundland.

Methods

In the commercial fishery, salmon were classified as small (~2 kg) or large (~4 kg) on the basis of whole weight. Typically, small salmon are one-sea-winter (Allan and Ritter, 1977) fish, some of which are non-maturing; large salmon are mainly virgin multi-sea-winter fish. In the recreational fishery and at fishways salmon were classified as grilse (< 63 cm) or large salmon (> 63 cm) according to length. Grilse are maturing one-sea-winter salmon. With the exception of southwestern Newfoundland, large salmon in Newfoundland are mainly repeat spawning grilse. In southwestern Newfoundland and Labrador, large salmon are mainly virgin multi-sea-winter salmon (Porter *et al.*, 1986). A smolt class refers to the year in which a salmon migrates to sea as a smolt. A smolt class of adults includes one-sea-winter salmon caught in one year and two-sea-winter salmon caught in the following year.

Data used in the analyses presented in this paper are contained or referenced in O'Connell *et al.* (1989). Comparisons were made among three time periods for each SFA and various groupings of SFAs. Methods of collecting and processing commercial and recreational fishery catch data were fairly consistent over the three time periods. The mandatory programme to tag all commercially caught salmon introduced in 1986 was not considered to have affected catch reporting rates. Time periods 1 (1974–1978) and 2 (1979–1983) were prior to the plan and period 3 (1984–1988) corresponded to the plan.

Three 5-year time periods were chosen because a preliminary examination of the data revealed that changes in the commercial fishery in the direction of those expected under the plan started prior to 1984, and 5 years corresponds roughly to one life cycle of salmon in most rivers of Newfoundland.

Statistical comparisons among time periods were made using the General Linear Models Procedure of SAS (SAS Institute, 1985). Tukey's Studentized Range test was used for multiple comparisons of means. All analyses were performed on rank transformed data (Conover, 1980; Conover and Iman, 1981) using the Rank Procedure of SAS.

Commercial fisheries

Timing of commercial catches

Information on the timing of commercial catches (by number) of large and small salmon by SFA was obtained by estimating the 10th, 25th and 50th (median) percentiles, and mean week of catch, for each year over the period 1974–1988. These estimates were used to compare timing of catches among the three time periods. Comparisons were also made between large and small salmon for each SFA. Statistically significant differences between plan and pre-plan periods may be interpreted as evidence that implementation of the plan (i.e. delayed opening of the commercial fishery) has changed the pattern of exploitation.

Percentage of large salmon and magnitude of catches

Information on commercial catches of large and small salmon was used to examine spatial (among SFAs) and temporal (among years) trends in the percentage of large salmon by year of catch (large/(small + large) × 100) and by smolt class (large in year i + 1/(small in year i + large in year i + 1) × 100). For initial comparisons among years, catches were aggregated over all SFAs, and for comparisons among SFAs, catches were aggregated over all years. Subsequently, comparisons were made over the three time periods within each SFA and groupings of SFAs. The magnitudes of commercial catches of large and small salmon by weight for each SFA and groupings of SFAs were also compared over the three time periods by year of catch and by smolt class.

Recreational fishery and counts at fishways

Catches of grilse (Newfoundland and Labrador) and large salmon (Labrador) in the recreational fishery for each SFA and groupings of SFAs were also compared among the three time periods. Because there were some years in which incomplete counts were obtained at fishways, statistical analyses for the same three time periods as used for commercial and recreational data were not possible. However, for certain fishways, analyses were carried out on years 1978–1983 (period 1) and 1984–1988 (period 2), and within these time periods, years with partial counts were omitted.

Results

Commercial fisheries

Timing of commercial catches

Comparisons of various percentiles of catch, and mean date of catch for small salmon indicated a significant difference between pre-plan and plan years for SFA 7 only (Table 2). This was the only SFA where a substantial proportion of the catch of small salmon was taken prior to 5 June (Fig. 7). More dramatic differences are evident when large salmon catches are compared (Table 3). Catches of large salmon were significantly later in SFAs 5–8 for the 10th and 25th percentiles, for the 10th percentile in SFA 10, and for all percentiles in SFA 11. For median (50th percentile) dates, only SFAs 7 and 8 indicated significant differences among the three time periods, while mean dates differed in SFAs 3, 5–8, and 11. When the two pre-plan time periods are combined (1974–83), mean dates were significantly later ($p < 0.05$) during the plan years for SFAs 5–8 and SFAs 10–11.

Median dates of catch occurred later in northern areas for both small and large salmon (Tables 2 and 3). Earliest catches usually occurred in SFAs 7 and 8, while the latest catches were in SFAs 1 and 2. Small salmon had a tendency to move into an area and be caught later in the season than large salmon. With respect to median date of capture, this was statistically significant ($p < 0.05$) for all SFAs except SFA 4 for the pre-plan years (1974–1983) but significant only in SFAs 5–8 during the plan years.

Similar comparisons for the timing of large salmon catches were made by re-analysing data with weeks standardized to begin week 23 (i.e. by omitting catches prior to 4 June in the pre-plan period). Out of 44 comparisons (10th and 25th percentiles, median, and mean for each of 11 SFAs), in only one (SFA 3) was there a statistically significant difference ($p = 0.03$) among time periods; less than would be expected by chance alone.

Percentage of large salmon

A simple linear model,

$$X_{ij} = \mu + \alpha_i + \beta_j$$

where X_{ij} = percentage of large salmon, α_i = SFA, i = 1–11, β_j = year, j = 1974–1988,

Table 2. Comparisons of the 10th, 25th, and 50th (median) percentiles, and mean date (standard week) of commercial catches (by number) of small salmon by SFA over three time periods; 1974–1978 (period 1), 1979–1983 (period 2), and 1984–1988 (period 3). Probability values (p) from statistical analyses are shown along with results of the multiple comparisons tests (MCT). Time periods underscored by the same line are not significantly different ($p > 0.05$).

	Percentiles of the catch (week)															Mean data of catch				
	10% Time periods					25% Time periods					50% Time periods					Time periods				
SFA	1	2	3	p	MCT	1	2	3	p	MCT	1	2	3	p	MCT	1	2	3	p	MCT
1	29.2	28.8	28.6	0.51		30.4	29.8	29.6	0.25		31.6	31.0	30.8	0.22		31.8	31.2	31.2	0.14	
2	27.0	26.4	27.0	0.34		27.4	27.2	27.8	0.43		28.4	25.0	28.6	0.27		28.7	28.3	28.7	0.50	
3	25.8	25.0	25.4	0.56		26.6	25.6	26.0	0.15		27.2	26.6	27.0	0.57		27.4	26.7	27.1	0.29	
4	25.0	24.8	25.0	0.99		26.0	25.8	25.8	0.98		27.2	26.6	27.4	0.46		27.4	27.1	27.6	0.80	
5	24.8	24.6	24.6	0.89		25.8	25.4	25.2	0.18		26.8	26.6	27.0	0.70		27.1	26.6	27.0	0.22	
6	23.8	24.4	24.4	0.54		25.4	25.4	25.8	0.86		26.6	26.8	27.2	0.52		26.8	26.9	27.6	0.45	
7	20.6	20.8	23.7	0.00	3 2 1	21.6	23.0	24.8	0.01	3 2 1	24.2	25.2	26.4	0.01	3 2 1	24.3	24.9	26.4	0.00	3 2 1
8	24.0	23.8	24.0	0.98		25.2	25.2	24.8	0.70		26.0	26.0	26.0	1.00		26.0	26.2	26.5	0.65	
9	23.8	24.0	24.6	0.34		25.4	25.8	25.8	0.73		27.2	27.0	27.0	0.92		27.3	27.1	27.4	0.71	
10	24.4	23.8	24.4	0.47		25.4	25.0	25.2	0.71		26.4	26.0	26.2	0.81		26.1	26.4	26.7	0.80	
11	23.8	24.0	24.0	0.92		24.6	25.0	24.6	0.64		26.2	25.8	25.2	0.13		26.2	26.1	25.8	0.73	

Table 3. Comparisons of the 10th, 25th, and 50th (median) percentiles, and mean date (standard week) of commercial catches (by number) of large salmon by SFA over three time periods; 1974–1978 (period 1), 1979–1983 (period 2), and 1984–1988 (period 3). Probability values (p) from statistical analyses are shown along with results of the multiple comparisons tests (MCT). Time periods underscored by the same line are not significantly different ($p > 0.05$).

	Percentiles of the catch (week)																			
	10% Time periods					25% Time periods					50% Time periods					Mean data of catch Time periods				
SFA	1	2	3	p	MCT	1	2	3	p	MCT	1	2	3	p	MCT	1	2	3	p	MCT
1	29.0	28.0	28.0	0.56		30.0	29.0	28.8	0.07		31.2	30.0	30.2	0.21		31.5	30.6	30.8	0.35	
2	26.2	25.6	25.8	0.34		26.8	26.4	26.6	0.72		27.2	27.0	27.4	0.82		27.7	27.4	28.2	0.35	
3	25.2	23.6	24.4	0.33		26.0	24.2	25.2	0.06		26.6	25.4	26.0	0.40		26.8	25.6	26.8	0.03	3 1 2
4	24.0	22.8	24.0	0.40		25.2	24.0	25.0	0.48		26.6	26.0	26.2	0.94		27.1	26.3	27.2	0.50	
5	21.6	21.2	23.2	0.01	3 1 2	22.6	22.4	24.2	0.04	3 1 2	23.8	23.8	25.2	0.10		24.5	24.3	26.0	0.05	3 1 2
6	21.2	21.2	23.0	0.00	3 1 2	21.8	22.2	24.0	0.00	3 2 1	23.2	24.0	25.2	0.07		23.7	24.7	26.2	0.02	3 2 1
7	20.2	20.0	23.0	0.00	3 1 2	21.0	21.2	23.8	0.00	3 2 1	22.2	23.4	24.8	0.00	3 2 1	22.9	23.4	25.5	0.00	3 2 1
8	20.2	20.8	23.0	0.00	3 2 1	21.0	22.4	23.2	0.00	3 2 1	22.2	24.0	24.2	0.01	3 2 1	22.9	24.0	25.0	0.00	3 2 1
9	23.0	23.6	23.7	0.18		24.0	24.4	25.0	0.33		25.8	26.0	26.6	0.79		25.8	26.3	26.7	0.44	
10	21.4	21.6	23.6	0.02	3 2 1	23.2	23.0	24.2	0.32		24.4	24.6	25.4	0.27		24.5	24.6	25.6	0.15	
11	21.4	21.8	23.2	0.00	3 2 1	22.4	22.4	24.0	0.00	3 1 2	23.6	24.2	24.6	0.25		23.8	24.1	25.1	0.02	3 2 1

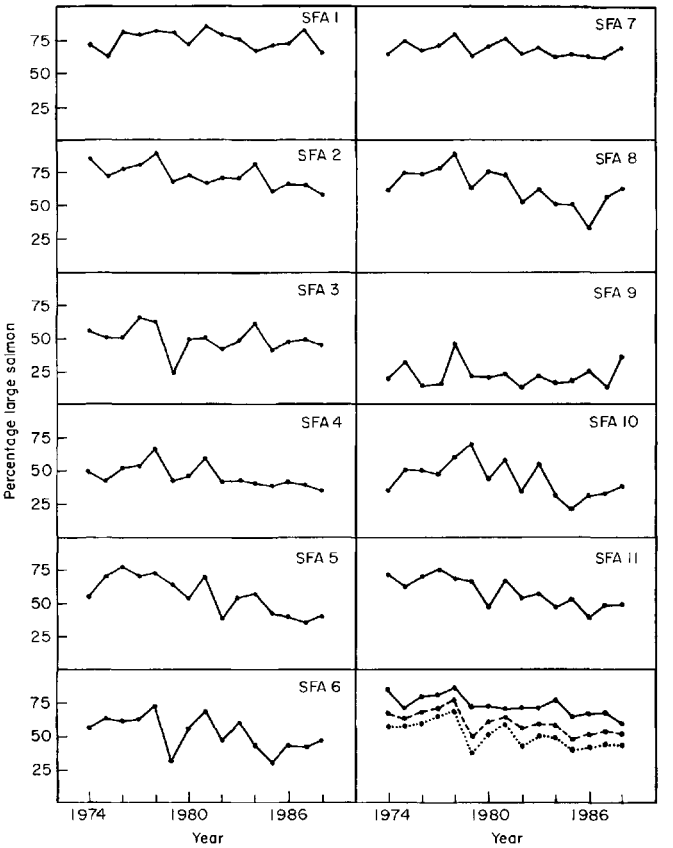

Figure 3. Percentage of large salmon in the commercial fishery by weight (metric tonnes) for each SFA, for Newfoundland and Labrador separately, and the total for all SFAs combined, 1974–1988. —●— = Labrador, · ·●· · = Newfoundland, – –●– – = total.

explained 82% of the variation in the percentage of large salmon (by weight) by year of catch. Both factors were highly significant ($p < 0.001$) with most of the variation occurring among SFAs. Overall, ranked variables indicated that the highest percentages of large salmon occurred from 1976 to 1978 and in 1981; with the exception of 1979 and 1982, the lowest percentages caught were during the plan years, 1984–1988 (Fig. 3).

SFAs with the highest percentage of large salmon were 1, 2, 7, and 8, while those with the lowest percentage of large salmon were SFAs 3, 4, 9, and 10 (Fig. 3). As previously indicated, large salmon were caught more commonly during the early part of the season. In weeks 20–22 (14 May to 3 June), large salmon often accounted for 50–90% of the total catch of Atlantic salmon in some SFAs prior to the initiation of the plan (Fig. 4).

Analyses of the variation in the percentage of large salmon (numbers of fish) in the catch with fishing weeks standardized to begin in week 23 (June 4) showed results similar to those above. That is, there was a significant decline in the percentage of large salmon in the catch prior to the institution of the plan in 1984. The plan may have augmented these changes to a greater degree than would normally have occurred. This is in contrast to the analyses of the timing of the large salmon catches which, when standardized to begin in week 23, showed no significant differences among time periods.

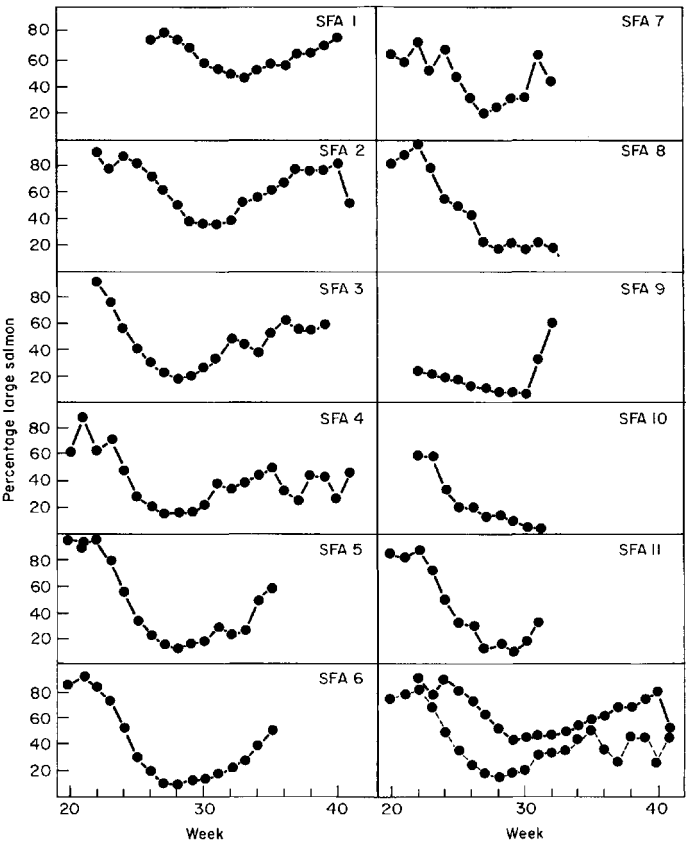

Figure 4. Percentage of large salmon in the commercial fishery (in numbers) by week for each SFA and for Newfoundland and Labrador. Catches are aggregated over all years (1974–1983). Week 23 corresponds to 4–10 June. —●— = Labrador, – –●– – = Newfoundland.

For analyses on the percentage of large salmon (by weight) by smolt class, a similar model explained 65% of the variation. Again, both SFA and year were highly significant ($p < 0.001$). In general, similar patterns as indicated above were observed in the ranked percentages of large salmon catches over years and SFAs.

Results of comparisons of the mean percentage of large salmon among time periods (multiple comparisons tests) indicated there was a progressive decline in the percentage of large salmon by year of catch and by smolt class over the three time periods (Table 4). Table 4 also summarizes the percentage change between periods 1 and 2 and between periods 2 and 3. Significant differences among time periods in the mean percentage of large salmon by year of catch were apparent for most SFAs and groupings of SFAs. Generally, period 1 was not significantly different from period 2 and in turn period 2 was not significantly different from period 3; however, period 1 was significantly different from period 3. For the percentage of large salmon by smolt class, means were significantly different only in the case of the entire Newfoundland portion of the region (SFAs 3-11). This analysis also shows evidence that the declines in the proportion of large salmon began prior to the implementation of the plan.

Landings

The previous sections examined differences between pre-plan and plan years in the timing of catches and in the

Table 4. Mean percentage of large salmon (by weight, metric tonnes) in the commercial fishery by year of catch and by smolt class for each SFA and groupings of SFAs compared among time periods 1974–1978 (1), 1979–1983 (2), and 1984–1988 (3) by multiple comparisons tests (MCT). Also shown is percentage change between periods 1 and 2 and between periods 2 and 3. Time periods 1 and 2 are pre-plan periods. Time period values underscored by the same line are not significantly different ($p > 0.05$).

	% large by year of catch				% large by smolt class			
	% change				% change			
SFA	(1) vs. (2)	(2) vs. (3)	p	MCT	(1) vs. (2)	(2) vs. (3)	p	MCT
LABRADOR								
1	+3.1	−9.4	0.33		−3.7	−6.6	0.21	
2	−13.9	−5.0	0.01	3 2 1	−6.1	−4.3	0.40	
1–2	−10.4	−6.1	0.009	3 2 1	−6.6	−4.3	0.35	
NEWFOUNDLAND NORTHEAST								
3	−25.0	+12.9	0.01	3 2 1	−17.4	+5.0	0.35	
4	−11.3	−16.2	0.001	3 2 1	−2.0	−22.0	0.41	
3–4	−21.1	+1.8	0.06		−12.7	−5.3	0.48	
EAST								
5	−18.6	−22.5	0.008	3 2 1	−18.8	−23.2	0.08	
6	−17.3	−24.5	0.004	3 2 1	−13.0	−16.2	0.32	
7	−4.7	−6.7	0.02	3 2 1	−4.1	+1.1	0.93	
8	−13.5	−22.3	0.006	3 2 1	0	−25.4	0.10	
5–8	−15.7	−20.6	0.002	3 2 1	−11.2	−18.9	0.17	
SOUTH								
9	−19.6	+6.7	0.98		−22.5	−1.4	0.53	
10	+4.9	−43.2	0.001	3 2 1	+14.8	−39.7	0.32	
11	−17.0	−17.8	0.001	3 2 1	−0.7	−24.6	0.33	
9–11	−18.2	−22.1	0.0001	3 2 1	−5.6	−24.1	0.20	
TOTAL								
3–11	−21.7	−8.7	0.004	3 2 1	−12.0	−12.7	0.04	3 2 1

percentage of large salmon in the catch. This section analyses changes in the amount of salmon caught.

Commercial catches of large and small salmon by weight (metric tonnes) for each SFA for the period 1974–1988 are presented in Figure 5. Results of comparisons of mean catches of large and small salmon among time periods (multiple comparisons tests) and percentage change between periods 1 and 2 and between periods 2 and 3 for each SFA and for various groupings of SFAs are given in Table 5. There was a progressive decline in mean catch of large salmon over the three time periods. There were significant differences among time periods for all SFAs (and groupings of SFAs) except SFAs 3 and 4, separately and combined (Table 5). The differences basically followed the same sequential pattern as described above for the mean percentage of large salmon. Overall declines in catches of large salmon began prior to the start of the plan.

For small salmon there was no overall consistent pattern of increase or decrease in mean catch over the three time periods (Table 5). Significant differences among time periods were only observed for SFAs 7 and 9. SFA 7 followed the same general pattern as observed for large salmon. For SFA 9, period 2 was significantly different from periods 1 and 3, which in turn were not significantly different.

River escapements

Recreational catches

Recreational catches (by number) of grilse (Newfoundland and Labrador) and large salmon (Labrador) for the period 1974–1988 are presented for each SFA in Figure 6. Results of comparisons of mean catches of grilse and large salmon among time periods (multiple comparison tests) and percentage change between periods 1 and 2 and between periods 2 and 3 for each SFA and groupings of SFAs are presented in Table 6. For SFAs in Newfoundland, 1987 is excluded from the

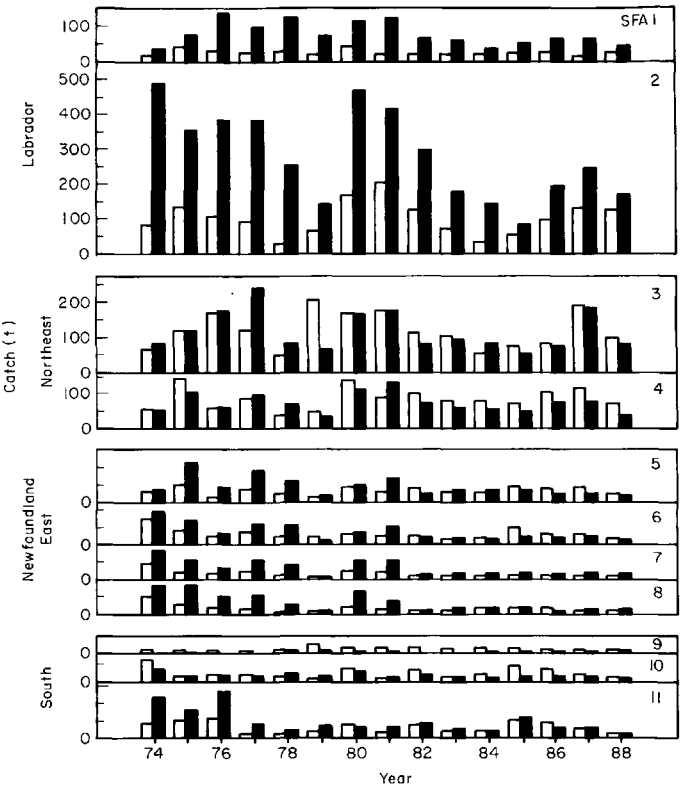

Figure 5. Commercial catches of small and large salmon by weight (metric tonnes) for each SFA for the period 1974–1988. □ = small salmon, ■ = large salmon.

means for period 3. This is because most rivers were closed for nearly the entire angling season in 1987 as a result of severe drought conditions. There were no such closures in Labrador. With the exception of the comparison of period 2 with period 3 for SFAs 1 through 4, there was a general increase in recreational catches of grilse over all time periods. With the exception of SFAs 5–8, the magnitude of increase was greater between periods 1 and 2 than between periods 2 and 3. For SFAs 5–8, the reverse occurred. Significant differences occurred for SFAs 3 and 4 separately and combined (Table 6). For SFA 3, period 2 was significantly different from periods 1 and 3, which in turn were not significantly different from each other. For SFA 4, SFAs 3–4, and SFAs 3–11, period 1 differed significantly from periods 2 and 3, while periods 2 and 3 were not significantly different. For SFA 11 and SFAs 9–11, period 1 was not significantly different from period 2, and in turn period 2 was not different from period 3; however, period 1 was significantly different from period 3.

For large salmon (Labrador), catches in SFA 1 declined over all time periods with the greatest declines occurring between periods 2 and 3. For SFA 2, catches increased between periods 1 and 2 and showed no change between periods 2 and 3. None of the changes were statistically significant ($p > 0.05$) (Table 6).

Counts at fishways

Counts of grilse and large salmon at fishways (1974–1988) are presented in Figure 7. Mean counts of grilse and large salmon for fishways located in Salmon Brook (Gander River), Middle Brook, lower Terra Nova River,

Table 5. Mean commercial catch (metric tonnes) of small and large salmon for each SFA and groupings of SFAs compared among time periods 1974–1978 (1), 1979–1983 (2), and 1984–1988 (3) by multiple comparisons tests (MCT). Also shown is percentage change between periods 1 and 2 and between periods 2 and 3. Time periods 1 and 2 are pre-plan periods. Time period values underscored by the same line are not significantly different ($p > 0.05$).

	Small salmon				Large salmon			
	% change				% change			
SFA	(1) vs. (2)	(2) vs. (3)	p	MCT	(1) vs. (2)	(2) vs. (3)	p	MCT
LABRADOR								
1	−16.1	−17.4	0.32		−8.1	−41.9	0.05	3 2 1
2	+43.1	−28.6	0.58		−19.5	−42.3	0.03	3 2 1
1–2	+29.1	−26.8	0.61		−17.2	−42.2	0.02	3 2 1
NEWFOUNDLAND NORTHEAST								
3	+44.0	−31.8	0.30		−17.4	−15.9	0.60	
4	+17.4	−0.9	0.65		+4.5	−29.3	0.51	
3–4	+32.9	−20.4	0.33		−9.7	−21.4	0.48	
EAST								
5	−5.9	+14.7	0.89		−45.9	−31.5	0.02	3 2 1
6	−44.2	+29.3	0.36		−56.9	−34.1	0.005	3 2 1
7	−47.3	−37.9	0.03	3 2 1	−47.4	−52.5	0.02	3 2 1
8	−48.7	+8.6	0.38		−54.0	−52.9	0.02	3 2 1
5–8	−35.8	+9.6	0.44		−51.0	−42.0	0.02	3 2 1
SOUTH								
9	+120.0	−47.0	0.01	2 3 1	+4.2	−41.2	0.33	
10	−31.3	+39.8	0.50		−27.0	−39.5	0.002	3 2 1
11	−28.7	+17.2	0.83		−58.7	−17.4	0.12	
9–11	−16.1	+9.1	0.96		−49.5	−25.9	0.03	3 2 1
TOTAL								
3–11	+2.4	−10.0	0.85		−34.9	−28.7	0.006	3 2 1

and Northeast River, Placentia are compared between time periods 1 (1978–1983) and 2 (1984–1988) specified earlier in Table 7. The SFA in which each fishway is located and the years excluded from the analyses due to partial counts are also shown. Counts for 1987 were probably incomplete because of the effects of drought conditions (O'Connell *et al.*, 1988) and hence they are omitted from the analyses. There was little change between pre-plan and plan periods in mean counts of grilse and large salmon for Salmon Brook. For Middle Brook, there was a significant decline in the mean count of grilse and while the decline for large salmon was higher than for grilse, the difference was not significant (Table 7). Mean counts of grilse and large salmon during the plan period were significantly higher than those of the pre-plan period for lower Terra Nova River. For Northeast River, Placentia, the mean grilse count increased while that of large salmon decreased; the differences were not significant (Table 7). Looking at individual years, it is evident that there were fewer large salmon entering Great Rattling Brook (Exploits River) during the plan period than in the pre-plan period; in the case of small salmon there was little difference between pre-plan and plan years (Fig. 7).

Discussion

The management plan appears to have achieved results consistent with expectations for commercially caught large and small salmon in terms of the delayed season. Specifically, timing of catches of large salmon, percentage of large salmon, and magnitude of catch of large salmon decreased relative to pre-plan time periods; timing and magnitude of catch of small salmon did not change appreciably. It was not possible to determine the effects of reductions in licensed commercial gear. With respect to river escapements, overall results were not consistent with plan expectations. Restrictions in the commercial fishery did not result in increased escapements of either large or small salmon.

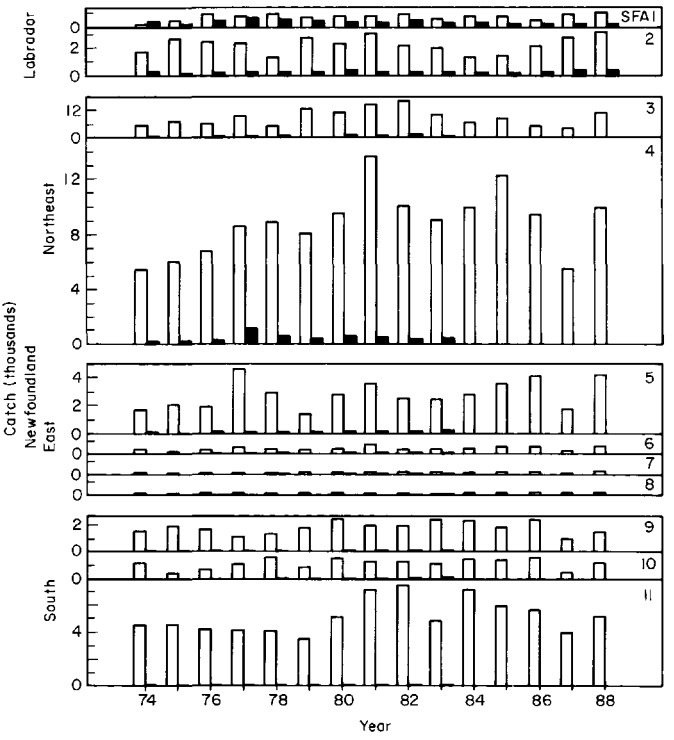

Figure 6. Recreational catches (thousands) of grilse and large salmon for each SFA for the period 1974–1988. □ = grilse, ■ = large salmon.

Environmental conditions at sea have been shown to alter the distribution of Atlantic salmon catches in the northwest Atlantic Ocean (Reddin and Shearer, 1987). Anomalous conditions in 1985 (O'Connell *et al.*, 1986, 1987) and 1987 (O'Connell *et al.*, 1988) could confound interpretations of the impacts of the plan on commercial catches. In these years, severe ice conditions and low sea-surface temperatures appear to have altered the distributions and catches of both large and small salmon.

Regardless of some altering of usual migration patterns during the plan years, however, it would be expected that the timing of commercial catches would be later during the plan than for pre-plan years as a function of the later start-up date of the fishery. This would be most pronounced for large salmon, given that this component generally enters the fishery earlier than small salmon, as indicated above. It appears that large salmon were potentially less available for capture as a result of the delayed season, and fish so affected in a given SFA were likely subject to redistribution to rivers or other fisheries.

The West Greenland fishery harvests virgin multi-sea-winter salmon originating in Canada. This fishery has been under quota control since 1976. Generally, catches have been either close to or have exceeded the quota, except in 1983 and 1984. In these years there was an overall low abundance in Canadian waters as well. During the time-frame of the present investigation, the relative exploitation at West Greenland has been consistent with respect to the potential impact of returns to Canadian waters and thus should not unduly influence the assessment of the plan in the Newfoundland Region.

Mean percentages of large and small salmon (by weight) taken prior to 5 June (expressed as a percentage of total catch in each size category) for the pre-plan periods 1 and 2 are shown for each SFA in Figure 8. From this it is possible to get an idea of the proportion of total catch of

Table 6. Mean recreational catch (No.) of grilse and large salmon for each SFA and groupings of SFAs compared among time periods 1974–1978 (1), 1979–1983 (2), and 1984–1988 (3) by multiple comparisons tests (MCT). Also shown is percentage change between periods 1 and 2 and between periods 2 and 3. Time periods 1 and 2 are pre-plan periods. Time period values underscored by the same line are not significantly different ($p > 0.05$).

	Grilse				Large salmon			
	% change				% change			
SFA	(1) vs. (2)	(2) vs. (3)	p	MCT	(1) vs. (2)	(2) vs. (3)	p	MCT
LABRADOR								
1	+12.0	+1.9	0.83		−27.4	−40.5	0.07	
2	+15.8	−10.8	0.76		+22.1	+0.3	0.60	
1–2	+18.8	−6.9	0.83		−12.1	−23.0	0.20	
NEWFOUNDLAND NORTHEAST								
3	+100.6	−41.8	0.006	2 3 1				
4	+41.9	+3.3	0.007	3 2 1				
3–4	+49.4	−4.5	0.002	2 3 1				
EAST								
5	−5.3	+46.3	0.19					
6	+30.7	+15.2	0.11					
7	+69.5	−15.0	0.07					
8	+23.3	+18.0	0.55					
5–8	+0.5	+39.3	0.25					
SOUTH								
9	+36.7	−4.6	0.09					
10	+20.3	+12.1	0.32					
11	+30.3	+5.8	0.04	3 2 1				
9–11	+30.2	+4.3	0.04	3 2 1				
TOTAL								
3–11	+33.9	+4.3	0.006	3 2 1				

large and small salmon forgone in each SFA as a result of the delayed season. In Labrador (SFAs 1 and 2), a very small proportion of the total catch of large salmon was taken prior to 5 June in both periods 1 and 2. This is because weather and ice conditions in Labrador rarely permitted fishing prior to 5 June. For Newfoundland, weather and ice conditions restricted fishing prior to 5 June in SFAs 3 and 4 (northeast) in some years, while in other years the effect was minimal (Reddin and O'Connell, unpubl. data). The highest proportions of large salmon caught prior to 5 June occurred in SFAs 5–11. In these SFAs, the fishing season normally began on the 15 May opening date. Theoretically, in Labrador, the delayed season should have had little impact on large salmon catches and proportions and there was no appreciable reduction in fishing effort between pre-plan and plan periods (Fig. 2). In this context, Labrador can be regarded as a control. Yet, catches and proportions of large salmon in Labrador declined both prior to and during the plan in a manner similar to that observed for Newfoundland, suggestive of an overall downward trend in abundance. This confounds interpretation of results in terms of the relative contribution of impacts of restrictions imposed under the plan. The plan probably contributed to an overall reduction in the exploitation of large salmon especially in SFAs 5–11.

In contrast to the situation for large salmon, with the exception of SFA 7, the proportion of small salmon taken prior to 5 June was low (Fig. 8).

Potential catches of large and small salmon (by weight) prior to 5 June in 1984–1988 (period 3) had the fishery opened on 15 May are shown in Figure 8. For each SFA, these values were arrived at by applying the proportion of catch prior to 5 June for periods 1 and 2 to the average total catch, 1984–1988. As expected, with respect to large salmon, the highest numbers of fish subject to redistribution would have been taken in SFAs 5–11 with SFAs 1 and 2 lowest and SFAs 3 and 4 intermediate. Total catches

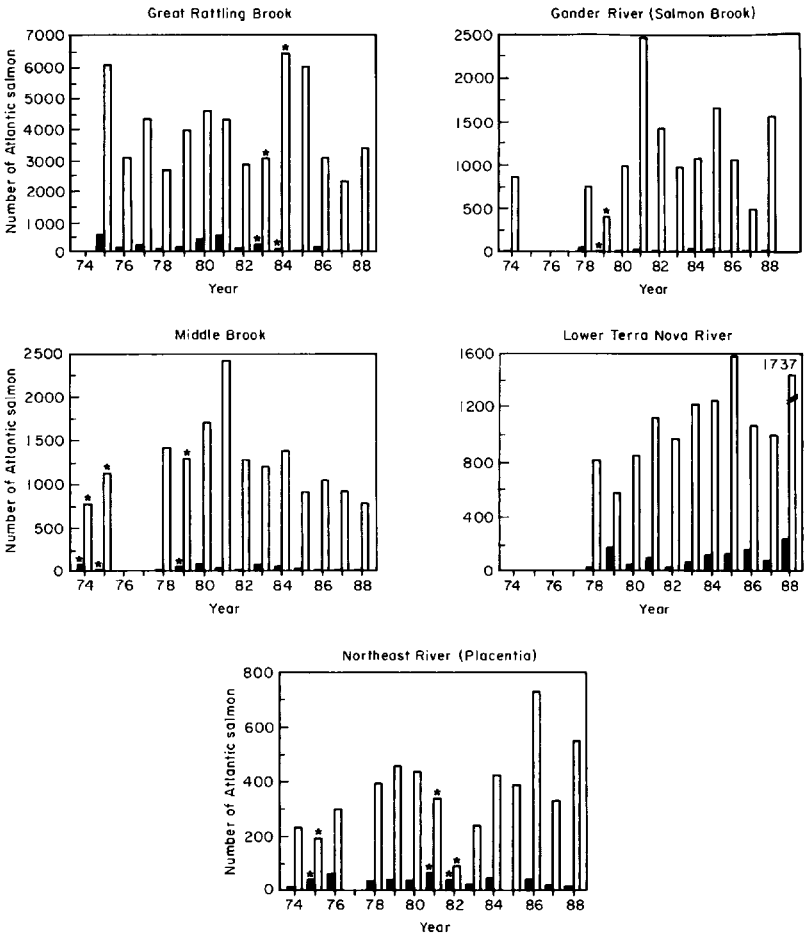

Figure 7. Counts of grilse and large salmon at selected fishways in Newfoundland. Great Rattling Brook (Exploits River) and Salmon Brook (Gander River) are located in SFA 4, Middle Brook, and lower Terra Nova River in SFA 5, and Northeast River, Placentia in SFA 10. □ = grilse, ■ = large salmon, * = partial count.

of large salmon subject to redistribution based on periods 1 and 2 would have been 74.3 and 78.1 metric tonnes, respectively.

While the delayed season appears to have achieved results consistent with the expectations outlined above for large salmon, it is not possible to determine the relative contribution of reductions in licensed gear in this regard. With respect to small salmon, results of delaying the opening of the fishery also conformed to expectations, namely little change between pre-plan and plan periods. Comparing periods 2 and 3, with a few exceptions (see below), given that the overall catch of small salmon in the commercial fishery did not change that much and also river escapements were similar as well, it appears that the overall abundance of this component did not change between periods. This suggests that the reductions in licensed gear had little effect on reducing commercial catches of small salmon. Logbook surveys of commercial

Table 7. Mean counts of grilse and large salmon at selected fishways compared between two time periods (in parentheses).

	Grilse (No.)								Large Salmon (No.)							
	Pre-plan			Plan					Pre-plan			Plan				
	1978–1983 (1)			1984–1988 (2)					1978–1983 (1)			1984–1988 (2)				
SFA and fishway	$\bar{X}$	SD	N	$\bar{X}$	SD	N	% change	p	$\bar{X}$	SD	N	$\bar{X}$	SD	N	% change	p
SFA 4																
Salmon Brook (Gander R.)[a]	1322.8	679.86	5	1342.5	314.56	4	+1.5	0.36	26.0	16.63	5	25.0	10.65	4	−3.9	0.91
SFA 5																
Middle Brook[b]	1601.2	493.95	5	1022.8	260.81	4	−36.1	0.04	48.0	33.49	5	28.3	20.06	4	−41.0	0.24
Lower Terra Nova R.[c]	918.2	230.36	6	1394.3	309.90	4	+51.9	0.02	66.0	57.40	6	141.3	45.54	4	+114.1	0.05
SFA 10																
Northeast R., Placentia[d]	377.5	99.95	4	517.8	154.09	4	+37.2	0.43	31.3	6.50	4	23.5	21.36	4	−24.9	1.00

[a,b]1979 is omitted from pre-plan; 1987 is omitted from plan.
[c]1987 is omitted from plan.
[d]1981 and 1982 are omitted from pre-plan; 1987 is omitted from plan.

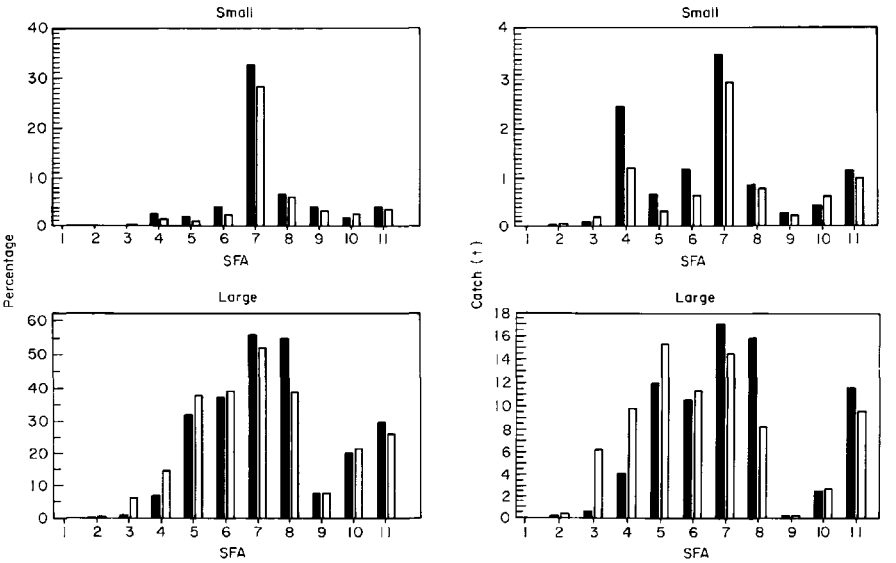

Figure 8. Mean percentages of large and small salmon taken prior to 5 June (expressed as a percentage of total catch in each size category) averaged over pre-plan time periods 1 (1974–1978) and 2 (1979–1983), and mean potential catches by weight (metric tonnes) prior to 5 June had the fishery opened 15 May, for each SFA. ■ = 1974–1978, □ = 1979–1983.

fishermen have shown that there can be a large discrepancy between the amount of gear fishermen are licensed to fish and the amount actually fished (O'Connell *et al.*, 1984; O'Connell, unpubl. data). Reasons for not using all gear include adverse environmental conditions (presence of Arctic pack ice and icebergs, bad weather), presence of net fouling organisms, salmon catch levels, and the relative importance of fishing for salmon compared to other species. The greatest availability of small salmon for exploitation occurs after that of large salmon. The survey also showed that because prices paid for large salmon were higher than for small salmon, higher actual effort was directed at large salmon than at small salmon. It is possible that during the plan, a greater proportion of licensed effort was directed at the small salmon component compared to pre-plan years in an attempt to compensate for the loss of harvest of large salmon. Other reasons could include: (1) many of the fishermen removed from the system may have been the least successful; and (2) individual catch rates for fishermen remaining in the system may have increased. The end result is that overall river escapements did not increase during the plan as expected.

The only direct means of assessing the impacts of restrictions in the commercial fishery on escapements of large salmon is by examining annual counts at fishways. With the exception of one instance (lower Terra Nova River), counts of large salmon during the plan decreased from those of the pre-plan period. This is not consistent with expectations under the plan, namely, that decreased exploitation of this component in the commercial fishery should have resulted in higher river escapements relative to pre-plan years. Scale analysis of fish sampled in the rivers in question has revealed that with the exception of Terra Nova River, all fish classified as large salmon were repeat spawning grilse (successive years) and not virgin multi-sea-winter (MSW) salmon (O'Connell and Ash, unpubl. data). Generally, the timing of entry of these fish into the rivers is similar to that observed for virgin grilse, which implies a similar susceptibility to the commercial fishery as for virgin grilse. Therefore repeat spawning grilse would not necessarily be affected by the delayed season, although the impact of reduced licensed effort is another matter. Comparing rivers, run timings of grilse and large salmon tended to be similar. Assuming that the migration timing of virgin MSW salmon in insular Newfoundland was similar to that of non-Newfoundland origin virgin MSW salmon, it would appear that except for Terra Nova River, very few of these fish are produced. Escapements of large salmon to lower Terra Nova River during the plan increased significantly over pre-plan

Table 8. Summary of statistically significant ($p < 0.05$) probability values resulting from analysing various factors in relation to evaluation of the 1984 Salmon Management Plan. Plan years (1984–1988) are compared with two pre-plan periods, 1974–1978 and 1979–1983. Non-significant results are blank.

	Factors analysed														
	Commercial fishery														
	Large salmon							Small salmon					Recreational catch		Fishways[3]	
		% Large		Timing					Timing							
SFA	Catch	YC[1]	SC[2]	10%	25%	50%	Mean	Catch	10%	25%	50%	Mean	Grilse	Large salmon	Grilse	Large salmon
1	0.05															
2	0.03	0.01														
3		0.01					0.03						0.00			
4		0.00											0.00			
5	0.02	0.00		0.01	0.04		0.05								0.04*	
															0.02**	0.05**
6	0.00	0.00		0.00	0.00		0.02									
7	0.02	0.02		0.00	0.00	0.00	0.00	0.03	0.00	0.01	0.01	0.00				
8	0.02	0.00		0.00	0.00	0.01	0.00									
9								0.01								
10	0.00	0.00		0.02												
11		0.00		0.00	0.00		0.02						0.04			

[1]YC = Year of catch; [2]SC = Smolt class; [3]Time periods are other than those for commercial and recreational fisheries, see text; *Middle Brook; **Lower Terra Nova River.

years. In conjunction with this, commercial catches of large salmon in SFA 5 decreased overall, which is consistent with plan expectations. Escapements of grilse during plan years increased at some fishways (Lower Terra Nova River and Northeast River, Placentia) relative to pre-plan years, but changed very little at Salmon Brook and Great Rattling Brook and decreased at Middle Brook. SFAs 5 and 10 showed increases (though not statistically significant) in recreational catches, which together with the increases in counts at lower Terra Nova River (SFA 5) and Northeast River, Placentia (SFA 10) fishways and little overall change in commercial catches, suggests that the abundance of small salmon in these SFAs was higher during the plan than prior to the plan. As noted above, for the remaining SFAs the overall abundance of small salmon did not appear to have changed significantly between plan and pre-plan periods.

Often, implementation of "cosmetic" management measures such as minor changes in season or size and bag limits have had minimal impact on increasing spawning escapement (Argue *et al.*, 1983). Modelling exercises on chinook and coho salmon demonstrated that usually a reallocation of catches to other fisheries occurs rather than an increased spawning escapement (Argue *et al.*, 1983). The 1984 Atlantic salmon management plan appears to have been more than "cosmetic" at least with respect to changes that occurred in the commercial fishery and the indication of improved returns to rivers in the Gulf of St Lawrence (Chadwick, 1989; Randall, 1990). Table 8 presents an overall summary of statistically significant results of analyses of the various factors used to evaluate the effectiveness of the management plan. Our study has demonstrated significant changes in catch timing, magnitude of catches, and in the proportion of this component taken in catches, all of which are consistent with expected impacts of the plan. Since the plan was largely designed to reduce the exploitation of non-Newfoundland origin large (MSW) salmon, the shortened season would not be expected to have had a major impact on this component of catch in Newfoundland (Newfoundland Region) rivers, which are characterized by grilse runs. Yet one would have expected to see increased escapements of grilse and repeat spawning grilse due to decreased exploitation resulting from lower levels of licensed effort. Possible reasons for this situation have been discussed in the foregoing.

Argue *et al.* (1983) suggested that it is often difficult to detect changes in say, escapement, the desired result, because of imprecise methods for escapement monitoring. In Newfoundland, the only means of assessing escapements of large salmon was through comparisons of pre-plan and plan counts determined at a limited number of fishways; analyses comparable to those carried out on catch data were not possible because of limitations on the availability of years with complete counts. The same limitations apply to counts of grilse, although this component was also monitored using angling data as an index of escapement. As pointed out by Argue *et al.* (1983), any attempt to manage adaptively requires accurate catch and escapement monitoring. In this context, it is imperative that existing river monitoring stations or "index" rivers (Chadwick, 1985) are maintained and indeed increased in number, and, as well, that every effort be made to obtain accurate commercial and recreational catch data. In areas where results in line with plan expectations should have been observed but were not, perhaps imprecision in our ability to measure the changes was at fault.

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