Biological assessment of Atlantic salmon in the Miramichi River, 1988

by

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ABSTRACT

During 1988, counts of salmon at Millbank trap indicated 21,667 MSW salmon and 121,867 1SW salmon returned to the Miramichi River, New Brunswick. Total returns were also estimated from mark-recapture data, which indicated fewer total returns (15,285 MSW salmon and 86,613 1SW salmon). Total egg deposition, based on the above estimates of returns to the river minus known removals by recreational and native fishermen, indicated target spawning levels were achieved (132 million eggs, mark-recapture data) or even exceeded (198 million eggs, Millbank data). The proportion of salmon that entered the river late in the season (after August 31) was greater in 1988 (about 50%) than has been the case in recent years (previous 5 year mean of < 20%). Angling catches of 1SW salmon in 1988 were 21% greater than in 1987, primarily because of increased catches during autumn. The management plan in 1988 resulted in a high spawner to returns ratio (0.92) compared to before the plan was initiated in 1984 (mean 1979 to 1983 ratio of 0.35). Assuming average returns of 1SW salmon in 1989, total returns could be about 83,000 fish, which would indicate about 60,000 grilse surplus to spawning requirements. The forecast of MSW salmon returns for 1989 is discussed in another document.

RESUME

En 1988, les dénombrements de saumon effectués au piège Millbank ont révélé que 21 667 redibermarins et 121 867 unibermarins sont revenus dans la rivière Miramichi, au Nouveau-Brunswick. Les chiffres totaux des remontées estimés d'après les recaptures de saumons étiquetés étaient inférieurs à ces résultats (15 285 redibermarins et 86 613 unibermarins). La ponte totale, fondée sur les estimations précitées dont on a déduit les retraits connus par les pêcheurs sportifs et autochtones, correspondait au niveau de reproduction cible (132 millions d'oeufs d'après les recaptures de saumons étiquetés) ou lui était supérieure (198 millions d'oeufs d'après les dénombrements de Millbank). La proportion de saumon qui est entré dans la rivière à la fin de la saison, soit après le 31 août, a été plus élevée en 1988 (environ 50 %) qu'au cours des dernières années (moyenne des cinq dernières années inférieure à 20 %). Les prises d'unibermarins par les pêcheurs à la ligne ont dépassé de 21 % celles de 1987, en raison principalement de la hausse des captures en automne. Le plan de gestion de 1988 a abouti à une plus forte proportion de reproducteurs dans les remontées (0,92) que durant les années antérieures à 1984, alors qu'il n'y avait pas de plan (moyenne de 1979 à 1983 : 0,35). En tablant sur des remontées moyennes d'unibermarins en 1989, environ 83 000 poissons pourraient revenir à la rivière, ce qui donnerait approximativement 60 000 madeleinaux de plus que le nombre nécessaire à la reproduction. Les prévisions de remontées de redibermarins pour 1989 font l'objet d'un autre document.

INTRODUCTION

The management plan for Atlantic salmon in the Miramichi River in 1988 was the final year of a five-year plan initiated in 1984 to conserve salmon stocks. The plan prohibited commercial fishing in Miramichi Bay and estuary. Anglers were allowed to keep only 1SW (< 63 cm); all MSW salmon were released. Season, possession and daily bag limits for anglers remained at 10, 6 and 2 fish respectively. Daily and seasonal bag limits did not include hooked-and-released salmon, but anglers were obliged to stop fishing after retaining the daily limit or after releasing a maximum number of fish equal to twice the daily limit. Catch-and-release regulations also applied to the kelt fishery (15 April to 15 May).

Native food fisheries at Burnt Church, Eel Ground and Red Bank were not restricted by quota as in previous years. Possession or sale of Atlantic salmon caught in non-salmon gear (by-catch) was illegal in all areas of New Brunswick.

The objective of this report is to identify the biological status of Atlantic salmon in Miramichi River in 1988. Catch-and-effort data from the angling and Native fisheries are summarized and interpreted. Salmon returns and spawning escapement are estimated using three sets of data: Millbank counts, tag recaptures from anglers, and parr densities.

METHODS

1. Catch and effort data

Angling catches of 1SW salmon in the Miramichi River were provided monthly by DFO fishery officers. Angling data from the upper Southwest Miramichi River (York and Carleton counties) were not available; landings from this area were estimated from the average proportion of catches from these two counties from 1974 to 1983. As in previous assessments, DFO landings were adjusted by correlation with historic landings (1969 to 1986) as estimated by Department of Natural Resources and Energy (DNRE), which are considered more accurate (Randall and Chadwick 1983) (Table 1). Angling effort was recorded in rod-days, where one rod-day was one angler fishing for any portion of one day. Angling seasons in 1988 were similar to 1987 for most Miramichi tributaries (Appendix I).

In the previous three assessments of salmon in the Miramichi River, the numbers of MSW salmon caught and released were estimated from a correlation between Millbank count of salmon and DNRE catch using data prior to the

introduction of the catch-and-release policy (1969 to 1983; Randall and Schofield 1988). However, this estimate has consistently been too low:

	estimate	actual
1985	5,291	9,622
1986	7,253	14,266
1987	4,234	11,932

For this assessment, numbers of MSW salmon were estimated from the average MSW/1SW ratio in the DNRE catch for the last four years (0.52, range 0.45 - 0.57) times the estimate of DNRE 1SW salmon catch in 1988. Note that the estimate of MSW salmon caught and released in 1988 was not used to interpret run strength; it was used to estimate the numbers of MSW salmon lost to catch-and-release mortality only.

Landings of MSW and 1SW salmon from Native fisheries at Burnt Church, Red Bank and Eel Ground were reported from Band Council offices periodically during the season.

2. Counting facilities and biological sampling

Returns of MSW and 1SW salmon entering the Miramichi River were monitored daily at Millbank trap from 15 May to 15 October, 1988. Most MSW salmon (n=245) and one in five 1SW salmon (n=330) were sampled (scales for aging, length and external sexing after 1 September) and one in ten 1SW salmon were sacrificed for internal sexing (before 1 September). In addition, many fish were tagged (Carlin tags with stainless steel ties), before being released; a total of 241 MSW salmon and 1278 1SW salmon were tagged in 1988. Tag recaptures were used to determine the angling exploitation rate in 1988.

Information on salmon counts were also available from two headwater barriers located in the Dungarvon and north branch of the SW Miramichi River (Fig. 1). Barrier counts have been available since 1981 at both locations. In 1988, the Dungarvon barrier was operated from 3 June to 15 October and the SW barrier was operated from 30 June to 24 October.

3. Recruitment

Electrofishing surveys were conducted at 15 sites in the Miramichi watershed during July of 1988. Densities of juvenile salmon were estimated by the removal method (Zippin 1956). Long term trends in parr densities were identified by comparing mean densities at the same 15 sites from 1970 to 1988. Densities of age 1+ parr were used to estimate spawning escapements from 1971 to 1988 (Method 2, discussed later).

4. Spawning escapement in 1988

Three methods were used to estimate spawning escapement in 1988:

Method 1: Millbank trap efficiency. For 1988, a Millbank trap catch efficiency of 0.015 (0.0117 - 0.020) was used. This efficiency was calculated from mark-recapture data collected from Millbank and two estuarial recapture traps from 1985 to 1987 (Table 2). Chi-square analysis indicated no significant difference in catch efficiency of 1SW and MSW salmon in any of the three years (Table 3), and there was also no difference in catch efficiency of either age-group among years (eg. for 1SW salmon, $X^2=1.68$, df=2, P=0.43). For calculating the average catch efficiency for the period 1985 to 1987, only data for 1SW salmon were used because sample sizes of recaptures were greater than for MSW salmon (Table 2). Spawning escapement was estimated as returns to Millbank (trap count divided by 0.015) minus the numbers of salmon harvested above Millbank.

Method 2: Ratio of spawner to Millbank trap count. Numbers of spawners from 1971 to 1988 were estimated from 1+ parr densities by assuming 10% survival from eggs to 1+ parr (Elson 1957; 1974; Chadwick 1982) and a total rearing area of 55×10^6 m^2 (Amiro 1983). Mean number of eggs per spawner in the Miramichi River was calculated by Randall (1985). The average ratio of spawner to trap count was 8.24 (Table 4). Spawning escapement was calculated as the product of this ratio and counts of salmon at Millbank in 1988. Two further adjustments were made: first, to account for the change in catch efficiency of Millbank trap from 1973 to 1985-87 (Randall and Schofield 1988), adjusted Millbank counts of 933 (MSW) and 6709 (1SW) were used. Second, estimated angling catches of MSW salmon were added to the estimated spawners; this was necessary because MSW salmon were released in 1988, whereas in most years when the ratio was calculated MSW salmon were landed.

Method 3: Angling exploitation rate. Angling exploitation rate during 1988 was estimated from tag returns from anglers. Spawning escapement of 1SW salmon was then calculated by dividing angling catch by the exploitation rate. Formulae, assumptions and a discussion of this method are given by Randall et al. (1989). Tag reporting rates of 0.6 and 0.7 were used; these values were higher than estimates from 1986 and 1987 (0.54 and 0.52; Randall et al. 1989) but were considered reasonable because the reward for tags was increased in 1988. Numbers of MSW spawners were estimated by applying the proportion of MSW salmon to total salmon at Millbank in 1988 (0.15) to the 1SW spawner estimate. This estimate assumes that the ratio of 1SW to MSW salmon at Millbank was representative of the entire population; this assumption seemed reasonable because proportions of MSW salmon at Millbank and in the angling catches were significantly correlated prior to 1984 (when catch-and-release was introduced) (Fig. 2).

For all three methods, salmon mortalities from disease and poaching were assumed to be 1,000 MSW salmon and 4,000 1SW salmon, as in previous assessments. Mortality rate attributed to catch-and-release stress of MSW salmon was assumed to be 0.03 (Currie 1985).

Total egg deposition requirements for the Miramichi River were estimated to be 132 X 10^6 eggs (Randall 1985). Based on average fecundities of Miramichi salmon, Randall (1985) estimated 23,600 MSW salmon and 22,600 1SW salmon are required to produce the required egg deposition. The average fecundity of 1SW and MSW salmon in 1988 was estimated from a length-fecundity relationship calculated for Miramichi salmon (Randall 1985) and average lengths and sex ratios of salmon in 1988, as determined from preliminary Millbank samples. Total egg deposition in 1988 was calculated as average fecundity times spawning escapement (numbers of fish).

5. Estimate of total returns, 1971 to 1988

Returns of 1SW and MSW salmon to the Miramichi River each year from 1971 to 1987 were estimated using Millbank trap data and calculated or assumed trap catch efficiencies. Efficiencies were calculated in 1973 (Turner 1983), and from 1985 to 1987 (Table 2). As in previous assessments, the 1973 trap efficiency was used for all years from 1971 to 1980. Efficiencies for the period 1981 to 1984 were calculated by correlation with DNRE angling data which indicated average efficiencies of 0.022 for MSW salmon and 0.034 for 1SW salmon (Randall and Schofield 1988). For both 1SW and MSW salmon, an average efficiency of 0.015 was used for the period 1985 to 1987 (Table 2).

6. Forecast of salmon returns in 1989

Expected returns of 1SW salmon in 1989, based on previous spawning escapement levels and historic averages, are discussed in this assessment. The Miramichi forecast model which is used to predict MSW salmon returns is discussed in detail in another document (Randall and Chadwick 1989), together with a prediction of MSW salmon returns to the Miramichi River in 1989.

RESULTS

1. Catch and effort data, 1988

Despite a slight reduction in angling effort from 1987 to 1988 (7%), catch of 1SW kelts increased by 40% (Table 5). Increased catches in 1988 were unexpected because angling catches and Millbank data indicated greater returns of 1SW salmon in 1986 than 1987. Catches of kelts in 1988 were greater in both April and May than in 1987.

Catches of bright 1SW salmon also increased from 1987 to 1988, by 21% (Table 5). Angling effort increased slightly between years (4%). Increased catches in 1988 occurred during the late angling season only; catches in June and July were actually lower than in 1987. Reported catches from DFO officers were adjusted upwards by correlation with historic DNRE data (Table 1), to give an adjusted estimate of 18,171 salmon. This catch estimate was about equal to the previous five-year average.

Numbers of MSW salmon caught and released by anglers were estimated to be about 9449 (Table 1).

Native fishermen at Burnt Church, Eel Ground and Red Bank reported catching 348 MSW salmon and 944 1SW salmon during 1988 (Table 6). Reported catches of MSW salmon decreased by 61% from 1987 to 1988, and 1SW salmon decreased by 26%. As in 1987, Native fishermen set gillnets in the Northwest Miramichi River above the head of tide (Big Hole Tract), whereas historically their fishing was restricted to tidal waters. No landings were available from the Big Hole Tract fishery.

Total reported landings of 1SW and MSW salmon in 1988 are compared to 1986 and 1987 landings in Table 7. Long term landings for the Miramichi River (1951 to 1987) are given in Table 8.

2. Millbank trap and protection barriers

At Millbank trap, counts of both 1SW and MSW salmon increased from 1987 to 1988 (Table 9). Counts of 1SW salmon increased by 44%, from 1272 in 1987 to 1828 in 1988. Counts of MSW salmon increased by only 12%, from 291 to 325. In 1988, counts of MSW salmon were about equal to the previous 5 year mean (1983 to 1987) of 330 fish; counts of 1SW salmon, however were above the mean by 59% (5 year mean was 1153 fish). The increase in run strength from 1987 to 1988 was restricted to the late run. Early-run counts actually decreased slightly from 1987 to 1988 (Table 9; Fig. 3), but late-run counts increased substantially, by 7 times for 1SW salmon and by 2 times for MSW salmon. Judging from Millbank data, the proportion of salmon that returned to the Miramichi River late in the season in 1988 was substantially greater than in recent years (Fig. 4).

Indications of run strength at two protection barriers, which probably reflect early-run fish because of their location in the headwaters, were variable. At the SW Miramichi barrier, MSW salmon counts were lower in 1988 from 1987 by 27%, and 1SW salmon counts were lower by 7% (Table 10). In contrast, Dungarvon River counts increased from 1987 to 1988, by 37% for MSW salmon and by 14% for 1SW salmon. However the Dungarvon barrier was installed earlier in 1988 and this affected the count relative to other years: revised counts were similar to 1987 (parenthesis in Table 10). All barrier counts in 1988 were above the long-term averages. Note that salmon in barrier pools have now been protected for more than one generation (6 years), and thus barrier counts may reflect enhanced returns to these localized tributaries.

Water levels in the Miramichi River were generally closer to long-term averages in 1988 than in 1987 (Fig. 5). Water flow was below normal in May and June, but close to or above normal in April, August, September and October.

3. Biological sampling

During 1988, 575 salmon (330 1SW and 245 MSW salmon) were sampled for age composition, length and sex ratio. Preliminary data on biological characteristics of subsamples of 201 1SW salmon and 69 MSW salmon are given in Table 11. A high proportion of both 1SW and MSW salmon smoltified at age 2; MSW salmon were therefore from the 1983 and 1984 year classes (year class is year of emergence) and 1SW salmon were from the 1984 and 1985 year classes. The percent female composition of the spawning run was 88.6% for MSW salmon and 21.8 % for 1SW salmon. Based on the mean fork lengths and sex ratios of salmon in 1988, and the length-fecundity relationship for Miramichi salmon (Randall 1985), reproductive potential (average eggs per spawner) was 6426 eggs for MSW salmon and 706 eggs for 1SW salmon in 1988.

4. Recruitment

Average densities of age 0+ and 1+ salmon parr at the 15 sites in 1988 were the highest on record (Table 12; Fig. 6). Mean densities of 0+ fry in 1988 were 2.6 times the long term average, and age 1+ parr were 1.5 times greater than average. In contrast, densities of large parr (primarily age 2+ parr) were 38% below average. Note that densities of age 0+ fry were particularly high at two of the 15 sites (2.5 and 3.7 fish per m^2, respectively) and this affected the overall mean density of this age group.

5. Returns and spawning escapement in 1988

Total returns and estimated spawning requirements in 1988 as estimated by the three methods are summarized below. Note that the harvest above Millbank includes an estimate of catch-and-release mortality of 283 salmon (0.03 X 9449):

	Method			
	1	2	3	
			0.6	0.7
MSW salmon				
1. Returns to Millbank	21,667	18,804	15,285	17,832
2. Harvest above Millbank	553	553	553	553
3. Poaching and disease	1,000	1,000	1,000	1,000
4. Broodstock	97	97	97	97
5. Trap mortalities	17	17	17	17
6. Estimated spawners	20,000	17,137	13,618	16,165
7. Required spawners	23,600	23,600	23,600	23,600
% of target achieved	85%	72%	58%	68%
1SW salmon				
1. Total returns	121,867	78,422	86,613	101,049
2. Harvest above Millbank	19,063	19,063	19,063	19,063
3. Poaching and disease	4,000	4,000	4,000	4,000
4. Meshed/sacrificed/brood	77	77	77	77
5. Spawners	98,727	55,282	63,473	77,909
6. Required spawners	22,600	22,600	22,600	22,600
% of target achieved	437%	127%	280%	345%

Reasonable upper and lower limits of spawning escapement are probably provided by Method 1 (trap efficiency of 0.015) and Method 3 (angling mark-recapture data with a reporting rate of 0.6). In terms of egg deposition, Method 1 indicates a total deposition of 198.2 million eggs (150% of requirements), while Method 3 indicates a deposition of 132.3 million eggs (100% of requirements).

Mark-recapture data used to estimate returns in 1988 are summarized in Table 13 and Table 14. Assuming a reporting rate of 0.6 indicates an exploitation rate of 0.23 for early-run fish, 0.19 for late-run fish and 0.21 for the whole season (Table 14).

6. Historic returns, 1971 to 1988

Returns and spawning escapement of 1SW and MSW salmon to the Miramichi River, 1971 to 1988, are estimated in Table 15. Estimates of MSW spawners were generally correlated with other indices of spawning escapement in the Miramichi River (Table 16). The relationship between estimated egg deposition and resulting fry and parr densities in the Miramichi River is illustrated in Fig. 7. Target egg deposition levels (132 million eggs) have apparently been met in the last three years (Table 17).

7. Forecast for 1989

Average 1SW salmon returns in the past five years was 82,958 fish. Returns of 1SW salmon in 1989 will be from the 1985 (smolt age 2) and 1984 (smolt age 3) spawning years. Spawning indices for these two year classes were compared to previous five-year averages:

spawning year	egg deposition	0+	1+
1984	-13%	+69%	+56%
1985	+15%	+47%	+49%

Most spawning indices indicated above average recruitment in both 1984 and 1985, and therefore 1SW returns in 1989 could be above average.

DISCUSSION

Returns of MSW salmon to the Miramichi River in 1988 were calculated to be between 15,285 (as estimated from angling mark-recapture data), and 21,667 fish (as estimated from Millbank data). These estimates were substantially below the forecast presented in the 1987 assessment (Randall and Schofield 1988); the above returns were 60% and 42% respectively of the forecast of 36,378 (16,950 - 55,805) fish. Reanalysis of data from the Miramichi River, however, suggests that the forecast model used in the previous two years was inappropriate, and tended to overestimate potential returns. A revised model, based on adjusted data from Millbank trap, would have predicted lower returns of MSW salmon in 1988 (Randall and Chadwick 1989). Even with the revised model, variances associated with forecasts are large and thus confidence intervals are unacceptably wide. Forecast models for the Miramichi stock are presently being investigated to identify additional factors that contribute to variation in MSW salmon returns (Randall and Chadwick 1989).

Returns of 1SW salmon in 1988 were estimated to be between 86,613 and 121,867 fish, indicating returns which were substantially above the previous five year mean (Table 15). Age 1SW salmon in 1988 were from two spawning years, 1983 and 1984, indicating many (55%) had smoltified at age 2. Returns of 1SW fish tend to be high in the Miramichi River when two smolt ages contribute to the run (Randall, unpublished data). Together, 1SW and MSW salmon produced a total egg deposition of between 132.3 and 198.2 million eggs. Therefore spawning requirements (132 million eggs) were met or exceeded in 1989. As in previous years, the management plan in effect had a major impact on spawning success. The spawner to returns ratio for 1988 was 0.92, compared to an average ratio in the five years prior to the introduction of the management plan of 0.35 (Table 15).

Analysis of tag recapture data from anglers provided a potentially useful method of estimating run size independent of Millbank trap data. For 1988, both sets of data gave reasonably similar estimates of spawning escapement (within 30 to 40%). A major weakness of mark-recapture data is the uncertainty of reporting and tag mortality rates which influence significantly the estimate of exploitation rate and therefore run size (Randall et al. 1989). For the Miramichi River, it would be useful in future if run size could be monitored with a counting fence at one or two tributaries; assumptions of the mark-recapture method could therefore be tested under controlled conditions. Results could then be applied to the entire river. Two tributaries will be considered for monitoring, the Bartholomew River (which has both an early and late run) and Rocky Brook (an early run stock). The use of mark-recapture data to estimate spawning escapement in future is discussed further by Randall et al. 1989.

If returns of 1SW salmon are average in 1989, total returns would be about 83,000 fish. Spawning indices in years that will contribute to 1SW salmon in 1989 suggest that returns may be above average. Potential surpluses to spawning requirements could be about 60,000 1SW salmon. As noted earlier, the forecast of MSW salmon returns for 1989 is discussed elsewhere (Randall and Chadwick 1989).

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Table 1. Angling statistics for MSW and 1SW salmon in the Miramichi River as estimated by DNRE and DFO, 1969 to 1988.

	MSW salmon		1SW salmon	
Year	DFO	DNRE	DFO	DNRE
1969	2,827	3,804	26,715	24,284
1970	2,057	3,268	19,662	19,610
1971	1,247	1,792	8,464	13,727
1972	5,456	8,933	15,472	19,101
1973	4,881	5,977	9,033	13,857
1974	5,895	7,184	17,957	18,232
1975	3,756	6,288	9,730	15,598
1976	5,319	7,374	14,749	27,182
1977	14,344	11,617	8,244	13,590
1978	4,196	4,893	5,353	8,265
1979	2,422	2,656	7,625	14,508
1980	5,422	6,546	7,533	11,997
1981	1,602	3,238	7,031	22,716
1982	2,642	4,608	9,217	21,402
1983	1,646	2,240	3,897	8,390
1984	---	[4,692]	9,892	10,397
1985	---	[9,622]	11,926	18,439
1986	---	[14,266]	28,299	26,163
1987	---	[11,932]	11,363	20,765
1988	---	[9,449][1]	13,732	[18,171][2]
Mean (69-87)	4,247	[6,365]	12,219	17,275

[1] MSW salmon caught and released in 1988 was based on the average ratio of MSW/1SW salmon, 1984-1987 (0.52, range 0.45 - 0.57) times the 1SW catch in 1988.

[2] 1SW salmon catch (DNRE) in 1988 was estimated from a correlation between DFO salmon (x) and DNRE salmon (y) from 1969 to 1987; y = 10,038.4 + 0.59 (x), r=0.71, P£0.0007.

Table 2. Summary of mark-recapture data from the Miramichi River, 1985 to 1987.

Year	M	C	R	N(95% CL)	Efficiency
1SW salmon					
1985	600 (480)	1,543	15	46,417 (28,785 - 79,007)	0.020 (0.012 - 0.032)
1986	1,587 (1,270)	2,351	26	110,718 (76,651 - 166,077)	0.016 (0.011 - 0.023)
1987	1,103 (882)	1,539	13	30,317 (58,361 - 172,129)	0.013 (0.007 - 0.022)
TOTAL	3,290 (2,632)	5,433	54	260,140 (200,108 - 337,446)	0.015 (0.0117 - 0.020)
MSW salmon					
1985	219 (175)	690	4	24,323 (10,859 - 60,808)	0.013 (0.005 - 0.029)
1986	400 (320)	849	8	30,317 (16,241 - 62,011)	0.016 (0.008 - 0.029)
1987	275 (220)	486	7	13,453 (6,987 - 28,323)	0.022 (0.010 - 0.042)
TOTAL	894 (715)	2,025	19	72,531 (47,406 - 116,049)	0.015 (0.009 - 0.0226)

Table 3. Test for heterogeneity in catch efficiency of Millbank trap for 1SW and MSW salmon 1985 to 1987.

Year		Proportion tagged	Recapture catch	Recaptures	Adjusted recaptures	X^2	P
1985	1SW	0.6579	1,543	15	23	1.44	0.231
	MSW	0.7042	690	4	6		
1986	1SW	0.9002	2,351	26	29	0.16	0.689
	MSW	0.8529	849	8	9		
1987	1SW	0.8671	1,539	13	15	0.75	0.388
	MSW	0.9450	486	7	7		

Table 4. Ratios of spawners to Millbank count, 1971 to 1986. Spawners were calculated from 1+ parr, assuming 10% survived from eggs to smolts, and a rearing area of 55 X 10^6 m^2.

Year (i)	Parr m^{-2} (year i + 2) 15 Sites	Eggs salmon	Millbank	Proportion MSW	Spawner	Spawner/Millbank
1971	0.030	1,206	399	0.17	2,312	5.79
1972	0.110	1,911	1,151	0.31	9,864	8.57
1973	0.128	2,125	1,132	0.32	10,470	9.25
1974	0.117	2,444	1,791	0.31	8,090	4.52
1975	0.084	2,149	1,208	0.25	5,460	4.52
1976	0.107	1,541	943	0.16	6,123	6.49
1977	0.090	3,761	1,934	0.56	7,402	3.83
1978	0.083	2,846	693	0.35	5,668	8.18
1979	0.070	1,370	318	0.11	3,171	9.97
1980	0.098	2,492	1,093	0.34	7,315	6.69
1981	0.067	956	199	0.08	3,232	16.24
1982	0.065	1,450	408	0.13	3,273	8.02
1983	0.089	1,832	245	0.23	6,205	25.33
1984	0.122	2,006	333	0.25	8,294	24.91
1985	0.131	2,006	311	0.25	9,134	29.37
1986	0.139	2,006	469	0.21	8,003	17.06
Sum			12,627		104,016	
Mean ratio						8.24

Table 5. Angling catch-and-effort data for 1SW salmon in the Miramichi River in 1988 as estimated by DFO fishery officers. Data for 1987 given for comparison.

	1988			1987		
	Kelts	Brights	Rod-days	Kelts	Brights	Rod-days
April	3,147	-------	3,268	2,244	-------	2,577
May	919	-------	2,058	652	-------	3,163
TOTAL	4,066		5,326	2,896		5,740
Mean weight (kg)	1.24			1.21		
June	-----	798	4,693	-----	1,189	4,878
July	-----	2,014	8,969	-----	3,441	11,658
August	-----	2,948	8,262	-----	2,770	9,109
September	-----	7,369	12,898	-----	3,605	8,246
October	-----	603	2,023	-----	358	1,438
TOTAL		13,732	36,845		11,363	35,329
Mean weight (kg)		1.66			1.71	

Table 6. Native fishery landings in Miramichi River and Bay, 1986 to 1988.

	1988		1987		1986	
	1SW	MSW	1SW	MSW	1SW	MSW
Red Bank	450	175	885	615	1,064	336
Eel Ground	442	95	373	262	908	287
Burnt Church	52	78	16	21	16	18
TOTAL	944	348	1,274	898	1,988	641

Table 7. Preliminary 1988 salmon landings in the Miramichi River and Bay. Landings for 1986 and 1987 are given for comparison.

	1988		1987		1986	
	1SW	MSW	1SW	MSW	1SW	MSW
Native	944	348	1,274	898	1,988	641
Angling[1]	18,171	(283)[2]	20,765	(358)[2]	26,163	(428)[2]
TOTAL	19,115	631	22,039	1,256	28,151	1,069

1 Angling landings from DNRE (Table 1).

2 Assuming a catch-and-release mortality rate of 0.03.

Table 8. Recorded catches of salmon in all fisheries, Miramichi River and Bay, 1951-88 (includes commercial, by-catch, recreatignal and Native). Kelts angled in year i are added to landings in year i-1. 1988 data are preliminary. All data are numbers x 10^3.

				ANGLING										
	COMMERCIAL			Kelts (yr i+1)			Bright (yr i)				NATIVE			GRAND
Year	1SW	MSW	Total	1SW	MSW	Total	1SW	MSW	Total	Total	1SW	MSW	Total	TOTAL
1951		27.6	27.6			12.0			9.6	21.6				49.2
1952		27.3	27.3			11.3			15.9	27.2				54.5
1953		24.4	24.4			10.1			18.2	28.3				52.7
1954		50.6	50.6			11.2			23.5	34.7				85.3
1955		15.3	15.3			8.9			14.7	23.6				38.9
1956		24.7	24.7			9.3			28.9	38.2				62.9
1957		29.9	29.9			8.4			19.5	27.9				57.8
1958		25.2	25.2			10.2			36.7	46.9				72.1
1959		37.3	37.3			9.5			10.3	19.8				57.1
1960		30.8	30.8			5.6			4.5	10.1				40.9
1961		30.0	30.0			9.5			11.0	20.5				50.5
1962		41.6	41.6			7.3			10.3	17.6				59.2
1963		40.7	40.7			5.2			50.9	56.1				96.8
1964		69.8	69.8			9.0			35.1	44.1				113.9
1965		69.5	69.5			16.0	38.7	3.9	42.6	58.6				128.1
1966		72.9	72.9			20.0	51.7	5.9	57.6	77.6				150.5
1967		102.2	102.2			14.1	41.8	4.1	45.9	60.0				162.2
1968		48.5	48.5			6.9	7.0	1.5	8.5	15.4				63.9
1969		41.3	41.3	3.7	1.6	5.3	24.3	3.8	28.1	33.4				74.7
1970		39.7	39.7	2.4	1.4	3.8	19.6	3.3	22.9	26.7				66.4
1971		18.3	18.3	1.5	0.5	2.0	13.7	1.8	15.5	17.5				35.8
1972		2.5	2.5	1.5	3.0	4.5	19.1	8.9	28.0	32.5				35.0
1973		0.9	0.9	1.5	3.0	4.5	13.9	6.0	19.9	24.4				25.3
1974		1.0	1.0	1.8	3.1	4.9	18.2	7.2	25.4	30.3				31.3
1975	0.4	0.7	1.1	2.3	1.4	3.7	15.6	6.3	21.9	25.6	0.4	0.2	0.6	27.3
1976	1.8	0.9	2.7	2.4	2.2	4.6	27.2	7.4	34.6	39.2	0.2	0.2	0.4	42.3
1977	0.4	6.9	7.3	1.4	2.1	3.5	13.6	11.6	25.2	28.7	0.5	0.4	0.9	36.9
1978	1.2	8.4	9.6	1.5	1.7	3.2	8.3	4.9	13.2	16.4	0.4	0.4	0.8	26.8
1979	5.5	1.7	7.2	2.2	1.5	3.7	14.5	2.7	17.2	20.9	0.1	0.2	0.3	28.4
1980	2.7	10.9	13.6	1.7	2.1	3.8	12.0	6.5	18.5	22.3	-	-	-	35.9
1981	1.6	7.8	9.4	2.7	1.4	4.1	22.7	3.2	25.9	30.0	1.0	0.5	1.5	40.9
1982	2.3	12.5	14.8	2.1	1.0	3.1	21.4	4.6	26.0	29.1	0.7	0.4	1.1	45.0
1983	1.6	17.1	18.7	0.9	0.7	1.6	8.4	2.2	10.6	12.2	0.4	0.2	0.6	31.5
1984	0.0	0.0	0.0	2.4	0.0	2.4	10.4	0.0	10.4	12.8	0.4	0.3	0.7	13.5
1985	0.0	0.0	0.0	2.5	0.0	2.5	18.4	0.0	18.4	20.9	0.5	0.3	0.8	21.7
1986	0.0	0.0	0.0	2.7	0.0	2.7	26.2	0.0	26.2	28.9	2.0	0.6	2.6	31.5
1987	0.0	0.0	0.0	---	0.0	---	20.8	0.0	20.8	20.8	1.3	0.9	2.2	23.0
1988	0.0	0.0	0.0	---	0.0	---	18.2	0.0	18.2	18.2	0.9	0.3	1.2	19.4

Data from: May and Lear (1971); Smith (1981); Swetnam and O'Neil (1985) and unpublished sources.

Table 9. Counts of 1SW and MSW salmon at Millbank, 1966 to 1988. Counts are divided into early (May-August) and late periods (September-November).

Year	Early		Late		Total		Proportion early	
	1SW	MSW	1SW	MSW	1SW	MSW	1SW	MSW
1966	4563	309	5426	1323	9989	1632	0.46	0.19
1967	1508	73	6215	924	7723	997	0.20	0.07
1968	2493	292	746	1122	3239	1414	0.77	0.21
1969	3224	339	1126	328	4350	667	0.74	0.51
1970	1826	125	658	120	2484	245	0.74	0.51
1971	1849	375	113	24	1962	399	0.94	0.94
1972	2377	934	166	217	2543	1151	0.93	0.81
1973	1490	478	960	654	2450	1132	0.61	0.42
1974	2948	864	1090	927	4038	1791	0.73	0.48
1975	2954	628	594	580	3548	1208	0.83	0.52
1976	4072	641	867	302	4939	943	0.82	0.68
1977	1249	1189	256	745	1505	1934	0.83	0.61
1978	1150	535	118	158	1268	693	0.91	0.77
1979	2157	257	343	61	2500	318	0.86	0.81
1980	1802	837	337	256	2139	1093	0.84	0.77
1981	2020	173	154	26	2174	199	0.93	0.87
1982	2593	392	72	16	2665	408	0.97	0.96
1983	770	226	40	19	810	245	0.95	0.92
1984	879	257	131	76	1010	333	0.87	0.77
1985	901	287	11	24	912	311	0.99	0.92
1986	1324	345	439	124	1763	469	0.75	0.74
1987	1146	223	126	68	1272	291	0.90	0.77
1988	884	173	944	152	1828	325	0.48	0.53
Mean (66-87)	2059	445	909	368	2967	812	0.80	0.65
Mean (83-87)	1004	268	149	62	1153	330	0.89	0.82

Table 10. Numbers of MSW and 1SW salmon counted at barriers in two tributaries of the Miramichi River, 1981 to 1988.

Tributary	Year	MSW	1SW	Total	Dates Operated	No. of Days
North Branch of SW Miramichi R.	1981	54	671	725	Jul. 5 - Oct. 4	91
	1982	282	621	903	Jun. 30 - Oct. 8	101
	1983	219	290	509	Jul. 4 - Oct. 10	98
	1984	297	230	527	Jul. 10 - Oct. 16	98
	1985	604	492	1,096	Jul. 1 - Oct. 20	112
	1986	1,138	2,072	3,210	Jun. 30 - Oct. 19	112
	1987	1,266	1,175	2,441	Jul. 2 - Oct. 19	110
	Mean	551	793	1,344		103
	1988	929	1,092	2,021	Jun. 30 - Oct. 24	117
Dungarvon R.	1981	112	550	662	Jun. 24 - Oct. 8	107
	1982	120	489	609	Jun. 28 - Oct. 15	110
	1983	126	330	456	Jun. 27 - Oct. 14	110
	1984	93	315	408	Jul. 5 - Oct. 12	100
	1985	162	536	698	Jun. 25 - Oct. 10	108
	1986	174	501	675	Jun. 25 - Oct. 21	119
	1987	202	744	946	Jun. 25 - Oct. 14	112
	Mean	141	495	636		109
	1988	277 (210)	851 (769)	1,128	Jun. 3 - Oct. 25	145

Table 11. Biological characteristics of adult salmon sampled at Millbank trap, 1988. (preliminary; based on 270 of 578 samples).

Sea Age	n	FL	(SD)	n	W	(sd)	n	% male
1SW	201	53.9	(3.39)	98	1.47	(0.29)	195	78.2
2SW	56	74.2	(3.13)	15	5.35	(0.96)	0	0.0
PS	13	87.6	(10.93)	3	5.92	(0.47)	0	0.0
MSW	69	76.7	(7.55)	18	5.45	(0.91)	158	11.4

		Percent at smolt age		
	n	2	3	4
1SW (1988)	201	54.7 (1985)[1]	42.8 (1984)	2.5 (1983)
2SW (1988)	55	54.6 (1984)	45.4 (1983)	0.0
1SW (1987)	310	41.0 (1984)[1]	58.1 (1983)	0.9 (1982)
2SW (1987)	51	47.1 (1983)	52.9 (1982)	0.0

[1] Year-class in parenthesis.

Table 12. Juvenile Atlantic salmon densities (number 100 m^2) in the Miramichi River, 1970 to 1988. (n=number of sites; 95% confidence interval in parenthesis).

		Standard Sites		
Year	n	Age 0+	Age 1+	Age 2+
1970	8	35.3 (8.1 - 154.8)	6.1 (3.1 - 12.0)	5.5 (3.1 - 9.8)
1971	14	20.1 (12.4 - 32.7)	7.9 (4.4 - 14.1)	2.4 (1.7 - 3.4)
1972	15	9.8 (5.1 - 18.5)	8.3 (4.9 - 13.9)	3.7 (2.3 - 6.0)
1973	15	24.9 (13.7 - 45.4)	3.0 (1.9 - 4.9)	1.1 (0.8 - 1.5)
1974	15	34.2 (14.6 - 80.3)	11.0 (5.6 - 21.3)	2.7 (1.6 - 4.6)
1975	15	40.0 (21.7 - 73.8)	12.8 (7.5 - 22.0)	2.4 (1.7 - 3.5)
1976	15	25.1 (15.4 - 40.8)	11.7 (6.6 - 20.9)	3.5 (2.1 - 5.6)
1977	15	51.8 (25.8 - 103.9)	8.4 (5.1 - 14.0)	3.7 (2.2 - 6.3)
1978	15	36.4 (17.3 - 76.6)	10.7 (4.7 - 24.3)	3.9 (2.4 - 6.5)
1979	15	19.7 (10.1 - 38.5)	9.0 (5.1 - 16.1)	2.8 (1.8 - 4.5)
1980	15	34.5 (14.8 - 80.5)	8.3 (4.4 - 15.6)	2.1 (1.4 - 3.2)
1981	15	53.6 (26.1 - 110.0)	7.0 (3.9 - 12.8)	2.8 (2.0 - 4.1)
1982	15	15.0 (8.9 - 25.4)	9.8 (5.7 - 16.9)	3.8 (2.2 - 6.5)
1983	15	44.5 (23.6 - 84.1)	6.7 (3.8 - 11.8)	3.6 (2.1 - 6.3)
1984	15	19.1 (11.0 - 33.1)	6.5 (4.1 - 10.2)	1.6 (1.1 - 2.4)
1985	14	56.4 (21.4 - 148.8)	8.9 (4.6 - 17.2)	0.8 (0.6 - 1.0)
1986	15	55.4 (24.9 - 123.0)	12.2 (6.3 - 23.9)	3.8 (2.4 - 6.2)
1987	15	74.5 (32.5 - 170.8)	13.1 (7.2 - 23.8)	2.5 (1.7 - 3.6)
1970-87 mean		36.1	9.0	2.9
1988	15	95.1 (59.7 - 151.5)	13.9 (6.8 - 28.1)	1.8 (1.3 - 2.4)

Table 13. Number of 1SW salmon tagged and number of tags returned by anglers during the 1988 angling season.

	early	late	total
Trap count	884	944	1,828
Tagged	692	586	1,278
Eligible tags[a]	687	586	1,273
Proportion	0.78	0.62	0.70
Recaptures	91	64	155
Late recaptures[b]	4	3	7
TOTAL	95	67	162

[a] 5 tags were returned by Native fishermen in tidal waters.

[b] Assuming late tag returns of 4.4% as in 1987.

Table 14. Summary of mark-recapture data from the angling fisheries in Miramichi River, 1988. Exploitation rates and estimated total returns are also calculated (95% ch in parenthesis).

1. Mark-recapture data and assumed reporting rate.

Reporting rate	Number tagged		Correction factor	Angling catch	Number recaptures	
	early	late			early	late
0.6	412.2	351.6	1.26	18171	95	67
0.7	480.9	410.2	1.26	18171	95	67
1.0	687.0	586.0	1.26	18171	95	67

2. Angling Exploitation

Reporting rate	Angling Exploitation rate		
	early	late	total
0.6	0.23 (0.19, 0.28)	0.19 (0.15, 0.24)	0.21 (0.18, 0.24)
0.7	0.20 (0.66, 0.24)	0.16 (0.13, 0.21)	0.18 (0.16, 0.21)
1.0	0.14 (0.11, 0.17)	0.11 (0.09, 0.15)	0.13 (0.11, 0.15)

3. Total returns

Reporting rate	Returns
0.6	86,613 (74,832 - 100,250)
0.7	101,049 (87,304 - 116,959)
1.0	144,355 (124,720 - 167,084)

Table 15. Estimates of spawning escapement (S) and total returns (R) of MSW salmon (upper) and 1SW salmon (lower) in the Miramichi River, 1971 to 1988.

YR	HE1	HE2	HR	MIL	PAD	E1	MILR	S	R	SR
MSW salmon										
71	15,128	3,140	1,792	399	1,000	0.043	9,279	3,347	24,407	0.14
72	2,282	163	8,933	1,151	1,000	0.043	26,767	16,671	29,049	0.57
73	866	0	5,977	1,132	1,000	0.043	26,326	19,349	27,192	0.71
74	941	22	7,184	1,791	1,000	0.043	41,651	33,445	42,592	0.79
75	724	19	6,626	1,208	1,000	0.043	28,093	20,448	28,817	0.71
76	871	7	7,591	943	1,000	0.043	21,930	13,332	22,801	0.58
77	6,865	0	12,060	1,934	1,000	0.043	44,977	31,917	51,842	0.62
78	8,377	0	5,287	693	1,000	0.043	16,116	9,829	24,493	0.40
79	1,659	0	2,854	318	1,000	0.043	7,395	3,541	9,054	0.39
80	10,899	0	6,546	1,093	1,000	0.043	25,419	17,873	36,318	0.49
81	7,137	699	3,738	199	1,000	0.022	9,045	3,608	16,182	0.22
82	12,213	298	4,989	408	1,000	0.022	18,545	12,258	30,758	0.40
83	16,788	269	2,409	245	1,000	0.022	11,136	7,458	27,924	0.27
84	1	0	449	333	1,000	0.022	15,136	13,687	15,137	0.90
85	5	0	611	311	1,000	0.015	20,733	19,122	20,738	0.92
86	18	0	1,051	469	1,000	0.015	31,267	29,216	31,285	0.93
87	21	0	1,344	291	1,000	0.015	19,400	17,056	19,421	0.88
88	78	0	667	325	1,000	0.015	21,667	20,000	21,745	0.92
1SW salmon										
71	0	0	13,727	1,962	4,000	0.055	35,673	17,946	35,673	0.50
72	39	0	19,101	2,543	4,000	0.055	46,236	23,135	46,275	0.50
73	0	0	13,857	2,450	4,000	0.055	44,545	26,688	44,545	0.60
74	0	0	18,232	4,038	4,000	0.055	73,418	51,186	73,418	0.70
75	393	0	16,040	3,548	4,000	0.055	64,509	44,469	64,902	0.69
76	1,780	39	27,381	4,939	4,000	0.055	89,800	58,380	91,580	0.64
77	379	28	14,089	1,505	4,000	0.055	27,364	9,247	27,743	0.33
78	1,232	2	8,700	1,268	4,000	0.055	23,055	10,353	24,287	0.43
79	5,510	2	14,605	2,500	4,000	0.055	45,455	26,848	50,965	0.53
80	2,697	0	11,997	2,139	4,000	0.055	38,891	22,894	41,588	0.55
81	1,332	296	23,716	2,174	4,000	0.034	63,941	35,929	65,273	0.55
82	1,997	314	22,068	2,665	4,000	0.034	78,382	52,000	80,379	0.65
83	1,360	229	8,746	810	4,000	0.034	23,824	10,849	25,184	0.43
84	1	0	10,777	1,010	4,000	0.034	29,706	14,929	29,707	0.50
85	0	0	18,985	912	4,000	0.015	60,800	37,815	60,800	0.62
86	16	0	28,135	1,763	4,000	0.015	117,533	85,398	117,549	0.73
87	16	0	22,023	1,272	4,000	0.015	84,800	58,777	84,816	0.69
88	52	0	19,140	1,828	4,000	0.015	121,867	98,727	121,919	0.81

HE1 = harvest in estuary below Millbank; HE2 = harvest in estuary above Millbank; HR = harvest in river; MIL = Millbank trap count; PAD = poaching and disease; E1 = Millbank catch efficiencies, MILR = returns to Millbank; S = spawners; R = returns.

Table 16. Indices of spawning escapement in Miramichi River, 1970 to 1988.

1 Year (i)	2 Kelt (i)	3 Bright (i-1)	4 0+ (i)	5 1+ (i+1)	6 Spawners (i-1)
1970	1,647	3,804	35.3	7.9	
1971	1,352	3,268	20.1	8.3	
1972	547	1,792	9.8	3.0	3,347
1973	2,970	8,933	24.9	11.0	16,671
1974	3,037	5,977	34.2	12.8	19,349
1975	3,111	7,184	40.0	11.7	33,445
1976	1,446	6,288	25.1	8.4	20,448
1977	2,156	7,374	51.8	10.7	13,332
1978	2,126	11,617	36.4	9.0	31,917
1979	1,668	4,893	19.7	8.3	9,829
1980	1,504	2,656	34.5	7.0	3,541
1981	2,118	6,546	53.6	9.8	17,873
1982	1,368	3,238	15.0	6.7	3,608
1983	960	4,608	44.5	6.5	12,258
1984	666	2,240	19.1	8.9	7,458
1985	3,771	5,299	56.4	12.2	13,687
1986	6,856	9,622	55.4	13.1	19,122
1987	5,099	14,266	74.5	13.9	29,216
1988		11,932	95.1		17,056

Correlations:

	n	r	P
2 with 3	18	0.71	0.001
2 with 4	18	0.70	0.001
2 with 5	18	0.83	0.001
2 with 6	16	0.51	0.040
3 with 4	19	0.72	0.001
3 with 5	18	0.70	0.001
3 with 6	17	0.77	0.001
4 with 5	18	0.70	0.001
4 with 6	17	0.42	0.089
5 with 6	16	0.64	0.007

Table 17. Estimated egg deposition in the Miramichi River, 1971 to 1988.

Year	Eggs/spawner		Egg deposition (millions)
	1SW	MSW	
1971	301	5,593	24.1
1972	636	4,766	94.2
1973	544	5,643	123.7
1974	894	5,928	244.0*
1975	752	6,160	159.4*
1976	689	6,125	121.9
1977	661	6,222	204.7*
1978	1,043	6,149	71.2
1979	771	6,218	42.7
1980	549	6,331	125.7
1981	696	4,278	40.4
1982	905	5,120	109.8
1983	838	5,224	48.1
1984	661	4,908	77.0
1985	665	5,484	130.0
1986	738	5,593	226.4*
1987	1,049	6,697	175.9*
1988	706	6,426	198.2*

* asterisks indicate years when target egg deposition levels were met (132.0 million eggs).

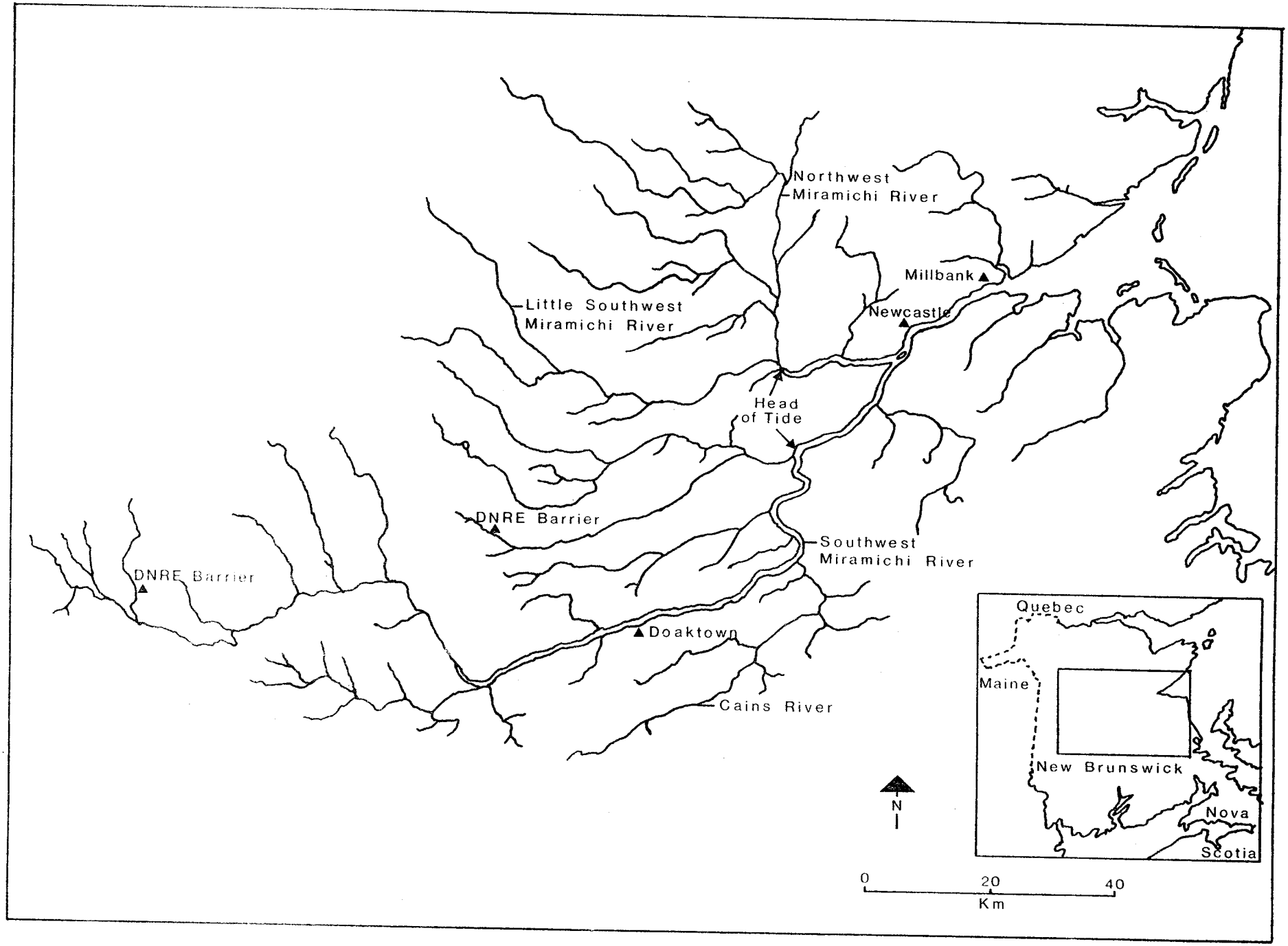


Figure 1. Map of the Miramichi River

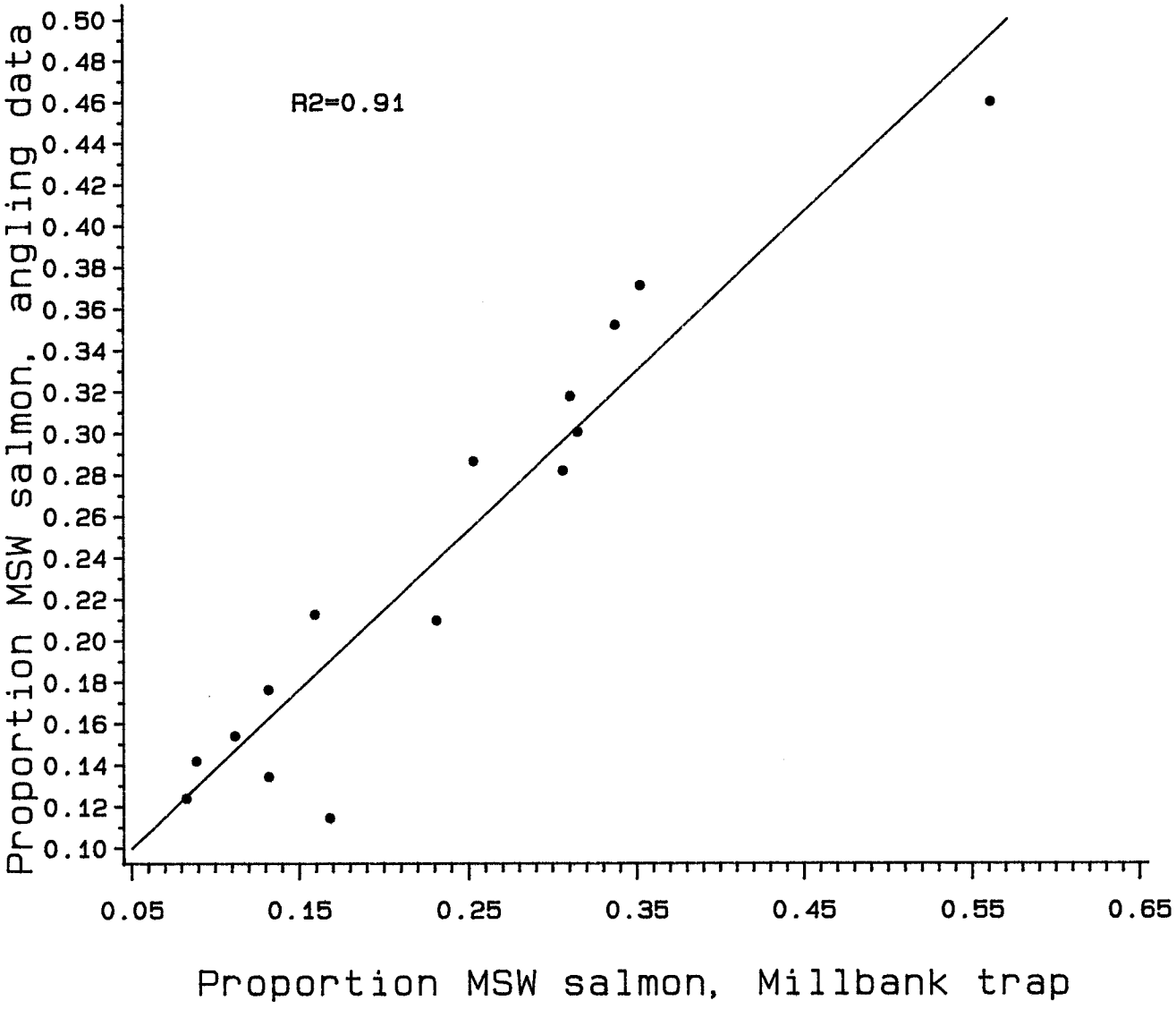
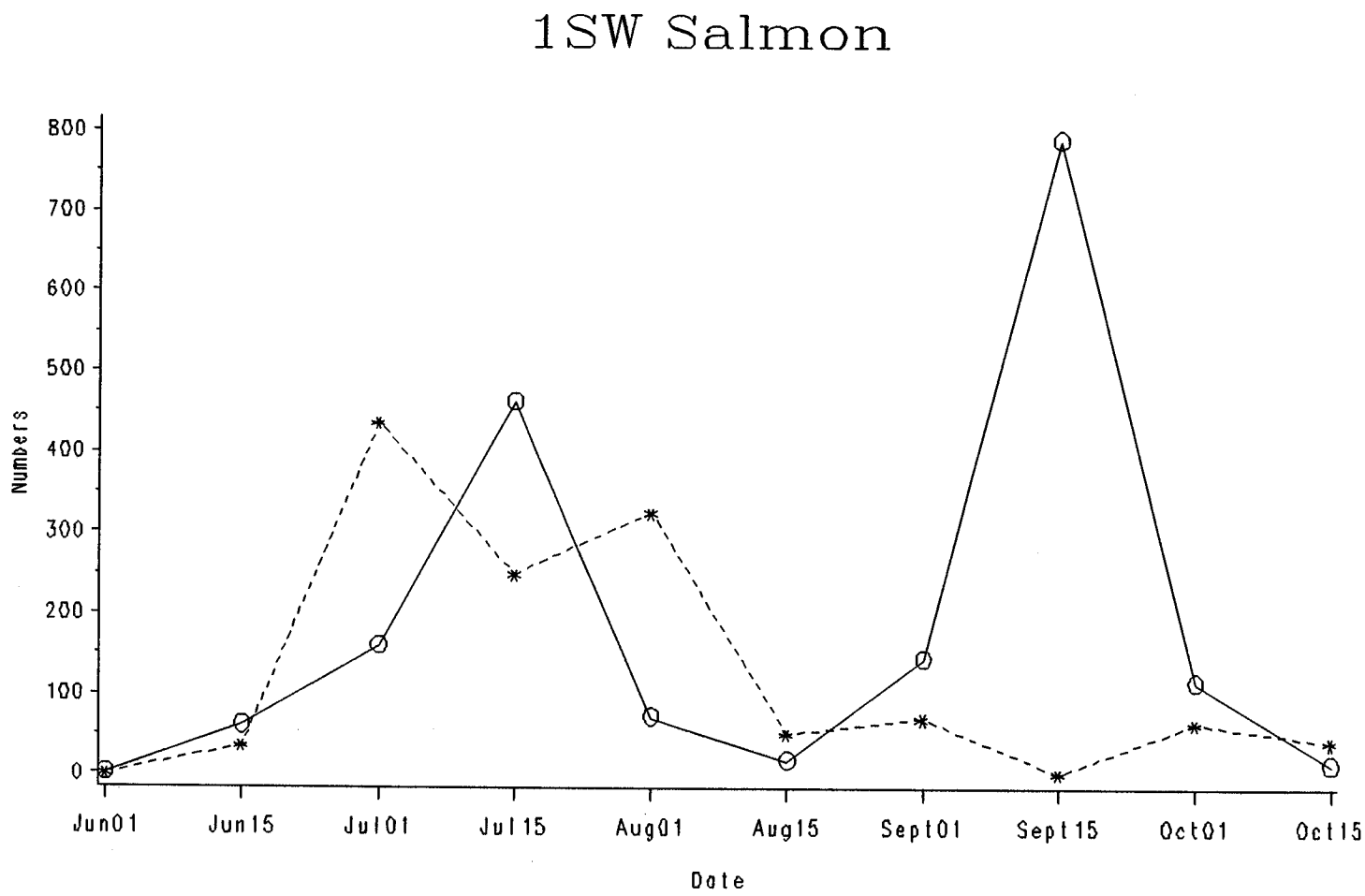


Figure 2. Relationship between the proportion of MSW salmon to total salmon (1SW plus MSW salmon) at Millbank trap and in angling catches, 1969 to 1983.



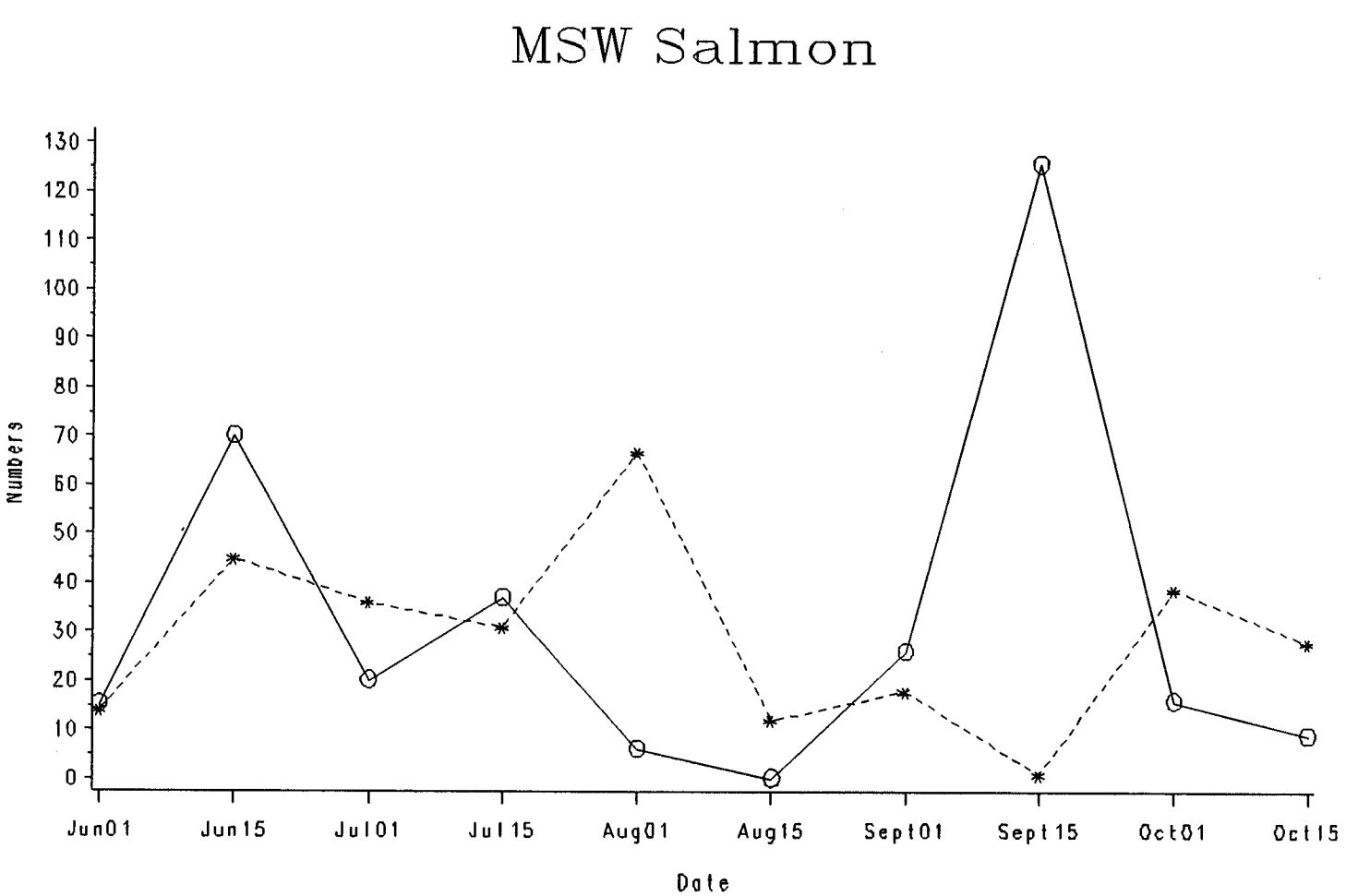


Fig. 3. Numbers of salmon caught at Millbank during half-month periods
Dashed line - 1987; solid line - 1988.

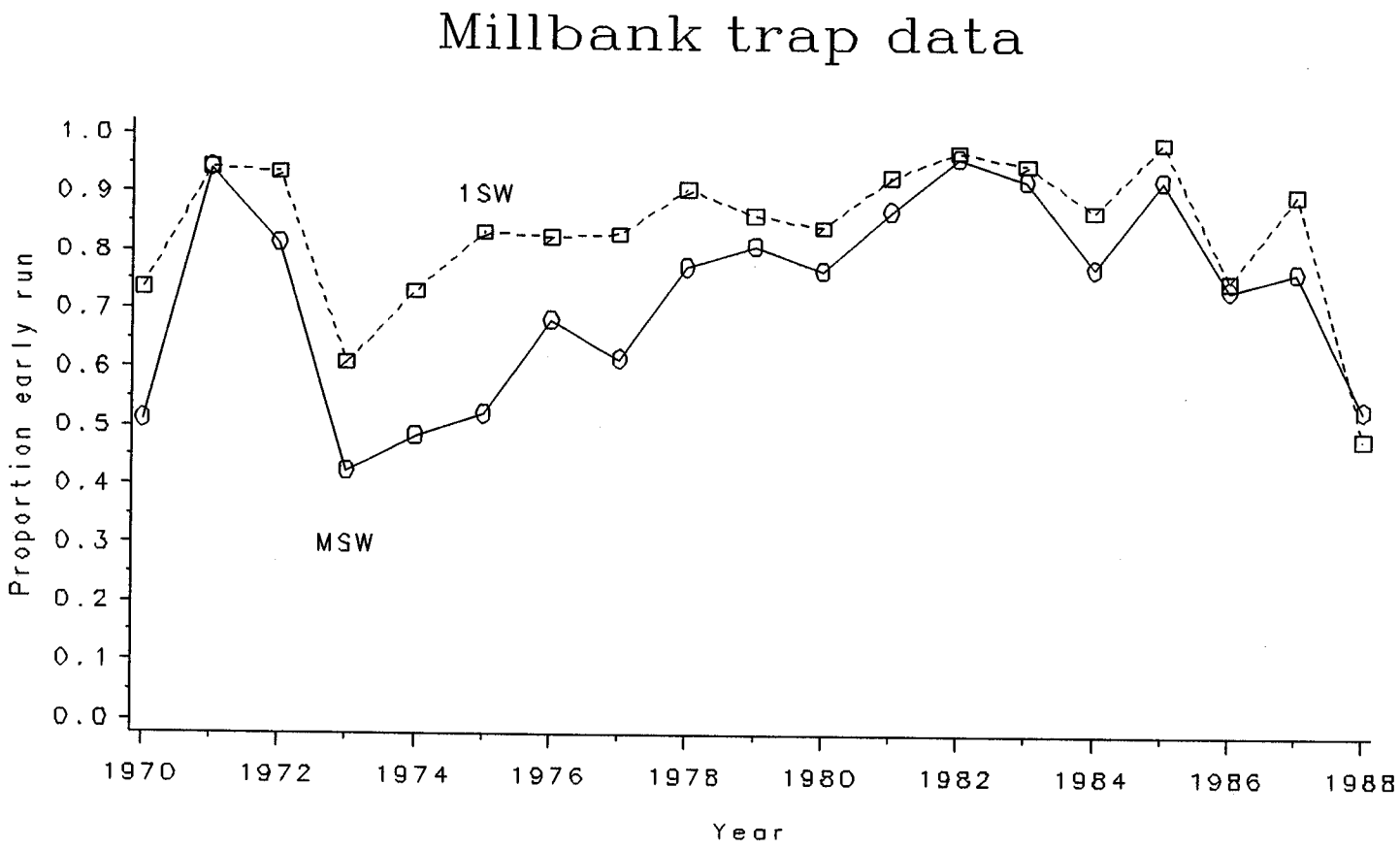


Figure 4. Proportion of early-run salmon (salmon returning from May to August) at Millbank trap, 1970 to 1988.

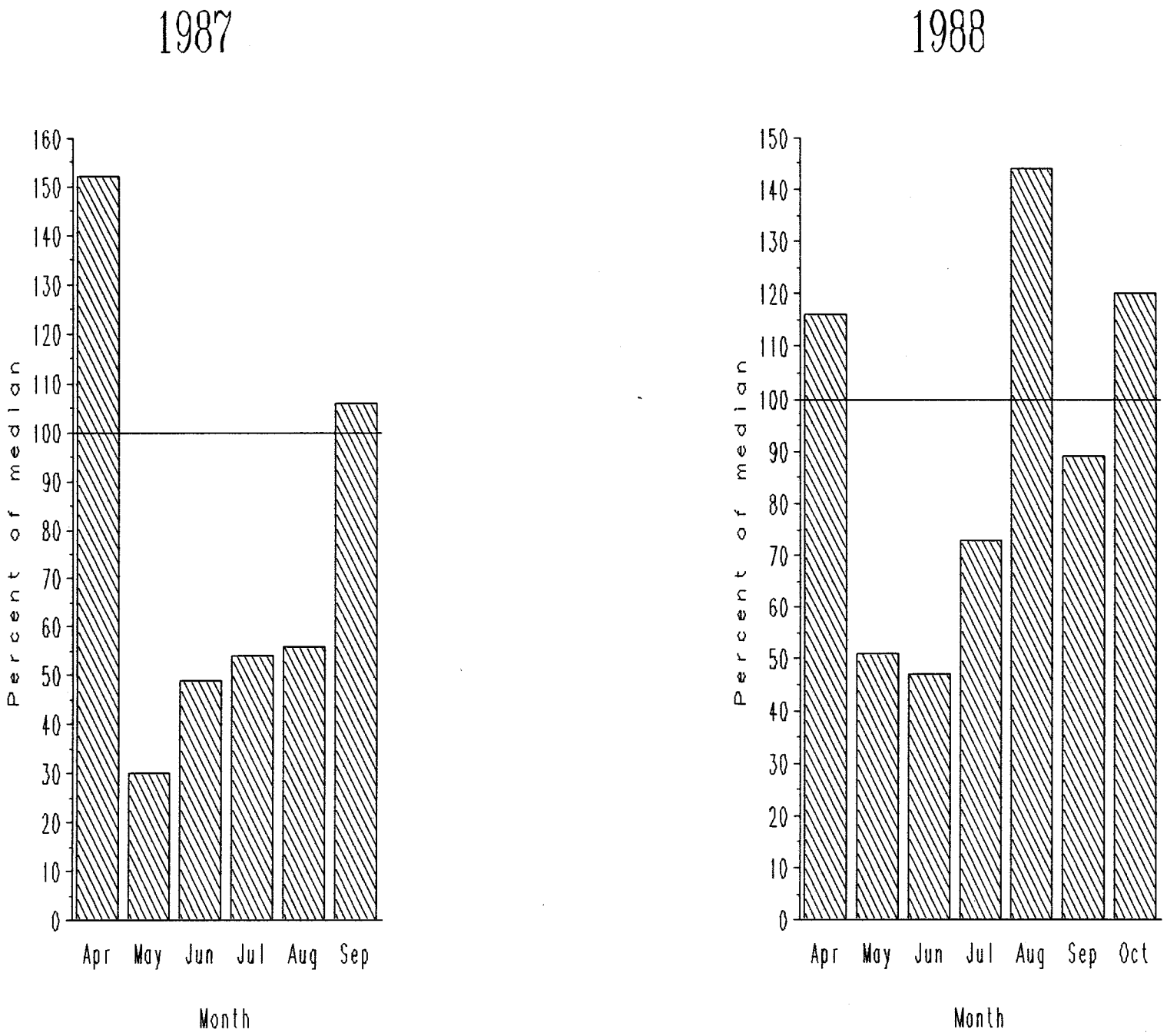


Figure 5. Water discharge rate, expressed as a percent of the long-term median) in the Southwest Miramichi River, 1987 and 1988.

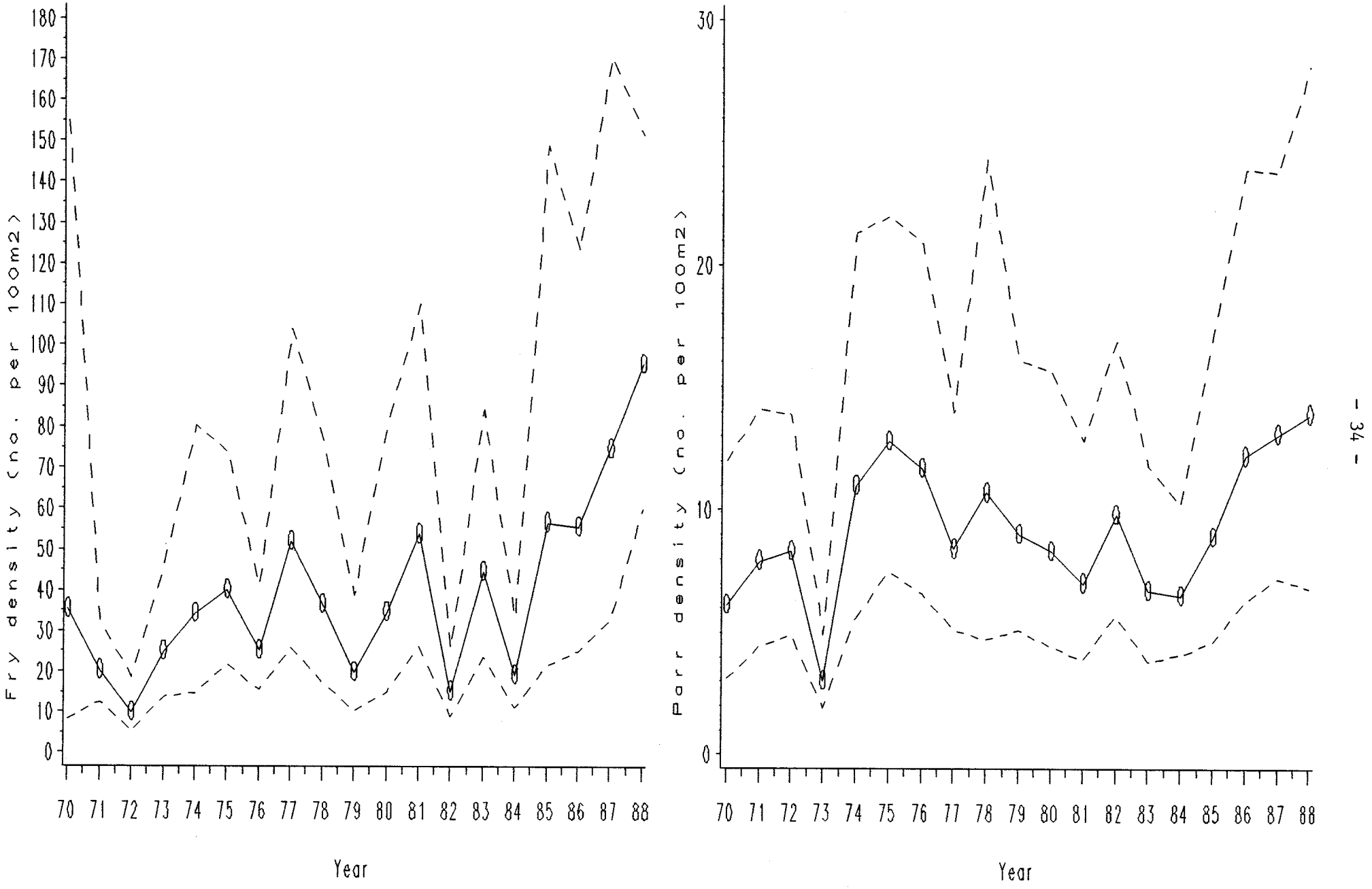
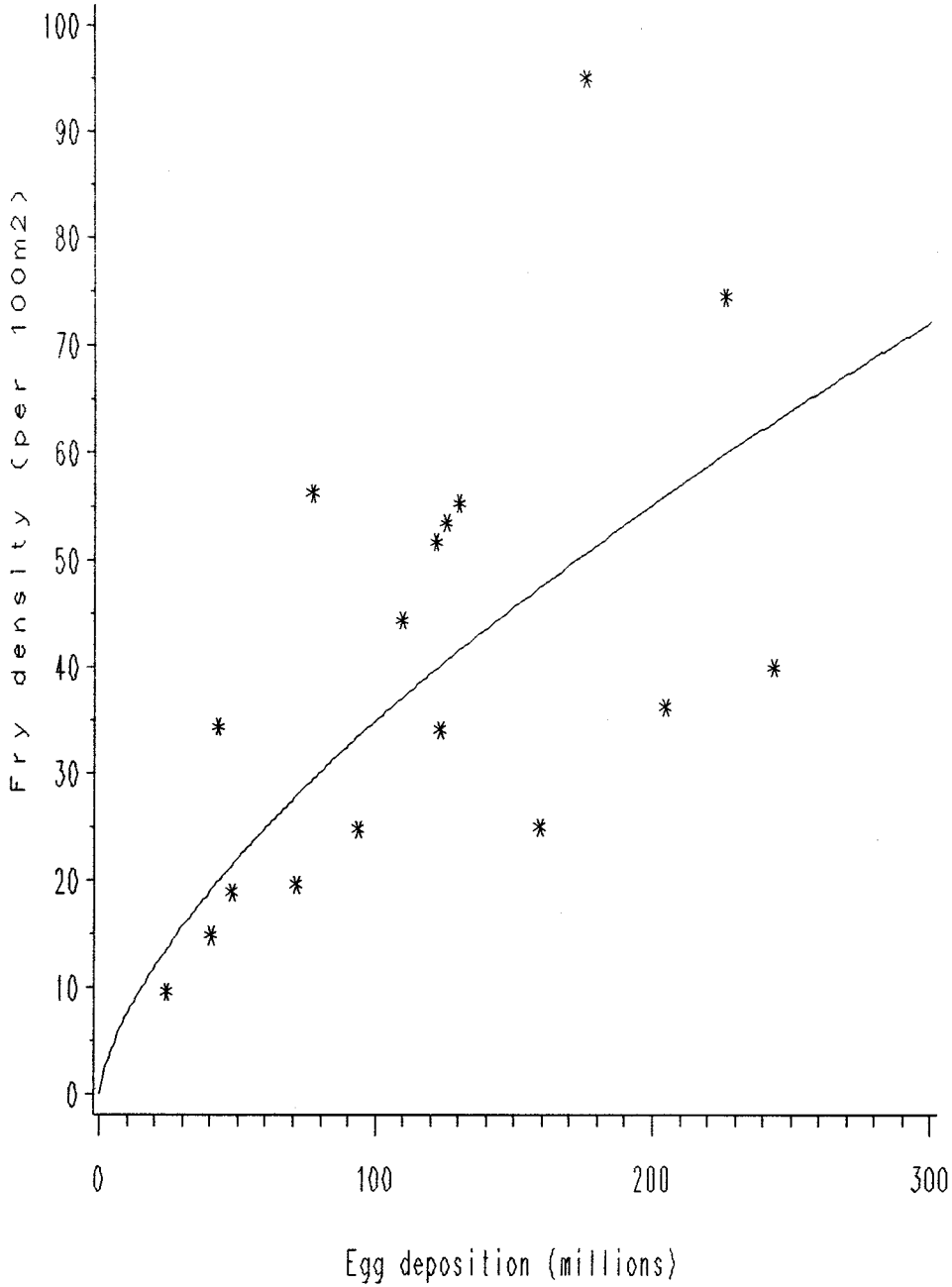


Figure 6. Mean densities of salmon fry (left) and age 1 parr (right) at 15 sites in the Miramichi River 1970 to 1988. Dashed lines indicate upper and lower 95% confidence intervals.



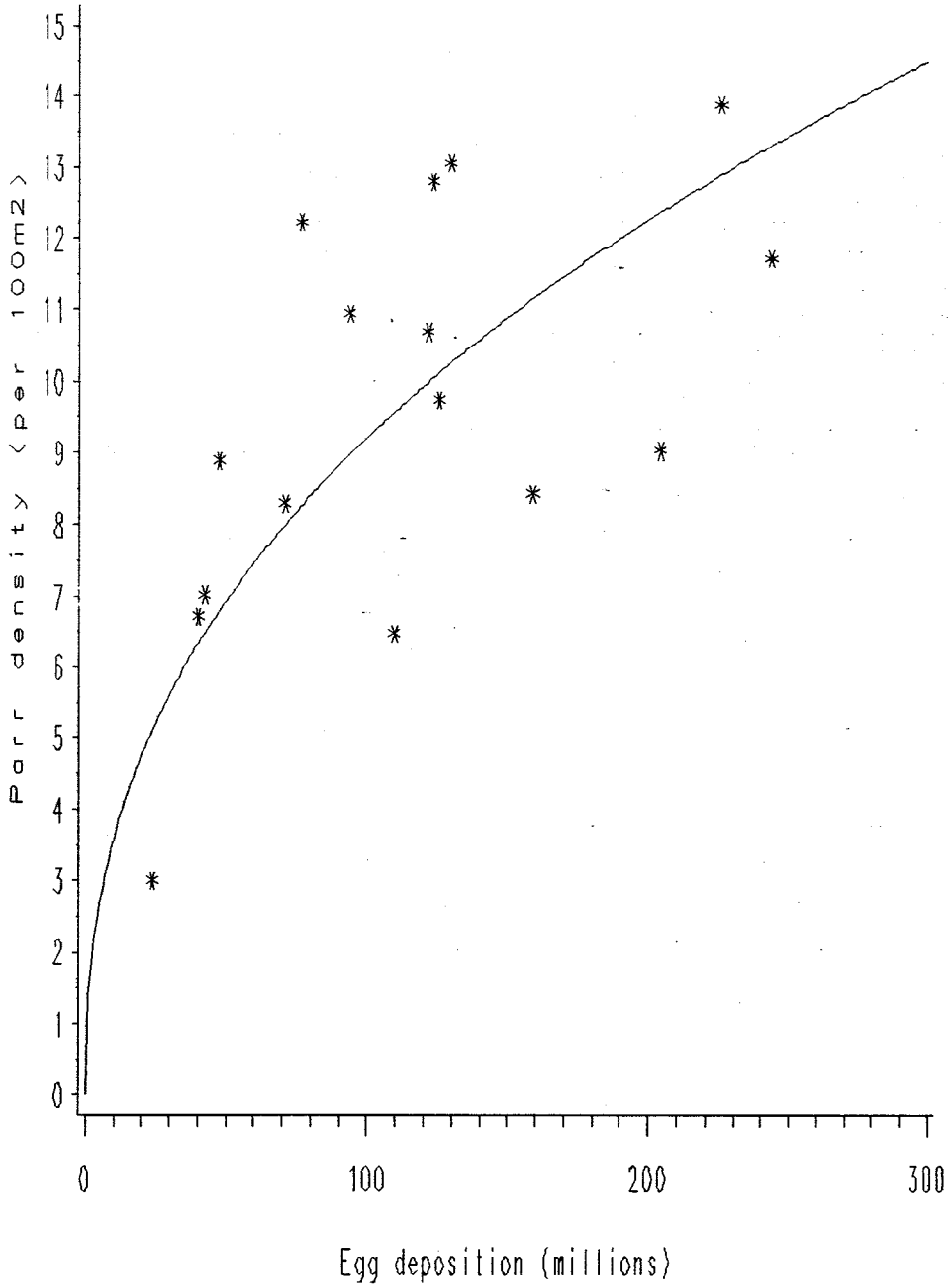


Figure 7. Relationship between estimated egg deposition and resulting fry and parr densities in the Miramichi River, 1970 to 1988.

APPENDIX I. Angling seasons on Miramichi tributaries, 1988 and 1987.

Tributary	Season 1988	Season 1987
General (bright salmon)	8 June - 30 September	8 June - 30 September
Exceptions		
Bartholomew	Closed	Closed
Bartibog	1 July - 29 October	1 July - 29 October
Cains	1 July - 15 October	1 July - 15 October
Dungarvon (above Underwood Brook)	8 June - 15 September	8 June - 15 September
Little Southwest (above Catamaran Brook)	8 June - 15 September	8 June - 15 September
Southwest (above MacKeil Brook)	8 June - 15 September	8 June - 15 September
Northwest (above Little River)	8 June - 31 August	8 June - 31 August
Renous (above North Renous)	8 June - 15 September	8 June - 15 September
Rocky Brook	1 June - 31 August	1 June - 31 August
Sevogle (above Square Forks)	8 June - 15 September	8 June - 15 September
Other tributaries of Main Southwest Miramichi (above Cains River - except Rocky Brook)	8 June - 15 September	8 June - 15 September