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Assessment of Atlantic Salmon of the Saint John River, N.B., 1988

by

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ABSTRACT

Estimated total returns to the Saint John River in 1988 were 19,300 1SW and 6,500 MSW salmon. Homewater losses of about 4,100 1SW and 2,400 MSW fish led to an estimated 1988 spawning escapement only 41 percent of the target number of MSW spawners. The forecast of 1989 homewater returns is about 19,000 1SW fish (11,400 more than the target escapement) and 12,100 MSW salmon (2,000 fish more than the target escapement). Homing tendencies of the MSW salmon will result in a surplus to spawning requirements of about 2,700 fish above Mactaquac. There will be a deficit of about 700 MSW fish to spawning escapement below Mactaquac. Variation between forecast and 'actual' fish returns continues to suggest the utility and value of multi-year management plans based on general trends in stock status rather than on a specific assessment.

RESUME

Les estimations de remontées totales dans le fleuve Saint-Jean en 1988 se chiffrent à 19 300 unibermarins et à 6 500 redibermarins. Toutefois, en raison de la perte d'environ 4 100 unibermarins et 2 400 redibermarins dans les eaux d'origine, les échappées de reproducteurs estimées n'ont été que de 41 % de la cible chez les redibermarins. Pour 1989, on prévoit qu'environ 19 000 unibermarins (11 400 de plus que le niveau-cible d'échappées) et 12 100 redibermarins (2 000 de plus que le niveau-cible d'échappées) reviendront dans leurs eaux d'origine. Les tendances de retour des redibermarins se traduiront par un excédent d'environ 2 700 poissons sur les besoins de reproducteurs en amont de Mactaquac. En revanche, on s'attend à un déficit d'environ 700 unibermarins sur les échappées de reproducteurs requises en aval de Mactaquac. Les écarts persistants entre les prévisions et les chiffres réels des remontées semblent prouver l'utilité et la valeur d'un plan de gestion pluriannuel fondé sur les tendances générales du stock plutôt que sur une évaluation donnée.

INTRODUCTION

This document is background to the management of Atlantic salmon stocks of the Saint John River, New Brunswick, and, as such, documents data and analyses available to November 1988 relevant to stock status in 1988 and forecasts for 1989.

BACKGROUND

Physical attributes of the Saint John River drainage, salmon production area, barriers to migration, fish collection and distribution systems, the role of fish culture operations and status of the salmon stocks since 1970 have previously been described by Marshall and Penney (MS 1983), Penney and Marshall (MS 1984), and Marshall (MS 1984, MS 1985, MS 1987, MS 1988).

Forecasts made in 1987 (Marshall MS 1988) suggested that total 1988 homewater returns would number approximately 14,800 1SW and 15,200 MSW salmon. CAFSAC advised managers (CAFSAC Advisory Document 87/24) that for 1988 there would in total be 7,200 1SW and 5,100 MSW salmon surplus to spawning requirements, including a surplus of 3,600 MSW salmon originating at/above Mactaquac.

The Management Plan for 1988 was identical to that of 1987 in that there was a total ban on homewater commercial fisheries, a prohibition on the retention of MSW salmon captured in the sport fisheries, the same open seasons for sport fishing, a 900-fish quota for the Indian Food Fishery at Kingsclear and a 150-fish license for the Oromocto Indian Band. The Kingsclear Indian Band again appeared to constrain their harvest to a level approximating their quota and the Oromocto Band again caught almost nothing. In contrast, the Tobique Indian Band conducted an illegal 'fish-in', Jul 29 to Aug 24 which, by various reports probably netted 25% of the MSW fish placed above Mactaquac. Summer discharges were again low, e.g., Tobique R. at Riley Brook and Nashwaak River at Durham Bridge, but unlike those of 1987 did not result in Closed Time Variation Orders to angling. Low water level and warm temperatures would appear, to have been contributory to the first confirmed outbreak of furunculosis-related deaths of adults on the Saint John River.

Sport-fishing success was fair-to-poor through August and good-to-excellent where seasons extended to mid and late October.

In general, estimates of total returns, removals and required spawners in 1988 and forecasts for 1989 were determined in a manner similar to that of Marshall (MS 1988). Slight variations include the allocations of specific losses to hook-and-release and poaching/disease and updates in return rates for hatchery-reared fish. An estimate of MSW returns in 1989, based on the product of 1SW returns in 1988 and the mean of MSW/1SW ratios (<1.0) in the 1980's is proposed as an alternative to that estimate derived from the regression of MSW fish on 1SW fish over the last 18 years.

METHODS

Total River Returns

Total returns of 1SW and MSW salmon of both wild and hatchery origin from both above and below Mactaquac Dam consist of the summation of Mactaquac counts, estimated catches by the Kingsclear Indian Band located between the Mactaquac Dam and Mactaquac Fish Culture Station, estimated angling catches in the mainstem area immediately below the Mactaquac Fish Culture Station, estimated by-catch and estimated returns to tributaries below Mactaquac Dam.

Mactaquac counts consist of those fish captured at the fish collection facilities at the Mactaquac Dam and at the smolt migration channel at the Mactaquac Fish Culture Station. The discontinuation in 1984 of clipping the adipose fin from smolts originating at Mactaquac Fish Culture Station has meant that the identification of 1SW and MSW returns in 1988 from 1-year smolts released at Mactaquac were dependent on fin erosion (principally dorsal fin) and on interpretation of patterns of freshwater growth on scales (every tenth fish collected). The institution of clipping the adipose fin from about one-third of all fall fingerlings placed above Mactaquac, prominent fin erosion on returns and interpretation of patterns of freshwater growth on scale contributed to the estimation of returns resulting from distribution of other hatchery products.

Estimates of removals by Kingsclear were obtained from federal and provincial sources. Relative exploitation rates for 1SW and MSW salmon of hatchery origin (previous tag recovery information) and proportions of hatchery and wild fish at the dam were used to apportion total removals into hatchery/wild and 1SW/MSW components.

By-catch was estimated to be 2% of the total 1SW and 5% of the total MSW river returns - values which approximate the mean estimates for the years 1981-1984. Subdivision into above/below and hatchery/wild components was assumed to be proportionate to their respective contributions to the total run.

Returns of wild salmon to tributaries below Mactaquac in 1988 were based on their proportionate contribution to the estimated total Saint John River returns 1970-1983, i.e., 0.48 for 1SW and 0.41 for MSW fish (App. 1). This method was used again because of the absence of sport data, especially for MSW fish, comparable to that of pre-1984. Hatchery returns from 1-year smolts released to tributaries below Mactaquac were calculated as the product of the number of smolts released and an adjusted return rate for fish released at Mactaquac. (Marshall MS 1988 and App. 2 this document.) Similarly, returns from hatchery-reared fall fingerlings released below Mactaquac were calculated as the product of their number and return rate for fall fingerlings released above Mactaquac. Hatchery returns from undersize smolts (<12 cm) or parr released both at and below Mactaquac in 1986 could not be evaluated because survivors at the time of smoltification (1 year after introduction) were unlikely to be proximate to the Mactaquac site and therefore unlikely to return to Mactaquac as adults. These fish were assigned return rates intermediate to those of smolts and fall fingerlings.

Total River Removals

Total removals include estimates of fish taken by the Kingsclear and Tobique Indian Reserves, preliminary provincial and federal estimates of sport catch on the main stem below Mactaquac, tributaries below Mactaquac (Nashwaak, Hammond, Kennebecasis, Gaspereau/Salmon and Canaan rivers, mainstem above Mactaquac (incl. Salmon River, Victoria Co.,) and the Tobique and a by-catch in the estuary. Additional removals include some fish; captured in the Mactaquac collection facilities and transferred to the Aroostook River, retained at Mactaquac for broodstock, mortalities encountered during collection-handling operations and sacrificed for analysis. Losses of MSW fish to hook-and-release mortality were estimated at 2% of the total run placed above Mactaquac and returning to tributaries below Mactaquac, i.e., similar to a previously used 10% loss on estimated MSW sport catch. New losses to spawning escapement not ascribed in previous assessments account for poaching and disease, i.e., 4% of 1SW and 10% of MSW fish placed above Mactaquac (exclusive of those lost to Tobique Indians) and 2% and 5% of 1SW and MSW fish, respectively, returning to tributaries below Mactaquac. Losses to both Tobique Indians and furunculosis were believed to be at unprecedented levels in 1988; losses to poaching (about 3% of MSW and 2% of 1SW) provide estimates of egg deposition in the Tobique River and overall spawner return ratios of about 3 percentage points less than those of previous years. For the most part, losses were apportioned into hatchery/wild components on the basis of the proportions estimated in each production area.

Required Spawners

An accessible salmon-producing substrate of 12,261,000 m^2 above Mactaquac and 15,928,000 m^2 below, an assumed requirement of 2.4 egg/m^2, a length-fecundity relationship ($\log_e$ Eggs = 6.06423 + 0.03605 Fork Length) applied to MSW and 1SW fish, 1972-1982, and the 1SW:MSW ratios in those years suggest that, on average, approximately 4,400 and 5,700 MSW fish are required above and below Mactaquac (Marshall and Penney MS 1983). Because 1SW fish normally contribute so few eggs (usually fewer than 5% females) a management philosophy limits 1SW requirements to that number which provided males for MSW females unaccompanied by MSW males, i.e., 3,200 above and 4,400 below (Marshall and Penney op. cit.).

Stock Forecasts

a) Above Mactaquac

i) 1SW Wild

The forecast of wild 1SW returns originating above Mactaquac was derived from a regression of total wild 1SW fish returning to the Saint John River which were produced above Mactaquac, 1973-1986, on adjusted (method in Penney and Marshall MS 1984, with data updates, App. 3, 4 and 5 this paper) egg depositions in the Tobique River, 1968-1969 to 1981-1982.

Egg depositions for the period 1981-1982 were adjusted in the same manner as Penney and Marshall (MS 1984) using freshwater age composition from 732 wild 1SW fish sampled at Mactaquac in 1988. Adjustment of the 1984 and 1985 egg depositions, principal contributors to 1SW returns in 1989, was done with the use of angular-transformed mean proportions for age 2:1 and age 3:1 1SW fish in the 1969 to 1983 year-classes.

To make multiplicative effects of environment, competition, variability in recruits etc. amenable to linear regression analysis, the natural logarithms of the observed values were used (Ricker 1975). The geometric mean (GM) Y resultant of the logarithmic relationship was converted to an arithmetic mean (AM) by the formula $\log_{10}$ (AM/GM) = 0.2172 s^2 (N-1)/N, where s is the standard deviation from the regression line of the normally-distributed natural logarithms of the variates (Ricker 1975, p. 274).

ii) MSW Wild

A forecast of MSW returns to homewaters in 1989 which originated above Mactaquac was again examined through the regression of the estimated MSW returns destined for Mactaquac, 1971-1988, on the estimated numbers of 1SW fish originating above Mactaquac returning to Saint John River in the previous year. Analysis included the use of natural logarithms and conversion of the GM to AM. Because the relationship has continuously lost ability to account for variation, is driven extensively by data from the late 1960's and does not quite encompass the 1988 1SW value, the product of 1SW returns in 1988 and the mean of MSW/1SW ratios (<1.0) in the 1980's is proposed as the best forecast. The high ratios of 1983-1984 and 1984-1985 were associated with cold sea temperatures and low catches in Greenland--conditions which were not repeated in 1988.

iii) 1SW Hatchery

The release since 1985, of 1-year smolts, as opposed to principally 2-year smolts 1967-1984, prevented the forecasting of 1SW or MSW hatchery returns by either the product of the long-term return rates and the number of smolts released or by regression technique. Instead, the return rate for 1SW fish in 1989 from 1988 1-year smolts released at Mactaquac was assumed to be the same as the mean (arcsin) of the adjusted 1986-1988 return rates. The ratio of the mean tag return rates to Mactaquac from releases of tagged smolts at and below Mactaquac was used to estimate the proportion of adults that would have returned to Mactaquac from smolts released in tributaries below (App. 2).

Additional 1SW returns of age 3:1 and age 2:1 are expected at Mactaquac in 1989 from fall fingerlings culled from the 1-year smolt program and released in tributaries above Mactaquac in 1985. Returns were calculated as the product of the numbers released and return rates to Mactaquac of releases of fall fingerlings above Mactaquac in 1984 and 1985 (Table 2).

iv) MSW Hatchery

Returns as MSW fish from 1-year smolts released at Mactaquac in 1987 were estimated as the product of their number and adjusted mean (arcsin) return rate for 1-year smolts released from Mactaquac in 1985 and 1986. As with 1SW hatchery returns, MSW fish below Mactaquac but destined to return to Mactaquac were based on tag returns, 1985-1988, numbers released and mean return rate to Mactaquac (App. 2).

As well, MSW returns of age 3:2 and age 2:2 were expected from fall fingerlings released above Mactaquac in 1984 and 1985. Returns of age 2:2 salmon were calculated as the product of their numbers and a return rate to Mactaquac of the 1984 release above Mactaquac. Age 3:2 salmon were given the same return rate but discounted by 0.7 on the assumption that most fall fingerlings from 1984 had already returned at age 2:2.

Maiden hatchery fish in 1988 are also expected to contribute to repeat spawning MSW fish in 1989. This return was approximated by applying return rates of 0.05 (1SW) and 0.146 (MSW), for combined consecutive - and alternate-year spawners (Marshall and MacPhail MS 1987) to 1988 adults of hatchery origin which were estimated to have spawned. This assumes that appropriate numbers of alternates would originate from the 1987 escapement.

b) Below Mactaquac

i) 1SW Wild

The 1989 return to homewaters of 1SW fish which originated below Mactaquac was again estimated from the forecast number of 1SW originating above Mactaquac and the proportion that the 1SW fish from below Mactaquac were of the total 1SW river returns, 1970-1983.

ii) MSW Wild

The 1989 return to homewaters of MSW salmon which originated below Mactaquac was based on the forecast number of MSW fish originating above Mactaquac and the proportion that the estimated returns of MSW fish below Mactaquac were of the estimated total MSW returns to the river, 1970-1983.

iii) 1SW Hatchery

Returns from 1-year smolts released below Mactaquac in 1988 were calculated as the product of their number, the estimated proportion that would not home to Mactaquac (1.0-0.22) and the estimated return rate for smolts released at Mactaquac (App. 2). Returns from 1-year parr released in parr habitat of tributaries below Mactaquac in 1986 were calculated as the product of their number and a survival rate intermediate to those of smolts and fall fingerlings returning to Mactaquac as 1SW fish.

Returns from 1-year parr released at Mactaquac were calculated in the same manner but discounted by 0.5 for the less-than-ideal habitat in the mainstem below Mactaquac.

Returns from fall fingerlings culled from the 1-year smolt program and placed in tributaries below Mactaquac in 1984 and 1985 were calculated in the same manner as for fall fingerlings placed above Mactaquac. Unfed fry, 1985, were accorded the same survival rate to age 2:2 as accorded to age 2:1 above Mactaquac.

iv) MSW Hatchery

MSW returns from 1-year smolts released in 1987, from fall fingerings released in 1985 and 1984 and 1-year parr released in 1986 to tributaries below Mactaquac were calculated in the same manner as for those returning to Mactaquac. One-year smolts were discounted by the estimated proportion that would home to Mactaquac (0.28; App. 2). One-year parr released at Mactaquac in 1986 were accorded 0.5 of the survival rate of those released to tributaries below while unfed fry released below Mactaquac in 1985 were accorded the return rate as unfed fry returning as 1SW fish in 1988. Repeat spawners from maiden hatchery returns were calculated in the same manner as those returning to Mactaquac. MSW returns from 1-year parr released at and below Mactaquac in 1985 were assumed to have completed their maiden returns in 1988.

RESULTS

Total River Returns

Estimated homewater returns in 1988 totalled 19,300 1SW fish (10,180 destined for above and 9,120 destined for below Mactaquac) and 6,506 MSW fish (3,537 destined for above and 2,969 destined for below Mactaquac; Table 1). Hatchery returns comprised 11% and 32% of the total 1SW and MSW returns, respectively.

Counts at Mactaquac were 90% of the 1SW and 74% of the MSW fish estimated to be destined for above Mactaquac (Table 1). The removal at Kingsclear was estimated at 950 fish comprised of approximately 190 1SW and 760 MSW salmon; the removal by anglers in the main stem immediately below Mactaquac is provisionally estimated at 595 1SW fish.

Releases of 38,387 and 39,445 hatchery smolts to tributaries below Mactaquac in 1986 and 1987 respectively, the adjusted 1988 return rates of 0.00672 and 0.00355 (Table 2), and releases of various other juvenile stages, 1984-1986, and their estimated return rates (Table 3) contributed to the estimation of 877 1SW and 1,145 MSW hatchery fish returning to below Mactaquac in 1988 (Table 1).

Total River Removals

Provisional sport 1SW removals additional to those in the main stem below Mactaquac consist of 1,160 fish above Mactaquac and 950 fish in tributaries below Mactaquac (Table 4). Removal by the Tobique Indian Band of 550 fish is the mid point of values provided by local Fishery Officers. Fishing was mostly conducted in the headpond with gill nets of various lengths

and mesh size and reportedly took more salmon than grilse. Hence, as with the Kingsclear fishery, the catch was assumed to consist of 80% MSW and 20% 1SW fish with hatchery and wild proportions similar to those placed above Mactaquac.

Losses to poaching and disease combined of 10% and 5% were ascribed to MSW fish placed above Mactaquac (exclusive of those taken by the Tobique Indians) and in tributaries below Mactaquac, respectively. 1SW losses to poaching and disease were set at 4% above and 2% below Mactaquac. Included in these losses are the fewer than 100 mostly MSW mortalities noted, heard-of or observed by provincial/federal officials working on the Tobique River. Fish sampled mostly from within the Half-Mile barrier pool by NBDNRE personnel and submitted to analyses for viral and bacterial pathogens revealed furunculosis. Mortalities on the Tobique were mostly observed in a 3-4 week period beginning June 26 during low water discharge (Fig 1a, b) after water temperatures had already reached 21°C (Fig. 2). Fewer than one dozen were from among 80 MSW salmon which had been carlin-tagged at Mactaquac before transport to- and release at- the Arthurette dump site on the Tobique River.

Dead salmon were not observed elsewhere on the Saint John; eleven fish collected at Mactaquac and tested for FHPR notifiables in Halifax, July 5, were clean and the numbers of wild salmon, especially MSW fish released at Woodstock and potentially ascending Beechwood, were not proportionally different from 1987 or the years 1976-1982 when hatchery fish were distinguished from wild fish as they were passed over Beechwood Dam (Fig. 3).

Removals by all factions were estimated at about 4,050 1SW fish of which 70 were released to the Aroostook River and about 2,370 MSW salmon of which 30 were transferred to the Aroostook and 382 retained as broodfish at Mactaquac.

Spawning Escapement

Collation of the total returns (Table 1), total removals (Table 4) and numbers of fish required on average to meet an egg deposition of 2.4 eggs/m^2 indicate that 35% and 46% of the required MSW spawners were attained above and below Mactaquac, respectively (Table 5). For 1SW fish, 233% of requirements were met above Mactaquac; 177% of requirements were met below Mactaquac.

The proportion of females among predominantly wild 1SW fish counted at Mactaquac was 0.12 in 1988 -- higher than previous years. This value excludes fish taken in July which either have a higher proportion of males or are less easily sexed by external characteristics and highlights the requirements for a review of sex ratios ascribed in previous years. At 12% females, however, the 4,250 and 3,400 1SW fish surplus to spawning requirements above and below Mactaquac, respectively (Table 5), would be equivalent to about 275 and 220 female (and male) MSW fish thereby providing an equivalent MSW escapement of about 41% and 50% of the requirements.

Stock Forecasts

a) Above Mactaquac

i) 1SW Wild

The 1989 forecast of wild 1SW fish returning to Mactaquac in the absence of homewater removals was based on the regression of returns to homewaters of 1SW fish which originated above Mactaquac on estimated Tobique River egg depositions adjusted for smolt age (Fig. 4). The AM estimate for 1SW returns in 1989 is 8,197 1SW fish (95% C.L. 5,846-11,492) (Table 6).

ii) MSW Wild

A forecast of wild MSW fish destined for Mactaquac in 1989 was provided by the product of the mean ratio (0.698) MSW/1SW 1980-1981 through 1987-1988, exclusive of the high ratios, 1983-1984, 1984-1985, and 8,930 1SW returns in 1988. The method suggests that MSW returns to Mactaquac in 1989 should be 6,236 fish. The regression $\log_e Y = 5.313 + 0.393 \log_e X$ (n=18; r=0.53; p=0.023; Table 6; Fig. 5) and the 8,930 1SW returns to Mactaquac in 1988 provided an AM estimate of 7,845 MSW fish (95% C.L. 5,719-10,719) destined for Mactaquac in 1989.

iii) 1SW Hatchery

The forecast of hatchery 1SW fish destined for Mactaquac in 1988 was in part calculated as the product of an estimated 142,195 1-year smolts released at Mactaquac and an adjusted 0.0100 return rate, i.e., 1,422 fish (Table 7). Another 158 would return from smolts placed below Mactaquac. In addition, it was estimated that fall fingerlings released above Mactaquac in 1984 and 1985 would contribute another 500 1SW fish (Table 7). The total forecast of hatchery 1SW returns to Mactaquac is 2,080 1SW fish.

iv) MSW Hatchery

MSW returns destined for Mactaquac in 1989 were calculated as the sum of the product of an estimated return rate of 0.00403 and 113,439 smolts released at Mactaquac (457 fish) and 0.28 of returns from 39,445 smolts released below Mactaquac in 1987 (45 fish), and the product of fall fingerlings released in 1985 and survival/return rates (Table 7). The forecast of total hatchery MSW returns to Mactaquac, including repeat spawners is 882 MSW fish (Table 7).

b) Below Mactaquac

i) 1SW Wild

Based on the 1970-1983 proportions of 0.52 of the total wild 1SW returns originating above Mactaquac and 0.48 originating below Mactaquac (App. 1) and the 1989 forecast of 1SW returns above Mactaquac, it is estimated that the number of wild 1SW fish below Mactaquac in 1989 will be 8,197/0.52-8,197 or 7,566 1SW fish.

ii) MSW Wild

In a manner similar to that for forecasting 1SW fish below, MSW salmon below Mactaquac were estimated from the 0.59: 0.41 proportion for MSW fish above:below, 1970-1983. The estimate using the mean MSW/1SW ratio method is 6,236/0.59-6,236 or 4,333 MSW fish. The estimate from regression analysis is 7,845/0.59-7,845 or 5,452 MSW fish.

iii) 1SW Hatchery

The forecast of hatchery 1SW fish destined for tributaries below Mactaquac in 1989 was in part calculated as the product of an estimated 71,812 smolts released and 0.78 of the 0.01000 mean (arcsin) return rate for 1-year smolts in 1986-1988, i.e., 560 1SW fish (Table 7). In addition it was estimated that 1-year parr released at Mactaquac and in parr habitat below Mactaquac would yield another 336 fish. Fall fingerlings and unfed fry are expected to yield another 302 1SW fish such that the total 1SW hatchery fish returning to tributaries below Mactaquac are expected to number 1,198 1SW fish.

iv) MSW Hatchery

MSW hatchery returns below Mactaquac in 1989 were in part forecast as the product of 0.72, the estimated 0.00403 return rate and 39,445 smolts released in 1986, i.e., 114 MSW fish (Table 7). Returns from 1-year parr released at and below Mactaquac are expected to yield another 130 MSW fish respectively. Fall fingerlings, released below Mactaquac in 1984 and 1985 are expected to yield another 157 MSW fish; maiden spawners will yield 166 repeat spawners. MSW returns of hatchery origin below Mactaquac are expected to total 641 fish.

Forecast Summary

The forecast of total homewater returns (Table 8) to the Saint John River in 1989 is 19,041 1SW (15,763 of wild and 3,278 hatchery origin) and 12,092 MSW fish (10,569 of wild and 1,523 of hatchery origin). For the total Saint John River the forecast returns minus the spawning requirements result in potential surpluses of 11,411 1SW and 1,992 MSW salmon. Separation to above- and below- Mactaquac origins indicates surpluses over target escapements of 7,077 1SW and 2,718 MSW salmon for the former and 4,364 1SW fish and minus 726 MSW salmon for the latter.

DISCUSSION

Total estimated river returns of 19,300 1SW and 6,500 MSW salmon in 1988 were 130% and 43% of those predicted. Predictions for 1988 were no better than in 1987, and for MSW fish, the worst since 1983:

	1983		1984		1985		1986		1987		1988	
Returns	1SW	MSW	1SW	MSW	1SW	MSW	1SW	MSW	1SW	MSW	1SW	MSW
Predicted	15.8	16.2	14.9	10.0	17.5	15.5	9.5	13.4	13.1	18.0	14.8	15.2
Estimated	11.3	8.4	13.0	14.7	10.8	14.8	16.5	11.3	17.1	8.0	19.3	6.5
Est/Pred	72%	52%	87%	147%	62%	95%	174%	84%	129%	45%	130%	43%

MSW returns including fish of hatchery origin are the lowest since 1979 (App. 6; Fig. 6). Returns of wild 1SW fish above and below Mactaquac were each 148% of forecasts; wild MSW fish above and below were 38% of forecast values. Hatchery 1SW and MSW returns were 67% and 60% of forecasts. Despite the lowest removals since 1973 (App. 7), spawning escapement of MSW fish above Mactaquac was only 35% of requirement; escapement below was 46% of requirement.

Marshall (MS 1988) suggested that higher than predicted 1SW returns and lower than expected MSW returns, in 1987, if accompanied by an increase in the proportion of females among 1SW fish, could be the result of a crossover of potential 2SW fish to earlier maturing 1SW fish. This appeared to explain some of the variation between 1SW and MSW returns to the Miramichi River (Marshall et al. 1982) but has not been demonstrated for the Saint John River where the females among 1SW returns ranged between only about 3% and 12%.

To examine the potential for detection of crossover of potential 2SW fish to maturing 1SW fish through an increase in the proportion of females among 1SW returns, the model of Marshall et al. (MS 1982) was reinvestigated using 5 values for each of: 1) the proportion females in the smolt class, 2) the proportion females in the 2SW returns and 3) the proportion of the stock that was destined to mature as 2SW fish, i.e., 5^3 possibilities:

1. Prop. female smolts	.52	.55	.58	.61	.64
2. Prop. 2SW in stock	.59	.62	.65	.68	.71
3. Prop. female 2SW	.80	.83	.86	.89	.92

The proportion of potential 2SW fish crossing over to maturing 1SW fish was set at 0.0, 0.04, 0.07, 0.10, 0.13 and 0.16.

The mean of positive proportions of females among 1SW fish for selected crossover proportion ranged from 0.16 to 0.25 indicating that many combinations of the above scenarios are unable to describe the current proportions of females among 1SW fish.

Examination of a 0.030 - 0.119 range of female proportions among 1SW fish (2nd, 3rd and 4th positive classes; Fig. 7) which approximates that range of values observed annually at Mactaquac revealed that values in this range resulted on 25 occasions with no crossover and on 14 occasions with 0.16 crossover. Ten of the cases with no crossover and 14 of the cases with 0.16 crossover occurred with females among smolts set at 0.52 and 0.55. Setting of female smolts at 0.58, 0.61 and 0.64 result in 15 cases at no crossover and only 1 case at .16 crossover. Hence, values within the 0.03 to 0.119 range,

females among 1SW fish, could be attributed solely to the multiplicative effect of error-free measurement of the proportion females among smolts, proportion of females among 2SW fish or proportion of 2SW fish in the stock.

Tag recovery information from smolts of Mactaquac origin, 1975-1985, (Marshall, MS 1988) had suggested that the MSW 'deficit', relative to forecast, of 1987, at least, was not likely the result of distant (Newfoundland-Labrador and Greenland) fishing mortality. The proportion of tags from distant fisheries in 1987 (non-maturing 1SW fish presumably destined to have been 2SW returns in 1988) relative to those reaching home in 1988 is, however, 0.53. This value is the highest of a 12-year data set (Fig. 8) and well above the 11-year mean (arcsin) of 0.33. After adjustment for non-reporting in Greenland (Anon. 1987), the proportion to Newfoundland-Labrador of 0.26 in 1987 is second only to the 0.29 value of 1977.

Tag data from 20 Saint John River 1SW fish potentially destined to be 2SW fish but recovered in Newfoundland, 1987, do not highlight any unusual pattern of distribution:

	SFA						
Month	1&2	3	4	5	6	7	8
June		1	1	3		2	2
July	1	3	1		1		
Aug	1	2					
Sept	1						
Oct		1					

Tag returns from distant fisheries in 1988 numbered only five, all from Greenland. They have no value as an index of 2SW stock levels in 1989. However, correlation analysis of arcsin proportions of tags to Newfoundland-Labrador (data of Fig. 8) and estimated MSW returns to Mactaquac had a correlation coefficient of 0.46 ($p=0.131$). Proportion of tags to both distant fisheries (Canada and Greenland) were significantly negatively correlated with MSW returns to Mactaquac ($r=0.59$; $p=0.044$; Fig. 9).

The preceding analysis on a stock that does not contribute any significant numbers of maturing 2SW salmon to distant fisheries suggests that the MSW 'deficit' at home in 1988 is most likely linked to distant fishing mortality in 1987. Conversely the MSW deficit in 1987 would not be linked to distant fishing mortality in 1986. Higher-than-usual natural mortality cannot be excluded from either case. However in the case of the 1986 smolts (1988 MSW fish) which provided higher than expected 1SW returns in 1987 and the highest tag return rate of the last six years, natural mortality would have to have been confined to a period in the second winter at sea. The 1985 smolt class (1987 MSW fish) which also contributed higher than expected levels of 1SW fish had a more average proportion of tags from distant fisheries. By deduction, the MSW deficit from the 1985 smolt-class (1987 MSW fish) could be explained by either an elevated level of natural mortality of post smolts destined to be 2SW fish or by crossover to mature 1SW fish.

ACKNOWLEDGEMENTS

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Table 1. Estimated total returns of wild and hatchery 1SW and MSW salmon destined for above and below Mactaquac Dam on the Saint John River, N.B., 1988.

Sea-age	Components	Number of fish: Above Mactaquac Wild	Above Mactaquac Hatch.	Above Mactaquac Total	Below Mactaquac Wild	Below Mactaquac Hatch.	Below Mactaquac Total	Total Wild	Total Hatch.	Total
1SW										
	Mactaquac counts	8,062	1,129	9,191	-	-	-	8,062	1,129	9,191
	Kingsclear catch[a]	167	23	190	-	-	-	167	23	190
	Angled MS below Mactaquac	522	73	595	-	-	-	522	73	595
	By-catch[b]	179	25	204	164	16	180	343	41	384
	Returns to tribs. below Mactaquac	-	-	-	8,079	861	8,940	8,079	861	8,940
	Totals	8,930	1,250	10,180	8,243[c]	877[d]	9,120	17,173	2,127	19,300
MSW										
	Mactaquac counts	1,930	670	2,600	-	-	-	1,930	670	2,600
	Kingsclear catch[a]	564	196	760	-	-	-	564	196	760
	By-catch[b]	131	46	177	91	57	148	222	103	325
	Returns to tribs. below Mactaquac	-	-	-	1,733	1,088	2,821	1,733	1,088	2,821
	Totals	2,625	912	3,537	1,824[c]	1,145[d]	2,969	4,449	2,057	6,506

a Estimated at 950 fish of which 1SW = 20%; MSW = 80%.
b Proportions of 2% total 1SW returns and 5% total MSW returns.
c Based on 1970-1983 proportion of production below (App. 1), i.e., 0.48 for 1SW and 0.41 for MSW.
d Derivation based on 'hatchery' returns and age analysis indicated in Tables 2 and 3.

Table 2. Estimated total numbers of 1SW and MSW returns to the Saint John River from hatchery-reared smolts released at[a] Mactaquac, 1974-1988.

Releases			Returns (1SW/MSW)									
				Mactaquac							% return	
Year	Smolts	Prop 1-yr	Year	Mig ch	Dam	Kings-clear	Angled main SJ	By-catch	Comm-ercial	Total	Unadj	Adj
1974	337,281	0.00	1975	1,771	3,564	28	977	34		6,374	1.890	
75	324,186	0.06	76	2,863	4,831	219	1,129	32		9,074	2.799	
76	297,350	0.14	77	1,645	4,533	36	708	70		6,992	2.351	
77	293,132	0.26	78	777	1,779	49	369	70		3,044	1.038	
78	196,196	0.16	79	799	2,722	100	186	20		3,827	1.951	
79	244,012	0.09	80	3,072	6,687	335	640	59		10,793	4.423	
80	232,258	0.12	81	921	2,861	139	350	74	385	4,730	2.037	
81	189,090	0.08	82	828	1,464	64	267	21	202	2,846	1.505	1.445
82	172,231	0.06	83	374	857	39	69	11	95	1,445	0.839	0.776
83	144,549	0.22	84	476	828	36	63	48		1,451	1.004	0.976
84	206,462	0.28	85	454	1,288	82	128	66		2,018	0.977	0.919
1974-84	2,636,747									52,594	1.995	
85	89,051	1.00	86	64	635	53	93	17		862	0.968	0.869
86	191,495	1.00	87	198	2,679	96	288	67		3,328	1.738	1.561
87	113,439	1.00	88[b]	(717)		15	46	16		794	0.700	0.672
88	142,195	1.00	89									
1974	337,281		1976	310	1,313	392	267	20		2,302	0.683	
75	324,186		77	341	1,727	206	417	34		2,725	0.841	
76	297,350		78	223	1,728	368	165	50		2,534	0.852	
77	293,132		79	145	747	210	65	21		1,188	0.405	
78	196,196		80	302	1,992	506	146	46		2,992	1.525	
79	244,012		81	126	963	252	125	147	999	2,612	1.070	
80	232,258		82	88	640	462	181	50	110	1,531	0.659	
81	189,090		83	44	255	76	17	23	166	581	0.307	0.285
82	172,231		84	84	722	201	5	103		1,115	0.647	0.559
83	144,549		85	73	492	189	5	116		875	0.605	0.553
84	206,462		86	16	471	266	4	40		797	0.386	0.346
1974-84	2,636,747									19,252	0.730	
85	89,051		87	4	338	110	4	24		480	0.539	0.454
86	191,495		88[b]	(511)		150	0	35		696	0.364	0.355
87	113,439		89									
88	142,195		90									

[a] Includes returns from down-river stocking of smolts, 1981-1987; adjusted return rate removes downriver returns to Mactaquac (see App. 2).

[b] 1SW hatchery fish at Mactaquac were 0.635, 0.288 and 0.077 age 1.1, 2.1 and 3.1, respectively. MSW hatchery fish at Mactaquac were 0.763, 0.119, 0.068 and 0.051 age 1.2, 2.2, 3.2 and 'repeats', respectively.

Table 3. Estimates of hatchery 1SW and MSW returns to the Saint John River, 1988, based on various numbers of juveniles released at (At) or above (Abv) Mactaquac and returns.

Release				Return		Returns in 1988			
						1SW		MSW	
Year	Loc.	Stage	Number	Rates	Age	To Mact	Bl Mact	To Mact	Bl Mact
1987	At	1-yr smolt	113,439	0.00672	1.1	762			
1987	Bl	1-yr smolt	39,445	0.00672 @ 0.12 & 0.88	1.1	32	233		
1986	At	1-yr parr	89,115	0.00398 x 0.5[b]	2.1		177		
1986	Bl	1-yr parr	14,337	0.00398[a]	2.1		57		
1985	Abv	Fall fing.	289,000	(0.288 x 1250/Number	2.1	360			
1985	Bl	Fall fing.	82,400	or 0.00125)	2.1		103		
1985	Bl	Unfed fry	623,000	0.00125 x 0.1[c]	2.1		78		
1984	Abv	Fall fing.	123,600	(0.077x1250/Number	3.1	96			
1984	Bl	Fall fing.	294,200	or 0.00078)	3.1		229		
1986	At	1-yr smolt	191,495	0.00355[e]	1.2			680	
1986	Bl	1-yr smolt	38,387	0.00355 @ 0.12 & 0.88	1.2			16	120
1985	At	1-yr parr	143,658	0.0022 x 0.5[b]	2.2				159
1985	Bl	1-yr parr	211,665	0.0022[a]	2.2				466
1984	Abv	Fall fing.	123,600	(0.119 x 912/Number	2.2			111	
1984	Bl	Fall fing.	294,200	(or 0.0009	2.2				265
Totals						1,250	877	807[d]	1,010(1,145)[e]

a Intermediate between smolt and fall fingerling rates.
b Discount for mainstem habitat.
c Fall fingerling rate discounted by 90%.
d Difference between 912 (Table 1) and 807 i.e., 105 fish, comprised of 3.2's and repeat spawners.
e Adjusted for 3.2's and repeats.

Table 4. Estimated homewater removals[a] of 1SW and MSW salmon destined for above and below Mactaquac Dam on the Saint John River, N.B., 1988.

Sea-age	Components	Number of fish								
		Above Mactaquac			Below Mactaquac			Total		
		Wild	Hatch.	Total	Wild	Hatch.	Total	Wild	Hatch.	Total
1SW	Kingsclear Indians	167	23	190	-	-	-	167	23	190
	Tobique Indians[b]	97	13	110	-	-	-	97	13	110
	Angled									
	Tobique River	757	103	860	-	-	-	757	103	860
	Mainstem above Mact.	264	36	300	-	-	-	264	36	300
	Mainstem below Mact.	522	73	595	-	-	-	522	73	595
	Tribs below Mactaquac	-	-	-	859	91	950	859	91	950
	Trucked to Aroostook R.	66	4	70	-	-	-	66	4	70
	Hatchery broodfish	26	5	31	17	0	17	43	5	48
	mortalities, etc.	7	3	10	0	0	0	7	3	10
	Poaching/disease[c]	314	44	358	162	17	179	476	61	537
	By-catch	179	25	204	164	16	180	343	41	384
	Totals	2,399	329	2,728	1,202	124	1,326	3,601	453	4,054
MSW	Kingsclear Indians	564	196	760	-	-	-	564	196	760
	Tobique Indians	330	110	440	-	-	-	330	110	440
	Angling hook-release									
	mortality[e]	26	9	35	35	22	57	61	31	92
	Trucked to Aroostook R.	25	5	30	-	-	-	25	5	30
	Hatchery broodfish	256	105	361	21	0	21	277	105	382
	mortalities, etc.	24	6	30	0	0	0	24	6	30
	Poaching/disease[d]	129	43	172	87	54	141	216	97	313
	By-catch	131	46	177	91	57	148	222	103	325
	Totals	1,485	520	2,005	234	133	367	1,719	653	2,372

a Previous to significant federal and provincial input; wild: hatchery composition per estimated returns.
b Estimated at 400-700 fish, predominantly MSW fish.
c Estimated at 4% of all fish placed above Mactaquac (exclusive of those to Tobique Indians) and 2% of returns to tribs below Mactaquac.
d Estimated at 10% of all fish placed above Mactaquac (exclusive of those to Indians) and 5% of returns to tribs below Mactaquac.
e Estimated at 2% of salmon released above Mactaquac (exclusive of those to Tobique Indians) and 2% of returns to tribs below Mactaquac.

Table 5. Estimated homewater returns, removals and spawning escapement of 1SW and MSW salmon destined for above and below Mactaquac Dam, Saint John River, 1988.

Sea-age	Category	Number of fish						
		Above Mactaquac		Below Mactaquac		Total		
		Wild	Hatch.	Wild	Hatch.	Wild	Hatch.	Both
1SW								
	Homewater returns	8,930	1,250	8,243	877	17,173	2,127	19,300
	Homewater removals[a]	2,399	329	1,202	124	3,601	453	4,054
	Spawners	6,531	921	7,041	753	13,572	1,674	15,246
	Target spawners[b]	3,200		4,400				7,600
	Percentage of target spawners	233		177				201
MSW								
	Homewater returns	2,625	912	1,824	1,145	4,449	2,057	6,506
	Homewater removals[a]	1,485	520	234	133	1,719	653	2,372
	Spawners	1,140	392	1,590	1,012	2,730	1,404	4,134
	Target spawners[b]	4,400		5,700				10,100
	Percentage of target spawners	35		46				41

a Includes broodfish for Mactaquac FCS (Table 4).
b Excludes broodfish for Mactaquac FCS (Table 4).

Table 6. Adjusted Tobique River egg deposition[a]/100 m^2 (yr i & i+1) recruiting to total wild 1SW and MSW salmon which would have returned to Mactaquac in the absence of homewater removals in yr i+5 and i+6, resultant MSW:1SW salmon ratios, and forecast numbers of 1SW and MSW fish to Mactaquac in the absence of homewater removals in 1988.

Eggs/100 m^2		Recruits				
		1SW		MSW		MSW/
Years (1)	Number (2)	Year	Number (3)	Year	Number (4)	1SW (5)
1965-66		1970	3,057	1971	4,715	1.54
1966-67		71	1,709	72	4,899	2.87
1967-68		72	908	73	2,518	2.77
1968-69	23.95	73	2,070	74	5,811	2.81
1969-70	40.58	74	3,656	75	7,441	2.04
1970-71	74.35	75	6,858	76	8,177	1.19
1971-72	122.34	76	8,147	77	9,712	1.19
1972-73	85.39	77	3,977	78	4,021	1.01
1973-74	81.66	78	1,902	79	2,754	1.45
1974-75	371.61	79	6,828	1980	10,924	1.60
1975-76	330.50	1980	8,482	81	5,991	0.71
1976-77	244.80	81	5,782	82	5,001	0.86
1977-78	288.96	82	4,958	83	3,447	0.69
1978-79	167.00	83	4,309	84	9,779	2.27
1979-80	239.74	84	8,311	85	10,436	1.26
1980-81	219.60	85	6,526	86	6,128	0.94
1981-82	167.64	86	7,904	87	4,352	0.55
1982-83		87	5,909	88	2,625	0.44
1983-84		88	8,930	89	7,845[c]	6,235[d]
1984-85	354.08	89	8,197[b]			

[a] See App. 3, 4 and 5 for derivation.

[b] Based on regression of 1SW returns to Mactaquac, 1973-1986, (col. 3) on adjusted egg deposition in Tobique River, 1968-1969 to 1980-1982, (col. 2):

$\log_e Y = 6.507 + 0.478 \log_e X$: n=14, r=0.69, p= 0.006

$Y_{1989} = 8,197$(AM): 95% C.L. = 5,846 to 11,493.

[c] Based on regression of MSW returns to Mactaquac, 1971-1988, (col. 4) on 1SW returns to Mactaquac, 1970-1987, (col. 3):

$\log_e Y = 5.313 + 0.393 \log_e X$; n=18, r=0.53, p= 0.023

$Y_{1989} = 7,845$(AM); 95% C.L. = 5,719 to 10,719

[d] Product of mean ratio (0.698) MSW/1SW, 1980-1981 to 1987-1988, excl. of 1983-1984 and 1984-1985 and 8,930 returns in 1988.

Table 7. Forecasts of hatchery 1SW and MSW returns to the Saint John River, 1989, as estimated from numbers of various juveniles released at (At) or above (Abv) and below (Bl) Mactaquac and estimated return rates.

Release				Return		Returns in 1989			
						1SW		MSW	
Year	Loc.	Stage	Number	Rates	Age	To Mact	Bl Mact	To Mact	Bl Mact
1988	At	1-yr smolt	142,195	0.0100[a]	1.1	1,422			
1988	Bl	1-yr smolt	71,812	0.0100[a] @ 0.22 & 0.78	1.1	158	560		
1987	At	1-yr parr	108,131	0.00398 x 0.5[b]	2.1		215		
1987	Bl	1-yr parr	30,519	0.00398[b]	2.1		121		
1986	Abv	Fall fing.	220,176	0.00125[b]	2.1	275			
1986	Bl	Fall fing.	108,256	0.00125[b]	2.1		135		
1986	Bl	Unfed fry	638,933	0.00125 x 0.1[b]	2.1		80		
1985	Abv	Fall fing.	289,000	0.00078[b]	3.1	225			
1985	Bl	Fall fing.	82,400	0.00078[b]	3.1		64		
1985	Bl	Unfed fry	623,000	0.00125 x 0.1 x 0.3[c]	3.1		23		
1987	At	1-yr smolt	113,439	0.00403[d]	1.2			457	
1987	Bl	1-yr smolt	39,445	0.00403[d] @ 0.28 and 0.72	1.2			45	114
1986	At	1-yr parr	89,115	0.0022 x 0.5[b]	2.2				98
1986	Bl	1-yr parr	14,337	0.0022[b]	2.2				32
1985	Abv	Fall fing.	289,000	0.0009[b]	2.2			260	
1985	Bl	Fall fing.	82,400	0.0009[b]	2.2				74
1985	Bl	Unfed fry	623,000	0.00125 x 0.1[b]	2.2				78
1984	Abv	Fall fing.	123,600	0.0009 x 0.3[c]	3.2			33	
1984	Bl	Fall fing.	294,200	0.0009 x 0.3[c]	3.2				79
		Adults 1988[e]		0.05 (1SW) 0.146 (MSW)	various			87	166
Totals						2,080	1,198	882	641

[a] Arcsin mean of 1986-1988 adjusted return rates (Table 2); proportions above and below (App. 2).
[b] Estimate, Table 3.
[c] Thirty percent of 1988 estimate on basis that most would be 2-yr smolts.
[d] Arcsin mean of 1987-88 adjusted return rate (Table 2); proportions above and below (App. 2)
[e] Rates (Marshall and MacPhail MS 1987) applied to estimated hatchery spawners (1988), i.e., 921 1SW and 284 MSW fish above Mactaquac and 753 1SW and 876 MSW fish below Mactaquac.

Table 8. Summary of the 1989 salmon forecast for the Saint John River, New Brunswick (95% C.L. in parentheses).

Requirement	1SW Wild	1SW Hatch	1SW Total	MSW Wild	MSW Hatch	MSW Total
Above Mactaquac	8,197 (5,846-11,493)	2,080	10,277	6,236	882	7,118
Target escpm.[a]			-3,200			-4,400
Surplus			7,077			2,718
Below Mactaquac	7,566	1,198	8,764	4,333	641	4,974
Target escpm.[a]			-4,400			-5,700
Surplus			4,364			-726
Total	15,763	3,278	19,041	10,569	1,523	12,092
Target escpm.[a]			-7,600			-10,100
Surplus			11,441			1,992

[a] Excludes broodfish for Mactaquac Fish Culture Station.

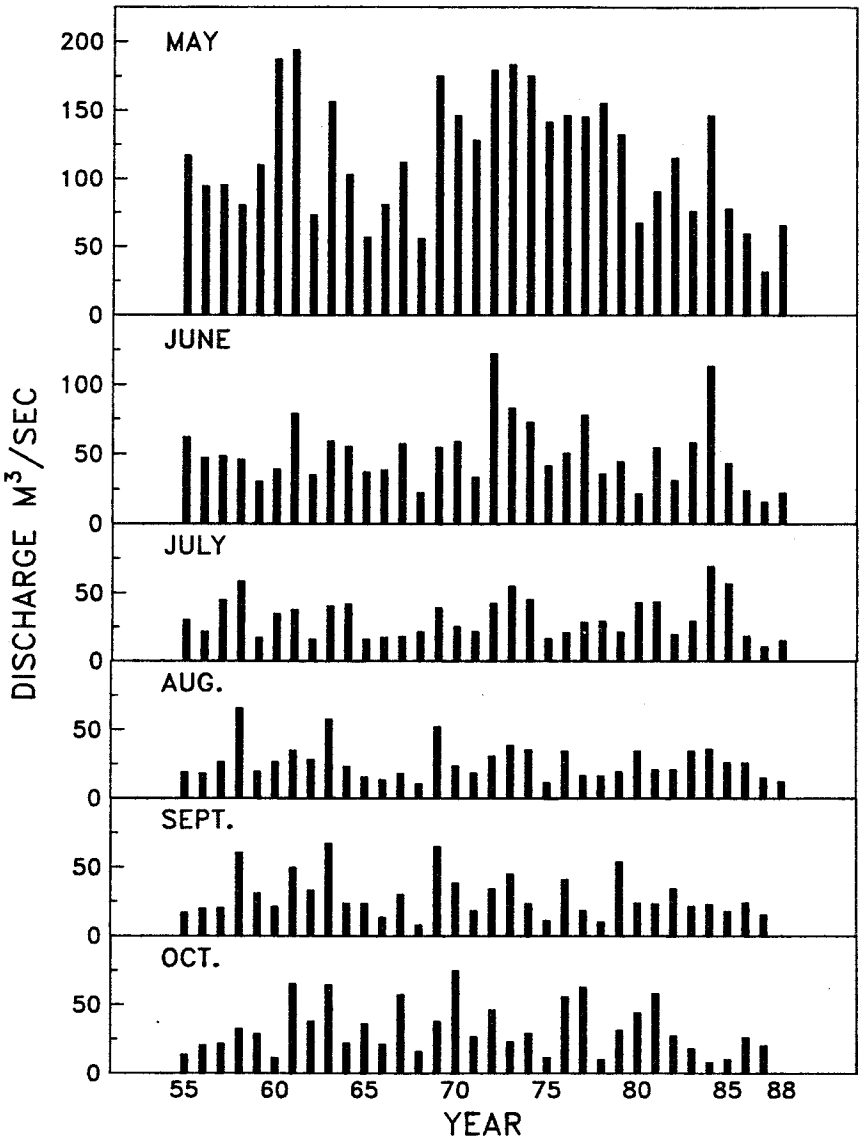

Fig. 1a. Mean monthly discharge (m^3/sec) May to October for the Tobique River at Riley Brook, 1955–1988.

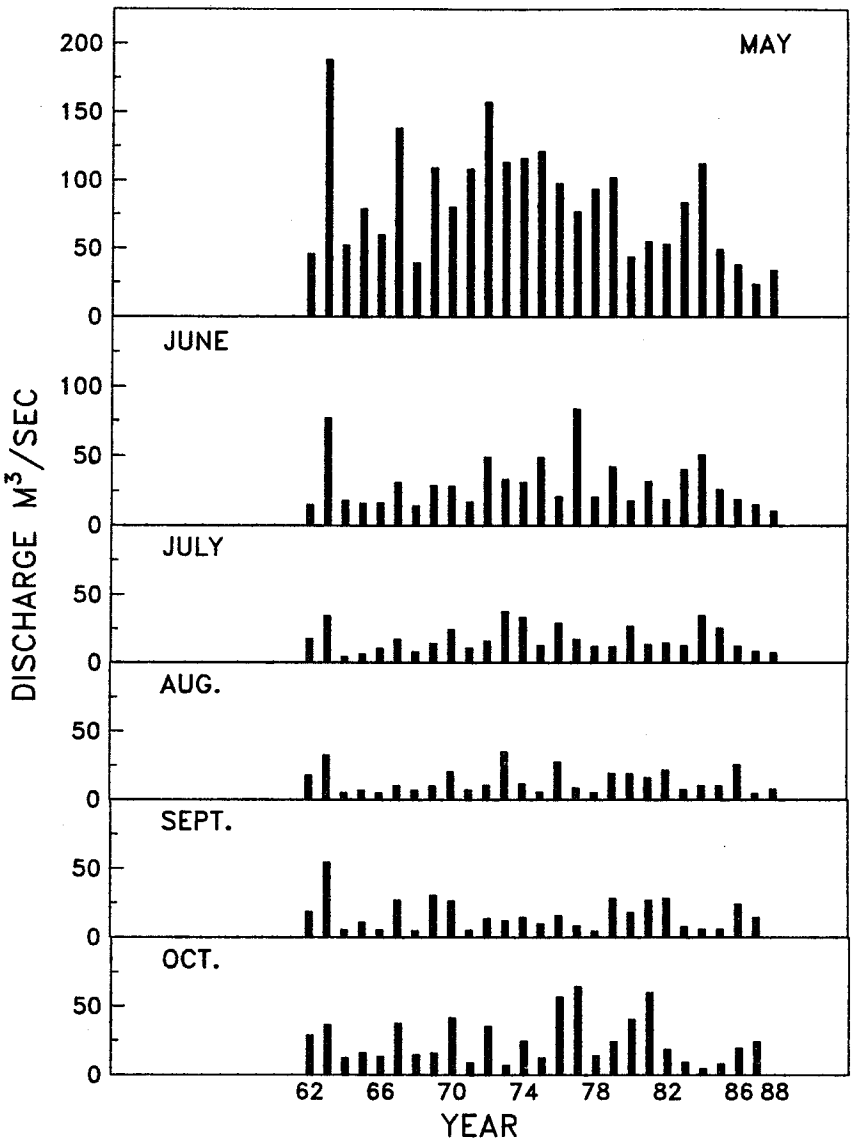

Fig. 1b. Mean monthly discharge (m^3/sec) May to October for the Nashwaak River at Durham Bridge, 1962–1988.

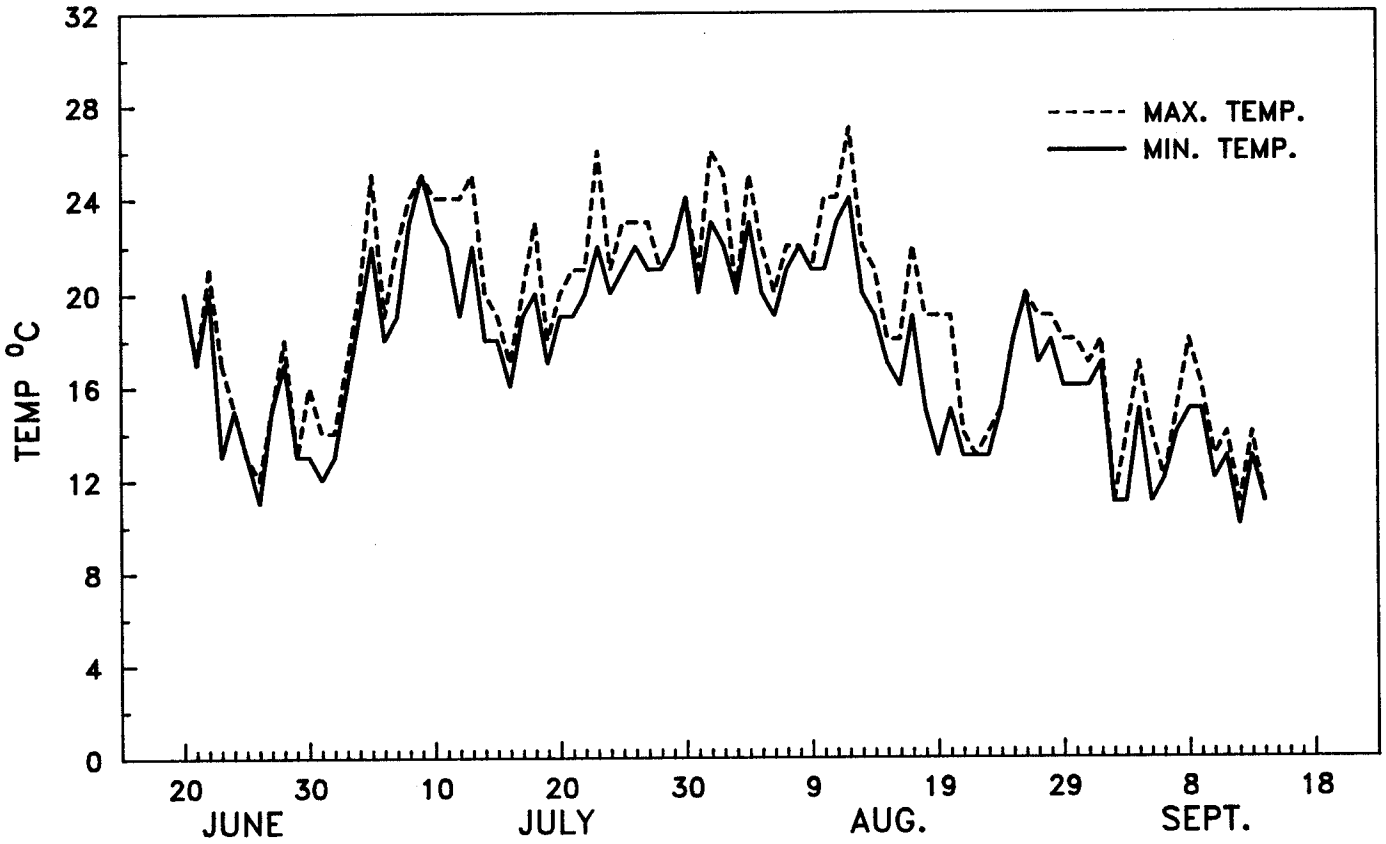

Fig. 2. Max–min temperatures at Half–mile pool, Tobique River June 20 – Sept. 15, 1988 (courtesy NBDNRE)

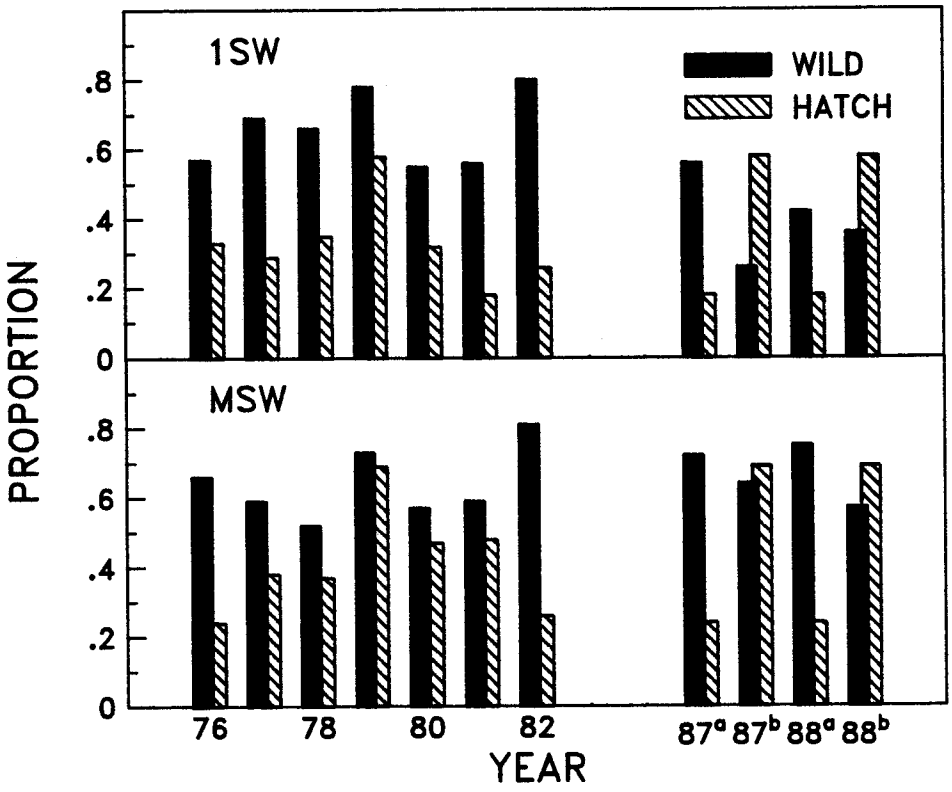

Fig. 3. Proportions of 1SW and MSW wild and hatchery fish released at Woodstock that ascended Beechwood 1976-1982 and range of possible proportions of wild 1SW and MSW salmon which ascended 1987-1988 under scenarios of minimum[a] and maximum[b] ascent by hatchery fish.

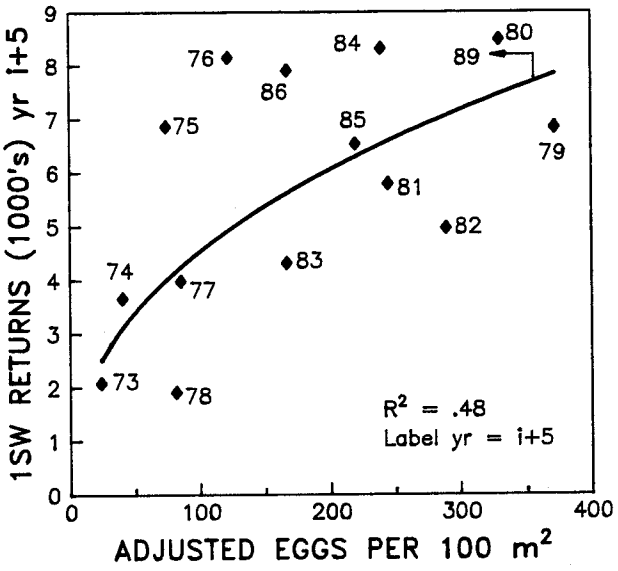

Fig. 4. Saint John, 1SW recruitment above Mactaquac.

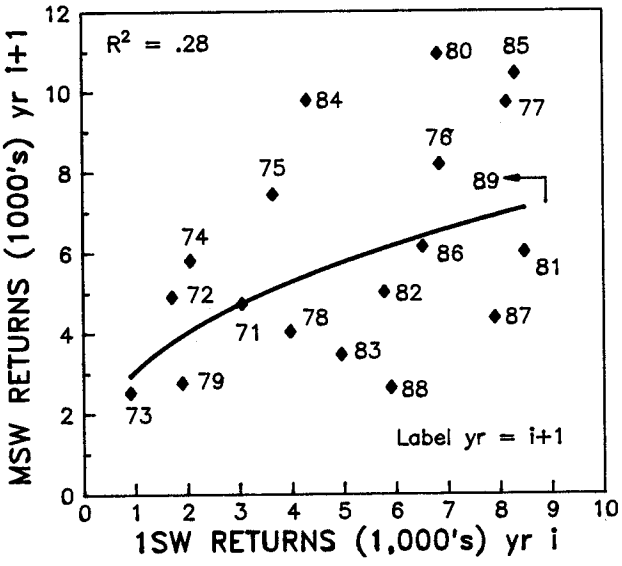

Fig. 5. Saint John, MSW recruitment above Mactaquac.

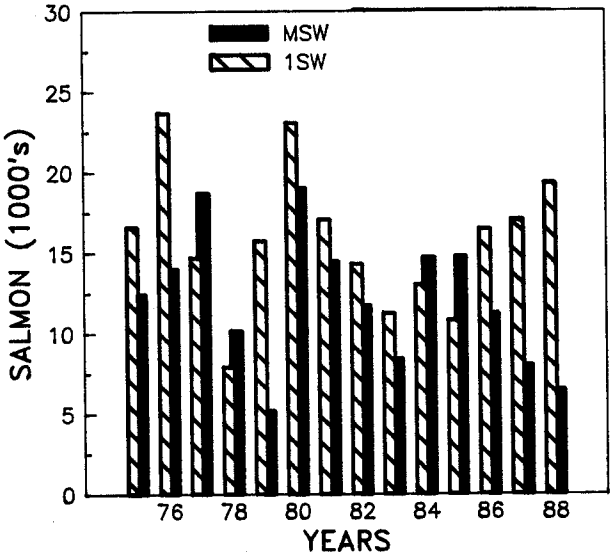

Fig. 6. Saint John, total hatchery and wild returns.

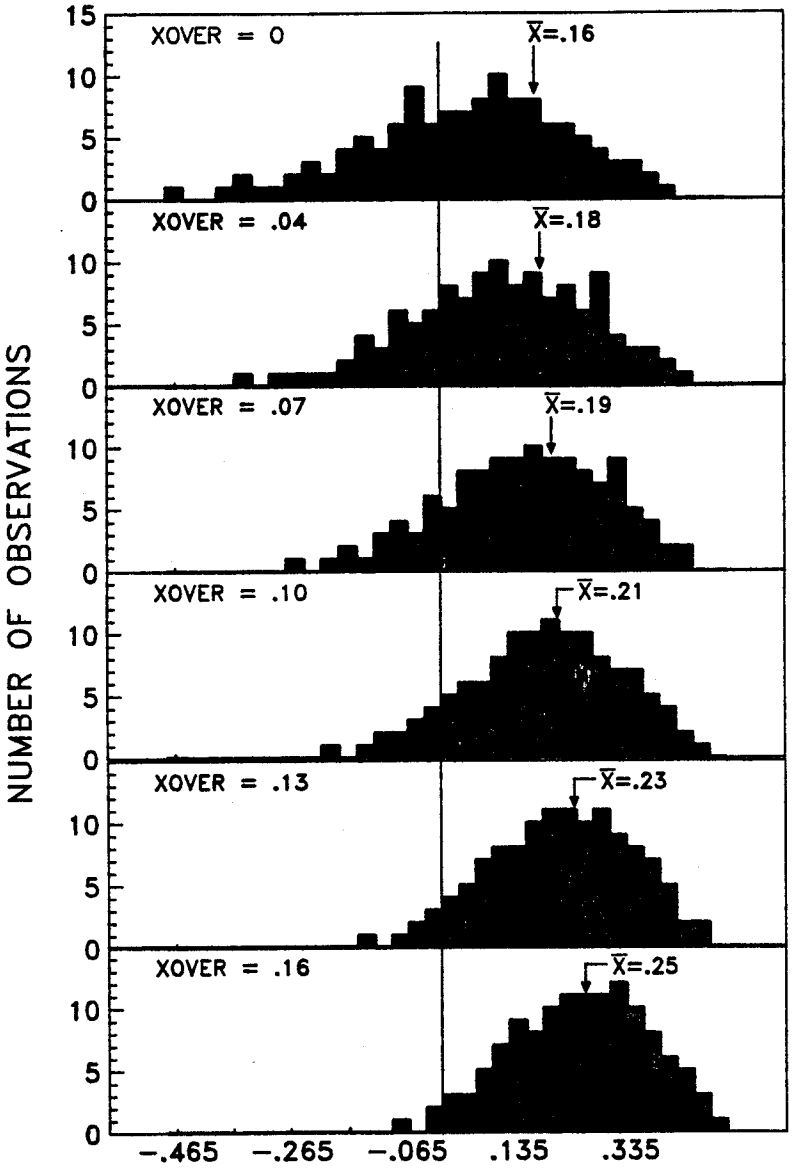

Fig. 7. Frequency distributions of the proportions of females among 1SW returns under assumed proportions of i) females among smolts, ii) females among 2SW returns and iii) the population destined to be maiden 2SW fish for the Saint John River, N.B (see text for details).

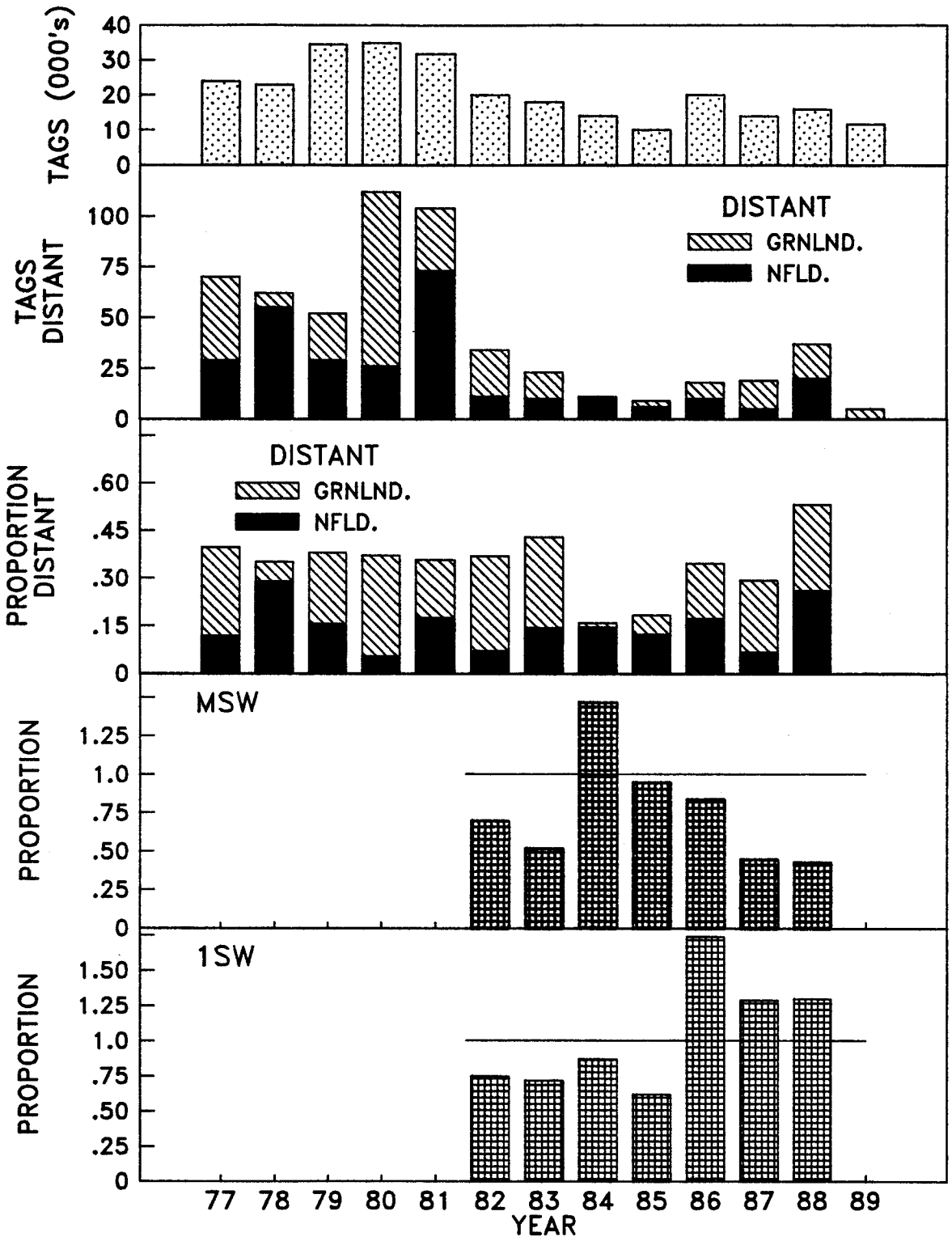

Fig. 8. Numbers of tagged smolts (yr-2); unadjusted numbers of tags returned from non-maturing 1SW fish (yr-i) captured in distant waters; adjusted proportions that distant tags (yr-1) were of themselves and mature 2SW in home waters (yr) and proportion that the total estimated homewater returns of 1SW and MSW fish (yr) were of the forecast for the Saint John River, N.B.

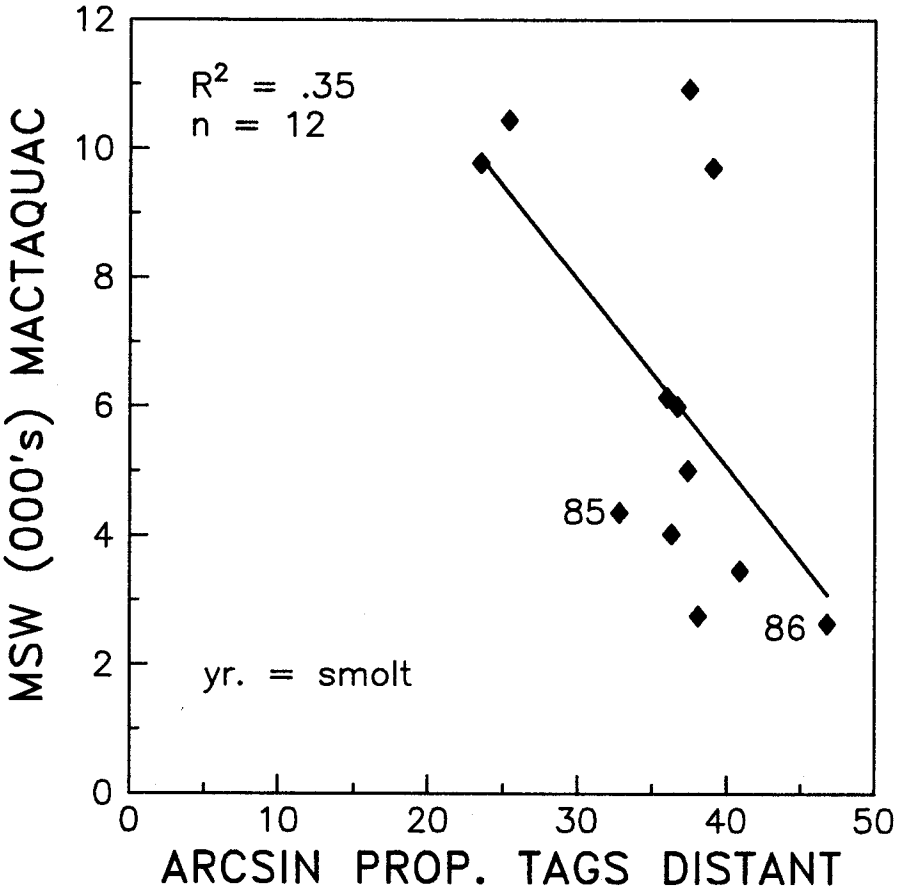

Fig. 9. Relationship between estimated number of wild MSW homewater returns destined for above Mactaquac Dam and proportion of total tag returns from immature and mature hatchery-origin 2SW salmon that were from Newfoundland and Greenland fisheries for the 1975-1986 smolt classes, Saint John River, N.B.

App. 1 Estimated total returns of wild 1SW and MSW salmon originating above and below Mactaquac Dam, Saint John River, 1970-1988.

Sea-age	Year	(1) Mact. count	(2) Kings-clear	(3) Angled main SJ	(4) Trib. Returns Bl. Mact.	(5) Comm. fishery Total	(6) Above	(7) Below	(8) By-catch Total	(9) Above	(10) Below	Total returns (proportions) Above	Below	Total
1SW														
	1970	2,874		78	2,732	200	105	98	3			3,057	2,830	5,887
	71	1,592		60	3,194	166	57	109	0			1,709	3,303	5,012
	72	784		83	1,420				107	41	66	908	1,486	2,394
	73	1,854		179	2,390				81	37	44	2,070	2,434	4,504
	74	3,389	27	214	4,502				59	26	33	3,656	4,535	8,191
	75	5,725	45	1,052	3,366				54	36	18	6,858	3,384	10,242
	76	6,797	307	1,014	6,456				52	29	23	8,147	6,479	14,626
	77	3,507	28	403	3,670				76	39	37	3,977	3,707	7,684
	78	1,584	43	231	2,912				113	44	69	1,902	2,981	4,883
	79	6,234	228	331	5,081				62	35	27	6,828	5,108	11,936
	80	7,555	378	503	3,790				67	46	21	8,482	3,811	12,293
	81	4,571	222	428	6,221	730	470	260	194	91	103	5,782	6,584	12,366
	82	3,932	171	466	4,492	1,482	352	1,130	79	37	42	4,958	5,664	10,622
	83	3,623	164	207	4,151	1,091	283	808	68	32	36	4,309	4,995	9,304
Mean												4,475(.52)	4,093(.48)	8,568(1.00)
	84	7,353	317	351	2,825				387	290	97	8,311	2,825	11,136
	85	5,331	389	460	1,874				443	346	97	6,526	1,971	8,497
	86	6,347	547	852	7,150				304	158	146	7,904	7,296	15,200
	87	5,095	184	512	5,339				227	118	109	5,909	5,448	11,357
	88	8,062	167	522	8,079				343	179	164	8,930	8,243	17,173
MSW	1970	2,449		59	2,935	6,934	3,204	3,749	19			5,712	6,684	12,396
	71	2,235		89	1,060	3,473	2,391	1,082	0			4,715	2,142	6,857
	72	4,831		62	2,277				9	6	3	4,899	2,280	7,179
	73	2,367		91	4,350				165	60	105	2,518	4,455	6,973
	74	4,775	569	459	3,575				13	8	5	5,811	3,580	9,391
	75	6,200	739	446	2,758				77	56	21	7,441	2,779	10,220
	76	5,511	1,646	950	3,528				101	70	31	8,177	3,559	11,736
	77	7,247	864	1,489	6,217				184	112	72	9,712	6,289	16,001
	78	3,034	645	263	3,559				151	79	72	4,021	3,630	7,651
	79	1,993	561	152	1,240				70	48	22	2,754	1,262	4,016
	80	8,157	2,069	533	5,037				244	165	79	10,924	5,116	16,040
	81	2,441	639	282	2,857	4,983	2,291	2,692	669	338	331	5,991	5,880	11,871
	82	2,262	1,626	592	2,989	2,440	359	2,081	332	162	170	5,001	5,240	10,241
	83	1,712	512	98	2,421	2,651	986	1,665	309	139	170	3,447	4,256	7,703
Mean												5,795(.59)	4,082(.41)	9,877(1.00)
	84	7,011	1,934	41	3,236				1,061	793	268	9,779	3,530	13,309
	85	6,391	2,337	53	2,763				2,156	1,655	501	10,436	3,264	13,700
	86	3,656	2,134	32	4,045				519	306	213	6,128	4,258	10,386
	87	3,088	1,010	36	2,873				369	218	151	4,352	3,024	7,376
	88	1,930	564	-	1,733				222	131	91	2,625	1,824	4,449

App. 2. Smolt release information background to the calculation of 'adjusted' return rates for smolts released at Mactaquac and adjustment of hatchery return rates, 1984-1988. A:-Number of tag returns, return rates and proportionate contribution to Mactaquac from smolts released at and below Mactaquac 1983-1987; B:-Total smolts released below Mactaquac which originated from Mactaquac F.C.S. (also numbers released at Mactaquac) and C: Calculation of adjusted return rate for 1987 smolts returning as 1SW fish in 1988.

A.

		Mactaquac tags			'Below' tags			
Sea-age	Return year	Ret'n Mact.	Smolts released	Ret'n rate (a)	Ret'n Mact.	Smolts released	Ret'n rate (b)	Ratio a:b
1SW	1984	64	10,000	0.00640	7	13,000	0.00054	1:0.0844
	1985	114	19,988	0.00570	26	15,996	0.00163	1:0.2860
	1986	97	15,900	0.00610	13	11,952	0.00109	1:0.1787
	1987	113	15,901	0.00711	20	4,975	0.00402	1:0.5654
	1988	59	11,550	0.00511	8	13,277	0.00060	1:0.1174
	$\bar{x}$(arcsin)			0.00607			0.00136	1:0.2240
2SW	1985	30	10,000	0.00300	11	13,000	0.00085	1:0.28333
	1986	24	19,988	0.00120	10	15,996	0.00063	1:0.52500
	1987	41	15,900	0.00258	9	11,952	0.00075	1:0.29070
	1988	26	15,901	0.00164	1	4,975	0.00020	1:0.12195
	$\bar{x}$(arcsin)			0.00204			0.00057	1:0.28109

B.

	No smolts released		
Year	Above	At	Below
1981		189,090	44,918[a]
1982		172,231	80,535
1983		144,549	48,706
1984		206,462	46,126
1985		89,051	56,992
1986		191,495	38,387
1987		113,439	39,445
1988		142,195	71,812

[a] not 'incl' 21,200 from Minto

C. Calculation of adjusted return rates for smolts released at Mactaquac

1. In 1988, 794 1SW fish return to Mactaquac from 113,439 smolts released at Mactaquac and some of 39,445 released below Mactaquac.

2. From A(above) smolts contributing to Mactquac were (113,439 x 1) + (39,445 x 0.1174) = 118,070.

3. Adjusted return rate = 794/118,070 or 0.00672.

4. Estimated number of 1SW fish returning to below Mactaquac from smolt releases below Mactaquac = [39,445-(39,445 x 0.1174)] x 0.00672 = 234.

App. 3. Freshwater age and number of wild 1SW fish (A) counted at Mactaquac fish passage facilities, Saint John River, 1976-1988, and (B) that would have returned to Mactaquac had they not been exploited within the river, 1976-1988.

Fresh-water age	Number of 1SW fish												
	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
A													
2	3,962	922	391	3,166	2,214	1,280	794	2,348	4,140	1,264	3,196	2,513	5,066
3	2,658	2,545	1,160	2,974	4,986	2,861	2,902	1,264	3,132	3,913	3,001	2,349	2,930
4	177	39	33	94	355	430	236	11	81	144	150	233	66
5										5			
6										5			
Total	6,797	3,506	1,584	6,234	7,555	4,571	3,932	3,623	7,353	5,331	6,347	5,095	8,062
B													
2	4,749	1,046	469	3,468	2,486	1,619	1,001	2,793	4,679	1,548	3,980	2,915	5,612
3	3,186	2,887	1,393	3,257	5,598	3,619	3,659	1,503	3,540	4,790	3,737	2,724	3,245
4	212	44	40	103	398	544	298	13	91	176	187	270	73
5										6			
6										6			
Total	8,147	3,977	1,902	6,828	8,482	5,782	4,958	4,309	8,311	6,526	7,904	5,909	8,930

[a] Preliminary.

App. 4. Number of wild 1SW salmon and proportion of age 2:1's of the total that would have returned to Mactaquac for the 1969-1983 year-classes.

Year-class (i)	Number at age of 1SW returns to Mactaquac				Prop. 2:1's of total
	2:1 (i+3)	3:1 (i+4)	4:1 (i+5)	Total	
1968		690	41		
1969	127	451	37	615	0.207
1970	1,578	1,901	68	3,547	0.445
1971	1,718	4,465	212	6,395	0.269
1972	2,325	3,186	44	5,555	0.419
1973	4,749	2,887	40	7,676	0.619
1974	1,046	1,393	103	2,542	0.411[a]
1975	469	3,257	398	4,124	0.114[a]
1976	3,468	5,598	544	9,610	0.361
1977	2,486	3,619	298	6,403	0.388
1978	1,619	3,659	13+6	5,296	0.306
1979	1,001	1,503	91+6	2,601	0.385
1980	2,793	3,540	176	6,509	0.429
1981	4,679	4,790	187	9,656	0.485
1982	1,548	3,737	270	5,555	0.279
1983	3,980	2,724	73	6,777	0.587
1984	2,915	3,245			
1985	5,612				

[a] Influenced by low survival of 1977 smolt-class.

App. 5. Number of eggs/100 m^2 deposited in the Tobique River, 1968-1984, and derivation of weighted number of eggs contributing to annual returns of wild 1SW fish at Mactaquac, 1973-1986 and 1989 (explanation in Penney and Marshall MS 1984).

Egg deposition		Proportion age at smoltification[a]		Eggs/100 m^2 contributing to 1SW fish		Total wt'd egg contrib/100 m^2 to 1SW fish @ Mact. (yr)
Year	Number	Age 2	Age 3	Yr i	Yr i+1	
1968	5.7	0.207				
			0.793		4.55	
1969	43.6	0.445		19.40		23.95 (1973)
			0.555		24.20	
1970	60.9	0.269		16.38		40.58 (1974)
			0.731		44.52	
1971	71.2	0.419		29.83		74.35 (1975)
			0.581		41.37	
1972	130.8	0.619		80.96		122.33 (1976)
			0.381		49.84	
1973	86.5	0.411		35.55		85.39 (1977)
			0.589		50.95	
1974	269.4	0.114		30.71		81.66 (1978)
			0.886		238.69	
1975	368.2	0.361		132.92		371.61 (1979)
			0.639		235.28	
1976	245.4	0.388		95.22		330.50 (1980)
			0.612		150.18	
1977	309.2	0.306		94.62		244.80 (1981)
			0.694		214.58	
1978	193.2	0.385		74.38		288.96 (1982)
			0.615		118.82	
1979	112.3	0.429		48.18		167.00 (1983)
			0.571		64.12	
1980	362.1	0.485		175.62		239.74 (1984)
			0.515		186.48	
1981	118.7	0.279		33.12		219.60 (1985)
			0.721		85.58	
1982	139.8	0.587		82.06		167.64 (1986)
			0.413		57.74	
1983	69.4					
1984	385.5					
			0.625[b]		240.94	
1985	301.7	0.375[b]		113.14		354.08 (1989)

[a] Derived from App. 3 and 4.
[b] Mean (n=15) calculated with angular transformation.

App. 6. Returns of wild and hatchery 1SW and MSW to above and below Mactaquac Dam, Saint John River, 1970-1988.

Year	Wild				Hatchery				Total returns	
	Above		Below		Above		Below			
	1SW	MSW	1SW	MSW	1SW	MSW	1SW	MSW	1SW	MSW
1970	3,057	5,712	2,830	6,684						
1971	1,709	4,733	3,303	2,142						
1972	908	4,899	1,486	2,280						
1973	2,070	2,518	2,434	4,455						
1974	3,656	5,811	4,535	3,580						
1975	6,858	7,441	3,384	2,779	6,374	2,210			16,616	12,430
1976	8,147	8,177	6,479	3,559	9,074	2,302			23,700	14,038
1977	3,977	9,712	3,707	6,289	6,992	2,725			14,676	18,726
1978	1,902	4,021	2,981	3,630	3,044	2,534			7,927	10,185
1979	6,828	2,754	5,108	1,262	3,827	1,188			15,763	5,204
1980	8,482	10,924	3,811	5,116	10,793	2,992			23,086	19,032
1981	5,782	5,991	6,584	5,880	4,730	2,612			17,096	14,483
1982	4,958	5,001	5,664	5,240	2,846	1,531	841		14,309	11,772
1983	4,309	3,447	4,995	4,256	1,445	581	516	145	11,265	8,429
1984	8,311	9,779	2,825	3,530	1,451	1,115	435	298	13,022	14,722
1985	6,526	10,436	1,971	3,264	2,018	875	305	193	10,820	14,768
1986	7,904	6,128	7,296	4,258	862	797	406	77	16,468	11,260
1987	5,909	4,352	5,448	3,024	3,328	480	2,378	181	17,063	8,037
1988	8,930	2,625	8,243	1,824	1,250	912	877	1,145	19,300	6,506

App. 7. Estimates of commercial, sport and Native landings of 1SW and MSW salmon (000's) on the Saint John River, 1955-1988.

Year	Commercial[a]			Sport[b]			Native			Grand Total
	1SW	MSW	Total	1SW	MSW	Total	1SW	MSW	Total	
1955	0.8	5.5	6.3							
1956	0.6	4.9	5.5							
1957	0.8	6.9	7.7							
1958	1.2	13.8	15.0							
1959	2.1	14.3	16.4							
1960	1.0	10.6	11.6							
1961	0.8	9.5	10.3							
1962	0.5	5.5	6.0							
1963	0.6	4.2	4.8							
1964	0.9	9.4	10.3							
1965	1.5	17.8	19.3							
1966	1.5	18.9	20.4							
1967	0.7	9.4	10.1							
1968	0.7	7.3	8.0							
1969	0.3	2.5	2.8	1.5	0.6	2.1				4.9
1970	0.4	5.4	5.8	1.3	1.3	2.6				8.4
1971	0.3	2.6	2.9	1.2	0.7	1.9				4.8
1972	0.1	0.1	0.1	0.9	1.6	2.5				2.6
1973	0.1	0.2	0.3	1.3	1.5	2.8				3.1
1974	0.1	0.1	0.1	2.0	2.5	4.5	0.1	0.6	0.6	5.2
1975	0.1	0.1	0.2	2.5	1.7	4.2	0.1	0.7	0.8	5.2
1976	0.1	0.1	0.2	4.7	2.8	7.5	0.5	2.0	2.5	10.2
1977	0.1	0.2	0.3	4.3	4.4	8.7	0.1	1.1	1.2	10.2
1978	0.2	0.2	0.4	1.7	2.2	3.9	0.1	1.0	1.1	5.4
1979	0.1	0.1	0.2	3.3	0.8	4.1	0.3	0.8	1.1	5.4
1980	0.1	0.3	0.4	4.7	5.4	10.1	0.8	2.6	3.4	13.9
1981	1.4	6.8	8.2	4.1	2.0	6.1	0.4	0.9	1.3	15.6
1982	1.8	2.9	4.7	3.4	2.0	5.4	0.2	2.1	2.3	12.4
1983	1.3	3.1	4.4	2.5	1.1	3.6	0.2	0.6	0.8	8.8
1984[c]	0.4	1.2	1.6	2.8	0.3	3.1	0.4	2.1	2.5	7.2
1985[c]	0.5	2.3	2.8	3.5	0.4	3.9	0.5	2.5	3.0	9.7
1986[c]	0.3	0.6	0.9	3.7	0.3	4.0	0.6	2.4	3.0	7.9
1987[c]	0.3	0.4	0.7	3.5	0.1	3.6	0.3	1.1	1.4	5.6
1988[d]	0.4	0.3	0.7	2.7	0.1	2.8	0.3	1.2	1.5	5.0

a Closure 1972 to 1980 incl., and 1984 to 1987 incl.; incl. est's of by-catch in recent years.
b New Brunswick DNRE data 1969-83; DFO/DNRE pers comm. data 1984-88.
c Includes 10% of estimated sport-caught MSW releases.
d Sport MSW equals 2% loss of run to hook-release mortality.