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Assessment of Atlantic Salmon of the Saint John River, N.B., 1986

by

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ABSTRACT

Estimated total returns to the Saint John River in 1986 were 16,027 1SW and 11,839 MSW salmon. Homewater removals of about 4,000 1SW and 4,400 MSW fish led to an estimated 1986 spawning escapement only 73 percent of the target number of MSW spawners. The forecast of 1987 homewater returns is 13,152 1SW fish (5,552 more than the target escapement) and 18,003 MSW salmon (7,403 fish more than the target escapement plus hatchery broodstock requirements). Homing tendencies of the MSW salmon to 'above' and 'below' Mactaquac origins will result in surpluses to spawning requirements of 6,081 fish 'above' Mactaquac and 1,322 fish 'below' Mactaquac. Variation between forecasts and 'actual' fish returns suggest the utility and value of multi-year management plans based on general trends in stock status rather than on a specific assessment.

RESUME

On a estimé à 16 027 unibermarins (un hiver en mer) et à 11 839 redibermarins (plusieurs hivers en mer) le nombre de saumons qui sont revenus dans le fleuve Saint-Jean en 1986. Des captures, dans les eaux d'origine, d'environ 4 000 unibermarins et 4 400 redibermarins ont permis de déterminer que l'effectif de frai atteignait en 1986 seulement 73 pour cent du nombre cible établi pour les reproducteurs redibermarins. On prévoit qu'en 1987 les retours dans les eaux d'origine se chiffreront à 13 152 unibermarins (soit 5 552 de plus que l'effectif de frai cible) et à 18 003 redibermarins (soit 7 403 de plus que l'effectif de frai cible et le stock reproducteur requis pour la pisciculture). Les tendances de retour des redibermarins dans les eaux d'origine en "amont" ou en "aval" du barrage de Mactaquac se traduiront par un surplus de 6 081 poissons en amont et de 1 322 poissons en aval, par rapport à l'effectif de frai cible. Les différences entre les retours prévus et les retours "reéls" témoignent de l'utilité de l'importance de plans de gestion pluriannuels fondés sur la tendance générale des stocks plutôt que sur une évaluation précise.

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 in November 1986 relevant to stock status in 1986 and forecasts for 1987.

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).

Forecasts made in 1985 (Marshall, MS 1985) suggested that total 1986 homewater returns would number approximately 9,400 1SW and 13,600 MSW salmon. CAFSAC advised managers (CAFSAC Advisory Document 85/22) that for 1986 there would in total be 1,900 1SW and 2,800 MSW salmon surplus to spawning requirements, including a deficit of 1,000 MSW salmon below spawning requirements returning to tributaries 'below' Mactaquac; and that there should be no increase in the exploitation of MSW salmon over that of 1985.

The Management Plan for 1986 was almost identical to that of 1985 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 and a 900 fish quota (blatantly ignored) for the Indian Food Fishery at Kingsclear. Differences from 1985 were that the Kingsclear Indian Band was unimpeded by mid-season closures (largely ignored in 1985) and that the Oromocto Indian Band was granted license to fish for 150 salmon. The reduction of open commercial seasons in Newfoundland, 1984-1986, and closure of Nova Scotia commercial fisheries, 1985-1986, are reflected in homewater returns but made little impact on MSW forecasts derived from a 17-year data set. River water levels were low in June, about average in July and among the highest of 20 years of record for August and September. Sport fishing success was generally regarded as "fair" at best, and down from 1985.

In general, estimates of total returns, removals and required spawners in 1986 and forecasts for 1987 were determined in a manner similar to that of Marshall (MS 1985).

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 (MC) 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 1986 were dependent on fin erosion (principally dorsal fin) and on interpretation of patterns of freshwater growth on scales.

Guesstimates of removals by Kingsclear were obtained from federal 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.

Estimates of by-catch removals were obtained from federal sources. Their subdivision into 1SW/MSW, 'above'/'below' components was approximated using the proportion of both hatchery and wild, 1984-1985 homewater returns that the wild 1SW and MSW salmon by-catch were of the potential total homewater wild returns to Mactaquac and 'below' Mactaquac. Hatchery/wild components of each were apportioned on the basis of the relative contribution to and 'below' Mactaquac of the 1984 (MSW) and 1985 (1SW) smolt releases.

The total angling catch from the main stem 'below' Mactaquac was assumed to approximate that of 1985. Ten percent of the assumed MSW catch was considered to have been removed from the spawning escapement either because of illegal retention or delayed release mortality.

Returns of wild salmon to tributaries 'below' Mactaquac in 1986 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 because there was, with the exception of 1SW removals from the Kennebecasis River, no estimate of angling catch or release 'below' Mactaquac. Hatchery returns to all tributaries 'below' Mactaquac were calculated as the product of the number of smolts released and the estimated return rate for fish released at Mactaquac.

Total River Removals

Total removals include estimates of those fish to the Kingsclear Indian Reserve (no estimate from Oromocto), mainstem sport fishery 'above' and 'below' Mactaquac, Tobique and Kennebecasis sport catches and the by-catch fishery. 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 some fish sacrificed for analysis.

Angling catches for the main stem 'above' Mactaquac and for the Tobique River were guesstimated by DFO personnel. Proportions of 1SW/MSW and hatchery/wild were based on the proportions released to each area. Angling catches of 1SW and MSW fish in the Nashwaak River were not available. An estimate of the 1SW catch in the Kennebecasis River was provided by DFO.

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 eggs/m^2, a length-fecundity relationship ($\log_e$ Eggs = 6.06423 + 0.03605 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 (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 4,000 '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, 1973-1984, on adjusted (method in Penney and Marshall (MS 1984) with data updates, App. 2, 3 and 4, this paper) egg depositions in the Tobique River, 1968-1969 to 1979-1980. Returns of 1SW fish originating 'above' Mactaquac in 1984 and 1985 were changed in accordance with a redivision of the by-catch to 'above' and 'below' origins. This change resulted from the utilization of 1986 fry densities in the Nashwaak River to reconstruct spawning escapement (method adjusted to account for MSW throwbacks) and returns to the Nashwaak River 1985 (App. 5) and revision of the exploitation rate and angler harvest on the Kennebecasis and Hammond rivers (App. 6).

Egg depositions for the period 1979-1980 were adjusted in the same manner as Penney and Marshall (MS 1984) using freshwater age composition from 552 wild 1SW fish sampled at Mactaquac in 1986. Adjustment of the 1982 and 1983 egg depositions, principal contributors to 1SW returns in 1987, was done with the use of angular-transformed mean proportions for age 2:1 and age 3:1 1SW fish in the 1969 to 1981 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

The 1987 forecast of MSW returns to homewaters which originated 'above' Mactaquac was based on the regression of the estimated MSW returns destined for Mactaquac, 1971-1986, on the estimated numbers of 1SW fish originating 'above' Mactaquac and returning to Saint John River in the previous year. As in the forecasting of 1SW salmon, analyses included the use of natural logarithms and conversion of the GM to AM.

iii) 1SW Hatchery

The release in 1985 and again in 1986 of all 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 techniques. Instead, the return rate for 1SW fish in 1987 from 1986 1-year smolts was assumed to be the same as for 1985 1-year smolts returning in 1986.

Additionally, 1SW returns are expected in 1987 from releases of parr in the spring of 1985 which did not attain the 12-cm length criteria of a "smolt". Returns of these parr as 1SW fish in 1987, which may/may not be discernible from wild fish, were estimated as the product of their number, a 0.0074 survival rate to 1SW fish (Ritter and Gray (MS 1977) corrected for non reporting of tags) and a factor of 0.5 for reduced survival in non-parr-like habitat of the main Saint John immediately below Mactaquac.

iv) MSW Hatchery

Returns as MSW fish for 1-year smolts released at Mactaquac in 1985 were estimated as the product of their number and return rates for tagged 1-year smolts released from Mactaquac in 1976, 1978 and 1979 prorated by the 1SW return rate for 1-year smolts returning in 1986. MSW returns from the 16,952 smolts tagged in the 1970's were about 3.2 times the 0.0015 return rate for 1SW salmon from the same smolts reported by Marshall (MS 1985).

b) 'Below' Mactaquac

i) 1SW Wild

The 1987 return to homewaters of 1SW fish which originated 'below' Mactaquac was 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, 1970-1985. The regression technique used previously (Marshall, MS 1985) increasingly deteriorated with the inclusion of estimated returns since 1984 and was therefore not used in this assessment.

ii) MSW Wild

The 1987 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, 1970-1985.

iii) 1SW Hatchery

Returns of 1SW fish from 1-year smolts released 'below' Mactaquac in 1986 were calculated in the same manner as for those smolts released 'above' Mactaquac. Returns from 'parr' released in parr habitat of tributaries below Mactaquac were calculated per the 'above' returns but without the 0.5 habitat quality discount factor.

iv) MSW Hatchery

MSW returns from 1-year smolts released in 1985 to tributaries 'below' Mactaquac were calculated in the same manner as for those returning 'above' Mactaquac.

RESULTS

Total River Returns

Estimated homewater returns in 1986 totalled 16,027 1SW fish (8,457 originating 'above' and 7,570 originating 'below' Mactaquac) and 11,839 MSW fish (7,216 originating 'above' and 4,623 originating 'below' Mactaquac; Table 1). Hatchery returns comprised 7.2% and 8.6% of the total 1SW and MSW returns, respectively.

Counts at Mactaquac were 83.3% of the 1SW and 57.4% of the MSW fish estimated to have originated 'at' or 'above' Mactaquac (Table 1).

The total removal at Kingsclear was conservatively guessed at 3,000 fish. Proportioning on the basis of the relative exploitation rates for hatchery 1SW and MSW fish at Kingsclear, (Marshall, MS 1985) provided estimates of approximately 600 1SW and 2,400 MSW salmon.

Releases of 46,134 and 56,992 hatchery smolts to tributaries 'below' Mactaquac in 1984 and 1985 respectively, and the 1985 return rates of 0.00934% and 0.00402% for smolts released at Mactaquac in the same years (Table 2) suggest respective returns in 1986 (Table 1) of approximately 532 1SW fish and 186 MSW fish 'below' Mactaquac.

Total River Removals

In the absence of timely provincial sport statistics and landings at Kingsclear, removals have been etimated at about 4,000 1SW and 4,400 MSW fish (Table 3).

Spawning Escapement

Collation of the total returns (Table 1), total removals (Table 3) and numbers of fish required to meet an egg deposition of 2.4 eggs/m^2 indicates that 80% and 68% of the required MSW spawners were attained 'above' and 'below' Mactaquac, respectively (Table 4). For 1SW fish, 184% of requirements were met 'above' Mactaquac; 140% of requirements were met 'below' Mactaquac. The proportion of females among 1SW and MSW fish counted at Mactaquac was 0.054 and 0.855, respectively - similar to the average of previous years.

Stock Forecasts

a) 'Above' Mactaquac

i) 1SW Wild

The 1987 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 (Table 5). The AM estimate for 1SW returns in 1987 is 4,989 1SW fish (95% C.L. 3,874-6,426) (Table 5).

ii) MSW Wild

The forecast of wild MSW fish destined for Mactaquac in 1987 was based on the regression $\log_e Y = 4.590 + 0.490 \log_e X$ (n=16; r=0.70; p= 0.003; Table 5). The 7,625 1SW returns to Mactaquac in 1986 provided an AM estimate of 8,327 MSW fish (95% C.L. 6,446-10,756) destined for Mactaquac in 1987.

iii) 1SW Hatchery

The forecast of hatchery 1SW fish destined for Mactaquac in 1987 was in part calculated as the product of an estimated 191,495 smolts released at Mactaquac and the 0.00934 return rate (Table 2) for 1-year smolts to Mactaquac in 1986, i.e., 1,789 fish. In addition, it was estimated that 143,658 parr released at Mactaquac in the spring of 1985 might experience a return rate of one-half the 0.0074 adjusted value of Ritter and Gray (MS 1977), i.e., 530 fish. The total forecast of hatchery 1SW returns to Mactaquac is then 2,319 1SW fish.

iv) MSW Hatchery

MSW returns destined for Mactaquac in 1987 were calculated as the product of an estimated return rate of 0.0298, i.e., 2.19 x 0.00934 and 89,051 smolts released in 1985. The forecast of hatchery MSW returns to Mactaquac is 2,654 MSW fish.

b) 'Below' Mactaquac

i) 1SW Wild

Based on the 1970-1985 proportions of 0.56 of the total wild 1SW returns originating 'above' Mactaquac and 0.44 originating 'below' Mactaquac (App. 1) and the 1987 forecast of 1SW returns 'above' Mactaquac, it is estimated that the number of 'wild' 1SW fish 'below' Mactaquac in 1987 will be 4,989/0.56-4989 or 3,920 1SW fish.

ii) MSW Wild

In a manner similar to that for forecasting 1SW fish 'below', MSW salmon 'below' Mactaquac were estimated from the 0.61: 0.39 proportion for MSW fish above:below, 1970-1985. Hence the estimate is 8,327/0.61-8,327 or 5,324 MSW fish.

iii) 1SW Hatchery

The forecast of hatchery 1SW fish destined for tributaries below Mactaquac in 1987 was in part calculated as the product of an estimated 38,387 smolts released and the 0.00934 return rate for 1-year smolts in 1986, i.e., 358 1SW fish. In addition it was estimated that 211,655 parr released in parr habitat below Mactaquac would yield 211,665 x 0.0074 or 1,566 fish. Total 1SW hatchery fish returning to tributaries below Mactaquac are expected to number 1,924 1SW fish.

iv) MSW Hatchery

MSW hatchery returns 'below' Mactaquac in 1987 were forecast as the product of the estimated 0.0298 return rate and 56,992 smolts released in 1985, i.e., 1,698 MSW fish.

Forecast Summary

The forecast of total homewater returns (Table 6) to the Saint John River in 1987 is 13,152 1SW (8,909 of wild and 4,243 of hatchery origin) and 18,003 MSW fish (13,651 of wild and 4,352 of hatchery origin). For the total Saint John River the forecast returns minus the spawning requirements result in potential surpluses of 5,552 1SW and 7,403 MSW salmon. Separation to 'above' and 'below' Mactaquac origins indicates surpluses over target escapements of 4,108 1SW and 6,081 MSW salmon for the former and 1,444 1SW fish and 1,322 MSW salmon for the latter.

DISCUSSION

Total estimated river returns in 1986 of 16,027 1SW and 11,839 MSW salmon were 170% and 87% of forecast returns. Returns of wild 1SW fish 'above' and 'below' Mactaquac were 150% and 170%, respectively of forecasts; wild MSW fish 'above' and 'below' were 83% and 99% of the respective forecast values. Hatchery 1SW and MSW fish were 710% and 73% of forecasts. Spawning escapement of MSW fish 'above' Mactaquac was 80% of requirement; escapement 'below' was 68% of requirement. 1SW returns which exceeded all forecast levels suggest that marine survival of the 1985 smolt class was higher than average.

Total returns are however a function of the estimate of removals--a major shortcoming at the time of assessment. Lack of angling data below Mactaquac completely precluded an index of abundance independent of returns to Mactaquac. Returns destined for Mactaquac were also uncertain, given that removals by Kingsclear were guessed conservatively, yet purportedly were numerous.

Failure to adequately document returns and removals results in the underestimation of the Saint John's production capacity and, in time, will contribute to the underestimation of future returns. Forecasts and corrected estimates of returns 1982 to 1985, presently suggest that forecasts in 4 out of 5 years have been higher than 'actual' returns:

Returns	1982		1983		1984		1985		1986	
/1000	1SW	MSW	1SW	MSW	1SW	MSW	1SW	MSW	1SW	MSW
Forecast	19.2	16.8	15.8	16.2	14.9	10.0	17.5	15.5	9.5	13.4
"Actual"	14.3	11.8	11.3	8.4	13.0	14.7	10.8	14.8	16.0	11.8
Act/Forec(%)	75	70	72	52	87	147	62	95	168	88

'Forecast' returns are the summation of estimates by different estimating procedures but are largely based on regression techniques applied to Mactaquac-based data since 1970. Forecasts of 1SW fish from estimated egg depositions above Mactaquac would be increasing relative to 'actual' if, in recent years, the MSW 'escapement' and egg deposition were overestimated because of proportionately more undocumented MSW removals than in early years (sport removals since 1984 are illegal). Forecasts of MSW fish from the presumed better quality estimates of 1SW returns, i.e., 1SW fish are less vulnerable to Indian, commercial and by-catch fisheries by virtue of selectivity of fishing gear for MSW fish, would be diminishing relative to estimates of 'actual' returns if in recent years there were increasing difficulties in estimating 'actual' MSW returns to home waters.

If it can be assumed that estimates of 1SW returns are reasonably precise, that distant exploitation/marine mortality and the ratio of wild MSW returns to wild 1SW returns are relatively constant between smolt classes and that forecasting models are appropriate, the wild MSW/1SW ratios for returns destined for Mactaquac may be suggestive of MSW data deficiencies (Table 5). Coincidences are: high ratios, 1971-1975, with public awareness of stock deficiencies and ban on commercial fishing; reduced ratios, 1976-1978, with the start-up of the Kingsclear Food Fishery (tag return data unadjusted for non-reporting) and reports of increasing by-catch in the Saint John Harbour; increased ratios, 1979-1980, with concerted effort to reduce by-catch; lowest ratios, 1981-1983, with the use of logbook data from a "quota-controlled" homewater commercial fishery; erratic ratios, 1984-1986, in the absence of MSW sport data comparable to pre-1984 data and complete breakdown of estimation procedures for removals by the Kingsclear Food Fishery.

The importance of annual forecasts have, of course, been down played by the current 1984-1988 Management Plan. Deficiencies of these assessments would support the continuation of multi-year management plans based on general trends in stock status rather than on a specific assessment.

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Table 1. Estimated total returns of wild and hatchery 1SW and MSW salmon originating 'above' and 'below' Mactaquac Dam to the Saint John River, N.B., 1986.

Sea-age	Components	Number of fish: Origin 'above' Mactaquac Wild	Hatch.	Total	Origin 'below' Mactaquac Wild	Hatch.	Total	Total Wild	Hatch.	Total
1SW										
	Mactaquac counts	6,347	699	7,046	-	-	-	6,347	699	7,046
	Kingsclear catch[a]	547	53	600	-	-	-	547	53	600
	Angled MS 'below' Mactaquac[b]	541	59	600	-	-	-	541	59	600
	By-catch[c]	190	21	211	260	20	280	450	41	491
	Returns to tribs. below Mactaquac	-	-	-	6,778	512	7,290	6,778	512	7,290
	Totals	7,625	832	8,457	7,038[d]	532[e]	7,570	14,663	1,364	16,027
MSW										
	Mactaquac counts	3,656	487	4,143	-	-	-	3,656	487	4,143
	Kingsclear catch[a]	2,134	266	2,400	-	-	-	2,134	266	2,400
	Angled MS 'below' Mactaquac[b]	53	7	60	-	-	-	53	7	60
	By-catch[c]	542	71	613	666	28	694	1,208	99	1,307
	Returns to tribs. 'below' Mactaquac	-	-	-	3,771	158	3,929	3,771	158	3,929
	Totals	6,385	831	7,216	4,437[d]	186[e]	4,623	10,822	1,017	11,839

a Estimated at 3,000 fish of which 1SW = 20%; MSW = 80%.
b 1985 values.
c Mean 1984, 1985 proportions of 2.5% total 1SW returns and 8.5% total MSW returns 'above'; 3.7% 1SW and 15% MSW 'below'.
d Based on 1970-1983 proportion of production 'below' (App. 1), i.e., 0.48 for 1SW and 0.41 for MSW.
e Product of return rates for 'above' and 46,134 smolts in 1984 & 56,992 smolts in 1985 where smolts 'above' were 206,462 in 1984 & 89,051 in 1985.

Table 2. Estimated total number of 1SW and MSW returns to the Saint John River from hatchery-reared smolts released 'at' Mactaquac, 1974-1986.

Releases			Returns (1SW/MSW)								
				Mactaquac							
Year	Smolts	Prop. 1-yr.	Year	MC	Dam	Kings-clear	Angled MS	By-catch	Comm-ercial	Total	% Return
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
82	172,231	0.06	83	374	857	39	69	11	95	1,445	0.839
83	144,549	0.22	84	476	828	36	63	48		1,451	1.004[a]
84	206,462	0.28	85	454	1,288	82	128	66		2,018	0.977[a]
1974-1984	2,636,747									52,594	1.995
85	89,051	1.00	86	64	635	53	59	21		832	0.934
86	191,495	1.00	87								
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
82	172,231		84	84	722	201	5	103		1,115	0.647[a]
83	144,549		85	73	492	189	5	116		875	0.605[a]
84	206,462		86	16	471	266	7	71		831	0.402
1974-1984	2,636,747									19,286	0.731
85	89,051		87								
86	191,495		88								

[a] Adjusted from Marshall (MS 1985) according to text: forecasts wild 1SW 'above'.

Table 3. Estimated homewater removals[a] of 1SW and MSW salmon originating 'above' and 'below' Mactaquac Dam on the Saint John River, N.B., 1986.

Sea-age	Components	Number of fish: Origin 'above' Mactaquac Wild	Hatch.	Total	Origin 'below' Mactaquac Wild	Hatch.	Total	Total Wild	Hatch.	Total
1SW	Kingsclear Indians Angled	547	53	600	-	-	-	547	53	600
	Tobique River	821	71	892		-	-	821	71	892
	Mainstem above Mact.	182	18	200		-	-	182	18	200
	Mainstem below Mact.	541	59	600		-	-	541	59	600
	Keswick	-	-	-	?	?	150	?	?	150
	Nashwaak River	-	-	-	?	?	600	?	?	600
	Hammond River	-	-	-	?	?	?	?	?	?
	Kennebecasis River	-	-		?	?	394	?	?	394
	Trucked to Aroostook R.	-	59	59	-	-	-	-	59	59
	Hatchery broodfish	-	-	-	0	0	0	0	0	0
	Mortalities, etc.	2	6	8	0	0	0	2	6	8
	By-catch	190	21	211	260	20	280	450	41	491
	Totals	2,283	287	2,570	260+	20+	1,424+	2,543+	307+	3,994+
MSW	Kingsclear Indians Angled[b]	2,134	266	2,400	-	-	-	2,134	266	2,400
	Tobique River	44	5	49	-	-	-	44	5	49
	Mainstem above Mact.	18	2	20	-	-	-	18	2	20
	Mainstem below Mact.	53	7	60	-	-	-	53	7	60
	Keswick	-	-	-	?	?	?	?	?	?
	Nashwaak River	-	-	-	?	?	?	?	?	?
	Hammond River	-	-	-	?	?	?	?	?	?
	Kennebecasis River	-	-	-	?	?	?	?	?	?
	Trucked to Aroostook R.	-	9	9	-	-	-	-	9	9
	Hatchery broodfish	421	94	515	40	-	40	461	94	555
	Mortalities, etc.	26	5	31	6	-	6	32	5	37
	By-catch	542	71	613	666	28	694	1,208	99	1,307
	Totals	3,238	459	3,697	712+	28+	740+	3,950+	487+	4,437+

[a] Previous to significant federal and provincial input.
[b] 10% of angled MSW fish assumed to be lost from spawning escapement.

Table 4. Estimated homewater returns, removals and spawning escapement of 1SW and MSW salmon originating 'above' and 'below' Mactaquac Dam, Saint John River, 1986.

Sea-age	Category	Number of fish 'Above' Mactaquac Wild	'Above' Mactaquac Hatch.	'Below' Mactaquac Wild	'Below' Mactaquac Hatch.	Total Wild	Total Hatch.	Total Both
1SW								
	Homewater returns	7,625	832	7,038	532	14,663	1,364	16,027
	Homewater removals	2,283	287	1,424				3,994
	Spawners	5,342	545	6,146				12,033
	Target spawners	3,200		4,400				7,600
	Percentage of target spawners	184		140				158
MSW								
	Homewater returns	6,385	831	4,437	186	10,822	1,017	11,839
	Homewater removals	3,238	459	712	28	3,950	487	4,437
	Spawners	3,147	372	3,725	158	6,872	530	7,402
	Target spawners	4,400[a]		5,700				10,100[a]
	Percentage of target spawners	80		68				73

[a] Excludes 500 broodfish required at Mactaquac FCS.

Table 5. 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 1987.

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	167.11	83	4,309	84	9,779	2.27
1979-80	240.71	84	8,311	85	10,436	1.26
1980-81		85	6,526	86	6,385	0.98
1981-82		86	7,625	87	8,327[c]	
1982-83	113.96	87	4,989[b]			

a See App. 2, 3 and 4 for derivation and update of Marshall (MS 1985).

b Based on regression of 1SW returns to Mactaquac, 1973-1984, (col. 3) on adjusted egg deposition in Tobique River, 1968-1969 to 1979-1980, (col. 2):

$$\log_e Y = 6.538 + 0.403 \log_e X: n=12, r=0.69, p= 0.013$$

$$Y_{1986} = 4,989(AM): 95\% C.L. = 3,874 \text{ to } 6,426.$$

c Based on regression of MSW returns to Mactaquac, 1971-1986, (col. 4) on 1SW returns to Mactaquac 1970-1985, (col. 3):

$$\log_e Y = 4.590 + 0.490 \log_e X; n=16, r=0.70, p= 0.003$$

$$Y_{1987} = 8,327(AM); 95\% C.L. = 6,446 \text{ to } 10,756.$$

Table 6. Summary of the 1987 salmon forecast for the Saint John River, New Brunswick (95% C.L. in parentheses).

Requirement	1SW			MSW		
	Wild	Hatch.	Total	Wild	Hatch.	Total
'Above' Mactaquac	4,989 (3,874-6,426)	2,319	7,308	8,327 (6,446-10,756)	2,654	10,981
Target escpm.			3,200			4,400[1]
Surplus			4,108			6,081
'Below' Mactaquac	3,920	1,924	5,844	5,324	1,698	7,022
Target escpm.			4,400			5,700
Surplus			1,444			1,322
Total	8,909	4,243	13,152	13,651	4,352	18,003
Target escpm.			7,600			10,100[1]
Surplus			5,552			7,403

[1] Excludes 500 broodfish for Mactaquac Fish Culture Station.

App. 1 Estimated total returns of wild 1SW and MSW salmon originating 'above' and 'below' Mactaquac Dam, Saint John River, 1970-1985.

Sea-age	Year	(1) Mact. count	(2) Kings-clear	(3) Angled MS	(4) Trib. Returns BL. Mact.[a]	(5) Comm. fishery Total	(6) Comm. fishery Above	(7) Comm. fishery Below	(8) By-catch Total	(9) By-catch Above[c]	(10) By-catch Below[d]	Total returns (proportions) Above	Below	Total
1SW														
	1970	2,874		78	2,732	200	105[b]	98[b]	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	4,338	1,482	352	1,130	79	37	42	4,958	5,510	10,468
	83	3,623	164	207	3,989	1,091	283	808	68	32	36	4,309	4,833	9,142
	84	7,353	317	351	2,674				387[e]	290	97	8,311	2,771	11,082
	85	5,331	389	460	1,723				443[f]	346	97	6,526	1,820	8,346
Mean												4,842 (.56)	3,848 (.44)	8,690 (1.00)
MSW	1970	2,449		59	2,935	6,934	3,204[b]	3,749[b]	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	2,363	2,651	986	1,665	309	139	170	3,447	4,198	7,645
	84	7,011	1,934	41	3,039				1,061[e]	793	268	9,779	3,307	13,086
	85	6,391	2,337	53	2,661				2,156[f]	1,655	501	10,436	3,162	13,598
Mean												6,334 (.61)	3,973 (.39)	10,307 (1.00)

[a]Reference App. 6.
[b]Values include by-catch.
[c]Columns (1+2+3+6)/columns (1+2+3+6+4+7) x Col. 8, where the 1970 and 1971 commercial and by-catch are combined and treated as by-catch in 1982; hatchery fish removed.
[d]Below = (Total-Above).
[e]Based on Fishery Officer estimates and a mean of 18% 1SW fish among the by-catch; 1982 hatchery fish removed.
[f]Fishery Officer estimates

App. 2. Freshwater age and number of 1SW fish (A) counted at Mactaquac fish passage facilities, Saint John River, 1976-1986, and (B) that would have returned to Mactaquac had they not been exploited within the river, 1976-1986.

Fresh-water age	Number of 1SW fish										
	1976	1977	1978	1979	1980	1981	1982	1983[a]	1984[b]	1985[b]	1986
A											
2	3,962	922	391	3,166	2,214	1,280	794	2,348	4,140	1,264	3,196
3	2,658	2,545	1,160	2,974	4,986	2,861	2,902	1,264	3,132	3,913	3,001
4	177	39	33	94	355	430	236	11	81	144	150
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
B											
2	4,749	1,046	469	3,468	2,486	1,619	1,001	2,793	4,679	1,548	3,840
3	3,186	2,887	1,393	3,257	5,598	3,619	3,659	1,503	3,540	4,790	3,605
4	212	44	40	103	398	544	298	13	91	176	180
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	7,625

[a] Changed from Penney and Marshall (MS 1984, Table 13) based on re-reading scale samples.

[b] Changed from Marshall (MS 1985) based on reproportioning of by-catch.

App. 3. Number of wild 1SW salmon and proportion of age 2:1's of the total that would have returned to Mactaquac for the 1969-1981 year-classes (numbers of 1SW fish from Table 10, Marshall (MS 1984), and App. 2)

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	180	9,649	0.485
1982	1,548	3,605			
1983	3,840				

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

App. 4. Number of eggs/100 m^2 deposited in the Tobique River, 1968-1983, and derivation of weighted number of eggs contributing to annual returns of wild 1SW fish at Mactaquac, 1973-1984 and 1987 (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		229.74 (1984)
			0.515		186.48	
1981	118.7					
1982	139.8					
			0.633[b]		88.49	
1983	69.4	0.367[b]		25.47		113.96 (1987)

a Derived from App. 2 and 3.

b Mean (n=13) calculated with angular transformation.

App. 5. Parameters and derivation of total returns of salmon and of angling exploitation rates for the Nashwaak River, 1970-1985.

Year	Sea-age	Eggs/F[a]	Prop. F	Prop. pop'n[b]	Eggs/fish[c]	Egg prop's	Total eggs[d] (1,000's)	No. F's[e]	No. M+F[f]	Provincial no. angled	Total returns	Exploit. rate
1970	1SW	3,592	0.23	0.487	402	0.118	1,226.6	341	1,484	811	2,295	0.35
	MSW	6,828	0.86	0.513	3,012	0.882	9,167.9	1,343	1,561	854	2,415	0.35
1971	1SW	3,389	0.23	0.781	609	0.323	1,448.2	427	1,858	733	2,591	0.28
	MSW	6,778	0.86	0.219	1,277	0.677	3,035.7	448	521	205	726	0.28
1972[g]	1SW		0.32							581	1,205	0.48
	MSW		0.83							926	1,890	0.49
1973[g]	1SW		0.20							408	1,447	0.28
	MSW		0.86							923	3,456	0.27
1974	1SW	3,238	0.16	0.533	276	0.074	1,049.1	324	2,025	495	2,520	0.20
	MSW	8,182	0.90	0.467	3,439	0.926	13,127.9	1,604	1,783	433	2,216	0.20
1975	1SW	3,238	0.23[h]	0.587	437	0.138	1,290.7	399	1,733	663	2,396	0.28
	MSW	7,677	0.86[h]	0.413	2,727	0.862	8,061.9	1,050	1,221	467	1,688	0.28
1976	1SW	3,692	0.23	0.650	552	0.198	1,666.0	451	1,962	1,746	3,708	0.47
	MSW	7,441	0.86	0.350	2,240	0.802	6,748.3	907	1,055	941	1,996	0.47
1977	1SW	3,492	0.23	0.479	385	0.102	1,012.9	290	1,261	1,096	2,357	0.46
	MSW	7,551	0.86	0.521	3,383	0.898	8,917.4	1,181	1,373	1,190	2,563	0.46
1978	1SW	3,676	0.23	0.469	397	0.100	1,574.7	428	1,862	451	2,313	0.20
	MSW	7,775	0.86	0.531	3,551	0.900	14,172.6	1,823	2,120	511	2,631	0.19
1979	1SW	3,368	0.23	0.813	630	0.328	1,443.1			960	2,823	0.35[i]
	MSW	8,018	0.86	0.187	1,289	0.672	2,956.6			221	650	0.35[i]
1980	1SW	3,891	0.23	0.483	432	0.114	1,252.5	322	1,400	1,107	2,507	0.44
	MSW	7,548	0.86	0.517	3,356	0.886	9,734.5	1,290	1,500	1,183	2,683	0.44
1981	1SW	3,233	0.23	0.685	509	0.201	1,986.1	614	2,671	1,085	3,756	0.29
	MSW	7,455	0.86	0.315	2,020	0.799	7,894.8	1,059	1,231	498	1,729	0.29
1982	1SW	4,084	0.23	0.617	580	0.192	1,098.8	269	1,170	1,278	2,448 (2,164)[j]	0.52
	MSW	7,390	0.86	0.383	2,434	0.808	4,624.3	626	728	792	1,520	0.52
1983	1SW	3,512[k]	0.23	0.618	499	0.166	1,186.9	338	1,470	420	1,890 (1,750)[j]	0.22
	MSW	7,609[k]	0.86	0.382	2,500	0.834	5,963.3	783	910	260	1,170 (1,127)[j]	0.22
1984	1SW	3,512[k]	0.23	0.510	412	0.114	826.4	235	1,022	434[n]	1,456 (1,296)[p]	0.30
	MSW	7,609[k]	0.86	0.490	3,206	0.886	6,422.7(2,414.6)[m]	844	981	410(41)[r]	1,391 (1,275)[p]	0.30
1985	1SW	3,512[k]	0.23	0.493	398	0.107	692.6	197	857	654	1,511 (1,317)[q]	0.43
	1SW	7,609[k]	0.86	0.507	3,318	0.893	5,780.7(3,965.5)[m]	759	883	673(67)[r]	1,556 (1,473)[q]	0.43

[a]Values for wild fish at Mactaquac.
[b]From Prov. angling.
[c]Product of first 3 columns.
[d]Egg prop.'s x eggs
[e]Eggs/eggs per F.
[f]No. F's/prop. F.
[g]Derived from fence data.
[h]Mean of fence and Westfield data.
[i]Mean of arcsin transformed data, 1970-1982
[j]Wild fish only; see footnote 'k' in Table 16 of Penney and Marshall (MS, 1984).
[k]Eleven-year mean at Mactaquac.
[m]eggs from released fish.
[n]Cronin, pers. comm.
[p]Wild fish only (hatchery 1SW, 16,000x0.01; hatchery 2SW, 18,000x0.00646).
[q]Wild fish only (hatchery 1SW, 20,164x0.00960; hatchery 2SW, 16,000x0.00519).
[r]10% mortality of hooked fish.

App. 6. Estimated returns of 1SW and MSW salmon to tributaries[a] 'below' Mactaquac Dam, Saint John River, 1970-1985.

Sea-age	Year	No. of wild salmon				
		Nashwaak	Nashwaak x 0.16	Kennebecasis and Hammond	Kennebecasis + Hammond x 0.49	Total
1SW	1970	2,295	368	46	23	2,732
	1971	2,591	415	126	62	3,194
	1972	1,205	193	15	7	1,420
	1973	1,447	232	477	234	2,390
	1974	2,520	403	1,060	519	4,502
	1975	2,396	383	394	193	3,366
	1976	3,708	593	1,446	709	6,456
	1977	2,357	377	628	308	3,670
	1978	2,313	370	154	75	2,912
	1979	2,823	452	1,212	594	5,081
	1980	2,507	401	592	290	3,790
	1981	3,756	601	1,251	613	6,221
	1982	2,164	346	1,227[b]	601	4,338
	1983	1,750	280	1,314[b]	645	3,989
	1984	1,296	207	786[cd]	385	2,674
	1985	1,317	211	131[ef]	64	1,723
MSW	1970	2,451	392	62	30	2,935
	1971	726	116	146	72	1,060
	1972	1,890	302	57	28	2,277
	1973	3,456	553	229	112	4,350
	1974	2,216	355	674	330	3,575
	1975	1,688	270	537	263	2,758
	1976	1,996	319	814	399	3,528
	1977	2,563	410	2,177	1,067	6,217
	1978	2,631	421	340	167	3,559
	1979	650	104	326	160	1,240
	1980	2,683	429	1,292	633	5,037
	1981	1,729	277	571	280	2,857
	1982	1,520	243	823	403	2,989
	1983	1,127	180	709[b]	347	2,363
	1984	1,275	204	1,047[cd]	513	3,039
	1985	1,473	236	639[ef]	313	2,661

[a] Where Nashwaak represents 31.0 percent and Hammond + Kennebecasis equals 42.9% of production area 'below' Mactaquac Dam.

[b] Wild fish only (hatchery fish removed as per footnote j, App. 5, where hatchery smolt releases to Kennebecasis + Hammond were 24,518 in 1981 and 24,714 in 1982).

[c] Based on DNR 'Fissys' estimate (303 1SW and 359 MSW) and exploitation rate of 0.30.

[d] Wild fish only (hatchery fish removed per the product of 24,714 smolts in 1982 and a return rate of 0.00646 and 23,000 smolts in 1983 and a return rate of 0.01).

[e] Based on DNR 'Fissys' estimate (134 1SW and 326 MSW fish) and exploitation rate of 0.43.

[f] Hatchery fish from 23,000 smolts in 1983 and 18,760 smolts in 1984, removed using respective return rates of 0.00519 and 0.00960.