Assessment of Atlantic salmon of the Saint John River, N.B., above Mactaquac, 1990

by

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ABSTRACT

Estimated river returns destined for Mactaquac, Saint John River, 1990, were 8,804 1SW and 4,125 MSW salmon. Homewater removals/losses of about 2,550 1SW fish indicate that 180 percent of the target number of 1SW spawners was met above Mactaquac. Low returns and removal of 1,250 MSW fish contributed to an estimated spawning escapement above Mactaquac of only 65 percent of the MSW target. Target egg requirements, which are largely dependent on MSW fish have been met only three times in the last 13 years (1980, 1984 and 1985).

Wild and hatchery 1SW returns in 1990 were 87 percent of the preseason forecast. MSW returns were only 58 percent of the preseason forecast. Since 1986, returns of 1SW fish have equalled or somewhat exceeded forecast values; returns of MSW salmon have been less than forecast.

A relationship between egg depositions and wild 1SW returns indicates a return in 1991 of 6,500 or 7,600 wild 1SW fish, depending on the forecast model. Another relationship between wild 1SW returns, their fork length and MSW returns suggests that the 7,300 1SW returns in 1990 will provide 3,400 or 4,000 wild MSW returns, depending on forecast model. The product of the numbers of hatchery releases and recent return rates suggest hatchery returns in 1991 of 3,400 1SW and 1,300 MSW salmon. Total 1SW returns could be 9,900 to 11,000 1SW fish; total MSW returns could be 4,700 to 5,200 MSW salmon.

RÉSUMÉ

Les estimations de remontées de saumons vers Mactaquac, fleuve Saint-Jean, en 1990 étaient de 8 804 unibermarins et 4 125 redibermarins. Compte tenu de retraits/pertes dans les eaux d'origine d'environ 2 550 unibermarins, l'échappée de reproducteurs unibermarins en amont de Mactacquac correspondait approximativement à 180 p. 100 de la cible. Quant aux redibermarins, du fait de leurs faibles remontées et du retrait de 1 250 d'entre eux, l'échappée estimée de reproducteurs en amont de Mactacquac n'était que de 65 p. 100 de la cible. En ce qui concerne les oeufs, dont la production dépend largement des redibermarins, le nombre cible n'a été atteint que trois fois au cours des 13 dernières années (en 1980, 1984 et 1985).

Les remontées d'unibermarins sauvages et d'écloserie atteignaient 87 p. 100 de la prévision de présaison pour 1990, tandis que celles de redibermarins n'étaient que d'environ 58 p. 100 de la prévision. Depuis 1986, les remontées d'unibermarins sont égales ou légèrement supérieures et les remontées de redibermarins inférieures aux prévisions.

D'après un rapport entre les oeufs déposés et les remontées d'unibermarins sauvages, on s'attend à ce que ces dernières soient de 6 500 ou 7 600 saumons en 1991, selon le modèle prévisionnel utilisé. Un autre rapport entre les remontées d'unibermarins sauvages, leur longueur à la fourche et les remontées de redibermarins semble indiquer que les 7 300 remontées d'unibermarins de 1990 se traduiront par 3 400 ou 4 000 remontées de redibermarins sauvages, selon le modèle utilisé pour la prévision. Par ailleurs, le produit du nombre de saumons d'écloserie relâchés et des taux de remontées récents donne pour 1991 des remontées de saumon d'écloserie de 3 400 unibermarins et de 1 300 redibermarins. C'est donc dire que les remontées totales d'unibermarins et de redibermarins pourraient être de 9 900 à 11 000 poissons pour les premières et de 4 700 à 5 200 poissons pour les secondes.

INTRODUCTION

This document is background to the management of Atlantic salmon stocks of the Saint John River above Mactaquac, New Brunswick, and, as such, provides data and analyses available into early January 1991 relevant to stock status in 1990 and forecasts for 1991.

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 (MS 1989, 1990).

Forecasts made in 1989 suggested that 1990 homewater returns to Mactaquac would number approximately 10,100 1SW and 7,075 MSW salmon. CAFSAC advised managers (CAFSAC Advisory Document 89/14) that in 1990 1SW returns would be "similar to those of 1989 and that MSW returns will exceed those of 1989 and possibly be surplus to spawning requirements".

The Management Plan for 1990 was identical to that of 1989 in that there was a total ban on homewater commercial fisheries, a prohibition on the retention of MSW salmon captured in the sport fisheries and the same open seasons for sport fishing. The Kingsclear Indian Band guided a sport fishery and the Oromocto Band did not fish. The Tobique Indian Band conducted a fishery between early-July and mid-September which, by their own and other reports, netted about 520 salmon. Summer discharges were sporadic with high peaks in each of July, August and September. The August peak caused extensive flooding and damage in the Woodstock/Hartland area.

METHODS

Returns destined for Mactaquac

Total returns of 1SW and MSW salmon of both wild and hatchery origin from and above Mactaquac Dam consist of the summation of Mactaquac counts, estimated angling catches in the mainstem area immediately below the Mactaquac Dam (including Kingsclear Indian Reserve) and estimated by-catch in downriver shad, gaspereau and "other" species fisheries.

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. Unlike 1989, fish collection facilities were open a "full" season. The identification of 1SW and MSW returns from 1-year smolts released at Mactaquac and juveniles released above Mactaquac was dependent on fin erosion (principally dorsal fin). By-catch was estimated to be 2% of the 1SW and 5% of the MSW river returns - values which approximate the mean estimates for the years 1981-1984. Both the by-catch and sport catch below Mactaquac were assumed to consist of fish of hatchery and wild origins in the same proportion as those counted at Mactaquac.

Removals of fish originating at/above Mactaquac

Removals include estimates of fish taken by the Tobique Indian Band, provincial, federal and native estimates of sport catch on the mainstem below Mactaquac, mainstem above Mactaquac (incl. Salmon River, Victoria Co.,) and the Tobique River and a by-catch in the estuary. The net catch at Tobique Indian Reserve, June - Sept, was based on catch reported by the Band after July 27. Other removals include some fish; monitored through the fish-lift at Tinker Dam on the Aroostook River, retained at Mactaquac for broodstock, and mortalities encountered during collection-handling operations or sacrificed for analysis. Losses of MSW fish to hook-and-release mortality were estimated at 2% of the run placed above Mactaquac (exclusive of those estimated to have been taken by the Tobique Indians), i.e., similar to a previously used 10% loss on estimated MSW sport catch. Losses to poaching and disease ascribed in the 1989 assessments were used in 1990, i.e., 4% of 1SW and 10% of MSW fish placed above Mactaquac (exclusive of those estimated to have been taken by the Tobique Indians). For the most part, losses were apportioned to hatchery/wild components on the basis of estimated stock composition.

Required Spawners

An accessible salmon-producing substrate of 12,261,000 m^2 above Mactaquac, (exclusive of the Aroostook River), 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 MSW fish are required above 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 provides males for MSW females unaccompanied by MSW males, i.e., 3,200 fish (Marshall and Penney op. cit.).

Stock Forecasts

1SW Wild

One 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, 1973-1988, on adjusted (method in Penney and Marshall MS 1984, with updates on freshwater age composition from wild 1SW fish, App. 1, 2 and 3 this paper) egg depositions in the Tobique River, 1968-1969 to 1983-1984. The 1986 and 1987 egg depositions, principal contributors to 1SW returns in 1991, were derived using angular-transformed mean proportions for age 2:1 and age 3:1 1SW fish in the 1969 to 1985 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 variate (Ricker 1975, p. 274).

A second forecast of wild 1SW returns in 1991 was derived with a non-parametric probability density function model described by Noakes (1989) and the above logged egg and grilse data. Harvie and Amiro (MS 1991) detail the steps in constructing a joint probability density function using two variables and the procedure by which the multivariate smoothing parameters were determined.

MSW Wild

Forecasts of MSW salmon returning to Mactaquac 1987-1990 have significantly over-estimated actual returns (Marshall MS 1990). New initiatives in parametric (Ritter et al. MS 1990) and non-parametric modelling (Harvie and Amiro, MS 1991) indicate that better predictions of wild MSW returns can be obtained from available data. Both approaches have focused on the use of the three variables: log MSW returns in year i+1 and 1SW returns and fork length of 1SW returns in year i. Harvie and Amiro (op.cit.) assessed the accuracy of the parametric and non-parametric approaches using preliminary data from Ritter et al. (op.cit.). This assessment provides forecasts of MSW returns in 1991 using current data, the regression of logged MSW returns on 1SW returns and fork length 1SW returns, and a 3-variable probability density fuction model for the same data.

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 age 1.1 fish returning to Mactaquac in 1991 was assumed to be the same as the mean (arcsine) of the 1988-1990 'adjusted' return rates (App.4). Age 1.1 returns were adjusted by removal of the estimated returns to Mactaquac from smolts released in tributaries below Mactaquac (Marshall MS 1990). No tags had been applied to downriver smolt releases in 1989 and, therefore, the mean ratio of 1988-1989 (0.116) was used in 1990.

Additional 1SW returns of age 3:1 and age 2:1 are expected at Mactaquac in 1991 from fall fingerlings (age 0^+) culled from the 1-year smolt program and released in tributaries above Mactaquac in 1986 and 1987. Returns were forecast as the product of return rates to Mactaquac of releases of fall fingerlings above Mactaquac in 1986 and 1987 (App. 5) and the numbers released. Returns from unfed fry were accorded about one-fifth the return rate of fall fingerlings.

MSW Hatchery

Returns as MSW fish from 1-year smolts released at Mactaquac in 1989 were estimated as the product of their small number and the adjusted mean (arcsine) return rate for 1-year smolts released from Mactaquac 1986-1988 (App.4). The proportion of age 1.2 fish assumed to have originated from 1988 smolt releases at Mactaquac is provisional until growth patterns on scale samples from fish with regenerated caudal fins (possible indicator of an aquaculture escapee) can be reassessed. As with 1SW hatchery returns, MSW

fish destined for Mactaquac from releases below were proportioned (0.13) on the basis of tag returns from 1988 smolts returning in 1990.

As well, MSW returns of age 3:2 and age 2:2 are expected from fall fingerlings released above Mactaquac in 1986 and 1987. Returns of age 2:2 salmon were forecast as the product of their numbers and a return rate to Mactaquac of the 1985 and 1986 releases above Mactaquac (App. 5).

Maiden hatchery fish of 1989 and 1990 are also expected to contribute as repeat-spawning MSW fish in 1991. 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 1990 adults of hatchery origin which were estimated to have spawned. This assumes that appropriate numbers of alternates would originate from the 1989 escapement.

RESULTS

Returns destined for Mactaquac

Estimated homewater returns in 1990 totalled 8,804 1SW and 4,125 MSW fish (Table 1). The removal by anglers in the mainstem immediately below Mactaquac is estimated at 721 1SW fish. Hatchery returns comprised 18% and 19% of the total 1SW and MSW returns, respectively.

Removals

Sport 1SW removals additional to those in the lower main stem consist of 889 fish above Mactaquac (Table 2). The Tobique Indian Band harvested an estimated 520 salmon. Fishing was conducted below the Tobique Narrows Dam (2-3 nets) and in the Tobique Headpond (6-8 nets). The catch was assumed to consist of hatchery and wild 1SW and MSW fish in proportions similar to those estimated to have been passed over the Beechwood Dam.

MSW losses above Mactaquac to poaching and disease combined were set at 10% (exclusive of those taken by the Tobique Indians). 1SW losses to poaching and disease were set at 4% (exclusive of those taken by nets in the Tobique Indian fishery). Known losses were similar to those of 1989; furunculosis was again detected at NBDNRE's Half-mile barrier pool on the Tobique River.

Removals by all factions were estimated at 2,546 1SW fish of which 46 made their way over Tinker Dam on the Aroostook River and 1,250 MSW salmon of which 18 were transferred over the Tinker Dam. Hatchery broodstock retained at Mactaquac numbered 336 MSW salmon.

Spawning Escapement

Collation of the total returns (Table 1), total removals (Table 2) and numbers of fish required on average to meet an egg deposition of 2.4 eggs/m^2 indicate that 2,875 (65%) of the required 4,400 MSW spawners were attained above Mactaquac (Table 3). For 1SW fish, 196% of requirements were met above Mactaquac. An estimated 8% of wild and 3% of hatchery 1SW fish were female

and had the potential to deposit about 1.5 million eggs (0.13/m^2), or the equivalent of about 200 MSW females.

Stock Forecasts

1SW Wild

A 1991 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. The AM estimate for 1SW returns in 1991 is 6,481 1SW fish (90% C.L. 5,470-7,680; Table 4). The method forecast 7,393 (5,601-9,757) 1SW fish for 1990; 7,263 fish were estimated to have returned.

A forecast of 7,602 (90% C.L. 3,183-10,224) 1SW fish was obtained from the probability density function in which maximum likelihood smoothing parameters were 0.80 (eggs) and 0.38 (1SW fish) (Table 4).

MSW Wild

A forecast of 3,415 (90% C.L. 1,865-6,080; Table 4) wild MSW fish destined for Mactaquac in 1991 was derived from the equation $\log_e$ MSW = 25.021 + 0.128E-3 1SW - 0.304 Length (R^2=0.560,F=13.11; p<.0001) developed by Ritter et al. (MS 1990). The probability density estimator (3-variable model) for the same data provides a forecast of 3,985 (90% C.L. 1,887-8,262) MSW fish (Table 4) where maximum likelihood smoothing parameters were 0.60 (1SW return) 0.43 (1SW fork length) and 0.74 (MSW salmon).

1SW Hatchery

The forecast of hatchery 1SW fish destined for Mactaquac in 1991 was in part calculated as the product of an estimated 241,078 1- and 2-year smolts released at Mactaquac and an adjusted 0.0060 return rate (Table 5), i.e., 1,446 fish. Another 214 and 34 would return from smolts placed above and below Mactaquac, respectively. In addition, it was estimated that fall fingerlings released above Mactaquac, Grand Falls in particular, in 1987 and 1988 would contribute another 1,584 1SW fish (Table 5). The total forecast of hatchery 1SW returns to Mactaquac is 3,400 1SW fish. The 1990 forecast, by these methods exceeded returns by about 43%, principally because adjusted return rates for hatchery 1SW fish in 1990 were the lowest (App. 4) of record.

MSW Hatchery

MSW returns destined for Mactaquac in 1991 were calculated as the sum of the product of an estimated return rate of 0.0034 and 238,204 smolts released at Mactaquac (810 fish) and 0.16 of returns from 34,994 smolts released below Mactaquac in 1989 (19 fish). Additional returns are expected from fall fingerlings released in 1986 and 1987 and 0.0002 and 0.0008 survival/return rate (Table 5). The forecast of total hatchery MSW returns to Mactaquac, including repeat spawners is 1,262 MSW fish (Table 5).

Forecast Summary

The forecast of total homewater returns to Mactaquac, Saint John River in 1991 is 9,881 or 11,002 1SW (6,481 or 7,602 of wild and 3,400 hatchery origin) and 4,677 or 5,247 MSW fish (3,415 or 3,985 of wild and 1,262 of hatchery origin). Forecast returns minus the spawning requirements of 3,200 1SW and 4,400 MSW salmon result in potential surpluses of 6,681 to 7,802 1SW and 277 to 847 MSW salmon.

DISCUSSION

Estimated returns in 1990 of 8,804 wild and hatchery 1SW and 4,125 wild and hatchery MSW salmon were 87% and 58% of predicted returns. Comparisons of predicted and actual (estimated) returns for each of wild and hatchery fish since 1984 are as follows:

Sea-age	Returns	1984	1985	1986	1987	1988	1989	1990
Wild								
1SW	Predicted	6,616	7,063	5,075	4,989	6,054	8,197	7,393
	Returned	8,311	6,526	7,904	5,909	8,930	9,522	7,263
	Ret/Pred	1.26	0.92	1.56	1.18	1.48	1.16	0.98
MSW	Predicted	4,896	8,413	7,702	8,327	6,983	6,232	6,325
	Returned	9,779	10,436	6,128	4,352	2,625	4,072	3,329
	Ret/Pred	2.00	1.24	0.80	0.52	0.38	0.65	0.53
Hatchery								
1SW	Predicted	3,106	4,292	117	2,319	2,165	2,080	2,710
	Returned	1,451	2,018	862	3,328	1,250	1,339	1,541
	Ret/Pred	0.47	0.47	7.37[a]	1.44	0.58	0.64	0.57
MSW	Predicted	1,342	873	1,134	2,654	1,023	882	750
	Returned	1,115	875	797	480	912	469	796
	Ret/Pred	0.83	1.00	0.70	0.18[a]	0.89	0.53	1.06

[a] First returns from 1-year smolts.

MSW returns, including fish of hatchery origin are the fourth lowest of a 16-year data set (Table 6). Returns of wild 1SW fish above Mactaquac were 98% of predicted; wild MSW fish above were 53% of the predicted value. Hatchery 1SW and MSW returns were 57% and 106% of forecasts. Despite the lowest harvest of MSW fish in two decades (Table 7), and equally low losses (Table 2), spawning escapement of MSW fish was only 65% of requirement. Deficits in spawning escapement, 1986-1989 (80, 63, 35 and 72% of requirements), together with that of 1990 should deter managers from allocating predicted surpluses during the next several years.

For the fourth year in a row wild MSW returns have been low relative to both the period of record and to those predicted. Concerns that MSW returns could not be adequately forecast from 1SW returns in the previous year have been flagged in previous assessments. Searches for a variable that would explain a general increase in 1SW returns and a decline in MSW returns during the latter part of the last decade have focused on hypotheses which include proportionately greater exploitation of non-maturing 1SW fish in distant fisheries, proportionately less exploitation on maturing 1SW fish and sea conditions contributing to more/less natural mortality.

The most-favoured hypothesis for Saint John River stocks proposed that favourable sea conditions were hastening the maturation of normally non-maturing 1SW fish ("crossover") in the fall or early winter of their first year at sea and leaving fewer fish at sea to return first as 2SW fish. A measure of "crossover" was annually sought through changes in the sex ratio of mature 1SW fish but changes have not been significant, perhaps because external sexing of early-run 1SW fish is inaccurate.

Investigations by Ritter et al. (MS 1990) determined that the inclusion of fork length of returning 1SW salmon (perhaps the most overlooked and best measured potential expression of annual variation in growth conditions - likely marine but not excluding freshwater) in the original 1SW :MSW forecast models permitted prediction of recent declines in MSW returns. MSW returns declined as 1SW returns and their length increased, i.e., better early growth at sea may lead to earlier maturation and return of normally non-maturing salmon.

A comparison of non-parametric and two-variable parametric forecasts of 1SW returns from eggs, 1968-1983 (Table 6), suggests that the non-parametric model may be the better of the two. The three-variable non-parametric model used to forecast MSW returns from 1SW returns and 1SW lengths has, since the provision of advice, been rejected because the number of cases were inadequate for appropriate mean square error terms (Harvie and Amiro, MS 1991). Harvie and Amiro (op.cit) now support the construction of the joint probability density function for three variables in steps, each using only two variables, i.e., the first step constructs the joint probability density function of MSW salmon returns and 1SW returns, the second step uses the residuals from step 1 and the 1SW lengths to produce the forecast. They (Harvie and Amiro, op.cit) examined the ability of four two-variable non-parametric and two parametric models to forecast MSW returns to Mactaquac and concluded that the parametric regression perfomed better than the non-parametric.

Forecasting of hatchery returns continues to be problematic, although in most recent years, the predicted and actual returns have comprised less than 20% of the run. For example, the forecast of age 1.2 fish in 1991 may be inflated by as much as 20% (about 135 fish; 11% of the forecast) if some 221 returns of age 1.2 fish in 1990 are found to have originated from smolts that were not released at Mactaquac.

Predictive capabilities for hatchery-origin fish are not only impeded by the same operands affecting returns of wild fish but as well by the limited data set for 1-year smolt returns (1986-1990), 1-year smolts that have not been high-graded to support the building of the aquaculture industry (1989,

1990) and on-going efforts to improve smolt quality. New initiatives relating salmon returns to smolt quality may account for enough variation to permit development of forecast models based on all smolts released since 1974.

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SUMMARY

Saint John River, N.B. (above Mactaquac) SFA 23

Life stage: 1SW, MSW salmon (wild and hatchery origin)
Target: 29.4 million eggs (4,400 MSW and 3,200 1SW fish)

Year		1985	1986	1987	1988	1989	1990	Min	Max	Mean
Recreational catch:	1SW	3060	1692	1650	1755	2304	1610	1151[1]	3580[1]	2303[1]
Other removals mortalities[2]:	1SW	962	1187	567	973	1377	936	567[3]	1377[3]	1013[3]
	MSW	5008	3406	2074	2005	1394	1250	1394[3]	5008[3]	2777[3]
Mactaquac counts:	1SW	7078	7046	7972	9191	9587	7907	4140[1]	17314[1]	9030[1]
	MSW	6960	4143	3430	2600	4291	3919	2010[1]	10451[1]	5374[1]
Rivers return:	1SW	8544	8766	9237	10180	10861	8804	4946[1]	19275[1]	10515[1]
	MSW	11311	6925	4832	3537	4541	4125	3537[1]	13916[1]	7879[1]
Spawn escpm:	1SW	4522	5887	7020	7452	7191	5758	4522[3]	7191[3]	6414[3]
	MSW	6303	3519	2758	1532	3147	2875	1532[3]	6303[3]	3452[3]
% target:	1SW	141	184	219	233	225	180	141[3]	233[3]	200[3]
	MSW	143	80	63	35	72	65	35[3]	143[3]	79[3]

[1] For the period 1975-1989.
[2] Incl. food fishery, broodstock and in-river mortality.
[3] For the period 1985-1989.

Recreational catches: MSW salmon have not been retained since 1984; up to 1990, 1SW landings have ranged from 311 in 1972 to 3,580 in 1976.

Data and assessment: Counts of fish obtained from the collection facility at Mactaquac Dam were augmented by estimates of down river removals. Smolts and juveniles of hatchery origin were counted at time of release.

State of the stock: Target egg requirements have been met only three times in the last 13 years (1980, 1984, 1985); 1SW escapement makes no significant contribution to egg deposition because most of these fish are males.

Forecast: A relationship between egg depositions and wild 1SW retruns indicates a return of 6,500 or 7,600 wild 1SW fish, depending on the forecast model. Another relationship between wild 1SW retruns, their fork length and MSW returns suggests that the 7,300 1SW returns in 1990 will provide 3,400 or 4,000 wild MSW returns, depending on forecast model. The product of the numbers of hatchery releases and recent return rates suggest hatchery returns in 1991 of 3,400 1SW and 1,300 MSW salmon. Total 1SW returns could be 9,900 to 11,000 1SW fish; total MSW returns could be 4,700 to 5,200 MSW salmon.

Table 1. Estimated total returns of wild and hatchery 1SW and MSW salmon destined for Mactaquac Dam on the Saint John River, N.B., 1990.

Sea-age	Components	Wild	Hatch.	Total
1SW				
	Mactaquac counts[a]	6,486	1,421	7,907
	Angled MS below Mact	632	89	721
	By-catch[b]	145	31	176
	Totals	7,263	1,541	8,804
MSW				
	Mactaquac counts	3,163	756	3,919
	By-catch[b]	166	40	206
	Totals	3,329	796	4,125

[a] Fishway closed Oct. 29, and counts not adjusted.

[b] Proportions of 2% total 1SW returns and 5% total MSW returns.

Table 2. Estimated homewater removals[a] of 1SW and MSW salmon destined for Mactaquac Dam on the Saint John River, N.B., 1990.

Components	1SW			MSW		
	Wild	Hatch	Total	Wild	Hatch	Total
Kingsclear Indians	0	0	0	0	0	0
Tobique Indians[b]	224	49	273	199	48	247
Angled						
Tobique River	442	87	529	-	-	-
Mainstem above Mact.	304	56	360	-	-	-
Mainstem below Mact.	632	89	721	-	-	-
Hook-release mort.[c]	0	0	0	53	12	65
Passed to Aroost.	39	7	46	14	4	18
Hatchery broodfish	0	0	0	256	80	336
mortalities, etc.	0	142	142	38	13	51
Poaching/disease[d]	250	49	299	266	61	327
By-catch	145	31	176	166	40	206
Totals	2,036	510	2,546	992	258	1,250

[a] Wild:hatchery composition per estimated returns.

[b] Estimated at 200 fish prior to July 27 and reported as 152 MSW and 168 1SW thereafter; 1SW:MSW ratio proportioned as reported.

[c] Estimated at 2% of MSW salmon released above Mactaquac (exclusive of those to Tobique Indians).

[d] Estimated at 4% of all 1SW and 10% of all MSW fish placed above Mactaquac (exclusive of those to Tobique Indians).

Table 3. Estimated homewater returns, removals and spawning escapement of 1SW and MSW salmon destined for and above Mactaquac Dam, Saint John River, 1990.

Sea-age	Components	Wild	Hatch.	Total
1SW				
	Homewater returns	7,263	1,541	8,804
	Homewater removals[a]	2,036	510	2,546
	Spawners	5,227	1,031	6,258
	Target spawners[b]			3,200
	% of target spawners			196
MSW				
	Homewater returns	3,329	796	4,125
	Homewater removals[a]	992	258	1,250
	Spawners	2,337	538	2,875
	Target spawners[b]			4,400
	% of target spawners			65

[a] Includes broodfish for Mactaquac FCS (Table 2).

[b] Excludes broodfish for Mactaquac FCS (Table 2).

Table 4. Adjusted Tobique River egg deposition[a]/100 m² (yr i & i+1) recruiting to total wild 1SW (and their mean fork length in cm) 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 parametric and non-parametric forecast numbers of 1SW and MSW fish to Mactaquac in the absence of homewater removals in 1991.

Eggs/100 m²		Recruits 1SW			MSW		
Years (1)	Number (2)	Year	Number (3)	Length (4)	Year	Number (5)	MSW/ 1SW (6)
1965-66		1970	3,057	54.7	1971	4,715	1.54
1966-67		71	1,709	55.8	72	4,899	2.87
1967-68		72	908	57.0	73	2,518	2.77
1968-69	23.95	73	2,070	54.6	74	5,811	2.81
1969-70	40.58	74	3,656	56.1	75	7,441	2.04
1970-71	74.35	75	6,858	55.5	76	8,177	1.19
1971-72	122.34	76	8,147	55.5	77	9,712	1.19
1972-73	85.39	77	3,977	56.1	78	4,021	1.01
1973-74	81.66	78	1,902	56.4	79	2,754	1.45
1974-75	371.61	79	6,828	56.4	1980	10,924	1.60
1975-76	330.50	1980	8,482	58.1	81	5,991	0.71
1976-77	244.80	81	5,782	56.3	82	5,001	0.86
1977-78	288.96	82	4,958	55.4	83	3,447	0.69
1978-79	167.00	83	4,309	55.4	84	9,779	2.27
1979-80	239.74	84	8,311	55.6	85	10,436	1.26
1980-81	219.60	85	6,526	55.8	86	6,128	0.94
1981-82	167.64	86	7,904	57.6	87	4,352	0.55
1982-83	88.97	87	5,909	58.1	88	2,625	0.44
1983-84	240.94	88	8,930	58.6	89	4,072	0.46
1984-85		89	9,522	59.1	1990	3,329	0.35
1985-86		1990	7,263	58.6	91	[d e]	
1986-87	184.52	91	[b c]				

[a] See App. 1, 2 and 3 for derivation.

[b] Based on regression of 1SW returns to Mactaquac, 1973-1988, (col. 3) on adjusted egg deposition in Tobique River, 1968-1969 to 1983-1984, (col. 2):
$\log_e Y = 6.526 + 0.420 \log_e X$; n=16, r^2=0.472, p<0.01
Y_{1991} = 6,481 (AM); 90% C.L. = 5,470 to 7,680.

[c] Probability distribution: Ln 1SW returns: Ln eggs;
most probable value = 7602; 90% C.L. = 3,183-10,224.

[d] Based on regression of MSW returns to Mactaquac, 1971-1990, (col. 5) on 1SW returns to Mactaquac 1970-1989 (col. 3) and their length (col. 4).
$\log_e$ MSW = 25.021 + 0.128E-3 1SW - 0.304 LEN; n = 20, R^2 = 0.560 (p<.001)
$\log_e MSW_{1991}$ = 3,415; 90% C.L. = 1,865-6,080.

[e] Probability density function: Ln MSW returns: 1SW returns and fork length; most probable value = 3985; 90% C.L. = 1,887-8,262.

Table 5. Forecasts of hatchery 1SW and MSW returns to Mactaquac, Saint John River, 1991, as estimated from numbers of various juveniles released at (At), above (Abv) or below (Bl), Mactaquac and estimated return rates.

Release				Returns in 1991			
Year	Loc.	Stage	Number	Rate	Age	1SW	MSW
1990	At	1-,2-yr smolt	241,078	0.0060[c]	1-,2.1	1,446	
1990	Bl[a]	1-yr smolt	48,105	0.0060[c] @ 0.116[d]	1.1	34	
1990	Abv	1-,2-yr smolt	71,403[b]	0.0030	1-,2.1	214	
1989	Abv	1+ parr	9,400	0.0020	2.1	19	
1988	Abv	Fall fing.	906,093[b]	0.0017	2.1	1,540	
1988	Abv	Unfed/fry	209,882[b]	0.0003	2.1	63	
1987	Abv	Fall fing.	145,428	0.0003	3.1	44	
1987	Abv	Unfed/fry	266,257	0.00015	3.1	40	
1989	At	1-,2-yr smolt	238,204	0.0034[c]	1-,2.2		810
1989	Bl[a]	1-yr smolt	34,994	0.0034[c] @ 0.16[d]	1.2		19
1989	Abv	1-,2-yr smolt	52,893	0.0017	1-,2.2		90
1987	Abv	Fall fing.	145,428	0.0008	2.2		116
1987	Abv	Unfedfry	266,257	0.0002	2.2		53
1986	Abv	Fall fing.	220,176	0.0002	3.2		44
		Adults 1990[•]		0.05 (1SW) 0.146 (MSW)			130
Totals						3,400	1,262

[a] Mactaquac origin, only.

[b] incl. 727,400 fall fings and 167,600 fry distributed by SALEN and 42,282 fry and 27,350 1-yr smolts distributed by Maine to Aroostook River.

[c] Arcsine mean 1988-1990 adjusted return rate:

[d] Marshall (MS 1990) App. 5, 1SW = mean of 1988-1989 returns; MSW = mean of 2SW 1989-1990, where 1990 ratio was 1:0.1295.

[•] Rates (Marshall and MacPhail MS 1987) applied to est. hatchery spawners (1990), i.e., 1031 1SW and 538 MSW fish above Mactaquac.

Table 6. Estimated river returns of Saint John wild and hatchery 1SW and MSW salmon destined for Mactaquac Dam, 1970-1990.

Year	Wild		Hatchery		Total	
	1SW	MSW	1SW	MSW	1SW	MSW
1970	3057	5712				
1971	1709	4715				
1972	908	4899				
1973	2070	2518				
1974	3656	5811				
1975	6858	7441	6374	2210	13232	9651
1976	8147	8177	9074	2302	17221	10479
1977	3977	9712	6992	2725	10969	12437
1978	1902	4021	3044	2534	4946	6555
1979	6828	2754	3827	1188	10655	3942
1980	8482	10924	10793	2992	19275	13916
1981	5782	5991	4730	2612	10512	8603
1982	4958	5001	2846	1531	7804	6532
1983	4309	3447	1445	581	5754	4028
1984	8311	9779	1451	1115	9762	10894
1985	6526	10436	2018	875	8544	11311
1986	7904	6128	862	797	8766	6925
1987	5909	4352	3328	480	9237	4832
1988	8930	2625	1250	912	10180	3537
1989	9522	4072	1339	469	10861	4541
1990[a]	7263	3329	1541	796	8804	4125

[a] Provisional.

Table 7. Estimated landings (numbers) of Native, sport, commericial and by-catch 1SW and MSW salmon originating at or above Mactaquac on the Saint John River, 1970-1990.

Year	Native[a]		Sport[b]		Commercial		By-catch[c]		Total	
	1SW	MSW	1SW	MSW	1SW	MSW	1SW	MSW	1SW	MSW
1970			392	333	105	3204			497	3537
1971			319	357	57	2391			376	2748
1972			311	770			41	6	352	776
1973			704	420			37	60	741	480
1974	27	569	2034	2080			26	8	2087	2657
1975	73	739	3490	1474			70	56	3633	2269
1976	526	2038	3580	2134			61	90	4167	4262
1977	64	1070	2540	3125			109	156	2713	4351
1978	92	1013	1151	899			114	129	1357	2041
1979	328	771	2456	589			55	69	2839	1429
1980	713	2575	3260	2409			105	211	4078	5195
1981	361	891	2454	1085	855	1228	165	485	3835	3689
1982	235	2088	1880	921	554	469	58	212	2727	3690
1983	203	588	1453	637	378	1152	43	162	2077	2539
1984	353	2135	1824				338	896	2515	3031
1985	471	2526	3060				412	1771	3943	4297
1986	600	2400	1692				175	346	2467	2746
1987	280	1120	1650				185	242	2115	1362
1988	300	1200	1755				204	177	2259	1377
1989	560	240	2304				217	227	3081	467
1990	273	247	1610				176	206	2059	453

[a] Kingsclear, 1974-88, Tobique 1988-90.

[b] DNRE and DFO sources.

[c] Guesstimates from various sources or assumed proportions of the run.

Table 8. 1SW returns, parametric and non-parametric forecasts of 1SW returns from Ln Eggs and the percent difference (forecast - actual/forecasts of 1SW x 100), 1973-1988.

Return Year	Actual 1SW returns	Non-parametric F'cast	Non-parametric % diff.	Parametric F'cast	Parametric % diff.
1973	2070	2060	0	2753	25
1974	3656	3796	4	3436	-6
1975	6858	6930	1	4430	-59
1976	8147	7394	-10	5461	-49
1977	3977	7059	48	4695	15
1978	1902	6994	73	4609	59
1979	6828	7602	10	8705	22
1980	8482	7673	-10	8290	-2
1981	5782	7673	25	7308	21
1982	4958	7673	35	7835	37
1983	4309	7602	43	6224	31
1984	8311	7673	-8	7244	-15
1985	6526	7673	15	6982	6
1986	7904	7602	4	6234	27
1987	5909	7059	16	4777	-24
1988	8930	7673	16	7259	-23
			4 cases > ± 30%		5 cases > ± 30%
			8 cases ≤ ± 10%		3 cases ≤ ± 10%

App. 1. Number of eggs/100 m² deposited in the Tobique River, 1968-1987, and derivation of weighted number of eggs contributing to annual returns of wild 1SW fish at Mactaquac, 1973-1988 and 1991 (explanation in Penney and Marshall MS 1984).

Egg deposition		Proportion age at smoltification[a]		Eggs/100 m² contributing to 1SW fish		Total wt'd egg contrib/100 m² 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	0.450		31.23		88.97 (1987)
			0.550		38.17	
1984	385.5	0.526		202.77		240.94 (1988)
			0.474		182.73	
1985	301.7					
1986	200.2[c]					
			.612[b]		122.52	
1987	159.8	.388[b]		62.00		184.52 (1991)

[a] Derived from App. 2 and 3.

[b] Mean (n=17) calculated with angular transformation.

[c] Revised from Marshall MS 1990.

App. 2. Number of wild 1SW salmon and proportion of age 2:1's of the total that would have returned to Mactaquac for the 1969-1985 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
1975	469	3,257	398	4,124	0.114
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	314	6,474	0.450
1985	5,612	4,771	291	10,674	0.526
1986	4,437	4,009			
1987	2,963				

App. 3. Freshwater age and number of wild 1SW fish (A) counted at Mactaquac fish passage facilities, Saint John River, 1977-1990, and (B) that would have returned to Mactaquac had they not been exploited within the river, 1977-1990.

Freshwater age	Number of 1SW fish													
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
A														
2	922	391	3,166	2,214	1,280	794	2,348	4,140	1,264	3,196	2,513	5,066	3,922	2,646
3	2,545	1,160	2,974	4,986	2,861	2,902	1,264	3,132	3,913	3,001	2,349	2,930	4,217	3,580
4	39	33	94	355	430	236	11	81	144	150	233	66	278	260
5									5					
6									5					
Total	3,506	1,584	6,234	7,555	4,571	3,932	3,623	7,353	5,331	6,347	5,095	8,062	8,417	6,486
B														
2	1,046	469	3,468	2,486	1,619	1,001	2,793	4,679	1,548	3,980	2,915	5,612	4,437	2,963
3	2,887	1,393	3,257	5,598	3,619	3,659	1,503	3,540	4,790	3,737	2,724	3,245	4,771	4,009
4	44	40	103	398	544	298	13	91	176	187	270	73	314	291
5									6					
6									6					
Total	3,977	1,902	6,828	8,482	5,782	4,958	4,309	8,311	6,526	7,904	5,909	8,930	9,522	7,263

App. 4. Estimated total number of 1SW and MSW returns to the Saint John River from hatchery-reared smolts released at Mactaquac, 1974-1990. (Age 1.2 fish in 1990 are provisional).

Releases			Returns (1SW/MSW)									
				Mactaquac							% return	
Year	Smolts	Prop 1-yr	Year	Mig ch	Dam	Kings-clear	Angled main SJ	By-catch	Commer-cial	Total[a]	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	0.920
85	89,051	1.00	86	64	635	53	93	17		862	0.968	0.868
86	191,495	1.00	87	198	2,679	96	288	67		3,328	1.738	1.570
87	113,439	1.00	88	(717)		15	46	16		794	0.700	0.672
88	142,195	1.00	89	(1,018)		0	107	23		1,148	0.807	0.763
89	238,204	0.98	90[b]	(903)		0	57	20		980	0.411	0.405
90	241,078	0.98										
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
85	89,051		87	4	338	110	4	24		480	0.539	0.453
86	191,495		88	(511)		150	0	35		696	0.364	0.354
87	113,439		89[b]	(379)		0	0	20		399	0.352	0.330
88	142,195			(480)		0	0	25		505	0.355	0.333
89	238,204											
90	241,078											

[a] Includes returns from downriver stocking of smolts, 1981-1989; adjusted return rate removes downriver returns to Mactaquac (Marshall MS 1989).

[b] 1SW hatchery fish at Mactaquac were estimated at 0.635, 0.104, 0.220 and 0.041 from smolts released "at" and above and age 2.1 and 3.1 fall fingerlings released above, respectively. MSW hatchery fish at Mactaquac were estimated at 0.635, 0.231, 0.077 and 0.06 age 1.2, 2.2, 3.2 and 'repeats', respectively. All estimates are preliminary.

App. 5. Estimates of hatchery 1SW and MSW returns to Mactaquac, Saint John River, 1990, as estimated from numbers of various juveniles released at (At) above (Abv) or below (Bl) Mactaquac and returns to Mactaquac.

Release				Returns in 1990			
Year	Loc.	Stage	Number	Rate	Age	1SW	MSW
1989	At	1-,2-yr smolt	238,204[a]	0.00405[•]	1-,2.1	964	
1989	Bl	1-yr smolt	34,994	0.00405 @0.116[f]	1.,2.1	15	
1989	Abv	1-,2-yr smolt	52,893[b]	0.00302	1-,2.1	160	
1987	Abv	Fall fing.	201,435[c]	0.00168[g]	2.1	339	
1987	Abv	Unfed/fry	266,257[d]	unknown	2.1	-	
1986	Abv	Fall fing.	220,176	0.00029[g]	3.1	63	
1988	At	1-yr smolt	142,195	0.00333[•]	1.2		474
1988	Bl	1-yr smolt	71,812	0.00333 @0.13	1.2		31
1986	Abv	Fall fing.	220,176	0.00083[g]	2.2		183
1985	Abv	Fall fing.	289,000	0.00021[g]	3.2		61
		Repeat spawners					47
Totals						1,541	796

[a] Incl. 2 groups of CWT Ad-clipped fish released at Mactaquac.

[b] Downstream passage trials above Mactaquac.

[c] Incl. 56,000 fish released above Grand Falls by SALEN.

[d] Not distinguishable from wild smolts.

[•] App. 4.

[f] See - Marshall 1990, App. 5 and footnote[d], Table 5 this document.

[g] Based on proportions, footnote App. 4.