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Assessment of Atlantic salmon of the Saint John River above Mactaquac and of the Nashwaak River, N.B., 1993

by

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ABSTRACT

Estimated river returns destined for Mactaquac, Saint John River, 1993, were 4,369 1SW and 3,389 MSW salmon - the fewest in 19 years. About 2,800 1SW and 2,150 MSW salmon were estimated to have spawned, i.e., 88 and 49% of the respective target spawning numbers and, in total, 51% of the target egg deposition. Hatchery fish comprised 26% of 1SW and 13% of MSW returns; return rates for hatchery smolts were virtually the lowest of record.

Partial counts of salmon ascending the Nashwaak River below Mactaquac indicated that about 950 1SW and 550 MSW salmon may have spawned, i.e., about 60% and 35% of the respective target spawning numbers and, in total, <40% of the target egg deposition.

Forecast 1SW returns destined for above Mactaquac in 1994 could number 8,000 fish (6,400 wild and 1,600 of hatchery origin). However, because of the very low marine survival in 1993 and, quite possibly in 1994, returns, like those of 1993, could be only one-half of the forecast value but still exceed the target spawning requirements.

Forecast MSW returns destined for above Mactaquac in 1994 could number 3,100 (2,300 wild and 800 of hatchery origin) or 4,800 fish (3,600 wild and 1,200 of hatchery origin) depending on models supposing either none or total benefits, respectively, from the moratoria in distant fisheries. The model that ascribed no benefits from the moratorium in Newfoundland best forecasted the 1993 MSW return. Neither MSW forecast fully accounts for potentially low marine survival in the winter of 1994 or the fact that the 1SW and fork length data used to predict MSW returns were, together, outside the range of data in the models. It is unlikely that MSW returns will be adequate to meet target spawning requirements above Mactaquac.

RÉSUMÉ

Les estimations de remontées de saumons vers Mactaquac, dans la Saint-Jean, en 1993, étaient de 4 369 unibermarins et 3 389 pluribermarins, ce qui représentait leur plus bas niveau en 19 ans. On a estimé à environ 2 800 unibermarins et 2 150 pluribermarins le nombre de saumons qui ont frayé, soit 88 % et 49 % des cibles respectives; la ponte totale correspondait à 51 % de la cible. La part du saumon d'écloserie dans les remontées se chiffrait à 26 % des unibermarins et à 13 % des pluribermarins; les taux de remontée des saumoneaux d'écloserie étaient virtuellement les plus bas à ce jour.

Des dénombrements partiels du saumon qui remontait la Nashwaak ont révélé qu'environ 950 unibermarins et 550 pluribermarins ont peut-être frayé, soit environ 60 % et 35 % des cibles respectives; la ponte totale correspondait à <40 % de la cible.

D'après les prévisions pour 1994, 8 000 saumons unibermarins (6 400 sauvages et 1 600 d'écloserie) pourraient remonter la rivière et se rendre en amont de Mactaquac. Toutefois, en raison du très faible taux de survie en mer en 1993, qui se maintiendra peut-être en 1994, les remontées pourraient, comme en 1993, n'atteindre que la moitié des prévisions, le nombre cible de reproducteurs étant cependant dépassé.

Quant aux pluribermarins, les prévisions de remontées jusqu'en amont de Mactaquac pourraient se chiffrer en 1994 soit à 3 100 (2 300 saumons sauvages et 800 saumons d'écloserie), soit à 4 800 (3 600 saumons sauvages et 1 200 saumons d'écloserie), selon que le modèle employé n'attribue aucun effet au moratoire sur les pêches distantes, ou qu'au contraire il lui attribue des effets maximaux. Les prévisions de 1993 fondées sur le modèle qui n'attribuait aucun effet au moratoire sur la pêche à Terre-Neuve se sont avérées les plus justes en ce qui a trait aux pluribermarins. Aucune des prévisions de remontées de pluribermarins ne tient pleinement compte d'une faible survie en mer éventuelle durant l'hiver 1994, ou du fait que les données sur les unibermarins et les longueurs à la fourche utilisées pour prévoir les remontées de pluribermarins se situaient hors de la gamme des données des modèles. Il est peu probable que les remontées de pluribermarins jusqu'en amont de Mactaquac seront suffisantes pour atteindre la cible.

INTRODUCTION

This document is background to the management of Atlantic salmon stocks of the Saint John River, New Brunswick. As in recent years, data and analyses pertain largely to stock status in 1993, and forecasts for 1994 of those stocks originating **above Mactaquac**. New for 1993, are data and analyses of the status of salmon in the **Nashwaak River**, below Mactaquac.

BACKGROUND

Physical attributes of the Saint John River drainage (Fig. 1), 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 (1989) and Marshall and Penney (1983). Forecasts made in 1992 suggested that 1993 homeriver returns to Mactaquac would number approximately 8,000 or 9,400 1SW and 4,800 or 5,400 (AM) MSW salmon, depending on forecasting technique (Marshall 1993).

The Management Plan for 1993 was identical to that of recent years 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. All fishing for salmon was curtailed in outer Bay of Fundy rivers of Salmon Fishing Area 23 on September 15 after in-season forecasts of end-of-season counts at Mactaquac indicated that only about one-half the target requirement of MSW spawners would be attained. The early closure effectively shortened the First Nations' food fisheries on the Tobique River by up to 15 days, the recreational fishery of the Saint John River upstream of Grafton Bridge and the Nashwaak River upstream of Stanley by 15 days, most remaining areas below Mactaquac by 30 days and the Kennebecasis River and a portion of the Hammond River by 46 days.

First Nation fisheries with gill nets, which began in earnest in 1991, was again conducted by the St. Mary's Band, June through July 22, on the main Saint John between Mactaquac (McKinley Ferry) and Fredericton and in the lower reaches of the Nashwaak River. Two experimental trap nets were also operated by the Band but with minimal success. The Oromocto Band again fished a trap net on the main river near Oromocto. A food fishery with both gill and trap nets was conducted above and below the Tobique Narrows Dam on the Tobique River. The Kingsclear First Nation guided a sport fishery as in the previous few years (inc. discrete removals of MSW fish by guides). Catch statistics were not provided by First Nations.

Mean daily river discharges at Mactaquac in June and the first part of July, 1993, were high as in 1992, but trailed off through the remainder of the summer (Fig. 2). The high discharge again generally limited the effectiveness of the gill nets below Mactaquac prior to their removal on July 22.

The assessment for stocks **above** Mactaquac follows the same basic approach as those taken in 1992 (Marshall 1993). In addition, tag data were used to derive "MSW return" data that would reflect returns to home waters had the moratorium on the insular Newfoundland **and Greenland** commercial fisheries been in effect for the last two decades. These data were then submitted to the previously used parametric forecast models; forecasts with non-parametric models (Harvie and Amiro 1991) were discontinued because of the awkwardness of the 3-variable models and inadequate numbers of years.

The status of the **Nashwaak River** (Fig. 1), salmon stocks in 1993 with respect to the "target" spawning requirement was based on the relation of the partial enumeration of migrants through a counting fence and the relatively complete counts at the same fence site in 1973 and 1975. Target spawning requirements for the Nashwaak River (Marshall *et al.* 1992) were adjusted to reflect the juvenile habitat above the fence; biological characteristics of fish sampled in 1993 were used to evaluate potential egg depositions.

METHODS

Returns destined for Mactaquac

Total returns of 1SW and MSW salmon of both wild and hatchery origin from above Mactaquac Dam consist of the summation of Mactaquac counts, estimated angling (including Kingsclear First Nation at Chapel Bar) and native netting in the main stem below the Mactaquac Dam and assumed by-catch in downriver shad, gaspereau and "other" species net 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. The fish collection facilities at the dam were open a "full" season; the migration channel at the Hatchery was reconstructed and therefore only open after Sept 15. Because only a few hatchery-origin fish have used the migration channel in recent years and because of the proximity of the alternate facility at the dam, counts of hatchery fish were not adjusted.

The identification of 1SW and MSW returns from 1-year and a smaller number of 2-year smolts released at Mactaquac and juveniles released above Mactaquac was principally dependent on erosion of the dorsal fin. Returns from hatchery origin unfed and feeding fry are unlikely to be distinguishable from wild fish. By-catch was assumed to be 2% of the 1SW and 5% of the MSW river returns - values which approximate the original mean of reports and estimates for the years 1981-1984. The by-catch, sport and native catches below Mactaquac were assumed to consist of fish of hatchery and wild origins in the same proportions as those counted at Mactaquac.

Returns to the Nashwaak River

Salmon were counted by St. Mary's First Nation, Aug 18 through Oct 12, 1993, at a 52-m fence located on the main Nashwaak, 23 km above its confluence with the Saint John River. The site and same base had been used in 1972, 1973 and 1975. Fish were measured for fork length, externally sexed and accorded a sea-age and origin on the basis of scales taken from slightly less than one-half the enumerated count.

The total run of 1SW and MSW fish above the fence in 1993 was estimated as the product of the counts in 1993 and the reciprocal of the proportion of the presumed complete counts (Francis and Gallop 1979) that were monitored between the same dates in 1972 and 1975. This assumed that run-timing of the salmon and river discharge/water temperatures which could inhibit their movement were similar in 1993, 1975 and 1973.

Removals of fish destined for Mactaquac

Removals include numbers of fish recorded by Fishery Officers who monitored the First Nation fisheries on the main stem below Mactaquac and numbers estimated from tag recoveries to have been netted on the Tobique River; provincial and federal statistics for sport catch on the main stem below Mactaquac, on the main stem above Mactaquac (inc. Salmon River, Victoria Co.,) and the Tobique River; and a by-catch in the estuary.

At the time of writing, removals in the recreational fishery below Mactaquac, i.e., Kingsclear First Nation (Chapel Bar Pool) and the public fishery below, were either not reported or were of only a very preliminary nature. For those reasons catches were estimated using a 7.4 % exploitation rate derived from 10 tag returns from sport fishers, a 50% reporting rate and a pool of 272 tagged 1SW fish. Most of the tagged 1SW fish had been intentionally recycled through the sport and native fishery for the purpose of determining by default (no tag returns) the exploitation rate of the native fisheries (see below).

The number of salmon harvested in a net fishery, mostly 5.0-5.5 in (127-140 mm) mesh gill nets, but including two experimental trap nets, below Mactaquac, i.e., Hartts and Savage islands and at McKinley Ferry (all between 2-9 km below the Dam) are largely those fish observed or known to Fishery Officers who intensely visited the sites between late May and the lifting of most gill nets on July 22. An independent estimate of the catch in nets was to have been based on 275 tagged 1SW salmon captured at Mactaquac and released in Fredericton below the fishery, July 6 - July 22. No estimate was possible because 85% of the fish returned to Mactaquac Dam, approximately 7% could be accounted for in the recreational fishery and the remaining 8% approximated the assumed percentage that might be lost to straying, handling mortality or tag loss, i.e., few tags could be accorded to the net fishery. Food fishery activity was again less than in 1992 because of high water in June, employment of a few fishermen in DFO-First Nation "partnership" programs and an agreement that removed gill nets from below Mactaquac by July 22.

Native fisheries also operated at the mouth of and within the Nashwaak River. Landings were estimated by Fishery Officers to have been about four salmon and two grilse. Fewer than a dozen fish were observed at downriver locations such as Gagetown and Coytown.

As in 1992, the estimated net catch by individuals of the Tobique First Nation, July - Sept 15, was based on an exploitation rate derived with Carlin tags recovered from the fishery (eight tags in 1993, all from 1SW fish tagged for the independent estimation of catch in the Native fishery below Mactaquac), an assumed non-reporting rate, an estimate of fish available to the fishery from releases below and above the Tobique Narrows Dam and the tag-based exploitation rate for the years 1989-1992 (Marshall 1993). Fishing was conducted with in excess of a dozen gill nets below the Tobique Narrows Dam and in the Tobique Headpond. Two DFO-provided trap nets were installed in the Headpond for purposes of a selective fishery for 1SW salmon.

Other removals include fish: monitored through the fish-lift at Tinker Dam on the Aroostook River, trucked from Mactaquac to the Tinker Headpond and from Mactaquac to above Grand Falls, 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 MSW salmon released above Mactaquac, exclusive of those to the native fishery at Tobique and losses to the Aroostook River and above Grand Falls. **Losses to poaching and disease** ascribed in recent assessments, i.e., 4% of 1SW and 10% of MSW fish placed above Mactaquac (exclusive of those estimated to have been taken in the net fishery at Tobique, the sport fishery or passed into the Aroostook or above Grand Falls) were calculated as in 1992 but **are considered as "spawners"** for purposes of evaluating the attainment of target spawning escapement. For the most part, losses were apportioned to hatchery/wild components on the basis of known or estimated stock composition in the vicinity of the event.

Removals of fish from the Nashwaak River

Removals of 1SW fish in the recreational fishery were restricted to estimates provided by District Offices of the New Brunswick Department of Natural Resources and Energy. Estimates were available for above and below the fence site but in part or total are superfluous to assessing whether or not the spawning escapement and, in particular, egg deposition targets were met in 1993.

Required Spawners above Mactaquac

An accessible salmon-producing substrate of 12,261,000 m^2 above Mactaquac, (exclusive of the main Saint John below Grand Falls, the Aroostook River and main Saint John and tributaries above Grand Falls), 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 1983). Because 1SW fish contribute few eggs relative to MSW salmon, 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.*).

Required Spawners, Nashwaak River

An accessible salmon-producing substrate of 4.938 million m^2, an assumed requirement of 2.4 egg/m^2, the above length-fecundity relationship for Mactaquac-origin MSW and 1SW fish and 1SW:MSW ratios in the Nashwaak sport fishery, 1974-1983, suggest that, on average, approximately 1,800 MSW and 1,700 1SW fish are required for the Nashwaak River (Marshall *et al.* 1992). As on the Saint John above Mactaquac, 1SW requirements were set at those which would provide a 1:1 male-to-female ratio in MSW fish. Requirements above the fence were based on habitat estimates from ortho-photo and air photo measurements of stream area and, as well, on the gradient-weighted production capacity for juvenile salmon (Amiro 1993).

Forecasts for Stocks Originating at or Above Mactaquac

1SW Wild

The potential for returns of wild 1SW returns originating above Mactaquac was examined through a regression of total wild 1SW fish returning to the Saint John River which were produced above Mactaquac, 1973-1990, on adjusted [method in Penney and Marshall (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 1986-1987. The 1989 and 1990 egg depositions, principal contributors to 1SW returns in 1994, were derived using angular-transformed mean proportions for age-2.1 and age-3.1 1SW fish in the previous decade.

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. 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).

MSW Wild

Recent approaches to modelling MSW returns have focused on the use of parametric statistics and three variables: log MSW returns in year i+1, 1SW numbers and fork length of 1SW returns in year i (Marshall 1993; Marshall *et al.* 1993). This assessment explores firstly, a forecast of MSW returns in 1994 using estimates of homewater returns, i.e., the multiple regression of logged MSW returns on 1SW returns and fork length of 1SW returns. As with forecast of 1SW salmon, the resultant GM value of MSW salmon (and confidence limits) was converted to a GM value (Ricker 1975 *op. cit.*). GM estimates and their confidence limits in previous assessments were converted to AM values for 1SW fish but were not converted in the case of MSW estimates (non-parametric values did not require conversion). AM values for MSW estimates, 1991-1993, are about 1.03 times the GM estimates.

Secondly, Saint John River MSW salmon are known to frequent distant waters and contribute to distant water fisheries as non-maturing 1SW fish. The moratoria on the commercial fisheries of insular Newfoundland, 1992, and in Greenland in 1993 could therefore result in returns in 1994 that are not reflected in the homewater MSW return data used in the above forecast model. Hence, tag return data from Insular Newfoundland and Greenland, varying rates (Table 5) for tag reporting, non-catch survival, tag retention rate and survival to home waters were used to estimate potential gains in 2SW salmon to the Saint John River as a result of the moratoria. Estimates of the potential gains in 22 of the 23 years used above were added to the MSW returns and examined in the above MSW forecast model. For comparative purposes the forecasts based on returns without potential gains from Newfoundland and Greenland were re-run for the same 22 years of data.

Finally, selected periods within the 22 years of data were tested by ANCOVA procedures to determine if an abbreviated or modified model would be more responsive in predicting 2SW returns from the low (lowest in 15 years) 1SW returns of 1993.

1SW Hatchery

Since the shift to age-1 smolts from Mactaquac in 1985, forecasts of hatchery returns have been simply the product of the mean return rate of recent years and the number of smolts (i.e., >12 cm) expected to contribute to 1SW returns. The rate for age-1.1 fish returning to Mactaquac in 1994, was, because of diminishing return rates (survival) and indices of overwintering habitat for salmon in the north Atlantic (Reddin *et al.* 1993), assumed to be the same as that of 1993.

Age-1.1 returns in 1994 may also be expected from smolts reared at Mactaquac but released into tributaries below the dam, now principally just the Nashwaak River. An 8-year mean ratio (return rate of tagged 1SW fish to Mactaquac from smolts released at Mactaquac : return rate of tagged 1SW fish to Mactaquac from smolts reared at Mactaquac but released below Mactaquac) of 1:0.21 was used for the 1994 returns, just as it was in 1993. No returns were in evidence in 1993 and the return rate was not adjusted (App. 4).

Additional 1SW returns of age-3.1 and age-2.1 fish are expected at Mactaquac in 1994 from fall fingerlings (age-0^{+}) graded from the age-1 smolt program at Mactaquac and released in tributaries above Mactaquac in 1990 and 1991. Returns of age-2.1 fish were forecast as the product of a 0.00111 return rate to Mactaquac (the value from returns in 1993 and that used for forecasting in 1992) and the numbers released in 1991. Age-3.1 fish were assigned a return rate of 0.0002 (1993 return rate). Returns from unfed fry were accorded a return rate of one-half of that given the fall fingerlings but are unlikely to be distinguishable from wild fish upon return to Mactaquac.

MSW Hatchery

Returns as MSW fish from age-1 smolts released at Mactaquac in 1992 were estimated as the product of the number released and a forecast return rate. The return rate was derived from a relationship between survival to home waters of 1SW and 2SW salmon originating from the same smolt releases at Mactaquac, 1974-1991. As with 1SW hatchery returns, MSW fish destined for Mactaquac from releases to tributaries below (Nashwaak) were proportioned (0.21) on the basis of MSW tag returns to Mactaquac from six different smolt classes.

As well, MSW returns of age-3.2 and age-2.2 are expected from fall fingerlings released above Mactaquac in 1989 and 1990. Returns of age-2.2 salmon were forecast as the product of their numbers and a return rate to Mactaquac of 0.0002, the same as that exhibited in 1993 (App. 5). Age-3.2 hatchery MSW fish, a rarity (App. 5) because of the generally large size of stocked fall fingerlings, were accorded the 1993 return rate of 0.00008.

Fish which returned as maiden fish, principally 1990-1993, are expected to comprise the repeat-spawning hatchery MSW component in 1994. The forecast return was simplified to be the product of the estimated escapement of hatchery fish in 1993 and a return rate of 0.04.

Because return rates used in forecasting hatchery MSW salmon exclude potential gains from the moratorium on commercial fishing in insular Newfoundland and the buy-out in Greenland, forecasts were raised in proportion to the difference between the forecast of wild MSW returns with and without potential gains from Newfoundland and Greenland.

RESULTS

Returns destined for Mactaquac

Estimated homewater returns in 1993 totalled 4,369 1SW (Table 1) and 3,389 MSW fish, the lowest of a 19-year record (Table 7). Returns included 60 1SW and 240 MSW fish estimated to have been taken in the Native fishery, 315 1SW fish taken in the sport fishery and 87 1SW and 169 MSW fish allotted to by-catch, all below Mactaquac. Counts of fish at Mactaquac in 1993 (Fig. 3) comprised 89 and 88% of respective 1SW and MSW returns estimated to have been destined for Mactaquac. Hatchery fish comprised 26% and 13% of 1SW and MSW counts, respectively, (Fig. 4); return rates for hatchery smolts were equivalent to or the lowest of record (App. 4).

Landings in the net fishery below Mactaquac were rounded upwards from Fishery Officer estimates by 15% (for unsampled days/locations) - to 60 1SW and 240 MSW salmon. These landings of fish estimated to have been available through July 22 suggest exploitation rates of approximately 0.03 and 0.12 for respective 1SW and MSW captures. Values in 1992 were 0.02 for 1SW fish and 0.092 for MSW fish (over the complete run); the average for the early 1980's was 0.04 for 1SW and 0.22 for MSW fish (Marshall 1985).

Returns to the Nashwaak River

Counts at the Nashwaak fence during the August 18 - October 10 operating dates numbered 83 1SW and 155 MSW salmon (Fig. 5). Interpretation of 92 scale samples revealed a sea-age composition of 0.33 1-year, 0.53 2-year, 0.02 3-year and 0.12 repeat spawners. Nineteen percent of 1SW fish and 41% of maiden 2SW fish smoltified at age-1. Among wild 1SW fish, freshwater ages were 0.33 age-2 and 0.67 age-3. Proportions among 2SW wild fish freshwater ages were 0.61 age-2 and 0.39 age-3.

In 1973 and 1975, when it was thought that entire runs (all wild fish) were monitored/estimated (Fig. 5), the period Aug 18 - Oct 10 accounted for 0.43 and 0.087 of 1SW and 0.279 and 0.392 of MSW salmon, respectively. Raising the 1993 counts by the lowest proportion of 1SW or MSW fish from either of 1973 or 1975, suggests that the total run past the fence in 1993 could have been as many as 954 (83/0.087) 1SW fish and 555 (155/0.279) MSW salmon. For this analysis we accepted the assumptions that run-timing of the stock had not changed in two decades and that river discharge (Fig. 6) and temperature conditions (Fig. 7) were adequate for salmon to pass the fence site in the same way as for the 1970s.

Removals of fish destined for Mactaquac

In addition to the few 1SW sport removals reported by the Kingsclear First Nation and NBDNRE in the lower main stem, 537 fish were reported caught above Mactaquac (Table 2). Tag returns and a 0.8 tag reporting rate suggested a net fishery exploitation rate at Tobique of 0.143 for 1SW fish and 0.321 for MSW salmon, virtually the same as the mean exploitation rate (based on return of 120 tags) for the years 1989-1993. These rates were applied equally to fish known to have had access to the fishery below Tobique Narrows Dam (counted over Beechwood or dumped directly at Andover) and 10% of wild and 60% of hatchery fish released above the Tobique Narrows Dam at Arthurette (dropback estimated from tracking of ultrasonic tagged fish in 1992). The catch (Table 2) was estimated to be 181 1SW and 222 MSW salmon.

MSW losses above Mactaquac to poaching and disease combined were set at 10% (exclusive of those taken in the net fishery or passed above Tinker Dam and Grand Falls) as in recent years. 1SW losses to poaching and disease were set at 4% (exclusive of those taken in the recreational and Tobique net fishery and passed above Tinker Dam and Grand Falls). As in 1992, only one salmon was lost at the Half Mile Barrier Pool on the Tobique River. No other mortalities were available to NBDNRE from that location for disease (furunculosis in particular) analyses.

Total river removals by all factions were estimated at 1,663 1SW fish of which 244 made their way above Tinker Dam and Grand Falls, and 1,455 MSW salmon of which 148 were transferred above Tinker Dam and Grand Falls. MSW hatchery broodstock retained at Mactaquac numbered 350 MSW fish; no 1SW salmon were sacrificed for recovery of coded nose-wire tags, but 73 were checked internally for sex or tested for disease. Most of the carcasses were distributed to First Nations.

Removals of Nashwaak River fish

Total estimated removals in the sport fishery, 1993, numbered 137 fish (P. Cronin[1] pers comm). Comparable estimates over recent years are as follows:

	1988	1989	1990	1991	1992
1SW fish	201	448	196	186	426

Although 88 of the angled 1SW fish were removed above the fence site it is difficult to postulate what portion would be from the fish estimated to have ascended the fence site prior to fence enumeration. Observed Native catches consisted of five salmon and two grilse. Losses to poaching and disease have not been estimated.

Spawning Escapement above Mactaquac

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 2,149 (49%) of the required 4,400 MSW spawners were attained above Mactaquac (Table 3). For 1SW fish, only 88% of requirement was met above Mactaquac. An estimated 6.1% of wild (internal sexing in August and early September confirmed external assessments) and 2.8% of hatchery 1SW fish were female and with respective mean lengths of 59.0 and 61.6 cm had the potential to deposit about 0.5 million eggs. Total egg deposition above Mactaquac, including losses to poaching and disease, was estimated at 15.03 million eggs or 51% of the target egg requirement.

Spawning escapement, Nashwaak River

Orthophoto and airphoto measurements provide a habitat area estimate (by stream gradient) that is 1.6 times greater than the currently used measure of area and an estimate that 79% of the total river substrate is above the fence site. Remote-sensed measures of river substrate include all water area whereas the original surveys likely excluded subjectively-evaluated poor/marginal habitat.

Most of the remote-survey area below the fence site is in the 23 km of low gradient main stem. Application of a gradient-weighted juvenile salmon production model (Amiro 1993) to the gradient-measured area for the entire Nashwaak River indicates that 94% of the salmon production capacity is above the fence. On these bases, the target for spawning requirements above the fence was chosen as 90% of the original 11.9 million eggs (1,800 MSW salmon and 1,700 1SW salmon), i.e., 10.7 million eggs (1,620 MSW and 1,530 1SW fish).

A complete escapement of the 1993 possible run of 954 1SW and 555 MSW past the fence site is only 59% and 36% of the target requirement. Mean lengths of hatchery and wild 1SW and MSW salmon, female proportions of 0.858 and 0.645 among wild and hatchery MSW fish, respectively, and 0.279 and 0.03 females among wild and hatchery (Mactaquac) 1SW salmon, and the 954 1SW and 555 MSW fish equate to 3.87 million eggs - 36% of the 10.7 million egg target.

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Stock Forecasts for above Mactaquac

1SW Wild

Potential returns of wild 1SW fish returning to Mactaquac in the absence of homewater removals in 1994 were examined through the regression of 1SW returns to home waters of which originated above Mactaquac on estimated Tobique River egg depositions adjusted for smolt age. [The variable "index of winter habitat" (Marshall *et al.* 1993) and survival of hatchery fish to Mactaquac (used in the 1SW hatchery forecast) were rejected ($p>0.15$) in stepwise procedures to improve the above model.] From the equation Log_e 1SW = 6.4698 + 0.4317 Log_e eggs (r^2=0.456, $p<0.001$, n=19), the estimate for 1SW returns in 1994 is **6,414** 1SW fish (90% CL 3,453- 11,914). Uncertainties in the estimate of returns include the inability of the model to respond to the recent decline in marine survival noted in 1SW hatchery-origin fish (App. 4) and potential impact of diminishing indices of winter habitat (Reddin *et al.* 1993). For 1993, the method had forecast 6,105 1SW fish; only 3,213 fish or 53% of the forecast was estimated to have returned.

MSW Wild

A potential return of **2,316** (90% CL 1,422- 3,772) wild MSW fish destined for Mactaquac in 1994 was derived from the equation Log_e MSW = 25.2768 + 0.129E-3 1SW - 0.3083 Length (R^2=0.684, $p<0.0001$, n=23). For 1993, the method forecast 3,462 (AM) returns; only 2,958 fish or 85% of that forecast was estimated to have returned. A concern with the 1994 forecast is that the predictor variables, i.e., 1SW fish (3,213) and their length (58.3cm) are, together, outside the range of observations in the model. The inclusion of the co-variate "period" in the model for MSW years 1971-1975; 1976-1984 and 1985-1993 and, as well, 1971-1975; 1976-1986 and 1987-1993 when trends in the ratio of MSW:1SW and lengths (Table 4) appeared to be different, was not significant (p=0.267 and p=0.252, respectively), i.e., there was no evidence to suggest a subset(s) of the data would provide a more appropriate model for forecasting.

Substitution of the estimated numbers of returning salmon in the absence of commercial fisheries in insular Newfoundland and Greenland, 1971-1992, (Table 5, one less year than in the above data set) would suggest a return of **3,614** (90% CL 2,018- 6,473) wild MSW fish destined for Mactaquac in 1994 (Log_e MSW = 27.1018 + 0.116E-3 1SW - 0.3315 Length; R^2=0.621, $p<0.0001$, n=22). This is 157% of the forecast of **2,307** MSW salmon (90% CL 1,438- 3,701) from the equation Log_e MSW = 26.2479 + 0.126E-3 1SW - 0.3248 Length; R^2=0.718, $p<0.0001$, n=22) using return data lacking Newfoundland and Greenland components, 1972-1993.

Concerns for the MSW estimates are the same as for the model without the added effects of the moratoria. Hence "period" hypotheses were also tested in the moratoria-impacted model and found to approach significance (p=0.053) only when the last period for MSW years was 1985-93. However, the difference between periods was effectively only between the first period (four years; 1971 missing) and the second and third periods combined (18 years). However an 18-year model was viewed to be of little advantage over the 22-year model in better forecasting from the 1993 predictor values. In the 1992 assessment the model which substituted estimated returns in the absence of the Newfoundland commercial fishery forecast 3,892 (AM) MSW salmon (GM of 3,785). This estimate was 115% of the preseasonal estimate which excluded the returns from the Newfoundland moratorium and 132% of the return in 1993, i.e., the component expected to have resulted from the moratorium in Newfoundland was potentially masked by the impact of decreased marine survival that was measured in hatchery 1SW fish.

1SW Hatchery

The forecast of hatchery 1SW fish destined for Mactaquac in 1994 was in part calculated as the product of an estimated 221,403 age-1 smolts released at Mactaquac in 1993 and a 0.00406 return rate (Table 6; the same as that estimated for the 1993 return), i.e., 899 fish. Interestingly, the same return rate can be derived from the equation Log% $Surv_{1SW} = -3.627 + 0.002$ Habitat $Index_{Mar}$ (r^2=0.54, p<0.001, n=18) and a value for March 1993 of 1,363 (millions of units) (assumes continued serial correlation between years noted by Marshall *et al.* 1993) . Another 11 fish could return from smolts released to the Nashwaak River. Fall fingerlings released above Mactaquac in 1990 and 1991 could contribute another 576 1SW fish (Table 6). The total forecast of hatchery 1SW returns to Mactaquac is **1,611** 1SW fish. The 1993 pre-seasonal forecast by these methods was 165% of the identified hatchery return and in hindsight did not account for the greater marine mortality experienced in 1993. (Unidentified fish of hatchery origin [accorded "wild" status] could have numbered about 200 individuals, i.e., the forecast may have been about 140% of the return).

MSW Hatchery

MSW returns destined for Mactaquac in 1994 were calculated as the sum of the product of an estimated return rate of 0.00288 (similar to that of the 1992 assessment) and 204,836 smolts released at Mactaquac in 1992 (590 fish) and 0.21 of returns from 13,645 smolts released below Mactaquac in 1992 (8 fish). The return rate for 1994 was estimated from the regression $Y = 0.183 + 0.259X$; r^2=0.55, p<0.001, n=18 (Fig. 8). Additional returns are expected from releases of fall fingerlings in 1989 and 1990 and 0.0002 and 0.00008 survival/return rates (Table 6). The conventional forecast, i.e., without gains from the moratorium in insular Newfoundland, of total hatchery MSW returns to Mactaquac, including repeat spawners, is **783** MSW fish (Table 6). Application of a 0.66 raising factor, a value which reflects the 36% difference between wild MSW salmon with and without returns from the moratoria in distant fisheries in the last seven years, suggests a potential return of **1,186** hatchery-origin MSW salmon if the impact of the moratoria is not overshadowed by an increase in marine mortality .

Forecast Summary

Forecast 1SW returns destined for above Mactaquac in 1994 could number 8,000 fish (6,400 wild and 1,600 of hatchery origin). However, because of the very low marine survival in 1993 and, quite possibly in 1994, returns, like those of 1993, could be only one-half of the forecast value but still exceed the target spawning requirements.

Forecast MSW returns destined for above Mactaquac in 1994 could number 3,100 (2,300 wild and 800 of hatchery origin) or 4,800 fish (3,600 wild and 1,200 of hatchery origin) depending on models supposing either none or total benefits, respectively, from the moratoria in distant fisheries. The model that ascribed no benefits from the moratorium in Newfoundland best forecasted the 1993 MSW return. Neither MSW forecast fully accounts for potentially low marine survival in the winter of 1994 or the fact that the 1SW and fork length data used to predict MSW returns were, together, outside the range of data in the models. It is unlikely that MSW returns will be adequate to meet target spawning requirements above Mactaquac.

DISCUSSION

Estimated returns in 1993, of 4,369 wild and hatchery 1SW and 3,389 wild and hatchery MSW salmon were 55% and 70% respectively, of returns predicted by regression methods. Comparisons of predicted and actual (estimated) returns for each of wild and hatchery fish since 1988 are as follows:

Sea-age	Returns	1988	1989	1990	1991	1992	1993[a]	1993[b]
Wild								
1SW	Predicted	6,054	8,197	7,393	5,786	5,786	6,105	
	Returned	8,930	9,522	7,263	6,256	6,683	3,213	
	Ret/Pred	1.48	1.16	0.98	1.08	1.16	0.53	
MSW	Predicted	6,983[c]	6,232[c]	6,325[c]	3,511[d]	4,041[d]	3,892[d]	3,397[d]
	Returned	2,625	4,072	3,329	4,491	4,104	2,958	2,958
	Ret/Pred	0.38	0.65	0.53	1.28	1.02	0.76	0.87
Hatchery								
1SW	Predicted	2,165	2,080	2,710	3,400	2,027	1,904	
	Returned	1,250	1,339	1,541+	2,495+	2,257+	1,156+	
	Ret/Pred	0.58	0.64	0.57+	0.74+	1.11+	0.61+	
MSW	Predicted	1,023	882	750	1,262	1,205	1,038	905
	Returned	912	469	796	724+	794+	431+	431+
	Ret/Pred	0.89	0.53	1.06	0.57+	0.66+	0.42+	0.48+

[a] With moratoria; [b] without moratoria; [c] model without fork length; [d] revised AM estimates;
+ returns from juveniles likely credited to 'wild' fish.

1SW and MSW returns, including fish of hatchery origin, were the lowest of a 19-year data set (Table 7). The spawning escapement of MSW fish, including estimated losses to poaching and disease, was 49% of requirement- well below the 78% average for the period 1987-1992, and an extension to 13 years out of the last 16 years in which the target for MSW spawners has not been met.

Preseasonal forecasts of all but wild MSW salmon (ignoring potential effects of the moratorium in Newfoundland) were below acceptable limits. Inferences that returns in 1993, particularly of 1SW maturing salmon, could be low were reflected in new analyses by the ICES Working Group on North Atlantic Salmon (Anon 1993). Through time series and regression techniques the Working Group forecast that pre-fishery abundance of non-maturing 1SW salmon available to the Greenland fishery would be low, i.e., low enough that the Greenlanders accepted in June 1993 a buy-out of their fishery. By extension, it was suggested that there could also be low numbers of 2SW salmon returning to North America (Reddin *et al.* 1993) unless perhaps tempered by moratoria in distant fisheries.

Fundamental to the ICES forecast of low abundance was the significant positive relationship between indexes of over wintering habitat in the North Atlantic, 1970-1993, and estimates of pre-fishery abundance. The index of suitable habitat in March, 1992, was the third lowest of the 24-year data set and coincided with a poor fishery in Greenland; the index of habitat in March 1993 was the lowest of record (Reddin *et al.* 1993).

Independent of these new analyses, some jurisdictions suggest that drought conditions in the summer of 1991 may have reduced juvenile survival and subsequent smolt outputs in 1992 and 1993. Age-3.1 fish (age-2+ juveniles in 1991) among 1SW returns in 1993 were proportionately the lowest of record (App. 2) but the reason is not clear. Tobique River discharges (partially controlled) in 1991 were low although not as low as those of 1987 (Fig. 9) - a generally accepted low discharge summer that has not yet been linked to lower production on the Saint John River. Temperature data have yet to be analyzed.

The forecast model for 1SW returns in 1994 only accounts for 46% of the variance between the 1SW and adjusted egg variables and performed poorly in forecasting returns in 1993. If the poor marine conditions in the North Atlantic persist into 1994, a strong possibility on the basis of serial correlation of habitat indices in year i and year i+1 (Marshall 1993), and if these conditions can be demonstrated as limiting or as a threshold to specific salmon stocks of North America, it is probable that forecasts for 1SW fish in 1994 may again be overestimated. Several investigators, including Reddin *et al.* (1993), have noted positive correlations between salmon habitat area at sea and abundance and such suggests that much uncertainty should accompany the 1SW forecast. Similarly the impact of low marine survival and coincidental low index of winter habitat in the North Atlantic may have impacted the non-maturing 1SW fish in 1993 that were destined to return in 1994. Management plans in 1994 should reflect this uncertainty based on in-season forecasts, particularly when it is unlikely that target requirements for MSW salmon will be met.

The significant shortfalls in egg deposition in 1993 above Mactaquac (50%) and in the Nashwaak River (<40%) may well reflect escapement levels in unmonitored portions of SFA 23. The Saint John area above Mactaquac (44%) and the Nashwaak River (17%) comprise 61% of the traditional estimate of total accessible salmon production area in the Saint John River basin. Estimated returns of fish 10^{-4} m^2 production area destined for Mactaquac, 1970-1985 (Marshall 1985), are:

	Wild 1SW	Wild MSW
Above Mactaquac	3.9	5.2
Below Mactaquac	2.4	2.5

A weak correlation between 1SW returns above and below Mactaquac, 1970-1985, (r^2=0.264, p=0.024, n=16) suggests that the record low returns of 1SW fish destined for Mactaquac in 1993 was paralleled by generally low 1SW returns below Mactaquac (evidenced in the estimated returns to the Nashwaak). Low 1SW returns inserted into MSW forecast models, such as those used above Mactaquac, provide correspondingly uncertain but low estimates of MSW returns the following year.

For the third consecutive year, wild MSW returns have been within 30% of those predicted. Investigations by Ritter *et al.* (1990) determined (Marshall *et al.* 1993 have since confirmed) 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 explained 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 early return of normally non-maturing salmon.

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Table 1. Estimated total returns of wild and hatchery 1SW and MSW salmon destined for Mactaquac Dam on the Saint John River, N.B., 1993.

Sea-age	Components	Wild	Hatch.	Total
1SW				
	Mactaquac counts(a)	2,873	1,034	3,907
	Angled MS below Mactaquac	232	83	315
	Native Food Fishery	44	16	60
	By-catch(b)	64	23	87
	Totals	3,213	1,156	4,369
MSW				
	Mactaquac counts(a)	2,601	379	2,980
	Native Food Fishery	209	31	240
	By-catch(b)	148	21	169
	Totals	2,958	431	3,389

(a) - Fishway closed Oct.26 (counts unadjusted); hatchery migration channel not operational until Sept. 15.

(b) - Proportions of 2% total 1SW returns and 5% total MSW returns, inc. unrecorded MSW losses to angling.

Table 2. Estimated homewater removals(a) of 1SW and MSW salmon destined for Mactaquac Dam on the Saint John River, N.B., 1993.

	1SW			MSW		
Components	Wild	Hatch.	Total	Wild	Hatch.	Total
Native Food Fishery						
Below Mact.	44	16	60	209	31	240
Above Mact.(b)	119	62	181	171	51	222
Recreational fishery						
Tobique River	286	86	372	-	-	-
Mainstem abv Mact.	125	40	165	-	-	-
Mainstem blw Mact.	232	83	315	-	-	-
Hook-release mort.(c)	0	0	0	35	4	39
Passed abv Tinker	99	36	135	74	10	84
Passed abv Grand F.	84	25	109	48	16	64
Passed blw Mact.	39	4	43	-	-	-
Hatchery broodfish	9	1	10	297	53	350
mortalities, etc.	32	41	73	60	12	72
Poaching/disease(d)	83	30	113	192	23	215
By-catch	64	23	87	148	21	169
Totals	1,216	447	1,663	1,234	221	1,455

(a) - Wild:hatchery composition per estimated availability.

(b) - Based on recovery of tags, assumed reporting rates and availability of fish (see text).

(c) - Assumed to be 2% of MSW salmon released above Mactaquac (excl. of those to food fishery abv Mact., Aroostook and Grand Falls).

(d) - Assumed to be 4% and 10% of all remaining 1SW and MSW fish respectively, above Mactaquac.

Table 3. Estimated homewater returns, removals and spawning escapement of 1SW and MSW salmon destined for/above Mactaquac Dam, Saint John River, 1993.

Sea-age	Components	Wild	Hatch.	Total
1SW				
	Homewater returns	3,213	1,156	4,369
	Homewater removals(a)	1,216	447	1,663
	Spawners(b)	2,080	739	2,819
	Target spawners			3,200
	% of target spawners			88
MSW				
	Homewater returns	2,958	431	3,389
	Homewater removals(a)	1,234	221	1,455
	Spawners(b)	1,916	233	2,149
	Target spawners			4,400
	% of target spawners			49

(a) - Includes Mactaquac broodfish and losses to poaching and disease (Table 2).

(b) - Excludes Mactaquac broodfish but includes losses to poaching and disease (Table 2).

Table 4. Adjusted Tobique River egg deposition/100m^2 (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 home-water removals in yr i+5 and i+6, and absence of removals in Newfoundland (col 8), and Greenland (col 9), and resultant MSW:1SW ratios. See App. 1-3 for derivation of col 2 and Table 5 for derivation of col 9.

Eggs/100m^2		1SW recruits (wild)			MSW recruits (wild)			Return + Nfld +Grnld	Ratio MSW /1SW
Years (1)	No. (2)	Year (3)	Number returns (4)	Length (5)	Year (6)	Number returns (7)	Return + Nfld (8)	(9)	(7/4)
1965-66		1970	3,057	54.7	1971	4,715			1.54
1966-67		1971	1,709	55.8	1972	4,899	5,724	10,599	2.87
1967-68		1972	908	57.0	1973	2,518	2,595	3,074	2.77
1968-69	42.70	1973	2,070	54.6	1974	5,811	6,411	10,011	2.81
1969-70	32.06	1974	3,656	56.1	1975	7,441	9,138	14,326	2.04
1970-71	66.26	1975	6,858	55.5	1976	8,177	11,913	15,181	1.19
1971-72	122.05	1976	8,147	55.5	1977	9,712	11,068	15,236	1.19
1972-73	82.47	1977	3,977	56.1	1978	4,021	5,637	5,975	1.01
1973-74	80.22	1978	1,902	56.4	1979	2,754	3,303	4,132	1.45
1974-75	391.21	1979	6,828	56.4	1980	10,924	11,684	16,197	1.60
1975-76	348.93	1980	8,482	58.1	1981	5,766	7,062	8,021	0.68
1976-77	267.20	1981	6,614	56.3	1982	5,528	5,934	7,773	0.84
1977-78	287.02	1982	5,174	55.4	1983	5,783	6,537	8,375	1.12
1978-79	173.40	1983	4,555	55.4	1984	9,779	11,484	11,694	2.15
1979-80	248.15	1984	8,311	55.6	1985	10,436	12,335	13,270	1.26
1980-81	229.42	1985	6,526	55.8	1986	6,128	7,803	9,269	0.94
1981-82	181.65	1986	7,904	57.6	1987	4,352	4,636	5,942	0.55
1982-83	99.63	1987	5,909	58.1	1988	2,625	4,132	5,615	0.44
1983-84	248.32	1988	8,930	58.6	1989	4,072	4,072	6,828	0.46
1984-85	362.09	1989	9,522	59.1	1990	3,329	4,333	5,075	0.35
1985-86	274.19	1990	7,263	58.6	1991	4,491	4,491	6,881	0.62
1986-87	208.86	1991	6,256	57.8	1992	4,104	4,104	5,505	0.66
1987-88		1992	6,683	58.5	1993	2,958	2,958	3,450	0.44
1988-89		1993	3,213	58.3	1994	_____		_____	
1989-90	180.20	1994	_____						

Table 5. Tag recoveries from non-maturing 1SW salmon in distant fisheries and 2SW salmon in homewaters; estimates of the raising factor for Saint John River 2SW returns in the absence of insular Newfoundland and Greenland commercial fisheries and estimates of theoretical MSW returns in the absence of those fisheries. (See Marshall 1993, for Nfld alone.)

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	2S	No. tag recoveries in smolt year + 1			Grnl	No. 2SW tags	Raise fact for home	Home	Home 2S ret + gain	Gain fr Nfld	MSW rtn Nfld+Grn
Smolt year	retn year	Nfld	Labr	Grnl	tag rept rate	recov'd at home	2SW rtns Nfld+Grn	2SW returns	Nfld+Grn (7/6)	+ Grn (8-7)	[Tab4(7)+ Tab5(9)]
1970	1972	2	0	12	0.8	14	0.4464	4,595	10,295	5,700	10,599
1971	1973	3	1	19	0.8	116	0.8096	2,362	2,917	556	3,074
1972	1974	3	0	16	0.7	32	0.5479	5,090	9,290	4,200	10,011
1973	1975	31	4	93	0.8	156	0.5031	6,972	13,858	6,885	14,326
1974	1976	23	5	23	0.9	60	0.5253	7,752	14,756	7,004	15,181
1975	1977	21	8	41	0.5	160	0.5980	8,216	13,741	5,524	15,236
1976	1978	44	11	7	0.6	127	0.6551	3,711	5,665	1,954	5,975
1977	1979	24	5	23	0.5	120	0.6131	2,184	3,562	1,378	4,132
1978	1980	19	7	86	0.6	316	0.6559	10,050	15,323	5,273	16,197
1979	1981	66	7	31	0.5	337	0.6999	5,259	7,513	2,255	8,021
1980	1982	8	3	23	0.5	120	0.6832	4,843	7,088	2,245	7,773
1981	1983	7	3	13	0.6	64	0.6803	5,517	8,109	2,592	8,375
1982	1984	8	2	1	0.8	56	0.8322	9,495	11,411	1,915	11,694
1983	1985	6	0	3	0.8	40	0.7804	10,071	12,904	2,834	13,270
1984	1986	9	1	8	0.8	38	0.6417	5,626	8,766	3,141	9,269
1985	1987	3	2	14	0.8	53	0.7153	3,995	5,585	1,590	5,942
1986	1988	17	3	17	0.8	36	0.4591	2,538	5,529	2,990	5,615
1987	1989	0	0	8	0.8	14	0.5858	3,897	6,653	2,756	6,828
1988	1990	4	2	3	0.8	15	0.6318	2,996	4,742	1,746	5,075
1989	1991	0	0	5	0.8	11	0.6400	4,248	6,638	2,390	6,881
1990	1992	0	0	4	0.8	14	0.7388	3,962	5,363	1,401	5,505
1991	1993	0	0	1	0.8	7	0.8498	2,783	3,276	492	3,450
						Mean, 1985-93 =	0.6714				

where:	Nfld tag rept rate=	0.7
	Labr tag rept rate =	0.9
	Survival home =	0.88
	Tag retention=	0.9
	Nfld/Lab n-ctch surv	0.9
	Grnl non-ctch surv=	0.8

Table 6. Forecasts of hatchery 1SW and MSW returns destined for Mactaquac, Saint John River, 1994, as estimated from numbers of various juveniles released at (At), above (Abv) or below (Bl), Mactaquac and estimated return rates.

Release				Returns in 1994			
Year	Loc.	Stage	Number	Rate	Age	1SW	MSW
1993	At	1-yr smolt	221,403	0.00406[d]	1.1	899	
1993	Bl	1-yr smolt(Nashw)	12,516	0.00406 @ 0.21[f]	1.1	11	
1991	Abv	Fall fing.	479,458[a]	0.00111[e]	2.1	532	
1991	Abv	Unfed/fry	173,524[a]	0.0003	2.1	52	
1990	Aroos	Adults ($eggs_{91}$)	105,000[b]	0.0004	2.1	42	
1990	Abv	Fall fing.	219,314	0.00020[e]	3.1	44	
1990	Abv	Unfed/fry	314,007[b]	0.00010?	3.1	31	
1992	At	1-yr smolt	204,836	0.00288[d]	1.2		590
1992	Bl[a]	1-yr smolt(Nashw)	13,645	0.00288 @0.21[f]	1.2		8
1990	Abv	Fall fing.	219,314	0.00020[e]	2.2		44
1990	Abv	Unfed/fry	314,007[b]	0.00010?	2.2		31
1989	Abv	Fall fing.	398,691[c]	0.00008[e]	3.2		32
1989	Abv	Unfed/fry	528,978[c]	0.00004?	3.2		21
		Repeat spawners		0.04 * $'93_{escpm}$			57
Totals						1,611	783

[a] Includes 139,323 fall fingerlings & 173,524 fry (5.0-5.6cm) to above Grand Falls.

[b] Not distinguishable from wild smolts.

[c] Inc. 242,245 fall fing. and 312,594 fry to Aroostook; 66,000 fry to above Grand Falls.

[d] See text for derivation.

[e] See App. 5.

[f] Marshall 1990, App.5, 1SW = mean of 1984-1989, 1991 '92 ratios; MSW = mean of 2SW 1985-1990 and 1992.

Table 7. Estimated river returns of Saint John River wild and hatchery 1SW and MSW salmon destined for Mactaquac Dam, 1970-1993.

	Wild		Hatchery		Total	
Year	1SW	MSW	1SW	MSW	1SW	MSW
1970	3,057	5,712				
1971	1,709	4,715				
1972	908	4,899				
1973	2,070	2,518				
1974	3,656	5,811				
1975	6,858	7,441	6,374	2,210	13,232	9,651
1976	8,147	8,177	9,074	2,302	17,221	10,479
1977	3,977	9,712	6,992	2,725	10,969	12,437
1978	1,902	4,021	3,044	2,534	4,946	6,555
1979	6,828	2,754	3,827	1,188	10,655	3,942
1980	8,482	10,924	10,793	2,992	19,275	13,916
1981	6,614	5,766	5,627	2,728	12,241	8,494
1982	5,174	5,528	3,038	1,769	8,212	7,297
1983	4,555	5,783	1,564	1,104	6,119	6,887
1984	8,311	9,779	1,451	1,115	9,762	10,894
1985	6,526	10,436	2,018	875	8,544	11,311
1986	7,904	6,128	862	797	8,766	6,925
1987	5,909	4,352	3,328	480	9,237	4,832
1988	8,930	2,625	1,250	912	10,180	3,537
1989	9,522	4,072	1,339	469	10,861	4,541
1990	7,263	3,329	1,541	796	8,804	4,125
1991	6,256	4,491	2,495	724	8,751	5,215
1992	6,683	4,104	2,257	794	8,940	4,898
1993	3,213	2,958	1,156	431	4,369	3,389

Table 8. Estimated landings (numbers of fish) of Native, sport, commercial and by-catch 1SW and MSW salmon originating at or above Mactaquac on the Saint John River, 1970-1993.

	Native(a)		Recreational(b)		Commercial		By-catch(c)		Total	
Year	1SW	MSW	1SW	MSW	1SW	MSW	1SW	MSW	1SW	MSW
1970			392	333	105	3,204			497	3,537
1971			319	357	57	2,391			376	2,748
1972			311	770			41	6	352	776
1973			704	420			37	60	741	480
1974	27	569	2,034	2,080			26	8	2,087	2,657
1975	73	739	3,490	1,474			70	56	3,633	2,269
1976	526	2,038	3,580	2,134			61	90	4,167	4,262
1977	64	1,070	2,540	3,125			109	156	2,713	4,351
1978	92	1,013	1,151	899			114	129	1,357	2,041
1979	328	771	2,456	589			55	69	2,839	1,429
1980	713	2,575	3,260	2,409			105	211	4,078	5,195
1981	361	891	2,454	1,085	2,749	3,666			5,564	5,642
1982	235	2,088	1,880	921	1,020	1,446			3,135	4,455
1983	203	588	1,453	637	786	4,173			2,442	5,398
1984	353	2,135	1,824				338	896	2,515	3,031
1985	471	2,526	3,060				412	1,771	3,943	4,297
1986	600	2,400	1,692				175	346	2,467	2,746
1987	280	1,120	1,650				185	242	2,115	1,362
1988	300	1,200	1,755				204	177	2,259	1,377
1989	560	240	2,304				217	27	3,081	267
1990	273	247	2,110				176	206	2,559	453
1991	657	957	1,690				175	261	2,522	1,218
1992	560	748	2,104				179	245	2,843	993
1993	241	462	852				87	169	1,180	631

(a)- Kingsclear, 1974-88, Tobique 1988-90, Kingsclear, St. Mary's, Oromocto and Tobique in 1991-93.

(b)- NBDNRE and DFO sources.

(c)- Guesstimates from various sources or assumed proportions (Table 1) of the run; inc. in commercial,1981-83.

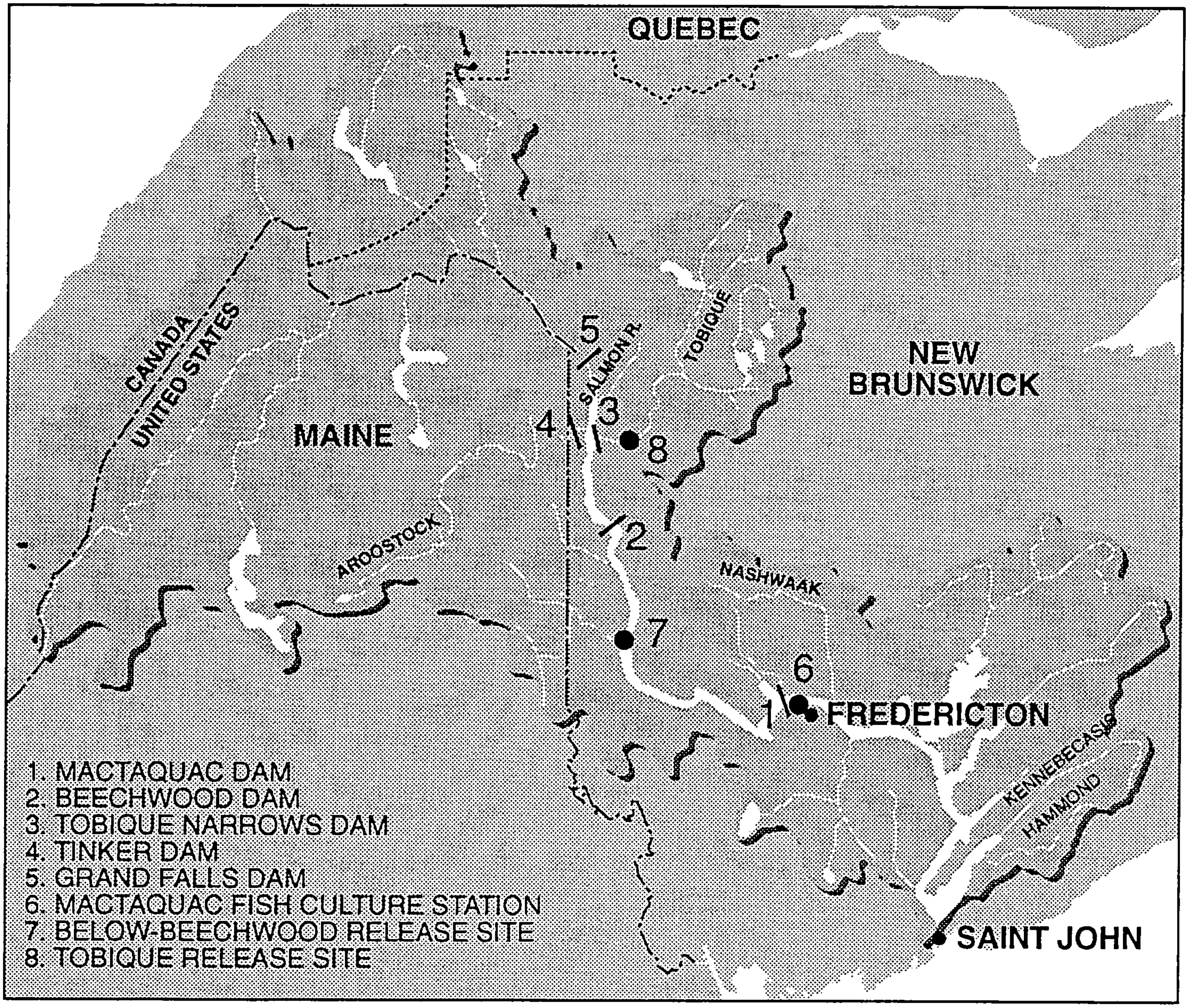


Fig. 1. Saint John River drainage, including major tributaries, dams and principal release sites for Atlantic salmon above Mactaquac.

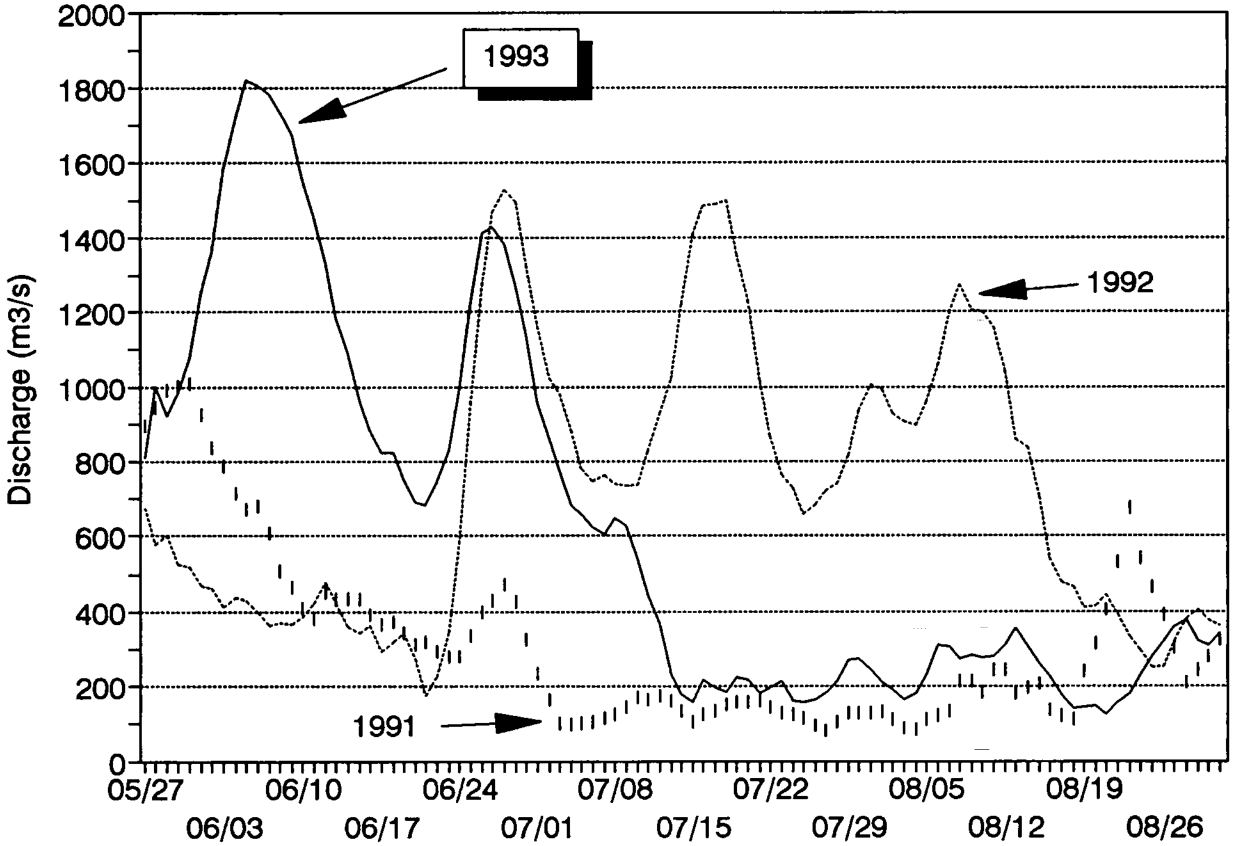


Fig. 2. Five-day moving averages of mean daily river discharge at Mactaquac, 1991 1992 and 1993.

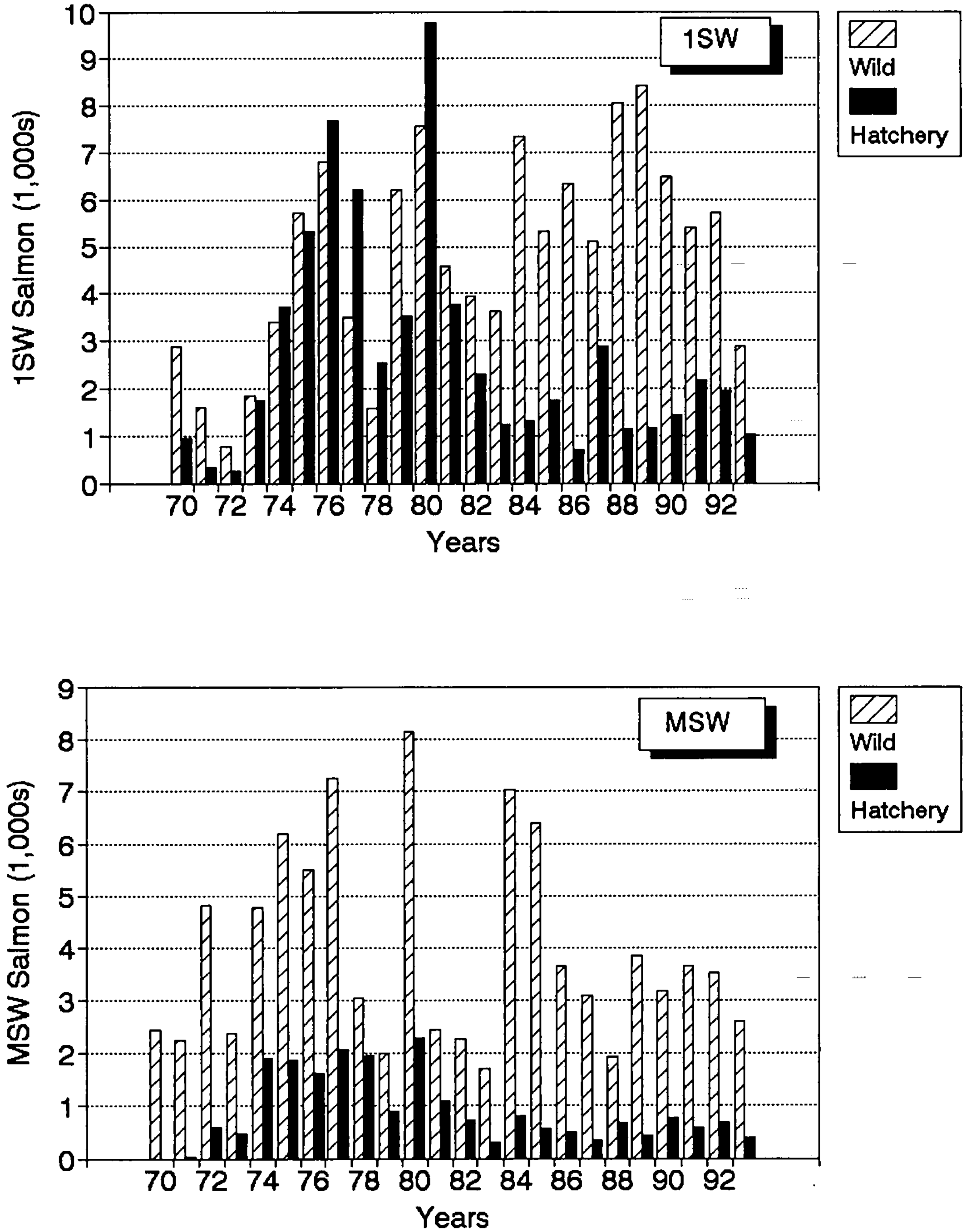


Fig. 3. Counts of wild and hatchery 1SW and MSW salmon at Mactaquac, 1970-1993.

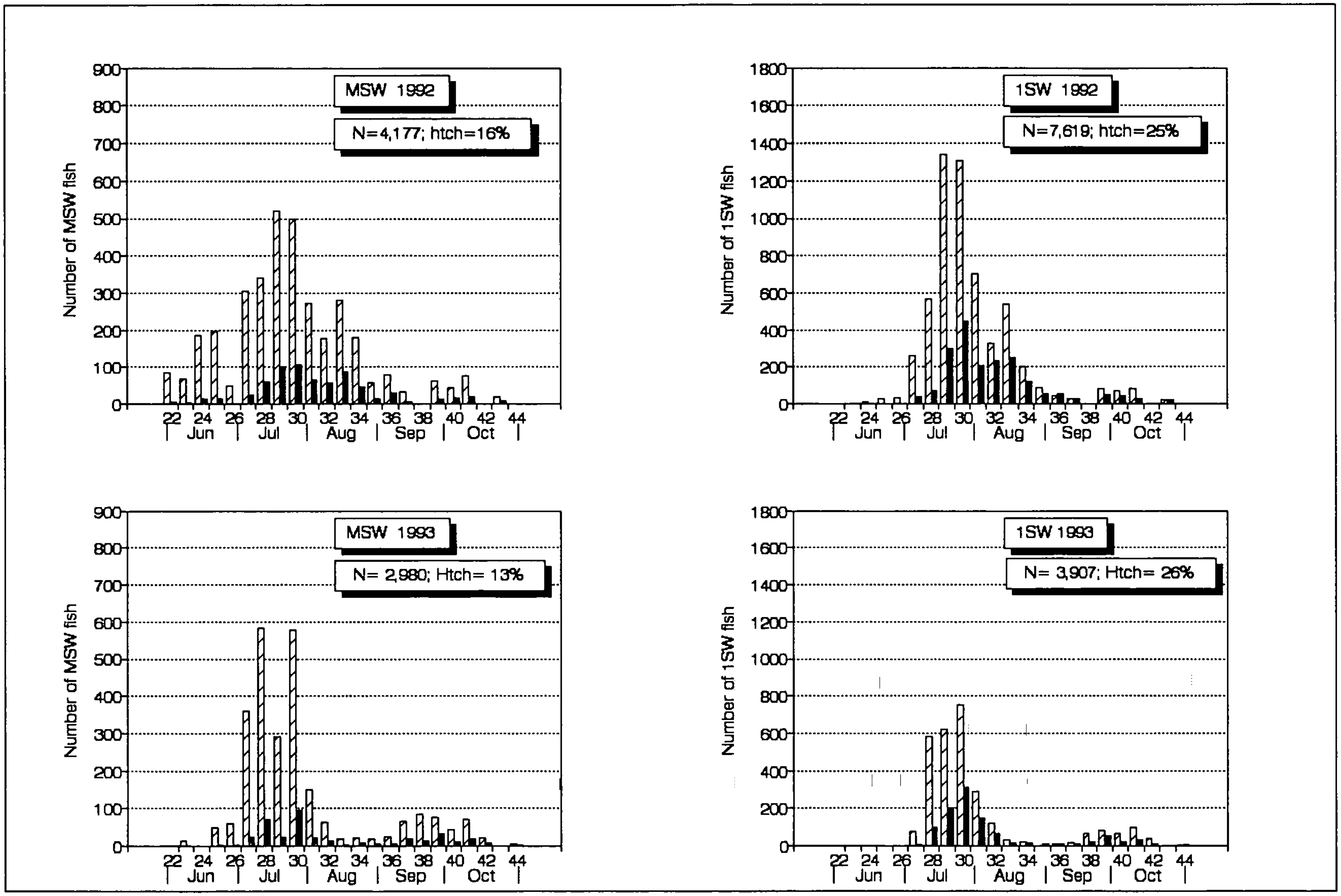


Fig.4. Weekly counts of wild (cross hatch) and hatchery (solid) 1SW and MSW salmon at the Mactaquac sorting facilities in 1992 (above) and 1993 (below).

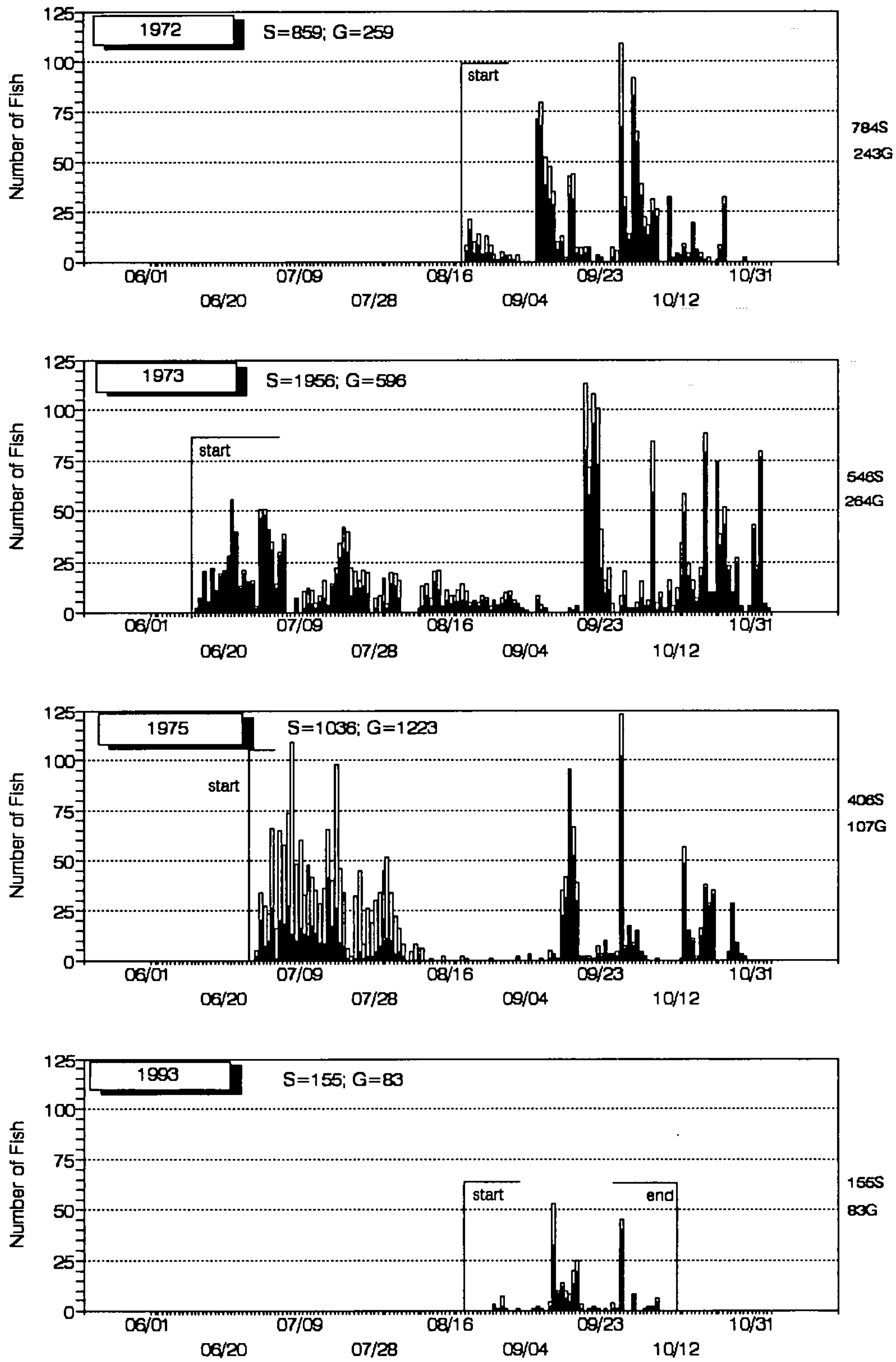


Fig. 5. Counts of 1SW (open bar) and MSW (filled bar) salmon at the Nashwaak River fence, 1972, 1973, 1975 and 1993. Numbers of fish in margin for period of operation in 1993.

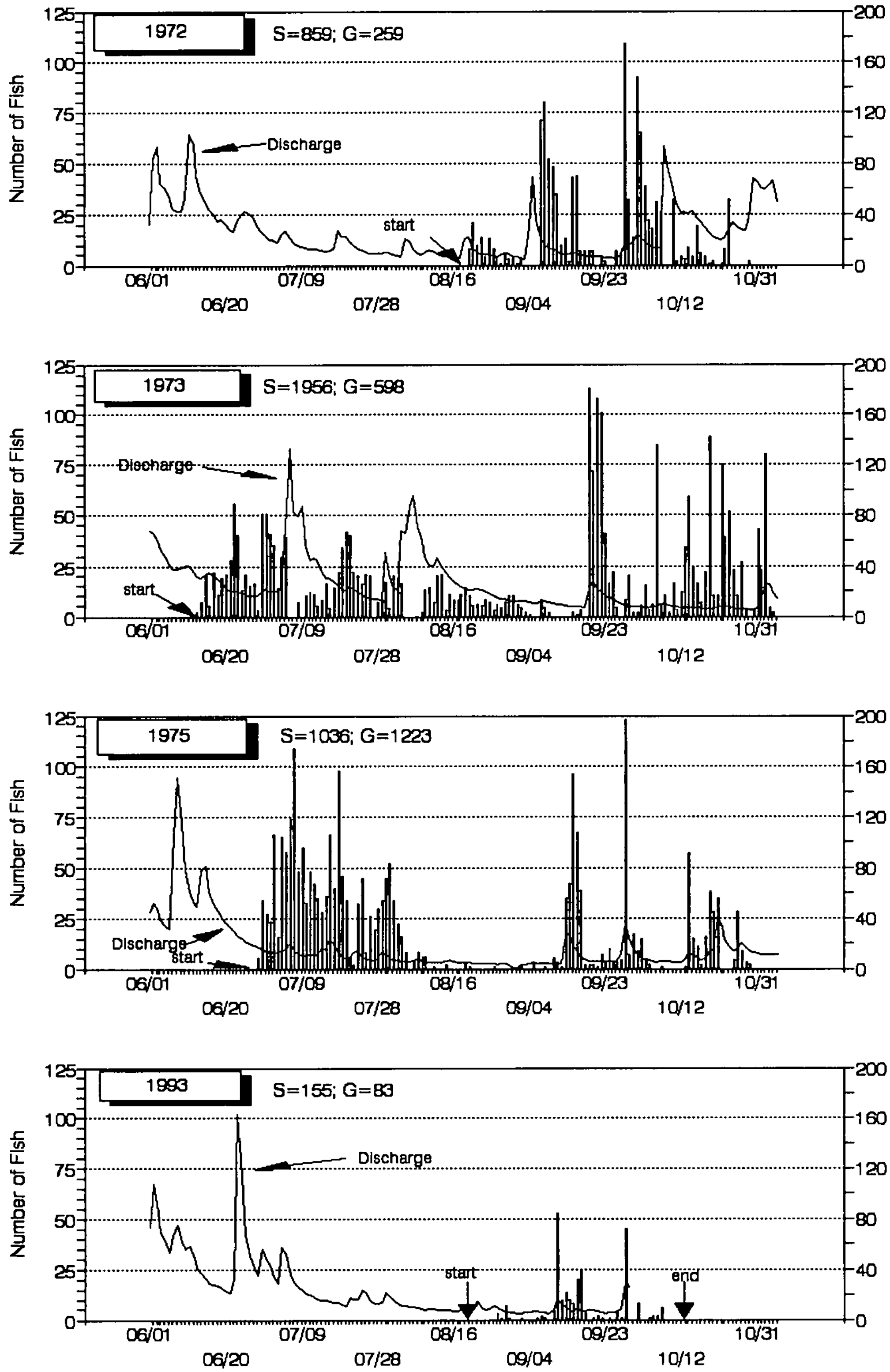


Fig. 6. Mean daily discharge (m3/s) at Durham Bridge and fence counts of salmon, Nashwaak River, 1972, 1973, 1975 and 1993.

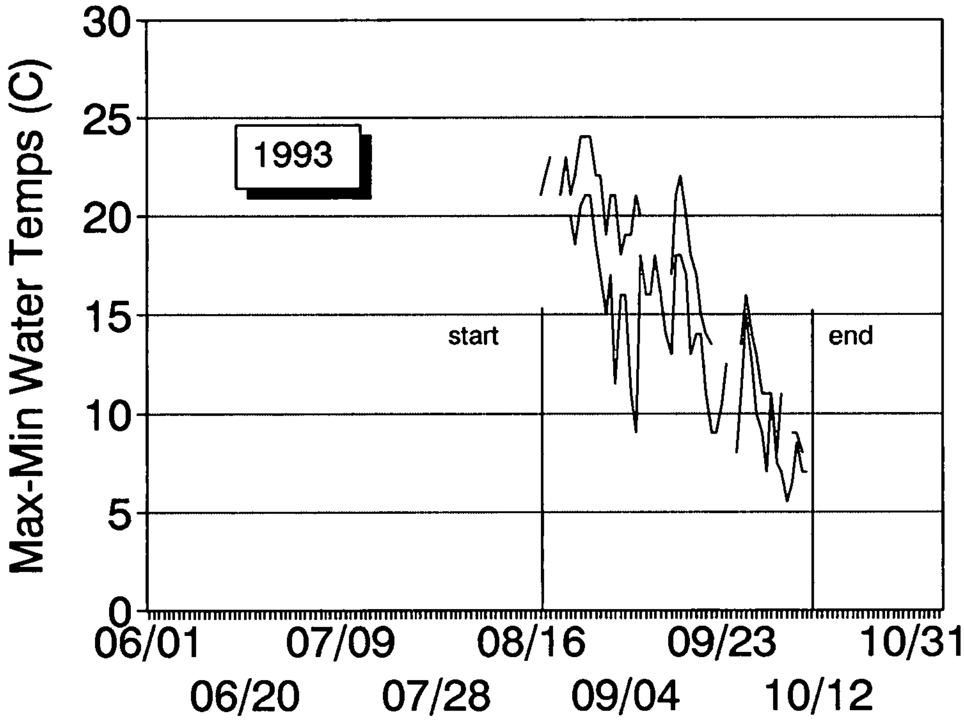
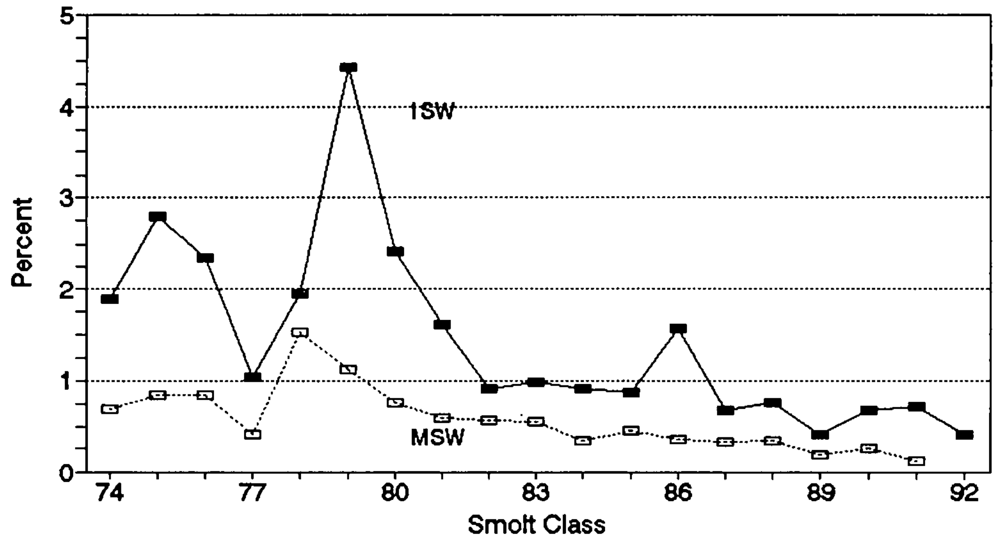


Fig. 7. Maximum-minimum water temperatures at the Nashwaak River fence, 1993.



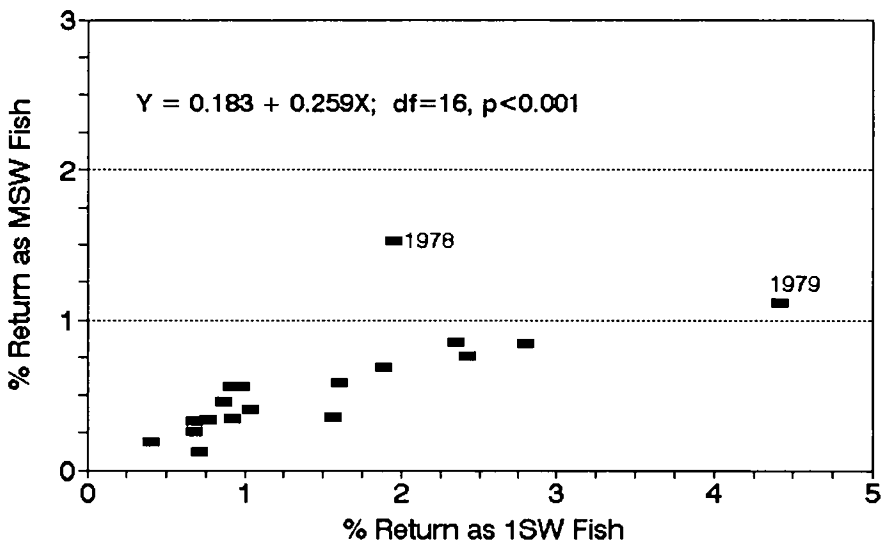


Fig. 8. Returns of 1SW and MSW (2SW) salmon from smolts released at Mactaquac, 1974 - 1992.

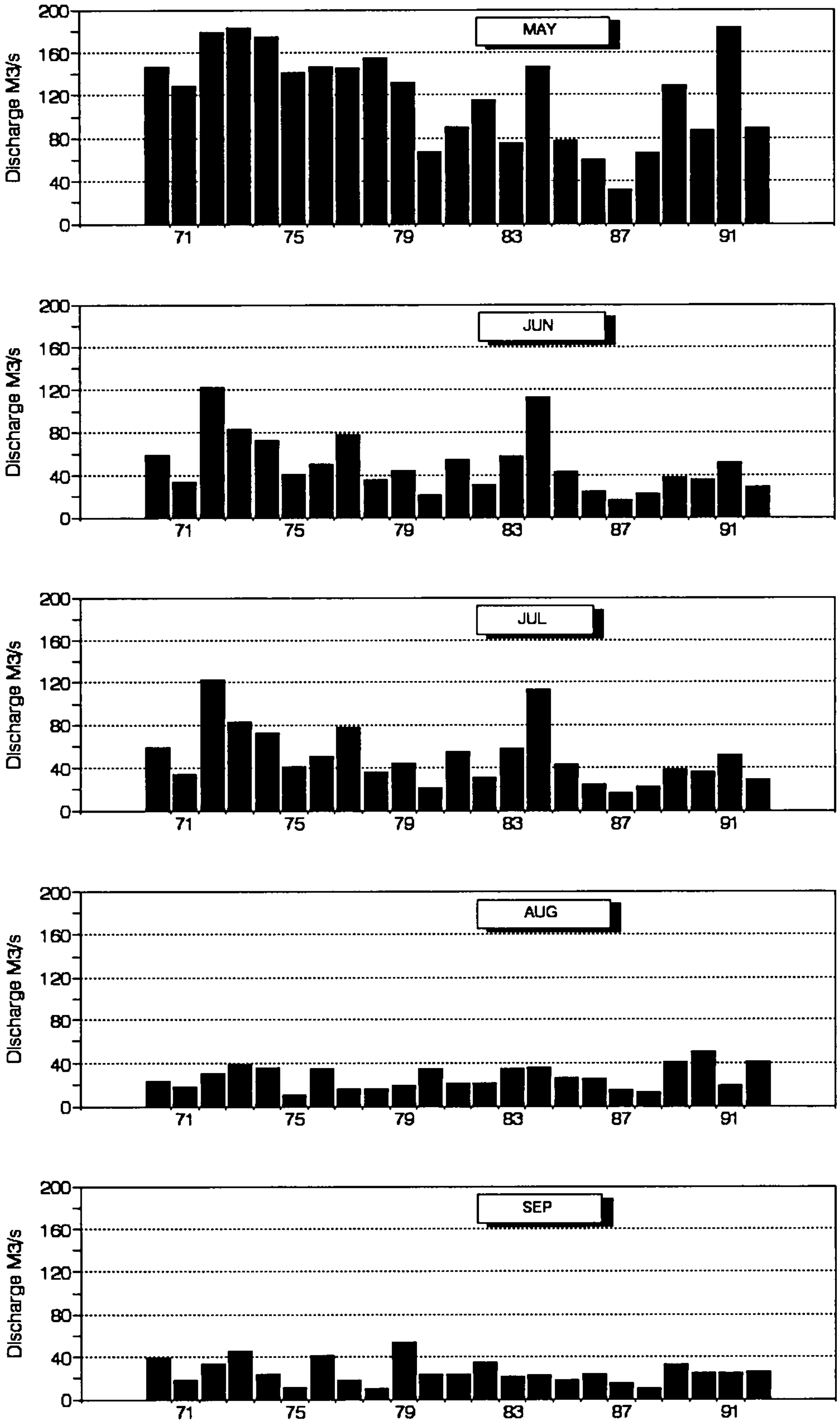


Fig. 9. Monthly mean discharge, Tobique R. at Riley Brook, 1970-1992.

App. 1. Number of eggs/100^2 deposited in the Tobique River, 1968-1990, and derivation of weighted number of eggs contributing to annual returns of wild 1SW fish at Mactaquac, 1973-1991 and 1994 (explanation in Penney and Marshall 1984; revisions per Marshall 1993).

Egg depostion		Proportion age at smoltification (a)		Eggs/100m^2 contributing to 1SW fish		Total wt'd egg contrib/ 100 m^2 to 1SW fish	
Year	Number	Age 2	Age 3	Yr i	Yr i+1	@ Mact	(year)
1968	34.6	0.207					
			0.793		27.44		
1969	34.3	0.445		15.26		42.70	(1973)
			0.555		19.04		
1970	48.4	0.269		13.02		32.06	(1974)
			0.731		35.38		
1971	73.7	0.419		30.88		66.26	(1975)
			0.581		42.82		
1972	128.0	0.619		79.23		122.05	(1976)
			0.381		48.77		
1973	82.0	0.411		33.70		82.47	(1977)
			0.589		48.30		
1974	280.0	0.114		31.92		80.22	(1978)
			0.886		248.08		
1975	399.8	0.358		143.13		391.21	(1979)
			0.642		256.67		
1976	257.7	0.358		92.26		348.93	(1980)
			0.642		165.44		
1977	313.1	0.325		101.76		267.20	(1981)
			0.675		211.34		
1978	197.6	0.383		75.68		287.02	(1982)
			0.617		121.92		
1979	116.2	0.443		51.48		173.40	(1983)
			0.557		64.72		
1980	378.2	0.485		183.43		248.15	(1984)
			0.515		194.77		
1981	124.2	0.279		34.65		229.42	(1985)
			0.721		89.55		
1982	156.9	0.587		92.10		181.65	(1986)
			0.413		64.80		
1983	77.4	0.450		34.83		99.63	(1987)
			0.550		42.57		
1984	391.9	0.525		205.75		248.32	(1988)
			0.475		186.15		
1985	340.3	0.517		175.94		362.09	(1989)
			0.483		164.36		
1986	224.6	0.489		109.83		274.19	(1990)
			0.511		114.77		
1987	195.2	0.482		94.09		208.86	(1991)
			0.518		101.11		
1988	137.3						
1989	185.5						
			0.536		99.43		
1990	174.1	0.464		80.78		180.21	(1994)

(a) Derived from App.2 and 3.

Underscored value is mean of last 10 years (angular transformation).

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 1969-1988 year-classes if they had not been exploited within the river, 1972-1993.

Year-class (i)	Number at age of 1SW returns to Mactaquac 2:1 (i+3)	3:1 (i+4)	4:1 (i+5)	Total	Prop. 2:1's of 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	622	9,688	0.358
1977	2,486	4,140	310	6,936	0.358
1978	1,852	3,819	14+6	5,691	0.325
1979	1,045	1,589	91+6	2,731	0.383
1980	2,952	3,540	176	6,668	0.443
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+12	10,686	0.525
1986	4,437	4,009	141	8,587	0.517
1987	2,963	2,952	148	6,063	0.489
1988	3,151	3,336	50	6,537	0.482
1989	3,199	963			
1990	2,200				

App. 3. Freshwater age and number of <u>wild</u> 1SW fish (A) counted at Mactaquac fish passage facilities, Saint John River, 1980-1993, and (B) that would have returned to Mactaquac had they not been exploited within the river, 1980-1993.

Fresh-water age	Number of 1SW fish													
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
A														
2	2,214	1,280	794	2,348	4,140	1,264	3,196	2,513	5,066	3,922	2,646	2,728	2,743	1,967
3	4,986	2,861	2,902	1,264	3,132	3,913	3,001	2,349	2,930	4,217	3,580	2,555	2,859	861
4	355	430	236	11	81	144	150	233	66	278	260	122	127	45
5							5					10		
6							5							
Total	7,555	4,571	3,932	3,623	7,353	5,331	6,347	5,095	8,062	8,417	6,486	5,415	5,729	2,873
B														
2	2,486	1,852	1,045	2,952	4,679	1,548	3,980	2,915	5,612	4,437	2,963	3,151	3,199	2,200
3	5,598	4,140	3,819	1,589	3,540	4,790	3,737	2,724	3,245	4,771	4,009	2,952	3,336	963
4	398	622	310	14	91	176	187	270	73	314	291	141	148	50
5							6					12		
6							6							
Total	8,482	6,614	5,174	4,555	8,311	6,526	7,904	5,909	8,930	9,522	7,263	6,256	6,683	3,213

App. 4. Estimated total number of 1SW and MSW returns to the Saint John River from **hatchery-reared smolts released at** Mactaquac, 1974-1993. (inc. potential sea-cage fish numbering 8, 56 and 34 of age 1.1 and 221, 24 and 16 of age 1.2 in 1990, 1991 and 1992, respectively).

Releases			Returns (1SW and MSW)									
		Prop		Mactaquac		Native	Angled	By-	Commer-		% return	
Year	Smolts	1-yr	Year	Mig ch	Dam	fishery	main SJ	catch	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		1,356	5,627	2.423	
81	189,090	0.08	82	828	1,464	64	267		415	3,038	1.607	
82	172,231	0.06	83	374	857	39	69		225	1,564	0.908	
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	(903)		0	57	20		980	0.411	0.405
90	241,078	0.98	91	(1,490)		88	108	35		1,721	0.714	0.676
91	178,127	0.97	92	(1,123)		26	135	26		1,310	0.735	0.711
92	204,836	1.00	93[b]	(743)		11	60	17		831	0.406	0.406
93	221,403	1.00										
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		1,262	2,728	1.118	
80	232,258		82	88	640	462	181		398	1,769	0.762	
81	189,090		83	44	255	76	17		712	1,104	0.584	
82	172,231		84	84	722	201	5	103		1,115	0.647	0.560
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	(379)		0	0	20		399	0.352	0.330
88	142,195		90	(480)		0	0	25		505	0.355	0.333
89	238,204		91	(359)		62	0	46		467	0.196	0.186
90	241,078		92	(546)		58	0	32		636	0.264	0.264
91	178,127		93[b]	(196)		16	0	11		223	0.125	0.125
92	204,836											

[a] Includes returns from downriver stocking of smolts, 1981-1992; adjusted return rate excludes downriver returns to Mactaquac (Marshall 1989). (Marginal numbers of returns from approx. 5,000 age 2.1 smolts not inc., 1989-'91.); no tag returns from downriver releases in 1993.

[b] 1SW and MSW fish at Mactaquac were assigned an origin on the basis of freshwater age (scale reading) and fin clips, i.e., 1SW93: age 1.1_{Mact} @ 0.72, age $2.1_{juv's}$ @ 0.21, age 3.1 @ 0.07; MSW_{93}: age 1.2 & 2.2_{Mact} @ 0.52, age 1.2 & $2.2_{abv\ Mact\ CWTs}$ @ 0.09, age 2.2 & $3.2_{juv's}$ @ 0.39. Erosion/ regeneration of upper + lower margin of caudal fin suggested only 6 fish (mostly MSW) of aquaculture origin.

App. 5. Estimated hatchery 1SW and MSW returns destined for Mactaquac, Saint John River, 1993, and return rates, as derived from numbers of various juveniles released at (At), above (Abv) or below (Bl) Mactaquac and subsequent returns.

Release				Returns in 1993			
Year	Loc.	Stage	Number	Rate	Age	1SW	MSW
1992	At	1-yr smolt	204,836[a]	0.00406	1.1	831	
1992	Bl[a]	1-yr smolt(Nashw)	13,645	0.0	1.1	0	
1990	Abv	Fall fing.	219,314	0.00111	2.1	243	
1990	Abv	Unfed/fry	314,007[e]	unknown	2.1	-	
1989	Abv	Fall fing.	398,691	0.00021	3.1	82	
1989	Abv	Unfed/fry	528,978[e]	unknown	3.1	-	
1991	At	1-,2-yr smolt	178,127[a]	0.00125	1-,2.2		223
1991	Bl[a]	1-yr smolt	37,106	0.0	1.2		0
1991	Abv	1-,2-yr smolt	49,836[b]	0.00078	1-,2.2		39
1990	Abv	1^+ parr (SALEN)	9,900		2.2		
1989	Abv	Fall fing.	398,691[d]	0.00020	2.2		82
1989	Abv	Unfed/fry	528,978[de]	unknown	2.2		-
1988	Abv	Fall fing.	906,039[c]	0.00008	3.2		73
1988	Abv	Unfed/fry	209,882[ce]	unknown	3.2		-
		Repeat spawners		0.00960			14
Totals						1,156	431

[a] Mactaquac origin, only; 1991 inc. two groups of CWT Ad-clipped fish.

[b] Downstream passage trials above Mactaquac.

[c] Inc. 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.

[d] Inc. 242,245 fall fing. and 312,594 fry to Aroostook; 66,000 fry to above Grand Falls

[e] Not distinguishable from wild smolts.

Appendix 6

STOCK: Saint John River, N.B. (*above Mactaquac*) SFA 23
TARGET: 29.4 million eggs (4,400 MSW and 3,200 1SW fish)

Year	1988	1989	1990	1991	1992	1993[3]	MIN	MAX	Mean
Harvest:									
Native									
Small	300	560	273	657	560	241	241[2]	657[2]	470[2]
Large	1200	240	247	957	748	462	240[2]	1200[2]	678[2]
Recreational:									
Small	1755	2304	2110	1690	2104	852	852[1]	3580[1]	2248[1]
Counts:									
1SW	9191	9587	7907	7575	7664	3907	3907[1]	17314[1]	8793[1]
MSW	2600	4291	3919	4226	4203	2980	2010[1]	10451[1]	5164[1]
Returns:									
1SW	10180	10861	8804	8751	8940	4369	4369[1]	19275[1]	10235[1]
MSW	3537	4541	4125	5215	4898	3389	3389[1]	13916[1]	7356[1]
Spawning:									
1SW	7810	7533	6057	5721	5128	2819	2819[2]	7810[2]	6450[2]
MSW	1704	3491	3202	3481	3269	2149	1704[2]	3491[2]	3029[2]
% of Target met:									
1SW	244	235	189	179	160	88	88[2]	244[2]	201[2]
MSW	39	79	73	79	74	49	39[2]	79[2]	69[2]
Eggs	50	95	85	87	81	51	50[2]	95[2]	80[2]

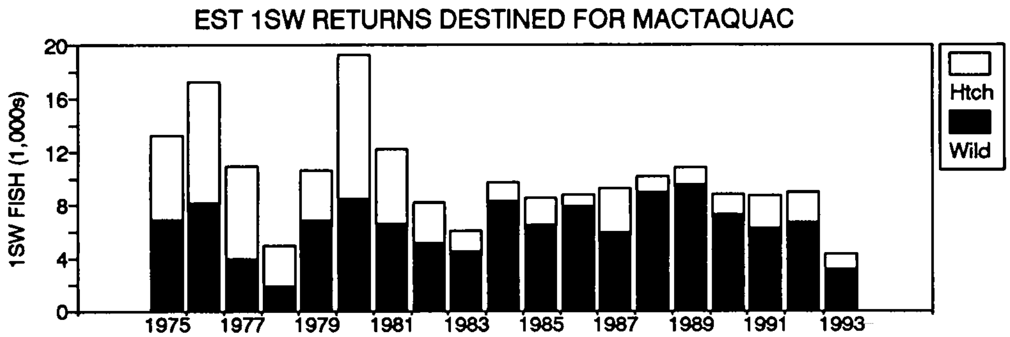
[1] For the period 1975-1992.
[2] For the period 1988-1992.
[3] Preliminary data.

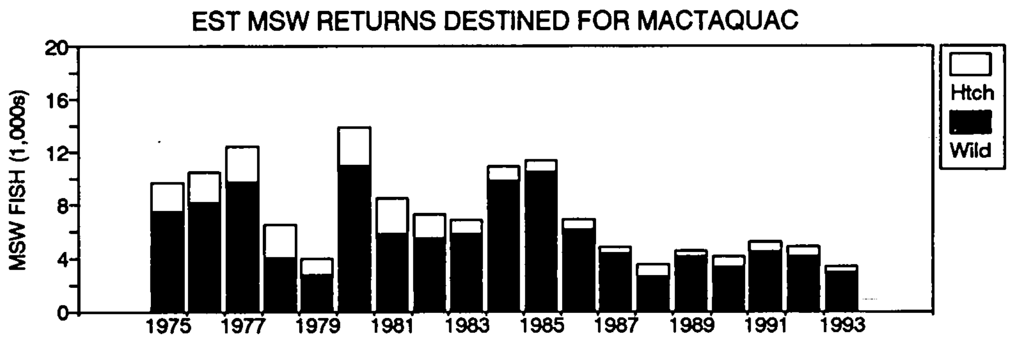
Harvests: The harvest by First Nations reflects poor river returns, voluntary lifting of some nets and a late closeure for conservation purposes. MSW salmon have not been retained since 1984; 1SW harvests were the lowest in 20 years because of low returns and a reduced angling season. The harvest by First Nations reflects poor river returns, voluntary lifting of some nets and a late closure for conservation purposes.

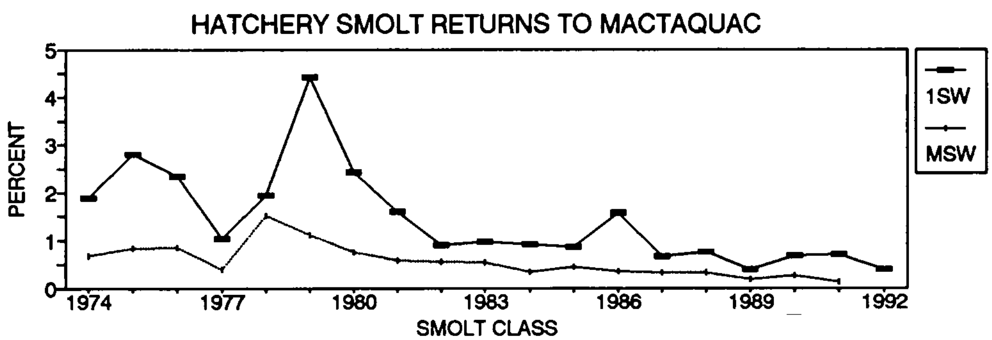
Data and methodology: Counts of fish obtained from the collection facility at Mactaquac Dam; returns to Dam equal counts plus estimates of down river removals. Spawners equal releases above Mactaquac minus estimates of upriver removals, not including poaching and disease.

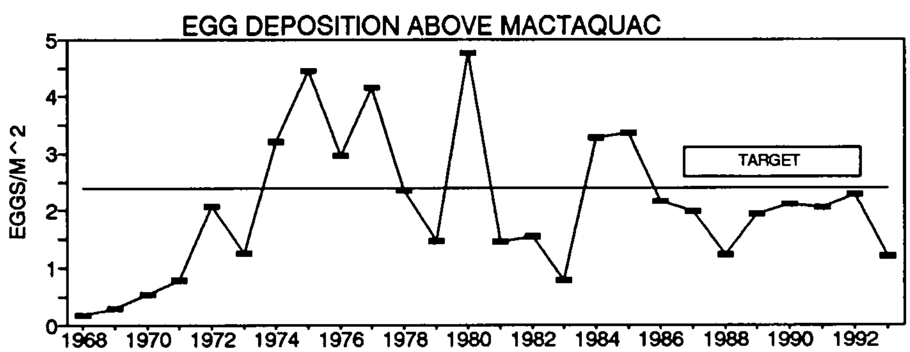
State of the stock(see over): 1SW and MSW returns were the fewest in 19 years. Egg deposition (nearly all from MSW fish) was 51% of requirement; the target has not been met since 1985. Hatchery fish comprised 26% of 1SW and 13% of MSW returns; return rates for hatchery smolts were virtually the lowest of record.

Forecast: 1SW returns destined for Mactaquac in 1994 could number 8,000 fish (6,400 wild and 1,600 of hatchery origin). However, because of the very low marine survival in 1993 and, quite possibly in 1994, returns, like those of 1993, could be only one-half of the forecast value. In any event, the return should exceed the target spawning requirements of 3,200 1SW fish above Mactaquac. Forecast MSW returns destined for Mactaquac in 1994 could number 3,100 (2,300 wild and 800 of hatchery origin) or 4,800 fish (3,600 wild and 1,200 of hatchery origin) depending on models supposing either none or total benefits, respectively, from the moratoria in distant fisheries. The model that ascribed no benefits from the moratorium in Newfoundland best forecasted the 1993 MSW return but the reason may have been the low marine survival. Neither MSW forecast fully accounts for potentially low marine survival in the winter of 1994 or the fact that the 1SW and fork length data used to predict MSW returns were, together, outside the range of data in the models. Therefore, it is likely that MSW returns will be inadequate, with incidental losses below Mactaquac and the removal of 400 MSW broodstock at Mactaquac, to meet the 4,400 target spawning requirements for MSW fish above Mactaquac or requirements for salmon development initiatives in the Aroostook River and above Grand Falls. Early in-season forecasts are the best basis for determining a tolerable level of harvesting in 1994.









App. 6. Stock status of Atlantic salmon, Saint John River above Mactaquac, various years to 1993.