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Status of Atlantic salmon stocks of the Saint John River and southwest New Brunswick, 1994

by

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[1]This series documents the scientific basis for the evaluation of fisheries resources in Atlantic Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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[1]La présente série documente les bases scientifiques des évaluations des ressources halieutiques sur la côte atlantique du Canada. Elle traite des problèmes courants selon les échéanciers dictés. Les documents qu'elle contient ne doivent pas être considérés comme des énoncés définitifs sur les sujets traités, mais plutôt comme des rapports d'étape sur les études en cours.

Les Documents de recherche sont publiés dans la langue officielle utilisée dans le manuscrit envoyé au secrétariat.

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ABSTRACT

Total 1SW (3,534) and MSW (2,375) returns destined for above Mactaquac were the fewest in at least 20 years. The proportion of the run identifiable as hatchery fish increased to 36% of 1SW and 22% of MSW returns; return rates for hatchery smolts were among the lowest of record. Spawners numbered 2,901 1SW fish and 1,647 MSW salmon, 91% and 37% of the respective targets. Egg deposition (89% from MSW fish) was 39% of requirement; the target has not been met since 1985.

Counts at the Nashwaak fence contributed to an estimated return of 661 1SW and 388 MSW salmon. Estimated spawners numbered 610 1SW and 349 MSW fish, or 40% and 22% of respective targets. Egg depositions were estimated at 31% of target - 5% less than in 1993.

External and scale characteristics of 1,064 1SW and 228 MSW salmon captured in the Magaguadavic River trap indicated that only 69 1SW and 61 MSW salmon were of wild origins - the lowest of record. The effective female escapement was estimated at 31 1SW and 91 MSW fish because many sea-cage fish were removed and the remainder were determined to be immature. Potential egg deposition was 56% of target; 44% of the eggs were of sea-cage origin fish. Returns to the St. Croix River remained among the lowest of record. Egg deposition was about 3% of requirement.

1SW returns destined for Mactaquac in 1995 may be no fewer than those of 1994 (3,500) and could number 4,000 or 5,000 fish if marine survival paralleled the slight improvement noted in the index of winter habitat, if increased hatchery stocking of juvenile salmon contributed to more smolts in 1994, and if, as suggested, turbine by-pass rates for 1994 smolts were the best in recent years. In any event, the return should equal and may exceed target spawning requirements of 3,200 1SW fish above Mactaquac.

MSW returns destined for Mactaquac in 1995 could number as few as 2,200 or 2,500 fish depending on models and assumptions. Hence it is highly unlikely that MSW returns will be adequate to meet the 4,400 target spawning requirements for MSW fish above Mactaquac.

RÉSUMÉ

Les remontées totales de saumons unibermarins (3 534) et pluribermarins (2 375) vers l'amont de Mactaquac, ont été les plus basses depuis au moins 20 ans. La contribution identifiable des saumons d'écloserie aux remontées a augmenté et s'est établie à 36 % des unibermarins et à 22 % des pluribermarins; les taux de remontée des saumoneaux d'écloserie étaient parmi les plus bas à ce jour. Le nombre de frayeurs s'établissait à 2 901 unibermarins et 1 647 pluribermarins, soit 91 % et 37 % des cibles respectives. La ponte (89 % provenant de pluribermarins) correspondait à 39 % des besoins, lesquels n'ont pas été comblés depuis 1985.

D'après les dénombrements effectués à la barrière de la Nashwaak, on a estimé les remontées à 661 unibermarins et 388 pluribermarins. Le nombre approximatif de frayeurs était de 610 unibermarins et 349 pluribermarins, soit 40 % et 22 % des cibles respectives; on a chiffré la ponte à environ 31 % de la cible, ce qui représente une diminution de 5 % par rapport à 1993.

D'après les caractéristiques extérieures et celles des écailles de 1 064 unibermarins et de 228 pluribermarins capturés au piège de la Magaguadavic, seuls 69 unibermarins et 61 pluribermarins étaient d'origine sauvage; ces chiffres sont les plus bas jamais enregistrés. On a estimé à 31 parmi les unibermarins et à 91 parmi les pluribermarins les échappées réelles de femelles, compte tenu du retrait de nombreux poissons provenant de cages marines et du fait que les poissons restants ont été jugés immatures. La ponte potentielle se situait à 56 % de la cible; 44 % des oeufs provenaient de poissons élevés en cage marine. Pour leur part, les remontées dans la St. Croix sont restées parmi les plus basses à ce jour. La ponte ne correspondait qu'à environ 3 % des besoins.

Il se pourrait que les remontées d'unibermarins vers Mactaquac en 1995 ne soient pas inférieures à celles de 1994 (3 500). Elles pourraient atteindre 4 000 ou 5 000 poissons si la survie en mer suit la légère amélioration observée dans l'indice de l'habitat hivernal, si l'accroissement des opérations d'empoissonnement en saumons juvéniles se traduit par une augmentation du nombre de saumoneaux en 1994 et si, comme cela le semble, les taux d'évitement des turbines par les saumoneaux en 1994 étaient les meilleurs des dernières années. Quoi qu'il en soit, les remontées devraient être égales, voire supérieures, aux besoins-cibles en géniteurs, chiffrés à 3 200 unibermarins, en amont de Mactaquac.

Quant aux remontées de pluribermarins vers Mactaquac en 1995, elles pourraient ne pas dépasser les 2 200 à 2 500 poissons, selon les modèles et les hypothèses. Il est donc peu probable qu'elles suffisent à combler les besoins-cibles en géniteurs pluribermarins, chiffrés à 4 400, en amont de Mactaquac.

SUMMARY SHEET (PART 1)

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

Year	1989	1990	1991	1992	1993	1994[3]	MIN	MAX	Mean
Harvest:									
Native									
Small	560	273	657	560	241	250	241[2]	657[2]	458[2]
Large	240	247	957	748	462	90	240[2]	957[2]	531[2]
Recreational:									
Small	2304	2110	1690	2104	852	0	852[1]	3580[1]	2174[1]
Counts:									
1SW	9587	7907	7575	7664	3907	3313	3907[1]	17314[1]	8552[1]
MSW	4291	3919	4226	4203	2980	2206	2010[1]	10451[1]	5050[1]
Returns:									
1SW	10861	8804	8751	8940	4369	3534	4369[1]	19275[1]	10057[1]
MSW	4541	4125	5215	4898	3389	2375	3389[1]	13916[1]	7333[1]
Spawning:									
1SW	7533	6057	5721	5128	2819	2901	2819[2]	7533[2]	6031[2]
MSW	3491	3202	3481	3269	2149	1647	2149[2]	3491[2]	3118[2]
% of Target met:									
1SW	235	189	179	160	88	91	88[2]	235[2]	170[2]
MSW	79	73	79	74	49	37	49[2]	79[2]	71[2]
Eggs	95	85	87	81	51	39	51[2]	95[2]	80[2]

[1] For the period 1975-1993.
[2] For the period 1989-1993.
[3] Preliminary data.

Harvests: The harvest by Native peoples reflects a late opening of the season, poor river returns, and ineffectiveness of some trapnets relative to retired gill nets. Hook-and-release regulations in the recreational fishery eliminated the harvest of 1SW fish.

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

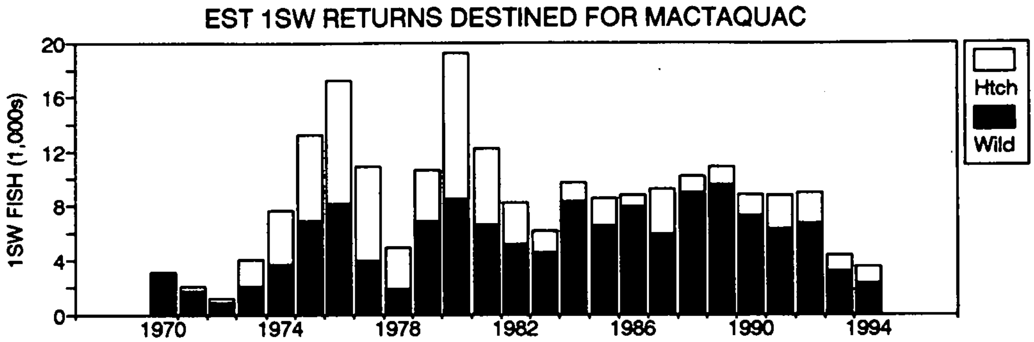
State of the stock: 1SW and MSW returns were the fewest in 20 years. Egg deposition (89% from MSW fish) was 39% of requirement; the target has not been met since 1985. Identifiable hatchery fish increased to 36% of 1SW and 22% of MSW returns; return rates for hatchery smolts correlate with a 20-year index of marine winter habitat and remain among the lowest of record.

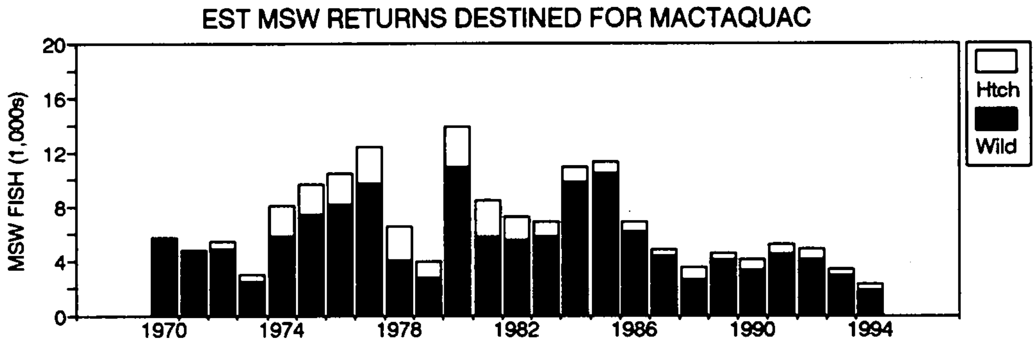
Forecasts: 1SW returns destined for Mactaquac in 1995 may be no fewer than those of 1994 (3,500) and could number 4,000 or 5,000 fish if marine survival paralleled the slight improvement noted in the index of winter habitat, if increased hatchery stocking of juvenile salmon contributed to more smolts in 1994, and if, as suggested, turbine by-pass rates for 1994 smolts were the best in recent years. In any event, the return should equal and may exceed target spawning requirements of 3,200 1SW fish above Mactaquac.

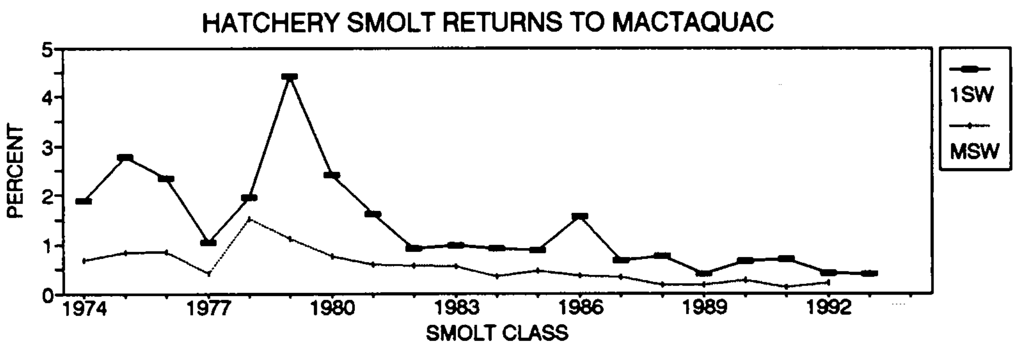
MSW returns destined for Mactaquac in 1995 could number as few as 2,200 or 2,500 fish depending on models and assumptions. Hence it is highly unlikely that MSW returns will be adequate to meet the 4,400 target spawning requirements for MSW fish above Mactaquac.

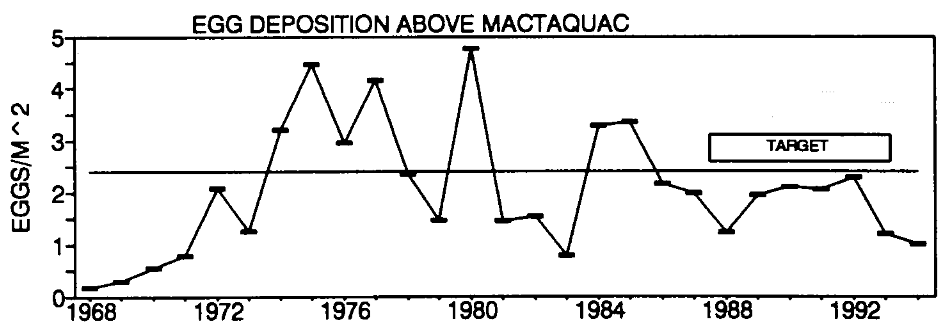
Early in-season forecasts and client consultations in 1995 will be necessary to determine the utility of any surplus 1SW fish.

SUMMARY SHEET (PART 2)









Stock status of Atlantic salmon, Saint John River above Mactaquac, various years to 1994.

INTRODUCTION

This document is background to the management of Atlantic salmon stocks of the **Saint John River above Mactaquac**, the **Nashwaak River** (tributary to the Saint John below Mactaquac), and the **Magaguadavic** and the **St. Croix** rivers of south and western New Brunswick. Each river and its stock is grouped within the "outer-Fundy" complex of rivers within Salmon Fishing Area 23 (SFA 23), New Brunswick. The stocks of these rivers differ from "inner-Fundy" rivers (east of the Saint John) in that they have a significant two-sea-winter (2SW) component that frequents distant waters of insular Newfoundland, Labrador and Greenland as non-maturing one-sea-winter (1SW) fish.

As in recent years, data and analyses of Saint John River stocks pertain largely to the status in 1994, and forecasts for 1995, of those stocks originating above Mactaquac. Data and analyses of the status of salmon in the Nashwaak River, below Mactaquac, were again possible because of cooperative agreements with the St Mary's (1993 and 1994) and Kingsclear First Nations (1994). Overviews provided by the Magaguadavic Watershed Management Committee of the status of stocks in the Magaguadavic River and by the St. Croix Recreational Fisheries Development Program for the St. Croix River are a continuation of base material included in the former annual series of Scotia-Fundy status reports on Atlantic salmon, e.g., Cutting et al. 1994. No significantly new approaches were taken in these assessments.

Fishery regulations common to all outer Fundy rivers of SFA 23 in 1994 were the continued closure of the commercial fishery, a new closure of the black salmon fishery and a hook-and-release recreational fishery for bright salmon (both multi-sea-winter [MSW] and 1SW fish) that was delayed to a July 15 opening (closing dates were river/area specific and unchanged from previous years). Native peoples fished for agreed-to quotas of 1SW salmon on the Saint John River and the Tobique tributary, beginning July 15. Capture methods were restricted to trapnets and hook-and-line. Some fish of sea-cage origin were provided to First Nations in the Fredericton area from the trap in the Magaguadavic fishway.

SAINT JOHN RIVER ABOVE MACTAQUAC

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 biology of the stocks have been previously described (Marshall and Penney 1983). The status of the salmon stocks since 1970 were variously estimated beginning in 1983 (Penney and Marshall 1984) and continued through 1993 (Marshall and Cameron 1994). Forecasts made in 1993 suggested that 1994 homeriver returns destined for Mactaquac could number as few as 4,000 or as many as 8,000 1SW fish. MSW returns were forecast to be as few as 3,100 or as many as 4,800 MSW fish. Evidence of recent low marine survival independent of forecast models suggested i) uncertainty in both forecasts, ii) that the lower estimates were perhaps most probable and iii) that the target escapement of 4,400 MSW salmon was unlikely to be met (Marshall and Cameron op cit).

This assessment for stocks above Mactaquac follows the same basic approach as that taken in 1993 (Marshall and Cameron 1994). In addition, results from non-parametric forecast models (Harvie and Amiro 1991; Marshall 1993) were re-examined, and ecological considerations respecting stock status are more focused.

Description of fisheries

The July 15 opening to hook-and-release only recreational fishery and food fishery for Native peoples was reviewed at the Zone 23 Management Advisory Committee on July 28 by government, Native peoples and commercial and recreational fishery stakeholders. Continuation of the fisheries was influenced by the results of an in-season forecast (Harvie and Marshall In prep) of the end-of-season count at Mactaquac.

Allocations of the numbers of 1SW fish to Native peoples was finalized just prior to July 15 and can be summarized as follows:

Native peoples	No. nets to be fished	No. 1SW fish
Oromocto FN	2	205
St. Mary's FN	2	330
Kingsclear FN	1	125
Woodstock FN	0	80[a]
Tobique FN	2	330
Aboriginal Peoples Council	2	225

[a] To be provided from a lethal sampling program at Mactaquac.

The Kingsclear First Nation did not guide a sport fishery at Chapel Bar Pool as in previous years, but Native peoples from the area did conduct a hook-and-line fishery for 1SW and MSW salmon off the mouth of the migration channel at the Mactaquac Fish Culture Station and below the Dam. Detailed catch statistics were provided only by the Aboriginal Peoples Fisheries Council who operated trapnets at Scovil and Coytown (below Oromocto).

The maritime province's commercial fishery for salmon has been closed since 1984 and, after several buy-backs of licences, has but four eligible licences remaining in the Saint John River area should the fisheries ever be reopened. The moratoria on commercial fisheries in insular Newfoundland and Greenland in 1993 (and continued in 1994) and the small quota allocated to fishermen in Labrador virtually eliminated distant fishing mortality (and tag recoveries) on outer-Fundy stocks destined to return in 1994.

Returns destined for Mactaquac

Methods

Total returns of 1SW and MSW salmon of both wild and hatchery origin from above Mactaquac Dam consist of the summation of Mactaquac counts, estimates of removals by Native peoples in the main stem below the Mactaquac Dam and assumed by-catch in May and early-June 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 facility at the

Dam was open May 24 - Oct 25; the migration channel at the Station was open May 24 - Oct 26.

Identification at the Mactaquac sorting facility of 1SW and MSW returns from 1-year smolts released at Mactaquac and juveniles (essentially fall parr) released above Mactaquac was principally dependent on erosion of the dorsal fin. Fish of sea-cage origin were identified by a form of "broomtail", or minimally, erosion on the upper and lower lobes of the caudal fin. Returns from hatchery-origin unfed and feeding fry are likely to have "clean" fins and be indistinguishable from wild fish.

The increased distribution of juvenile salmon, particularly fry and summer parr has increased the difficulty of ensuring that "wild" looking returns are the result of natural rather than artificial recruitment. Scale samples are taken from every tenth "wild" fish and every fifth fish with external characteristics of hatchery fish (exceptions included the sampling of all broodstock, earliest-run fish and sea-cage fish). Survival rates of hatchery fish, in particular, were developed from the interpretation of scales and reconstruction of an unweighted sample that checked external classification of MSW and 1SW salmon (63cm length criteria never used at Mactaquac) and origin, especially those fish originating from 1-year smolts. At the same time, externally identified hatchery fish of freshwater age-2 or age-3 were assigned to appropriate fall parr origins. Misclassification error has traditionally been minimal and offsetting and, hence, general estimates of returns removals and spawning escapements continue to be based on sea-age and hatchery/wild designations ascribed by external characteristics of fish sorted at Mactaquac.

Removals by Native peoples fishing below Mactaquac were formally reported only by the Aboriginal Peoples Council and, of those, 50% were assumed (on the basis of run-timing and production area between the fishing sites and Mactaquac Dam) to have originated below Mactaquac. Unreported landings below Mactaquac were broadly based on fish observed by or known to Fishery Officers.

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, and Native peoples catches below Mactaquac were assumed to consist of fish of hatchery and wild origins in the same proportions as those counted at Mactaquac. Estimates of catch (release) and effort are with the exception of the Tobique drainage, provided by District personnel of NBDNRE (P. Cronin[1] pers comm).

Results

Counts of fish at Mactaquac in 1994 (Table 1) totalled 3,313 1SW and 2,206 MSW salmon. Counts of wild fish were essentially only 50% or less of the previous 5- or 10- year means (Table 2) and the lowest of record even in the absence of significant in-river fisheries (Fig. 2). Hatchery fish comprised 36% and 22% of 1SW and MSW counts, respectively (Fig. 3). Scale analyses indicated that 67% of a scale-corrected hatchery 1SW count (exclusive of a few sea-cage fish) was age 1.1 and that 85% of the MSW count was age 1.2, i.e., were smolts grown at Mactaquac. Thirty-three and 15% of 1SW and MSW fish, respectively, were externally identifiable hatchery fish originating from juvenile distributions other than smolts. Of wild 1SW fish, 0.49 were freshwater age-2 and age-3 (0.02 were age-4). Among wild maiden 2SW salmon, 0.75 were freshwater age-2; the remainder was age-3. Repeat spawners comprised 0.067 of the MSW fish.

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[1] Regional Biologist, NBDNRE, RR#6 Kingsclear, N.B. E3B 4X7.

Removals of fish presumed destined for Mactaquac by Native peoples fishing below Mactaquac Dam were estimated at 150 1SW and 50 MSW salmon, including one-half of the 99 1SW and 9 MSW salmon reported retained by the Aboriginal Peoples' Council. A twenty-year-low count at the fishway and difficulties in fishing their trap nets between Fredericton and Mactaquac supported claims that few salmon were caught in the trapnets provided to Native peoples. Another 71 1SW fish and 119 MSW fish were ascribed to by-catch, a category that could as well include unknown losses to in hook-and-release/ net-and-release fisheries below Mactaquac. The hook-and-release recreational fishery between Mactaquac and Burton (just below Oromocto) yielded an estimated 99 small and 28 large salmon – about a 70% reduction in catch and effort from that of 1993 (P. Cronin[1] pers comm).

Estimated homewater returns in 1994 totalled 3,534 1SW (Table 1) and 2,375 MSW fish, the lowest in over 20 years (Table 3; Fig. 4). Counts comprised 94 and 93% of respective 1SW and MSW returns estimated to have been destined for Mactaquac. The adjusted return rate of 1-year smolts as 1SW fish destined for Mactaquac, (corrected by excluding sea-cage fish and returns from smolts released to the Nashwaak River [on the basis of tag recaptures at Mactaquac and in the Nashwaak]) was 0.00393 - essentially the lowest (with that of 1993) of a 21-year data set (Table 4a). The adjusted return rate of 1-year smolts as 2SW salmon (Table 4b) was 0.00214 - nearly double that of 1993 but appreciably lower than any values prior to 1990.

Removals of fish destined for Mactaquac

Methods

Removals include the estimate of salmon retained by Native peoples on the main stem below Mactaquac (described above) and in the Tobique River; hook-and-release mortality in the recreational fishery on the main stem above Mactaquac (inc. Salmon River, Victoria Co.,) and the Tobique River; and a by-catch in the estuary. Additional removals from the potential spawning escapement in the traditional production areas above Mactaquac include fish trucked above Grand Falls, passed or trucked above Tinker Dam on the Aroostook, held at Mactaquac as broodstock or estimated to have been lost to poaching/disease.

The estimated catch by individuals of the Maliseet First Nation at Tobique, was based on observed fishing effort, effectiveness of methods additional to the trapnets, availability of fish as ascertained at fishways at Tobique Narrows and Beechwood and numbers trucked from Mactaquac to Perth-Andover and Arthurette dump sites.

Estimated loss of 1SW fish to hook-and-release mortality in the recreational fishery was based on the same 2% value accorded MSW fish released above Mactaquac, exclusive of those to the Native fishery at Tobique and losses to the Aroostook River and above Grand Falls. 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 verification of external sexing.

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 halved in 1994 because of the paucity of persons observed on the river 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.

Results

Removals by Native peoples at Tobique were approximated at 100 1SW and 40 MSW salmon (Table 5). Sixty 1SW and 25 MSW fish were ascribed to capture by hook-and-line in the tailrace near the fishway entrance and in the headpond near the fishway exit. A further 40 1SW and 15 MSW fish were ascribed to trap and other nets. Total estimated removals by Native peoples numbered 321 1SW and 209 MSW salmon - the lowest in the 20-year record (Table 6).

Diversions above Mactaquac to the Aroostook River consisted of 118 1SW and 21 MSW salmon. Only 14 of the 1SW and 5 of the MSW fish ascended the fishway (closed between July 11 and September 5); the remainder was trucked from Mactaquac. 1SW losses to poaching and disease were set at 4% (exclusive of those lost to hook-and-release, Native peoples fisheries and passed above Tinker Dam and Grand Falls). Only three salmon were lost at the Half Mile Barrier Pool on the Tobique River; one, a MSW salmon that had been trucked from Mactaquac, was indicated to have had furunculosis.

Total river removals by all factions were estimated at 690 1SW fish, of which 180 were placed above Tinker Dam or Grand Falls, and 811 MSW salmon, of which 38 were transferred above Tinker Dam or Grand Falls. MSW hatchery broodstock retained at Mactaquac numbered 444 fish; 42 1SW fish were checked internally for sex or tested for disease.

Conservation requirements

Target

An accessible salmon-producing substrate of 12,261,000 m^2 above Mactaquac, (exclusive of riverine habitat on the main Saint John below Grand Falls and Beechwood, the Aroostook River and main Saint John and tributaries above Grand Falls), and an assumed requirement of 2.4 eggs/m^2, yields a target deposition of 29.4 million eggs. A length-fecundity relationship ($\log_e$ Eggs = 6.06423 + 0.03605 Fork Length) applied to 1SW and MSW fish data, 1972-1982, and the 1SW:MSW ratios in those years suggested 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).

Escapement

Collation of the total returns (Table 1), and total removals (Table 5) indicates that 1,647 (37%) of the required 4,400 MSW spawners was attained above Mactaquac (Table 7). For 1SW fish, 91% of requirement was met above Mactaquac. Biological data for spawners released above Mactaquac are:

Biological parameter	1SW wild	1SW htch	MSW wild	MSW htch
Prop. female	0.144	0.063	0.940	0.837
Mean length, female (cm)	60.08	60.06	76.09	76.17

Mean lengths, the length-fecundity relationship and estimated escapement indicate that total potential deposition was 11.4 million eggs (0.93 eggs/m^2) or 38.6% of the target - the lowest level since 1983.

Eggs from 1SW fish comprised 11% of the total deposition; eggs from hatchery fish potentially contributed to 20% of the total deposition.

Forecasts

1SW wild (Methods)

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, 1973-1991, on adjusted egg depositions in the Tobique River, 1968-1969 to 1987-1988 [method in Penney and Marshall (1984), with updates on freshwater age composition from wild 1SW fish, App. 1, 2 and 3 this paper]. The 1990 and 1991 egg depositions, principal contributors to 1SW returns in 1995, were derived using angular-transformed mean proportions for age-2.1 1SW fish in the previous 10-year period.

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).

As in 1992 (Marshall 1993), a forecast of 1SW returns was constructed from the same data using a joint probability density function (Harvie and Amiro 1991).

1SW wild (Forecasts)

Potential returns of wild 1SW fish returning to Mactaquac in the absence of homewater removals in 1995 were examined through the regression of 1SW returns to home waters which originated above Mactaquac on estimated Tobique River egg depositions adjusted for smolt age (i.e., column 4 on column 2, Table 8). From the equation Log_e 1SW = 6.4670 + 0.4326 Log_e eggs (r^2=0.461, p<0.001, n=20), the estimate for 1SW returns in 1995 is **6,408** 1SW fish (90% CL 3,571- 11,500). For 1994, the method forecast 6,414 1SW fish; only 2,276 fish or 35% of the forecast was estimated to have returned. A forecast of **7,158** (90% CL 3,885-10,329) 1SW fish was obtained from the probability density function. Unfortunately, neither model yet incorporates low 1SW returns in 1993 and 1994 which, with approximated egg values reflect significant reductions in survival from data within the model (Fig. 5).

MSW wild (Methods)

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 and Cameron 1994; Marshall et al. 1993). This assessment forecasts MSW returns in 1995 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 the forecast of 1SW salmon, the resultant GM value of MSW salmon (and confidence limits) was converted to an AM value (Ricker 1975). As well, the previously used joint probability density function (Marshall 1993) for three variables in steps, each using only two variables was reassessed. The first step constructs the joint probability density function of MSW returns and 1SW returns while the second step uses the residuals from step one and 1SW lengths to produce the forecast and confidence interval (Harvie and Amiro 1991).

Saint John River MSW salmon were 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, since 1992, and in Greenland since 1993, could therefore result in returns in 1995 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 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 (Table 5; Marshall and Cameron 1994). 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. These data were also submitted to the probability density function.

Finally, selected periods (co-variate "period") within the 23 or 24 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 1SW fork length and low (lowest in 16 years) 1SW returns of 1994.

MSW wild (Forecasts)

A potential return of **1,613** (90% CL 978-2,657) wild MSW fish destined for Mactaquac in 1995 was derived from the equation $\mathrm{Log_e}$ MSW = 25.9206 + 0.135E-3 1SW - 0.3204 Length (R^2=0.738, $p<0.0001$, n=24 columns 5 and 7 on column 4, Table 8). For 1994, the method forecast 2,316 returns; only 1,844 fish or 80% of that forecast was estimated to have returned. The probability density estimator provides a forecast of **3,981** (90% CL 0- 11,452) MSW salmon in 1995. The inclusion of the co-variate "period" in the model for MSW years 1971-1975; 1976-1984 and 1985-1994 and, as well, 1971-1975; 1976-1986 and 1987-1994 when trends in the ratio of MSW:1SW (Fig. 5) and lengths (Table 8) appeared to be different, was not significant (p=0.198 and p=0.187, 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 (moratoria model), 1971-1992, (Table 8, one less year than in the above data set) would suggest a return of **2,240** (90% CL 1,180- 4,251) wild MSW fish destined for Mactaquac in 1995 ($\mathrm{Log_e}$ MSW = 29.1611 + 0.135E-3 1SW - 0.3702 Length; R^2=0.682; $p<0.0001$; n=23). For 1994, the method forecast 3,614 returns - nearly double the actual returns. A forecast of **9,650** (90% CL 0- 20,089) was obtained from the probability function.

Period hypotheses were also tested for the model with the added effects of the moratoria and found to be significant when the last period for MSW years was either 1985-1994 (p=0.015) or 1987-1994 (p=0.033). The subset model for the period 1985-1994, $\mathrm{Log_e}$ MSW = 24.1767 + 0.194E-3 1SW - 0.2924 Length (R^2=0.780; n=10) was significant (p=0.002) while the model for the period 1987-1994 only approached significance (p=0.055). The model for the latter two subsets combined, i.e., MSW years 1976-1994, is $\mathrm{Log_e}$ = 27.7884 + 0.180E-3 1SW - 0.3522 Length (R^2 =0.795; $p<0.001$; n=19). The forecast from this model is **1,782** (90% CL 1,032- 3,074) wild MSW salmon. A forecast of **3,629** (90% CL 0- 13,728) was obtained from the probability density function.

1SW hatchery (Methods)

Since the shift to age-1 smolt production 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 1995 from releases at Mactaquac 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 average of the 1993 and 1994 values (Table 4a). Age-1.1 returns in 1995 may also be expected at the Mactaquac Dam from smolts reared at Mactaquac but released into the Nashwaak River. The return rate for these smolts was assumed to be the estimate (rounded to 3-places) determined from tag returns in 1994.

Additional 1SW returns of age-3.1 and age-2.1 fish are expected at Mactaquac in 1995 from fall fingerlings (age-0^+) graded from the age-1 smolt program at Mactaquac and released in tributaries above Mactaquac in 1991 and 1992. Selection of return rates, in part constrained by evidence that recent wild recruits do not appear to be replacing spawners (return rate from eggs of 0.0003 should equal replacement) considered values estimated for returns in 1994 or 1993 relative to those used for forecasting the 1994 returns. Returns of age-2.1 fish were forecast as the product of a 0.0004 return rate to Mactaquac (the value for returns in 1994; Table 9) and the numbers released in 1992. Age-3.1 fish were assigned a return rate of 0.0008. Returns from unfed fry were accorded a return rate of one-half of that given the fall fingerlings but most are likely to be indistinguishable from wild fish upon return to Mactaquac.

1SW hatchery (Forecasts)

A forecast of hatchery 1SW fish destined for Mactaquac in 1995 is **1,860** fish (Table 10), i.e., about 15% greater than forecast for return in 1994. Age 1.1 salmon, perhaps the best forecast element, would contribute to only 48% of the hatchery-origin recruits and 60% of the identifiable hatchery-source returns (excludes egg and fry origins).

MSW hatchery (Methods)

Returns as MSW fish from age-1 smolts released at Mactaquac in 1993 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, 1974-1992. Hatchery smolt 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 and are, for the moratoria model(s), raised by the average effect of the last 8 years. As with 1SW hatchery returns, MSW fish destined for Mactaquac from releases to the Nashwaak River were given the same proportioned rate of return as for 1SW fish.

Selection of return rates for MSW salmon from juveniles and eggs was guided by the average 0.5 ratio MSW/1SW during the last 8 return years (Table 8) and values estimated for return in 1994 or 1993 relative to those used for forecasting 1994 returns. 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 observed in 1994 (Table 9) and 1993. Age-3.2 hatchery MSW fish, usually a rarity because of the generally large size of stocked fall fingerlings, were accorded 0.5 the return rate exhibited by their 1SW component.

Fish which returned as maiden fish, mainly 1993-1994, are expected to comprise the repeat-spawning hatchery MSW component in 1995. The forecast return was based on a 0.00135 return rate estimated for 1994 from 1992-1993 mostly maiden fish (Table 9).

MSW hatchery (Forecasts)

Total returns of MSW fish of hatchery-, Aroostook- and above Grand Falls- origins destined for Mactaquac in 1995 are **631** fish (Table 10). The 566 mostly identifiable fish would exceed the 1994 identifiables by about 10% and are about 48% of the identifiable number of the 1994 1SW returns from the same year class. Some 443 age-1.2 fish from the 1993 smolts, the principal component, are based on the regression Arcsin MSW return rate = 0.8525 + 0.5027 Arcsin 1SW return rate ($r^2 = 0.72$; $p<0.001$; $n=19$), i.e., a forecast return rate of 0.002.

Application of a 0.68 raising factor, a value which reflects the 32% difference between wild MSW salmon with and without returns from the moratoria in distant fisheries in the last eight years, would yield a return of **928** hatchery-origin MSW salmon.

Ecological considerations

In-river

The weekly cumulative proportions of 1SW and MSW salmon captured in the fishway at Mactaquac Dam in each of 22 seasons is the basis of a model used to predict end-of season counts (Harvie and Marshall In prep). For 1SW models, mean daily river discharge in the weeks preceding July 15, 22, and 29, and for MSW models, total discharge in the weeks preceding July 8, 15, 22, and 29, explains a significant amount of the annual variation in cumulative counts to date ($p < 0.05$)

The effect of below average mid-June to early-July river discharges, for example, is to increase the proportion of the eventual total run seen to date (Fig. 6). The interpretation is that fish arrive in the reaches below the dam at about the same time annually but that, for example, low discharges from turbines allow fish to find the attraction water from the fish collection facility more easily; high discharge from turbines/spill delays salmon in locating and entering the collection facility.

In 1994, late-June, early-July discharge (Fig. 7) was above the 22-year average and contributed to a "raising" of early in-season estimates of end-of-season counts. In hindsight the early estimates were overly optimistic - at least relative to 1993 (Fig. 8). Weekly compilations of fish sorted for the entire season as well as 1992 and 1993 are illustrated in Fig. 3. Since above average discharges are unlikely to have contributed to above average proportions in July it appears that some of the reduction in returns in 1994 and perhaps 1993, is the result of missing late-run fish.

Downstream passage of smolts through turbines at Tobique has been cited by MacEachern (1961) as resulting in a mortality of up to 15%. The cumulative mortality, through three sets of turbines, i.e., Tobique, Beechwood and Mactaquac could be about 40% and, perhaps, is a detectable effect on adult recruitment which has, on the Saint John River, never been investigated. Plots of discharge at Mactaquac and the "level" at which river flow is spilled, is approximated in Fig. 9. Spill, or the window of opportunity to by-pass turbines, has been variable in the last 8 years but cursory examination suggests that the 1994 smolt class (1SW returns in 1995) may have had more opportunity (to about May 20) to avoid turbines than any other smolt class in the preceding 7 years.

Marine

For the second consecutive year the ICES Working Group on North Atlantic Salmon (Anon 1994) forecasted from a March index of overwinter habitat in the North Atlantic that pre-fishery abundance of non-maturing 1SW salmon available to a Greenland fishery would be low. By extension, Reddin et al. (1993) suggested that there should be low numbers of 2SW salmon returning to homewaters in 1994. An appreciably unimproved habitat index value for 1994 (Anon 1993 and Fig. 10) could presumably lead to low numbers of 2SW returns in 1995.

For the Saint John River wild stock of Atlantic salmon, indices of winter habitat for the first or second winter of a 2SW fish at sea were either a statistically non significant addition to the MSW (homewater returns) predictor models or, because of a significant but negative slope, not immediately interpretable (Marshall et al. 1993). However several other relationships with perhaps more robust data from survival of hatchery reared fish appear to implicate the "index" of over-winter habitat to the well-being of 1SW and MSW hatchery components.

A significant relationship between the March index of habitat and return rates for 1SW salmon from hatchery smolts (Arcsin 1SW return rate = 0.0075 March - 6.2428; r^2 = 0.589; p< 0.001; n=20) indicates decreasing 1SW returns with a declining index of habitat (Fig. 11). Similar relationships exist between return rates of hatchery 2SW salmon originating from hatchery smolts and the index of habitat for the first year at sea (r^2=0.474; p<0.001; n=19); the second year at sea (r^2=0.296; p=0.011; n=18) and first and second years together (R^2=0.40; p=0.008; n=18). Further, the length of wild 1SW returns (hatchery not tested) and March index of habitat are also negatively correlated (r^2= 0.152; p=0.03; n=25) as is the fork length and proportion of 1SW salmon from a smolt class (Arcsin prop. 1SW = 5.1542 Length - 247.57; r^2= 0.627; p<0.001; n=24; Fig. 10). The linkage between proportion 1SW (and by corollary, 2SW fish) and fork length has been previously interpreted by Ritter et al. (1990) as an expression of environmentally induced "cross-over" of potential non-maturing 1SW fish to maturing 1SW fish, i.e., above average growth of fish at some time and place during the first year at sea results in an increase in the proportion of 1SW returns (and decrease in 2SW returns) from a smolt class.

In total, the above elements implicate recent low index values of overwinter habitat with low rates of 1SW and MSW marine survival and, as well, increasing mean length of mature 1SW fish. Explanations for reduced survival include potential increases in distance or rigours in reaching that habitat, i.e., a window or gauntlet condition has narrowed. Increased growth among returning 1SW fish could be the result of selective mortality on smaller, later or earlier run smolts or the result of above average growth conditions for those fish successfully crossing the threshold and within reach of the overwinter zone - albeit reduced in size but not necessarily in quality.

Forecast summary

1SW salmon

1SW returns destined for Mactaquac were forecast to be 8,300 (6,400 wild [parametric] and 1,900 hatchery) or 9,100 (7,200 wild [non-parametric] and 1,900 hatchery). The non-parametric forecast exceeds the parametric forecast and, from past experience, more seriously overestimated returns. Parametric forecasts of wild returns in 1993 and 1994 were at best 53 and 35%, respectively, of the wild returns. [This possibility was strongly suggested because of the low winter habitat values:smolt survival linkages alluded to in Marshall and Cameron (1994).] Because neither 1993 nor 1994 returns are incorporated in the model for wild fish and because of the linkage between reduced survival of hatchery fish and a continuing low index of winter habitat, the wild forecasts are likely inappropriate. Forecasts of hatchery fish better reflect recent trends in low survival but for other than smolts require several assumptions. Discounting wild parametric forecasts by 50% and 35% (3,200 and 2,240) or the mean of the wild returns in the last two years (2,740) may be more indicative of wild returns in 1995. The forecast for total 1SW returns may more realistically be **4,000** (1,900 + [6,400* 0.35]) to **5,000** (1,900 + [6,400*0.5]) fish. Hopefully, a greater hatchery contribution to potential smolts in 1994, the large window of opportunity for smolts in 1994 (compared to recent years) and a possible bottoming out of the index of winter habitat could mean that returns in 1995 will be at least **no worse than those of 1994** - i.e., the 3,200 spawning requirement may be met and perhaps slightly exceeded.

MSW salmon

Total wild and hatchery MSW returns destined for Mactaquac were forecast to be 2,200, 2,700 or 3,100 fish when based on parametric models and 4,500, 4,600 or 11,900 when based on non-parametric models. In the past, non-parametric forecasts were more distant to actual returns than parametric forecasts. The parametric forecasts of wild MSW fish for 1995 were 1,600 (no effect of the moratoria), 1,800 for the 19 year subset (moratoria included) and 2,200 (moratoria included). Wild returns in 1993 and 1994 were 87% and 80% of the model without the effect of the moratoria and only 75% and 50% of the forecasts with moratoria included. Unlike 1SW models, MSW models, including forecasts of hatchery-sourced returns reflect low survival of 1SW returns in 1993 and 1994. The most realistic forecasts of MSW returns may be **2,200** (1,600 wild + 600 hatchery) from the model without the effect of the moratoria or **2,500** (1,800 wild + 700 hatchery [631* 1,800/1,600]) based on the abbreviated subset with effects of the moratoria. It is **highly unlikely that returns will meet conservation requirements.**

NASHWAAK RIVER

With a drainage area of about 1,700 km^2, the Nashwaak River flows approximately 110 km in an easterly and southerly direction from Nashwaak Lake on the York/Carleton county line to its confluence with the Saint John River in Fredericton North (Fig. 1). The river is the largest single salmon-producing tributary of the Saint John below Mactaquac - its production area having been estimated at 4.9 million m^2 or 31% of the total below Mactaquac (Marshall and Penney 1983). A salmon counting fence at kilometre 23 from the confluence with the Saint John was operated by DFO in 1972, 1973 and 1975, and by Native peoples in 1993 and 1994 - principally those of the St Mary's and Kingsclear First Nations.

Returns

Methods

The total run of 1SW and MSW fish above the fence in 1994 was estimated by two methods. First, as the product of the counts in 1994 and the reciprocal of the proportion of the presumed complete counts (Francis and Gallop 1979) that were monitored between the same dates in 1973 and 1975 (method used in Marshall and Cameron 1994). This analysis assumed that run-timing of the salmon and river discharge/ water temperatures in 1994 (Fig 13) which could inhibit or prevent their upriver movement were similar to those conditions of 1973 and 1975.

Secondly, adjusted Petersen mark-and-recapture estimates ($N = M(C+1)/R+1$ where N= population size, M= numbers of marked fish, C= sample taken for census and, R= recaptured marks; Ricker 1975, p. 77-79) were derived to estimate numbers of fish that ascended the river prior to installation of the fence. Marks were applied to fish that were captured at the fence; two pools were seined on Aug 23 and four pools were seined on each of Sep 27 and Oct 19. An end-of-season estimate of 1SW and MSW fish above the fence was taken as the mean of the individual estimates for each date. An individual estimate was [Total season fence count + Mark-recapture estimate to date + Estimated removals - Count at fence previous to seining date].

Results

Counts of 1SW and MSW fish (adjusted by scale analyses) at the Nashwaak fence during the Jul 15 - Oct 25 operating dates numbered 403 1SW and 274 MSW salmon (Fig. 13). In 1973 and 1975, when it was assumed that entire runs (all wild fish) were monitored/estimated (Fig. 5; Marshall and Cameron 1994), the period Jul 15 - Oct 25, accounted for an average of 0.685 1SW and 0.740 MSW salmon. Raising the adjusted 1994 counts by those proportions suggests that the total run past the fence in 1994 could have been **588** 1SW fish and **370** MSW salmon. These potential counts are 0.75 and 0.36 of the 1SW and 0.22 and 0.41 of the MSW counts in 1973 and 1975, respectively.

Results of seining for marked fish and subsequent Petersen estimates (unadjusted by scale analyses) can be summarized as follows:

Date	1SW "M"	1SW "C"	1SW "R"	Est.	MSW "M"	MSW "C"	MSW "R"	Est
Aug 23	77	9	2	260	22	6	0	-
Sep 27	112	18	7	267	32	13	4	92
Oct 19	147	9	3	370	74	12	5	162

The mean of the individual estimates of end-of season count (unadjusted) was 555 1SW and 442 MSW including an estimated 40 1SW and 30 MSW salmon believed to have been harvested from the Nashwaak by Native peoples. Calculations using adjusted numbers of 1SW and MSW fish suggested returns of **661** 1SW and **388** MSW salmon - the greatest number of returns (1,049) derivable from the described methods. No account has been made of by-catch in the Harbour or of removals by Native peoples (fishing in the main Saint John below the confluence of the Nashwaak River) which may have been destined for the Nashwaak River.

Removals

Removals are believed restricted to the above 40 1SW and 30 MSW salmon by Native peoples and 11 MSW and 9 1SW salmon collected as broodstock for the Mactaquac Fish Culture Station. There were no legal removals in the recreational fishery; only 30 1SW and 14 MSW fish were reported as captured and released (P. Cronin[1] pers comm). The average 1SW harvest, 1989-1993, was 279 fish.

Conservation requirements

Target

An accessible salmon-producing substrate of 4.938 million m^2, an assumed requirement of 2.4 eggs/m^2 (11.9 million total), the length-fecundity relationship for Mactaquac-origin 1SW and MSW fish and 1SW:MSW ratios in the Nashwaak recreational fishery, 1974-1983, suggested that, on average, approximately 1,700 1SW and 1,800 MSW fish are required for the entire Nashwaak River (Marshall et al. 1992). As on the Saint John River above Mactaquac, 1SW requirements were set at those which would provide a 1:1 male-to-female ratio for female MSW fish. The target for spawning requirements above the fence site is 10.7 million eggs (1,530 1SW and 1,620 MSW fish) or 90% of that of the entire river (Marshall and Cameron 1994). Egg deposition and spawners were estimated on the basis of lengths, external sexing and interpretation of age from scales collected from approximately every third fish passed through the fence.

Escapement

Escapement, based on returns to the fence of 1,049 fish (adjusted counts and Petersen mark-and-recapture method) and removals by Native peoples and the Mactaquac Fish Culture Station left 959 spawners above the fence. Sea-age, origins, female composition and mean lengths for spawners above the fence can be summarized as follows:

Biological parameter	1SW wild	1SW htch	MSW wild	MSW htch
Number	569	41	320	29
Prop. female	0.517	0.417	0.850	0.781
Mean length female (cm)	58.8	59.8	78.7	75.8

Numbers of 1SW and MSW salmon were only 40 and 22% of the respective targets. Egg depositions were estimated at 3.26 million or 31% of the egg requirement. 1SW females contributed 34% of the total estimated egg deposition. The estimated egg deposition in 1993, based on adjusted numbers (proportional method) and an escapement of 1,509 fish was only 3.87 million eggs or 36% of the target (Marshall and Cameron 1994).

Interpretation of 204 scale samples from wild fish revealed a sea-age composition of 0.59 1-year, 0.32 2-year, 0.01 3-year and 0.08 repeat spawners (but 0.20 of MSW salmon). Among wild 1SW fish, freshwater ages were 0.45 age-2, 0.50 age-3 and 0.05 age-4. Freshwater ages among wild 2SW fish were age-2, 0.39, and age-3, 0.61.

MAGAGUADAVIC RIVER

The Magaguadavic River originates in Magaguadavic Lake in southwest New Brunswick and flows southeasterly for 80 km emptying into the Bay of Fundy at St. George, N.B. (Fig 14; Martin 1984). A 13.4m high dam at the head-of-tide with turbines and generating capacity of 3.7 megawatts is the location of a fishway and, at its top, a fish trap. In 1992 and 1993 the trap was operated and data were provided by the Atlantic Salmon Federation. In 1994, the trap was operated and data were provided by the Magaguadavic Watershed Management Association (J. Carr[2] pers comm).

Returns

Counts of salmon, adjusted by scale analyses, at the fishway numbered 1,064 1SW and 228 MSW fish as well as 55 post smolts. External characteristics and scales suggested that only 69 1SW and 61 MSW fish were of wild origins - the remainder were of sea-cage origin, (J. Carr[2] pers comm.) principally torn cages resultant of a storm on Labour day weekend. Counts made by the Atlantic Salmon Federation in 1992-1993 and previously by DFO but without distinction as to possible aquaculture origins are summarized in Table 2. Wild returns in 1994 were less than 40% of recent (since 1983) years for which there are data.

[2] Magaguadavic Watershed Management Association, c/o General Delivery, St. George, N.B. E0G 2Y0.

Removals

Four hundred and twenty-five (425) 1SW, 75 MSW and 30 post-smolt salmon externally identified as being of sea-cage origin were harvested from the fishway. After lethal sampling of some for residual therapeutic drugs used in the aquaculture industry, 365 were distributed to 4 Maliseet First Nations.

Unlike previous years when the recreational fishery harvested between 60 and 179 1SW fish, hook-and-release regulations precluded the retention of any Atlantic salmon. Only 23 salmon and grilse were estimated to have been hooked-and-released (P. Cronin[1] pers comm).

Conservation requirements

Target
An interim target egg deposition of 1.35 million eggs is based on an estimated 563,000 m^2 of juvenile rearing substrate and a deposition of 2.4 eggs/m^2 (Anon 1978). Spawners necessary to obtain those eggs were estimated at 230 MSW and 185 1SW salmon. Remote-measured areas identify considerably more area of appropriate gradient for stream production but these await ground surveys of their potential for Atlantic salmon.

Escapement
External characteristics, scale analyses, lethal sampling and behaviour of several ultra-sonically tagged fish of sea-cage origin indicated that the "effective" female escapement (most aquaculture fish were sexually immature) was 37 1SW fish (16 of sea-cage origin) and 91 MSW fish (39 of sea-cage origin) (J. Carr pers comm). Mean lengths of 76.2 and 77.4cm for wild and sea-cage MSW females, respectively and 59.2 and 59.5cm for wild and sea-cage 1SW females, respectively, and the length-fecundity relationship for Saint John River salmon (Marshall and Penney 1983) indicate a potential egg deposition of 757,200 eggs or 56% of target. Forty-four percent of the total was estimated to have been of sea-cage origin.

ST. CROIX RIVER

The St. Croix River, a US/Canada international river bordering the State of Maine and Province of New Brunswick, drains southwesterly into Passamaquoddy Bay of the Bay of Fundy. Approximately 1,619 km^2 of the drainage basin is in New Brunswick and 2,616 km^2 is in Maine (Fig. 14). Once a significant producer of Atlantic salmon, the river and stocks succumbed to industrial development - initially cotton mills, then pulp mills, and now, dams and headponds at 3 hydroelectric facilities. The main stem and East Branch (84km), the Chiputneticook lakes (66km) and Monument Brook (19km) determine 169km of the international boundary (Anon 1988) - the fluvial portions of which comprise the bulk of the potential rearing area for Atlantic salmon.

Regulations for the recreational fishery were essentially those of SFA 23 except that a Variation Order permitted fishing for kelts released by the State of Maine from the Green Lake (Maine) Hatchery. The river is essentially a development project and cannot now or for the foreseeable future be expected to yield any significant number of salmon.

Returns

Counts of salmon have been made at the Milltown fishway, just above tide-head - most recently under the St. Croix Recreational Fisheries Development Program (Table 2). Counts, scale samples and external characteristics provided by L. Sochasky[3] (pers comm), in 1994 indicate a return comprised of only 24 and 19 wild 1SW and MSW salmon, respectively. Twenty-three 1SW and 18 MSW fish of hatchery origin could be credited to a smolt stocking program conducted by the Atlantic Sea-Run Salmon Commission (Maine), the 97 1SW fish of sea-cage origin were classified on the basis of "broom" tails and gross fin degeneration. Sea-cage fish were believed to be of the same sources as those entering the Magaguadavic River and also mostly immature.

Removals

Removals were, as far as is known, restricted to 29 fish delivered to Mactaquac Fish Culture Station as broodstock. Eleven females yielded nearly 70,000 eggs; eight large 1SW fish of probable sea-cage origin were sexually immature.

Conservation requirements

Target

Spawning requirements are based on an area of 3.079 million m^2 of juvenile production habitat and an average requirement of 2.4 eggs/m^2 (Anon 1988). Egg requirements total 7.389 million. Adult requirements have been calculated on the basis of MSW salmon of male:female ratio 1:1 and females producing an average of 7,200 eggs. Adult requirements total 2,040 salmon. A recent re-evaluation of adult requirements in 1993 acknowledges the potential contribution to egg deposition by 1SW females and allowed that 1,710 MSW and 680 1SW fish might produce the egg requirement.

Escapement

Effective river escapement in 1994 was probably limited to 18 MSW females and perhaps 47 female 1SW fish. Fish of sea-cage origins were assumed to be non-contributors, the 1SW fish were assumed to be of 50:50 males to females. Eggs from 1SW fish were estimated from the length-fecundity relationship for the Saint John River. A mean length of 57cm was determined from 15 1SW fish captured prior to Labour Day weekend. The resultant egg deposition totalled about 210,000 eggs or 3% of requirements.

[3] St. Croix International Waterway Commission, St Stephen, N.B., E3L 2Y7.

MANAGEMENT CONSIDERATIONS (SFA 23)

Forecast models and forecasts for 1SW returns destined for Mactaquac Dam in 1995 incorporate a significant amount of uncertainty. If the poor marine conditions in the North Atlantic persist into 1995, which is a strong possibility on the basis of serial correlation of habitat indices in year i and year i+1 (Marshall et al. 1993), it is probable that long-term data-based forecasts for 1SW fish in 1995 may again be inappropriate. Indeed, after two years of a low index of winter habitat and subsequently disappointing 1SW returns, it would be most responsible to initially consider management strategies for 1995 that would have been appropriate in 1994. Finalized management plans will have to be based on in-season assessments of abundance, particularly when it is unlikely that more than 50% of target requirements for MSW salmon will be met above Mactaquac.

The significant shortfalls in egg deposition in 1994 above Mactaquac (39% of requirement) and in the Nashwaak River (31%) may reflect escapement levels in unmonitored drainages 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. Relative production above and below Mactaquac, 1970-1985 (data in Marshall 1985), can be inferred from the product of the estimated returns and 1/estimated production area ($m^2 * 10^{-4}$).

Location	1SW (wild)	MSW (wild)
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 15-year low return of 1SW fish destined for Mactaquac in 1993 and 1994 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 low estimates of MSW returns the following year.

A low return of wild 1SW fish to the Magaguadavic River in 1994, relative to that of any previous year, does not auger well for the number of wild MSW returns to the Magaguadavic River in 1995. The same may be said for the St.Croix River. In total, it is reasonable to expect that target escapements of MSW salmon in 1995 are unlikely to be met in any of the outer Bay of Fundy rivers.

Escapement of sea-cage origin fish to outer-Fundy rivers such as the Magaguadavic, have the potential of swamping the native stock with other genetic material - most probably that of Saint John River salmon. This may be the case in 1995 if the abundant, predominantly non-maturing escapees of 1994 and potential new escapees in 1995 again seek out rivers in the Passamaquoddy Bay area. With the exception of the St. Croix River above tide-head, which is virtually devoid of endemic genetic material, selective harvests of sea-cage origin fish should be encouraged in all outer-Fundy rivers.

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PEER REVIEW/OUTSIDE CONSULTATIONS

Vetting of the contents of this document took place during the week of Feb 7-10, 1995 in Moncton, N.B. Reviewers included staff of the Diadromous Division of DFO, biologists from the Province of Quebec, Parks Canada and Newfoundland Region as well as faculty of Moncton, St. Francis Xavier, Dalhousie and McGill universities. Science Branch (1995) also documents a regional overview, a precis of the assessment, research recommendations and main points raised during the meeting.

Formal consultations re: status of stocks in 1993, pre-season forecasts for 1994, early returns in 1994 and elements of in-season forecasting were conducted by the authors (Marshall, with one exception) in the company of the Area Manager (DFO) with Band Managers/Councillors and or Chiefs of St. Mary's First Nation (July 6) Oromocto First Nation (July 19), Woodstock First Nation (July 19) and Kingsclear First Nation (July 20). Maliseet First Nation at Tobique was consulted on several occasions but in less formal settings. No "minutes" were taken by DFO at the afore-mentioned meetings.

Formal consultations background to in-season management measures were discussed at a full meeting of the Salmon Management Advisory Committee (ZMAC 23), July 28 in Fredericton. Second and third meetings of the same Committee for purposes of reviewing stock status and formulation of management strategies for 1995 took place in Fredericton on Dec 8, 1994, and January 27, 1995. Minutes of all ZMAC 23 meetings are available from the Secretary, Conservation and Protection Branch, DFO, P.O. Box 277, Fredericton, N.B. E3B 4Y9.

Table 1. Estimated total returns (a) of wild and hatchery 1SW and MSW salmon destined for Mactaquac Dam on the Saint John River, N.B., 1994.

Sea-age	Components	Wild	Hatch.	Total
1SW				
	Mactaquac counts(b)	2,133	1,180	3,313
	Angled MS below Mactaquac	0	0	0
	Native Food Fishery	97	53	150
	By-catch(c)	46	25	71
	Totals	2,276	1,258	3,534
MSW				
	Mactaquac counts(b)	1,713	493	2,206
	Native Food Fishery	39	11	50
	By-catch(c)	92	27	119
	Totals	1,844	531	2,375

(a) - Hatchery/wild origins per external characteristics as in previous assessments and are within 5% of ages and origins interpretable on scales.

(b) - Fishway closed Oct.25 (counts unadjusted); hatchery migration channel operational all season.

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

Table 2. Counts of wild, hatchery, and where identified by fishway operators, sea-cage origin Atlantic salmon from traps in fishways/ fences of rivers in southwest and central New Brunswick.

	Saint John					Nashwaak						Magaguadavic					St. Croix(e)						
	Wild		Hatchery			Wild		Hatchery				Wild		Aquaculture			Wild		Hatchery		Aquaculture		
Year	1SW	MSW	1SW	MSW		1SW	MSW	1SW	MSW	Dates of Operation		1SW	MSW	1SW	MSW		1SW	MSW	1SW	MSW	1SW	MSW	
1967	1,181	1,271	-	-																			
1968	1,203	770	-	-																			
1969	2,572	1,749	-	-																			
1970	2,874	2,449	94	-																			
1971	1,592	2,235	336	37																			
1972	784	4,831	246	583		259	859	-	-	8/18-10/29													
1973	1,854	2,367	1,760	475		596	1,956	-	-	6/10-11/05													
1974	3,389	4,775	3,700	1,907																			
1975	5,725	6,200	5,335	1,858		1,223	1,036	-	-	6/28-10/29													
1976	6,797	5,511	7,694	1,623																			
1977	3,504	7,257	6,201	2,075																			
1978	1,584	3,034	2,556	1,951																			
1979	6,234	1,993	3,521	892																			
1980	7,555	8,157	9,759	2,294																			
1981	4,571	2,441	3,782	1,089																			
1982	3,931	2,254	2,292	728													10	51	-	-			
1983	3,613	1,711	1,230	299								282	607	21	30	b	22	78	-	-			
1984	7,353	7,011	1,304	806								255	512				166	64	6	8			
1985	5,331	6,390	1,746	571								169	466				41	264	8	31			
1986	6,347	3,655	699	487													38	204	25	53			
1987	5,106	3,091	2,894	344													128	135	67	42			
1988	8,062	1,930	1,129	670								291	398				93	190	9	102			
1989	8,417	3,854	1,170	437	a												79	94	37	21			
1990	6,486	3,163	1,421	756	a												10	52	2	46			
1991	5,415	3,639	2,160	587	a												16	75	37	79			
1992	5,729	3,522	1,935	681	a							155	139	83	62	cf							
1993	2,873	2,601	1,034	379	a	72	113	11	42	8/19-10/12	f	112	125	96	52	cf	3	30	5	66			f
1994	2,133	1,713	1,180	493	a	376	251	27	23	7/15-10/25	f	69	61	995	167	cf	24	19	23	18	97	-	f
Means:																							
1989-93	5,784	3,356	1,544	568		-	-	-	-			186	221	90	57		27	63	20	53			
1984-93	6,112	3,886	1,549	572		-	-	-	-			211	375	67	48		64	123	22	50			
1994 as % of:																							
1989-93	37%	51%	76%	87%		-	-	-	-			37%	28%	1112%	293%		89%	30%	114%	34%			
1984-93	35%	44%	76%	86%		-	-	-	-			33%	16%	1493%	348%		38%	15%	106%	36%			

a- Small numbers of sea-cage fish, see Tables 4a&b. b- No record of stocking in years previous. c- Aquaculture.
e- Hatchery designation to be reviewed; sea-cage fish could be among hatchery fish prior to 1994. f- Corrected by scale analysis

Table 3. Estimated river returns of Saint John River wild and hatchery 1SW and MSW salmon destined for Mactaquac Dam, 1970-1994.

	Wild		Hatchery		Total	
Year	1SW	MSW	1SW	MSW	1SW	MSW
1970	3,057	5,712	100	0	3,157	5,712
1971	1,709	4,715	365	77	2,074	4,792
1972	908	4,899	285	592	1,193	5,491
1973	2,070	2,518	1,965	505	4,035	3,023
1974	3,656	5,811	3,991	2,325	7,647	8,136
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
1994	2,276	1,844	1,258	531	3,534	2,375

Table 4a. Estimated total number of **1SW** returns to the Saint John River, 1975-1994, from **hatchery-reared smolts released at** Mactaquac, 1974-1993, inc. counts of 8, 56, 34, 0 and 0 potential sea-cage fish in 1990, 1991, 1992, 1993 and 1994, respectively.

Releases			Returns									
				Mactaquac							% return	
Year	Smolts	Prop 1-yr	Year	Mig ch	Dam	Native fishery	Angled main SJ	By-catch	Commercial	Total[a]	Unadj	Adj[b]
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	0.401
90	241,078	0.98	91	(1,490)		88	108	35		1,721	0.714	0.649
91	178,127	0.97	92	(1,123)		26	135	26		1,310	0.735	0.688
92	204,836	1.00	93	(743)		11	60	17		831	0.406	0.406
93	221,403	1.00	94[c]	(828)		37		18		883	0.399	0.393
94	225,037	1.00										

[a] Includes some returns from smolts stocked downriver of Mactaquac, 1981-1991 and 1993 and in sea-cages (erosion of margins of upper and lower caudal fins).

[b] Adjusted return rates exclude smolts stocked downriver from Mactaquac (Marshall 1989) and new, since 1990, fish of potential sea-cage origin. (Marginal numbers of returns from approx. 5,000 age 2.1 smolts, 1989-1991 are not included; no returns from tagged smolts released to the Nashwaak River, 1992.)

[c] Hatchery origin 1SW fish at Mactaquac in 1994, were assigned an origin on the basis of freshwater age (scale reading) and fin condition, i.e., age 1.1 @ 0.669, age 2.1 @ 0.150, age 3.1 @ 0.172 and age 4.1 @ 0.009.

Table 4b. Estimated total number of **MSW** returns to the Saint John River, 1976-1994, from **hatchery-reared smolts released at** Mactaquac, 1974-1992, inc. counts of 221, 24, 16, 6 and 28 potential sea-cage fish in 1990, 1991, 1992, 1993 and 1994, respectively.

Releases			Returns									
				Mactaquac							% return	
Year	Smolts	Prop 1-yr	Year	Mig ch	Dam	Native fishery	Angled main SJ	By-catch	Commercial	Total[a]	Unadj	Adj[b]
1974	337,281	0.00	1976	310	1,313	392	267	20		2,302	0.683	
75	324,186	0.06	77	341	1,727	206	417	34		2,725	0.841	
76	297,350	0.14	78	223	1,728	368	165	50		2,534	0.852	
77	293,132	0.26	79	145	747	210	65	21		1,188	0.405	
78	196,196	0.16	80	302	1,992	506	146	46		2,992	1.525	
79	244,012	0.09	81	126	963	252	125		1,262	2,728	1.118	
80	232,258	0.12	82	88	640	462	181		398	1,769	0.762	
81	189,090	0.08	83	44	255	76	17		712	1,104	0.584	
82	172,231	0.06	84	84	722	201	5	103		1,115	0.647	0.560
83	144,549	0.22	85	73	492	189	5	116		875	0.605	0.553
84	206,462	0.28	86	16	471	266	4	40		797	0.386	0.346
85	89,051	1.00	87	4	338	110	4	24		480	0.539	0.453
86	191,495	1.00	88	(511)		150	0	35		696	0.364	0.354
87	113,439	1.00	89	(379)		0	0	20		399	0.352	0.330
88	142,195	1.00	90	(480)		0	0	25		505	0.355	0.170
89	238,204	0.98	91	(359)		62	0	46		467	0.196	0.173
90	241,078	0.98	92	(546)		58	0	32		636	0.264	0.256
91	178,127	0.97	93	(196)		16	0	11		223	0.125	0.121
92	204,836	1.00	94[c]	(435)		10		23		468	0.229	0.214
93	221,403	1.00										

[a] Includes some returns from smolts stocked downriver of Mactaquac, 1981-1990 and in sea-cages (erosion of margins of upper and lower caudal fins).

[b] Adjusted return rates exclude smolts stocked downriver from Mactaquac (Marshall 1989) and new, since 1990, fish of potential sea-cage origin. (Marginal numbers of returns from approx. 5,000 age 2.1 smolts, 1989-1991 are not included; no returns from tagged smolts released to the Nashwaak River, 1992.)

[c] Hatchery origin MSW fish at Mactaquac in 1994 were assigned an origin on the basis of freshwater age (scale reading) and fin condition, i.e., age 1.2 @ 0.852, age 2.2 @ 0.068, age 3.2 @ 0.046 and repeat spawners @ 0.034.

Table 5. Estimated homewater removals(a) of 1SW and MSW salmon destined for Mactaquac Dam on the Saint John River, N.B., 1994.

Components	1SW Wild	1SW Hatch.	1SW Total	MSW Wild	MSW Hatch.	MSW Total
Native Food Fishery						
Below Mact.	97	53	150	39	11	50
Above Mact.(b)	63	37	100	31	9	40
Recreational fishery						
Tobique River	-	-	-	-	-	-
Mainstem abv Mact.	-	-	-	-	-	-
Mainstem blw Mact.	-	-	-	-	-	-
Hook-release mort.(c)	37	21	58	25	7	32
Passed abv Tinker	78	40	118	18	3	21
Passed abv Grand F.	38	24	62	11	6	17
Passed blw Mact.	-	-	-	-	-	-
Hatchery broodfish	23	8	31	337	107	444
mortalities, etc.	20	22	42	5	0	5
Poaching/disease(d)	37	21	58	64	18	82
By-catch	46	25	71	92	27	119
Totals	439	251	690	622	188	811

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

(b) - Guesstimate based on recovery of tags, reported and observed catches in trap nets and by other gear.

(c) - Assumed to be 2% of 1SW and MSW salmon released above Mactaquac (excl. of those to food fishery abv Mactaquac, Aroostook and Grand Falls).

(d) - Assumed to be 2% and 5% of all remaining 1SW and MSW fish respectively, above Mactaquac, i.e., 0.5 of values used in previous assessments when there was significantly more angling effort.

Table 6. 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, 1970-1994.

	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
1994	250	90	0				71	119	321	209

(a)- Kingsclear, 1974-88, Tobique 1988-90, Kingsclear, St. Mary's, Oromocto and Tobique in 1991-94, and Aboriginal Peoples Council, 1994.

(b)- NBDNRE and DFO sources.

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

Table 7. Estimated homewater returns, removals and spawning escapement of 1SW and MSW salmon destined for/above Mactaquac Dam, Saint John River, 1994.

Sea-age	Components	Wild	Hatch.	Total
1SW				
	Homewater returns	2,276	1,258	3,534
	Homewater removals(a)	439	251	690
	Spawners(b)	1,874	1,028	2,901
	Target spawners			3,200
	% of target spawners			91
MSW				
	Homewater returns	1,844	531	2,375
	Homewater removals(a)	622	188	811
	Spawners(b)	1,286	361	1,647
	Target spawners			4,400
	% of target spawners			37

(a) - Includes Mactaquac broodfish and losses to poaching and disease (Table 5).

(b) - Excludes Mactaquac broodfish but includes losses to poaching and disease (Table 5).

Table 8. 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 homewater 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.

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	205.60	1992	6,683	58.5	1993	2,958	2,958	3,450	0.44
1988-89		1993	3,213	58.3	1994	1,844	1,844	1,844	0.57
1989-90		1994	2,276	58.9	1995	_____		_____	
1990-91	180.18	1995	_____						

Table 9. Hatchery releases contributory to adult returns to Mactaquac in 1994, and estimates (based on external characteristics and age interpretation from scales) of 1SW and MSW returns and their return rates. Total returns vary slightly from "official" returns in Table 1 because scales of some fish revealed origins or sea-ages different from those ascribed from external characteristics and because fish of sea-cage origin have been omitted.

Release					Returns in 1994				
Year	Loc	Stage	Number		Age	1SW	MSW	Rate	
1993	At	1-yr smolt	221,403		1.1	869		0.00392	
1993	Bl	1-yr smolt(Nashw)	12,516		1.1	14		0.00112	
1992	Aroos	1-yr parr	16,400		2.1	-			
1991	Abv	Fall fing	479,458	a	2.1	198		0.00041	e
1991	Abv	Unfed/fry	173,524	a	2.1	-			
1990	Aroos	Adults(eggs'91)	105,000	b	2.1	-			
1990	Abv	Fall fing	219,314		3.1	226		0.00103	
1990	Abv	Unfed/fry	314,007	b	3.1	-			
1989	-	Fry/fing	-		4.1	12			
1992	At	1-yr smolt	204,836		1.2		438	0.00214	
1992	Bl	1-yr smolt(Nashw)	13,645		1.2		0	0.00000	
1990	Abv	Fall fing	219,314		2.2		35	0.00016	
1990	Abv	Unfed/fry	314,007	b	2.2		-		
1989	Abv	Fall fing	398,691	c	3.2		23	0.00006	
1989	Abv	Unfed/fry	528,978	bc	3.2		-		
		Repeat spawners	13,365	d	#.#.#		18	0.00135	
Totals						1,319	514		

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

b - Not expected to be distinguishable from wild fish upon return.

c - Includes 242,245 fall fingerlings and 312,594 fry to Aroostook; 66,000 fry to above Grand Falls.

d - Total estimated escapement above Mactaquac, 1992-1993.

e - Includes the 1-year parr.

Table 10. Numbers of hatchery fish released at (At), above (Abv) or below (Bl) Mactaquac that have potential to return to Mactaquac, possible return rates and, potential numbers of 1SW and MSW fish returning to the Saint John River and destined for Mactaquac in 1995. (Numbers do not include releases of unfed fry hatched from a total of 50,000 eggs provided to stakeholders for stream-side incubation in each of 1991 and 1992.)

Release					Returns in 1995			
Year	Loc	Stage	Number		Age	Rate(e)	1SW	MSW
1994	At	1-yr smolt	225,037		1.1	0.00400	900	
1994	Bl	1-yr smolt(Nashw)	15,059		1.1	0.00100	15	
1992	Abv	Fall fing	508,445	a	2.1	0.00040	203	
1992	Abv	Unfed/fry	600,441	ac	2.1	0.00020	120	
1991	Aroos	Adults(eggs'92)	370,000	c	2.1	0.00020	74	
1991	Abv GF	Adults(eggs'92)	370,000	c	2.1	0.00020	74	
1991	Abv	Fall fing	479,458	b	3.1	0.00080	384	
1991	Abv	Unfed fry	173,524	bc	3.1	0.00040	69	
1990	Aroost	Adults(eggs'91)	105,000	c	3.1	0.00020	21	
1993	At	1-yr smolt	221,403		1.2	0.00200		443
1993	Bl	1-yr smolt(Nashw)	12,516		1.2	0.00050		6
1992	Aroos	1-yr parr	16,400		2.2	0.00020		3
1991	Abv	Fall fing	479,458	b	2.2	0.00020		96
1991	Abv	Unfed/fry	173,524	bc	2.2	0.00010		17
1990	Aroos	Adults(eggs91)	105,000	c	2.2	0.00010		11
1990	Abv	Fall fing	219,314		3.2	0.00005		11
1990	Abv	Unfed/fry	314,007	c	3.2	0.00010		31
		Repeat spawners	9,516	d	#.#.#	0.00135		13
Totals							1,860	631

a - Includes 135,309 fall fingerlings and 411,678 fry (5.8-6.4cm) to above Grand Falls.

b - Includes 139,323 fall fingerlings and 173,524 fry (5.0-5.6cm) to above Grand Falls.

c - Not expected to be distinguishable from wild fish upon return.

d - Total estimated escapement above Mactaquac, 1993-1994.

e - Return rates for 1SW fish, based on those derived in Table 9, this document and, App. 5, Marshall and Cameron 1994; those of MSW fish were selected as 0.5 of 1SW values given that the present 1SW:MSW ratio is about 2:1. Return rates for other-than-smolts may be optimistic given that natural egg depositions above Mactaquac, 1989-1990, averaged about 90% of target (~26*10^6 eggs) and yielded only 2,276 "wild" 1SW (age 2.1 & 3.1) fish in 1994, i.e., return rate of 0.00009. The total required return rate to replace the stock (a pair of recruits from a female) is about 0.003.

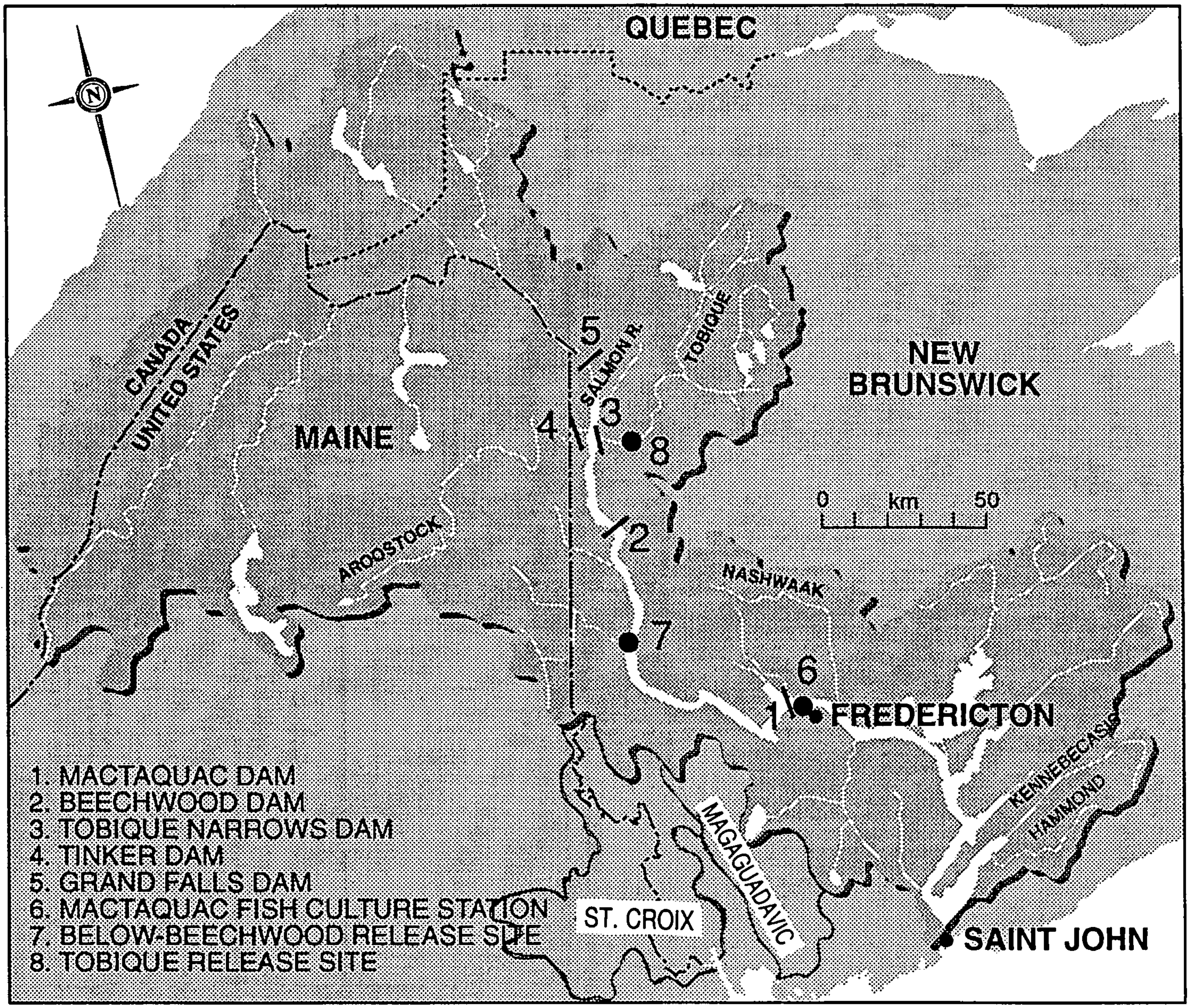
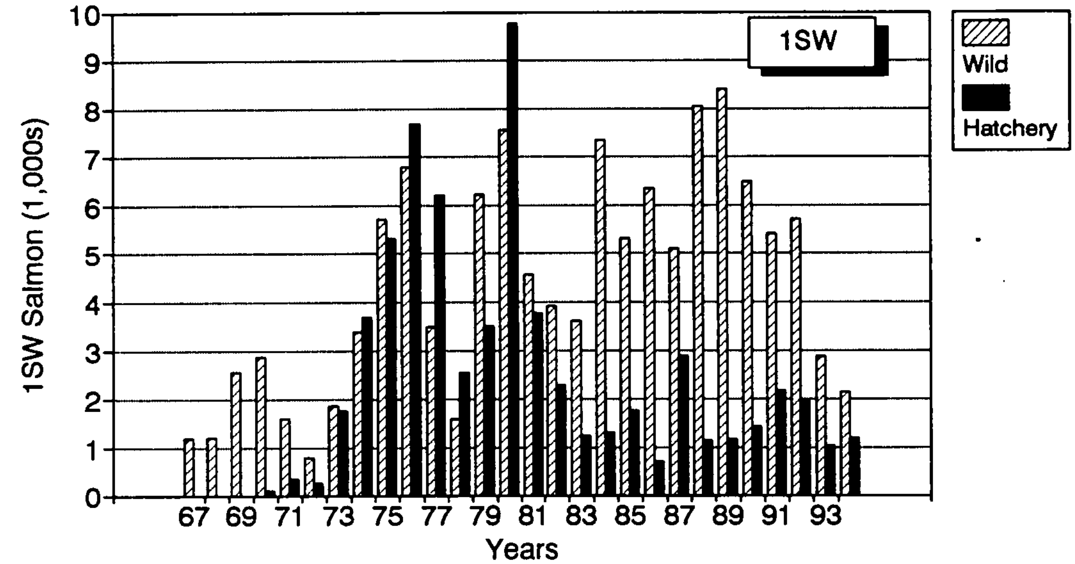


Fig.1 Saint John River drainage, including major tributaries, dams and principal release sites for Atlantic salmon above Mactaquac, Magaguadavic and St. Croix drainages.



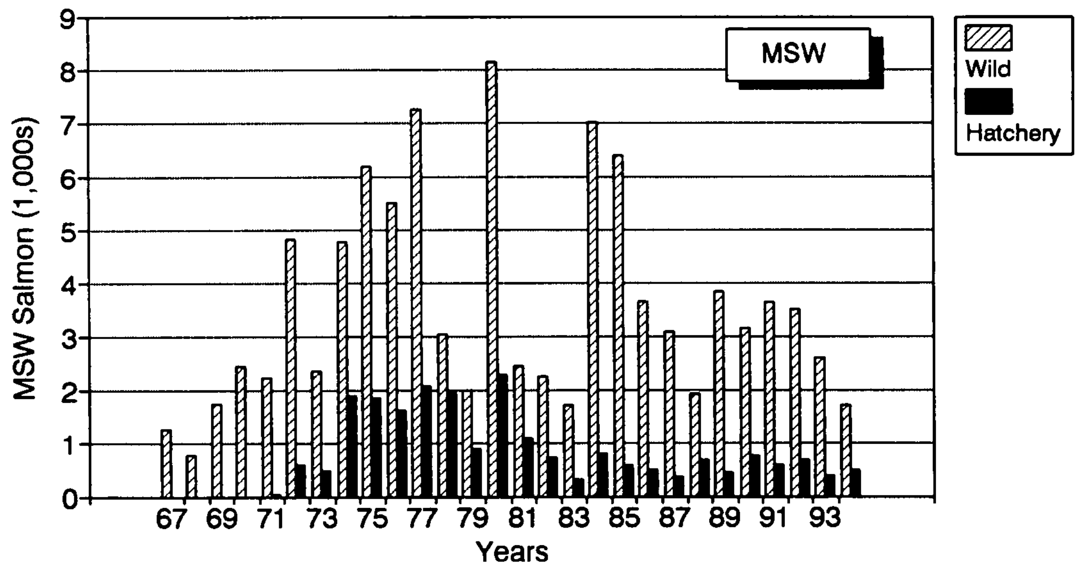


Fig. 2. Counts of wild and hatchery 1SW and MSW salmon at Mactaquac, 1967-1994.

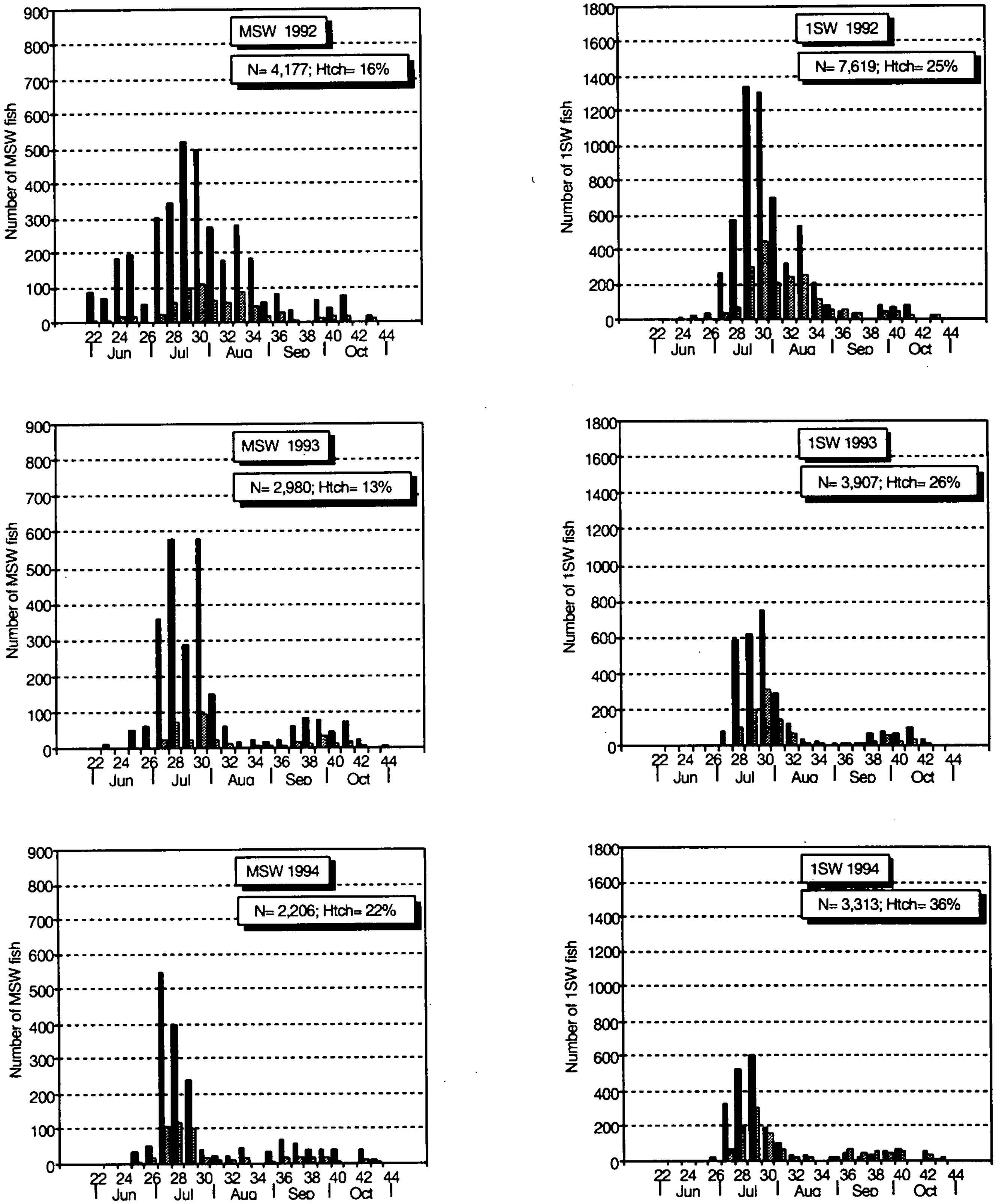
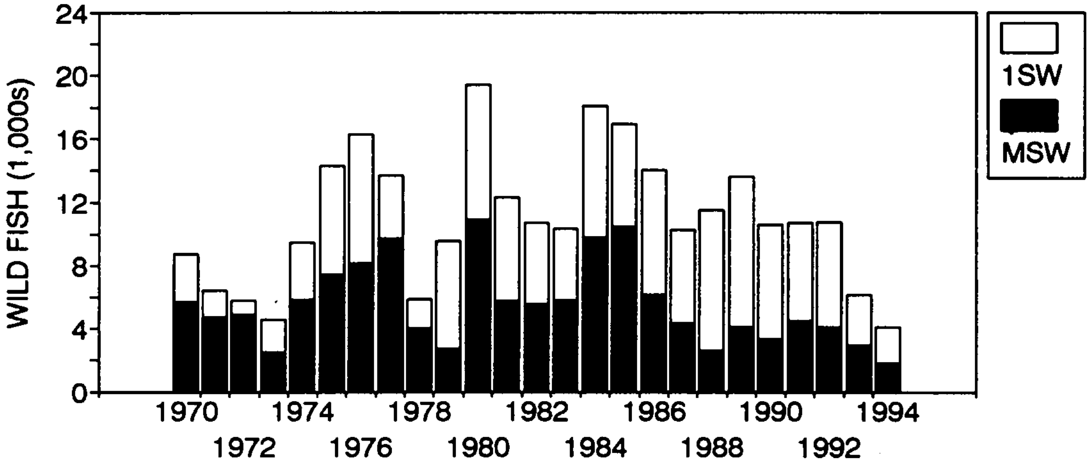


Fig. 3. Weekly counts of wild (dark) and hatchery (light) 1SW and MSW salmon at the Mactaquac sorting facilities, 1992-1994.



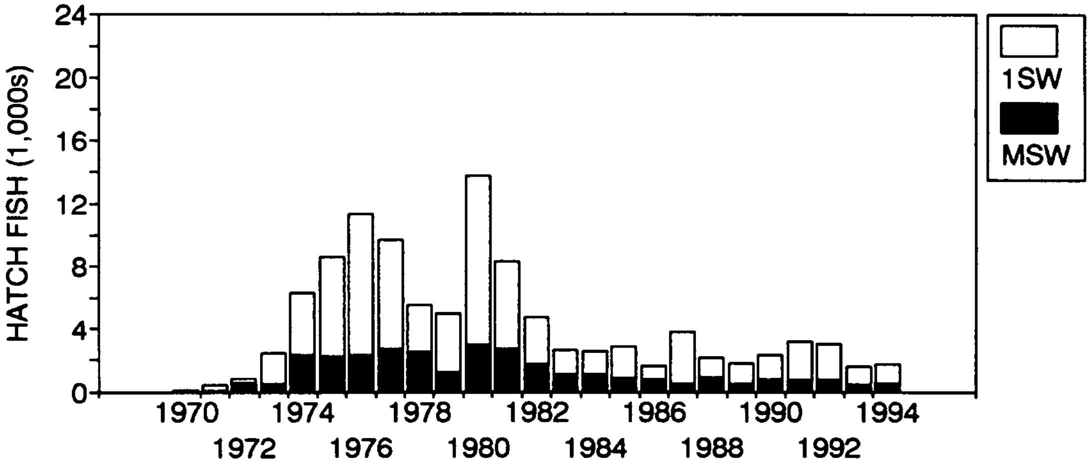
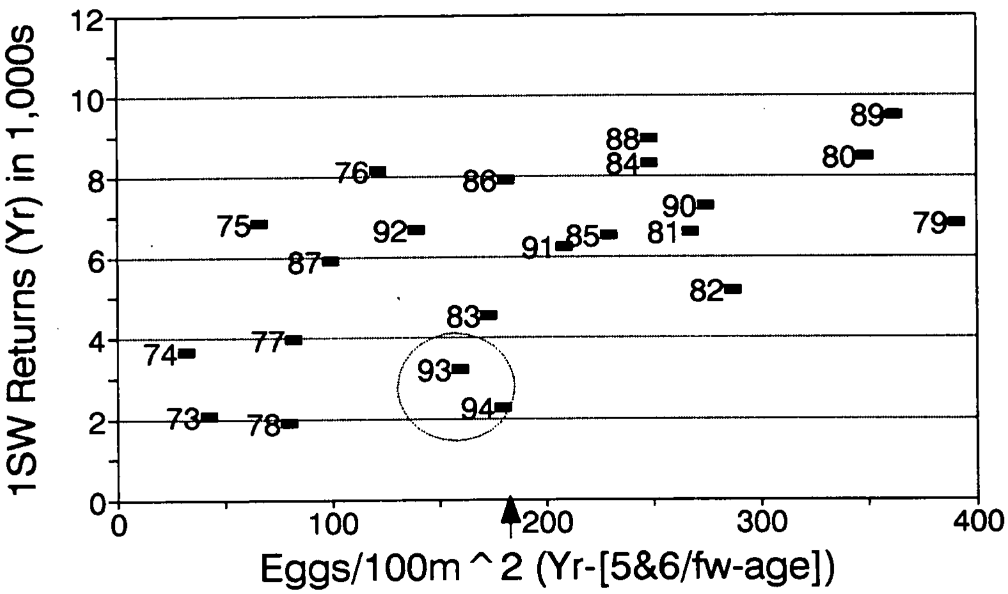


Fig. 4. Estimated numbers of wild and hatchery 1SW and MSW fish that returned to the Saint John River that were destined for Mactaquac, 1970-1994.



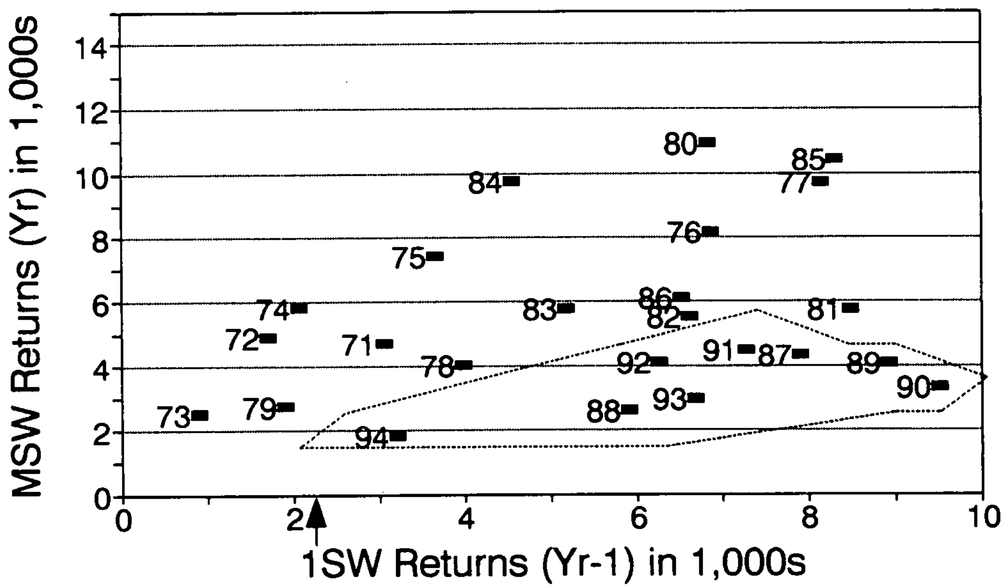


Fig. 5. Uncertainities in forecasting. Above - 1SW forecast model and approximate position of eggs with respect to 1SW returns in 1993 and 1994. Below - MSW forecast model (without length), without effect of moratoria but indicating 1987-94 subset. Arrows indicate approximate position from which "Y" would be estimated in 1995.

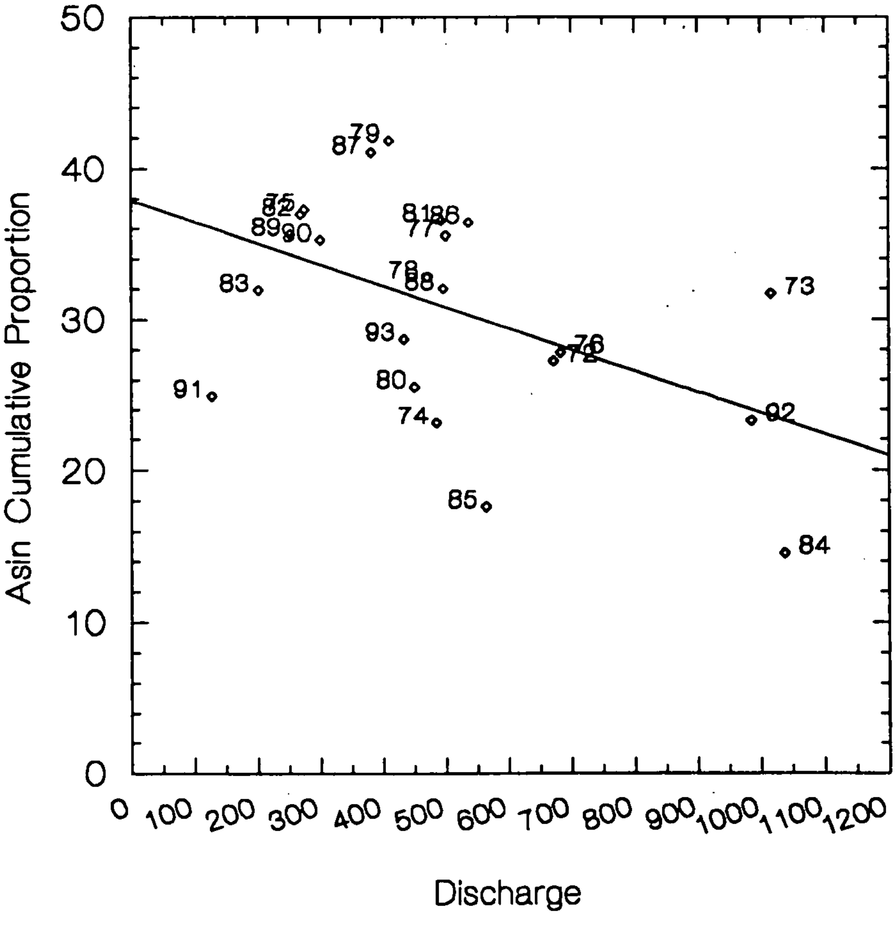


Fig. 6. Average daily discharge (m^3/s) at Mactaquac Dam, late-June - early-July, and proportion of the total season-end count of wild 1SW fish sorted to July 15, 1972-1993.

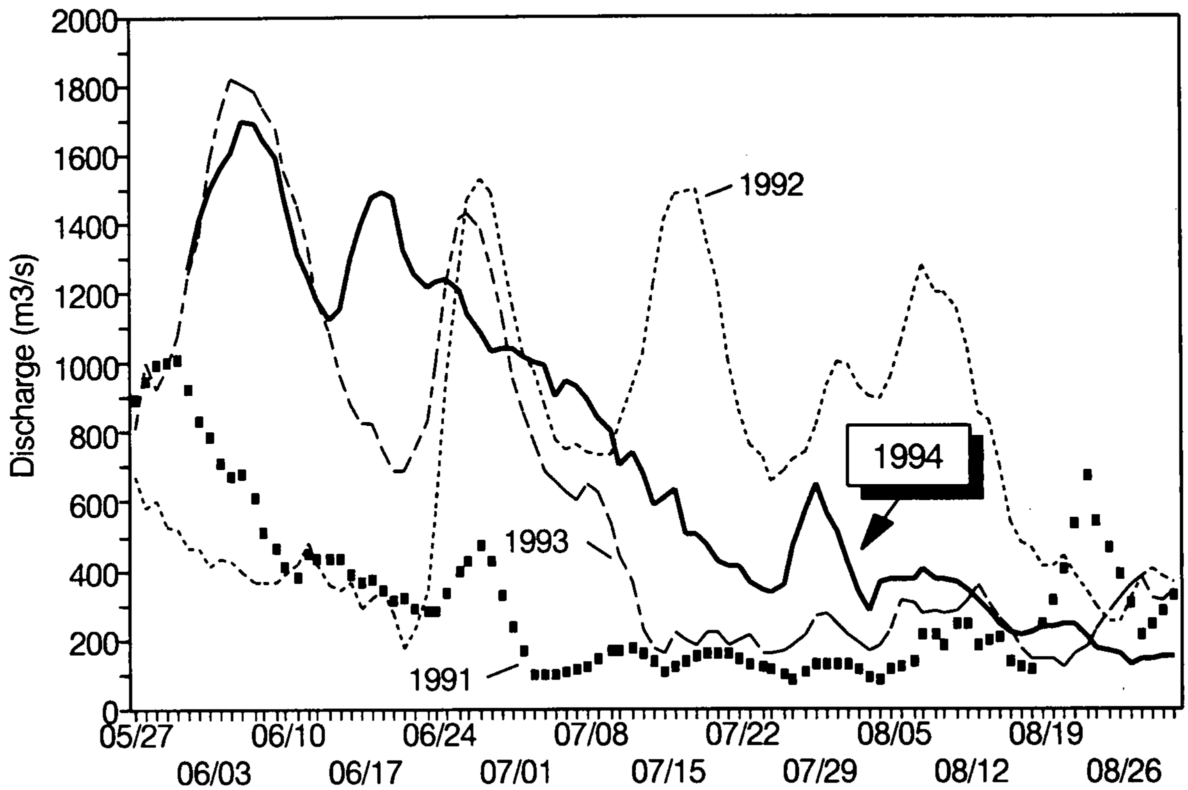


Fig. 7. Five-day moving averages of mean daily river discharge at Mactaquac, June through August, 1991-1994.

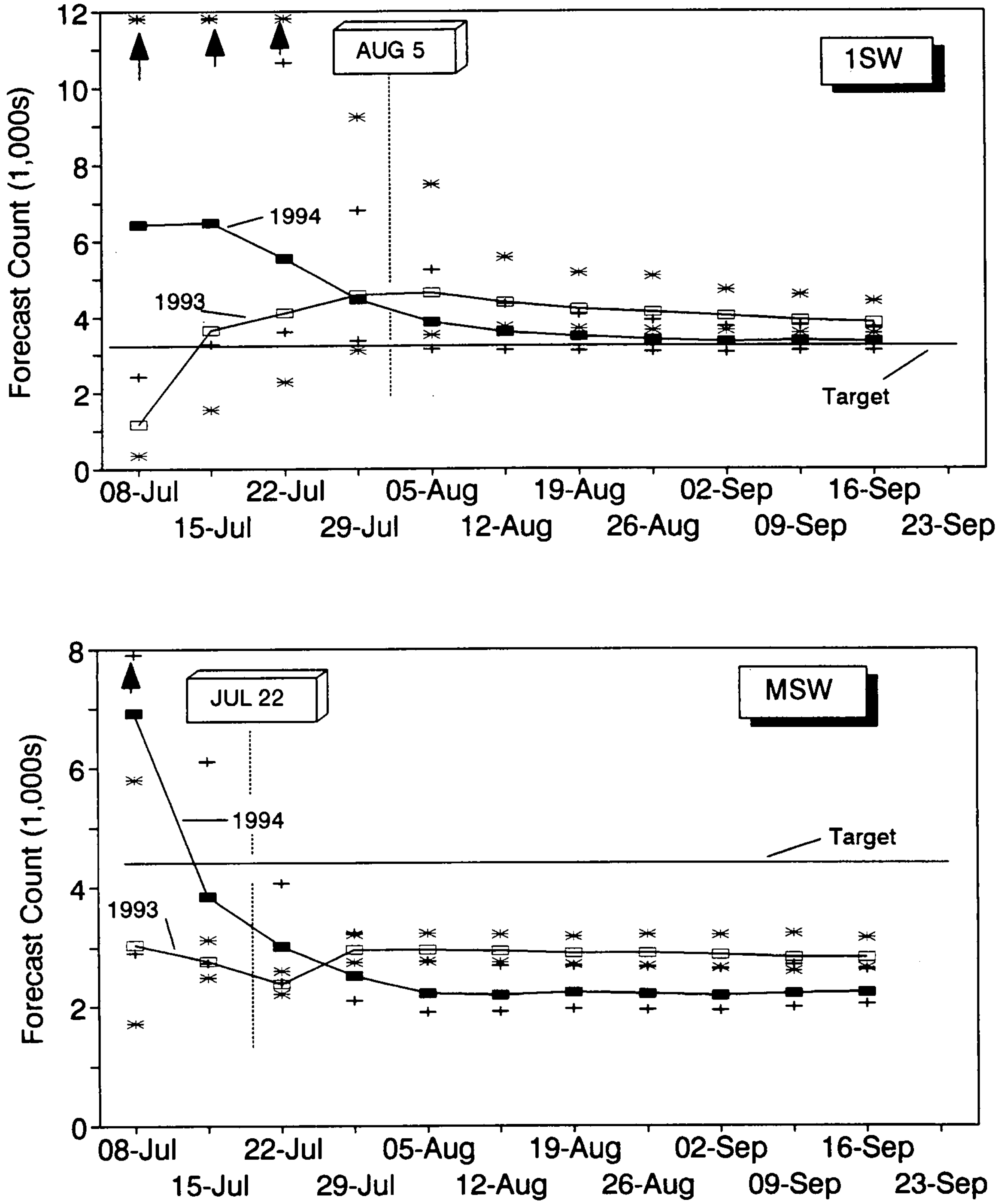


Fig. 8. In-season forecasting (forecasts and 90% confidence intervals), 1993-1994.

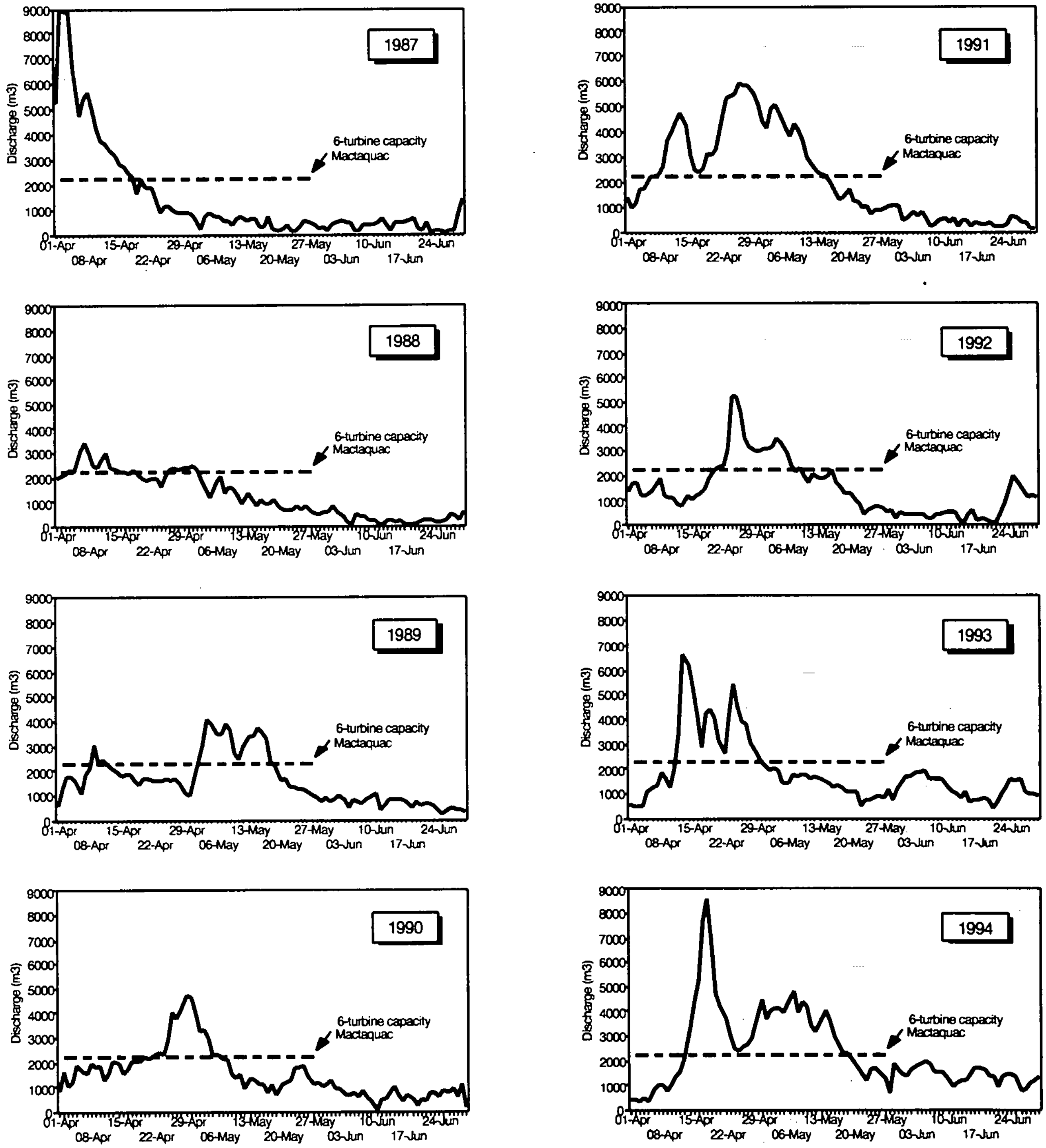


Fig. 9. Discharge of the Saint John River at Mactaquac, April through June, relative to the 6-turbine capacity of the generators.

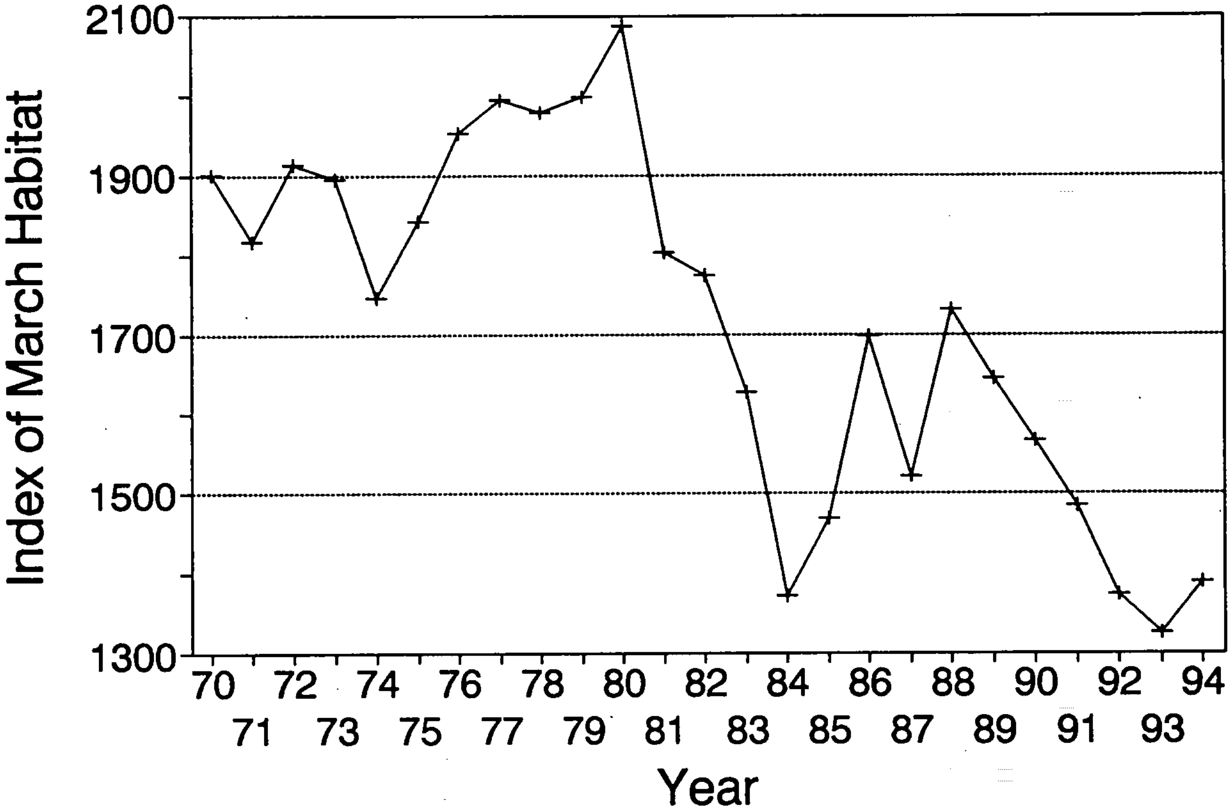


Fig. 10. March index of over-wintering habitat in the Labrador Sea, 1970-1994 (Anon 1994).

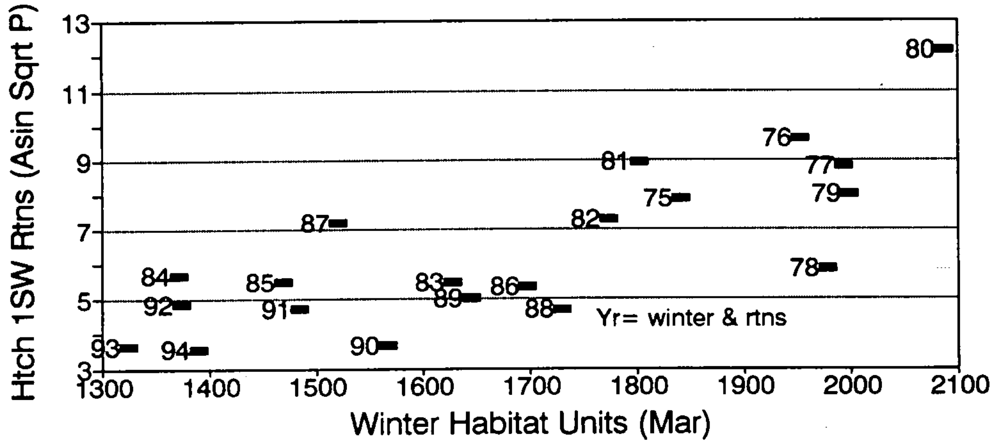


Fig. 11. March index (yr i) and return rate of hatchery 1SW fish (yr i) stocked as smolts from Mactaquac, 1975-1994.

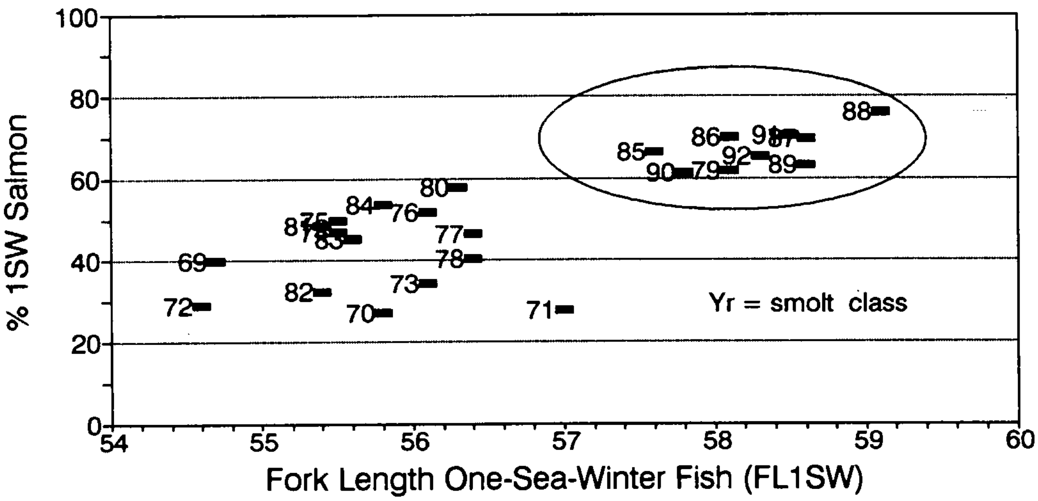


Fig. 12. Mean fork length of wild 1SW fish at Mactaquac and proportion of total recruits from a smolt class that returned as 1SW fish.

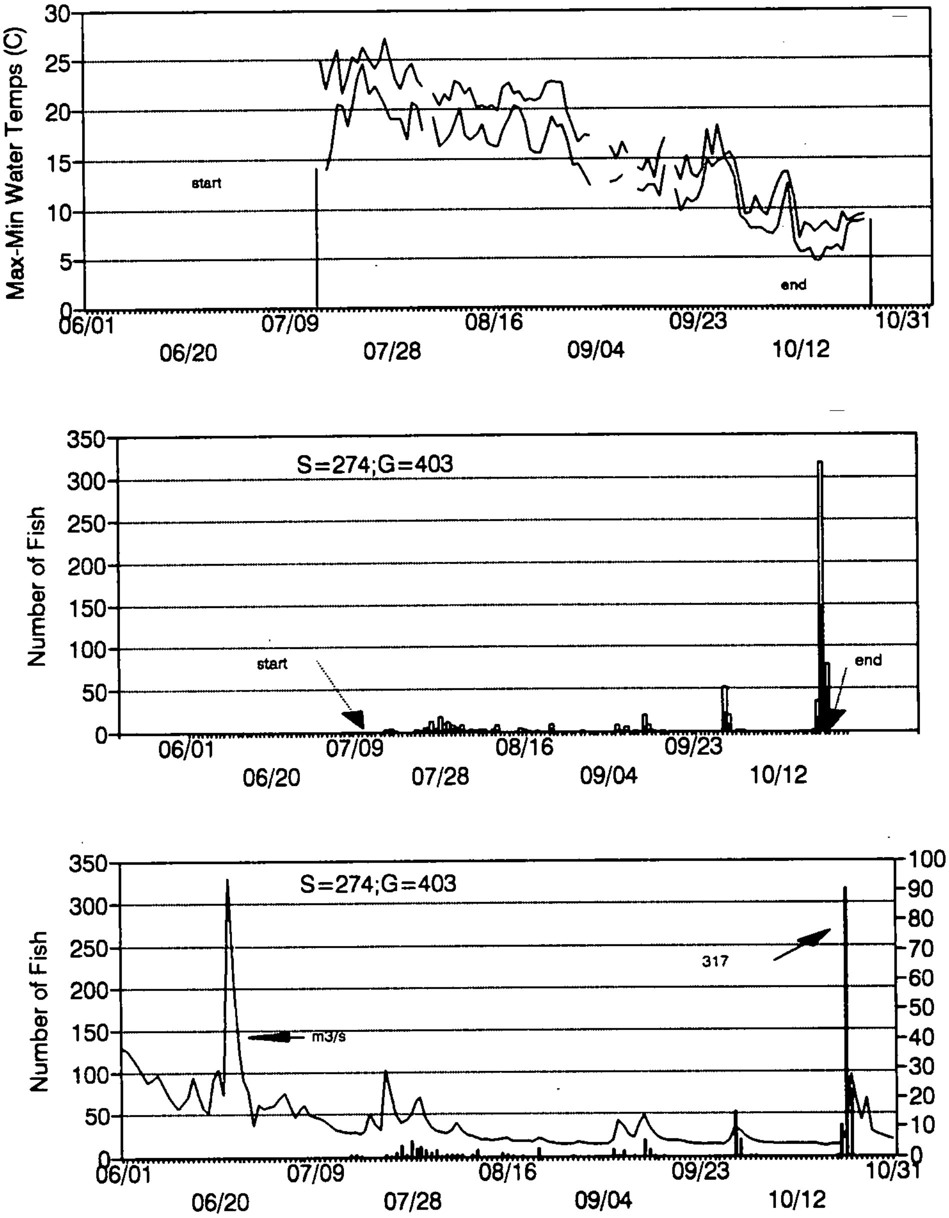


Fig.13. Maximum-minimum water temperature (upper), fence counts of 1SW "open bar"; MSW "solid bar" (middle) and total salmon with mean daily discharge (lower) at Durham Bridge, Nashwaak River, 1994.

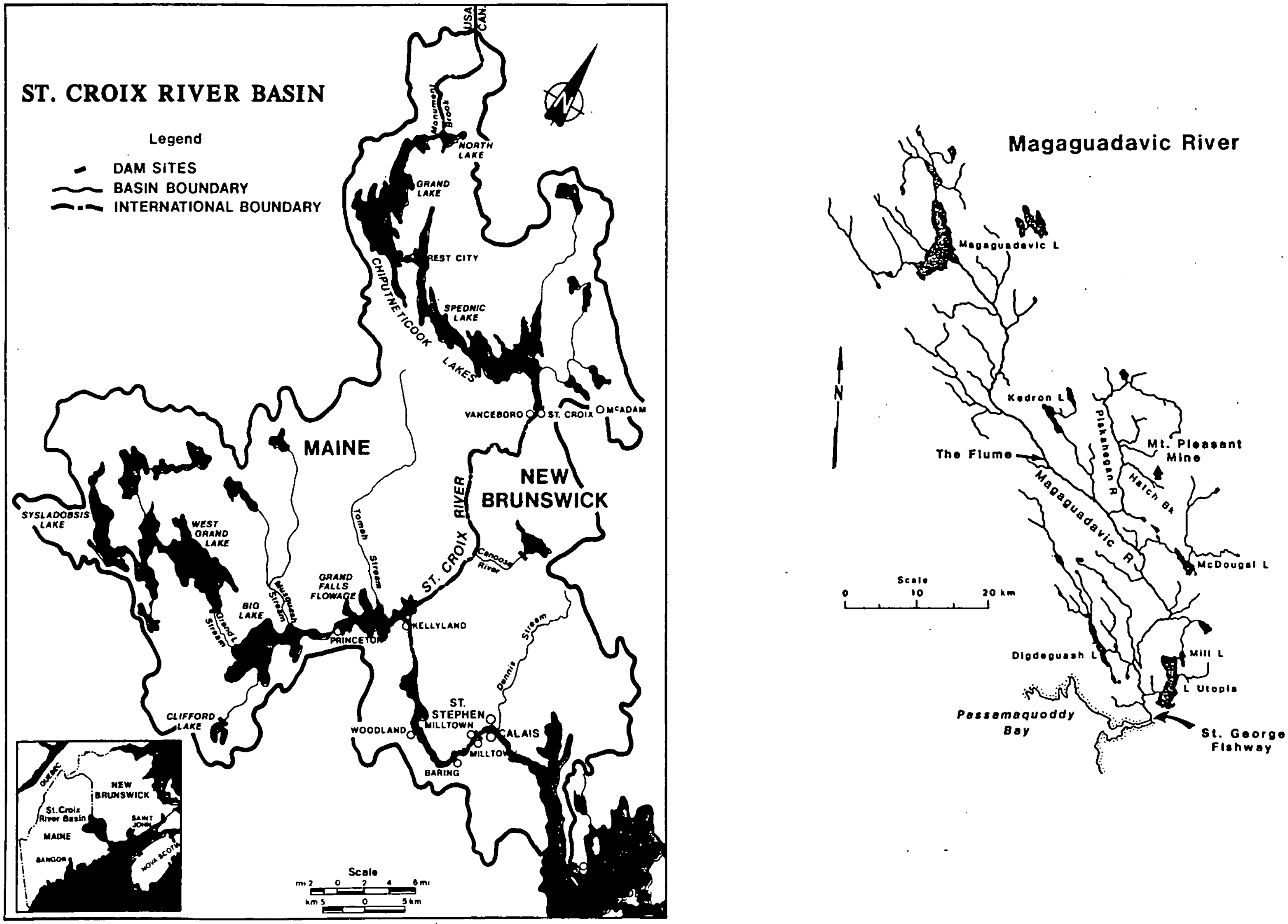


Fig. 14. St. Croix and Magaguadavic river systems of southwest N.B.

App. 1. Number of eggs/100^2 deposited in the Tobique River, 1968-1991, and derivation of weighted number of eggs contributing to annual returns of wild 1SW fish at Mactaquac, 1973-92 and 1995 (explanation in Penney and Marshall 1984).

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 @ Mact	
Year	Number	Age 2	Age 3	Yr i	Yr i+1		(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	0.761		104.49		205.60	(1992)
			0.239		32.81		
1989	185.5						
1990	174.1						
			0.498		86.63		
1991	186.2	0.502		93.55		180.18	(1995)

(a) Derived from App.2 and 3; underscored values are means of last 10 years (angular transformation).

App. 2. Number of wild 1SW salmon and proportion of age 2:1's of the total potential returns from the 1969-1989 year classes in the Saint John River destined for Mactaquac. Data from App. 3.

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	43	4,205	0.761
1990	2,200	1,101			
1991	1,101				

App. 3. Freshwater age and number of wild 1SW fish (A) counted at Mactaquac fish passage facilities, Saint John River, 1981-1994, and (B) that would have returned to Mactaquac had they not been exploited within the river, 1981-1994.

Fresh-water age	Number of 1SW fish													
	1981	1982	1982	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994[a]
A														
2	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	1,037
3	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	1,032
4	430	236	11	81	144	150	233	66	278	260	122	127	45	40
5						5					10			
6						5								
Total	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	2,104
B														
2	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	1,101
3	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	1,101
4	622	310	14	91	176	187	270	73	314	291	141	148	50	43
5						6					12			
6						6								
Total	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	2,245

[a] Total count (A) based on external characteristics and interpretation of scales from wild fish; total estimate (B) reflects ratio between count and estimate based only on external characteristics (Table 1).