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Assessments of Atlantic Salmon Stocks in South Western New Brunswick (Outer Portion of SFA 23): An Update to 2008

Évaluations des stocks de saumon atlantique dans le sud-ouest du Nouveau-Brunswick – mise à jour pour 2008

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ABSTRACT

The purpose of this document is to provide a review of DFO Science information for Southwest New Brunswick Atlantic salmon (*Salmo salar*) populations in support of a review of the conservation status of Atlantic salmon in Eastern Canada by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Information pertaining to populations in New Brunswick's outer Bay of Fundy (oBoF) portion of Salmon Fishing Area (SFA) 23 is compiled in this review, including the Saint John River upriver of Mactaquac Dam, the Nashwaak River (a tributary to the Saint John River downriver of Mactaquac Dam), the Magaguadavic River and the St. Croix River.

Adult salmon counts and estimates of returns to counting facilities (fishway, counting fence) are evaluated against conservation requirements that were determined for each index river based on accessible habitat area and the biological characteristic information of the returning adult salmon. Estimates of emigrating juvenile salmon (pre-smolt, smolt) using rotary screw traps as well as mean parr densities by electrofishing on two tributaries of the Saint John River are assessed against reference levels.

Overall, the available data on salmon in the outer portion of SFA 23 indicates that populations are persisting at low abundance levels. Estimated adult abundance on the Saint John River upriver of Mactaquac and on the Nashwaak River is presently 5% and 23% of their respective conservation requirements, and estimated egg deposition has declined at rates in excess of 65% over the last 15 years. Pre-smolt and smolt estimates for the Tobique River in 2008 were approximately half those in 2007, and smolt abundance on the Nashwaak River was 67% lower. Juvenile densities in the Tobique and Nashwaak rivers were an order of magnitude below reference values (Elson's norm) in 2008. Adult returns to other rivers in SFA 23 were extremely low, and decline rates in excess of 95% over the last 15 years were predicted for these populations (Magaguadavic and St. Croix rivers). Considering total escapement to SFA 23 over the last 15 years, declines of 62% and 87% respectively, are predicted for 1SW and MSW returning adults.

Within this region, numerous threats are likely affecting the current status and trends in abundance of these populations. Mortalities associated with the operation of hydro facilities are predicted to result in a 5-30% loss in spawner abundance on an annual basis. Freshwater threats include the effects of forestry and agriculture activities, invasive fish predators and escapes from the nearby aquaculture industry, but their population-level impact has yet to be quantified. Although some illegal fishing persists, commercial fisheries affecting these populations have been closed since 1984, and the recreational and native fisheries have been closed since 1998. To deal with the issue of low marine survival, the salmon enhancement program at the Mactaquac Biodiversity Facility was re-focused in 2001 to produce captive spawning adults from wild-caught juvenile salmon. However, freshwater threats, combined with low marine survival, still appear to be limiting recovery of the populations in the region.

RÉSUMÉ

Le présent document passe en revue l'information sur les populations de saumon atlantique (*Salmo salar*) du sud ouest du Nouveau Brunswick dont disposent les Sciences du MPO à l'appui d'une évaluation sur l'état des populations de saumon atlantique par le Comité sur la situation des espèces en péril au Canada (COSEPAC). On y trouvera aussi de l'information sur les populations de la partie de la zone de pêche du saumon (ZPS) 23 située dans l'avant baie de Fundy, au Nouveau Brunswick, comprenant la rivière Saint Jean en amont du barrage de Mactaquac, la rivière Nashwaak (un affluent de la rivière Saint Jean en aval du barrage de Mactaquac), la rivière Magaguadavic et la rivière St. Croix .

Les résultats des dénombrements de saumons adultes et les estimations des montaisons aux installations de dénombrement (passes migratoires et barrières de dénombrement) sont évalués par rapport aux impératifs de conservation établis pour chaque rivière repère en fonction de l'étendue de l'habitat accessible et des données sur les caractéristiques biologiques des saumons adultes de montaison. Les estimations, obtenues au moyen de pièges rotatifs à poissons, du nombre de saumons juvéniles (présaumoneaux et saumoneaux) qui émigrent et les densités moyennes des tacons établies par électropêche dans deux affluents de la rivière Saint Jean sont comparées aux niveaux de référence.

Dans l'ensemble, les données disponibles sur le saumon dans la partie périphérique de la ZPS 23 révèlent que l'abondance des populations reste basse. Les estimations de l'abondance des adultes dans la rivière Saint Jean en amont de Mactaquac et dans la rivière Nashwaak représentent actuellement 5 % et 23 %, respectivement, des impératifs de conservation dans ces rivières et la ponte estimée a diminué dans des proportions supérieures à 65 % sur les 15 dernières années. Les nombres estimés de présaumoneaux et de saumoneaux dans la rivière Tobique en 2008 se situaient à environ la moitié de ceux de 2007, tandis que dans la rivière Nashwaak l'abondance des saumoneaux avait diminué de 67 %. Les densités de juvéniles dans les rivières Tobique et Nashwaak étaient inférieures d'un ordre de grandeur aux valeurs de référence (norme d'Elson) en 2008. Les montaisons d'adultes dans les autres rivières de la ZPS 23 étaient extrêmement basses, et on prévoyait des déclins supérieurs à 95 % sur les 15 dernières années parmi ces populations (rivières Magaguadavic et St. Croix). Si on considère les échappées totales des 15 dernières années dans la ZPS 23, les déclins prévus sont de 62 % et 87 %, respectivement, chez les unibermarins et les pluribermarins adultes qui remontent les rivières.

Dans cette région, de nombreuses menaces influent vraisemblablement sur la situation actuelle et sur les tendances d'abondance de ces populations. On prévoit que la mortalité associée à l'exploitation de centrales hydrauliques se soldera par une perte annuelle de 5 % à 30 % dans l'abondance des reproducteurs. En eau douce, il faut compter parmi les menaces les effets des activités forestières et agricoles, les poissons prédateurs envahissants et les évadés des installations aquacoles voisines, mais les effets de ces menaces sur les populations de saumon n'ont pas encore été quantifiés. Bien qu'une certaine pêche illégale subsiste, les pêches commerciales qui touchaient ces populations sont fermées depuis 1984 et les pêches récréatives et autochtones sont fermées depuis 1998. Face au problème que représente la faible survie en mer, le programme de mise en valeur du saumon du Centre de biodiversité de Mactaquac a été recentré en 2011 sur la production en captivité de reproducteurs adultes à partir de saumons sauvages juvéniles capturés. Toutefois, la combinaison des menaces présentes en eau douce et de la faible survie en mer semble toujours limiter le rétablissement des populations dans la région.

INTRODUCTION

The purpose of this document is to provide a review of DFO Science information for Southwest New Brunswick Atlantic salmon (*Salmo salar*) populations in support of the development of a status report of Atlantic salmon in eastern Canada by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Information pertaining to populations in New Brunswick's outer Bay of Fundy (oBoF) portion of Salmon Fishing Area (SFA) 23 is compiled in this review, including the Saint John River upriver of Mactaquac Dam, the Nashwaak River (a tributary to the Saint John River downriver of Mactaquac Dam), the Magaguadavic River and the St. Croix River. These outer Bay of Fundy populations have been grouped as a separate Conservation Unit (CU 17) in DFO and MNRF (2008). The Big Salmon River which is part of the "endangered" inner Bay of Fundy salmon population complex is not included.

Population status of Atlantic salmon in the Saint John River is assessed annually from data collected at Mactaquac Dam, as well as from the Tobique and the Nashwaak rivers, the largest salmon-producing tributaries upstream and downstream respectively of Mactaquac Dam. Adult salmon counts and estimates of returns to counting facilities (at Mactaquac Dam and in the Nashwaak River) are evaluated against conservation requirements that were determined for each index river based on accessible habitat area and the biological characteristics of the returning adult salmon. Programs based on mark-recapture experiments to estimate smolt production take place on the Tobique and Nashwaak rivers. For the Tobique River, this includes an estimate of the fall pre-smolt migration the year before. Electrofishing surveys, from which the density of age-0, age-1, and age-2 and older juveniles are estimated and assessed against reference levels, take place on the Tobique and Nashwaak rivers. Outside of the Saint John River system, the only other assessment activities in the outer portion of SFA 23 are adult counts of returning salmon to the fishway on the Magaguadavic River. The fishway on the St. Croix River has not been monitored since 2006.

Many of the outer Bay populations face a multitude of constraints. These include hydroelectric dams (with upriver passage facilities but most are devoid of safe downstream passage), artificial flow regimes, headponds, significant industrial and municipal effluents, run-off from intensive agricultural and forestry operations, and communities of invasive predators (i.e. muskellunge, smallmouth bass, chain pickerel and rainbow trout). As well, juvenile and adult salmon escapes from the Fundy-Isle (NB) or Cobscook Bay (ME) aquaculture facilities are the most probable sources of aquaculture origin salmon identified at all primary counting facilities.

The Maritime Provinces' commercial salmon fishery has been closed since 1984 and, after several buy-backs of licences, has only four eligible but inactive licences remaining in the Saint John River area. Due to the persistent failure of populations to achieve the conservation requirement, the Aboriginal food fisheries and the recreational fisheries have been closed on the Saint John River system since 1998. Similarly, the aboriginal food fishery and recreational fisheries have been closed since 1998 on the Magaguadavic and St. Croix rivers. However, there is some by-catch of salmon in net fisheries in the Saint John River estuary as well as some illegal fishing taking place throughout the Saint John River system.

SAINT JOHN RIVER UPRIVER OF MACTAQUAC DAM

Physical attributes, salmon production area (updated in Marshall et al. 1997), barriers to migration, fish collection and distribution systems, the role of fish culture operations (updated in Jones et al. 2004) and biology of the populations of the Saint John River drainage (Fig. 1), have been previously described in Marshall and Penney (1983). In 1983, the status of the salmon populations, since 1970, was evaluated (Penney and Marshall 1984) and continued through to 2005 (Jones et al. 2006). The assessment documents for the 1998 and 1999 returns were less detailed than those done previous to 1998 (Marshall et al. 1999a, 1999b; Marshall et al. 2000). From 2000 to 2002, stock status was reported in the status overview documents for Atlantic Salmon in the Maritime Provinces (DFO 2001, 2002, and 2003). The approach used in this assessment is similar to that of the last two detailed assessments completed in 2003 (Jones et al. 2004) and 2005 (Jones et al. 2006) with additional data and analyses added to assist COSEWIC in their review of Atlantic salmon in Canadian waters.

Revisions to Mactaquac Fish Culture Program

The Mactaquac Biodiversity Facility (formerly Fish Culture Station) has been involved in mitigation efforts to offset declines in salmon production from hydroelectric projects on the Saint John River. Since construction, the facility has emphasized smolt production as a method of augmenting river returns and access to the resource by fishers. Each year, hatchery broodstock for the program came from 200-300 wild sea-run adults captured at Mactaquac Dam. Rapidly diminishing returns of wild and hatchery salmon to Mactaquac and failure to meet the conservation requirement has resulted in closures of in-river fisheries. Furthermore, concerns have arisen regarding smolt production as an effective method of conservation for wild salmon populations due to: a) the increasing proportion of identified hatchery fish among total returns; b) the increasing possibility that “wild”-appearing returns were F2 or F3 hatchery; c) the increasing proportion of wild MSW returns required to sustain hatchery smolt production; d) the loss of those wild broodstock from natural spawning; e) the high proportion of hatchery-origin smolt returns that are male 1SW fish with limited potential to augment the population; f) the possibility that Mactaquac-origin returns might be less capable of selecting viable spawning areas than homing wild fish and, g) the possibility that artificial mating of broodstock may produce smolts that are less fit than their randomly-mating wild counterparts.

In response to these concerns, the program at the Mactaquac Biodiversity Facility was re-focused towards conservation, predominantly by scaling back traditional smolt production. Beginning in 2001 with the capture of 2,500 smolts, wild and hatchery (at least one year in natural environment) juvenile salmon have been captured in rotary screw traps (RSTs) from the Tobique River, reared to adulthood, spawned in the biodiversity facility, and age-0 fall parr have been released upriver of Mactaquac. The benefits of collecting juveniles include: a) increased natural egg deposition upriver of Mactaquac, b) increased utilization of proven freshwater habitat, c) natural selection on subsequent progeny, and d) the additional escapement of 200 wild fish that would otherwise have been used as hatchery broodstock. For research purposes, a few hundred captive-reared broodstock have been retained and bred to produce age-0 fall parr and a limited number of smolts for release. Smolt production at Mactaquac has been scaled back from greater than 300,000 smolts released annually to between 50,000 - 100,000 smolts available for various assessment activities.

In-stream studies to assess spawning of the captive-reared fish were conducted in the Pokiok Stream (Jones et al. 2004) and in the Odell River in 2004 (Jones et al. 2006) and have shown some evidence of successful spawning. In the Odell study, redds were observed and age-0 parr or fry were captured the following year by electrofishing. In the Pokiok experiment, high water prevented the completion of the redd survey and tissue samples from the age-0 parr that were captured by electrofishing the following year have not been processed. In both cases the proportion of adults that spawned, as well as survival of progeny of these releases is not known.

In addition to the captive-reared program, between 40 and 60 sea-run salmon are retained for special broodstock purposes. These early-run broodstock for the most part include the unique 2SW salmon referred to as the 'Serpentine' stock – these salmon enter the Saint John River estuary in November and ascend the river in June and spawn that fall (DFO and MNRF 2009).

Returns Destined for Upriver of Mactaquac Dam

Methods

Adult salmon are captured and counted at the fish collection facilities at the Mactaquac Dam and at an adult trap operated in the smolt migration channel at the Mactaquac Biodiversity Facility. During 2008, both of these collection facilities were operated from May 28 to October 28.

Returning salmon were sorted at the Mactaquac Biodiversity Facility sorting facility and were classified as small or large and as either wild origin, hatchery origin, captive-reared origin or aquaculture escape. Hatchery origin salmon that were released as 1-year smolts at the smolt migration channel at the Mactaquac Biodiversity Facility or as juveniles (essentially fall parr) released upriver of Mactaquac, were principally identified by the absence of an adipose fin. Fish with an adipose fin but with some fin erosion were classified as hatchery origin if interpretation of scale patterns confirmed that they were not an aquaculture escape. Captive-reared origin fish previously released as mature adults and returning to Mactaquac Dam as reconditioned adults were identified by a v-notch in their adipose fin. Suspected aquaculture escapes were identified by considerable erosion and partial regeneration of fin rays on all fins including the upper and/or lower lobes of the caudal fin, the presence of an adipose fin and the interpretation of scale samples. All other fish were classified as wild origin, including returns from hatchery origin unfed and feeding fry as well as progeny from captive-reared spawners (released primarily to the Tobique River since 2003). Both of these groups are indistinguishable from wild origin fish.

Marshall and Jones (1996) described the difficulty of distinguishing between adult returns from natural versus artificial recruitment because of the increasing numbers of unmarked hatchery distributions in the early and mid 1990's. Since 1998, the majority of the fall fingerling parr and spring smolts released upriver of Mactaquac Dam have had the adipose fin removed (Appendix *i*, Appendix *ii*, Fig. 2a, Fig. 2b). Scale samples are taken from approximately every second hatchery and wild fish (exceptions include the complete sampling of all broodstock). The proportion of wild and hatchery origin in the count was adjusted based on interpretation of these scales. The procedures used to adjust counts in 2008 were identical to those used since 1995 and described in Marshall and Jones (1996). The adjusted counts at Mactaquac Dam were used to estimate the returns and return rates for hatchery fish released as age-1 smolts and as age-0 parr.

As in previous years, salmon by-catch in the lower river and in the Saint John Harbour from shad and gaspereau net fisheries was monitored by DFO fishery officers. Consistent with previous assessments, the assumed catch rates were 1% of the 1SW and 2.5% of the MSW river returns. These catch rates are thought to include any losses due to poaching. Catches of salmon destined for upriver of Mactaquac Dam and caught downriver were assumed to consist of hatchery and wild origin salmon in the same proportions as the adjusted counts at Mactaquac. Therefore, estimated total returns of 1SW and MSW salmon (wild and hatchery origin) from upriver of Mactaquac Dam was the sum of the adjusted counts at Mactaquac Dam and the estimated removals in the main stem downriver of Mactaquac Dam (from poaching and by-catch).

Results

Unadjusted counts of salmon at Mactaquac in 2008 totalled 1,757 1SW and 300 MSW salmon (Tables 1 and 2). Twenty-six (8.7%) of the 300 MSW salmon counted at Mactaquac were reassigned to the 1SW category on the basis of scale interpretation (Table 1). Interpretation of scales shifted the hatchery component among 1SW fish from 49.6% (Table 1) to 55.8% and among MSW fish from 45.7% to 49.3%. The adjusted counts proportioned by age composition among hatchery and wild components since 1992 are tabled in Appendix *iii*. There were no aquaculture escapes or repeat spawning captive-reared origin fish identified among the salmon returns in 2008 (Table 1).

DFO fisheries officers reported illegal fishing in the main stem downriver of Mactaquac Dam in 2008 but did not observe any salmon being removed from the river. Total removals in 2008 were estimated to be 18 1SW and seven MSW salmon from by-catch in the shad and gaspereau nets in the lower river and in the Saint John Harbour area (Table 1).

Adjusted wild origin and hatchery origin returns in 2008 were 1,801 1SW and 281 MSW fish (Table 1; Fig. 3). Adjusted returns of wild origin 1SW salmon increased by 62% from those of 2007, but were the eighth lowest annual estimate since 1970 (Table 3). Adjusted returns of wild origin MSW salmon were the lowest in 39 years and were well below the five and ten year mean estimates (Table 3). The adjusted return rate to Mactaquac Dam of hatchery origin 1SW fish released as 1 year-old smolts was 0.70%, a 3-fold improvement from the previous year and the highest value observed in the past decade (Table 4a; Fig. 4). The 2007 1 year-old smolt class was the second release from the captive-reared broodstock program. The return rate of 1 year-old smolts to Mactaquac Dam as virgin hatchery origin 2SW salmon (Table 4b; Fig. 4) was 0.05%, the third lowest value on record. Besides being about half that of the previous year, the estimate was consistent with the poor 1SW return rate (0.21%) observed in 2007 from the same smolt class (Table 4a). Prior to 2006, all hatchery origin smolts released were progeny of sea-run adults.

Removals of Fish Upriver of Mactaquac Dam

Methods

Removals from the potential spawning escapement destined for the traditional production areas upriver of Mactaquac Dam include: a) salmon passed or trucked upriver of Tinker Dam on the Aroostook River (Fig. 1), b) salmon retained at Mactaquac biodiversity facility as broodstock or mortalities from handling operations at Mactaquac, and c) salmon estimated to have been lost to poaching upriver of the Dam. Losses to poaching include those estimated to have been taken in the net fishery on the Tobique River as well as known mortalities from fishways (Beechwood, Tobique and/or Tinker Dam) or the Tobique Half Mile Barrier. If detailed information was not available for the losses, they were apportioned to hatchery/wild components on the basis of the composition of fish released upriver of Mactaquac.

Results

Reports from area fisheries officers indicated that there was illegal fishing activity near Tobique Narrows Dam in 2008 but the total number of fish harvested was unknown. While evaluating the efficiency of the fishway, Jones et al. (2004) estimated that fishing mortality in this region was 9.4% and 6.1% respectively for 1SW and MSW salmon, based on tag returns. Applying this value to the number of fish passed upriver of Beechwood Dam means 70 fish would have been removed by this illegal fishery. Since 2005, no adult salmon from Mactaquac have been transported to the

Aroostook River upriver of Tinker Dam, although there were 20 1SW and five MSW fish counted at the Tinker Dam fishway (Table 5). The area upriver of Tinker Dam was excluded from the "upriver of Mactaquac" conservation requirement (Marshall et al. 1997), so these 25 fish were not included in the escapement estimates.

Total river removals from all sources (upriver and downriver of Mactaquac Dam) were estimated at 127 1SW and 74 MSW fish (Table 5) of which 20 (17 males and three females) 1SW and 35 (13 males and 22 females) MSW salmon were held at Mactaquac for broodstock. These early-run 'Serpentine' broodstock yielded about 128,000 eggs.

Conservation Requirements

The conservation requirement for the Saint John River upriver of Mactaquac Dam is based on an accessible salmon-producing rearing area of 13,472,200 m^2 with stream gradients >0.12% and <5.0% (Amiro 1993). This rearing area excludes the Aroostook River, the hydro dam head ponds, and 21 million m^2 of river with gradient <0.12% (Marshall et al. 1997). Given the conservation egg deposition rate of 2.4 eggs/m^2 (Elson 1975; CAFSAC 1991), the conservation requirement is 32,330,000 eggs. The numbers of spawners necessary to obtain the conservation requirement has been estimated to be 4,900 MSW and 4,900 1SW salmon (Marshall et al. 1997). Similar to previous years, egg deposition and the number of spawners in 2008 were estimated on the basis of length, external sexing and interpretation of age from scales collected from fish captured at the Mactaquac Dam fishway (Jones et al. 2006).

Escapement

Sea-Run

Collation of the total sea-run (excluding captive-reared spawners) returns (Table 1) and total removals (Table 5) of wild and hatchery fish indicates that escapement was 207 MSW salmon and 1,674 1SW salmon (Table 6).

Differences in biological characteristics from 2007 included a large increase in mean length (+4.4 cm) for female hatchery 1SW salmon. A similar increase in mean length (+4.5) was also observed for female wild 1SW salmon. However, the mean length of both groups in 2008 was very similar to values observed from 1996 to 2006. The proportion of females among wild and hatchery MSW fish increased by 0.15 and 0.05, respectively, from 2007 (Table 7a). Very little change in mean length of wild (-0.2 cm) and hatchery (+0.2 cm) female MSW spawners was observed between 2007 and 2008. Using the length-fecundity relationship calculated for Saint John River salmon (eggs = $430.19e^{0.03605 X \text{fork length}}$; Marshall and Penney 1983), as well as the mean lengths and estimated escapement in 2008 upriver of Mactaquac Dam, the total estimated egg deposition was 1.50 million eggs (0.133 eggs per m^2) or 5% of the conservation requirement. This is about 70% of the value estimated in 2007 and the lowest estimate in 39 years (Fig. 5). Estimated eggs from wild and hatchery 1SW fish comprised 18% of the total deposition. Eggs from hatchery origin 1SW and MSW salmon potentially contributed 54% of the total deposition (Table 7a).

Captive-Reared

In 2008, adult releases from the captive-reared broodstock program were distributed to sites in the Tobique River and just downriver of the confluence with the main Saint John River near Perth-Andover. Using the mean length for each age category and a length-fecundity relationship (eggs = $337.93e^{0.0436 X \text{fork length}}$; Jones et al. 2006) for captive-reared broodstock, the sexually mature females potentially produced another 2.80 millions eggs (Table 7b), or an additional 9% of the conservation requirement.

Trends in Returns and Escapement

Methods

We analyzed trends in abundance for the salmon population upriver of Mactaquac Dam from wild 1SW and MSW returns, hatchery 1SW and MSW returns, and combined wild and hatchery 1SW and MSW returns, as well as total egg deposition from wild and hatchery 1SW and MSW spawners (Table 3). Trends in these four groups were analyzed over the most recent 15-year time period using two methods described by Gibson et al. (2006). The first approach was the commonly used "log-linear model":

$$N_t = N_0 e^{zt}.$$

where N_0, the population size at the start of the time series, and z, the instantaneous rate of change in abundance, are estimated parameters. The change in population size over the full time period is given by e^{zt}. This model was fit using least squares after transformation of the data to a log scale.

The second approach was to calculate the extent of the decline as the ratio of the population size at the start (1993) and the end (2008) of the time period. In order to dampen the effect of year-to-year variability when using this approach, we used a 5-year mean population size (missing values were dropped during the smoothing) when calculating the ratio. The five-year time period for smoothing was chosen to represent approximately one generation. In order to calculate confidence intervals, Gibson et al. (2006) parameterized the model into the form:

$$N_t = \begin{pmatrix} N_1 & s_t = 1 \\ N_1 p & s_t = 2 \end{pmatrix},$$

where s is a state variable that indicates whether a year is in the first or second time period. The average abundance during the first time period (N_1) and the change in abundance between the two time periods (p), are parameters to be estimated. This model, termed here the "ratio model", estimates the extent of decline while not being influenced by data between the time periods of interest. Confidence intervals were estimated using likelihood ratios. We used a lognormal distribution for the error structure when fitting this model. Where a sufficient time series was available, both models were fit to 15-year time periods (the 15-year time period corresponds roughly to the three generation time period used by COSEWIC when evaluating conservation status).

Results

Plots of abundance and the log-linear fit for wild, hatchery and wild/hatchery returns all indicate considerable declines in population abundance over the past 15 years (Fig. 6), with predicted decline rates of 82.4%, 84.1% and 85.2%, respectively (Table 8). The ratio model indicated a higher rate of decline for wild returns (90.1%) and wild/hatchery combined (86.2%), but lower rates for hatchery returns (70.1%; Table 8). The predicted decline rates for egg deposition were even greater, at 91.3% and 90.6% from the log-linear model and ratio method respectively (Table 8, Fig. 6).

Tobique River

The Tobique River is located in north-western New Brunswick, Canada (46° 46' N, 67° 42' W) and is 148 km long. The Tobique River is the largest salmon producing tributary of the Saint John River, upstream of the Mactaquac Dam. The salmon production area of the Tobique River has been estimated from orthophoto measurements (Amiro 1993) at 7.86 million m^2 (gradient > 0.12 and <5.0%) or 58.3% of the total salmon production area upriver of Mactaquac Dam (Marshall et al. 1997, Table 9). The Tobique Narrows Dam is located 1.5 km upriver of the confluence of the Tobique and Saint John rivers and has a pool and weir fishway for upstream migrants.

Parr Densities

In 2004, DFO increased the spatial coverage (number of sites) of its electrofishing surveys on the Tobique River in order to detect changes in juvenile salmon densities potentially related to the release of captive-reared spawners (Jones et al. 2006).

Methods

Densities (number of fish per 100 m^2 of habitat) of age-1 and older parr at open sites were calculated from the adjusted Petersen method (Ricker 1975) for a two-pass mark-recapture survey or a mean probability of capture derived in Jones et al. (2004) for a single-pass site. Numbers of parr by age were determined from stratified sampling of large parr in 0.5 cm length intervals. Generally one parr was scale sampled for each interval. For the mark-recapture sites, the number of fry (age-0 parr) for the site was determined by applying the capture efficiency for age-1 and older parr to the number of fry captured during the marking pass. Similar to recent years, a mean probability of capture was applied to sites done in 2008 in which zero parr were marked or recaptured or if only the marking pass was completed (Jones et al. 2004).

To evaluate the status of juvenile salmon upriver of Mactaquac Dam, mean densities of fry and parr were calculated from established sites on the Tobique River. Sampling at each site has taken place periodically since 1992, but the majority of sites have been fished each year. In 2008, all 16 of the historical sites were completed. An additional 16 sites were completed to increase spatial coverage within the Tobique watershed. The densities presented are for wild (or adipose fin present) parr only. Since 2004, wild parr could be progeny from either sea-run or captive-reared adults. For the most part, prior to 1998, all fall fingerling parr and unfed fry were released unmarked (Fig. 2a and 2b) and suspected hatchery origin parr captured during electrofishing surveys were determined by observations of fin erosion or condition made by field staff. Since 1998, most of the fall fingerling parr released have been adipose clipped (with exception of 2004 and 2008) and very few unfed fry (with exception of 2000) were released (Fig. 2a and 2b), making identification of wild parr more precise.

Results

The mean density of wild fry at 16 sites on the Tobique River in 2008 was 1.4 fish per 100 m^2. This value was the second lowest density observed since 1992 (Table 10, Fig. 7). With the exception of 1995, mean densities at the index sites have been well below the "Elson norm" of 29 fry per 100 m^2 (Elson 1967). Using data from all 32 sites surveyed in 2008, the mean fry density increases slightly to 3.9 fish per 100 m^2. No wild fry were captured at 15 (47%) of the 32 electrofishing sites completed.

Mean density of age-1 and older wild parr at the 16 index sites was 2.1 parr per 100 m^2 in 2008. These values are well below Elson's (1967) "normal index" of 38 small and large parr per 100 m^2 (Fig. 7). This value is the lowest mean density observed in the time series for age-1 and older parr combined, and was approximately 60% of the mean density calculated using the 32 sites (Table 10). Despite the low densities, parr appear to be well distributed throughout the watershed as only two sites were devoid of wild parr.

Tobique and Beechwood Pre-smolt and Smolt Investigations

In collaboration with the Tobique Salmon Protective Association, NB Wildlife Trust and Atlantic Salmon Federation fall pre-smolt and spring smolt investigations upriver of Mactaquac Dam have been conducted since 1998 and 2000, respectively. Several sampling techniques and assessment methods are used. The objectives are: 1) to estimate the numbers of wild and hatchery pre-smolt and smolts emigrating from the Tobique River, 2) to obtain data on the fall and spring migration patterns of Tobique River pre-smolts and smolts and 3) to collect juvenile salmon for the captive-reared program at the Mactaquac Biodiversity Facility that was initiated in 2001. Parr that had a silvery appearance or faint-to-no parr marks were classified as pre-smolt. Fall telemetry studies have shown that some pre-smolts from the Tobique River migrate past Tobique Narrows Dam and overwinter in the main stem of the Saint John River (Carr 1999; Jones and Flanagan 2007).

Methods

Pre-smolt -2007

Juvenile salmon were captured at two different locations (Nictau and Three Brooks; Fig. 8) on the main stem of the Tobique River using four rotary screw traps (RSTs). Three were constructed by E.G. Solutions of Corvallis, Oregon, U.S. (5-foot diameter) and the other by Key Mill Construction Ltd. of Ladysmith, B.C., Canada (6-foot diameter) as described in detail in Chaput and Jones (2004). At the upper most site referred to as Nictau (Fig. 8), the Canadian constructed RST was operated from October 1 until November 14, 2007. All salmon (fry, parr, and pre-smolts) were identified to origin (wild – adipose present or hatchery – adipose clipped or fin erosion) and measured for weight and length (up to a maximum of 125 per day). The majority of the wild parr and pre-smolts were retained in a streamside rearing facility and later transported to Mactaquac Biodiversity Facility (MBF) for the captive reared program. All of the wild fry were released unmarked. No juvenile salmon were marked and released for assessment purposes at this site.

At the lower site (Three Brooks; Fig. 8), three American constructed RSTs were situated in the main stem of the Tobique River just below the confluence of the Three Brooks tributary and were operated from October 1 until November 12, 2007. Identical to the Nictau site, all juvenile salmon were identified to stage, to origin and measured for fork length. One in five wild origin parr and pre-smolts were measured for weight and scale sampled, while all hatchery origin parr and pre-smolts were measured for weight and scale sampled. All wild origin parr and two thirds of the wild pre-smolts were retained for the captive reared program. The remaining one-third of the wild origin and all hatchery origin pre-smolts were streamer tagged and then released in the main stem near Plaster Rock; approximately 3.5 km upriver of the RSTs (Fig. 8). These pre-smolts will be further referred to as "recycled" releases.

The wheels were generally fished once daily. Other species were counted and released at both capture locations. Hourly water temperature readings were recorded using a Vemco© [1] minilog installed in the main stem of the Tobique River at the Arthurette Bridge (Fig. 8). Environment Canada collected discharge data at a gauging station located in Riley Brook (Fig. 8). Discharge is affected by NB Power water storage facilities on four tributaries upriver of the Riley Brook gauging station.

The intake gatewells at the Beechwood Power Generating Station were sampled on 6 days for emigrating pre-smolts during the fall migration period. A square framed nylon mesh net was used to capture smolts in the intake gatewells (Jones et al. 2004). All captured pre-smolts were identified for origin, measured for fork length and weight, and approximately 20% of the smolts were scale sampled for later age determination. The majority of pre-smolts were transported to the MBF for the captive-reared program and the remainders were released downriver of Beechwood Dam.

Smolt -2008

One Canadian and one American constructed rotary screw trap were installed in the main stem of the Tobique River just downriver of the confluence of Three Brooks tributary (Fig. 8) from May 5 until June 2, 2008. The wheels were continuously operated and checked once daily in the morning except on weekends when it was checked on either Saturday or Sunday. All smolts were identified for origin, measured for fork length, weighed, marked and released with numbered streamer tags, and scale sampled for later age determination. All fry and parr were identified for origin, measured for fork length, weighed, and released at the RST. To estimate the efficiency of the wheels, the majority of the captured smolts were released in main stem near Plaster Rock; approximately 3.5 km upriver of the RSTs (Fig. 8). These smolts will be further referred to as “recycled” releases. In addition to the recycled smolts, age-1 hatchery smolts from Mactaquac Biodiversity Facility were released upriver of the RSTs on four separate occasions to estimate the capture efficiency of the wheels (Jones et al. 2004). Hourly water temperature readings and discharge data were recorded identical to the pre-smolt study. The intake gatewells at the Beechwood Power Generating Station were sampled for emigrating smolts for three days (June 10, 11 and 13) during the later part of the spring migration period. Smolts were captured, sampled and handled similar to the pre-smolt project.

Results

Pre-smolt -2007

The three wheels operated at the Three Brooks site captured a total of 774 pre-smolts (87.2% wild) and 151 parr (90.8% wild) during the six weeks of operation (Table 11). Of these catches, 484 wild pre-smolts and 110 wild parr were retained and transported to the Mactaquac Biodiversity Facility for the captive-reared program (Table 12).

To estimate pre-smolt migration from the Tobique River, a total of 297 wild and hatchery pre-smolts were streamer tagged and released up river at Plaster Rock. Of the 297 fish that were tagged and transported upstream approximately 3.5 km, 29 were recaptured, resulting in an efficiency of 9.7% and an estimated run of 7,940 fish (2.5 and 97.5 percentiles; 6,220 – 13,300) or 6,920 wild and 1,020 hatchery pre-smolts (Table 11, Fig. 9). The 2007 wild pre-smolt estimate was about 60% of the estimated number in 2006 and only about 65% of the five-year

[1] Vemco Limited, Shad Bay, NS

mean (Table 11, Fig. 10). The hatchery pre-smolt estimate in 2007 was only 14% of the 2006 estimate and 35% of the five-year mean.

The majority of the wild parr and pre-smolt captured at the Nictau RST and the intake gatewells at Beechwood were retained for the captive-reared program. Nictau collections were 539 wild pre-smolts and 240 wild parr while another 524 wild pre-smolts and three wild parr were added to the captive reared program from Beechwood (Table 12).

Smolt -2008

In 2008, a total of 40 and 36 unmarked wild and hatchery smolts respectively were captured during the four weeks of operation at Three Brooks (Table 11). The first smolt was captured on May 6 while 50% of the total catch had occurred by May 19 (Fig. 11). The date of 50% of the cumulative catch was latest since 2001 and was likely related to cooler water temperatures observed in 2008. Eighty percent of the smolt catch occurred over a two and a half week period between May 9 and May 26 (Fig. 11).

Only 55 smolts were tagged with numerical streamer tags and released at Plaster Rock. One of the tagged smolts was recaptured in the RST at Three Brooks, resulting in an overall efficiency of 1.8%. The smolt run was not estimated using this data because of the small sample sizes.

A total of 1,969 age-1 hatchery smolts were released near Plaster Rock at the same location as the recycled smolts on four dates throughout the smolt migration period. Twenty (1.02%) of these age-1 hatchery smolts from Mactaquac Biodiversity Facility were recaptured at Three Brooks, typically one day after being released. It has been documented on the Tobique (2002, 2003, 2006, and 2007), Nashwaak (2002 and 2003) and Big Salmon (2002 and 2003) rivers that using hatchery smolts released in the spring to estimate RST efficiencies can potentially overestimate the wild smolt run (Fig. 12). To account for the bias, an adjustment factor (updated from Jones et al. 2006) [0.4542 (calculations summarized below)] of the mean recapture rates of recycled wild versus spring-released hatchery smolts was used to calculate the preferred spring smolt run estimate of 3,400 (2.5 and 97.5 percentiles; 2,910 – 4,330) (Fig. 9) or 1,790 wild and 1,610 hatchery smolts.

Tobique River data only	recapture rates	
	hatchery	recycled
2002	0.0412	0.0521
2003	0.0142	0.0432
2006	0.0313	0.0663
2007	0.0160	0.0643
mean	**0.0257**	**0.0565**
adjustment factor	**0.4542**	
(hatchery mean / recycled mean)		
Recaps at Three Brooks		20
Adjusted number of Recaps		**44**

Sampling at the Beechwood Dam intake gatewells also occurred with some degree of success in 2008 as a total of 62 wild and four unmarked hatchery smolts were captured. Forty-five wild smolts were retained and transported to Mactaquac Biodiversity Facility for the captive-reared program (Table 12). Twenty-four of the age-1 hatchery smolts that were released near Plaster Rock were also captured at Beechwood.

Biological Characteristics

The mean length of all wild smolts combined has fluctuated annually between 14-15 cm since monitoring began in 2000 (Fig. 13). Wild smolts sampled on the Tobique River since 2000 were slightly smaller (< 1 cm) than those sampled on the Nashwaak River (Fig. 13). In 2008, the analysis of scale samples (n=39) collected from wild smolts in the Tobique River indicated that the majority (79.5%) were age-2 (Fig. 14). The remainder were age-3 smolts; no smolts were age-4 or older in 2008. Age-2 smolts have comprised more than 70% of the total wild smolt estimate in all but three years since 2001 (Fig. 14).

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 New Brunswick York/Carleton County line to its confluence with the Saint John River in Fredericton North (Figs. 1 and 15). It is the largest single salmon-producing tributary of the Saint John River downriver of Mactaquac Dam (Table 9). The salmon production area of the Nashwaak River has been estimated from orthophoto measurements (Amiro 1993) at 5.69 million m^2 (gradient > 0.12%) or 28.5% of the total salmon production area downriver of Mactaquac Dam (Marshall et al. 1997). A salmon counting fence 23 km upriver from the confluence with the Saint John River (Fig. 15) was operated by DFO in 1972, 1973 and 1975 (Francis and Gallop 1979), and by DFO in cooperation with Aboriginal peoples from 1993 - 2008. In 2008, the fence was jointly operated by Kingsclear and Oromocto First Nations.

Returns

Methods

From May 30 until October 22, 2008, all fish captured at the counting fence were counted, measured for fork length, categorized as either small or large salmon, classified as hatchery or wild on the basis of fin deformities and/or presence of adipose fin, and marked with a hole punch of the caudal (hatchery fish) or adipose (wild fish) fin. All adipose clipped salmon (hatchery fish) and large wild salmon (>= 60cm) were scale sampled along with every second small wild fish (< 60 cm) to determine the age composition of the adult returns. Exceptions were made to the sampling routine when water temperatures at the fence exceeded 22°C. During these periods trap checks were made and fish were classified as 1SW or MSW salmon based on size, but no additional sampling occurred. Holding pools upriver of the fence were seined in mid September so that mark-recapture procedures (Gazey and Staley, 1986) could be used to estimate the number of fish that may have bypassed the fence either before installation or when the fence could not operate properly due to high water.

Results

Raw counts at the Nashwaak River counting fence in 2008 were 523 1SW and 81 MSW salmon. The start date and finish dates were similar to previous years but because of extremely high water levels that topped the fence in late September and early October, very few fish were captured after September 28, 2008 (Table 13).

After scale analysis, 1SW and MSW salmon components were slightly revised to 526 1SW and 78 MSW salmon (Table 2). The final hatchery counts were 10 1SW and one MSW salmon and represented less than 2% of the total 1SW and MSW salmon counts. The four high water events when the trap was fishing poorly prevented any meaningful comparison of the run timing in 2008 to previous years but the majority of 1SW and MSW salmon were counted during the month of July (Fig. 16). Scale samples revealed that that the age composition of wild adults in 2008 was 88% 1SW fish, 11% virgin 2SW fish and 1% previous spawners. The proportion of 1SW and 2SW salmon returns is similar to values observed in 14 of the last 16 years; the exceptions being 1997 and 2001 (Fig. 17). Since 1993, the proportion of 1SW salmon in the total returns has been increasing. Since 2000, the sea age of Nashwaak River wild salmon returns has been very similar to those wild salmon returning to Mactaquac Dam (Fig. 17). From 1993 to 2002, previous spawners averaged about 25% of the returning Nashwaak River MSW salmon, but have only comprised about 11% of the MSW returns since 2003. All harvest fisheries have been closed on the Saint John River since 1998, so the lower proportion of previous spawners in the MSW returns is likely related to an increase in natural mortality at sea which has been observed in the Nashwaak River (Fig. 18) and elsewhere in Atlantic Canada (Gibson et al. 2006). Very few virgin 3SW salmon were observed in either population (Fig. 17).

Seining and diver observations in six pools (Fig. 15) upriver of the salmon counting fence on September 18 -19, 2008 resulted in the capture or visual observation of 83 small and 24 large salmon. Thirty-six of the 83 small salmon and 7 of the 24 large salmon were previously adipose punched (marked) at the counting fence.

Mark-recapture data were incorporated into a Bayesian estimation procedure to estimate total returns up to September 17, 2008 (immediately prior to seining). This analysis gives a population estimate of 1,348 fish (2.5 and 97.5 percentiles; 1,108 -1,780; Fig. 19) or 1,188 1SW and 211 MSW salmon. The sum of this estimate and the age-adjusted fence counts after September 17 yielded a return estimate of 1,237 1SW (2.5 and 97.5 percentiles; 1,025 – 1,617) and 173 MSW (2.5 and 97.5 percentiles; 145 - 225) salmon. The 1SW salmon estimate was the third highest while the MSW return estimate was the fifth lowest since 1993 (Table 14). Because the fence did not operate during the high water flows that occurred between September 28 and October 10 (Fig. 16) additional fish may have been missed. Based on observations related to run timing and discharge in previous years (Fig. 16 and Jones et al. 2006) total returns in 2008 were likely underestimated.

In 2008, estimated wild returns totalled 1,213 1SW and 171 MSW fish (Fig. 20). Estimated 1SW returns increased 3-fold from 2007 and were the highest estimate since 1998. Multi-sea-winter returns increased by 71% from 2007 and were slightly above the 5-year mean, but were the fifth lowest estimate since 1993. The return rate of the 2007 wild smolt class as 1SW salmon in 2008 was 5.63%, the third highest return rate since wild smolt assessments were initiated in 1998 (Table 15). The return rate of the 2006 wild smolt class as 2SW salmon in 2008 was 0.62%, the second lowest return rate observed and only 41% of the rate from the previous year (Table 15). Estimated hatchery returns in 2008 totalled 24 1SW and two MSW fish.

Removals

As in previous years, no attempt has been made to estimate salmon by-catch in the shad and gaspereau net fisheries in the Saint John Harbour that may have been destined for the Nashwaak River. Between June 9 and June 23, 20 1SW salmon and five MSW salmon were removed from the fence trap and transported to Mactaquac Biodiversity Facility for restoration initiatives. No salmon mortalities were observed during the counting fence operation in 2008. DFO fishery officers reported no illegal activities targeting salmon destined for or within the Nashwaak watershed. Therefore, no corrections were made for illegal removals.

Conservation Requirements

Salmon production area upriver of the counting fence is estimated to be 5.35 million m^2 (90% of the total river estimate) and the conservation requirement is 12.8 million eggs (Marshall et al. 1997). The numbers of spawners necessary to obtain the conservation requirement upriver of the counting fence are estimated to be 2,040 MSW and 2,040 1SW salmon (Marshall et al. 1997). As in previous assessments, egg deposition and the number of spawners in 2008 were estimated on the basis of length, external sexing and interpretation of age from scales collected from fish passing through the fence.

Escapement

After accounting for removals to the biodiversity facility, total escapement upriver of the fence was estimated to be 1,217 1SW and 168 MSW salmon (Table 14). Sea-age, origin, proportion female and mean length for spawners upriver of the fence are summarized below:

	1SW salmon		MSW salmon	
Biological characteristics	Wild	Hatchery	Wild	Hatchery
Number	1,193	24	166	2
Proportion female	0.496	0.400	0.736	1.000
Mean length female (cm)	57.7	54.7	77.2	78.4

Numbers of 1SW and MSW spawners were 60% and 8% of the conservation requirements, respectively. Escapement of 1SW fish in the most recent five years has been similar to values seen in the 1990's. In 2008, the estimate of MSW spawners increased by 71% from the 2007 value, but was similar to both the 5-year and 10-year means. Egg deposition was estimated to be 2,931,700 eggs (0.55 eggs m^{-2} or 23% of the egg requirement), a doubling from 2007 and the highest estimate in the past decade (Table 14). One-sea-winter females contributed 71% of the total estimated egg deposition.

Trends in returns and escapement to the Nashwaak River were analysed using the ratio method and the log-linear model described for the salmon population upriver of Mactaquac. The same four data sets were analysed: 1) wild 1SW and MSW returns, 2) hatchery 1SW and MSW returns, 3) combined wild and hatchery 1SW and MSW returns and 4) combined eggs deposited from wild and hatchery 1SW and MSW spawners (Table 14). Given that data spanned 1993 to 2008, it was possible to calculate the log-linear model for a 15-year time period, but the ratios were calculated for two 5-year time periods ending in 1997 and 2008 (effectively comparing the beginning of the abundance time series with the end). Plots of abundance and the log-linear fit for wild, wild/hatchery combined and total egg deposition all suggest considerable declines in population abundance over the past 15 years (Fig. 21). Predicted decline rates from the log-linear model over the past 15 years for wild, hatchery and wild/hatchery combined were 45.3, 78.4 and 50.0, respectively (Table 8). However, the confidence intervals on these fits include zero, indicating that the regression is not significant and it is possible that there was no change or even an increase in abundance in the past 15 years. This is likely a result of the high wild return estimate in 2008 as well as the variability in recent hatchery returns (hatchery returns are obviously non-linear). For total escapement, the log-linear model predicts a significant decline of 65.9% over the last 15 year period. Comparing the two 5-year averages, the ratio model predicts a significant decline rate for hatchery returns (76.5%) and total egg deposition (50.3%) (Table 8, Fig. 21).

Parr Densities

Methods

Densities of juvenile salmon have been monitored annually at seven sites on the Nashwaak River since 1981 (Fig. 15). Densities prior to 1981 along with site characteristics and locations were reported by Francis (1980). Densities (number of fish per 100 m² of habitat) of age-1 and older parr at these open sites were derived using either mark-recapture techniques and the adjusted Petersen method (Ricker 1975) or a mean probability of capture derived in Jones et al. (2004). As in the Tobique River, numbers of parr by age were determined from stratified sampling of large parr in 0.5 cm length intervals. Generally one parr was scale sampled for each interval. For the mark-recapture sites, the number of age-0 parr or fry for the site was determined by applying the capture efficiency for age-1 and older parr to the number of fry captured during the marking pass. Similar to recent years, a mean probability of capture was applied to sites done in 2008 in which zero parr were marked or recaptured or if only the marking pass was completed (Jones et al. 2004). In addition to the seven sites fished annually since 1981, the Nashwaak River juvenile surveys were expanded in 2004. In 2008, an additional 10 sites were electrofished.

The densities presented are for wild (or adipose fin present) parr only. For the most part, prior to 1998 all fall fingerling and unfed fry were released unmarked and suspected hatchery origin parr captured during electrofishing surveys were determined through observations made by field staff of fin erosion or condition (Appendix *iv*). Between 1999 and 2006, most fall fingerlings released were adipose clipped and there were fewer unfed fry releases, thereby making the identification of wild parr easier and more accurate. In 2008, unclipped hatchery origin parr were determined by field staff based on fin erosion or condition.

Results

Analysis of the historical mark-recapture data (which included Nashwaak River data) using the empirical Bayes method (Gibson et al. 2003) determined that the mean probability of capture was 34.7% (Jones et al. 2004). This mean probability of capture was applied to data from three of the seven historical sites and three of the ten additional sites electrofished on the Nashwaak in 2008 (Table 15). Using the mean probability of capture may have underestimated densities in 2008 because the water conditions experienced during the surveys were higher than normal (Fig. 16).

Mean density of wild fry (age-0) at the seven historical sites in 2008 (one downriver and six upriver of the counting fence) was 5.0 fry per 100 m^2 (Table 15). Since 1993, mean densities at the seven sites have been below the “Elson norm”, fluctuating between 3 and 18 fry per 100 m^2 (Fig. 22). Including data from the ten additional sites raised the mean density estimate to 7.4 fry per 100 m^2 (Table 15).

Mean density of age-1 and older wild parr at the seven historical sites was 6.1 fish per 100 m^2 and improved slightly to 6.4 fish per 100 m^2 when the ten additional sites were included in the analysis. These values represent a slight increase from 2007 and were similar to the densities observed in the last decade (with the exception of 2001), but are well below Elson’s (1967) “normal index” of 38 small and large parr per 100 m$^{\mathbf{2}}$ (Fig. 22).

Smolt Assessment

A collaborative project between DFO and the Nashwaak Watershed Association Inc. (NWAI) to estimate the wild smolt production of the Nashwaak River has been ongoing since 1998. The smolt production estimates are valuable in examining recent trends in salmon populations for the following reasons: 1) they contribute to the development of current expectations for and limitations to salmon production on the Nashwaak River and probably other tributaries of the Saint John River downriver of Mactaquac Dam, 2) they provide a marine survival estimate examined through smolt-to-adult return rates where adult returns are derived from data collected at the Nashwaak River counting fence, and 3) they provide a basis for evaluating freshwater production which can be examined through parr-to-smolt and egg-to-smolt survival rates when estimates of juvenile densities of salmon and eggs deposition are available.

Methods

Two American constructed RSTs were installed and operated from May 2 until June 5, 2008 in the main stem of the Nashwaak River just downriver of Durham Bridge. The wheels were checked once daily from May 5 – 23 and less frequently (every other day) as the daily catches decreased. All unmarked smolts were identified for origin (wild or hatchery). Up to a maximum of 100 wild smolts were marked with numbered streamer tags and released upriver near the confluence of the Tay River (Fig. 15). A random sample of these smolts (maximum of 25) was measured for fork length, weighed, and scale sampled on a daily basis. Marking and detailed sampling occurred on all hatchery origin smolts.

Hourly water temperature readings were recorded using a minilog thermometer installed in the main stem of the Nashwaak River at the adult counting fence location (500 meters downriver of the RST). Environment Canada collected discharge data at a gauging station located near Durham Bridge.

Results

A total of 875 untagged smolts (779 wild; 96 hatchery-fall fingerling) were captured during RST operations. In 2008, the cooler spring water temperatures appeared to delay the smolt migration. Similar delays have occurred in three of the previous four years (exception being 2006). In six of the first seven years of monitoring, at least 50% of the cumulative smolt catch had occurred by May 9 (Fig. 23). In 2008, 50% of the cumulative smolt catch had occurred by May 15. Only seven wild and one hatchery smolt were captured during the last two weeks of operation.

For the mark-recapture experiment, 669 wild smolts were tagged with numbered streamer tags and released upriver of the RST at the mouth of the Tay River (Fig. 15). Of these, 80 (11.5%) were recaptured at the RST. This mark-recapture data generated a most probable Bayesian estimate of 6,520 wild smolts (2.5 and 97.5 percentiles; 5,400 - 8,220) emigrating from the Nashwaak River in 2008. High water prevented the installation of wings (deflectors to increase efficiency) until May 14. Two significantly different efficiencies were noted (pre and post wings) so the mark and recapture data were separated into two time periods. The most probable Bayesian estimate for each period added together resulted in preferred estimate of 7,310 wild smolts emigrating from the Nashwaak River in 2008 (Table 16; Fig. 24). This represents a decrease of 67% from 2007, is 50% of the five-year mean, and is the second lowest estimated total since smolt assessments commenced in 1998 (Table 16, Fig. 25). Based on the capture efficiencies of 7.9% and 14.7% estimated from the recycled wild smolt for the two time periods (before May 14, after May 14), an additional 930 hatchery smolts (released as fall fingerlings in 2005 and 2006) were estimated to have emigrated in 2008.

Biological Characteristics

The average fork length of all the wild smolts sampled in 2008 was 14.5 cm (n=477), which is the smallest mean length recorded in the past six seasons (Fig. 12). Mean fork length values for age-2 smolts have averaged 14.6 cm (ranged from 14.1 – 15.2) over the past eleven years. Consistent with the past decade, wild smolts were predominately age-2 (74%) with the remainder being age-3 (Fig. 26). The average fork length for wild age-3 smolts was 16.2 cm.

Egg to Smolt Survival

Egg to smolt survival on the Nashwaak River has been monitored since the spawning class of 1995. This has been possible with the annual wild smolt estimates (and corresponding age data) which began 1998. With one exception (the year class of 2003), egg to smolt survival has fluctuated between 0.3 and 1.0% (Fig. 27). Since mean fry (2004) and parr (2005) densities (Fig. 22) from that particular year class were not substantially higher than the previous years, it is thought that increased survival was the result of a mild winter in 2005. This is consistent with data from the Tobique River, where the parr density estimate in 2005 (Fig. 7) could not solely explain the higher than anticipated smolt estimate in 2006; the highest wild smolt estimate in the recent time-series (Fig. 10).

MAGAGUADAVIC RIVER

Originating in Magaguadavic Lake, the Magaguadavic River flows southeasterly for 97 km to the Passamaquoddy Bay, Bay of Fundy, at St. George, N.B. (Fig. 28; Martin 1984). The 13.4 m-high dam and 3.7 megawatt hydroelectric station (with four Francis turbines) located at the head-of-tide was replaced with a new 15 megawatt hydroelectric station (with two Kaplan turbines) in 2004 (Jones et al 2006). Upstream passage is provided by a fishway. A new downstream bypass and assessment facility was constructed in the new hydroelectric station. Assessment of the anadromous fish using the fishway is done with a trap in the third pool from the top of the fishway. In 2008, the fishway trap was monitored for salmon from late April until early December. Salmon count data and analyses were provided by Atlantic Salmon Federation[2]. In 2008, similar to the previous year, no fish of aquaculture origin captured at the trap were released back into the river. All salmon of suspected aquaculture origin were sacrificed for sampling of pathogens.

Wild returning salmon have been rapidly declining since 1992 and have averaged less than ten fish per year in the last ten years. A salmon conservation program coordinated by the Magaguadavic River Salmon Recovery Group and the Atlantic Salmon Federation has been supplementing the wild population with hatchery releases since 2002 (Appendix v). Aquaculture fish are escapes from aquaculture cages in the Fundy Isle area which, in 2008, produced approximately 35,000 tonnes of Atlantic salmon.

[2] Jon Carr- Atlantic Salmon Federation, PO Box 429, St. Andrews, NB, E0G 2X0

Returns

Counts of 1SW salmon in the trap numbered four wild fish and two aquaculture escapes in 2008 (Table 2). There were four MSW aquaculture escapes and no wild or hatchery MSW salmon counted in 2008. It is possible that some of the “wild” salmon counted may have been the result of early life stage juvenile escapes from any of the three private hatcheries in the drainage. Counts made since 1992, when aquaculture escapes were identified, and those in 1983 - 1985 and 1988, when escapes were largely unnoticed, are in Table 2. Unlike other oBoF rivers, an increase in the total counts of wild 1SW salmon was not observed in 2008. Even counts of suspected aquaculture escapes were well below the 5- and 10-year means but were similar to the previous two years (Table 2).

Removals

All aquaculture fish were sacrificed for disease testing. No fish tested positive for the ISA virus. No fish were removed for broodstock and there were no reported illegal removals. There has been no commercial fishery since 1983, and the Aboriginal food fishery and the recreational fishery have been closed since 1998.

Conservation Requirements

The conservation requirement of 1.35 million eggs is based on an estimated 563,000 m^2 of juvenile rearing habitat (Anon 1978) and a conservation deposition rate of 2.4 eggs per 100 m^2 (Elson 1975; CAFSAC 1991). The numbers of spawners necessary to obtain the conservation requirement are estimated at 230 MSW and 140 1SW salmon (Marshall and Cameron 1995).

Escapement

Four 1SW salmon were released upriver of the fishway. Using the mean length-fecundity relationship for Saint John River salmon (eggs = $430.19e^{0.03605 X \text{fork length}}$; Marshall and Penney 1983) and the estimated number of females, potential egg deposition was 3,500 eggs, less than 2% of the requirement. Estimates of escapement and attainment of the conservation requirement have steadily declined since 1994.

Decline rates for the Magaguadavic River salmon population were calculated using combined wild and hatchery 1SW and MSW returns (Table 2) over the most recent 15-year time period using the log-linear model and ratio method described above. Plots of abundance and the log-linear fit for all returns predict substantial declines (97.8%) in population abundance over the past 15 years (Table 8, Fig. 29). The ratio method predicts a similarly high rate of decline (97.7%)

ST. CROIX RIVER

The St. Croix River, a USA/Canada international river bordering the State of Maine and Province of New Brunswick, drains southeasterly into Passamaquoddy Bay in 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. 30). Historically a significant producer of Atlantic salmon, this salmon population has succumbed to industrial development - initially cotton mills, then pulp mills, and now dams and headponds at three hydroelectric facilities. The main stem and East Branch (84 km), the Chiputneticook lakes (66 km) and Monument Brook (19 km) determine 169 km of the international boundary (Anon 1988), the fluvial portions of which comprise the bulk of the potential rearing area for Atlantic salmon.

From 1997 to 2006, no naturally returning adult salmon has been released upriver. Recent returns have been dependent on hatchery programs. Without a dramatic shift in survival at sea, these conservation efforts are not expected to yield any significant number of naturalized salmon in the near future. Hatchery releases since 1981 are tabled in Appendix *vi*. No broodstock have been collected and no hatchery fish have been released since 2006. Any future returns would be dependent on natural production in the river, either from the progeny of hatchery releases or wild strays from other rivers.

Returns

The Milltown fishway near head-of-tide on the St. Croix River, previously monitored by the St. Croix International Waterway Commission[3] until 2006, was again not monitored in 2008. There were no wild returning adult salmon to Milltown fishway between 2000 and 2006 with the exception of one 1SW salmon in 2004 (Table 2). Since fishway monitoring did not take place in 2007 and 2008, the number of wild and hatchery 1SW and MSW returns is not available, but is expected to be extremely low if not zero.

Conservation Requirements

The conservation requirement of 7,389,000 eggs on the St. Croix River is based on an area of 3.079 million m^2 of juvenile production habitat (Anon 1988) and a conservation egg deposition rate of 2.4 eggs 100 m^{-2} (Elson 1975; CAFSAC 1991). Unlike other rivers, adult requirements have been calculated on the basis of MSW salmon only. Based on a male to female ratio of 1:1 and an average female fecundity of 7,200 eggs, adult requirements total 2,052 MSW salmon. A re-evaluation of adult requirements in 1993 acknowledged the potential contribution to egg deposition by 1SW females and suggested 1,710 MSW and 680 1SW fish could potentially produce the egg requirement (Marshall and Cameron 1995).

Decline rates for the St. Croix River salmon population were calculated using combined wild and hatchery 1SW and MSW returns (Table 2) over the most recent 15-year time period (ending in 2006) using the log-linear model and ratio method. Plots of abundance and the log-linear fit for all returns were very similar to the Magaguadavic River, with predicted declines in abundance of 97.1% over the 15 year period (Table 8, Fig. 31). The ratio model indicates a similarly high rate of decline (96.1%) between two time periods ending in 1991 and 2008.

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

SFA 23

Area of Occupancy

The total amount of wetted habitat as well as the amount of productive habitat for the outer portion of SFA 23 is summarized in Table 9. The amounts for the Saint John River system are identical to those documented in Marshall et al. 1997. These estimates are for the amount of accessible habitat based on air photos and orthophotographic maps; while areas with a gradient less than 0.12% are considered unproductive (Amiro 1993). The habitat estimates for the "other rivers" is not as detailed and includes all wetted area independent of gradient (Table 9).

No expanded electrofishing surveys were conducted by DFO in 2008 to assess salmon presence/absence (area of occupancy) or relative abundance in other rivers in SFA 23. To determine area of occupancy, evidence of salmon present in the past decade is noted in Table 9. Since 2004, juvenile surveys have been concentrated on the two index rivers (Tobique and Nashwaak) within the Saint John system. Within the past decade, DFO has not done any salmon assessment work on the "other oBoF rivers" listed in Table 9. However, adult and juvenile salmon assessment activities conducted by the Atlantic Salmon Federation were very informative in completing this section (Carr and Whoriskey 2003).

Combining the DFO and ASF electrofishing surveys completed within the past 10-years indicates that all of the surveyed river systems had juvenile salmon present with the exception of Bellisle Creek (Table 9). Although not tabled in this document, the calculated densities of juvenile salmon were generally well below the Elson's norm. The survey data from the past decade indicates that rivers in which juvenile salmon were present represented more than 89% of the total habitat within the outer portion of SFA 23 (Table 9). An expanded electrofishing survey is planned for 2009.

Total Returns

Total 1SW and MSW returns to the Saint John River from 1993 to 2008 were calculated from the estimated returns to the Nashwaak River (upriver of the counting fence, Table 14) multiplied by the amount of habitat assessed (Total Nashwaak; 0.285* proportion above fence; 0.90 = 0.2565) plus the total returns destined for Mactaquac (Table 3). The 1SW and MSW returns to other outer Bay of Fundy rivers were determined using the total returns to both the Magaguadavic and St. Croix rivers (Table 2) multiplied by the amount of habitat assessed (0.7082) and added to the estimated Saint John River returns which provided the total estimated 1SW and MSW returns to the outer portion of SFA 23.

Total estimated 1SW returns to the outer portion of SFA 23 in 2008 was 6,629 fish (Table 17). The estimated 1SW returns in 2008 were 55% and 61% higher respectively than the previous 5- and 10-year means. The total estimated MSW returns to the same rivers was 955 fish, slightly higher than the 2007 estimate but only 90% and 70% respectively of the 5- and 10-year means (Table 17). Total estimated returns (1SW and MSW combined) were above the average returns observed in the past decade but were still well below the conservation requirement for the area.

Similar the four index populations in SFA 23, trends in 1) 1SW returns 2) MSW returns, and 3) combined 1SW and MSW returns (Table 17) were analysed for the outer Bay portion of SFA 23 over the last 15 years using the log-linear and ratio models. Plots of abundance and the log-linear fit for the groups indicate considerable declines in population abundance over the past 15 years (Fig. 32). Predicted decline rates from the log-linear model for 1SW, MSW and combined returns were 62.2%, 86.8% and 71.5%, respectively (Table 8). The ratio model indicated lower rates of decline for all three groups (48.1%, 77.3% and 58.6%) when the earliest 5 years and the last 5 years of data were compared (Table 8).

Threats

In the Conservation Status report a large number of potential sources of mortality to the outer Bay populations were examined semi-quantitatively for their effect on population abundance (DFO and MNRF, 2009). These included directed salmon fishing, by-catch, fisheries on prey species, municipal water use, habitat alterations, aquaculture and other fish culture/stocking, military activities, scientific research, air pollutants (acid rain), ecotourism, invasive species, and ecosystem change.

Of these potential threats, the effects of agricultural and forestry operations, developing communities of invasive predators (i.e. muskellunge, smallmouth bass, chain pickerel and rainbow trout) and aquaculture escapes are, for the most part, uncertain. The results of a study using isotope mixing and bioenergetic models to determine the number of salmon smolts consumed by muskellunge on Saint John River salmon were quite different and thus inconclusive in determining the potential impact of introduced predators on emigrating smolts (Curry et al. 2007). Juvenile and adult salmon escapes from the Fundy-Isle (NB) or Cobscook Bay (ME) aquaculture facilities are the most probable sources of aquaculture origin salmon identified at all primary counting facilities (Table 2, Table 3). Although the effect these aquaculture escapes is uncertain, the numbers and proportions of these identified escapes in relation to total salmon counts on the Magaguadavic and St. Croix rivers were some of the highest observed in eastern North America (Morris et al. 2008).

Directed fisheries on outer Bay salmon from recreational and aboriginal users have been closed since 1998. Illegal gillnet fishing in an area below Tobique Narrows Dam still persists by the evidence of net marks on surviving spawners passing through the adult fishway. In 2008, 8% of the salmon counted at the fishway had fresh net marks.

Since 1974, an increase in the estimated marine mortality rates of hatchery smolts has been observed for the population upriver of Mactaquac Dam (Table 4a, Table 4b, Fig. 5). The factors contributing to the higher marine mortality are not apparent, and rates are still lower than those currently observed for inner Bay of Fundy salmon populations (Gibson et al. 2008). Smolt to adult return rates for the wild population monitored on the Nashwaak River range from 2% to 14% and average 5% for maiden spawners (Table 16). The return rates have been higher (more than 5%) in 4 of the past 5 years. Despite the closure of most of the high seas fisheries, there is evidence that the survival rate of repeat spawning salmon in the Nashwaak River has decreased since 1993 (Fig. 18). This decrease has also been noted in the population upriver of Mactaquac Dam but contrasts with expanding spawning history structure observed for the Atlantic salmon population in the Miramichi River, where the number of year classes and repeat spawner abundance is increasing (Chaput and Jones 2006).

Sources of mortality with a predicted spawner loss of 5% to 30% of the population were associated with hydro facilities (DFO and MNRF, 2009). Based on the return rates of smolts marked with coded nose wire tags and released at numerous locations within the Saint John River, smolt mortality attributable to passage through and between the Tobique Narrows, Beechwood and Mactaquac dams was estimated to be 24.7, 13.6, and 15.9%, respectively (Carr 2001). At least 42% of the habitat within the outer portion of SFA 23 has hydro facilities that negatively affect the salmon populations within those watersheds (Table 9). A case study by Gibson et al. (2009) used an equilibrium model to analyze the dynamics of the Tobique population to identify stessors and to predict the population level response to potential recovery actions. The study indicated that recovery efforts would need to focus on multiple threats, i.e. improving both freshwater habitat and fish passage, in order to produce a viable population.

CONCLUSIONS

Overall, the available data on salmon in the outer portion of SFA 23 indicates that populations are persisting at low abundance levels. This conclusion is consistent for all monitored life stages. Estimated adult abundance on the Saint John River upriver of Mactaquac Dam and on the Nashwaak River is presently 5% and 23% of their respective conservation requirements, and estimated egg deposition has declined at rates in excess of 65% over the last 15 years. Pre-smolt and smolt estimates for the Tobique River in 2008 were approximately half those in 2007 but were similar to long-term (2001-2008) mean values. Smolt abundance on the Nashwaak River in 2008 was 67% lower than in 2007 and was only 50% of the 5-year mean. Juvenile densities in the Tobique and Nashwaak Rivers were an order of magnitude below reference values (Elson's norm) in 2008. Estimated densities of fry and parr in both river systems have remained relatively constant over the last decade. Adult returns (n=6) to the Magaguadavic River were extremely low in 2008, and have averaged less than 10 fish for the past decade. With the exception of one 1SW salmon in 2004, there have been no returning salmon of wild origin captured during monitoring activities on the St. Croix River from 2000 to 2006. For the second consecutive year, the fishway was not monitored, but returns were expected to be extremely low. Decline rates in excess of 95% were predicted for both the Magaguadavic and St. Croix Rivers. Considering total escapement to SFA 23, declines of 62% for 1SW and 87% for MSW over the last 15 years are predicted.

Within this region, numerous threats are likely affecting the current status and trends in abundance of these populations. Mortalities associated with the operation of hydro facilities are predicted to result in a 5-30% loss in spawner abundance on an annual basis. Freshwater threats include the effects of forestry and agriculture activities, invasive fish predators and escapes from the nearby aquaculture industry, but their population-level impact has yet to be quantified. Although some illegal fishing persists, commercial fisheries affecting these populations have been closed since 1984, and the recreational and native fisheries have been closed since 1998. To deal with the issue of low marine survival, the salmon enhancement program at the Mactaquac Biodiversity Facility was re-focused in 2001 to produce captive spawning adults from wild-caught juvenile salmon. However, freshwater threats, combined with low marine survival, still appear to be limiting recovery of the populations in the region.

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Table 1. Estimated total (adjusted) returns of wild, hatchery and aquaculture 1SW and MSW salmon destined for Mactaquac Dam on the Saint John River, N.B., 2008.

Sea-age	Components	Wild	Hatchery	Captive-Reared	Aquaculture	Total
1SW						
	Mactaquac counts[a]	886	871	0	0	1,757
	Mactaquac counts adjusted[b]	788	995	0	0	1,783
	By-catch[c]	8	10	0	0	18
	Totals	796	1,005	0	0	1,801
MSW						
	Mactaquac counts[a]	163	137	0	0	300
	Mactaquac counts adjusted[b]	139	135	0	0	274
	Native Food Fishery	0	0	0	0	0
	By-catch[c]	4	3	0	0	7
	Totals	143	138	0	0	281

[a]Hatchery/wild origin per external characteristics in previous assessments; fishway closed Oct. 28, 2008.
[b]Adjusted by analyses of scales from sampled fish (Marshall and Jones 1996).
[c]Estimated to be 1% of total 1SW returns and 2.5% total MSW returns and is considered to include losses to poaching.

Table 2. Counts of wild, hatchery and aquaculture origin Atlantic salmon (as identified by fishway operators) trapped at fishways and/or fences in four rivers in southwest and central New Brunswick.

	Saint John				Nashwaak				Magaguadavic						St. Croix[c]					
	Wild		Hatchery		Wild		Hatchery		Wild		Hatchery		Aquaculture		Wild		Hatchery		Aquaculture	
Year	1SW	MSW	1SW	MSW	1SW	MSW	1SW	MSW	1SW	MSW	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	-	- e												
1973	1,854	2,367	1,760	475	596	1,956	-	- e												
1974	3,389	4,775	3,700	1,907																
1975	5,725	6,200	5,335	1,858	1,223	1,036	-	- e												
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											53	15	27	3		df
1983	3,613	1,711	1,230	299					282	607			21	30	33	62	2	28		df
1984	7,353	7,011	1,304	806					255	512					120	40	63	17		df
1985	5,331	6,390	1,746	571					169	466					36	250	12	46		df
1986	6,347	3,655	699	487											31	128	29	130		df
1987	5,106	3,091	2,894	344											43	147	181	21		df
1988	8,062	1,930	1,129	670					291	398					45	22	55	274		df
1989	8,417	3,854	1,170	437											46	19	95	73		df
1990	6,486	3,163	1,421	756 a											11	40	4	54		df
1991	5,415	3,639	2,160	587 a											30	83	42	52		df
1992	5,729	3,522	1,935	681 a					155	139			83	62 bd						
1993	2,873	2,601	1,034	379 a	72	113	11	42 de	112	125			96	52 bd	3	30	5	66		d
1994	2,133	1,713	1,180	493 a	376	251	27	23 de	69	61			1,059	81 bd	24	19	23	18	97	
1995	2,429	1,681	2,541	598 a	544	294	25	14 de	49	30			491	168 bd	7	14	7	19	7	6 d
1996	1,552	2,413	4,603	726 a	854	391	86	38 de	48	21			174	20 bde	10	32	13	77	15	5 d
1997	380	1,147	2,689	629 a	332	339	38	27 d	35	24			59	23 bd	7	8	26	2	11	16 d
1998	476	367	4,413	624 a	464	142	1	9 de	28	3			211	3 bd	12	6	20	3	14	11 df
1999	700	1,112	2,511	680 a	303	84	2	0 de	19	5			80	10 bd	7	2	1	3	23	0 df
2000	1,408	393	1,573	200 a	428	161	0	0 de	13	1			25	2 bd	0	0	15	5	30	0 df
2001	730	680	942	521 a	242	271	2	1 d	8	9			120	4 bd	0	0	13	7	33	23 df
2002	709	212	1,616	178 a	342	73	1	6 d	7	0			29	0 bd	0	0	14	6	2	4 d
2003	443	279	838	464 a	181	82	7	3 de	3	3			14	2 bd	0	0	13	2	3	3 df
2004	863	446	562	296 a	473	168	13	4 de	2	0			0	17 bd	1	0	5	4	0	4 d
2005	862	269	264	94	405	94	20	3 ade	5	0	4	0	62	1 bd	0	0	2	4	30	3 d
2006	823	303	467	68 a	376	116	29	2 de	14	3	9	1	4	2 bd	0	0	2	2	4	3 d
2007	574	204	334	111	218	95	3	6 de	4	0	0	0	4	1 bd	n/a					
2008	886	163	871	137	516	77	10	1 de	4	0	0	0	2	4 bd	n/a					

a- Small numbers of aquaculture fish, see Tables 3,4a & b. b- Aquaculture. c- Hatchery designation to be reviewed; sea-cage fish could be among hatchery fish prior to 1994.
d- Corrected by scale analysis. e- Partial count. f- breakdown changed from Jones et al. 2004, n/a - no monitoring.

Table 3. Estimated total returns and egg depositions of wild, hatchery and aquaculture 1SW and MSW salmon destined for Mactaquac Dam, Saint John River, 1970-2008.

	Wild		Hatchery		Total (W+H)		Aquaculture[a]		Total
Year	1SW	MSW	1SW	MSW	1SW	MSW	1SW	MSW	Egg Deposit
1970	3,057	5,712	100	0	3,157	5,712			6,743,577
1971	1,709	4,715	365	77	2,074	4,792			9,686,229
1972	908	4,899	285	592	1,193	5,491			25,380,372
1973	2,070	2,518	1,965	505	4,035	3,023			15,326,312
1974	3,656	5,811	3,991	2,325	7,647	8,136			39,357,968
1975	6,858	7,441	6,374	2,210	13,232	9,651			54,684,280
1976	8,147	8,177	9,074	2,302	17,221	10,479			36,292,706
1977	3,977	9,712	6,992	2,725	10,969	12,437			50,883,354
1978	1,902	4,021	3,044	2,534	4,946	6,555			28,813,466
1979	6,828	2,754	3,827	1,188	10,655	3,942			18,023,742
1980	8,482	10,924	10,793	2,992	19,275	13,916			58,362,594
1981	6,614	5,766	5,627	2,728	12,241	8,494			17,778,521
1982	5,174	5,528	3,038	1,769	8,212	7,297			18,882,016
1983	4,555	5,783	1,564	1,104	6,119	6,887			9,686,229
1984	8,311	9,779	1,451	1,115	9,762	10,894			40,216,241
1985	6,526	10,436	2,018	875	8,544	11,311			41,197,125
1986	7,904	6,128	862	797	8,766	6,925			26,483,866
1987	5,909	4,352	3,328	480	9,237	4,832			24,276,877
1988	8,930	2,625	1,250	912	10,180	3,537			14,835,870
1989	9,522	4,072	1,339	469	10,861	4,541			27,955,192
1990	7,263	3,329	1,533	575	8,796	3,904	8	221	25,135,151
1991	6,256	4,491	2,439	700	8,695	5,191	56	24	25,748,203
1992	6,683	4,104	2,223	778	8,906	4,882	34	16	23,786,435
1993	3,213	2,958	1,156	425	4,369	3,383	0	6	15,081,091
1994	2,276	1,844	1,258	503	3,534	2,347	0	28	11,402,776
1995	2,168	1,654	2,907	599	5,075	2,253	4	102	13,477,345
1996	1,326	2,309	5,394	1,002	6,720	3,311	3	10	18,277,454
1997	343	1,128	2,912	843	3,255	1,971	0	0	9,780,394
1998	341	320	4,641	647	4,982	967	0	4	5,912,196
1999	472	837	2,785	967	3,257	1,804	7	13	10,087,002
2000	1,343	277	1,725	267	3,068	544	3	3	3,564,850
2001	686	644	1,014	562	1,700	1,206	12	2	6,482,071
2002	634	199	1,724	177	2,358	376	5	8	1,867,321
2003	381	240	921	511	1,302	751	2	1	3,912,005
2004	864	400	623	312	1,487	712	0	1	4,067,287
2005	863	254	296	96	1,159	350	0	0	1,916,912
2006	797	283	536	64 [b]	1,333	347	1	0	1,840,252
2007	492	205	411	131 [b]	903	336	0	0	1,550,959
2008	796	143	1005	138	1,801	281	0	0	1,528,238

[a] 1990-94, 1SW and MSW classification based on lengths and count data; 1995-2005, count raised by estimated removals downstream of Mactaquac and adjusted according to ages from scale samples.
[b] excludes 3 captive-reared MSW fish in 2006 and one captive-reared 1SW fish in 2007.

Table 4a. Estimated total number of 1SW returns to the Saint John River, 1975-2008, from hatchery-reared smolts released at Mactaquac, 1974-2007.

Releases			Returns									
		Prop	Mactaquac			Native	Angled	By-	Com-		% return	
Year	Smolts	1-yr	Year	Mig ch	Dam	fishery	main SJ	catch	mercial	Total[a]		
				(combined)							Unadj	Adj[bcf]
1974	337,281	0.00	1975	1,771	3,564	28	977	34		6,374	1.890	
1975	324,186	0.06	1976	2,863	4,831	219	1,129	32		9,074	2.799	
1976	297,350	0.14	1977	1,645	4,533	36	708	70		6,992	2.351	
1977	293,132	0.26	1978	777	1,779	49	369	70		3,044	1.038	
1978	196,196	0.16	1979	799	2,722	100	186	20		3,827	1.951	
1979	244,012	0.09	1980	3,072	6,687	335	640	59		10,793	4.423	
1980	232,258	0.12	1981	921	2,861	139	350		1,356	5,627	2.423	
1981	189,090	0.08	1982	828	1,464	64	267		415	3,038	1.607	
1982	172,231	0.06	1983	374	857	39	69		225	1,564	0.908	
1983	144,549	0.22	1984	476	828	36	63	48		1,451	1.004	0.976
1984	206,462	0.28	1985	454	1,288	82	128	66		2,018	0.977	0.920
1985	89,051	1.00	1986	64	635	53	93	17		862	0.968	0.868
1986	191,495	1.00	1987	152	2,063	74	222	52		2,563	1.338	1.170
1987	113,439	1.00	1988	(717)		15	46	16		794	0.700	0.672
1988	142,195	1.00	1989	(1,018)		0	107	23		1,148	0.807	0.763
1989	238,204	0.98	1990	(903)		0	57	20		980	0.411	0.401
1990	241,078	0.98	1991	(1,490)		88	108	35		1,721	0.714	0.649
1991	178,127	0.97	1992	(1,132)		26	135	26		1,319	0.740	0.688
1992	204,836	1.00	1993	(779)		11	60	17		867	0.423	0.406
1993	221,403	1.00	1994	(841)		37	0	18		896	0.405	0.393
1994	225,037	1.00	1995	(1,509)		15		15		1,539	0.684	0.661
1995 [d]	251,759	1.00	1996	(2,649)		215	0	29		2,893	1.149	1.140
1996	286,400	1.00	1997	(1,543)		58	0	16		1,617	0.565	0.558
1997	286,485	1.00	1998	(2,112)		0	0	21		2,133	0.745	0.745
1998	297,012	1.00	1999	(1,672)		0	0	17		1,689	0.569	0.468
1999	305,073	1.00	2000	(1,403)		0	0	14		1,417	0.464	0.464
2000	311,825	1.00	2001	(839)		0	0	8		847	0.272	0.272
2001	305,321	1.00	2002	(1,358)		0	0	14		1,372	0.449	0.449
2002	241,971	1.00	2003	(815)		0	0	8		823	0.340	0.340
2003	155,701	1.00	2004	(499)		0	0	5		504	0.324	0.324
2004	52,178	1.00	2005	(197)		0	0	2		199	0.381	0.381
2005	77,271	1.00	2006	(426)		0	0	4		430	0.556	0.384
2006 [e]	113,847	1.00	2007	(273)		0	0	3		276	0.242	0.213
2007 [e]	84,088	1.00	2008	(686)		0	0	7		696	0.828	0.703
2008 [g]	55,253	1.00										

[a]Includes some returns from smolts stocked downriver of Mactaquac or escaped from sea-cages (Table 3: as determined from erosion of margins of upper and lower caudal fins).

[b]Adjusted return rates exclude smolts stocked downriver from Mactaquac (Marshall 1989) and fish of probable 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 or 1997; 1997 count yielded 2 tagged 1SW fish from among 2,000 tagged smolts released to the Nashwaak in 1996 (9,017 smolts total).

[c]1997 adjustment to return years 1995-97, based on Ad-clipped age1.1 returns from age-0+ fall fingerlings stocked above Mactaquac, 1993-95. Total estimated returns number 22, 22 and 10 in 1995, 1996 and 1997, respectively.

[d] Revised "smolts released" includes 11,177 age-1 smolts released to the migration channel from Saint John Hatchery.

[e] Smolts were from the Tobique River captive-reared program.

[f] 2006-08 adjustment to return year based on Ad-clipped age 1.1 returns from age-0+ fall fingerlings stocked above Mactaquac in 2004-06. Total estimated returns numbered 133 fish in 2006, 34 fish in 2007 and 105 fish in 2008.

[g] 2008 smolts were 36,394 from sea-run crosses and 18,859 from captive-reared crosses.

Table 4b. Estimated total number of virgin 2SW returns to the Saint John River, 1976-2008, from hatchery-reared smolts released at Mactaquac, 1974-2006.

Releases			Returns									
		Prop	Mactaquac			Native	Angled	By-	Com-		% return	
Year	Smolts	1-yr	Year	Mig ch	Dam	fishery	main SJ	catch	mercial	Total[a]		
				(combined)							Unadj	Adj[bcf]
1974	337,281	0.00	1976	310	1,313	392	267	20		2,302	0.683	
1975	324,186	0.06	1977	341	1,727	206	417	34		2,725	0.841	
1976	297,350	0.14	1978	223	1,728	368	165	50		2,534	0.852	
1977	293,132	0.26	1979	145	747	210	65	21		1,188	0.405	
1978	196,196	0.16	1980	302	1,992	506	146	46		2,992	1.525	
1979	244,012	0.09	1981	126	963	252	125		1,262	2,728	1.118	
1980	232,258	0.12	1982	88	640	462	181		398	1,769	0.762	
1981	189,090	0.08	1983	44	255	76	17		712	1,104	0.584	
1982	172,231	0.06	1984	84	722	201	5	103		1,115	0.647	0.560
1983	144,549	0.22	1985	73	492	189	5	116		875	0.605	0.553
1984	206,462	0.28	1986	16	471	266	4	40		797	0.386	0.346
1985	89,051	1.00	1987	4	338	110	4	24		480	0.539	0.453
1986	191,495	1.00	1988	(511)		150	0	35		696	0.363	0.354
1987	113,439	1.00	1989	(379)		0	0	20		399	0.352	0.330
1988	142,195	1.00	1990	(480)		0	0	25		505	0.355	0.170
1989	238,204	0.98	1991	(359)		62	0	46		467	0.196	0.173
1990	241,078	0.98	1992	(590)		58	0	32		680	0.282	0.256
1991	178,127	0.97	1993	(242)		16	0	11		269	0.151	0.145
1992	204,836	1.00	1994	(303)		10	0	23		336	0.164	0.159
1993	221,403	1.00	1995	(398)		5	0	11		414	0.187	0.187
1994	225,037	1.00	1996	(567)		18	0	15		600	0.267	0.267
1995 [d]	251,759	1.00	1997	(412)		45	0	12		469	0.186	0.186
1996	286,400	1.00	1998	(229)		0	0	6		235	0.082	0.082
1997	286,485	1.00	1999	(554)		0	0	14		568	0.198	0.198
1998	297,012	1.00	2000	(173)		0	0	4		177	0.060	0.060
1999	305,073	1.00	2001	(462)		0	0	12		474	0.155	0.155
2000	311,825	1.00	2002	(142)		0	0	4		146	0.047	0.047
2001	305,321	1.00	2003	(443)		0	0	11		454	0.149	0.149
2002	241,971	1.00	2004	(265)		0	0	7		272	0.112	0.112
2003	155,701	1.00	2005	(78)		0	0	2		80	0.051	0.051
2004	52,178	1.00	2006	(44)		0	0	1		45	0.086	0.086
2005	77,271	1.00	2007	(89)		0	0	2		91	0.118	0.110
2006 [e]	113,847	1.00	2008	(71)		0	0	2		73	0.064	0.052
2007 [e]	84,088	1.00										

[a]Includes some returns from smolts stocked downriver of Mactaquac or escaped from sea-cages (Table 3: erosion of margins of upper and lower caudal fins).

[b]Adjusted return rates exclude smolts stocked downriver from Mactaquac (Marshall 1989) and fish of probable 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; possibly 3 returns from 12,516 smolts >12cm to Nashwaak in 1993; no returns from 15,059 stocked in the Nashwaak in 1994 and 2 returns from 3,989 tagged [13,283 total] in 1995.

[c]1997 adjustment to return year 1997 based on Ad-clipped age 1.2 returns from age-0+ fall fingerlings stocked above Mactaquac in 1994. Total estimated returns numbered 9 fish in 1997.

[d]Revised "smolts released" includes 11,177 age-1 smolts released to the migration channel from Saint John Hatchery.

[e] Smolts were from the Tobique River captive-reared program.

[f] 2007-08 adjustment to return year based on Ad-clipped age 1.2 returns from age-0+ fall fingerlings stocked above Mactaquac in 2006-07. Total estimated returns numbered 6 fish in 2007 and 14 fish in 2008.

Table 5. Estimated removals of 1SW and MSW salmon destined for Mactaquac Dam on the Saint John River, N.B., 2008.

	1SW			MSW		
Components	**Wild**	**Hatch**	**Total**	**Wild**	**Hatch**	**Total**
Passed above Tinker	16	4	20	1	4	5
Mortality @ Beechwood	17	2	19	2	0	2
Tobique Barrier Morts	0	0	0	0	0	0
Hatchery broodfish	16	4	20	33	2	35
mortalities, etc.	0	1	1	2	1	3
Poaching	23	26	49	10	12	22
By-catch [a]	8	10	18	4	3	7
Totals	**80**	**47**	**127**	**52**	**22**	**74**

[a] Wild:hatchery composition per adjusted counts and assumed availability.

Table 6. Estimated returns, removals and spawning escapement of 1SW and MSW salmon destined for upriver of Mactaquac Dam, Saint John River, 2008.

Sea-age	**Components**	**Wild**	**Hatch**	**Total**
1SW				
	Returns	796	1,005	1,801
	Removals[a]	80	47	127
	Spawners	716	958	1,674
	Conservation requirement			4,900
	% of requirement			34
MSW				
	Returns	143	138	281
	Removals[a]	52	22	74
	Spawners	91	116	207
	Conservation requirement			4,900
	% of requirement			4

[a] Refer to Table 5 for details.

Table 7a. Number, biological characteristics and estimated number of eggs from wild and hatchery 1SW and MSW salmon released upriver of Mactaquac, 1996 - 2008.

Sea-Age Origin	Year	Female Mean Length (cm)	Estimated Fecundity	Prop Female	Total (M+F) Counts Escape	Total Eggs	Prop Total
Wild 1SW							
	1996	58.8	3,587	0.132	1,082	512,310	0.03
	1997	61.3	3,927	0.061	313	74,979	0.01
	1998	58.5	3,550	0.135	311	148,573	0.03
	1999	62.3	4,066	0.109	432	192,076	0.02
	2000	59.8	3,717	0.177	1,208	795,471	0.22
	2001	59.6	3,692	0.112	548	225,894	0.03
	2002	59.9	3,728	0.126	544	254,698	0.14
	2003	59.7	3,701	0.137	281	142,091	0.04
	2004	59.2	3,635	0.120	759	330,803	0.10
	2005	58.2	3,506	0.068	804	190,824	0.08
	2006	60.2	3,767	0.064	736	178,759	0.10
	2007	56.0	3,239	0.048	440	67,731	0.04
	2008	60.5	3,810	0.038	716	103,005	0.07
	mean	**59.6**	**3,687**	**0.102**			**0.07**
Hatchery 1SW							
	1996	58.8	3,584	0.118	4,394	1,858,276	0.10
	1997	62.0	4,021	0.092	2,429	898,565	0.09
	1998	58.6	3,551	0.113	4,311	1,734,600	0.29
	1999	59.5	3,672	0.101	2,530	940,495	0.09
	2000	58.0	3,486	0.089	1,587	493,507	0.14
	2001	60.8	3,855	0.041	915	144,907	0.02
	2002	60.2	3,769	0.047	1,621	287,235	0.15
	2003	58.1	3,494	0.073	855	218,951	0.06
	2004	59.6	3,688	0.062	580	132,273	0.02
	2005	61.4	3,935	0.037	256	37,589	0.03
	2006	60.5	3,803	0.041	522	82,202	0.04
	2007	56.2	3,262	0.050	392	63,748	0.04
	2008	60.6	3,823	0.046	958	167,199	0.11
	mean	**59.6**	**3,688**	**0.070**			**0.09**
Wild MSW							
	1996	78.6	7,313	0.861	1,700	10,704,039	0.59
	1997	77.0	6,896	0.949	786	5,143,823	0.53
	1998	79.7	7,617	0.929	188	1,330,139	0.22
	1999	78.0	7,146	0.953	582	3,963,315	0.39
	2000	77.9	7,131	0.953	129	877,003	0.25
	2001	78.0	7,149	0.947	470	3,181,509	0.49
	2002	79.5	7,557	0.896	92	623,097	0.33
	2003	77.3	6,981	0.946	161	1,063,337	0.27
	2004	78.9	7,395	0.816	343	2,070,079	0.62
	2005	77.1	6,930	0.900	193	1,203,131	0.71
	2006	78.2	7,206	0.965	182	1,265,022	0.69
	2007	76.6	6,807	0.821	150	838,424	0.54
	2008	76.4	6,758	0.974	91	599,074	0.39
	mean	**77.9**	**7,145**	**0.916**			**0.46**
Hatchery MSW							
	1996	77.0	6,906	0.921	818	5,202,829	0.28
	1997	77.8	7,102	0.931	554	3,663,027	0.37
	1998	77.3	6,976	0.881	439	2,698,884	0.46
	1999	77.5	7,021	0.940	756	4,991,116	0.49
	2000	77.6	7,051	0.982	202	1,398,869	0.39
	2001	77.0	6,903	0.895	474	2,929,761	0.45
	2002	78.4	7,263	0.826	117	702,291	0.38
	2003	76.7	6,831	0.924	394	2,487,626	0.64
	2004	77.9	7,133	0.785	274	1,534,132	0.26
	2005	76.3	6,733	0.901	80	485,368	0.17
	2006	77.0	6,898	0.949	48	314,269	0.17
	2007	76.6	6,807	0.783	109	581,056	0.37
	2008	76.8	6,856	0.829	116	658,960	0.43
	mean	**77.2**	**6,960**	**0.888**			**0.37**

Table 7b. Number, biological characteristics and estimated number of eggs from captive-reared salmon released upriver of Mactaquac, 2003 - 2008.

Age	Year	Female Mean Length (cm)	Estimated Fecundity	Prop Female	# of Female	Total (M+F) Counts Escape	Total Eggs	Prop Total
1 year adult								
	2003	48.6	2,817	0.588	227	386	639,459	1.00
	2004	51.6	3,205	0.426	88	207	282,630	0.09
	2005	48.3	2,776	0.569	115	202	319,240	0.06
	2006	48.2	2,764	0.344	77	223	211,878	0.04
	2007	49.3	2,900	0.534	142	267	413,153	0.12
	2008			0.000	0	69	0	-
	mean	**49.2**	**2,892**	**0.410**				**0.22**
2 year adult								
	2003							-
	2004	60.8	4,787	0.749	585	780	2,798,178	0.91
	2005	65.6	5,902	0.830	703	847	4,149,106	0.80
	2006	60.0	4,623	0.790	629	797	2,909,082	0.61
	2007	61.8	5,001	0.693	287	414	1,434,892	0.40
	2008	59.0	4,426	0.765	457	597	2,021,355	0.72
	mean	**61.4**	**4,948**	**0.765**				**0.57**
3 year adult								
	2003							-
	2004							-
	2005	66.0	6,006	0.906	116	128	696,696	0.13
	2006	76.0	9,288	0.818	117	143	1,086,696	0.23
	2007	77.0	9,702	0.754	86	114	834,372	0.23
	2008	70.4	7,276	0.766	108	141	785,808	0.28
	mean	**72.4**	**8,068**	**0.811**				**0.15**
Repeat Spawner	2003							-
	2004							-
	2005	73.0	8,141	0.128	5	39	40,705	0.01
	2006	80.3	11,203	0.437	52	119	582,556	0.12
	2007	70.7	7,371	0.605	118	195	869,778	0.24
	2008	67.0	6,273	0.022	2	90	12,546	0.00
	mean	**72.7**	**8,247**	**0.298**				**0.06**

Table 8. Summary of declines in adult Atlantic salmon abundance for five populations in Southwest New Brunswick. The regression method is a log-linear model fit via least squares. The step function is the change in the 5-year mean population size ending on the years given in the time period column (the number of years differs between the methods). The standard errors and 95% confidence intervals are in brackets. Fifteen years corresponds to about three generations. A negative value for the decline rate indicates an increasing population size. Model fits are shown in Fig. 6, 21, 29, 31, and 32.

			Log-linear model			Ratio method
Population	Time Period	No of Years	Slope (SE)	1 yr decline rate (%)	Decline over time period (%)	Decline over time period (%)
Mactaquac Wild Returns	1993 - 2008	15	-0.116 (0.025)	10.9 (6.5,15.2)	82.4 (63.3, 91.6)	90.1 (86.7, 92.7)
Mactaquac Hatc Returns	1993 - 2008	15	-0.122 (0.032)	11.5 (5.8,16.9)	84.1 (59.2, 93.8)	70.1 (53.6, 80.7)
Mactaquac Total Returns	1993 - 2008	15	-0.127 (0.013)	12.0 (9.7, 14.2)	85.2 (78.3, 89.9)	86.2 (81.9, 89.7)
Mactaquac Total Escape	1993 – 2008	15	-0.162 (0.019)	15.0 (11.7, 18.2)	91.3 (84.5,95.1)	90.6 (86.7,93.3)
Nashwaak Wild Returns	1993 – 2008*	15	-0.040 (0.025)	3.9 (-0.9, 8.5)	45.3 (-13.8,73.7)	28.5 (-13.1,54.8)
Nashwaak Hatc Returns	1993 – 2008*	15	-0.102 (0.250)	9.7 (-47.5, 44.7)	78.4 (-33843.1,99.9)	76.5 (48.2,89.1)
Nashwaak Total Returns	1993 – 2008*	15	-0.460 (0.026)	4.5 (-0.4, 9.2)	50.0 (-5.9,76.4)	33.3 (-5.9,57.8)
Nashwaak Total Escape	1993 – 2008*	15	-0.072 (0.025)	6.9 (2.2, 11.5)	65.9 (28.1,83.9)	50.3 (27.8,65.6)
Magag. Total Returns	1993 – 2008	15	-0.253 (0.037)	22.4 (16.5, 27.8)	97.8 (93.3,99.2)	97.7 (90.9,99.3)
St. Croix Total Returns	1991 – 2006	15	-0.237 (0.022)	21.1 (17.5, 24.5)	97.1 (94.5,98.5)	96.1 (92.1,98.1)
SFA 23 1SW Returns	1993 – 2008*	15	-0.060 (0.022)	6.3 (2.2, 10.2)	62.2 (28.0, 80.2)	48.1 (20.6, 66.2)
SFA 23 MSW Returns	1993 – 2008*	15	-0.135 (0.018)	12.6 (9.5, 15.7)	86.8 (77.5, 92.3)	77.3 (69.2, 83.1)
SFA 23 Total Returns	1993 – 2008*	15	-0.084 (0.018)	8.0 (4.7, 11.3)	71.5 (51.3, 83.4)	58.6 (40.4, 71.1)

* ratio model spans 1997 to 2008

Table 9. Estimates of accessible juvenile salmon habitat (total and productive) units (100 m²) and evidence of occupancy within the past decade for the outer portion of SFA 23 (CU 17).

Location	Area (100m^2) units			Percentage				Evidence of occupancy in past 10 years				
				Saint John River					Last		Last	
Tributary	Total	<0.12%	Productive	Upriver	Downriver	Total	CU 17	Juveniles	Year	Adults	Year	References
Saint John River, Upriver of Mactaquac Dam												
Accessible Habitat												
Salmon R.	13,500	746	12,754	9.47		3.81	3.55	Yes	2008			
Tobique R.	145,730	67,168	78,562	58.31		23.49	21.89	Yes	2008	Yes	2008	
Aroostook R. (not included) [a]												
Shikatehawk R.	4,540	-	4,540	3.37		1.36	1.26	Yes	2008			
Becaguimec R.	14,110	3,410	10,700	7.94		3.20	2.98	Yes	2008			
Nackawic River (60% accessible)	7,656	-	7,656	5.68		2.29	2.13					
Mainstem Hartland-Beechwood	87,640	87,640	-	0.00		0.00	0.00					
Mainstem Aroostook-Grand Falls	50,900	45,500	5,400	4.01		1.61	1.50					
Little R., Tilley	-	-										
Muniac Str.	-	-										
Mactaquac R.	-	-										
Presquile R. [a]	7,050	240	6,810	5.05		2.04	1.90					
Meduxnekeag R. [a]	13,960	5,660	8,300	6.16		2.48	2.31	Yes	2008			
Eel R.	-	-										
Shogomoc R.	-	-										
Pokiok R.	-	-										
River DeShute	-	-										
Inaccessible Habitat												
Monquart R.(inacc)	5,110	-	5,110									
Nackawic R.(inacc)@0.4	5,104	-	5,104									
Total Upriver (accessible)	345,086	210,364	134,722	100.00		40.28	37.53					
Saint John River, Downriver of Mactaquac Dam												
Keswick R.	14,200	4,100	10,100		5.06	3.02	2.81	Yes	2003			3
Nashwaak R.	77,110	20,190	56,920		28.50	17.02	15.86	Yes	2008	Yes	2008	
Little R. Gr Lk	13,500	3,340	10,160		5.09	3.04	2.83	Yes	1999			
Gaspereau R. Gr. Lk	18,890	650	18,240		9.13	5.45	5.08	Yes	1999			
Salmon R. Gr. Lk	35,970	19,690	16,280		8.15	4.87	4.54	Yes	1999			
Canaan R.	46,600	22,730	23,870		11.95	7.14	6.65	Yes	2003			3
Kennebecasis R.	37,290	16,600	20,690		10.36	6.19	5.76	Yes	2003	Yes	1998	3, 4
Hammond R.	26,400	9,780	16,620		8.32	4.97	4.63	Yes	2003	Yes	2008	3
Nerepis R.	12,410	5,650	6,760		3.38	2.02	1.88	Yes	1999			
Nashwaaksis R.	3,990	1,420	2,570		1.29	0.77	0.72					
Portabello Cr. Gr. Lk	1,960	610	1,350		0.68	0.40	0.38					
Noonan Br., Gr. Lk	-	-					0.00					
Burpe Mill Str., Gr. Lk.	2,190	-	2,190		1.10	0.65	0.61					
Newcastle Cr., Gr. Lk	5,220	-	5,220		2.61	1.56	1.45					
Coal Cr., Gr. Lk.	5,450	1,730	3,720		1.86	1.11	1.04					
Cumberland Bay Gr. Lk	1,150	-	1,150		0.58	0.34	0.32					
Youngs Cove Gr. Lk.	-	-										
Bellisle Creek	4,360	460	3,900		1.95	1.17	1.09	No	1999			
Total Downriver	306,690	106,950	199,740		100.00	59.72	55.65					
Total Saint John	651,776	317,314	334,462			100.00	93.18					
Other Rivers in Conservation Unit (CU17)												
New [b]	469		469				0.13	Yes	2003			1
Pocologan [b]	643		643				0.18	Yes	2003			1
Digdeguash	4,220		4,220				1.18	Yes	2001			1
Bocabec [b]	783		783				0.22					1
Magaguadavic R.	5,630		5,630				1.57	Yes	2008	Yes	2008	
Waweig [b]	201		201				0.06	Yes	2003	Yes	2002	1
Dennis Stream [b]	838		838				0.23	Yes	2001	Yes	2002	1
Saint Croix [c]	11,700		11,700				3.26	Yes	2002	Yes	2006	3
Total other rivers	24,484	-	24,484				6.82					
Total Conservation Unit	676,260		358,946				100.00					

[a] - A proportion of the estimated area would be in American waters.
[b] - The 2,350 units reported from "other rivers" in Anon. 1978 was divided between New, Pocologan, Bocabec, Waweig and Dennis Stream based on km's of accessible habitat.
[c] - Approximately 62% of the St. Croix drainage is in American waters, habitat area is 30,790*0.38=11,700.
References - 1, Carr and Whoriskey 2003; 2, Jones et al. 2004; 3, DFO 2003; 4, Marshall et al. 2000

Table 10. Annual means and standard errors (std error) of fry (age-0), age-1, and age-2 and older parr Atlantic salmon densities (number per 100m²) in the Tobique River, upriver of Mactaquac Dam, estimated during electrofishing surveys between 1992 to 2008.

		Wild					
	Number	age-0		age-1		age-2 and older	
Year	of Sites	Mean	std error	Mean	std error	Mean	std error
	"Historical"						
1992	7	18.1	7.7	6.0	2.7	1.5	0.9
1993	9	21.6	7.9	6.8	2.5	2.3	1.3
1994	7	13.6	8.8	4.8	1.5	0.6	0.2
1995	8	33.0	16.9	8.3	3.2	3.0	0.8
1996	15	5.9	2.3	4.8	0.8	1.4	0.4
1997	15	11.0	3.1	4.7	0.7	1.2	0.3
1998	16	9.3	3.9	8.3	1.5	0.9	0.2
1999	16	7.5	2.5	5.4	1.0	1.6	0.3
2000	15	11.4	3.5	3.2	0.9	0.6	0.2
2001	15	7.2	3.5	6.6	1.2	0.6	0.1
2002	13	5.1	2.4	3.0	0.6	0.4	0.1
2003	16	0.5	0.3	5.5	1.1	0.5	0.2
2004	16	7.8	3.3	1.9	0.6	0.8	0.2
2005	16	5.3	2.9	5.1	1.3	0.4	0.2
2006	16	3.0	1.7	3.3	1.3	0.2	0.1
2007	16	6.7	3.5	2.3	1.5	0.5	0.2
2008	16	1.4	0.8	1.7	0.7	0.4	0.1
	"Historical + Expanded"						
2004	58	11.1	3.5	2.4	0.4	0.9	0.3
2005	58	9.2	2.0	4.2	0.6	0.4	0.1
2006	62	5.5	1.4	3.9	0.6	0.4	0.1
2007	34	11.4	3.3	5.5	1.2	0.8	0.2
2008	32	3.9	1.4	2.9	0.6	0.6	0.1

Table 11. Dates of operation, pre-smolt and smolt catches at RST(s) (Three Brooks location only), and data used to estimate emigrating pre-smolts and smolts on the Tobique River.

Details	2001	2002	2003	2004	2005	2006	2007	2008
Three Brooks RST operation								
Start Date	24-Sep-01	2-Oct-02	29-Sep-03	24-Sep-04	29-Sep-05	25-Sep-06	1-Oct-07	
End Date	13-Nov-01	16-Nov-02	9-Nov-03	14-Nov-04	21-Nov-05	1-Dec-06	12-Nov-07	
Lost Fishing Days	0	8	9	3	5	6	4	
# of RST's Fished	2	2	2	2	2	3	3	
Estimated Efficiency	12.0%					8.3%	9.7%	
Catches								
Pre-smolt (Wild)	1,317	1,453	566	222	338	944	675	
Pre-smolt (Hatchery)	64	101	34	26	47	638	99	
Parr (Wild)	233	255	222	62	77	300	138	
Parr (Hatchery)	11	6	1	9	7	38	13	
Fry	957	941	76	86	130	168	291	
Population Estimates								
Pre-smolt (Wild)								
Marked	1,496					558	297	
Recap	189					68	29	
Catch	1,319					1,510	774	
	a	b	b	b	b	c	c	
Estimate	10,400	5,740	9,760	7,050	18,500	11,560	6,920	
2.5th percentile	9,200					9,389	5,421	
97.5th percentile	12,000					15,033	11,591	
Pre-smolt (Hatchery)								
Marked	98					558	297	
Recap	3					68	27	
Catch	63					1,510	774	
	a	b	b	b	b	c	c	
Estimate	2,100	1,290	904	1,550	3,700	7,480	1,020	
2.5th percentile	1,100					6,076	799	
97.5th percentile	14,100					9,727	1,709	
Pre-smolt (Wild and Hatchery)								
Total estimates						19,040	7,940	
2.5th percentile						15,465	6,220	
97.5th percentile						24,760	13,300	

a) Wild and hatchery pre-smolt estimates calculated separately using the mark and recapture data by origin.
b) Pre-smolt estimates are estimated from the ratio of fall pre-smolts in 2001, 2006 to the spring smolts in 2002, 2007.
c) Wild and hatchery data (marked, recap, catch) combined and proportion of catches used to split estimate into wild and hatchery.

Details	2001	2002	2003	2004	2005	2006	2007	2008
Three Brooks RST operation								
Start Date	4-May-01	24-Apr-02	07-May-03	23-Apr-04	4-May-05	25-Apr-06	29-Apr-07	5-May-08
End Date	28-May-01	05-Jun-02	28-May-03	09-Jun-04	8-Jun-05	30-May-06	30-May-07	2-Jun-08
Lost Fishing Days								
# of RST's Fished	2	3	2	2	1	2	2	2
Estimated Efficiency - recycled wild/hff	7.4%	5.2%	4.3%	6.2%	1.6%	6.6%	6.4%	1.8%
Estimated Efficiency - hatchery garment		4.1%	1.4%		1.1%	3.1%	1.6%	1.0%
Catches								
Smolt (Wild)	176	318	119	291	63	591	303	40
Smolt (Hatchery)	86	176	50	49	25	214	289	36
Smolt Wild/Hatchery								
Marked	149	422	139	275	62	784	575	55
Recap	11	22	6	17	1	52	37	1
Catch	262	494	169	340	88	805	592	76
Smolt (Hatchery) Garment Tag								
Marked		2,357	1,483		1,400	991	1,996	1,969
Recap		97	21		15	31	32	20
Catch		494	169		88	805	592	76
Population Estimates								
Smolt (Wild and Hatchery)								
Total estimates	3,560	9,500	3,900	5,500	4,750	12,140	9,210	3,400
2.5th percentile	2,280	6,770	2,250	3,785	3,640	9,520	7,040	2,910
97.5th percentile	7,960	15,870	12,755	9,875	7,120	16,200	13,270	4,330

Table 12. Number and status of wild and hatchery juvenile Atlantic salmon collected during the spring and fall seasons for the captive-reared broodstock program at Mactaquac Biodiversity Facility, from the Tobique River and at Beechwood Dam.

Collection		Pre-Smolt		Parr		Fry		Number	Adults	Current	Year of
Year	Location	Wild	Hatchery [a]	Wild	Hatchery [a]	Wild	Total	on Hand [b]	Released [c]	Stage	Spawning
2001	Nictau	603	3	756	2	48	**1,412**				
2001	Three Brooks	555	5	119	1	437	**1,117**				
Smolt Class 2002		**1,158**	**8**	**875**	**3**	**485**	**2,529**	0	970		2003-04-05-06
2002	Nictau	338	1	298	23	5	**665**				
2002	Three Brooks	1,439	4	250		170	**1,863**				
2002	Beechwood	832	1	5			**838**				
Smolt Class 2003		**2,609**	**6**	**553**	**23**	**175**	**3,366**	-	1,349		2004-05-06-07
2003	Nictau	1,005	57	726	22		**1,810**				
2003	Three Brooks	563	26	221			**810**				
Smolt Class 2004		**1,568**	**83**	**947**	**22**		**2,620**	-	1,036		2005-06-07-08
2004	Nictau	536		367	1		**904**				
2004	Three Brooks	221		61			**282**				
2005	Three Brooks	63	[d]				**63**				
2005	Beechwood	15	[d]	1	[d]		**16**				
2005	Plaster Rock	2	[d]				**2**				
Smolt Class 2005		**837**		**428**	**1**		**1,267**	44	657	Adult	2006-07-08-09
2005	Nictau	878	2	331			**1,211**				
2005	Three Brooks	338		74			**412**				
2006	Beechwood	1,678	- [d]				**1,678**				
Smolt Class 2006		**2,894**	**2**	**405**	**0**		**3,301**	423	619	Adult	2007-08-09-10
2006	Nictau	964		480			**1,444**				
2006	Three Brooks	501		254			**755**				
2007	Beechwood	295	[d]				**295**				
Smolt Class 2007		**1,760**	**2**	**1,139**			**2,494**	925	366	Adult	2008-09-10-11
2007	Beechwood	524		3			**527**				
2007	Nictau	539		240			**779**				
2007	Three Brooks	450		110			**560**				
2008	Beechwood	45	[d]				**45**				
Smolt Class 2008		**1,558**		**353**			**1,911**	1,130		post-smolt	2009-10-11-12
2008	Nictau	415		512			**927**				
2008	Three Brooks	883		185			**1,068**				
Smolt Class 2009		**1,298**	**-**	**697**			**1,995**	1,823		pre-smolt	2010-11-12-13
Grand Total		**13,682**	**101**	**5,397**	**49**	**660**	**19,483**	**4,345**	**4,997**		

[a] Stocked previous year as fall fingerling.
[b] Number of fish at Mactaquac Biodiversity Facility as of December 2005. Excludes mortalities and releases.
[c] Total # of fish released from that year class.
[d] Collected from spring projects at "smolt" stage. Fish collected from the Beechwood gatewells were generally in poor condition and therefore corresponding survival at the MBF was lower for this group.

Table 13. Start and finish dates for the operation of an adult salmon counting fence on the Nashwaak River as well as the assessment technique used to estimate the total returns upriver of the fence site.

Year	Start and Finish Date	Days in which fence was not fishing 100%	Assessment Technique	Estimate up to
1993	Aug 19 - Oct 12		Historical Run Timing	
1994	Jul 15 - Oct 25		Seining; Mark Recap	Oct. 25
1995	Jul 12 - Oct 18		Historical Run Timing	
1996	Jun 13 - Oct 18	July 9-10, July 14-31	Seining; Mark Recap	Oct. 18
1997	Jun 18 - Nov 2		Count; No Washouts	Nov. 1
1998	Jun 8 - Oct 27	Aug 12-14, Oct 2-5	Seining; Mark Recap	Oct. 27
1999	Jun 3 - Oct 13	Sept 17-20, Sept 23-28	Seining; Mark Recap	Oct. 13
2000	Jun 19 - Oct 26	Oct 10-11	Seining; Mark Recap	Oct. 26
2001	Jun 21 - Nov 1	Aug 3-17 [a]	Count; No Washouts	Nov. 1
2002	Jun 10 - Oct 28		Count; No Washouts	Oct. 28
2003	Jun 5 - Oct 26	Aug 6-8, Oct 15-17, Oct 21-23	Seining; Mark Recap	Oct. 15 [b]
2004	Jun 3 - Oct 26	Aug 31- Sept 2, Sept 9-12	Seining; Mark Recap	Oct. 26
2005	Jun 9 - Oct 7	Jun 18-19, Aug 30-Sept 2, Sept17-20 & 27-28	Seining; Mark Recap	Oct. 7
2006	Jun 1 - Oct 20	Jun 4-5, Jun 9-26, July 5-6	Seining; Mark Recap	Oct. 20
2007	May 30 - Oct 30	Oct 13-14, Oct 21 [c]	Seining; Mark Recap	Oct. 30
2008	May 30 - Oct 22	Jun 29-Jul 4,Aug 2-7, Aug 9-14, Sept 28-Oct 10	Seining; Mark Recap	Sept. 28 [d]

[a] Fence was removed and base crib was raised 45 cm.
[b] - only two 1SW salmon were counted after Oct. 15, 2003.
[c] - a couple holes large enough for a grilse to pass though were discovered in the fence around July 19, 2007.
[d] - only four 1SW and one MSW salmon were counted after Sept. 28, 2008.

Table 14. Estimated returns, escapement, eggs deposited and percent of conservation attained for the Nashwaak River, 1993 - 2008.

	Estimated Returns		Escapement		% of Requirement		Total Egg Deposition	
Year	1SW	MSW	1SW	MSW	1SW	MSW	Eggs Deposited	% CR
1993	954	555	866	555	42%	27%	3,947,841	31%
1994	661	388	610	349	30%	17%	3,264,340	26%
1995	940	436	940	436	46%	21%	4,222,157	33%
1996	1829	657	1804	641	88%	31%	6,202,877	48%
1997	370	366	364	362	18%	18%	2,888,199	23%
1998	1259	315	1238	309	61%	15%	3,917,071	31%
1999	665	275	658	269	32%	13%	2,468,024	19%
2000	509	192	489	189	24%	9%	1,886,981	15%
2001	244	272	224	266	11%	13%	2,034,132	16%
2002	343	79	320	69	16%	3%	725,198	6%
2003	297	113	280	109	14%	5%	950,300	7%
2004	590	207	569	201	28%	10%	2,116,130	17%
2005	731	162	712	155	35%	8%	2,007,482	16%
2006	716	195	681	186	33%	9%	2,044,636	16%
2007	469	106	442	98	22%	5%	1,166,495	9%
2008	1237	173	1217	168	60%	8%	2,931,693	23%
Conservation Requirement (CR):					2040	2040	12.8 Million Eggs	

Table 15. Annual mean density and standard error of fry (age-0), age-1, and age-2 and older parr (number per 100m²) on the Nashwaak River, downriver of Mactaquac Dam, estimated during electrofishing surveys between 1981 to 2008.

		Wild					
	Number	age-0		age-1		age-2 and older	
Year	of Sites	Mean	std error	Mean	std error	Mean	std error
	"Historical"						
1981	6	63.6	9.7	16.4	6.3	5.4	3.5
1982	7	43.2	14.7	10.0	3.3	2.9	1.2
1983	7	16.7	9.6	6.2	2.6	2.5	1.4
1984	7	34.6	11.0	4.9	2.3	1.6	0.5
1985	7	36.8	10.0	5.6	2.2	2.5	0.8
1986	7	40.3	9.2	7.5	2.4	2.3	1.2
1987	7	52.5	17.3	10.7	3.6	0.8	0.5
1988	7	41.9	21.0	8.3	3.8	0.6	0.4
1989	7	38.8	15.6	7.9	3.7	1.5	0.8
1990	7	33.9	11.9	8.6	3.7	0.7	0.4
1991	7	27.6	10.7	7.9	2.8	0.9	0.4
1992	7	30.8	10.3	13.0	4.4	0.8	0.3
1993	7	14.0	4.0	6.5	2.4	1.4	0.8
1994	7	4.6	1.2	3.1	1.1	0.6	0.2
1995	7	11.6	3.4	8.1	3.7	1.5	0.7
1996	7	9.8	2.6	3.9	2.0	0.7	0.3
1997	7	15.2	2.6	5.4	1.8	0.8	0.5
1998	7	3.4	1.2	4.4	2.3	0.7	0.4
1999	7	8.7	3.0	4.1	1.0	1.3	0.6
2000	7	14.5	5.6	4.9	1.6	0.2	0.2
2001	7	11.8	2.7	11.1	3.7	1.5	0.6
2002	7	17.8	7.3	6.1	2.7	1.3	0.5
2003	7	4.7	0.9	5.1	1.8	1.1	0.6
2004	7	4.2	1.4	2.4	1.1	0.5	0.2
2005	7	5.8	2.4	4.3	1.5	0.7	0.2
2006	6	3.1	1.6	4.3	1.4	1.0	0.6
2007	7	4.1	1.6	3.1	1.5	0.5	0.3
2008	7	5.0	1.6	5.2	1.9	0.9	0.7
	"Historical + Expanded"						
2004	26	6.2	1.2	2.9	0.5	1.4	0.4
2005	26	7.3	1.7	4.7	0.9	0.8	0.2
2006	25	3.1	0.6	7.3	1.3	1.1	0.4
2007	26	6.7	1.4	3.8	0.8	1.3	0.4
2008	17	7.4	2.3	5.4	1.2	1.0	0.4

Table 16. Estimates of wild smolt emigration from upriver of Durham Bridge (and 2.5 and 97.5% percentiles), production per unit area of habitat (smolts/100m^2) and the smolt-to-adult return rates for the Nashwaak River, 1998 – 2008.

	Wild Smolt Estimate			Production per unit area	Return Rate (%)	
Year	Mode	2.5 perc.	97.5 perc.	(smolts/ 100m^2)	1SW	2SW
1998	22,750	17,900	32,850	0.43	2.91	0.67
1999	28,500	25,300	33,200	0.53	1.79	0.84
2000	15,800	13,400	19,700	0.30	1.53	0.28
2001	11,000	8,100	17,400	0.21	3.11	0.90
2002	15,000	12,300	19,000	0.28	1.91	1.26
2003	9,000	6,800	13,200	0.17	6.38	1.58
2004	13,600	10,060	20,800	0.25	5.13	1.28
2005	5,200	3,200	12,600	0.10	12.73	1.52
2006	25,400	21,950	30,100	0.47	1.81	0.62
2007	21,550	16,675	30,175	0.40	5.63	1.26
2008	7,300	5,500	11,180	0.14	3.86	

Table 17. Total 1SW and MSW returns to the outer portion of SFA 23 from 1993 to 2008.

	1SW Returns					
		Saint John River	.		other	
Year	Nashwaak	Downriver	Upriver	Mag + St. C	oBoF rivers	CU 17
1993	954	3,719	4,369	120	169	8,258
1994	661	2,577	3,534	116	164	6,275
1995	940	3,665	5,079	63	89	8,833
1996	1,829	7,131	6,723	71	100	13,954
1997	370	1,442	3,255	68	96	4,794
1998	1,250	4,873	4,982	60	85	9,940
1999	665	2,593	3,257	27	38	5,888
2000	510	1,988	3,068	28	40	5,096
2001	244	951	1,700	21	30	2,681
2002	343	1,337	2,358	21	30	3,725
2003	297	1,158	1,302	16	23	2,482
2004	590	2,300	1,487	8	11	3,798
2005	731	2,850	1,159	11	16	4,024
2006	716	2,791	1,333	25	35	4,160
2007	469	1,828	903	4	6	2,737
2008	1,237	4,823	1,801	4	6	6,629

	MSW Returns						Total (1SW&MSW)
		Saint John River	.		other		Mature
Year	Nashwaak	Downriver	Upriver	Mag + St. C	oBoF rivers	CU 17	Individuals
1993	555	2,164	3,383	221	312	5,859	14,117
1994	388	1,513	2,347	98	138	3,998	10,273
1995	436	1,700	2,253	63	89	4,042	12,874
1996	657	2,561	3,311	130	184	6,056	20,010
1997	366	1,427	1,971	34	48	3,446	8,239
1998	315	1,228	967	12	17	2,212	12,152
1999	275	1,072	1,804	10	14	2,890	8,778
2000	190	741	544	6	8	1,293	6,389
2001	272	1,060	1,206	16	23	2,289	4,970
2002	79	308	376	6	8	692	4,417
2003	113	441	751	5	7	1,199	3,681
2004	207	807	712	4	6	1,525	5,323
2005	162	632	350	4	6	987	5,012
2006	195	760	347	6	8	1,116	5,275
2007	106	413	336	0	-	749	3,486
2008	173	674	281	0	-	955	7,585

Note1 - Assessed portion of the Nashwaak represents 0.2565 (0.285*0.9) of downriver habitat (Table 9).
Note2 - Magaguadavic and St. Croix represent 0.7082 of other oBoF river habitat (Table 9)

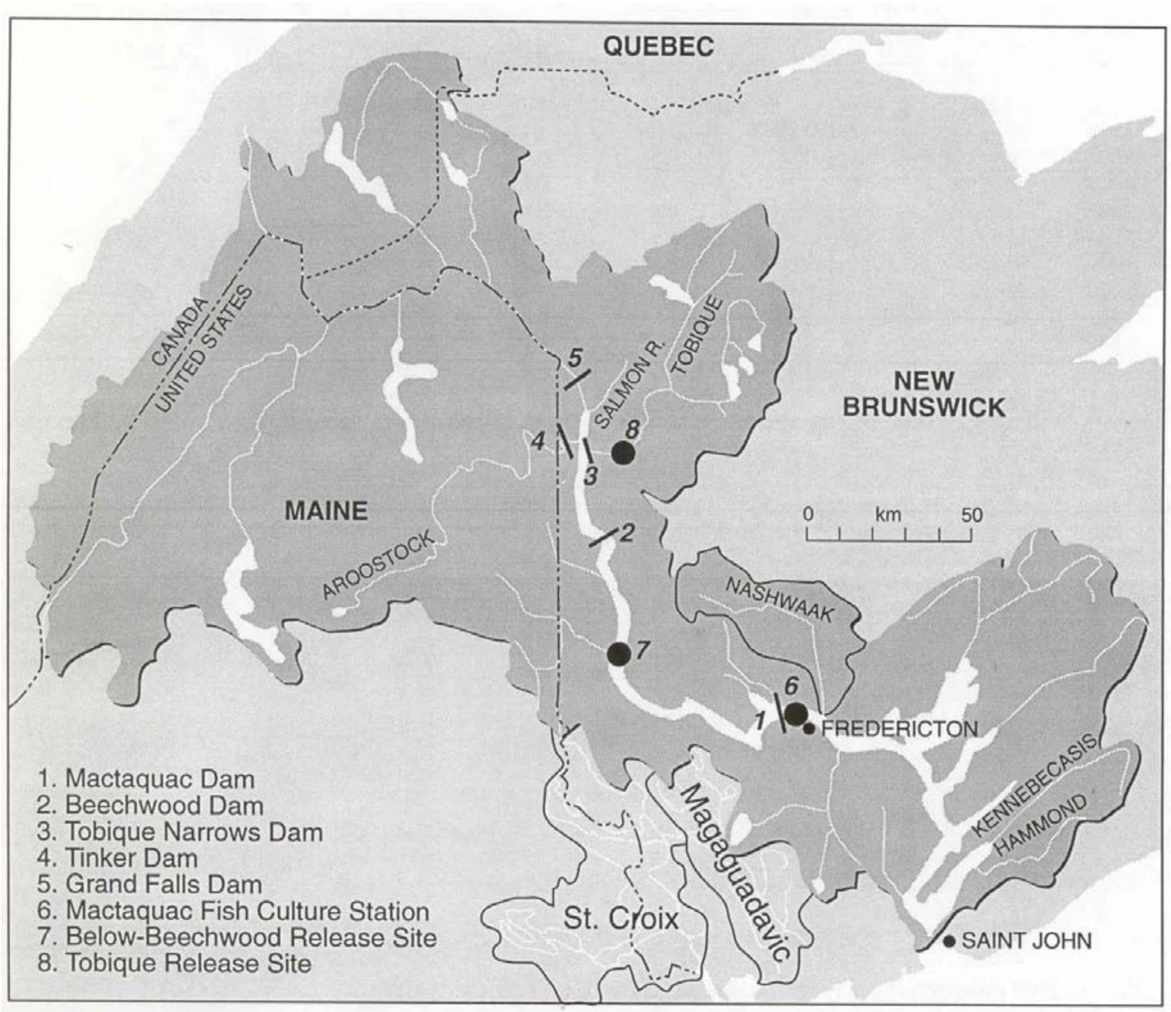


Fig. 1. Map of the Magaguadavic, St. Croix and Saint John River drainages including Tobique and Nashwaak rivers and other major tributaries, dams, and principal release sites for Atlantic salmon upriver of Mactaquac Dam. Fish trapping locations on the Tobique and Nashwaak drainages are shown in Fig. 8 and Fig. 15. Note that the Mactaquac Fish Culture Station is now referred to as the Mactaquac Biodiversity Facility.

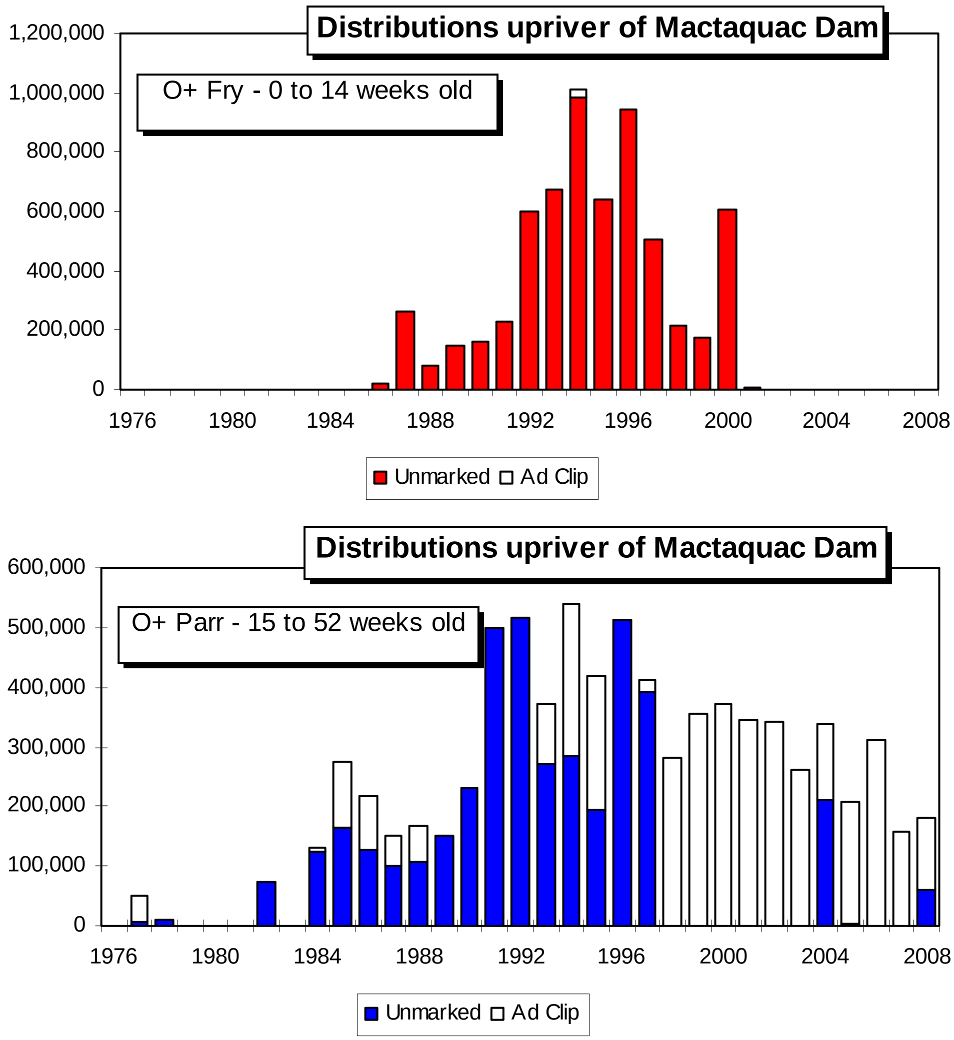
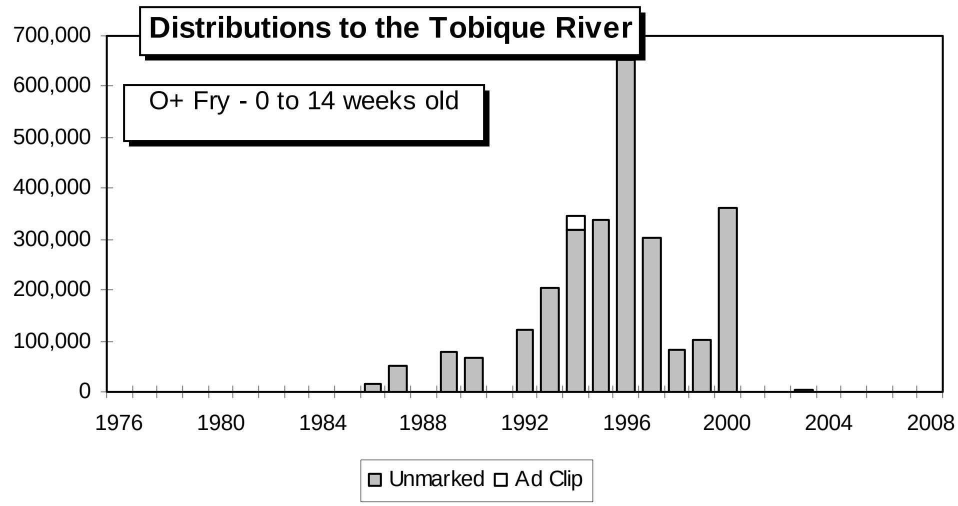


Fig. 2a. Number of juvenile salmon less than 52 weeks old (excludes age-1 smolts) released or distributed to tributaries upriver of Mactaquac Dam on the Saint John River, 1976 - 2008.



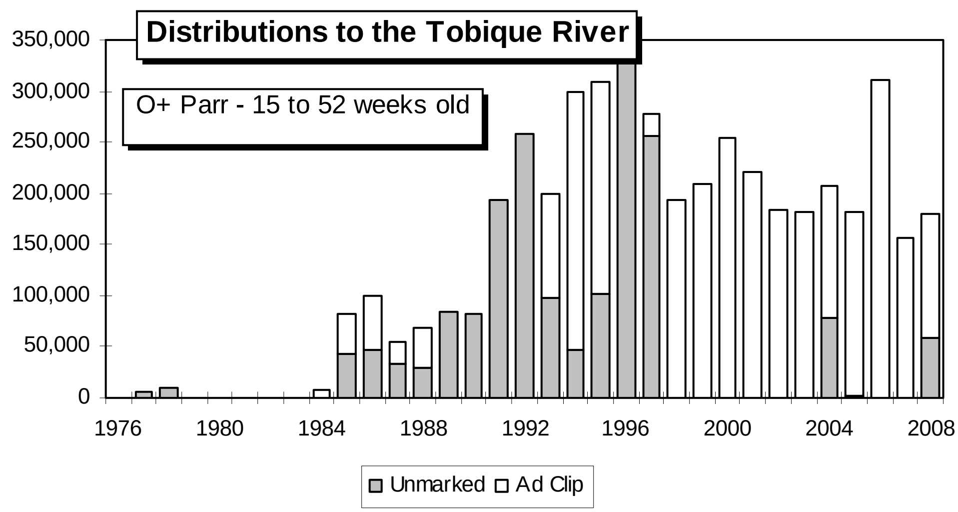
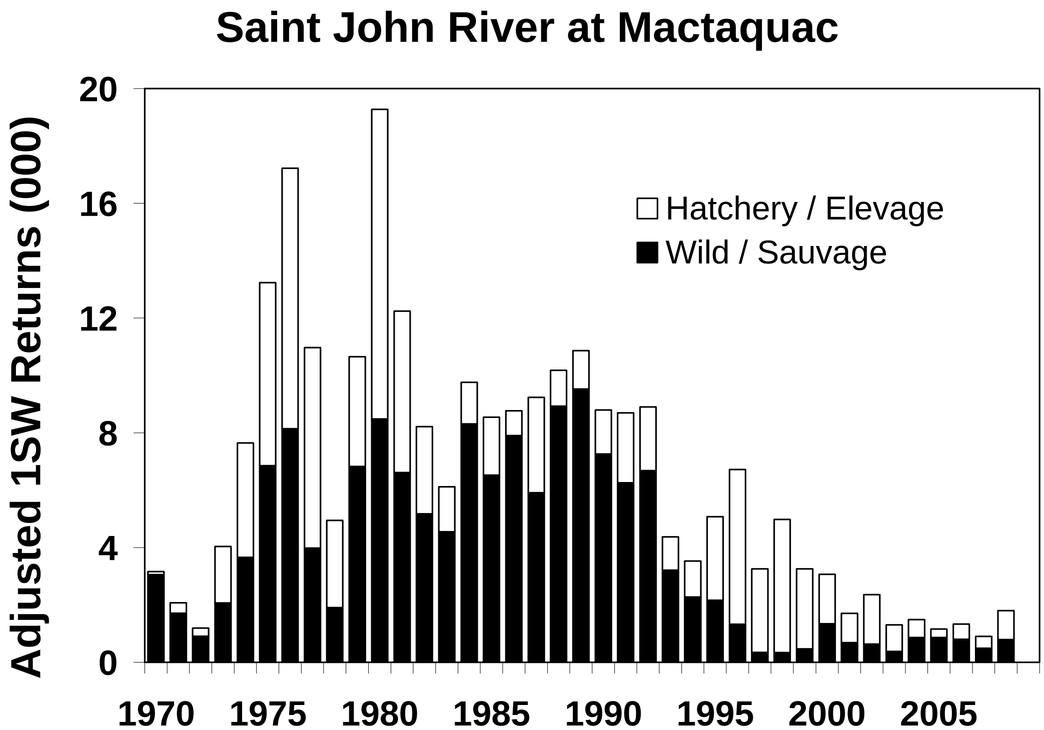


Fig. 2b. Number of juvenile salmon less than 52 weeks old (excludes age-1 smolts) released or distributed to the Tobique River, 1976 - 2008.



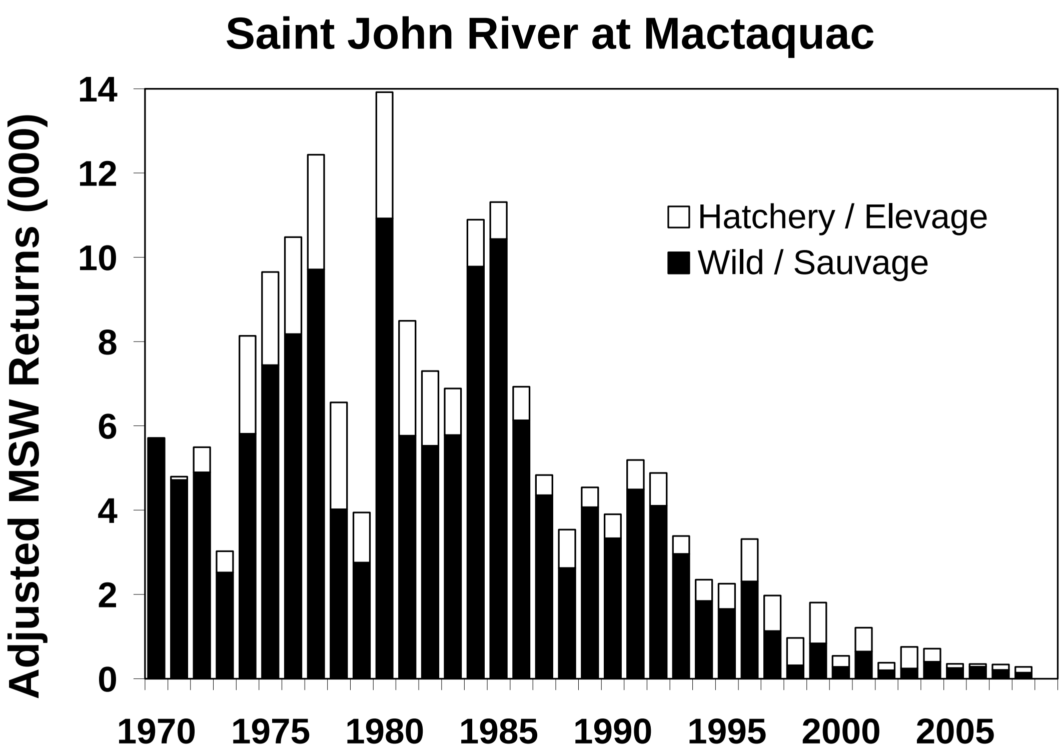


Fig. 3. Estimated total adjusted returns of wild and hatchery 1SW and MSW salmon destined for Mactaquac Dam on the Saint John River, 1970 - 2008.

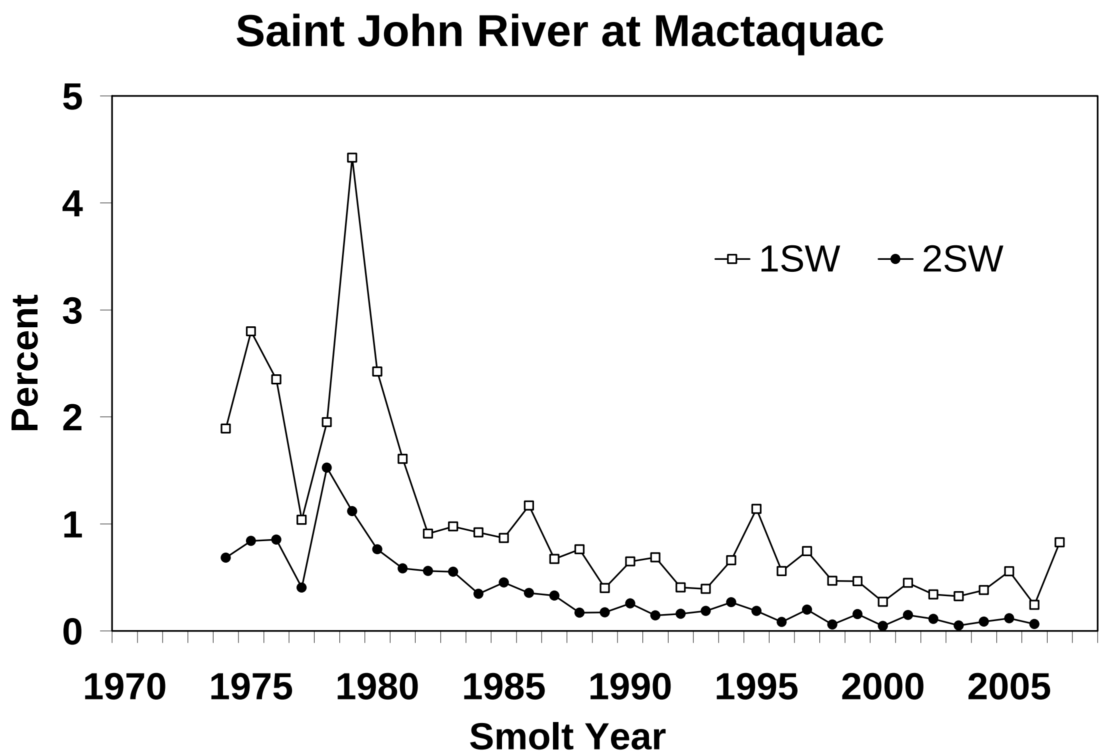


Fig. 4. Return rates of hatchery reared smolts to virgin 1SW and virgin 2SW salmon destined for Mactaquac Dam on the Saint John River by smolt year, 1974 – 2007. The 2006 and 2007 smolt classes were from captive-reared broodstock originating in the Tobique River.

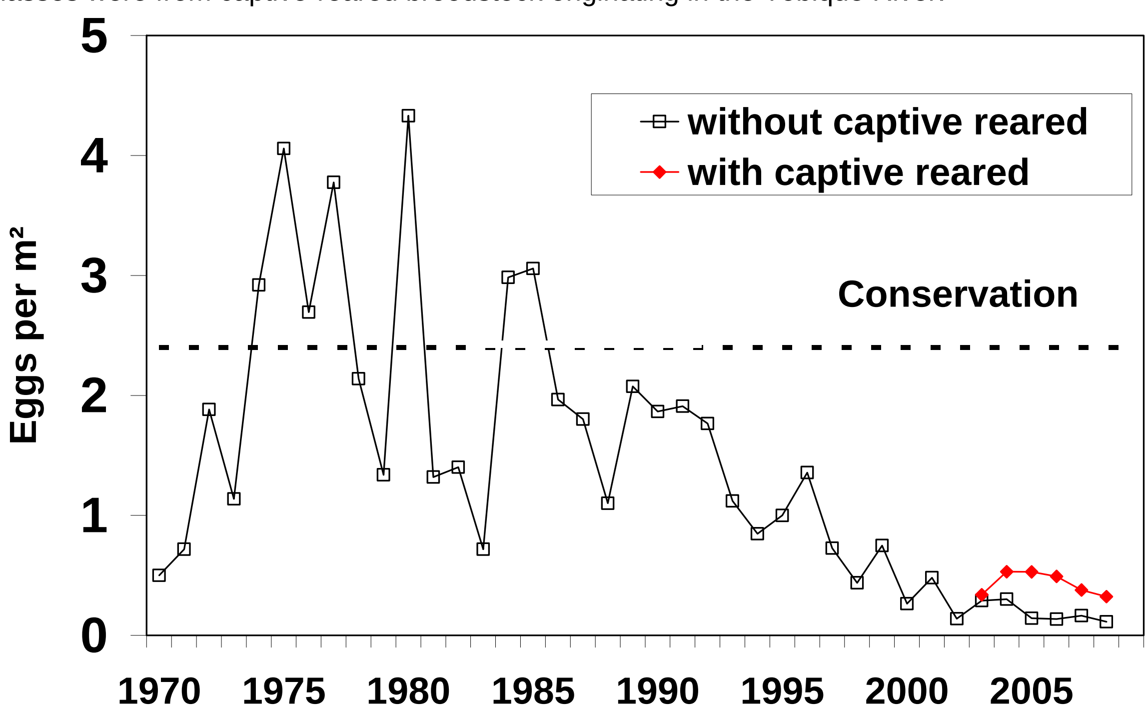


Fig. 5. Estimated egg deposition upriver of Mactaquac Dam on the Saint John River, 1970 - 2008.

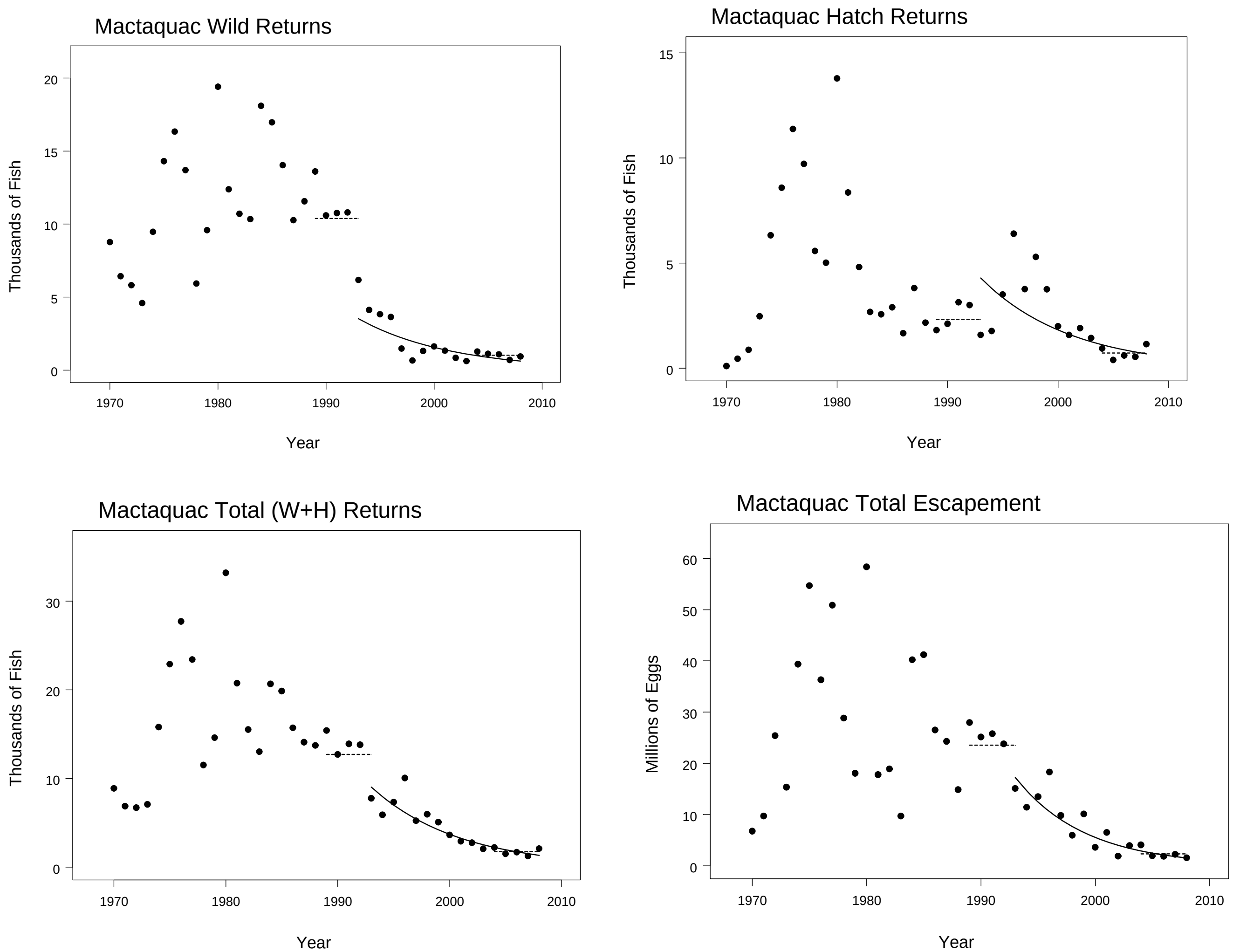
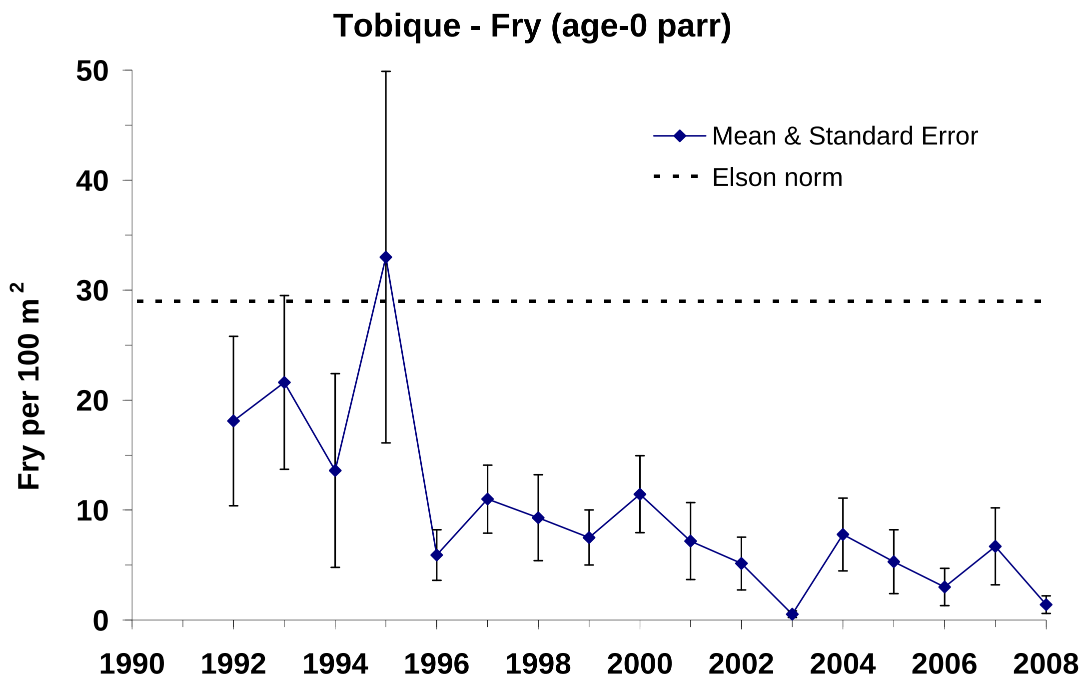


Fig. 6. Trends in abundance of adult Atlantic salmon in the Saint John River, upriver of Mactaquac Dam, during the last 15 years. The solid line is the predicted abundance from a log-linear model fit by least squares. The dashed lines show the 5 year mean abundance for 2 time periods ending in 1994 and in 2008. The points are the observed data. Model coefficients are provided in Table 8.



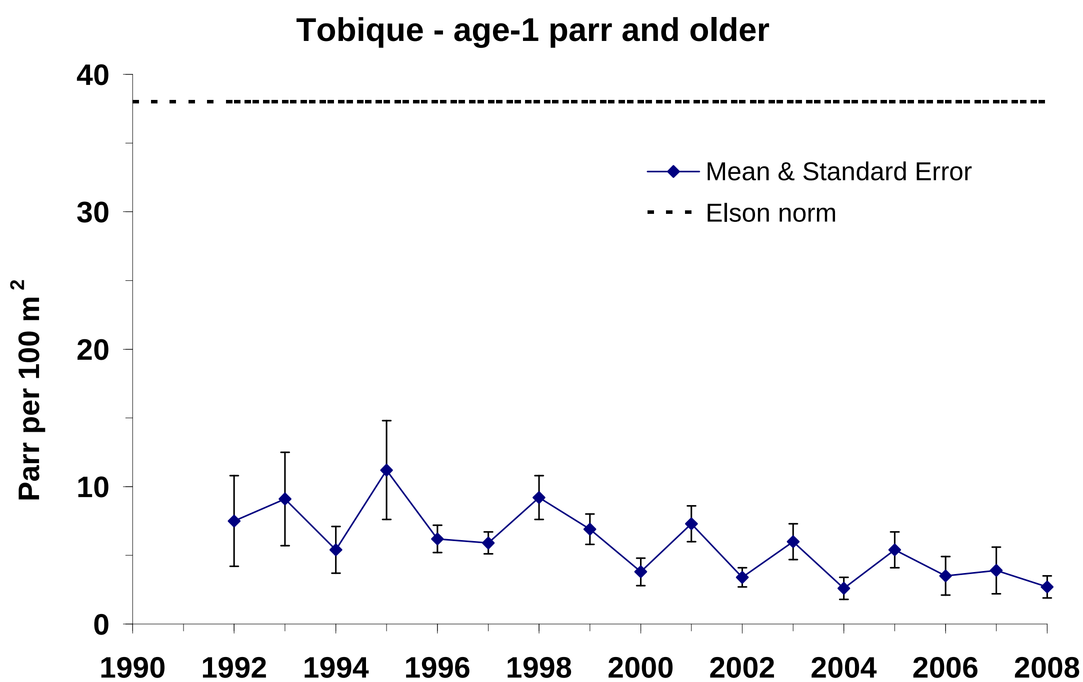


Fig. 7. Mean densities of age-0 (fry) (upper panel) and age-1 and older parr (lower panel) from electrofishing sites on the Tobique River in relation to the “Elson Norm” from 1992 to 2008.

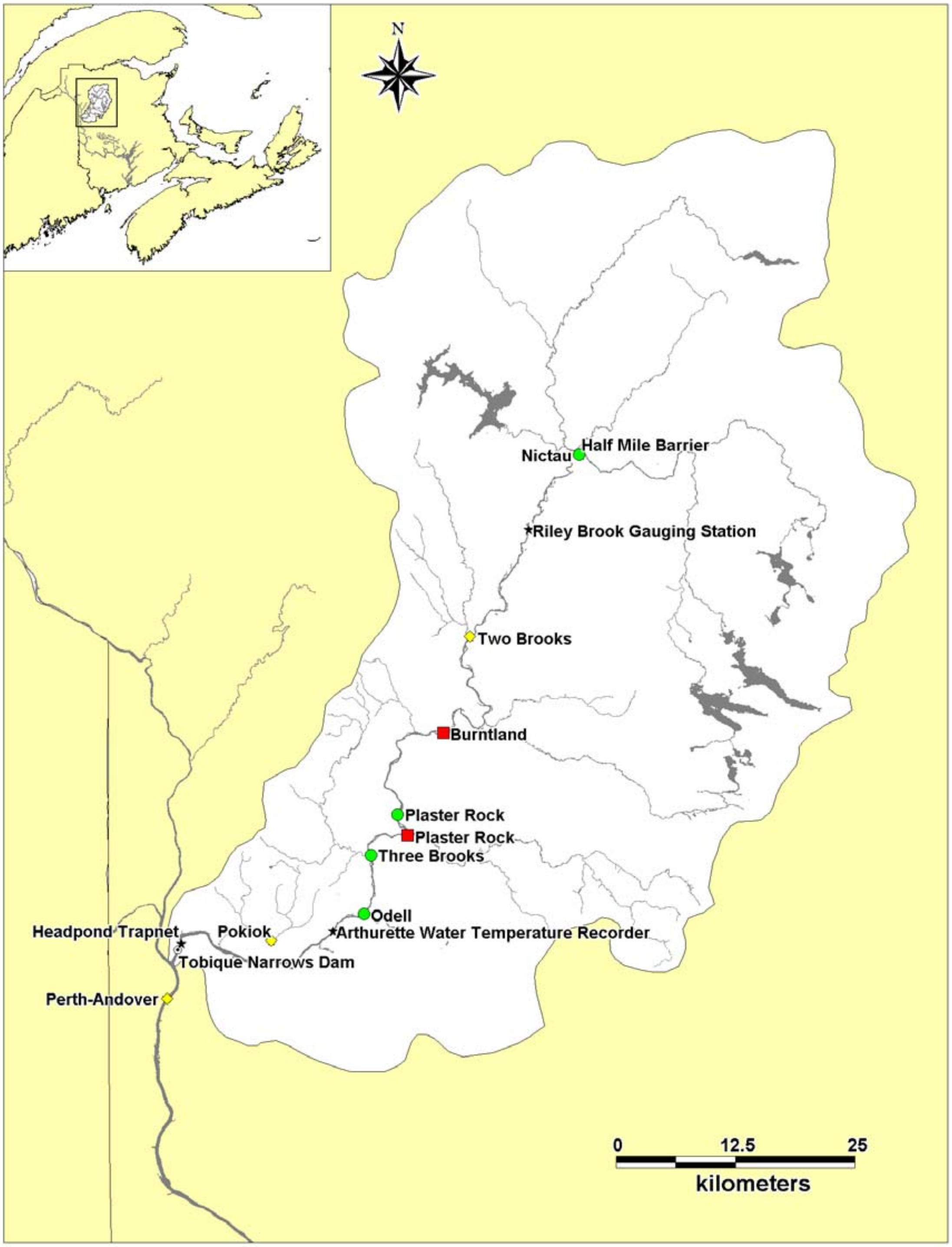
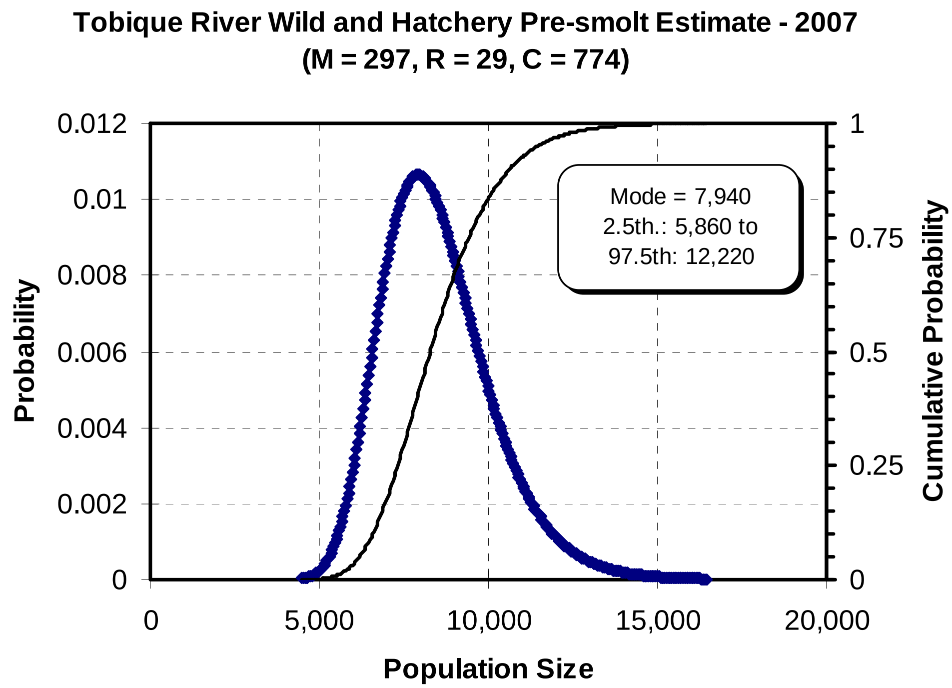


Fig. 8. Map of Tobique River showing the location of the rotary screw traps (circles), release sites for smolts (squares) and adults (diamonds), the temperature recorder (star), the trapnet (star), the half mile fish protection barrier (circle) and river gauging station (star) sites.



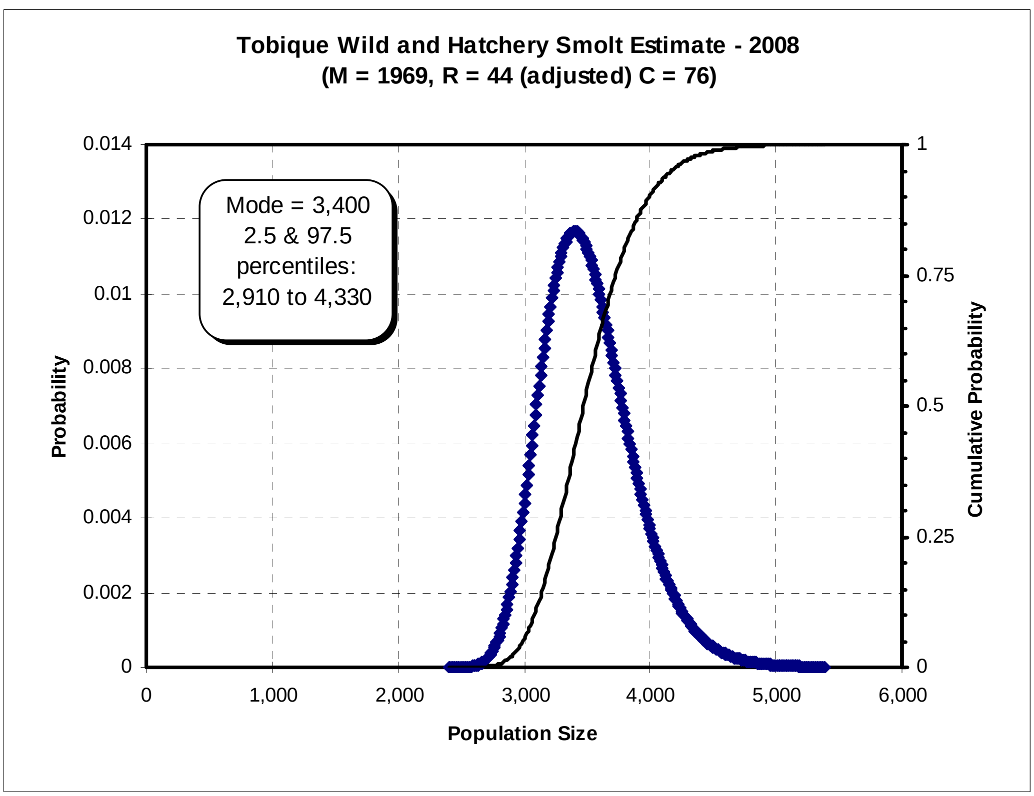
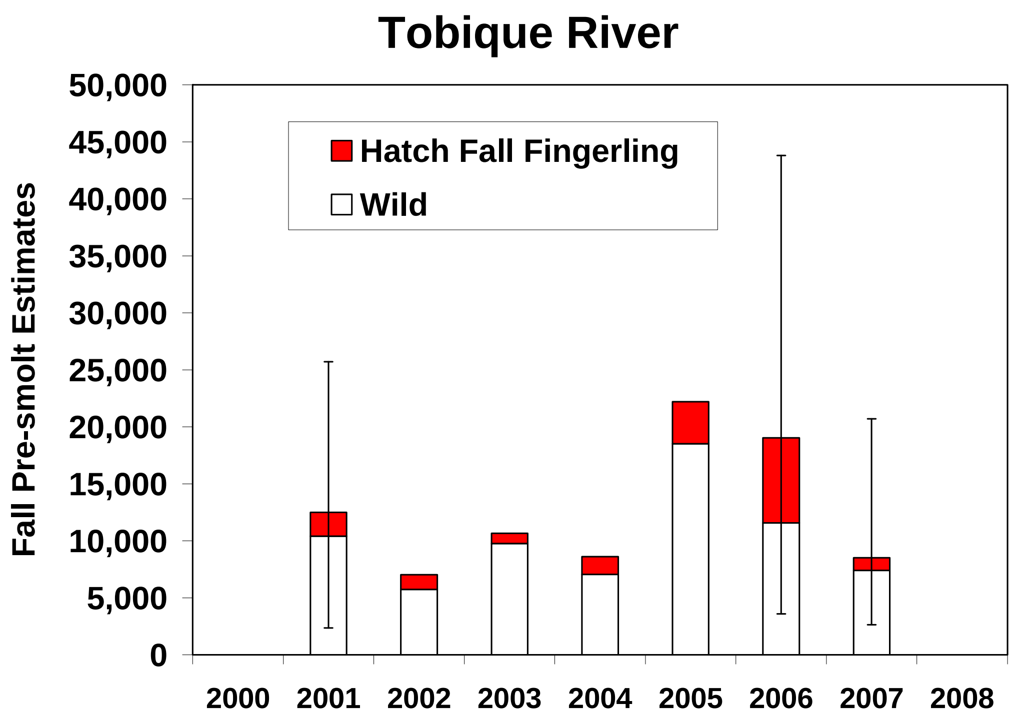


Fig. 9. Probability density (dots) and cumulative probability (black line) of a Bayesian analysis based on an adjusted Peterson estimate from mark-recapture data, for the number of wild and hatchery Atlantic salmon pre-smolts (upper panel) and smolts (lower panel) emigrating from the Tobique River (Three Brooks).



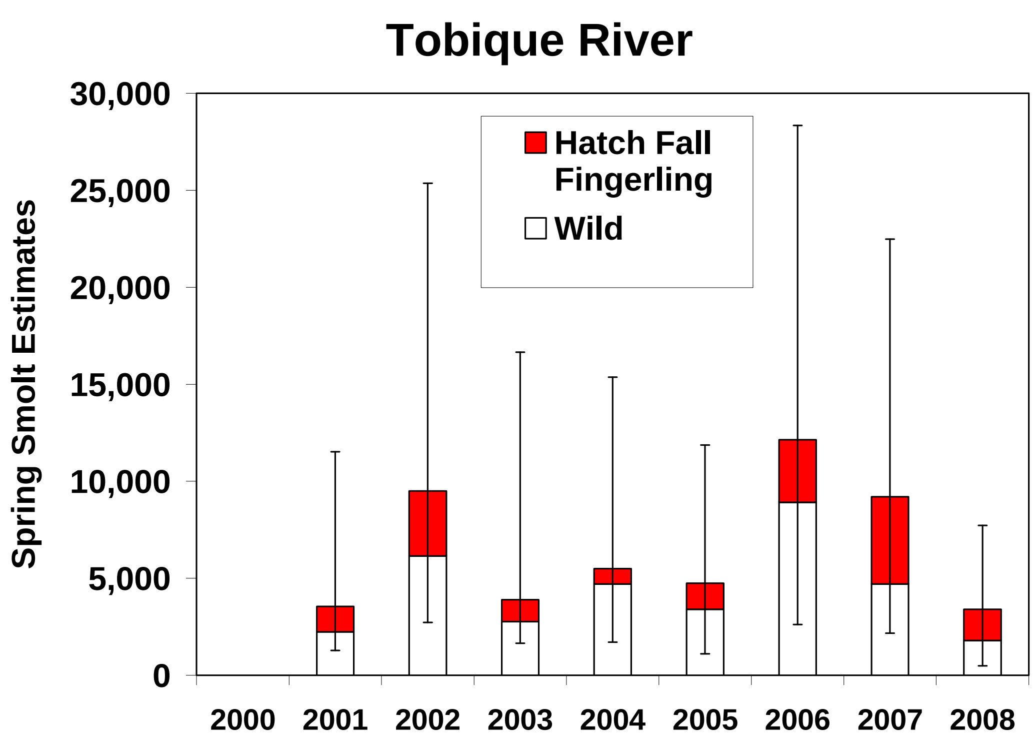


Fig. 10. Estimated number (and 2.5 and 97.5 percentiles) of wild and hatchery fall pre-smolt (upper) and spring smolts (lower) emigrating from the Tobique River, 2001 to 2008.

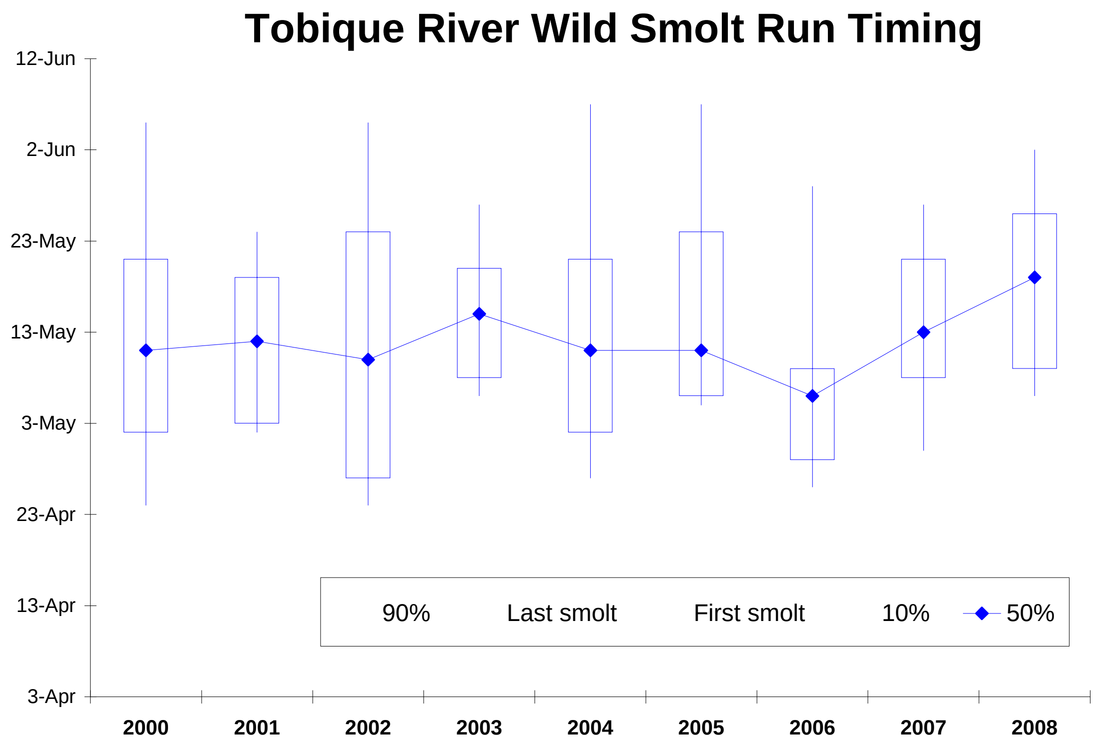


Fig. 11. Distribution of wild smolt RST captures on the Tobique River (Odell; 2000 and Three Brooks; 2001-2008) by date and year; showing the first and last smolts captured as well as the 10%, 50% and 90% cumulative proportion of catch from 2000 to 2008.
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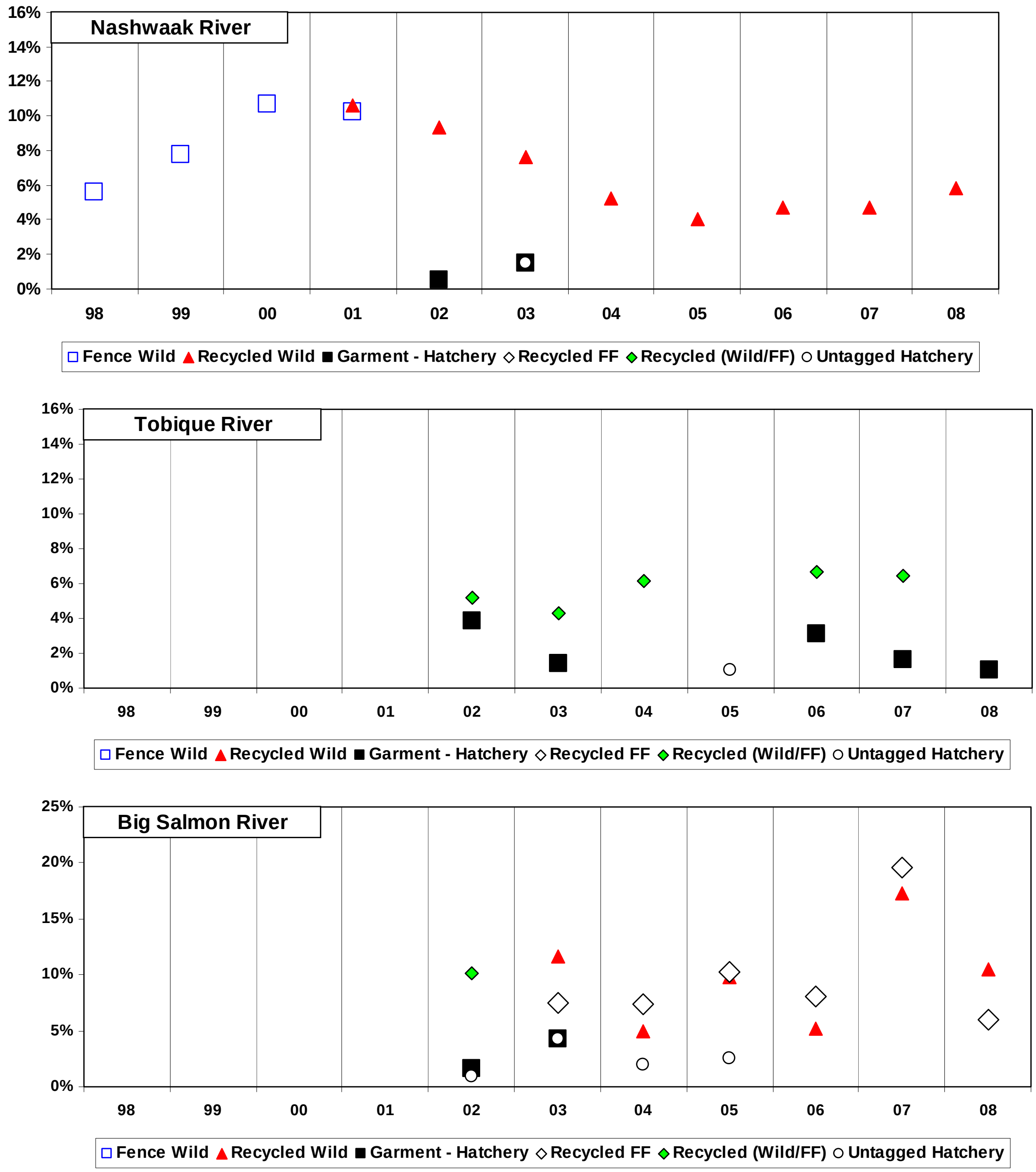


Fig. 12. Various rotary screw trap (or RST) capture efficiencies of wild, hatchery – fall fingerling (FF), hatchery – spring released (untagged and tagged) smolts from the Tobique, Nashwaak, and Big Salmon rivers.

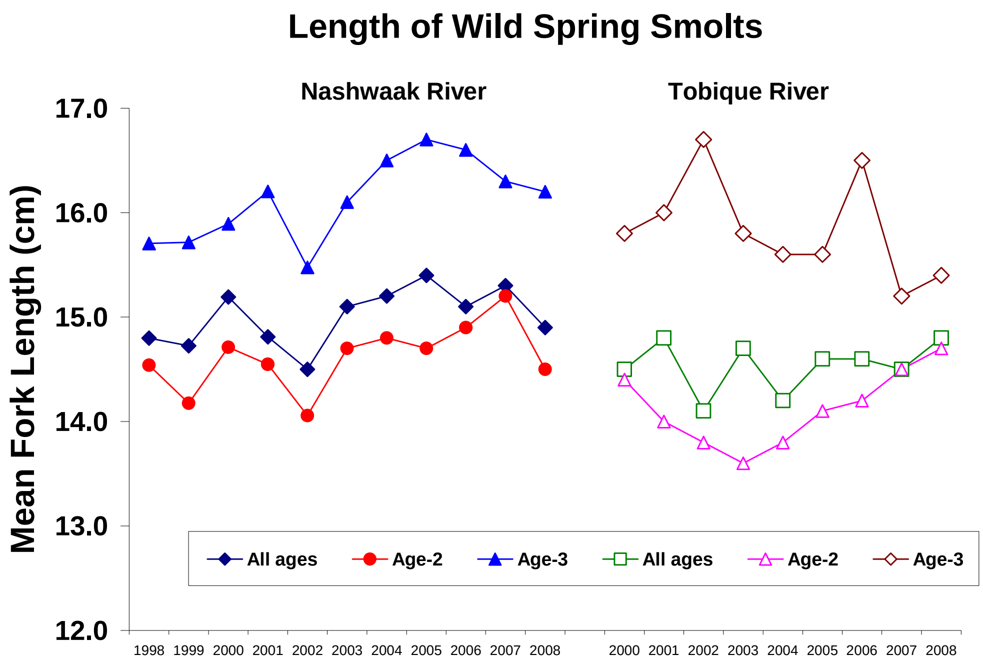


Fig. 13. Mean fork length by age for wild smolts sampled during assessment projects on the Nashwaak (1998 - 2008) and Tobique (2000 - 2008) rivers.

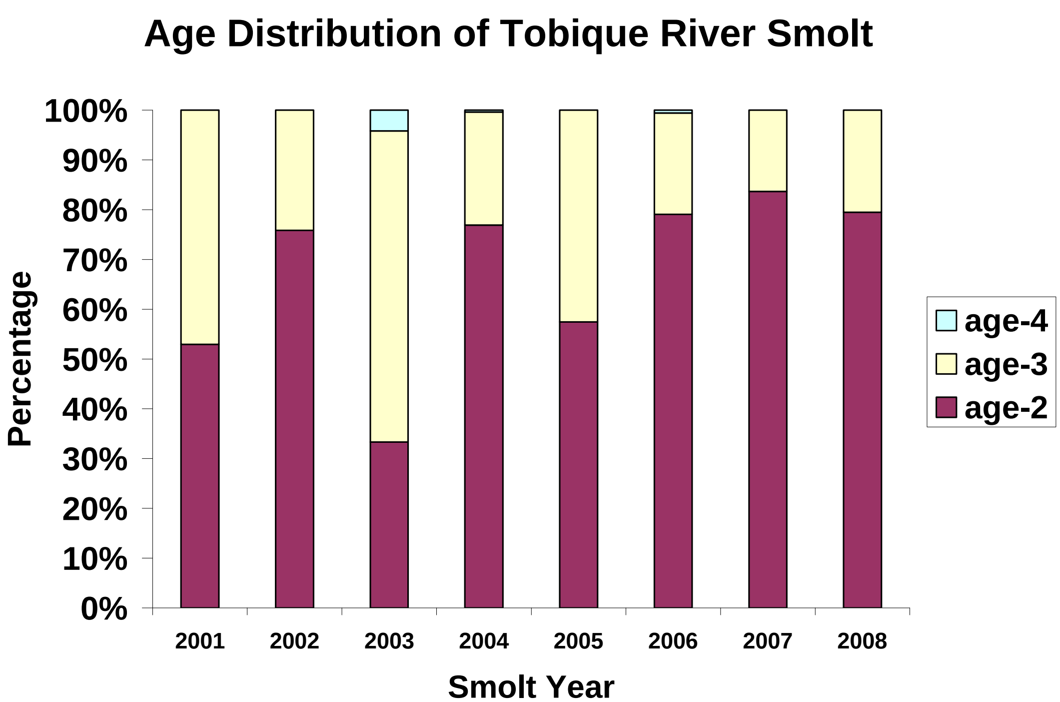


Fig. 14. Percentages of age-2, age-3 and age-4 wild smolts emigrating from the Tobique River from 2001 to 2008.

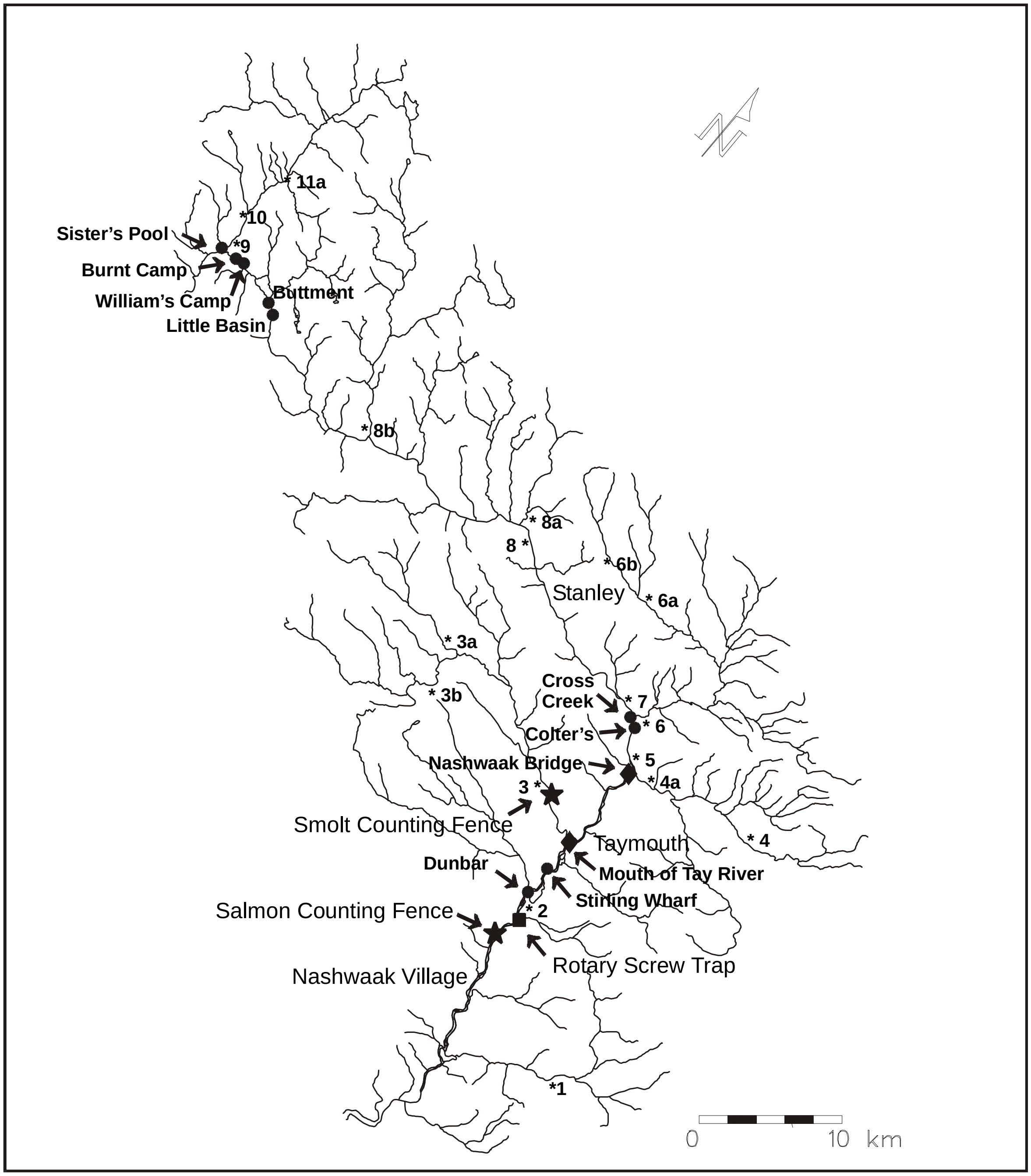


Fig. 15. Map of the Nashwaak River, indicating the adult counting fence site (star), rotary screw trap site (square), smolt fence (star), seined pools (circles), and electrofishing sites (*). Historical index sites used in Table 15 are 1, 2, 3, 5, 8, 9, and 10.

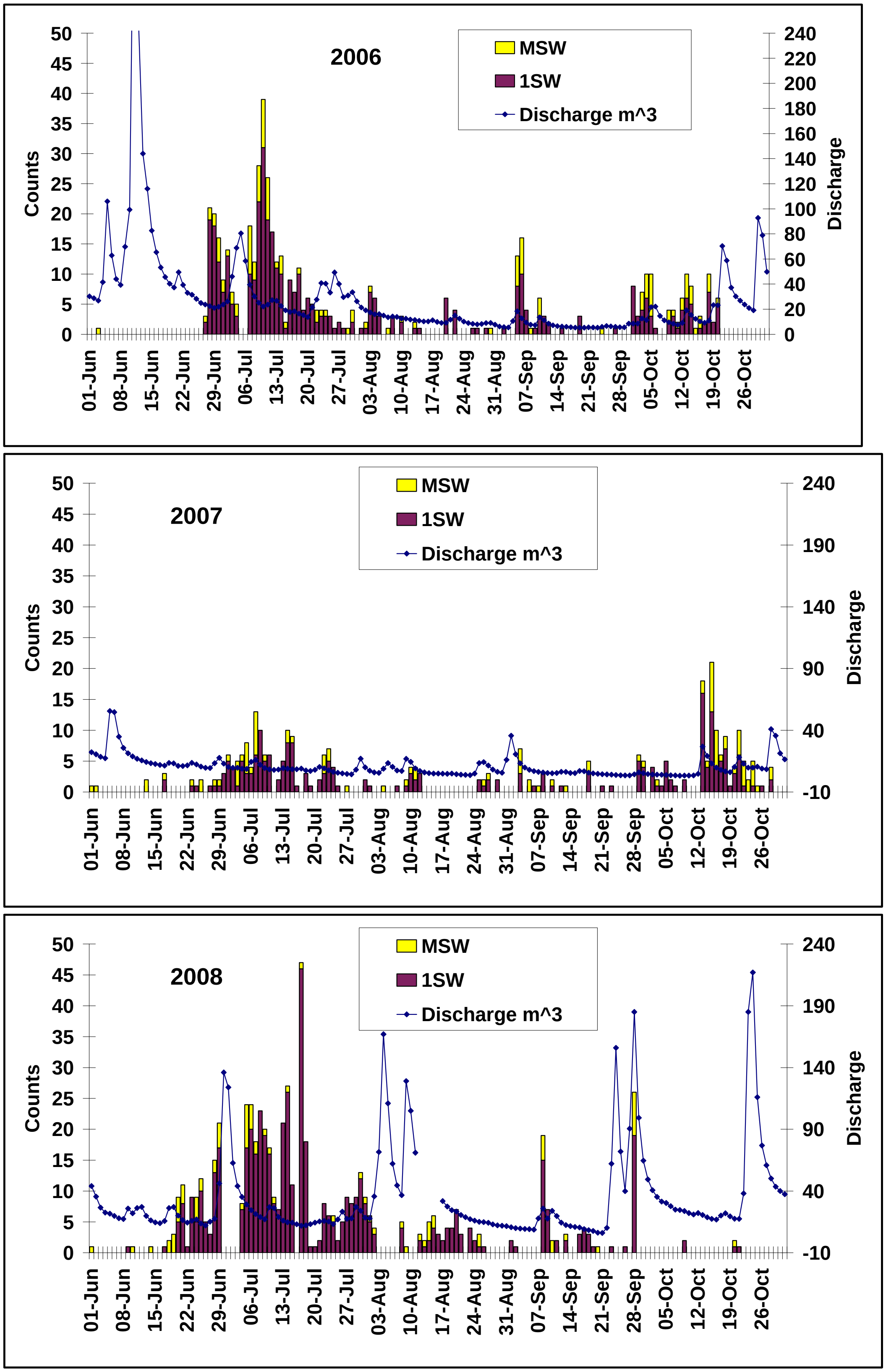
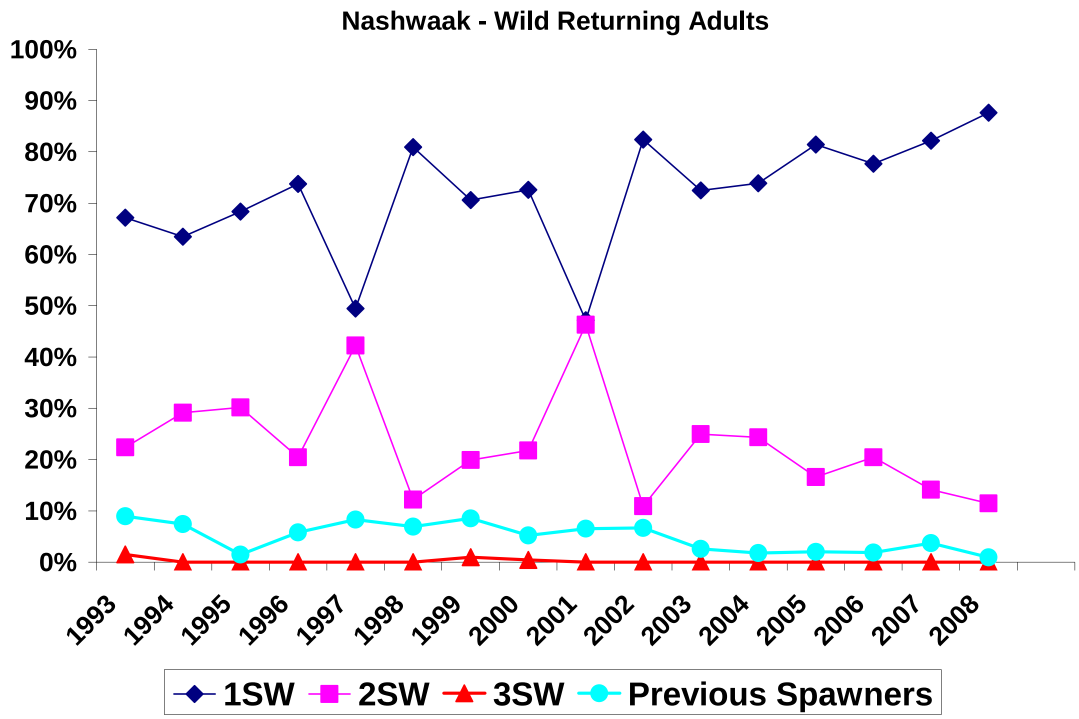


Fig. 16. Average daily discharge (m³/sec) at Durham Bridge and adjusted fence counts of 1SW and MSW salmon on the Nashwaak River, 2006 - 2008.



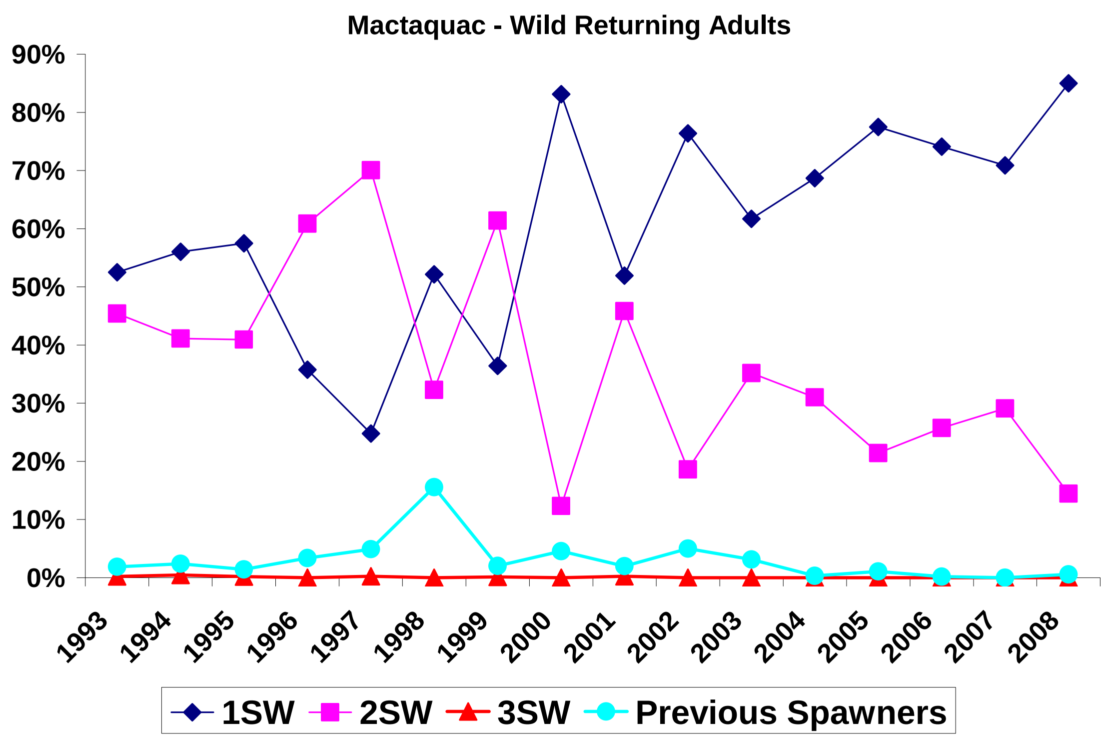


Fig. 17. The percentages of wild virgin 1SW, 2SW, 3SW and previous spawning (repeat spawning) Atlantic salmon in the total returns to the Nashwaak River and to Mactaquac, from 1993 to 2008.

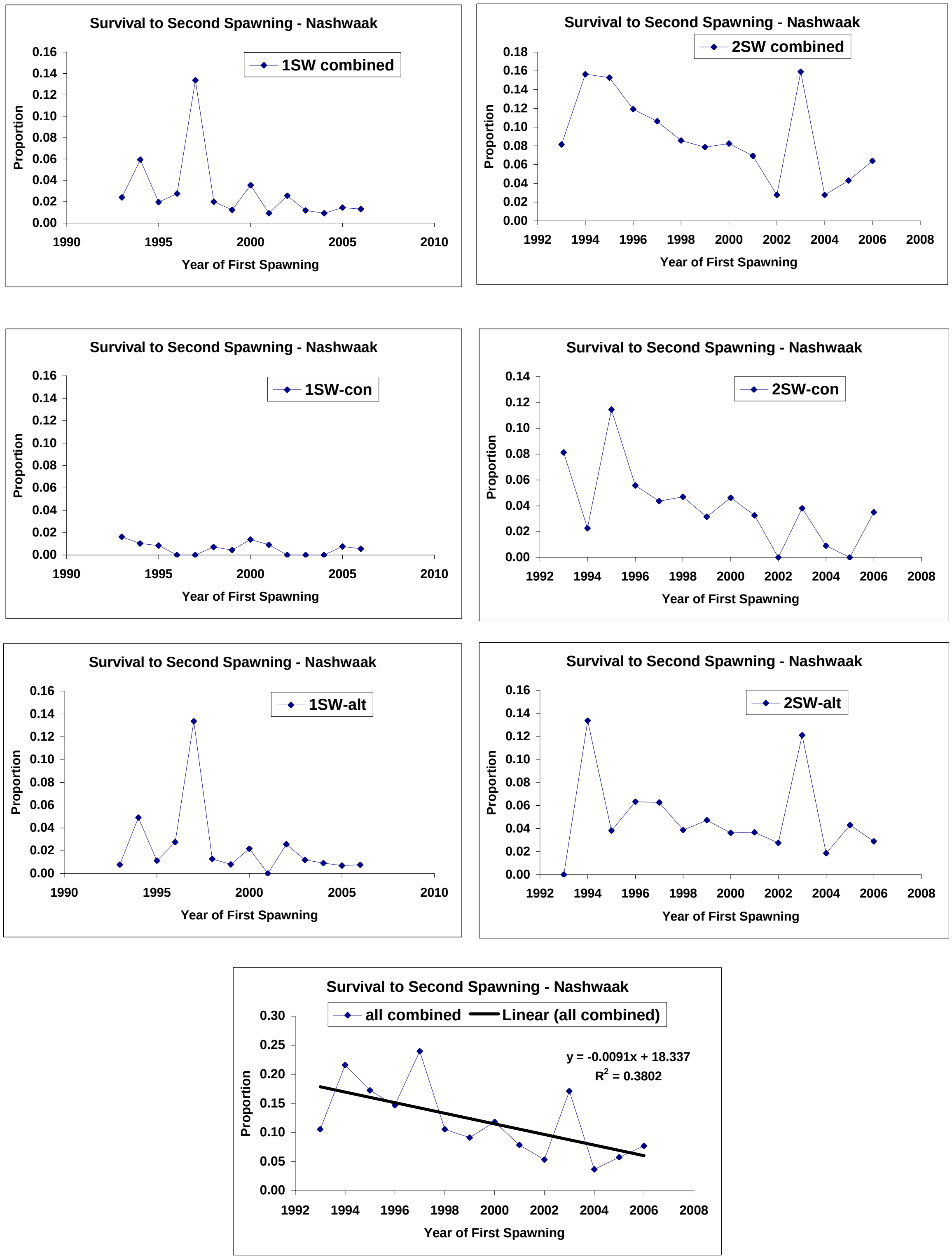


Fig. 18. Proportion of maiden 1SW and 2SW salmon surviving to spawn as a consecutive (i+1) or alternate (i+2) repeat spawner on the Nashwaak River, 1993- 2008.

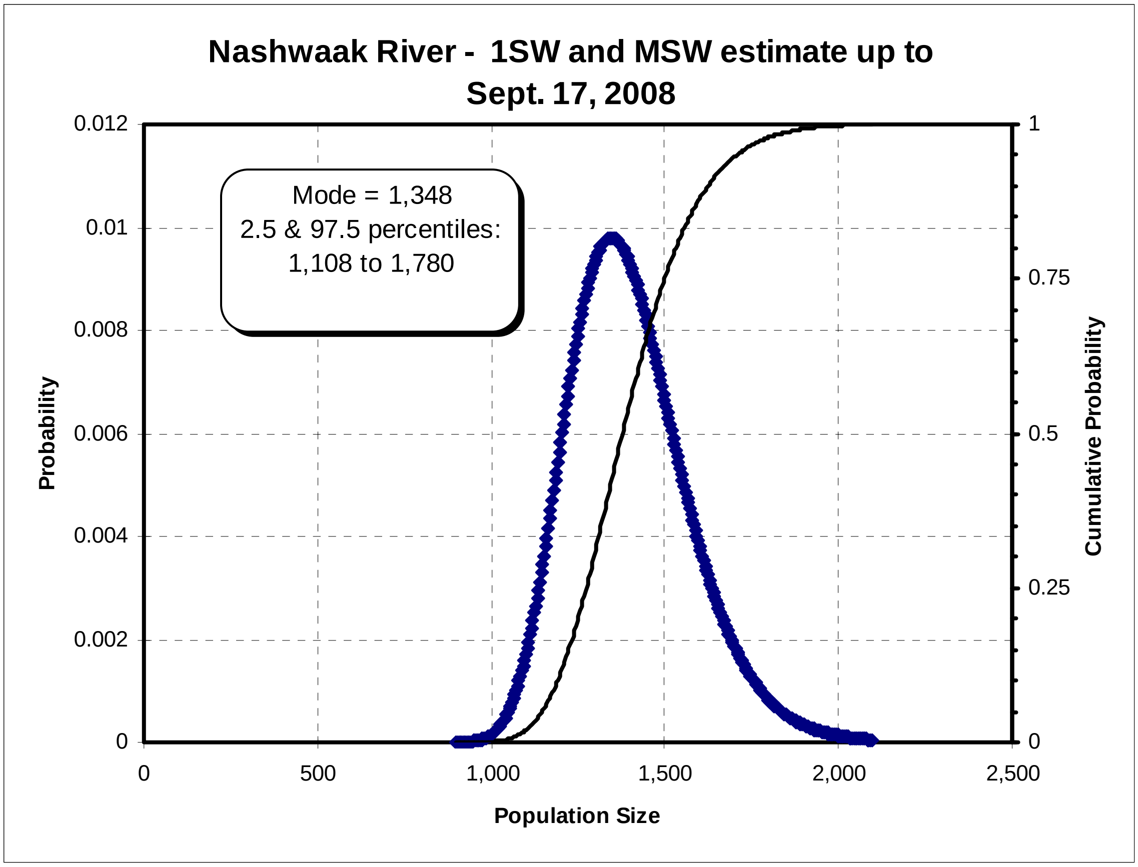
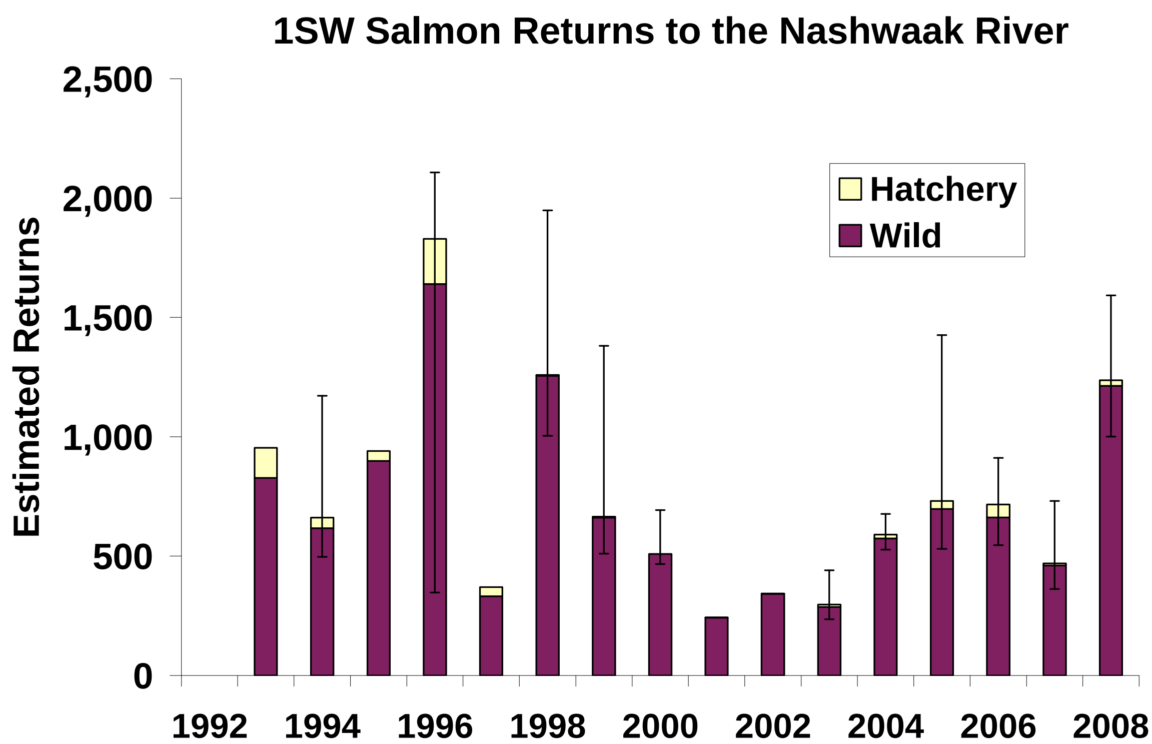


Fig. 19. Probability density (dots) and cumulative probability (black line) of a Bayesian analysis based on an adjusted Peterson estimate from mark-recapture data, for the number of 1SW and MSW salmon returning to the Nashwaak River up to September 17, 2008.



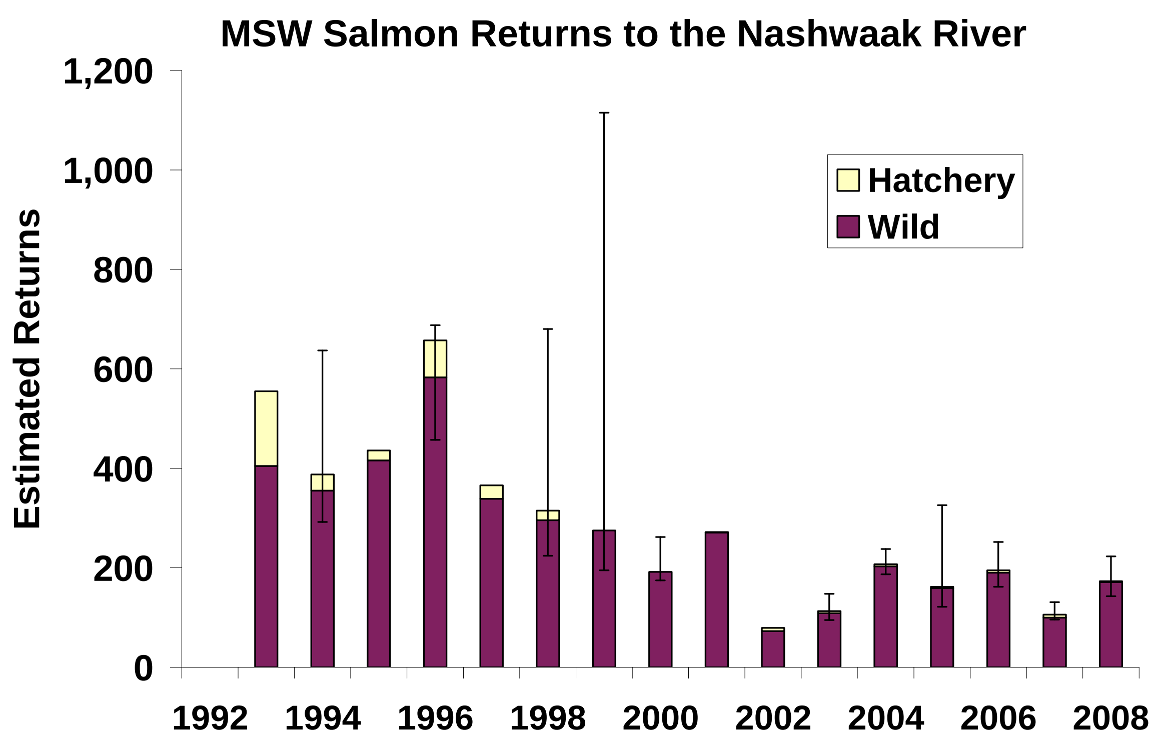


Fig. 20. Estimated wild and hatchery 1SW and MSW salmon returns (and 2.5 and 97.5 percentiles) to the Nashwaak River, 1993 to 2008.

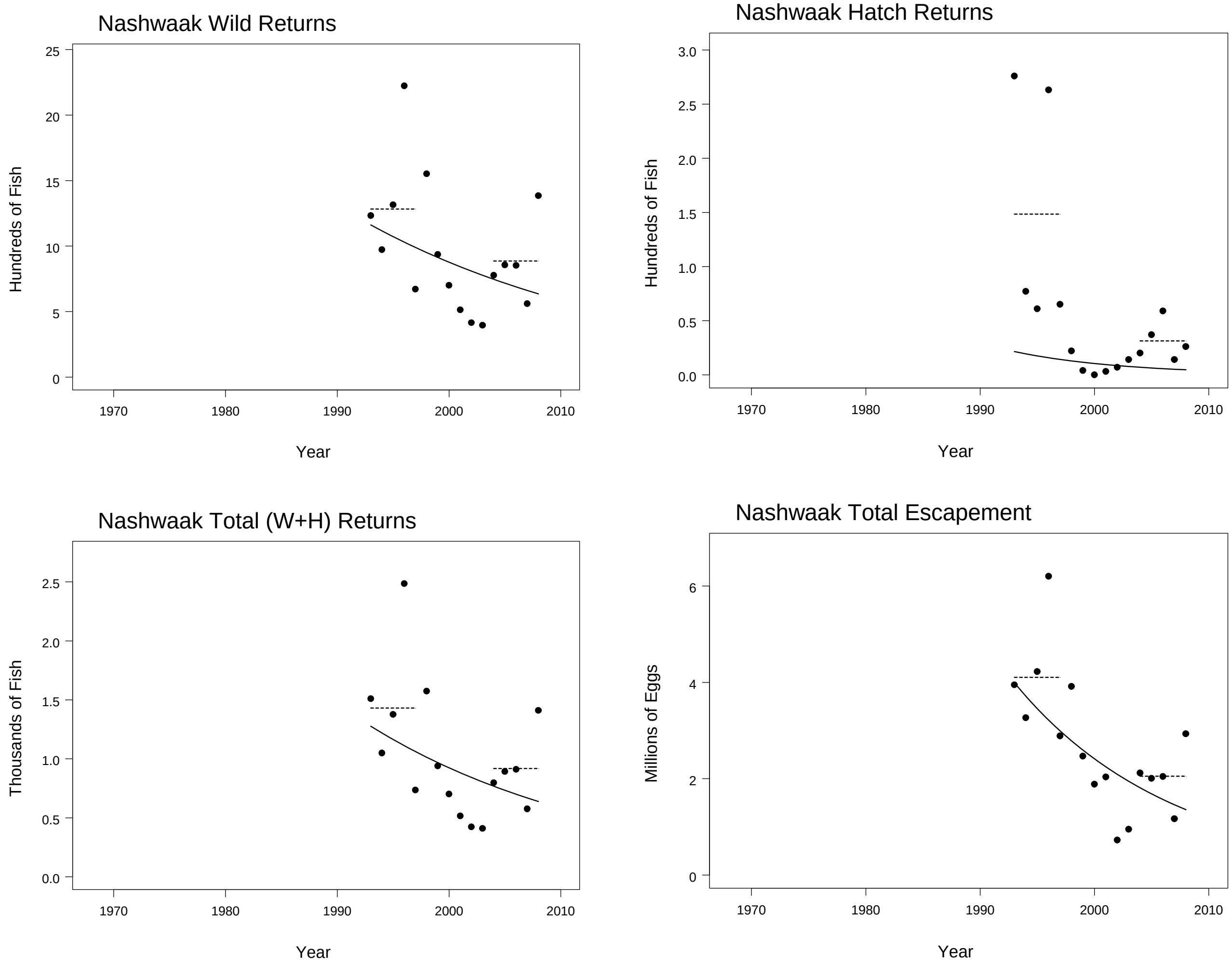
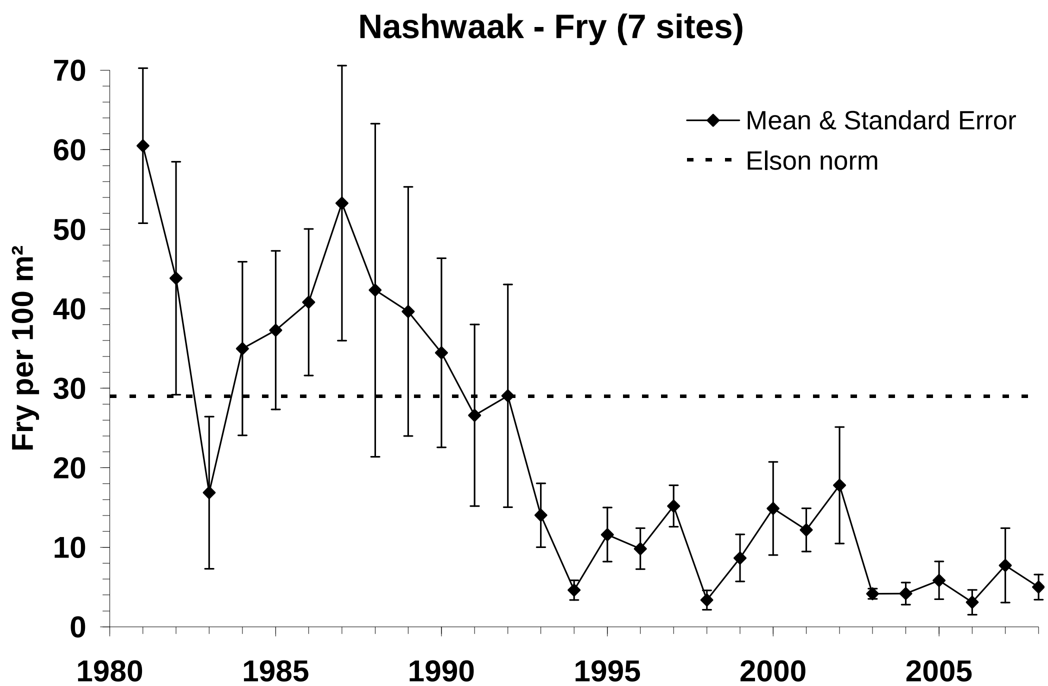


Fig. 21. Trends in abundance of adult Atlantic salmon in the Nashwaak River during the last 15 years. The solid line is the predicted abundance from a log-linear model fit by least squares over a 15 year time period. The dashed lines show the 5 year mean abundance for 2 time periods ending in 1997 and 2008. The points are the observed data. Model coefficients are provided in Table 8.



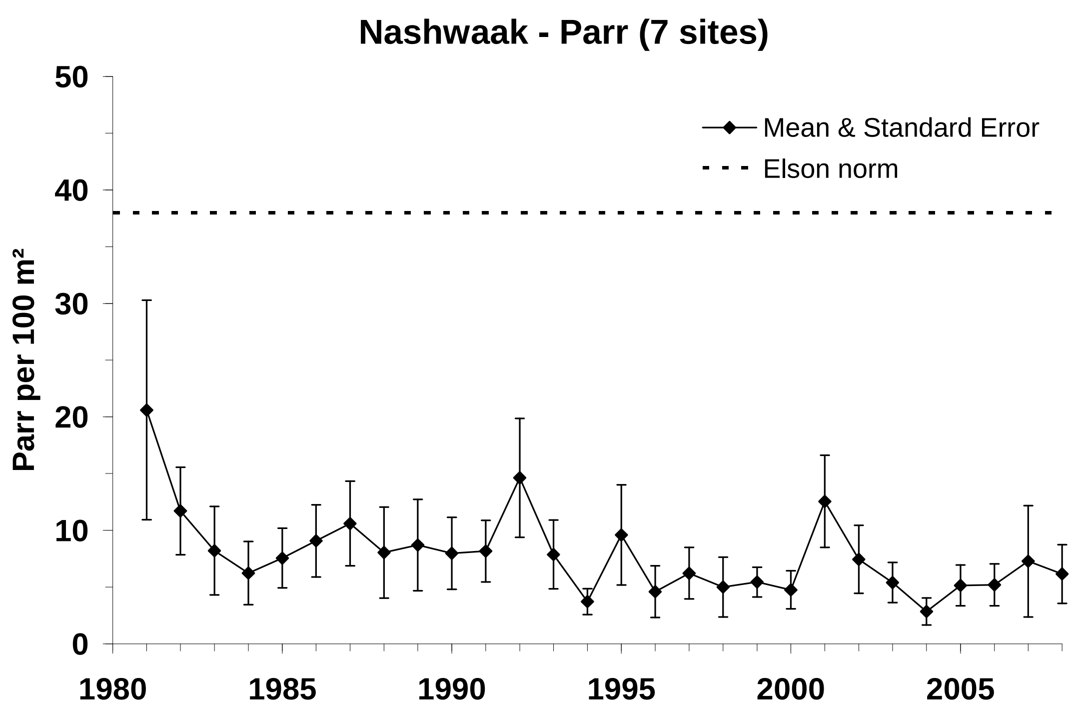


Fig. 22. Mean densities of age-0 (fry) (upper panel) and age-1 and older parr (lower panel) from electrofishing sites on the Nashwaak River in relation to the “Elson Norm” from 1981 to 2008.

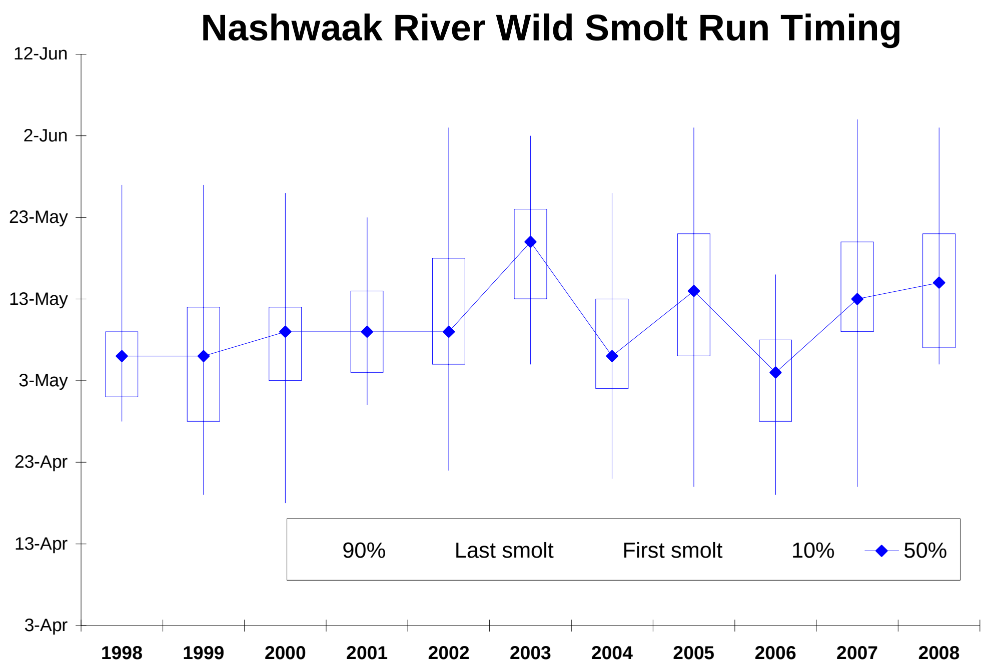
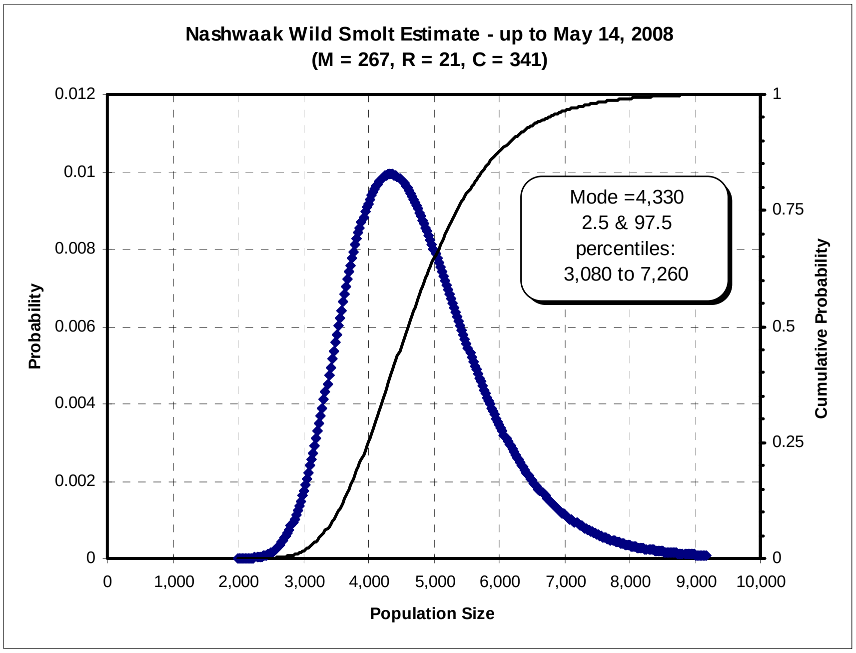


Fig. 23. Distribution of smolt RST captures on the Nashwaak River by date and year; showing the first and last smolts captured as well as the 10%, 50% and 90% cumulative proportion of catch from 1998 to 2008.



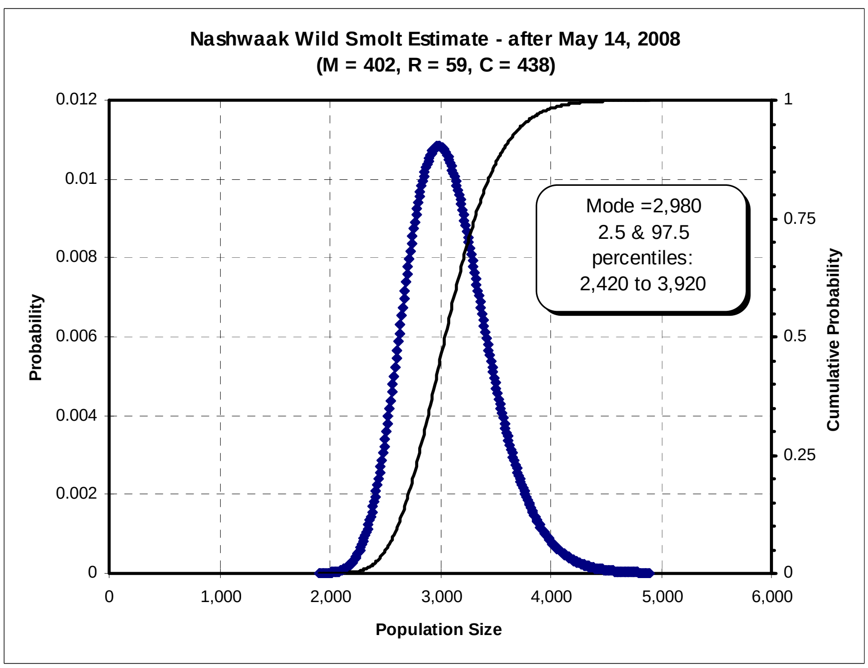


Fig. 24. Probability density (dots) and cumulative probability (black line) of a Bayesian analysis based on an adjusted Peterson estimate from mark-recapture data, for the number for the number of wild Atlantic salmon smolts emigrating from the Nashwaak River, 2008.

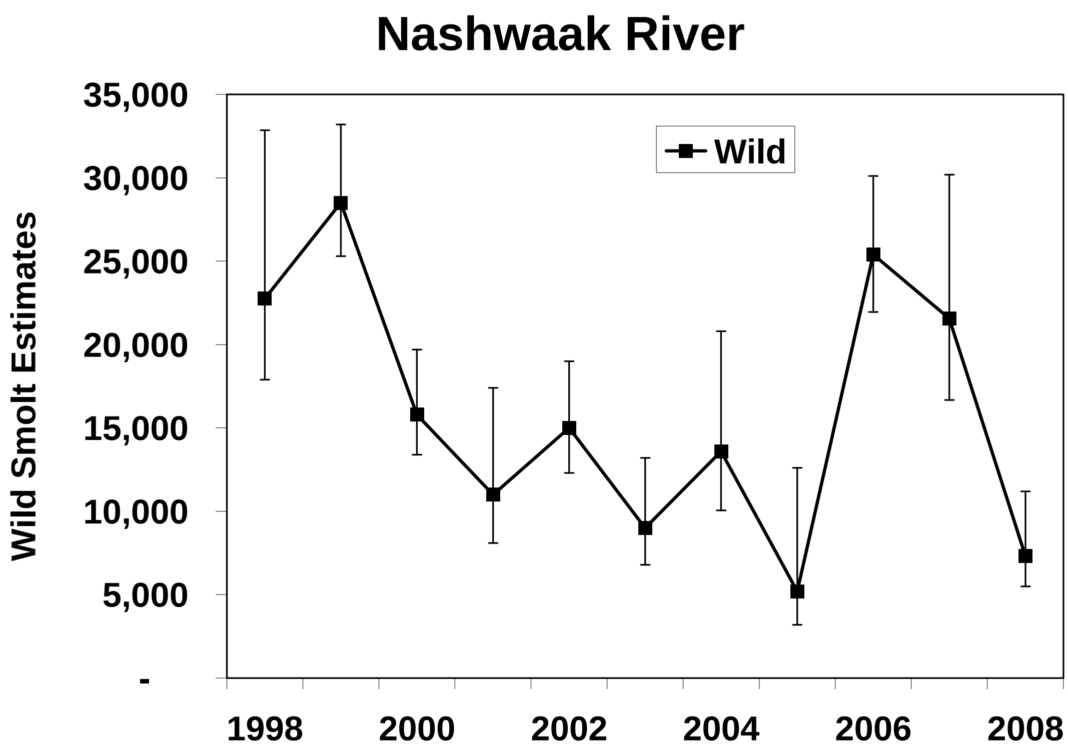


Fig. 25. Estimated numbers of wild smolts (and 2.5 and 97.5 percentiles) emigrating from the Nashwaak River, 1998 to 2008.

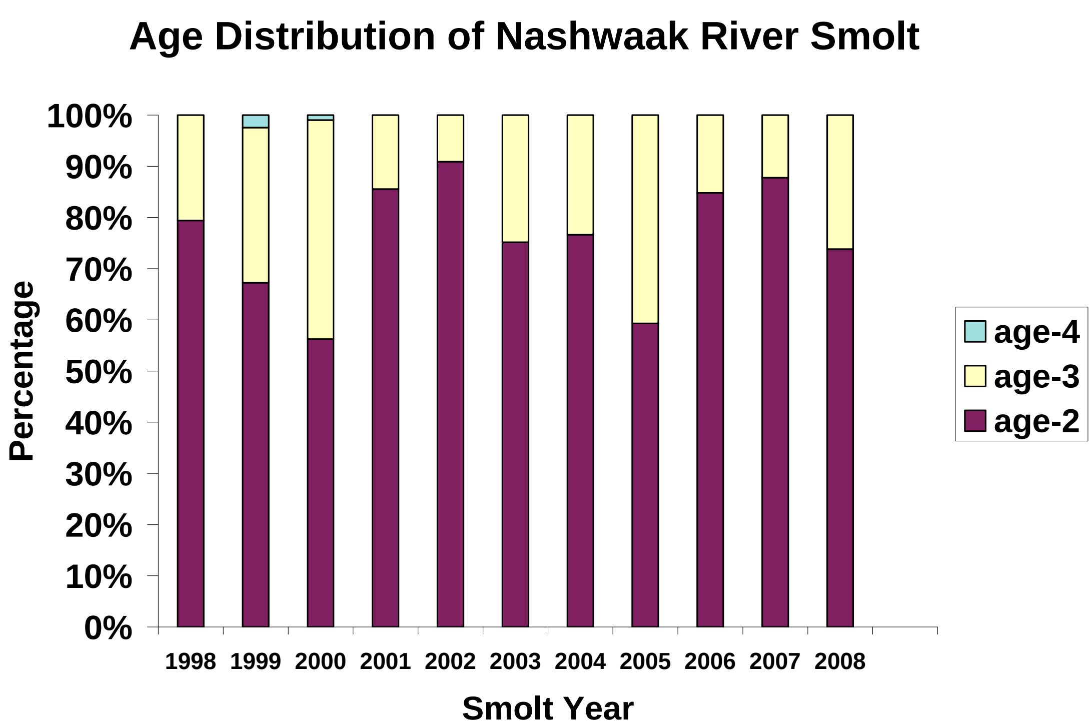


Fig. 26. Percentages of age-2, age-3 and age-4 wild smolts emigrating from the Nashwaak River from 1998 to 2008.

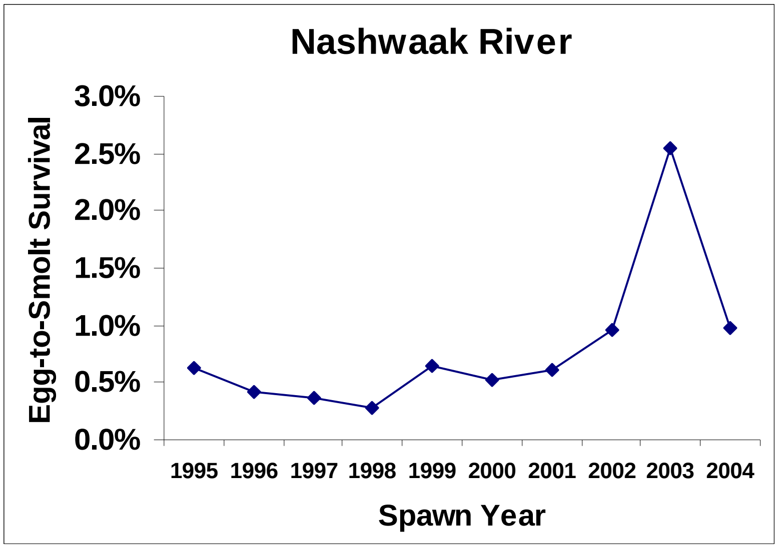


Fig. 27. Egg-to-smolt survival on the Nashwaak River, 1995 – 2004.

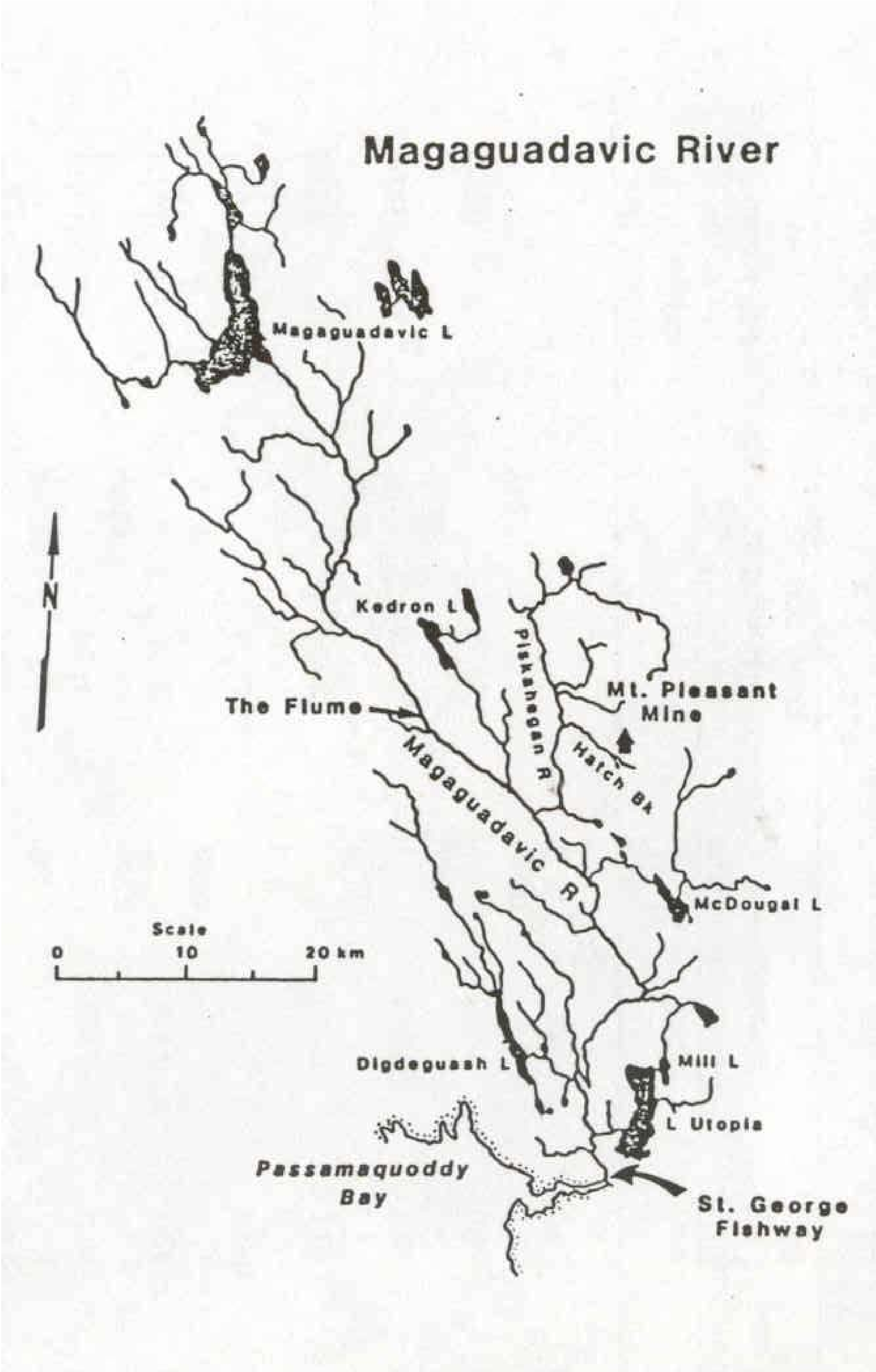


Fig. 28. Map of the Magaguadavic Watershed.

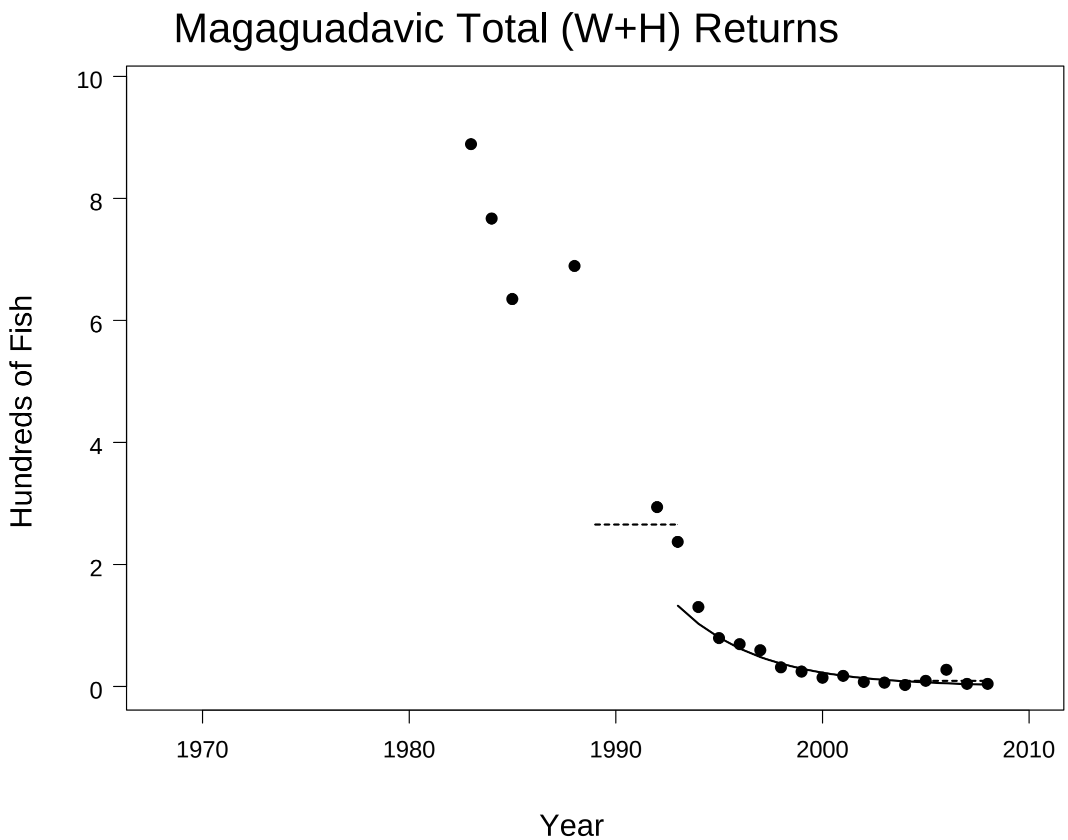


Fig. 29. Trends in abundance of adult Atlantic salmon in the Magaguadavic River. The solid line is the predicted abundance from a log-linear model fit by least squares over the last 15-year time period. The dashed lines show the 5 year mean abundance for 2 time periods ending in 1993 and 2008. The points are the observed data. Model coefficients are provided in Table 8.

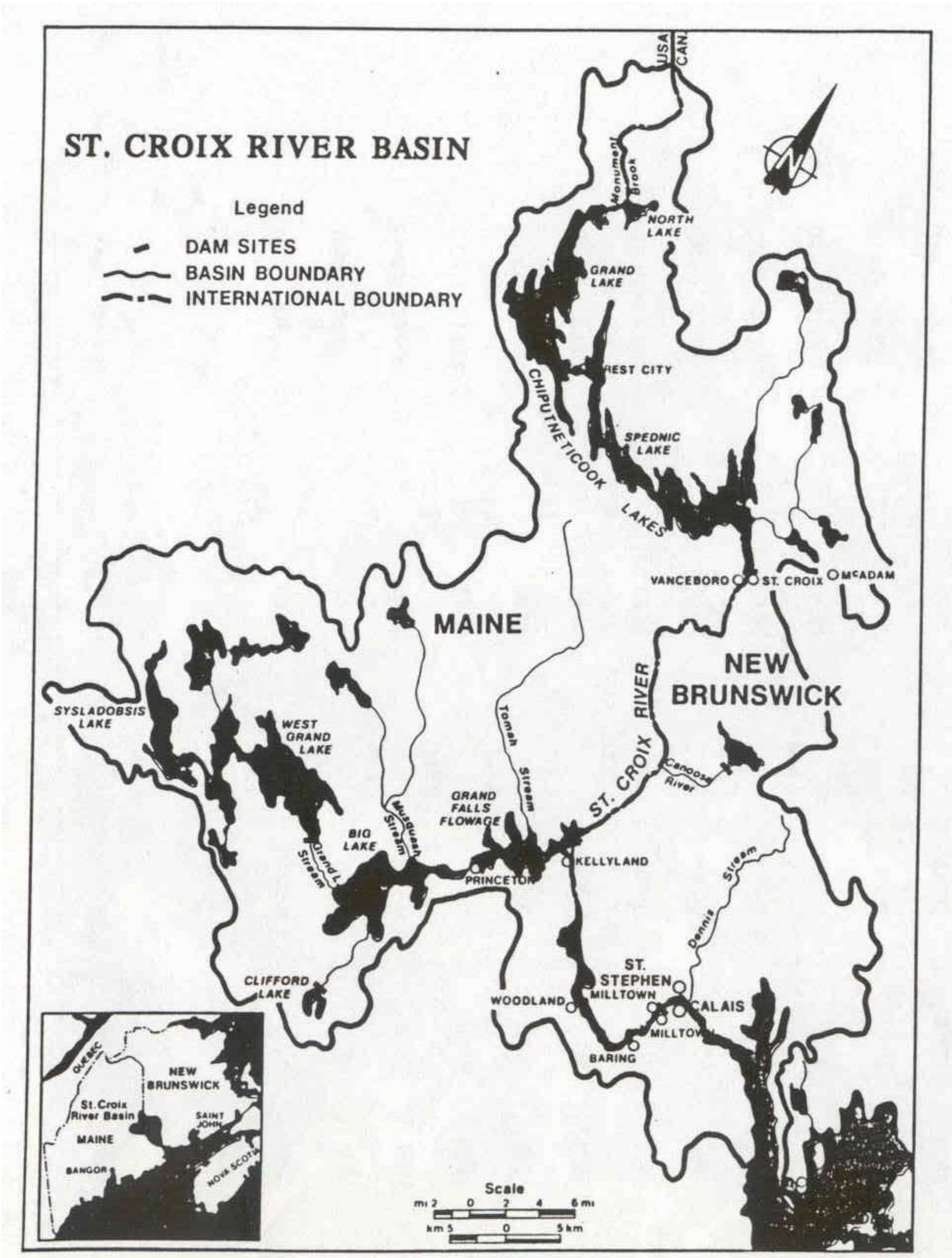


Fig. 30. Map of the St. Croix Watershed.

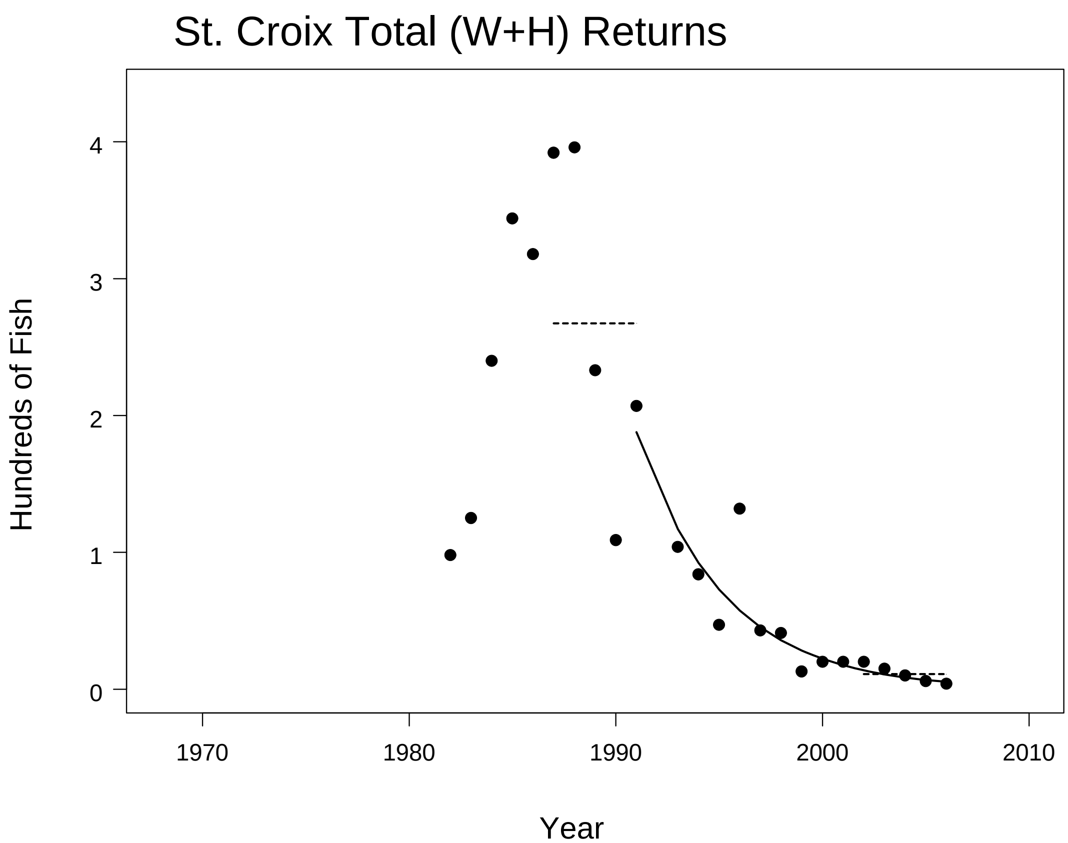


Fig. 31. Trends in abundance of adult Atlantic salmon in the St. Croix River. The solid line is the predicted abundance from a log-linear model fit by least squares for the last 15 years assessed (1992-2006). The dashed lines show the 5 year mean abundance for 2 time periods ending in 1991 and 2008. The points are the observed data. Model coefficients are provided in Table 8.

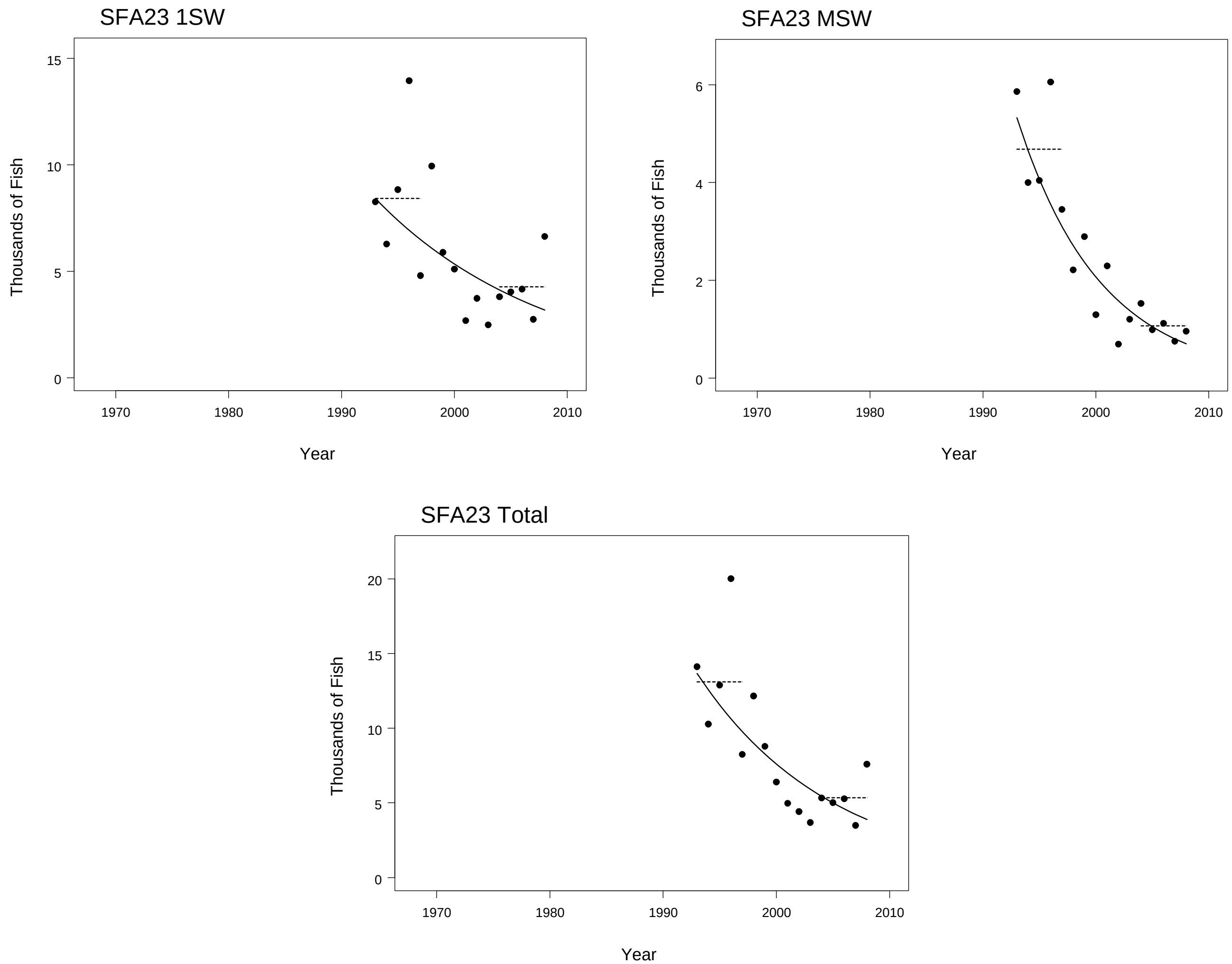


Fig. 32. Trends in abundance of adult Atlantic salmon in the outer portion of SFA 23. The solid line is the predicted abundance from a log-linear model fit by least squares for the last 15 years. The dashed lines show the 5 year mean abundance for 2 time periods separated by years. The points are the observed data. Model coefficients are provided in Table 8.

Appendix *i*. Numbers of juvenile hatchery salmon and wild captive-reared adults distributed to sites up river of Mactaquac Dam (excluding distributions to the Aroostook River), 1976 - 2008. Fry are between zero and 14 weeks old, 0+ parr are at least 14 weeks old but less than one year old and 1+ parr are at least one year old but less than two years old.

	0+ Fry		O+ Parr		1+ Parr			1 yr smolt			2 yr smolt			Captive Reared Adults			
Year	**No Mark**	**Ad Clip**	**No Mark**	**Ad Clip**	**No Mark**	**Ad Clip**	**Tagged**	**No Mark**	**Ad Clip**	**Tagged**	**No Mark**	**Ad Clip**	**Tagged**	**1 yr**	**2yr**	**3yr**	**Repeats**
1976						52,662	5,000										
1977			6,042	44,021													
1978			9,163														
1979																	
1980													5,995				
1981													5,998				
1982			75,210														
1983																	
1984			123,757	8,517													
1985			164,947	110,569	24,544												
1986	17,300		126,692	91,808													
1987	266,257		101,052	50,283													
1988	79,948		107,478	60,472													
1989	150,384		151,562					4,680	30,011		20,000						
1990	164,005		232,291					2,877	24,026			17,140					
1991	227,535		499,130						30,181			19,646					
1992	600,408		514,662														
1993	672,797		272,824	99,939				819									
1994	983,549	30,000	285,988	253,730													
1995	642,830		193,208	226,391													
1996	940,962		511,771														
1997	504,488		391,860	20,991													
1998	213,973			282,491													
1999	172,220			356,635													
2000	609,802			371,751					1,996								
2001	8,330			344,618													
2002	500			342,176						2,357							
2003	2,723			261,852						1,483				387			
2004			210,075	129,147										240	847		
2005			2,500	206,533				1,400						202	847	128	39
2006	1,294			310,947						1,986				224	803	143	119
2007				157,142						1,999				268	413	114	195
2008			59,185	121,299						1,968				69	617	141	88
Total	**6,259,305**	**30,000**	**4,039,397**	**3,851,312**	**24,544**	**52,662**	**5,000**	**9,776**	**86,214**	**9,793**	**20,000**	**36,786**	**11,993**	**1,390**	**3,527**	**526**	**441**

Appendix *ii*. Numbers of juvenile hatchery salmon and wild captive-reared adults distributed to sites on the Tobique River, 1976 - 2008. Fry are between zero and 14 weeks old, 0+ parr are at least 14 weeks old but less than one year old and 1+ parr are at least one year old but less than two years old.

	0+ Fry		O+ Parr		1+ Parr			1 yr smolt			2 yr smolt			Captive Reared Adults			
Year	**No Mark**	**Ad Clip**	**No Mark**	**Ad Clip**	**No Mark**	**Ad Clip**	**Tagged**	**No Mark**	**Ad Clip**	**Tagged**	**No Mark**	**Ad Clip**	**Tagged**	**1 yr**	**2yr**	**3yr**	**Repeats**
1976							5,000										
1977			6,042														
1978			9,163														
1979																	
1980													5,995				
1981													5,998				
1982																	
1983																	
1984				8,517													
1985			43,211	38,687													
1986	17,300		46,563	53,782													
1987	52,882		33,505	21,950													
1988			28,723	40,038													
1989	80,012		83,846					2,255	9,995								
1990	68,707		83,075					534	9,944								
1991			194,173						4,995			4,953					
1992	119,987		257,732														
1993	203,950		98,738	99,939				819									
1994	317,996	30,000	46,376	253,730													
1995	337,080		101,900	207,683													
1996	651,045		333,320														
1997	302,000		256,578	20,991													
1998	83,995			193,756													
1999	101,204			209,358													
2000	360,390			254,473					1,996								
2001				221,014													
2002	500			184,349						2,357							
2003	2,723			181,630						1,483				339			
2004			78,052	129,147										213	797		
2005			2,500	179,713				1,400						202	577	128	39
2006				310,947						1,986				224	720	115	119
2007				157,142						1,999				230	380	114	195
2008			59,185	121,299						1,968				69	358	94	88
Total	**2,699,771**	**30,000**	**1,762,682**	**2,888,145**	**0**	**0**	**5,000**	**5,008**	**26,930**	**9,793**	**0**	**4,953**	**11,993**	**1,277**	**2,832**	**451**	**441**

Appendix *iii*. Adjusted counts by age of wild and hatchery 1SW and MSW salmon to Mactaquac Dam, 1992 - 2008. The smolt age distribution for the 1992-1994 returns was completed without exploring the possibility of month to month sampling differences within a year, so these numbers may change slightly and should be considered temporary.

Category **Origin**	**Smolt.Sea Age**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
1SW Salmon																		
Wild	2.1	2,573	1,865	993	957	601	150	147	150	823	485	368	270	404	549	553	396	554
	3.1	3,075	883	1,035	1,154	585	146	185	290	459	191	258	103	415	285	232	91	232
	4.1	80	74	42	43	28	32	7	27	48	3	2	4	36	20	4	0	2
Wild	Total	**5,728**	**2,822**	**2,070**	**2,154**	**1,214**	**328**	**338**	**467**	**1,330**	**679**	**628**	**377**	**855**	**854**	**789**	**487**	**788**
Hatchery	1.1	1,132	779	841	1,509	2,649	1,543	2,112	1,672	1,403	839	1,358	815	499	197	426	273	686
	2.1	527	240	214	834	1,354	521	968	480	207	129	263	83	98	79	65	116	213
	3.1	259	52	227	483	867	627	1,459	569	66	35	86	13	19	14	40	15	96
	4.1	17	1	13	2	69	88	56	36	32	1	0	1	1	3	0	3	0
Hatchery	Total	**1,935**	**1,072**	**1,295**	**2,828**	**4,939**	**2,778**	**4,595**	**2,757**	**1,708**	**1,004**	**1,707**	**912**	**617**	**293**	**531**	**407**	**995**
1SW Salmon	**Total**	**7,663**	**3,894**	**3,365**	**4,982**	**6,153**	**3,106**	**4,933**	**3,224**	**3,038**	**1,683**	**2,335**	**1,289**	**1,472**	**1,147**	**1,320**	**894**	**1,783**
MSW Salmon																		
Wild	2.2	1,897	1,156	1,098	976	1,128	428	64	359	137	507	124	160	348	149	249	148	113
	3.2	1,297	1,247	413	523	925	473	145	412	58	91	29	55	38	87	25	52	21
	4.2	17	38	8	35	13	26	1	16	2	1	0	0		0	0	0	0
Previous Spawners & 3SW		181	112	105	59	114	68	101	28	73	29	41	19	4	12	2	0	5
Wild	Total	**3,392**	**2,553**	**1,624**	**1,593**	**2,181**	**995**	**312**	**816**	**270**	**628**	**194**	**234**	**390**	**248**	**276**	**200**	**139**
Hatchery	1.2	590	242	303	398	567	412	229	554	173	462	142	443	265	78	44	89	71
	2.2	136	76	142	95	221	143	120	209	57	49	22	38	32	13	14	33	61
	3.2	82	97	19	47	137	158	177	158	19	9	2	10	5	1	2	6	3
	4.2	1	6	0	2	10	4	13	3	1	0	0	0	0	0	0	0	0
Previous Spawners & 3SW		3	19	66	30	13	26	92	19	10	28	7	7	2	2	2	0	0
Hatchery	Total	**812**	**440**	**530**	**572**	**947**	**744**	**631**	**943**	**260**	**548**	**173**	**498**	**304**	**94**	**62**	**128**	**135**
MSW Salmon	**Total**	**4,204**	**2,993**	**2,154**	**2,165**	**3,128**	**1,739**	**943**	**1,759**	**530**	**1,176**	**367**	**732**	**694**	**342**	**338**	**328**	**274**
Total	**Total**	**11,867**	**6,887**	**5,519**	**7,147**	**9,281**	**4,845**	**5,876**	**4,983**	**3,568**	**2,859**	**2,702**	**2,021**	**2,166**	**1,489**	**1,658**	**1,222**	**2,057**
Total Mean Age - Wild Only		**3.90**	**3.92**	**3.91**	**3.90**	**4.16**	**4.32**	**4.32**	**4.24**	**3.64**	**3.75**	**3.70**	**3.73**	**3.75**	**3.63**	**3.52**	**3.51**	**3.44**
Prop of all MSW that are 2SW		**0.96**	**0.96**	**0.92**	**0.96**	**0.96**	**0.95**	**0.79**	**0.97**	**0.84**	**0.95**	**0.87**	**0.96**	**0.99**	**0.96**	**0.99**	**1.00**	**0.98**

Appendix *iv*. Numbers of juvenile hatchery salmon distributed to sites within the Nashwaak River, 1976 - 2008. Fry are between zero and 14 weeks old, 0+ parr are at least 14 weeks old but less than one year old and 1+ parr are at least one year old but less than two years old.

	0+ Fry		0+ Parr		1+ Parr		1+ Smolt			2+ Smolt		
Year	**No Mark**	**Ad Clip**	**No Mark**	**Ad clip**	**No Mark**	**Ad Clip**	**No Mark**	**Ad clip**	**Tagged**	**No Mark**	**Ad Clip**	**Tagged**
1976	203,265		18,964		11,117	1,210						
1977	137,187	650	22,044		7,200	3,196						
1978			106,375		1,320							
1979			85,113		22,476							
1980	134,884				18,240							
1981					25,254	32,880				20,336		
1982			57,750							5,183	12,776	
1983											8,053	7,998
1984			47,129								12,158	8,005
1985	11,000		13,043		46,643	12,344			7,966			
1986			23,071				18,734					
1987	71,614		17,931				13,205		6,500			
1988	121,711		17,114				16,788		4,001			
1989	13,703		50,508				11,914					
1990	47,172		25,568				15,248		3,999			
1991	16,397		18,102				15,903		4,000			
1992	26,302		26,553				9,658		3,995			
1993	17,310		22,500				9,270		3,881			
1994	51,320		16,817				11,059		4,000			
1995	32,450		16,802				6,633		6,648			
1996							9,027 [a]		3,004			
1997												
1998												
1999	2,500			6,000								
2000	8,424			6,000								
2001	7,009			11,713								
2002				3,837					2,148			
2003	2,693		7,000	21,491				4,918	1,780			
2004												
2005	2,439			10,000								
2006			6,000	33,689								
2007			41,643	21,998								
2008			11,000	16,000								
Total	**907,380**	**650**	**651,027**	**130,728**	**132,250**	**49,630**	**137,439**	**4,918**	**51,922**	**25,519**	**32,987**	**16,003**

a - 3,014 one year old smolt were released from the Mactaquac Migration Channel.

Appendix *v*. Numbers of juvenile hatchery salmon and wild captive-reared adults distributed to sites within the Magaguadavic River, 1976 - 2008. Fry are between zero and 14 weeks old, 0+ parr are at least 14 weeks old but less than one year old and 1+ parr are at least one year old but less than two years old.

	0+ Fry		0+ Parr		1+ Parr		1+ Smolt			2+ Smolt			Captive Reared Adults			
Year	**No Mark**	**Ad Clip**	**No Mark**	**Ad clip**	**No Mark**	**Ad Clip**	**No Mark**	**Ad clip**	**Tagged**	**No Mark**	**Ad Clip**	**Tagged**	**1 yr**	**2yr**	**3yr**	**Repeats**
1976																
1977																
1978																
1979																
1980																
1981																
1982																
1983																
1984																
1985																
1986																
1987			14,644													
1988							2,034									
1989										5,771	5,000					
1990																
1991																
1992																
1993																
1994																
1995																
1996																
1997				2,767												
1998																
1999																
2000																
2001																
2002	29,033													99		
2003	20,556		5,000	7,336												
2004	24,873			8,434				1,828								
2005	6,656			2,007			644	896								
2006									924							
2007	20,099					706								49		
2008									1,593					17		
Total	**101,217**	**-**	**19,644**	**20,544**	**-**	**706**	**2,678**	**2,724**	**2,517**	**5,771**	**5,000**	**-**				

Appendix *vi*. Numbers of juvenile hatchery salmon and wild captive-reared adults distributed to sites within the St. Croix River, 1976 – 2008. Fry are between zero and 14 weeks old, 0+ parr are at least 14 weeks old but less than one year old and 1+ parr are at least one year old but less than two years old.

	0+ Fry		0+ Parr		1+ Parr		1+ Smolt			2+ Smolt			
Year origin	**No Mark**	**Ad Clip**	**No Mark**	**Ad clip**	**No Mark**	**Ad Clip**	**No Mark**	**Ad clip**	**Tagged**	**No Mark**	**Ad Clip**	**Tagged**	**Adults**
1976-80	[a]												
1981				9,800									
1982-90	[a]												
1991 Penobscot	51,025			40,001				60,205					
1992 Penobscot	85,307			71,474				50,342					
1993 Penobscot				100,950				40,110					
1994 St. Croix			38,600										
1994 Penobscot	87,200							60,600					
1995 St. Croix			20,962					17,537					
1995 Penobscot	400												
1996 St. Croix	1,525			52,120				15,583					
1996 Penobscot	364												
1997 St. Croix	1,025		103,000			19,720							
1997 Penobscot	1,236			400									
1998 St. Croix	520			31,870									
1998 Penobscot	1,553												
1999 St. Croix	580			22,450									
1999 Penobscot	1,406							21,314					
2000 St. Croix	145			18,963									48
2000 Penobscot	1,266							19,984					702
2001 St. Croix	300			6,299									
2001 Penobscot	834							8,146					524
2002 St. Croix	197			15,404									
2002 Penobscot	. [b]							4,147					
2003 St. Croix	656			16,779									
2003 Penobscot	215							3,232					
2004 St. Croix	12			2,845									
2004 Penobscot	. [b]							4,098					
2005 St. Croix / Tobique				24,815									
2005 Penobscot	. [b]												
2006 St. Croix / Tobique				27,578									
2007	[a]												
2008	[a]												
Total	**235,766**	**-**	**162,562**	**441,748**	**-**	**19,720**	**-**	**305,298**	**-**	**-**	**-**	**-**	**1,274**

[a] no releases

[b] incomplete data - numbers not available