Migrations and Biological Characteristics of Atlantic Salmon (*Salmo Salar*) Smolts from the Northwest Miramichi River, 1998 to 2000

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by

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ABSTRACT

The results of Atlantic salmon (*Salmo salar*) smolt studies conducted on the Northwest Miramichi in 1998 to 2000 are presented. Smolt migration through the estuary was best described as prolonged with a sharp peak of abundance of short duration. In 1998 to 2000, the peak catches in the estuary trapnet occurred when the mean water temperature first exceeded 15ºC. There was no apparent association of estuary catches with discharge. Over the three years of study, dates of peak abundance of smolts in the estuary varied by almost two weeks. Tagged smolts took from 2 to 4 days to migrate 30 km downstream from the freshwater tagging location to the estuary recapture site with the migration rate increasing over the season. Smolts from the Northwest Miramichi had modal fork lengths of 120 to 135 mm with size increasing with migration date. The smolt runs of the Northwest Miramichi in 1998 to 2000 were comprised of about two-thirds 3-year old smolts and one-third 2-year old smolts. Female smolts outnumbered males in 1999 and 2000 but were equally abundant in the 1998 smolt run. Smolt production was estimated by mark and recapture experiments at 390,000 fish (2.3 smolts per 100 m^2 of juvenile habitat area) in 1999 and about 160,000 smolts in 2000 (1 smolt per 100 m^2). The smolt studies in the Northwest Miramichi are being used to predict abundance of adult salmon in subsequent years and to address the issue of lower than expected Atlantic salmon abundance in the Miramichi River.

RÉSUMÉ

Ce rapport présente les résultats d’études entreprises sur les saumonneaux du saumon atlantique (*Salmo salar*) de la rivière Miramichi Nord-ouest depuis 1998 à 2000. La migration des saumonneaux dans l’estuaire est plutôt prolongée avec une crête aigue de courte durée. Durant 1998 à 2000, on observait les meilleures captures dans les filets-trappes en estuaire lorsque la température moyenne de l’eau dépassait un seuil de 15ºC. Il n’y avait aucune association entre les captures et le débit quotidien. Durant les trois années d’études, la date d’abondance maximale dans l’estuaire a varié de presque 14 jours. Les saumonneaux marqués prenaient entre 2 et 4 jours pour effectuer la migration en aval d’environ 30 km du site de marquage en eau douce au site de capture en estuaire. Le taux de migration augmentait avec la saion. Les saumonneaux de la rivière Miramichi Nord-ouest avaient une longueur à la fourche modale de 120 à 135 mm. La taille augmentait selon la date de migration. La distribution d’âge était environ deux tiers saumonneaux de trois ans et un tiers saumonneau de deux ans. Dans la dévalaison de 1999 et 2000, les femelles étaient plus abondantes que les mâles mais les deux sexes étaient représentés équitablement dans la dévalaison de 1998. La dévalaison totale des saumonneaux a été estimée par des expériences de captures-marquages-captures. En 1999, la dévalaison était de l’ordre de 390 000 saumonneaux (soit 2,3 saumonneaux par 100 m^2 d’habitat à juvénile) tandis qu’en 2000, la dévalaison était environ 160 000 saumonneaux (soit 1 saumonneau par 100 m^2). Ces recherches sur les saumonneaux de la rivière Miramichi Nord-ouest servent aux prévisions des saumons adultes des années ultérieures et pour essayer de comprendre pourquoi l’abondance du saumon dans la rivière Miramichi est inférieure à nos attentes.

INTRODUCTION

The Miramichi River (Lat. 47º N) contains the largest, naturally reproducing population of Atlantic salmon (*Salmo salar*) in North America. The potential economic benefits of the entire recreational fishery to the province of New Brunswick have been estimated at $31 million with the Atlantic salmon recreational fishery contributing in the order of $14 million to the provincial economy (Loftus et al. 1993). Upwards of 23,000 Atlantic salmon angling licenses were purchased in 1997 and 80% of the angling effort for salmon occurred on the Miramichi.

The returns of Atlantic salmon to eastern Canada have been declining and in 1997, more than half of the rivers in New Brunswick were closed to fishing during part of the regular angling season as a result of poor returns of salmon (DFO 1999). This restricted management plan remained in effect into 2000 (DFO 2001a). Returns of small salmon (< 63 cm fork length) to the Miramichi River in 1997 were the lowest observed since 1971 while the large salmon (>= 63 cm fork length) returns were the lowest since 1984 (Chaput et al. 1998b). Returns of small salmon were modestly improved in 1998 to 33,000 but still substantially below the average returns from 1986 to 1996 of close to 80,000 fish (Chaput et al. 1999). Large salmon returns in 1998 were the second lowest since 1971, as expected from the low returns of small salmon in 1997.

These lower returns occurred despite juvenile abundances in the river which are at historically high levels (Chaput et al. 2001). The freshwater habitat and production within the Miramichi River appears to be in good health but it is not known if the present juvenile levels are at carrying capacity. High juvenile abundance does not necessarily result in high smolt output and subsequent adult returns. Winter conditions have been suggested as a possible factor limiting survival of parr prior to smoltification (Cunjak 1996; Cunjak et al. 1998). Sea survival in the few monitored stocks of eastern Canada has been depressed in recent years (DFO 2001a,b). It is not known if the Miramichi River smolts are being subjected to the same sea survival depression. Neither of these hypotheses can be tested in the absence of smolt production estimates from the Miramichi.

This reports presents the results of Atlantic salmon smolt studies conducted on the Northwest Miramichi in 1998 to 2000. It includes estimates of the smolt production from the river. Biological characteristics of salmon smolts including size, age, sex ratio and run timing of the smolts are described and compared to other populations in eastern Canada.

MATERIALS AND METHODS

Geographic Area

The Northwest Miramichi River is one of the two principal branches of the Miramichi River covering 3,900 km^2 of the 13,799 km^2 of total drainage area of the Miramichi River (Randall et al. 1989) (Fig. 1). The maximum headwater elevation of the Northwest Miramichi is about 470 m above sea level and the entire watershed is accessible to salmon (Randall et al. 1989). The average annual discharge for the Miramichi River is about 320 m^3/s and annual precipitation is about 1000 mm. The monthly maximum air temperature occurs in July, at about 18.8ºC, while the miminum temperature occurs in January, at about –11.8ºC (Caissie and El-Jabi 1995). The river and bay are ice covered in the winter, usually from December until early April. The average tidal amplitude in Miramichi Bay is 1.0 m (Chiasson 1995) but upriver in the Northwest Miramichi, tidal ranges are frequently as high as 1.5 m. Saltwater intrusion is generally limited to a few kilometres upstream of the confluence of the Northwest and Southwest branches.

Field Operations

Smolts were sampled in tidal waters using picket type smolt trapnets (Fig. 1). The trapnets were of a design similar to that used for adult sampling but of smaller mesh size (1.9 cm stretched, knotless webbing) (Fig. 2). The leader (mesh size 12.5 cm stretched mesh) was set perpendicular to shore with the trap opening for downstream migrants only. A 5 cm splitter mesh was installed halfway into the holding area at both ends to sieve smolts and smaller fish from the larger fish migrating through the estuary at that time (black salmon, striped bass, speckled trout, gaspereau, shad, eels). Continuous hourly water temperature measurements were obtained at the estuary trapnets every year during the period of operation using VEMCO Minilog@ recorders installed at about 2 m above bottom.

Smolts were identified as wild origin on the basis of the presence of an adipose fin. However, not all hatchery products are adipose-clipped and therefore some smolts with adipose fins intact could have been of hatchery origin (Chaput et al. 1998b, 1999).

Smolts were marked just anterior to the dorsal fin with small, green, minimally intrusive streamer tags (Fig. 3). The tags were individually numbered to provide information on movement rates and for exploring temporally stratified mark and recapture models.

A daily subsample of up to 100 smolts was measured from one of the estuary trapnets from which every fifth sampled smolt was sacrificed for detailed analysis (length, weight, sex, origin, scale sample). Age was determined from the scales. The extent of spring plus growth was described based on the number of widely spaced circuli after the last annulus at the edge of the scale. Fish condition (weight at a given length) was modelled using analysis of covariance for differences between sexes and among years. Length and weight at age were modelled using analysis of variance. Sex ratio at age and overall were tested for differences using Chi-square tests of homogeneity.

Mark and recapture experiments were conducted to estimate the efficiency of the estuary trapnets. Both temporal stratified (Darroch model; Arnason et al. 1996; Warren and Dempson 1995) and aggregated (Peterson, Ricker 1975; Bayesian, Gazey and Staley 1986) models were used to estimate the efficiency of the trapnets and the population size of smolts migrating from the Northwest Miramichi.

Operations specific to each year are described below.

In 1998, one trapnet was installed in the estuary of the Northwest Miramichi at a location referred to as Cassilis, about 5 km below the confluence of the Little Southwest and Northwest Miramichi branches (Fig. 1). Attempts were made to capture smolts in fresh water in the Northwest Miramichi at a location referred to as Big Hole Tract using a partial counting fence. This was not successful as less than 100 smolts were captured over a five week period which was characterized by high flow conditions. An alternative method was undertaken to calibrate the estuary trapnet by using hatchery smolts reared in McCormack Lake (collaborative project of the Northumberland Salmon Protection Association and Heath Steele Inc.). Just over 5,300 adipose-clipped smolts were marked with streamer tags on May 26 to 28 in three separate batches and released into Little River, a tributary of the Northwest Miramichi River (Fig. 1), on May 27 to 29.

The estuary trapnet fished continuously during the period May 11 to June 15, 1998 with the exception of the 24 hour period between May 23 and 24 when it was raised to prevent damage to the gear (brailed) as a result of high water conditions. The trapnet was checked once per day, usually towards slack tide.

In 1999, two trapnets of design similar to that of 1998 were installed in the tidal waters of the Northwest Miramichi (Fig. 1). The trapnet at Cassilis was installed at the same location as in 1998 and was used as the primary marking location. A lower trapnet was installed below Northwest Millstream (site locally called Hackett's Beach) and served as the principal recapture site. The lower trapnet was operational May 7 while the upper trapnet (Cassilis) was operational May 12, 1999.

Trapnets were fished daily, generally at low tide. Smolts were sorted from the rest of the catch (mostly rainbow smelt; *Osmerus mordax*). At Cassilis, attempts were made to mark as many smolts as possible. Smolts were marked with small individually numbered streamer tags in a fashion identical to 1998. Generally when catches were less than 500 fish, almost all the smolts were marked before release. At the recapture trapnet, smolts were sorted and identified as to origin (wild or adipose-clipped) and tag numbers from recaptured smolts were noted.

Additionally in 1999, smolts were captured and marked from the Little Southwest Miramichi using a rotary screw trap (Fig. 4). The trap was installed about 1 km downstream of Catamaran Brook at the head of a pool (Fig. 1). The trap fished without interruption from 11 May to 8 June. Catches were processed in the morning. All smolts were marked with individually numbered streamer tags before being released downstream of the wheel. Other fish species were identified and counted before release.

A sample of 559 smolts was removed from the Cassilis trapnet for an experiment to assess the possible effects of endocrine disrupting compounds on smolt survival and growth. The results of this experiment are not reported here.

Field operations in 2000 were identical to those of 1999. The trapnet at Cassilis was installed at the same location as in 1998 and 1999 and was used as the primary marking location. A lower trapnet was installed below Northwest Millstream at Hackett's Beach, similar to 1999. The lower trapnet was operational May 6 while the upper trapnet (Cassilis) was operational May 11, 2000. Continuous hourly temperature records were obtained at both trapnets.

As in 1999, smolts were captured and marked from the Little Southwest Miramichi using a rotary screw trap. The trap was installed at the same location as in 1999 (Fig. 1) and operated continuously from 4 May to 14 June. Catches were processed in the morning. All smolts were marked with individually numbered streamer tags before release. Other fish species were identified and counted before release.

A sample of 342 smolts was removed from the Cassilis trapnet between May 17 and 22 for an experiment to assess the possible effects of endocrine disrupting compounds on smolt survival and growth. The results of this experiment are not reported here.

RESULTS

During 1998 to 2000, only one day of trapnet fishing was lost (in 1998) as a result of preventative brailing (tie-up of the gear out of the water) due to high water discharge. Discharges in all years were highest at the start of the trapnet operations and declined through the period of operation (Fig. 5). Discharges in May 1998 to 2000 were relatively low compared to those observed since 1995 (Fig. 5). Discharges in the Little Southwest did not hamper the operation of the rotary screw trap and these were also low compared to recent years (Fig. 5).

Temperatures increased throughout the period of operation (Fig. 6). Estuary temperatures averaged 8 to 12ºC at the start of operations and were generally above 20ºC when trapping operations finished. Temperatures were especially warm in 1999 compared to the other two years. Temperatures in the Little Southwest Miramichi were similar to those observed in the estuary (Fig. 6).

Catches at the estuary trapnets

From May 11 to June 15, 1998, a total of 6,877 smolts (both wild and adipose-clipped) were captured in the estuary trapnet at Cassilis (Table 1). The largest daily catch of more than 1800 smolts was counted on May 16 but this was only a partial count of the catch because darkness set in. The trap was reset without counting all the smolts. The trap crew indicated that there was easily as many smolts left in the trap as had been counted. On the morning of May 17, the trap was fished and just over 1,000 smolts were counted indicating that many of the smolts from the previous night had escaped. This was followed by a catch of almost 1600 smolts on May 22. The trapnet was not fishing from May 23 to 24 because of high discharge. Wild smolts outnumbered adipose-clipped smolts; 6,562 wild (95%) versus 315 adipose-clipped smolts (5%). The majority of the adipose-clipped smolts were releases from the cage-rearing program in McCormack Lake. Adipose-clipped smolts originating from parr stocking programs (not McCormack Lake reared fish) numbered 68 fish, or 22% of the total adiposed-clipped smolts sampled. These non-McCormack Lake origin smolts represented 1% of the total smolt run.

In 1999, 11,202 wild and adipose-clipped smolts were captured at the upper marking trapnet (Cassilis) between May 11 and June 7 (Table 2). The biggest daily catch was observed on May 19 with 4,233 smolts counted followed by May 21 with 2,262 smolts enumerated. On May 20, fishing was switched from end of day to early morning such that the low catch on May 20 was partly the result of the trapnet having fished only one tidal cycle or about 12 hours rather than the usual 24 hours and two tidal cycles. The recapture trapnet at Hackett's Beach captured a total of 5,534 wild and adipose-clipped smolts between May 6 and June 7, 1999 (Table 3). The largest daily catch of 930 smolts was sampled on May 17. Wild smolts outnumbered adipose-clipped smolts, the former representing 99% of the total smolt catch at both trapnets. Adipose-clipped smolts from the McCormack lake releases were easily identified in the catches based on their size and fin condition. At the upper trapnet, these lake-cage reared smolts comprised 99% of the total adipose-clipped smolts captured (140 fish).

Between May 12 and June 21, 2000, a total of 3,280 wild and adipose-clipped smolts were captured at the Cassilis trapnet (Table 4; Fig. 7c). The biggest daily catch of 1,112 smolts occurred on June 2 with all other daily catches less than 250 smolts. The catch at the lower trapnet between May 9 and June 19 totalled 715 smolts, less than 13% of the 1999 catch (Table 5; Fig. 8). The biggest daily catch of 101 smolts occurred on May 30. A total of 3 adipose-clipped smolts were observed in the combined catches at the two estuary trapnets in 2000.

In 1998 to 2000, the first few days when the average water temperature in the estuary reached 15ºC corresponded to the days of the peak catches at the estuary trapnet (Fig. 7). There were also some occasional associations between catches of smolts and discharge. Generally, the first big catches of smolts occurred in the absence of any increases in discharge (Fig. 7a,b,c). However, in 1998, the second peak catch coincided with an increased discharge from May 21 to 22 (Fig. 7a).

Catches at the rotary screw trap in the Little Southwest Miramichi

In the Little Southwest Miramichi, a total of 1,844 smolts were captured between May 10 and June 12, 1999 (Fig. 9a). The largest daily catches of 226 to 233 smolts occurred on May 20 and 21 when the mean daily temperature rose above 15ºC but a similarly large catch near 200 smolts occurred on May 26, when the water temperature was averaging 12 to 13ºC (Fig. 9a). Catches increased at the rotary screw trap as discharge declined but the second peak of abundance on May 26 coincided with a slight increase in discharge (Fig. 9a).

In 2000, a total of 1,235 smolts were captured between May 4 and June 14 (Fig. 9b).The peak daily catch of 87 smolts occurred on June 2 but several nearly as large catches were enumerated on May 20, 28 and June 1. Smolts were caught consistently when temperatures were below 15ºC with some of the higher catches in early June associated with temperatures rising above 15ºC (Fig. 9b). There was no apparent association between catches at the rotary screw trap and discharge other than the first large catch of smolts coinciding with a small increase in discharge on May 19 (Fig. 9b).

Only one adipose-clipped smolt was observed in the catches at the rotary screw trap in 1999 and none were observed in 2000.

Run-timing of smolts

Run-timing of wild smolts in the estuary was characterized by a prolonged period of migration with a sharp peak of short duration. Smolts were present in the estuary in low numbers when the trapnets became operational in early May and were essentially absent in the catches by June 15 (Fig. 7, 8). Two peaks of abundance were observed in 1998 but only one in 1999 and 2000. Peak abundance in the estuary was between May 16 and 23 in 1998 and 1999 but it was substantially later, June 2, in 2000 (Fig. 7). The 25th percentile date of the catch was May 16 in 1998 and May 19 in 1999 but it was delayed to May 25 in 2000. The median date of run-timing in 1998 was before May 19 (accounting for the incomplete count on May 16), May 19 in 1999 and June 1 in 2000 (Fig. 7). The catches at the lower trapnet in 2000 were too small to infer a pattern in run-timing (Fig. 8).

The run-timing of wild smolts in the Little Southwest Miramichi was delayed in 2000 relative to 1999 but less so than in the estuary (Fig. 9). The 25th percentile of the catch occurred on May 18 in 1999 as compared to May 20 in 2000. The median date of catch was May 20-21 in 1999 versus May 25 in 2000. Smolt catches had declined to less than 20 fish per day by May 29, 1999 but this occurred after June 4 in 2000 (Fig. 9).

Tagged wild smolts from the Little Southwest completed the approx. 30 km of river to the upper estuary trapnet within 2 to 4 days post-tagging (Fig. 10, 11; Table 6; Appendix 1a, 1b, 2). The migration to the upper estuary trapnet was faster in 1999 (median = 2 days) than in 2000 (median = 3 to 4 days) (Fig. 10, 11; Tables 6, 7). The longest time to recapture in either year was seven days. Tagged smolts from the Little Southwest took one day longer to reach the lower trapnet than the upper trapnet (data for 1999 only, Fig. 10). There were no apparent differences in migration rates to the estuary of smolts relative to the run components; the median date to recapture in the estuary of smolts tagged in June 2000 was similar to the median date of smolts tagged in May 2000 (Table 7; Appendix 2). Recaptures in 1999 were few but there was a suggestion of slower migration of smolts at the end of the run relative to the those from the peak of the run (Table 6; Appendix 1a, 1b). Only one smolt tagged at the rotary screw trap was recaptured again at the rotary trap in both years of sampling; tagged on May 29, 2000 and recaptured on June 1, 2000.

Movement rates of smolts between the upper and lower estuary trapnets (approx. 8 km) were slower than from the Little Southwest Miramichi to the estuary (Appendix 3, 4). Smolts tagged at the upper estuary trapnet were recovered 2 to 3 days later in the lower trapnet in 1999 (median = mode = 2 days) and 3 to 4 days later in 2000 (median = mode = 3 days) (Fig. 12, 13; Table 8). In 1999, the movement rate was fastest for the smolts tagged after the peak (median time to recapture = 1 day), second fastest for those during the peak (median time to recapture = 2 days) and slowest for those at the start of the migration (median time to recapture = 3 days) (Table 8). Recaptures in 2000 were too few to infer any within season differences in migration rates.

Relatively slow rates of migrations of smolts through the estuary resulted from smolts staying (perhaps staging) in the upper estuary for an extended period of time. Smolts tagged at the upper estuary trapnet were frequently recaptured in subsequent days at the upper trapnet in both 1999 and 2000 (Tables 9, 10; Appendix 5, 6). Just under 5% of the smolts tagged at the upper trapnet in 1999 were recaptured again at the upper trapnet, some as long as nine days post tagging (Table 9; Appendix 5). Fewer of the post-peak migration smolts were recovered again at the upper trapnet and the median time to recapture was one day compared with 1-2 days for the peak migration and 1-4 days at the beginning of the migration (Table 9). The opposite situation was observed in 2000. First, the upper trapnet recaptured a lower proportion of the tagged smolts (1.9%) and the median overall time to recapture was one day (Table 10; Appendix 6). Smolts tagged after the peak of the migration were recaptured over a longer period of time than those marked earlier with a median time to recapture of the late migrants of 2 days (Table 10).

Adipose-clipped smolts

The adipose-clipped smolts reared in McCormack Lake and released in Little River (Northwest Miramichi) in 1998 and 1999 were observed in the estuary within 1 to 2 days post release (May 27 to 31), a downstream distance of just under 50 km (Fig. 14, 15; Table 11). Movement of these cage reared smolts after release was very rapid in both years and about one week to ten days later than the peak abundance of wild smolts (Fig. 7, 15). The adipose-clipped smolts resulting from satellite rearing and stocking of fall fingerlings had similar run-timing in 1998 to the wild smolts; peaks on May 16-17 and May 22 (Fig. 7, 15). Catches of adipose-clipped smolts not of cage-reared origin in 1999 and 2000 were insufficient to describe run-timing.

Biological characteristics

Length

Wild smolts from the Northwest Miramichi ranged between 105 and 240 mm fork length with rare individuals greater than 180 mm (Fig. 16). Modal lengths of smolts (daily samples weighted by daily catch) increased from 1998 to 2000: 120 – 130 mm in 1998, 125 – 135 mm in 1999, and 135 mm in 2000 (Fig. 16). The 5^{th}-95^{th} percentile ranges in lengths were identical in all years (110 mm – 150 mm).

The length distribution of the adipose-clipped smolts in 1998 and 1999 was bimodal, reflecting the larger overall size of the smolts reared from McCormack Lake (Fig. 17). The other adipose-clipped smolts were the result of in-river stocking of parr at the 0+ stage (satellite-reared fish) in previous years and 1+ parr stocked in the spring of 1997 (Chaput et al. 1998b). These latter groups of smolts were of similar size to the wild smolts; modal length of 130 mm in 1998 and 130 to 135mm in 1999.

Average daily fork lengths at the trapnets were variable but generally showed an increase with time (Fig. 18). The average fork length of wild smolts increased from between 120 and 130 mm at the beginning of the smolt run to over 130 mm by the end of May 1998 (Fig. 18). Increases in size during the smolt run of over 10 mm fork length were also noted in 1999 and 2000 (Fig. 18).

Increases in average size of smolts corresponded to growth in length during the spring for the later migrating smolts. Plus growth, defined as the zone of widely spaced circuli after the last visible annulus (zone of narrow spaced circuli), was negligible (0 circuli) on the scales of smolts sampled at the beginning of the migration (Fig. 19). By the end of May, the majority of the smolt scales had visible plus growth with all smolts by the last sampling date having generally 3 to 7 circuli of plus growth (Fig. 19). Back-calculated size to the last annulus was not estimated from the samples.

Length at age

In all years, age 3 year old smolts were slightly longer than the 2 year old smolts (Table 12). The only reasonable sample of age 4 year old smolts was from 1999 and these were on average significantly longer ($P < 0.05$), by 2 cm, than age 3 and age 2 year old smolts.

There were no significant differences in length between male and female smolts in 1998 and 1999 but female smolts age 2 in 2000 were longer ($P = 0.06$) than males of the same age by almost one cm (Table 12). Similarly in 1999, the age 4 male smolts were longer than the age 4 females.

Weight and conditon

Atlantic salmon smolts from the Northwest Miramcihi averaged 21 g whole weight (samples only), ranging between 8 and 52 g, over the three years sampled (Fig. 20). There was no significant difference ($P > 0.05$) in the predicted weight at length of male versus female smolts in any year but there was a statistically significant ($P < 0.01$) difference in the intercept, but not the slope, among years, sexes combined (Fig. 20). Smolts from 2000 weighed on average 5% less than those of 1998 and 1999, the latter two were of similar weight.

Least-square adjusted mean weight (g) (for an average smolt length of 127 mm)		
Year	Estimate	2 std errors range
1998	20.7	20.4 – 21.0
1999	20.9	20.7 – 21.1
2000	19.9	19.6 – 20.2

Age and sex composition

In 1998 to 2000, about two-thirds of the smolts of the Northwest Miramichi migrated to sea at three years of age and about one-third migrated after two years (Table 12). A very small percentage (1-2%) spent four years in the river before migrating. The older smolts tended to migrate earlier with age 2 year old smolts more prominent in the last half of the run (Fig. 21).

In two of the three years sampled, there was a higher percentage of females (about 60%) than males in the smolt run (Table 12). In 1998, the sex ratio in the total smolt run was essentially 50:50. There was no significant difference ($P > 0.10$) in the sex ratios by smolt age in all three years sampled. The disparity in the overall sex ratio for 1998 is the result of the lower proportion female in the 3-year old smolts relative to 1999 and 2000 (Table 12). Since this is the dominant age in the smolt run, it defines the sex ratio of the entire run.

Population estimates

The use of individually numbered tags allows for the exploration of temporally stratified models to estimate intra-season variations in trapnet efficiency. These models (Darroch) require a large number of recaptures.

1998

About 5% of the smolts tagged at the lake cages at McCormack Lake died within 24 hours before release (Table 1). The mortalities were the result of the tagging operations which included anesthetic bath, handling for tagging and recovery in pursed cages. The mortality was higher than expected and was probably exacerbated by the lateness of the tagging operation and smolt release; the majority of the smolt run was complete by the time the smolts were released (Fig. 7, 15). A total of 5,330 tagged smolts were released into Little River, tributary of the Northwest Miramichi over a three day period, May 27 to 29. From these releases, 247 smolts were recaptured at the Cassilis trapnet representing about 4.6% of the total tagged smolts released (Table 2, 13, Fig. 22). Assuming this efficiency for the entire period of trapping in 1998, then the estimated smolt run from the Northwest Miramichi was about 150,000 smolts (6,877 smolts captured at Cassilis / 4.6% efficiency = 149,000 smolts) (Table 13; Fig. 23). This is a minimum estimate of the smolt run for two reasons:

1 - the trap catch count of more than 1,800 smolts on May 16 was not completed because darkness set in. The trap was reset without emptying the smolts from the trap. The trap crew felt that there was easily as many smolts left in the trap as had been counted.On the morning of May 17, the trap was fished and just over 1,000 smolts were counted indicating that many of the smolts from the previous night had escaped.

2 - the trap was lifted on May 23 for almost 24 hours because of high water conditions. Some of the smolt run was likely missed during that event.

It is not possible to assess how much higher the estimated smolt run in 1998 should be because of the incomplete count on May 16 which represented the largest catch of the season.

1999

The mark and recapture experiment in 1999 consisted of smolts tagged at the upper trapnet and recovered at the lower trapnet. Alternatively, models with smolts tagged from the rotary screw trap in the Little Southwest Miramichi and recovered at the upper trapnet or the lower trapnet were explored.

Tag retention and tagging mortality verifications were not conducted in 1999. Previous studies from Conne River indicated that tag retention of streamer tags was 100% and mortality from tagging and handling was 5% for fish held for 10 days (0.5% per day) (Dempson and Stansbury 1991). For the short time to recapture within the tidal waters of the Miramichi (1 to 8 days, Fig. 10, 11), tag retention was expected to be high and mortality low. In the absence of verification, however, a tag loss and tagging mortality rate of 10% was assumed, a rate similar to that used in the adult salmon mark and recapture program (Chaput et al. 2000).

A total of 5,563 smolts were tagged and released from the upper trapnet (Table 2). At the lower trapnet, a total of 71 of these were recaptured out of a total catch of 5,534 smolts (Table 3) for an estimated marked proportion of the total run of 1.3%. The estimated run size of smolts in 1999 from the Northwest Miramichi was 390,000 fish (316,000 to 506,000 fish; 95% C.I.) (Table 14; Fig. 23). The recaptures at the lower trapnet were well distributed throughout the run (Appendix 5) and there was no difference in catchability through the run (Table 8; Chi-square test: $P > 0.10$). A total of 11,202 smolts were captured at the upper trapnet resulting in an estimated efficiency for smolts of 2.9% (2.2% to 3.6%) after adjusting for 10% tag loss and mortality (Fig. 22; Table 14).

Estimates of trapnet efficiencies using the smolts tagged at the Little Southwest Miramichi rotary screw trap and assuming a 10% mortality and tag loss factor are less than half those estimated using the estuary tagging experiment (Table 15). Recoveries of Little Southwest tagged smolts were evenly distributed through the run at the Cassilis trapnet (Appendix 1a) so that disproportionate efficiency relative to run timing was unlikely. Recovery rates of Little Southwest tags were significantly lower than expected at the upper trapnet relative to the lower trapnet (Chi-square test; $P < 0.01$). If we assume that the estimated efficiency of the Cassilis trapnet derived from the recoveries at the lower trapnet is correct (2.9%), then the combined mortality and tag loss factor of Little Southwest smolts to Cassilis must have been 61% (median) (95% C.I. 53% to 71%) rather than the 10% factor assumed. A similar calculation for the lower trapnet recoveries suggested mortality rates on tagged smolts of 45% (95% C.I. 30% to 56%). Predation on tagged smolts by large speckled trout was observed by the trap crews and reported by anglers fishing the pool directly below the rotary screw trap in the Little Southwest. In 1999, it would appear that mortality rates on tagged smolts between the tagging location and the recapture sites in the estuary (30 km) may have been as high as 45% to 61%.

2000

The mark and recapture experiments in 2000 consisted of smolts tagged at the upper trapnet and recovered at the lower trapnet. Alternatively, models with smolts tagged from the rotary screw trap in the Little Southwest Miramichi and recovered at the upper trapnet or to both estuary trapnets were explored.

As in 1999, a tag loss and tagging mortality rate of 10% was assumed.

A total of 2,834 smolts were tagged and released from the upper trapnet (2,551 assuming 10% tag loss and mortality) (Table 4; Appendix 4). Only seven of these tagged fish of a total catch of 715 fish were seen again at the lower trapnet (Appendix 4). The aggregated model estimate is 260,000 fish with a wide (95%) confidence interval range of 155,000 to 740,000 fish. This estimated run size results in an estimated efficiency for the lower trapnet of 0.3% and for the upper trapnet of 1.3%.

Estimates of trapnet efficiencies using the smolts tagged at the Little Southwest Miramichi rotary screw trap and assuming a 10% mortality and tag loss factor were higher than those based on the estuary trapnets experiment (Table 16). A total of 1,233 smolts were tagged and released at the rotary screw trap between May 5 and June 14, 2000 (Table 7; Appendix 2). Of these releases, 23 fish were seen again at the upper trapnet (0.72% of the total catch) and four were seen again at the lower trapnet (0.56% of the total catch) (Table 5). These tagged proportions were not significantly different (Chi-square test; $P > 0.10$). Recoveries of Little Southwest tagged smolts were not evenly distributed through the run at the Cassilis trapnet (Table 7; Appendix 2). The proportion of tagged fish seen again increased through the season (Table 7; Appendix 6) with essentially no smolts from the May 5-23 tagging (509 fish) seen again in the estuary trapnet. Conversely, 2 of 4 recaptures at the lower trapnet were from the early tagging group (May 5-14) (Table 5).

For purposes of estimation, the marking event was stratified into two time periods: May 5 – 31, and June 1 –14 (Table 16). Upper trapnet efficiency based on the temporally stratified model (Darroch) was estimated at 1.3% for the season whereas the aggregated models (Peterson and Bayesian) provided estimated efficiencies of just over 2% (Table 16; upper panel). By combining the catches at the lower and upper trapnets, efficiencies of 0.3% for the lower and 1.5% for the upper trapnet are estimated using the Darroch model. The aggregated models provided estimates of efficiencies in the order of 2.0% for the upper trapnet and 0.4% for the lower trapnet (Table 16). Run size estimates for smolts in 2000 were about 160,000 fish (Pooled Bayesian) with a 95% confidence interval range of 111,000 to 258,000 fish (Table 16).

DISCUSSION

The three years of study undertaken in the Northwest Miramichi have provided some insights into the dynamics of the smolt migration, the smolt characteristics, and smolt abundance. It also provides the starting point to address the links between juvenile abundance in the river and subsequent adult returns. Juvenile abundance has increased several fold in the last fifteen years as a result of increased egg depositions associated with reduced exploitation rates on the adult spawners (Chaput et al. 2000). Despite these increases in juvenile abundance, adult abundance peaked in the early 1990s and has declined rapidly to a low level of abundance since 1997, a level only seen previously when there was high exploitation on the stock (Chaput et al. 2000). In monitored rivers, sea survivals of smolts to the 1SW and 2SW adults have declined throughout eastern Canada (DFO 2001a,b). Because smolts have not been monitored in the Miramichi system, we can only infer that the salmon from the Miramichi are also being subjected to low marine survival. Additionally, the high abundance of juveniles may not produce as many smolts as expected if there is an important bottleneck in the parr to smolt transition, particularly during the winter (Cunjak et al. 1998). High juvenile abundance would be expected to produce a shift in smolt age as competition for limited resources reduces the growth rates and increases the time required to reach a threshold length for smoltification. These smolts may also be of smaller size and reduced relative weight which may subsequently effect sea survival. In the absence of information on the smolt stage, the cause(s) of the low abundance of Atlantic salmon in the Miramichi cannot be explored.

Smolt migration through the estuary can be best described as prolonged with a sharp peak of abundance of short duration. The brief period of peak abundance would correspond to a staging of smolts in the estuary. Movements from the upper trapnet to the lower trapnet (about 8 km) occurred within 1 to 3 days with faster migration rates in the later parts of the run. Moore et al. (1995) describe transit times of 64 to 67 hours (just over 2.5 days) for smolts through the 4 km section of the River Conwy (Wales UK) delineating the head of tide and maximum extent of saline influence. As in this study, migration rates were faster for smolts from the later part of the run (Moore et al. 1995).

Downstream migration rates from fresh water to the Northwest Miramichi estuary were generally 2 to 4 days with the migration rate increasing over the season. Adipose-clipped smolts released in Little River in 1998 and 1999 were captured at the estuary trapnet 50 km downstream within 24 hours indicating that migration rates can be very rapid, especially towards the end of the run at higher temperatures. In de la Trinité River, smolts generally took less than one day to travel the 500 metres between the marking and recapture sites in freshwater although some at the beginning of the run took as long as 12 days to negotiate the short distance (Caron et al. 1998a, b). In the Saint-Jean River, smolts migrated the 2 km distance between marking and recaptures sites in fresh water within 1.1 days on average, with the longest taking 6 days (Caron and Raymond 2000).). In these studies, migration rates also increased for the later migrating smolts. In Conne River (Newfoundland), the average time to recapture was 1.71 days for 10 km of river (Dempson and Stansbury 1991). In the River Conwy, mean times for tagged smolts to travel the

4.7 km stretch from the freshwater tagging site to the head of tide was on average greater than 4 days (Moore et al. 1995).

Run timing in fresh water at the rotary screw trap was less peaked than in the estuary but large movements over one day have been observed at the Catamaran Brook counting fence with over half of the total run for the year being counted in one day (Hardie et al. 1998). The peak daily count of smolts at the Curventon counting fence of the Northwest Miramichi in 1965 represented 16% of the total count for the year (Forsythe 1967). In 1962, the maximum daily count of smolts at the Curventon fence represented less than 10% of the total count for the year (Saunders 1967). Trapping operations in the freshwater portions of other rivers tend to show a similarly smooth transition in the catches with the peak daily catch rarely exceeding 10% of the total catch for the year (Caron and Raymond 1999, 2000; Caron et al. 1998a,b). This contrasts with the smolt runs from Big Salmon River where peak daily counts at the fence represented from under 10% to as high as 45% of the total count for the year (Jessop 1975).

In the Northwest Miramichi during 1998 to 2000, the peak catches in the estuary trapnet occurred when the mean water temperature (well-mixed from surface to bottom) first exceeded 15ºC but no such association with temperature was observed in the Little Southwest Miramichi. There was no apparent association with discharge as the latter decreased through the period of the smolt run. There was similarly no association with the phase of the moon, a surrogate for tidal amplitude, which could effect the distribution and staging of smolts in the estuary. Other studies on smolt migration triggers indicate a similar association with rising temperature. Smolt runs of the Big Salmon River were generally initiated when maximum daily water temperature reached 10ºC and were fully established when mean daily water temperature reached 10ºC (Jessop 1975). A similar association to the 10ºC threshold was reported for a river in the UK (Moore et al. 1995). Temperature increase has been recognized as an important trigger for smolt migration (McCormick et al. 1998). Jessop (1975) indicated that the peak of the run was associated with a freshet in 5 of 6 years but that there was no association of absolute daily counts of smolts and water levels. Similar decoupling of smolt run size and discharge or water level has been reported by Moore et al. (1995). McCormick et al. (1998) indicated that smolts migrate more quickly at higher water levels but that water velocity was not necessarily the cue to initiate movements.

Run-timing of Atlantic salmon smolts differs geographically and tends to follow a latitudinal gradient, although with some exceptions. A median date of capture in the Northwest Miramichi estuary (Lat. 46º56'N) of May 16 to 19 in 1998 and 1999 is 4 to 11 days earlier than the smolt run-timing of the St. Jean River (Gaspé, Québec Lat. 48º 47' N) and three weeks earlier than the smolt run of de la Trinité River on the Québec north shore of the St. Lawrence (Lat. 49º 24') (Caron and Raymond 1999, 2000; Caron et al. 1998a,b). Smolt runs from the Big Salmon River (Lat. 45º25'N) during 1966 to 1971 had median dates of May 29 to June 11 (Jessop 1975), surprisingly late for a river of that southerly latitude. Conne River (Newfoundland), (Lat. 48ºN) is just north but much farther east than the Miramichi with median run-timing varying around mid-May (Dempson et al. 1998). In Little Codroy River, latitude 47º46' N, the median dates of smolt counts varied from June 11 to 30 between 1954 and 1963 (Murray 1968). In Campbellton River Newfoundland, latitude 49º20' N, peak smolt migration was as early as mid-May in 1996 but generally occurred in the first two weeks of June (Downton and Reddin 1998). For smolts from Western Arm Brook Newfoundland (Lat. 51º11' N), median migration date has been as early as the first week of June but generally occurs after June 10 and was as late as June 24 (Dempson et al. 1998).

Over the three years of study in the Northwest Miramichi River, dates of peak abundance of smolts in the estuary varied by almost two weeks. In 2000, the median date of the smolt run was 12 days later than in 1998 and 1999. Median dates of the smolt runs in the Big Salmon River varied by 14 days over a six year period of study (Jessop 1975). Variations in median date of as much as 20 days have been observed in some Newfoundland rivers with variations of 10 days common in five of the six monitored systems (Dempson et al. 1998). The Little Codroy River on the southwest coast of Newfoundland had median dates of run timing varying by 19 days over a period of 10 years (Murray 1968).

The size of smolts tended to increase with migration date with older smolts migrating earlier than younger aged smolts. Increased size through the smolt run was reported previously in the Northwest Miramichi by Forsythe (1967) and Saunders (1967). It has also been reported in the Saint-Jean River and de la Trinité River (Caron and Raymond 2000; Caron et al. 1998a,b). The larger size of smolts in the latter part of the Northwest Miramichi run was attributed to plus growth in the spring of the year of migration (this study; Forsythe 1967). Plus growth on the scales of late migrating smolts was also observed for smolts from the Saint-Jean and de la Trinité rivers (Caron and Raymond 2000; Caron et al. 1998a,b).

Northwest Miramichi smolts are of similar size to smolts from the Quebec rivers but substantially smaller than the smolts from Newfoundland rivers. Modal fork lengths of 12.5 to 13.0 cm in the Northwest Miramichi are slightly larger than the 11.2 to 11.8 cm fork length from Saint-Jean River (Caron and Raymond 1999, 2000) but similar to the 12.2 to 13.2 cm fork length from de la Trinité River (Caron et al. 1998a, b). With few exceptions, smolts from Newfoundland rivers are longer. Conne River smolts average about 15 cm fork length whereas smolts from Campbellton River are between 17 and 18 cm average fork length (Dempson et al. 1998). Smaller smolts predominate in multi-seawinter stocks such as the mainland rivers relative to larger smolts from the one-sea-winter (1SW) stocks of Newfoundland (Chadwick et al. 1987).

The smolt runs of the Northwest Miramichi in 1998 to 2000 were comprised of about two-thirds 3-year old smolts and one-third 2-year old smolts. There were few 4-year old smolts in the runs. This is characteristic of the Northwest Miramichi stock as similar dominance of 3-year olds smolts was reported by Forsythe (1967) for the 1965 smolt run and similar to smolt age composition from Catamaran Brook (P. Hardie; unpubl. Data). In the Miramichi, the smolt age distribution among returning adults has varied annually. Three year old smolts were more dominant in the 1970s but two-year old smolts increased in proportion through the 1980s, especially in the two-sea-winter salmon component (Moore et al. 1992). Mean smolt age has a significant positive association with latitude which parallels growth conditions (photoperiod and temperature) for salmon juveniles (Metcalfe and Thorpe 1990). Smolts from Big Salmon River were of approximately similar proportions of two and three years olds, dependent on the size of the cohorts (Jessop 1986) whereas smolts from sampled rivers in Quebec and throughout

Newfoundland are dominated by three and four year olds (Caron and Raymond 2000: Dempson et al. 1998).

Female smolts outnumbered males in 1999 and 2000 but were equally abundant in the 1998 smolt run. In most sampled populations, females outnumber males, particularly in the preodminantly 1SW stocks of Newfoundland (Caron and Raymond 2000; Chadwick et al. 1987; Dempson et al. 1998; Jessop 1975).

The mark and recapture experiments conducted in 1998 to 2000 to estimate the number of smolts migrating from the Northwest Miramichi provide imprecise estimates because of the low capture efficiencies of all the gear. Precision in mark and recapture experiments depends principally upon the number of recaptures observed. The most reliable estimate was obtained in 1999 when the marking and recapture traps functioned well. This was not the case in 2000, especially for the recapture trapnet. In many cases, efficiency can also change through the smolt run as discharge declines and temperature increases. Temporally stratified models can be used to account for variations in catchability but these models are data intensive (Arnason et al. 1996; Warren and Dempson 1995). There was little difference (within 3% and 4%) in the estimated smolt run for 1999 between the temporally stratified model and the aggregated models and the precisions were similar (95% confidence interval width +/- 29% for temporally stratified model, +/- 18% to 30% for aggregated models). In 2000, the temporally stratified model estimate was about 60% higher than the aggregated model estimates with similarly poor precision with all models (25% to 60%). Improved precision could be achieved by increasing the marking effort upriver which is more feasible than improving the efficiency of the recapture gears. Options to be explored include running additional marking gears (second smolt wheel in the Northwest Branch of the system) and / or marking of smolts at the recapture trapnet for subsequent transfer upstream.

The Northwest Miramichi has an estimated 16.8 million m^2 of habitat available for rearing of juveniles (Amiro 1983). Based on this area, the smolt production rates were 2.3 smolts per 100 m^2 (95% confidence interval range: 1.6 to 3.0) in 1999 and about 1 smolt per 100 m^2 (95% confidence interval range: 0.7 to 1.5) in 2000. These values are low relative to the 3 to 5 smolts per 100 m^2 considered to be suitable production rates for the Miramichi River (Elson 1975). Estimates of smolt production for the entire Miramichi River between 1953 and 1958 ranged from 0.8 to 2.6 million smolts which equates to a production rate of 1.5 to 4.8 smolts per 100 m^2 (Kerswill 1971). In monitored rivers of eastern Canada, smolt production rates have varied between 1 and almost 8 smolts per 100 m^2 of fluvial habitat with the high values generally associated with the presence of lacustrine habitat used by juveniles (Newfoundland rivers) or high egg depositions (Big Salmon River) (Chaput et al. 1998a). The production rates in the Northwest Miramichi are lower than expected based on the increased and high parr abundance levels in the river over the last 30 years (Chaput et al. 2000). Habitat limitations resulting from low discharge and freshet events have been implicated in reduced and low overwinter survival of juveniles (Cunjak 1996; Cunjak et al. 1998).

The smolt studies in the Northwest Miramichi of 1998 to 2000 have provided the first information on the population characteristics and dynamics within this river. These findings are being used to predict abundance of adult salmon in subsequent years, and to address the issue of lower Atlantic salmon abundance in the Miramichi River. Variations in the freshwater environment (both physical and biological) in which Atlantic salmon juveniles spend from two to four years prior to migrating to the ocean should have consequences for growth, survival and maturation at sea. Objectives based on ensuring a high abundance of juveniles in the river may be insufficient and perhaps even inappropriate if high juvenile densities result in shifts in age at smoltification, reductions in smolt size and condition which may lead to lower smolt production overall and reduced sea survival. Several more years of juvenile, smolt and adult abundance data will be required before this question can be addressed.

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Table 1. Catch matrix of Atlantic salmon smolts at the Cassilis trapnet (upper) and the tagging and release matrix for cage-reared smolts from McCormack Lake in the Northwest Miramichi, 1998.

		Released				Removals			
				Recaptured		Mortality			
Month	Day	Untagged	Lost	NW Miramichi	McCormack Lake	Untagged	Recaptured	Experimental	Total
May	12	15	0	0	0	0	0	23	38
	13	63	0	0	0	0	0	0	63
	14	94	0	0	0	0	0	0	94
	15	30	0	0	0	0	0	0	30
	16	1839	0	0	0	2	0	0	1841
	17	998	0	0	0	0	0	16	1014
	18	72	1	0	0	0	0	14	87
	19	244	0	0	0	0	0	9	253
	20	163	0	0	0	0	0	0	163
	21	174	0	0	0	0	0	104	278
	22	1552	0	1	0	0	0	15	1568
	23	39	0	0	0	0	0	7	46
	24	.	.	.	.	.	.	.	.
	25	57	0	0	0	0	0	2	59
	26	45	0	0	0	0	0	5	50
	27	132	0	0	0	1	0	0	133
	28	199	0	0	19	0	0	7	225
	29	443	0	0	123	0	0	8	574
	30	44	0	0	68	0	0	0	112
	31	19	0	0	17	0	0	0	36
June	1	9	0	0	7	0	2	0	18
	2	0	0	0	4	2	0	16	22
	3	11	1	0	3	0	1	0	16
	4	17	0	0	0	0	0	0	17
	5	31	0	0	1	1	1	0	34
	6	0	0	0	0	0	0	1	1
	7	16	0	0	0	0	0	0	16
	8	5	1	0	0	0	0	0	6
	9	5	0	0	0	0	0	0	5
	10	0	0	0	0	0	0	3	3
	11	25	0	0	1	0	0	0	26
	12	8	0	0	0	0	0	0	8
	13	0	0	0	0	0	0	6	6
	14	5	0	0	0	0	0	0	5
	15	30	0	0	0	0	0	0	30
Total		6384	3	1	243	6	4	236	6877

McCormack Lake Tagging	Release groups			
	May			
	27	28	29	Total
Total smolts	1068	2545	2391	6004
Tagged and released	968	2402	1960	5330
Mortality from tagging	71	91	104	266
Released untagged	25	50	323	398
Escaped to lake	4	2	4	10

Table 2. Tagging and recapture matrices for Atlantic salmon smolts at the Cassilis trapnet in the Northwest Miramichi, 1999.

		Released						**Removals / Mortality**				
						Recapture			from Cassilis			**Total**
Month	**Day**	Untagged	Injured	Lost	Tagged	Cassilis	Little SW	Untagged	Recapture	Tagging	Experimental	**Catch**
May	12	0	1	1	85			0	0	0	0	87
	13	0	0	0	94	1		0	0	0	0	95
	14	0	0	0	217	2		0	0	0	0	219
	15	2	0	0	297	8	1	0	0	0	0	308
	16	2	0	0	228	4		0	0	0	0	234
	17	0	0	2	175			0	0	0	0	177
	18	468	0	0	300	8	1	3	0	0	209	989
	19	2602	0	0	1294	28	3	0	1	5	300	4233
	20	0	0	0	60	5	1	1	0	0	0	67
	21	1375	0	0	828	54	3	1	1	0	0	2262
	22	191	0	0	598	101	3	0	0	0	0	893
	23	0	0	0	86	3		0	0	0	0	89
	24	1	0	0	128	2		1	0	0	0	132
	25	0	0	0	85	1	2	0	0	0	0	88
	26	5	0	0	411		1	1	0	0	0	418
	27	11	0	0	59	1		0	0	0	0	71
	28	82	0	0	75			0	0	0	0	157
	29	39	0	0	138	4	1	1	0	0	0	183
	30	12	0	0	150	4	3	0	0	0	25	194
	31	2	0	0	74	11		1	0	0	25	113
June	1	6	0	0	58	1		0	0	0	0	65
	2	0	0	0	8			0	0	0	0	8
	3	1	0	0	82			0	0	0	0	83
	4	0	0	0	9	3		0	0	0	0	12
	5	0	0	0	7			0	0	0	0	7
	6	0	0	0	7			0	0	0	0	7
	7	0	0	0	10	1		0	0	0	0	11
Total		4799	1	3	5563	242	19	9	2	5	559	**11202**

Table 3. Catch and recapture matrices for Atlantic salmon smolts at the Hackett's Beach trapnet in the Northwest Miramichi, 1999.

		Released				**Removals / Mortality**			
				Recapture			Recapture		**Total**
Month	**Day**	Untagged	Lost	Cassilis	Little SW	Untagged	from Cassilis	Experimental	**Catch**
May	7	1	0	0	0	0	0	0	1
	8	.	.	.	.	.	.	.	.
	9	.	.	.	.	.	.	.	.
	10	112	0	0	0	0	0	0	112
	11	242	0	0	0	0	0	20	262
	12	80	0	0	0	0	0	20	100
	13	130	0	0	0	0	0	20	150
	14	100	0	0	0	0	0	20	120
	15	230	0	0	1	0	0	19	250
	16	446	0	4	1	0	0	23	474
	17	889	0	4	0	17	0	20	930
	18	570	1	3	0	15	1	20	610
	19	235	0	5	1	11	0	20	272
	20	12	0	0	0	0	0	7	19
	21	545	0	14	1	11	1	20	592
	22	52	0	1	0	2	0	16	71
	23	25	0	2	0	8	0	6	41
	24	647	0	22	7	26	1	20	723
	25	183	0	4	1	13	0	20	221
	26	44	0	0	0	0	0	10	54
	27	283	0	6	2	20	0	20	331
	28	16	0	0	0	0	0	2	18
	29	77	0	0	0	0	0	19	96
	30	7	0	1	0	0	0	1	9
	31	1	0	0	0	0	0	0	1
June	1	26	0	0	0	0	0	3	29
	2	2	0	0	0	0	0	0	2
	3	7	0	0	0	2	0	1	10
	4	18	0	0	0	0	0	4	22
	5	2	0	1	0	0	0	0	3
	6	6	0	1	0	0	0	1	8
	7	3	0	0	0	0	0	0	3
Total		4991	1	68	14	125	3	332	5534

Table 4. Tagging and recapture matrices for Atlantic salmon smolts at the Cassilis trapnet in the Northwest Miramichi, 2000.

		Released							Removals		
						Recaptured by tag origin					Total
Month	Day	Tagged	Unsampled	Injured	Lost	Cassilis	Little SW	Catamaran	Experimental	Mortality	Catch
May	13	10									10
	14	3									3
	15	2									2
	16	13									13
	17	0							56		56
	18	0						1	78		79
	19	0							73		73
	20	0	1						36		37
	21	0							77		77
	22	0			1				22		23
	23	65			1						66
	24	232				1					233
	25	143	2		3	4					152
	26	36									36
	27	80									80
	28	169					1				170
	29	205				2					207
	30	18				2		1			21
	31	42		1							43
June	1	210				2	1				213
	2	1082			2	5	8			11	1108
	3	58				14					72
	4	32				2					34
	5	71				4	1				76
	6	147					6			1	154
	7	27				1	1				29
	8	22		1		4	2				29
	9	9									9
	10	39					1				40
	11	11				4					15
	12	11				1					12
	13	19				4	1				24
	14	23				1					24
	15	38				1					39
	16	5				1					6
	17	6	2								8
	18	2					1				3
	19	1									1
	20	1									1
	21	2									2
Total		2834	5	2	7	53	23	2	342	12	3280

Table 5. Catch and recapture matrices for Atlantic salmon smolts at the Hacketts Beach trapnet in the Northwest Miramichi, 2000.

		Released				Removals		
				Recaptured				Total
Month	Day	Untagged	Lost	LSW	Cassilis	Mortality	Experimental	Catch
May	10	2						2
	11	4					1	5
	12	8		1			1	10
	13	26		1		1	6	34
	14	6					1	7
	15	4						4
	16	70				1	15	86
	17	61					15	76
	18	9					2	11
	19	2						2
	20	8					2	10
	21	27					6	33
	22	24					5	29
	23	4						4
	24	1						1
	25	13	1				3	17
	26	2						2
	27	16					4	20
	28	3						3
	29	70					15	85
	30	83		2	1		15	101
	31	36					8	44
June	1	12					3	15
	2	3						3
	3	40			1	3	10	54
	4	3	1		1			5
	5	1			1			2
	6	18				2	4	24
	7	3			1			4
	8							0
	9	0			2		0	2
	10	3						3
	11	7					1	8
	12	6					1	7
	13							0
	14							0
	15							0
	16							0
	17	1						1
	18							0
	19					1		1
Total		576	2	4	7	8	118	715

Table 6. Days since tagging of Little Southwest Miramichi smolts recaptured at the Cassilis trapnet in 1999. Number in parentheses is number of tags recovered.

	Tagging group			
Days since tagging	All groups	May 11-13	May 14 -23	May 24-June 8
0	0	0	0	0
1	5.3% (1)	0	7.1% (1)	0
2	42.1% (8)	0	57.1% (8)	0
3	21.1% (4)	0	14.3% (2)	50.0% (2)
4	26.3% (5)	100% (1)	14.3% (2)	50.0% (2)
5	0	0	0	0
6	5.3% (1)	0	7.1% (1)	0
7	0	0	0	0
8	0	0	0	0
Total	100% (19)	100% (1)	100% (14)	100% (4)
Total tagged	1822	55	1204	563
% Recaptured	1.0%	1.8%	1.2%	0.7%

Table 7. Days since tagging of Little Southwest Miramichi smolts recaptured at the Cassilis trapnet in 2000. Number in parentheses is number of tags recovered.

	Tagging group				
Days since tagging	All groups	May 5 - 14	May 15 -23	May 24-31	June 1 - 14
0	0	0	0	0	0
1	4.3% (1)	0	0	0	7.7% (1)
2	17.4% (4)	0	0	22.2% (2)	15.4% (2)
3	21.7% (5)	0	0	22.2% (2)	23.1% (3)
4	21.7% (5)	0	0	22.2% (2)	23.1% (3)
5	17.4% (4)	0	100.0% (1)	22.2% (2)	7.7% (1)
6	13.0% (3)	0	0	11.1% (1)	15.4% (2)
7	4.3% (1)	0	0	0	7.7% (1)
8	0	0	0	0	0
Total	100% (23)	0	100% (1)	100% (9)	100% (13)
Total tagged	1233	133	376	433	291
% Recaptured	1.9%	0.0%	0.3%	2.1%	4.5%

Table 8. Days at large of smolts tagged at the upper trapnet and recaptured at the lower trapnet in 1999.

	Tagging group			
Days since tagging	All groups	May 12 to 17	May 18 to 22	May 23 to June 15
0	0	0	0	0
1	12.7% (9)	0	2.4% (1)	66.7% (8)
2	47.9% (34)	23.5% (4)	66.7% (28)	16.7% (2)
3	22.5% (16)	35.3% (6)	21.4% (9)	8.3% (1)
4	5.6% (4)	17.6% (3)	2.4% (1)	0
5	5.6% (4)	5.9% (1)	4.8% (2)	8.3% (1)
6	5.6% (4)	17.6% (3)	2.4% (1)	0
7	0	0	0	0
8	0	0	0	0
Total	100% (71)	100% (17)	100% (42)	100% (12)
Total tagged	5,563	1,096	3,080	1,387
% Recaptured	1.3%	1.6%	1.4%	0.9%

Table 9. Days since tagging at the Cassilis trapnet and recaptured at the Cassilis trapnet in 1999. Number in parentheses is number of tags recovered.

	Tagging group			
Days since tagging	All groups	May 12-17	May 18-23	May 24-June 8
0	0	0	0	0
1	59.0% (144)	23.1% (12)	67.7% (113)	76.0% (19)
2	21.3% (52)	15.4% (8)	25.7% (43)	4.0% (1)
3	8.2% (20)	15.4% (8)	5.4% (9)	12.0% (3)
4	5.3% (13)	21.2% (11)	0.6% (1)	4.0% (1)
5	2.9% (7)	11.5% (6)	0.6% (1)	0
6	1.6% (4)	7.7% (4)	0	0
7	0.8% (2)	1.9% (1)	0	4.0% (1)
8	0.4% (1)	1.9% (1)	0	0
9	0.4% (1)	1.9% (1)	0	0
Total	(100%) 244	100% (52)	100% (167)	100% (25)
Total tagged	5563	1096	3166	1301
% Recaptured	4.4%	4.7%	5.3%	1.9%

Table 10. Days since tagging at the Cassilis trapnet and recaptured at the Cassilis trapnet in 2000. Number in parentheses is number of tags recovered.

	Tagging group				
Days since tagging	All groups	May 23-26	May 27-30	May 31-June 4	June 5-21
0	1.9% (1)	0	0	0	6.3% (1)
1	66.0% (35)	83.3% (5)	75.0% (3)	85.2% (23)	25.0% (4)
2	13.2% (7)	0	0.0%	7.4% (2)	31.3% (5)
3	15.1% (8)	16.7% (1)	25.0% (1)	0	37.5% (6)
4	0	0	0	0	0
5	0	0	0	0	0
6	1.9% (1)	0	0	3.7% (1)	0
7	1.9% (1)	0	0	3.7% (1)	0
8	0	0	0	0	0
Total	(100%) 53	100% (6)	100% (4)	100% (27)	100% (16)
Total tagged	2834	476	472	1424	434
% Recaptured	1.9%	1.3%	0.8%	1.9%	3.7%

Table 11. Catch matrix of Atlantic salmon smolts tagged at McCormack Lake and recaptured at the Cassilis trapnet in the Northwest Miramichi, 1998.

		Release Date					
Recapture date		May					Total
Month	Day	27	28	29	Unknown	Total	Catch
		968	2402	1960		5330	
May	12						38
	13						63
	14						94
	15						30
	16						1841
	17						1014
	18						87
	19						253
	20						163
	21						278
	22						1568
	23						46
	24						0
	25						59
	26						50
	27						133
	28	19				19	225
	29	12	110	1		123	574
	30		27	35	6	68	112
	31	1	1	15		17	36
June	1		4	5		9	18
	2			5		5	22
	3		1	2		3	16
	4					0	17
	5			2		2	34
	6					0	1
	7					0	16
	8					0	6
	9					0	5
	10					0	3
	11			1		1	26
	12					0	8
	13					0	6
	14					0	5
	15					0	30
For tag group		32	143	66	6	247	6877
% seen again		3.3%	6.0%	3.4%		4.6%	

Table 12. Summary of biological characteristics of Atlantic salmon smolts from the Northwest Miramichi River, 1998 to 2000.

		Fork length (mm) at age					
		2		3		4	
Year	Sex	Mean	Std. Error (N)	Mean	Std. Error (N)	Mean	Std. Error (N)
1998	Female	125	2.1 (37)	126	1.4 (49)	-	-
	Male	123	2.7 (25)	126	1.5 (51)	131	- (1)
1999	Female	124	1.1 (74)	129	0.9 (123)	129	1.9 (6)
	Male	121	1.6 (38)	129	1.2 (79)	148	9.4 (3)
2000	Female	133	2.4 (27)	128	1.6 (38)	-	-
	Male	125	3.0 (16)	129	2.3 (26)	138	- (2)

	Proportion weighted to catch (*samples only*)		
	1998	1999	2000
Smolt age			
2	28% (*36%*)	36% (*38%*)	34% (*41%*)
3	71% (*63%*)	62% (*59%*)	63% (*57%*)
4	1% (*1%*)	2% (*2%*)	3% (*2%*)
Sample size	189	385	114

	Percent female (sample size)			
	1998	1999	2000	Chi-square
Smolt age				
2	60% (68)	66% (112)	63% (43)	NS
3	49% (119)	61% (203)	59% (64)	< 0.10
4	- (1)	67% (9)	- (2)	-
Chi-square	NS	NS	NS	
Female Weighted to catch (*samples only*)	49% (*53%*)	63% (*63%*)	58% (*60%*)	

Table 13. Tagging and recapture matrices and estimates of run size and Cassilis trapnet efficiency in the Northwest Miramichi, 1998.

1998									
			Recaptured at Cassilis trapnet					**Pooled summary**	
McCormack Lake Releases			May	May	May	May	June	May 12 to	June 15
Release date		Tagged	28	29	30	31	1-15		
May	27	968	19	12	0	1	0	Marks =	5330
May	28	2402	0	110	30	1	5	Recaptures =	247
May	29	1960	0	1	38	15	15		
	Total	5330							
Catch at Cassilis trapnet			225	574	112	36	213	Catch =	6877

Estimates of trapnet efficiencies

		Efficiency (May 28 - June 15)		
Model		Estimate	95% Confidence interval	
Darroch		4.5%	5.5%	3.8%
Pooled Peterson		4.6%	5.1%	4.2%
Pooled Bayesian		4.6%	5.1%	4.1%

Estimates of population size

		Population size (season)		
Model		Estimate	95% Confidence interval	
Darroch		152,800	125,000	181,000
Pooled Peterson		149,500	134,800	163,700
Pooled Bayesian		149,500	134,800	167,700

Table 14. Estimates of trapnet efficiencies and population size based on tagging from the Cassilis trapnet and recapturing at the Hacketts trapnet, 1999. Tagging and handling mortality and tag loss is assumed to be 10%.

1999 Cassilis trapnet to Hacketts trapnet							
Assuming 10% tag loss and mortality		Recapture period				Pooled summary	
Tagging period	Tagged	May 10-19	May 20-25	May26-June 7		May 10 to June 7	
May 12-17	986	17	0	0		Marks =	5007
May 18-23	2849	0	45	0		Recaptures =	71
May 24-June 7	1171	0	0	9			
Total	5007						
Catch at Hacketts trapnet		3280	1667	586		Catch =	5533
Estimates of Cassilis trapnet efficiency							
		Population size (season)				**Season catch**	
Model		Estimate	95% Confidence interval			**at Cassilis**	
Darroch		3.0%	4.2%	2.3%		**11202**	
Pooled Peterson		2.9%	3.6%	2.3%			
Pooled Bayesian		2.9%	3.6%	2.2%			
Estimates of Hacketts trapnet efficiency							
		Population size (season)				**Season catch**	
Model		Estimate	95% Confidence interval			**at Hacketts**	
Darroch		1.5%	2.1%	1.2%		**5533**	
Pooled Peterson		1.4%	1.8%	1.1%			
Pooled Bayesian		1.4%	1.8%	1.1%			
Estimates of population size							
		Population size (season)					
Model		Estimate	95% Confidence interval				
Darroch		372,000	265,600	478,500			
Pooled Peterson		384,800	309,400	487,000			
Pooled Bayesian		390,500	315,500	506,000			

Table 15. Estimates of trapnet efficiencies and population size based on tagging from the Little Southwest Miramichi and recapturing at the Cassilis trapnet and at the Hacketts trapnet, 1999. Tagging and handling mortality and tag loss is assumed to be 10%.

1999 Little Southwest to Cassilis trapnet

Assuming 10% tag loss and mortality		Recapture period			Pooled summary	
Taggin period	Tagged	May 12-22	May 23-June 7		May 12 - June 7	
May 11-22	1054	12	3		Marks =	1640
May 23 - June 8	586	0	4		Recapture:	19
	1640					
Catch at Cassilis		9564	1638		Catch =	11202

Estimates of Cassilis trapnet efficiency

		Efficiency (season)			Season catch at Cassilis
Model		Estimate	95% Confidence interval		
Darroch		na	na	na	11202
Pooled Peterson		1.2%	1.8%	0.8%	
Pooled Bayesian		1.2%	1.7%	0.7%	

Estimates of population size

		Population size (season)		
Model		Estimate	95% Confidence interval	
Darroch		na	na	na
Pooled Peterson		919,200	617,900	1,453,100
Pooled Bayesian		964,000	670,000	1,696,000

1999 Little Southwest to Hacketts trapnet

Assuming 10% tag loss and mortality		Recapture period			Pooled summary	
Taggin period	Tagged	May 10-22	May 23-June 7		May 10 - June 7	
May 11-20	767	4	2		Marks =	1640
May 21 - June 8	873	0	8		Recapture:	14
Total	1640					
Catch at trapnets		3962	1571		Catch =	5533

Estimates of Hacketts trapnet efficiency

		Population size (season)			Season catch at Hacketts
Model		Estimate	95% Confidence interval		
Darroch		na	na	na	5533
Pooled Peterson		0.9%	1.4%	0.5%	
Pooled Bayesian		0.8%	1.3%	0.4%	

Estimates of population size

		Population size (season)		
Model		Estimate	95% Confidence interval	
Darroch		na	na	na
Pooled Peterson		605,400	385,500	1,030,100
Pooled Bayesian		660,000	435,000	1,285,000

Table 16. Estimates of trapnet efficiencies and population size based on tagging from the Little Southwest Miramichi and recapturing at the Cassilis trapnet (upper) and at both trapnets (lower), 2000. Tagging and handling mortality and tag loss is assumed to be 10%.

2000 Little Southwest to Cassilis trapnet

Assuming 10% tag loss and mortality			Recapture period			Pooled summary	
Tagging period		Tagged	May 13 -June 4	June 5 - 21		May 13 - June 21	
May	5 - 31	848	10	0		Marks =	1110
June	1 - 14	262	0	13		Recapture:	23
	Total	1110					
Catch at Cassilis			2787	440		Catch =	3227

Estimates of Cassilis trapnet efficiency

	Efficiency (season)				Season catch
Model	Estimate	95% Confidence interval			at Cassilis
Darroch	1.3%	3.2%	0.8%		3227
Pooled Peterson	2.2%	3.1%	1.4%		
Pooled Bayesian	2.1%	2.9%	1.3%		

Estimates of population size

	Population size (season)		
Model	Estimate	95% Confidence interval	
Darroch	245,200	99,800	390,600
Pooled Peterson	149,400	103,900	226,000
Pooled Bayesian	156,000	111,000	258,000

2000 Little Southwest to Cassilis and Hacketts trapnets

Assuming 10% tag loss and mortality			Recapture period			Pooled summary	
Tagging period		Tagged	May 10 -June 4	June 5 - 21		May 10 - June 21	
May	5 - 31	848	14	0		Marks =	1110
June	1 - 14	262	0	13		Recapture:	27
	Total	1110					
Catch at Cassilis			3450	492		Catch =	3942

Estimates of Cassilis trapnet efficiency

	Efficiency (season)				Season catch
Model	Estimate	95% Confidence interval			at Cassilis
Darroch	1.5%	2.9%	1.0%		3227
Pooled Peterson	2.1%	2.9%	1.4%		
Pooled Bayesian	2.0%	2.7%	1.3%		

Estimates of population size

	Population size (season)		
Model	Estimate	95% Confidence interval	
Darroch	218,900	110,400	327,300
Pooled Peterson	156,500	111,600	229,100
Pooled Bayesian	162,000	118,000	256,000

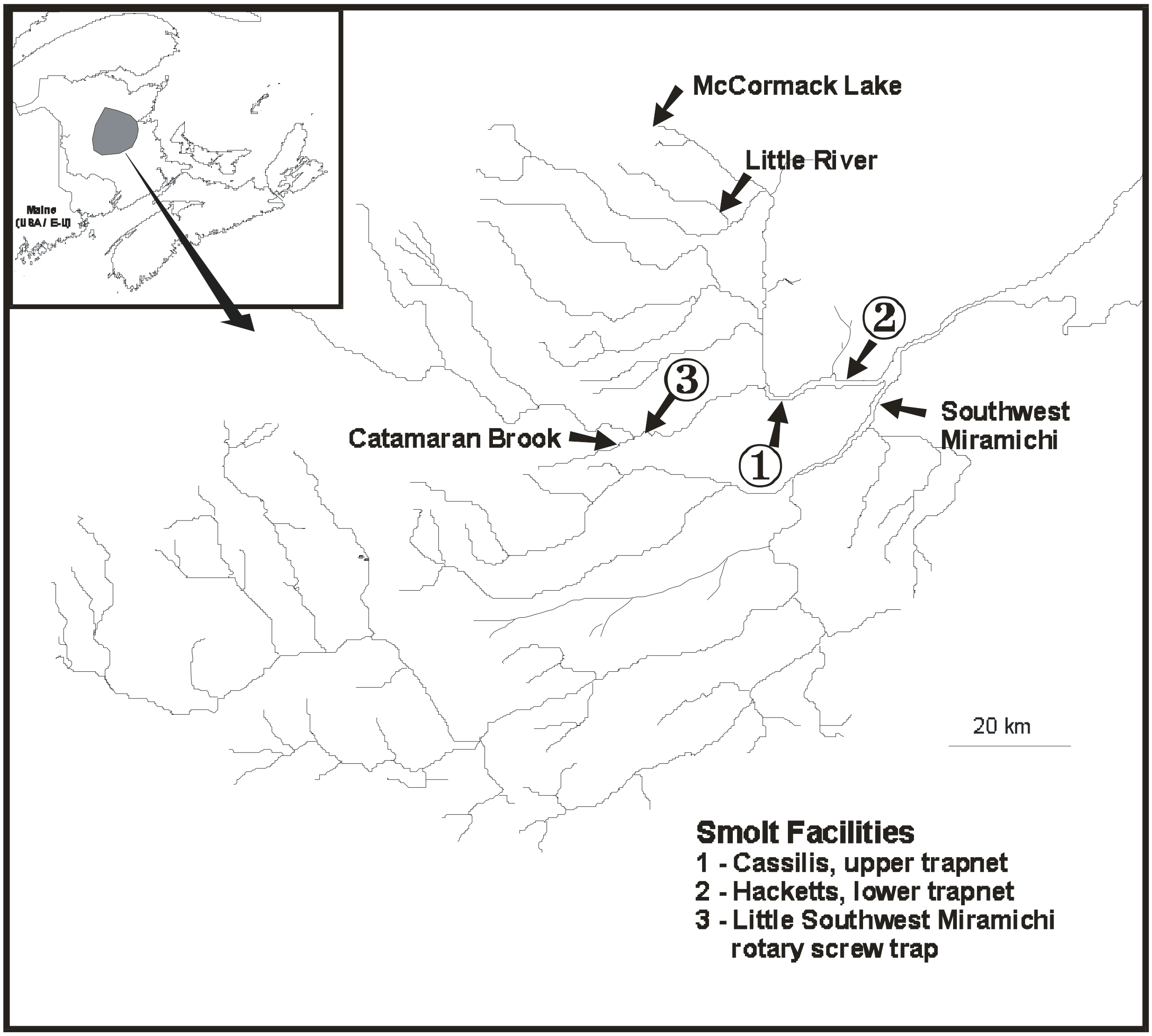


Figure 1. The Miramichi River indicating the location of the smolt sampling facilities in the Northwest Miramichi and other locations mentioned in the document.

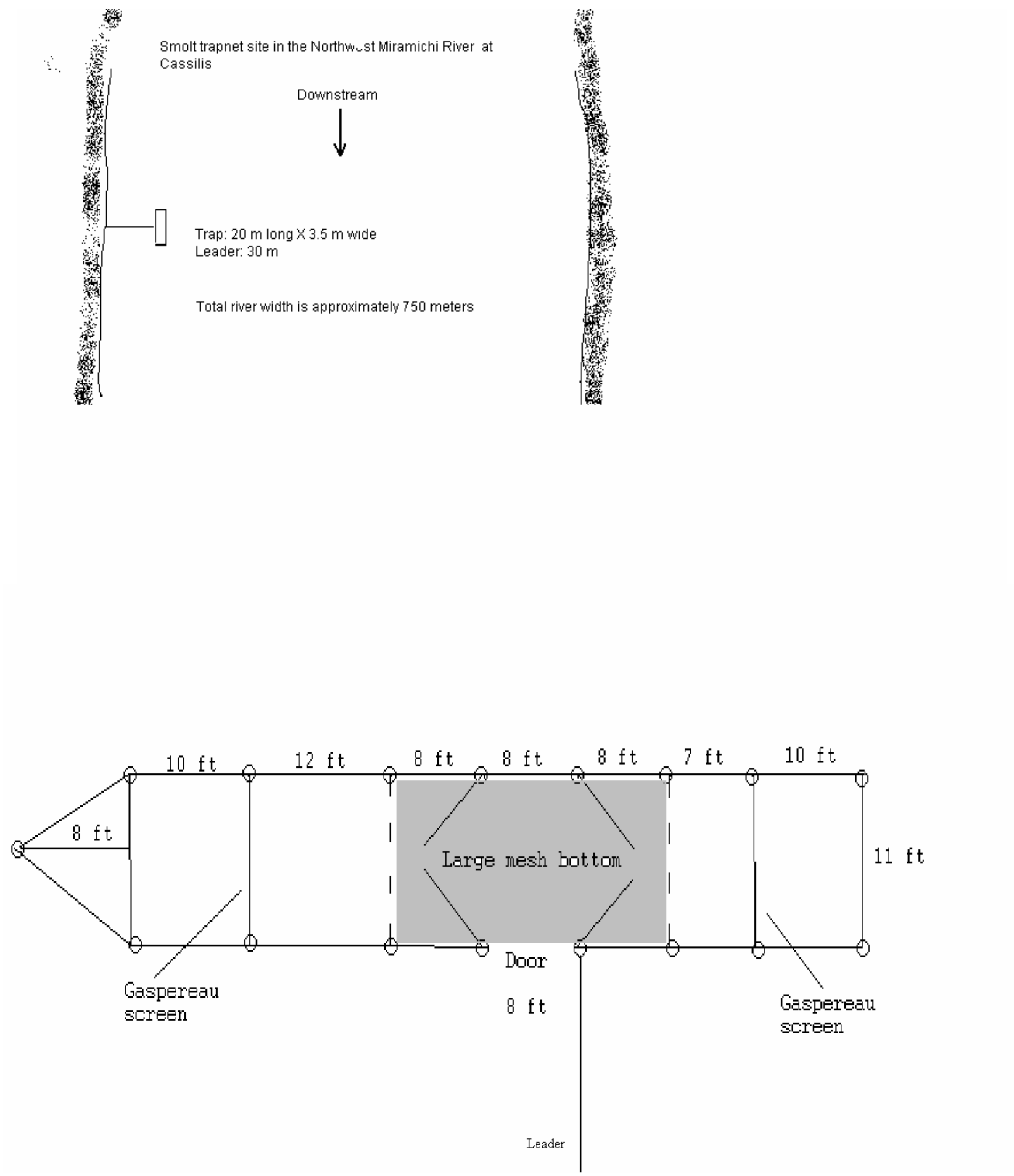


Figure 2. Installation and construction of estuary trapnet in the Northwest Miramichi. The Cassilis installation is shown as an example.

Figure 3. Photograph of streamer tag used to identify date and location of tagging of Atlantic salmon smolts from the Northwest Miramichi, 1998 to 2000.

Figure 4. Photograph of placement of rotary screw trap in the Little Southwest Miramichi, 1999 and 2000.

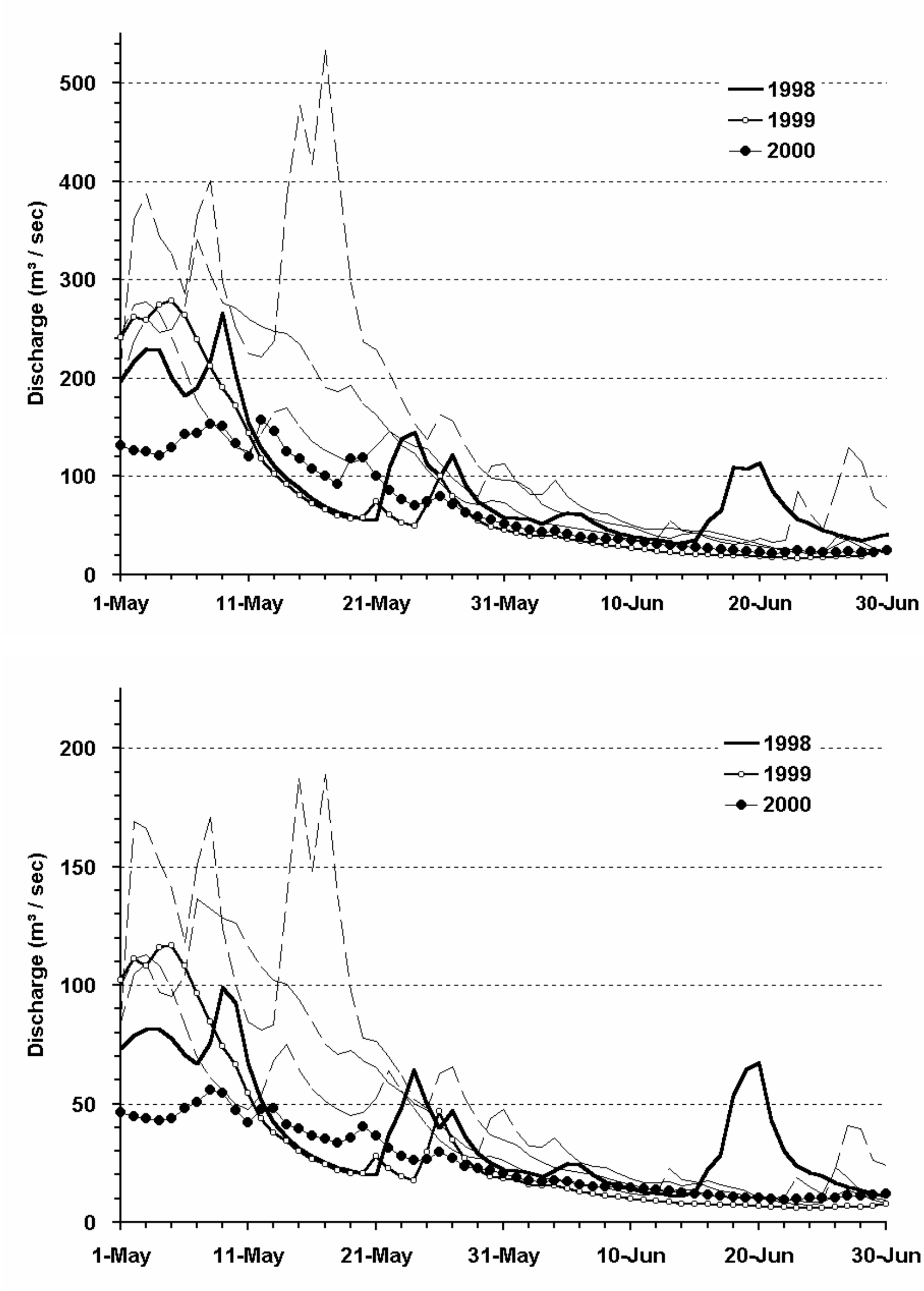
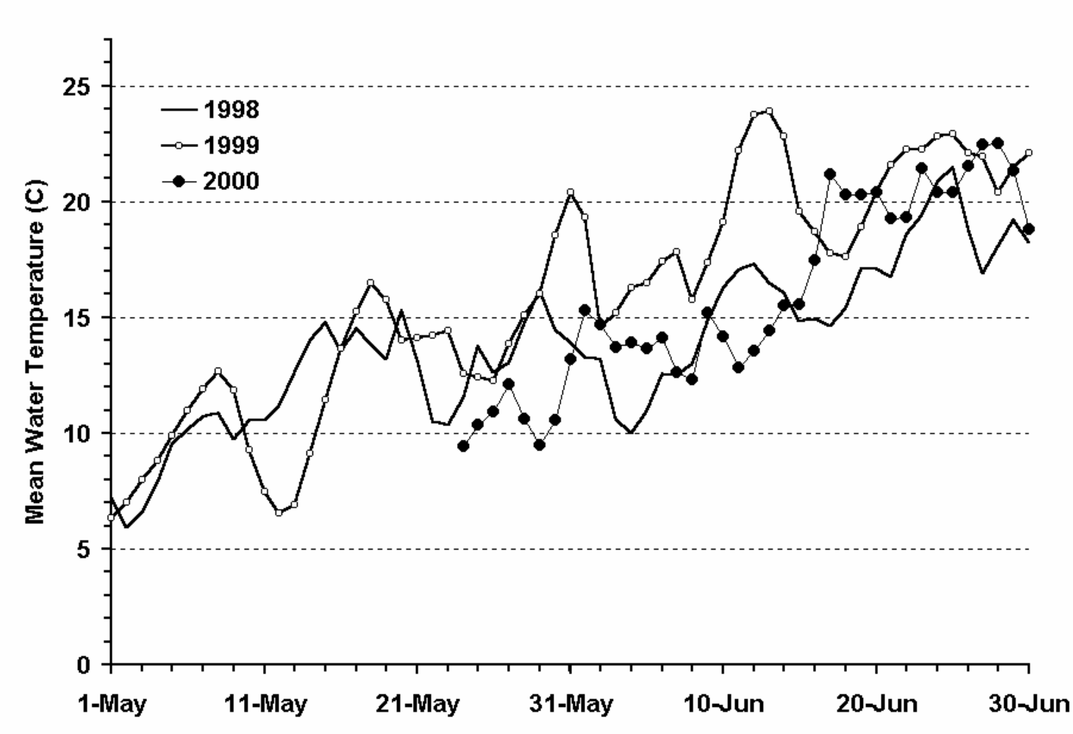


Figure 5. Mean daily discharge of the Northwest Miramichi (sum of Little Southwest and Northwest Miramichi stations) (upper) and the Little Southwest Miramichi (lower), 1995 to 2000. The faint dashed lines are for 1995 to 1997 with the peak discharge in mid-May observed during 1997.



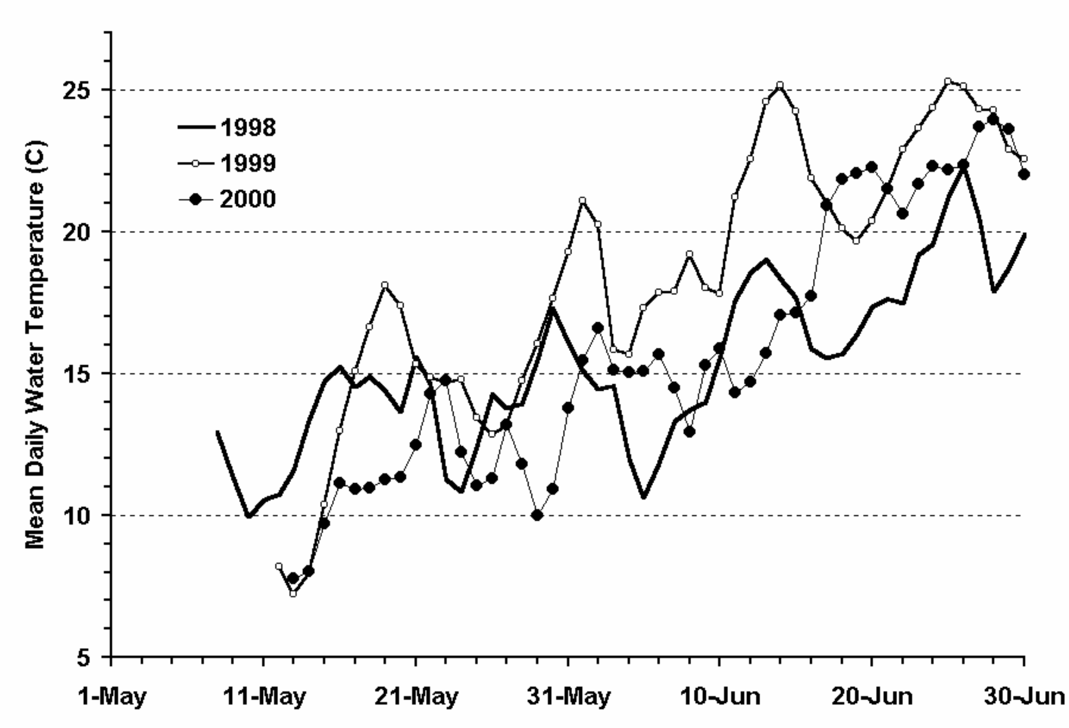
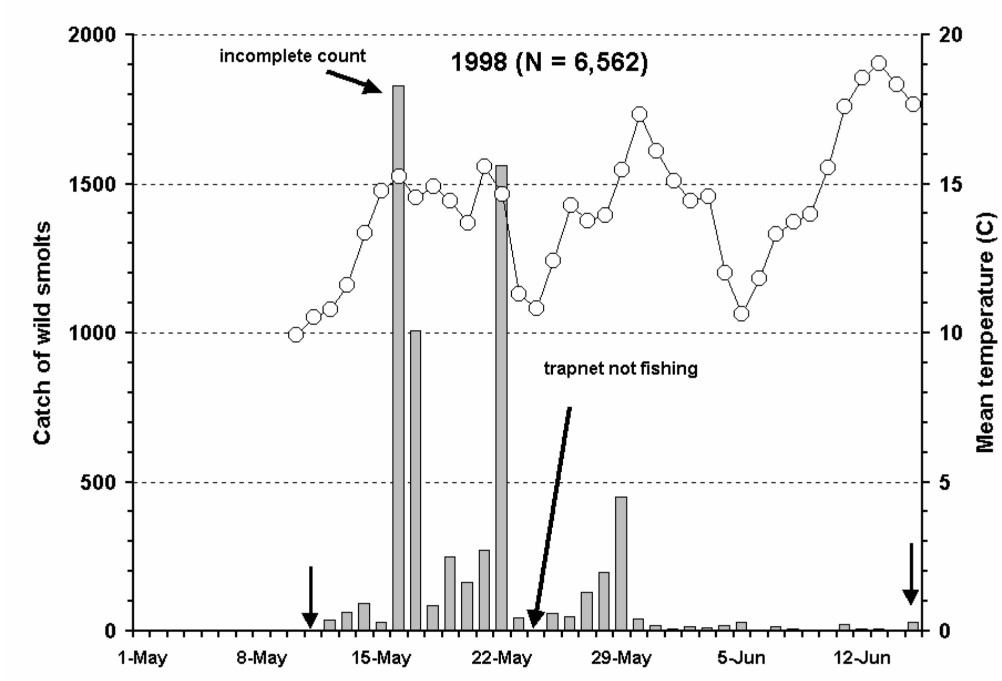


Figure 6. Mean daily water temperature at the rotary screw trap site in the Little Southwest Miramichi (upper) and at the Cassilis estuary trapnet (lower) during the smolt migrations of 1998 to 2000.



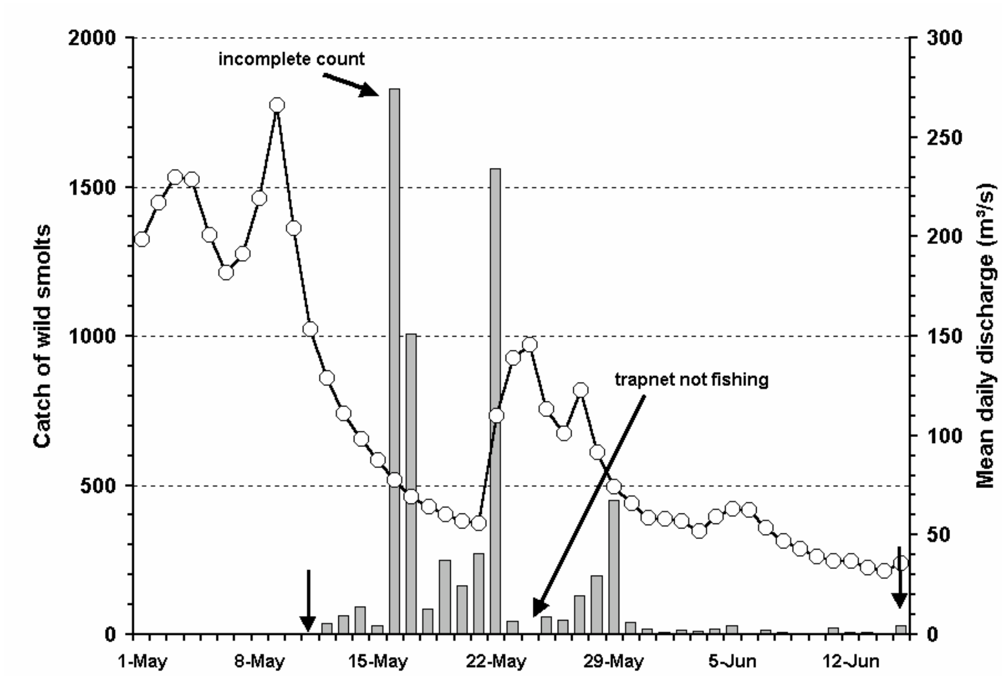
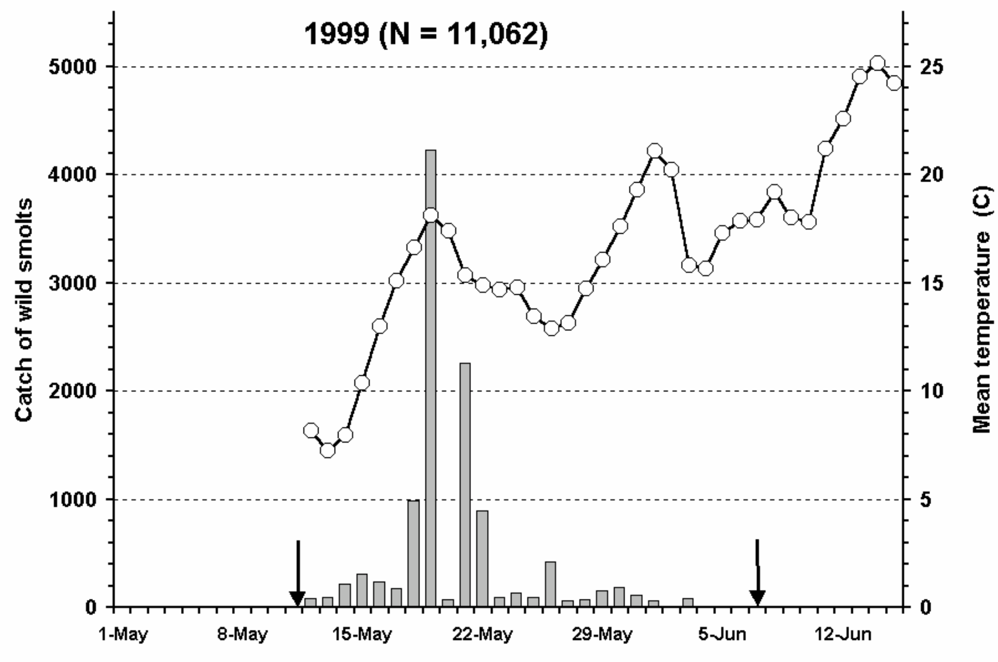


Figure 7a. Timing of catches of wild smolts at the Cassilis tidal water trapnet in the Northwest Miramichi in 1998 relative to mean daily water temperature (C; upper) and mean daily discharge in the Northwest Miramichi (sum of Northwest and Little Southwest Miramichi discharges) (m^3/s; lower). Arrows indicate first and last days of operation.



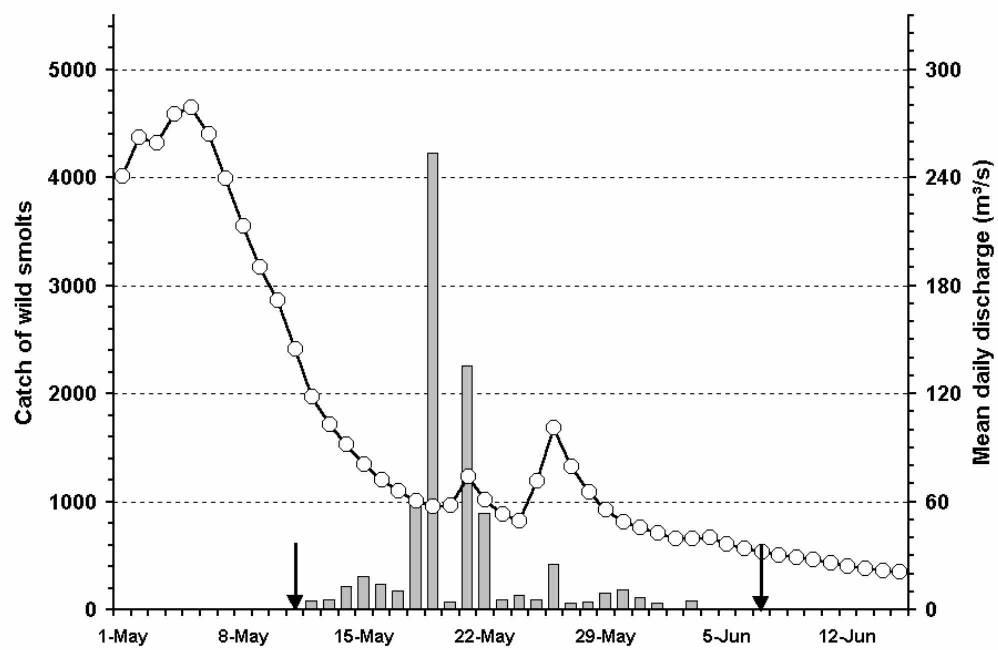


Figure 7b. Timing of catches of wild smolts at the Cassilis tidal water trapnet in the Northwest Miramichi in 1999 relative to mean daily water temperature (C; upper) and mean daily discharge in the Northwest Miramichi (sum of Northwest and Little Southwest Miramichi discharges) (m^3/s; lower). Arrows indicate first and last days of operation.

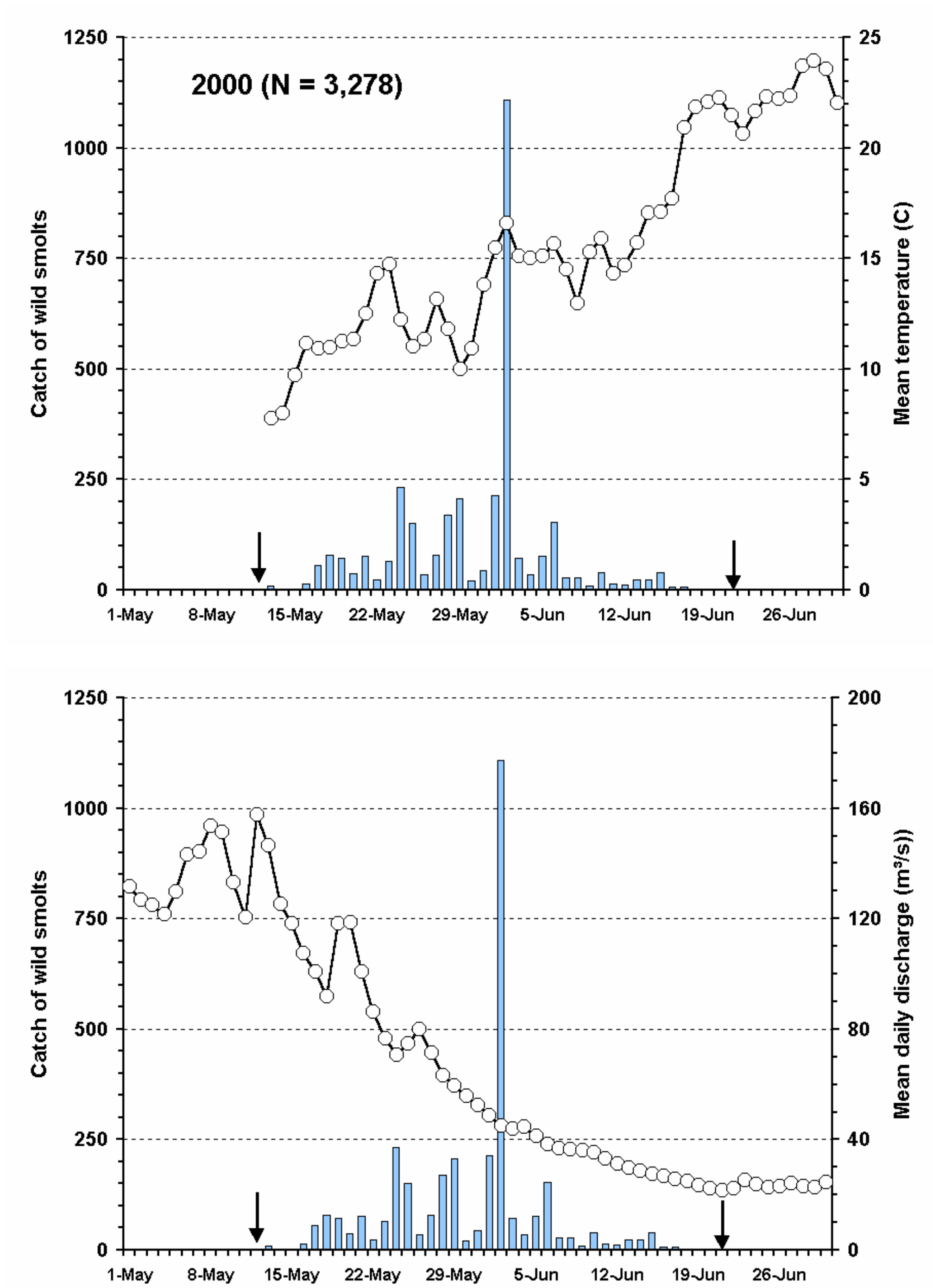


Figure 7c. Timing of catches of wild smolts at the Cassilis tidal water trapnet in the Northwest Miramichi in 2000 relative to mean daily water temperature (C; upper) and mean daily discharge in the Northwest Miramichi (sum of Northwest and Little Southwest Miramichi discharges) (m^3/s; lower). Arrows indicate first and last days of operation.

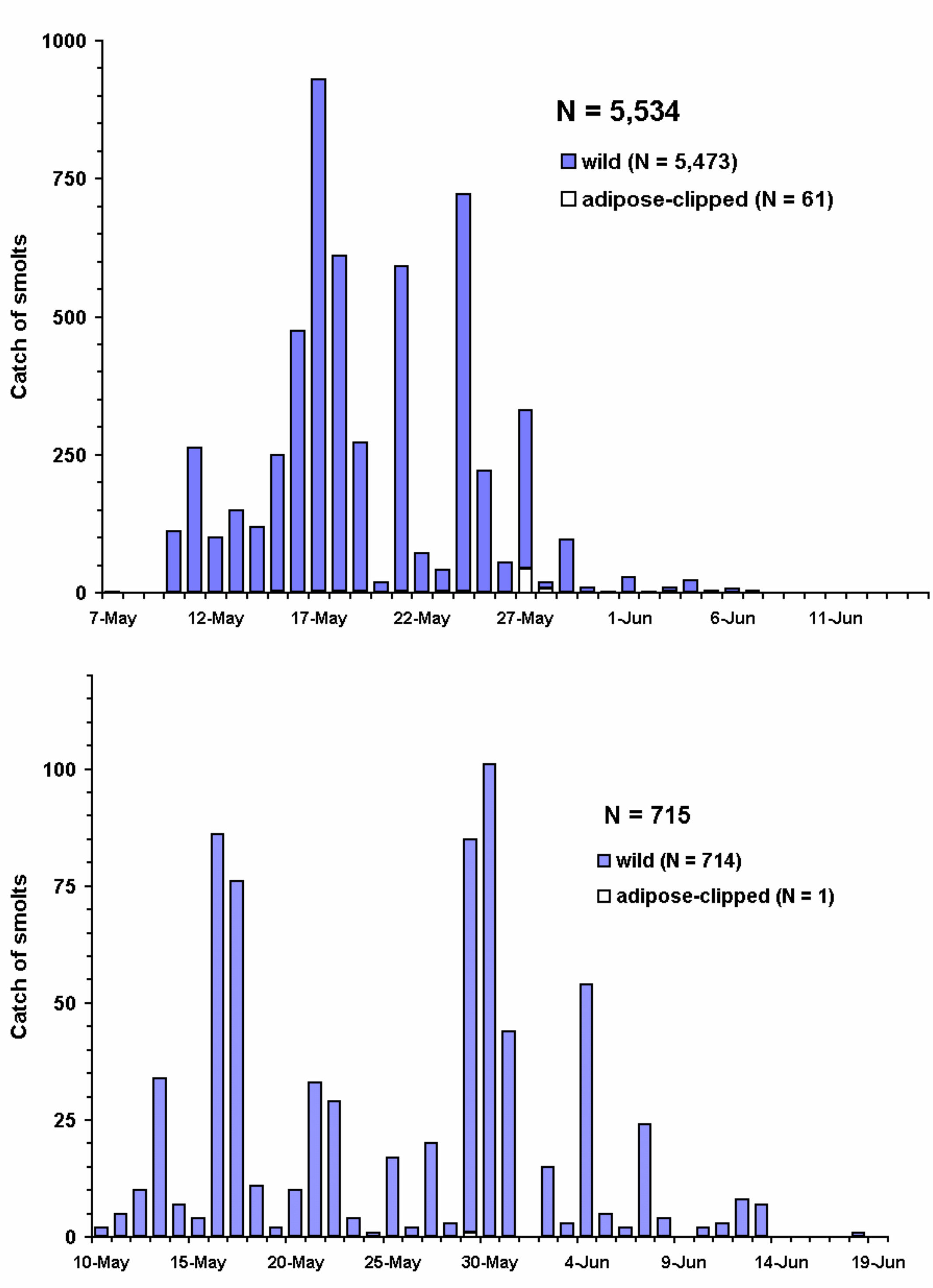


Figure 8. Timing of catches of wild smolts at the Hackett's Beach tidal water trapnet in the Northwest Miramichi in 1999 and 2000.

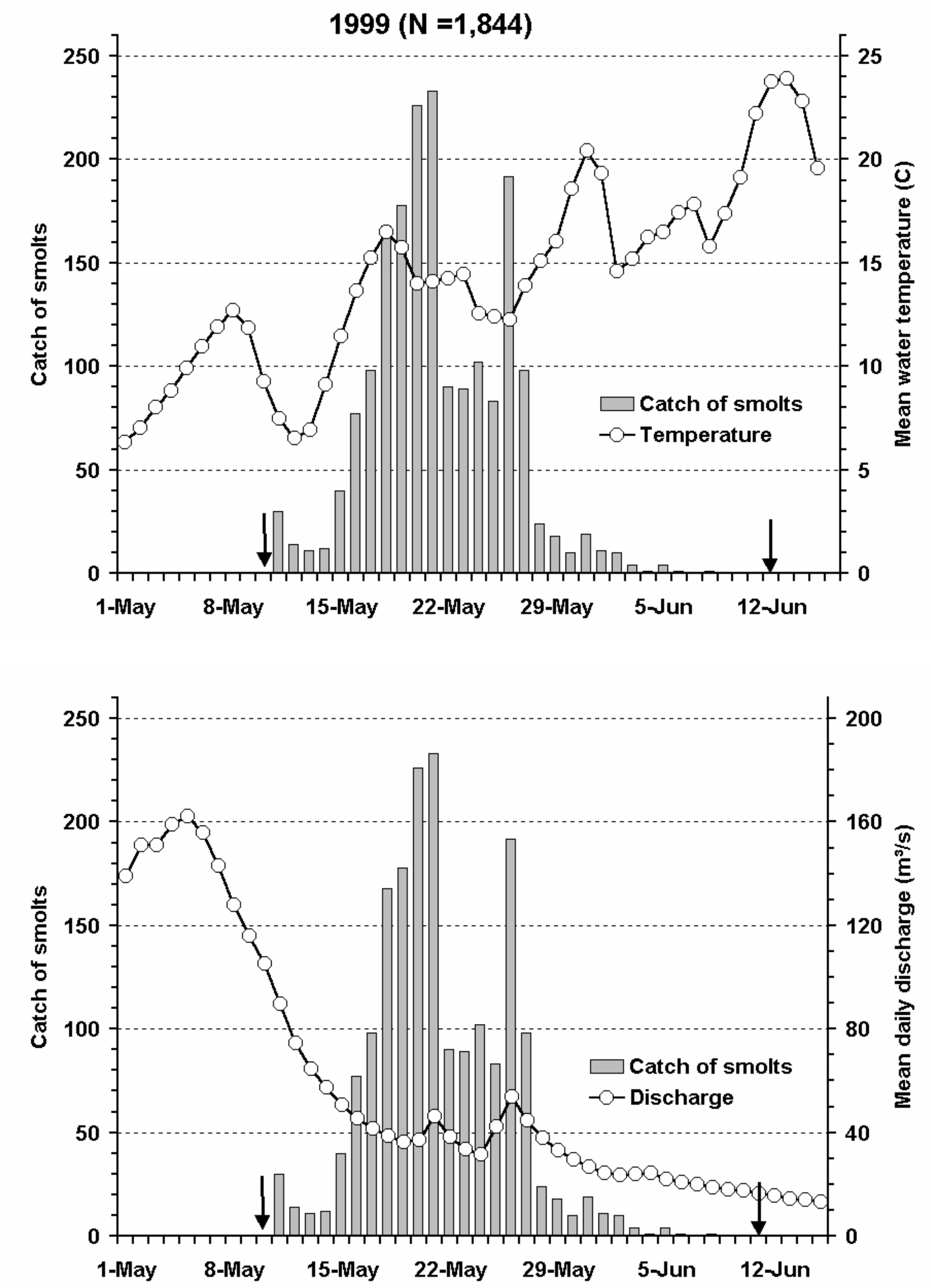


Figure 9a. Timing of catches of smolts at the rotary screw trap in the Little Southwest Miramichi, in 1999 relative to mean daily temperature (ºC; upper) and mean daily discharge (m^3/s; lower). Arrows indicate first and late days of operation.

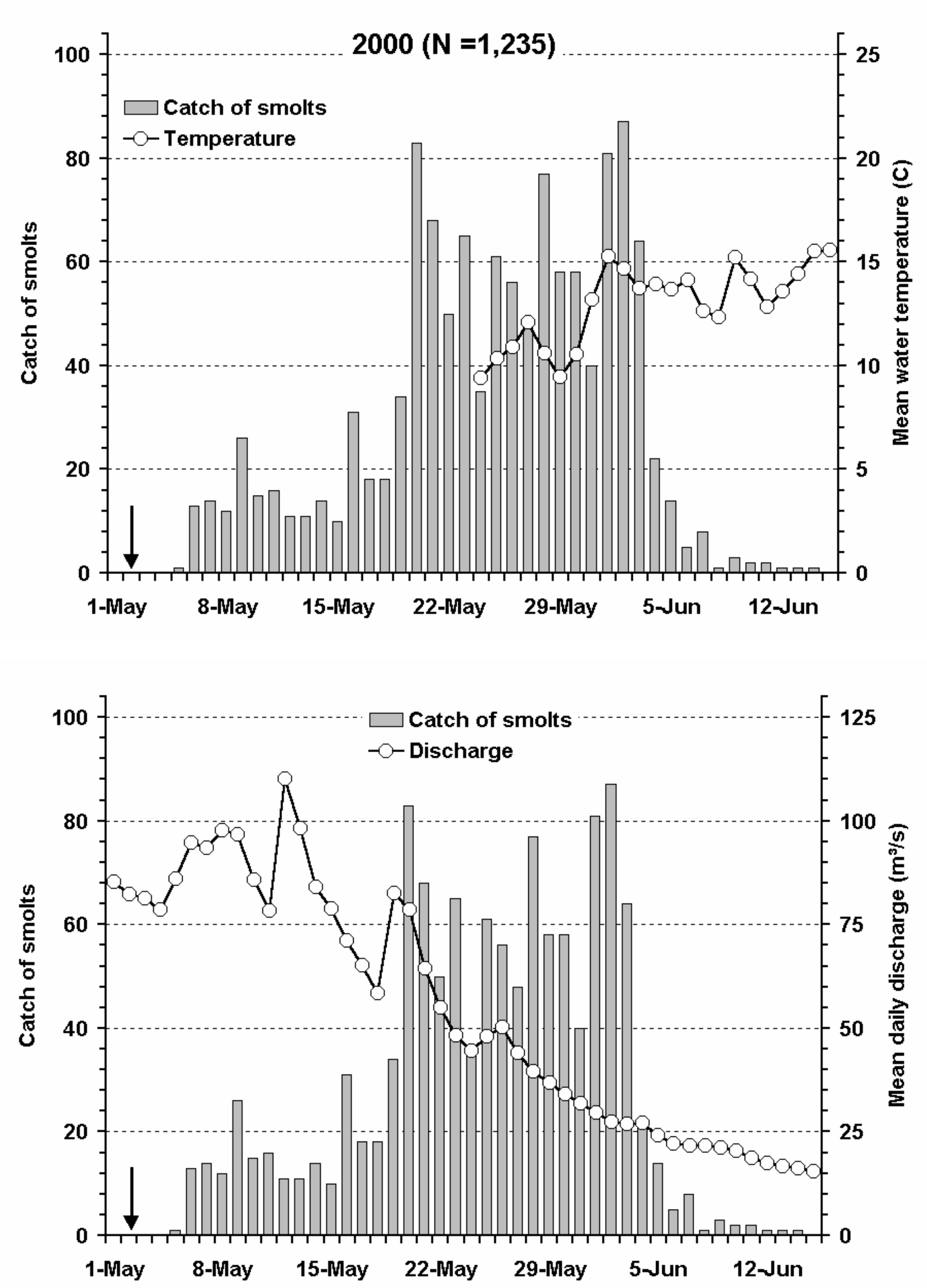
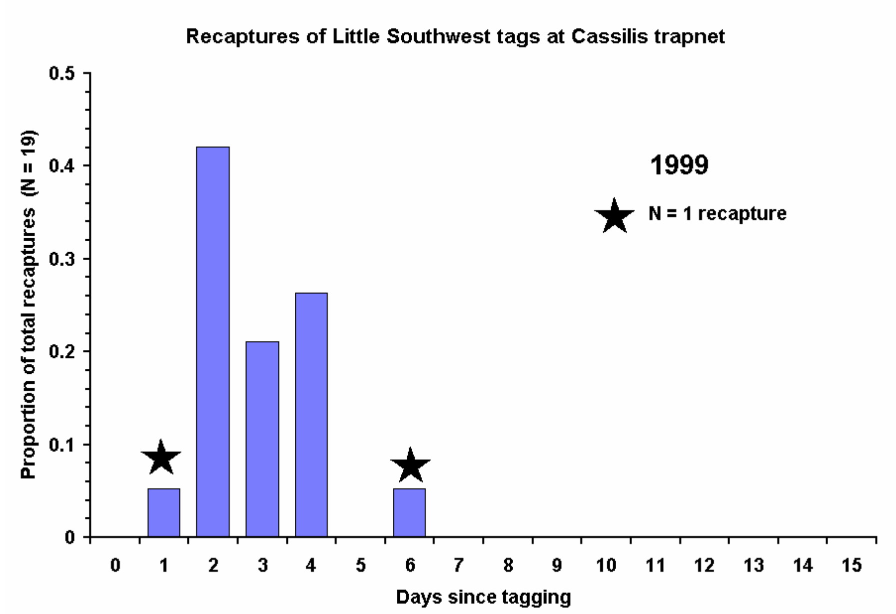


Figure 9b. Timing of catches of smolts at the rotary screw trap in the Little Southwest Miramichi, in 2000, relative to mean daily temperature (ºC; upper) and mean daily discharge (m^3/s; lower). Arrow indicates date of installation. Last smolt captured on June 14 and trap removed June 27, 2000.



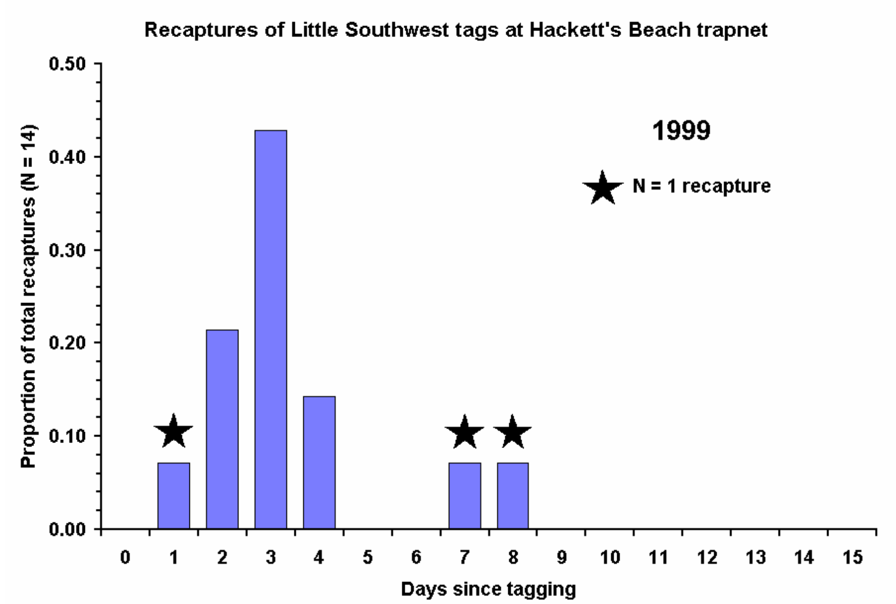
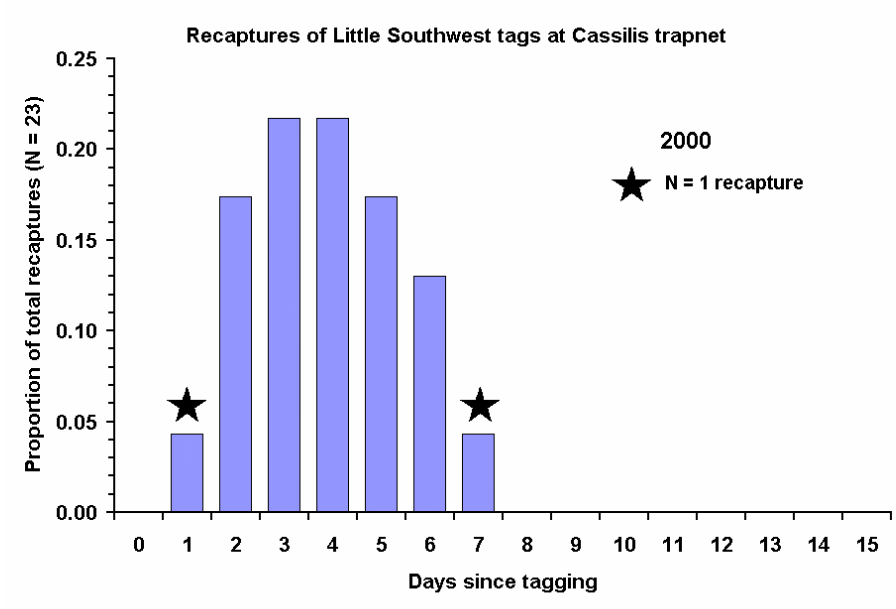


Figure 10. Timing of smolt movements from freshwater of the Little Southwest Miramichi to the tidal waters trapnets of the Northwest Miramichi estuary, 1999.



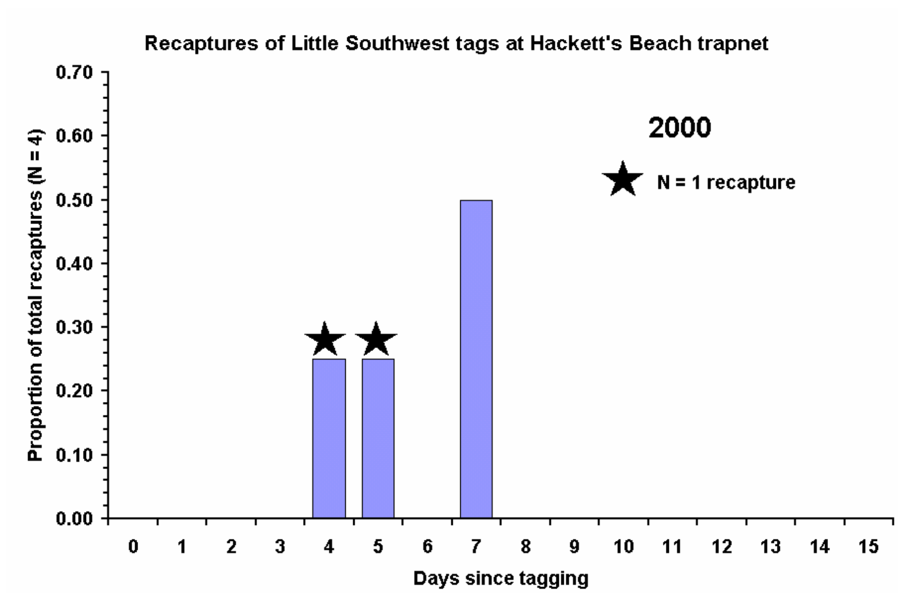
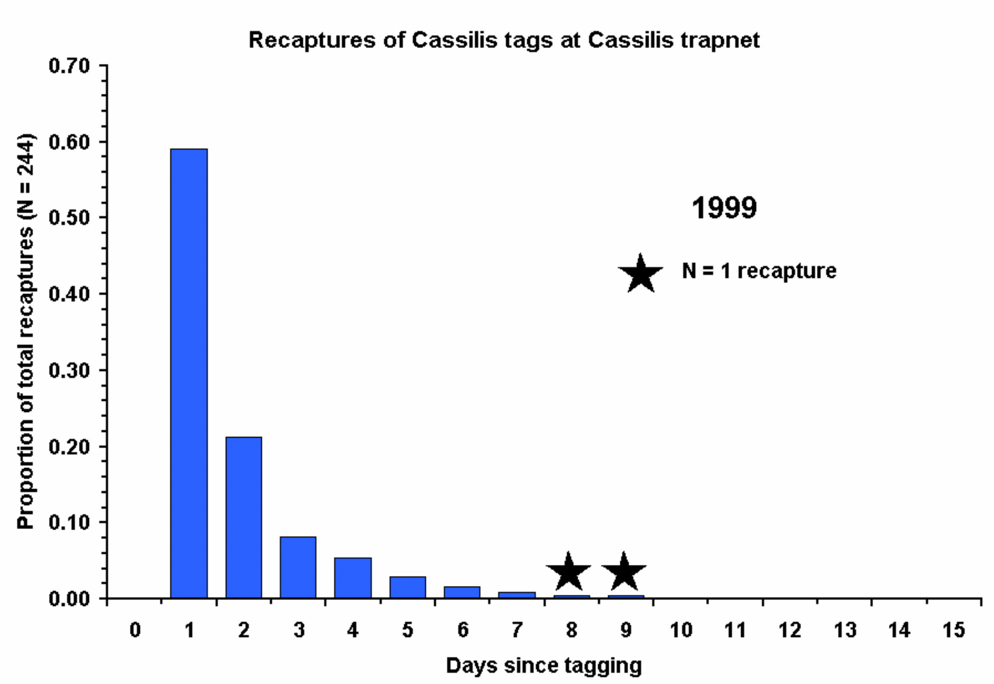


Figure 11. Timing of smolt movements from freshwater of the Little Southwest Miramichi to the tidal waters trapnets of the Northwest Miramichi estuary, 2000.



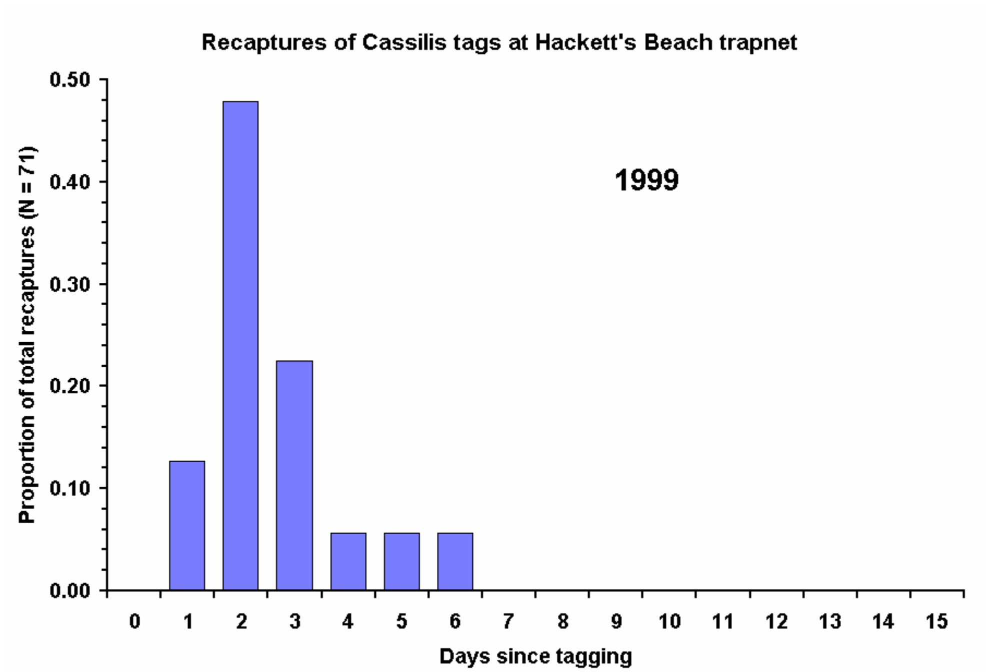


Figure 12. Timing of smolt movements through tidal waters of the Northwest Miramichi estuary, 1999.

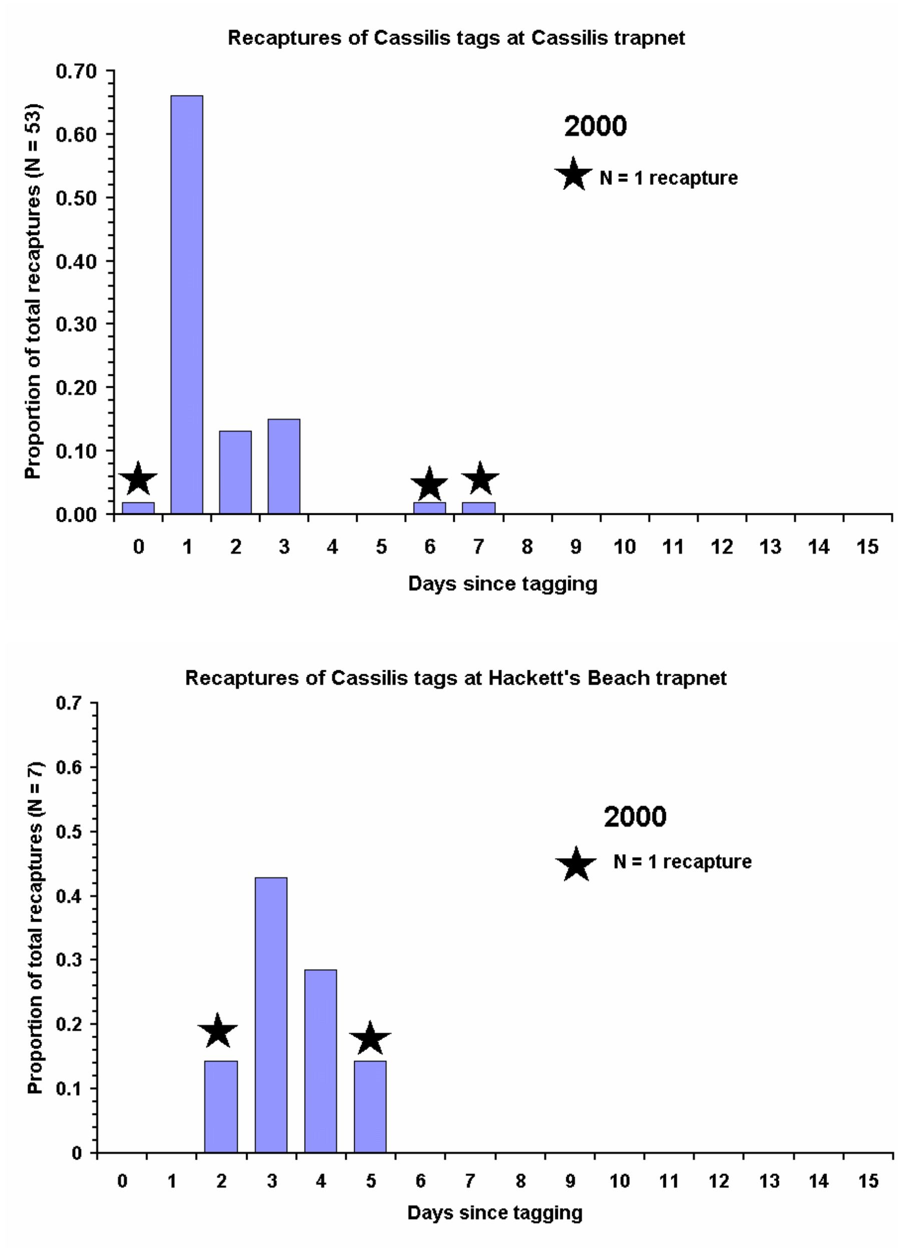


Figure 13. Timing of smolt movements through tidal waters of the Northwest Miramichi estuary, 2000.

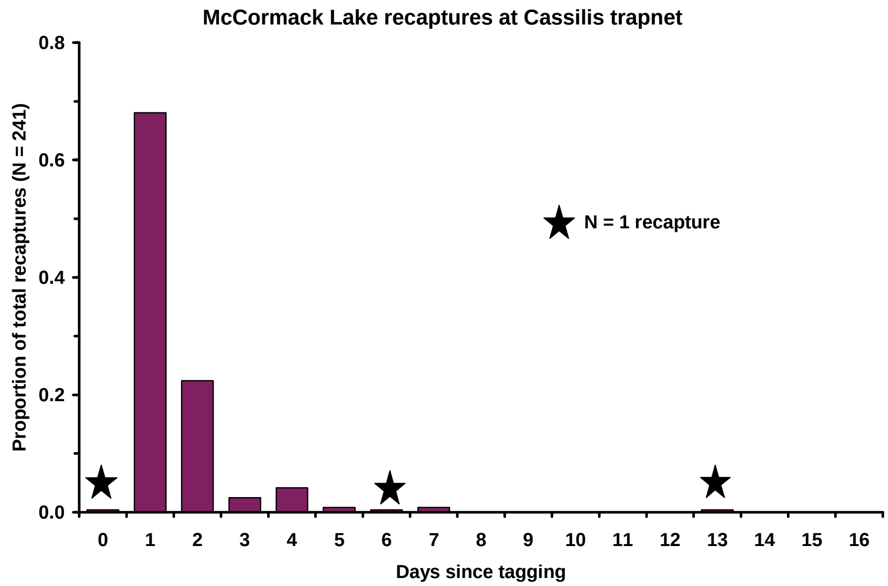


Figure 14. Timing of recaptures at the estuary trapnet of McCormack Lake cage reared smolts released into Little River (Northwest Miramichi) in 1998.

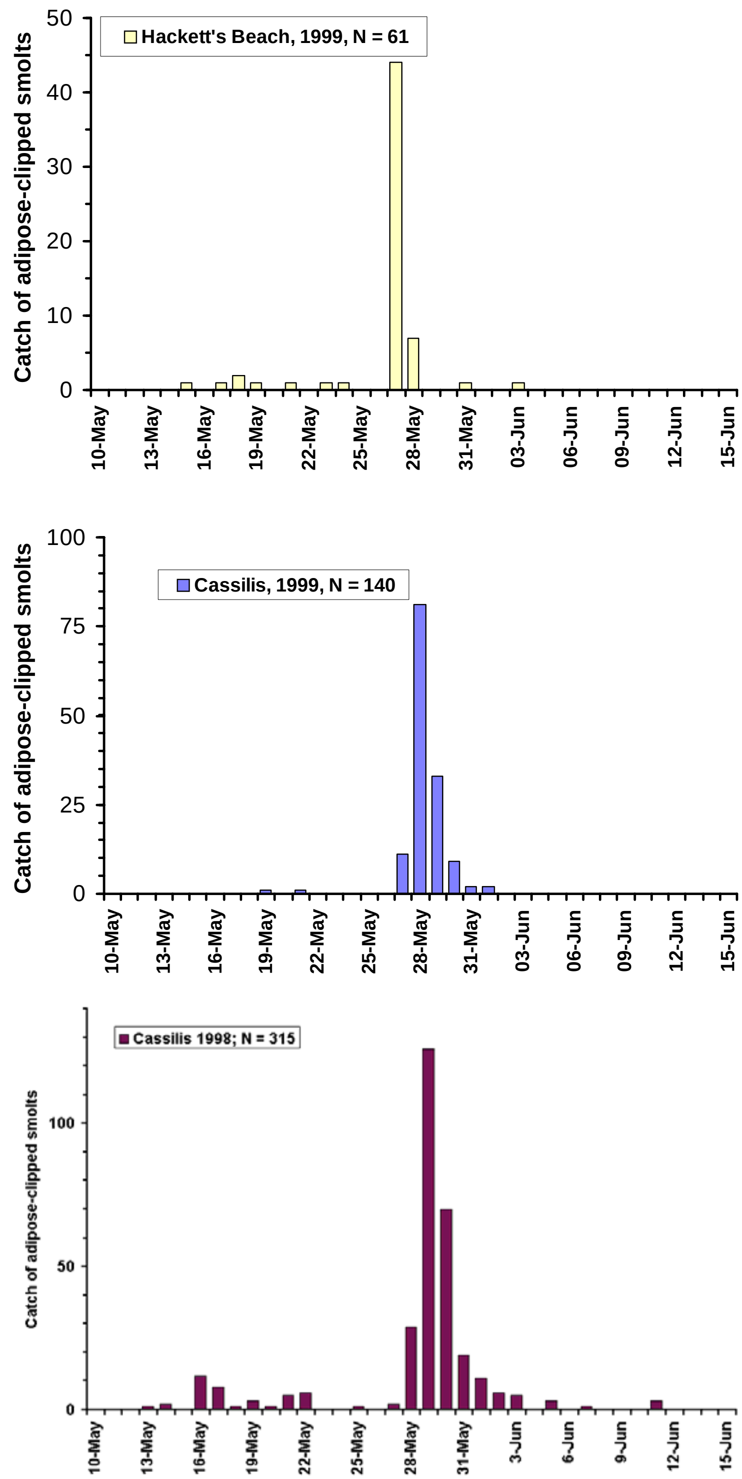


Figure 15. Timing of catches of adipose-clipped smolts at the tidal water trapnets in the Northwest Miramichi in 1998 and 1999. Less than five adipose-clipped smolts were observed at each trapnet in 2000.

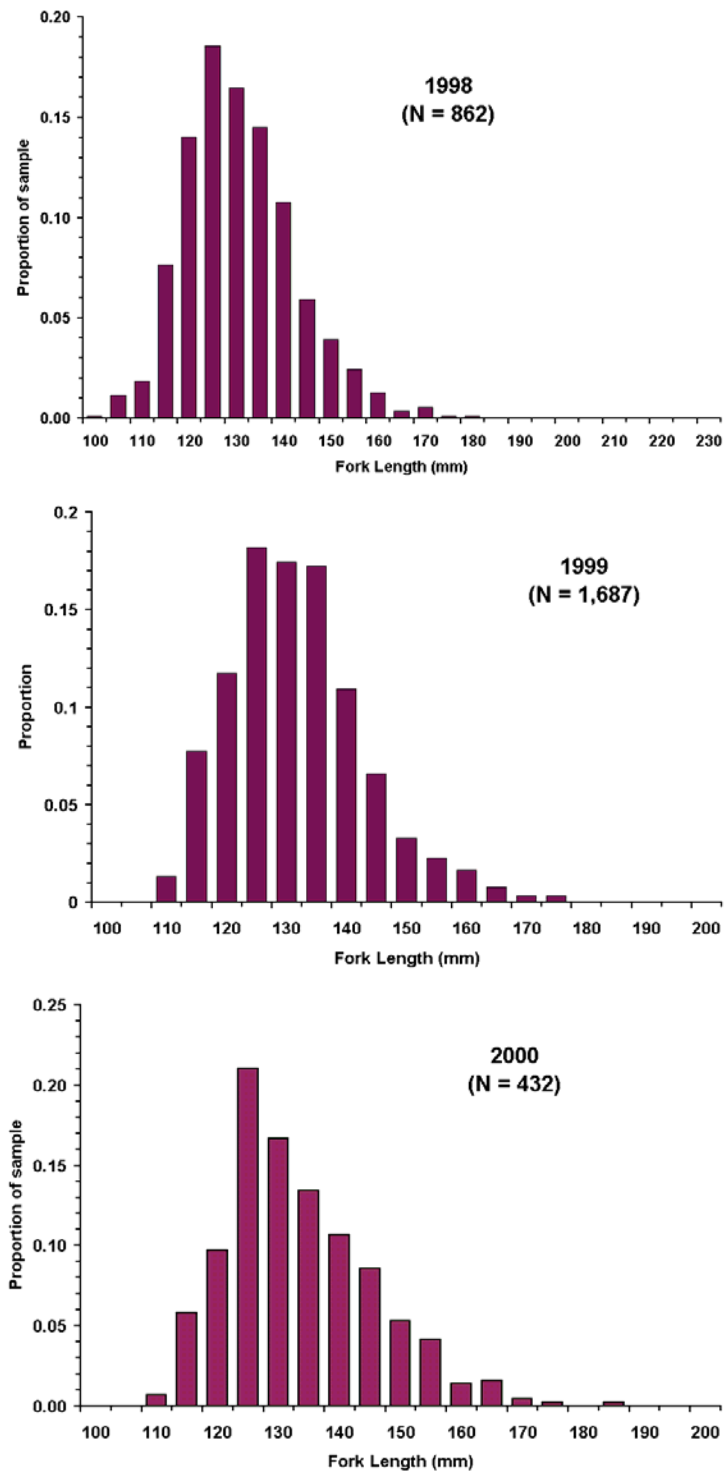


Figure 16. Fork length (mm) distribution of wild smolts (daily samples weighted by daily total catch) from the Northwest Miramichi, 1998 to 2000. Lenghts are from the upper trapnet in 1998, from the lower trapnet in 1999 and from both trapnets in 2000.

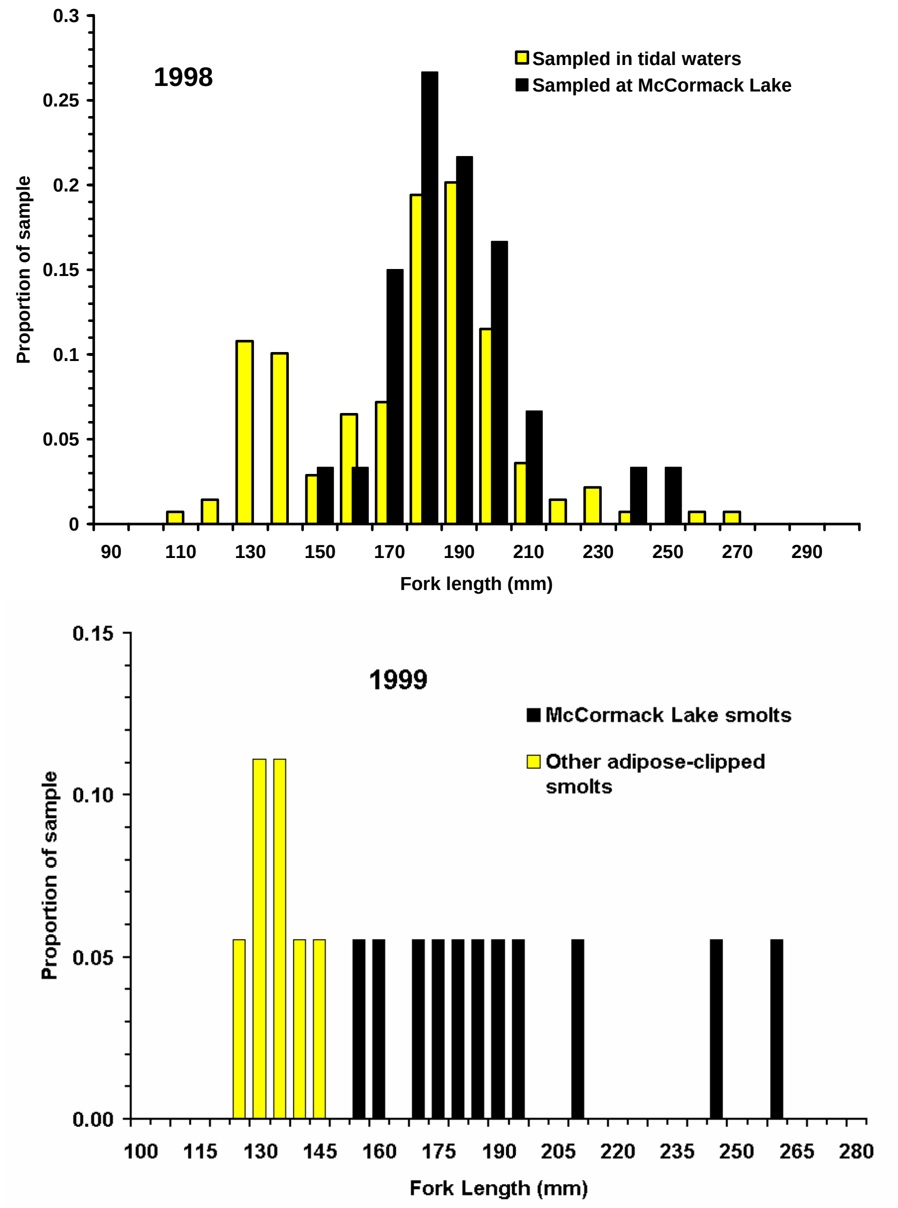


Figure 17. Fork length (mm) distributions of adipose-clipped smolts (all samples, unweighted) sampled from the Cassilis trapnet in tidal waters in 1998 and the Hacketts Beach trapnet in tidal waters in 1999. In 1998, the adipose-clipped smolt size distribution of the McCormack Lake cage-reared smolts is shown in comparison to the overall length distribution of adipose-clipped smolt sampled in the estuary.

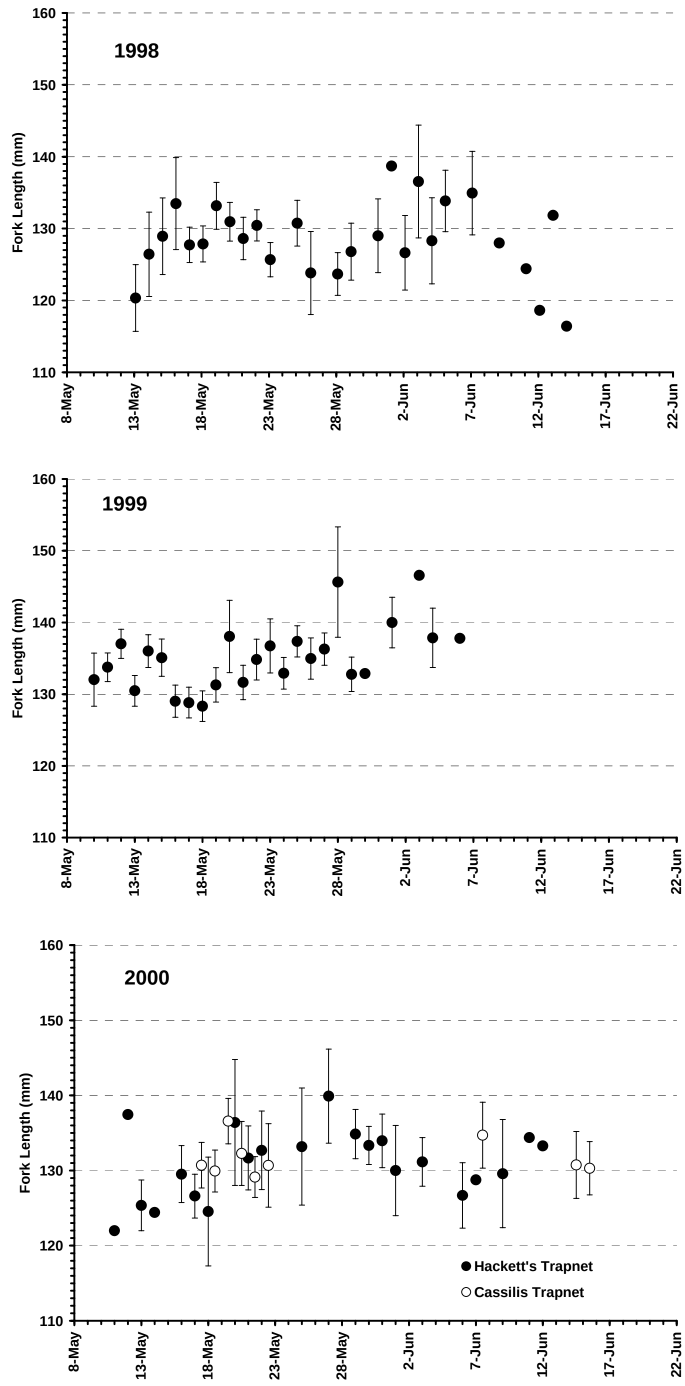


Figure 18. Mean daily fork length of wild smolts from the Northwest Miramichi River, 1998 to 2000. Means are shown when more than 5 fish were measured on any given day. Standard error bars (+/- 2X) are shown when at least 10 fish were measured on any given day.

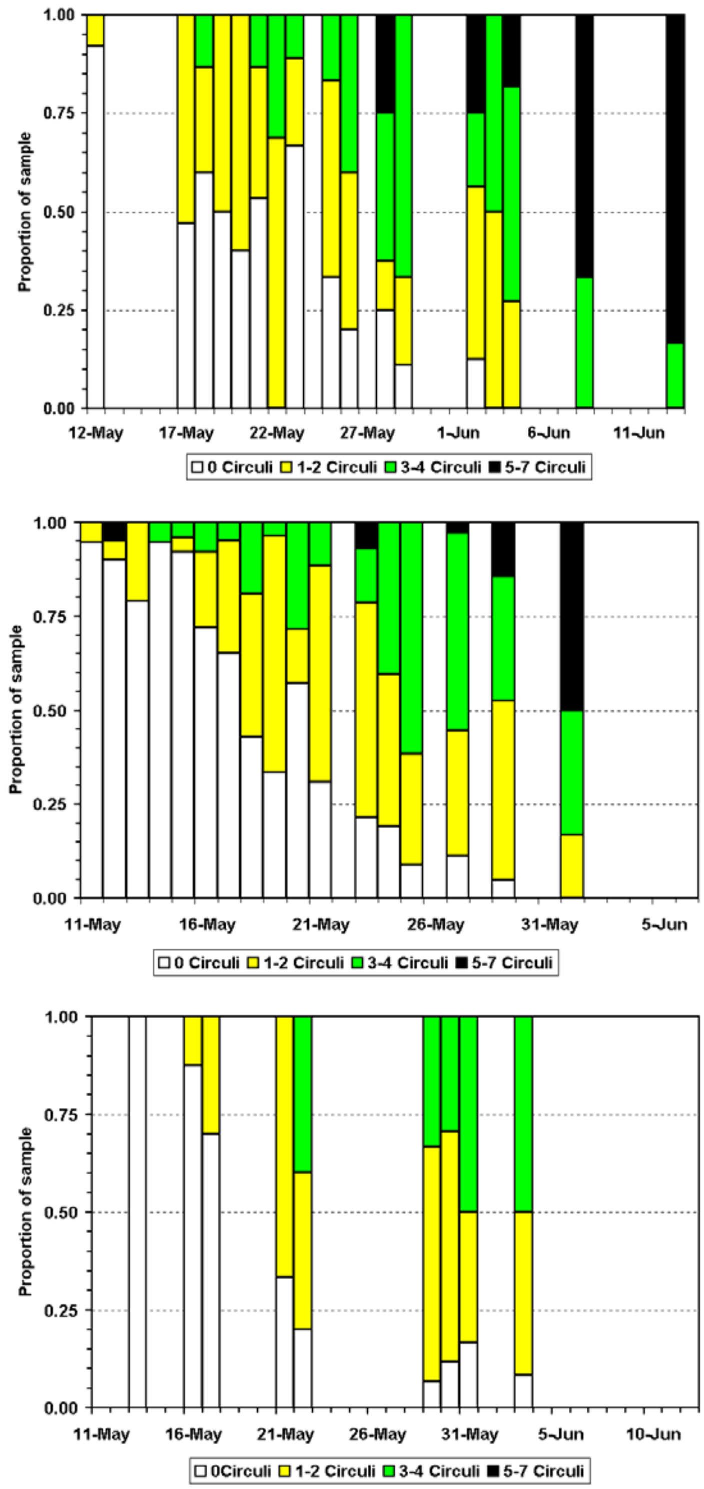


Figure 19. Extent of plus growth after the last annulus on scales of Atlantic salmon smolts relative to the date of capture at the tidal water trapnets in 1998 (upper), 1999 (middle) and 2000 (lower). Only dates when five or more samples were available are shown.

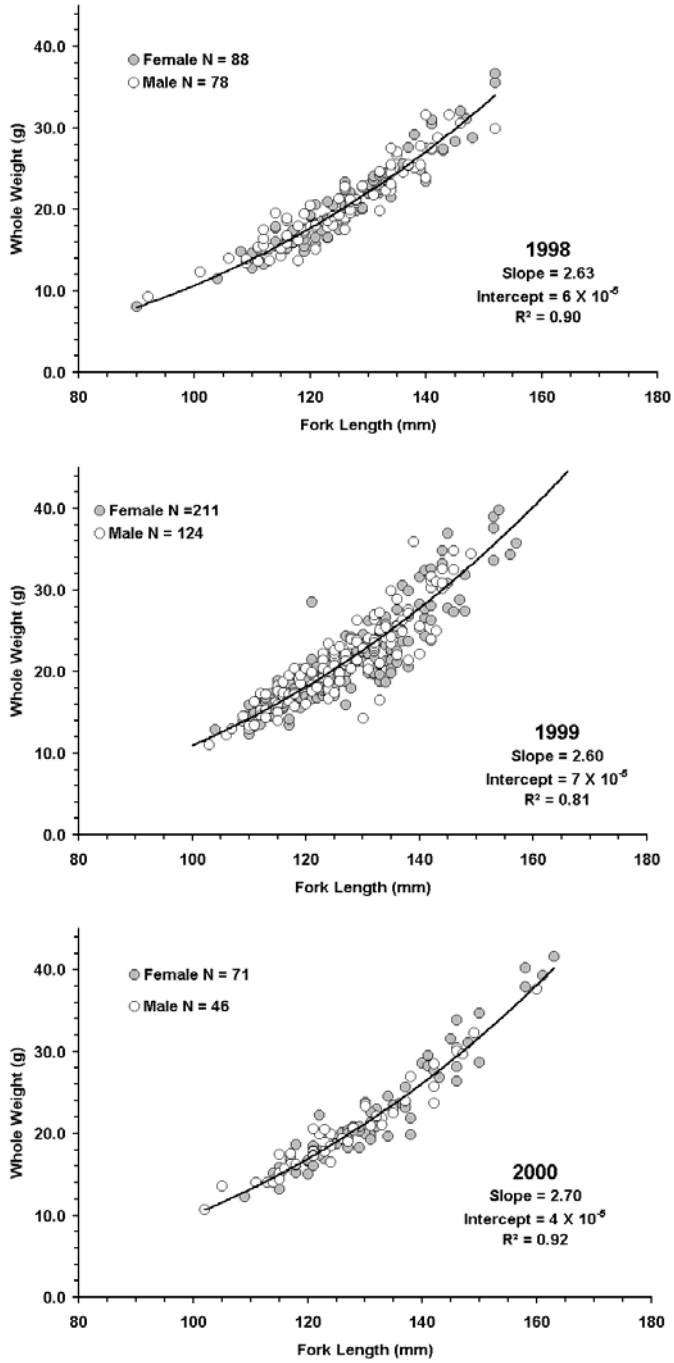


Figure 20. Length weight relationhsips for wild Atlantic salmon smolts from the Northwest Miramichi River for 1998 (upper), 1999 (middle) and 2000 (lower). The slope and intercept values in each panel are the values of the power function (Weight = **intercept** * Length $^{\textbf{slope}}$) for sexes combined.

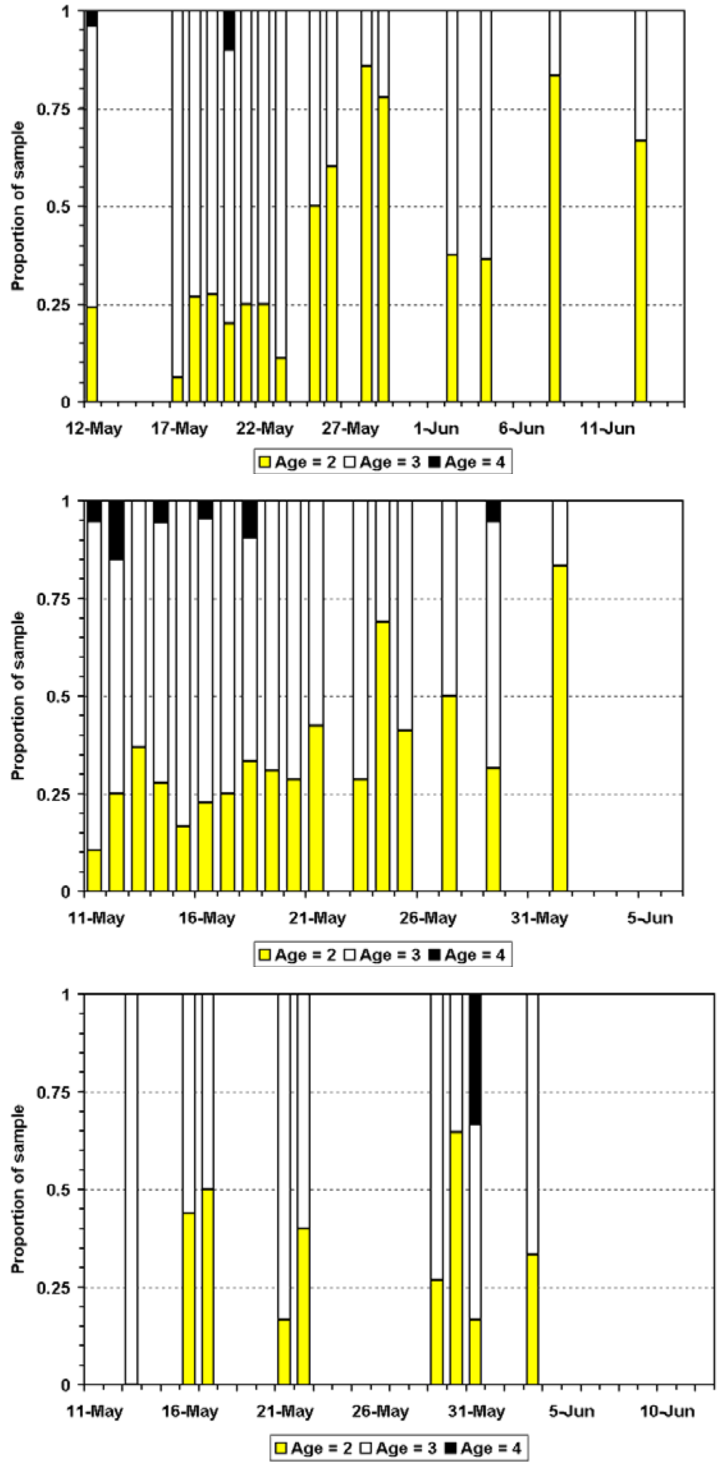


Figure 21. Smolt age distribution relative to date sampled in the smolt run of the Northwest Miramichi for 1998 (upper), 1999 (middle) and 2000 (lower). Only dates when at least five samples were aged are shown.

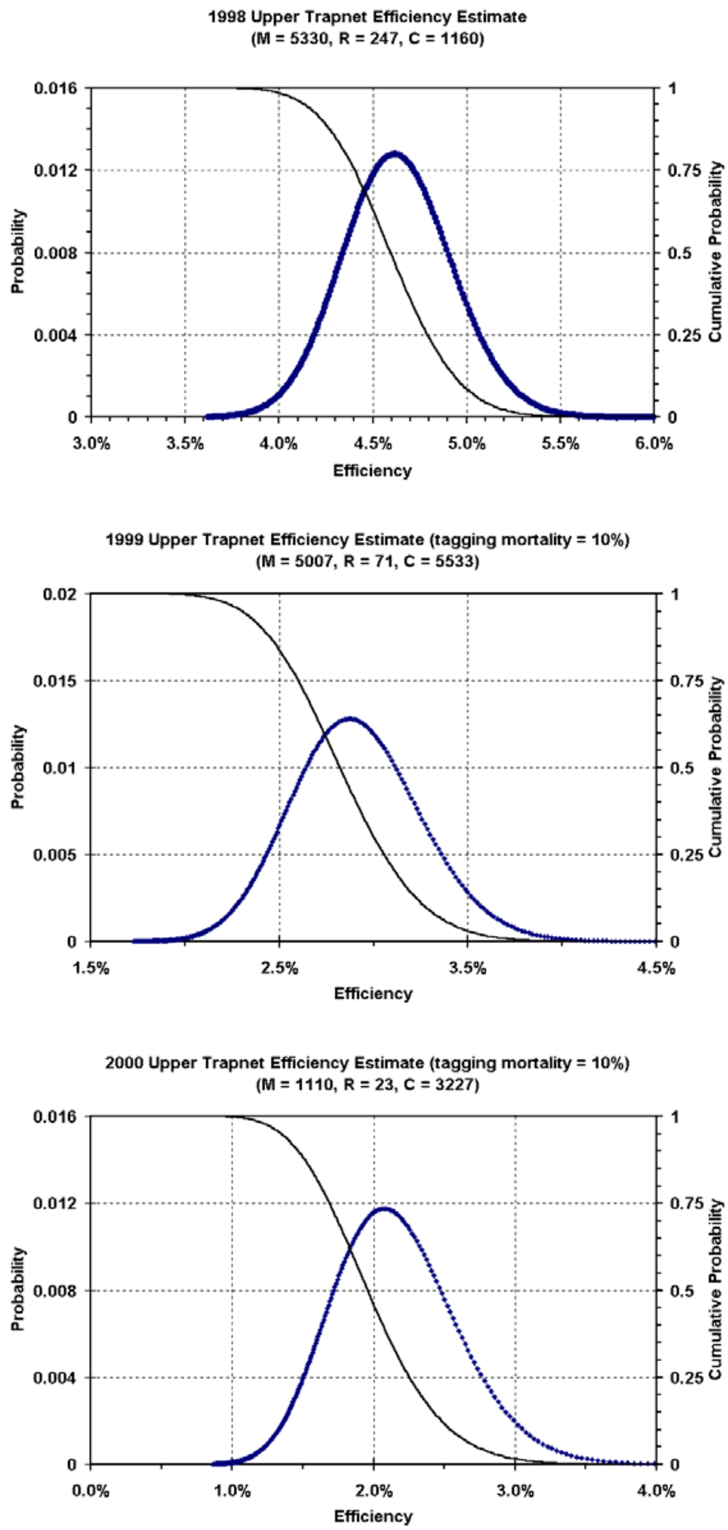


Figure 22. Pooled Bayesian estimates of Cassilis estuary trapnet efficiency for 1998, 1999 and 2000.

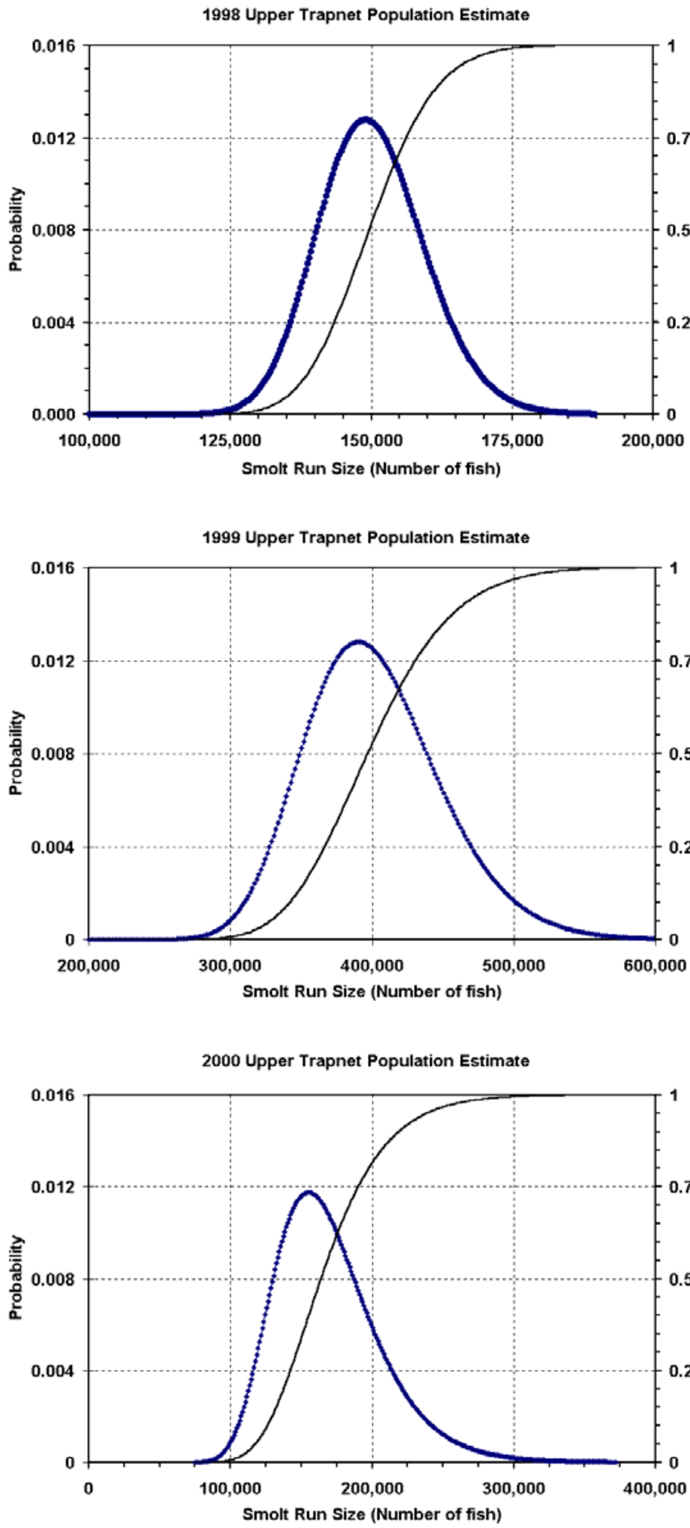


Figure 23. Pooled Bayesian estimates of Northwest Miramichi smolt run size for 1998, 1999 and 2000.

Appendix 1a. Recoveries of Atlantic salmon smolts at the Cassilis trapnet originally tagged at the rotary screw trap in the Little Southwest Miramichi, 1999.

Tagged at			Recaptured at Cassilis																												
Little Southwest			May																				June							For Tag	% Seen
Month	Day	Tagged	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	Group	Again
May	11	30				1																								1	3.3%
	12	14																												0	0.0%
	13	11																												0	0.0%
	14	12																												0	0.0%
	15	40																												0	0.0%
	16	77							1	1																				2	2.6%
	17	98								1		1																		2	2.0%
	18	168								1	1																			2	1.2%
	19	176										2																		2	1.1%
	20	226											3				1													4	1.8%
	21	230														1														1	0.4%
	22	89														1														1	1.1%
	23	88																												0	0.0%
	24	101																												0	0.0%
	25	82																												0	0.0%
	26	188																		1	2									3	1.6%
	27	91																			1									1	1.1%
	28	24																												0	0.0%
	29	17																												0	0.0%
	30	10																												0	0.0%
	31	19																												0	0.0%
June	1	10																												0	0.0%
	2	10																												0	0.0%
	3	4																												0	0.0%
	4	1																												0	0.0%
	5	4																												0	0.0%
	6	1																												0	0.0%
	7	0																													
	8	1																												0	0.0%
Total		1822	0	0	0	1	0	0	1	3	1	3	3	0	0	2	1	0	0	1	3	0	0	0	0	0	0	0	0	19	1.0%
Catch at Cassilis			87	95	219	308	234	177	989	4233	67	2262	893	89	132	88	418	71	157	183	194	113	65	8	83	12	7	7	11	11202	

Appendix 1b. Recoveries of Atlantic salmon smolts at the Hacketts Beach trapnet originally tagged at the rotary screw trap in the Little Southwest Miramichi, 1999.

Tagged at			Recaptured at Hackett's Beach																																Total	
Little Southwest			May																									June							for tag	% seen
Month	Day	Tagged	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	group	again
May	7	.																																	.	.
	8	.																																	.	.
	9	.																																	.	.
	10	.																																	.	.
	11	30																																	0	0.0%
	12	14									1	1																							2	14.3%
	13	11																																	0	0.0%
	14	12																																	0	0.0%
	15	40																																	0	0.0%
	16	77																		1															1	1.3%
	17	98													1																				1	1.0%
	18	168																																	0	0.0%
	19	176															1																		1	0.6%
	20	226																					1												1	0.4%
	21	230																		5	1														6	2.6%
	22	89																		1															1	1.1%
	23	88																																	0	0.0%
	24	101																																	0	0.0%
	25	82																																	0	0.0%
	26	188																					1												1	0.5%
	27	91																																	0	0.0%
	28	24																																	0	0.0%
	29	17																																	0	0.0%
	30	10																																	0	0.0%
	31	19																																	0	0.0%
June	1	10																																	0	0.0%
	2	10																																	0	0.0%
	3	4																																	0	0.0%
	4	1																																	0	0.0%
	5	4																																	0	0.0%
	6	1																																	0	0.0%
	7	0																																	0	.
	8	1																																	0	0.0%
Total		1822	0							0	1	1	0	0	1	0	1	0	0	7	1	0	2	0	0	0	0	0	0	0	0	0	0	0	14	0.8%
Catch at Hackett's Beach			1	.	.	112	262	100	150	120	250	474	930	610	272	19	592	71	41	723	221	54	331	18	96	9	1	29	2	10	22	3	8	3		5534

Appendix 2. Recoveries of Atlantic salmon smolts at the Cassilis trapnet originally tagged at the rotary screw trap in the Little Southwest Miramichi, 2000.

Tagged at			Recaptured at Cassilis																																								Total	
Little Southwest			May																			June																					for tag	% seen
Month	Day	Tagged	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	group	again
May	5	1																																									0	0.0%
	6	13																																									0	0.0%
	7	14																																									0	0.0%
	8	12																																									0	0.0%
	9	26																																									0	0.0%
	10	15																																									0	0.0%
	11	16																																									0	0.0%
	12	11																																									0	0.0%
	13	11																																									0	0.0%
	14	14																																									0	0.0%
	15	10																																									0	0.0%
	16	31																																									0	0.0%
	17	18																																									0	0.0%
	18	18																																									0	0.0%
	19	33																																									0	0.0%
	20	83																																									0	0.0%
	21	68																																									0	0.0%
	22	50																																									0	0.0%
	23	65																1																									1	1.5%
	24	35																																									0	0.0%
	25	61																																									0	0.0%
	26	56																																									0	0.0%
	27	48																					1																				1	2.1%
	28	77																					2																				2	2.6%
	29	58																					2																				2	3.4%
	30	58																				1	2																				3	5.2%
	31	40																					1																				1	2.5%
June	1	80																																									0	0.0%
	2	87																									1																1	1.1%
	3	64																									3	1	1														5	7.8%
	4	22																								1	2		1		1												5	22.7%
	5	14																																									0	0.0%
	6	5																																									0	0.0%
	7	8																																1									1	12.5%
	8	1																																									0	0.0%
	9	3																																									0	0.0%
	10	2																																									0	0.0%
	11	2																																					1				1	50.0%
	12	1																																									0	0.0%
	13	1																																									0	0.0%
	14	1																																									0	0.0%
Total		1233	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	8	0	0	1	6	1	2	0	1	0	0	1	0	0	0	0	1	0	0	0	23	1.9%
Catch at Cassilis			10	3	2	13	56	79	73	37	77	23	67	232	148	36	81	171	207	22	44	210	1096	63	37	71	148	28	23	9	39	12	11	19	23	38	5	8	2	1	1	2	3227	
(marked and unmarkd excluding Cassilis recaptures)																																												

Appendix 3. Catch of Atlantic salmon smolts tagged at the Cassilis trapnet and recaptured at the Hackett's Beach trapnet in the Northwest Miramichi, 1999.

Tagged at Cassilis			Recaptured at Hackett's Beach																																Total	
			May																									June							for tag	% seen
Month	Day	Tagged	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	group	again
May	7	.																																	.	.
	8	.																																	.	.
	9	.																																	.	.
	10	.																																	.	.
	11	.																																	.	.
	12	85										1	1	3																					5	5.9%
	13	94										1	1																						2	2.1%
	14	217										2	1																						3	1.4%
	15	297											1	1	1																				3	1.0%
	16	228													3																				3	1.3%
	17	175													1																				1	0.6%
	18	300																																	0	0.0%
	19	1294															15	1		2	1														19	1.5%
	20	60																																	0	0.0%
	21	828																	1	6	1														8	1.0%
	22	598																	1	12	2														15	2.5%
	23	86																		3															3	3.5%
	24	128																					1												1	0.8%
	25	85																																	0	0.0%
	26	411																					5												5	1.2%
	27	59																																	0	0.0%
	28	75																								1									1	1.3%
	29	138																																	0	0.0%
	30	150																																	0	0.0%
	31	74																																	0	0.0%
June	1	58																															1		1	1.7%
	2	8																																	0	0.0%
	3	82																														1			1	1.2%
	4	9																																	0	0.0%
	5	7																																	0	0.0%
	6	7																																	0	0.0%
	7	10																																	0	0.0%
Total		5563	0							0	0	4	4	4	5	0	15	1	2	23	4	0	6	0	0	1	0	0	0	0	0	1	1	0	71	1.3%
Catch at Hackett's Beach			1	.	.	112	262	100	150	120	250	474	930	610	272	19	592	71	41	723	221	54	331	18	96	9	1	29	2	10	22	3	8	3		5534

Appendix 4. Matrix of smolts tagged at Cassilis and recaptured at the Hackett's Beach trapnet, 2000.

Tagged at Cassilis			Recaptured at Hackett's Beach																																										Total	
			May																							June																			for tag	% seen
Month	Day	Tagged	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	group	again
May	13	10																																									0	0.0%
	14	3																																									0	0.0%
	15	2																																									0	0.0%
	16	13																																									0	0.0%
	17	.																																									.	.
	18	.																																									.	.
	19	.																																									.	.
	20	.																																									.	.
	21	.																																									.	.
	22	.																																									.	.
	23	65																																									0	0.0%
	24	232																																									0	0.0%
	25	143																																									0	0.0%
	26	36																																									0	0.0%
	27	80																																									0	0.0%
	28	169																					1																				1	0.6%
	29	205																																									0	0.0%
	30	18																																									0	0.0%
	31	42																																									0	0.0%
June	1	210																																									0	0.0%
	2	1082																									1	1	1														3	0.3%
	3	58																																									0	0.0%
	4	32																																									0	0.0%
	5	71																													1		1										2	2.8%
	6	147																															1										1	0.7%
	7	27																																									0	0.0%
	8	22																																									0	0.0%
	9	9																																									0	0.0%
	10	39																																									0	0.0%
	11	11																																									0	0.0%
	12	11																																									0	0.0%
	13	19																																									0	0.0%
	14	23																																									0	0.0%
	15	38																																									0	0.0%
	16	5																																									0	0.0%
	17	6																																									0	0.0%
	18	2																																									0	0.0%
	19	1																																									0	0.0%
	20	1																																										
	21	2																																										
Total		2834	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	1	0	1	0	2	0	0	0	0	0	0	0	0	0	0	7	0.2%
Catch at Hackett's			0	2	5	10	34	7	4	86	76	11	2	10	33	29	4	1	17	2	20	3	85	101	44	15	3	54	5	2	24	4	0	2	3	8	7	0	0	0	0	1	0	1		715

Appendix 5. Recapture matrix of smolts tagged at the Cassilis trapnet and recaptured at the Cassilis trapnet, 1999.

Tagged at Cassilis			Recaptured at Cassilis																											Total	
			May																				June							for tag	% seen
Month	Day	Tagged	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	group	again
May	12	85		1		2	1					1																		5	5.9%
	13	94			2				1	1																				4	4.3%
	14	217				6			2	3		1	1																	13	6.0%
	15	297					3		4	7		3																		17	5.7%
	16	228							1	2		1																		4	1.8%
	17	175								7		1	1																	9	5.1%
	18	300								9		5	1																	15	5.0%
	19	1294									5	40	4																	49	3.8%
	20	60										3	2																	5	8.3%
	21	828											92																	92	11.1%
	22	598												3	1			1												5	0.8%
	23	86													1															1	1.2%
	24	128														1														1	0.8%
	25	85																					1							1	1.2%
	26	411																		1										1	0.2%
	27	59																												0	0.0%
	28	75																		3		2								5	6.7%
	29	138																			4	1								5	3.6%
	30	150																				8								8	5.3%
	31	74																												0	0.0%
June	1	58																												0	0.0%
	2	8																												0	0.0%
	3	82																								3			1	4	4.9%
	4	9																												0	0.0%
	5	7																												0	0.0%
	6	7																												0	0.0%
	7	10																												0	0.0%
Total		5563	0	1	2	8	4	0	8	29	5	55	101	3	2	1	0	1	0	4	4	11	1	0	0	3	0	0	1	244	4.4%

Appendix 6. Recapture matrix of smolts tagged at the Cassilis trapnet and recaptured at the Cassilis trapnet, 2000.

Tagged at Cassilis			Recaptured at Cassilis																																								Total	
			May																			June																					for tag	% seen
Month	Day	Tagged	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	group	again
May	13	10																																									0	0.0%
	14	3																																									0	0.0%
	15	2																																									0	0.0%
	16	13																																									0	0.0%
	17	.																																									.	.
	18	.																																									.	.
	19	.																																									.	.
	20	.																																									.	.
	21	.																																									.	.
	22	.																																									.	.
	23	65												1																													1	1.5%
	24	232													4																												4	1.7%
	25	143																																									0	0.0%
	26	36																	1																								1	2.8%
	27	80																																									0	0.0%
	28	169																	1																								1	0.6%
	29	205																		2		1																					3	1.5%
	30	18																																									0	0.0%
	31	42																				1																					1	2.4%
June	1	210																					5					1															6	2.9%
	2	1082																						14	2																		16	1.5%
	3	58																																									0	0.0%
	4	32																								3						1											4	12.5%
	5	71																								1																	1	1.4%
	6	147																											3														3	2.0%
	7	27																											1														1	3.7%
	8	22																														1											1	4.5%
	9	9																																									0	0.0%
	10	39																														2	1	3									6	15.4%
	11	11																																									0	0.0%
	12	11																																1	1	1							3	27.3%
	13	19																																			1						1	5.3%
	14	23																																									0	0.0%
	15	38																																									0	0.0%
	16	5																																									0	0.0%
	17	6																																									0	0.0%
	18	2																																									0	0.0%
	19	1																																									0	0.0%
	20	1																																									0	0.0%
	21	2																																									0	0.0%
Total		2834	0	0	0	0	0	0	0	0	0	0	0	1	4	0	0	0	2	2	0	2	5	14	2	4	0	1	4	0	0	4	1	4	1	1	1	0	0	0	0	0	53	1.9%