ATLANTIC SALMON (*Salmo salar*) SMOLT MIGRATION FROM THE MARGAREE RIVER, 2001 TO 2003

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ABSTRACT

Clément, M., G. Chaput and P. Leblanc. 2007. Atlantic salmon (S*almo salar*) smolt migration from the Margaree River, 2001 to 2003. Can. Tech. Rep. Fish. Aquat. Sci. 2693: x + 60p.

Production and biological information on Atlantic salmon (*Salmo salar*) smolts (e.g. run timing, sex ratio, size and age) and other fish species from the Margaree River (Nova Scotia) is presented for the years 2001 to 2003. The smolt migration was of short duration (7 weeks) and occurred at the same time each year. During each year, the migration began in early May, peaked in late May - early June and finished by the end of June. The beginning of the smolt migration and peak catches occurred when the mean daily water temperature exceeded 7°C and 13°C, respectively. Increased catch with variation in water discharge was observed in 2002 and 2003. The smolt run was dominated by 2-year old (41% to 55% annually) and 3-year old smolts (43% to 57% annually) with a small proportion (< 4% annually) of 4-year olds. Most (> 70%) smolts were females but the majority (10 of 11) of the 4-year olds were males. No estimate of total smolt production is available for 2001 because of the low number of recaptures. In 2002, production was estimated at 63,200 smolts using a stratified estimate (Darroch model) which accounts for the changes in efficiency through the season. In 2003, the stratified estimate was 83,050 smolts. Based on the stratified model estimates, production in 2002 was 2.3 smolts per 100 m² and increased to 3.0 smolts per 100 m² in 2003.

RÉSUMÉ

Clément, M., G. Chaput and P. Leblanc. 2007. Atlantic salmon (*Salmo salar*) smolts migration from the Margaree River, 2001 to 2003. Can. Tech. Rep. Fish. Aquat. Sci. 2693: x + 60p.

La production et les caractéristiques biologiques des saumoneaux du saumon atlantique (*Salmo salar*) (par ex. calendrier de la migration, rapport mâles:femelles, la taille et l'âge) et d'autres espèces de poissons de la rivière Margaree (Nouvelle Ecosse) sont présentées pour les années 2001 à 2003. La durée de la migration des saumoneaux a été courte (7 semaines) et s’est produite durant la même période de temps à toutes les années. Au cours de chaque année, la migration des saumoneaux a débuté en mai, a culminée vers la fin mai - début juin et s’était terminée par la fin juin. Le commencement de la migration des saumoneaux et les captures substantielles ont été enregistrés lorsque les températures journalières moyennes ont dépassées le seuil de 7°C et 10°C, respectivement. L’augmentation des captures était associée à la variation du débit en 2002 et 2003. La dévalaison était dominée par des saumoneaux âgés de 2 ans (41% à 55% annuellement) et 3 ans (43% à 57% annuellement) avec une faible proportion (< 4% annuellement) de saumoneaux âgés de 4 ans. La plus part (> 70%) des saumoneaux étaient des femelles tandis que pour les saumoneaux âgés de 4 ans, la majorité (10 de 11) étaient des mâles. Aucun estimé de la production totale des saumoneaux est disponible pour 2001 dû au faible nombre de re-captures. Selon un estimé stratifié qui prend en considération les variations d’efficacité durant la saison (modèle de Darroch), la production a été estimée à 63 200 saumoneaux en 2002. En 2003, l’estimé stratifié était de 83 050 saumoneaux. La production en 2002 était de 2,3 saumoneaux par 100 m² et a augmenté à 3,0 saumoneaux par 100 m² en 2003.

INTRODUCTION

The decline of Atlantic salmon stocks in eastern Canada is generally believed to be the result of poor marine survival, particularly during the post-smolt phase (Holtby *et al.* 1990, Ritter 1993, Friedland et al. 2003). Marine mortality has been reported to be the highest during the first year at sea (Chadwick 1987) and is negatively related to the size of the smolts, such that the smallest smolt have the highest mortality (Lundqvist *et al.* 1994).

Size and age of smolts are largely determined by earlier freshwater environmental conditions (Thorpe *et al.* 1989). For example, Metcalfe and Thorpe (1990) found a positive correlation between age of smolts and latitude and concluded that age at smoltification could be predicted based on latitude and an index of growth opportunity. Metcalfe (1998) predicted that short-term fluctuations of environmental conditions during the initial growth period of juvenile salmon could induce high variations in subsequent life history traits. According to Metcalfe's model, environmental conditions which favor juvenile growth during the spring or early summer will result in a decrease of smolt age and a balanced sex ratio. Alternatively, smolt age and the proportion of mature parr will increase under poor growth conditions. Under this scenario, the sex ratio of the smolts will be skewed toward females because of the lower survival of the mature parr and the smolt production will be reduced (Metcalfe 1998). However, fast-growing parr smoltify at an earlier age and smaller size than slow-growing parr (Økland *et al.* 1993) and experience lower survival rates when entering the marine environment (Klemetsen et al. 2003).

Salmon growth rates may be reduced if water temperatures exceed values which are optimum for growth (Metcalfe and Thorpe 1990). Power and Power (1994) predicted that an increase of water temperature in the Miramichi River would result in a decrease of the juvenile growth rate, increase of smolt age and ultimately lead to a decrease in smolt production. Similarly, Minns *et al*. (1995) predicted an increase of smolt age distribution caused by climate change. Changes in the freshwater temperatures may also perturb the adaptive value of the timing of the migration (e.g. de-synchronization between the timing of the smolt migration and optimum marine conditions; Gargett *et al.* 2001, Friedland *et al.* 2003). The importance of timing of migration is further suggested by DeVries *et al.* (2004) who concluded that chinook salmon (*Oncorhynchus tshawytscha*) use lunar phase (apogee or quarter moon) as a cue for optimal timing of migration to the estuary but found a weaker relationships between lunar phase and both coho salmon (*O. kisutch*) and sockeye salmon(*o. nerka*) movements.

In contrast to the rivers in the Inner Bay of Fundy and the Atlantic coast of Nova Scotia, increased juvenile densities have been observed in several rivers of the southern Gulf of St. Lawrence including the Margaree River and the Miramichi River since the 1970's (Chaput and Claytor 1989, Chaput *et al.* 2001, Swansburg *et al*. 2002, Leblanc and Chaput 2003). Although adult returns declined (DFO 2003), electrofishing surveys indicated that egg depositions appeared adequate to maintain juvenile populations. However, smolt production from most rivers in the Maritime provinces remains unknown, principally due to the difficulty of operating fish counting stations during high water discharge events. Although counting fences can be used in small streams to estimate the number of migrating smolts (e.g. Cunjak *et al.* 1993), partial count and mark-recapture methods are needed for estimating smolt production in larger rivers (e.g. Dempson and Stansbury 1991). The development of the rotary screw fish trap (RST) in the 1980s facilitated smolt enumeration in large rivers and programs to quantify smolt production began in 1998 in several rivers in New Brunswick (Chaput *et al*. 2002, Chaput *et al*. 2004, Chaput and Jones 2004).

The smolt program was initiated in the Margaree River (Nova Scotia) in 2001 to estimate smolt production and obtain biological information on the migrating salmon (e.g. run timing, sex ratio, size and age) and other species present in the Margaree River. This report describes the methods and results of the first three years (2001 - 2003) of smolt monitoring in the Margaree River.

MATERIALS AND METHODS

Geographic Area

The Margaree River (46°30'N, 61°10'W) is located on the Northwest coast of Cape Breton Island (Inverness County, Nova Scotia), and has a drainage basin area of 1,178 km^2 (Fig. 1). The Southwest Margaree River originates from Lake Ainslie and the Northeast Margaree River from the Cape Breton Highlands. The two main branches converge at the Margaree Forks and become the Margaree River.

Field operations

The RST (diameter = 1.82 m, Key Mill Construction Ltd., Ladysmith, BC) was installed approximately 600 m upstream of the head of tide in a constricted area of the Margaree River (Figs. 1, 2a; see Chaput and Jones (2004) for a detailed description of the RST design and operation). The RST was anchored using an overhead cable, and lights, buoys and warning signs were installed on and/or upstream of the RST (Fig. 2b). The RST could be moved vertically, laterally and longitudinally depending on water depth and water flow.

The RST was accessed with a motorized scow and approached from downstream. The RST was fished in the morning. All fish were identified to species and counted. Fish other than Atlantic salmon wild smolts were measured (maximum of 50 per day) and released unmarked at the trap. Detailed sampling protocols for Atlantic salmon during each sampling season are described below.

The lower size limit of smolts was established at 10.5 cm (fork length, FL) based on length frequency analysis and anatomic features (loss of parr marks, silver coloration and black edges on fins). A subsample of wild smolts was marked anterior to the dorsal fin with individually numbered polyethylene streamer tags (size 13P, Hallprint©). Marked smolts were transported upriver and released 5.3 km upstream at Doyles Bridge (Fig.

1). Fork length, weight, age and sex were obtained from a sample of the captured smolts.

The efficiency of the RST for catching Atlantic salmon smolts was determined using mark and recapture experiments. Stratified (Darroch, Arnason *et al.* 1996) and simple (Bayesian, Peterson; Gazey and Staley 1986) models were fitted to the data. Dempson and Stansbury (1991) reported a survival rate of 97.7% of marked smolts kept in holding box during 10 days. To be conservative, we assumed that survival of tagged smolts to recapture was 90% in a wild environment. Tag loss could be determined by the presence of tagging scars anterior to the dorsal fin.

The Aquatic Development Association of Margaree (ADAM) has stocked smolts and fall fingerlings of Margaree River origin in the Margaree for a number of years (Appendix 1). Hatchery-reared smolts captured in the RST were identified by the absence of an adipose fin. The hatchery origin was also verified based on scale analysis. However, some hatchery-reared smolts were not clearly fin clipped and recently released smolts were identified by the green coloration of their body and fin wear caused by rearing the fish in tanks. Some fingerlings with unclear fin-clipping and released the previous fall may have been misidentified as wild smolts. All hatchery-reared smolts were measured (FL) before release at the trap.

A water temperature logger (Minilog 12 TR, Vemco©) was installed at the RST and the water temperature was recorded hourly. Water discharge from the Northeast Margaree River was obtained from a hydrometric station operated by Environment Canada (Fig. 1).

<u>2001</u>

The RST was set on 10 May and removed on 30 June, 2001 (Table 1). However, the RST was not fishing from 12 May to 14 May because of high water discharge (Appendix 2). Debris often accumulated in the drum and the RST was frequently jammed and not turning when the crew arrived in the morning, particularly in May (Appendix 2). The actual time of jamming was unknown and the catches may have varied according to periods when the RST stopped operating. Overall, the RST was operating properly during 85% of the fishing nights.

In 2001, wild smolts were marked using individually numbered green streamer tags. All marked smolts were immediately released at Doyles Bridge in the morning. Fork length measurements were only obtained from the unmarked smolts to reduce handling stress. Every fifth measured smolt was sacrificed (maximum of 10 smolts per day) and dissected for sex determination. The weight and scale samples for age determination were also obtained from the sacrificed smolts.

2002

The RST was set on 6 May and removed on 26 June, 2002 (Table 1). The RST was moved downstream to a position of higher flow on 29 May. However, the RST was relocated to its original position on 12 June due to high mortality occurring at the second location. The RST was not fishing during the night of 8 May and its capture efficiency may have been reduced by the accumulation of debris during 6 other fishing nights (Appendix 2). Nonetheless, the RST was operating properly during 88% of the fishing nights.

Wings were attached to the RST to increase the capture efficiency during the spring of 2002 (Fig. 3). In contrast to 2001, the smolts were marked with transparent streamer tags, transported to a holding box (1.2m x 1.2 m x 1.2m) installed at Doyles Bridge and released at dusk to decrease the risk of predation. Because of the low recapture rate during the previous spring, most of the captured smolts were marked and released for subsequent recapture in 2002. The majority of the marked smolts were measured. As in 2001, every fifth measured smolt was sacrificed (maximum of 10 smolts per day) for sex determination. The weight and scale samples were also obtained from these smolts.

However, sacrificing was terminated on 6 June, 2002 because of high mortality events which occurred in the holding box of the RST or after handling.

2003

The RST was operational from 7 May to 25 June, 2003 (Table 1) and was installed at the position of highest flow during the entire fishing period. Debris and a defective axle of the RST likely reduced the capture efficiency during 6 and 4 fishing nights, respectively (Appendix 2). The RST was operating properly during 80% of the fishing nights.

The protocol used in 2003 was similar to the procedures conducted in 2002 except the length of the holding box of the RST was increased by 61 cm and a screen was placed at the back of the box to decrease water turbulence and mortalities in the holding box (Table 1). Because of the high number of smolt captured in 2003, a daily maximum of 250 smolts was initially marked. The number of marked smolts was reduced to 200 on 29 May and 100 on 4 June, 2003. A daily maximum of 30 - 35 unmarked smolts were measured (FL) and every fifth measured smolt was sacrificed (maximum of 10 smolts per day).

RESULTS

The water discharge measured at the hydrometric station was high at the start of operation in 2001 and remained so through May (maximum: 161.0 m^3/s; Fig. 4a). Comparatively, water discharge at the start of operation was less than 100 m^3/s in May 2002 and less than 40 m^3/s in May 2003 (Figs. 4b, 4c). Water discharge during June declined to less than 30 m^3/s in all three years (Fig. 4).

Daily mean water temperature was above 6º C in early May and remained generally cooler in 2001 compared to 2002 and 2003. The first date when mean daily water temperature reached 10ºC varied from 20 May in 2003, 22 May in 2002 and 27 May in

2001. Daily mean temperatures reached 15ºC on 1 June in 2002 and 2003 but not until 13 June in 2001. End of season temperatures were, however, warmer in 2001, reaching 19ºC compared to about 17ºC in 2002 and 2003 (Fig. 4).

Wild Atlantic salmon smolts

A total of 1,165 wild smolts were captured in the RST in 2001 (Table 2). The catch of wild smolts increased to 2,340 in 2002 and 8,053 in 2003 (Tables 3, 4). Higher catches in 2002 and 2003 were in part due to the increased efficiency of the RST resulting from installation of deflector wings and relocation to faster water in those years.

There were relatively few incidental mortalities in 2001 (3%; Table 2), the highest mortality occurred on 19 May coincident with an overnight accumulation of woody debris in the RST. Mortalities were greater in number and percentage in 2002 (299 smolts; 13%; Table 3). Ninety-three percent of these mortalities occurred when the RST was relocated to the position of higher water flow (29 May to 12 June, 2002; Table 3). Fewer than 20 smolts died when the RPM was < 6 in 2002 (7 - 28 May, 13 - 26 June; Table 3). The holding box on the RST was elongated and modified in 2003 and the percentage of mortalities decreased (6%) although the absolute number of mortalities increased relative to 2001 and 2002 (Table 4). The RST remained in the area of highest water flow during the entire smolt run in 2003. There was a significant relationship between the mortalities and the total number of fish captured in the RST in 2002 and 2003 ($P < 0.0001$, Fig. 5). However, mortalities often occurred when the RST was jammed with debris or due to mechanical failure. For example, the large mortality of smolts (58 fish) observed on 11 June, 2003 occured when the drum axle broke and the RST jammed overnight (Table 4; Appendix 2).

Run timing

In all years, only a few smolts (maximum daily catches ≤ 6 smolts) were captured at the beginning of the operations (Fig. 6). The timing of catches at the RST was similar among years, with a median date of catch occurring on 30 May in 2002 followed by 2003 at 2 June and 2001 at 5 June. These medians are unadjusted for the variation in RST efficiency. The migration began in early May, peaked in late May - early June and finished by the end of June. Catches of wild smolts generally increased after 15 May, when the mean daily water temperature was near or above 7°C (Figs. 4, 6). In all years, the first large catches of wild smolts occurred when the mean daily water temperature approached 10ºC (Figs. 4, 6). The maximum daily catches in 2002 were obtained after the relocation of the RST to an area of higher water flow (29 May, Fig. 6). In that year, the second highest daily catch coincided with an increase in water discharge (Fig. 4, 6). Daily maximum catch in 2003 was observed on 29 May but it was not associated with a variation in water discharge. Similarly to 2002, the second highest daily catch coincided with an increase in water discharge. Peak catch in 2003 occurred one day after the lunar apogee and catches increased after the new moon (Fig. 6c). However, no consistent pattern was observed between catches of smolts and lunar phase (full moon, last quarter, new moon, and first quarter) or its position (apogee and perigee) among years (Fig. 6).

Biological characteristics

Wild Atlantic salmon smolts in the Margaree River measured predominantly between 10.5 and 16.0 cm fork length (Fig. 7). Maximum observed fork lengths of wild smolts were 16.3 cm in 2001, 28.9 cm in 2002, and 26.0 cm in 2003. Smolt fork lengths in 2001 were on average smaller (mean ± SE = 12.3 ± 1.09 cm) compared to the smolts in 2002 (mean ± SE = 13.0 ± 1.31 cm) and 2003 (mean ± SE = 13.3 ± 1.52 cm). The differences in mean fork lengths (corrected for the sampling date) were statistically significant among years (ANOVA and scheffé test, $P < 0.05$). Mean fork length increased during the smolt run, particularly in 2002 and 2003 (Fig. 8). Average fork length fluctuated around 12 cm at the beginning to 13 cm at the end of smolt run in 2001 (Fig. 8a). The average fork length generally ranged between 12 cm and 13 cm at the beginning of the run and reached a maximum daily average of 15.8 cm and 15.4 cm in late June 2002 and 2003, respectively (Figs. 8b, 8c).

There were statistically significant differences in the length to weight relationships of wild smolts in the Margaree but the weight at a given length was similar among years. Wild smolts of 13.0 cm had mean predicted weights of 20.7 to 20.9 g over the three years (Fig. 9).

The smolt run in the Margaree River was dominated by 2-year old (41% to 55% annually) and 3-year old smolts (43% to 57% annually) with a small proportion (<4% annually) of 4-year old smolts (Table 5). Most (> 70%) of the smolts were females whereas the majority (10 of 11) of 4-year old smolts were male (Table 5). Mean fork length and weight increased with smolt age but there were no significant differences in the mean lengths among males and females of the same smolt age group (Table 5; ANOVA $P > 0.1$).

<u>Run size estimates</u>

The number of smolts marked and released upstream for subsequent recapture varied from 513 smolts in 2001 to 3,815 smolts in 2003 (Tables 2 to 4; Appendix 3). In 2001, 3 of the 5 recaptures migrated from Doyles Bridge to the RST in 2 days. The other 2 recaptured smolts covered this distance in 1 and 3 days (Table 6). In 2002, all but one smolt were recaptured within 2 days (Table 7). The number of days since tagging could not be determined for 2 of the 106 recaptured smolts because of lost tags (identified by a tagging scar anterior to the dorsal fin). The smolts showed higher variation in the time to cover the distance between Doyles Bridge and the RST in 2003 but the majority (82%) of the smolts was recaptured within 2 days (Table 8).

There were only five recaptures in 2001, too few to estimate the efficiency of the RST. These recaptures occurred in June (Tables 2, 6).

In 2002, a total of 2,340 first time catches of wild smolts were sampled at the RST, of which a total of 1,884 smolts were tagged, transported upriver and released. Nine marked smolts captured on 23 - 24 June were excluded from the sample because it was unknown if these smolts had time to migrate to the RST before it was removed from the water on 26 June (Table 3). Overall, 106 tagged smolts were subsequently recaptured at the RST (Table 3). Based on an adjusted for mortality (10%) tag group of 1,696 smolts released between 17 May and 22 June, the Bayes model estimated that 37,700 smolts migrated from the Margaree River in 2002 (95% C.I. 31,555 to 45,800) (Fig. 10). The efficiency of the RST was estimated at 6.3% (95% C.I. 5.1% to 7.4%). Ninety percent of the recaptures in 2002 occurred after the RST was relocated to higher water flows (29 May to 12 June; Tables 2, 7 and Appendix 3b). The Darroch model was used to estimate the run size and efficiency using a stratified matrix of marks, recaptures and catches corresponding to the displacement of the RST (Table 9). The run size estimate which accounts for a possible change in RST efficiency was 63,200 smolts (95% C.I. 34,578 to 91,823; Table 9). The RST efficiency was highest in the 29 May to 12 June period at 8.5% and lowest in the initial period at 1.7% (Table 9). Overall efficiency for the year based on the Darroch estimate was 3.7% (95% C.I. range of 2.5% to 6.8%) (Table 9).

In 2003, a total of 8,053 first time catches of wild smolts were sampled at the RST. A total of 3,815 smolts were tagged, transported upriver and released (Table 4). Of these, 399 were subsequently recaptured at the RST (Table 4). Based on an adjusted for mortality (10%) tag group of 3,434 smolts released between 8 May and 20 June, the Bayes model estimated that 69,350 smolts migrated from the Margaree River in 2003 (95% C.I. 63,200 to 76,550) (Fig. 10). The efficiency of the RST was estimated at 11.6% (95% C.I. 10.5% to 12.8%). The run size estimate which accounts for a possible change in RST efficiency (Darroch model), was 83,050 smolts (95% C.I. 69,081 to 97,019; Table 10). During the spring of 2003, most (80%) of the recaptures occurred between

28 May and 14 June (Table 4, 8 and appendix 3c). The RST efficiency increased from 3% at the beginning of the smolt run to 22% between 8 June and 14 June, 2003 (Table 10). Overall efficiency based on the Darroch model was 9.7% (95% C.I. range of 8.3% to 11.7%) (Table 10).

The Margaree River has an estimated 2.8 million m^2 of salmonid rearing habitat (Marshall 1982). Based on the stratified model estimates, smolt production in 2002 equalled 2.3 smolts per 100 m^2 and increased to 3.0 smolts per 100 m^2 in 2003.

Hatchery-reared smolts

Most hatchery smolts were clearly identified. It is possible that some hatchery fingerlings released the previous fall were considered as wild smolts, however, we consider that the proportion of hatchery smolts misidentified as wild smolts is low and did not significantly affect the estimated wild smolt production.

The number of hatchery smolts captured in the RST increased from 21 in 2001 to 1,248 in 2003 (Table 11). Hatchery smolts were captured between 21 May to 25 June in 2001 (Fig. 11). In 2002, the highest catches of hatchery-reared smolts occurred when the RST was placed at the location of highest flow. In 2003, the highest catches of hatchery smolts occurred on 13 June, following the release of 15,500 one-year old hatchery smolts to the river (Fig. 11; Appendix 1).

The fork length distributions of the hatchery-reared smolts ranged between 9.5 to 16.7 cm (Fig. 12).

Other salmon life stages

More than 300 juvenile wild Atlantic salmon (parr) were captured in the RST in 2001 and 2003 but only 78 parr were captured in 2002 (Table 11; Appendix 4). Most (90%) of these parr were captured before 7 June in all years (Fig. 13; Appendix 4). Wild parr fork lengths ranged from 4.5 to 10.4 cm with most in the 5.5 to 7.5 cm length range (Fig. 7).

A total of five adipose clipped parr were recovered at the RST in each of the three years; most were observed in May (Table 11; Appendix 4). They all measured between 9.2 and 10.4 cm fork length.

Other fish species

Sticklebacks (*Gasterosteus* spp.) and gaspereau (*Alosa pseudoharengus*, *A. aestivalis*) were the two most abundant species caught at the RST, after salmon (Table 11; Appendix 4). Few gaspereau were caught in 2001 and few sticklebacks were captured in 2002. Sticklebacks and gaspereau were generally captured at the end of May and in June (Figs. 14, 15; Appendix 4). The number of white suckers (*Catastomus commersoni*) captured in the RST increased in June in 2001 and 2003 but the daily catches remained constant in June 2002 (Fig. 16; Appendix 4). Eels (*Anguilla rostrata*) were also captured in considerable numbers (112 in total), mostly in 2003 (Table 11). The highest daily catch of eels was obtained in late May, 2003 (Fig. 17; Appendix 4).

Ten other fish species were captured in the RST but in low numbers (total < 65; Table 11).

DISCUSSION

The smolt migration in the Margaree River in 2001 to 2003 was of short duration and occurred at the same time each year. The migration began in early May, peaked in late May - early June and was finished by the end of June. The initial small number of smolts captured indicates that the migration had just started when the RST was installed and the 7 weeks of operation covered the majority of the smolt migration in each year. Similar migration patterns (May – June) were observed in other rivers in New Brunwick (Miramichi River and Restigouche River; Chaput *et al.* 2002, 2004), Newfoundland (Conne River, Dempson and Stansbury 1991) and Québec (St-Jean River and Trinity River, Caron *et al.* 2004). However, earlier downstream movement (late April to late May) occurred in the Tobique River and Nashwaak River (tributaries of the Saint John River, New Brunswick (Jones *et al*. 2004)) and in three tributaries of the West River, Vermont, USA (Whalen *et al.* 1999).

The process of smoltification is under genetic influence (Thorpe and Morgan 1978, Nielsen *et al.* 2001) but is largely regulated by environmental factors. It is generally believed that the parr-smolt transformation is principally triggered by photoperiod (McCormick *et al.* 1987, Duston and Saunders 1995). Water temperature also plays a role in regulating the physiological aspect of smoltification (Johnston and Saunders 1981, Muir *et al.* 1994, Staurnes *et al*. 1994, Whalen *et al.* 1999). However, temperature is thought to principally determine the timing of the smolt migration while water discharge influences the migration speed (Jonsson and Ruud-Hansen 1985, Whalen *et al.* 1999, McCormick *et al.* 1998). The beginning of the smolt migration or the first substantial catches is often associated with mean daily water temperatures exceeding 10°C (Jessop 1975, Dempson and Stansbury 1991, Chaput *et al*. 2002). Similar results were obtained in the Margaree River, with the beginning of the smolt migration and first substantial catches occurring when the mean daily water temperature exceeded 7°C and 10°C, respectively. Peak catches occurred when water temperature exceeded 13°C. In contrast, the smolt migration was initiated at colder water temperatures (≥ 4°C) in southwest New Brunswick and Vermont rivers (Jones *et al*. 2004; Whalen *et al.* 1999). Similarly, low water temperatures were associated with the start of the smolt migration in the Restigouche River, a northern New Brunswick river (Chaput *et al.* 2004). Hvidsten *et al*. (1995) observed the start of the smolt run at water temperatures of 1.7 - 4.4°C in Orkla River (Norway). Jonsson and Ruud-Hansen (1985) concluded that the timing of the smolt migration of Atlantic salmon in the Imsa River (Norway) was not regulated by a specific temperature threshold but was under the influence of a combination of temperature increases during the spring.

Peak catches of Atlantic salmon smolts tended to be associated with freshets in some rivers (e.g. Margaree River (this study), Tobique River (Jones *et al*. 2004), West River (Whalen *et al.* 1999) and Orkla River (Hvidsten *et al*. 1995) but not in others (e.g. Nashwaak River (Jones *et al*. 2004) and Imsa River (Jonsson and Ruud-Hansen 1985)). Antonsson and Gudjonsson (2002) observed an increase in the number of emigrating smolts during periods of higher discharge in a southwest Icelandic river but increased discharge was associated with decreased water temperatures and lower catches in northern rivers.

There is some evidence that the lunar position (apogee and perigee i.e. the moon is at the farthest and closest point to the earth, respectively) or phase (new, first quarter, full and last quarter) may also influence the timing of migration of smolts. It is hypothesized that high tides occurring when the moon is at perigee or new and full moon would decrease the predation rate of the migrating smolts entering the ocean (Hvidsten *et al.* 1995). However, moon phases induce changes in illumination and a decline in fish movement during full moon has been observed (Thorpe *et al.* 1988). The smolt migration of coho salmon was strongly associated with the new moon in a British Columbia stream under stable discharge conditions (Mason 1975). Yamauchi *et al*. (1985) associated the first substantial catches of masu salmon (*O. masou*) with the new moon and precipitation. Hvidsten *et al.* (1995) observed peak catches of Atlantic salmon smolts near the new moon but also full moon in Orkla River. In contrast, DeVries *et al*. (2004) indicated that the start of the smolt migration of chinook salmon was related to the date of lunar apogee and quarter moon (period of low tides). Weaker relationships were found between the lunar position and timing of migration for the coho and sockeye salmon (DeVries *et al*. 2004). Consistent with the results obtained by Jonsson and Ruud-Hansen (1985), the smolt migration of Atlantic salmon in the Margaree River was not associated with the lunar position and phases in 2001 and 2002. In 2003, peak catch occurred one day after the lunar apogee and catches increased after the new moon. However, the influence of lunar position and phase on smolt migration remains unclear and further analysis is required to enable a better understanding of the influence of environmental factors on the timing of the smolt migration.

Smolt age is an important variable that can be incorporated in stock-recruitment models (e.g. Chaput *et al.* 1998). Jessop (1975) and Englund et al. (1999) observed high annual variations in the age composition of smolts within rivers. The age composition of the smolts in the Margaree River was relatively constant between 2001 and 2003. Similar percentages of 2 year old (41% - 54%) and 3 year old (43% - 57%) were observed in the sampled smolts from the Margaree River. Based on scale analysis, between 54% - 83% of the sampled adults returning to the Margaree River were 2 year old smolts (Claytor *et al.* 1995, Leblanc *et al.* 2005). This contrasts with the majority (62% to 71%) of 3 year old smolts observed in the Northwest Miramichi River (Chaput *et al*. 2002). Age 4 smolts represented only 6.3% (11 smolts) of the aged sample from the Margaree River. Most (10 out of 11) of these age 4 smolts were male, possibly the result of precocious (mature) parr remaining in the river for an additional year after maturing. Between 71% and 76% of the sampled smolts in the Margaree River were female, compared to 49% to 63% observed in the Northwest Miramichi (Chaput *et al*. 2002). The higher proportion of females we observed could be attributed in part to the lower probability of smolting of mature parr (Whalen *et al.* 2000, Letcher *et al.* 2002).

The estimated production rates (smolts per 100 m² of fluvial habitat) of smolts in the Margaree River are within the range observed in other rivers in the Maritimes (Chaput *et al*. 2004). However, the estimate for the Margaree in 2002 should be interpreted with caution. The size of the smolt run estimated from the temporally stratified data in 2002 (63 200 smolts; 95% C.I. 34,578 to 91,823) was almost twice the value obtained from pooled data (37,700 smolts; 95% C.I. 31,555 to 45,800). Warren and Dempson (1995) concluded that no gain in accuracy and precision of the estimates was obtained by using a temporal stratification to estimate the size of the smolt run in Conne River (Newfoundland). In our study, the stratified estimator appeared to best estimate the efficiency of the RST. In 2002, the RST was highly efficient when moved to the location of very fast flow. This time period comprise 90% of the recaptures (95 smolts) compared to 8 recaptures at the start and the 3 recaptures at the end of the run, when the RST was placed in a less constricted flow area. However, stratifying the data induces larger confidence intervals compared to pooled data and the uncertainty associated with the Darroch estimates was high in 2002. The variation in capture probability with time observed in 2003 also suggests that the Darroch estimator is appropriate to estimate the smolt production in Margaree River. The high number of recaptures (399 smolts) improved the accuracy of the estimate in 2003. The 95% confidence interval was within 20% of the Darroch estimate in 2003 and can be considered reliable (Cousens *et al*. 1982). Although hatchery smolts were released in the Margaree River in 2003, they were easily identified and were excluded from the estimation of the wild smolt run. We assumed that the majority of smolts which were stocked as hatchery fingerlings during the previous fall year were clearly identified based on fin clipping. Therefore, we consider that the potential bias induced by hatchery fish in the wild smolt run estimate is small.

The observed capture efficiency of the RST was low (1.1%) in 2001. Based on the Darroch estimator, the capture efficiency increased from 3.7% in 2002 to 9.7% in 2003. In the mark and recapture experiments conducted in this study, we assumed that tagging and releasing the smolts upstream for recapture had minimal effect on fish behaviour and that the probability of capture of the marked smolts was similar to unmarked smolts, conditional of the date of migration. Salmon smolts exhibit shoaling behaviour during migration (Boeuf 1993). In this study, it is reasonable to assume that uniform redistribution of the marked smolts occurred over the 5 km between the release (Northeast Margaree River) and recapture locations (constricted area in the Main Margaree River). Capture efficiency can be influenced by several factors, including water discharge, location of the RST, accumulation of debris in the trap, and trap avoidance behaviour (Thedinga *et al.* 1994). In Margaree River, the accumulation of debris in the RST and/or broken axle possibly reduced the capture efficiency of the RST during an annual maximum of 10 fishing nights. However, the refinement of the trap operation with time (e.g location, use of wings) combined with low water discharge has likely contributed to the increase in capture efficiency. In addition, the use of clear streamer tags and releasing the smolts at dusk in 2002 and 2003 may have decreased the predation rate on the presumably stationary smolts during day light. Handeland *et* *al.* (1996) showed that smolts under physiological stress experience a decrease in the effectiveness of antipredator behaviour and experience subsequent higher predation rate. Although delayed stress-induced mortality remains unknown, an assumed 10% mortality after release of the marked fish appears reasonable. Holding the smolts until dusk also permitted us to release only those smolts which appeared fully recovered from handling. The majority of the marked smolts covered the distance between the release and capture sites within 2 days, which further suggests low post-release mortality during this short time period.

However, the immediate mortality rates observed in the holding box of the RST or after handling deserves a particular attention. Sampling mortality is inevitable when capturing and handling fish and a 5% mortality is usually acceptable in fisheries research. However, the high sampling mortality rate observed in the Margaree River in 2002 was of concern. Jessop (1975) observed tagging mortality rates of 33% and 41% of smolts captured toward the end of the smolt run in a counting fence installed in the Big Salmon River (New Brunswick). He attributed this increase of mortality to a decline in smolt condition (visually quantified). As with Jessop (1975), the counting station in the Margaree River was located near the head of tide and the smolts captured near sea entrance could be more susceptible to handling mortality. However, the mortality rates in the Margaree River did not increase as the smolt run progressed and the highest daily mortality occurred when the axle of the RST broke toward the end of the run in 2003. Although mortality was related to the number of fish captured in the RST, the number of captured smolts tripled and the mortality rate decreased by half in 2003 compared to 2002. This decrease of mortality may be attributed to the modifications made to the holding box in 2003. Although high mortality occurred when the RST was moved to the area of highest flow in 2002, the rotation speed remained < 10 RPM during the 3 years of operation. Rotation speed of 10 RPM is commonly observed in other rivers and has not been associated with mortalities (Chaput and Jones 2004). The handling mortality we observed further re-enforces the need to quantify the negative effects (e.g. stress and mortality) of capturing fish with RSTs in order to reduce the potential harmful effects of this capture technique and increase the precision of the population size estimates.

Understanding the biological characteristics of smolt runs and the mechanisms under which the timing of the smolt migration is regulated would be of use in answering questions such as the potential effects of climate changes on salmon survival. Synchronization between smolt migration and marine conditions for optimal survival and growth is crucial (Friedland 1998, McCormick *et al.* 1999, Friedland *et al.* 2003). McCormick *et al.* (1998) illustrated the short physiological and environmental “window” in which smolts must migrate to sea. If the smolt migration is principally triggered by water temperature, climate change may induce smolt migrations which are not synchronized with optimum oceanic conditions (Friedland *et al.* 2003). Most studies conducted on the effects of climate on Atlantic and Pacific salmon populations focused on the marine environment (e.g. Friedland 1998, Friedland *et al*. 2000, Mueter et al. 2005). The freshwater environment may be as important in regulating recruitment. There is a need to clarify the link between freshwater and marine environments and to develop models which include the entire life cycle of salmon (Lawson *et al.* 2004). Understanding the population dynamics in both environments is essential for the establishment of adequate stock-recruitment relationships which would lead toward improved management and conservation of Atlantic salmon.

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Table 1: Summary of the field operations, gear modifications, tagging and release procedures for the Atlantic salmon smolt monitoring program in the Margaree River, 2001 to 2003.

	Year		
	2001	2002	2003
RST set date	10-May	6-May	7-May
RST finish date	30-Jun	26-Jun	25-Jun
Number of days RST not fishing or jammed	10	7	10
Deflector wings	No	Yes	Yes
Size of the holding box	Original	Original	Enlarged
Wheel operating range - RPM	5.5 to 7.5	2.8 to 11	5 to 9
Tag type	Green streamer	Clear streamer	Clear streamer
Fish held before release	No	Yes	Yes
Time of release	Morning	Evening	Evening

Table 2: Daily catch and treatment of wild smolts at the rotary screw trap in the Margaree River, 2001.

		First capture					Recapture	
			Released		Mortalities			
Month	Day	Total Catch	Unmarked	Marked	Sacrificed	Mortalities (Holding box or after handling)	Live	Mortalities
May	11	1				1		
	12							
	13							
	14							
	15	4	4					
	16	3	3					
	17	7	7					
	18	12	11			1		
	19	13	2			11		
	20	24	21		3			
	21	23	20		3			
	22	26	21		5			
	23	32	7	20	4	1		
	24	21	3	15	3			
	25	29	5	18	4	2		
	26	25	5	16	4			
	27	31	5	21	5			
	28	52	3	38	9	2		
	29	59	12	38	9			
	30	50	43		7			
	31	23	2	18	3			
June	1	29	1	23	5			
	2	33	29		4			
	3	32		26	6			
	4	18	15		3		1	
	5	47	38		8	1	1	
	6	29	1	23	4	1		
	7	18	15		3			
	8	10	9		1		1	
	9	16		13	3			
	10	34		27	6	1		
	11	1	1					
	12	49	1	38	9	1		
	13	47	1	37	9			
	14	28	24		4			
	15	45	1	37	7			
	16	43	33		8	2		
	17	51	0	39	10	2	1	
	18	63	53		9	1		
	19	60	28	21	10	1		
	20	29	2	21	5	1		
	21	13		11	2		1	
	22	17		13	2	2		
	23	6	5		1			
	24	4	3			1		
	25	1	1					
	26	1	1					
	27	4	4					
	28	2	2					
	29							
	30							
Total		**1,165**	**442**	**513**	**178**	**32**	**5**	**0**

Table 3: Daily catch and treatment of wild smolts at the rotary screw trap in the Margaree River, 2002.

		First capture						Recapture	
			Released		Mortalities				
Month	Day	Total Catch	Unmarked	Marked	Sacrificed	Mortalities (Holding box)	Mortalities (After handling)	Live	Mortalities
May	7	5	4		1				
	8	4	4						
	9								
	10	4	3		1				
	11								
	12	5	4		1				
	13	1				1			
	14	4	3		1				
	15								
	16	9	8		1				
	17	13		10	2		1		
	18	10	8		1	1		1	
	19	15		12	3				
	20	11		9	2				
	21	26	1	20	5				
	22	52		46	6				
	23	124		114	10			2	
	24	133		121	10		2	3	
	25	118		108	9		1	1	
	26	83		73	10				
	27	24		20	4				
	28	59		49	10			1	
	29	337		282		25	30	6	
	30	135		119	7	1	8	2	
	31	299		287		5	7	13	
June	1	86	1	75	8	2		1	
	2	87		73	10		4	32	
	3	20		17		3		3	
	4	50		41		6	3	17	
	5	119	1	91		10	17	2	
	6	43	1	24		16	2	1	
	7	23		18	3		2	3	
	8	94		72		11	11	3	
	9	79	1	45		24	9	1	
	10	42		18		9	15	2	
	11	46	2	23		3	18	8	
	12	57		20		32	5	1	
	13	19		19					
	14	25		24			1	1	
	15	5		5				1	
	16	12	1	4		1	6		
	17	3		3					
	18	22		18		1	3		
	19	13		11			2		
	20	3		3				1	
	21	8		8					
	22	2		2					
	23	1		1					
	24	9		8		1			
	25	1	1						
	26								
	Total	**2,340**	**43**	**1,893**	**105**	**152**	**147**	**106**	**0**

Table 4: Daily catch and treatment of wild smolts at the rotary screw trap in the Margaree River, 2003.

		First capture						Recaptures		
			Released		Mortalities					
Month	Day	Total Catch	Unmarked	Marked	Sacrificed	Mortalities (Holding box)	Mortalities (After handling)	Live	Mortalities	Recaptured twice
May	8	2		1	1					
	9									
	10									
	11	2				2				
	12									
	13	6		4	1	1				
	14	3		2	1					
	15	4		4						
	16	10		8	2					
	17	30	3	22	5					
	18	36		29	7					
	19	67		40	4	22	1			
	20	9	2	5	1	1				
	21	95		84	10	1		1		
	22	168	15	141	10	2		1		
	23	117		106	10		1	3		
	24	155		143	10	2		6		
	25	231	20	198	10	2	1	5		
	26	102	1	91	10			7		
	27	151	1	136	10	2	2	4		
	28	525	186	308	10	8	13	25	1	
	29	805	577	197	9	19	3	18	3	1
	30	229	16	199	10	3	1	11		
	31	296	75	194	5	16	6	13		1
June	1	551	326	200	5	20		32		
	2	481	223	247	5	3	3	8	1	
	3	588	366	195	5	17	5	66	2	
	4	311	190	98	5	17	1	13		1
	5	258	138	97	5	15	3	9		
	6	191	82	91	5	4	9	6		
	7	105	1	86	5	13		2	2	
	8	397	246	107	5	32	7	5	3	
	9	517	396	100	5	16		22		
	10	153	47	97	5	1	3	9		
	11	376	221	92	5	50	8	20	2	
	12	238	126	95	5	7	5	9	1	
	13	148	39	98	5	4	2	16	4	
	14	258	76	87		82	13	22	2	
	15	44	4	6		26	8	5	3	
	16	17		11		2	4	4	1	
	17	77	3	62		3	9	8		1
	18	29	3	23	2		1	7	1	
	19	77	35	38		2	2	6		
	20	77	3	73		1		1	2	
	21	30	29			1		4		
	22	32	32					2		
	23	31	31					1		
	24	7	7							
	25	17	14		3					
	Total	**8,053**	**3,534**	**3,815**	**196**	**397**	**111**	**371**	**28**	**4**

Table 5: Percent (number), mean fork length and weight of the wild smolts captured (sacrificed only) according to the age and sex from the Margaree River, 2001 to 2003. The means are shown when daily number (n) ≥ 5 smolts and the standard error of the means is shown when n ≥ 10 smolts. NA = not available.

		Sex combined	Female			Male		
Year	Age	% (N)	%	Mean FL (SE)	Mean WT (SE)	%	Mean FL (SE)	Mean WT (SE)
2001	Age 2	41.1 (69)	69.6	12.0 (0.11)	17.0 (0.49)	30.4	12.0 (0.12)	17.3 (0.70)
2001	Age 3	57.1 (96)	72.9	12.8 (0.11)	19.9 (0.52)	27.1	12.8 (0.18)	20.4 (0.88)
2001	Age 4	1.8 (3)	33.3	NA	NA	66.7	NA	NA
2001	**All**	**100.0 (168)**	**70.8**	**12.5 (0.09)**	**18.8 (0.41)**	**29.2**	**12.5 (0.13)**	**19.2 (0.61)**
2002	Age 2	54.5 (48)	79.2	12.2 (0.17)	17.9 (0.82)	20.8	12.5 (0.33)	19.1 (2.02)
2002	Age 3	43.2 (38)	71.1	12.9 (0.20)	20.9 (0.87)	28.9	13.1 (0.30)	21.5 (1.07)
2002	Age 4	2.3 (2)	0.0	NA	NA	100.0	NA	NA
2002	**All**	**100 (88)**	**73.9**	**12.5 (0.13)**	**19.2 (0.62)**	**26.1**	**12.9 (0.24)**	**20.7 (1.0)**
2003	Age 2	44.9 (79)	79.7	12.3 (0.15)	18.6 (0.81)	20.3	12.6 (0.29)	20.1 (1.36)
2003	Age 3	51.7 (91)	76.9	13.2 (0.11)	21.5 (0.54)	23.1	13.3 (0.25)	22.9 (1.50)
2003	Age 4	3.4 (6)	0.0	NA	NA	100.0	14.35	28.90
2003	**All**	**100 (176)**	**75.6**	**12.8 (0.10)**	**20.1 (0.5)**	**24.4**	**13.2 (0.19)**	**22.7 (1.0)**

Table 6: Percent (number) of wild smolts recaptured according to the number of days since tagging and release in the Margaree River during the spring of 2001.

	Date of recapture				
Days since tagging	4 - 8 June	9 - 13 June	14 - 18 June	19 - 23 June	24 - 30 June
1	0	0	0	100 (1)	0
2	66.7 (2)	0	100 (1)	0	0
3	33.3 (1)	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0
6	0	0	0	0	0
7	0	0	0	0	0
8	0	0	0	0	0
9	0	0	0	0	0
10	0	0	0	0	0

Table 7: Percent (number) of wild smolts recaptured according to the number of days since tagging and release in the Margaree River during the spring of 2002.

	Date of recapture						
Days since tagging	18 - 22 May	22 - 26 May	27 - 31 May	1 - 5 June	6 - 10 June	11 - 15 June	16 - 20 june
1	100 (1)	100 (6)	54.6 (12)	89.7 (35)	82.4 (14)	33.3 (1)	0
2	0	0	40.9 (9)	7.7 (3)	17.7 (3)	33.3 (1)	100 (1)
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
6	0	0	4.6 (1)	0	0	0	0
7	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0
Unkown*	0	0	0	2.6 (1)	0	33.3 (1)	0

* Unkown = Tag missing but the presence of a scar indicated that the fish was marked

Table 8: Percent (number) of wild smolts recaptured according to the number of days since tagging and release in the Margaree River during the spring of 2003.

Days since tagging	Date of recapture						
and release	21 - 25 May	26 - 30 May	31 May - 4 June	5 - 9 June	10 - 14 June	15 - 19 June	20 - 23 June
1	43.8 (7)	62.3 (43)	68.1 (92)	38.8 (19)	36.5 (31)	31.4 (11)	20.0 (2)
2	37.5 (6)	23.2 (16)	24.4 (33)	44.9 (22)	38.8 (33)	25.7 (9)	50.0 (5)
3	6.25 (1)	8.7 (6)	2.2 (3)	10.2 (5)	12.9 (11)	22.9 (8)	20.0 (2)
4	0	1.4 (1)	2.2 (3)	2.0 (1)	8.2 (7)	2.9 (1)	0
5	0	2.9 (2)	0	0	1.2 (1)	5.7 (2)	0
6	12.5 (2)	0	0	0	1.2 (1)	5.7 (2)	0
7	0	0	0	0	0	0	0
8	0	0	0.7 (1)	0	0	0	10.0 (1)
9	0	0	0	0	0	0	0
10	0	1.4 (1)	0.7 (1)	0	0	0	0
Unkown*	0	0	1.5 (2)	4.1 (2)	0	5.7 (2)	0

* Unkown = Tag missing but the presence of a scar indicated that the fish was marked

Table 9: Stratified matrix and population size estimates of Atlantic salmon smolts from the Margaree River, 2002, based on a Darroch model.

Marking period	**Marked (adjusted for 10% mortality)**	**Recapture period** 7 May - 28 May	29 May - 12 June	13 June - 26 June	P (captured)
7 May - 27 May	480	8	1	0	0.011
28 May - 11 June	1,111	0	94	0	0.066
12 June - 22 June	105	0	0	3	0.024
Total	1,696	8	95	3	
Total first catch		700	1,517	123	
					Total
Population size estimate (95% C.I.)		40,966	17,930	4,305	**63,200 (34,578 - 91,823)**
Recapture probability (RST efficiency)		0.017	0.085	0.029	**0.037 (0.025 - 0.068)**

Table 10: Stratified matrix and population size estimates of Atlantic salmon smolts from the Margaree River, 2003, based on a Darroch model.

Marking period	**Marked (adjusted for 10% mortality)**	**Recapture period**					
		7 May - 24 May	25 May - 31 May	1 June - 7 June	8 June -14 June	15 June - 25 June	P (captured)
7 May - 23 May	401	11	6	0	0	0	0.016
24 May - 30 May	1,145	0	81	14	0	0	0.041
31 May - 6 June	1,010	0	0	127	7	0	0.059
7 June -13 June	608	0	0	0	108	14	0.055
14 June - 20 June	270	0	0	0	0	31	0.170
Total	3,434	11	87	141	115	45	
Total first catch		704	2,339	2,485	2,087	438	
							Total
Population size estimate (95% C.I.)		20,747	29,949	19,146	9,393	3,815	**83,050 (69,081 - 97,019)**
Catch probability (RST efficiency)		0.034	0.078	0.130	0.222	0.115	**0.097 (0.083 - 0.117)**

Table 11: Catches of fish other than wild smolts at the rotary screw trap in the Margaree River, 2001 - 2003. H = hatchery-reared and W = wild.

	Year			
Species / Life stage	**2,001**	**2,002**	**2,003**	**Total**
Atlantic salmon smolt (H)	21	72	1,248	**1,341**
Atlantic salmon parr (H)	5	5	5	**15**
Atlantic salmon parr (W)	360	78	316	**754**
Stickleback	182	30	560	**772**
Gaspereau	4	251	427	**682**
White sucker	95	56	198	**349**
Eel	23	11	78	**112**
Lamprey	14	4	14	**32**
Mummichog	7	12	8	**27**
Dace	13	1	11	**25**
Brook trout	5	6	11	**22**
Smelt	0	1	14	**15**
White Perch	1	2	8	**11**
Golden shiner	0	2	4	**6**
Tadpole	1	1	2	**4**
Brown trout	0	0	1	**1**
Unknown	0	1	0	**1**
Total	731	533	2,905	**4,169**

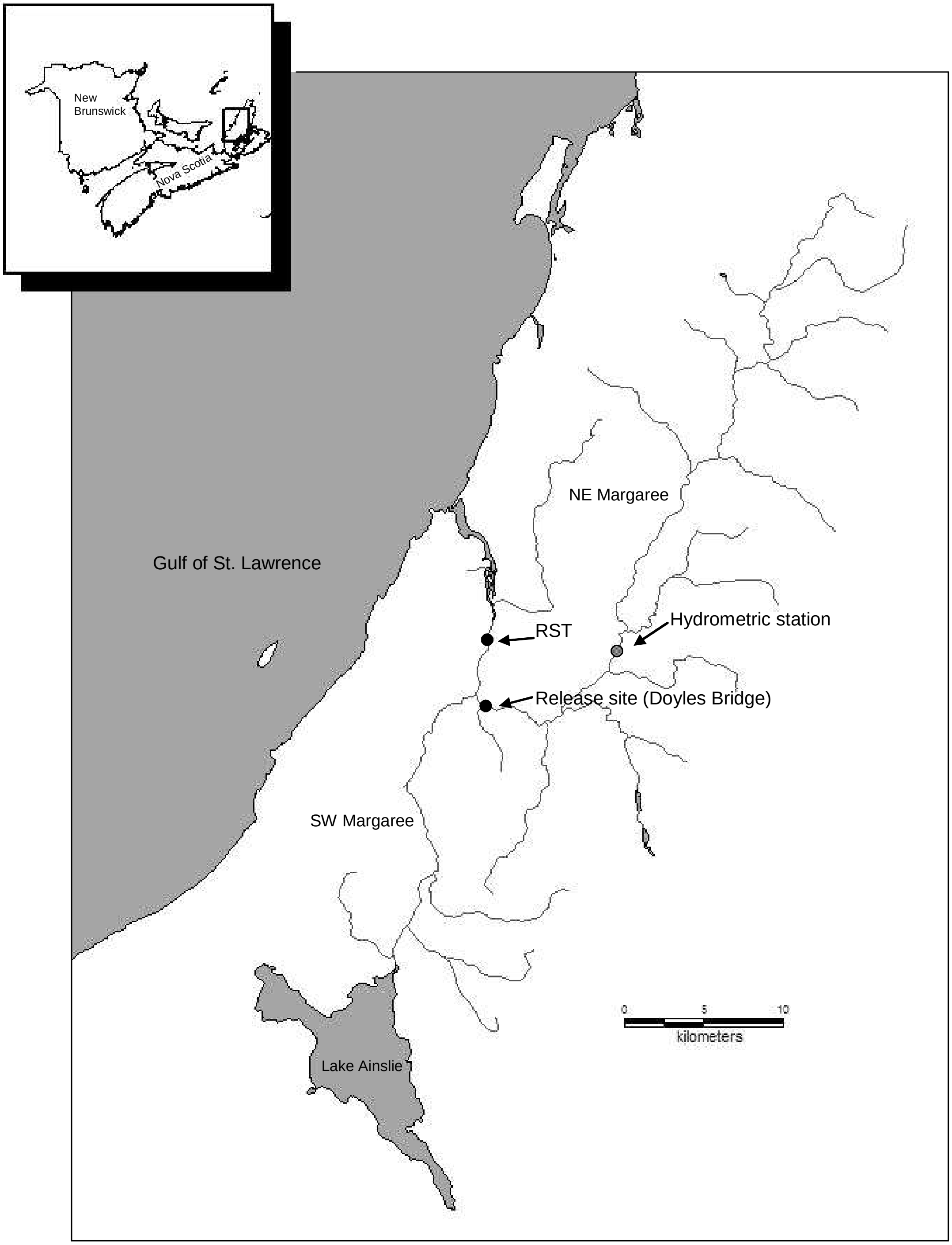


Figure 1: Location of the rotary screw trap (RST), release site of the marked smolts (Doyles Bridge) and hydrometric station in the Margaree River, 2001 - 2003.

a)

b)

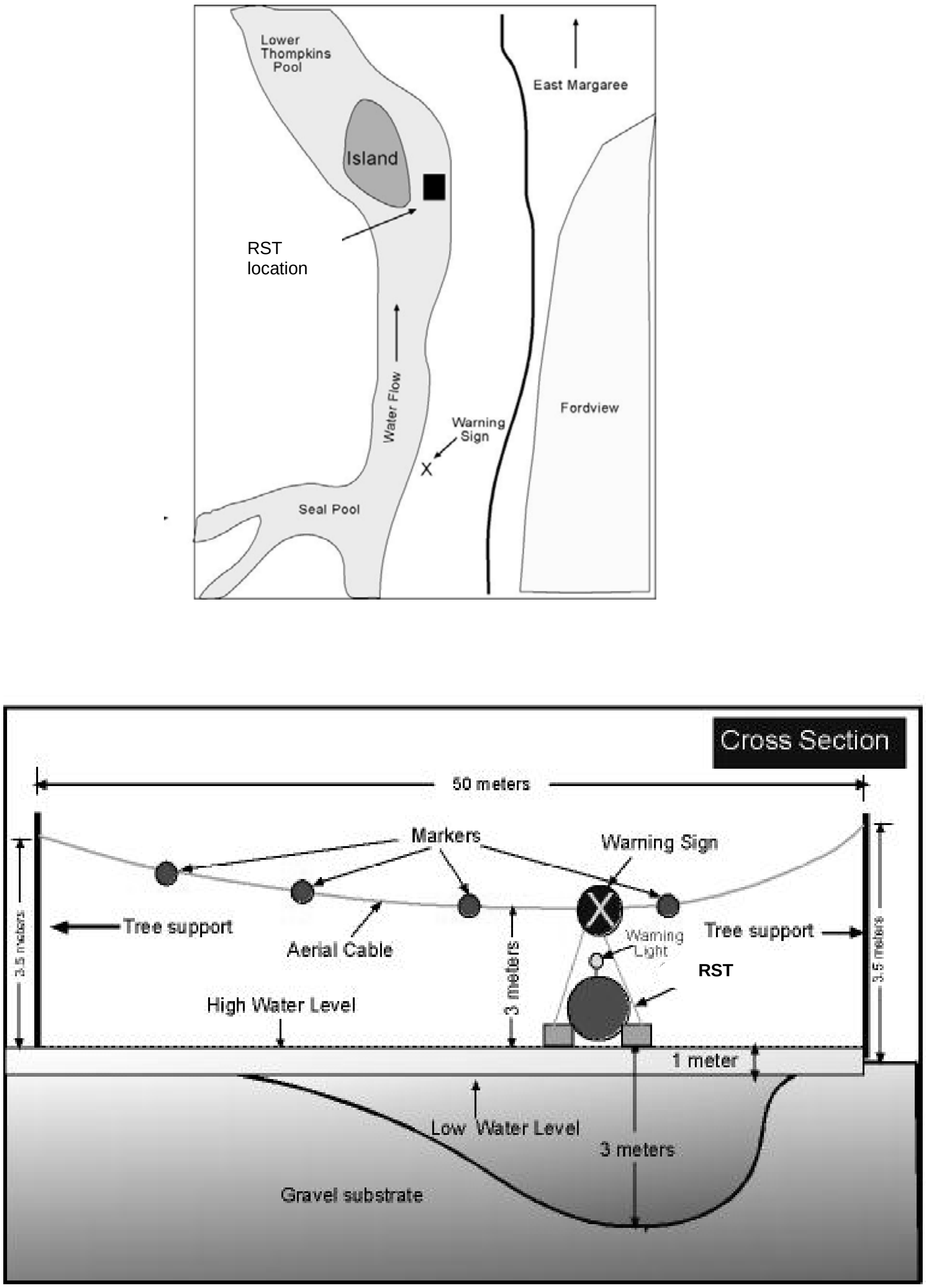


Figure 2: Location of the rotary screw trap in the constricted area of the Margaree River (a) and details of the installation (b).

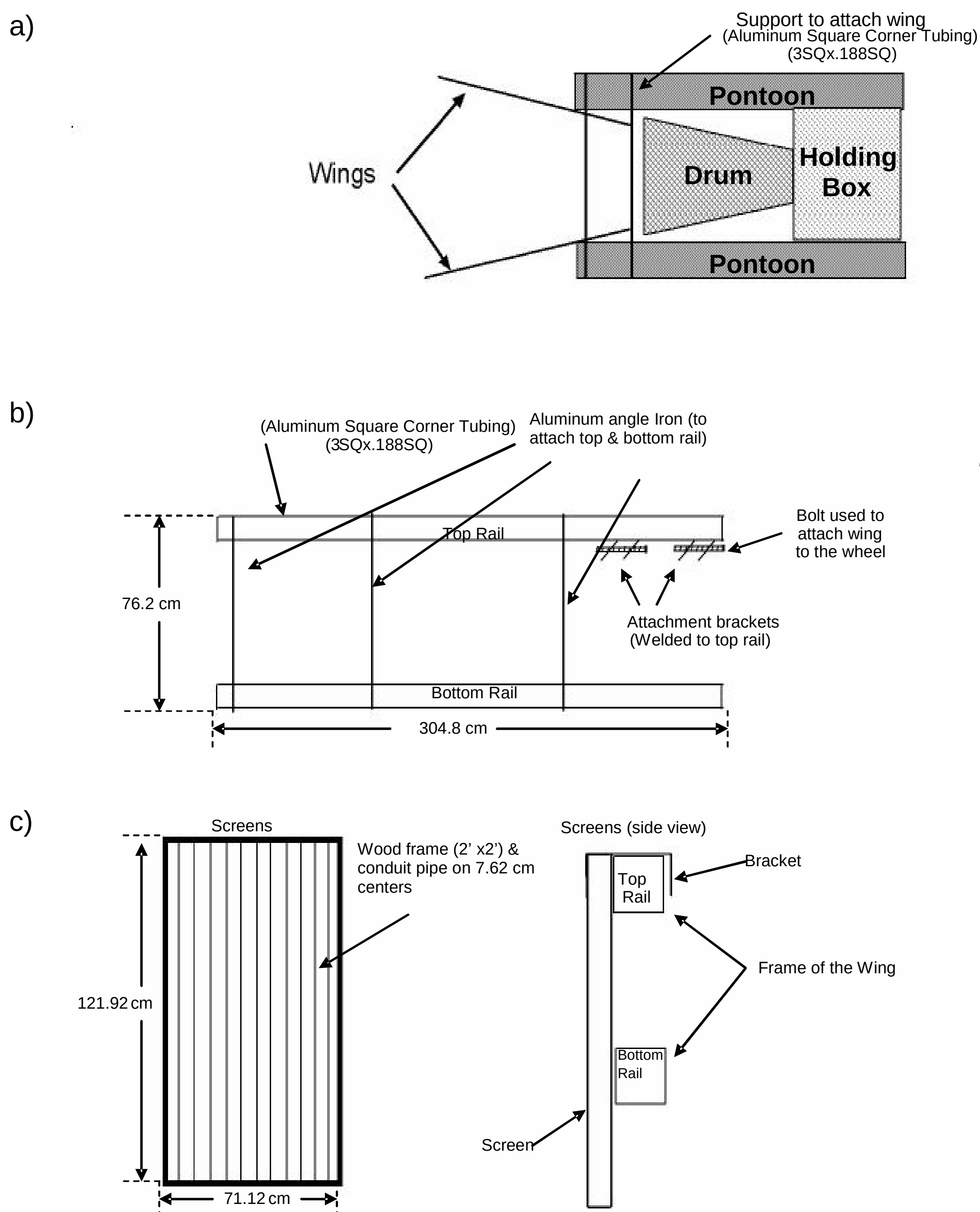


Figure 3: Diagram of the wing design added to the rotary screw trap in 2002 and 2003: a) rotary screw trap and the wings, b) frame of the wings and c) screens attached to the frame of the wings.

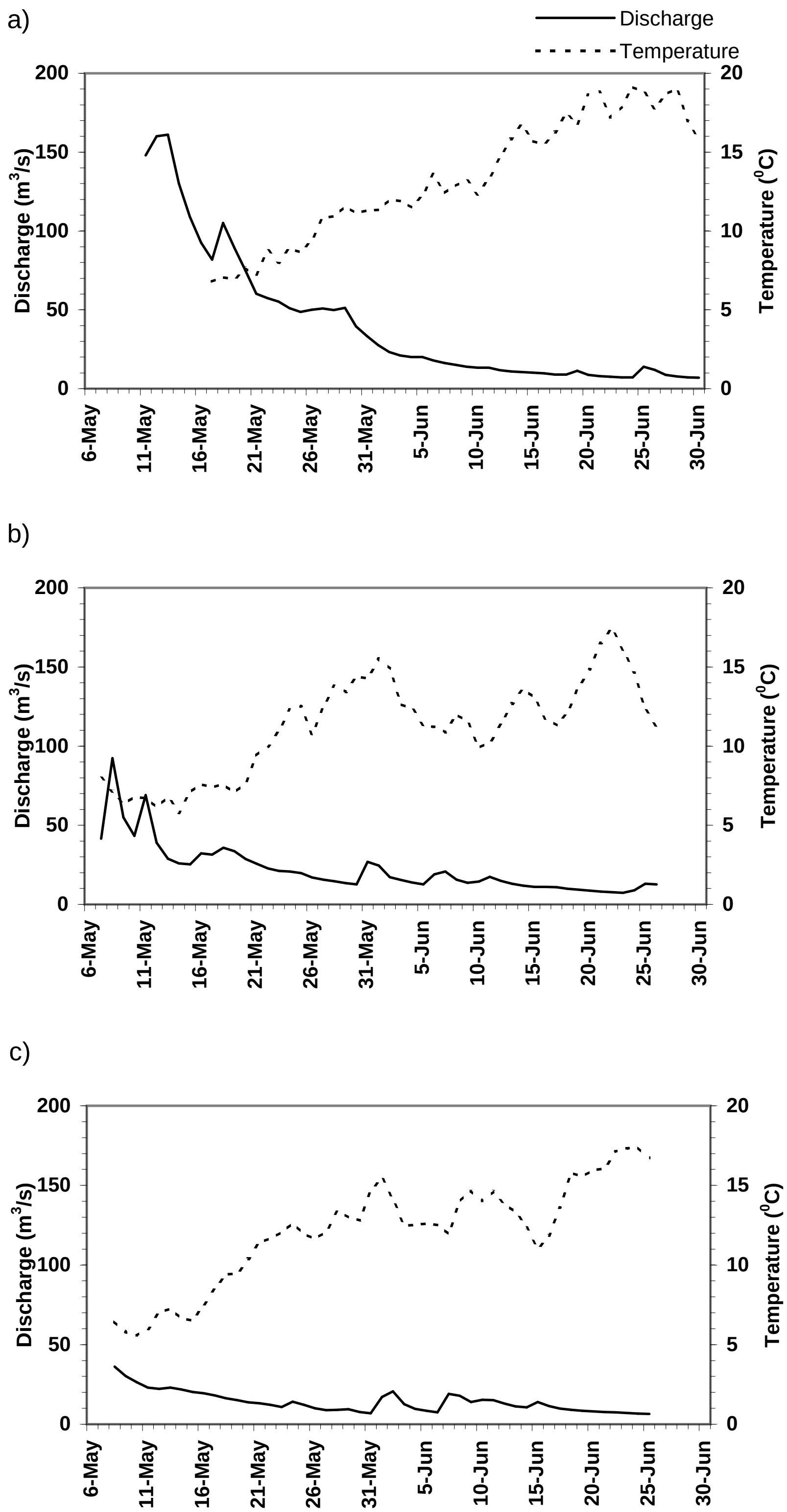


Figure 4: Mean daily water discharge (m^3s^{-1}) measured at the hydrometric station in the Northeast Margaree River and water temperature (^0C) in the Margaree River during the spring of a) 2001, b) 2002 and c) 2003.

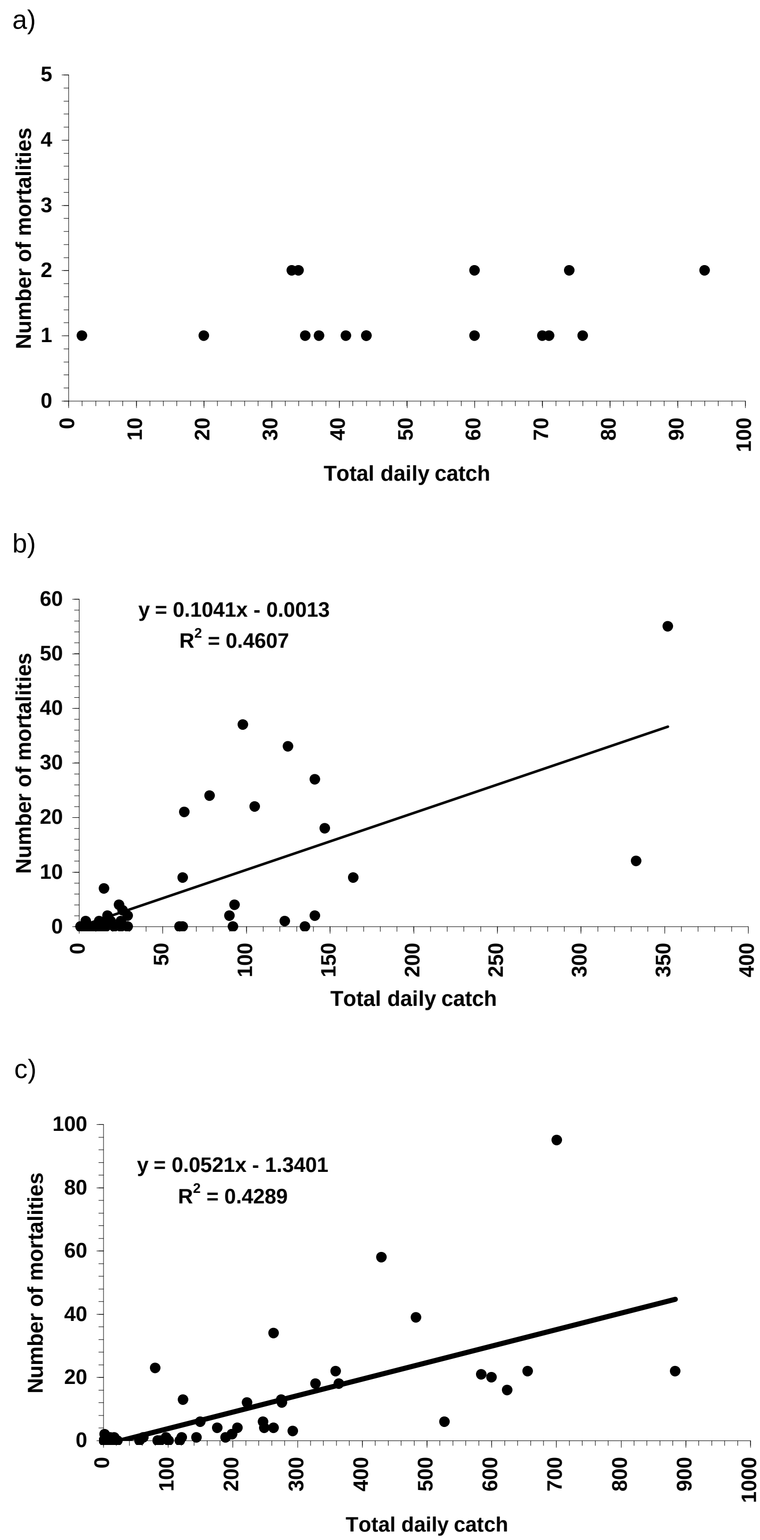


Figure 5: Relationship between the number of wild smolt mortalities and the total daily catch (all species combined) in the rotary screw trap from the Margaree River during the spring of a) 2001, b) 2002 and c) 2003.

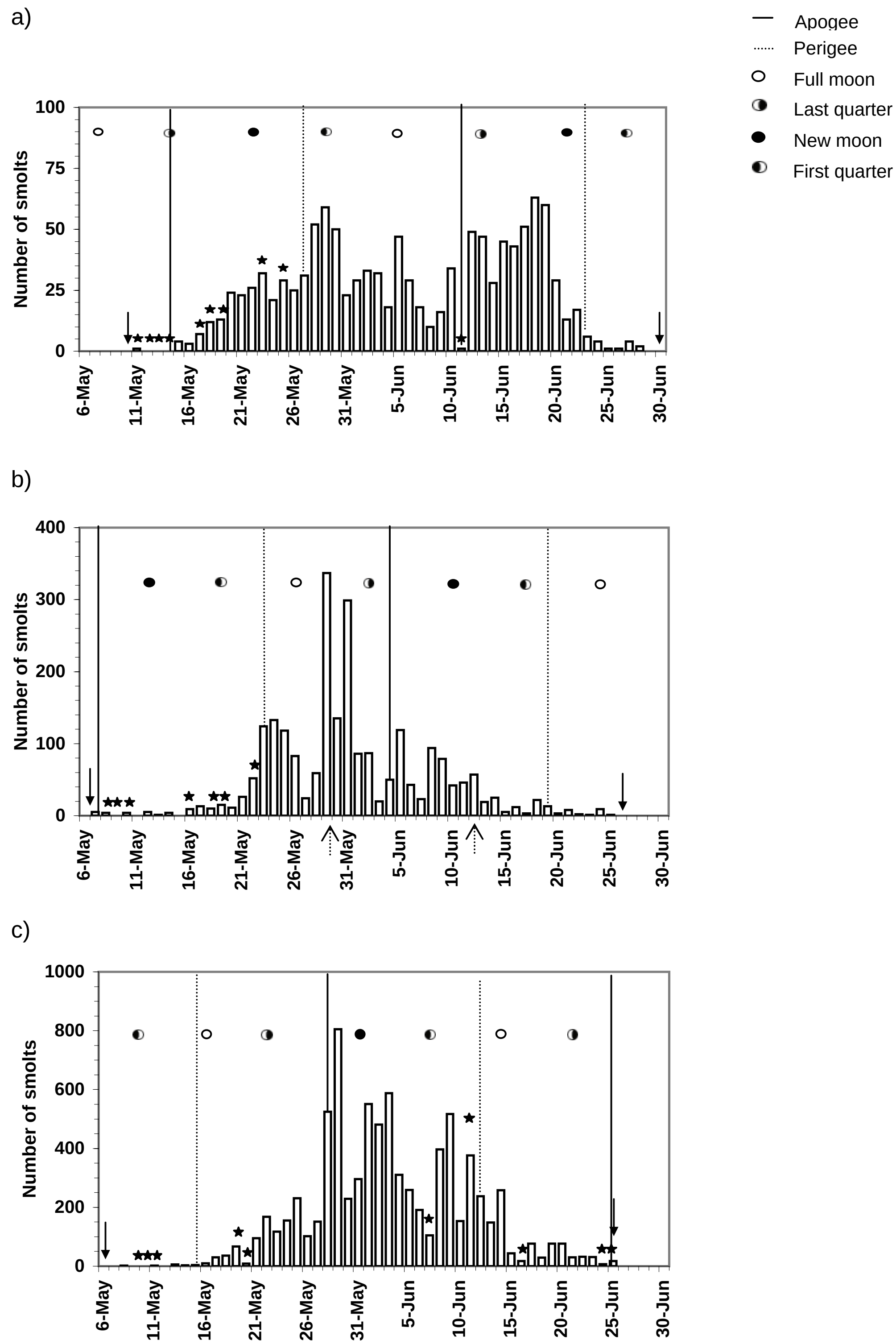


Figure 6: Run timing of wild smolts from the Margaree River in 2001 (a), 2002 (b) and 2003 (c) as inferred from catches in the rotary screw trap (RST). Solid arrows indicate start and finish dates, stars indicate dates when the RST was jammed in the morning or not set. The dashed arrows indicate the period at which the trap was moved to the location of highest water flow in 2002. The number of smolts which migrated overnight was reported the following morning.

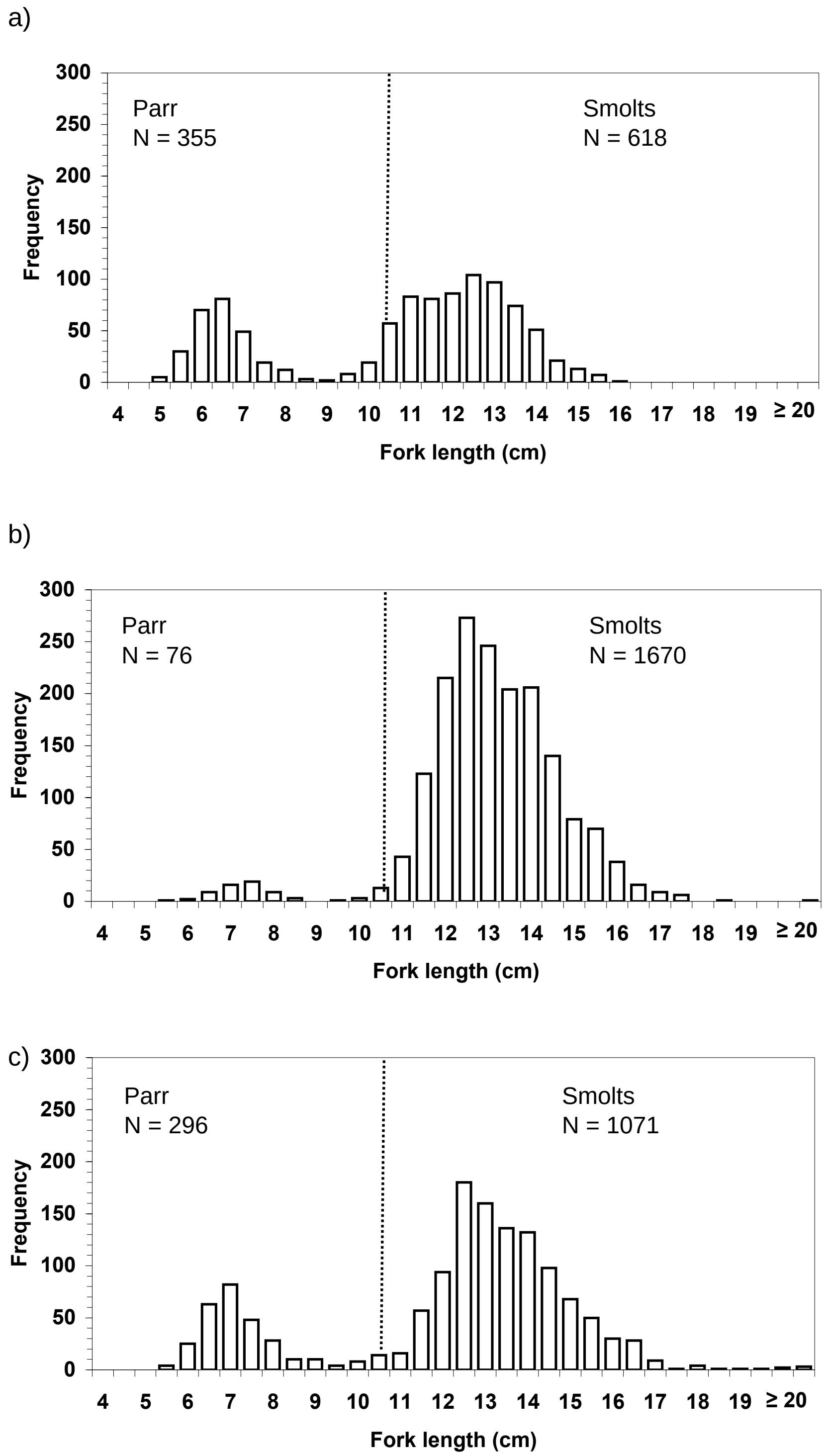


Figure 7: Fork length (cm) distribution of wild Atlantic salmon parr and smolts captured at the rotary screw trap in the Margaree River during the spring of a) 2001, b) 2001 and c) 2003. The fork length labels are the lower limits of the class interval.

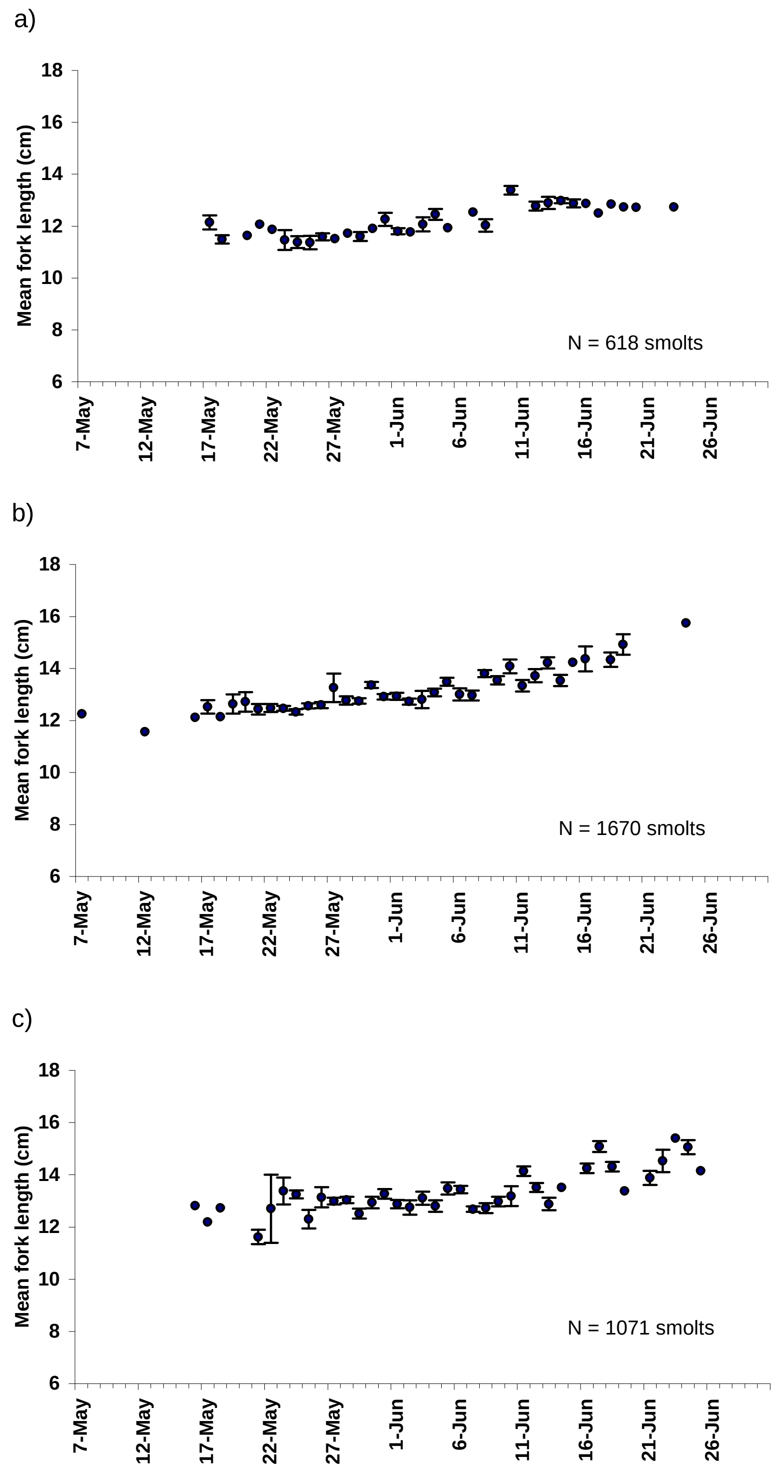


Figure 8: Mean daily fork length of wild smolts (samples of sacrificed and live smolts combined) from the Margaree River during the spring of a) 2001, b) 2002 and c) 2003. The means are shown when the daily number (n) ≥ 5 smolts. Vertical bars denote the standard error of the means and the values are shown when n ≥ 10 smolts.

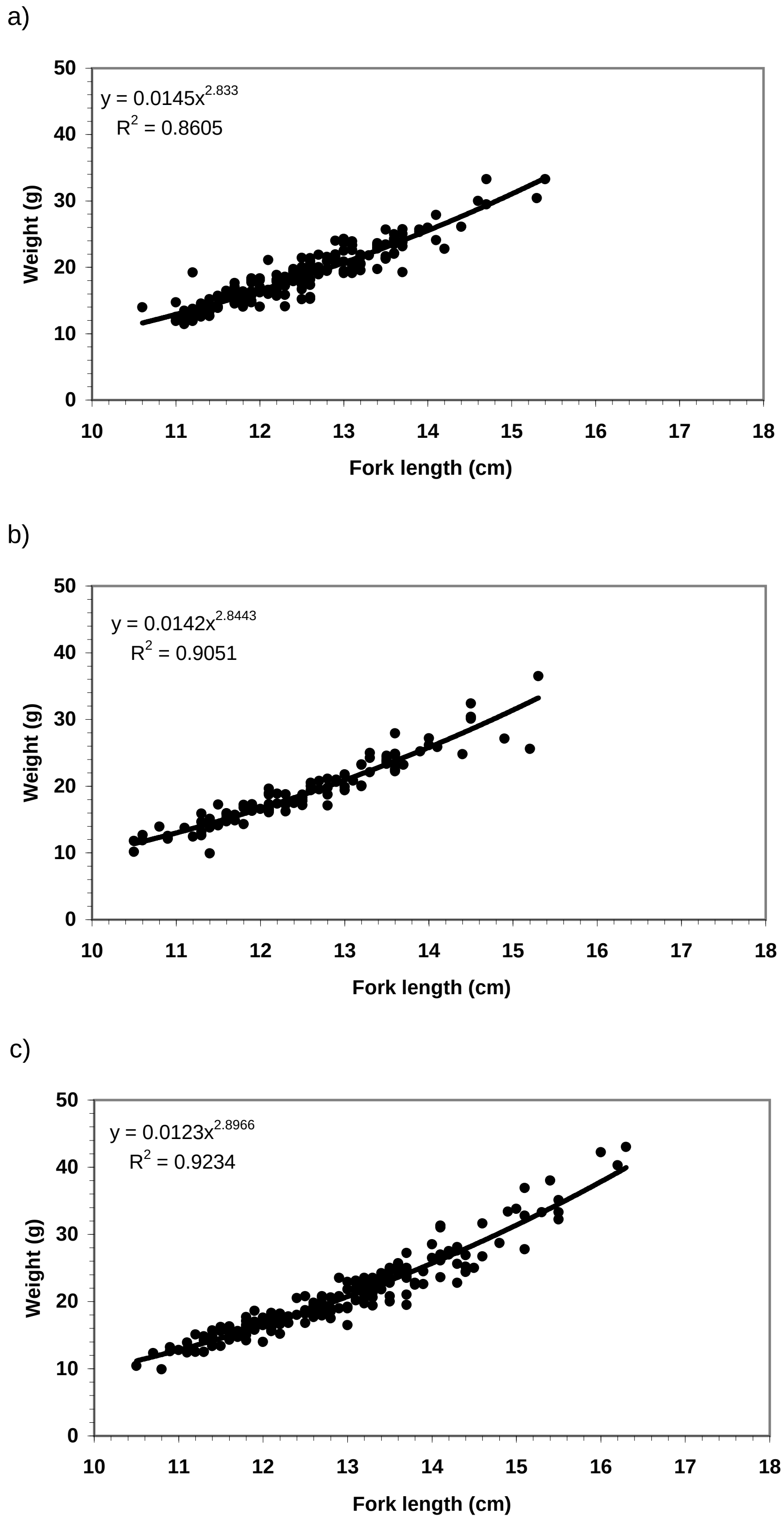
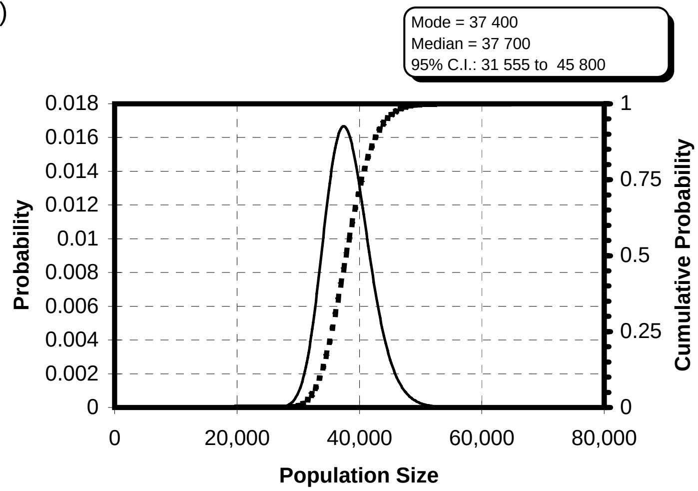


Figure 9: Length-weight relationships of wild Atlantic salmon smolts (sacrificed only) from the Margaree River during the spring of a) 2001, b) 2002 and c) 2003.

a)



b)

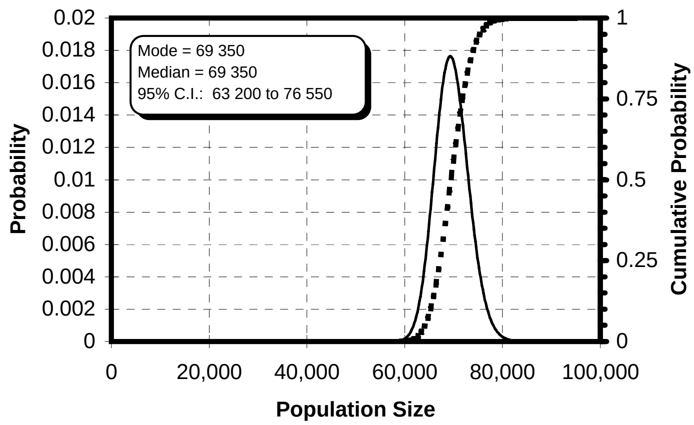
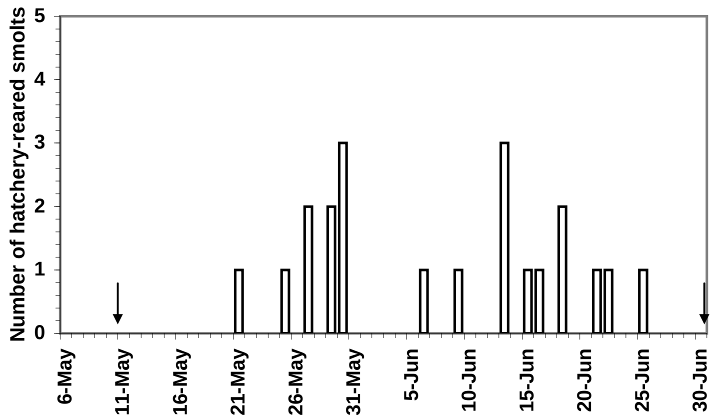
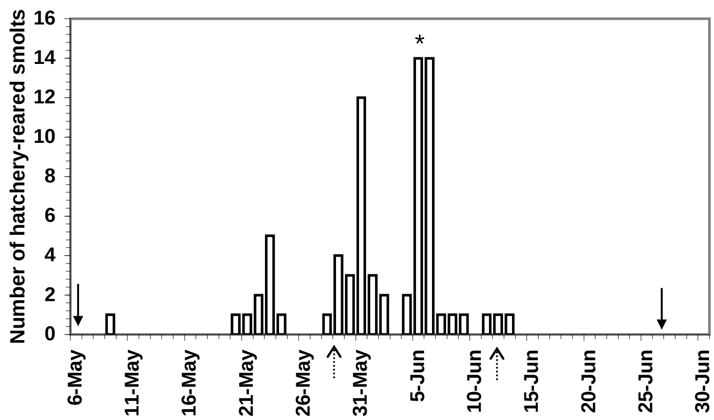


Figure 10: Bayesian estimate of the number of Atlantic salmon smolts emigrating from the Margaree River during the spring of 2002 (a) and 2003 (b). The solid line represents the probability density and the dashed line represents the cumulative probability.

a)



b)



c)

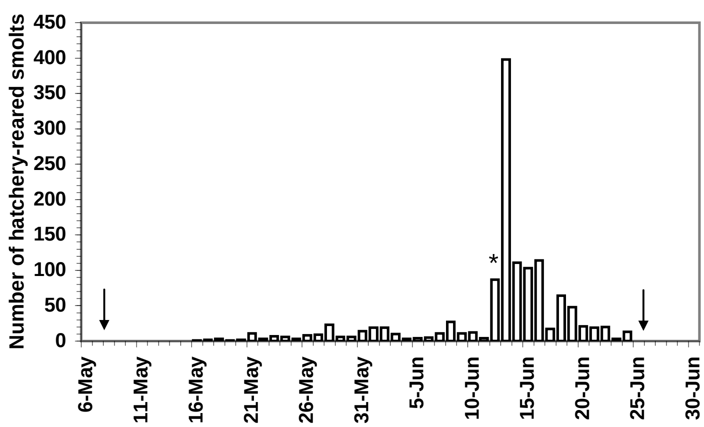


Figure 11: Daily catch of hatchery-reared Atlantic salmon smolts at the rotary screw trap in the Margaree River during the spring of a) 2001, b) 2002 and c) 2003. Stars indicate the release date of 1 year old smolts. The solid arrows indicate the start and finish dates of operation. The dashed arrows indicate the period at which the trap was moved to the location of highest water flow in 2002.

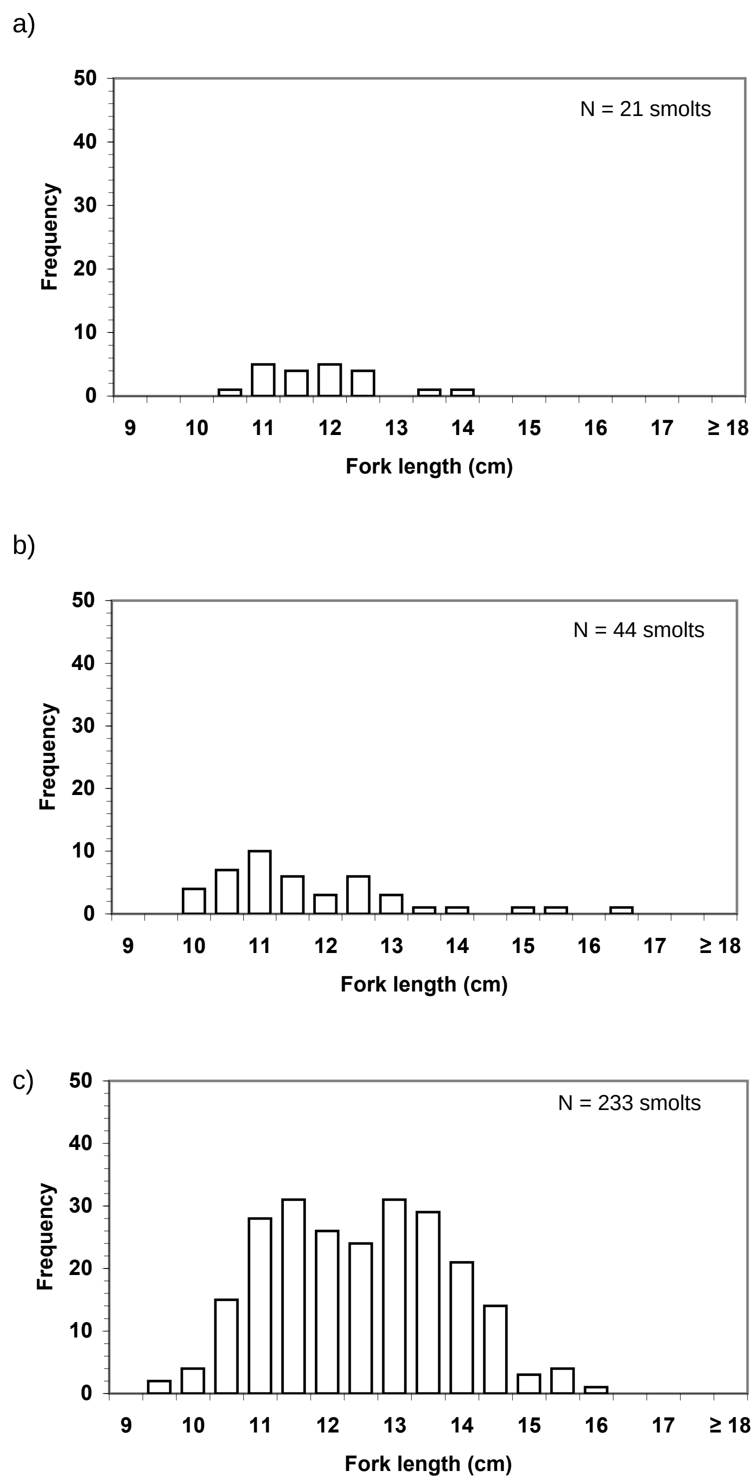


Figure 12: Fork length distribution of hatchery-reared smolts at the rotary screw trap in the Margaree River during the spring of a) 2001, b) 2002 and c) 2003. The x-axis indicates the lower limits of the class interval.

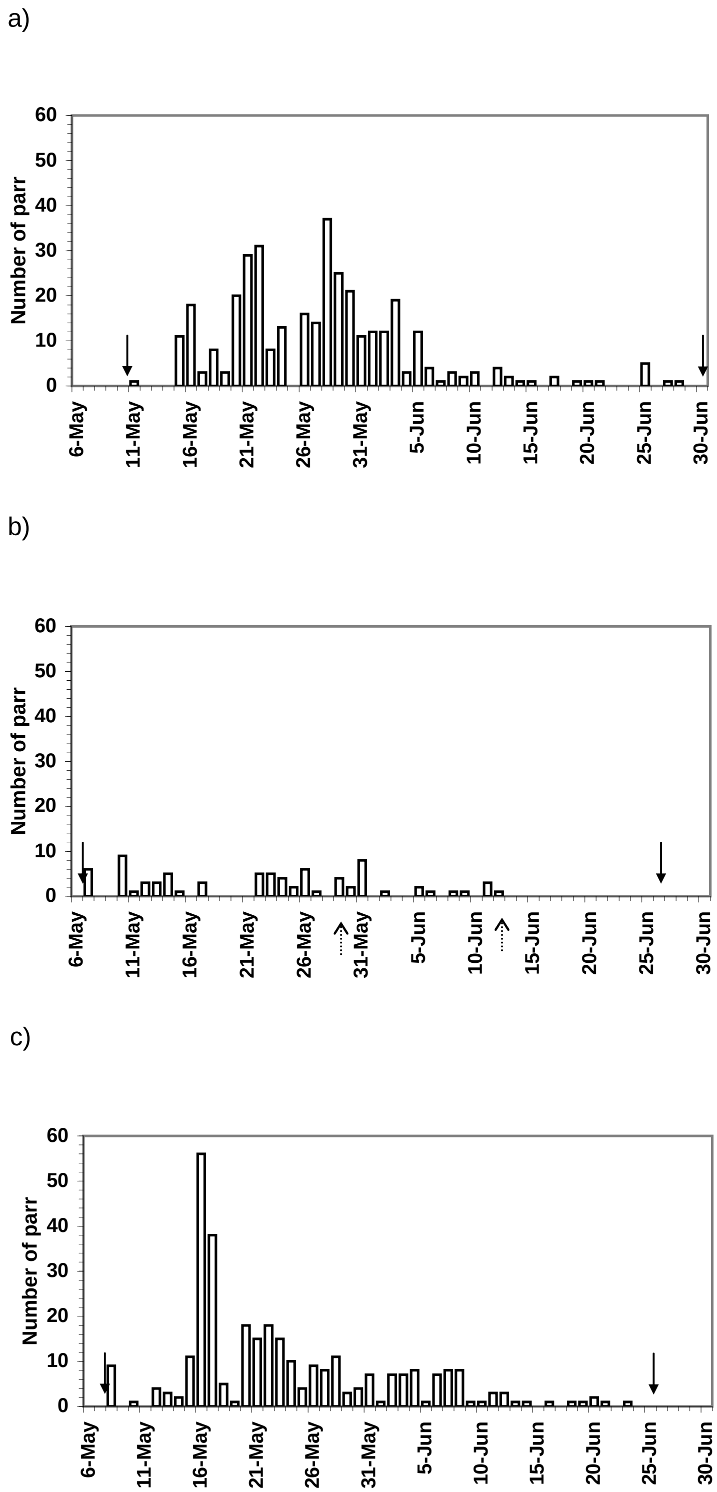
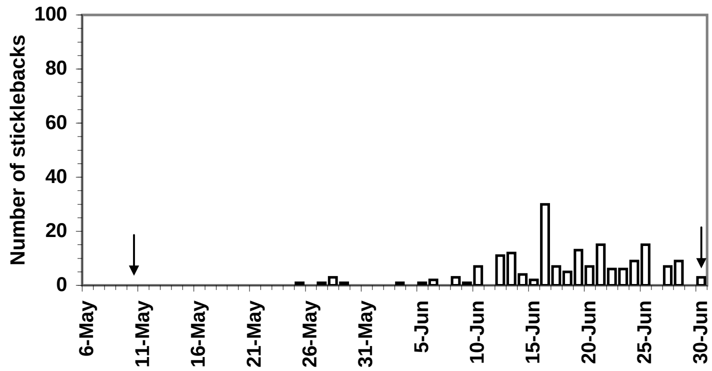
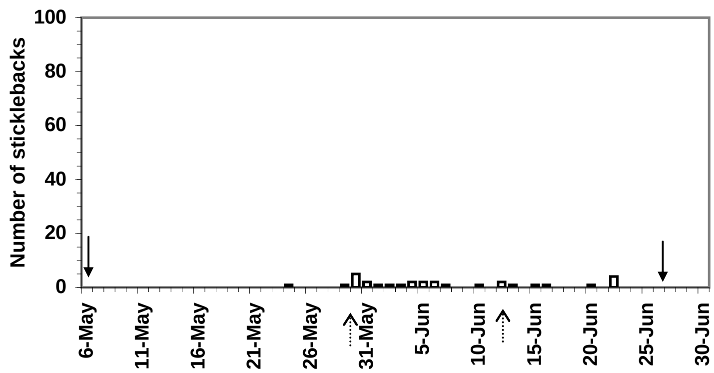


Figure 13: Daily catch of wild Atlantic salmon parr captured at the rotary screw trap in the Margaree River during a) 2001, b) 2002 and c) 2003. The solid arrows indicate the start and finish dates of operation. The dashed arrows indicate the period at which the trap was moved to the location of highest water flow in 2002.

a)



b)



c)

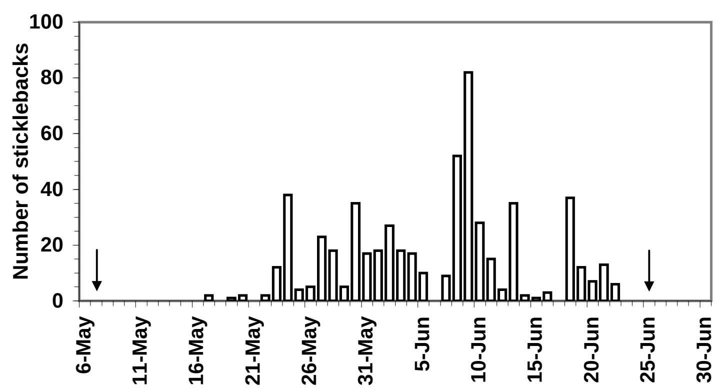
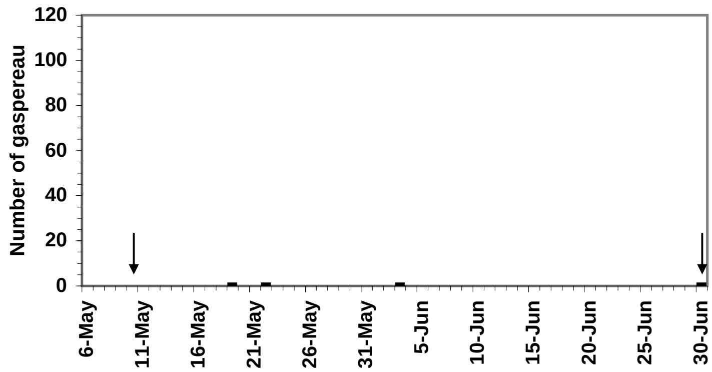
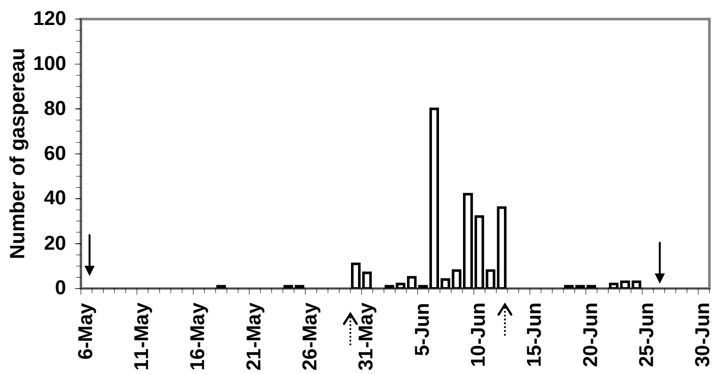


Figure 14: Daily catch of sticklebacks at the rotary screw trap in the Margaree River during the spring of a) 2001, b) 2002 and c) 2003. The solid arrows indicate the start and finish dates of operation. The dashed arrows indicate the period at which the trap was moved to the location of highest water flow in 2002.

a)



b)



c)

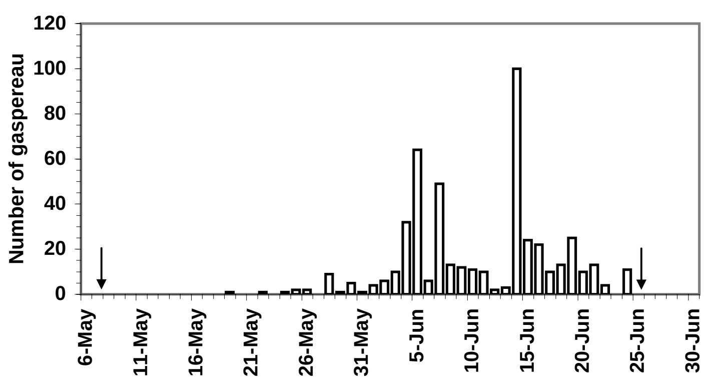
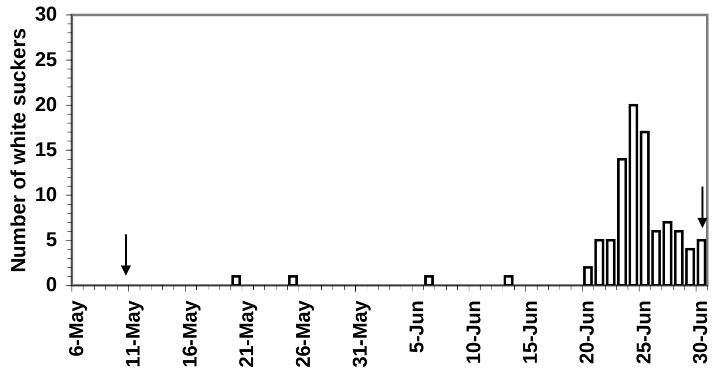
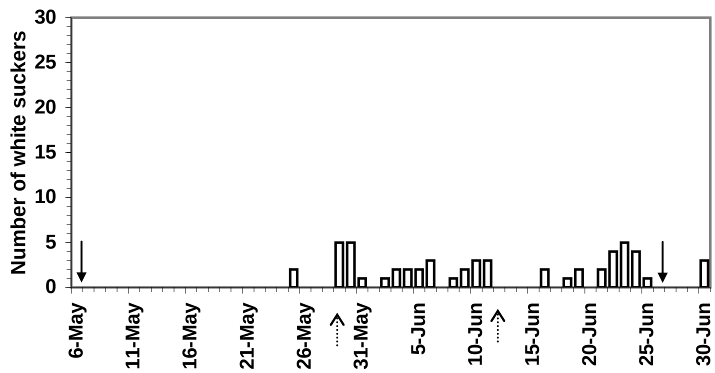


Figure 15: Daily catch of gaspereau at the rotary screw trap in the Margaree River during the spring of a) 2001, b) 2002 and c) 2003. The solid arrows indicate the start and finish dates of operation. The dashed arrows indicate the period at which the trap was moved to the location of highest water flow in 2002.

a)



b)



c)

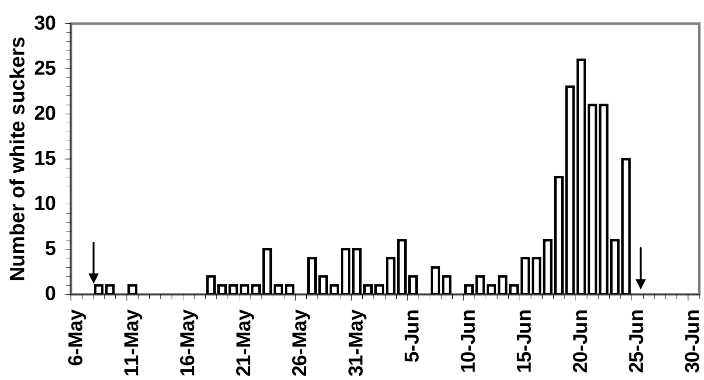


Figure 16: Daily catch of white suckers captured at the rotary screw trap in the Margaree River during the spring of a) 2001, b) 2002 and c) 2003. The solid arrows indicate the start and finish dates of operation. The dashed arrows indicate the period at which the trap was moved to the location of highest water flow in 2002.

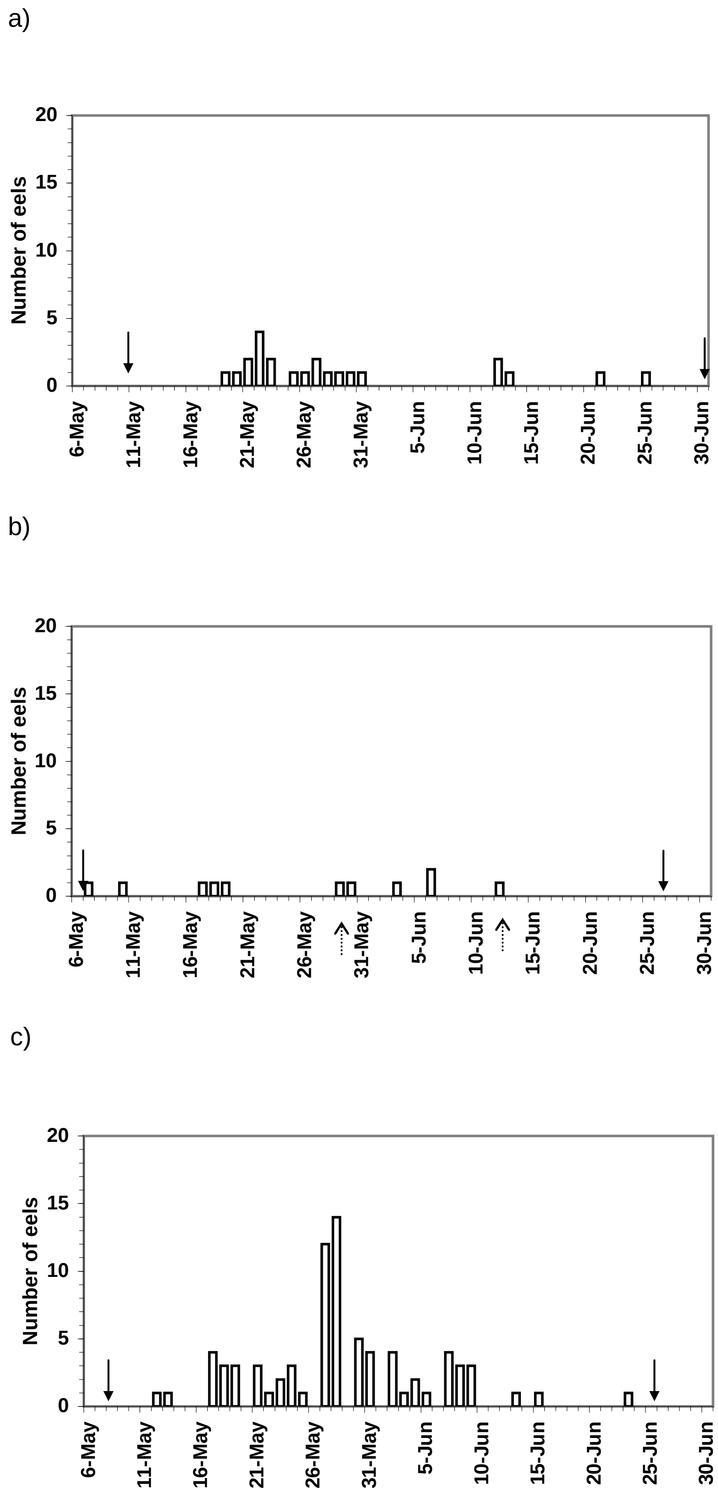


Figure 17: Daily catch of eels at the rotary screw trap in the Margaree River during the spring of a) 2001, b) 2002 and c) 2003. The solid arrows indicate the start and finish dates of operation. The dashed arrows indicate the period at which the trap was moved to the location of highest water flow in 2002.

Appendix 1: Number of juvenile salmon stocked and percent which were adipose clipped (in parentheses) as fall fingerlings (0+ parr) and smolts (1-year old, 2-year old) to the Margaree River, 1997 to 2003. Data provided by the Aquatic Development Association of Margaree (ADAM).

Year	Life stage		
	0+ parr	1 year old smolt	2 year old smolt
1997	135,758 (48)	0	881 (100)
1998	99,476 (35)	0	0
1999	147,315 (44)	0	0
2000	100,712 (32)	0	0
2001	106,770 (100)	0	0
2002	88,866 (100)	0	0
2003	129,966 (100)	15,534 (100)	0

Appendix 2: Operating conditions of the rotary screw trap in the Margaree River during the spring of 2001 - 2003. Clogged = Clogged with debris and drum not turning, FP = fishing properly, L&NF = Drum intentionally lifted and RST not fishing, NA = Not applicable, NT = Drum not turning, SET = first day of operation.

Date	Year		
	2001	2002	2003
6-May	NA	SET	NA
7-May	NA	FP	SET
8-May	NA	Clogged & NT	FP
9-May	NA	L&NF	Clogged & NT
10-May	SET	FP	Clogged & NT
11-May	Clogged & NT	Clogged & NT	Clogged & NT
12-May	L&NF	FP	FP
13-May	L&NF	FP	FP
14-May	L&NF	FP	FP
15-May	FP	FP	FP
16-May	FP	Clogged & NT	FP
17-May	Clogged & NT	FP	FP
18-May	Clogged & NT	Clogged & NT	FP
19-May	Clogged & NT	Clogged & NT	Clogged & NT
20-May	FP	FP	Clogged & NT
21-May	FP	FP	FP
22-May	FP	Clogged & NT	FP
23-May	Clogged & NT	FP	FP
24-May	FP	FP	FP
25-May	Clogged & NT	FP	FP
26-May	FP	FP	FP
27-May	FP	FP	FP
28-May	FP	FP	FP
29-May	FP	FP	FP
30-May	FP	FP	FP
31-May	FP	FP	FP
1-Jun	FP	FP	FP
2-Jun	FP	FP	FP
3-Jun	FP	FP	FP
4-Jun	FP	FP	FP
5-Jun	FP	FP	FP
6-Jun	FP	FP	FP
7-Jun	FP	FP	Clogged & NT
8-Jun	FP	FP	FP
9-Jun	FP	FP	FP
10-Jun	FP	FP	FP
11-Jun	Clogged & NT	FP	Axle broke & NT
12-Jun	FP	FP	FP
13-Jun	FP	FP	FP
14-Jun	FP	FP	FP
15-Jun	FP	FP	FP
16-Jun	FP	FP	Axle broke & NT
17-Jun	FP	FP	FP
18-Jun	FP	FP	FP
19-Jun	FP	FP	FP
20-Jun	FP	FP	FP
21-Jun	FP	FP	FP
22-Jun	FP	FP	FP
23-Jun	FP	FP	FP
24-Jun	FP	FP	Axle broke & NT
25-Jun	FP	FP	Finish
26-Jun	FP	Finish	
27-Jun	FP		
28-Jun	FP		
29-Jun	FP		
30-Jun	Finish		

Appendix 3a: Recapture matrix of wild Atlantic salmon smolts at the rotary screw trap in the Margaree River, 2001.

	Recapture date																											
Release	June																											
date	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total
11-May																												0
12-May																												0
13-May																												0
14-May																												0
15-May																												0
16-May																												0
17-May																												0
18-May																												0
19-May																												0
20-May																												0
21-May																												0
22-May																												0
23-May																												0
24-May																												0
25-May																												0
26-May																												0
27-May																												0
28-May																												0
29-May																												0
30-May																												0
31-May																												0
1-Jun	1																											1
2-Jun																												0
3-Jun		1																										1
4-Jun																												0
5-Jun																												0
6-Jun					1																							1
7-Jun																												0
8-Jun																												0
9-Jun																												0
10-Jun																												0
11-Jun																												0
12-Jun																												0
13-Jun																												0
14-Jun																												0
15-Jun														1														1
16-Jun																												0
17-Jun																												0
18-Jun																												0
19-Jun																												0
20-Jun																		1										1
21-Jun																												0
22-Jun																												0
23-Jun																												0
24-Jun																												0
25-Jun																												0
26-Jun																												0
27-Jun																												0
28-Jun																												0
29-Jun																												0
30-Jun																												0
Total	**1**	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**5**

Appendix 3b: Recapture matrix of wild Atlantic salmon smolts at the rotary screw trap in the Margaree River, 2002.

Release	Recapture date																																									
	May															June																										
date	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	22	23	24	25	26	Total
7-May																																										**0**
8-May																																										**0**
9-May																																										**0**
10-May																																										**0**
11-May																																										**0**
12-May																																										**0**
13-May																																										**0**
14-May																																										**0**
15-May																																										**0**
16-May																																										**0**
17-May		1																																								**1**
18-May																																										**0**
19-May																																										**0**
20-May																																										**0**
21-May																																										**0**
22-May							2																																			**2**
23-May								3																																		**3**
24-May									1																																	**1**
25-May																																										**0**
26-May																1																										**1**
27-May												1																														**1**
28-May													6																													**6**
29-May														2	9																											**11**
30-May															4																											**4**
31-May																																										**0**
1-Jun																	32																									**32**
2-Jun																		3	2																							**5**
3-Jun																			15	1																						**16**
4-Jun																				1																						**1**
5-Jun																					1	1																				**2**
6-Jun																						2																				**2**
7-Jun																							3																			**3**
8-Jun																								1																		**1**
9-Jun																									2	2																**4**
10-Jun																										6																**6**
11-Jun																											1															**1**
12-Jun																																										**0**
13-Jun																													1	1												**2**
14-Jun																																										**0**
15-Jun																																										**0**
16-Jun																																										**0**
17-Jun																																										**0**
18-Jun																																			1							**1**
19-Jun																																										**0**
20-Jun																																										**0**
21-Jun																																										**0**
22-Jun																																										**0**
23-Jun																																										**0**
24-Jun																																										**0**
25-Jun																																										**0**
26-Jun																																										**0**
Total	0	1	0	0	0	0	2	3	1	0	0	1	**6**	2	13	1	32	**3**	17	2	1	**3**	**3**	1	2	8	**1**	**0**	1	1	0	**0**	0	0	1	0	0	0	0	0	0	**106**

Appendix 3c: Recapture matrix of wild Atlantic salmon smolts at the rotary screw trap in the Margaree River, 2003.

Release	Recapture date																																			
	May											June																								
date	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	22	23	24	25	Total
8-May																																					**0**
9-May																																					**0**
10-May																																					**0**
11-May																																					**0**
12-May																																					**0**
13-May																																					**0**
14-May																																					**0**
15-May																																					**0**
16-May																																					**0**
17-May			1																																		**1**
18-May				1				1																													**2**
19-May	1																																				**1**
20-May																																					**0**
21-May		1		1							1																										**3**
22-May			2	3			1																														**6**
23-May				1	2		1																														**4**
24-May					3	2	2		1																												**8**
25-May						5		3																													**8**
26-May								4	1					1																							**6**
27-May								18	2																												**20**
28-May									17	8																											**25**
29-May										3	6																										**9**
30-May											6	9	1	3																							**19**
31-May												23	3	1																							**27**
1-Jun													5	8	1	1																					**15**
2-Jun														55	8	1																					**64**
3-Jun															4	4	2																				**10**
4-Jun																3	4																				**7**
5-Jun																		2	1																		**3**
6-Jun																		2	4	1	1																**8**
7-Jun																			3	10	1	1															**15**
8-Jun																				11	4	3	2	1	1												**22**
9-Jun																					3	7	1	2													**13**
10-Jun																						11	6	3	1	1											**22**
11-Jun																							1	8	3			1									**13**
12-Jun																								6	9	1	1										**17**
13-Jun																									10	5	3			1		1					**20**
14-Jun																										1	1	4		1							**7**
15-Jun																																					**0**
16-Jun																												3	1								**4**
17-Jun																													7	4	1						**12**
18-Jun																															1						**1**
19-Jun																															1	2					**3**
20-Jun																																1	2	1			**4**
21-Jun																																					**0**
22-Jun																																					**0**
23-Jun																																					**0**
24-Jun																																					**0**
25-Jun																																					**0**
Total	**1**	**1**	**3**	**6**	**5**	**7**	**4**	**26**	**21**	**11**	**13**	**32**	**9**	**68**	**13**	**9**	**6**	**4**	**8**	**22**	**9**	**22**	**10**	**20**	**24**	**8**	**5**	**8**	**8**	**6**	**3**	**4**	**2**	**1**	**0**	**0**	**399**

Appendix 4a: Daily catches of fish other than wild Atlantic salmon smolts at the rotary screw fish trap in the Margaree River, 2001. W = wild, H = hatchery-reared.

		Atlantic salmon																	
Month	Day	Smolt (H)	Parr (H)	Parr (W)	Stickleback	Gaspereau	White sucker	Eel	Lamprey	Mummichog	Dace	Brook trout	Smelt	White Perch	Golden Shiner	Brown trout	Tadpole	Unknown	**Total**
	11			1															**1**
	12																		**0**
	13																		**0**
	14																		**0**
	15			11						1									**12**
	16			18															**18**
	17			3															**3**
	18			8															**8**
	19			3		1		1		1									**6**
	20		1	20			1	1											**23**
	21	1	2	29				2											**34**
	22			31		1		4		1									**37**
	23		1	8				2		1									**12**
	24			13						1				1	1				**16**
	25	1			1		1	1											**4**
	26			16				1											**17**
	27	2		14	1			2											**19**
	28			37	3			1			1								**42**
	29	2		25	1			1											**29**
	30	3		21				1											**25**
	31			11				1	1		2								**15**
June	1			12															**12**
	2		1	12							1								**14**
	3			19	1	1					3								**24**
	4			3															**3**
	5			12	1														**13**
	6	1		4	2		1												**8**
	7			1															**1**
	8			3	3														**6**
	9	1		2	1														**4**
	10			3	7														**10**
	11																		**0**
	12			4	11			2	1		2	1							**21**
	13	3		2	12		1	1											**19**
	14			1	4				1										**6**
	15	1		1	2							1							**5**
	16	1			30														**31**
	17			2	7														**9**
	18	2			5					1									**8**
	19			1	13				1		1								**16**
	20			1	7		2					2							**12**
	21	1		1	15		5	1											**23**
	22	1			6		5		2		3								**17**
	23				6		14		1	1									**22**
	24				9		20		2										**31**
	25	1		5	15		17	1	3										**42**
	26						6		1			1							**8**
	27			1	7		7												**15**
	28			1	9		6		1										**17**
	29						4												**4**
	30				3	1	5												**9**
Total		**21**	**5**	**360**	**182**	**4**	**95**	**23**	**14**	**7**	**13**	**5**	**0**	**1**	**1**	**0**	**0**	**0**	**731**

Appendix 4b: Daily catches of the different fish species at the rotary screw trap in the Margaree River, 2002. W = wild, H = hatchery-reared.

		Atlantic salmon																	
Month	Day	Smolt (H)	Parr (H)	Parr (W)	Stickleback	Gaspereau	White sucker	Eel	Lamprey	Mummichog	Dace	Brook trout	Smelt	White Perch	Golden Shiner	Brown trout	Tadpole	Unknown	**Total**
May	7		1	6				1											**8**
	8																		**0**
	9	1																	**1**
	10			9				1											**10**
	11			1															**1**
	12			3															**3**
	13			3															**3**
	14			5								1							**6**
	15			1															**1**
	16																		**0**
	17		1	3				1				1							**6**
	18					1		1											**2**
	19							1											**1**
	20	1								3									**4**
	21	1								1					1				**3**
	22	2		5						3									**10**
	23	5		5						1									**11**
	24	1		4	1	1												1	**8**
	25			2		1	2												**5**
	26			6						2			1						**9**
	27			1															**1**
	28	1																	**1**
	29	4		4	1		5	1											**15**
	30	3		2	5	11	5	1			1						1		**29**
	31	12	3	8	2	7	1			1									**34**
June	1	3			1														**4**
	2	2		1	1	1	1												**6**
	3				1	2	2	1											**6**
	4	2			2	5	2							1					**12**
	5	14		2	2	1	2					1							**22**
	6	14		1	2	80	3	2				1			1				**104**
	7	1			1	4													**6**
	8	1		1		8	1												**11**
	9	1		1		42	2												**46**
	10				1	32	3												**36**
	11	1		3		8	3			1		1							**17**
	12	1		1	2	36		1											**41**
	13	1			1														**2**
	14																		**0**
	15				1														**1**
	16				1		2												**3**
	17																		**0**
	18					1	1												**2**
	19					1	2		1										**4**
	20				1	1													**2**
	21						2												**2**
	22				4	2	4		1										**11**
	23					3	5		1			1							**10**
	24					3	4		1					1					**9**
	25						1												**1**
	26						3												**3**
Total		**72**	**5**	**78**	**30**	**251**	**56**	**11**	**4**	**12**	**1**	**6**	**1**	**2**	**2**	**0**	**1**	**1**	**533**

Appendix 4c: Daily catches of the different fish species at the rotary screw trap in the Margaree River, 2003. W = wild, H = hatchery-reared.

Month	Day	Atlantic salmon Smolt (H)	Parr (H)	Parr (W)	Stickleback	Gaspereau	White sucker	Eel	Lamprey	Mummichog	Dace	Brook trout	Smelt	White Perch	Golden Shiner	Brown trout	Tadpole	Unknown	**Total**
May	8			9			1												**10**
	9						1												**1**
	10			1															**1**
	12																		**0**
	11						1												**1**
	13			4				1											**5**
	14			3				1					1						**5**
	15			2															**2**
	16			11									1						**12**
	17	1		56									1						**58**
	18	2		38	2			4		1			1						**48**
	19	3		5			2	3											**13**
	20	1		1	1	1	1	3											**8**
	21	2	1	18	2		1					2							**26**
	22	11		15			1	3				1							**31**
	23	3		18	2	1	1	1		1									**27**
	24	7		15	12		5	2	1	1							1		**44**
	25	6		10	38	1	1	3			1	1	1						**62**
	26	3		4	4	2	1	1			1								**16**
	27	8		9	5	2			1										**25**
	28	9		8	23		4	12				1			2				**59**
	29	23	1	11	18	9	2	14	1										**79**
	30	6	1	3	5	1	1					2			1				**20**
	31	6	1	4	35	5	5	5			2								**63**
June	1	14		7	17	1	5	4				1							**49**
	2	19		1	18	4	1				2					1			**46**
	3	19		7	27	6	1	4			1	1	2						**68**
	4	10		7	18	10	4	1			1	1		1					**53**
	5	3		8	17	32	6	2					2						**70**
	6	4		1	10	64	2	1					1		1				**84**
	7	5		7		6													**18**
	8	11		8	9	49	3	4	1								1		**86**
	9	27		8	52	13	2	3		1			1						**107**
	10	11		1	82	12		3					1						**110**
	11	12		1	28	11	1			1									**54**
	12	4		3	15	10	2			1	3								**38**
	13	87		3	4	2	1							2					**99**
	14	398		1	35	3	2	1		2				1					**443**
	15	111		1	2	100	1		1				1	2					**219**
	16	103			1	24	4	1											**133**
	17	114		1	3	22	4						1						**145**
	18	17				10	6												**33**
	19	64		1	37	13	13		1					1					**130**
	20	48	1	1	12	25	23		2										**112**
	21	21		2	7	10	26							1					**67**
	22	19		1	13	13	21		2										**69**
	23	20			6	4	21		2										**53**
	24	3		1			6	1	2										**13**
	25	13				11	15												**39**
Total		**1248**	**5**	**315**	**560**	**477**	**198**	**78**	**14**	**8**	**11**	**10**	**14**	**8**	**4**	**1**	**2**	**0**	**2953**