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Review of DFO Science information for Atlantic salmon (*Salmo salar*) populations in the Southern Upland region of Nova Scotia

Examen de l'information scientifique détenue par le MPO sur les populations de saumon atlantique (*Salmo salar*) dans la région des hautes-terres du sud de la Nouvelle-Écosse

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ABSTRACT

The purpose of this document is to review available information for Atlantic salmon populations in the Southern Upland region of Nova Scotia in support of an assessment of the extinction risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). As such, annually collected monitoring data on all life stages of salmon from two index river populations, as well as adult and juvenile abundance and distribution data from other populations in the Southern Upland, were assessed relative to conservation requirements and other reference values. Trends in abundance and distribution, changes to life-history parameter values, overall population viability, and threats to population persistence were quantified where possible.

For the two index populations (LaHave and St. Mary's rivers), current abundance of all life stages is low and populations have undergone declines in excess of 50% over the previous three generations. Mortality rates of immature and adult salmon at sea are high, and there is some indication that freshwater productivity has declined over the last 20 years. Surveys to assess the status of surrounding populations relative to the index populations suggest that current adult and juvenile abundance is critically low in most rivers, and that population extirpations may have occurred. For rivers in which salmon were found, juvenile abundance has declined markedly over the last eight years. Furthermore, estimated declines in adult escapement, as determined by changes in recreational catch or monitoring at fishways, exceed 95% in some rivers.

Estimates of current life-history parameter values for salmon in the index rivers indicate that populations may be viable at low overall population size. However, the maximum reproductive rates of the populations are extremely low, indicating little capacity for a compensatory response to further decreases in population size. This places populations at risk from the cumulative effects of environmental variability or stochastic events. In terms of recovery potential, increases to freshwater productivity have the potential to enhance long-term population viability but will not recover populations to levels above the conservation requirement without an increase in survival at sea.

Acidification is known to have substantially reduced the capacity of rivers in the Southern Upland to produce salmon and populations in highly acidified rivers are likely extirpated. Other threats to Atlantic salmon in the Southern Upland are thought to affect a large proportion of populations, yet their impact on spawner abundance in any specific population tends to be low or uncertain. However, equilibrium analyses suggest that population viability could be enhanced via increased freshwater productivity, although the extent to which habitat restoration efforts can increase freshwater production is not known. Given the current trends in salmon abundance in the Southern Upland, any actions to promote recovery will have to be timely to be effective.

RÉSUMÉ

Le présent document a pour but d'examiner l'information disponible au sujet des populations de saumon atlantique dans la région des hautes-terres du sud de la Nouvelle-Écosse en appui à une évaluation du risque d'extinction par le Comité sur la situation des espèces en péril au Canada (COSEPAC). Par conséquent, on a évalué les données recueillies annuellement à tous les stades de vie du saumon dans deux populations de rivières-repères, ainsi que les données sur l'abondance et la répartition des adultes et des juvéniles issus d'autres populations des hautes-terres du sud, à la lumière des exigences de conservation et d'autres valeurs de référence. Dans la mesure du possible, on a quantifié les tendances relatives à l'abondance et à la répartition, les changements apportés aux valeurs des paramètres du cycle vital des poissons, la viabilité de la population et les menaces à la pérennité de la population.

Pour les deux populations-repères (rivières LaHave et Ste-Marie), l'abondance actuelle à tous les stades de vie est faible et les populations ont enregistré des diminutions de plus de 50 p. 100 par rapport aux trois générations précédentes. Le taux de mortalité des saumons immatures et adultes en mer est élevé, et tout semble indiquer que le rendement en eau douce a diminué au cours des 20 dernières années. Les relevés visant à évaluer la situation des populations environnantes par rapport aux populations-repères suggèrent que l'abondance actuelle de saumons adultes et juvéniles est dangereusement faible dans la plupart des rivières, et on craint que des extirpations se soient produites. Pour les rivières où l'on a repéré des saumons, l'abondance de juvéniles avait diminué considérablement au cours des huit dernières années. De plus, les diminutions estimées des échappements des saumons adultes, déterminées par les changements observés dans les prises de pêche récréative ou la surveillance effectuée dans les passes à poissons, surpassaient 95 p. 100 dans certaines rivières.

Les estimations des valeurs des paramètres du cycle vital des saumons des rivières-repères indiquent que les populations pourraient être viables malgré une taille globale réduite de la population. Cependant, le taux de reproduction maximal des populations est extrêmement faible, ce qui révèle une capacité limitée à déployer un mécanisme d'adaptation en vue d'éviter d'autres diminutions de la taille de la population. Cela pose un risque pour les populations confrontées aux effets cumulatifs de la variabilité environnementale ou aux phénomènes stochastiques. Relativement au potentiel de rétablissement, les hausses de rendement en eau douce auraient le potentiel d'améliorer la viabilité à long terme des populations, mais cela ne permettrait pas de rétablir les populations à des niveaux supérieurs aux exigences de conservation fixées sans une augmentation du taux de survie en mer.

On sait que l'acidification a contribué à diminuer considérablement la capacité des rivières des hautes-terres du sud à produire des saumons et que les populations présentes dans les rivières hautement acidifiées risquent de disparaître. On pense que d'autres menaces à la survie du saumon atlantique dans les hautes-terres du sud touchent une vaste proportion des populations, et pourtant leur incidence sur l'abondance des saumons reproducteurs dans toute population tend à être faible ou incertaine. Cependant, les analyses d'équilibre suggèrent que la viabilité de la population pourrait être améliorée par le biais d'une hausse du rendement en eau douce, bien que la mesure selon laquelle les efforts de remise en état de l'habitat puissent accroître le rendement en eau douce ne soit pas connue. Étant donné les tendances actuelles observées relativement à l'abondance de saumon dans les hautes-terres du sud, toute mesure visant à promouvoir le rétablissement devra être opportune pour être efficace.

1.0 INTRODUCTION

This document contains an assessment of the current status, abundance trends and dynamics of salmon populations throughout the Southern Upland region of Nova Scotia. The Southern Upland includes all rivers along the Eastern Shore and southwestern portion of the province that drain into the Atlantic Ocean (Figure 1). It has been divided into two Salmon Fishing Areas (SFAs) for management purposes: SFA 20 (Eastern Shore) and SFA 21 (Southwest Nova Scotia).

Owing to the dominant geological substrate types of the region (Roland 1982), rivers in the Southern Upland are characterized by organic acid-stained water and are typically low in dissolved minerals, which make them less productive than more mineral-rich rivers (Watt 1987). In addition, the region has been extensively impacted by sulfate deposition (acid precipitation), which has lowered the pH in many rivers. At a mean annual pH below 5.1, salmon production is considered unstable and only remnant populations may persist (LaCroix 1985). Interspersed within the Southern Upland are limestone-rich soils (drumlins) that provide some rivers with less-acidified water.

Within the previous century, 63 rivers in the Southern Upland are known to have supported anadromous Atlantic salmon populations (DFO and MNRF 2008). As of 1986, at least 14 of these rivers were heavily acidified (pH < 4.7) and were no longer able to support salmon (Amiro et al. 2000, Watt 1987). A further 20 rivers were partially acidified (pH ranges from 4.7 to 5.0) and were thought to support only remnant populations.

Atlantic salmon commercial fisheries within the Maritimes Region were closed in 1985, and in-river closures of recreational fisheries for the Southern Upland began in 1998. In 2007, retention-angling fisheries for small salmon (< 63 cm fork length) were restricted to four heavily acidified rivers (East River, Sheet Harbour; Mersey; Jordan; and Clyde). Five other eastern and southern shore rivers were open to a catch-and-release fishery of at least 45 days duration. Aboriginal communities have respected these conservation initiatives and generally restricted their harvests to hatchery adipose-clipped small salmon from nine rivers in Nova Scotia using methods that facilitate the live release of wild fish.

Supplementation through captive breeding and rearing has been used to enhance Atlantic salmon populations in the Maritimes Region for over a century. However, recent assessments in the Southern Upland have shown continued declines (relative to the 1980s) in the abundance of both the wild and enhanced components of salmon populations. In the cases of the acidified Liscomb, Medway, East and Tusket rivers, population enhancement of smolts did not sustain adult escapement, presumably because of low marine survival coupled with high freshwater acidity (Amiro et al. 2000).

Monitoring effort since 1986 has been focused on low- or non-acidified rivers (pH > 5.0) in the Southern Upland, with the St. Mary's River in SFA 20 and the LaHave River in SFA 21 being chosen as index rivers for long-term population monitoring (Amiro et al. 2000). The status for most, if not all, low- or non-acidified rivers is expected to be similar to or worse than that of the index rivers (O'Neil et al. 1998, Amiro et al. 2000). Inference of trends obtained from the index rivers to other rivers throughout the Southern Upland is made based on recreational catch and effort data, adult count data from fish ladders, and region-wide electrofishing data.

Additional information about these populations, as well as previous assessment documents, can be found in Canadian Science Advisory Secretariat documents published by the Department of

Fisheries and Oceans (DFO) in Ottawa, the most recent being: Amiro et al. (2006) and DFO (2008).

2.0 LIFE-HISTORY CHARACTERISTICS OF SOUTHERN UPLAND SALMON

Wild Atlantic salmon have a complex hierarchical population structure, and their nearly precise homing to natal streams restricts gene flow among fish at different spawning locations. This can lead to local adaptation and dissimilarities in life-history characteristics among fish inhabiting geographically distant or environmentally distinct rivers. As such, anadromous Atlantic salmon populations returning to rivers in the Southern Upland exhibit a range of life-history characteristics, with differences in growth, maturation, run timing, and sex ratio among populations (Hutchings and Jones 1998, O'Connell et al. 2006).

In general, adults return to Southern Upland rivers as first-time spawners after one or two winters at sea and most enter the rivers throughout the spring (May/June) and summer (July/August) months. Timing is partially determined by river flow. Spawning takes place in late October or November, and spawned-out adults (kelts) either return to sea immediately or remain in fresh water until the following spring (O'Connell et al. 2006). Juveniles emerge from the gravel in early spring and typically spend three years in fresh water before undergoing smoltification. The abundance of juvenile salmon in fresh water is regulated by density-dependent factors, although the timing of density dependence is variable among populations (Gibson 2006). No evidence for density-dependent survival has been found in the marine environment, presumably because survival in the marine environment is not resource-limited for Southern Upland populations.

3.0 PRESENT STATUS AND RECENT TRAJECTORIES IN ABUNDANCE, RANGE AND NUMBER OF POPULATIONS

3.1 St. Mary's River

3.1.1 Background

The St. Mary's River is one of the major river systems in SFA 20 and consists of two main branches: the West Branch and the East Branch. In general, water in the East Branch is less acidified than water in the West Branch because the underlying soils are rich in base minerals; however, there is variation in pH among tributaries throughout the system. In addition, geological changes to the course of the river system over time (Roland 1982) have resulted in differences between the two branches in terms of the distribution of salmon habitat and the resulting productivity. Anecdotal reports also note a difference in the life-history characteristics of the returning adult population, with a higher proportion of large multi-sea-winter (MSW) fish historically returning to the East Branch (O'Neil and Harvie 1995).

In the St. Mary's River, approximately 80% of Atlantic salmon juveniles spend two years in fresh water and migrate to sea as two-year-old smolts (Amiro et al. 2006). Smolts exit the river in May, while adults return to the river predominantly during mid-spring and early summer (June/July/August). Historically, adult returns to the system were characterized by a relatively high proportion of two-sea-winter (2SW) and three-sea-winter (3SW) salmon (14% and 9%, respectively), of which approximately 60% were female (Marshall 1986), although one-sea-winter (1SW) salmon are thought to have been more prevalent in the West Branch. More recent assessments have shown a reduction in the number of virgin 3SW adults returning to the river

(O'Neil and Harvie 1995). Current assessments in the West Branch indicate that most salmon are maturing after one winter at sea (e.g., 92%; Amiro et al. 2006). The length-fecundity relationship (Marshall 1986) calculated from adult broodstock collections during the period 1972 to 1985 is:

$$\text{Fecundity} = 340.832e^{0.0389 * \text{Fork Length}}.$$

Conservation Requirement

Although alternate calculations exist (O'Connell et al. 1997), the conservation requirement used for recent assessments on the St. Mary's River is 7.4 million eggs, which is equivalent to approximately 3,155 adult salmon (O'Neil et al. 1998, Amiro et al. 2006). This egg requirement is based on the estimated habitat area suitable for juvenile production in the river and a target egg deposition rate of 2.4 eggs/m^2 (Marshall 1986).

3.1.2 Status

The annual status of salmon in the St. Mary's River is assessed using a combination of approaches including fishery-independent adult counts, smolt counts and juvenile surveys. Prior to 1996, adult escapement estimates were derived from recreational catches and the mean annual exploitation rate imported from the LaHave River (O'Neil et al. 1998). However, river-specific escapement estimates have been calculated since 1997 using mark-recapture seining experiments to estimate adult abundance (Table 1). Although attempts were made to sample both the East and West branches of the river, sufficient marks and recaptures could only be obtained for salmon in the West Branch. Recent seining efforts have focused on the West Branch exclusively. From 2002 to 2005, high water levels after the initial seining date precluded a second seining attempt to complete the mark-recapture experiment. Therefore, it was necessary to assume that the efficiency was equal to the mean catchability calculated for 1997 to 2001. Catchability for the marking pass is the number of fish caught on the marking pass divided by the adult population estimate. In past assessments, an attempt was made to scale the West Branch results up to the entire river by dividing the West Branch estimate by 0.55, which is the proportion of habitat available in the West Branch compared to that of the entire river (Amiro 1993, Amiro et al. 2000). The possibility that environmental factors like water quality, discharge, or substrate distribution differentially affect habitat production capacities among the West Branch, East Branch and Main River is not accounted for when production is scaled solely based on habitat area. For this reason, the most recent assessments have reported adult abundance estimates for the West Branch only.

Adults

The mark-recapture seining experiment on the West Branch typically takes place at the end of September and beginning of October each year, once the majority of adult salmon have entered the river. Three separate pools are seined over two days during both the marking and the recapture trips using a knotless nylon net (~ 100 ft. x 8 ft.). All salmon caught are sampled for biological characteristics (sex, length, scale and DNA samples), and fish from the three pools are given a different mark during the marking pass (used to evaluate the degree of mixing among pools). Other fish species present (generally brook trout and white sucker) are counted but population estimates are not attempted. Approximately two weeks separate the marking trip from the recapture trip to allow for random mixing of marked fish in the population.

In 2008, a total of 30 salmon were marked, 63 were captured and 4 were recaptured, giving a corrected Petersen estimate of escapement of 397 salmon (95% C.I. = 175 - 781). This estimate represents the first notable increase in escapement in 5 years (Table 1). Based on the scale samples taken from captured fish, 91% of the population was 1SW, 7% was 2SW and 2% were repeat spawners (Table 2). No 3SW fish were captured.

The estimated escapement in 2008 for the West Branch of the St. Mary's River (397 fish) is approximately 23% of the conservation requirement for the West Branch (55% of 3,155 salmon), which is the highest value recorded within the last 4 years (Table 5).

Smolts

Smolt monitoring on the St. Mary's River uses a rotary screw trap (RST) anchored off Glenelg Bridge on the West Branch. The RST is typically deployed in late April and is fished daily until early June. All smolts captured have biological samples taken (length and scale samples) and all other fish species are counted. A mark-recapture experiment, where all captured smolts are marked and released upstream of the RST, is used to calculate the efficiency of the RST. Smolt population estimates (2005-2008) are calculated based on a corrected Petersen estimate of the total number of marked and recaptured smolts.

In 2008, the RST was deployed on April 30, but some mechanical problems prevented sampling until May 8. In total, 485 smolts were captured, and, of these, 15 fish were tagged, indicating that they had been captured a second time. This gives a population estimate of 15,217 (95% C.I. = 9,451 - 24,154) smolts and a capture efficiency of 3.1% for the smolt wheel. These values are slightly below the 2007 estimates of 16,110 (95% C.I. = 12,735 - 20,835) smolts with a capture efficiency of 5.4%. Of the smolts sampled in 2008 (n = 254), 91% were age-2 and 9% were age-3. On average, age-2 smolts were approximately 2 cm smaller than age-3 smolts, with mean fork lengths of 14.5 cm and 16.4 cm, respectively.

The estimated area of the juvenile habitat in the St. Mary's River is 3,078,000 m^2 (Marshall 1986), 55% (1,692,900 m^2) of which is located in the West Branch. Based on this value, smolt production in 2008 was 0.90 smolts per 100 m^2. This estimate is low relative to the previous 2 years (Table 3) and to the reference value of 3.8 smolts/100 m^2 sometimes used for Atlantic salmon (Symons 1979). Given the productive habitat area in the West Branch of the St. Mary's River, 3.8 smolts/100 m^2 would place the natural production capacity for the branch at 64,330 smolts annually.

Juveniles

Electrofishing sampling sites on the St. Mary's River were chosen using a random stratified design, where gradient strata were sampled in proportion to the amount of juvenile habitat (based on stream gradient and distance from the river mouth) (Amiro et al. 1989, Amiro 1993). Between 9 and 37 sites throughout the St. Mary's River have been electrofished annually, typically starting in July and finishing in August of each year. Provided that a sufficient number of juveniles were initially captured, salmon abundance within a site was estimated using Petersen mark-recapture methods, and catchability was estimated by dividing the number of marked fish by the number caught during the recapture pass (Amiro et al. 1989). Annual mean catchability was used to estimate fish abundance for sites where mark-recapture was not possible. The densities of three age classes, age-0, age-1, and age-2+ (age-2 plus the small proportion of individuals that remained in the river for longer than two years) were estimated for each site based on ages determined by reading scales.

In 2008, the mean densities in the entire St. Mary's River were calculated based on data from 12 sites. Estimated overall age-0, age-1 and age-2+ densities were 6.1, 2.5 and 0.3 fish per

100 m^2, respectively, and were relatively consistent between the two branches (Table 4). Fry (age-0) and age-1 parr densities were lower in 2008 than in 2007, but the density of age-2 parr was approximately double the 2007 value (Figure 2).

The mean fry density observed in 2008 is consistent with the predicted linear relationship between estimated adult salmon returns for the years 1993-2007 and subsequent fry density in the following year (Figure 3). The similarity between the predicted and observed estimate of fry density for 2008 suggests that adult escapement in 2007 (203 fish) and 2008 fry densities are consistent with each other.

3.2 LaHave River

3.2.1 Background

The LaHave River drains approximately 1,670 km^2 of the Southern Upland region of Nova Scotia, and is one of the largest watersheds in SFA 21. It contains 113 lakes with a total surface area of 7,515 ha, and consists of five major sub-drainages: West Branch, North Branch, Ohio River, North River and the Main Stem (Gray et al. 1989). Throughout its length, the LaHave River contains several natural and manmade barriers to salmon migration. One of the larger obstacles is a natural waterfall named Morgans Falls, which is presently the site of a hydroelectric facility built in 1995. Morgans Falls is on the Main Stem of the LaHave River and is downstream of the Ohio and North river sub-drainages. Prior to the 1960s, Atlantic salmon had limited access to the watershed upstream of Morgans Falls. In the late-1960s, a fishway was constructed to bypass the falls and DFO began a stocking program to enhance the developing salmon run. Counts of adult salmon returning to the fishway began in 1970.

The smolt enhancement program on the LaHave River ran from 1969 to 2003. The first broodstock were taken from the nearby Medway River, and the first hatchery-reared smolts were released above Morgans Falls in 1971. From 1971 to 2005 (excluding 1982), the LaHave River was stocked annually with hatchery-reared smolts. From 1972 to 2003, all broodstock were collected at the Morgans Falls fishway. From 1996 to 2003, broodstock selection was proportional to the wild and hatchery components of the returning population (Amiro et al. 2006). The proportion of adults of hatchery origin contributing to annual egg deposition has ranged from 0% to 94%. Overall, 1SW salmon (wild and hatchery) contribute approximately 1,240 eggs per fish annually, while 2SW salmon contribute an average of 5,120 eggs per fish. Despite differences in the spawning escapement among large (> 63 cm fork length) and small (≤ 63 cm fork length) salmon, each size class contributes approximately 50% of the total annual egg deposition above Morgans Falls (Amiro, unpublished data).

Conservation Requirement

The annual assessment on the LaHave River is based primarily on an estimate of the egg deposition upstream of Morgans Falls, determined from the salmon counts and biological data collected at the Morgans Falls fishway. This value is compared to the conservation requirement for that area. There is some uncertainty of the effects of acidification on the provision of appropriate conservation requirements for the LaHave River above Morgans Falls. Cutting and Grey (1984) calculated the required number of spawners for the entire LaHave River (3,312 fish) based on the target egg deposition rate of 2.4 eggs/m^2, an estimated rearing area of 2,046,228 m^2, and an average fecundity of 1,482 eggs per fish. The current conservation requirement of 1.96 million eggs for the LaHave River upstream of Morgans Falls assumes the same fecundity per fish and target egg deposition rate but is based on the assumption that only 40% of the rearing area is usable (Amiro et al. 1996). This interim conservation requirement has been used to assess the status of the population in recent years (Amiro et al. 2006), although alternate calculations for both rearing area (Amiro et al. 1996) and conservation requirements (O'Connell et al. 1997) exist.

3.2.2 Status

Upstream-migrating adult salmon have been counted at the Morgans Falls fishway since 1970, and downstream migrating smolts have been counted each May since 1996 (Amiro et al. 2006). Currently, scale samples are taken from all wild adults in the fishway and from every fifth smolt for aging purposes. The collection of adult broodstock for enhancement ceased at Morgans Falls in 2003, with the last release of hatchery-reared smolts occurring in 2005.

Adults

The total count of adult salmon at the Morgans Falls fishway in 2008 was 691 fish (593 small and 98 large salmon), none of which were of hatchery origin (Figure 4). This is consistent with values for total returns observed since 1997, but represents a notable increase from returns in 2007. Age and spawning history were determined using scale samples from 684 of the captured adults, indicating that 86% of the population were 1SW salmon, 13% were 2SW salmon and 1% were repeat spawners (Table 6).

The estimated egg deposition above Morgans Falls was 1,078,475 eggs in 2008, equating to 55% of the conservation requirement (Figure 6, Figure 7). Because all adults captured at Morgans Falls from 1970 to 2008 were aged, it was possible to do a cohort analysis to calculate the number of adult recruits per adult spawner. Recent values of this statistic are negative, which demonstrates that successive generations of the salmon population above Morgans Falls in the LaHave River have not replaced themselves since the 1985 escapement year (Figure 8).

Smolts

Similar to the St. Mary's River, captured smolts are marked and released upstream of Morgans Falls for a mark-recapture experiment. A corrected Petersen estimate of the total number of marked and recaptured smolts is used to estimate population size. The catchability of the downstream fishway is estimated as the proportion of recaptured to marked fish. In 2008, a total of 14,450 wild smolts (90% C.I. = 13,500 - 15,500) were estimated to have migrated from above Morgans Falls, a 41% decline from the 2007 value and less than the 1996-2007 mean of 16,589 smolts (Table 7).

In 2008, approximately 20% of the smolts that were captured at Morgans Falls were measured and aged (1,239 individuals). Of these, 87% were age-2, 13% were age-3, and 0.3% were age-4. Mean fork lengths of age-2, age-3, and age-4 smolts were 16.4 cm (range: 13.0-20.1 cm), 18.9 cm (range: 16.0-23.5 cm), and 23.7 cm (range: 20.6-28.5 cm), respectively. These values are higher than those for smolts found in the St. Mary's River.

Smolt production in 2008 was 0.55 smolts per 100 m^2, less than the long-term mean (1996-2007) of 0.64 smolts per 100 m^2 (Table 7). Egg-to-smolt survival was 1.3%, similar to the long-term mean (1996-2007) of 1.2%. Both of these parameters indicate relatively low freshwater production of juvenile salmon in 2008.

The ratio between smolt production and subsequent adult returns provides an estimate of the return rate of smolts (indicative of at-sea survival). For the LaHave River above Morgans Falls, return rates have ranged from 1.13% to 7.95% for 1SW adults and 0.11% to 0.86% for 2SW adults (Table 7). The estimate of the return rate of wild smolts emigrating from above Morgans Falls in 2007 to 1SW returns in 2008 was 2.33%, less than the long-term mean of 2.8%. The estimate of the return rate of wild smolts emigrating in 2006 to 2SW returns in 2008 was 0.4%, a value identical to the long-term mean.

Juveniles

Electrofishing site selection and mark-recapture methods for estimating juvenile densities are the same as on the St. Mary's River (see Section 3.1.2). The number of electrofishing sites fished annually on the LaHave River has ranged from 7 to 30. In 2008, a total of 8 electrofishing sites, three located above Morgans Falls and five located below, were surveyed (Table 8). All juvenile salmon captured were marked during the initial electrofishing pass at each site, and 5 of the 8 sites were revisited for the recapture pass. The density of each age class (age-0, age-1 and age-2+) at each 2-pass site was calculated using a Petersen estimate (Gibson et al. 2003, Gibson and Amiro 2003), and density at each single-pass site was estimated based on total catch multiplied by the 2-year (2007 and 2008) mean estimate of efficiency for age-1 parr on an electrofishing pass. Unfortunately, density at one site in 2008 could not be calculated using either method because the area that was electrofished was not recorded.

Parr density (age-1, age-2, and older juveniles combined) in 2008 was higher below Morgans Falls than above, with mean parr densities of 13.9 and 4.5 parr per 100 m^2, respectively (Appendix 1, Figure 5). The 2008 mean parr density above Morgans Falls was the lowest estimate since 1984, yet the 2008 mean parr density below Morgans Falls was the highest estimate since 1999.

3.3 Abundance Trends and Information for other Southern Upland Rivers

3.3.1 2008 Electrofishing Survey

In 2008, a region-wide electrofishing survey for Atlantic salmon juveniles and other fish species was undertaken in the Southern Upland. A catchability of 42.8% for salmon (Gibson et al. 2003) was used to calculate density at single-pass electrofishing sites and a depletion experiment was used to calculate efficiency at multi-pass sites. A total of 143 sites were surveyed in 51 rivers, with between 1 and 12 sites fished per river (Figure 9, Appendix 2). Considering only the first pass of each survey, 143,385 seconds of shocking effort was applied over 98,019 m^2 of habitat, resulting in the capture of 3,474 fish, 977 of which were Atlantic salmon (Appendix 2). Salmon juveniles were captured at 52 of the 143 sites (36.4%) and were found in 20 of the 51 rivers surveyed (39.2%). American eel were the most commonly captured species (1,555 fish), followed by juvenile salmon (994 fish), and then by brook trout (333 fish).

Where present, the observed densities of juvenile salmon ranged from 0.3 to 33.9 fish per 100 m^2 (Figure 10). Observed densities of fry (age-0) ranged from 0.3 to 28.0 fish per 100 m^2 and of parr (age-1 and age-2) ranged from 0.2 to 16.2 fish per 100 m^2, with the highest values being recorded on the Musquodoboit River (Table 9). In six rivers, only one life stage was found (either fry or parr), yet it is likely that additional effort or alternate site selection would have resulted in the capture of the other life stage in the system. In rivers where both life stages were found, mean age-0 densities (range: 0.04-10.3 fish/100 m^2) were typically higher than age-1 and older densities (range: 0.04-7.5 fish/100 m^2). In general, the mean density of either age class was much lower than Elson's norm (30 age-0 fish/100 m^2 and 24 age-1 and older fish/100 m^2), values that have been used as a reference for juvenile production in fresh water (Elson 1967, Elson 1975).

3.3.2 Comparison of the 2000 and 2008 Electrofishing Surveys

Electrofishing surveys in the Southern Upland during 2000 (Figure 11, Appendix 3) and 2008 (Figure 9, Appendix 2) were similar in terms of total effort and coverage. Marginally more sites were completed in 2008 (143 versus 128), yet one less river was visited (51 versus 52). Total shocking time was slightly greater in 2008 (143,385 seconds versus 104,331 seconds), but the total area surveyed on the first pass at each site was lower (98,019 m^2 versus 128,842 m^2). However, less than half as many fish were captured on the first pass in 2008 (3,474) as in 2000 (7,825), including approximately one quarter as many salmon (977 versus 3,733). In 2000, juvenile Atlantic salmon were found in 54% of the rivers (28 of 52) rather than 39% (20 of 51) as in 2008.

At sites were juvenile salmon were captured, the total juvenile salmon density in 2000 ranged from 0.1 to 99.6 fish per 100 m^2 (Figure 12), which is approximately 3 times higher than maximum densities at a site in 2008. Observed densities of the total number of fry ranged from 0.1 to 86.3 fish per 100 m^2, and of parr ranged from 0.1 to 31.2 fish per 100 m^2 in 2000, with the highest values recorded on the Musquodoboit River (Table 10). Overall, the mean density of age-0 juveniles declined from 5.0 to 1.2 fish per 100 m^2 between 2000 and 2008, while the mean density of age-1 and older parr decreased from 3.5 to 0.9 fish per 100 m^2. In addition, juvenile salmon were absent in 7 sites and 2 rivers in 2008, where they were previously found in 2000 (Figure 13).

Of the sites surveyed in both years (n = 74), total juvenile density decreased in 43% (n = 32) and increased in 8% (n = 6) (Figure 14). The remainder of the sites (n = 36) had recorded densities of zero for both years. Any increase from the 2000 density was very small (as shown by the proximity of the points to the 1:1 line) while declines tended to be quite large. When the data were separated by age class, similar results were obtained. Any increase in fry (age-0) density was relatively small, while the declines were much larger, the most extreme example being a site with > 80 fry per 100 m^2 in 2000, but < 5 fry per 100 m^2 in 2008 (Figure 15). The trend was not as dramatic for parr (age-1 and older), but the most extreme example still shows a reduction in density from > 30 parr per 100 m^2 in 2000 to < 6 parr per 100 m^2 in 2008 (Figure 16).

3.3.3 Recreational Catch and Effort

Catch and effort data from the annual recreational salmon fishery have been collected using a license-stub return program since 1983. After the close of the fishing season, anglers send in their stubs during autumn and winter. Preliminary estimates of the season's catch and effort are provided the following spring, and estimates are finalized during the next year.

In 2007, the majority of rivers were closed to angling, except for 5 rivers in SFA 20 and 9 rivers in SFA 21 which were open from June 1 to July 15 (Appendix 4). Total fishing effort in 2007 was concentrated in 2 rivers: the St. Mary's in SFA 20 (597 rod-days) and the LaHave in SFA 21 (497 rod-days), with 297 adult salmon caught on the St. Mary's and 117 caught on the LaHave (Appendix 4). Catches and effort on nearly all other rivers were an order of magnitude lower. Of the 8 other rivers open to angling in SFA 21, at least one salmon was caught on 3 rivers and the highest number caught was 13. In 2007, salmon were caught on all of the other 4 rivers open to angling in SFA 20, but the greatest number caught was only 35 fish. The majority of fish captured were small salmon (74%) and a total of five of these were retained (i.e., removed from the river).

To summarize changes in reported recreational catch and effort (Appendix 5, Appendix 6), log mean catch and effort for each of the time periods of: 1988-1993, 1994-1999 and 2000-2007 were compared with the log mean from 1983-1987. Increases or decreases in catch or effort were summarized in terms of a percent change between the two time periods. In this way, it was possible to demonstrate progressive changes in effort and catch over time. Each time period corresponds to roughly one generation for Atlantic salmon in SFAs 20 and 21, except for the most recent time period (2000-2007) that was grouped together because of the scarcity of data (many rivers were closed to angling in 1998).

For the majority of rivers in SFA 20, a comparison of the reported recreational catch during the 1983-1987 time period with the 2000-2007 time period shows that the reported catch has declined, often by > 95% (Figure 17). Four of the 5 rivers open to angling in 2007 show a >90% decline in recreational catch. Concurrent with the decline in reported catch has been a decline in reported effort on most rivers, which dropped by nearly 100% before the rivers were closed to angling (Figure 18). One exception in terms of catch and fishing effort has been St. Francis Harbour River (labeled Saint Francis on Figures 17 and 18), which has seen an increase in recreational fishing effort and catch in recent years compared with the 1983-1987 time period. Although the increase appears substantial, it represents a change from 2 salmon caught in 4 rod-days in 1983 (with no salmon captured from 1984 to 1987), to 7 salmon caught in 3 rod-days in 2007 (the river was closed to recreational fishing from 2000 to 2006) (Appendix 5).

For the majority of rivers in SFA 21, reported recreational catch has declined over time. Of the 9 rivers that remained open to angling in 2007, all of them have shown a > 75% reduction in recreational catch between 1983-1987 and 2000-2007 (Figure 19). In conjunction, fishing effort has declined by > 95% in most rivers (Figure 20), with the exception being the Sackville River where a stocking program has been in place since the 1980s. Both recreational catch and effort have increased on the Sackville River since the stocking program began (Figures 19 and 20). However, the mean catch and fishing effort for the most recent time period (2000-2007) is low, at 3.4 salmon caught in 34.4 rod-days (Appendix 6).

In general, any decline in reported recreational effort lagged behind the decline in reported recreational catch. For example, in the early 1990s the distribution of recreational effort in SFA 20 changed slightly, with approximately the same number of rivers showing an increase as a decrease (Figure 18). However, with the exception of four rivers, recreational catches declined between the 1983-1987 and 1988-1993 time periods (Figure 17). This pattern is also evident for rivers in SFA 21, where the river-specific decline in recreational catch tends to be greater than the decline in fishing effort for a given time period.

3.3.4 Trends in Adult Salmon Abundance in the Southern Upland

Adult abundance time series data are available for four populations in the Southern Upland. These are the St. Mary’s and LaHave populations, described above, as well as counts of adult salmon ascending fishways on the East River, Sheet Harbour and the Liscomb River. Counting facilities on the East River, Sheet Harbour and the Liscomb River are relatively close to the mouth of their respective river system so the counts are thought to be representative of the majority of returns in each year. On the Liscomb River, returns were predominantly 1SW adults and counts peaked in 1987 when 1,614 1SW and 88 MSW fish returned to the river (Table 11). Beginning in 1990, annual counts declined progressively until the last year of monitoring in 1999, when only nine 1SW and no MSW adults returned to the river. Counts in East River, Sheet Harbour were low relative to the other rivers in the Southern Upland, and generally ranged from 25-100 1SW and < 10 MSW adults annually (Table 11). However, in the most recent 9 years, the highest count has been 3 salmon. The low counts in more recent years relative to the rest of the time series suggest that salmon populations in the Liscomb River and in East River, Sheet Harbour have substantially declined.

When assessing the status of wildlife in Canada, COSEWIC uses trends in abundance over 10 years or 3 generations (whichever is longer) as one of the criteria for determining the extent to which a species is at risk of extinction. Here, two different methods were used to evaluate declines over the previous 3 generations for Southern Upland populations following the approach of Gibson et al. (2006). The first was to calculate the extent of the decline as the ratio of the population size in two 5-year time periods separated by 15 years (or as close to 15 years as possible given the available monitoring data). The model was fit using maximum likelihood and confidence intervals for the step function were calculated using likelihood ratios. The second method estimated decline rates using a log-linear model, which was fit to the data using least-squares after transformation onto the log scale.

Declines in total escapement for 4 rivers in the Southern Upland (St. Mary's, LaHave, Liscomb, and East River Sheet Harbour) could be assessed using the models described above. In all cases, similar decline rates were found using the 2 models (*c.f.* 15-Year and Step function in Table 12 for St. Mary's, LaHave, and East River, Sheet Harbour; and 10-Year and Step function for Liscomb) and the confidence intervals did not straddle zero, indicating that the declines were significantly different from zero (Table 12). Decline rates on the St. Mary's (slope = -0.080) and LaHave rivers (slope = -0.056) were much lower than those predicted for East River, Sheet Harbour (slope = -0.243) or Liscomb River (slope = -0.458). Over the last 10 years when data were available, the salmon population in the Liscomb River was predicted to have declined by > 99% (Figure 21). The predicted population decline over the last three generations of salmon in East River, Sheet Harbour is also extreme, at > 97% (Figure 22). Although decline rates have been lower on the LaHave and St. Mary's, the populations are still predicted to have declined by > 56% (Figure 23) and > 69% (Figure 24), respectively, over the previous three generations.

4.0 POPULATION DYNAMICS

The population dynamics of Southern Upland salmon were analyzed using a population model consisting of two parts: a freshwater production model that provides estimates of the expected smolt production as a function of egg deposition, and an egg-per-smolt model that provides estimates of the rate at which smolts produce eggs throughout their lives. These components are combined via an equilibrium analysis that provides estimates of the abundance at which the population would stabilize if the input parameters remained unchanged. This combined model can also be used to evaluate how population size would be expected to change in response to changes in carrying capacity, survival, or life stage transition probabilities.

4.1 Freshwater Production Model

The values of several demographic parameters were estimated, including freshwater carrying capacity, age- and stage-specific survival rates, smoltification probabilities and maturation rates using the model of Gibson et al. (2009). The model begins with the annual egg deposition in the river, and it uses estimates of age-specific survival and smoltification probabilities to link egg deposition to smolt production:

Let $P_{t,0}$ be the number of age-0 salmon (fry) in year *t*. The relationship between the number of age-0 salmon in the spring and egg production during the previous fall is modeled as:

$$P_{t,0} = Egg_{t-1}(1 - M_{Egg}) \text{ ,}$$

where Egg_t is egg deposition in year t, and M_{Egg} is the density-independent mortality of eggs and newly emerged fry (i.e., all mortality that occurs from the time of egg deposition to the time of sampling by electrofishing the following summer).

For Atlantic salmon, density dependence is known to occur in fresh water (Chaput and Jones 2006, Gibson 2006), but little or no evidence exists for its presence in the marine environment (Jonsson et al. 1998. Armstrong 2005, Gibson 2006), presumably because marine survival is not resource-limited. Therefore, density dependence is modeled as density-dependent survival in fresh water. This is the equivalent of assuming that the carrying capacity of the freshwater habitat limits production and that, as a result of competition for limited resources, survival decreases as cohort size increases. In a comparison of nine populations, Gibson (2006) found that the timing of density dependence in fresh water varied among populations. In the case of the St. Mary's and LaHave populations, it occurred between age-0 and age-1. No evidence of overcompensation was found in his analyses, so density dependence is incorporated into the model using a Beverton-Holt function (Hilborn and Walters 1992).

In year t, the number of age-1 parr, $P_{t,1}$, is given by:

$$P_{t,1} = \frac{\alpha P_{t-1,0}}{1 + \frac{\alpha P_{t-1,0}}{R_{asy} h}}(1 - j_1) \text{ ,}$$

where α is the slope at the origin of the Beverton-Holt function and describes the maximum survival rate between age-0 and age-1, R_{asy} is the asymptotic density of age-1 parr (number per 100 m^2 habitat units), h is the number of habitat units available to the population, and j_1 is the probability that a fish emigrates as a smolt at age-1. Thus, $R_{asy}h$ is the carrying capacity of the river for wild age-1 parr. The model is formulated this way because the electrofishing data, used as indices of the abundance of parr, are reported as a density (number per 100 m^2), whereas the total number of parr in the river are of interest here.

For a given age a, the number of age-2 and older parr is determined by the number of parr in the cohort from the previous year, the annual mortality rate of parr M_{Parr} (assumed to be density-independent), and the age-specific probability of smoltification j_a:

$$P_{t,a} = P_{t-1,a-1}(1 - M_{Parr})(1 - j_a) \text{ .}$$

Wild age-1 smolts have not been observed in the St. Mary's River, and all parr have undergone smoltification by age 3. The number of smolts in year *t* of age *a* ($S_{t,a}$) is then:

$$S_{t,a} = P_{t-a,a-1}(1 - M_{Parr})\, j_a$$

4.1.1 Data Available to Parameterize the Freshwater Production Model

St. Mary's River

For the St. Mary's River, data inputs for the life-history model were exclusively from monitoring on the West Branch of the river. This was done to avoid any uncertainty in the model associated with scaling up abundance estimates calculated from the West Branch to the entire river based on habitat area. The observed data that were used in the life-history model were: (1) smolt counts and biological characteristics (age and size distribution) from the years 2005 to 2008 (Table 3), (2) mark-recapture electrofishing survey data from which juvenile density by age class was estimated from 1990 to 2008 (Table 13), (3) recreational catch estimates by size class from a volunteer license-stub return program for the years 1984 to 1996 (Table 14), and (4) mark-recapture seining estimates of adult abundance in the West Branch from 1997 to 2008 (Table 1).

The life-history model was fit using data spanning 3 overlapping time periods: 1984-2008, 1993-2008 and 1997-2008. The first time period corresponds to the years when egg deposition data could be calculated either from the recreational catch (with an assumed catch rate equal to the median catch rate observed on the LaHave River) or from mark-recapture experiments and the length-fecundity relationship for adults on the St. Mary's River. The second time period encompasses the previous 3 generations of Atlantic salmon in the St. Mary's River. The third time period corresponds to the years during which fishery-independent data are available to estimate escapement. Given the overlap in the data, parameter estimates obtained for each time period are correlated and cannot be directly compared with one another (i.e., to test for changes in parameter values over time). However, it is useful to present multiple analyses of the dataset and to look at how conclusions drawn from each differ with respect to salmon status in the St. Mary's River.

LaHave River

For the LaHave River, estimates of annual egg deposition were available for the period 1973 to 2008 (Table 15), and estimates of the number and age composition of emigrating smolts were available for the years 1996 to 2008 (Table 6). When applied to this population, the life-history model above was simplified into a Beverton-Holt stock-recruit function describing freshwater production from egg to smolt. Given that smolt data have only recently been collected, the estimated freshwater carrying capacity and maximum rate of population increase from egg to smolt describe current freshwater conditions (post-1996) in the LaHave River.

4.1.2 Parameter Estimation

St. Mary's River

For the St. Mary's River, parameter estimates were calculated by simultaneously fitting the model to the observed data using maximum likelihood, by minimizing the value of an objective function, $O.F.V.$ (Quinn and Deriso 1999). The $O.F.V.$ equals the sum of the negative log-likelihoods for the juvenile electrofishing data ($\ell_{electro}$), the smolt age-frequency data (ℓ_{age}^{smolt}), the egg deposition data (ℓ_{egg}) and the smolt count data (ℓ_{smolt}). Lognormal error structures (Myers et al. 1995) were used for all likelihoods except the smolt age-frequency data, for which a multinomial likelihood (Quinn and Deriso 1999) was used. Following the approach by Gibson et al. (2009), the mean standard deviation of the likelihood functions (σ) was set at 0.33:

$$\ell_{electro} = \sum_a \left(-n \ln \sigma_{elect} \sqrt{2\pi} - \sum_t P_{t,a}^{obs} - \frac{1}{2\sigma_{electro}^2} \sum_t (\ln P_{t,a}^{obs} - \ln(P_{t,a} / h))^2 \right),$$

$$\ell_{smolt} = -n \ln \sigma_{smolt} \sqrt{2\pi} - \sum_t S_t^{obs} - \frac{1}{2\sigma_{smolt}^2} \sum_t (\ln S_t^{obs} - \ln S_t)^2,$$

$$\ell_{egg} = -n \ln \sigma_{egg} \sqrt{2\pi} - \sum_t Egg_t^{obs} - \frac{1}{2\sigma_{egg}^2} \sum_t (\ln Egg_t^{obs} - \ln Egg_t)^2,$$

$$\ell_{age}^{smolt} = \sum_t \log\left(\frac{n_{smolt,t}!}{(x_{smolt,t,1}!)(x_{smolt,t,2}!) \ldots\ldots (x_{smolt,t,r}!)} p_{smolt,t,1}^{x_{smolt,t,1}} \ldots\ldots p_{smolt,t,r}^{x_{smolt,t,r}} \right),$$

$$O.F.V. = -(\ell_{egg} + \ell_{smolt} + \ell_{electro} + \ell_{age}^{smolt}).$$

The model was programmed using AD Model Builder (Fournier 1996). AD Model Builder (ADMB) uses the C++ auto-differentiation library for rapid fitting of complex non-linear models, has Bayesian and profile likelihood capabilities, and is designed specifically for fitting these types of models.

LaHave River

For the LaHave River, the stock-recruit function was fit to the egg deposition and smolt production data using maximum likelihood (with a log-normal error distribution) in S-Plus.

4.1.3 Results

St. Mary's River

In setting up the model, a decision was required on how best to treat the habitat parameter, h. For the St. Mary's River, total habitat area (i.e., the amount of habitat with a gradient greater than 0.12 % (3,985,400 m^2, Amiro 1993)) had been estimated based on measurements from orthophoto maps (aerial photographs corrected for bias from which actual distances can be measured), as well as from in-stream survey measurements (3,078,500 m^2; MacEachern 1954 cited in Marshall 1986). The latter value has been used in previous assessments for calculating the conservation requirement for the St. Mary's River (Amiro et al. 2006). Calculating h from the in-stream habitat measurements as compared to the orthophoto map measurements leads to a significant reduction of the $O.F.V.$ function, indicating a better fit of the life-history model to the data. Additionally, the biological plausibility of the resulting estimate for parr mortality (M_{Parr}) and the habitat carrying capacity for age-1 parr (R_{asy}) were improved. Therefore, h is described in the results as 1,693,200 m^2 (55% of 3,078,500).

In total, 5 parameters were estimated from the freshwater production model ($M_{Egg}, M_{Parr}, \alpha, R_{asy}, j_2$), and the model was fit to data from each of the 3 time periods: 1984-2008, 1993-2008 and 1997-2008. Parameter estimates obtained from the freshwater production model (Table 16) were biologically plausible (e.g., mortality estimates between 0 and 1) and the standard errors of the estimates were not large relative to the means, indicating reasonable model fits. The observed electrofishing data series and the predicted densities of parr (Figure 25) both show declining trends for each time period and in all juvenile age classes.

Scatterplots of the abundance of Atlantic salmon within a cohort in sequential age classes (Figure 26) illustrate the asymptotic behaviour (characteristic of density dependence) for age-1 at relatively low densities of both age-0 and age-1 fish. Estimated relationships appear to fit the data reasonably well. The predicted sizes of the smolt run from the model intersect the data (Figure 27), although residuals are greater than those for the younger age classes. This was expected given that process error would accumulate as fish get older.

It is interesting to note that the most pronounced difference among the 3 time periods modeled was the change in carrying capacity for age-1 parr. Estimated carrying capacity for age-1 parr was 47.1 fish/100 m^2 of habitat based on the 1984-2008 time period, which dropped to 17.2 for data from the 1993-2008 time period, and to 10.8 for the 1997-2008 time period (Table 16). The standard deviations of all parameter estimates tended to overlap, which is an indication that changes may not be statistically significant among time periods. However, such a pronounced change in freshwater carrying capacity is suggestive of a decline in freshwater habitat quality over time, and warrants further investigation to determine if the change is real.

Given that the predicted abundances of each age class were similar to the observed data series, it is likely that the life-history model is accurately predicting life-history parameter values. Therefore, it was possible to use the predicted smolt abundance series and the observed 1SW adult returns to calculate return rates to the St. Mary's River over time. These were calculated for each of the 3 time periods (1984-2008, 1993-2008 and 1997-2008) and were compared with return rates observed on the LaHave River from 1996 to 2007 (Figure 28). The 3 series of return rates predicted for the St. Mary's track each other closely and, in general, follow the trends observed in smolt return rates to the LaHave River (i.e., increasing or decreasing in the same year). The mean, maximum and minimum return rates predicted for the 1997-2008 time period were chosen as the input series for the marine component of the equilibrium model (see Section 4.2.1). Using this data series had two advantages: (1) information on the age distribution and spawning history of returning adults could be used to estimate the 2SW return rate, and (2) the level of uncertainty in the abundance estimates for all age classes was higher in the earlier years of data collection (1984-1997), which would have increased the uncertainty in any parameters estimated from these data.

LaHave River

Two parameter values were estimated from the LaHave freshwater production model: the maximum rate of smolt production ($\breve{\alpha}$ = 0.032) and the carrying capacity of the river for smolt ($\breve{R}_{asy}$ = 25,001). These values represent current freshwater conditions in the LaHave River given that smolt aging data (necessary to calculate total abundance from a single egg cohort) were only available from 1996-2008.

4.2 Egg-per-smolt Model and Equilibrium Modeling

4.2.1 Egg-per-smolt Model

The egg-per-smolt model includes terms for the probability of maturing at sea-age-1, size-specific fecundity, and post-spawning survival (survival between spawning events). The number of eggs produced by a smolt throughout its life (EPS) is given by:

$$EPS = \sum_{c=1}^{2} Egg_c \ ,$$

where

$$Egg_1 = (1 - M_{Sea})(m_1)\left(f_1 + \sum_{1}^{\max p} (1 - M_{Adult})^p f_2 \right),$$

$$Egg_2 = (1 - M_{Sea})^c (1 - m_1) \sum_{0}^{\max p} (1 - M_{Adult})^p f_2 ,$$

where c is the number of years spent at sea prior to maturity, M_{Sea} is the annual mortality rate of immature salmon at sea, m_1 is the probability of maturing after one winter at sea, f_c is either the fecundity of first-time spawners (f_1) or older salmon (f_2), p is the number of previous spawnings, and M_{Adult} is the adult mortality rate. As written above, all repeat spawning is sequential and a maximum of 3 sequential spawning events is assumed per individual (based on observed data for this population). The parameter M_{Sea} is a composite parameter that includes all sources of mortality in the marine environment, and the parameter M_{Adult} includes mortality associated with overwintering in fresh water as well as with post-spawning downstream migration.

To describe survival at sea and maturity, the survival rate for immature salmon is assumed to be the same during the first and second years at sea and the model is written in terms of a survival and a maturity parameter, calculated from the observed proportions of 1SW and 2SW salmon returning each year. For the St. Mary's River, data on the ages of returning adults exist from 1997-2008, corresponding to years when seining took place. Using the predicted smolt abundance series for 1997-2008 from the life-history model, the mean, minimum and maximum return rates from 1997 to 2007 were converted into survival and maturity parameters for the population. For the LaHave River, return rates from 1996-2007 could be calculated from observed data exclusively (given that smolts had been monitored at the fishway since 1996). Similar to the St. Mary's, the mean, minimum and maximum return rates were converted to survival and maturity parameters for the population (Table 17). For each river, these values represent the range of variation in marine conditions experienced by the population in recent years.

To estimate M_{Adult}, a cohort analysis on the spawning history of adults sampled in the St. Mary's or LaHave rivers was used to calculate the survival rate of repeat spawners. Data from the previous 5 years (2002-2007) were used to ensure that the estimates represent current conditions. For the St. Mary's River, the mean percentage of adults that returned to spawn in consecutive years was 3.7%, leading to an adult mortality estimate of 96.3%. For the LaHave River, the mean percentage of adults returning to spawn in consecutive years was 5.5%, giving an adult mortality estimate of 94.5%.

4.2.2 Equilibrium Calculations

Equilibrium modeling splits the life cycle of a species into two (or more) parts and determines the population size at which the productivity of both halves of the lifecycle are balanced (Gibson and Myers 2003). The equilibrium point is the size that the population will tend towards if the life-history parameter values used as model inputs do not change.

Equilibrium models are ideal for assessing the recovery potential of diadromous fish like Atlantic salmon because their life cycle is naturally split into two parts (at the egg and smolt life stages, roughly equivalent to freshwater production and marine growth and survival). The freshwater production model (smolt-per-egg model) gives the relationship between egg deposition and survival through to the smolt life stage. The marine production model (egg-per-smolt model) gives the rate at which smolts produce eggs throughout their lives. The equilibrium population size occurs where the rate at which eggs produce smolts equals the inverse of the rate at which smolts produce eggs.

For the St. Mary's and LaHave rivers, the parameter values used in the smolt-per-egg model (freshwater production component) were derived from the life-history model described above (Section 4.1). Parameter values for the egg-per-smolt model (EPS) are derived from observed data using the equations below, following the approach outlined in Gibson et al. (2009).

The number of eggs produced by the number of smolts (S) in year t is:

$$Egg_t = EPS \cdot S_t$$

Equilibrium numbers of eggs and recruitment levels (denoted with asterisks) are found by solving this equation for S, and substituting the result in the freshwater production model (Quinn and Deriso 1999):

$$\frac{Egg^*}{EPS} = \frac{\breve{\alpha} Egg^*}{1 + \frac{\breve{\alpha} Egg^*}{\breve{R}_{asy}}}.$$

Note that here, $\breve{\alpha}$ and $\breve{R}_{asy}$ have been rescaled for the St. Mary's River to represent the maximum survival rate from egg to smolt and the asymptotic recruitment level for smolt (these parameters were estimated directly for the LaHave River). The equilibrium spawning biomass (Egg^*) is then:

$$Egg^* = \frac{(\breve{\alpha} EPS - 1)\breve{R}_{asy}}{\breve{\alpha}}$$

and the equilibrium number of smolts (S^*) is found by substituting Egg^* into the freshwater production model:

$$S^* = \frac{\breve{\alpha} Egg^*}{1 + \frac{\breve{\alpha} Egg^*}{\breve{R}_{asy}}}.$$

4.2.3 Results

St. Mary's River

Under recent freshwater conditions in the St. Mary's River (1997-2008), the maximum number of smolts produced per egg ($\breve{\alpha}$) was estimated to be 0.044 with an asymptotic population size ($\breve{R}_{asy}$) of 61,360 smolts. This latter estimate equates to approximately 3.6 smolts per 100 m^2 of habitat. Over 3 generations (1993-2008), the estimated maximum number of smolts produced per egg is slightly lower, at 0.039 (owing to a lower value for α for age-1 parr), but the asymptotic smolt population size is substantially higher, at 123,863 (7.3 smolts/100 m^2 of habitat). For the longest time period (1984-2008), the maximum number of smolts produced per egg is even lower, at 0.03, but the asymptotic smolt population size is 234,038 smolts

(13.8 smolts/100 m^2 of habitat). The latter estimate of smolt production is very high and is unlikely to be representative of the St. Mary's River. High-grading during electrofishing site selection during the earlier time period could bias this estimate upwards. However, the other 2 estimates are closer to rates of smolt production that have been observed in rivers in the past (Symons 1979), and are more likely to represent freshwater production potential in the St. Mary's River.

At the mean return rates predicted for 1SW and 2SW adults on the St. Mary's River, lifetime egg production per smolt was 36.1 eggs. At the minimum return rates, this value dropped to 13.1 eggs, while at the maximum return rates the value increased to 64.9 eggs. Given the freshwater production estimates above, one smolt would have to produce between 22 and 33 eggs (the inverse of 0.044 and 0.03 smolts produced per egg, respectively) throughout its life to ensure an equilibrium population size greater than zero. As such, the population could decline to extinction in the absence of human intervention due to natural variation in return rates, particularly if there is any further downturn in marine survival or freshwater productivity. Furthermore, the equilibrium model for the St. Mary's River predicts a very low maximum lifetime reproductive rate for the population. Multiplying the maximum rate of population increase for smolt ($\breve{\alpha}$) by the number eggs produced per smolt (at the mean return rates for adults) gives a maximum lifetime reproductive rate of 1.59.

For the 1997-2008 freshwater data series, small equilibrium population sizes are predicted when return rates equal the mean or maximum predicted values (Figure 29; intersection of lines (b) and (C), or lines (c) and (C), respectively). However, the predicted population sizes are well below 50% of the conservation requirement for the river, suggesting that the population is likely to remain small. Even at the two higher levels of freshwater production predicted from the 1993-2008 and 1984-2008 data series, there is little difference in equilibrium population size at the minimum or mean return rates (Figure 29, intersection of lines (a) and origin, or lines (b) and (A), (B) or (C)). However, the predicted equilibrium increases from approximately 3 million eggs, to 5 million, to 7 million when return rates to the St. Mary's are high and freshwater production increases (Figure 29, intersection of lines (c) and (C), (B) and (A), respectively). This suggests that any improvement to freshwater habitat (i.e., through restoration activities) could promote population growth and help restore salmon abundance in the St. Mary's River, but a decrease in marine mortality is necessary to restore populations to levels above the conservation requirement. None of the 3 modeled scenarios predict population sizes in excess of the conservation requirement, which suggests that population recovery to levels above the conservation requirement on the St. Mary's River will be difficult to achieve even with a change in at-sea survival. However, increases in freshwater productivity should increase population viability, albeit at lower population sizes.

LaHave River

Under recent freshwater conditions in the LaHave River (1996-2008), the maximum number of smolts produced per egg ($\breve{\alpha}$) was estimated to be 0.032 with an asymptotic population size ($\breve{R}_{asy}$) of 25,001 smolts. This latter estimate equates to approximately 0.96 smolts per 100 m^2 of habitat, based on the estimated 2,605,200 m^2 of juvenile habitat available in the watershed above Morgans Falls. Compared to the St. Mary's River, this estimate of smolt production is very low and could be indicative of relatively poor freshwater productivity in the LaHave River. However, it could partially result from variability in the observed smolt and egg data series. The 2005 smolt cohort (2002 egg deposition year) was extremely small, potentially due to irregular water flow patterns in the LaHave River prior to the smolt migration. If this data point is removed from the series, $\breve{\alpha}$ = 0.012 and R_{asy} = 92,389, which increases the smolt production estimate to 3.5 smolts per 100 m^2 of habitat. Given that the 2005 smolt abundance estimate is low relative to both the 2004 parr density and the number of 2006 1SW returns, these later values are likely more representative of current freshwater productivity in the LaHave River above Morgans Falls.

At the mean return rates observed for 1SW and 2SW adults on the LaHave River, lifetime egg production per smolt was 78.1 eggs. At the minimum return rates, this value decreased to 32.7 eggs, while at the maximum return rates, it increased to 206.5 eggs. Given the freshwater production estimate above, one smolt would have to produce 31.3 eggs (the inverse of 0.032 smolts per egg) throughout its life to ensure an equilibrium population size greater than zero. At the lowest observed return rates, the maximum lifetime reproductive rate for salmon in the LaHave River is estimated to be 1.05. Values less than 1 indicate that a population cannot replace itself and is in decline, a result collaborated by the survival index calculated for the LaHave River in Section 3. At the average observed return rates, the maximum lifetime reproductive rate is 2.50. This value is still low relative to many fish populations, but does indicate a greater resiliency to environmental fluctuations than was estimated for salmon in the St. Mary's River.

At the mean return rates observed on the LaHave River, the predicted equilibrium population size is approximately 55% of the conservation requirement if all observed smolt data are used (Figure 30, intersection of lines (b) and (B)) and is approximately 25% of the conservation requirement if the 2005 smolt cohort year is not included (Figure 30, intersection of lines (b) and (A)). An extremely small equilibrium population is predicted at the minimum return rates, but only under the lower freshwater production scenario (Figure 30, intersection of lines (a) and (B)). However, an equilibrium well in excess of the conservation requirement is predicted at the maximum return rates for both levels of freshwater production (Figure 30, intersection of lines (c) and (A), or (c) and (B)). This suggests that the population has the potential to increase or decrease in size depending on the level of mortality experienced in the marine environment. Any decline in marine mortality should lead to population recovery even in the absence of changes to freshwater productivity.

5.0 THREATS TO POPULATIONS

Threats to Atlantic salmon populations include any factors or activities that contribute to their decline or limit their recovery, and can affect the population at any life stage in the marine or freshwater environments. One issue known to be affecting salmon populations throughout the Southern Upland is reduced survival in the marine environment, although the factors leading to the mortality are poorly understood (Amiro et al. 2008, Gibson et al. 2008). Current mortality rates in the marine environment (as estimated in Section 4) are 96% for first-time spawners and 95% for repeat spawners returning to the St. Mary's River, and 92% for first-time spawners and 95% for repeat spawners returning to the LaHave River. Although these mortality rates are not as extreme as those affecting populations in the inner Bay of Fundy (Gibson et al. 2008), the equilibrium analysis in Section 4 demonstrates the limiting nature of marine mortality on both current population size and future population recovery.

In the freshwater environment, sulfate deposition in the form of acid rain has lowered the pH of many rivers in the Southern Upland to the point that they may no longer be able to support viable salmon populations. The last region-wide assessment of pH was completed in 1986, where 22 rivers in the Southern Upland were classified as low- or non-acidified (pH > 5.0), 20 rivers were partially acidified (pH ranges from 4.7 - 5.0) and 14 rivers were heavily acidified (pH < 4.7) (Watt 1987, Amiro et al. 2000). At a pH below 5.1, salmon production is considered unstable and only remnant populations may persist (LaCroix 1985). Estimates of the loss in productive potential attributable to acidification for salmon throughout the Southern Upland range from 24% (Amiro 2000) to 50% (Watt 1989), with the majority of the impact taking place prior to 1986. Despite reductions in acid precipitation in recent years, the pH in rivers of the Southern Upland has not recovered at rates observed in other geographic areas (Watt 1987). Based on the electrofishing surveys done in 2000 and 2008, both the proportion of rivers in which juvenile salmon are present and the estimated densities of juvenile salmon are decreasing. It is likely that the low pH of many rivers is a contributing factor to these observed declines. The loss of productivity related to acidification would likely exacerbate the negative effects of low marine survival and further increase a population's vulnerability to extirpation (Amiro 2000).

Other factors with the potential to impact salmon abundance or distribution in the Southern Upland have been reviewed in a semi-quantitative manner in a recent draft conservation status report (DFO and MNRF 2009). The broad categories of threats include: directed salmon fishing, by-catch, fisheries on prey species, municipal water use, habitat alterations, aquaculture and other fish culture/stocking, military activities, scientific research, air pollutants (acid rain), ecotourism, invasive species, and ecosystem change. Impacts on salmon populations are measured in two ways: (1) the proportion of salmon populations that are likely to be influenced by a given activity, and (2) the population-level impact of a given activity on spawner abundance.

Fishing activities (including directed fisheries, incidental by-catch and fisheries on prey species) have a high cumulative effect on salmon populations given that they are thought to impact more than 30% of salmon populations throughout the Southern Upland. However, the overall impact on spawner abundance is low or uncertain. Multiple steps have been taken to reduce the impact of fisheries on salmon populations, such as permitting only catch-and-release angling, negotiating fishing agreements with Aboriginal communities and closing domestic retention fisheries. Furthermore, the impacts of fisheries on marine or freshwater habitat quality and quantity are thought to be low. Reported by-catch, illegal retention, and interception by distant commercial fisheries are low. However, any removal of pre-spawning adult salmon could have significant population-level impacts given the small size of populations throughout the Southern Upland.

Habitat alteration and water extraction, through activities such as mining, forestry, agriculture, infrastructure development and maintenance, municipal water use, and hydroelectric power generation, impacts more than 30% of salmon populations in the Southern Upland. However, the impact in terms of spawner loss is typically uncertain. Given that these activities take place predominantly in freshwater and estuarine environments, they have the potential to impact all life stages of Atlantic salmon. Furthermore, development activities that alter habitat and change the hydrology of rivers have no known positive effects on salmon populations. As such, spawner loss could be substantial.

In general, activities in the marine environment affect the majority of salmon populations in the Southern Upland, yet their impact on spawner abundance is relatively low or uncertain. This result is surprising given current marine mortality rates (> 90%), and it suggests that further research on the cumulative nature of multiple threats leading to changes in spawner abundance is necessary. Similarly, the only factor in the freshwater environment that is known to have a high impact on spawner abundance is acid precipitation. However, recent declines in the predicted carrying capacity of the St. Mary's River (a non-acidified river) and the low production potential of the LaHave River (a low-acidified river) suggest that factors other than acidification are reducing salmon production in fresh water throughout the Southern Upland.

6.0 DISCUSSION

Overall, the available data on salmon in rivers throughout the Southern Upland demonstrate that some populations are presently extirpated and that the healthiest populations are persisting at low abundance levels. This conclusion is consistent for all monitored life stages of the index populations and for the region-wide assessments of adults and juveniles. The estimated abundances of age-0, age-1, and age-2 parr and smolts are well below reference values for salmon production in freshwater, and adult abundance remains well below the conservation requirements established for the St. Mary's and LaHave rivers. The predicted decline rates for adult escapement over the last two or three generations for populations in the Southern Upland indicate declines in excess of 50% for the index rivers and in excess of 95% for other populations. Life-history modeling indicates that freshwater carrying capacity is low on both index rivers and is potentially decreasing in the St. Mary's River. Furthermore, equilibrium modeling demonstrates the limiting nature of high marine mortality and low freshwater productivity on abundance and recovery potential for populations in the Southern Upland.

Recent region-wide surveys indicate very low salmon abundance in the majority of rivers in the Southern Upland. Recreational catches in 2007 were extremely low, with 85% of the catch concentrated in two of the larger river systems: the St. Mary's and the LaHave. Fishery-independent data on juvenile abundance and distribution corroborate the results of the recreational catch data, indicating extremely low juvenile density in the majority of rivers in the Southern Upland. No Atlantic salmon juveniles were observed in 31 of 50 rivers, and the mean density in a river system did not exceed 10.8 fry per 100 m^2 or 7.5 parr per 100 m^2, with the majority of values being much lower. The current distribution of salmon in the Southern Upland appears to be increasingly restricted, and actual abundance within those systems with salmon is extremely low.

Although populations in the index rivers are thought to be large relative to those in the other rivers in the Southern Upland, current monitoring indicates that abundance in the index rivers is low relative to the conservation requirement and other indicators. On the St. Mary's River, adult escapement is less than 25% of the conservation requirement and smolt production is an order of magnitude lower than that expected from a healthy salmon population. The LaHave River attained 55% of the adjusted conservation requirement in 2008, but the total count of adult salmon was one of the lowest values observed in the past 3 decades. Similarly, freshwater production in the LaHave was low (as indicated by smolt production as well as the egg-to-smolt survival rate in 2008), and the survival index suggests that the population is not able to replace itself under current conditions (i.e., it is gradually decreasing in size).

At a regional level, the recreational catch data and electrofishing surveys demonstrate the continued decline in abundance and restriction in range of Atlantic salmon populations throughout the Southern Upland. For the majority of rivers, reported recreational catch has declined steadily through time with a slight lag in the reduction in fishing effort. From 1983 to 2007, catches on most rivers dropped by more than 95%, and many rivers were closed to angling in 1998 due to concerns over abundance. Similarly, when the results from the 2008 electrofishing survey were compared with those from 2000, both the estimated density of each life stage and the number of rivers in which salmon were found were significantly lower. Only 54% of rivers in the Southern Upland were found to contain salmon in 2000 (Amiro et al. 2000) and only 38% were found to contain salmon in 2008. Such a dramatic change in the estimated density and distribution of juvenile salmon suggests that population extirpations are occurring throughout the Southern Upland and that abundance is critically low in many rivers.

The decline rates predicted over the previous three generations for salmon populations in the Liscomb River and East River, Sheet Harbour meet the criteria outlined by COSEWIC for a population designation of 'Endangered.' The salmon populations in the St. Mary's River and LaHave River meet the criteria for a designation of 'Threatened,' provided the cause of the decline is known and has ceased, or a designation of 'Endangered' if the cause of the decline is unknown and on-going. In other rivers throughout the Southern Upland, the trends in recreational catch over time and juvenile salmon abundance suggest that population declines have been as severe, if not greater (i.e., leading to extirpation), for salmon in these rivers. Although acidification has been identified as a major threat to salmon populations throughout the Southern Upland (Watt 1987), the effects have not been entirely mitigated in any river, although a liming station does exist in the West River, Sheet Harbour (SFA 20) that raises the pH of approximately 30% of the total watershed area. Other significant stressors to salmon populations in the Southern Upland include high marine mortality, which is also affecting populations throughout the inner Bay of Fundy (Amiro et al. 2008, Gibson et al. 2008, Trzcinski et al. 2004); hydroelectric power generation; and potentially reduced freshwater habitat quantity or quality (as evidenced by the decline in R_{asy} over time on the St. Mary's River).

When all data sources were combined into the equilibrium model, small viable populations were predicted for the St. Mary's and LaHave rivers under current conditions. However, at the minimum return rates of 1SW and 2SW adults, both populations have an equilibrium size that is near zero, which suggests that natural variation in life-history parameters (particularly survival at sea) could drive the population to extinction in the absence of human intervention or a change in population vital rates. Given the low maximum lifetime reproductive rates, population growth back to the (low) equilibrium size is expected to be slow if random events further depress abundance. If marine mortality were to decline, current freshwater productivity should allow abundance to increase in excess of the conservation requirement on the LaHave River above Morgans Falls. This situation differs from that in the St. Mary's River, where increases in freshwater productivity and marine survival would be necessary before the population could significantly increase in size. Replacement rates calculated for the LaHave and St. Mary's river salmon indicate that the populations have low resiliency to environmental variability, thereby increasing their overall risk of extinction. Populations with maximum lifetime reproductive rates close to one have limited ability to increase in size following any change in abundance, while populations with rates less than one are not able to increase in size. It is expected that populations in surrounding rivers would be less likely to be viable under current conditions, given that the salmon populations in the LaHave and St. Mary's rivers are the largest.

While not fully explored here, there are major differences in the dynamics of salmon populations in the Southern Upland and inner Bay of Fundy. Within the inner Bay, smolt-to-adult return rates are roughly 0.3% (Gibson et al. 2008), or an order of magnitude lower than those reported here for Southern Upland populations. The marine survival rates observed for inner Bay of Fundy populations are so low that they cannot be offset by increased freshwater productivity. In the absence of an increase in survival at sea, populations in that region are expected to extirpate in the absence of human intervention, such as live gene banking. In contrast, the equilibrium analyses and threats information herein indicate that freshwater production for many Southern Upland populations is depressed, and that increasing freshwater productivity can increase the viability of populations in this region (although an increase in survival at sea will be required to restore populations to levels above their conservation requirement). Given the well documented effects of captive rearing on the genetic integrity of fish populations (Fraser 2008), an emphasis on restoration of freshwater habitat or mitigation of identified threats in the marine environment should be preferred over live gene banking (see description below) as a mechanism to maintain these populations.

All indicators suggest that there is a strong likelihood for continuing decline in the abundance and distribution of Atlantic salmon in the Southern Upland. There are very few remaining populations with any appreciable abundance and of these, none are close to the conservation requirement for the river. The number of rivers with sufficient abundance of salmon remaining for recovery to occur is likely small. Within the inner Bay of Fundy, a key rescue activity was the establishment of a Live Gene Bank (O'Reilly and Doyle 2007), the goal of which was to protect remaining genetic diversity within remnant populations. Given that small viable populations are predicted at current life-history parameter values for populations in the Southern Upland, recovery actions aimed at increasing freshwater production potential or marine survival are potentially alternatives to the establishment of a Live Gene Bank. However, if current trends in the Southern Upland continue, any actions will have to be timely to be effective.

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8.0 TABLES

Table 1. Adult escapement estimates based on mark-recapture seining experiments on the West Branch of the St. Mary's River from 1997 to 2008. Estimates from years where the mark-recapture was not completed are shown in bold type, and were calculated from the average seining catchability from 1997 to 2001.

Year	Marks	Captures	Recaptures	Escapement Estimate	Coefficient of Variation	Catchability
1997	67	117	8	892	30.39	0.075
1998	152	268	37	1083	14.84	0.140
1999	38	82	8	360	29.86	0.106
2000	76	191	43	336	13.09	0.226
2001	41	52	5	371	35.59	0.111
2002	31			**236**		
2003	95	4	3	**722***	20.00	0.754
2004	64			**486**		
2005	26			**198**		
2006	142	50	30	240	11.07	0.592
2007	112	107	59	203	8.54	0.551
2008	30	63	4	397	39.2	0.076

* Due to the low number of adults captured on the recapture pass, mean catchability was used to calculate this estimate.

Table 2. Age, spawning history, and fork length of adult salmon seined from the West Branch of the St. Mary's River in 2008. The 'Age' designation gives the sea-age of salmon, followed by the age of the fish at previous spawning events (sp).

			Length (cm)					
	Number		Mean		Maximum		Minimum	
Age	Males	Females	Males	Females	Males	Females	Males	Females
1	52	49	56.7	54.8	63.3	61.7	50.0	50.5
3 sp 1		1				73.5		73.5
2		8		74.4		79.1		71.2
3 sp 2		1				82.0		82.0

Table 3. The estimated annual wild smolt production (90% C.I.) and smolt wheel efficiency on the West Branch of the St. Mary's River during 2005 to 2008.

Year	Wheel Efficiency	Abundance Estimate	90% CI		Production per unit area (smolts/100 m^2)
2005	0.103**	7350	6000	9100	0.43
2006	0.028	25100	18700	40300	1.48
2007	0.054	16110	12735	20835	0.95
2008	0.031	15217	9451	24154	0.90

** two wheels were deployed side-by-side.
Approximately 55% of the juvenile habitat is thought to be contained in the West Branch.

Table 4. Summary of the electrofishing sites surveyed on the St. Mary's River in 2008, including catch and estimated density for the three age classes of juvenile salmon for the East and West branch.

Site		Date		Standard Area	Fry				age1				age2				Density (per 100 m²) Parr			Density (per 100 m²) Fry
Number	Name	marked	recap	m²	M	C	R	mort	M	C	R	Mort	M	C	R	Mort	age-1+	age-2+	total	age-0+
STMR854.2*	McKeen	16-Sep		783	10	no recapture			4	no recapture			0	no recapture			1.3	0.0	1.3	3.3
STMR854.4*	McKeen	16-Sep		673	36	no recapture			13	no recapture			0	no recapture			5.0	0.0	5.0	13.9
STMR923*	Gunn's Hole	26-Sep		2,709	17	no recapture			5	no recapture			3	no recapture			0.5	0.3	0.8	1.6
STMR863.1*	East River	26-Sep		1,145	44	no recapture			0	no recapture			2	no recapture			0.0	0.5	0.5	10.0
STMR867.1*	Moose River	26-Aug		740	32	no recapture			4	no recapture			1	no recapture			1.4	0.4	1.8	11.2
STMR8510.8*	Moose River	26-Aug		703	15	no recapture			15	no recapture			1	no recapture			5.5	0.4	5.9	5.5
East Branch Means																	2.3	0.2	2.5	7.6
STMR855.1*	Indian Man	26-Aug		485	2	no recapture			10	no recapture			0	no recapture			5.3	0.0	5.3	1.1
STMR858.1*	Mitchel	15-Sep		380	0	no recapture			0	no recapture			0	no recapture			0.0	0.0	0.0	0.0
STMR859.4*	West branch	17-Sep		3,104	28	no recapture			6	no recapture			1	no recapture			0.5	0.1	0.6	2.3
STMR924*	Caledonia	25-Sep		4,389	47	no recapture			21	no recapture			3	no recapture			1.2	0.2	1.4	2.8
STMR925.1+.2	Barren Brook	15-Sep	19-Sep	521	48	34	18	0	18	18	11	0	4	2	0	0	9.0	2.0	10.9	17.3
STMR928*	Nelson River	15-Sep		1,363	25	no recapture			2	no recapture			1	no recapture			0.4	0.2	0.6	4.8
West Branch Means																	2.7	0.4	3.1	4.7
Overall Mean																	**2.5**	**0.3**	**2.8**	**6.1**

Counts at the mark run (M)
Total count at the capture run (C)
Numbers of recaptures in the capture run (R)
Numbers of mortalities (Mort)
* estimates obtained using mean age-1 efficiency from mark-recapture sites in 2007 and 2008 (0.386)

Table 5. Estimated escapement of adult Atlantic salmon relative to the conservation requirement in the West Branch of the St. Mary's River for the years 1995 to 2008.

Year	1SW	MSW	% Egg Conservation
1995	1121	240	78
1996	844	325	67
1997	390	61	26
1998	1059	41	63
1999	307	83	22
2000	315	25	20
2001	319	106	24
2002	220	16	14
2003	600	122	42
2004	464	23	28
2005	192	8	12
2006	222	18	14
2007	182	23	12
2008	361	36	23

Table 6. Age, spawning history, and size composition of the adult salmon captured at Morgans Falls fishway on the LaHave River in 2008. Age is divided into years in freshwater (fresh) and years at sea (sea) as well as sea-age at previous spawnings (s1 or s2).

Age				Fork Length (cm)					Weight (kg)				
Fresh	Sea	s1	s2	Number	Mean	Min.	Max.	Std. dev.	Number	Mean	Min.	Max.	Std. dev.
	1			6	55.4	53.2	58.4	1.7	6	1.9	1.6	2.0	0.2
2	1			449	54.9	48.6	62.5	2.1	449	2.0	1.2	3.2	0.3
3	1			135	55.7	48.0	62.0	2.3	135	2.1	1.2	2.6	0.3
	2			2	71.8	70.8	72.8	1.0	2	4.6	4.3	4.9	0.3
2	2			80	72.1	65.6	79.8	2.5	80	5.0	3.4	7.0	0.7
3	2			5	73.5	68.8	76.0	2.5	5	5.3	4.4	5.8	0.5
2	3	1		7	72.2	69.3	74.5	1.8	7	5.1	4.0	6.2	0.7

Table 7. The estimated production (90% C.I.), density and return rate of wild smolts above Morgans Falls on the LaHave River during 1996 to 2008.

Wild smolts				
		per	Return rate	
Year	Estimate	100 m^2	1SW	2SW
1996	20,511 (19,886 - 21,086)	0.79	1.47%	0.23%
1997	16,550 (16,000 - 17,100)	0.63	4.33%	0.43%
1998	15,600 (14,675 - 16,600)	0.60	2.04%	0.34%
1999	10,420 (9,760 - 11,060)	0.40	4.82%	0.86%
2000	16,300 (15,950 - 16,700)	0.63	1.16%	0.11%
2001	15,700 (15,230 - 16,070)	0.60	2.70%	0.59%
2002	11,860 (11,510 - 12,210)	0.46	1.95%	0.45%
2003	17,845 (8,821 - 26,870)	0.68	1.75%	0.17%
2004	20,613 (19,613 - 21,513)	0.79	1.13%	0.33%
2005	5,270 (4,670 - 5,920)	0.20	7.95%	0.54%
2006	22,971 (20,166 - 26,271)	0.88	1.48%	0.40%
2007	24,430 (23,000 - 28,460)	0.98	2.33%	
2008	14,450 (13,500 - 15,500)	0.55		

Table 8. Summary of the electrofishing sites surveyed on the LaHave River in 2008, including catch and estimated density for the three age classes of juvenile salmon for sites above and below Morgans Falls.

Site		Date		Standard Area	Fry				age1				age2				Density (per 100 m^2) Parr			Density (per 100 m^2) Fry
Number	Name	marked	recap	m^2	M	C	R	mort	M	C	R	Mort	M	C	R	Mort	age-1+	age-2+	total	age-0+
LHav008*	Meisner's	02-Sep		1,456	64	no recapture			2	no recapture			1	no recapture			0.6	0.3	1.0	20.5
LHav101*	Cherryfield	19-Aug		1,061	47	no recapture			19	no recapture			1	no recapture			8.3	0.4	8.8	20.7
LHav114*	Ohio River	22-Aug		900	0	no recapture			7	no recapture			0	no recapture			3.6	0.0	3.6	0.0
Above Morgan Falls																	4.2	0.3	4.5	13.7
LHav001	West branch	28-Aug	04-Sep		16	30	3	0	7	9	0	0	1	1	0	0				
LHav105	Fire Brook	22-Aug	26-Aug	774	19	19	1	0	18	28	7	0	0	1	0	0	8.9	0.3	9.2	25.8
LHav106	Wentzell Rd.	28-Aug	29-Aug	752	2	6	2	0	11	19	3	0	4	3	0	0	8.0	2.7	10.6	0.9
LHav107	Frauzel Rd.	28-Aug	29-Aug	768	18	24	0	0	27	13	1	0	1	2	0	0	25.5	0.8	26.3	61.8
LHav108	Campground	21-Aug	02-Sep	1,051	23	68	3	0	10	17	1	0	0	1	0	0	9.4	0.2	9.6	39.4
Below Morgan Falls																	13.0	1.0	13.9	32.0
Overall Mean																	**9.2**	**0.7**	**9.9**	**24.2**

Counts at the mark run (M)
Total count at the capture run (C)
Numbers of recaptures in the capture run (R)
Numbers of mortalities (Mort)
* estimates obtained using mean age-1 efficiency from mark-recapture sites in 2007 and 2008 (0.214)

Table 9. Summary of the densities (number per 100 m^2) of age-0 and age-1 and older Atlantic salmon estimated by electrofishing in Nova Scotia's Southern Upland rivers during 2008. An asterisk (*) denotes rivers where at least one site used a mean area value (rather than measured area) to calculate overall density. N is the number of electrofishing sites.

		Age-0					Age-1 and older				
River	**N**	**mean**	**std. dev.**	**min**	**max**	**median**	**mean**	**std. dev.**	**min**	**max**	**median**
Annapolis	7	0.00	0.00	0.00	0.00	0.00	0.31	0.45	0.00	1.18	0.00
Annis	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Bear	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Belliveau	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Blacks Brk	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Chegoggin	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Clyde	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
East (Chester)	3	0.26	0.45	0.00	0.78	0.00	0.00	0.00	0.00	0.00	0.00
East (Lockport)	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
East (St Margarets)	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
East Brk (Porter's Lake)	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ecum Secum	4	0.00	0.00	0.00	0.00	0.00	2.40	4.81	0.00	9.62	0.00
Gaspereau Brk	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Gegogan Brk	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Gold *	7	1.23	2.01	0.00	4.57	0.00	2.19	2.88	0.00	6.20	0.00
Granite Village Brk	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Halfway Brk	1	5.03	NA	5.03	5.03	5.03	0.00	NA	0.00	0.00	0.00
Indian	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Ingram	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jordan	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
LaHave *	9	2.93	2.59	0.00	5.87	1.76	2.73	2.84	0.00	9.14	2.57
Little West	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Martin's	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Medway *	4	2.71	3.74	0.00	8.16	1.34	1.42	1.75	0.00	3.59	1.05
Mersey	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Middle (Chester)	2	0.29	0.05	0.25	0.32	0.29	1.85	0.12	1.77	1.94	1.85
Mosher	3	0.95	1.65	0.00	2.85	0.00	1.01	1.07	0.00	2.14	0.90
Mushamush	4	0.12	0.24	0.00	0.47	0.00	0.48	0.35	0.00	0.75	0.58
Musquodoboit	4	10.27	12.85	0.00	28.04	6.53	7.45	6.69	0.00	16.16	6.82
Nine Mile	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Petite	3	0.30	0.27	0.00	0.50	0.41	0.14	0.23	0.00	0.41	0.00
Purney Brk	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Quoddy	4	0.17	0.35	0.00	0.69	0.00	0.29	0.58	0.00	1.15	0.00
Rodney Brk	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Roseway	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Round Hill	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Sable	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salmon (Digby)	3	0.33	0.57	0.00	0.99	0.00	0.33	0.57	0.00	0.99	0.00
Salmon (Halifax)	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salmon (Lake Major)	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salmon (Lawrencetown)	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salmon (Port Dufferin)	2	1.26	1.79	0.00	2.53	1.26	0.14	0.20	0.00	0.28	0.14
Ship Harbour	1	0.00	NA	0.00	0.00	0.00	4.17	NA	4.17	4.17	4.17
Smith Brk	1	4.81	NA	4.81	4.81	4.81	0.44	NA	0.44	0.44	0.44
St. Mary's	12	5.33	4.04	0.00	11.80	4.11	1.67	1.22	0.00	3.35	1.48
Tangier	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tidney	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Tusket	8	0.04	0.12	0.00	0.35	0.00	0.00	0.00	0.00	0.00	0.00
West Brk (Porter's Lake)	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
West River Sheet Harbour *	7	0.05	0.12	0.00	0.33	0.00	0.04	0.11	0.00	0.30	0.00
West Taylor Bay	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 10. Summary of the densities (number per 100 m^2) of age-0 and age-1 and older Atlantic salmon estimated by electrofishing in Nova Scotia's Southern Upland rivers during 2000. An asterisk (*) denotes sites where a mean area value (rather than measured area) was used to calculate overall density. N is the number of electrofishing sites.

		Age-0					Age-1 and older				
River	N	mean	std. dev.	min	max	median	mean	std. dev.	min	max	median
Annis	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Argyle	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Belliveau	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Chezzetcook	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Clyde	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Country Harbour	2	15.97	9.36	9.35	22.59	15.97	10.32	0.28	10.12	10.51	10.32
East (Chester)	2	2.85	3.95	0.06	5.65	2.85	3.59	4.84	0.17	7.01	3.59
East (Lockport)	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
East (St Margarets)	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
East Brk (Porter's Lake)	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
East Taylor Bay	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Ecum Secum	1	0.61	NA	0.61	0.61	0.61	9.55	NA	9.55	9.55	9.55
Gaspereau Brk	2	0.63	0.89	0.00	1.25	0.63	2.23	3.15	0.00	4.45	2.23
Gegogan Brk	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Gold	2	5.79	5.03	2.23	9.35	5.79	5.89	0.29	5.69	6.09	5.89
Indian	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Indian Harbour Lakes	3	0.00	0.00	0.00	0.00	0.00	0.46	0.80	0.00	1.38	0.00
Ingram	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Issac's Harbour	2	0.00	0.00	0.00	0.00	0.00	0.62	0.88	0.00	1.25	0.62
Jordan	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kirby	2	18.17	3.67	15.58	20.77	18.17	17.80	3.15	15.58	20.03	17.80
Lahave *	18	5.25	5.69	0.00	19.47	3.86	8.95	7.00	0.00	20.02	9.96
Liscombe	1	0.50	NA	0.50	0.50	0.50	7.84	NA	7.84	7.84	7.84
Little West	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Martin's *	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Medway	3	5.35	6.65	0.00	12.80	3.25	2.03	1.94	0.00	3.86	2.23
Mersey	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Middle	2	1.40	1.98	0.00	2.80	1.40	2.32	0.90	1.69	2.96	2.32
Mosher	2	6.25	8.46	0.27	12.24	6.25	6.01	5.66	2.00	10.01	6.01
Mushamush *	2	33.66	0.49	33.32	34.01	33.66	6.90	2.00	5.49	8.31	6.90
Musquodoboit	2	43.14	61.01	0.00	86.29	43.14	22.21	12.64	13.28	31.15	22.21
New Harbour	3	0.00	0.00	0.00	0.00	0.00	0.13	0.22	0.00	0.39	0.00
Nine Mile	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Petite *	5	9.44	20.28	0.00	45.71	0.65	1.34	1.24	0.37	3.27	0.78
Quoddy *	3	0.05	0.08	0.00	0.14	0.00	1.35	0.79	0.73	2.23	1.08
Round Hill	2	0.44	0.62	0.00	0.88	0.44	2.01	0.86	1.40	2.62	2.01
Sable	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Salmon (Digby)	2	3.27	4.63	0.00	6.54	3.27	6.85	9.69	0.00	13.71	6.85
Salmon (Halifax)	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salmon (Lake Major)	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Salmon (Lawrencetown)	3	0.02	0.03	0.00	0.06	0.00	0.02	0.03	0.00	0.06	0.00
Salmon (Port Dufferin)	2	0.60	0.85	0.00	1.21	0.60	0.40	0.57	0.00	0.81	0.40
Ship Harbour	2	2.57	3.63	0.00	5.13	2.57	1.97	2.78	0.00	3.94	1.97
Sissibo	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Smith Brk	1	2.50	NA	2.50	2.50	2.50	10.01	NA	10.01	10.01	10.01
St. Mary's River	14	14.21	23.52	0.00	85.08	4.64	3.36	3.30	0.00	11.21	2.21
Tangier *	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tidney	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Tusket	2	0.00	0.00	0.00	0.00	0.00	2.61	0.06	2.57	2.66	2.61
West Brk (Porter's Lake)	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
West River Sheet Harbour	3	4.47	4.80	0.00	9.55	3.86	1.90	1.50	0.20	3.05	2.44
West Taylor Bay	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00

Table 11. Total (wild + hatchery) escapement estimates for 1SW and MSW salmon in the four Southern Upland rivers on which adult monitoring has taken place. The values for LaHave above Morgans Falls; East River, Sheet Harbour; and the Liscomb River are based on total counts at a fishway. The size of the salmon observed on the East River, Sheet Harbour in 2008 was not recorded. The values for the St. Mary's River (total river) are based on recreational catch estimates from 1974 to 1996 and on mark-recapture seining experiments on the West Branch (rescaled by habitat area) thereafter.

	SFA 21		SFA 20					
Year	LaHave above M.F.		East Sheet Harbour		Liscomb		St. Mary's	
	1SW	MSW	1SW	MSW	1SW	MSW	1SW	MSW
1970	2	4	31					
1971	3		19	1				
1972	17	2	111					
1973	152	16	29	4				
1974	471	21	87				3227	722
1975	504	73	89	4			558	242
1976	646	131	120	6			2763	427
1977	1266	109	83	1			2128	528
1978	842	276	13	3			1138	427
1979	1920	166	19	0	60		4889	290
1980	1973	777	53	6	111		12840	669
1981	3047	592	59	1	76	6	3549	1197
1982	1420	486	5	0	252	10	3213	268
1983	1156	313	59	3	520	15	4246	787
1984	2293	420	66	4	606	48	3453	767
1985	1445	715	26	1	507	87	3654	2853
1986	1724	662	9	2	736	117	7353	3147
1987	3102	611	46	4	1614	88	1744	1070
1988	3520	449	32	3	477	76	6675	2313
1989	2530	694	57	9	532	75	1715	1540
1990	2476	508	16	1	955	44	6010	913
1991	604	326	31	5	586	38	4998	880
1992	2489	273	22	4	145	27	1583	507
1993	1158	205	33	1	134	11	2697	1320
1994	848	247	17	2	134	10	462	100
1995	948	228	27	2	150	6	2038	437
1996	1130	196	11	1	85	9	1535	590
1997	449	131	4	1	27	1	709	110
1998	919	137	1	0	9	0	1926	74
1999	452	132	15	0	9	0	559	150
2000	794	120	1	0			572	46
2001	379	182	1	0			580	193
2002	1133	71	0	0			400	29
2003	437	207	1	0			1092	221
2004	638	122	1	0			843	41
2005	416	84					349	15
2006	425	115					404	32
2007	341	41					331	42
2008	593	98	3 total				656	65

Table 12. Summary of declines in adult Atlantic salmon abundance (large and small size categories combined) for four rivers on Nova Scotia's Southern Upland. The regression method is a log-linear model fit via least squares. The step function is the change in the 5-year mean population size ending on the years given in the time period column (the number of years differs between the methods). The standard errors and 95% confidence intervals are in parentheses. Fifteen years correspond to about three generations. A negative value in the decline columns indicates an increasing population size. Model fits for the 15-year time period are shown in Figures 21-24.

Fishing area	Population	Length of time series (years)	Time Period	Slope (SE)	Regression		Step Function
					1 Year decline rate (%)	Decline over time period (%)	Decline over time period (%)
20	Liscomb	10	1989-1999	-0.458 (0.052)	36.7 (29.9,42.8)	99.3 (98.0,99.8)	95.9 (87.3,98.7)
20	East River, SH	15	1994-2008	-0.243 (0.104)	21.6 (3.9,36.0)	97.4 (44.8,99.9)	93.1 (86.1,96.3)
20	St. Mary's	15	1994-2008	-0.080 (0.032)	7.6 (1.7,13.3)	69.6 (22.1,88.2)	81.8 (54.2,92.7)
21	LaHave	15	1994-2008	-0.056 (0.018)	5.4 (2.0,8.7)	56.6 (26.7,74.3)	65.7 (43.4,78.9)

Table 13. Mean juvenile density by age class on the West and East branches of the St. Mary's River as estimated from mark-recapture electrofishing surveys for the years 1990-2008. Surveys in years marked with asterisks were completed by the St. Mary's River Association and the ages of the juveniles captured were approximated from length-frequency information.

	EAST				WEST			
Year	N	0+ parr	1+ parr	2+ parr	N	0+ parr	1+ parr	2+ parr
1990*	11	3.40	7.76	0.89	3	4.70	7.80	0.90
1991*	9	3.41	5.39	0.56	5	25.80	4.20	0.40
1992*	14	6.72	2.87	0.70	8	22.00	5.40	0.90
1993*	3	34.65	7.71	0.56	3	143.70	10.20	0.60
1994*	9	2.54	7.33	0.41	5	1.40	2.80	0.20
1995	11	19.99	4.13	1.00	4	16.60	2.61	0.36
1996	8	14.50	3.71	1.40	3	11.15	3.23	0.46
1997	7	32.67	3.01	0.36	8	25.22	10.44	0.80
1998	7	6.06	5.89	0.32	8	23.41	6.88	1.75
1999	7	14.29	1.68	1.18	8	12.37	3.44	1.53
2000	6	19.37	1.81	0.14	8	6.66	4.06	0.32
2001	4	24.02	9.51	0.60	5	5.91	5.43	0.71
2002	8	2.85	5.28	1.33	6	3.92	2.14	0.72
2003	6	4.85	2.23	2.58	6	4.23	5.27	0.48
2004	6	2.53	2.63	0.39	6	3.63	0.63	0.36
2005	5	13.98	5.23	1.18	4	7.72	5.58	0.87
2006	5	5.95	2.87	0.23	6	3.78	0.78	0.43
2007	6	17.06	6.25	0.24	7	4.02	2.51	0.06
2008	6	7.58	2.29	0.24	6	6.15	2.51	0.33

Table 14. Estimates of 1SW and MSW adult returns to the St. Mary's River for the years 1984 to 1996. Values are based on the reported recreational catch for the entire river and the mean catch rate for each size class observed on the LaHave River.

Year	1SW	MSW	Total
1984	3453	767	4220
1985	3654	2853	6507
1986	7353	3147	10499
1987	1744	1070	2814
1988	6675	2313	8989
1989	1715	1540	3255
1990	6010	913	6924
1991	4998	880	5878
1992	1583	507	2090
1993	2697	1320	4017
1994	462	100	562
1995	2038	437	2475
1996	1535	590	2125

Table 15. Estimated egg deposition (thousands) by Atlantic salmon above Morgans Falls on the LaHave River, based on annual counts at Morgans Falls fishway, the biological characteristics of the returning population, and the length-fecundity relationship calculated for female salmon from the LaHave.

	No. of eggs ('000s)			
Year	Wild	Hatchery	Total deposition	Prop. wild
1973	50	87	137	0.36
1974	25	372	397	0.06
1975	91	501	592	0.15
1976	190	727	917	0.21
1977	396	1,086	1,482	0.27
1978	452	1,367	1,819	0.25
1979	1,292	1,284	2,576	0.50
1980	2,698	1,680	4,378	0.62
1981	3,263	1,641	4,904	0.67
1982	1,683	1,779	3,462	0.49
1983	1,968	335	2,303	0.85
1984	3,059	248	3,307	0.93
1985	3,421	413	3,834	0.89
1986	4,079	499	4,578	0.89
1987	4,899	720	5,619	0.87
1988	4,381	958	5,339	0.82
1989	4,315	1,024	5,339	0.81
1990	3,414	652	4,066	0.84
1991	1,354	376	1,730	0.78
1992	2,867	508	3,375	0.85
1993	1,140	522	1,662	0.69
1994	1,177	455	1,632	0.72
1995	926	446	1,372	0.67
1996	1,085	519	1,604	0.68
1997	507	440	946	0.54
1998	903	431	1,334	0.68
1999	717	359	1,076	0.67
2000	926	499	1,425	0.65
2001	829	785	1,614	0.51
2002	870	972	1,842	0.47
2003	877	1068	1,945	0.45
2004	1,027	926	1,953	0.53
2005	628	515	1,143	0.55
2006	915	216	1,131	0.81
2007	540	20	561	0.96
2008	1,078	0	1,078	1

Table 16. Estimates of freshwater production parameters from the life-history model for the St. Mary's River for the three time periods of data presented.

	1997-2008		1993-2008		1984-2008	
Parameter	Value	Standard dev.	Value	Standard dev.	Value	Standard dev.
M_{Egg}	0.880	0.022	0.872	0.020	0.904	0.013
α	0.723	0.241	0.606	0.145	0.499	0.123
R_{asy}	10.787	7.266	17.243	9.851	47.088	90.703
M_{Parr}	0.504	0.107	0.460	0.113	0.402	0.122
j_2	0.796	0.038	0.800	0.037	0.810	0.035
$\breve{\alpha}$	0.044		0.039		0.030	
$\breve{R}_{asy}$	61,360		123,863		234,038	

Table 17. Minimum, mean and maximum return rates for the St. Mary's River and LaHave River Atlantic salmon populations and the calculated probabilities of mortality at sea (M_{Sea}) and maturation after 1SW (m_1) used in the equilibrium analysis.

		Return rate (%)			
Population		1SW	2SW	M_{Sea}	m_1
St. Mary's River	Minimum	0.61	0.004	0.990	0.596
	Mean	1.44	0.09	0.962	0.373
	Maximum	2.25	0.26	0.936	0.353
LaHave River	Minimum	1.13	0.11	0.961	0.564
	Mean	2.78	0.40	0.921	0.351
	Maximum	7.95	0.86	0.859	0.287

9.0 FIGURES

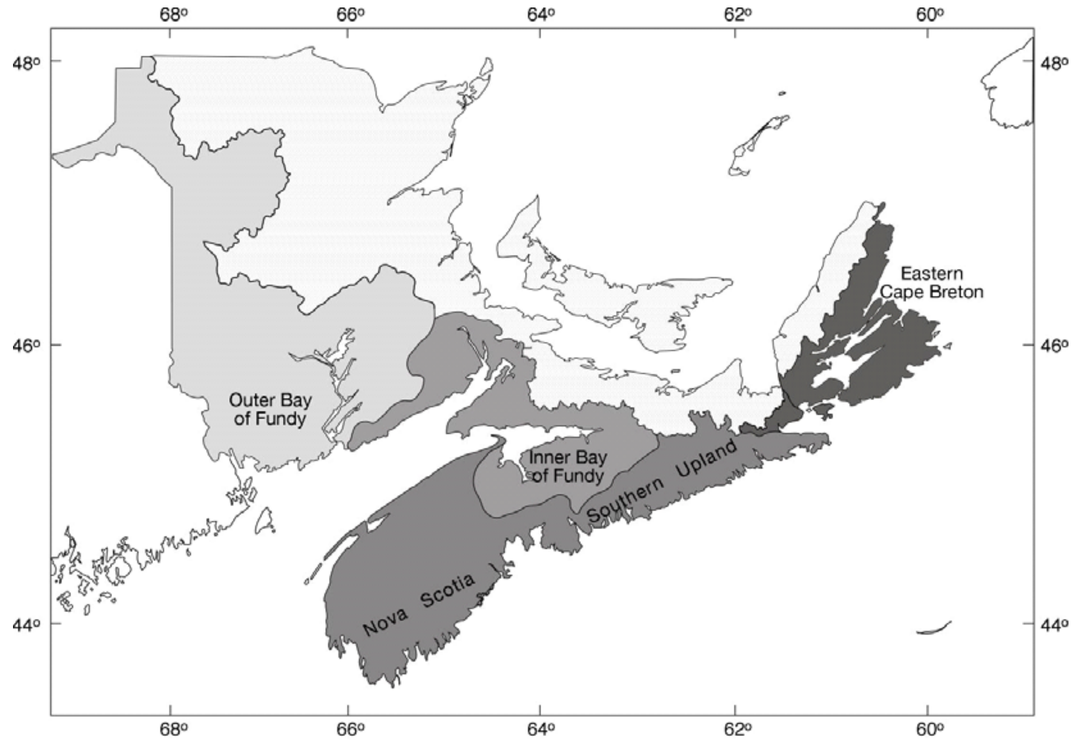

Figure 1. Map showing the location of the Southern Upland region relative to the three other Atlantic salmon management regions in the Maritimes Region.

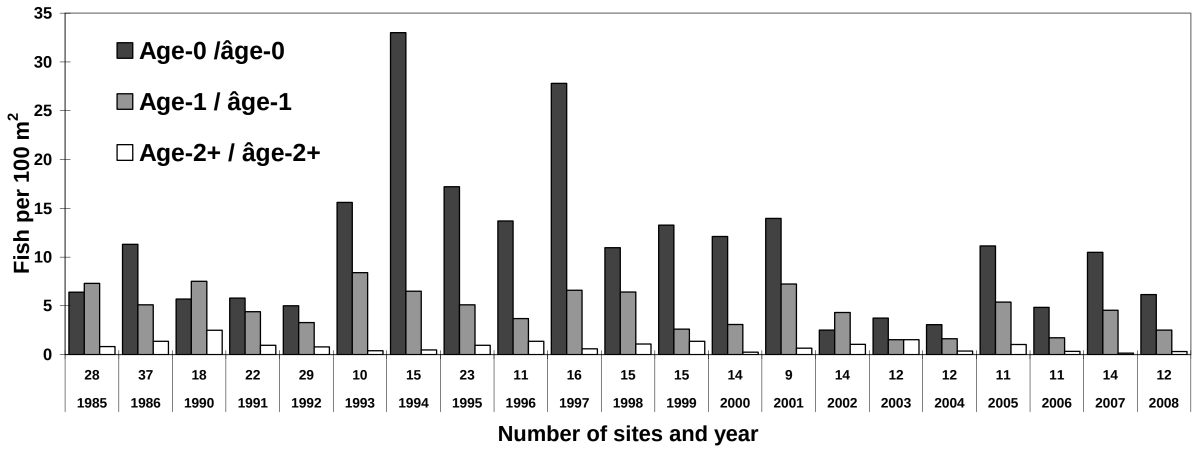

Figure 2. Mean density for the three age classes of juvenile salmon (age-0, age-1, and age-2+) in the St. Mary's River during 1985-1986 and 1990-2008. The number of sampling sites on which the mean is based is listed immediately below the x-axis.

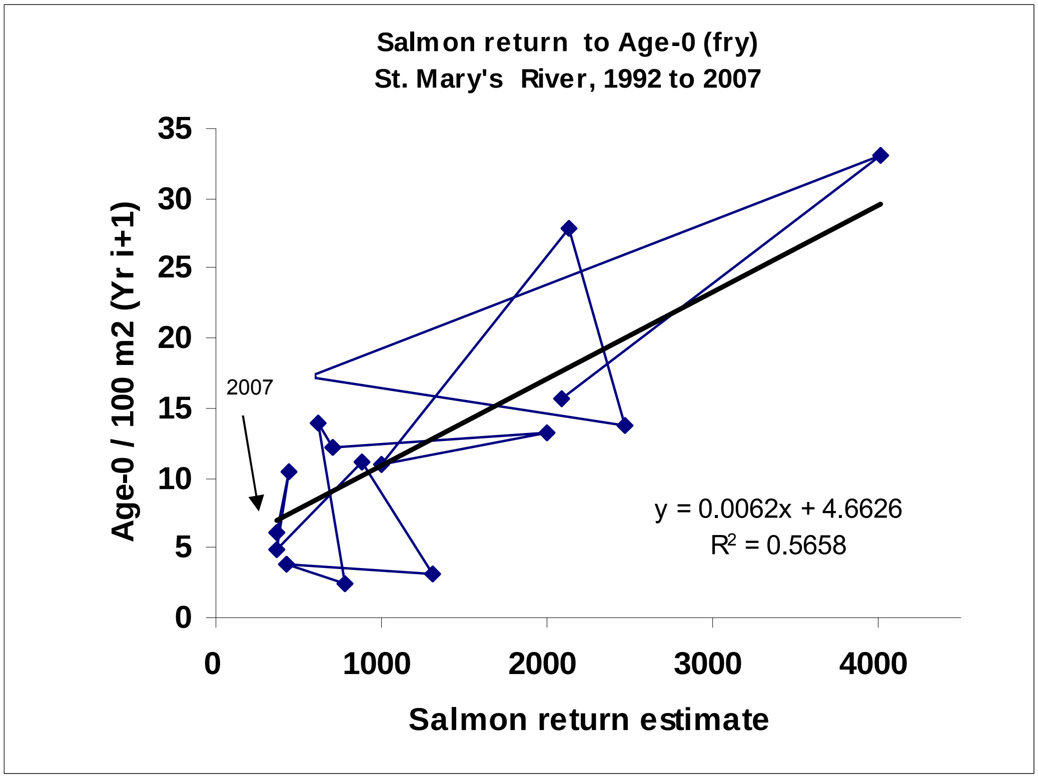

Figure 3. Observed fry density as a function of estimated adult returns to the St. Mary's River for the return years 1992 to 2007. The linear equation for the predicted relationship (thick line), as well as the associated R^2 value for the regression are given.

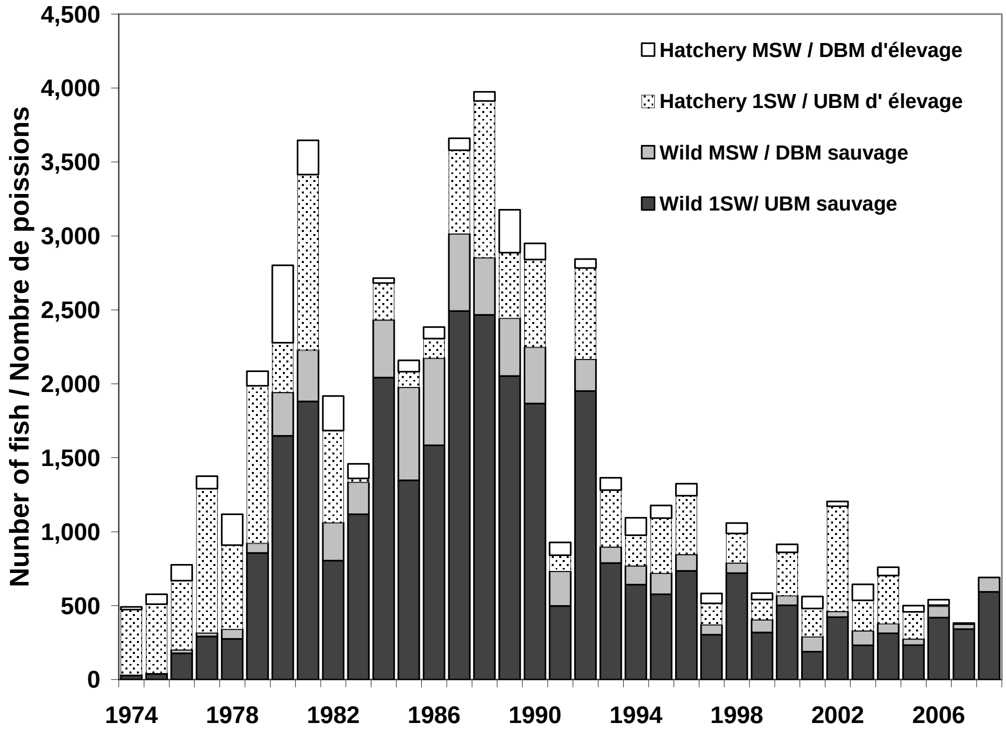

Figure 4. Counts of Atlantic salmon at Morgans Falls fishway on the LaHave River, NS, from 1974 to 2008, divided into the proportions of wild-origin and hatchery-origin 1SW and MSW adults.

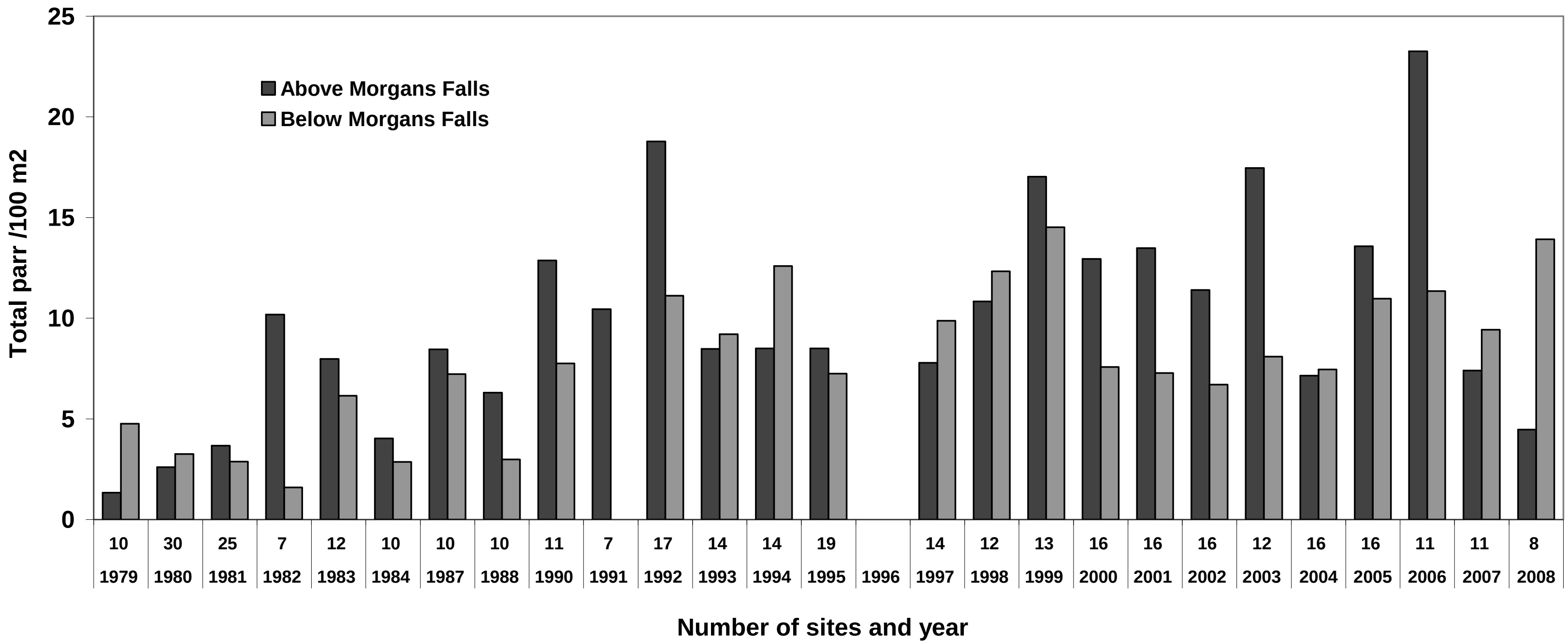

Figure 5. Total mean parr density (age-1 and age-2) per 100 m^2 as determined by electrofishing in the LaHave River for the years 1979 – 1984, 1987, 1988, 1990 – 1995, and 1997 – 2008. The number of sampling sites each year is listed immediately below the x-axis.

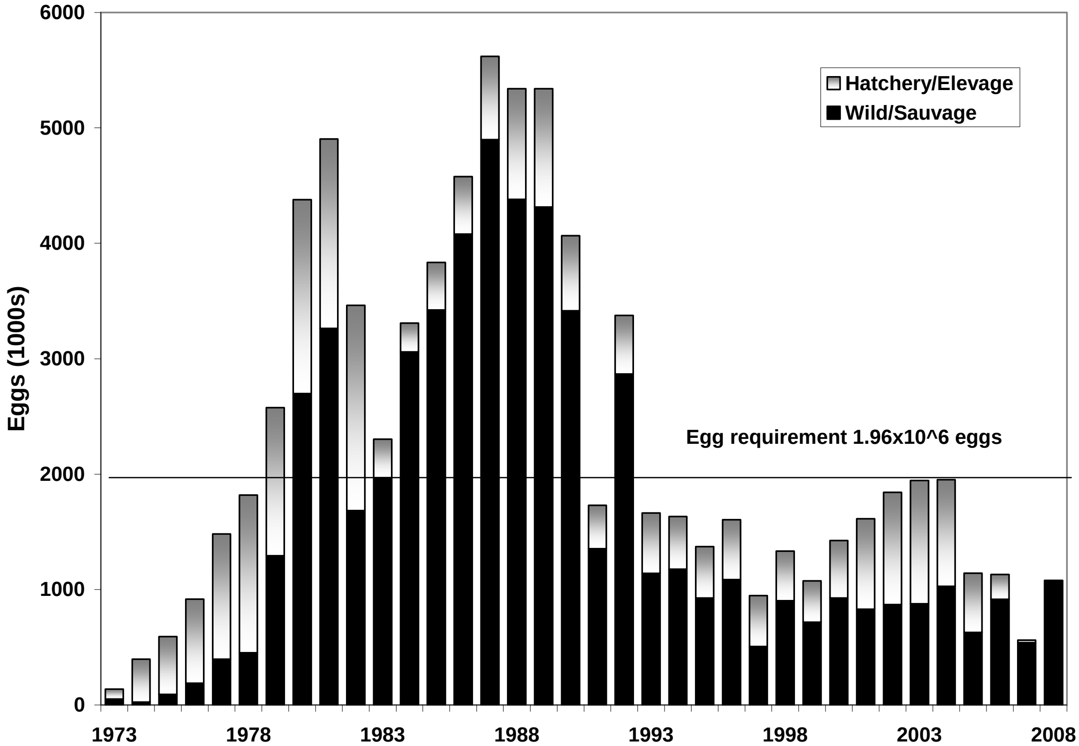

Figure 6. Estimated egg deposition (1000s) relative to the conservation requirement by wild and hatchery Atlantic salmon above Morgans Falls from 1973-2008. No adults of hatchery origin contributed to egg deposition in 2008.

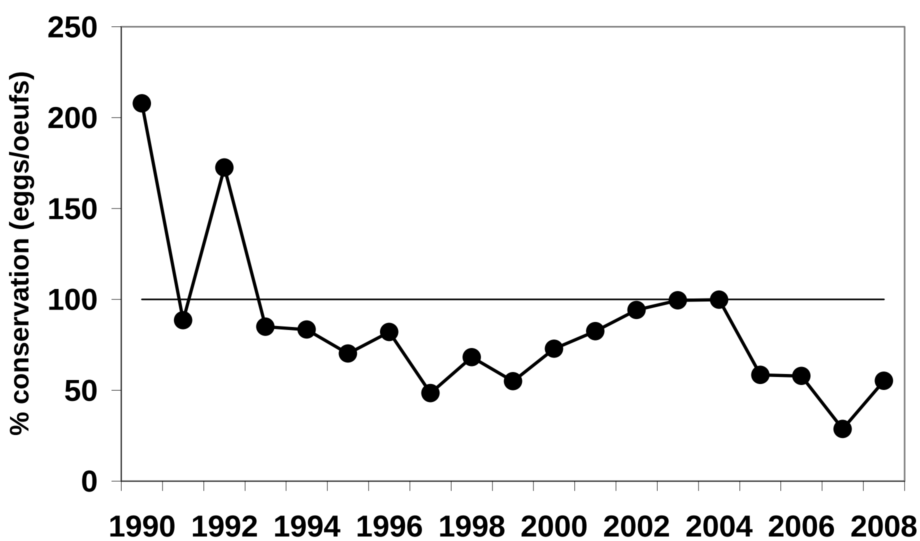

Figure 7. Percent of the conservation requirement (1.96x10^6 eggs) attained annually above Morgans Falls on the LaHave River from 1990-2008.

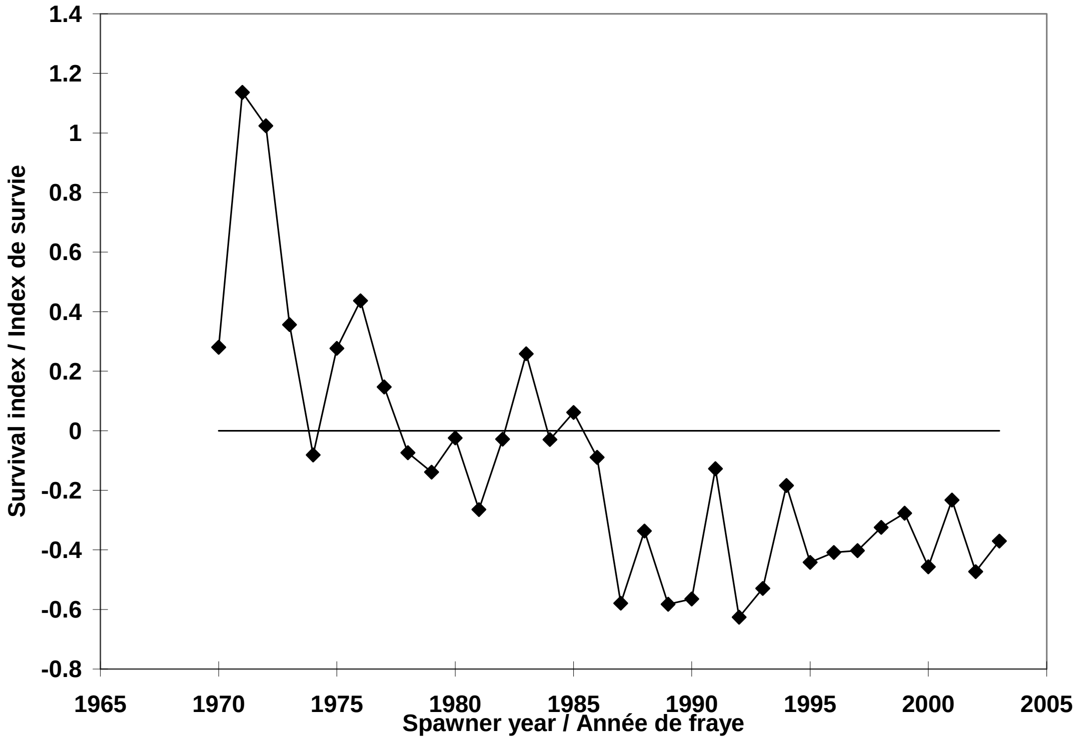

Figure 8. Survival index (Ln Recruits/spawning salmon) of Atlantic salmon above Morgans Falls on the LaHave River for the spawning escapements in 1970-2003 and the associated returns of adults from 1974-2007.

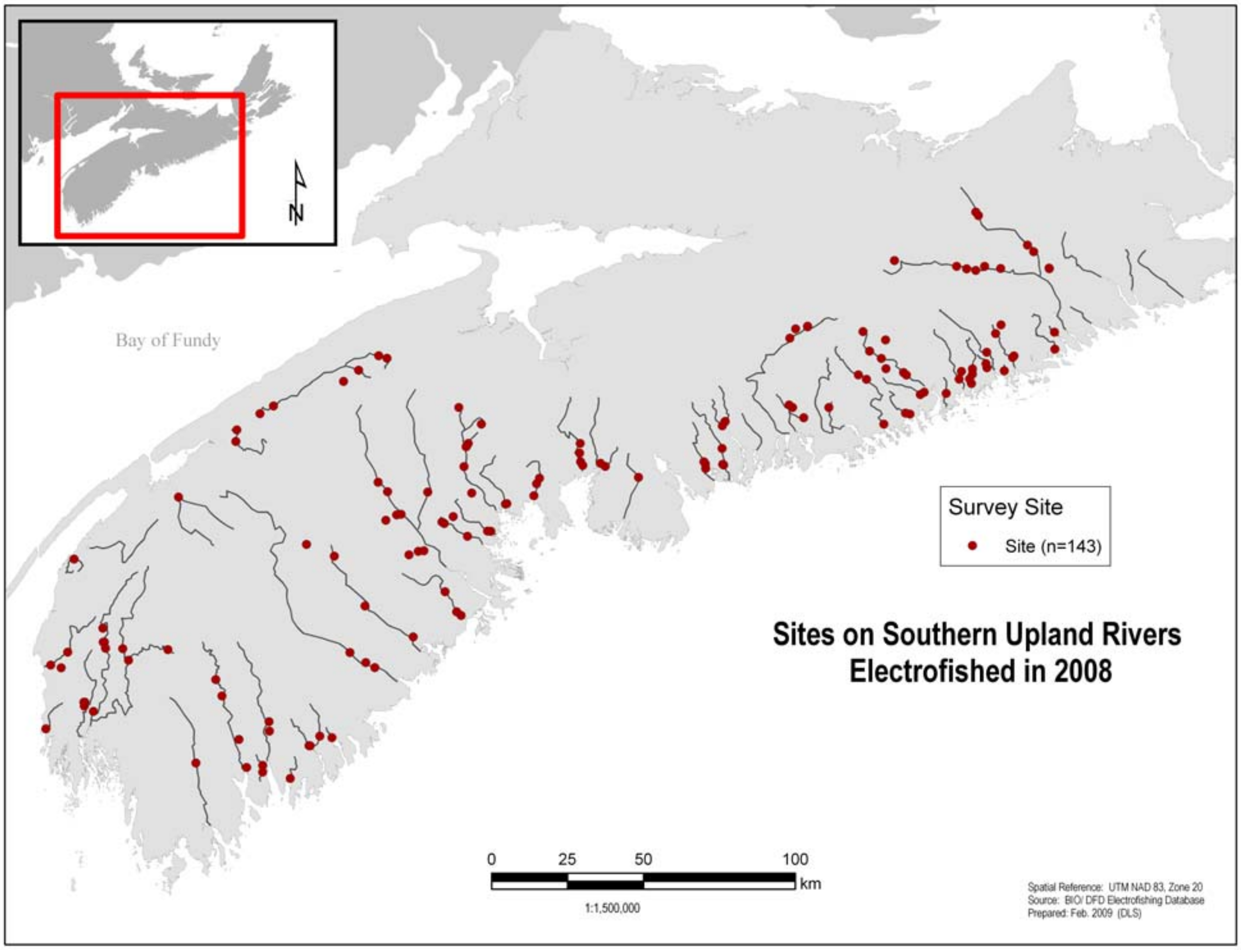

Figure 9. Distribution of the sites visited during the electrofishing survey for Atlantic salmon juveniles throughout the Southern Upland in 2008.

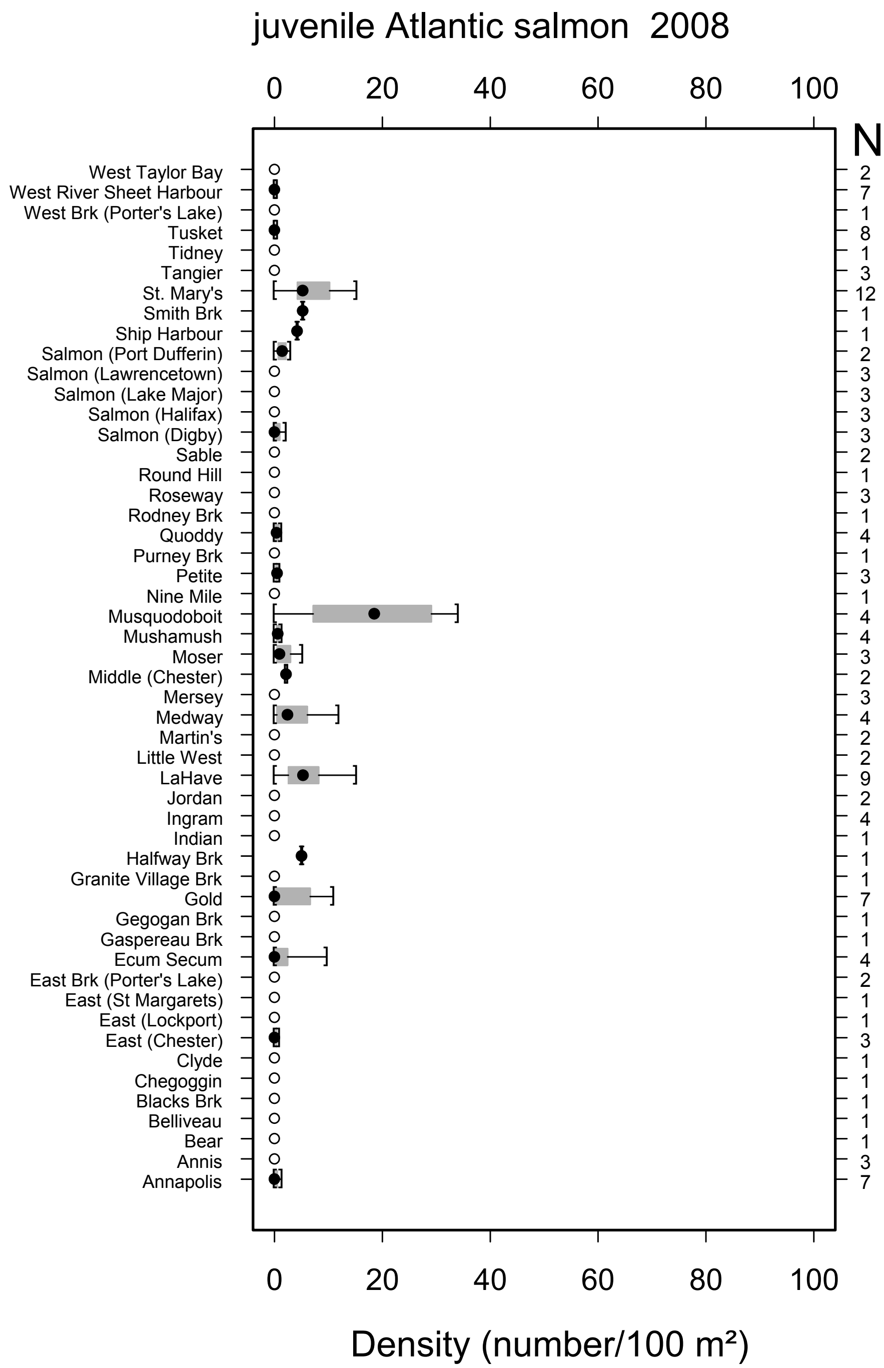

Figure 10. Box plots showing the density of Atlantic salmon in Southern Upland rivers based on electrofishing during 2008. The black dot shows the median density and the box shows the inter-quartile spread. Hollow dots indicate zero salmon density at sites in that watershed. The whiskers are drawn to the minimum and maximum. "N" is the number of sites that were electrofished in each river.

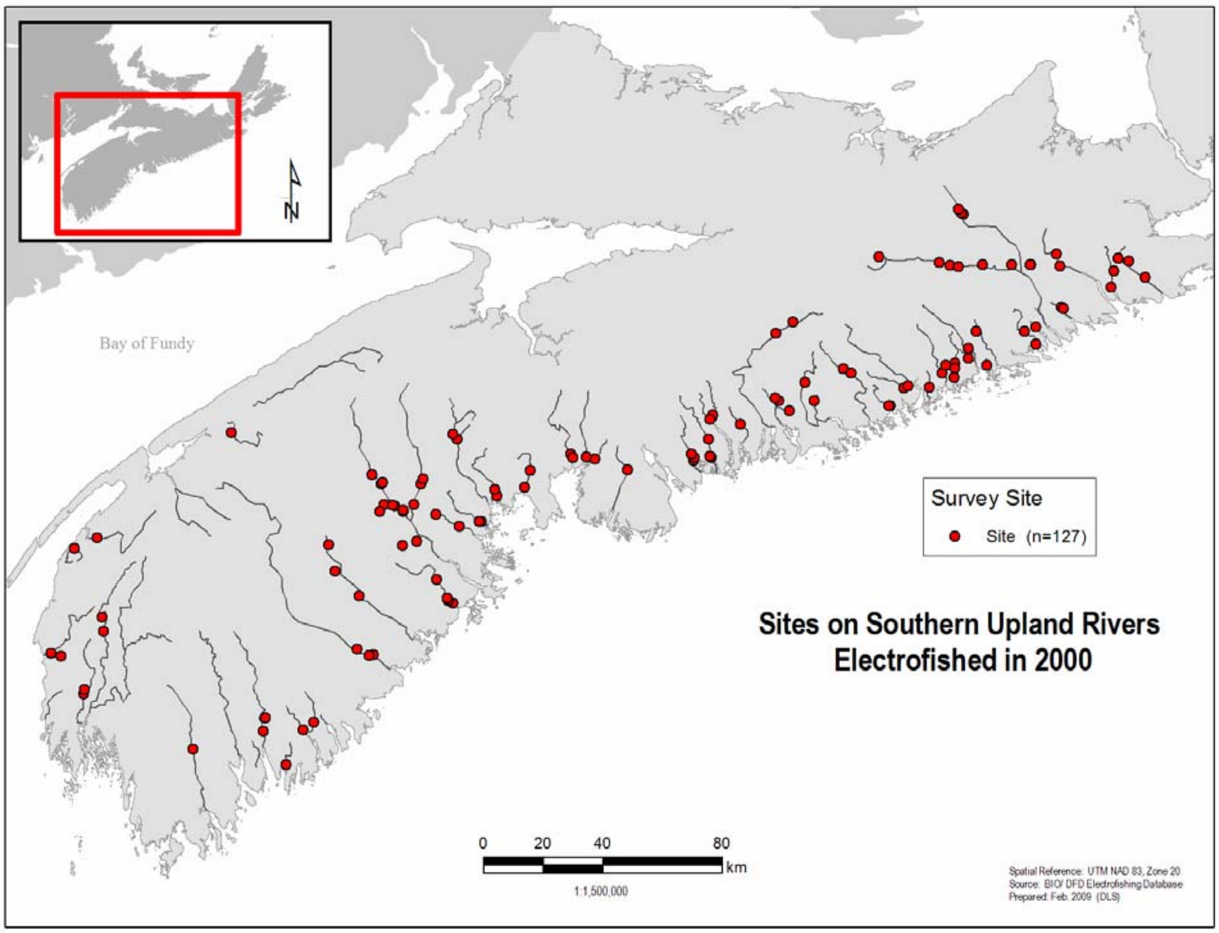

Figure 11. Distribution of the sites visited during the electrofishing survey for Atlantic salmon juveniles throughout the Southern Upland in 2000.

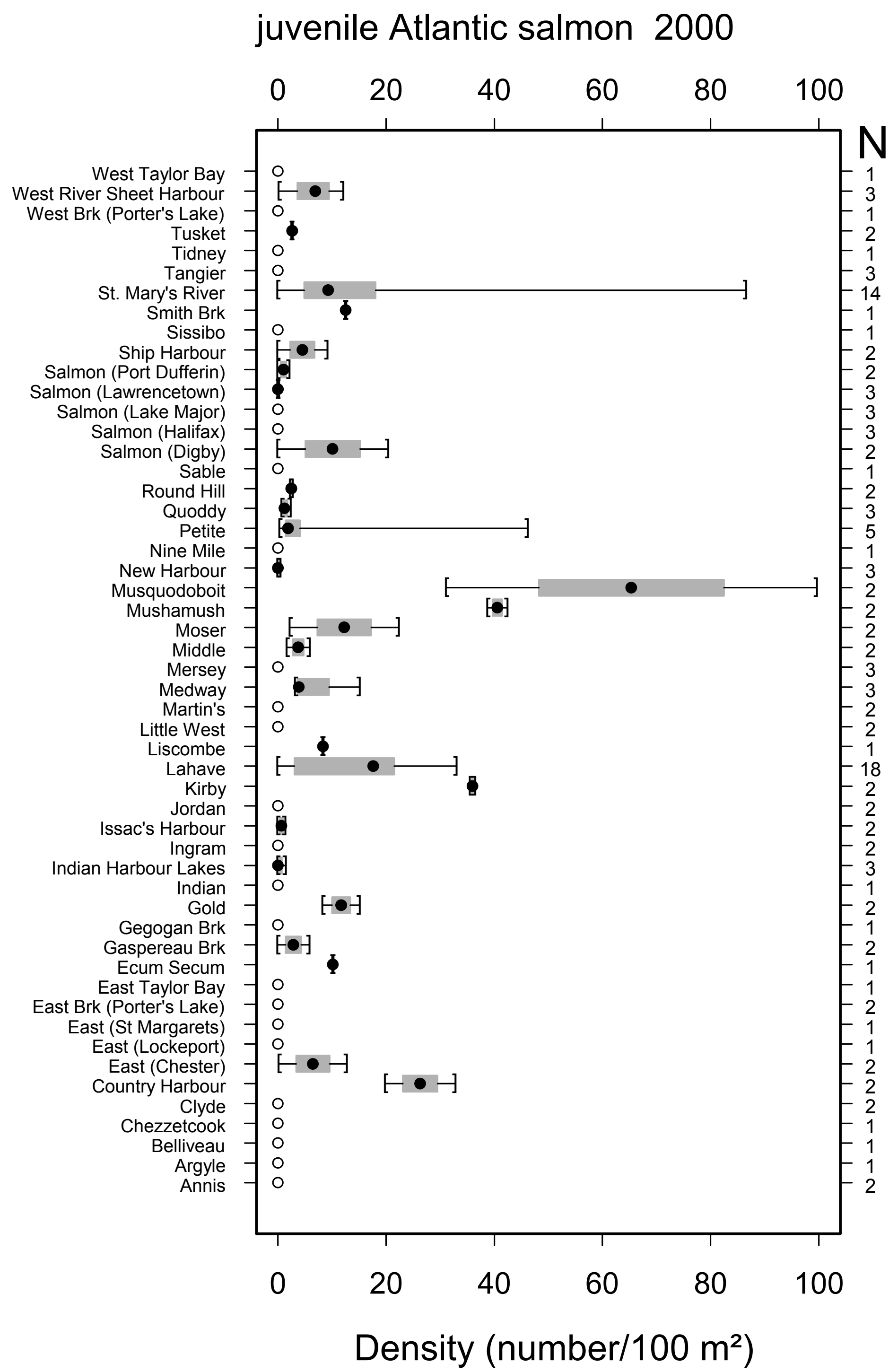

Figure 12. Box plots showing the density of Atlantic salmon in Southern Upland rivers based on electrofishing during 2000. The black dot shows the median density and the box shows the inter-quartile spread. Hollow dots indicate zero density at sites on that watershed. The whiskers are drawn to the minimum and maximum. "N" is the number of sites that were electrofished in each river.

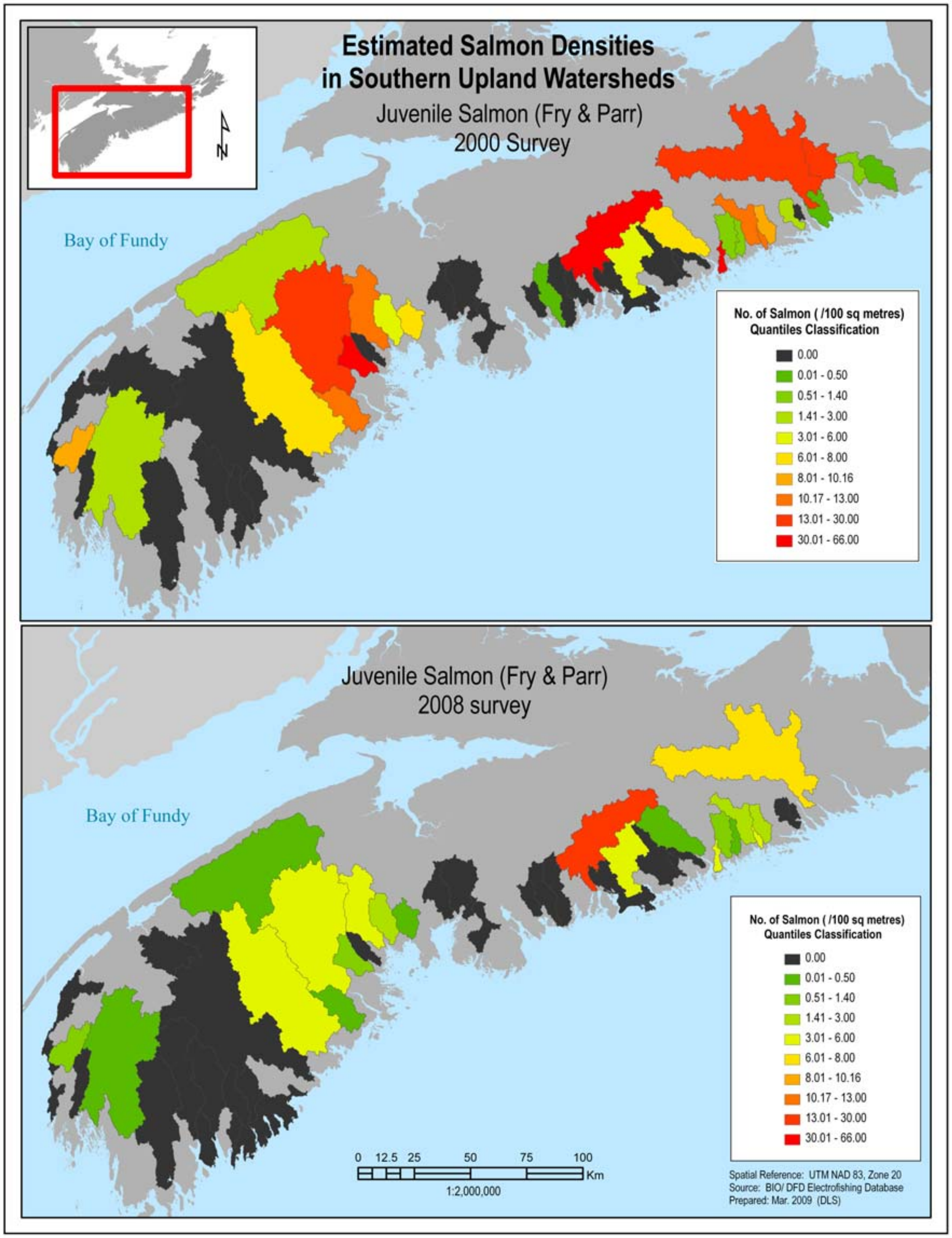

Figure 13. A comparison of the mean juvenile densities (all age classes combined) in watersheds throughout the Southern Upland in 2000 and 2008. Watersheds in which no salmon were captured are shown in black.

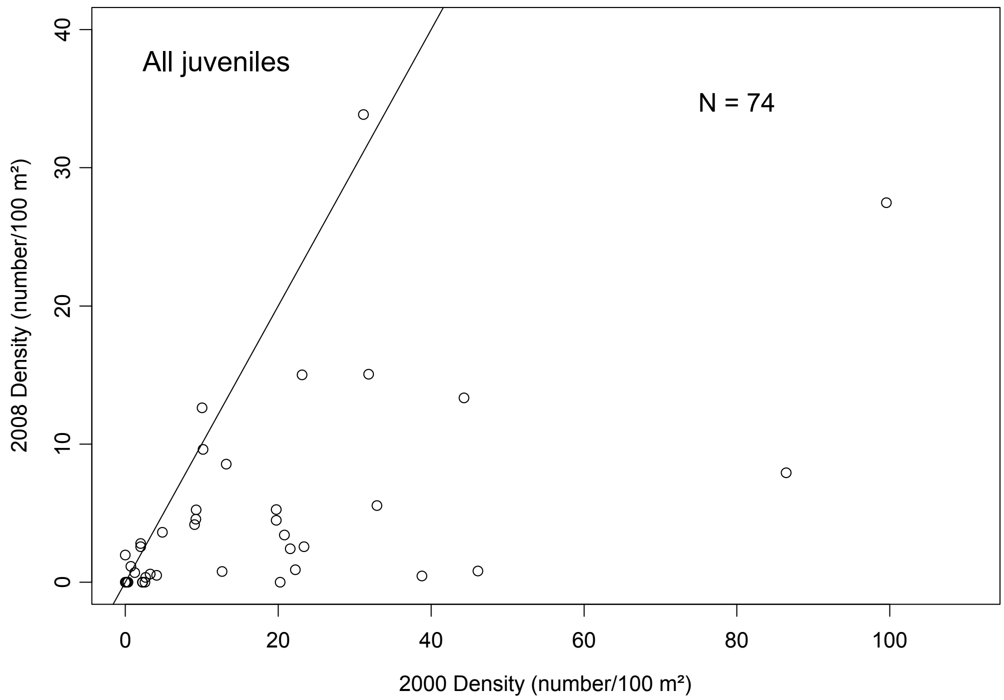

Figure 14. Comparison of densities of juvenile salmon (all age categories) at sites that were electrofished in 2000 and again in 2008. The line is the one-to-one line, above which densities have increased from 2000 to 2008 and below which they have decreased.

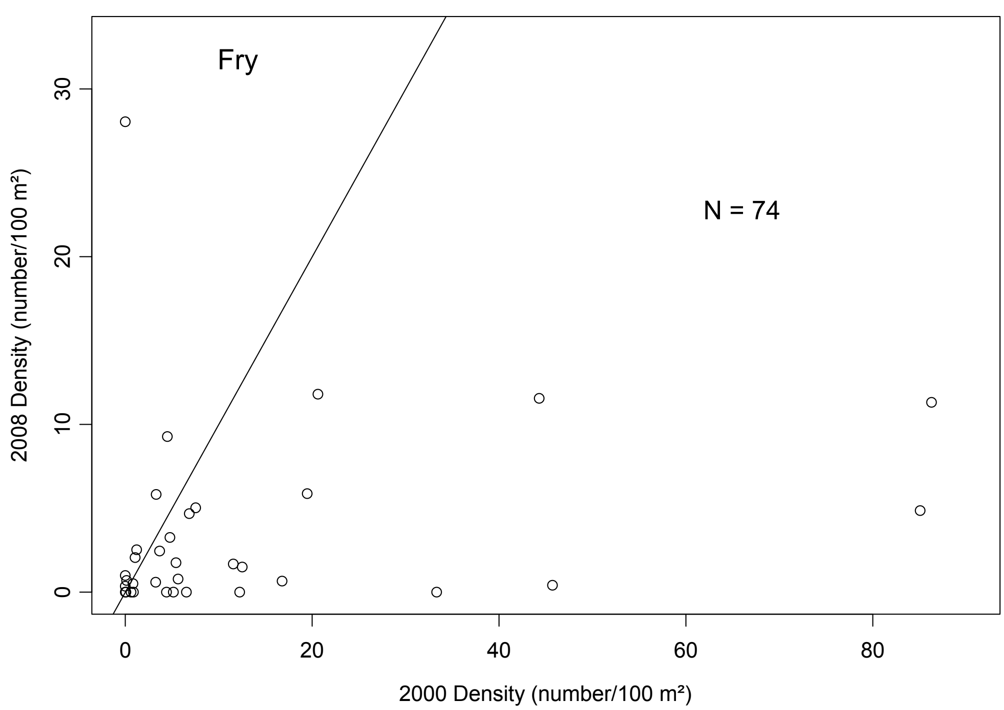

Figure 15. Comparison of densities of juvenile salmon fry at sites that were electrofished in 2000 and again in 2008. The line is the one-to-one line, above which densities have increased from 2000 to 2008 and below which they have decreased.

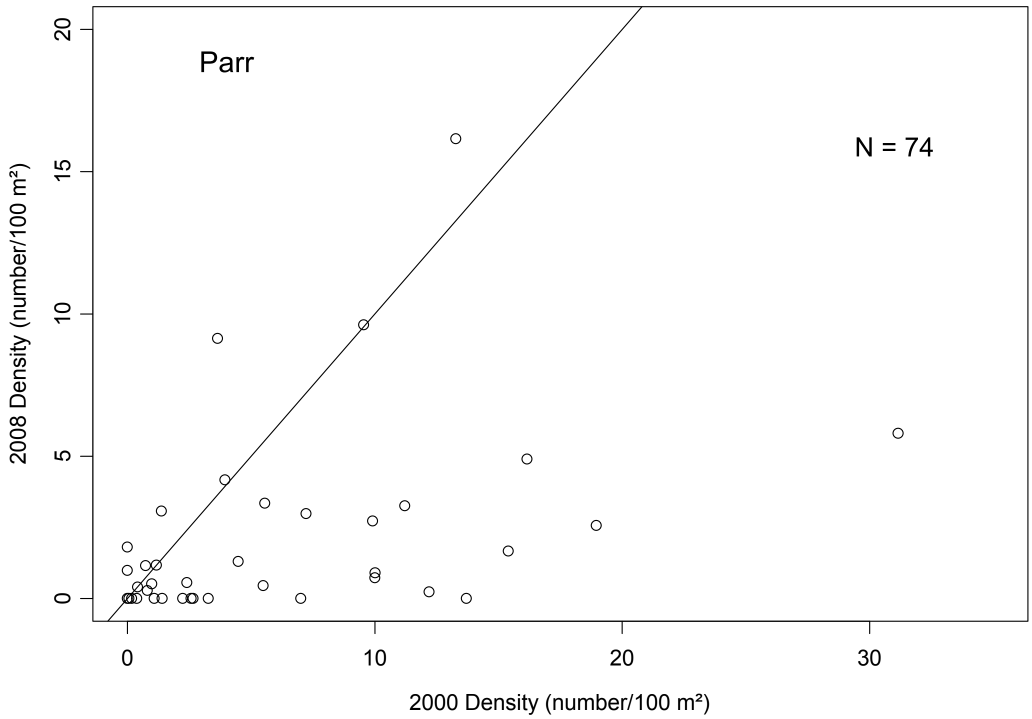

Figure 16. Comparison of densities of juvenile salmon parr at sites that were electrofished in 2000 and again in 2008. The line is the one-to-one line, above which densities have increased from 2000 to 2008 and below which they have decreased.

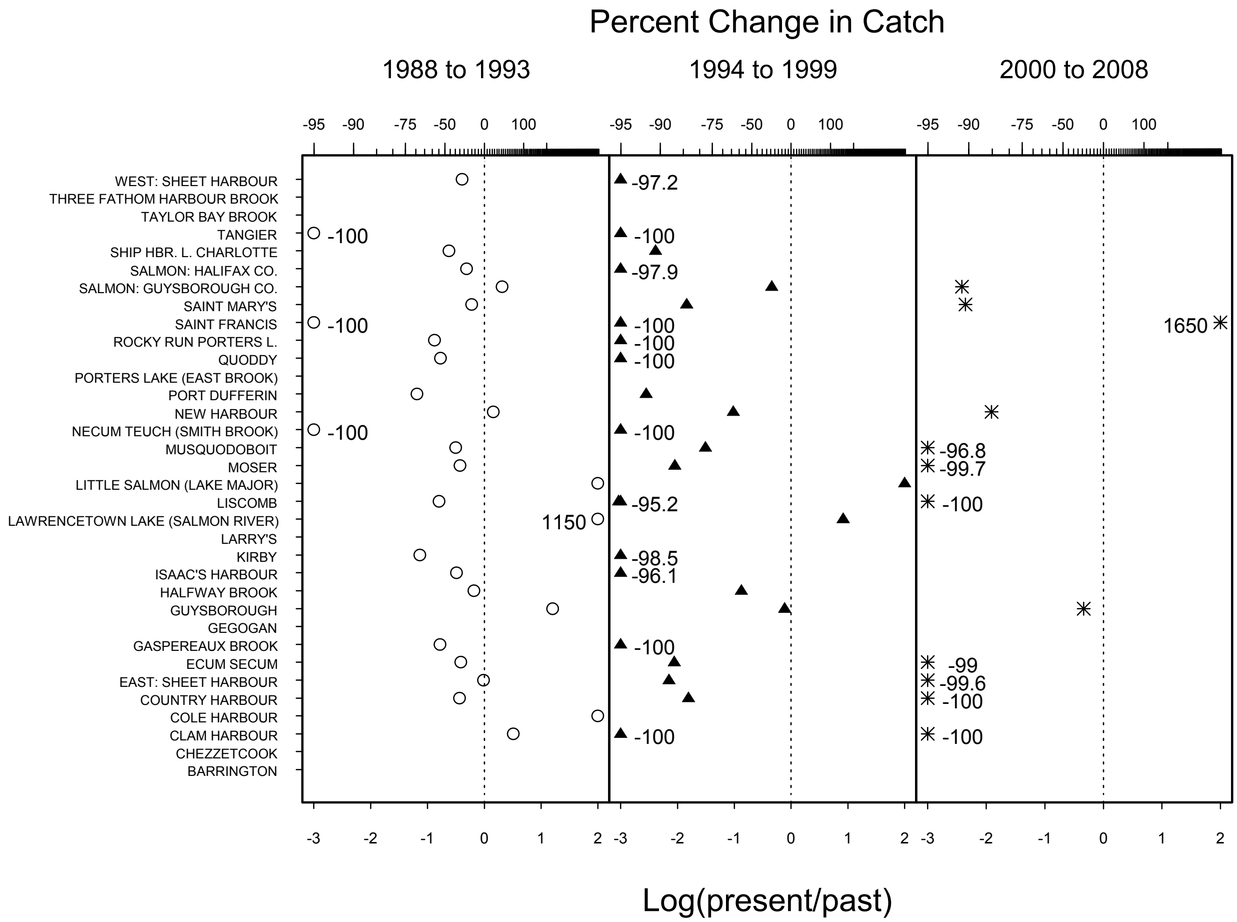

Figure 17. The percent change in reported recreational catch for all rivers in SFA 20, where the mean catch in three time periods was compared with the mean during 1983-1987. Rivers in which the decline in catch was > 95% or the increase was > 200% are labeled with the actual value. Missing points in the most recent time period represent rivers that have been closed to angling for the full 5-year period.

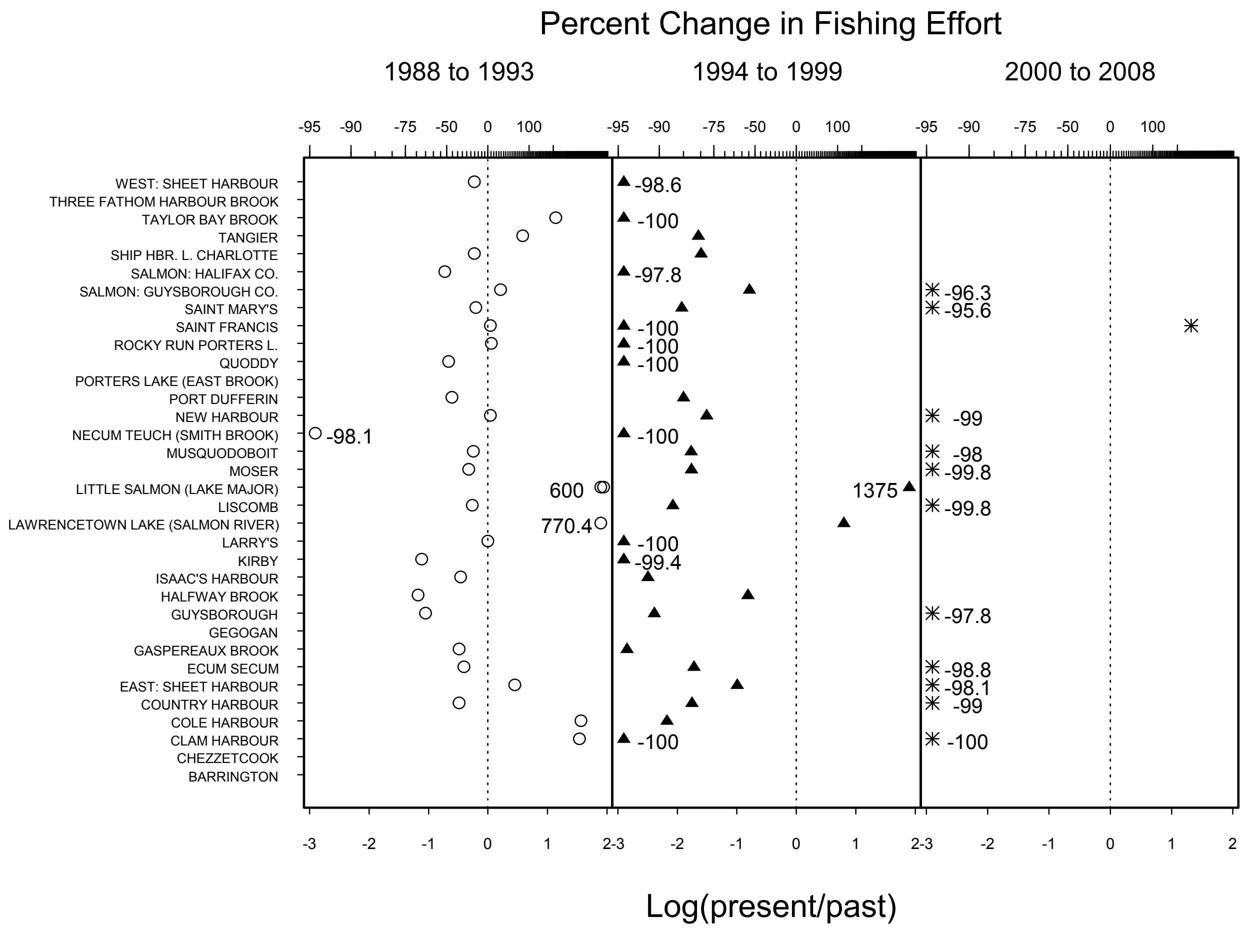

Figure 18. The percent change in reported recreational fishing effort for all rivers in SFA 20, where mean effort in three time periods was compared with mean effort during 1983-1987. Rivers in which the decline in catch was > 95% or the increase was > 200% are labeled with the actual value. Missing points in the most recent time period represent rivers that have been closed to angling.

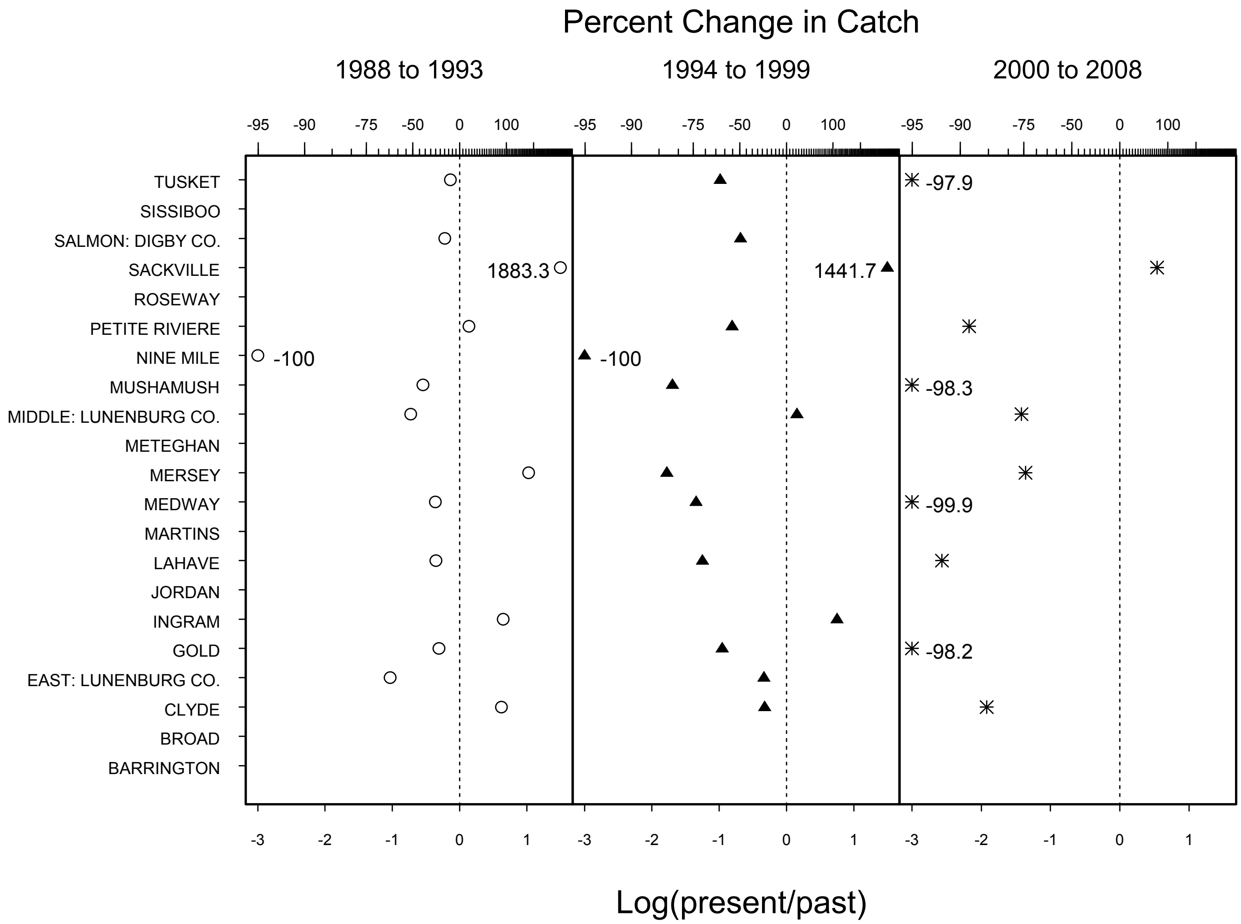

Figure 19. The percent change in reported recreational catch for all rivers in SFA 21, where the mean catch in three time periods was compared with the mean during 1983-1987. Rivers in which the decline in catch was > 95% or the increase was > 200% are labeled with the actual value. Missing points in the most recent time period represent rivers that have been closed to angling.

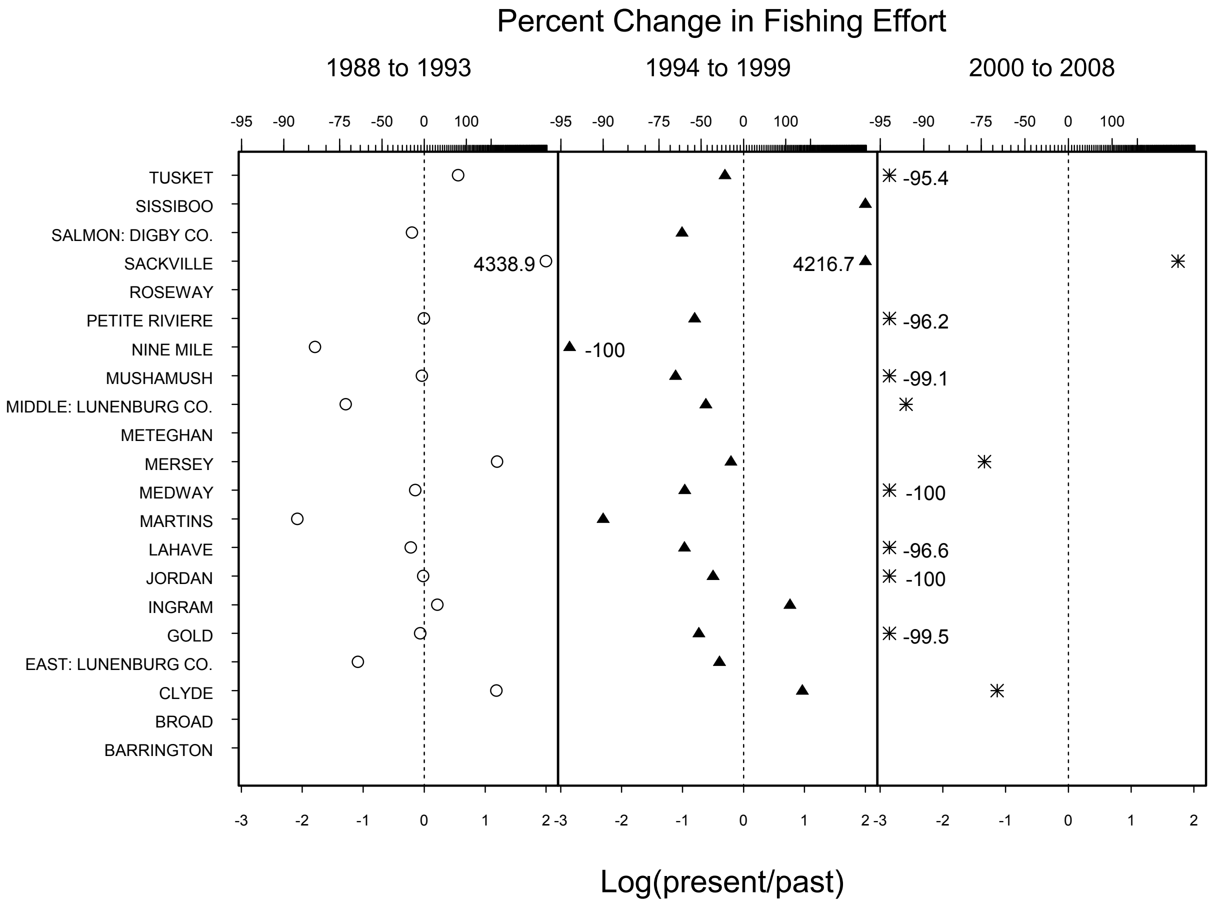

Figure 20. The percent change in reported recreational fishing effort for all rivers in SFA 21, where mean effort in three time periods was compared with mean effort during 1983-1987. Rivers in which the decline in catch was > 95% or the increase was > 200% are labeled with the actual value. Missing points in the most recent time period represent rivers that have been closed to angling.

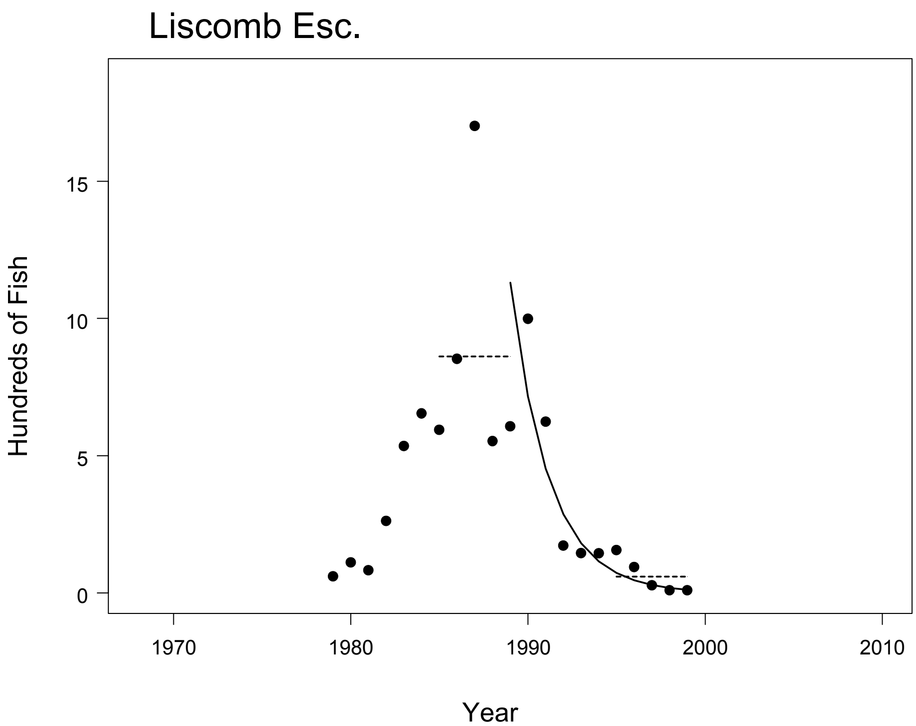

Figure 21. Observed adult escapement from 1979 to 1999 (points) and predicted 10-year population declines from the ratio method (horizontal dashed lines) and log-linear model (solid line) for the Liscomb River.

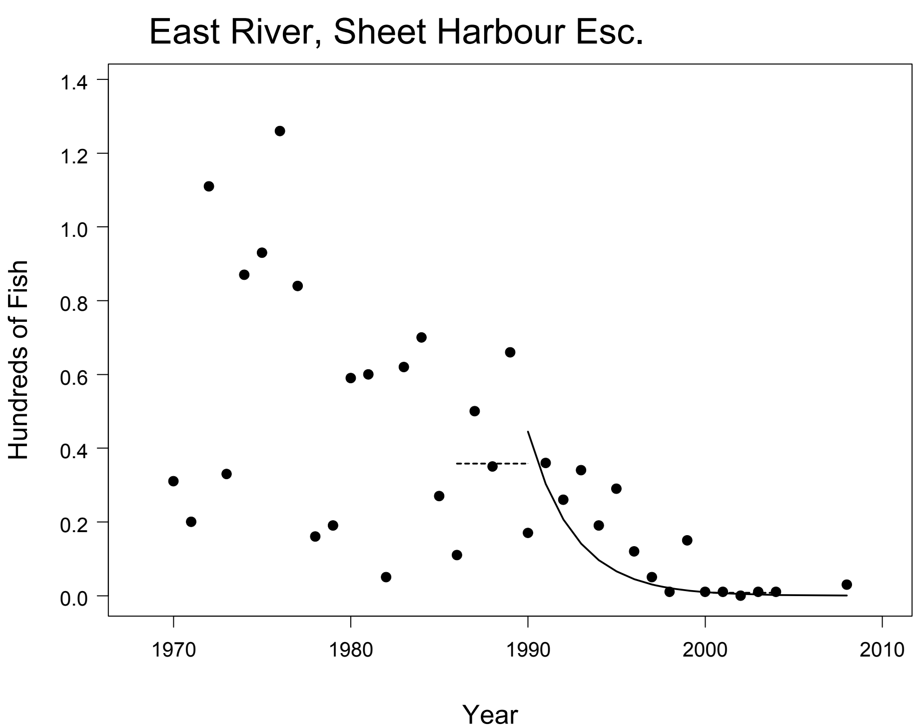

Figure 22. Observed adult escapement from 1970 to 2008 (points) and predicted 15-year population declines from the ratio method (horizontal dashed lines) and log-linear model (solid line) for East River, Sheet Harbour.

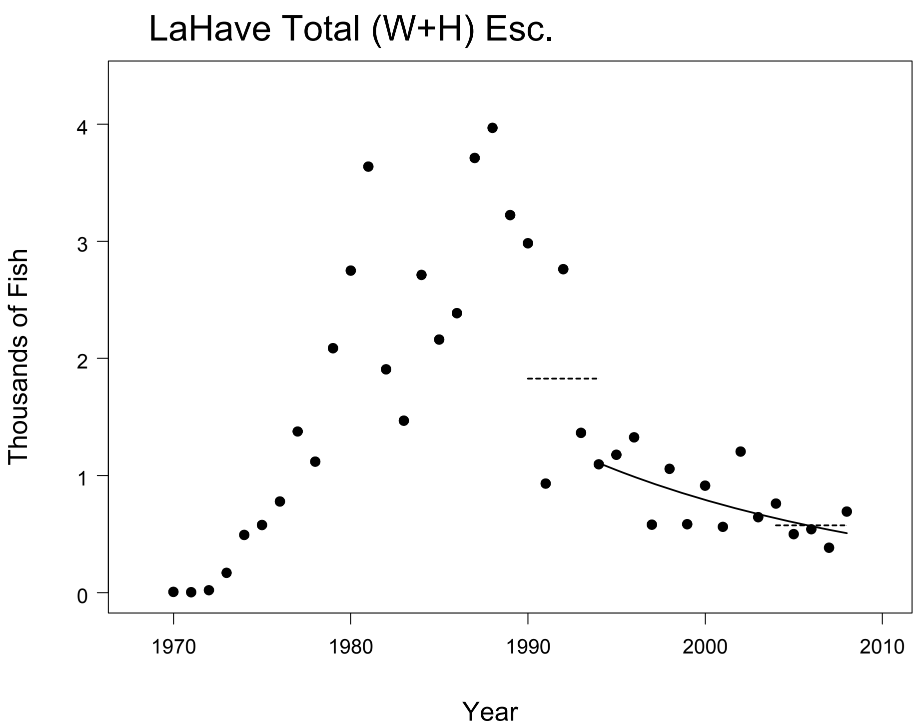

Figure 23. Observed adult escapement from 1970 to 2008 (points) and the predicted 15-year population declines from the ratio method (horizontal dashed lines) and log-linear model (solid line) for the LaHave River above Morgans Falls.

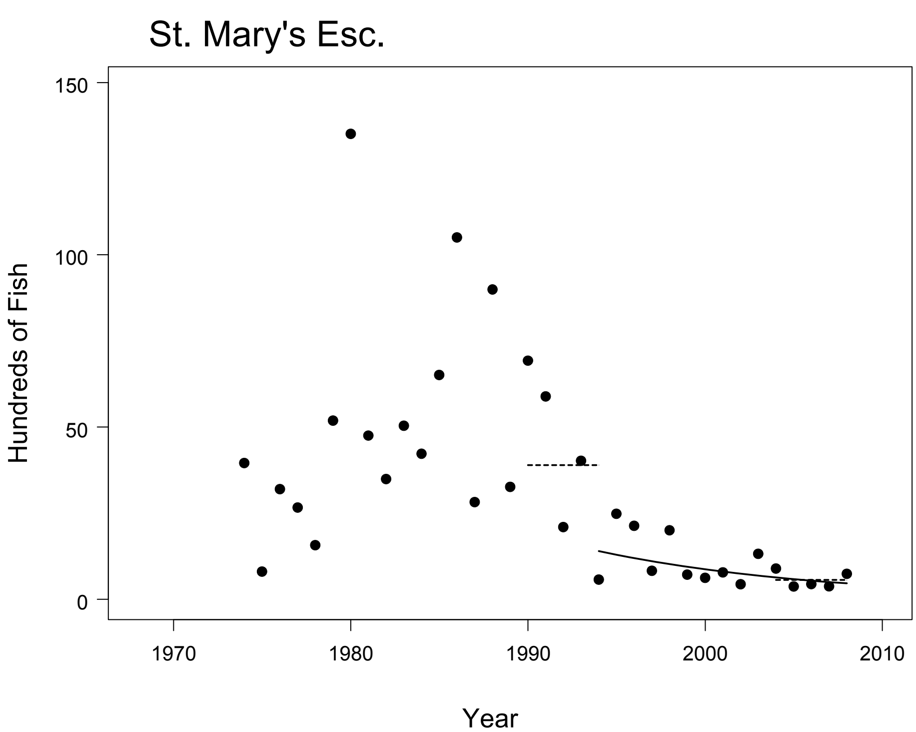

Figure 24. Observed adult escapement from 1974 to 2008 (points) and the predicted 15-year population declines from the ratio method (horizontal dashed lines) and log-linear model (solid line) for the St. Mary's River.

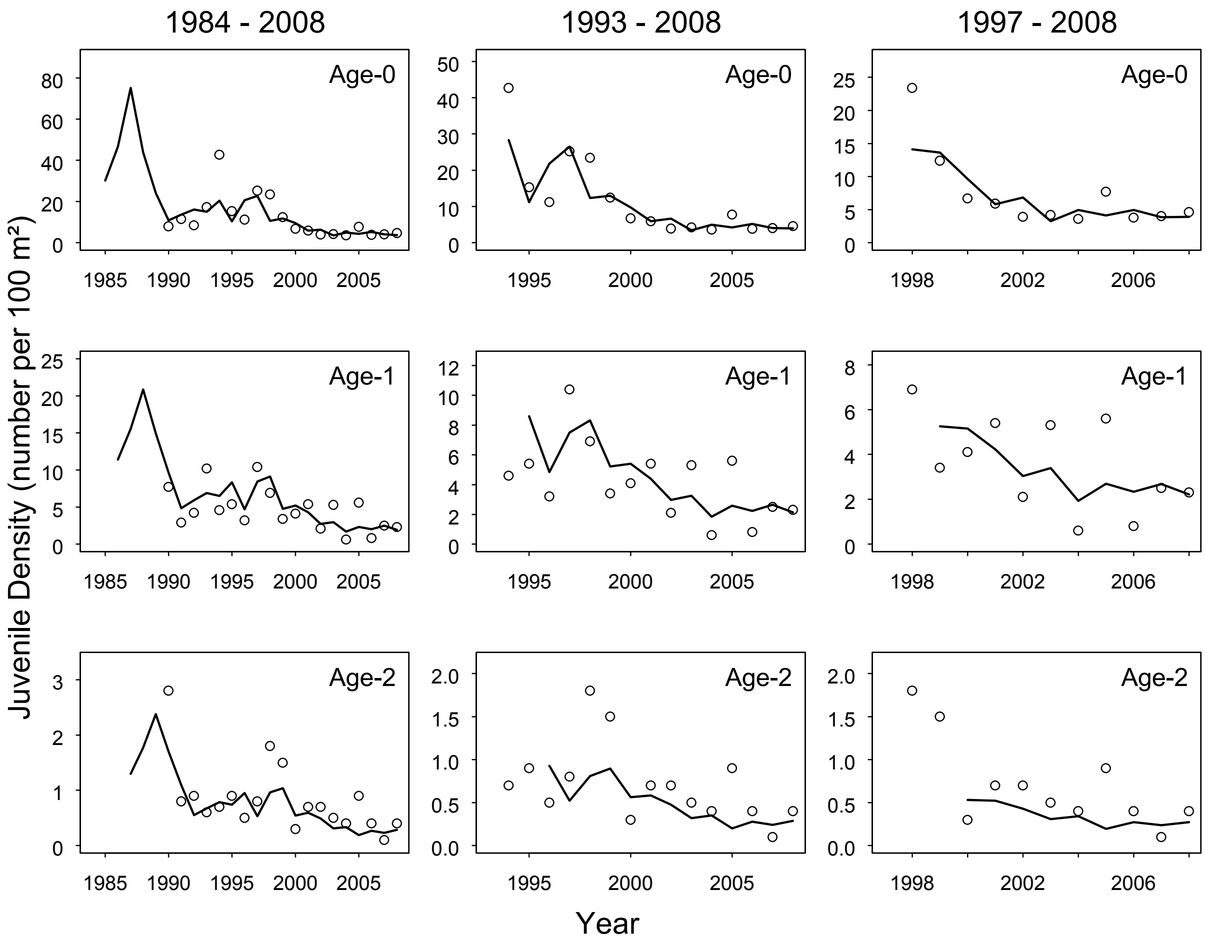

Figure 25. Observed (points) and predicted (lines) densities of juvenile Atlantic salmon from the freshwater production model for the West Branch of the St. Mary's River. Models were fit to data spanning three time periods (as labelled for each column).

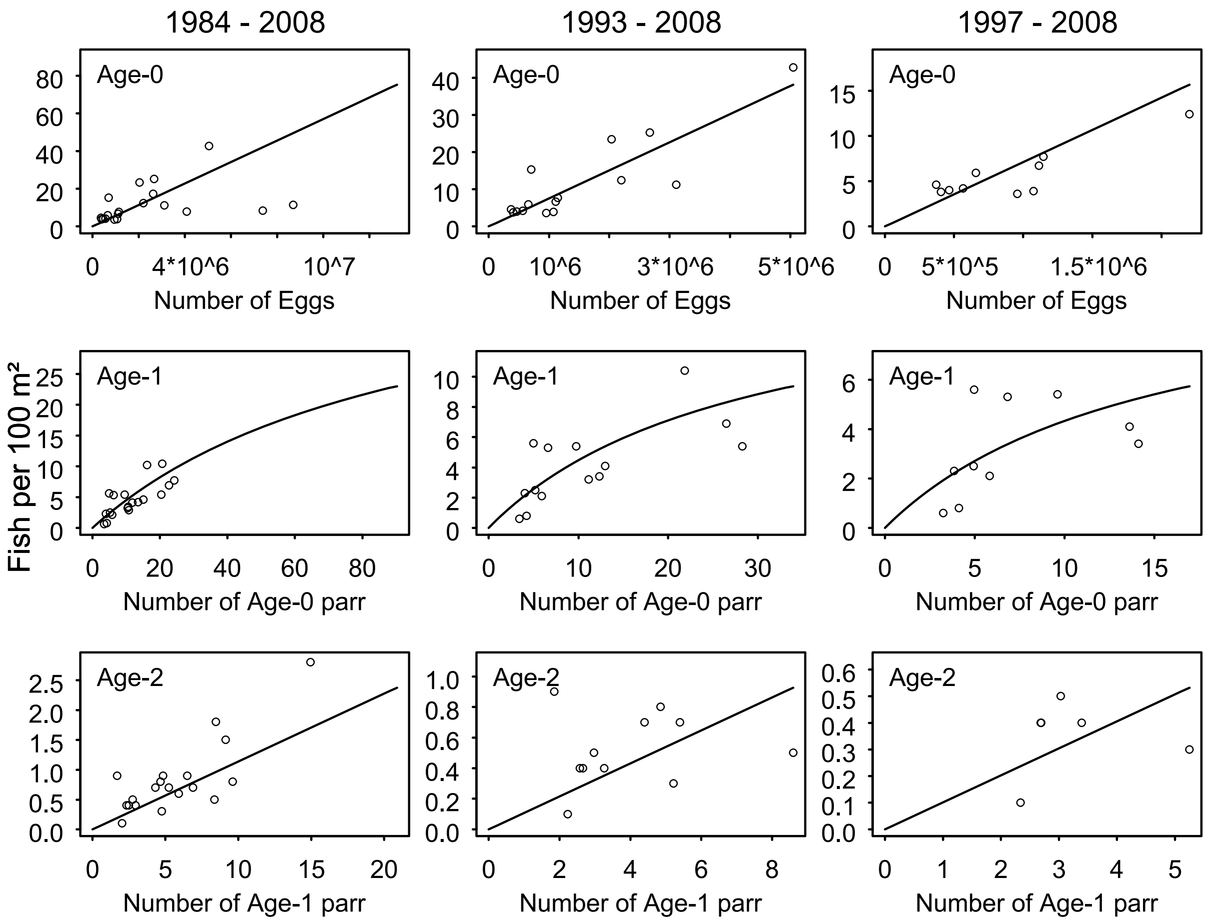

Figure 26. Functional relationships between three ages of Atlantic salmon from the freshwater production model for the St. Mary's River. Models were fit to data spanning three time periods (as labelled for each column). The points are the observed data while the lines show the fitted relationship.

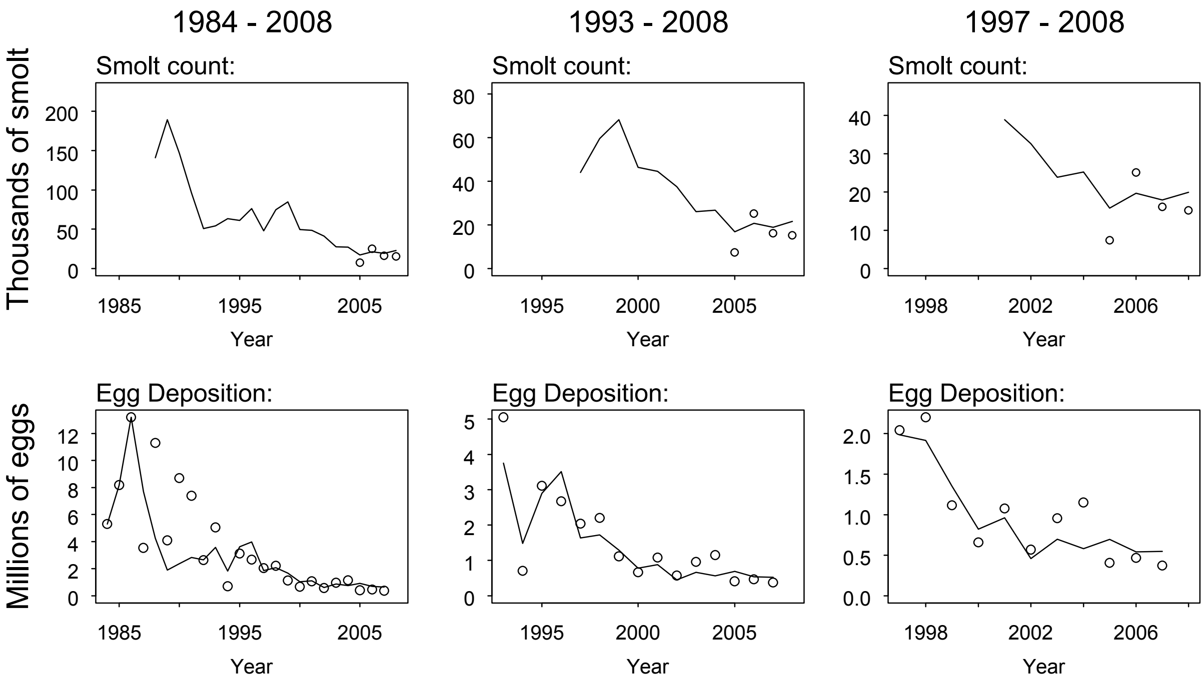

Figure 27. Observed (points) and predicted (lines) abundance of Atlantic salmon smolt and egg deposition from the freshwater production model for the St. Mary's River. Models were fit to data spanning three time periods (as labelled for each column).

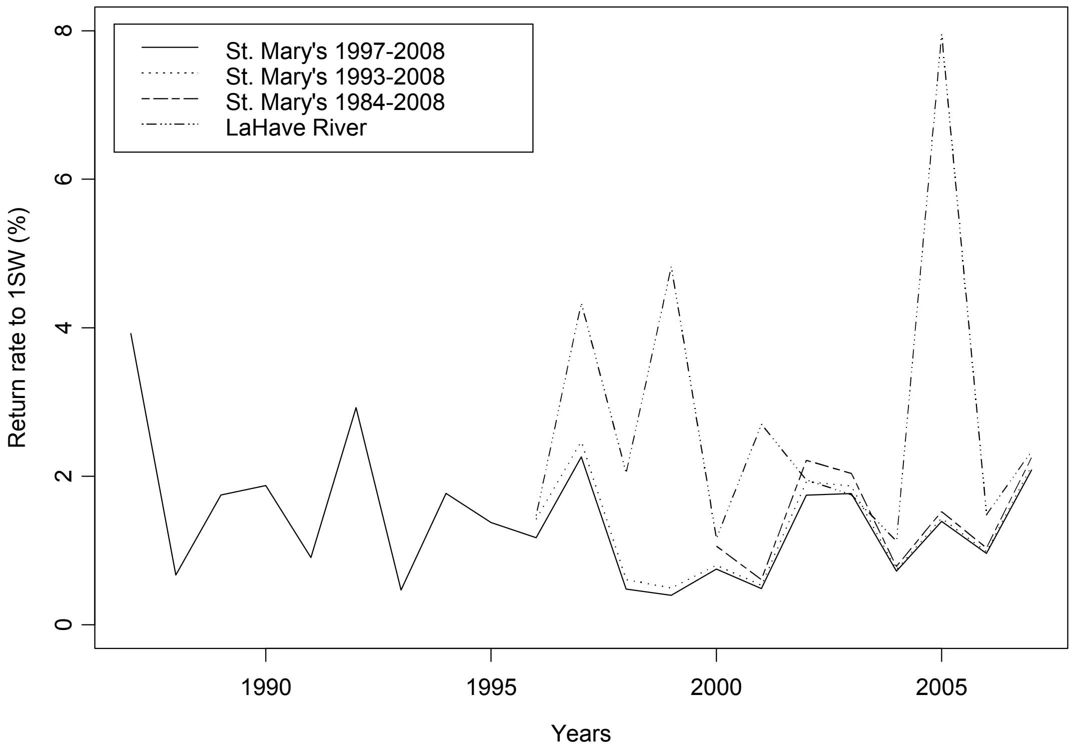

Figure 28. Comparison of the smolt-to-1SW return rates predicted from the life-history model for the St. Mary's River for three time periods: 1984-2008, 1993-2008 and 1997-2008. Return rates observed on the LaHave River from 1996-2007 are plotted for comparison.

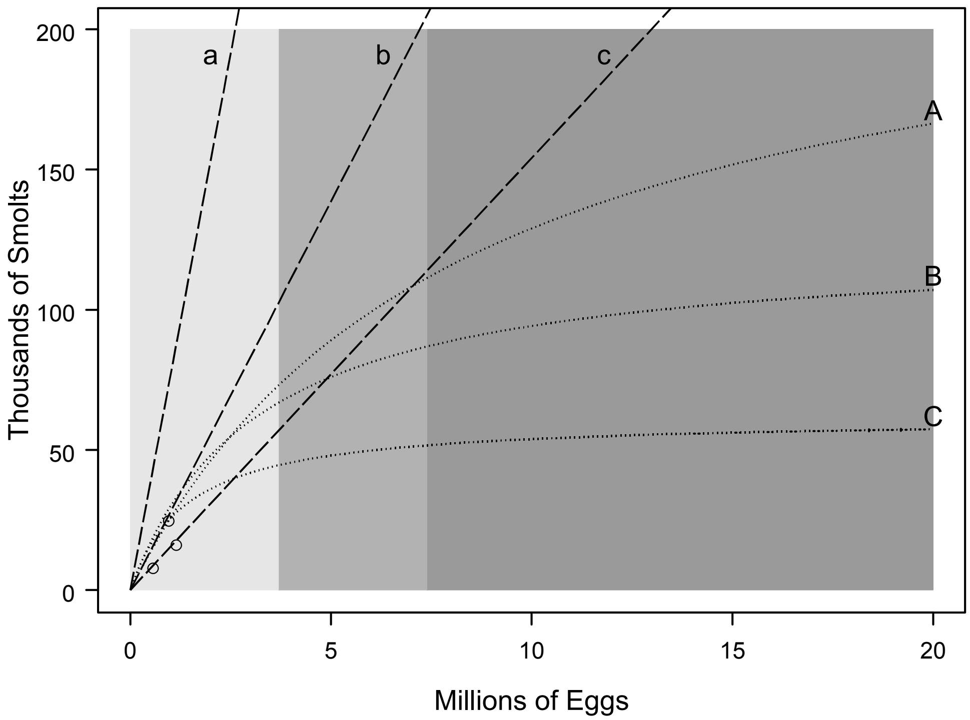

Figure 29. Equilibrium analysis of the salmon population dynamics in the St. Mary's River. The points are the observed egg depositions and smolt production for the 2003 to 2005 cohort years. The curved, dashed lines represent freshwater production as calculated from data spanning 1984-2008 (A), 1993-2008 (B) and 1997-2008 (C). The straight, dashed lines represent marine production as calculated at the minimum observed return rates (a), the mean observed return rates (b) and the maximum observed return rates (c) for 1SW and 2SW adults. Dark shading indicates egg depositions above the conservation egg requirement, medium shading is between 50% and 100% of the egg requirement, and the light shading is below 50% of the requirement.

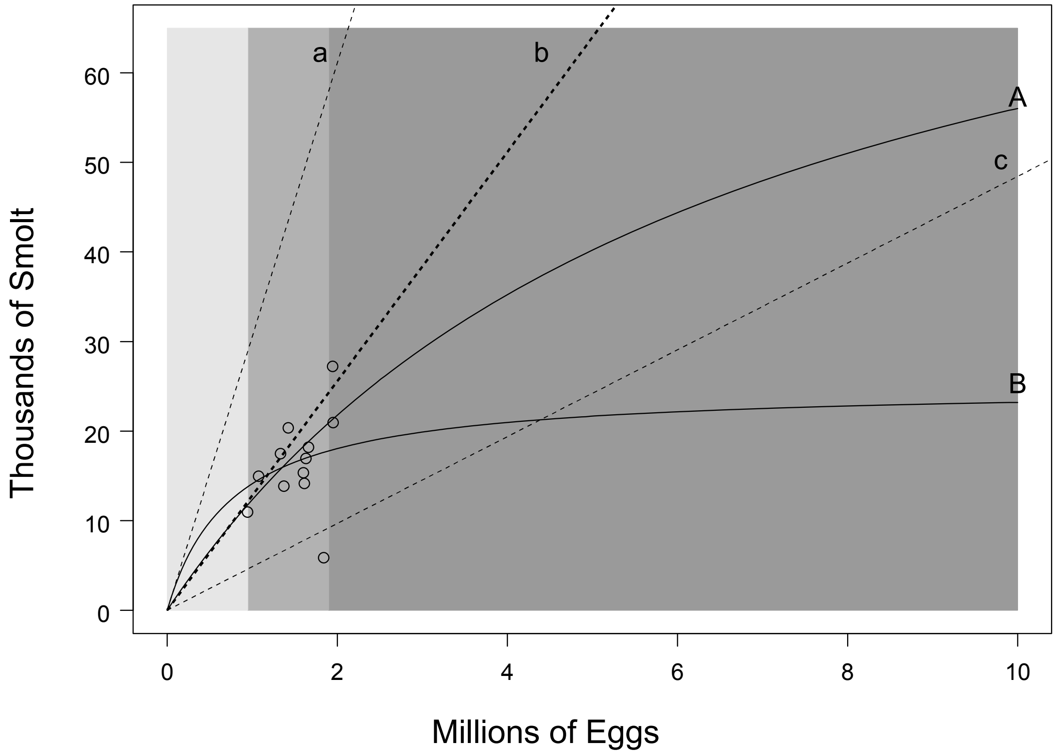

Figure 30. Equilibrium analysis of the salmon population dynamics in the LaHave River above Morgans Falls. The points are the observed egg depositions and smolt production for the 1994 to 2005 cohort years. The curved, solid line (B) represents current freshwater production, as calculated from smolt abundance and egg deposition data from 1996-2008. The curved, solid line (A) represents current freshwater production if the 2005 smolt cohort is not included in the analysis. The straight, dashed lines represent marine production as calculated at the minimum observed return rates (a), the mean observed return rates (b), and the maximum observed return rates (c) for 1SW and 2SW adults. Dark shading indicates egg depositions above the conservation egg requirement, medium shading is between 50% and 100% of the egg requirement, and the light shading is below 50% of the requirement.

10.0 APPENDICES

Appendix 1. Atlantic salmon parr (age-1 and age-2) densities from the annual electrofishing survey on the LaHave River, for sites above and below Morgans Falls during 1979 to 2008.

Site	Year	1979	1980	1981	1982	1983	1984	1987	1988	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
	N	10	30	25	7	12	10	10	10	11	7	17	14	14	19		14	12	13	16	16	16	12	16	16	11	11	8
Above Morgan Falls																												
Misners #8			3.70	5.80	8.99	12.34	5.97	8.62	6.75	9.50	9.60	20.40	6.50	8.90	8.10		12.40	9.10	18.00	14.30	9.60	15.30		5.60	15.46	21.95	2.61	1.00
Cherryfield above bridge									4.60	12.30	14.90	18.10	7.70	5.10	6.10			10.50	15.10	13.00	19.30	22.60	24.80	11.59	14.56	32.76	9.94	8.80
Cherryfield #10		4.51	7.78	6.05		8.59		7.50																				
Falkland Ridge Bridge			8.94	8.09		4.18					7.60	13.00	7.20	6.90	2.80		12.20	9.20		14.40	8.60	6.40	18.50	3.02	8.63			
Ohio R. site #6		0.00	3.13	1.99			1.74			5.00	4.10	19.00					6.30	10.50	7.60	18.10	20.60	8.80	9.10	1.81	21.63	9.97	13.31	3.60
#7		0.00	0.00	0.37													1.60	3.40		0.40	0.10	5.20		7.58	3.08			
#34			0.00	3.21																								
#36			3.35	3.72																								
#37			1.32	0.00																								
Ohio R. behind Conrad's											6.30	11.00					6.40			11.60	10.10	4.40		4.13	13.66	9.13	0.00	
North R. #14		2.78	7.04	4.91	4.37	7.25	4.40	9.24	10.63	24.70	29.70	31.20	15.40	13.10	17.00			22.30	27.40	18.80	26.10	17.10		16.30	18.00	42.49	11.12	
#21		0.45	0.48	0.95	6.16																							
#40			3.39	4.29		7.52																						
North River (below Moosehorn)											0.90		5.60															
Above Armstrong Lake									3.22																			
Sixty Bk. #26		0.28	2.46	7.04	20.54																							
#41			0.00	0.00																								
#42			0.00	0.00	9.28																							
#47				5.82	11.76																							
Mason Med Bk.#38			0.00	9.46																								
#39			0.00	0.59																								
Yearly Averages		**1.34**	**2.60**	**3.66**	**10.18**	**7.98**	**4.04**	**8.45**	**6.30**	**12.88**	**10.44**	**18.78**	**8.48**	**8.50**	**8.50**		**7.78**	**10.83**	**17.03**	**12.94**	**13.49**	**11.40**	**17.47**	**7.15**	**13.57**	**23.26**	**7.40**	**4.47**
Below Morgan Falls																												
Main river #30			2.63	2.44		1.15	5.58	3.61																				
#31			3.17	2.17		7.78		7.12	2.58	7.50		5.40	6.70	3.30	3.00		1.00		0.20	0.10	0.20	0.50	0.40	0.24	0.00			
#32			7.45	1.18		1.23	4.07	15.91	1.58	0.80		10.10	5.10	1.60	2.30		4.10			1.80	0.10	0.00	0.10	0.23	0.00			
#3			2.00	0.00																								
West Br. #1		5.10	4.08	4.01			1.62																					
#22		5.09	2.03																									
#23		3.96	0.54																									
West Br. Wentzell Rd.										8.20		12.70	16.00	10.90	7.40		9.00	14.40	12.80	11.50	13.80	7.00	5.90	5.42	10.64	14.91	0.00	10.60
West Br. Frauzel Rd.										15.00		13.60	12.20	8.70	9.70		6.60	13.90	19.20	4.70	9.40	5.70	16.80	7.43	10.03	7.49	13.28	26.30
#24		4.87	3.29			3.65																						
West Br. Fire Brook									5.27			5.90	16.50	21.50	16.00				32.50	22.80	20.00	25.60	18.10	20.67	32.61	8.24	19.38	9.20
North Br. #16			4.75	6.00			3.93	4.99																				
#19			0.88			3.28		11.86	2.65																			
#20							1.30						1.60															
#43			3.61					2.43																				
#44			7.66			3.17	2.46	4.62																				
#45			0.95	1.28	1.60	22.73	1.03																					
#46			2.49	5.93																								
North Br. above Fancy Pool (upper)															3.20													
North Br. above Fancy Pool									2.69	3.10		7.20	5.80		6.20		5.90											
North Br. above MacKay's Bridge									3.15	6.40		12.40		11.90	3.90		12.30	10.10	7.90	5.20	4.10	1.50	2.40	3.88	8.56			
North Br. Holland's Cabin												20.10		18.40	7.90		13.00	12.70	4.00	0.30	1.00	0.00	1.30	2.02	0.00	3.71	0.00	
North Br. Veinot's Campground												17.50	11.40	31.80	14.30		16.40	12.50	43.30	10.60	11.80	16.20	19.10	13.51	18.40	23.93	23.93	9.60
North Br. above Texas Lake										13.30		11.20	7.50	13.30	12.80		20.60	10.40	10.30	11.20	5.10	3.90	8.80	13.68	18.52	9.85	0.00	
North Br., Lake Paul Brook															5.30													
North Br.,above County Line Lake															4.60													
North Br., Hardwood Lake Brook															6.50													
North Br. below Sherbrooke Lake												6.20		4.50	5.60				0.50									
Yearly Averages		**4.76**	**3.25**	**2.88**	**1.60**	**6.14**	**2.86**	**7.22**	**2.99**	**7.76**		**11.12**	**9.20**	**12.59**	**7.25**		**9.88**	**12.33**	**14.52**	**7.58**	**7.28**	**6.71**	**8.10**	**7.45**	**10.97**	**11.35**	**9.43**	**13.93**

Appendix 2. Summary of the electrofishing survey in the Southern Upland during 2008. Site IDs correspond with the Diadromous Fish Division (DFD) electrofishing database. Catch is the number of fish captured on the first pass of the survey. Other species include yellow perch, mummichog, banded killifish, brown bullhead, chain pickerel, sea lamprey, gaspereau and alosa spp. Organizations were the DFO Diadromous Fish Division (DFD BIO), the Nova Scotia Department of Agriculture and Fisheries (NSDoAF) and the Bluenose Coastal Action Foundation (BCAF).

		UTM							Catch										
River	Site ID	Easting	Northing	Organiz.	Area (m^2)	Mo.	Day	Shocking Time (s)	Atlantic salmon	American eel	Brook trout	Brown trout	White sucker	SMouth-bass	Chub spp.	Other Cyprinids	Stickle-back spp.	Others
Annapolis	SU105	321913	4968332	DFD BIO	197	8	5	768	0	16	0	0	3	0	0	0	0	0
Annapolis	SU104	344908	4976408	DFD BIO	574	8	5	971	0	5	0	0	6	0	13	7	0	0
Annapolis	SU109	309804	4960452	DFD BIO	381	8	7	773	1	12	0	0	0	0	5	2	0	0
Annapolis	SU108	317421	4965759	DFD BIO	604	8	7	1011	1	15	2	0	7	0	6	0	0	1
Annapolis	SU110	356468	4984811	DFD BIO	530	8	8	549	0	10	0	0	0	0	4	0	0	0
Annapolis	SU111	359218	4983996	DFD BIO	666	8	8	952	0	12	1	0	3	0	4	0	0	0
Annapolis	SU107	349917	4980092	DFD BIO	795	8	7	1087	4	15	0	0	3	0	21	1	0	0
Annis	SU9C	259496	4870901	DFD BIO	305	7	30	793	0	7	0	0	2	0	0	0	0	1
Annis	SU9B	259748	4870901	DFD BIO	603	7	31	1984	0	35	0	0	0	1	0	0	0	8
Annis	SU9A	259670	4869618	DFD BIO	772	7	31	1263	0	36	0	0	0	0	0	0	0	0
Bear	SU3B	290609	4938330	DFD BIO	414	8	1	820	0	3	2	0	0	0	0	0	0	0
Belliveau	SU5A	256260	4917970	DFD BIO	174	7	29	494	0	10	3	0	0	0	0	0	0	0
Blacks Brk	SU102	313067	4849444	DFD BIO	934	8	1	743	0	8	2	0	0	0	0	0	0	0
Chegoggin	SU106	247041	4862117	DFD BIO	234	8	6	525	0	6	0	0	0	0	0	0	9	8
Clyde	SU13B	296352	4850891	DFD BIO	733	7	30	836	0	35	0	0	0	0	0	0	0	1
East (St Margarets)	SU31A	431035	4948451	DFD BIO	4077	7	14	955	0	11	11	0	4	0	0	0	0	0
East (Chester)	SU27B	409385	4944546	DFD BIO	301	7	23	1002	1	15	0	0	0	0	0	0	0	0
East (Chester)	SU27C	408453	4942713	DFD BIO	320	7	15	545	0	1	0	0	6	0	0	0	0	1
East (Chester)	SU27A	407560	4938806	DFD BIO	498	7	15	1110	0	6	0	0	0	0	5	2	0	0
East (Lockport)	SU16A	327403	4845846	DFD BIO	515	7	30	767	0	5	0	0	0	0	0	0	0	0
East Brook (Porter's Lake)	SU38A	470352	4963085	DFD BIO	560	7	9	703	0	12	0	0	0	0	0	0	0	0
East Brook (Porter's Lake)	SU38B	470485	4963226	DFD BIO	405	7	9	556	0	16	0	0	0	0	0	0	0	0
Ecum Secum	SU54A	559416	4992152	DFD BIO	267	8	26	1327	11	15	2	0	0	0	0	0	0	0
Ecum Secum	SU54B	565491	4984766	DFD BIO	222	9	18	812	0	8	1	0	0	0	0	2		0
Ecum Secum	SU54C	565005	4984243	DFD BIO	201	9	18	821	0	4	3	0	1	0	0	0	0	0
Ecum Secum	SU54D	561250	4994977	DFD BIO	236	9	18	959	0	10	1	0	0	0	0	0	0	0
Gaspereau Brk	Gasb003	578938	4986969	DFD BIO	533	9	19	923	0	16	0	0	0	0	0	0	0	2

		UTM							Catch									
River	Site ID	Easting	Northing	Organiz.	Area (m^2)	Mo.	Day	Shocking Time (s)	Atlantic salmon	American eel	Brook trout	Brown trout	White sucker	SMouth-bass	Chub spp.	Other Cyprinids	Stickle-back spp.	Others
Gegogan Brk	SU57A	578807	4992603	DFD BIO	390	8	25	910	0	34	0	0	1	0	0	0	0	0
Gold	Gold002	385312	4954982	BCAF	440	9	22	484	18	0	6	0	0	0	0	0	0	0
Gold	Gold003	385934	4956026	BCAF	670	8	22	905	0	0	9	0	0	0	0	0	0	0
Gold	Gold005	384532	4948356	BCAF		9	18	997	33	3	0	0	5	0	0	11	0	1
Gold	Gold015	387104	4939677	BCAF	636	9	8	859	0	4	0	0	0	0	0	0	0	1
Gold	Gold016	382814	4967805	BCAF	523	9	2	716	0	3	0	0	0	0	0	8	0	0
Gold	Gold017	390284	4962345	BCAF	610	9	5	351	0	1	0	0	0	0	0		0	2
Gold	Gold018	385236	4954914	BCAF	711	8	29	696	11	1	7	0	0	0	0	4	0	0
Granite Village Brk	SU103	341129	4859242	DFD BIO	788	8	1	804	0	4	0	0	0	0	0	0	0	0
Halfway Brk	Hafb003	543164	4972466	DFD BIO	186	9	19	749	4	13		0	0	0	3	0	0	0
Indian	SU30A	429462	4949492	DFD BIO	752	7	14	490	0	2	13	0	0	0	0	0	0	0
Ingram	SU29B	423642	4948781	DFD BIO	441	7	15	1138	0	17	3	0	0	0	0	0	0	0
Ingram	SU29A	422930	4949962	DFD BIO	643	7	15	1047	0	34	1	0	0	0	0	0	0	0
Ingram	SU29C	422584	4952851	DFD BIO	303	9	5	946	0	13	5	0	0	0	0	0	0	0
Ingram	SU29D	422798	4956021	DFD BIO	357	9	5	940	0	8	3	0	0	0	0	0	0	0
Jordan	SU15B	320531	4861372	DFD BIO	334	7	31	528	0	11	0	0	0	0	0	0	0	0
Jordan	SU15C	320441	4864508	DFD BIO	254	8	29	798	0	0	0	0	0	0	0	0	0	0
LaHave	LHav008	359406	4940137	DFD BIO	2975	9	2	2654	67	1	0	0	2	27	0	0	0	0
LaHave	LHav101	356321	4943231	DFD BIO	1887	8	19	2013	69	0	0	0	3	0	11	0	0	0
LaHave	LHav105	371358	4920720	DFD BIO	2529	8	22	n/a	37	1	0	0	2	0	3	0	0	0
LaHave	LHav106	363843	4932713	DFD BIO	n/a	8	28	1996	17	3	0	0	3	0	0	0	0	0
LaHave	LHav107	366437	4919392	DFD BIO	n/a	8	28	n/a	46	2	0	0	1	0	3	0	0	0
LaHave	LHav108	372650	4940027	DFD BIO	3195	8	21	2874	33	5	0	0	0	5	0	0	0	0
LaHave	LHav114	358860	4930747	DFD BIO	637	8	22	1756	7	1	0	0	1	3	0	0	0	0
LaHave	LHav001	369489	4920500	DFD BIO	n/a	8	28	n/a	25	3	1	0	2	0	3	0	0	0
LaHave	LHav016	362400	4932490	DFD BIO	575	9	9	n/a	0	0	17	0	6	0	5	0	0	0
LaHave	LHav106	363843	4932713	DFD BIO	440	8	28	1996	17	3	0	0	3	0	0	0	0	0
Little West	SU46B	535940	4972807	DFD BIO	552	7	18	835	0	35	0	0	1	0	0	0	0	0
Little West	SU46A	534694	4972090	DFD BIO	312	7	18	405	0	13	0	1	0	0	0	0	0	0
Martin's	SU24A	393365	4927080	DFD BIO	988	8	8	1112	0	12	1	0	4	0	0	0	0	0
Martin's	SU24B	392275	4927203	DFD BIO	571	9	4	1469	0	29	0	0	1	0	0	0	0	0
Medway	Medw108	341858	4918886	DFD BIO	1227	9	10		22	6	3	0	0	0	1	0	0	23
Medway	Medw109	367838	4892343	DFD BIO	716	9	11	1387	36	22	8	0	3	0	0	0	0	7
Medway	SU20C	351993	4902512	DFD BIO	1200	8	25		3	5	6	0	0	0	0	0	0	0

		UTM							Catch									
River	Site ID	Easting	Northing	Organiz.	Area (m^2)	Mo.	Day	Shocking Time (s)	Atlantic salmon	American eel	Brook trout	Brown trout	White sucker	SMouth-bass	Chub spp.	Other Cyprinids	Stickle-back spp.	Others
Medway	Medw101	332773	4922777	DFD BIO	300	9	11		0	2	1	0	2	0	0	0	0	0
Mersey	SU19D	352217	4883899	DFD BIO	838	7	24	1081	0	4	0	0	0	0	0	0	0	0
Mersey	SU19C	355212	4882299	DFD BIO	849	7	24	780	0	35	0	0	0	0	0	0	0	0
Mersey	SU19E	347046	4887243	DFD BIO	132	7	24	344	0	0	0	0	2	0	0	0	0	0
Middle (Chester)	Midd001	398211	4936046	BCAF	926	9	10	933	8	0	10	0	2	0	0	5	0	1
Middle (Chester)	Midd002	398676	4936162	BCAF	722	9	12	533	7	0	14	0	3	0	0	6	0	0
Mosher	SU52C	556590	4980877	DFD BIO	177	8	26	500	0	10	5	0	0	0	0	0	0	0
Mosher	SU52A	556245	4982251	DFD BIO	519	8	26	1318	2	28	5	0	1	0	1	0	0	0
Mosher	SU52D	556552	4986000	DFD BIO	328	9	17	955	7	4	1	0	0	0	0	2	0	0
Mushamush	SU23A	385698	4925430	DFD BIO	986	7	18	1514	5	17	0	0	0	1	0	0	0	0
Mushamush	SU23B	378077	4929624	DFD BIO	517	7	18	915	1	4	0	0	1	0	0	0	0	0
Mushamush	SU23D	381032	4931963	DFD BIO	310	9	12	892	1	5	0	0	0	0	0	0	0	0
Mushamush	SU23C	377311	4930183	DFD BIO	250	9	12	978	0	10	0	0	0	3	0	0	0	0
Musquodoboit	SU40A	491778	4990608	DFD BIO	145	8	11	703	17	1	35	0	0	0	0	0	0	0
Musquodoboit	SU40B	497596	4994368	DFD BIO	242	8	11	705	35	0	35	0	0	0	0	0	0	0
Musquodoboit	SU40D	493631	4993652	DFD BIO	214	9	10	820	0	0	8	0	0	0	0	0	0	0
Musquodoboit	SU40C	497566	4994541	DFD BIO	269	9	10	1023	11	0	7	0	0	0	0	0	0	0
Nine Mile	SU32A	441988	4944810	DFD BIO	697	7	14	947	0	6	0	0	2	0	0	0	0	1
Petite	SU21A	383595	4899418	DFD BIO	665	7	25	1183	0	14	14	0	0	0	0	0	0	0
Petite	SU21B	378331	4907214	DFD BIO	574	7	25	978	2	0	0	0	0	0	0	0	0	1
Petite	SU21C	382175	4900622	DFD BIO	1399	7	25	797	3	22	0	0	0	0	0	0	0	0
Purney Brk	SU100	318343	4850131	DFD BIO	541	7	31	679	0	13	0	0	0	0	0	0	0	0
Quoddy	SU51B	551817	4978810	DFD BIO	264	9	16	915	0	10	2	0	0	0	1	0	0	0
Quoddy	SU51A	551808	4980531	DFD BIO	337	9	16	982	1	25	0	0	1	0	8	0	0	0
Quoddy	SU51D	550845	4977212	DFD BIO	65	9	16	377	0	9	0	0	2	0	0	0	0	0
Quoddy	SU51C	551508	4975684	DFD BIO	203	9	17	877	1	33	0	0	0	0	0	0	0	0
Rodney Brk	SU101	318306	4847940	DFD BIO	521	7	31	916	0	10	1	0	0	0	0	0	0	1
Roseway	SU112A	310499	4858650	DFD BIO	243	8	28	417	0	0	0	0	0	0	0	0	0	0
Roseway	SU112B	304917	4872963	DFD BIO	315	8	28	736	0	9	0	0	0	0	0	0	0	0
Roseway	SU112C	302865	4878314	DFD BIO	125	8	28	562	0	0	19	0	0	0	0	0	0	0
Round Hill	SU2B	309503	4956659	DFD BIO	542	7	29	1148	0	5	0	0	0	0	0	1	0	0
Sable	SU17A	333537	4856649	DFD BIO	1055	7	30	1060	0	10	1	0	0	0	0	0	0	0
Sable	SU17B	333960	4856577	DFD BIO	295	7	31		0	18	0	0	0	0	0	0	0	0
Salmon (Lake Major)	SU35A	464095	4947750	DFD BIO	511	7	4	817	0	9	1	0	0	0	0	0	0	0

		UTM							Catch									
River	Site ID	Easting	Northing	Organiz.	Area (m^2)	Mo.	Day	Shocking Time (s)	Atlantic salmon	American eel	Brook trout	Brown trout	White sucker	SMouth-bass	Chub spp.	Other Cyprinids	Stickle-back spp.	Others
Salmon (Lake Major)	SU35B	463950	4949263	DFD BIO	1912	7	10	1473	0	17	0	0	0	0	0	0	0	2
Salmon (Lake Major)	SU35C	463513	4949944	DFD BIO	2089	7	4	1364	0	24	0	0	0	0	0	0	0	0
Salmon (Halifax Co.)	SU41A	496311	4964468	DFD BIO	233	7	16	363	0	1	0	0	0	0	0	0	0	0
Salmon (Halifax Co.)	SU41B	492615	4967838	DFD BIO	265	7	16	360	0	2	0	0	0	0	0	0	0	0
Salmon (Halifax Co.)	SU41C	491486	4968638	DFD BIO	507	7	16	490	0	4	0	0	0	0	0	0	0	0
Salmon (Lawrencetown)	SU36A	469956	4948862	DFD BIO	722	7	8	957	0	27	0	0	7	0	0	0	0	6
Salmon (Lawrencetown)	SU36B	469669	4949135	DFD BIO	728	7	8	1311	0	30	0	0	1	0	0	0	0	14
Salmon (Lawrencetown)	SU36C	469465	4954326	DFD BIO	1082	7	10	1131	0	40	0	0	2	0	0	0	0	0
Salmon (Digby)	SU8C	254166	4887363	DFD BIO	213	7	31	607	0	12	0	0	0	0	0	0	0	0
Salmon (Digby)	SU8A	248621	4883096	DFD BIO	465	8	6	538	0	35	0	0	0	0	0	0	0	0
Salmon (Digby)	SU8B	252041	4882194	DFD BIO	1420	8	6	1553	12	23	0	0	0	0	0	0	0	1
Salmon (Port Dufferin)	SU50B	548235	4979707	DFD BIO	263	7	23	545	0	0	4	0	0	0	0	0	0	0
Salmon (Port Dufferin)	SU50A	547465	4977140	DFD BIO	833	7	28	1020	10	2	0	0	3	0	0	0	0	0
Ship Harbour	SU42B	504608	4967832	DFD BIO	448	7	16	1149	8	24	0	0	6	0	8	0	0	0
Smith Brk	SU53A	562330	4979886	DFD BIO	535	7	28	1016	12	12	8	0	0	0	0	0	0	0
St. Mary's	STMR854.2	577086	5013497	DFD BIO	718	9	16	1485	14	2	1	0	0	0	0	0	0	0
St. Mary's	STMR854.4	577040	5013648	DFD BIO	908	9	16	1809	49	7	1	0	0	0	0	0	0	0
St. Mary's	STMR855.1	561110	5013537	DFD BIO	626	8	26	1515	12	5	17	0	0	0	2	0	0	0
St. Mary's	STMR858.1	549950	5013416	DFD BIO	242	9	15	592	0	5	6	0	0	0	0	0	0	0
St. Mary's	STMR859.4	552876	5012910	DFD BIO	3172	9	17	4641	35	28	0	0	17	0	16	0	0	1
St. Mary's	STMR8510.8	553790	5030955	DFD BIO	914	8	26	1552	31		0	0	2	0	1	0	0	0
St. Mary's	STMR863.1	569912	5021222	DFD BIO	1145	9	26	1336	46	12	1	0	2	0	0	2	1	0
St. Mary's	STMR867.1	552930	5032085	DFD BIO	648	8	26	1414	37	2	0	0	0	0	0	0	0	2
St. Mary's	STMR923	571938	5019086	DFD BIO	1121	9	26	1294	25	12	0	0	0	0	0	0	1	1
St. Mary's	STMR924	546607	5014243	DFD BIO	4600	9	25	5096	71	26	3	0	16	0	27	2	1	1
St. Mary's	STMR925.1+2	555837	5014230	DFD BIO	574	9	15	1267	37	2	0	0	0	0	1	0	0	0
St. Mary's	STMR928	526196	5016130	DFD BIO	1247	9	15	2922	28	8	0	0	5	0	0	0		0
Tangier	SU43C	522667	4962362	DFD BIO	801	7	17	783	0	35	0	0	0	0	0	0	0	0
Tangier	SU43A	514284	4978523	DFD BIO	509	7	17	809	0	6	0	0	0	0	0	0	0	0

		UTM							Catch									
River	Site ID	Easting	Northing	Organiz.	Area (m^2)	Mo.	Day	Shocking Time (s)	Atlantic salmon	American eel	Brook trout	Brown trout	White sucker	SMouth-bass	Chub spp.	Other Cyprinids	Stickle-back spp.	Others
Tangier	SU43B	516961	4977079	DFD BIO	847	7	17	1211	0	37	0	0	2	0	0	0	0	0
Tidney	SU18A	337120	4859709	DFD BIO	902	7	30	727	0	9	0	0	0	0	0	0	0	0
Tusket	SU10A	265735	4895220	DFD BIO	670	7	30	1627	1	32	0	0	4	3	0	0	0	3
Tusket	SU10C	262640	4867840	DFD BIO	259	8	5	665	0	11	16	0	0	0	0	0	0	0
Tusket	SU10B	266239	4890674	DFD BIO	479	7	30	1243	0	2	0	0	0	0	0	0	0	0
Tusket	SU10E	266646	4888596	DFD BIO	1224	8	6	1086	0	13	0	0	1	4	0	0	0	19
Tusket	SU10D	265850	4890632	DFD BIO	457	8	6	757	0	4	3	0	0	0	0	0	0	36
Tusket	SU10F	272318	4888521	DFD BIO	855	8	7	1199	0	21	0	0	0	0	0	0	0	7
Tusket	SU10G	287151	4888210	DFD BIO	306	8	7	957	0	7	0	0	0	0	0	0	0	1
Tusket	SU10H	274190	4884688	DFD BIO	1380	8	7	1046	0	2	0	0	0	0	0	0	0	6
West Brook (Porter's Lake)	SU37A	469518	4961793	DFD BIO	539	7	9	928	0	31	0	0	0	0	0	0	0	0
West Sheet Harbour	WRSH001	515810	4992742	NSDoAF		7	30	1098	0	4	0	0	0	0	0	0	0	0
West Sheet Harbour	WRSH002	523366	4980562	NSDoAF	611	7	30	528	0	0	0	0	0	0	0	0	0	0
West Sheet Harbour	WRSH003	529134	4979288	NSDoAF	784	8	19	1568	1	6	0	0	2	0	0	0	0	1
West Sheet Harbour	WRSH004	530096	4978469	NSDoAF	910	8	19	2371	0	7	0	0	1	0	2	0	0	3
West Sheet Harbour	WRSH005	523224	4990034	NSDoAF		8	19	1115	1	1	0	0	1	0	2	0	0	0
West Sheet Harbour	WRSH006	521871	4983915	NSDoAF		8	19	1386	0	3	0	0	0	0	5	0	0	0
West Sheet Harbour	WRSH007	518005	4986360	NSDoAF	826	8	20	1012	0	3	1	0	2	0	12	0	0	0
West Taylor Bay	SU45A	531239	4965654	DFD BIO	111	7	17	438	0	4	1	0	0	0	0	0	0	0
West Taylor Bay	SU45B	529810	4965986	DFD BIO	390	7	17	738	0	9	1	0	0	0	0	0	0	0

Appendix 3. Summary of the Southern Upland electrofishing survey in 2000. Site IDs correspond with the Diadromous Fish Division (DFD) electrofishing database. Catch is the number of fish captured on the first pass of the survey. Other species include yellow perch, striped bass, banded killifish, sea lamprey and Alosa spp. Organizations were the DFO Diadromous Fish Division (DFD BIO), the Nova Scotia Department of Agriculture and Fisheries (NSDoAF) and the Bluenose Coastal Action Foundation (BCAF).

		UTM							Catch									
River	Site ID	Easting	Northing	Organiz.	Area (m^2)	Mo.	Day	Shocking Time (s)	Atlantic salmon	American eel	Brook trout	Brown Trout	White sucker	SMouth bass	Chub spp.	Other Cyprinids	Stickle-back spp.	Other species
Annis	SU9A	259678	4869480	DFD BIO	900	9	20	320	0	0	0	0	0	0	0	0	0	0
Annis	SU9B	259744	4870867	DFD BIO	900	9	20	650	0	0	0	0	0	0	0	0	0	0
Argyle	SU11A	n/a	n/a	DFD BIO	420	10	5	350	0	3	0	0	0	0	0	0	0	0
Belliveau	SU5A	256445	4918260	DFD BIO	100	9	12	382	0	0	0	0	0	0	0	0	0	0
Chezzetcook	SU39A	479941	4959980	DFD BIO	1,500	9	7	509	0	17	19	8	2	0	0	0	0	0
Clyde	SU13A	n/a	n/a	DFD BIO	750	9	22	320	0	0	0	0	0	0	0	0	0	3
Clyde	SU13B	296283	4850920	DFD BIO	600			581	0	0	0	0	0	0	0	0	0	0
Country Harbour	SU61A	586952	5013180	DFD BIO	300	9	20	457	42	31	4	0	0	0	0	0	0	0
Country Harbour	SU61B	585771	5017097	DFD BIO	200	9	20	370	17	23	1	0	1	0	0	0	0	0
East (Chester)	SU27A	407490	4938745	DFD BIO	4,125	9	14	2180	4	0	8	0	0	0	0	0	0	0
East (Chester)	SU27B	409428	4944517	DFD BIO	1,200	9	18	1619	65	0	0	0	0	0	2	0	0	0
East (Lockport)	SU16A	327515	4845781	DFD BIO	300	9	22	380	0	0	0	0	0	0	0	0	0	0
East (St Margarets)	SU31A	430946	4948417	DFD BIO	300	9	28	494	0	0	0	0	0	0	0	0	0	0
East Brk (Porter's Lake)	SU38A	470234	4962381	DFD BIO	2,550	9	7	762	0	23	3	0	4	0	0	0	0	0
East Brk (Porter's Lake)	SU38B	470465	4963168	DFD BIO	240	9	7	265	0	14	1	0	1	0	0	0	0	0
East Taylor Bay	SU44A	530138	4966196	DFD BIO	150	9	13	442	0	27	4	0	0	0	0	0	0	0
Ecum Secum	SU54A			DFD BIO					50	28	0	0	0	0	1	0	0	0
Gaspereau Brk	SU56A	578936	4986937	DFD BIO	450	9	19	178	0	56	0	0	2	0	0	0	0	0
Gaspereau Brk	SU56B	575100	4991275	DFD BIO	1,680	9	19	2724	41	136	3	0	0	0	0	0	0	0
Gegogan Brk	SU57A	578885	4992601	DFD BIO	275	9	20	299	0	36	0	0	0	0	0	0	0	6
Gold	SU25A	384757	4955032	DFD BIO		9	8	2135	74	0	9	0	0	0	0	0	0	0
Gold	SU25B	383447	4956600	DFD BIO		9	8	1345	41	0	0	0	0	0	0	0	0	0
Indian	SU30A	428156	4949125	DFD BIO	600	9	27	675	0	0	8	0	0	0	0	0	0	0
Indian Harbour Lakes	SU59A	558974	4991323	DFD BIO	245	9	20	352	0	147	4	2	0	0	0	0	0	1
Indian Harbour Lakes	SU59B	587529	4999337	DFD BIO	210	9	20	191	0	44	4	0	0	0	0	0	0	0
Indian Harbour Lakes	SU59C	588069	4998726	DFD BIO	338	9	20	200	2	0	15	2	0	0	0	0	0	0

		UTM							Catch										
River	Site ID	Easting	Northing	Organiz.	Area (m^2)	Mo.	Day	Shocking Time (s)	Atlantic salmon	American eel	Brook trout	Brown Trout	White sucker	SMouth bass	Chub spp.	Other Cyprinids	Stickle-back spp.	Other species
Ingram	SU29A	422975	4949929	DFD BIO	4,500	9	26	2292	0	0	1	0	0	0	0	0	0	0
Ingram	SU29B	423579	4948756	DFD BIO	910	9	26	674	0	0	0	0	0	0	0	0	0	0
Issac's Harbour	SU62A	605129	5011544	DFD BIO	600	9	21	479	0	2	10	0	0	0	0	0	0	0
Issac's Harbour	SU62B	604190	5006040	DFD BIO	750	9	21	508	4	300	0	0	1	0	0	0	0	1
Jordan	SU15A	319911	4856886	DFD BIO	1,500	9	7	410	0	11	0	0	0	0	0	0	0	2
Jordan	SU15B	320548	4861404	DFD BIO	300	9	7	693	0	10	0	0	0	0	0	0	0	0
Kirby	SU49A	543165	4972464	DFD BIO	105	9	13	442	16	17	0	0	1	0	0	0	0	0
Kirby	SU49B	543120	4972339	DFD BIO	90	9	13	322	14	0	0	0	2	0	0	0	0	0
Lahave	LHav002	366869	4930705	DFD BIO	1806	8	25		2	0	0	0	0	47	0	0	0	0
Lahave	LHav008	359406	4940137	DFD BIO	1456	7	21	2843	123	0	0	0	8	0	3	0	0	5
Lahave	LHav013	n/a	n/a	DFD BIO	n/a	8	29	2115	16	4	71	0	45	0	55	9	0	0
Lahave	LHav031	n/a	n/a	DFD BIO	n/a	8	4	480	0	0	11	0	0	0	0	0	0	0
Lahave	LHav101	356321	4943231	DFD BIO	1061	7	13	2603	60	0	0	0	0	0	8	0	0	0
Lahave	LHav102	n/a	n/a	DFD BIO	753	8	25	520	3	0	7	0	2	0	0	0	0	2
Lahave	LHav103	n/a	n/a	DFD BIO	1081	8	4	1334	79	0	1	0	21	0	10	0	0	0
Lahave	LHav104	366639	4931248	DFD BIO	1728	8	29	1374	22	36	0	0	0	102	0	0	0	2
Lahave	LHav105	371358	4920720	DFD BIO	774	7	19	2566	69	2	2	0	0	2	7	0	0	0
Lahave	LHav106	363843	4932713	DFD BIO	752	7	26	1385	106	0	1	0	1	0	3	0	0	2
Lahave	LHav107	366437	4919392	DFD BIO	768	8	21	654	76	0	0	0	1	0	3	0	0	0
Lahave	LHav108	372650	4940027	DFD BIO	1051	7	14	2740	97	1	0	8	0	0	0	0	0	0
Lahave	LHav109	373431	4941739	DFD BIO	1018	8	23	1457	79	14	0	0	0	0	11	0	0	0
Lahave	LHav110	n/a	n/a	DFD BIO	1051	8	22	1266	30	47	0	0	0	16	0	0	0	0
Lahave	LHav111	370359	4933069	DFD BIO	605	8	21	778	6	0	0	0	3	8	0	0	0	0
Lahave	LHav112	359758	4940617	DFD BIO	607	7	26	1741	73	0	0	0	5	0	6	0	0	5
Lahave	LHav113	360310	4933221	DFD BIO	1290	8	25	2078	117	0	1	0	3	0	2	0	0	3
Lahave	LHav114	358860	4930747	DFD BIO	900	7	21	1415	90	0	0	0	10	0	1	0	0	1
Liscombe	SU55A	n/a	n/a	DFD BIO	1,400				50	12	1	0	5	0	3	0	3	0
Little West	SU46A	534624	4972076	DFD BIO	2,100	9	13	522	0	39	1	0	0	0	0	0	0	0
Little West	SU46B	535951	4972813	DFD BIO	910	9	13	405	0	59	0	0	0	0	0	0	0	0
Martin's	SU24A	392951	4927524	DFD BIO	n/a	8	31	343	0	0	0	0	0	0	0	0	0	0
Martin's	SU24B	392289	4927380	DFD BIO	900	8	31	492	0	0	0	0	0	0	0	0	0	0
Medway	SU20A	341672	4919524	DFD BIO	n/a	9	5	2097	74	0	5	0	0	0	0	0	0	0
Medway	SU20B	343918	4910857	DFD BIO	n/a	9	6	1608	19	0	0	0	0	0	0	0	0	0
Medway	SU20C	351993	4902512	DFD BIO	n/a	9	6	671	16	0	21	0	0	0	0	0	0	0

		UTM							Catch									
River	Site ID	Easting	Northing	Organiz.	Area (m^2)	Mo.	Day	Shocking Time (s)	Atlantic salmon	American eel	Brook trout	Brown Trout	White sucker	SMouth bass	Chub spp.	Other Cyprinids	Stickle-back spp.	Other species
Mersey	SU19A	351349	4884623	DFD BIO	675	9	27	770	0	0	0	4	0	0	0	0	0	0
Mersey	SU19B	356688	4882683	DFD BIO	120	9	27	340	0	0	0	0	0	0	0	0	0	0
Mersey	SU19C	355231	4882314	DFD BIO	700	9	7	526	0	0	0	0	0	0	0	0	0	2
Middle	SU26A	398230	4936017	DFD BIO	3,000	9	14	2256	74	0	8	0	0	0	0	0	0	0
Middle	SU26B	397579	4938060	DFD BIO	1,800	9	14	2165	13	0	13	0	0	0	0	0	0	0
Mosher	SU52A	556233	4982256	DFD BIO	630	9	15	1006	60	36	0	0	1	0	0	0	0	0
Mosher	SU52B	556285	4985530	DFD BIO	1,750	9	15	590	17	32	0	0	1	0	0	0	0	40
Mushamush	SU23A	385626	4925671	DFD BIO	900	8	31	1964	163	0	0	0	0	0	0	0	0	1
Mushamush	SU23B	377794	4929736	DFD BIO	n/a	8	31	2192	191	0	0	0	0	0	0	0	0	0
Musquodoboit	SU40A	491834	4990569	DFD BIO	106	9	7	651	45	0	43	0	2	0	0	0	1	0
Musquodoboit	SU40B	497514	4994320	DFD BIO	105	9	8	560	14	0	21	0	0	0	0	0	0	0
New Harbour	SU63A	606411	5015844	DFD BIO	350	9	21	420	0	21	2	0	1	0	0	0	0	0
New Harbour	SU63B	609935	5014855	DFD BIO	495	9	21	452	0	21	6	0	0	0	0	0	0	0
New Harbour	SU63C	615608	5009214	DFD BIO	600	9	21	395	1	23	2	0	0	0	0	0	0	0
Nine Mile	SU32A	441921	4944765	DFD BIO	2,160	9	28	1266	0	0	0	0	0	0	0	0	0	2
Petite	SU21A	383425	4899966	DFD BIO	2,500	9	1	537	4	0	0	0	0	0	0	0	0	0
Petite	SU21B	377846	4907845	DFD BIO	n/a	9	1	625	227	0	1	0	0	0	0	0	0	0
Petite	SU21C	381953	4900703	DFD BIO	2,000	9	13	1299	35	0	0	0	0	0	0	0	0	0
Petite	SU21D	381594	4901577	DFD BIO	1,800	9	13	875	11	0	0	0	0	0	0	0	0	0
Petite	SU21E	381613	4901787	DFD BIO	2,500	9	13	1393	20	0	0	0	0	0	0	0	0	0
Quoddy	SU51A	551780	4980480	DFD BIO	1,725	9	14	939	9	0	2	0	8	0	4	0	0	1
Quoddy	SU51B	551818	4978808	DFD BIO	n/a	9	14	1168	11	211	10	0	2	0	4	0	0	2
Quoddy	SU51C	551510	4975720	DFD BIO	320	9	14	366	1	46	2	0	2	0	2	0	0	0
Round Hill	SU2A	363125	4932829	DFD BIO	2,500	9	11	1215	28	0	2	0	0	0	0	0	0	0
Round Hill	SU2B	309183	4957206	DFD BIO	4,000	9	11	2820	39	0	8	0	0	0	0	0	0	0
Sable	SU17A	333288	4857493	DFD BIO	2,250	9	7	373	0	5	0	0	0	0	0	0	0	0
Salmon (Digby)	SU8A	252045	4882174	DFD BIO	750	9	19	2800	65	0	0	0	0	0	0	0	0	0
Salmon (Digby)	SU8B	248584	4883140	DFD BIO	1,050	9	19	350	0	0	1	0	0	0	0	0	0	1
Salmon (Halifax)	SU41A	496319	4964487	DFD BIO	360	9	11	303	0	0	0	0	0	0	0	0	0	0
Salmon (Halifax)	SU41B	492615	4967838	DFD BIO	320	9	11	304	0	2	4	0	0	0	0	0	0	3
Salmon (Halifax)	SU41C	491579	4968797	DFD BIO	1,365	9	11	708	0	12	3	0	0	0	0	0	0	0
Salmon (Lake Major)	SU35A	464089	4947787	DFD BIO	900	9	6	600	0	25	6	0	4	0	0	0	0	2
Salmon (Lake Major)	SU35B	464285	4948899	DFD BIO	80	9	6	70	0	0	0	0	0	0	0	0	0	0

River	Site ID	UTM Easting	UTM Northing	Organiz.	Area (m^2)	Mo.	Day	Shocking Time (s)	Catch: Atlantic salmon	American eel	Brook trout	Brown Trout	White sucker	SMouth bass	Chub spp.	Other Cyprinids	Stickle-back spp.	Other species
Salmon (Lake Major)	SU35C	463504	4949986	DFD BIO	455	9	6	389	0	53	0	0	10	0	0	0	0	4
Salmon (Lawrencetown)	SU36A	470064	4948869	DFD BIO	1,800	9	6	431	0	90	0	0	0	0	0	0	0	26
Salmon (Lawrencetown)	SU36B	469587	4949205	DFD BIO	4,100	9	6	1150	2	115	0	0	2	0	0	0	0	9
Salmon (Lawrencetown)	SU36C	469158	4955033	DFD BIO	480	9	7	340	0	11	3	0	0	0	0	0	0	0
Salmon (Port Dufferin)	SU50A	547463	4977058	DFD BIO	2,320	9	14	1505	20	17	1	0	4	0	2	0	0	0
Salmon (Port Dufferin)	SU50B	548523	4979891	DFD BIO	225	9	14	388	0	0	15	0	0	0	2	0	0	0
Ship Harbour	SU42A	501468	4974180	DFD BIO	960	9	11	460	0	17	0	0	3	0	0	0	0	0
Ship Harbour	SU42B	504637	4967824	DFD BIO	1,365	9	12	1690	53	51	5	0	0	0	0	0	0	1
Sissibo	SU4A	264248	4922044	DFD BIO	1,500	9	12	393	0	0	0	0	0	0	0	0	0	0
Smith Brk	SU53A	562351	4979865	DFD BIO	1,120	9	19	1219	60	16	12	0	0	0	0	0	0	0
St. Mary's River	STMR8510.2	554478	5030442	DFD BIO	1,109	8	9		12	17	0	0	2	0	0	3	0	0
St. Mary's River	STMR8510.8	553790	5030955	DFD BIO	681	8	9		252	13	0	0	11	0	3	14	0	0
St. Mary's River	STMR853.1	n/a	n/a	DFD BIO	298	8	15		10	6	4	4	1	0	2	0	0	0
St. Mary's River	STMR853.2	570795	5013550	DFD BIO	678	8	15		14	3	12	12	3	0	1	0	0	0
St. Mary's River	STMR854.2	577086	5013497	DFD BIO	783	8	1		31	15	0	0	2	0	0	0	0	236
St. Mary's River	STMR854.4	577040	5013648	DFD BIO	673	8	1		29	17	1	1	0	0	0	0	0	0
St. Mary's River	STMR855.1	561110	5013537	DFD BIO	485	7	11		41	4	16	16	8	0	7	0	0	0
St. Mary's River	STMR858.1	549950	5013416	DFD BIO	380	7	11		0	6	33	33	0	0	0	0	0	0
St. Mary's River	STMR859.4	552876	5012910	DFD BIO	3,104	8	15		27	15	0	0	26	0	15	7	0	4
St. Mary's River	STMR867.1	552930	5032085	DFD BIO	865	8	8		164	11	0	0	2	0	0	1	0	1
St. Mary's River	STMR867.2	552850	5032138	DFD BIO	808	8	8		45	22	1	1	8	0	3	1	0	0
St. Mary's River	STMR924	546607	5014243	DFD BIO	4,389	8	25		91	25	1	1	19	0	8	10	0	0
St. Mary's River	STMR925.1+2	n/a	n/a	DFD BIO	521	8	1		71	9	1	0	5	0	9	1	0	2
St. Mary's River	STMR928	526196	5016130	DFD BIO	1,363	8	11		54	27	2	2	39	0	20	2	0	0
Tangier	SU43A	514331	4978572	DFD BIO	805	9	12	708	0	17	0	0	0	0	0	0	0	2
Tangier	SU43B	517069	4977081	DFD BIO	1,190	9	12	345	0	22	0	0	0	0	0	0	0	3
Tangier	SU43C	n/a	n/a	DFD BIO		9	12	250	0	125	0	0	0	0	0	0	0	0
Tidney	SU18A	336728	4860030	DFD BIO	1,725	9	7	472	0	6	0	0	0	0	0	0	0	0
Tusket	SU10A	265831	4895172	DFD BIO	2,200	9	19	1820	25	0	0	0	0	0	0	0	0	30
Tusket	SU10B	266254	4890619	DFD BIO	3,000	9	19	1727	33	0	1	0	0	0	0	0	0	0
West Brk (Porter's Lake)	SU37A	469564	4961764	DFD BIO	1,350	9	7	830	0	17	19	0	2	0	0	0	0	0

		UTM							Catch									
River	Site ID	Easting	Northing	Organiz.	Area (m^2)	Mo.	Day	Shocking Time (s)	Atlantic salmon	American eel	Brook trout	Brown Trout	White sucker	SMouth bass	Chub spp.	Other Cyprinids	Stickle-back spp.	Other species
West River Sheet Harbour	SU47A	n/a	n/a	DFD BIO	n/a				59	5	0	0	4	0	1	0	0	13
West River Sheet Harbour	SU47B	n/a	n/a	DFD BIO	n/a				1	3	1	0	9	0	16	0	0	0
West River Sheet Harbour	SU47C	n/a	n/a	DFD BIO	n/a				34	4	0	0	2	0	1	0	0	0
West Taylor Bay	SU45A	529632	4966094	DFD BIO	1,200	9	13	429	0	26	1	0	0	0	0	0	0	0

Appendix 4. Recreational catch and effort data from the license-stub return program in SFAs 20 and 21 for 2007.

River name	Year	Status	Number of anglers	One-sea-winter Retained	One-sea-winter Released	One-sea-winter Total	Two-sea-winter Retained	Two-sea-winter Released	Two-sea-winter Total	Total catch	Effort (rod-days)	Confidence Interval 5%	Confidence Interval 95%	CPUE
Salmon Fishing Area 20														
BARRINGTON	2007	River Closed												
CHEZZETCOOK	2007	River Closed												
CLAM HARBOUR	2007	River Closed												
COLE HARBOUR	2007	River Closed												
COUNTRY HARBOUR	2007	River Closed												
EAST: SHEET HARBOUR	2007		1	0	0	0	0	1	1	1	7	7	8	0.20
ECUM SECUM	2007	River Closed												
GASPEREAUX BROOK	2007	River Closed												
GEGOGAN	2007	River Closed												
GUYSBOROUGH	2007	River Closed												
HALFWAY BROOK	2007	River Closed												
ISAAC'S HARBOUR	2007	River Closed												
KIRBY	2007	River Closed												
LARRY'S	2007	River Closed												
LAWRENCETOWN LAKE (SALMON RIVER)	2007	River Closed												
LISCOMB	2007	River Closed												
LITTLE SALMON (LAKE MAJOR)	2007	River Closed												
MOSER	2007	River Closed												
MUSQUODOBOIT	2007		18	0	27	27	0	8	8	35	126	121	131	0.32
NECUM TEUCH (SMITH BROOK)	2007	River Closed												
NEW HARBOUR	2007	River Closed												
PORT DUFFERIN	2007	River Closed												
PORTERS LAKE (EAST BROOK)	2007	River Closed												
QUODDY	2007	River Closed												
ROCKY RUN PORTERS L.	2007	River Closed												
SAINT FRANCIS	2007		1	0	6	6	0	1	1	7	3	3	3	2.50
SAINT MARY'S	2007		69	3	205	208	0	89	89	297	597	573	621	0.49
SALMON: GUYSBOROUGH CO.	2007		7	2	10	11	0	3	3	14	55	53	58	0.24
SALMON: HALIFAX CO.	2007	River Closed												
SHIP HBR. L. CHARLOTTE	2007	River Closed												
TANGIER	2007	River Closed												
TAYLOR BAY BROOK	2007	River Closed												
THREE FATHOM HARBOUR BROOK	2007	River Closed												
WEST: SHEET HARBOUR	2007	River Closed												
Salmon Fishing Area 21														
BARRINGTON	2007	River Closed												
BROAD	2007	River Closed												
CLYDE	2007		1	0	0	0	0	0	0	0	1	1	2	0.00
EAST: LUNENBURG CO.	2007	River Closed												
GOLD	2007	River Closed												
INGRAM	2007	River Closed												
JORDAN	2007		0	0	0	0	0	0	0	0	0	0	0	0.00
LAHAVE	2007		46	0	94	94	0	23	23	117	497	477	517	0.23
MARTINS	2007	River Closed												
MEDWAY	2007	River Closed												
MERSEY	2007		0	0	0	0	0	0	0	0	0	0	0	0.00
METEGHAN	2007	River Closed												
MIDDLE: LUNENBURG CO.	2007		1	0	3	3	0	0	0	3	3	3	3	1.00
MUSHAMUSH	2007		0	0	0	0	0	0	0	0	0	0	0	0.00
NINE MILE	2007	River Closed												
PETITE RIVIERE	2007		2	0	10	10	0	3	3	13	33	32	34	0.41
ROSEWAY	2007	River Closed												
SACKVILLE	2007		7	0	1	1	0	0	0	1	49	47	51	0.03
SALMON: DIGBY CO.	2007	River Closed												
SISSIBOO	2007	River Closed												
TUSKET	2007		0	0	0	0	0	0	0	0	0	0	0	0.00

Appendix 5. Reported recreational catch and effort in SFA 20 from 1983 to 2007. Missing values indicate a river has been closed to recreational angling.

		Year																								
River	Variable	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
BARRINGTON	Catch Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Catch Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Retained Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
CHEZZETCOOK	Catch Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Catch Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Retained Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
CLAM HARBOUR	Catch Small	1	0	0	0	0	0	0	2	0	0	0	0	0	0	0		0	0							
	Catch Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0							
	Retained Small	2	0	1	0	0	1	0	2	2	1	0	0	0	0	0		0	0							
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0							
	Effort (rod days)	4	0	1	0	0	1	0	20	5	2	0	0	0	0	0		0	0							
COLE HARBOUR	Catch Small	0	0	0	0	0	0	0	7	9	0	0	0	0	0	0										
	Catch Large	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0										
	Retained Small	0	1	0	0	0	0	0	2	1	1	0	0	0	1	0										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	0	11	0	0	0	0	0	6	34	23	0	0	0	1	0										
COUNTRY HARBOUR	Catch Small	25	34	32	43	46	22	23	38	34	4	15	1	24	3	0		0							0	
	Catch Large	11	5	7	15	7	13	7	5	11	1	2	0	4	5	0		0							0	
	Retained Small	21	24	24	20	33	19	21	17	20	9	16	1	13	1	0		0							1	
	Retained Large	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0							0	
	Effort (rod days)	187	187	200	259	197	198	116	156	150	66	76	7	159	12	0		0							2	
EAST: SHEET HARBOUR	Catch Small	0		110	2	91	148	66	26	14	24	37	0	1	31	3	0	4	0	0	0	0	0	0	0	0
	Catch Large	0		16	2	19	17	12	0	1	6	5	0	0	0	3	0	0	0	0	0	1	0	0	0	1
	Retained Small	2		38	15	38	53	57	34	17	32	47	4	2	23	7	3	1	0	1	3	1	1	0	1	1
	Retained Large	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	2		466	63	278	686	437	176	83	205	319	34	13	231	158	7	6	0	3	5	3	5	0	8	7
ECUM SECUM	Catch Small	88	108	103	74	91	101	69	89	16	56	41	12	17	25	3		2				1				
	Catch Large	6	10	13	9	21	10	14	5	1	9	5	1	2	5	0		0				0				
	Retained Small	78	69	56	61	59	66	53	53	27	40	42	18	22	11	4		1				1				
	Retained Large	3	6	0	0	0	0	0	0	0	0	0	0	0	0	0		0				0				
	Effort (rod days)	664	819	914	846	661	603	420	828	359	459	465	151	284	94	167		2				9				
GASPEREAUX BROOK	Catch Small	11	3	4	1	6	2	11	2	0	1	0	0	0	0	0										
	Catch Large	2	0	1	0	1	0	0	0	0	0	0	0	0	0	0										
	Retained Small	11	9	5	6	6	4	7	7	1	3	2	1	1	0	1										
	Retained Large	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	106	31	18	20	40	21	47	48	2	28	13	7	2	0	1										

River	Variable	Year																								
		1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
GEGOGAN	Catch Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0								
	Catch Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0								
	Retained Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0								
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0								
	Effort (rod days)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0								
GUYSBOROUGH	Catch Small	1	2	1	1	0	5	3	2	1	0	3	0	1	0	0								1		
	Catch Large	2	0	0	0	0	3	0	5	3	0	3	2	2	0	0								0		
	Retained Small	15	8	2	4	8	7	2	3	2	1	4	2	2	0	0								1		
	Retained Large	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0								0		
	Effort (rod days)	110	43	11	32	35	40	8	19	11	2	17	5	12	0	0								1		
HALFWAY BROOK	Catch Small	3	0	0	0	0	2	0	0	1	0	0	0	1	0	0										
	Catch Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Retained Small	5	2	0	0	0	2	2	0	2	1	0	1	1	0	0										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	48	14	0	0	0	7	9	0	5	2	0	11	11	0	0										
ISAAC'S HARBOUR	Catch Small	15	10	20	33	32	25	18	30	3	7	6	0	4	0	0										
	Catch Large	12	1	5	1	0	5	0	1	0	0	0	0	0	0	0										
	Retained Small	21	10	16	12	11	14	14	10	5	5	5	2	5	2	0										
	Retained Large	12	1	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	194	93	141	137	116	145	94	123	58	60	36	14	21	10	0										
KIRBY	Catch Small	17	12	28	18	0	6	9	4	1	3	2	1	0	0	0										
	Catch Large	0	0	4	4	0	0	7	0	0	0	0	0	0	0	0										
	Retained Small	7	5	18	10	3	3	6	5	1	4	3	1	0	0	1										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	95	53	105	112	25	13	39	23	25	26	28	1	0	0	1										
LARRY'S	Catch Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Catch Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Retained Small	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	0	0	0	5	0	0	0	5	0	1	0	0	0	0	0										
LAWRENCE-TOWN LAKE (SALMON RIVER)	Catch Small	0	0	0	0	0	0	2	7	5	0	0	1	0	1	0										
	Catch Large	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0										
	Retained Small	2	0	0	0	1	0	2	5	7	1	1	2	1	1	0										
	Retained Large	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	8	0	0	0	1	0	11	34	42	5	2	8	3	5	0										
LISCOMB	Catch Small	71	65	81	235	289	115	52	154	54	17	14	18	23	1	3	0	0	0	0	0					
	Catch Large	10	1	8	28	27	19	7	5	4	0	0	1	1	0	0	0	0	0	0	0					
	Retained Small	121	66	72	178	191	157	119	100	80	98	77	37	33	14	5	1	0	0	1	1					
	Retained Large	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
	Effort (rod days)	859	522	318	899	1103	780	653	643	441	549	349	275	212	49	20	1	0	0	3	1					
LITTLE SALMON (LAKE MAJOR)	Catch Small	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0										
	Catch Large	0	0	0	0	0	0	10	0	0	0	1	0	0	7	0										
	Retained Small	1	0	1	0	0	0	1	1	0	0	1	0	0	1	0										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	1	0	4	0	0	0	31	6	0	0	5	0	0	59	0										

		Year																								
River	Variable	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
MOSER	Catch Small	195	256	254	184	183	225	152	221	110	71	120	36	58	32	1						0	2		0	
	Catch Large	48	17	29	53	12	20	5	18	10	4	10	0	0	0	0						0	0		0	
	Retained Small	192	150	151	145	113	147	111	115	69	81	93	36	46	17	4						1	1		1	
	Retained Large	42	4	0	0	0	0	0	0	0	0	0	0	0	0	0						0	0		0	
	Effort (rod days)	1651	1309	1750	1258	765	1161	1005	1087	544	959	1107	379	459	75	12						1	2		5	
MUSQUODOBOIT	Catch Small	97	153	400	535	298	313	242	281	110	54	175	60	107	194	20	14	19	1	0	14	25	15	1	27	27
	Catch Large	111	58	388	372	188	226	131	113	120	20	105	41	94	107	16	10	10	1	3	3	0	2	4	3	8
	Retained Small	330	197	340	545	394	470	353	365	250	113	359	124	183	76	27	5	8	3	6	7	6	7	6	14	18
	Retained Large	106	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	2925	1530	3217	5201	2793	3564	2641	3010	1841	617	3057	806	1588	558	168	49	47	4	20	104	62	38	25	115	126
NECUM TEUCH (SMITH BROOK)	Catch Small	4	3	1	3	2	0	0	0	0	0	0	0	0	0	0										
	Catch Large	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0										
	Retained Small	2	5	2	3	1	1	0	0	0	0	0	0	0	0	0										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	5	14	5	12	8	1	0	0	0	0	0	0	0	0	0										
NEW HARBOUR	Catch Small	18	22	41	25	18	12	25	90	19	26	13	17	21	1	0						4				
	Catch Large	1	2	3	5	0	0	1	2	1	1	0	0	0	0	0						0				
	Retained Small	37	40	31	29	23	15	24	45	28	34	21	21	18	3	3						1				
	Retained Large	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0						0				
	Effort (rod days)	360	347	286	328	220	201	271	552	288	392	226	123	120	20	11						3				
PORT DUFFERIN	Catch Small	42	37	79	20	41	31	4	26	4	2	19	5	9	1	0										
	Catch Large	4	2	8	0	7	1	0	0	0	0	1	0	0	0	0										
	Retained Small	37	30	42	24	21	27	6	20	14	10	18	12	5	2	0										
	Retained Large	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	294	275	354	200	173	211	72	168	102	101	195	111	38	7	0										
PORTERS LAKE (EAST BROOK)	Catch Small							1	0	0	0	0	0	0	0	0										
	Catch Large							0	0	0	0	0	0	0	0	0										
	Retained Small							1	0	0	0	0	0	0	0	0										
	Retained Large							0	0	0	0	0	0	0	0	0										
	Effort (rod days)							3	0	0	0	0	0	0	0	0										
QUODDY	Catch Small	4	5	8	0	0	8	0	1	0	0	0	0	0	0	0										
	Catch Large	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0										
	Retained Small	10	5	7	6	5	4	3	4	3	1	2	0	0	0	0										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	53	33	30	23	19	28	9	23	15	8	15	0	0	0	0										
ROCKY RUN PORTER'S L.	Catch Small	0	0	2	0	0	0	1	0	0	0	0	0	0	0	0										
	Catch Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Retained Small	2	0	1	0	0	0	1	1	0	0	0	0	0	0	0										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	13	0	9	0	0	0	26	2	0	0	0	0	0	0	0										
SAINT FRANCIS	Catch Small	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0										6
	Catch Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										1
	Retained Small	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0										1
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										0
	Effort (rod days)	4	0	0	0	0	0	4	0	0	0	1	0	0	0	0										3

River	Variable	Year																								
		1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
SAINT MARY'S	Catch Small	746	919	1453	1416	612	1197	517	1794	816	281	905	33	439	553	98	18	4		95	38		39	13	219	208
	Catch Large	239	231	856	945	321	578	365	238	221	134	395	23	106	164	35	2	1		75	13		21	0	69	89
	Retained Small	1067	726	846	999	693	908	782	789	650	603	840	274	473	168	76	4	7		43	33		13	32	57	69
	Retained Large	178	66	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0		0	0	0	0
	Effort (rod days)	8703	5571	6896	7714	4241	6810	5334	5706	4725	3763	6197	1268	3072	976	425	40	19		244	194		105	119	476	597
SALMON: GUYSBOROUGH CO.	Catch Small	44	271	176	71	173	197	231	247	178	278	215	164	195	147	148		0		18	14	1	19	43	10	11
	Catch Large	19	40	346	152	52	101	166	197	123	174	105	49	134	65	53		1		10	5	0	12	14	8	3
	Retained Small	98	132	125	109	106	131	177	157	127	157	137	103	129	34	30		8		8	8	1	4	9	5	7
	Retained Large	16	20	0	0	0	0	0	0	0	0	0	0	0	0	0		0		0	0	0	0	0	0	0
	Effort (rod days)	1164	1569	1129	1131	1015	1236	1468	1560	1555	1663	1454	761	1404	257	297		15		43	54	3	25	87	43	55
SALMON: HALIFAX CO.	Catch Small	25	8	6	8	4	7	13	19	2	0	3	0	1	0	0										
	Catch Large	3	2	2	1	0	2	4	2	0	0	0	0	0	0	0										
	Retained Small	25	10	16	13	5	8	19	11	5	6	4	0	4	0	1										
	Retained Large	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	257	100	129	85	50	73	110	109	26	11	32	0	10	0	1										
SHIP HARBOUR LAKE CHARLOTTE	Catch Small	36	56	54	28	23	43	39	21	4	0	24	1	15	1	0		0								
	Catch Large	7	12	4	4	4	6	3	2	0	1	4	0	4	0	0		0								
	Retained Small	26	33	32	43	29	38	36	22	16	14	27	12	17	1	1		0								
	Retained Large	7	2	0	0	0	0	0	0	0	0	0	0	0	0	0		0								
	Effort (rod days)	394	531	398	432	244	424	383	255	227	204	419	192	207	1	4		0								
TANGIER	Catch Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Catch Large	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0										
	Retained Small	1	1	0	5	2	5	5	4	3	1	2	1	1	0	0										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	4	3	0	17	2	13	11	13	15	2	2	2	2	0	0										
TAYLOR BAY BROOK	Catch Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Catch Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Retained Small	1	0	0	0	0	0	0	0	1	1	1	0	0	0	0										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	4	0	0	0	0	0	0	0	3	3	9	0	0	0	0										
THREE FATHOM HARBOUR BROOK	Catch Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Catch Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Retained Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
WEST: SHEET HARBOUR	Catch Small	107	189	150	139	170	79	247	138	63	52	75	0	4	18	1	1									
	Catch Large	17	31	24	30	25	18	21	8	6	3	7	0	0	1	0	0									
	Retained Small	134	119	102	101	94	79	107	74	52	79	80	3	2	4	2	1									
	Retained Large	16	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0									
	Effort (rod days)	1426	1377	1197	1412	1242	813	1726	962	742	926	1195	14	4	62	11	1									

Appendix 6. Reported recreational catch and effort in SFA 21 from 1983 to 2007. Missing values indicate rivers that are closed to fishing.

		Year																								
River	Variable	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
BARRINGTON	Catch Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Catch Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Retained Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
BROAD	Catch Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Catch Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Retained Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
CLYDE	Catch Small	0	11	33	4	121	116	11	26	13	101	56	22	29	43	17	3	8	35	0	0	0	0	0	0	0
	Catch Large	0	0	3	0	3	38	9	0	0	13	9	5	5	13	2	1	4	5	1	0	0	0	0	0	0
	Retained Small	0	11	24	4	87	96	10	25	13	93	53	11	28	35	17	3	7	30	0	0	0	0	0	0	0
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	1	83	126	66	509	711	359	414	305	640	654	542	463	674	257	327	213	215	181	4	0	0	3	0	1
EAST: LUNENBURG CO.	Catch Small	0	3	1	2	1	1	0	1	0	0	0	0	0	1	0										
	Catch Large	0	0	0	0	0	0	1	0	0	0	0	0	0	2	1										
	Retained Small	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	30	33	10	12	4	8	5	7	0	7	9	1	3	40	4										
GOLD	Catch Small	59	280	423	314	305	185	422	340	46	179	261	28	148	174	119						13		0		
	Catch Large	33	93	175	171	83	25	99	79	21	27	29	9	26	66	25						1		0		
	Retained Small	47	245	382	294	284	165	379	277	43	171	223	23	126	156	101						0		0		
	Retained Large	30	30	0	0	0	0	0	0	0	0	0	0	0	0	0						0		0		
	Effort (rod days)	2033	1934	2442	2524	2100	1747	2557	2690	935	1685	2802	886	1388	1197	769						23		1		
INGRAM	Catch Small	1	1	7	4	4	4	9	3	3	7	14	5	6	7	0										
	Catch Large	0	0	1	0	2	0	0	0	0	0	6	4	12	0	0										
	Retained Small	1	1	7	0	0	4	5	2	2	6	6	3	3	5	0										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	53	48	63	51	33	32	45	44	58	65	125	84	203	98	40										
JORDAN	Catch Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Catch Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	11	0	0	0	0	0	0	0	6	2	5	0	1	1	3	3	0	0	0	0	0	0	0	0	0
LAHAVE	Catch Small	300	1507	1871	2118	2948	1374	2255	2071	232	992	1118	123	513	1407	427		59	0	88	201	154	121	165	211	94
	Catch Large	221	295	994	952	465	258	529	505	119	160	241	91	194	304	185		40	0	61	43	113	34	61	65	23
	Retained Small	271	1362	1686	1847	2567	1263	1932	1747	195	902	917	105	450	1011	385		3	0	0	0	0	0	0	0	0
	Retained Large	209	125	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0
	Effort (rod days)	11056	10403	10110	13026	12456	9800	11127	12272	3747	7746	10289	3926	5377	7880	4081		448	0	288	389	573	325	599	476	497

River	Variable	Year																								
		1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
MARTINS	Catch Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0								
	Catch Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0								
	Retained Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0								
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0								
	Effort (rod days)	4	0	0	3	13	0	0	3	0	0	0	0	0	0	0		2								
MEDWAY	Catch Small	145	395	475	635	870	515	480	536	42	452	265	56	91	455	101		0						1	0	
	Catch Large	72	104	299	311	138	162	163	125	40	46	64	31	26	82	55		0						0	0	
	Retained Small	140	375	454	604	826	474	454	513	40	418	236	52	86	415	90		0						0	0	
	Retained Large	69	61	0	0	0	0	0	0	0	0	0	0	0	0	0		0						0	0	
	Effort (rod days)	5905	4207	4140	4606	5017	4710	4428	4776	2267	4127	4414	2369	1810	3218	1690		6						1	3	
MERSEY	Catch Small	5	9	5	47	77	102	98	134	61	41	15	4	0	5	3	5	5	11	1	17	4	17	4	0	0
	Catch Large	0	1	1	12	6	23	45	8	17	1	2	5	1	0	3	0	2	0	3	1	0	5	4	0	0
	Retained Small	5	9	5	46	65	88	95	124	55	39	15	4	0	5	3	5	5	11	0	10	4	17	1	0	0
	Retained Large	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	201	254	159	661	1207	1511	1668	1931	1936	1422	1378	975	358	396	148	486	60	135	141	189	75	444	62	0	0
METEGHAN	Catch Small											1	3	9	12	0										
	Catch Large											1	1	5	5	0										
	Retained Small											1	0	2	2	0										
	Retained Large											0	0	0	0	0										
	Effort (rod days)											2	27	75	92	0										
MIDDLE: LUNENBURG CO.	Catch Small	0	10	12	5	3	4	6	3	1	0	2	4	10	13	1									0	3
	Catch Large	0	0	0	1	0	0	1	0	0	0	1	1	0	0	0									0	0
	Retained Small	0	4	10	2	1	0	3	1	1	0	0	1	6	10	1									0	0
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0									0	0
	Effort (rod days)	46	28	43	21	61	7	16	19	5	2	17	3	35	39	9									3	3
MUSHAMUSH	Catch Small	0	3	56	56	63	20	25	33	9	18	16	0	13	18	4		0		0	0	1	0	1	3	0
	Catch Large	0	0	8	11	10	2	6	7	0	3	5	0	1	2	0		0		0	0	0	0	0	0	0
	Retained Small	0	3	49	54	58	20	24	32	9	16	12	0	11	16	4		0		0	0	0	0	0	0	0
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0		0	0	0	0	0	0	0
	Effort (rod days)	2	33	190	380	317	279	252	289	32	76	138	18	67	171	47		0		0	0	1	0	5	6	0
NINE MILE	Catch Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Catch Large	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0										
	Retained Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	25	0	2	8	5	4	4	0	0	0	0	0	0	0	0										
PETITE RIVIERE	Catch Small	43	110	123	90	94	104	157	144	30	178	80	11	26	117	43		4								10
	Catch Large	2	13	46	36	14	22	16	21	5	10	20	10	9	15	15		5								3
	Retained Small	34	103	121	72	85	95	135	136	29	163	73	8	26	91	40		4								0
	Retained Large	2	8	0	0	0	0	0	0	0	0	0	0	0	0	0		0								0
	Effort (rod days)	1125	829	786	863	756	847	915	831	469	1030	1125	433	513	570	389		56								33
ROSEWAY	Catch Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Catch Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Retained Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										

River	Variable	Year																								
		1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
SACKVILLE	Catch Small					2	11	44	40	23	56	12	0	21	131	16	2	0		0	1	7	0	3	7	1
	Catch Large					0	2	8	12	11	11	8	0	2	13	0	0	0		4	0	1	0	0	0	0
	Retained Small					2	9	30	30	16	21	11	0	18	47	12	0	0		0	0	0	0	0	0	0
	Retained Large					0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0
	Effort (rod days)					6	41	135	257	342	398	425	80	403	824	230	15	2		15	34	54	31	30	28	49
SALMON: DIGBY CO.	Catch Small	15	24	46	90	79	82	67	49	18	29	15	12	17	88	0		0								
	Catch Large	11	15	12	33	10	24	7	19	6	2	5	0	9	40	3		0								
	Retained Small	14	22	33	77	70	66	64	44	15	27	14	12	16	77	0		0								
	Retained Large	11	8	0	0	0	0	0	0	0	0	0	0	0	0	0		0								
	Effort (rod days)	602	535	333	531	540	560	573	582	301	262	219	160	219	492	55		0								
SISSIBOO	Catch Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Catch Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Retained Small	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0										
	Effort (rod days)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0										
TUSKET	Catch Small	40	72	30	123	394	154	106	120	57	133	56	19	43	124	28		6		3	1	11	5	0	0	0
	Catch Large	19	32	30	58	69	119	29	36	42	34	21	17	13	51	22		1		0	1	2	3	0	0	0
	Retained Small	29	68	27	115	358	139	91	111	48	113	54	14	34	97	22		6		0	0	0	0	0	0	0
	Retained Large	15	4	0	0	0	0	0	0	0	0	0	0	0	0	0		0		0	0	0	0	0	0	0
	Effort (rod days)	558	495	466	533	1546	1481	1175	1230	1119	1213	1334	613	624	876	480		59		60	24	75	62	12	0	0