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Recovery Potential Assessment for Southern Upland Atlantic Salmon: Status, Past and Present Abundance, Life History and Trends

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Foreword

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

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ABSTRACT

The purpose of this research document is to provide background information on the present status and recent trends of Atlantic salmon populations in the Southern Upland region of Nova Scotia in support of recovery planning for this designatable unit. Information related to abundance, trends, and recovery targets is provided.

The available data indicate that the abundances of Southern Upland Atlantic salmon populations are low and declining. Annual adult abundance data from four rivers show declines of 88% to 99% from maximum abundance, a pattern consistent with trends in the recreational catch in the region. Region-wide comparisons of juvenile density data from more than 50 rivers indicate significant ongoing declines and provide evidence for river-specific extirpations. Comparing juvenile densities at locations surveyed in 2000 and again in 2008/09, total juvenile density decreased substantially in the majority of locations and juvenile Atlantic salmon were not found at nine sites and in four rivers where they had been found in 2000. Although river acidification has significantly contributed to the deterioration or extirpation of populations from many rivers in the region during the last century, contemporary declines in non-acidified rivers indicate that other factors are impacting populations.

Recommended recovery targets for Atlantic salmon populations in the Southern Upland have both abundance and distribution components. The conservation requirements based on the amount of habitat area and an egg deposition rate of 2.4 eggs/m^2 are proposed as river-specific abundance targets, until the dynamics of recovered populations can be studied. Distribution targets should encompass the range of variability among populations, here described genetically and with river-specific environmental characteristics. There is the expectation that including a wider variety of populations in the distribution target will enhance short-term persistence, as well as facilitate recovery in the long term. Recovery targets will need to be revisited as information about the dynamics of the recovering population becomes available.

Évaluation du potentiel de rétablissement du saumon de l'Atlantique des hautes terres du Sud : Situation, abondance passée et actuelle, cycle biologique et tendances

RÉSUMÉ

Le présent document de recherche a pour objet de fournir des renseignements généraux à propos de la situation actuelle et des tendances récentes relatives aux populations de saumon de l'Atlantique dans la région des hautes terres du sud de la Nouvelle-Écosse à l'appui de la planification du rétablissement de cette unité désignable. Des renseignements concernant l'abondance, les tendances et les objectifs de rétablissement sont fournis.

Les données disponibles indiquent que l'abondance des populations de saumon de l'Atlantique des hautes terres du Sud est faible et en déclin. Les données annuelles sur l'abondance d'adultes dans quatre rivières démontrent une baisse de 88 % à 99 % par rapport à l'abondance maximale, un déclin qui concorde avec les tendances associées aux prises de la pêche récréative dans la région. Les comparaisons dans toute la région des données sur la densité des juvéniles provenant de plus de 50 rivières indiquent d'importants déclins continus. Elles fournissent également des preuves de disparition dans certaines rivières. Selon les comparaisons de la densité des juvéniles aux emplacements analysés en 2000, puis en 2008-2009, la densité totale des juvéniles a diminué considérablement dans la plupart des emplacements et aucun saumon de l'Atlantique juvénile n'a été trouvé à neuf sites et dans quatre rivières où l'on en avait trouvé en 2000. Bien que l'acidification des rivières ait contribué considérablement à la détérioration ou à la disparition de populations dans de nombreuses rivières de la région au cours du dernier siècle, les déclins contemporains dans les rivières non acides indiquent que d'autres facteurs ont des répercussions sur les populations.

Les objectifs de rétablissement recommandés pour les populations de saumon de l'Atlantique des hautes terres du Sud comportent des composantes d'abondance et de répartition. Les exigences en matière de conservation établies en fonction de la taille de la zone d'habitat et du taux de ponte de 2,4 œufs/m^2 sont proposées en tant qu'objectifs d'abondance par rivière, jusqu'à ce que la dynamique des populations rétablies puisse être étudiée. Les objectifs de répartition doivent englober la plage de variabilité entre les populations, décrite ici de façon génétique et avec les caractéristiques environnementales propres aux rivières. En incluant une plus grande variété de populations dans les objectifs de répartition, on s'attend à améliorer la persistance à court terme et à faciliter le rétablissement à long terme. Les objectifs de rétablissement devront être revus au fur et à mesure que des renseignements sur la dynamique de la population en rétablissement seront disponibles.

INTRODUCTION

In Canada, Atlantic salmon (*Salmo salar*) populations are found in rivers from the Maine-New Brunswick border and along the north and south shores of the Gulf of St. Lawrence, to the Labrador coast into Ungava Bay (Parrish et al. 1998). Canada is second only to Norway in the number of rivers containing Atlantic salmon, thus representing a significant proportion of the species range. Canadian Atlantic salmon populations have reportedly declined by at least 75% from 1970 to 2000 (WWF 2001). Despite closures (1985, 1992 and 2000) of commercial fisheries for Atlantic salmon and restrictive recreational fishing regulations since 1983, populations in many rivers continue to decline (DFO and MNRF 2009).

The Southern Upland Designatable Unit (DU) of Atlantic Salmon occupy rivers in a region of Nova Scotia extending from the northeastern mainland (approximately 45° 39' N, 61° 25' W) into the Bay of Fundy at Cape Split (approximately 45° 20' N, 64° 30' W) (COSEWIC 2010). This region includes all rivers south of the Canso Causeway on both the Eastern Shore and South Shore of Nova Scotia draining into the Atlantic Ocean (Figure 1), as well as the Bay of Fundy rivers south of Cape Split. Historically, it has been divided into three Salmon Fishing Areas (SFAs) for management and assessment purposes: SFA 20 (Eastern Shore), SFA 21 (Southwest Nova Scotia), and part of SFA 22 (Bay of Fundy rivers inland of the Annapolis River). Southern Upland Atlantic salmon have been designated as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC 2010).

To aid in consultative processes following the designation, and to serve as a basis for recovery planning, information about Southern Upland Atlantic salmon populations has been compiled into four research documents. This document contains information about recent abundance trends and the current status of salmon populations in the Southern Upland DU, as well as information about recovery targets. Two of the other documents contain information about: (1) habitat requirements, availability and status, as well as threats to populations and habitat allocation options (Bowlby et al. 2013), and (2) life history, equilibrium and scenario analyses to describe recent and past population dynamics, as well as to identify and prioritize among recovery alternatives (Gibson and Bowlby 2013). The fourth research document summarizes information about genetic structuring among salmon populations in the Southern Upland (O'Reilly et al. 2012).

The specific Terms of Reference addressed by this document are:

STATUS AND TRENDS

1. Evaluate present abundance and range.
2. Evaluate recent trajectory for species abundance and range.
3. (in part) Estimate, to the extent that information allows, the current or recent life-history parameters (total mortality, natural mortality, fecundity, maturity, recruitment, etc.) or reasonable surrogates; and associated uncertainties for all parameters.

RECOVERY TARGETS

1. Estimate expected abundance and distribution targets for recovery, according to DFO guidelines (DFO 2011).

Additional information about status and previous assessments for Southern Upland Atlantic salmon can be found from the Canadian Science Advisory Secretariat (CSAS) published by

Department of Fisheries and Oceans (DFO) in Ottawa (Ontario, Canada) (most recent: DFO 2011, Gibson et al. 2009).

OVERVIEW OF SOUTHERN UPLAND POPULATIONS

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), although, several characteristics are similar among populations (Chaput et al. 2006). Within the region, there are at least 72 rivers thought to contain (Bowlby et al. 2013), or to historically have contained Atlantic salmon, although it is likely salmon would also have used the smaller coastal or un-assessed rivers in the region.

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). Coupled with the hardrock geology and low buffering capacity, poor soils, and an abundance of acidic heaths, peatlands and bogs throughout the region (Watt et al. 1983, Watt 1987, 1997, Korman et al. 1994), acid precipitation 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 result in some rivers and tributaries with less-acidified water. Of the rivers that have been classified relative to pH (Table 2.1.2 in Bowlby et al. 2013), 13 are heavily acidified (pH < 4.7) and are no longer able to support salmon. An additional 20 rivers are partially acidified (pH ranges from 4.7 to 5.0) and are thought to support only remnant populations (Amiro 2000, Watt 1987). Population supplementation through artificial breeding and rearing was widely applied and appeared to be numerically viable throughout the 1980s. However, recent assessments in SFA 21 have shown continued abundance declines (relative to the 1980s) in both the wild and enhanced components of salmon populations (Amiro et al. 2006). In the cases of the acidified Liscomb, Medway, East River (Sheet Harbour), and Tusket rivers, population enhancement of smolts did not sustain adult escapement (Amiro 2000).

1. PRESENT STATUS

Within the Southern Upland, certain populations (referred to as index populations) have been chosen for long-term monitoring, and the results from this monitoring have been shown to be roughly indicative of trends throughout the region (Amiro 2000, DFO 2011, O'Neil et al. 1998). Monitoring data on all life stages of Atlantic salmon have been collected for two populations: the LaHave River (above Morgan Falls) in SFA 21 and the St. Mary's River (West Branch) in SFA 20. Data collected on other rivers consists of adult counts on the East River, Sheet Harbour (1970-2010), and Liscomb River (1979-1999), recreational catch and effort data, as well as widespread electrofishing surveys for juveniles in 2000 and 2008/09 (Gibson et al. 2009).

Most of analytical methods used to assess Southern Upland Atlantic salmon populations in terms of present abundance, recent abundance trends, and status are described in Gibson et al. (2009). In addition, the field methods used to assess the different life stages (juveniles, smolts, adults) for the index and the other populations have been described in previous assessment documents (e.g. DFO 2011, Amiro et al. 2006). Methods summaries for these previously established techniques are provided here, and the results from Gibson et al. (2009) have been updated to include data from 2009 and 2010.

As a general overview, juvenile densities by age class are estimated using either mark-recapture and a Peterson estimate, or the catch from a single electrofishing pass multiplied by mean capture efficiency and scaled by site area. On the index rivers, the electrofishing sites were initially established as a random-stratified survey of stream gradient categories and are thought to be representative of all habitat types in the watershed (Amiro 1993). More recently, with a few exceptions, the same set of sites from the random-stratified survey are electrofished annually (a fixed-station design). Smolt abundance monitoring has taken place for the LaHave River (above Morgan Falls) and St. Mary's River (West Branch) populations and uses a mark-recapture experiment to estimate annual smolt production. Adult abundance is estimated from counts of adult salmon ascending fish ladders for populations in the LaHave River (above Morgan Falls) and East River, Sheet Harbour, and via a mark-recapture experiment for the St. Mary's River (West Branch) population. An adult count also took place on the Liscomb River in the past, but was discontinued in 2000. Recreational catch data, considered roughly indicative of abundance, is collected annually on rivers open to recreational fishing. Scale samples from all life stages (juveniles, smolts and adults) are used to determine ages, and in the case of adults, previous spawning history.

1.1 Juveniles

Index Rivers

During 2010, electrofishing for juveniles in the LaHave River took place at nine of the established sites, four above and five below Morgan Falls. Only single-pass surveys were done, so the mean catchability from 2007 and 2008 (0.214) was used to estimate juvenile densities (Gibson et al. 2009). Parr densities were similar above and below Morgan Falls, with mean age-1 densities of 9.7 and 13.7 fish per 100 m^2, respectively, and mean age-2+ densities of 0.5 fish and 0.5 fish per 100 m^2, respectively (Table 1.1.1). However, the estimated mean fry density below Morgan Falls (20.7 fish per 100 m^2) was nearly double the estimate for above (12.4 fish per 100 m^2). Total parr densities (age-1 and age-2+ combined) both above and below Morgan Falls were more than double those estimated for 2009, but were similar to estimates within the last five years (Figure 1.1.1).

In the St. Mary's River, electrofishing for juveniles took place at 13 of the established sites (Gibson et al. 2009) in 2010, six on the East Branch and seven on the West Branch of the river. Mark-recapture experiments to estimate abundance were only possible at four sites, so juvenile densities at the remainder were estimated using mean catchability. Estimated overall age-0, age-1 and age-2+ densities were 7.7, 5.8 and 0.3 fish per 100 m^2, respectively, and were relatively consistent between the two branches for age-0 and age-2+ densities. However, age-1 density on the West Branch was more than double that estimated for the East Branch (Table 1.1.2). Relative to 2009, age-0 density was lower, age-1 density was substantially higher, and age-2+ density was similar to values estimated in 2010 (Figure 1.1.2).

Other Rivers

The most recent region-wide electrofishing survey for Atlantic salmon juveniles and other fish species in the Southern Upland was undertaken in 2008 and 2009 (Gibson et al. 2009, Gibson et al. 2011). The majority of rivers in the survey were electrofished in 2008. However, as water conditions in 2008 prevented sampling in several rivers (predominantly north of the St. Mary's River), the survey was continued in 2009 to fill in this gap. For both years, a catchability of 42.8% (Gibson et al. 2003) was used to calculate densities of juvenile salmon at the electrofishing sites.

Summarizing from Gibson et al. (2011), 151 sites were electrofished in 54 rivers, with between 1 and 12 sites fished per river (right panel, Figure 1.1.3). Considering only the first pass of each survey, 150,827 seconds of shocking effort was applied over 107,639 m^2 of habitat, resulting in the capture of 3,587 fish, 1,019 of which were Atlantic salmon. Salmon juveniles were captured at 55 of the 151 sites (36.4%) and were found in 21 of the 54 rivers surveyed (38.9%). American eel (*Anguilla rostrata*) were the most commonly captured species (1,693), followed by juvenile salmon (1,019 fish), and then by brook trout (*Salvelinus fontinalis*) (378).

Where present, the observed densities of juvenile salmon ranged from 0.3 to 33.8 fish per 100 m^2 (Figure 1.1.3). 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 16.1 fish per 100 m^2, with the highest values being recorded on the Musquodoboit River (Table 1.1.3). In six rivers, only one life stage was found (either fry or parr), but it is likely that additional effort or alternate site selection would have resulted in the capture of both life stages within 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, Gibson et al. 2011).

1.2 Smolts

During 2010, smolt abundance was monitored only for the LaHave River (above Morgan Falls) population. The method for estimating smolt abundance (the mark-recapture experiment) on the LaHave River was changed in 2010 from a corrected-Peterson estimate (Gibson et al. 2009) to a stratified estimate (Carlson et al. 1998) to account for the differences in capture efficiency expected during periods of power generation vs. non-generation at Morgan Falls Power. When power generation occurs, nearly all water is directed through the smolt collection facility rather than spilled over the natural falls. This re-direction of water leads to substantially higher capture efficiencies in the smolt collection facility, and has the potential to cause over- or under-estimation of the smolt run if average collection efficiency (for the entire smolt run) is used to estimate abundance.

To calculate total smolt abundance from above Morgan Falls on the LaHave River in 2010, release and recapture events were classified into two discrete strata (generation, non-generation) and Peterson estimates of within-strata abundance were summed (Carlson et al. 1998). This technique is a simplification of more typical stratified mark-recapture experiments in which marking takes place in discrete strata but recaptures are continuous during the sampling period (e.g. Dempson and Stansbury 1991). The numbers of smolts recaptured over time were insufficient to use the more typical stratification methods.

In 2010, a total of 16,215 smolts (90% CI (confidence intervals) = 15,160 to 17,270) were estimated to have emigrated from above Morgan Falls on the LaHave River. This is nearly double the number estimated for 2009 and is slightly above the 1997-2009 average of 15,797 (Table 1.2.1). Of the smolts that were aged, approximately 80% were age-2, 20% were age-3, and less than 1% were age-4. Smolt production per unit juvenile rearing area (2,605,200 m^2) was estimated to be very low at 0.62 smolts per 100 m^2 relative to values obtained for other populations (e.g. 3.8 smolts per 100 m^2 of habitat; Symons 1979).

The most recent estimate of smolt abundance for the St. Mary's River (West Branch) salmon population is from 2009. Monitoring took place using a rotary screw trap and abundance was estimated from a mark-recapture experiment using a Peterson estimate (Gibson et al. 2009, DFO 2010). In 2009, the estimated efficiency of the smolt wheel was 2.6% and the population estimate was 14,820 smolts (95% CI = 8,600 to 28,001). This value was similar to those estimated for the preceding two years (Table 1.2.2). Based on an estimated 2,191,970 m^2 of juvenile habitat contained in the West Branch of the St. Mary's River, smolt production in 2009 was, like the LaHave River, estimated to be low at 0.68 smolts per 100 m^2. The majority of the smolts were age-2 (97%), with the remainder being age-3.

1.3 Adults

Index Rivers

Adult abundance monitoring occurred for both of the two index populations in 2010: the LaHave River (above Morgan Falls) population and the St. Mary's River (West Branch) population.

Adult abundance estimates for the LaHave River (above Morgan Falls) population are obtained from counts of small and large salmon ascending the fishway at Morgan Falls. Small salmon are < 63 cm fork length and are mostly all one-sea-winter (1SW) salmon. Large salmon are ≥ 63 cm fork length, and include two-sea-winter (2SW) salmon, three-sea-winter (3SW) salmon and most repeat spawning salmon (in this document, 2SW, 3SW and all repeat spawning salmon are collectively referred to as multi-sea-winter (MSW) salmon). In 2010, the count of adult salmon at the Morgan Falls fishway was 353 fish (Figure 1.3.1), consisting of 300 small salmon and 53 large salmon. This count is similar to those observed since 1997, and shows a slight increase over the count in 2009. Based on the scale samples taken from captured fish, 84% of the population were 1SW salmon, 13% were 2SW salmon and 3% were repeat spawners (Table 1.3.1). The most recent release of captive-reared smolts into the LaHave occurred in 2005 (Section 2.3; Gibson et al. 2009) and as expected, no returning adults of hatchery origin were observed in 2010.

Adult salmon counts at the Morgan Falls fishway showed an increase in the number of small salmon in 2010 (i.e. 300 small salmon counted in 2010 versus 168 small salmon counted in 2009), whereas the large salmon count of 53 fish was the same in 2010 and 2009.

Prior to 1996, adult escapement estimates for the St. Mary's River were derived from recreational catches and an assumed exploitation rate (O'Neil et al. 1997). River-specific escapement estimates have been calculated since 1997 using mark-recapture seining experiments (1997-2001, 2006-2008, 2010) or seining and seining efficiency estimates (2002-2005) to estimate adult abundance in the West Branch (Gibson et al. 2009). In 2009, only one seining attempt was possible, during which no salmon were captured. Therefore, the mean ratio of escapement estimates for the St. Mary's River (West Branch) relative to the LaHave River (above Morgan Falls) was used to estimate escapement (DFO 2010). For 2010, two adult escapement estimates are given here, one based on the mark-recapture seining experiment, and the other based on the ratio between the abundances in the two rivers (as was calculated in 2009).

For the mark-recapture experiment, a total of 23 Atlantic salmon were marked, 36 captured, and nine recaptured, giving a Peterson estimate of escapement of 90 salmon (95% CI = 57 to 164) to the West Branch of the St. Mary's River. This escapement estimate is the lowest recorded for the West Branch of the St. Mary's River (Table 1.3.2). Based on the scale samples taken from captured fish, 84% of the population were 1SW salmon, 12% were 2SW salmon and 4% were repeat spawners (Table 1.3.3). No 3SW fish were captured.

The ratios of escapement estimates for the St. Mary's (West Branch) population relative to the LaHave River (above Morgan Falls) population for 2004-2008 range from 0.40 – 0.64 with a mean of 0.52. Under the assumption that this ratio equals the mean value in 2010, the adult escapement estimate for West Branch of the St. Mary's River is 186 adult salmon (171 1SW and 15 MSW) for 2010 (Table 1.3.4). Applying separate ratios for 1SW (almost all small salmon) and MSW (almost all large salmon) yields a similar escapement estimate.

Regional Estimates

Catch and effort data from the annual recreational Atlantic salmon fishery have been monitored using a license-stub return program since 1983. After the close of the fishing season, anglers return license stubs on which they have recorded the dates and locations where they fished, as well as their catch of large (≥ 63 cm fork length) and small (< 63 cm) salmon. The catch is corrected for non-reporting using a regression developed from the change observed in the reported catch resulting from sending multiple reminder letters to license holders to increase the number of returned stubs.

Recreational fishing seasons for salmon in this region are managed on a river-specific basis and may be open on some rivers but not others based on the status of populations in each river. In 2010, all rivers in the Southern Upland region were closed to salmon fishing (DFO 2010). In 2009, there were 13 rivers open for salmon fishing on at least part of the river, but over 75% of the effort (and 85% of the catch) took place on the LaHave and the St. Mary's rivers. A total of 813 rod-days were expended in 2009, with a total catch of 130 small and 89 large salmon (Table 1.3.5). Total catch per unit effort was 0.27 salmon per rod-day, which is quite low relative to values observed both in the past and in other regions.

The regional abundance of Atlantic salmon is calculated annually for the International Council for the Exploration of the Sea (ICES) Working Group on North Atlantic Salmon, which provides annual catch advice to the North Atlantic Salmon Conservation Organization (NASCO) for high-seas fisheries. An estimate of regional abundance by sea age class (minimum and maximum values) is used as an input into the model used to generate this advice (ICES 2012). The method used to calculate regional estimates of Atlantic salmon production (for SFAs 19 to 21) relies on the recreational catch data because it was the only widespread monitoring method employed in these fishing areas. The total recreational catch is scaled up to a regional abundance estimate using: (1) the catch rate estimated for the LaHave River population, and (2) the ratios of the recreational catch on the LaHave River relative to that in each of the other rivers (as estimated when all rivers were open to recreational fishing: 1984 to 1997), as described in Amiro et al. (2008). Commercial landings from 1970 to 1984 are accounted for and the 90% confidence limits for adult abundance by age class (based on maximum likelihood) are carried forward as the minimum and maximum values. Although all major river systems in SFAs 19 to 21 are included in the calculation when this information is provided annually to ICES, only rivers in SFA 20 and 21 (i.e. those in the Southern Upland region) were included in the estimates provided here. There are two potential biases in the method. During the 1970s, the LaHave River (above Morgan Falls) population was building, which would mean it would likely under-represent the total abundance in the region (Gibson and Bowlby 2013) during that time period. In more recent years, many populations in the Southern Upland have extirpated, which would cause regional abundance to be over-estimated due to the method's reliance on the count at Morgan Falls (a healthier population).

Spawning escapement in 2010 was estimated to be in the range of 3,176 to 4,311 1SW adults and 616 to 866 MSW adults in the Southern Upland region (Table 1.3.6). This represents an increase from 2009 for the 1SW component, but essentially no change in the MSW component. Current estimates are quite low relative to historical values.

1.4 Return Rates of Adults

The ratio between smolt production and subsequent adult returns provides an estimate of the return rate of smolts. Return rates are not completely analogous to survival estimates because of the unknown proportion of the population that matures after one or two winters at sea (Hubley and Gibson 2011). However, return rates are expected to be highly correlated with survival and are often used as a proxy for survival at sea.

Index Rivers

For the LaHave River (above Morgan Falls), return rates have ranged from 1.1% to 7.9% for 1SW adults (smolt year classes 1996-2009), and from 0.11% to 0.86% for 2SW (smolt year classes 1996-2008) (Table 1.2.1). The estimate of the return rate of wild smolts emigrating from above Morgan Falls in 2009 to 1SW returns in 2010 was 3.47%. The estimate of the return rate of wild smolts emigrating in 2008 to 2SW returns in 2010 was 0.3%. Longer return rate time series were derived by Gibson and Bowlby (2013) for both the LaHave River (above Morgan Falls) and St. Mary's River (West Branch).

Smolt to 1SW return rates are available for the 2005-2009 smolt year classes and smolt to 2SW return rates are available for the 2005-2008 smolt year classes on the St. Mary's River (West Branch). Return rates have ranged from 0.5% to 3.0% for 1SW adults and 0.09% to 0.3% for 2SW (Table 1.4.1). The estimate of the return rate of wild smolts in 2009 to 1SW returns in 2010 was 1.0%. The estimate of the return rate of wild smolts emigrating in 2008 to 2SW returns in 2010 was 0.09%.

1.5 Status Relative to Recovery Targets

Evaluation of the status of Atlantic salmon populations in the Southern Upland is done relative to river-specific conservation requirements (CRs), values that are proposed as recovery targets in Section 3. The CR is calculated by multiplying the amount of fluvial habitat of suitable gradient for juvenile Atlantic salmon production by a target egg deposition rate of 2.4 eggs/m^2 (O'Connell et al. 1997). Populations are assessed relative to these values by calculating the expected egg deposition from the annual escapement estimate, taking into account the biological characteristics of the returning adults (mean length, sex ratio, and age distribution) in combination with length-fecundity relationships. As described in Section 3, the CRs are proposed as river-specific recovery targets.

Index Rivers

There have been a few different values calculated for CRs for both the LaHave and St. Mary's rivers. Generally, the differences among them resulted from differences in the methods used to estimate the number of habitat units (i.e. rearing area) in the watershed. Original estimates of available rearing area in select rivers (including the LaHave and St. Mary's) were done from *in-situ* habitat surveys (e.g. Cutting and Grey 1984, O'Neil et al. 1998). More recent estimates of habitat area come from orthophoto map measurements and take into account the suitability of stream reaches for juvenile salmon production based on gradient (Amiro 1993). This latter method was adopted for all rivers when a comprehensive list of CRs for Atlantic salmon populations in Eastern Canada was developed (O'Connell et al. 1997).

There has been one attempt to account for the expected reduction in productivity associated with a specific threat when calculating CRs. This was proposed for the LaHave River (above Morgan Falls) to account for the uncertain but expected reduction in productivity associated with acidification (Amiro et al. 1996). However, the precautionary approach framework that has since been adopted by DFO states that the removal reference levels should include mortality from all anthropogenic sources (DFO 2006), with the implication that the upper stock reference and limit reference points should not be adjusted downwards based on the expected impact of existing sources of human-induced mortality. Therefore, the status of the population was not assessed relative to the acid-adjusted CR in this document, even though this has been done in assessments since 1997 (e.g. Amiro et al. 2006, DFO 2010).

At a recent review of fisheries reference points (DFO 2012), the CRs listed in O'Connell et al. (1997) were recommended as limit reference points for Atlantic salmon populations in the Maritimes region (including the Southern Upland). This was based on an evaluation of how the CR estimated by O'Connell et al. (1997) for the LaHave River (above Morgan Falls) compared with alternative reference points given the life history dynamics of the population (Gibson and Claytor 2012). Here, the status of the LaHave and St. Mary's salmon populations are presented relative to the CRs listed in O'Connell et al. (1997), although alternate (or interim) values have been used in assessments prior to 2011.

For the entire LaHave River, the CR is 12.2 million eggs (O'Connell et al. 1997). An estimated 51% of the productive area in the watershed is above Morgan Falls (Amiro et al. 1996); giving a CR of 6.22 million eggs for the LaHave River above Morgan Falls. Estimated egg deposition above Morgan Falls was 687,094 eggs in 2010, over 200,000 eggs higher than in 2009 (Figure 1.5.1). This equates to 11% of the CR. Since the fishway was opened in the 1970s, estimated egg deposition above Morgan Falls has not reached the CR, although the population did come close in the late 1980s (Figure 1.5.1). Based on the population growth rates in Gibson and Bowlby (2013), it would not be expected that the population above Morgan Falls would have exceeded the CR given the length of time between opening the fishway and the onset of declines in the 1980s.

The CR for the entire St. Mary's River is 9.6 million eggs (O'Connell et al. 1997). Approximately 55% of the area suitable for juvenile production is thought to be contained in the West Branch (Amiro et al. 2006), which gives a CR for the West Branch of 5.3 million eggs. Estimated escapement from the seining mark-recapture survey in 2010 was approximately 3% of the CR for the West Branch, which is the lowest value ever recorded (Table 1.3.3). This value increases to 6% of the CR if escapement in 2010 is estimated based on the ratio between the abundance estimates on the LaHave River (above Morgan Falls) and the St. Mary's River (West Branch). Note that these estimates are different from the ones reported in DFO (2011) because of the higher CR value used here (but also refer to DFO (2011) – Sources of Uncertainty for more information).

Regional Estimates

Conservation requirements are calculated using estimates of the amount of habitat with gradients between 0.12% and 25% included in the area calculation (Amiro et al. 2003, O'Connell et al. 1997). Information on the amount of habitat contained in each gradient classification was available for 48 of the 72 watersheds thought to support or to have supported salmon populations (Amiro 2000, Bowlby et al. 2013 - Table 2.1.1). In order to estimate the habitat area for the other rivers, a regression was done between the total watershed area (determined from the Secondary Watersheds Layer developed by the Nova Scotia Department of the Environment using ArcGIS®) and the productive habitat area for the 48 rivers for which both sets of data are available. The regression was highly significant (p-value <<0.001) with an R^2 value of 0.898 (Bowlby et al. 2013 – Figure 2.1.2). The productive habitat area for the remaining rivers was then estimated from their total watershed area using this relationship. The resulting value for productive area was then multiplied by 2.4 eggs/m^2 of habitat to determine the river-specific CR (see Bowlby et al. 2013 – Table 2.1.2).

Combining the estimates of productive area for each of the 72 rivers, total productive area for juvenile Atlantic salmon in the Southern Upland was estimated to be 783,142 habitat units (1 habitat unit has an area of 100 m^2). This leads to an estimated regional CR of 187.95 million eggs. To relate current abundance estimates for adults (refer back to Section 1.3) with the regional CR, it was necessary to calculate the approximate egg contribution per returning adult spawner. Using the average (1996-2010) biological characteristics of LaHave River adult salmon and the length-fecundity regression developed for the LaHave (Cutting et al. 1987), one estimate would be 2,055 eggs per fish. Other estimates of egg deposition per returning adult salmon include 1,482 eggs/fish for the LaHave River in the early 1980s (Cutting and Grey 1984), as well as 2,151 eggs/fish and 2,862 eggs/fish for the Musquodoboit River and Salmon River (Guysborough County) populations, respectively, for 1996 (O'Neil et al. 1998). Using the current estimate of total adult production in the Southern Upland region (3,792 to 5,177 adults; age classes combined), and this range of egg production values (1,482-2,862 eggs/fish), it is expected that the Southern Upland region would be producing less than 8% (5.62–14.82 million eggs) of the regional CR.

2. ABUNDANCE TRENDS FOR SALMON THROUGHOUT THE SOUTHERN UPLAND

There are four sources of information available to assess trends in Southern Upland salmon populations: (1) fishery-independent data which includes the annual electrofishing surveys for juveniles on index rivers, as well as count data of adult populations on four rivers, (2) regional electrofishing surveys completed in 2000 and 2008/09, (3) contributions from stocking and subsequent returns of hatchery fish from three rivers, and (4) recreational catch data for adult salmon for 55 rivers.

2.1 Trends based on Fishery-independent Data

Adults

Time series data on wild adult abundance are available for four populations in the Southern Upland. These are the LaHave (above Morgan Falls) populations and St. Mary's (West Branch), described above, as well as counts of adult salmon ascending fishways on the Liscomb River and East River, Sheet Harbour (Table 2.1.1). Here, the adult count data over the previous 15 years (roughly three generations) were analysed, using the log-linear model (Gibson et al. 2009) to characterize the trends. Additionally, declines from the maximum observed abundance were also analysed. As no recent monitoring has taken place on the Liscomb, the results presented here for the wild component of the population are identical to those presented in Gibson et al. (2009). For the other three rivers (LaHave, St. Mary's and East River, Sheet Harbour), the analyses here have been updated to include data from 2009 and 2010.

The model results indicate significant declines in the abundance of adult salmon in all four rivers (Table 2.1.2, Figure 2.1.1). In all cases, 95% CI did not straddle zero, indicating that the declines were significantly different from zero (Table 2.1.2). During the last three generations, decline rates on the LaHave (slope = -0.076) and St. Mary's (slope = -0.117) were lower than those predicted for East River, Sheet Harbour (slope = -0.152), or Liscomb River (slope = -0.805). Over the last 10 years when data were available, the salmon population in the Liscomb River was estimated to have declined by > 95% (Figure 2.1.1). Although decline rates have been lower for the LaHave and St. Mary's, the populations are estimated to have declined by 70.5% and 84.7%, respectively, over the previous three generations (Table 2.1.2, Figure 2.1.1). Declines from the maximum observed abundances are greater (Table 2.1.2).

Consistency among Life Stages

Adult abundance from the two index rivers were analysed in conjunction with juvenile electrofishing data to determine if the observed trends were consistent among age classes (i.e. are similar decline rates seen in juvenile data as in adult abundance data). This analysis used a nested log-linear model (that considered age class as a factor) to describe trends in adult abundance, egg deposition and juvenile density over time in the LaHave River (above Morgan Falls) and St. Mary's River (West Branch) Atlantic salmon populations (Bowlby and Gibson 2012). The same model was used to predict separate slope estimates (i.e. decline rates) for all age classes, as well as deviates from the adult slope estimate for each of the other age classes (to test for significant differences among slopes).

To facilitate comparison, the same time period (1990 to 2010) was used to predict trends in the LaHave River (above Morgan Falls) and St. Mary's River (West Branch). For the LaHave River above Morgan Falls, significant declines were predicted for all age classes except age-2, leading to overall declines in excess of 67% (Figure 2.1.2, Table 2.1.3). For this river, only age-2 density had a significantly different decline rate estimate when compared with adult abundance. For the West Branch of the St. Mary's River, significant declines were predicted for all age classes except age-1 parr, leading to overall decline rate estimates in excess of 73% (Figure 2.1.3; Table 2.1.3). None of the deviates were significantly different from the slope estimated for adults, indicating no significant differences among age classes in the estimated decline rates. Overall, these results strongly suggest that juvenile densities have undergone declines of similar magnitude as adult abundance, although density dependence, environmental stochasticity and variation in life history parameters have likely influenced trends in the older juvenile age classes (Bowlby and Gibson 2012).

2.2 Regional Electrofishing Survey

Gibson et al. (2011) compared the results of electrofishing surveys in the Southern Upland during 2000 (Appendix 1) and 2008/09 (Appendix 2) and found them to be similar in terms of total effort and coverage. More sites were completed in the more recent survey (151 vs. 128) and two more rivers were visited (54 rather than 52). In addition, total shocking time was greater (150,827 seconds vs. 104,331 seconds), but the total area surveyed on the first pass at each site was lower (107,639 m^2 vs. 128,842 m^2). However, less than half as many fish were captured on the first pass in the 2008/09 survey (3,587) than in 2000 (7,825), including approximately one quarter as many salmon (1,019 vs. 3,733). In 2000, juvenile Atlantic salmon were found in 54% of the rivers (28 of 52) rather than 39% (21 of 54) as in the recent survey.

When present at a site, juvenile salmon density (all age classes combined) in 2000 ranged from 0.1 to 99.6 fish per 100 m^2 (Figure 1.1.3). The upper value is approximately three times higher than maximum density at a site in 2008/09. 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. Overall, the mean density of age-0 juveniles declined from 5.0 to 1.2 fish per 100 m^2 between 2000 and 2008/09, 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 nine sites and three rivers in 2008/09 where they were previously found in 2000 (Figure 1.1.3).

Of the sites surveyed in both years (n = 81), total juvenile density decreased in 36 sites (44%) and increased in 6 (7%). The remainder of the sites (n = 39) had recorded densities of zero for both years (Figure 2.2.1; Gibson et al. 2011). A Wilcoxon test on paired site data indicated a near-zero probability that juvenile densities were the same during both surveys, and juvenile salmon were not found at nine sites (in four rivers) where they were present in 2000 (Gibson et al. 2011).

2.3 Contributions from Stocking

Over the last 30 years, the many of the larger river systems in the Southern Upland have been affected by stocking programs (Appendix 3). In the past, stocking was primarily intended for fishery enhancement, i.e. for increasing commercial and recreational fishing opportunities. Additionally, on a river-specific basis, it was also used as a method to accelerate the growth of populations once access was provided to previously inaccessible areas (e.g. LaHave River above Morgan Falls). More recently, it has also been used as an attempt to slow the abundance declines in some rivers, typically via the grow-out of parr captured in the wild to maturity as adults, at which time the adults are released back into the river to spawn in the wild. This section is not intended to be an in-depth analysis of the population-level impacts of stocking. Rather, it is meant to provide some background data for specific rivers that can be used in evaluating if stocking programs were successfully used for population increase or maintenance. Trends in the return rates of stocked salmon also give some indication of the relative contribution of these individuals to populations over time.

The stocking database used in these analyses spans the years from 1976 to 2007, although there were stocking programs that existed for many years prior to 1976. In general, the broodstock used and the life stages released into a particular river system varied from year-to-year in a given river system, particularly when native broodstock (i.e. adults originating in the natal river) were not available (Appendix 3). In general, the most commonly released life stages were parr (20 to 26 weeks or 26 to 52 weeks of age) and smolts (ages 1 to 3). Although all available data are provided in Appendix 3, specific information on the LaHave, Liscomb and East River, Sheet Harbour, are included in this section. These three are among the most extensively stocked river systems in the Southern Upland and other adult assessment data (i.e. adult counts and biological characteristics) are available for each population.

Stocking on the LaHave River occurred at locations both above and below Morgan Falls, but returning adults were only enumerated at the fishway at Morgan Falls. Therefore, the stocking numbers analysed here only include releases from above Morgan Falls given that adults are expected to return to the general vicinity of their release location as juveniles or smolts. In addition, there were multiple life stages released with adipose clips (parr and smolts), which would not necessarily be expected to emigrate to the marine environment in the same year (based on age and time of release). Amiro and Jefferson (1998) used assumed mortality rates among age classes (0.6 for age-0 to age-1 parr, and 0.4 for age-1 parr to age-2 smolt) to calculate an estimated annual smolt output from 1971 to 1997, accounting for differences in smolt quality among years (Frantsi et al. 1972). From this, the return rates for 1SW and 2SW hatchery adults to the mouth of the LaHave River and to the LaHave River above Morgan Falls were determined, accounting for the number of fish that were stocked above but removed by the recreational fishery below Morgan Falls (Amiro and Jefferson 1998). Here, this analysis was extended until 2005 (the last year in which smolts were released in the LaHave River), using data from the stocking database. The correction for smolt quality was removed because it could not be estimated in recent years (i.e. after 1997). These data are intended to be representative of general trends and are useful as a relative index of hatchery smolt output over time. However, it is recognized that the assumed mortality rates may cause annual smolt outputs to be overestimated in the beginning of the time series, because a greater number of younger age classes were released. This would mean that the return rates during those years would be underestimated.

On the LaHave River above Morgan Falls, estimated annual smolt output from stocked juveniles varied considerably, from 2,550 in 1982 to over 89,000 in 1978 (Table 2.3.1). The average contribution from stocked fish was 37,619 smolts annually. In general, the estimated output of hatchery smolts was high in the 1970s, lowest in the 1980s and increased again throughout the 1990s and 2000s until the last year of the program (Figure 2.3.1). Return rates for 1SW salmon were an average of 1.4% in the 1970s, 1.7% in the 1980s, 0.9% in the 1990s and 0.5% in the 2000s. Similarly, return rates for 2SW salmon peaked in the 1980s. These were an average of 0.3% in the 1970s, 0.5% in the 1980s, 0.2% in the 1990s and 0.1% in the 2000s (Table 2.3.1).

The stocking program on the East River, Sheet Harbour, as well as the monitoring program run by DFO at Ruth Falls (part of a larger management strategy implemented in 1994; O'Neil et al. 1998) were discontinued in 2003, so data from 1976 to 2003 are presented (Table 2.3.2). On the East River, Sheet Harbour, the number of stocked smolts ranged from 3,980 in 1981 to 64,146 in 1977, with an average of approximately 18,000 released annually (Figure 2.3.2). Return rates of these fish were low, never exceeding 1% for 1SW and 0.1% for 2SW (Table 2.3.2). Comparing the 1980s with the 1990s, the number of smolts released annually roughly doubled in the more recent time period, and remained relatively high until stocking was discontinued in 2003 (Figure 2.3.1). However, return rates of 1SW individuals were nearly an order of magnitude lower in the most recent seven years of monitoring than at the beginning of the time series (Table 2.3.2).

The stocking program on the Liscomb River began in 1977 and a fish trap was operated in the fishway at Liscomb Falls beginning in 1979 (O'Neil et al. 1998). Both of these programs were discontinued in 2000 (Gibson et al. 2009). On the Liscomb River, the number of age-1 smolts stocked ranged from 7,978 to 59,028, with an average of approximately 36,000 released annually (Table 2.3.3). The number of smolts stocked annually was higher for five years in the 1980s than in the 1990s, but there was no progressively declining trend in the data (Figure 2.3.3). Conversely, the number of hatchery returns (and the return rates of those fish) did progressively decline from higher values in the 1970s and 1980s to consistently low values in the 1990s (Table 2.3.3). Before the 1990s, return rates ranged from 0.37% to 2.9% for 1SW and 0.05 to 0.23% for MSW salmon. During the 1990s, 1SW return rates were consistently less than 1% and reached a minimum of 0.06% in 1997. Return rates for MSW salmon remained below 0.05% and declined to essentially zero in 1997 (Table 2.3.3).

There are two general conclusions that can be drawn from the stocking examples in these three rivers. First, despite relatively constant (Liscomb) or generally increasing (LaHave and East River, Sheet Harbour) numbers of stocked smolts during the 1980s and 1990s, the number of returning hatchery adults progressively declined. This indicates that stocking programs were not able to maintain populations in the absence of other recovery actions to address threats (Liscomb and East River, Sheet Harbour), or that stocking does not necessarily cause population increase after colonization of a new area (LaHave). Second, return rates of stocked fish are typically lower than return rates of wild individuals, and demonstrate similar declining trends over recent years (compare with Section 2.2 in Gibson and Bowlby 2013). This suggests that stocked individuals experience higher mortality rates than wild individuals in similar environments, and that they may be less resilient to changes in environmental conditions.

2.4 Trends in Recreational Catch

To summarize changes in reported recreational catch and effort, log mean catch and effort for each of the time periods of: 1988-1993, 1994-1999 and 2000-2009 were compared with the log mean from 1983-1987 (Gibson et al. 2009). Increases or declines 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 Southern Upland Atlantic salmon, except for the most recent time period (2000-2009) which was grouped together because of the scarcity of data as many rivers were closed to angling in 1998.

Up until 1993, recreational catches had declined slightly in the majority of rivers when compared to recreational catches of the previous generation. However, a comparison of the reported recreational catch during the 1983-1987 time period with the 2000-2009 time period shows that the catch has declined markedly through time, often by > 95% (Figure 2.4.1. Concurrent with the decline in reported catch has been a decline in reported effort on most rivers, which dropped by nearly 100% before they were closed to angling (Figure 2.4.2). The two exceptions in which fishing effort and catch have increased in the 2000-2009 time period relative to the 1983-1987 time period are the Sackville and St. Francis Harbour rivers. Although the increase appears substantial, it represents a very small number of salmon. On the St. Francis Harbour River, two salmon were caught in four rod-days in 1983 (with no salmon captured from 1984 to 1987), which changed to seven salmon caught in three rod-days in 2007 (the river was closed to recreational fishing from 2000 to 2006, and 2008 to 2009). On the Sackville River, the mean catch and fishing effort for the most recent time period (2000-2009) was extremely low, at 3.4 salmon caught in 34.4 rod-days.

3. ABUNDANCE AND DISTRIBUTION TARGETS FOR POPULATION RECOVERY

Long-term goals for the recovery of Atlantic salmon in the Southern Upland region likely include increasing both the size and total number of populations. However, determining how many populations need to be included in the recovery strategy or how large they must be to ensure recovery of an Atlantic salmon DU is difficult from a quantitative perspective (Gibson et al. 2008), given that the dynamics of the recovered populations of are not known. Previous research on abundance targets, as well as theoretical research on how species distribution relates to persistence or recovery can be used as a basis for decision-making.

3.1 Recovery Targets for Abundance

Overall population size is positively related to population persistence for a range of fish species (Dulvy et al. 2003), which suggests that increasing population size for salmon in the Southern Upland region is important for recovery. However, population size alone is not an indicator of population viability, and exactly how large populations need to be depends on their dynamics when populations are rebuilding. In the absence of knowledge of these dynamics, targets are proposed and used to evaluate recovery probability in this recovery potential assessment.

As was the case with inner Bay of Fundy salmon, the use of the CR as a recovery target for Southern Upland Atlantic salmon is proposed. This advice is based on the terminology used by Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) when developing the CR, an assessment of population dynamics relative to several reference levels, as well as past abundance.

In response to a need for a definition of conservation for Atlantic salmon (Chaput 2006), a subcommittee of the CAFSAC adopted the egg deposition rate of 2.4 eggs/m^2 of fluvial rearing habitat as the level below which CAFSAC would strongly recommend that no fishing should occur. Summarizing from Gibson et al (2009): CAFSAC considered that this level provided a modest margin of safety, and that the further spawning escapement is below the biological reference level (BRL), and the longer it remains below the BRL (even at levels only slightly below), the greater the risks of irreversible damage to the stock (CAFSAC 1991). Risks to the populations included:

“accentuation of annual fluctuations in run size and reduction in the long-term capability of the stock to sustain native food fisheries, recreational fisheries, or commercial fisheries; increased susceptibility to extinction from genetic, demographic, or environmental catastrophes and consequent decreases in productivity; permanent changes in demographic characteristics of the spawning population; [and] replacement in the ecosystem by other competing fish species of potentially less social and economic value.” (CAFSAC 1991).

DFO (2005) summarizes the outcome of a national workshop held to consider what constitutes recovery in the context of a species-at-risk, where participants attempted to determine where recovery targets fit within the precautionary approach framework for fisheries management. The precautionary approach framework has three zones:

“Critical: Zone where stock biomass is evaluated as being at or below a level where there is a high risk of serious or irreversible harm to stock productivity. When stock biomass is within this zone, exploitation rates should be as low as possible, with no directed fisheries and practical by-catch reduction measures in place. Rebuilding of the stock should be the sole consideration in allocating surplus production.

Healthy: Zone where stock biomass is evaluated as being within the historical range of the stock when science advisors did not recommend that priority be given to rebuilding the stock. When stock biomass is in this zone, exploitation should be at rates which are sustainable in the long *term, but social and economic considerations are the main factor in deciding what proportion of surplus production from the stock should be devoted to harvests.*

Cautious: Zone between the Critical and Healthy Zones, which reflects uncertainty about the estimation of annual stock status and the biomasses at which stock productivity begins to decline and becomes at risk of serious or irreversible harm. Exploitation rate should decline progressively from sustainable in the long term at the Healthy-Cautious Boundary to as near zero as possible at the Cautious-Critical Boundary, as the priority given to stock rebuilding grows and the priority given to social and economic uses of surplus production declines." (DFO 2005).

The use of both the critical-cautious boundary and the cautious-healthy boundary as recovery targets were reviewed at the workshop. While both positions had strengths and weaknesses, it was concluded that "*any reasonable description of "recovery" would be at least a stock healthier than either the critical-cautious boundary or the risk criteria of COSEWIC*" (DFO 2005).

Gibson and Claytor (2012) reviewed the historical use of the CRs and compared it to other proposed fishery reference points using the dynamics of the LaHave River (above Morgan Falls) population. They concluded that the CRs was more consistent with the definition of a limit reference point (as originally intended by CAFSAC) rather than an upper reference level as defined in the precautionary framework for fishery management (DFO 2006). As such, the use of the CR as a recovery target for Southern Upland salmon would be consistent with its use as the lower limit reference point (defining the critical-cautious boundary) in the precautionary framework.

In many rivers in the Maritimes Region (e.g. Stewiacke, Big Salmon, North), population sizes well in excess of the CR have been seen historically (Gibson et al. 2008). In the 1980s, abundances of up to 2.5 times the CR were estimated for the St. Mary's River, and the average population estimate for those 10 years was approximately 1.3 times the CR. However, this result is sensitive to the catch rate assumed for the recreational fishery (see Appendix 3 in Gibson and Bowlby 2013). Abundances above the CRs have not been observed for the LaHave River (above Morgan Falls) population, although they came very close in the late 1980s. Given that the run above Morgan Falls was first developing throughout the 1970s, the population had only three to four generations to build before abundance began to decline in the late 1980s.

Taken together, results from the Southern Upland and surrounding regions indicate that the CR is unlikely to be unduly large relative to historical abundance and would be appropriate as a recovery target for river-specific populations (Gibson et al. 2008). River-specific targets are provided in Table 2.1.2 of Bowlby et al. (2013), with the caveat that the distribution target is sufficient such that enough populations are recovered to ensure longer term viability. As was recommended for inner Bay of Fundy Atlantic salmon, recovery targets should be revisited once recovery is underway (Gibson et al. 2008).

3.2 Recovery Targets for Distribution: Identification and Grouping of Landscape-level Variation

The initial steps in protecting biological diversity involve first identifying diversity, and then defining the units of diversity that require preservation (Wood 2001). Therefore, setting appropriate distribution targets for the recovery of Southern Upland Atlantic salmon populations partially relies on knowledge of the diversity among populations in the DU. Environmental variation both within and among river systems, coupled with the natural homing ability of Atlantic salmon, act in concert to promote and maintain the variability in life history characteristics found among Atlantic salmon populations in the Southern Upland. Such local adaptation (and consequently biological diversity) would be expected to be the largest among the most dissimilar watersheds, provided that gene flow was relatively restricted among them. As a step towards identifying diversity, an inventory the physical and geological characteristics of rivers (indicative of variability in freshwater habitats) is discussed in this section, and used to group watersheds into those of similar type. The habitats contained within watersheds can be characterized using properties that define the geological and physical processes that shape the freshwater environment (Holtby and Ciruna 2007). For Atlantic salmon, these include factors such as: surface and bedrock geology, gradient, drainage area, stream length, elevation, and so on.

Data Compilation and Statistical Methods

Several sources were used to compile the environmental data used in these analyses (details are in Appendix 1 of Bowlby et al. 2013). Topographic data were obtained from Geobase in the form of a digital elevation model on a provincial scale, and was used to generate statistics on the elevation, slope and change in elevation within 100 m blocks for each of the Southern Upland watersheds. Hydrological data describing the size and shape of watersheds, as well as the length of watercourse (flow network) and the amount of surface water or inland water (e.g. lakes) was calculated from the National Hydro Network. Data describing ecological land classification (e.g. natural forest disturbance regimes), as well as bedrock and surface geology types were obtained from the Nova Scotia Department of Natural Resources. The proportion of each feature type contained within watersheds in the Southern Upland was calculated. Combined, this led to 40 variables that described each watershed (Table 3.2.1).

Environmental data such as bedrock geology or natural forest disturbance regime have several fields of data (feature classes) summarizing predominantly one environmental variable (Table 3.2.1). For example, there are six different types of measurements that would all summarize information related to distance or area in a watershed. Including all of these fields as separate environmental variables would artificially weight the analysis towards data sources with the most classes (e.g. surficial geology) and would give less weight to variables with fewer or a single feature class (e.g. the proportion of inland water). Classification techniques such as hierarchical clustering depend on the removal of known structure in the data (i.e. multiple variables that describe the same feature or characteristic) for this reason (Venables and Ripley 2002). For environmental data with multiple feature classes (Table 3.2.1), a non-metric multidimensional scaling (MDS) analysis was used to summarize the variability into two main axes for further analysis. For example, the six feature classes that combine to determine bedrock geology type would be represented by two MDS axes (Table 3.2.1). Non-metric multidimensional scaling is thought to be the most effective ordination method for ecological data given that it is well-suited for non-normal, as well as categorical data (Ciruna et al. 2007). Data were transformed using the Wisconsin transformation prior to the MDS analysis to ensure that all feature classes were given equivalent weight (Legendre and Gallagher 2001). Multiple random starts were chosen to minimize the probability that the model converged on local minima and Euclidean distance was used to describe the differences between points.

The axes from Table 3.2.1 were input into a hierarchical cluster analysis to identify the natural groupings of rivers based on environmental data inputs. The cluster analysis works by first grouping watersheds into small pre-clusters, containing rivers that are more similar to each other than to the rest of the river systems in the analysis (typically two or three rivers). Then, an iterative top-down process is used to sequentially partition broadly similar rivers (i.e. very large clusters) into smaller and smaller groupings, while maintaining the original pre-clusters. The groupings are based on the degree of dissimilarity among rivers (i.e. how different they are from each-other based on all the environmental data). This approach combines the strengths of top-down (i.e. partitioning data into smaller and smaller groups) and bottom-up (i.e. amalgamating data into larger and larger groups) clustering methods. It is recognized as the most efficient analysis for large data sets and it effectively handles both categorical and continuous data (Ciruna et al. 2007). To determine the significance of the identified clusters, a discriminant function analysis (Legendre and Legendre 1983) was done on the identified watershed groupings. This analysis determines how well watersheds can be re-assigned to their identified cluster based on their environmental characteristics by contrasting the variation within and among identified groups.

Watershed Groupings

The hierarchical cluster analysis identifies three major groups of rivers in the Southern Upland region (Table 3.2.2), and the height of the joins suggests that the third group is more divergent from the other two (Figure 3.2.1). There is a geographical separation of the first and third groups, where the first grouping consists of watersheds located exclusively in Southwestern Nova Scotia (SFA 21) and the third group consists of watersheds located predominantly along the Eastern Shore (SFA 20) (Figure 3.2.2). The second group is interspersed in both regions, but tends to include rivers that are closer to the coast.

The results of the discriminant function analysis indicate that there are highly significant (p-value <<0.001) differences among group means along the various axes, based on multivariate goodness-of-fit statistics (Table 3.2.3). Cross validation of the results using the leave-one-out method (i.e. predicting how well a particular watershed can be re-assigned to a given cluster based only on its environmental characteristics) resulted in a low overall misclassification rate of 11%. All 24 watersheds in group 1 were correctly classified, and only one (out of 27) was incorrectly classified for group 3. Group 2 had the highest misclassification rate, with six watersheds misclassified as group 1 and one watershed misclassified as group 3 (out of a total of 21). Taken together, these results suggest that there are significant differences among the identified watershed groupings, and that there are more similarities between group 2 and group 1 watersheds than group 2 and group 3.

It is important to keep in mind that these clusters are completely dependent on the data inputs. In other words, considering additional or different environmental variables, as well as more or fewer feature classes within a variable, could affect the particular watersheds contained in the predicted number of clusters (Venables and Ripley 2002). Also, because MDS analyses are iterative and stop once the solution has reached acceptance criteria for convergence, the ordination (i.e. axes) obtained are not unique and subsequent analyses on the same data could result in a slightly different solution (Holland 2008). Therefore, the watershed groupings should not be considered fixed in the sense that no other groupings are possible. However, the cluster analysis is a meaningful way of grouping landscape-level patterns and demonstrates that all watersheds in the Southern Upland region cannot be considered equivalent in terms of protecting the biological diversity of Atlantic salmon populations.

3.3 Recovery Targets for Distribution: Identifying and Grouping Genetic Variation

O'Reilly et al. (2012) used 17 microsatellite loci from sample collections in 11 rivers in the Southern Upland to characterize within-population genetic variation of Southern Upland Atlantic salmon, as well as to quantify present-day genetic structuring within the DU. Such information can be used to prioritize among these 11 populations during recovery planning and gives an indication of the relative magnitude of genetic differentiation throughout the region. The specific rivers surveyed were distributed throughout the Southern Upland (Figure 1 in O'Reilly et al. 2012) and most samples were collected from electrofishing at multiple sites during the years 1999 to 2002 (Table 1 in O'Reilly et al. 2012). Samples collected from the populations in the Nashwaak River in the outer Bay of Fundy, the Kedgwick River in the Gulf region, and the Stewiacke and Gaspereau rivers in the inner Bay of Fundy were included in the analysis in order that the Southern Upland results could be interpreted in the context of the variation observed among populations in different regions (O'Reilly et al. 2012).

Within-population genetic variation was lower in populations from the Southern Upland region than in the populations from the Gulf or outer Bay of Fundy regions in terms of allele richness, gene diversity and observed heterozygosity. However, there were differences in these measures among populations within the Southern Upland region as well, with Round Hill River being the most genetically depauperate (i.e. exhibiting the least amount of genetic variability - O'Reilly et al. 2012). Samples from the Medway River, St. Mary's River (two groups: total river collection from 2000 and East Branch collection from 2007) and Salmon River (Guysborough County) were the most variable, while the LaHave, Gold, Moser, West Branch of St. Mary's, and Country Harbour samples were intermediate, and the Salmon River (Digby County), Tusket and Musqudoboit were the least variable. It is interesting that the levels of within-population genetic variation in these latter three populations were similar to the levels in the reference populations from the inner Bay of Fundy. Overall, the observed levels of allelic richness and heterozygosity in Southern Upland populations suggest that they may be experiencing inbreeding depression or reduced survival and reproductive success, and have undergone recent population bottlenecks (Cornuet and Luikart 1996, Luikart and Cornuet 1999). Both of these results would be expected for populations at low abundance (O'Reilly et al. 2012).

Earlier studies or samples collected in the same rivers in varying years could be used to assess changes in the genetic characteristics of populations over time. Within-population genetic variation in the Salmon River (Digby County), LaHave, Gold, Country Harbour, and St. Mary's (2 groups: East and West Branches) from samples of parr collected in the early 1990s were analysed by McConnell et al. (1997). These samples had two loci in common with those analysed by O'Reilly et al. (2012) and could also be used for relative comparisons among rivers for the purpose of assessing changes in levels of genetic variation through time. Overall, gene diversity was similar among rivers assessed from both studies, indicating relatively little change in diversity over the time period encompassed by these two studies (this does not preclude the possibility that genetic diversity was lost prior to 1995). However, samples from Salmon River (Digby County) provide some evidence of a modest acceleration in the loss of genetic diversity for that population from the 1990s to 2000 based on the results in O'Reilly et al. (2012).

There is also some evidence that the levels of genetic variation exhibited by different groups of Atlantic salmon in the St. Mary's River are heterogeneous, with the East and the West branches showing different patterns over time. Comparing the results of McConnell et al. (1997) with those of O'Reilly et al. (2012), salmon in the East Branch of the St. Mary's River exhibit levels of gene diversity and allelic richness in 2007 that are similar to levels in 1990. However, the West Branch samples from 2007 exhibited significantly lower gene diversity and heterozygosity than either the East Branch samples in 2007 or the combined river samples from 2000 (Table 2 in the O'Reilly et al. 2012). Taken together, these results indicate that genetic variation (as measured at neutral markers) has declined on the West Branch of the St. Mary's River, and this reduction has occurred over three or four generations. These results suggest that salmon ascending the West Branch are somewhat reproductively isolated from salmon in the East Branch, and that the total number of spawners in the West Branch is quite small (O'Reilly et al. 2012).

Although most of the genetic variation was observed within populations (Table 2 in O'Reilly et al. 2012), there was some differentiation among populations in the Southern Upland region as well (Table 3 in O'Reilly et al. 2012). Round Hill River was the most genetically divergent, although, as described by O'Reilly et al. (2012), it is possible that this represents rapid genetic drift at low population size rather than a pattern arising from long-term genetic isolation (i.e. genetic changes resulting from the combined influence of mutation, genetic drift, gene flow and selection). For other rivers, the amount of genetic variation among populations was similar to that seen over similar geographic scales (McConnell et al. 1997, King et al. 2001, Vandersteen Tymchuk et al. 2010). In general, populations clustered into two relatively distinct groups corresponding to populations in Southwest Nova Scotia (SFA 21) and the Eastern Shore (SFA 20) (Figure 3 in O'Reilly et al. 2012). Genetic similarities among populations in Southwest Nova Scotia closely parallel the geographic locations of these populations based on coastal distance. This would suggest a reduction in stray rates among populations with increasing coastal distance and/or decreased spawning success of strays along an environmental gradient, possibly reflecting local adaptation among rivers (O'Reilly et al. 2012). A similar geographic pattern is not evident for populations from the Eastern Shore, although salmon in the St. Mary's, Country Harbour, and Salmon River (Guysborough County) rivers may constitute a second major grouping. Overall, Musquodoboit and Moser rivers are genetically differentiated from all the other populations (see Figures 2 and 3 in O'Reilly et al. 2012).

3.4 Setting Recovery Targets for Distribution

Distribution targets are harder to define quantitatively than abundance targets for Southern Upland Atlantic salmon because the amount of population-level variation and the contribution from straying that are necessary to ensure long-term persistence of Atlantic salmon in the DU have not been quantified. Historically, Southern Upland Atlantic salmon have been widely distributed within the region (see Section 2.1 in Bowlby et al. 2013) and there is no information that suggests they did not use all available freshwater habitats at least intermittently. However, it is impractical to assume that populations need to be restored in all watersheds in the Southern Upland region. During recovery planning, decisions will need to be made relative to the perceived degree of risk of how many watersheds constitute an acceptable distribution target. From a biological perspective, the following criteria can be used to help prioritize among river systems when setting distribution targets: current population size, complexity (in terms of population life history, local adaptation and genetic distinctiveness), connectivity with surrounding populations (metapopulation structure), and the number and location of source populations (DFO 2008).

Theoretical Basis for Maintaining Variation

There is population and genetic structuring within the Southern Upland region (refer to Section 3.3), which means all populations of Atlantic salmon cannot be considered equivalent. Further, each population has the potential to contribute genetically and/or demographically to the long term persistence of Southern Upland Atlantic salmon (and possibly the species itself) so it is intrinsically important. Preserving the maximum amount of genetic variation that is practical will maximize the evolutionary potential (Fraser 2008, Wood 2001) of Southern Upland Atlantic salmon, meaning that the DU as a whole will have the greatest ability to respond or adapt to environmental change, as well as the greatest chance of re-colonizing rivers that have been extirpated. Genetic variation has also been linked to population persistence (i.e. lower extinction risk as genetic variation increases) and the ability to increase in size following catastrophic events (Willi and Hoffmann 2009). This suggests that preserving populations with varying genetic characteristics will be important for recovery. If populations were prioritized for recovery based on within-river genetic variation, the Medway, St. Mary's (East Branch) and Salmon River (Guysborough County) rivers would all contain important populations as they exhibit the highest levels of allele richness (O'Reilly et al. 2012). If populations were prioritized based on genetic divergence, the Moser and Musquodoboit rivers would become important given their relative differentiation from other populations in the Southern Upland (O'Reilly et al. 2012). When prioritizing populations, it is important to keep in mind that the genetic analysis presented in Section 3.3 was based on neutral genetic markers. Although the differences described among populations in the Southern Upland are important and merit consideration, they do not necessarily reflect genetic variation in adaptive traits (e.g. life history variation) among populations.

Second, local adaptation among populations is thought to result primarily from environmental heterogeneity (i.e. habitat variation), and to be maintained by the homing behaviour of Atlantic salmon (Fraser et al. 2011). Therefore, preserving or re-establishing populations in rivers with a wide range of environmental characteristics would be expected to maximize the amount of adaptive genetic variation maintained within the Southern Upland region. This should result in the benefits described above, e.g. minimizing extinction risk or increasing evolutionary potential of Atlantic salmon in the DU. There were three main groups of rivers identified on the basis of environmental variation in Section 3.2. At a minimum, all three groups should be represented in the distribution target for Southern Upland Atlantic salmon, but choosing populations representative of the six smaller groupings identified in the cluster analysis would further increase the diversity maintained. Although local adaptation is not thought to be as important as genetic drift and reproductive isolation in leading to genetic variation in neutral markers, it is interesting to note that both the genetic data and the cluster analysis of watershed characteristics suggest a general divide between populations found in Southwestern Nova Scotia and those found along the Eastern Shore. In addition, the St. Mary's, Country Harbour, and Salmon River (Guysborough County) watersheds are closely clustered based on watershed characteristics (Figure 3.2.1), as well as genetics analyses. This suggests that local adaptation to environmental characteristics may have contributed to the genetic structuring (as measured by neutral markers) of populations in the Southern Upland.

Third, metapopulation structure is known to be an important consideration in the conservation of salmonids (Cooper and Mangel 1999). Having multiple populations rather than a single large population can increase regional persistence (Hanski 1998), even if straying rates among the smaller populations are very low (Legault 2005). Stray rates calculated from the historical tagging data (Section 2.3 in Bowlby et al. 2013) are quite low (< 1%) for Southern Upland Atlantic salmon (data not shown). However, the probability of long-term persistence would still be expected to increase as the number of rivers in which salmon are recovered is increased. Furthermore, a distribution target that includes some or many of the larger rivers (which can support larger populations) would aid in the re-establishment of populations in other rivers. It is generally accepted that larger rivers are better source populations for emigration and colonization than are smaller rivers, a result that has been demonstrated for populations in the inner Bay of Fundy (Fraser et al. 2008). In addition, the larger rivers typically contain larger populations and these tend to be more genetically variable. Large river systems are distributed throughout the Southern Upland (Figure 2.1.1 in Bowlby et al. 2013) and also tend to be those with remaining wild Atlantic salmon populations (Table 2.1.2 in Bowlby et al. 2013), which makes them good candidates for inclusion into the distribution target.

If the short-term distribution target were to include all rivers identified as high priority for freshwater habitat allocation (Figure 4.4.1 in Bowlby et al. 2013), this would satisfy many of the criteria mentioned above in terms of preserving genetic variation, protecting larger populations, maintaining metapopulation structure and representing environmental variation. Longer-term goals might expand on this distribution target. It is expected that, as populations start to recover, the distribution target would need to be modified (either increased or decreased) depending on the dynamics of recovered populations to ensure persistence of Southern Upland salmon, as was recommended for inner Bay of Fundy Atlantic salmon (Gibson et al. 2008).

CONCLUSIONS

The available data strongly support the view that some populations of Southern Upland Atlantic salmon may have extirpated and that the largest populations are at very low abundance levels and continue to decline. This conclusion is consistent with adult abundance trends from both adult monitoring and the recreational catch data, as well as for the region-wide assessments of juvenile density. The adult trends and juvenile surveys presented here are also consistent with previous modeling results that predicted population extirpations resulting just from acidification (Korman et al. 1994) and from acidification and low marine survival (Amiro 2000). The estimated abundances of age-0, age-1 and age-2+ parr, and smolts are well below reference values for salmon populations in productive freshwater habitat, and the majority of juvenile life stages show strongly declining trends (> 80%) over the range of available data. Adult abundance remains well below the CRs established for the LaHave or St. Mary’s rivers and the estimated declines from the maximum abundances observed exceed 80% for the index populations and 99% for the other two populations. Regional abundance estimates for adults in the Southern Upland are extremely low: less than 8% of the summed river-specific CRs for Southern Upland rivers.

Consistent with the trends observed for adult salmon, recent region-wide electrofishing surveys for juvenile salmon in both 2000 and 2008/09 indicate very low salmon abundance in the majority of rivers in the Southern Upland. Data on juvenile abundance and distribution indicate extremely low juvenile density in the majority of rivers in the Southern Upland. No Atlantic salmon juveniles were observed in 33 out of 54 rivers in the 2008/09 survey. The adult abundance data, the recreational catch data and the results from the two regional electrofishing surveys, together demonstrate the continued decline in abundance and distribution of Atlantic salmon populations throughout the Southern Upland.

The analyses of trends indicate substantial declines in abundance over the preceding three or four generations for adult populations, with a corresponding decline in juvenile abundance in fresh water. For the three populations included in the trends analyses that also had a substantial stocking program, increasing contributions from hatchery smolts during the 1980s and 1990s did not prevent substantial population decline.

Recovery targets for Southern Upland Atlantic salmon populations can be defined in terms of an abundance component and a distribution component. Here, the use of the river-specific CRs as abundance targets (an approach that is consistent with their use as a limit reference point in the precautionary framework) is proposed. Once recovery is underway for a given population, the recovery target for abundance will need to be revised when information about the dynamics of the recovering population is available. The distribution target for recovery should take into consideration the substantial variation in both the genetic characteristics of populations and the environmental variability among rivers. The rivers identified as high priority for freshwater habitat allocation would meet the goals of preserving genetic variation, protecting larger populations, maintaining metapopulation structure and representing environmental variation, making them an appropriate distribution target for recovery of Atlantic salmon in the Southern Upland DU.

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TABLES

Table 1.1.1. Summary of the electrofishing sites surveyed on the LaHave River in 2010, including catch and estimated density for the three age classes of juvenile salmon for sites above and below Morgan Falls.

Site		Date		Standard Area	Area Fished	Fry				Age-1				Age-2				Density (per 100 m2) Parr			Density (per 100 m2) Fry
Number	Name	marked	recap	m2	m2	M	C	R	Mort	M	C	R	Mort	M	C	R	Mort	Age-1+	Age-2+	total	Age-0+
LHav008	Main Stem	23-Aug		1456	3132	24	no recapture		1	7	no recapture		0	0	no recapture		0	2.2	0.0	2.2	7.7
LHav101	Main Stem	24-Aug		1061	2646	9	no recapture		1	41	no recapture		0	2	no recapture		0	18.0	0.9	18.9	4.0
LHav112	North River	25-Aug		607	1826	11	no recapture		0	6	no recapture		0	1	no recapture		0	4.6	0.8	5.4	8.4
LHav114	Ohio River	27-Aug		900	847	57	no recapture		0	27	no recapture		0	1	no recapture		0	14.0	0.5	14.5	29.5
Above Morgan Falls																		9.7	0.5	10.3	12.4
LHav006	North Branch	13-Sep			1660	10	no recapture		0	3	no recapture		0	1	no recapture		0	0.8	0.3	1.1	2.8
LHav104	Main Stem	13-Sep		1728	2133	5	no recapture		0	0	no recapture		0	0	no recapture		0	0.0	0.0	0.0	1.3
LHav105	West Branch	30-Jul		774	2911	51	no recapture		1	41	no recapture		0	1	no recapture		0	24.7	0.6	25.3	30.7
LHav106	West Branch	30-Aug		752	921	38	no recapture		2	28	no recapture		0	3	no recapture		0	17.4	1.9	19.2	23.6
LHav107	West Branch	05-Aug		768	1418	74	no recapture		2	42	no recapture		0	0	no recapture		0	25.5	0.0	25.5	44.9
Below Morgan Falls																		13.7	0.5	14.2	20.7
Overall Mean																		11.9	0.5	12.5	17.0

Notes:
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 1.1.2. Summary of the electrofishing sites surveyed on the St. Mary's River in 2010, including catch and estimated density for the three age classes of juvenile salmon for the East and West branches.

Site		Date		Standard Area	Area Fished	Fry				Age-1				Age-2				Using Efficiencies Density (per 100 m^2) Parr			Fry	Mark-recapture Density (per 100 m^2) Parr			Fry
Number	Name	marked	recap	m^2	m^2	M	C	R	Mort	M	C	R	Mort	M	C	R	Mort	Age-1	Age-2+	total	Age-0	Age-1	Age-2+	total	Age-0
STMR8510.8	Moose River	13-Aug		703	984	48	no recapture		0	9	no recapture		0	1	no recapture		0	3.0	0.3	3.3	16.0				
STMR854.2	McKeen Brook	18-Aug		783	560	0	no recapture		0	5	no recapture		0	2	no recapture		0	1.5	0.6	2.1	0.0				
STMR854.4	McKeen Brook	18-Aug		673	751	0	no recapture		0	10	no recapture		0	3	no recapture		0	3.5	1.0	4.5	0.0				
STMR863.1+2	East River St. Mary's	17-Aug		2733	1302	129	no recapture		4	46	no recapture		0	6	no recapture		0	3.9	0.5	4.5	11.0				
STMR867.1	Moose River	10-Aug		740	1004	44	no recapture		1	4	no recapture		0	0	no recapture		0	1.3	0.0	1.3	13.9				
STMR867.2	Moose River	10-Aug	13-Aug	808	676	38	22	11	1	13	10	6	0	1	0	0	0	3.8	0.3	4.1	11.0	2.7	0.2	3.0	9.4
East Branch Means																		2.8	0.5	3.3	8.7	2.7	0.2	3.0	9.4
STMR855.1	Indian Man Brook	09-Aug	11-Aug	485	754	34	52	9	3	26	31	13	0	0	1	0	0	12.5	0.0	12.5	16.4	12.7	0.4	13.1	38.5
STMR858.1	Mitchell Brook	11-Aug		380	277	4	no recapture		0	24	no recapture		0	0	no recapture		0	14.8	0.0	14.8	2.5				
STMR859.4	West River St. Mary's	12-Aug		3104	1591	12	no recapture		0	11	no recapture		0	1	no recapture		0	0.8	0.1	0.9	0.9				
STMR925.1+2	Barren Brook	09-Aug	12-Aug	521	482	12	18	3	1	16	16	9	0	1	1	0	0	7.2	0.4	7.6	5.4	5.5	0.8	6.3	12.0
STMR928a	Nelson River	16-Aug	19-Aug		670	35	48	17	0	27	15	5	0	2	1	0	0	9.4	0.7	10.1	12.2	11.1	0.9	12.0	14.6
STMR004	South Brook	20-Aug			471	4	no recapture		1	5	no recapture		0	0	no recapture		0	2.5	0.0	2.5	2.0				
STMR034a	Archibald Brook (Glencross)	19-Aug			308	12	no recapture		0	14	no recapture		0	0	no recapture		0	10.6	0.0	10.6	9.1				
West Branch Means																		8.3	0.2	8.4	6.9	9.8	0.7	10.5	21.7
Overall Mean																		5.8	0.3	6.1	7.7	8.0	0.6	8.6	18.6

Notes:
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).

Table 1.1.3. Summary statistics for the densities of ‘Age-0’ and ‘Age-1 and older’ Atlantic salmon (number per 100 m^2) estimated by electrofishing on Nova Scotia’s Southern Upland rivers during 2008/09. A catchability coefficient (0.428) has been applied to the calculation of density. N is the number of electrofishing sites.

Year 2008/09		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	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 (Porters 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 Bk	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Gegogan Bk	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Gold	7	1.23	2.00	0.00	4.53	0.00	2.18	2.87	0.00	6.15	0.00
Granite Village	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
Kirby	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	2.92	2.58	0.00	5.82	1.76	2.71	2.82	0.00	9.06	2.57
Little East	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	2.69	3.71	0.00	8.09	1.34	1.41	1.74	0.00	3.56	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	2	0.29	0.05	0.25	0.32	0.29	1.85	0.12	1.77	1.94	1.85
Moser	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	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	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 (Lake Echo)	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 Bk	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 Bk	1	0.00	NA	0.00	0.00	0.00	0.00	NA	0.00	0.00	0.00
West River, Sheet Hbr	7	0.05	0.12	0.00	0.32	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
Indian Harbour Lakes	3	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	0.00	0.00	0.00	0.00	0.00
Country Harbour	3	4.49	5.32	0.00	10.37	3.11	3.86	4.51	0.00	8.82	2.76

Table 1.2.1. The estimated production (90% CI), density and return rate of wild smolts (as calculated directly from the monitoring data) for the LaHave River (above Morgan Falls) Atlantic salmon population from 1996 to 2010.

	Wild Smolts			
	Estimate	Per 100 m^2	Return Rate	
Year			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%	0.16 %
2008	14,450 (13,500 - 15,500)	0.55	1.16%	0.30%
2009	8,644 (7,763 - 9,659)	0.33	3.47%	
2010	16,215 (15,160 - 17,270)	0.62		

Table 1.2.2. The estimated annual wild smolt production and smolt wheel efficiency on the West Branch of the St. Mary's River during 2005 to 2009.

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
2009	0.026	14820	8600***	28001***	0.68

Notes:
** two wheels were deployed side-by-side.
*** 95 % CI.

Table 1.3.1. Age and size composition of wild adult Atlantic salmon sampled at Morgan Falls on the LaHave River, May to October, 2010. Age is shown as years to smolt (fresh), post-smolt years (sea) and ages at previous spawnings (s1,s2).

	Age				Fork Length (cm)					Weight (kg)				
Origin	Fresh	Sea	s1	s2	Number	Mean	Min.	Max.	Std. dev.	Number	Mean	Min.	Max.	Std. dev.
Wild														
	2	1			236	54.0	48.0	62.0	22.1	236	1.9	1.3	2.6	0.3
	3	1			53	55.3	50.2	61.0	25.5	53	2.0	1.4	2.6	0.3
	4	1			2	58.6	55.7	61.5	29.0	2	2.4	1.9	2.8	0.5
	2	2	1		3	58.8	57.4	61.5	19.1	3	2.2	1.9	2.7	0.3
	2	2			45	72.5	68.5	78.0	23.6	45	4.8	3.7	7.0	0.6
	3	2			1	77.3	77.3	77.3	0.0	1	6.3	6.3	6.3	0.0
	2	3	1		3	73.3	72.0	74.0	9.4	3	4.8	4.5	5.2	0.3
	3	3	1		1	73.6	73.6	73.6	0.0	1	4.7	4.7	4.7	0.0
	2	4	2		2	85.8	83.2	88.4	26.0	2	8.9	8.0	9.7	0.9

Table 1.3.2. Adult escapement estimates based on mark-recapture seining experiments on the West Branch of the St. Mary's River from 1997 to 2010. Estimates from years where a single seining event was conducted are shown in bold type, and escapement was 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	39.20	0.076
2009**				114		
2010***	23	36	9	90	25.76	0.256

Notes:

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

** Seining was unsuccessful in 2009. The ratio of escapement estimates for the West Branch of the St. Mary's relative to the LaHave River above Morgan Falls for the past 5 years ranges from 0.40 – 0.64 (mean 0.52). Under the assumption that this ratio is the same in 2009, the escapement estimate for 2009 for the West Branch of the St. Mary's River is 114 adult salmon.

*** The mortality that occurred during the marking pass was accounted for when estimating escapement.

Table 1.3.3. Age, spawning history, and fork length of adult salmon seined from the West Branch of the St. Mary's River in 2010. 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	26	16	55.4	51.5	63.5	54.6	48.5	48.1
2 sp 1		1		59.0		59.0		59.0
2		6		73.4		78.0		69.0
3 sp 2	1		68.1		68.1		68.1	

Table 1.3.4. Estimated escapement of adult Atlantic salmon relative to the conservation requirement (CR) in the West Branch of the St. Mary's River for the years 1997 to 2010.

Year	1SW	MSW	% CR
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
2009	96	15	6
2010	76 [a] 171 [b]	14 [a] 15 [b]	3 [a] 6 [b]

Note:
[a] Mark-recapture population estimate.
[b] Ratio of escapement estimates.

Table 1.3.5. Recreational catch and effort data for grilse (fish < 63 cm fork length) and salmon (fish > 63 cm fork length) in the Southern Upland for the last five year period. Rivers that were open to angling in at least one of the years are included. No rivers were open for recreational angling in 2010. Mandatory release of all large salmon has been in effect since 1984.

	2009 (Preliminary)				2008				5-Year Mean (2004-2008)							
	Grilse		Salmon	Effort	Grilse		Salmon	Effort	Grilse				Salmon		Mean Effort	
	Retained	Released	Released	Rod-days	Retained	Released	Released	Rod-days	Retained	95% CI	Released	95% CI	Released	95% CI	Rod-days	95% CI
SFA 20: EASTERN SHORE																
Country Harbour				River Closed					0	N/A	0	N/A	0	N/A	1.6	N/A
East: Sheet Harbour	0	0	0	0	0	0	0	0	0	0	0	0	0.3	0.8	4.2	4.9
Ecum Secum	0	0	3	7												
Guysborough				River Closed					0	N/A	1.3	N/A	0	N/A	1.3	N/A
Moser				River Closed					0	N/A	0.9	N/A	0	N/A	3.3	N/A
Musquodoboit	0	0	0	41	0	10	10	34	0	0	16.1	13.9	5.2	4.1	67.6	60.5
St. Francis				River Closed					0	N/A	6	N/A	1.5	N/A	3	N/A
St. Mary's	0	65	51	301	0	247	72	488	0.9	1.7	144.5	135.8	50	46.9	357.1	283.6
Salmon: Guysborough Co.	0	17	20	44	0	2	0	43	0.3	0.9	16.8	19.9	7.5	7.5	50.7	28.2
SFA Totals :	0	82	75	393	0	259	82	564	1.2	2.5	179.2	127.2	63.4	44	482	331.1
SFA 21: SOUTHERN UPLANDS																
Clyde	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.8	1.5
Gold				River Closed					0	N/A	0	N/A	0	N/A	1.3	N/A
Jordan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lahave	0	38	14	311	0	29	12	209	0	0	124.1	86	39.1	28.9	421.3	191
Medway				River Closed					0	N/A	0.7	N/A	0	N/A	2.2	N/A
Mersey	0	0	0	0	0	0	0	0	3.7	9.3	0.5	1.5	1.8	3.1	101	240
Middle: Lunenburg Co.				River Closed					0	N/A	1.5	N/A	0	N/A	3.1	N/A
Mushamush	0	0	0	0	0	0	0	0	0	0	0.9	1.7	0	0	2.3	4
Petite Riviere	0	3	0	31	0	2	5	7	0	N/A	6.3	N/A	3.8	N/A	20.1	N/A
Sackville	0	7	0	79	0	0	0	7	0	0	2.1	3.4	0	0	29.2	18.6
Tusket	0	0	0	0	0	0	0	0	0	0	1	2.8	0.7	1.9	14.7	33.3
SFA Totals :	0	48	14	420	0	31	17	223	3.7	9.3	132	88.5	43.1	27.4	579.9	296.6

Table 1.3.6. Total spawning escapement for the Southern Upland region (SFA 20 and 21), as estimated from recreational catch data using the maximum likelihood model described in Amiro et al. (2008). The minimum and maximum values represent the 90% confidence limits from the model.

	1SW abundance		MSW abundance	
Year	minimum	maximum	minimum	maximum
1970	8660	15943	1833	3250
1971	6778	12477	1193	2116
1972	6860	12629	1307	2318
1973	8690	15998	1780	3156
1974	15711	28923	1768	3135
1975	5546	10209	1585	2811
1976	13548	24940	1155	2048
1977	13332	24544	2275	4035
1978	2258	4157	1605	2847
1979	13565	24973	1370	2429
1980	16555	30476	3349	5938
1981	18152	33417	3972	7043
1982	9249	17026	1477	2620
1983	4805	8845	1735	3077
1984	11282	20769	1214	2152
1985	15163	27913	6657	11805
1986	15809	29102	6505	11535
1987	17606	32412	3014	5345
1988	15716	28932	4130	7324
1989	17023	31338	4301	7626
1990	19286	35504	3306	5863
1991	5924	10905	1861	3300
1992	8680	15980	1520	2696
1993	8978	16529	2145	3804
1994	2071	3812	759	1346
1995	5721	10532	1634	2897
1996	9730	17911	2068	3667
1997	2544	4683	828	1468
1998	7623	10346	802	1127
1999	3367	4569	1011	1421
2000	5315	7213	779	1094
2001	2001	2716	1174	1650
2002	4479	6078	442	621
2003	2446	3319	1150	1617
2004	3314	4498	767	1078
2005	2467	3348	500	702
2006	4426	6006	918	1290
2007	3610	4900	407	572
2008	6279	8521	1139	1601
2009	1779	2414	604	849
2010	3176	4311	616	866

Table 1.4.1. Return rate estimates for the St. Mary's River (West Branch) Atlantic salmon population for 1SW and 2SW adults as calculated directly from the adult and smolt abundance data.

Smolt Year	Smolt Estimate	Returns		Return Rate	
		1SW	2SW	1SW	2SW
2005	7350	222	23	3.02%	0.32%
2006	25100	182	36	0.73%	0.14%
2007	16110	361	15	2.24%	0.09%
2008	15217	96	14	0.63%	0.09%
2009	14820	76[a] 154[b]		0.5%[a] 1.0%[b]	

Notes:
[a] Returns estimated from mark-recapture.
[b] Returns estimated from the ratio between recreational catch on the St. Mary's and LaHave rivers.

Table 2.1.1. 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 Morgan Falls, East River, Sheet Harbour, and the Liscomb River are based on total counts at a fishway. The values for the St. Mary's River (West Branch) population are derived from adult mark-recapture experiments and recreational catch data, as described in Gibson and Bowlby (2013).

	SFA 21		SFA 20					
	LaHave above Morgan Falls		East Sheet Harbour		Liscomb		St. Mary's West Branch	
Year	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				2,226	278
1975	504	73	89	4			305	93
1976	646	131	120	6			1,779	164
1977	1266	109	83	1			776	203
1978	842	276	13	3			256	164
1979	1920	166	19	0	60		1,951	112
1980	1973	777	53	6	111		2,527	257
1981	3047	592	59	1	76	6	1,454	461
1982	1420	486	5	0	252	10	959	103
1983	1156	313	59	3	520	15	994	339
1984	2293	420	66	4	606	48	1,284	384
1985	1445	715	26	1	507	87	1,999	1,551
1986	1724	662	9	2	736	117	1,969	1,712
1987	3102	611	46	4	1614	88	832	581
1988	3520	449	32	3	477	76	1,637	1,047
1989	2530	694	57	9	532	75	697	661
1990	2476	508	16	1	955	44	2,509	431
1991	604	326	31	5	586	38	1,149	400
1992	2489	273	22	4	145	27	377	243
1993	1158	205	33	1	134	11	1,251	715
1994	848	247	17	2	134	10	52	42
1995	948	228	27	2	150	6	627	192
1996	1130	196	11	1	85	9	1,002	297
1997	449	131	4	1	27	1	390	61
1998	919	137	1	0	9	0	1,059	41
1999	452	132	15	0	9	0	307	83
2000	794	120	1	0			315	25
2001	379	182	1	0			319	106
2002	1133	71	0	0			220	16
2003	437	207	1	0			600	122
2004	638	122	1	0			464	23
2005	416	84					192	8
2006	425	115					222	18
2007	341	41					182	23
2008	593	98	3 total*				361	36
2009	168	53	0				96	15
2010	300	53	1 total*				123	14

Note:
* count was not separated by size class.

Table 2.1.2. Summary of declines in adult Atlantic salmon abundance (large and small size categories combined) for four populations in the Southern Upland DU estimated using log-linear regression fit via least squares. Standard errors (for the slope) and 95% CI (for the declines) are provided in the brackets. Models were fit for two time periods: the last 15 years (corresponding to approximately three generations) and from the maximum abundance during the time period. The slope estimate corresponds to the 15 decline rate estimate. Data are provided in Table 2.1.1.

Fishing Area	Population	Number of Years	Time Period	Slope	15 Years	From Maximum
20	Liscomb	10	1989-1999	-0.805 (0.120)	98.2 (94.3, 99.8)	99.5 (98.5, 93.4)
20	East (Sheet Harbour)	15	1995-2010	-0.152 (0.061)	91.3 (40.3, 98.7)	99.1 (96.8, 99.7)
20	St. Mary's (West Branch)	15	1995-2010	-0.117 (0.024)	84.7 (67.1, 92.9)	93.9 (85.1, 97.5)
21	LaHave (above Morgan Falls)	15	1995-2010	-0.076 (0.018)	70.5 (47.4, 83.4)	88.7 (80.7, 93.4)

Table 2.1.3. Fits from the nested log-linear model considering age class as a factor to Atlantic salmon abundance or density estimates from populations in the West Branch of the St. Mary's River and the LaHave River above Morgan Falls. Two alternative display methods from a single model structure are shown: one that estimates separate slopes for each age class and one that calculates the deviate for each age class from the adult slope estimate. The decline rate in percent is given for each age class during the years 1990 to 2010, and significant values, as well as confidence intervals that do not include zero are shown in bold.

		Separate Slopes			Deviate from Adult Slope			Decline Rate (%)
River	Life Stage	Estimate	s.e.	p-value	Estimate	s.e.	p-value	(95% CI)
St. Mary's	adult	-0.102	0.024	**<0.001**				**88 (68, 96)**
St. Mary's	eggs	-0.124	0.024	**<0.001**	-0.023	0.034	0.506	**93 (80, 97)**
St. Mary's	age-0	-0.120	0.027	**<0.001**	-0.018	0.036	0.611	**92 (76, 97)**
St. Mary's	age-1	-0.042	0.026	0.105	0.060	0.035	0.092	59 (-19, 86)
St. Mary's	age-2	-0.122	0.028	**<0.001**	-0.020	0.037	0.577	**92 (76, 98)**
St. Mary's	total parr	-0.064	0.028	0.024	0.038	0.037	0.303	**74 (18, 92)**
LaHave	adult	-0.084	0.021	**<0.001**				**81 (57, 92)**
LaHave	eggs	-0.057	0.021	0.009	0.027	0.030	0.378	**68 (26, 86)**
LaHave	age-0	-0.082	0.022	**<0.001**	0.002	0.030	0.959	**81 (55, 92)**
LaHave	age-1	-0.090	0.024	**<0.001**	-0.006	0.032	0.857	**83 (58, 94)**
LaHave	age-2	-0.015	0.026	0.560	0.069	0.034	0.043	26 (-105, 74)
LaHave	total parr	-0.094	0.027	**0.001**	-0.010	0.034	0.765	**85 (56, 95)**

Notes:
Standard error (se).
Confidence interval (CI).

Table 2.3.1. Historical stocking of LaHave River above Morgan Falls, showing the estimated annual smolt output and the return rates of 1SW and 2SW hatchery adults in percent. The analysis presented in Amiro and Jefferson (1998) has been updated from 1998 to 2005 using data on juvenile stocking from the distributions database and the recreational tagging database (to calculate the expected number of juveniles stocked above Morgan Falls but recaptured below in the fishery). Return rates to both the mouth of the LaHave River and to Morgan Falls are given.

Year of release	age-0 parr number	age-1 parr number	age-1 smolt number	age-2 smolt number	Estimated hatchery smolt output[1]	Hatchery adult returns to Morgan Falls			Stocked above angled below Morgan Falls		Return rate % To LaHave River			Return rate % To Morgan Falls		
						1SW	2SW	Total	1SW	2SW	1SW	2SW	Total	1SW	2SW	Total
1970									0	0						
1971		9,440	4,892		4,892				104	32						
1972		6,790	8,400	6,450	18,626	138	19	157	353	63	2.64	0.44	3.07	0.74	0.10	0.84
1973	51,643*	43,133	9,166	18,526	30,408	442	62	504	514	56	3.14	0.39	3.53	1.45	0.20	1.66
1974	0	3,735	19,815	14,435	51,503	466	72	538	346	133	1.58	0.40	1.98	0.90	0.14	1.04
1975	0	18,883	0	0	13,888	468	34	502	471	51	6.76	0.61	7.37	3.37	0.24	3.61
1976	0	6,875	45,259	5,769	58,581	974	197	1171	387	61	2.32	0.44	2.76	1.66	0.34	2.00
1977	0	44,314	74,577	5,370	82,697	567	99	666	120	42	0.83	0.17	1.00	0.69	0.12	0.81
1978	0	7,108	72,067	0	89,793	1064	524	1588	480	45	1.72	0.63	2.35	1.18	0.58	1.77
1979	30,753*	0	33,910	0	36,753	336	184	520	61	95	1.08	0.76	1.84	0.91	0.50	1.41
1980	10,626*	0	62,225	16,039	78,264	1186	113	1299	556	86	2.23	0.25	2.48	1.52	0.14	1.66
1981	0	0	25,482	0	32,863	623	54	677	189	34	2.47	0.27	2.74	1.90	0.16	2.06
1982	0	0	0	0	2,550	25	33	58	5	11	1.18	1.74	2.92	0.98	1.29	2.27
1983	0	0	28,451	0	28,451	249	61	310	89	11	1.19	0.25	1.44	0.88	0.21	1.09
1984	32,900*	0	15,000	0	15,000	105	55	160	68	39	1.15	0.63	1.78	0.70	0.36	1.06
1985	10,804	0	4,996	0	4,996	133	55	188	32	13	3.30	1.37	4.66	2.66	1.11	3.77
1986	55,722	0	16,864	0	24,760	564	50	614	305	55	3.51	0.42	3.93	2.28	0.20	2.48
1987	19,650	0	33,353	0	35,946	1059	268	1327	291	59	3.76	0.91	4.66	2.95	0.74	3.69
1988	42,481	0	16,018	0	29,391	442	85	527	273	74	2.43	0.54	2.97	1.50	0.29	1.79
1989	0	0	30,004	0	34,720	592	69	661	309	88	2.60	0.45	3.05	1.71	0.20	1.90
1990	82,432	0	15,970	0	26,165	109	45	154	26	16		0.23	0.23	0.42	0.17	0.59
1991	83,223	0	21,943	0	21,943	617	79	696	156	27	3.52	0.48	4.01	2.81	0.36	3.17
1992	48,587	0	27,516	0	47,300	383	104	487	195	50	1.22	0.33	1.55	0.81	0.22	1.03
1993	44,512	0	19,748	0	39,722	207	77	284	21	18	0.57	0.24	0.81	0.52	0.19	0.71
1994	34,827	0	26,110	0	37,771	372	78	450	141	60	1.36	0.36	1.72	0.98	0.21	1.19
1995	0	0	19,155	0	29,838	396	58	454	251	73	2.17	0.44	2.61	1.33	0.19	1.52
1996	0	0	49,526	0	57,884	144	57	201	77	35	0.38	0.16	0.54	0.25	0.10	0.35
1997	0	0	25,261	0	25,261	200	38	238	0	0	0.79	0.15	0.94	0.79	0.15	0.94
1998	0	0	45,695	0	45,695	136	46	182	2	0	0.30	0.10	0.40	0.30	0.10	0.40
1999	0	0	41,639	0	41,639	292	78	370	0	0	0.70	0.19	0.89	0.70	0.19	0.89
2000	0	0	50,108	0	50,108	190	22	212	2	8	0.38	0.06	0.44	0.38	0.04	0.42
2001	0	0	93,543	0	93,543	710	104	814	8	17	0.77	0.13	0.90	0.76	0.11	0.87
2002	0	0	36,737	0	36,737	206	56	262	4	31	0.57	0.24	0.81	0.56	0.15	0.71
2003	0	0	50,870	0	50,870	325	41	366	3	10	0.65	0.10	0.75	0.64	0.08	0.72
2004	0	0	36,219	0	36,219	183	36	219	3	11	0.51	0.13	0.64	0.51	0.10	0.60
2005	0	0	1,880	0	1,880	7	6	13	0	0	0.38	0.34	0.72	0.37	0.32	0.69

Notes:
* Unmarked individuals.
[1] Mortality rates assumed to be 0.6 from age-0 to age-1 parr and 0.4 from from age-1 parr to age-2 smolt.

Table 2.3.2. Stocking data and counts of wild and hatchery adults from monitoring at Ruth Falls fishway on East River, Sheet Harbour, from 1976 to 2003. Return rates are for the hatchery component of the population and assume that the MSW fish observed at the fishway were essentially all 2SW. Adult count data are given in O'Neil et al. (1998) and smolt release data were updated from information in the distributions database.

	Smolts	Adult Returns							Return rate (%)	
Year of	released	Hatchery		Total	Wild		Total		1SW	MSW
release	year i	1SW	MSW	Hatchery	1SW	MSW	Wild	Total	yr(i+1)	yr(i+2)
1976	21,731	145	3	148	120	6	126	274		
1977	64,146	32	4	36	83	1	84	120	0.15	
1978	13,112	143	1	144	13	3	16	160	0.22	0.00
1979	17,009	70	10	80	19	0	19	99	0.53	0.02
1980	7,039	108	1	109	53	6	59	168	0.63	0.01
1981	3,980	46	4	50	59	1	60	110	0.65	0.02
1982	4,733	6	0	6	5	0	5	11	0.15	0.00
1983	7,107	35	4	39	59	3	62	101	0.74	0.10
1984	5,869	48	2	50	66	4	70	120	0.68	0.04
1985	9,592	5	1	6	26	1	27	33	0.09	0.01
1986	12,119	10	5	15	9	2	11	26	0.10	0.09
1987	13,397		3		46	4	50	352		0.03
1988	12,014	62	5	67	32	3	35	102	0.46	0.04
1989	15,676	72	8	80	57	9	66	146	0.60	0.06
1990	10,449	25	1	26	16	1	17	43	0.16	0.01
1991	21,449	7	1	8	31	5	36	44	0.07	0.01
1992	26,977	33	5	38	22	4	26	64	0.15	0.05
1993	26,575	57	1	58	33	1	34	92	0.21	0.00
1994	26,769	85	3	88	17	2	19	107	0.32	0.01
1995	36,933	96	4	100	27	2	29	129	0.36	0.02
1996	18,630	135	16	151	11	1	12	163	0.37	0.06
1997	22,147	14	1	15	4	1	5	20	0.08	0.00
1998	24,496	7	1	8	1	0	1	9	0.03	0.01
1999	22,026	16	2	18	15	0	15	33	0.07	0.01
2000	9,779	50	1	51	1	0	1	52	0.20	0.00
2001	18,621	3	1	4	1	0		5	0.03	0.005
2002	12,909	16	1	17	0	0		17	0.09	0.010
2003	14,300	16	0	16	1	0		17	0.12	

Table 2.3.3. Historical stocking of age-1 smolts in the Liscomb River plus the return rates of 1SW and MSW hatchery fish. Adult count data are given in O'Neil et al. (1998) and smolt release data were updated from information in the distributions database.

Smolt year i	Smolts Stocked	1SW returns (year i+1)	% 1SW returns	MSW returns (year i+2)	% MSW returns
1977	7,978				
1978	48,783	585	1.20	66	0.14
1979	57,745	1206	2.09	57	0.10
1980	26,907	287	1.07	47	0.17
1981	42,394	907	2.14	68	0.16
1982	43,860	622	1.42	42	0.10
1983	58,166	353	0.61	49	0.08
1984	52,098	194	0.37	109	0.21
1985	29,612	861	2.91	55	0.19
1986	22,919	585	2.55	44	0.19
1987	31,367	496	1.58	71	0.23
1988	48,404	305	0.63	22	0.05
1989	34,801	490	1.41	22	0.06
1990	22,388	189	0.84	12	0.05
1991	25,129	133	0.53	12	0.05
1992	36,831	134	0.36	8	0.02
1993	22,555	126	0.56	7	0.03
1994	28,220	106	0.38	5	0.02
1995	35,737	228	0.64	10	0.03
1996	27,460	46	0.17	1	0.00
1997	59,028	36	0.06	1	0.00
1998		15			
1999	56,047				
2000	17,396				

Table 3.2.1. The types of variables (group) and the feature classes within those variables used in the hierarchical cluster analysis to identify watershed groupings. The axes for variables with multiple feature classes were created from non-metric multidimensional scaling.

Group	Feature Classes	Axes
distance	perimeter length	distance1
	Area	distance2
	inferred flow length	
	stream length	
	total flow length	
	Inland water length	
topography	Mean slope	topo1
	max elevation	topo2
	min elevation	
	Mean elevation	
	standard deviation elevation	
	topographic roughness	
ecosections	proportion frequent class	eco1
	proportion gap class	eco2
	proportion infrequent class	
	proportion open seral	
surface geology	proportion alluvial	surface1
	proportion bedrock	surface2
	proportion colluvial	
	proportion glaciolacustrine	
	proportion glaciomarine	
	proportion hummocky morraine	
	proportion kame fields	
	proportion marine deposits	
	proportion none	
	proportion organic deposits	
	proportion outwash fans + deltas	
	proportion residuum	
	proportion silty drumlin	
	proportion silty till	
	proportion stony drumlin	
	proportion stony till	
bedrock geology	proportion granites	bedrock1
	proportion sandstone	bedrock2
	proportion slate + sandstone	
	proportion slates	
	proportion undefined	
	proportion other	
geographical proximity		Number
proportion of inland water		p.inland.water

Table 3.2.2. Watershed groupings identified from the hierarchical cluster analysis. River numbers are the same as those listed in Table 2.1.2 of Bowlby et al. (2013).

Group 1		Group 2		Group 3	
1	Annapolis/Nictaux	9	Salmon (Digby)	39	Sackville
2	Round Hill	12	Tusket	41	Salmon (L. Echo)
3	Le Quille	14	Barrington	42	Porters Lake (West Bk. + East Bk.)
4	Bear	21	Granite Village	44	Musquodoboit
5	Sissibo	23	Mersey	50	West (Sh Hbr)
6	Belliveau	24	Medway	51	East (Sh Hbr)
7	Boudreau	25	Petite	52	Kirby (Halfway Bk)
8	Meteghan	27	Mushamush	53	Salmon (P.D.)
10	Chegoggin	31	East (Chester)	54	Quoddy
11	Annis	33	Hubbards	55	Moser
13	Argyle	34	Ingram	56	Smith
15	Clyde	35	Indian	57	Ecum Secum
16	Roseway	37	Nine Mile	58	Liscomb
17	Jordan	38	Pennant	59	Gaspereau Bk
18	East (Lockeport)	40	Salmon (L Major)	60	Gegogan
19	Sable	43	Chezzetcook	61	St Mary's
20	Tidney	45	Salmon (Hfx)	62	Indian Harbour Lakes
22	Broad	46	Ship Harbour (Fish River - L. Charlotte)	63	Indian
26	Lahave	47	Tangier	64	Country Harbour
28	Martins	48	W Taylor Bay	65	Issacs Harbour
29	Gold	49	Little West (Grand Lake)	66	New Harbour
30	Middle			67	Larrys
32	Little East			68	Cole Harbour (Dickie Brook)
36	East (St. Margarets)			69	Salmon (Guys.)
				70	Guysborough
				71	Clam Harbour
				72	St. Francis Harbour

Table 3.2.3. Group means for the environmental variables considered in the hierarchical cluster analysis and the associated F-values and p-values from four multivariate tests for equivalency among group means.

	Group 1	Group 2	Group 3
number	0.385	0.505	0.870
p.inland.water	4.669	6.170	5.131
distance1	151.874	162.471	156.675
distance2	-274.009	-316.324	-299.923
topo1	1.981	7.687	-5.253
topo2	-117.039	-106.824	-113.525
eco1	-13.149	-13.020	-12.346
eco2	-10.638	-9.235	-14.171
surface1	5.929	-1.366	-10.539
surface2	-31.668	-22.623	-34.681
bedrock1	2.398	4.457	10.399
bedrock2	-12.339	-11.260	-10.486

	Statistics	F	df1	df2	Pr
Wilks' Lambda	0.0653	14.084	24	116	<< 0.001
Pillai Trace	1.4454	12.815	24	118	<< 0.001
Hotelling-Lawley Trace	6.4956	15.427	24	114	<< 0.001
Roy's Greatest Root	4.8984	24.084	12	59	<< 0.001

Notes:
F-Stat (F).
Degrees of Freedom 1 and 2 (df1 and df2).
Probability (Pr).

FIGURES

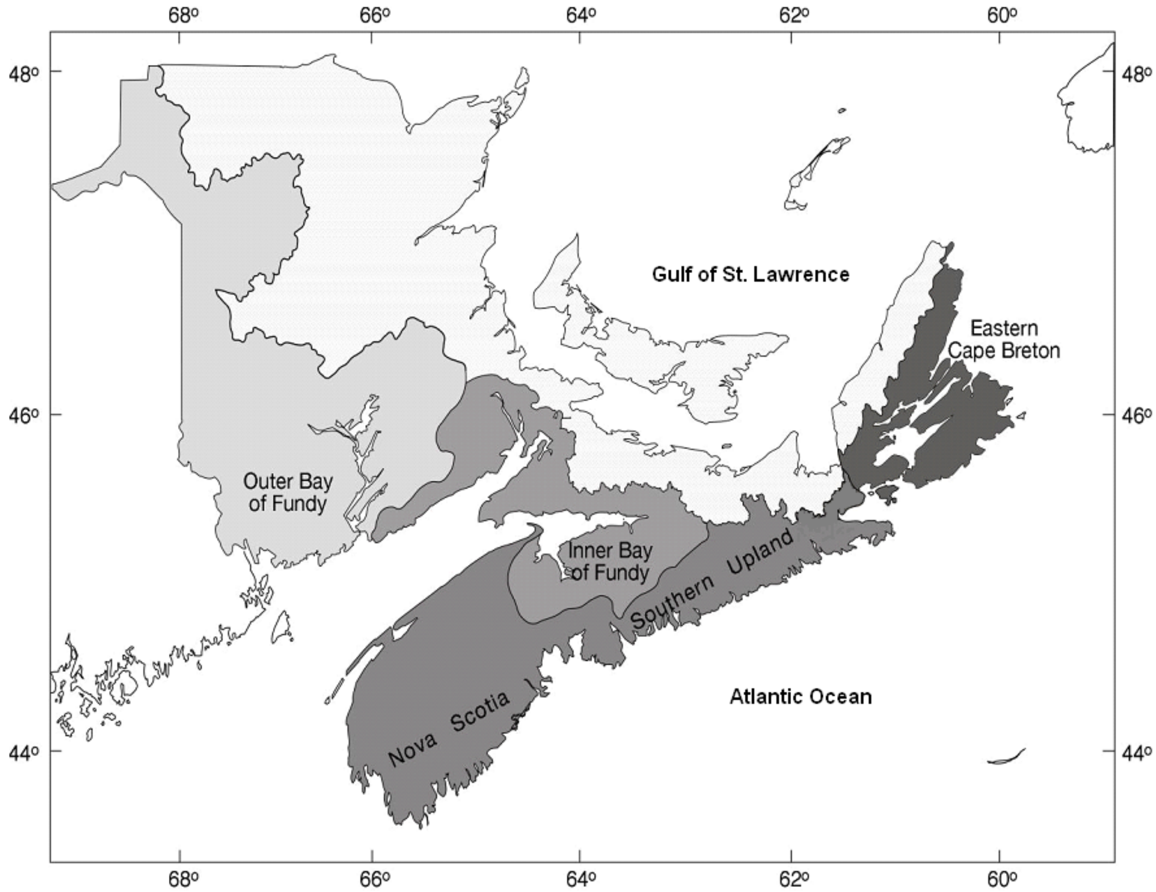

Figure 1. Map showing the location of the Southern Upland relative to the three other DUs for Atlantic salmon in the Maritimes.

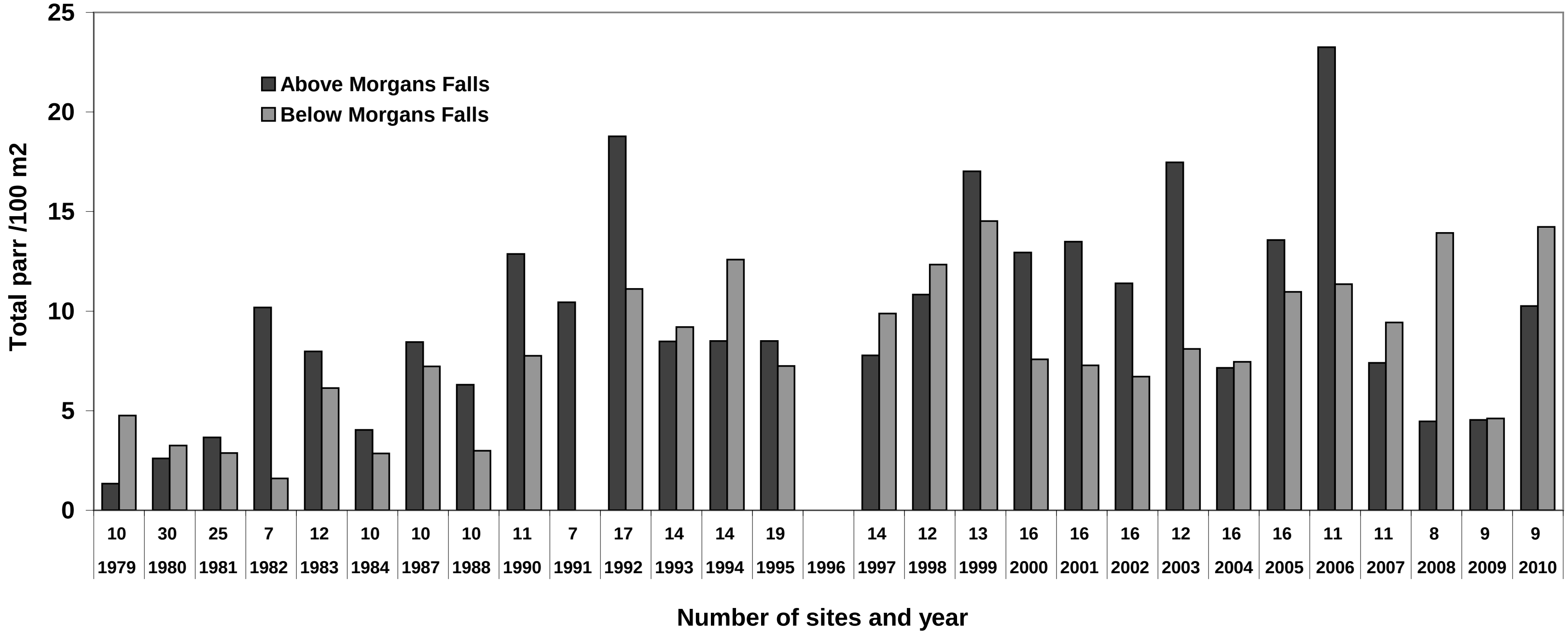

Figure 1.1.1. Total mean parr density (age-1 and age-2+) per 100 m^2 as determined by electrofishing in the LaHave River for the years 1979 – 1984, 1987, 1988, 1990 – 1995, and 1997 – 2010. The total number of sampling sites (above and below Morgan Falls) each year is listed immediately below the x-axis.

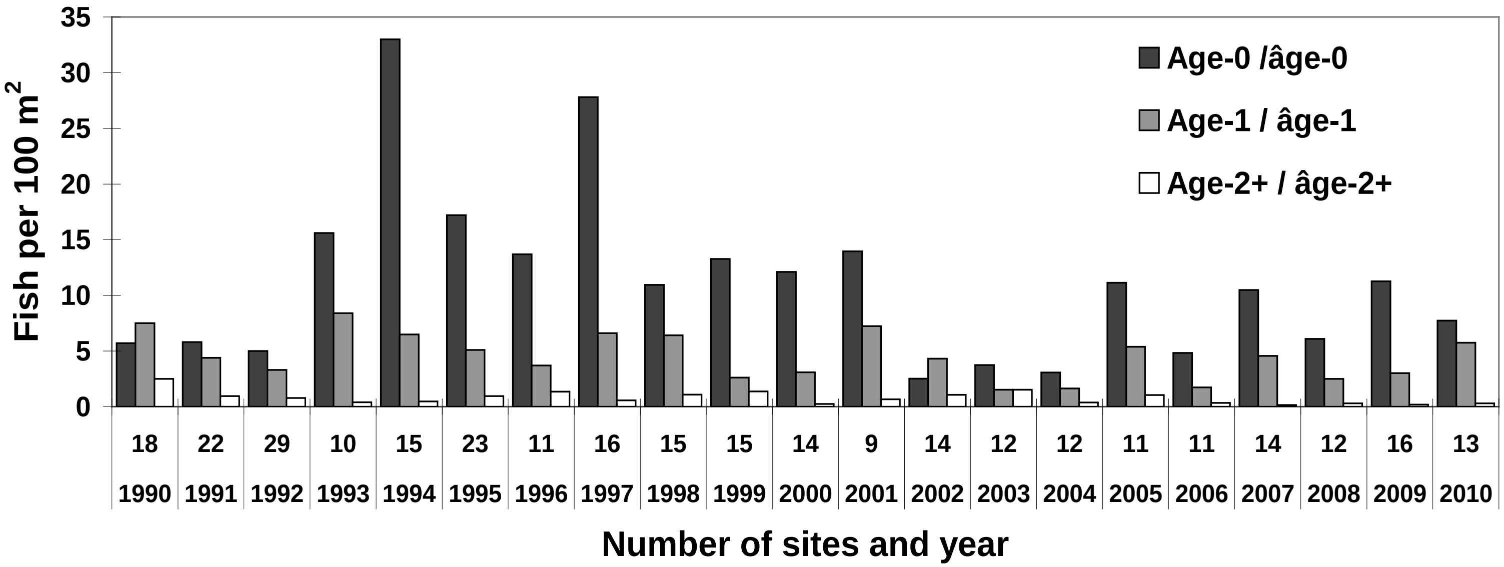

Figure 1.1.2. Mean density for the three age classes of juvenile salmon (age-0, age-1, and age-2+) in the St. Mary's River during 1990 to 2010 (East and West branches combined). The number of sampling sites on which the mean is based is listed immediately below the x-axis.

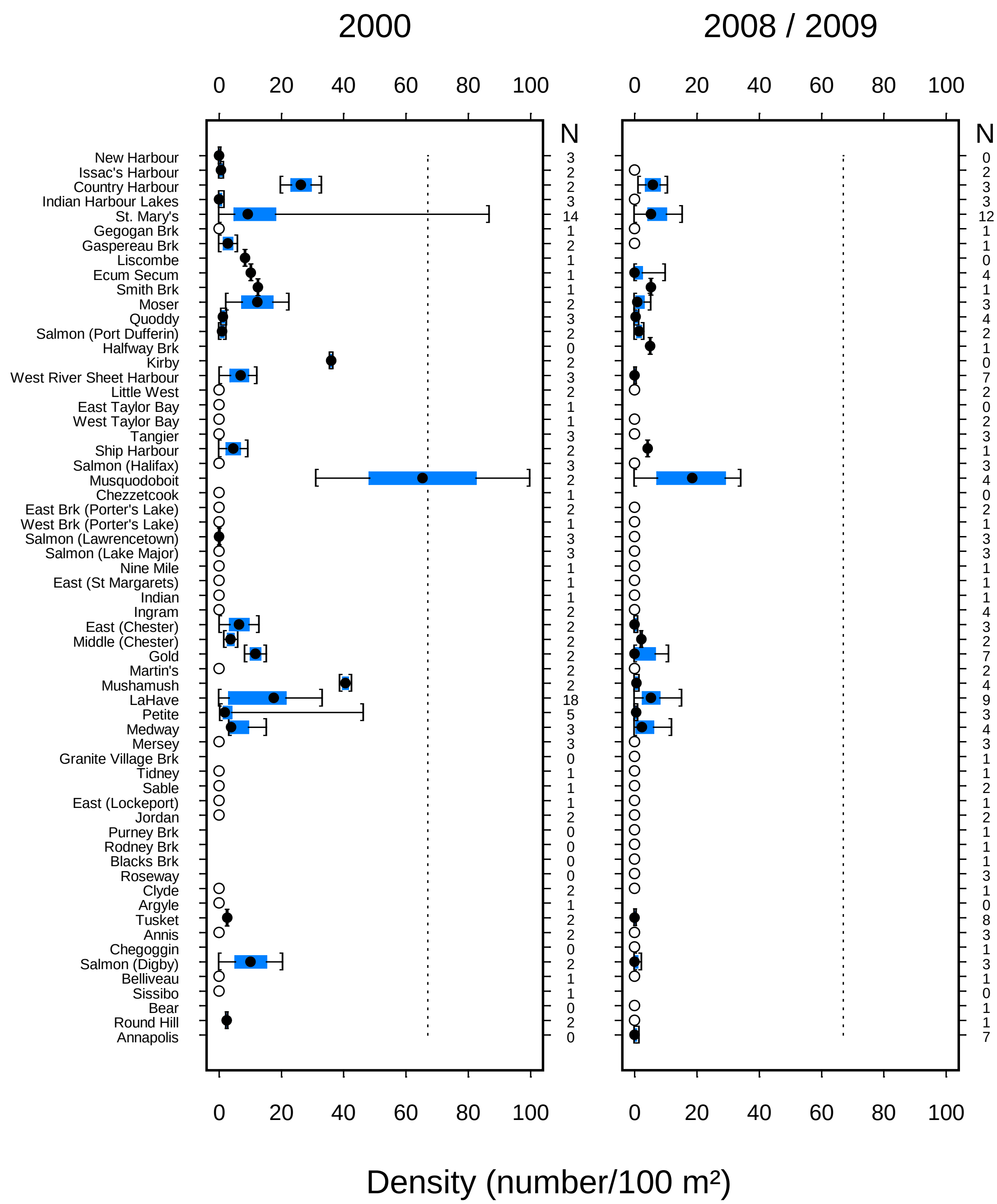

Figure 1.1.3. Boxplots of the median (and interquartile range) juvenile density (age-0, age-1, and age-2+ combined) at all rivers sampled by electrofishing during the survey in 2000 (left panel) and in 2008/09 (right panel). The number of sites fished in each river is given on the right-hand axis in both panels, and sites in which no salmon were captured are represented by open circles. The vertical dotted line shows Elson's norm for total juvenile abundance in both panels. Reprinted from Gibson et al. (2011).

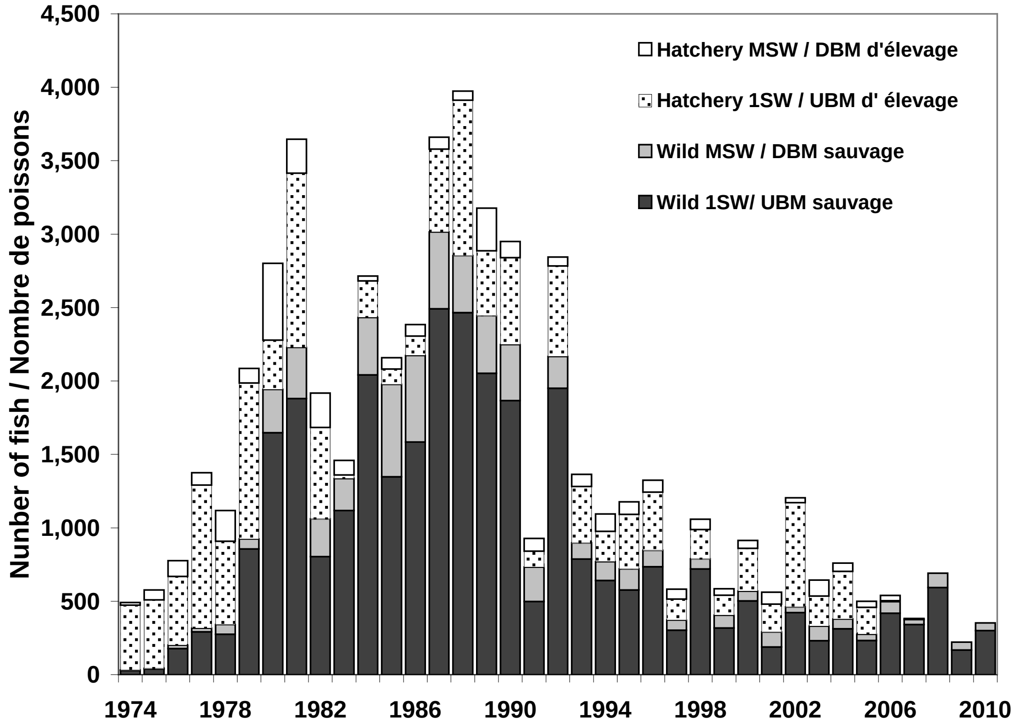

Figure 1.3.1. Counts of Atlantic salmon at Morgan Falls fishway on the LaHave River from 1974 to 2010, divided into the proportions of wild-origin and hatchery-origin 1SW and MSW adults.

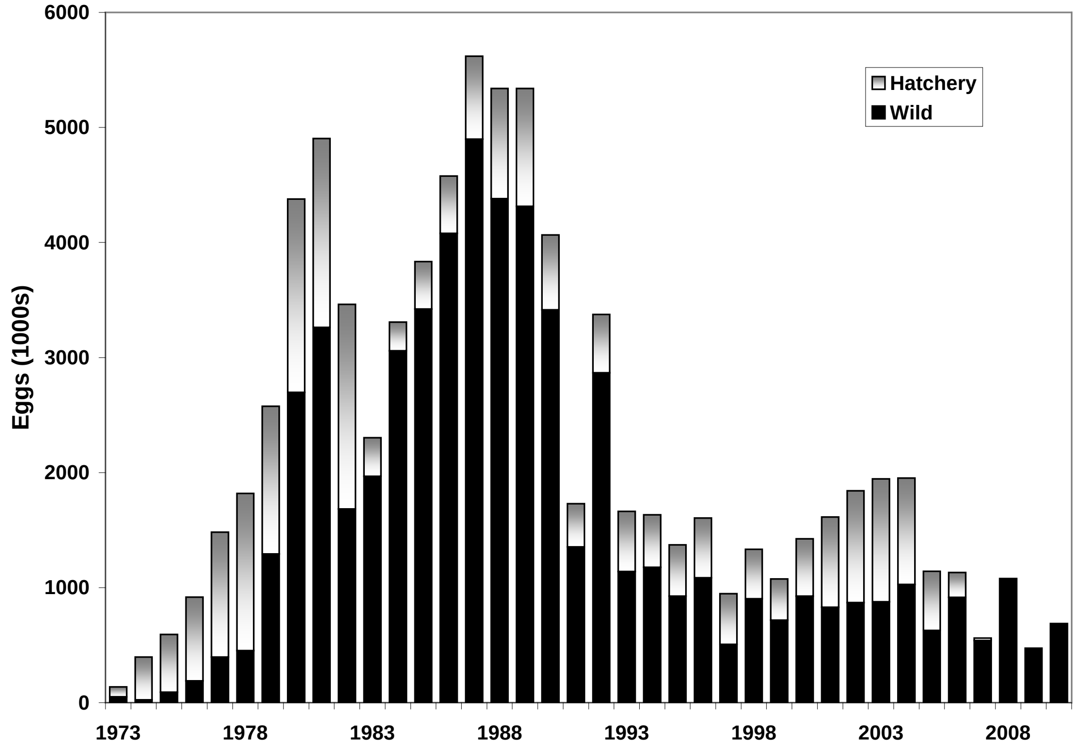

Figure 1.5.1. Estimated egg deposition (1000s) by wild and hatchery Atlantic salmon above Morgan Falls from 1973 to 2010. No adults of hatchery origin contributed to egg deposition in 2010.

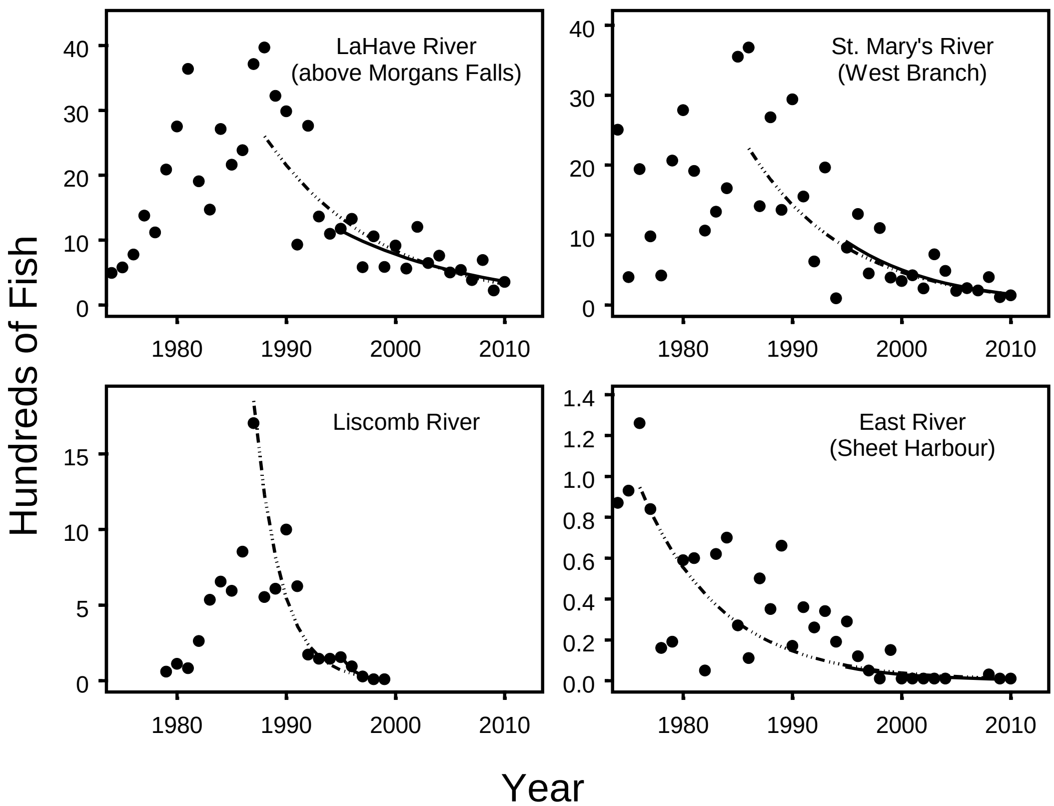

Figure 2.1.1. Estimated Atlantic salmon escapement from adult count data (points) for four rivers in the Southern Upland from 1974 to 2010. The lines show then trends estimated by log-linear regression over the previous three generations (solid lines) and from the maximum abundance (dashed lines).

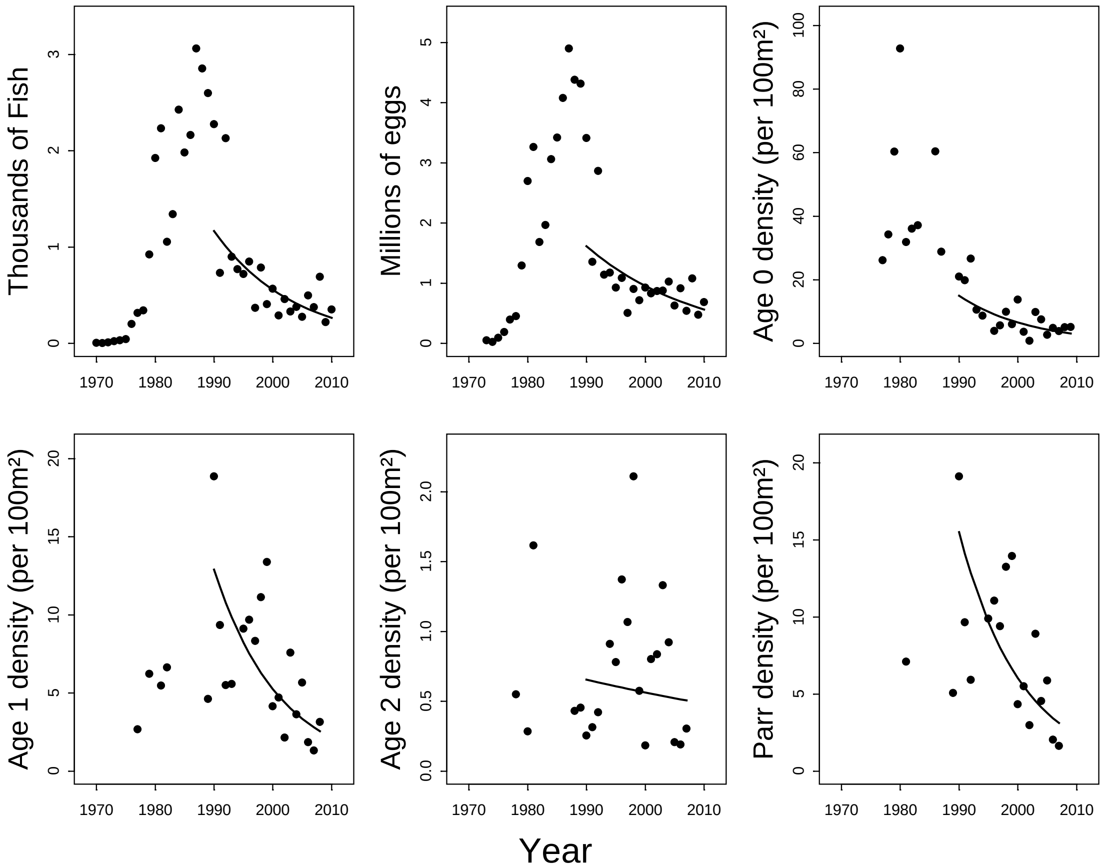

Figure 2.1.2. Adult abundance, egg deposition and juvenile density (separated by age class) of Atlantic salmon from the LaHave River above Morgan Falls. Points represent the available data for each life stage and lines represent the fit of a log-linear model spanning the years between 1990 and 2010. For comparison, data are lined up by adult cohort.

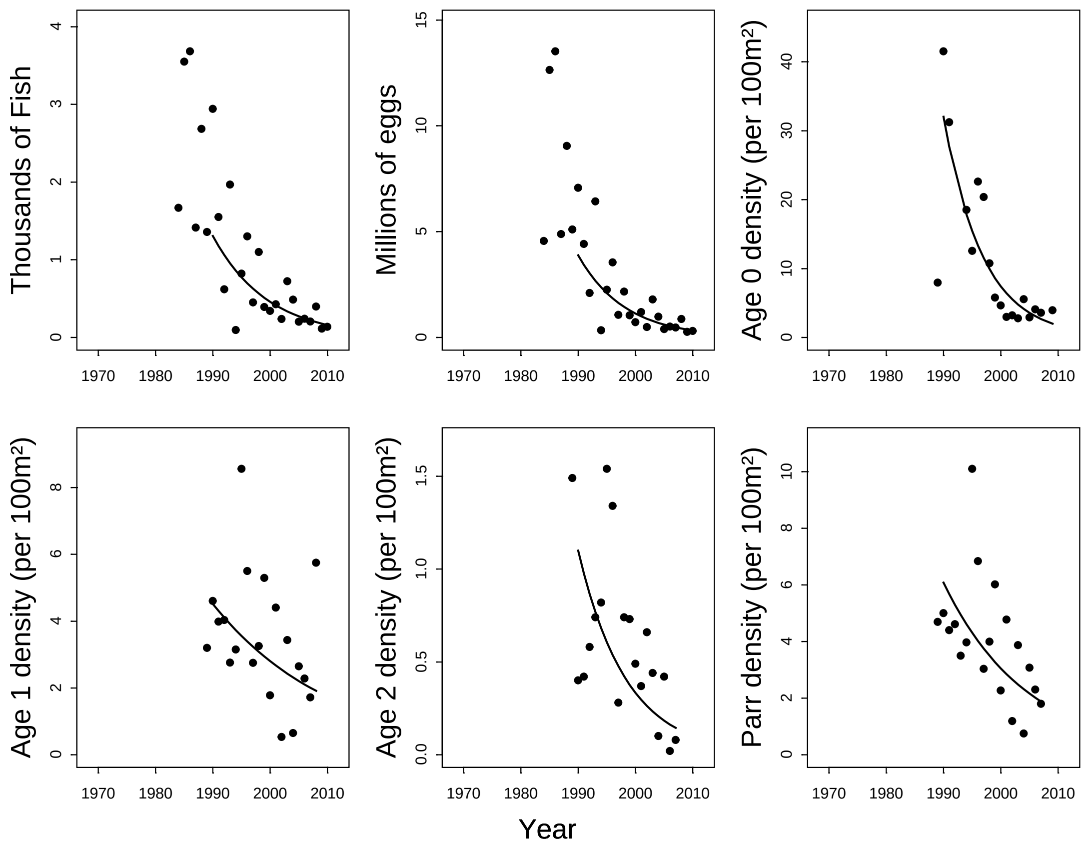

Figure 2.1.3. Adult abundance, egg deposition and juvenile density (separated by age class) of Atlantic salmon from the West Branch of the St. Mary's River. Points represent the available data for each life stage and lines represent the fit of a log-linear model spanning the years between 1990 and 2010. For comparison, data are lined up by adult cohort.

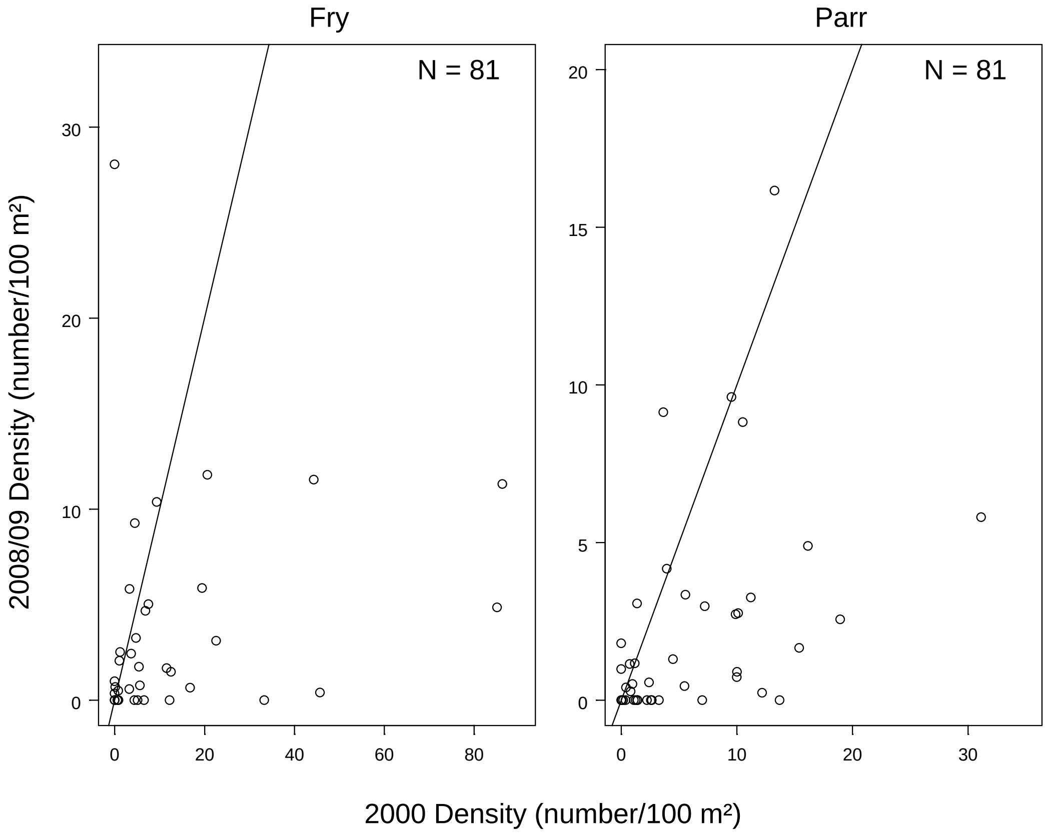

Figure 2.2.1. Change in fry (age-0) and parr (age-1 and age-2+) density at the 81 sites electrofished in 2000 and again in 2008/09. The line is a 1:1 line (i.e. no change in density) among time periods, points to the right of the line show a decline in density, while points to the left show an increase.

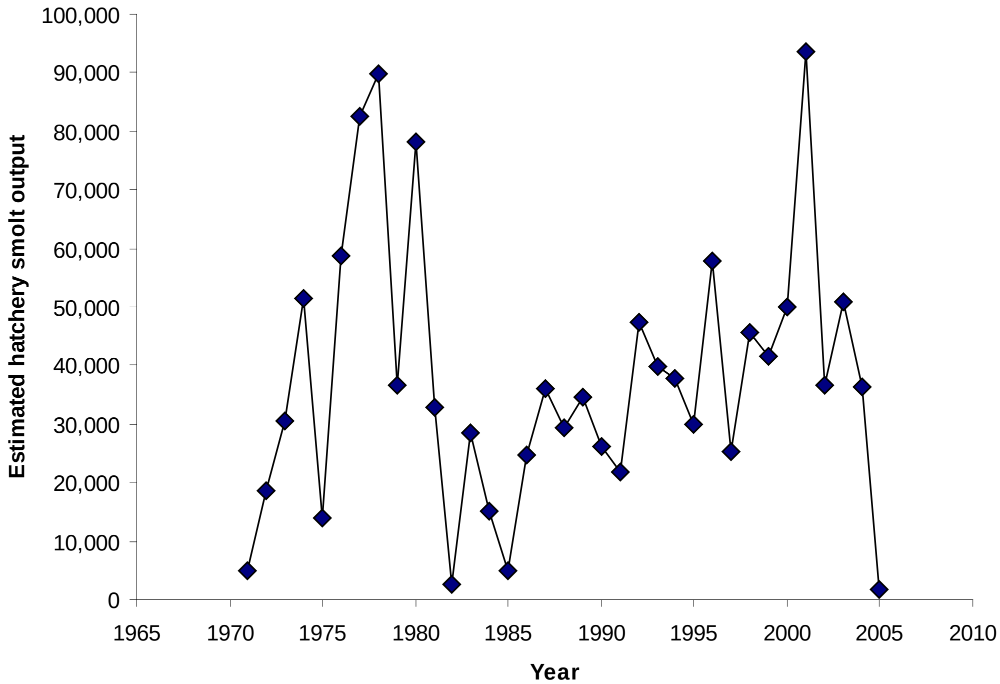

Figure 2.3.1 Estimated annual number of hatchery smolts resulting from releases of age-0 parr, age-1 parr, age-1 smolt and age-2 smolt from the stocking program on the LaHave River above Morgan Falls. The estimation method is described in Amiro and Jefferson (1998) and estimates are extended to 2005 (the end of the program) using data from the stocking database maintained by the Population Ecology Division of DFO.

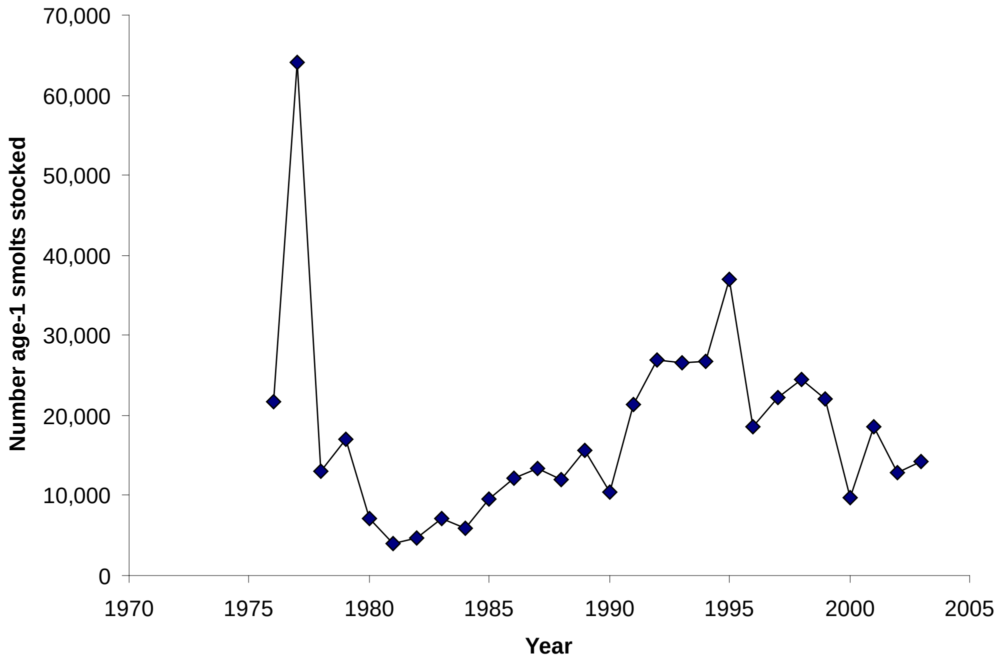

Figure 2.3.2. Number of smolts stocked annually at Ruth Falls fishway on the East River, Sheet Harbour, from 1976 to 2003. Data are from the stocking distributions database maintained by the Population Ecology Division of DFO.

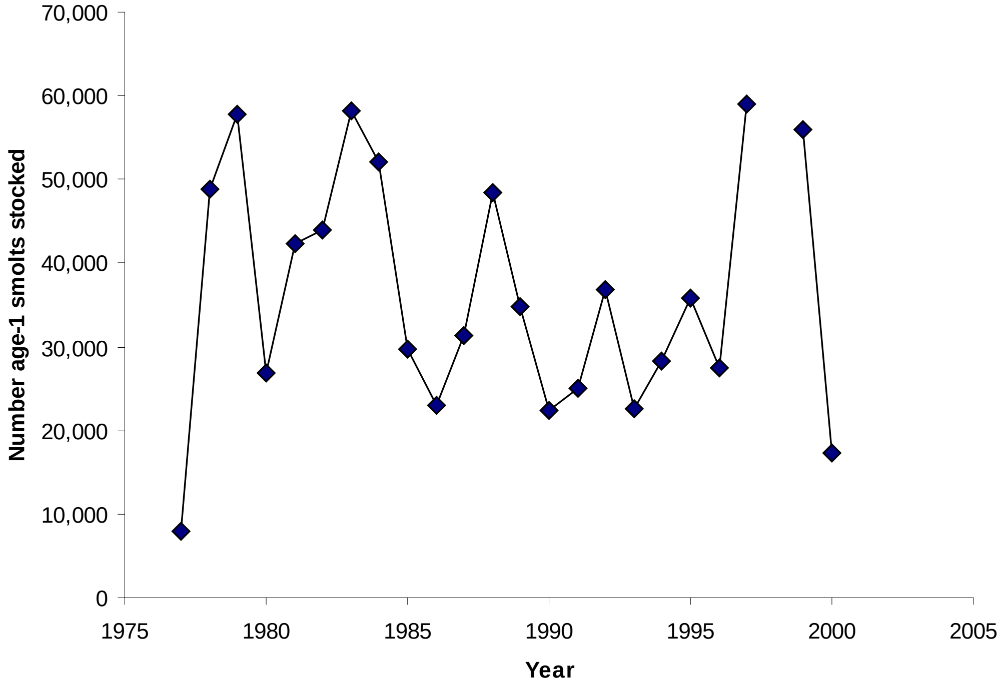

Figure 2.3.3. Number of age-1 smolts stocked annually on the Liscomb River from 1976 to 2000 (the end of the program). Data are from the stocking distributions database maintained by the Population Ecology Division of DFO.

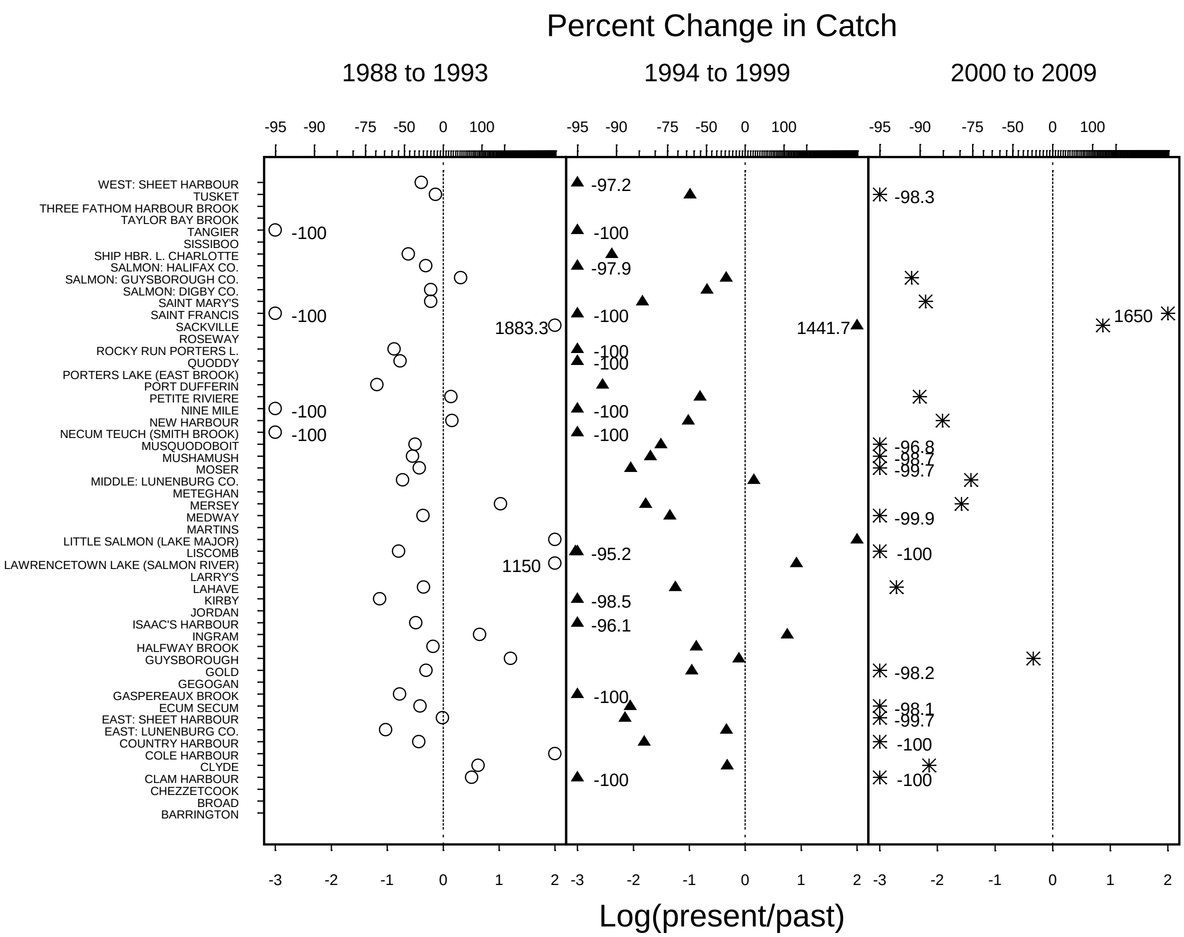

Figure 2.4.1. The percent change in reported recreational catch for all rivers in the Southern Upland, where the mean catch in three time periods was compared with the mean during 1983-1987. Rivers in which the decline in catch was > 95% or the increase was > 200% are labeled with the actual value. Missing points in the most recent time period represent rivers that have been closed to angling for the full five-year period.

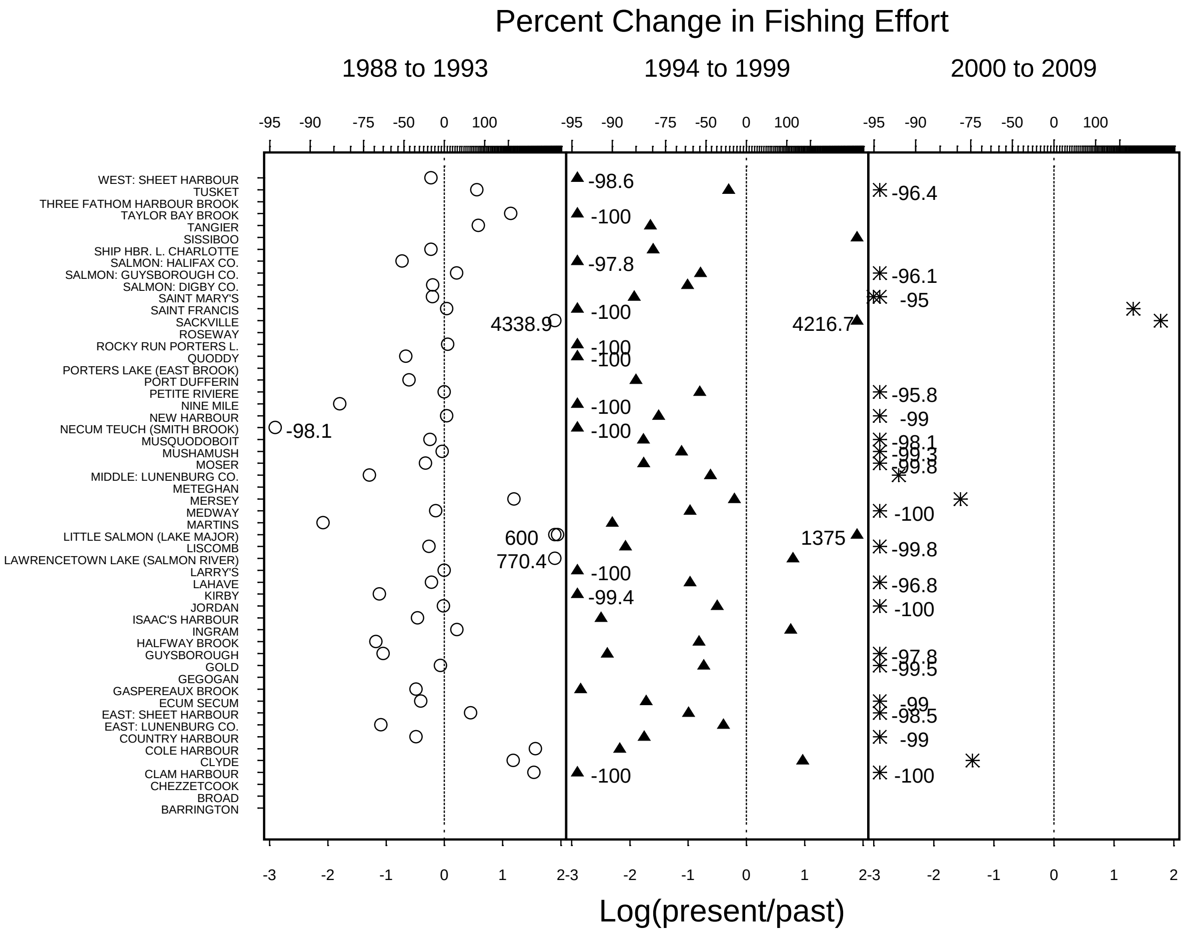

Figure 2.4.2. The percent change in reported recreational fishing effort for all rivers in the Southern Upland, where mean effort in three time periods was compared with mean effort during 1983-1987. Rivers in which the decline in catch was > 95% or the increase was > 200% are labeled with the actual value. Missing points in the most recent time period represent rivers that have been closed to angling.

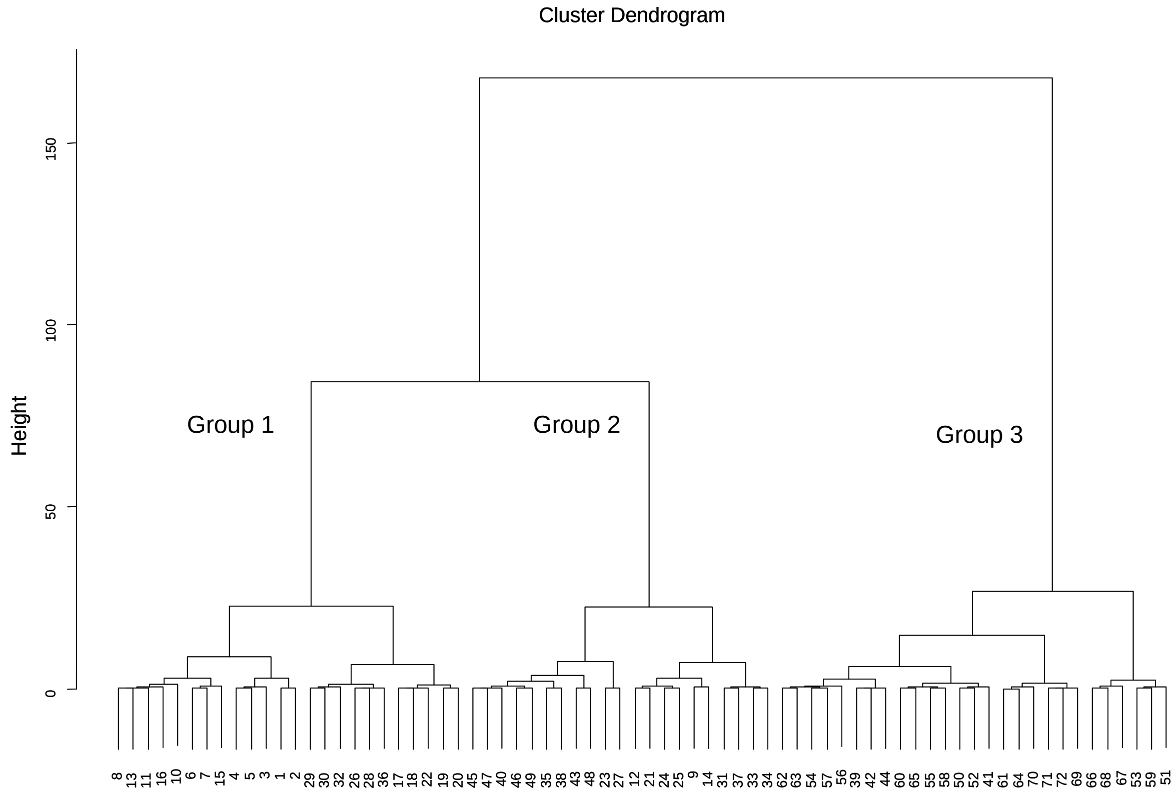

Figure 3.2.1. Dendrogram representing the degree of dissimilarity among watersheds (refer to Table 3.2.2 for the names corresponding to each river number) as identified by the hierarchical cluster analysis. More similar watersheds are more closely joined, and three large groupings are evident from the data.

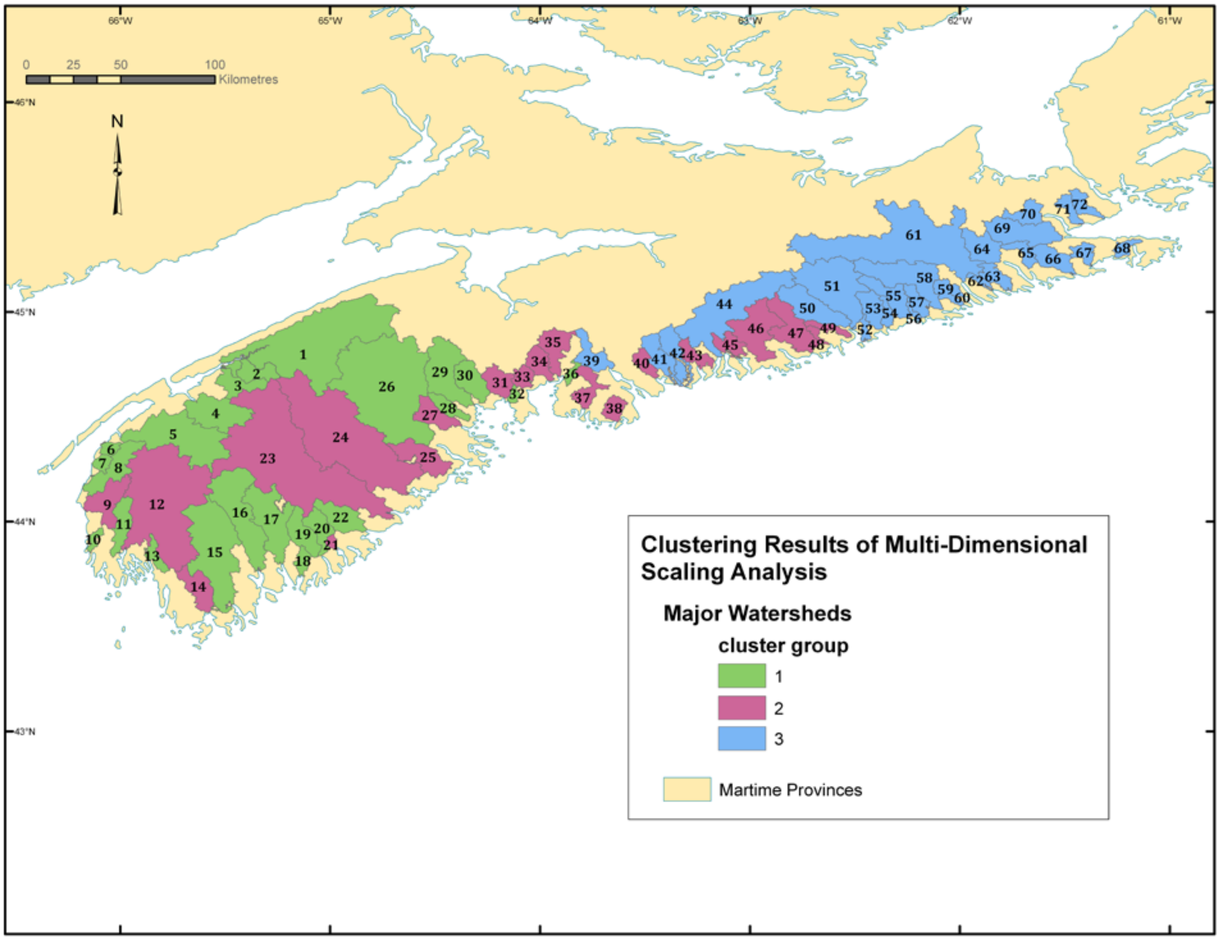

Figure 3.2.2. Map showing the geographical distribution of the three groups of watersheds identified from the hierarchical cluster analysis of environmental variables. Watershed numbers correspond to those listed in Table 3.2.2.

APPENDICES

Appendix 1. Electrofishing survey data from 2000.

		UTM coordinate							catch								
River	Site ID	Easting	Northing	Organization	Area (m2)	Month	Day	Shocking Time (s)	Atlantic salmon	American eel	brook trout	brown trout	white sucker	smallmouth bass	Chub spp	Other Cyprinids	Other Spp
Annis	SU9A	259678	4869480	DFD BIO	900	9	20	320	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
Argyle	SU11A	n/a	n/a	DFD BIO	420	10	5	350	0	3	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
Chezzetcook	SU39A	479941	4959980	DFD BIO	1,500	9	7	509	0	17	19	8	2	0	0	0	0
Clyde	SU13A	n/a	n/a	DFD BIO	750	9	22	320	0	0	0	0	0	0	0	2	1
Clyde	SU13B	296283	4850920	DFD BIO	600	n/a	n/a	581	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
Country Harbour	SU61B	585771	5017097	DFD BIO	200	9	20	370	17	23	1	0	1	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
East (Chester)	SU27B	409428	4944517	DFD BIO	1,200	9	18	1619	65	0	0	0	0	0	2	0	0
East (Lockeport)	SU16A	327515	4845781	DFD BIO	300	9	22	380	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
East Brk (Porter's Lake)	SU38A	470234	4962381	DFD BIO	2,550	9	7	762	0	23	3	0	4	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
East Taylor Bay	SU44A	530138	4966196	DFD BIO	150	9	13	442	0	27	4	0	0	0	0	0	0
Ecum Secum	SU54A	n/a	n/a	DFD BIO	1,150	n/a	n/a		50	28	0	0	0	0	1	0	0
Gaspereau Brk	SU56A	578936	4986937	DFD BIO	450	9	19	178	0	56	0	0	2	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
Gegogan Brk	SU57A	578885	4992601	DFD BIO	275	9	20	299	0	36	0	0	0	0	0	6	0
Gold	SU25A	384757	4955032	DFD BIO	1,150	9	8	2135	74	0	9	0	0	0	0	0	0
Gold	SU25B	383447	4956600	DFD BIO	1,150	9	8	1345	41	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
Indian Harbour Lakes	SU59A	558974	4991323	DFD BIO	245	9	20	352	0	147	4	2	0	0	0	1	0
Indian Harbour Lakes	SU59B	587529	4999337	DFD BIO	210	9	20	191	0	44	4	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
Ingram	SU29A	422975	4949929	DFD BIO	4,500	9	26	2292	0	0	1	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
Issac's Harbour	SU62A	605129	5011544	DFD BIO	600	9	21	479	0	2	10	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	1
Jordan	SU15A	319911	4856886	DFD BIO	1,500	9	7	410	0	11	0	0	0	0	0	2	0
Jordan	SU15B	320548	4861404	DFD BIO	300	9	7	693	0	10	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
Kirby	SU49B	543120	4972339	DFD BIO	90	9	13	322	14	0	0	0	2	0	0	0	0
Lahave	LHav002	366869	4930705	DFD BIO	1806	8	25		2	0	0	0	0	47	0	0	0
Lahave	LHav008	359406	4940137	DFD BIO	1456	7	21	2843	123	0	0	0	8	0	3	5	0
Lahave	LHav101	356321	4943231	DFD BIO	1061	7	13	2603	60	0	0	0	0	0	8	0	0
Lahave	LHav102	n/a	n/a	DFD BIO	753	8	25	520	3	0	7	0	2	0	0	0	2

Continued on next page.

Appendix 1. Continued.

		UTM coordinate							catch								
River	Site ID	Easting	Northing	Organization	Area (m2)	Month	Day	Shocking Time (s)	Atlantic salmon	American eel	brook trout	brown trout	white sucker	smallmouth bass	chub spp	Other Cyprinids	Other Spp
Lahave	LHav103	n/a	n/a	DFD BIO	1081	8	4	1334	79	0	1	0	21	0	10	0	0
Lahave	LHav104	366639	4931248	DFD BIO	1728	8	29	1374	22	36	0	0	0	102	0	0	2
Lahave	LHav105	371358	4920720	DFD BIO	774	7	19	2566	69	2	2	0	0	2	7	0	0
Lahave	LHav106	363843	4932713	DFD BIO	752	7	26	1385	106	0	1	0	1	0	3	1	1
Lahave	LHav107	366437	4919392	DFD BIO	768	8	21	654	76	0	0	0	1	0	3	0	0
Lahave	LHav108	372650	4940027	DFD BIO	1051	7	14	2740	97	1	0	8	0	0	0	0	0
Lahave	LHav109	373431	4941739	DFD BIO	1018	8	23	1457	79	14	0	0	0	0	11	0	0
Lahave	LHav110	n/a	n/a	DFD BIO	1051	8	22	1266	30	47	0	0	0	16	0	0	0
Lahave	LHav111	370359	4933069	DFD BIO	605	8	21	778	6	0	0	0	3	8	0	0	0
Lahave	LHav112	359758	4940617	DFD BIO	607	7	26	1741	73	0	0	0	5	0	6	5	0
Lahave	LHav113	360310	4933221	DFD BIO	1290	8	25	2078	117	0	1	0	3	0	2	3	0
Lahave	LHav114	358860	4930747	DFD BIO	900	7	21	1415	90	0	0	0	10	0	1	0	1
Lahave	LHav013	n/a	n/a	DFD BIO	1,150	8	29	2115	16	4	71	0	45	0	55	9	0
Lahave	LHav031	n/a	n/a	DFD BIO	1,150	8	4	480	0	0	11	0	0	0	0	0	0
Liscombe	SU55A	n/a	n/a	DFD BIO	1,400	n/a	n/a		50	12	1	0	5	0	3	0	3
Little West	SU46A	534624	4972076	DFD BIO	2,100	9	13	522	0	39	1	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
Martin's	SU24A	392951	4927524	DFD BIO	1,150	8	31	343	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
Medway	SU20A	341672	4919524	DFD BIO	1,150	9	5	2097	74	0	5	0	0	0	0	0	0
Medway	SU20B	343918	4910857	DFD BIO	1,150	9	6	1608	19	0	0	0	0	0	0	0	0
Medway	SU20C	351993	4902512	DFD BIO	1,150	9	6	671	16	0	21	0	0	0	0	0	0
Mersey	SU19A	351349	4884623	DFD BIO	675	9	27	770	0	0	0	4	0	0	0	0	0
Mersey	SU19B	356688	4882683	DFD BIO	120	9	27	340	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	2	0
Middle	SU26A	398230	4936017	DFD BIO	3,000	9	14	2256	74	0	8	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
Moser	SU52A	556233	4982256	DFD BIO	630	9	15	1006	60	36	0	0	1	0	0	0	0
Moser	SU52B	556285	4985530	DFD BIO	1,750	9	15	590	17	32	0	0	1	0	0	0	40
Mushamush	SU23A	385626	4925671	DFD BIO	900	8	31	1964	163	0	0	0	0	0	0	1	0
Mushamush	SU23B	377794	4929736	DFD BIO	1,150	8	31	2192	191	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
Musquodoboit	SU40B	497514	4994320	DFD BIO	105	9	8	560	14	0	21	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
New Harbour	SU63B	609935	5014855	DFD BIO	495	9	21	452	0	21	6	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
Nine Mile	SU32A	441921	4944765	DFD BIO	2,160	9	28	1266	0	0	0	0	0	0	0	2	0
Petite	SU21A	383425	4899966	DFD BIO	2,500	9	1	537	4	0	0	0	0	0	0	0	0

Appendix 1. Continued.

		UTM coordinate							catch								
River	Site ID	Easting	Northing	Organization	Area (m2)	Month	Day	Shocking Time (s)	Atlantic salmon	American eel	brook trout	brown trout	white sucker	smallmouth bass	chub spp	Other Cyprinids	Other Spp
Petite	SU21B	377846	4907845	DFD BIO	1,150	9	1	625	227	0	1	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
Petite	SU21D	381594	4901577	DFD BIO	1,800	9	13	875	11	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
Quoddy	SU51A	551780	4980480	DFD BIO	1,725	9	14	939	9	0	2	0	8	0	4	1	0
Quoddy	SU51B	551818	4978808	DFD BIO	1,150	9	14	1168	11	211	10	0	2	0	4	1	1
Quoddy	SU51C	551510	4975720	DFD BIO	320	9	14	366	1	46	2	0	2	0	2	0	0
Round Hill	SU2A	363125	4932829	DFD BIO	2,500	9	11	1215	28	0	2	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
Sable	SU17A	333288	4857493	DFD BIO	2,250	9	7	373	0	5	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
Salmon (Digby)	SU8B	248584	4883140	DFD BIO	1,050	9	19	350	0	0	1	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
Salmon (Halifax)	SU41B	492615	4967838	DFD BIO	320	9	11	304	0	2	4	0	0	0	0	3	0
Salmon (Halifax)	SU41C	491579	4968797	DFD BIO	1,365	9	11	708	0	12	3	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	2
Salmon (Lake Major)	SU35B	464285	4948899	DFD BIO	80	9	6	70	0	0	0	0	0	0	0	0	0
Salmon (Lake Major)	SU35C	463504	4949986	DFD BIO	455	9	6	389	0	53	0	0	10	0	0	4	0
Salmon (Lawrencetown)	SU36A	470064	4948869	DFD BIO	1,800	9	6	431	0	90	0	0	0	0	0	1	25
Salmon (Lawrencetown)	SU36B	469587	4949205	DFD BIO	4,100	9	6	1150	2	115	0	0	2	0	0	8	1
Salmon (Lawrencetown)	SU36C	469158	4955033	DFD BIO	480	9	7	340	0	11	3	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
Salmon (Port Dufferin)	SU50B	548523	4979891	DFD BIO	225	9	14	388	0	0	15	0	0	0	2	0	0
Ship Harbour	SU42A	501468	4974180	DFD BIO	960	9	11	460	0	17	0	0	3	0	0	0	0
Ship Harbour	SU42B	504637	4967824	DFD BIO	1,365	9	12	1690	53	51	5	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
Smith Brk	SU53A	562351	4979865	DFD BIO	1,120	9	19	1219	60	16	12	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
St. Mary's River	STMR8510.8	553790	5030955	DFD BIO	681	8	9		252	13	0	0	11	0	3	14	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
St. Mary's River	STMR853.2	570795	5013550	DFD BIO	678	8	15		14	3	12	12	3	0	1	0	0
St. Mary's River	STMR854.2	577086	5013497	DFD BIO	783	8	1		31	15	0	0	2	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
St. Mary's River	STMR855.1	561110	5013537	DFD BIO	485	7	11		41	4	16	16	8	0	7	0	0
St. Mary's River	STMR858.1	549950	5013416	DFD BIO	380	7	11		0	6	33	33	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	8	3
St. Mary's River	STMR867.1	552930	5032085	DFD BIO	865	8	8		164	11	0	0	2	0	0	1	1
St. Mary's River	STMR867.2	552850	5032138	DFD BIO	808	8	8		45	22	1	1	8	0	3	1	0

Continued on next page.

Appendix 1. Continued.

		UTM coordinate							catch								
River	Site ID	Easting	Northing	Organization	Area (m2)	Month	Day	Shocking Time (s)	Atlantic salmon	American eel	brook trout	brown trout	white sucker	smallmouth bass	chub spp	Other Cyprinids	Other Spp
St. Mary's River	STMR924	546607	5014243	DFD BIO	4,389	8	25		91	25	1	1	19	0	8	10	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	2
St. Mary's River	STMR928	526196	5016130	DFD BIO	1,363	8	11		54	27	2	2	39	0	20	2	0
Tangier	SU43A	514331	4978572	DFD BIO	805	9	12	708	0	17	0	0	0	0	0	2	0
Tangier	SU43B	517069	4977081	DFD BIO	1,190	9	12	345	0	22	0	0	0	0	0	2	1
Tangier	SU43C	n/a	n/a	DFD BIO	1,150	9	12	250	0	125	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
Tusket	SU10A	265831	4895172	DFD BIO	2,200	9	19	1820	25	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
West Brk (Porter's Lake)	SU37A	469564	4961764	DFD BIO	1,350	9	7	830	0	17	19	0	2	0	0	0	0
West River Sheet Harbour	SU47A	n/a	n/a	DFD BIO	1,150	n/a	n/a		59	5	0	0	4	0	1	13	0
West River Sheet Harbour	SU47B	n/a	n/a	DFD BIO	1,150	n/a	n/a		1	3	1	0	9	0	16	0	0
West River Sheet Harbour	SU47C	n/a	n/a	DFD BIO	1,150	n/a	n/a		34	4	0	0	2	0	1	0	0
West Taylor Bay	SU45A	529632	4966094	DFD BIO	1,200	9	13	429	0	26	1	0	0	0	0	0	0

Appendix 2. Electrofishing survey data from 2008/09.

River	Site ID	UTM coordinate Easting	UTM coordinate Northing	Organization	Area (m2)	Month	Day	Shocking Time (s)	catch Atlantic salmon	American eel	brook trout	brown trout	white sucker	smallmouth bass	chub spp.	other Cyprinids	other spp.
Annapolis	SU104	344908	4976408	DFD BIO	573.7	8	5	971	0	5	0	0	6	0	0	0	0
Annapolis	SU105	321913	4968332	DFD BIO	197.21	8	5	768	0	16	0	0	3	0	0	0	0
Annapolis	SU107	349917	4980092	DFD BIO	794.74	8	7	1087	4	15	0	0	3	0	0	0	0
Annapolis	SU108	317421	4965759	DFD BIO	603.84	8	7	1011	1	15	2	0	7	0	0	0	0
Annapolis	SU109	309804	4960452	DFD BIO	381.29	8	7	773	1	12	0	0	0	0	0	0	0
Annapolis	SU110	356468	4984811	DFD BIO	530.25	8	8	549	0	10	0	0	0	0	0	0	0
Annapolis	SU111	359218	4983996	DFD BIO	666.23	8	8	952	0	12	1	0	3	0	0	0	0
Annis	SU9A	259670	4869618	DFD BIO	772	7	31	1263	0	36	0	0	0	0	0	0	0
Annis	SU9B	259748	4870901	DFD BIO	602.7	7	31	1984	0	35	0	0	0	1	0	0	0
Annis	SU9C	259496	4870901	DFD BIO	304.59	7	30	793	0	7	0	0	2	0	0	0	0
Bear	SU3B	290609	4938330	DFD BIO	413.59	8	1	820	0	3	2	0	0	0	0	0	0
Belliveau	SU5A	256260	4917970	DFD BIO	173.88	7	29	494	0	10	3	0	0	0	0	0	0
Blacks Brk	SU102	313067	4849444	DFD BIO	934.34	8	1	743	0	8	2	0	0	0	0	0	0
Chegoggin	SU106	247041	4862117	DFD BIO	233.94	8	6	525	0	6	0	0	0	0	0	0	0
Clyde	SU13B	296352	4850891	DFD BIO	733.24	7	30	836	0	35	0	0	0	0	0	0	0
East (Chester)	SU27A	407560	4938806	DFD BIO	497.65	7	15	1110	0	6	0	0	0	0	0	0	0
East (Chester)	SU27B	409385	4944546	DFD BIO	300.95	7	23	1002	1	15	0	0	0	0	0	0	0
East (Chester)	SU27C	408453	4942713	DFD BIO	319.57	7	15	545	0	1	0	0	6	0	0	0	0
East (Lockport)	SU16A	327403	4845846	DFD BIO	515.39	7	30	767	0	5	0	0	0	0	0	0	0
East (St Margarets)	SU31A	431035	4948451	DFD BIO	4077	7	14	955	0	11	11	0	4	0	0	0	0
East Brk (Porter's Lake)	SU38A	470352	4963085	DFD BIO	559.91	7	9	703	0	12	0	0	0	0	0	0	0
East Brk (Porter's Lake)	SU38B	470485	4963226	DFD BIO	404.98	7	9	556	0	16	0	0	0	0	0	0	0
Ecum Secum	SU54A	559416	4992152	DFD BIO	267.22	8	26	1327	11	15	2	0	0	0	0	0	0
Ecum Secum	SU54B	565491	4984766	DFD BIO	221.76	9	18	812	0	8	1	0	0	0	0	0	0
Ecum Secum	SU54C	565005	4984243	DFD BIO	200.64	9	18	821	0	4	3	0	1	0	0	0	0
Ecum Secum	SU54D	561250	4994977	DFD BIO	235.64	9	18	959	0	10	1	0	0	0	0	0	0
Gaspereau Brk	SU56A	578938	4994977	DFD BIO	532.8	9	19	923	0	16	0	0	0	0	0	0	0
Gegogan Brk	SU57A	578807	4994977	DFD BIO	390.16	8	25	910	0	34	0	0	1	0	0	0	0
Gold	Gold002	385312	4994977	BCAF	439.53	9	22	484	18	0	6	0	0	0	0	0	0
Gold	Gold003	385934	4994977	BCAF	670	8	22	905	0	0	9	0	0	0	0	0	0
Gold	Gold005	384532	4994977	BCAF	722	9	18	997	33	3	0	0	5	0	0	0	0
Gold	Gold015	387104	4994977	BCAF	636	9	8	859	0	4	0	0	0	0	0	0	0
Gold	Gold016	382814	4994977	BCAF	522.99	9	2	716	0	3	0	0	0	0	0	0	0
Gold	Gold017	390284	4994977	BCAF	610	9	5	351	0	1	0	0	0	0	0	0	0
Gold	Gold018	385236	4994977	BCAF	710.6	8	29	696	11	1	7	0	0	0	0	0	0
Granite Village Brk	SU103	341129	4994977	DFD BIO	787.55	8	1	804	0	4	0	0	0	0	0	0	0
Halfway Brk	SU49A	543164	4994977	DFD BIO	185.71	9	19	749	4	13	0	0	0	0	0	0	0
Indian	SU30A	429462	4994977	DFD BIO	751.95	7	14	490	0	2	13	0	0	0	0	0	0

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Appendix 2. Continued.

		UTM coordinate							catch								
River	Site ID	Easting	Northing	Organization	Area (m2)	Month	Day	Shocking Time (s)	Atlantic salmon	American eel	brook trout	brown trout	white sucker	smallmouth bass	chub spp.	other Cyprinids	other spp.
Ingram	SU29A	422930	4949962	DFD BIO	642.72	7	15	1047	0	34	1	0	0	0	0	0	0
Ingram	SU29B	423642	4948781	DFD BIO	440.85	7	15	1138	0	17	3	0	0	0	0	0	0
Ingram	SU29C	422584	4952851	DFD BIO	303.22	9	5	946	0	13	5	0	0	0	0	0	0
Ingram	SU29D	422798	4956021	DFD BIO	357.29	9	5	940	0	8	3	0	0	0	0	0	0
Jordan	SU15B	320531	4861372	DFD BIO	334.46	7	31	528	0	11	0	0	0	0	0	0	0
Jordan	SU15C	320441	4864508	DFD BIO	253.97	8	29	798	0	0	0	0	0	0	0	0	0
LaHave	LHav001	369489	4920500	DFD BIO	722	8	28		25	3	1	0	2	0	0	0	0
LaHave	LHav008	359406	4940137	DFD BIO	2975	9	2	2654	67	1	0	0	2	27	0	0	0
LaHave	LHav016	362400	4932490	DFD BIO	575	9	9		0	0	17	0	6	0	0	0	0
LaHave	LHav101	356321	4943231	DFD BIO	1887.1	8	19	2013	69	0	0	0	3	0	0	0	0
LaHave	LHav105	371358	4920720	DFD BIO	2528.6	8	22		37	1	0	0	2	0	0	0	0
LaHave	LHav106	363843	4932713	DFD BIO	722	8	28	1996	17	3	0	0	3	0	0	0	0
LaHave	LHav107	366437	4919392	DFD BIO	722	8	28		46	2	0	0	1	0	0	0	0
LaHave	LHav108	372650	4940027	DFD BIO	3194.8	8	21	2874	33	5	0	0	0	5	0	0	0
LaHave	LHav114	358860	4930747	DFD BIO	637	8	22	1756	7	1	0	0	1	3	0	0	0
Little West	SU46A	534694	4972090	DFD BIO	311.75	7	18	405	0	13	0	1	0	0	0	0	0
Little West	SU46B	535940	4972807	DFD BIO	551.54	7	18	835	0	35	0	0	1	0	0	0	0
Martin's	SU24A	393365	4927080	DFD BIO	988.06	8	8	1112	0	12	1	0	4	0	0	0	0
Martin's	SU24B	392275	4927203	DFD BIO	571.39	9	4	1469	0	29	0	0	1	0	0	0	0
Medway	Medw108	341858	4918886	DFD BIO	1,227	9	10		22	6	3	0	0	0	0	0	0
Medway	Medw109	367838	4892343	DFD BIO	722	9	11	1387	36	22	8	0	3	0	0	0	0
Medway	SU20C	351993	4902512	DFD BIO	1,200	8	25		3	5	6	0	0	0	0	0	0
Medway	Medw101	332773	4922777	DFD BIO	300	9	11		0	2	1	0	2	0	0	0	0
Mersey	SU19C	355212	4882299	DFD BIO	848.64	7	24	780	0	35	0	0	0	0	0	0	0
Mersey	SU19D	352217	4883899	DFD BIO	837.75	7	24	1081	0	4	0	0	0	0	0	0	0
Mersey	SU19E	347046	4887243	DFD BIO	132.08	7	24	344	0	0	0	0	2	0	0	0	0
Middle (Chester)	Midd001	398211	4936046	BCAF	925.64	9	10	933	8	0	10	0	2	0	0	0	0
Middle (Chester)	Midd002	398676	4936162	BCAF	721.68	9	12	533	7	0	14	0	3	0	0	0	0
Moser	SU52C	556590	4980877	DFD BIO	177.36	8	26	500	0	10	5	0	0	0	0	0	0
Moser	SU52D	556552	4986000	DFD BIO	327.67	9	17	955	7	4	1	0	0	0	0	0	0
Moser	SU52A	556245	4982251	DFD BIO	519.03	8	26	1318	2	28	5	0	1	0	0	0	0
Mushamush	SU23A	385698	4925430	DFD BIO	986.31	7	18	1514	5	17	0	0	0	1	0	0	0
Mushamush	SU23B	378077	4929624	DFD BIO	517.35	7	18	915	1	4	0	0	1	0	0	0	0
Mushamush	SU23C	377311	4930183	DFD BIO	250.34	9	12	978	0	10	0	0	0	3	0	0	0
Mushamush	SU23D	381032	4931963	DFD BIO	310.25	9	12	892	1	5	0	0	0	0	0	0	0
Musquodoboit	SU40A	491778	4990608	DFD BIO	144.58	8	11	703	17	1	35	0	0	0	0	0	0
Musquodoboit	SU40B	497596	4994368	DFD BIO	241.6	8	11	705	35	0	35	0	0	0	0	0	0
Musquodoboit	SU40C	497566	4994541	DFD BIO	268.5	9	10	1023	11	0	7	0	0	0	0	0	0

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Appendix 2. Continued.

River	Site ID	UTM coordinate		Organization	Area (m2)	Month	Day	Shocking Time (s)	catch								
		Easting	Northing						Atlantic salmon	American eel	brook trout	brown trout	white sucker	smallmouth bass	chub spp.	other Cyprinids	other spp.
Musquodoboit	SU40D	493631	4993652	DFD BIO	213.87	9	10	820	0	0	8	0	0	0	0	0	0
Nine Mile	SU32A	441988	4944810	DFD BIO	697.33	7	14	947	0	6	0	0	2	0	0	0	0
Petite	SU21A	383595	4899418	DFD BIO	665.26	7	25	1183	0	14	14	0	0	0	0	0	0
Petite	SU21B	378331	4907214	DFD BIO	574.2	7	25	978	2	0	0	0	0	0	0	0	0
Petite	SU21C	382175	4900622	DFD BIO	1399.4	7	25	797	3	22	0	0	0	0	0	0	0
Purney Brk	SU100	318343	4850131	DFD BIO	541.2	7	31	679	0	13	0	0	0	0	0	0	0
Quoddy	SU51A	551808	4980531	DFD BIO	336.97	9	16	982	1	25	0	0	1	0	0	0	0
Quoddy	SU51B	551817	4978810	DFD BIO	263.81	9	16	915	0	10	2	0	0	0	0	0	0
Quoddy	SU51C	551508	4975684	DFD BIO	202.86	9	17	877	1	33	0	0	0	0	0	0	0
Quoddy	SU51D	550845	4977212	DFD BIO	64.86	9	16	377	0	9	0	0	2	0	0	0	0
Rodney Brk	SU101	318306	4847940	DFD BIO	520.97	7	31	916	0	10	1	0	0	0	0	0	0
Roseway	SU112A	310499	4858650	DFD BIO	243.5	8	28	417	0	0	0	0	0	0	0	0	0
Roseway	SU112B	304917	4872963	DFD BIO	314.73	8	28	736	0	9	0	0	0	0	0	0	0
Roseway	SU112C	302865	4878314	DFD BIO	124.9	8	28	562	0	0	19	0	0	0	0	0	0
Round Hill	SU2B	309503	4956659	DFD BIO	542.38	7	29	1148	0	5	0	0	0	0	0	0	0
Sable	SU17A	333537	4856649	DFD BIO	1055.3	7	30	1060	0	10	1	0	0	0	0	0	0
Sable	SU17B	333960	4856577	DFD BIO	294.5	7	31		0	18	0	0	0	0	0	0	0
Salmon (Digby)	SU8A	248621	4883096	DFD BIO	464.91	8	6	538	0	35	0	0	0	0	0	0	0
Salmon (Digby)	SU8B	252041	4882194	DFD BIO	1419.6	8	6	1553	12	23	0	0	0	0	0	0	0
Salmon (Digby)	SU8C	254166	4887363	DFD BIO	212.98	7	31	607	0	12	0	0	0	0	0	0	0
Salmon (Halifax)	SU41A	496311	4964468	DFD BIO	232.75	7	16	363	0	1	0	0	0	0	0	0	0
Salmon (Halifax)	SU41B	492615	4967838	DFD BIO	264.92	7	16	360	0	2	0	0	0	0	0	0	0
Salmon (Halifax)	SU41C	491486	4968638	DFD BIO	507.42	7	16	490	0	4	0	0	0	0	0	0	0
Salmon (Lake Major)	SU35A	464095	4947750	DFD BIO	511.01	7	4	817	0	9	1	0	0	0	0	0	0
Salmon (Lake Major)	SU35B	463950	4949263	DFD BIO	1912	7	10	1473	0	17	0	0	0	0	0	0	0
Salmon (Lake Major)	SU35C	463513	4949944	DFD BIO	2088.6	7	4	1364	0	24	0	0	0	0	0	0	0
Salmon (Lawrencetown)	SU36A	469956	4948862	DFD BIO	721.6	7	8	957	0	27	0	0	7	0	0	0	0
Salmon (Lawrencetown)	SU36B	469669	4949135	DFD BIO	727.62	7	8	1311	0	30	0	0	1	0	0	0	0
Salmon (Lawrencetown)	SU36C	469465	4954326	DFD BIO	1081.9	7	10	1131	0	40	0	0	2	0	0	0	0
Salmon (Port Dufferin)	SU50A	547465	4977140	DFD BIO	832.5	7	28	1020	10	2	0	0	3	0	0	0	0
Salmon (Port Dufferin)	SU50B	548235	4979707	DFD BIO	263.13	7	23	545	0	0	4	0	0	0	0	0	0
Ship Harbour	SU42B	504608	4967832	DFD BIO	447.93	7	16	1149	8	24	0	0	6	0	0	0	0
Smith Brk	SU53A	562330	4979886	DFD BIO	534.59	7	28	1016	12	12	8	0	0	0	0	0	0
St. Mary's	STMR8510.8	553790	5030955	DFD BIO	914.05	8	26	1552	31	0	0	0	2	0	0	0	0
St. Mary's	STMR854.2	577086	5013497	DFD BIO	717.5	9	16	1485	14	2	1	0	0	0	0	0	0
St. Mary's	STMR854.4	577040	5013648	DFD BIO	907.5	9	16	1809	49	7	1	0	0	0	0	0	0
St. Mary's	STMR855.1	561110	5013537	DFD BIO	626.45	8	26	1515	12	5	17	0	0	0	0	0	0
St. Mary's	STMR858.1	549950	5013416	DFD BIO	241.56	9	15	592	0	5	6	0	0	0	0	0	0

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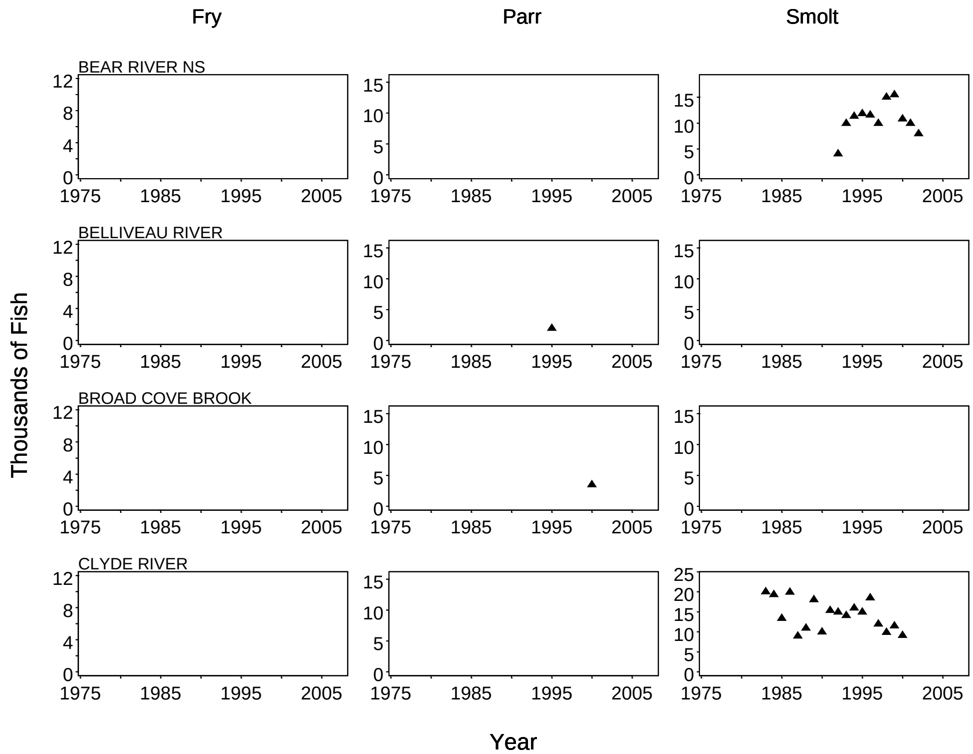
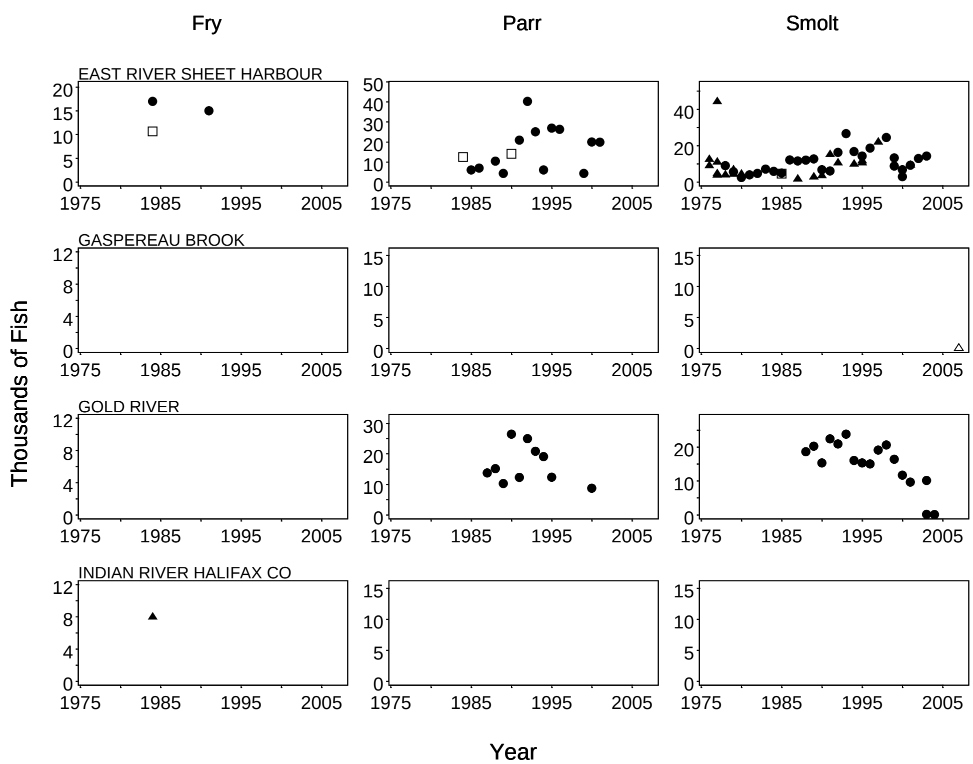
Appendix 2. Continued.

		UTM coordinate							catch								
River	Site ID	Easting	Northing	Organization	Area (m2)	Month	Day	Shocking Time (s)	Atlantic salmon	American eel	brook trout	brown trout	white sucker	smallmouth bass	chub spp.	other Cyprinids	other spp.
St. Mary's	STMR859.4	552876	5012910	DFD BIO	3172.4	9	17	4641	35	28	0	0	17	0	0	0	0
St. Mary's	STMR863.1	569912	5021222	DFD BIO	1145.3	9	26	1336	46	12	1	0	2	0	0	0	0
St. Mary's	STMR867.1	552930	5032085	DFD BIO	647.52	8	26	1414	37	2	0	0	0	0	0	0	0
St. Mary's	STMR923	571938	5019086	DFD BIO	1121.1	9	26	1294	25	12	0	0	0	0	0	0	0
St. Mary's	STMR924	546607	5014243	DFD BIO	4599.8	9	25	5096	71	26	3	0	16	0	0	0	0
St. Mary's	STMR925.1+2	555837	5014230	DFD BIO	574.2	9	15	1267	37	2	0	0	0	0	0	0	0
St. Mary's	STMR928	526196	5016130	DFD BIO	1247.4	9	15	2922	28	8	0	0	5	0	0	0	0
Tangier	SU43A	514284	4978523	DFD BIO	508.95	7	17	809	0	6	0	0	0	0	0	0	0
Tangier	SU43B	516961	4977079	DFD BIO	847.03	7	17	1211	0	37	0	0	2	0	0	0	0
Tangier	SU43C	522667	4962362	DFD BIO	800.83	7	17	783	0	35	0	0	0	0	0	0	0
Tidney	SU18A	337120	4859709	DFD BIO	901.53	7	30	727	0	9	0	0	0	0	0	0	0
Tusket	SU10A	265735	4895220	DFD BIO	669.7	7	30	1627	1	32	0	0	4	3	0	0	0
Tusket	SU10B	266239	4890674	DFD BIO	478.83	7	30	1243	0	2	0	0	0	0	0	0	0
Tusket	SU10C	262640	4867840	DFD BIO	259.17	8	5	665	0	11	16	0	0	0	0	0	0
Tusket	SU10D	265850	4890632	DFD BIO	457.1	8	6	757	0	4	3	0	0	0	0	0	0
Tusket	SU10E	266646	4888596	DFD BIO	1224.3	8	6	1086	0	13	0	0	1	4	0	0	0
Tusket	SU10F	272318	4888521	DFD BIO	855	8	7	1199	0	21	0	0	0	0	0	0	0
Tusket	SU10G	287151	4888210	DFD BIO	306.2	8	7	957	0	7	0	0	0	0	0	0	0
Tusket	SU10H	274190	4884688	DFD BIO	1380.3	8	7	1046	0	2	0	0	0	0	0	0	0
West Brk (Porter's Lake)	SU37A	469518	4961793	DFD BIO	538.69	7	9	928	0	31	9	0	0	0	0	0	0
West River Sheet Harbour	WRSH001	515810	4992742	NSDoAF	722	7	30	1098	0	4	0	0	0	0	0	0	0
West River Sheet Harbour	WRSH002	523366	4980562	NSDoAF	722	7	30	528	0	0	0	0	0	0	0	0	0
West River Sheet Harbour	WRSH003	529134	4979288	NSDoAF	784	8	19	1568	1	6	0	0	2	0	0	0	0
West River Sheet Harbour	WRSH004	530096	4978469	NSDoAF	910	8	19	2371	0	7	0	0	1	0	0	0	0
West River Sheet Harbour	WRSH005	523224	4990034	NSDoAF	722	8	19	1115	1	1	0	0	1	0	0	0	0
West River Sheet Harbour	WRSH006	521871	4983915	NSDoAF	722	8	19	1386	0	3	0	0	0	0	0	0	0
West River Sheet Harbour	WRSH007	518005	4986360	NSDoAF	825.6	8	20	1012	0	3	1	0	2	0	0	0	0
West Taylor Bay	SU45A	531239	4965654	DFD BIO	110.83	7	17	438	0	4	1	0	0	0	0	0	0
West Taylor Bay	SU45B	529810	4965986	DFD BIO	390.21	7	17	738	0	9	1	0	0	0	0	0	0

Appendix 3. Annual stocking of juvenile Atlantic salmon into rivers in the Southern Upland region. Stock origins are coded as follows: filled circles represent the natal river, filled triangles represent a local Southern Upland river, open squares represent hybrids (either native x local or local x local) and open triangles represent recent supplementation for conservation purposes using local stocks. Database spans the years 1976 to 2007.





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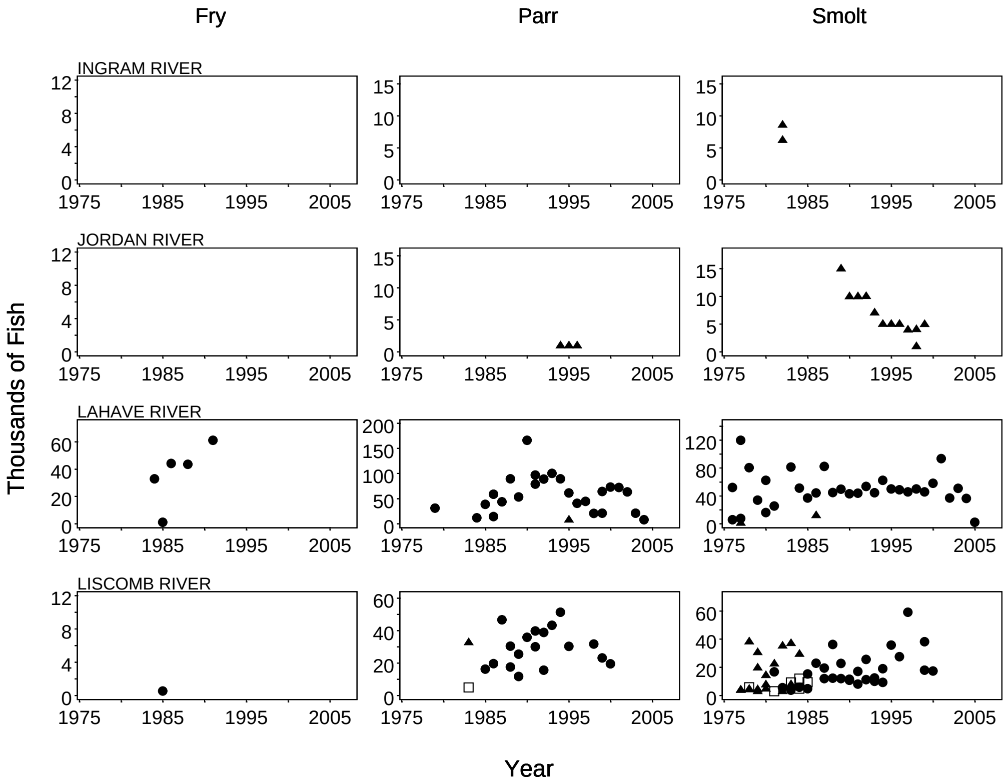
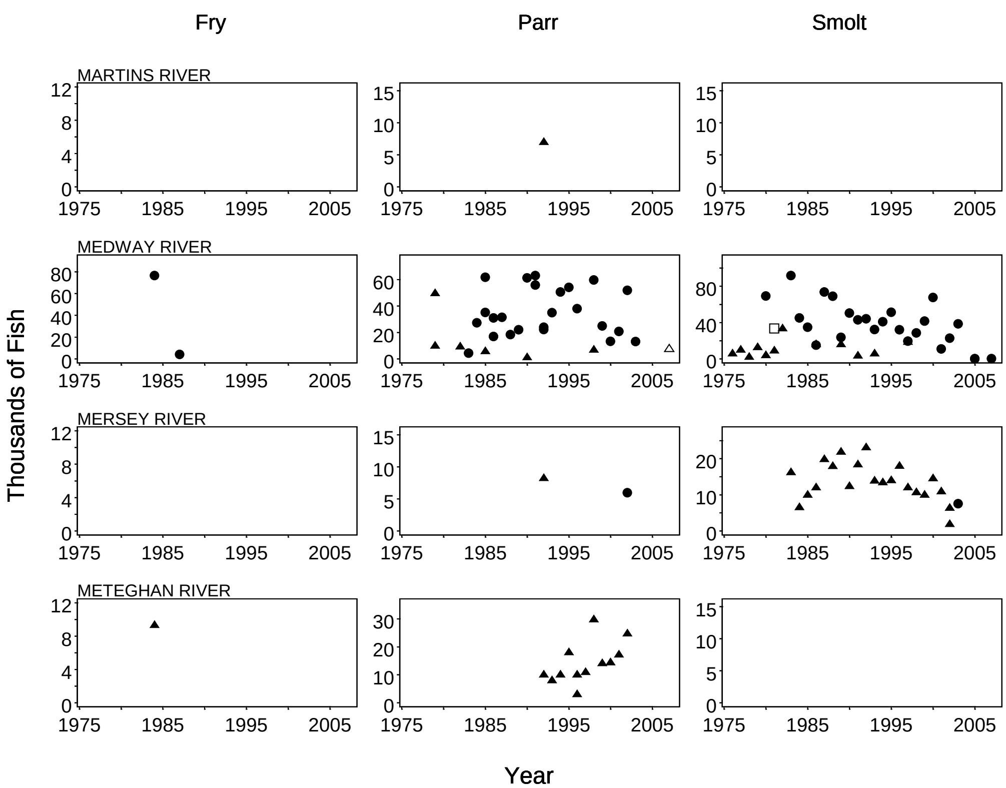
Appendix 3. Continued.





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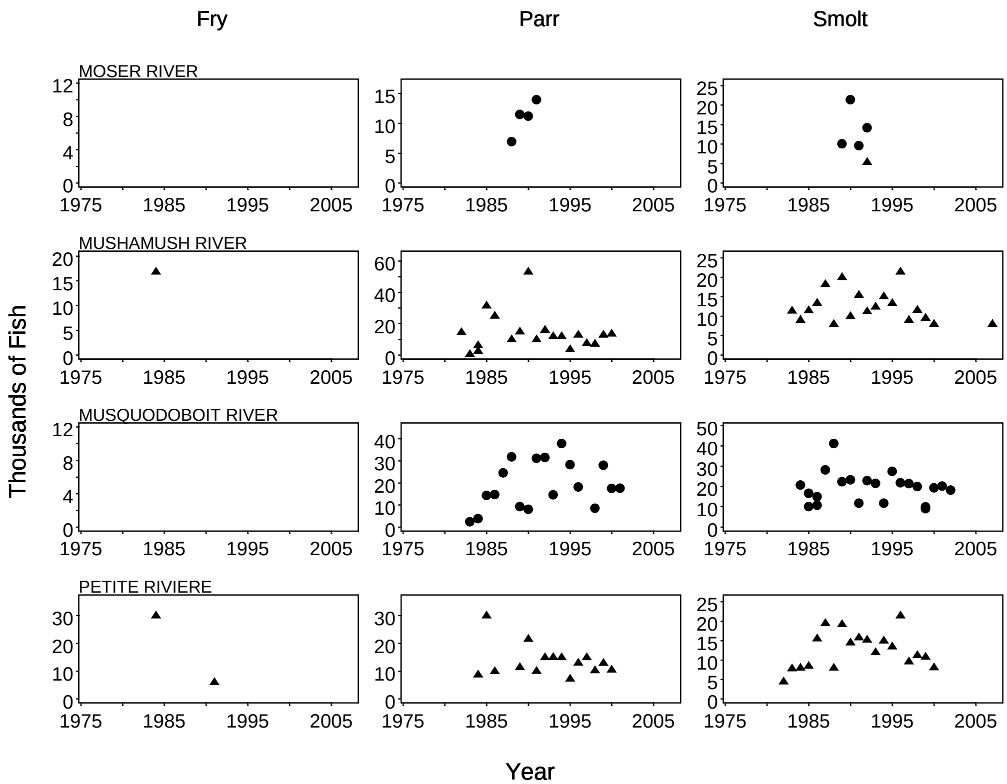
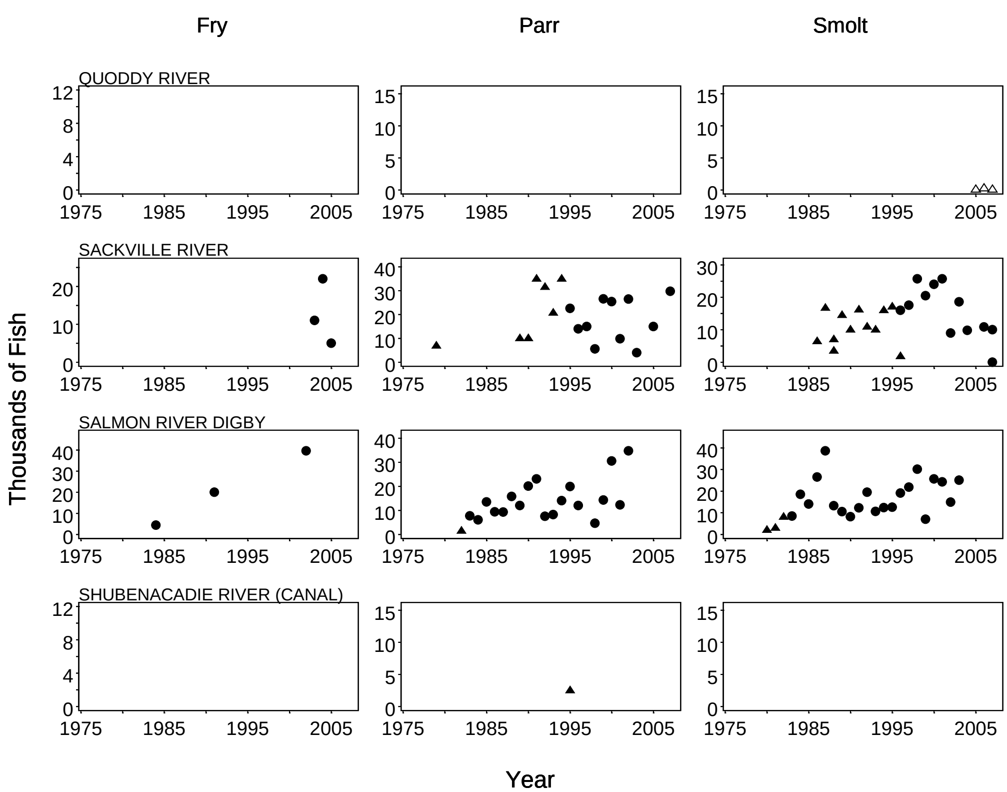
Appendix 3. Continued.





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Appendix 3. Continued.