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Review of DFO Science information for Atlantic salmon (*Salmo salar*) populations in the eastern Cape Breton region of Nova Scotia

Examen de l'information scientifique détenue par le MPO sur les populations de saumon atlantique (*Salmo salar*) dans la région de l'est du Cap Breton, en Nouvelle-Écosse

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ABSTRACT

The purpose of this document is to provide background information on Atlantic salmon in the eastern Cape Breton region (Salmon Fishing Area 19) of Nova Scotia in support of a review of the status of Atlantic salmon populations in eastern Canada by the Committee on the Status of Endangered Wildlife in Canada. There are 30 rivers with reported Atlantic salmon catches within SFA 19, although salmon may be or may have been present in other smaller streams in the region. Salmon populations on the east side of the Bras d'Or Lakes generally inhabit lower gradient streams and mature at a younger age than salmon populations on the west side of the lakes, suggesting that there may be some genetic structuring among populations within this region.

Salmon population monitoring in eastern Cape Breton is focused on five river systems: Middle, Baddeck, North, Grand and Clyburn. Assessments in these rivers are based on recreational catches, as well as fishery-independent counts of salmon by diver surveys, except in Grand River where only recreational catch data are used at present. An index-based assessment model for the Middle and Baddeck populations is used for the first time in this assessment. Of these five populations, two (Grand and Clyburn) show marked declines in adult abundance over the last 15 years and a third (North) has declined significantly over the last 20 years. The other two populations (Middle and Baddeck) appear to be more or less stable but at abundance levels well below their conservation requirements. Only one population (North) is estimated to be above its conservation requirement.

Status of salmon in other rivers is based on recreational catch data and intermittent electrofishing surveys. In recent years, reported recreational fishing effort has been concentrated on the North, Baddeck and Middle rivers and has remained relatively unchanged on the rivers where salmon are known to occur. These observations could indicate that abundance is low in most other rivers. This result is consistent with the electrofishing data which shows that juvenile salmon abundance is not high at many locations, even though juvenile salmon are still widely distributed in eastern Cape Breton. Overall, the status of salmon populations in SFA 19 with respect to extinction risk is uncertain, although abundance tends to be low. This conclusion is consistent with the geographic location of these populations. To the south is the Southern Uplands where declines are ongoing and river-specific extirpations have occurred, and to the west in western Cape Breton and the Gulf of St. Lawrence where abundance in at least some populations is increasing.

RÉSUMÉ

Le présent document de recherche a pour objet de fournir de l'information contextuelle sur le saumon atlantique dans la région de l'est du Cap Breton (zone de pêche du saumon (ZPS) 19) de la Nouvelle-Écosse en appui à l'examen de la situation des populations de saumon atlantique dans l'est du Canada par le Comité sur la situation des espèces en péril au Canada (COSEPAC). On a signalé des prises de saumon atlantique dans 30 rivières de la ZPS 19, mais le saumon peut être ou ne pas être présent dans d'autres petits cours d'eau de la région. Les populations de saumon sur le côté est du lac Bras d'Or se trouvent habituellement dans les ruisseaux en contrebas et viennent à maturité plus vite que les populations de saumon sur le côté ouest du lac, ce qui porte à croire que ces populations au sein de la région pourraient présenter une structuration génétique.

La surveillance de la population de saumon dans la région est du Cap Breton porte sur cinq réseaux fluviaux : Middle, Baddeck, North, Grand et Clyburn. Les évaluations de ces rivières sont fondées sur les prises récréatives, ainsi que sur des relevés indépendants de la pêche au saumon effectués par des plongeurs, sauf à Grand River, où seules les données sur les prises récréatives sont utilisées pour le moment. Pour cette évaluation, on utilise pour la première fois un modèle indiciel pour les populations de Middle et de Baddeck. Sur ces cinq populations, deux (Grand et Clyburn) affichent une baisse marquée du nombre d'adultes depuis les 15 dernières années et une troisième (North) a diminué énormément au cours des 20 dernières années. Les deux autres populations (Middle et Baddeck) semblent plus ou moins stables; cependant, en ce qui concerne les niveaux d'abondance, elles sont loin de satisfaire les besoins de conservation. On estime qu'une seule population (North) dépasse ses besoins de conservation.

La situation du saumon dans d'autres rivières est établie en s'appuyant sur les données concernant les prises récréatives qui ont été déclarées et sur les études intermittentes au moyen de la pêche à l'électricité. Au cours des dernières années, la pêche récréative a été pratiquée surtout dans les rivières North, Baddeck et Middle et sa pratique n'a guère changé dans les rivières où le saumon est présent. Ces observations pourraient indiquer que l'abondance est faible dans la plupart des autres rivières. Ce résultat concorde avec les données obtenues au moyen de la pêche à l'électricité, lesquelles montrent que l'abondance de saumons juvéniles n'est pas élevée à de nombreux endroits, même si les saumons juvéniles sont toujours nombreux dans la région est du Cap Breton. Globalement, la situation des populations de saumon dans la ZPS 19, en ce qui concerne le risque d'extinction, est incertaine, même si l'abondance tend à être peu élevée. Cette conclusion correspond à l'emplacement géographique de ces populations. Au sud se trouve Southern Uplands (Hauts plateaux du sud), où les déclins se poursuivent et où des extirpations se sont produites dans certaines rivières, tandis que dans la région ouest du Cap Breton et dans le golfe du Saint-Laurent, l'abondance d'au moins certaines populations augmente.

1.0 INTRODUCTION

This document contains an assessment of the status of Atlantic salmon (*Salmo salar*) populations in eastern Cape Breton Island (Salmon Fishing Area 19), prepared in support of a review of the conservation status of Atlantic salmon in eastern Canada by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). It updates material presented by Amiro et al. (2006), the most recent research document summarizing status in this area, and provides a summary of data available for assessing conservation status. There are 30 rivers with reported Atlantic salmon catches within this region (Figure 1.1), although salmon may be or may have been present in other smaller streams throughout the region.

Salmon population monitoring in eastern Cape Breton is focused on five major river systems: Middle, Baddeck, North, Grand and Clyburn. Of these, the Grand River has the lowest mean stream gradient, and its seasonal water flow and temperature are influenced by mid-reach lakes (Robichaud-LeBlanc and Amiro 2004). The remaining four rivers originate in small headwater lakes in the Cape Breton Highlands and are characterized by steeper stream gradients, as well as relatively good water quality. Over 80% of the annual recreational fishing effort in eastern Cape Breton takes place on these four Highland rivers.

Adult assessments by the Department of Fisheries and Oceans (DFO) in Salmon Fishing Area 19 (SFA 19) are based on recreational catches, which are reported through a license-stub return program, as well as fishery-independent counts of salmon by diver surveys in Middle, Baddeck and North rivers. Parks Canada monitors adult abundance on the Clyburn River using similar diver surveys. In past assessments, separate abundance time series have been estimated from the dive surveys and the recreational catch. Here, an index-based assessment model is used to integrate these adult data series, in conjunction with the intermittent electrofishing data, into a single abundance time series more conducive to evaluating status and assessing abundance trends. The utility of the recreational catch data for assessing abundance in smaller rivers is also examined in this document, and the juvenile electrofishing time series are updated to include data collected during 2007.

In a review of the conservation status of Atlantic salmon in eastern Canada (DFO and MNRF 2008), it was proposed that populations in the eastern part of SFA 19 (such as Grand River) be considered a separate conservation unit from populations in rivers flowing off the Cape Breton Highlands. This proposal was based on differences in river gradient expected to lead to local adaptations, as well as differences in the proportion of fish maturing after one winter at sea between these areas.

2.0 INDEX RIVERS

2.1 Middle River

Habitat

The main stem of the Middle River, Victoria County, arises in the Cape Breton Highlands, about 450 m above sea level (Figure 1.1). From there, it flows in a southward direction to its confluence with Nyanza Bay, in the St. Patrick’s Channel of the Bras d’Or Lakes. Throughout its length, Middle River is unobstructed and is not impacted by acid precipitation, but is exposed to agricultural practices in the lower valley (Marshall et al. 2000).

Biological Characteristics

Salmon in the Middle River generally spend two to three years in freshwater prior to undergoing smoltification. Based on the recreational catch data from 1983 to 2008, 29.2% of the population is 1SW adults, leading to a run composed primarily of large (> 63 cm fork length) salmon, with no indication of a trend in this proportion. The current population returns to spawn in autumn (Marshall et al. 1997); the component of the population which returned to the river during summer has disappeared in recent years (Marshall et al. 2000). This population was stocked prior to 1995 for recreational fishery enhancement, but there is no stocking of hatchery-reared salmon in this system at present. Escapes from aquaculture sites in the Bras D'Or Lakes have been detected in this system in the past (Marshall et al. 2000).

Conservation Requirement

The conservation requirement for Middle River, 2.07 million eggs, was calculated based on an estimated 864,600 m^2 of available spawning habitat and a target egg deposition of 2.4 eggs/m^2 (Marshall et al. 2000). This egg deposition is expected from about 470 large and 80 small salmon (O'Connell et al. 1997).

Assessment Data

Data available for assessing the status of salmon in Middle River include annual recreational catch estimates from salmon license stub returns and counts of adult salmon made while snorkeling in the river (termed dive counts), as well as intermittent electrofishing data which provides an index of the abundance of juvenile salmon.

1. Recreational catch and effort (Table 2.1.1):
   Data from the recreational fishery for the years 1983 to 2008 provide estimates of catch and effort using consistent methods throughout the time period. Large salmon (fork length of 63 cm or larger) and small salmon (less than 63 cm fork length) are recorded separately. The data include the number of salmon caught and released, the number harvested and fishing effort in each year, as estimated from salmon license stub returns. Effort is estimated in rod days where any portion of a day fished by one angler was recorded as one rod day.

2. Dive surveys (Table 2.1.2):
   The numbers of large and small salmon counted during dive surveys in Middle River from 1994 to 2008 provide indices of spawning escapement for this population. These surveys typically take place during the last week of October, just prior to the end of the fishing season. Details of the methods are described in Robichaud-LeBlanc and Amiro (2004). In brief, divers (snorkelers) swim down most of the river and count the number of large and small salmon observed during the survey. In years when conditions are favourable and abundance is sufficiently high, the dive surveys include a mark-recapture component. Several pools are seined prior to the counts and the captured fish are marked with a disk tag that is quite visible to the divers. During the subsequent swim, the divers record large and small counts, as well as the number of marked salmon observed (size classes combined) to obtain an estimate of the proportion of the population observed during the survey.

3. Juvenile abundance indices obtained by electrofishing (Table 2.1.3):
   Electrofishing surveys were conducted intermittently on Middle River. Data are available for 10 years, spanning the time period 1985 to 2006. These data can be used as indices of egg deposition in previous years: the number of age 0 salmon in year t as an index of egg deposition in year t-1, and the number of age 1 and older salmon in year t as an index of

egg deposition in year t-2. This latter assumption is made knowing that some parr are older than age 1, but aging data is not available for most of the electrofishing surveys.

Status

In order to estimate abundance of salmon in Middle River, we adapted the approaches of Gibson and Amiro (2003) for Stewiacke River salmon and Gibson et al. (2003) for Big Salmon River salmon. The estimates incorporated all of the assessment data listed above. Model details and full model results are presented in Appendix 1. A summary of the results is provided here. Overall, the analyses indicate a stable or slightly declining abundance trend with the population presently in the range of 30% to 40% of its conservation requirement.

A time series of the maximum likelihood estimates (MLE) of the number of salmon available to spawn after the recreational fishery is shown in Figure 2.1.1. The series shows an increase until 1996, followed by a slight decrease. During the 1984 to 1988 time period, spawning escapement averaged 259 fish. From 1994 to 1998, it averaged 399 fish and from 2004 to 2008 it averaged 317 fish (Table A1.1). The five-year mean population size has likely decreased during the last 10 years, but increased over 15- and 20-year time periods (Figure 2.1.2). Egg depositions (Figure 2.1.3) show a similar pattern with very little chance that the population has met its conservation requirement since 1983 (Figure 2.1.3). Estimates of the percent of the conservation requirement achieved have been less than 37% for the last three years.

We examined the ratio of the population size in a given year to the size in the previous year. Since 1983, the population size has increased over the previous year on 12 occasions, and has decreased on 13 occasions. During the last three generations, the MLE for the log mean ratio is -0.0273, equating to an overall decline rate of 2.7% per year with little to no chance that the population increased during that time period. This is slightly greater than the rate of 2.4% per year obtained by log-linear regression (details in Appendix 1).

We used the Dennis-type population viability analysis (PVA) to project the population forward through time (Figure 2.1.4). The rapidly increasing trajectories obtained in some simulations are unrealistic because a carrying capacity is not included in the model. The results suggest that if the recent future is similar to the recent past, the population is expected to continue to decrease, although the trajectory is highly uncertain.

2.2 Baddeck River

Habitat

The Baddeck River, Victoria County, lies in SFA 19 between the Middle and North rivers (Figure 1.1). The river arises in the Cape Breton Highlands at about 430 m elevation and flows in a south and westward direction to its confluence with Nyanza Bay, St. Patrick’s Channel of the Bras d’Or Lakes at a point less than 4 km east of the mouth of Middle River. Of the area in the Baddeck River accessible to salmon, the average gradient profile is steeper than that of the neighbouring Middle River, but not as steep as that of the North River (Robichaud-LeBlanc and Amiro 2004).

Biological Characteristics

The majority of adult salmon return to the Baddeck River in the fall. Based on the aging of scale samples collected from returning adults, most parr migrate seaward between the ages of two and four. Based on the recreational catch from 1983 to 2008, 23.8% of the population are 1SW adults, leading to a run composed primarily of large salmon (Table 2.2.1). There is a slight increasing trend in the proportion of 1SW adults.

Conservation Requirements

The conservation requirement for the Baddeck River is based on a substrate area of 836,300 m^2 of habitat, which is >0.12% orthograde and a target egg deposition rate of 2.4 eggs/m^2 (Elson 1975; Marshall et al. 1998). The requirement of 2.0 million eggs is the expected egg deposition from about 450 large and 80 small salmon.

Assessment Data

Data available for assessing the status of salmon in Baddeck River include annual recreational catch estimates from salmon license stub returns and counts of adult salmon made while snorkeling in the river (termed dive counts), as well as intermittent electrofishing data which provides an index of abundance of juvenile salmon.

1. Recreational catch and effort (Table 2.2.1):
   Data from the recreational fishery for the years 1983 to 2008 provide estimates of catch and effort using consistent methods throughout the time period. Large and small salmon are recorded separately. The data include the number of salmon caught and released, the number harvested and fishing effort in each year, as estimated from salmon license stub returns. Effort is estimated in rod days where any portion of a day fished by one angler was recorded as one rod day.

2. Dive surveys (Table 2.2.2):
   The numbers of large and small salmon counted during dive surveys in Baddeck River from 1994 to 2008 provide indices of spawning escapement for this population. These surveys typically take place during the last week of October, just prior to the end of the fishing season. Details of the methods are described in Robichaud-LeBlanc and Amiro (2004). Methods are similar to those on Middle River.

3. Juvenile abundance indices obtained by electrofishing (Table 2.2.3):
   Electrofishing surveys are conducted intermittently on Baddeck River, but no surveys have been conducted recently. Data are available for six years, spanning the time period from 1996 to 2001. As is the case for Middle River, these data can be used as indices of egg deposition in previous years.

Status

The overall abundance of salmon returning to the Baddeck River was estimated in the same way as in Middle River, by adapting the approach of Gibson and Amiro (2003) and Gibson et al. (2003) for estimating abundance from the indices described above. Model details and full model results are presented in Appendix 2. A summary of the results is provided here. Overall, the analyses indicate a stable or slightly increasing abundance trend with the population in the range of 20% to 25% of its conservation requirement. The data do not preclude the possibility that the population is in decline.

A time series of the MLE's of the salmon escapement after the recreational fishery is shown in Figure 2.2.1. Overall, the series increases until 1996, followed by a decrease. During the 1984 to 1988 time period, the spawning escapement averaged 192 fish, while from 1994 to 1998 it averaged 255 fish, and from 2004 to 2008 it averaged 189 fish (Table A2.1). The five-year mean population size has decreased during the last 10 years, but has been relatively stable over a 15-year time period and may have increased slightly over a 20-year time period (Figure 2.2.2). The data do not preclude the possibility that the population has declined during the last 20 years. Egg depositions show a similar pattern with very little chance that the population has met its conservation requirement since 1983 (Figure 2.2.3). Estimates of the percent of the conservation requirement that has been achieved are less than 25% for the last three years.

We examined the ratio of the population size in a given year to the size in the previous year. Since 1983, the population size has increased over the previous year on 13 occasions and has decreased on 12 occasions. During the last three generations, the MLE for the log mean ratio is 0.0172 (Table A2.1), equating to an increase in population size of approximately 1.7% per year with little chance that the population decreased during that time period. However, an estimate of the decline rate obtained by log-linear regression indicates a decline of 2.9% per year (Table A2.1), more or less consistent with that predicted for Middle River.

We used the Dennis-type PVA to project the population forward through time (Figure 2.2.4). The rapidly increasing trajectories obtained in some simulations are unrealistic because a carrying capacity is not included in the model. The results suggest that if the recent future is similar to the recent past, the population is expected to continue to slightly increase, although the trajectory is highly uncertain.

2.3 North River

Habitat

The North River, Victoria County, lies on the eastern slope of the Cape Breton Highlands (Figure 1.1). The headwaters are at an elevation of approximately 475 m and the river flows 30 km to its outflow in St. Ann's Harbour. Gradients are steep with many small falls and several barriers to upstream fish passage. Water quality is thought to be good (Amiro and Marshall 1990) as the North River is not impacted by acid precipitation or agriculture.

Biological Characteristics

Adult salmon are thought to return earlier to the North River than to the Middle or Baddeck rivers. Stocking of hatchery fish of North River origin occurred in the late 1980's and concluded in 1995 (Marshall et al. 1998). There is currently no stocking of hatchery-reared salmon in this system. Based on the recreational catch data from 1983 to 2008, the population is comprised of 35.4% 1SW salmon, with a slightly increasing trend in this value (Table 2.3.1).

Conservation Requirement

The conservation requirement for the North River is based on an estimated 382,700 m^2 of habitat, which is >0.12% orthograde and a target egg deposition rate of 2.4 eggs/m^2 (Marshall et al. 1998). The requirement is 0.85 million eggs, which is the expected egg deposition from about 200 large and 30 small salmon.

Assessment Data

Similar to the Middle and Baddeck rivers, recreational catch estimates from salmon license stub returns and counts of adult salmon made while snorkeling are available for assessing the status of salmon in North River. In some years, the dive surveys also included a mark-recapture component.

1. Recreational catch and effort (Table 2.3.1):
   Consistent methods were used to derive recreational catch and effort statistics for the years 1983 to 2008, and large and small salmon were recorded separately. The data include the number of salmon caught and released, the number harvested and fishing effort in each year, as estimated from salmon license stub returns. Effort is estimated in rod days where any portion of a day fished by one angler is recorded as one rod day.

2. Dive surveys (Table 2.3.2):
   Due to its higher gradient, dive surveys on the North River are more difficult than on the Baddeck or Middle rivers, particularly at higher flows. For this reason, counts have not been completed every year. When possible, the dive survey typically takes place during the last week of October, just prior to the end of the fishing season. In years when surveys are conducted, they provide an index of the numbers of large and small salmon available to spawn after the recreational fishery. Mark recapture experiments are only available for four years in the mid-1990's; in part due to reduced abundance and in part due to the difficulties in gaining access to seining pools. Details of the methods are described in Robichaud-LeBlanc and Amiro (2004). Methods are similar to those on Middle and Baddeck rivers.

Status

We attempted to fit the same model used to estimate abundance for the Middle and Baddeck populations, but ran into an issue with the data from North River. There was a large reduction in recreational fishing effort starting in 1994, the same year that the dive surveys started (Table 2.3.1). In the model, fishing effort is used to estimate the relationship between catch and abundance. When the recreational fishing effort is used to estimate catch rates, unrealistic estimates of salmon catchability prior to 1994 are necessary in order for the model to accurately capture the trends in recreational catch. The model predicts catch rates of 1.0 for these earlier years. Given this issue, the model results are not presented. The assessment presented here uses the method from past years in which an escapement time series is derived using the dive surveys, and an estimate of the number of salmon returning to the river is based on the recreational catch.

Returns to North River in 2008 were estimated using the preliminary recreational catch data and a mean catch rate derived for this river. Recreational catches were estimated to be 148 large and 98 small salmon. Based on recreational catch rates of 0.41 for large and 0.69 for small salmon, the estimated returns are therefore 404 large and 153 small salmon. Losses of salmon from the North River in 2008 were estimated to be four large and three small salmon, all from catch-and-release angling mortality. This population has shown a declining trend since the 1980's, but based on the recreational catch, appears to be above its conservation requirement at present (Figure 2.3.1).

2.4 Grand River

Habitat

The Grand River, Richmond County, drains an area of 217 km^2 (Amiro and Longard 1990). The mainstem flows southerly for 15.7 km from Loch Lomond Lake to its outflow in the Atlantic. Grand River has a low average gradient and headwater elevation (~100 m). On average, the gradients of Grand River tributaries accessible to salmon are the lowest of the rivers assessed in this document. When river discharge rates are low, Grand River is obstructed to salmon passage by a falls located 10.2 km upstream of head-of-tide. About 45% of the total juvenile production potential is estimated to be upstream of the falls, while 55% is below the falls (Amiro and Longard 1990). A fishway at the falls is estimated to pass 57% of small and 43% of large salmon (Amiro and Longard 1990, 1995).

Biological Characteristics

Unlike most other Cape Breton Island stocks, adult salmon originating from the Grand River are principally small (1SW) and return in June or July. The few large salmon are mostly repeat-spawning 1SW fish. Based on recreational catch data from 1983 to 2008, 82.8% of salmon in this river mature after one winter at sea. This river was stocked during the late 1980's and into the 1990's, but the program ceased in 1997 (Marshall et al. 1998). There have been no stocked fish contributing to returns since 1999 (DFO 2001).

Conservation Requirement

Conservation requirements for the Grand River are based on a habitat area of 461,800 m^2 that has >0.12% orthograde and a target egg deposition rate of 2.4 eggs/m^2 (Marshall et al. 1998). The total requirement for the river is 1.1 million eggs or 545 salmon (large and small combined), of which 475,000 eggs or 234 salmon are required upstream of the fishway.

Assessment Data

Data available for assessing the status of salmon in Grand River include recreational catch estimates from salmon license stub returns and counts of adult salmon ascending the fishway at Grand River falls.

1. Recreational catch and effort (Table 2.4.1):
   Recreational catch data are available from 1983 to 2008, and statistics were estimated using consistent methods throughout the time period. Large salmon (63 cm or larger) and small salmon (less than 63 cm) were recorded separately. The data include the number of salmon caught and released, the number harvested and fishing effort in each year, as estimated from salmon license stub returns. As on other rivers, effort is estimated in rod days where any portion of a day fished by one angler was recorded as one rod day.

2. Fishway counts (Table 2.4.2):
   Returns to Grand River were estimated from adult counts at the fishway from 1988 to 1998 (Marshall et al. 1998), and from partial fishway counts in 1999 and 2000 (Marshall et al. 2000, DFO 2001). The number of salmon returning to the Grand River above Grand River falls was estimated by assuming that 80% of the total run was counted and that 40% of small and 57% of large salmon by-passed the fishway in a given year. Adult salmon ascending the Grand River fishway have not been monitored since 2000.

Status

Returns to the river in recent years have been estimated from recreational catches with an assumed catch rate of 0.5. Based on returned salmon license stub returns, the recreational catch in 2008 was five small and no large salmon, giving an estimate of total returns of 10 small salmon, a very low value relative to past abundance (Figure 2.4.1). Note that these estimates are based on an extremely low sample size, three anglers fishing for an estimated seven rod days, and may be underestimated. However, the population appears to be well below its conservation spawner requirement. There are anecdotal reports of more salmon in the river than are estimated here (e.g. of about 30 salmon in a pool downstream of the fish ladder), but these values are also low relative to past abundance.

2.5 Clyburn River (Brook)

Clyburn Brook is found on the eastern side of Cape Breton Highlands National Park near Ingonish (Figure 1.1) and runs over a length of 19.4 km. Parks Canada has conducted annual dive surveys on this river from 1987 to 2008 where counts of large and small salmon are made during the survey. Although the observation efficiency is not known, the time series provides a relatively consistent index of abundance for this river. Counts in this river were highest in 1987 at 175 salmon (Figure 2.5.1), but have only exceeded 20 salmon twice since 1999.

2.6 Trends in Index Rivers

We analyzed trends in abundance for populations in the Middle, Baddeck, North, Grand, and Clyburn rivers. Large and small salmon abundances (Table 2.6.1) were combined for the analysis. Trends were analysed over three time periods using two methods. The first approach to estimating declines used a “log-linear model”:

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

Here, N_0, the population size at the start of the time series, and z, the instantaneous rate of change in abundance, are estimated parameters. The change in population size over the time period spanned by the data is given by e^{zt}. This model was fit using least squares after transformation of the data to a log scale. Because the model uses all data within the time period, marked changes in abundance cause the standard error of z to increase. When log transformed, zero abundances are difficult to include (small values must be added). Additionally, if residuals are not appropriately distributed, depending on when and how abundance changes during the time period, some points can have either high leverage or little influence on the model fit.

The second approach is to calculate the extent of the decline as the ratio of the population size at the start and the end of the time period. In order to dampen the effect of year-to-year variability when using this approach, we used the five-year average population size (missing values were dropped during the smoothing) when calculating the ratio. The five-year time period for smoothing was chosen to represent approximately one generation. Although this method is easy to implement, a drawback is that confidence intervals for parameter estimates cannot easily be calculated. We therefore re-parameterised the model into the form:

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

where s is a state variable that indicates whether a year is in the first or second time period. The parameters to be estimated are N_1, the average abundance during the first time period, and p, the change in abundance between the two time periods. This model, termed here the “ratio model”, estimates the extent of decline and is not influenced by data between the time periods of interest. Confidence intervals were estimated using likelihood ratios. We used a lognormal distribution for the error structure when fitting this model. Both models were fit to 10-year, 15-year and 20-year time periods (the 15-year time period corresponds roughly to the three generation time period used by COSEWIC when evaluating conservation status).

Of these populations, Grand and Clyburn show a declining trend irrespective of the time period used (Figure 2.6.1; Table 2.6.2). North River has declined markedly since the late 1980’s, but may have been increasing during the last ten or more years. Middle and Baddeck have both increased and decreased slightly over the range of available data. Confidence intervals on the rates of decline (or increase) are large for these latter two populations.

3.0 OTHER RIVERS

3.1 Recreational Catch Data

Catch and effort data for the recreational fishery, estimated from salmon license stub returns, are available for 30 rivers in SFA 19 for the years 1983 to 2007 (Appendix 3). Large salmon (63 cm or larger) and small salmon (less than 63 cm) are recorded separately, and the numbers harvested, as well as caught and released are estimated. Effort is estimated in rod days where any portion of a day fished by one angler was recorded as one rod day. Values are adjusted for non-reporting using a relationship based on the reported catch as a function of the number of reminder letters sent to licensed anglers.

Although there are exceptions, recreational catches tended to be higher in the 1980’s and early 1990’s than at present (Figure 3.1.1). However, the fishing effort in these earlier years was also higher (Figure 3.1.1). A comparison of the recreational catches for the five-year time period ending in 1987 with the five-year time period ending in 2007 (Figure 3.1.2) indicates that the recreational catch has declined by more than 75% during that time in all but four rivers. Of these four, one (Aconi Brook) had a very low catch throughout the time period. The other three rivers are Middle, North and Baddeck, which account for 87% of the recreational catch during the 2003 to 2007 time period. The recreational catch tracks the estimated effort very closely (Figure 3.1.1). Fishing effort has also declined on most rivers in a pattern similar to the recreational catch (Figure 3.1.3). Little to no fishing effort is presently being reported on most rivers in SFA 19. While this issue makes interpreting the recreational catch statistics as an abundance index difficult, it does suggest that fishing effort has contracted down to those few rivers within the SFA that contain an appreciable number of Atlantic salmon.

3.2 Electrofishing Data

Electrofishing surveys take place intermittently in SFA 19 and have relatively limited spatial coverage. The results of these surveys up until 2002 were last reported by Robichaud-LeBlanc and Amiro (2004). Surveys did not take place again in SFA 19 until 2006, when 24 sites were electrofished in nine rivers, and 2007, when eight sites were electrofished in six rivers. The results of these recent surveys are presented here, as well as a summary of the results presented by Robichaud-Lebanc and Amiro (2004).

Electrofishing Survey in 2006

In general, the methods used in 2006 and 2007 follow those described by Chaput et al. (2005) and are different from methods used in previous surveys. Sites ranged from approximately 90–230 m^2 and encompassed the entire width of the river, except on the main channel of the North, where waters in the center of the channel were too deep and fast to be waded, so electrofishing sites were bounded by the bank on one side and deep water on the other. For sites where no barrier nets were used (31 open sites), sampling was done by a single pass with the electrofisher, moving in an upstream direction (Chaput et al. 2005). For one site on the North Aspy River in 2006, barrier nets were installed and a depletion survey was done with four passes by the electrofisher, moving in a downstream direction (Edwards et al. 2004). Species were identified and their length (fork length) and weight (grams) were measured. Total catch of age 0, age 1 and age 2 juvenile salmon at each site was determined through scale aging. Juvenile density (number of fish per 100 m^2 of habitat area) was calculated using the catch-per-unit-effort (CPUE) method described by Chaput et al. (2005) for single-pass electrofishing at open sites.

Of the 32 sites fished (Table 3.2.1), half of them had been sampled since 1996, while the other half were either new or had last been electrofished in the 1970's and 80's. Atlantic salmon were found in all but three of the sites visited: two upstream of a large barrier falls on the Clyburn River (Cly002 and Cly003) and one on the Sydney River (Sydney002) (Table 3.2.2). Estimated densities of fry ranged from 157 individuals per 100 m^2 in the Middle River to 4 individuals per 100 m^2 in Black Brook (Table 3.2.3). The highest age 1 parr density (112 individuals per 100 m^2) was obtained at a site on North River, but parr densities were less than 10 per 100 m^2 in River Denys, Grand River, Sydney River, Mira River, and Black Brook. Age 2 parr were absent from the sites sampled on River Denys, the Ingonish and Grand rivers in 2006, and in Sydney River in 2007. No individuals older than age 2 were found in any river.

A time-series of juvenile densities for the Middle, Grand, North and Sydney rivers is shown in Figure 3.2.1. Based on mean annual density (1996 – 2002, 2006 and 2007), there were no trends obvious in the data. Density estimates for 2006 and 2007 were within the range of those sampled in the 1996-2002 period, except for parr (age 1 and age 2 combined) in the North River, which was more than double any previous estimate. However, given that the method used in the recent surveys differed from previous surveys, this result should be interpreted with caution.

In general, fry and parr densities at most sites are low relative to the indices of normal abundance, developed by Elson (1967), of 29 individuals per 100m^2 for fry and 38 individuals per 100 m^2 for parr (age 1 and age 2 combined). However, the densities estimated for rivers in eastern Cape Breton tend to be above those observed in rivers along the Atlantic coast of mainland Nova Scotia.

Older Electrofishing Surveys

Robichaud-LeBlanc and Amiro (2004) provided a comparison of fry densities from 1998 to 2002 to the Elson (1967) norm of 29 fry per 100 m^2 for some rivers in SFA 19 (Figure 3.2.2). Fry densities estimated in the most recent years of sampling (2001 and 2002) were above the norm in only three of 21 rivers sampled. Similarly, parr (age 1 and older) densities have typically been below the Elson (1967) norm for age 1 and older parr (38 parr per 100 m^2) since 1998 (Figure 3.2.3).

4.0 BIOLOGICAL CHARACTERISTICS

Atlantic salmon in eastern Cape Breton are not as well studied as salmon on mainland Nova Scotia, so there is less information available for summarizing their biological characteristics. The two sources of data with widespread coverage are the recreational catch data and information on stream gradient (although stream gradient is not a biological characteristic, it is a habitat attribute expected to lead to local adaptation).

DFO and MNRF (2008) suggested that populations in the eastern part of SFA 19 could be considered distinct from populations inhabiting rivers to the west of the Bras d'Or Lakes. This suggestion was based on differences in river gradient expected to lead to local adaptations, as well as differences in the proportion of fish maturing after one winter-at-sea between these areas, although these differences were not quantified at the time.

We analysed the recreational catch data to determine whether populations on the east side of the lakes had a higher proportion of small (1SW) salmon. For each river in each year with an annual catch greater than 20 salmon, we calculated the annual proportion of the catch that were small salmon, and then calculated the mean and standard deviation of this parameter across years. With the exception of Indian Brook, all populations to the east of the Bras d'Or Lakes have a higher proportion of small salmon than populations to the west of the lakes (Figure 4.1). Robichaud-LeBlanc and Amiro (2004) provided a summary of the amount of habitat by stream gradient in 17 eastern Cape Breton rivers (adapted here as Table 4.1). With the exception of Middle River, rivers to the west of the Bras d'Or Lakes generally have a lower proportion of their habitat in gradient categories of less than 1%. Both these analyses provide evidence that support the proposal that salmon populations to the east of the Bras d'Or Lakes are distinct from salmon to the west of the lakes.

5.0 THREATS TO POPULATIONS

Threats to Atlantic salmon populations in eastern Cape Breton are not well documented. As part of the process for developing the conservation status report for Atlantic salmon, a list of activities that could potentially threaten salmon in this SFA was developed based on perceptions of individuals familiar with salmon and rivers in the area. The list (DFO and MNRF *in prep.*), which is semi-quantitative and is not yet peer reviewed, is in draft form. The principal threats considered were: directed salmon fishing, bycatch of salmon in other fisheries, fisheries impacts on salmon habitat, mortality associated with habitat use, habitat alterations, shipping and transport noise, fisheries on prey of salmon, aquaculture, fish culture/stocking (non-commercial), scientific research, military activities, air pollution, introductions of non-native species, international high seas fisheries (targeted), ecotourism and recreation, and ecosystem change (including climate change). While many of these threats have the potential to impact a high proportion of salmon in eastern Cape Breton, none were thought to have a high impact (defined as greater than 30% spawner loss) on individual populations. Directed fishing was thought to have a medium impact (5% to 30% spawner loss). The remainder were considered to be either low impact or the effect was uncertain. Readers are referred to DFO and MNRF (*in prep.*) for further details, including subcategories for these threats.

6.0 SUMMARY AND CONCLUSIONS

Overall, the data presented in this report do not provide a particularly positive view of status of Atlantic salmon in the eastern Cape Breton region. Of the five populations for which adult abundance estimates are available, two (Grand and Clyburn) show marked declines over the last 15 years and a third (North) has declined significantly over the last 20 years. The other two populations (Middle and Baddeck) appear to be more or less stable, but at abundance levels well below their conservation requirements. Only one population (North) is estimated to be above its conservation requirement. Although reported recreational fishing effort was distributed over many rivers in the past, it has recently contracted to primarily the North, Baddeck and Middle rivers. Given that fishing is still being reported on these rivers (with relatively unchanged effort for Middle River), it is likely that fishing effort has declined markedly on other rivers, suggestive of low abundance on other rivers. This suggestion is supported by the electrofishing data, which shows that juvenile salmon abundance is low at many locations in eastern Cape Breton. However, on a more positive note, juvenile salmon were found in most rivers, adult abundance in two of the index rivers appears to be stable, and the North River population may be increasing (although this increase is not statistically significant). In short, status with respect to extinction risk is uncertain, although most indications are that populations in this region do not appear overly healthy.

Sufficient data collection to estimate adult abundance in eastern Cape Breton exists for five rivers (or four: given the low reported recreational catch on Grand River). Given the low reported recreational catch on most other rivers, these data are no longer useful for estimating abundance other than for broad inferences like the one in the previous paragraph. Inferences from the electrofishing data are also limited to broad statements. Data are not sufficient to evaluate freshwater productivity, survival at-sea or the tradeoffs between these two major components of the life cycle as is being done for populations in southwest New Brunswick (Gibson et al. 2009a) or Nova Scotia’s Southern Upland (Gibson et al. 2009b). As such, the present data is not sufficient to evaluate the effectiveness of recovery actions for these populations except by analogy with populations further to the south.

The models used to estimate abundance for Middle and Baddeck rivers are an improvement over previous assessments in that the indices are combined to provide a single estimate of abundance. The agreement between the recreational catch data, the diver counts and fry densities is suggestive that abundance is reasonably well estimated. The models could potentially be improved by using a mixed effects structure for the fishing catchability and dive observation coefficients rather than the constant values used herein. This is a topic for future research.

Given the overall status of populations in this area, a continued conservative approach to management (or a transition to a more conservative approach) is recommended. Additionally, if the abundance of salmon is low through the region (only one population appears to be above its conservation requirement and at least two are in decline), the importance of the remaining populations for the recovery of salmon throughout the region should be a management consideration.

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9.0 TABLES

Table 2.1.1. Summary of the recreational fishery statistics for large and small Atlantic salmon in Middle River, Victoria Co., from 1983 to 2008. The number of anglers is the number that reported fishing in Middle River. Other values are corrected for non-reporting. The 2008 estimates are preliminary (Feb. 01, 2009 database query).

Year	No. of Anglers	Small Kept	Small Released	Total Small	Large Kept	Large Released	Total Large	Effort	CPUE	% Large
1983	133	12	0	12	36	5	41	935	0.058	78.0
1984	83	24	11	34	1	77	78	509	0.202	69.5
1985	39	15	6	21	0	29	29	160	0.28	57.1
1986	76	36	8	44	0	108	108	388	0.41	70.9
1987	114	53	4	58	0	116	116	725	0.243	66.9
1988	131	30	11	41	0	118	118	596	0.276	74.2
1989	144	32	9	41	0	221	221	723	0.395	84.3
1990	153	69	24	93	0	171	171	878	0.313	64.7
1991	169	15	8	23	0	156	156	736	0.257	87.3
1992	66	7	3	10	0	27	27	190	0.198	72.7
1993	110	25	5	31	0	48	48	406	0.202	61.1
1994	122	0	18	18	0	128	128	444	0.393	87.6
1995	72	0	30	30	0	41	41	243	0.317	57.7
1996	125	2	55	58	0	132	132	454	0.415	69.5
1997	52	3	15	18	0	80	80	175	0.542	81.7
1998	99	5	26	31	0	60	60	312	0.303	66.2
1999	138	0	30	30	0	95	95	369	0.346	76.1
2000	92	0	20	20	0	67	67	311	0.297	76.7
2001	25	0	10	10	0	15	15	92	0.290	60.0
2002	60	1	27	28	0	35	35	231	0.284	56.0
2003	76	0	23	23	0	137	137	336	0.489	85.7
2004	45	0	22	22	0	44	44	185	0.382	66.7
2005	128	0	38	38	0	133	133	458	0.387	77.8
2006	78	0	44	44	0	87	87	416	0.327	66.3
2007	120	0	42	42	0	95	95	506	0.260	69.3
2008	52	0	40	40	0	51	51	331	0.275	56.4

Table 2.1.2. The number of large and small salmon counted during dive surveys in Middle River, Victoria Co., from 1994 to 2008. The number of salmon (size classes combined) that were marked and then observed during the dive count are shown for years when mark-recapture experiments were conducted.

	Number Counted		Mark-Recapture		
Year	Small Salmon	Large Salmon	No. Marked	No. of Observed Marks	Observation Efficiency
1994	35	289	17	13	0.76
1995	23	160	12	6	0.50
1996	75	284	16	10	0.63
1997	42	216	17	11	0.65
1998	52	96	18	12	0.67
1999	45	187	15	11	0.73
2000	22	102	23	13	0.57
2001	29	81			
2002	30	61			
2003	19	174	22	7	0.32
2004	31	149	17	8	0.47
2005	57	217			
2006	34	95			
2007	38	115			
2008	83	134			

*Table 2.1.3. Means and standard deviations of age 0 and age 1+ densities (number/100m^2) of Atlantic salmon in the Middle River, Victoria Co., NS, estimated during electrofishing surveys from 1985 to 2006. "*N*" is the number of sites electrofished in each year.*

		Age 0		Age 1+	
Year	N	mean	s.d.	mean	s.d.
1985	2	48.1	29.6	58.2	13.8
1994	2	20.4	18.5	28.5	11.3
1995	3	129.8	38.4	42.8	29.7
1996	4	64.3	71.3	55.2	13.8
1997	4	34.1	27.0	68.9	41.1
1998	4	21.4	11.4	46.8	8.3
1999	4	55.3	25.7	43.8	10.0
2000	4	58.0	40.9	54.1	15.4
2001	4	9.4	6.6	41.9	12.8
2006	4	85.2	68.4	62.8	22.9

Table 2.2.1. Summary of the recreational fishery statistics for large and small Atlantic salmon in Baddeck River, Victoria Co., from 1983 to 2008. The number of anglers is the number that reported fishing in Baddeck River. Other values are corrected for non-reporting. The 2008 estimates are preliminary (Feb. 01, 2009 database query).

Year	No. of Anglers	Small Kept	Small Released	Total Small	Large Kept	Large Released	Total Large	Effort	CPUE	% Large
1983	86	5	1	6	39	6	45	391	0.136	87.8
1984	60	4	2	7	2	44	46	275	0.189	87.5
1985	34	4	0	4	0	13	13	100	0.17	75.0
1986	67	19	6	26	0	126	126	289	0.540	83.1
1987	90	26	14	40	0	126	126	436	0.404	75.9
1988	86	16	15	30	0	145	145	369	0.492	82.8
1989	98	7	8	14	0	195	195	408	0.559	93.2
1990	103	35	26	62	0	158	158	510	0.446	72.0
1991	110	24	19	43	0	178	178	550	0.427	80.6
1992	129	44	6	50	0	146	146	613	0.327	74.4
1993	146	33	15	48	0	107	107	786	0.212	69.2
1994	74	1	11	12	0	48	48	271	0.265	79.4
1995	61	6	43	49	0	57	57	285	0.403	53.8
1996	70	0	43	43	0	154	154	337	0.580	78.2
1997	43	0	14	14	0	64	64	206	0.390	81.7
1998	87	0	57	57	0	81	81	335	0.442	58.6
1999	96	1	14	15	0	79	79	290	0.335	83.7
2000	54	1	11	12	0	55	55	212	0.363	82.0
2001	31	0	11	11	0	20	20	104	0.321	64.0
2002	59	0	19	19	0	38	38	204	0.303	66.0
2003	50	0	23	23	0	80	80	221	0.497	77.3
2004	40	2	14	15	0	53	53	185	0.392	77.5
2005	93	0	40	40	0	109	109	397	0.373	73.5
2006	57	0	21	21	0	88	88	316	0.425	81.2
2007	55	2	15	16	0	66	66	254	0.300	80.4
2008	32	0	21	21	0	35	35	256	0.218	62.5

Table 2.2.2. The number of large and small salmon counted during dive surveys in Baddeck River, Victoria Co., from 1983 to 2008. The number of salmon (size classes combined) that were marked and then observed during the dive count are shown for years when mark-recapture experiments were conducted.

Year	Number Counted		Mark-Recapture		
	Small Salmon	Large Salmon	No. Marked	No. of Observed Marks	Observation Efficiency
1994	17	93	12	9	0.75
1995	42	112	28	12	0.43
1996	43	171	17	11	0.65
1997	35	103	32	19	0.59
1998	30	74	13	7	0.54
1999					
2000	8	84	43	27	0.63
2001					
2002	12	44			
2003	7	60	15	3	0.20
2004	18	38	4	1	0.25
2005	34	121			
2006	21	60			
2007	27	64			
2008	63	74			

Table 2.2.3. Means and standard deviations of age 0 and age 1+ densities (number/100 m^2) of Atlantic salmon in the Baddeck River Victoria Co., NS, estimated during electrofishing surveys from 1996 to 2001. "N" *is the number of sites electrofished in each year.*

Year	N	Age 0		Age 1+	
		mean	s.d.	mean	s.d.
1996	3	63.3	5.9	36.0	13.9
1997	3	113.4	64.5	38.7	12.0
1998	3	64.7	33.0	30.1	9.3
1999	3	95.2	77.3	32.6	16.0
2000	3	141.8	53.8	32.1	21.2
2001	3	47.5	27.3	27.0	18.2

Table 2.3.1. Summary of the recreational fishery statistics for large and small Atlantic salmon in North River, from 1983 to 2008. The number of anglers is the number that reported fishing in North River. Other values are corrected for non-reporting. The 2008 estimates are preliminary (Feb. 01, 2009 database query).

Year	No. of Anglers	Small Kept	Small Released	Total Small	Large Kept	Large Released	Total Large	Effort	CPUE	% Large
1983	290	36	9	44	150	8	158	1880	0.105	78.0
1984	162	57	9	66	96	58	154	1182	0.183	70.0
1985	170	149	13	162	0	425	425	1012	0.559	72.4
1986	297	185	50	235	0	1010	1010	2050	0.640	81.1
1987	263	177	50	226	0	546	546	1668	0.475	70.7
1988	202	99	14	112	0	445	445	1316	0.438	79.9
1989	162	97	32	128	0	316	316	1119	0.433	71.2
1990	219	176	57	233	0	531	531	1612	0.491	69.5
1991	172	123	32	156	0	297	297	1197	0.402	65.6
1992	205	162	36	198	0	486	486	1619	0.433	71.1
1993	217	63	20	83	0	164	164	1246	0.196	66.4
1994	73	0	57	57	0	75	75	361	0.435	56.5
1995	77	1	135	136	0	169	169	436	0.759	55.4
1996	81	0	162	162	0	115	115	526	0.525	41.7
1997	58	1	69	70	0	137	137	384	0.537	66.2
1998	84	0	108	108	0	104	104	448	0.497	49.1
1999	79	0	35	35	0	45	45	292	0.282	56.2
2000	49	0	32	32	0	27	27	261	0.232	45.8
2001	46	0	37	37	0	60	60	264	0.376	62.2
2002	44	0	34	34	0	45	45	269	0.341	57.1
2003	51	0	81	81	0	156	156	525	0.475	65.9
2004	37	0	70	70	0	152	152	505	0.468	68.5
2005	54	1	54	55	0	171	171	441	0.512	75.6
2006	51	0	56	56	0	104	104	445	0.445	64.8
2007	59	0	92	92	0	134	134	491	0.582	59.2
2008	36	0	98	98	0	148	148	445	0.551	60.2

Table 2.3.2. The number of large and small salmon counted during dive surveys in North River from 1983 to 2008. The number of salmon (size classes combined) that were marked and then observed during the dive count are shown for years when mark-recapture experiments were conducted.

	Number Counted		Mark-Recapture		
Year	Small Salmon	Large Salmon	No. Marked	No. of Observed Marks	Observation Efficiency
1994	48	119	22	8	0.36
1995	57	124	28	13	0.46
1996	184	138	14	8	0.57
1997	54	281	25	11	0.44
1998	59	165	13	6	0.46
1999					
2000					
2001	44	73			
2002	7	19			
2003					
2004	30	68			
2005					
2006	3	9			
2007	40	66			
2008					

Table 2.4.1. Summary of the recreational fishery statistics for large and small Atlantic salmon in Grand River, from 1983 to 2008. The number of anglers is the number that reported fishing in Grand River. Other values are corrected for non-reporting. The 2008 estimates are preliminary (Feb. 01, 2009 database query).

Year	No. of Anglers	Small Kept	Small Released	Total Small	Large Kept	Large Released	Total Large	Effort	CPUE	% Large
1983	371	197	35	232	31	39	71	4266	0.069	23.3
1984	268	349	53	403	4	30	34	3009	0.148	7.8
1985	312	472	71	543	0	132	132	3093	0.224	19.6
1986	326	299	62	361	0	194	194	3019	0.180	35.0
1987	262	309	34	343	0	107	107	2078	0.208	23.8
1988	277	252	18	269	0	84	84	2754	0.133	23.8
1989	247	229	17	247	0	59	59	2257	0.148	19.4
1990	240	291	68	359	0	88	88	2497	0.186	19.7
1991	178	97	11	107	0	15	15	1707	0.076	12.3
1992	182	131	10	141	0	39	39	1689	0.109	21.6
1993	183	119	22	140	0	25	25	1496	0.105	15.2
1994	44	0	55	55	0	15	15	366	0.231	21.6
1995	4	0	4	4	0	10	10	41	0.368	71.4
1996	26	0	83	83	0	23	23	261	0.405	21.7
1997	20	3	28	31	0	6	6	173	0.202	15.4
1998	20	0	75	75	0	12	12	246	0.321	13.6
1999	7	0	17	17	0	3	3	47	0.429	16.7
2000	14	0	20	20	0	1	1	81	0.266	5.9
2001	6	0	1	1	0	0	0	9	0.143	0.0
2002	11	0	31	31	0	0	0	84	0.375	0.0
2003	8	0	16	16	0	3	3	63	0.302	15.4
2004	4	0	7	7	0	2	2	35	0.263	20.0
2005	6	0	20	20	0	0	0	13	1.5	0
2006	8	0	15	15	0	0	0	28	0.5	0
2007	5	0	6	6	0	2	2	34	0.174	25
2008	3	0	5	5	0	0	0	7	0.667	0

Table 2.4.2. Returns of Atlantic salmon above Grand River falls on the Grand River, NS, from 1988 to 2000 as estimated from count data at the fishway.

	Small and large fish combined					
Year	Returns	Esc.	% Hatch	Wild Esc.	Wild Rtns	% Req'm
1988	694	626	0	626	694	268
1989	607	453	0	453	607	194
1990	626	442	43	252	357	108
1991	442	348	45	191	243	82
1992	186	133	38	82	115	35
1993	132	97	45	53	73	23
1994	208	201	14	173	179	74
1995	281	281	32	191	191	82
1996	345	345	61	135	135	58
1997	152	147	31	101	105	43
1998	245	241	73	65	66	28
1999*	103	93	34	62	68	26
2000*			0			
*only partial counts were done						

Table 2.6.1. Adult Atlantic salmon abundance time series for five rivers in eastern Cape Breton.

	Middle River[1]		Baddeck River[1]		North River[2]		Grand River[1]	Clyburn River[3]	
Year	Small	Large	Small	Large	Small	Large	Small+ Large	Small	Large
1983	2	27	4	37					
1984	29	194	9	95	101	412			
1985	62	174	12	63	253	1162		4	38
1986	46	299	27	255	367	2756		9	18
1987	23	202	29	194	353	1490		35	140
1988	29	235	29	248	211	1460	626	40	77
1989	22	386	13	313	253	1091	453	17	68
1990	43	264	44	223	418	1664	442	31	65
1991	15	269	29	241	290	969	348		
1992	25	138	16	188	350	1501	133	19	51
1993	31	128	20	124	128	439	97		
1994	52	437	30	153	115	205	201	24	45
1995	43	251	79	196	212	461	281	24	22
1996	120	416	78	299	253	314	345		
1997	68	353	61	181	109	374	147	19	52
1998	81	174	57	141	169	284	241	10	32
1999	71	298	25	204	55	123	93	5	5
2000	38	172	15	142	50	74	26	5	3
2001	50	139	42	93	58	164	2	9	20
2002	53	113	23	83	53	123	46	8	11
2003	34	343	14	128	126	426	39	13	18
2004	55	252	33	78	109	415	18	3	8
2005	89	361	62	215	86	467	29	5	7
2006	60	175	38	117	87	284	35	5	11
2007	64	198	48	121	144	366	16	3	7
2008	128	206	108	125	153	404	10	8	8

1. escapement series
2. return series
3. index series

Table 2.6.2. Summary of declines in adult Atlantic salmon abundance (large and small size categories combined) for five rivers in eastern Cape Breton. The regression method is a log-linear model fit via least squares. The step function is the change in the five-year mean population size ending on the years given in the time period column (the number of years differs between the methods). The standard errors and 95% confidence intervals are in brackets. Fifteen years corresponds to about three generations. A negative value in the decline columns indicates an increasing population size. Model fits for the 15-year time period are shown in Figure 2.6.1.

				Regression		Step Function
Population	Time Period	Length of time series (years)	Slope (SE)	1 yr decline rate (%)	Decline over time period (%)	Decline over time period (%)
Middle River	1989 - 2008	20	-0.00 (0.02)	0.17 (3.02 – -2.76)	3.34 (45.84 – -72.49)	-7.42 (20.56 – -44.94)
	1994 - 2008	15	-0.25 (0.02)	2.44 (6.33 – -1.62)	30.93 (62.55 – -27.31)	-20.65 (22.97 – -89.41)
	1999 - 2008	10	0.03 (0.04)	-2.74 (4.47 – -10.50)	-31.04 (4.48 – -171.45)	14.78 (37.99 – -17.89)
Baddeck River	1989 - 2008	20	-0.03 (0.01)	2.71 (5.06 – 0.29)	42.25 (64.62 – 5.73)	15.07 (52.42 – -52.15
	1994 - 2008	15	-0.03 (0.02)	2.88 (6.73 – -1.13)	35.51 (64.84 – -18.29)	13.43 (40.48 – -25.71)
	1999 - 2008	10	0.02 (0.04)	-2.42 (4.58 – -9.94)	-27.04 (37.42 – -157.89)	30.16 (51.22 – 0.13)
North River	1989 - 2008	20	-0.07 (0.02)	6.53 (11.07 – 1.74)	74.06 (90.44 – 29.64)	72.17 (79.46 – 62.03)
	1994 - 2008	15	0.01 (0.03)	-1.32 (4.96 – -8.02)	-21.83 (53.34 – -218.14)	48.94 (74.06 – -1.67)
	1999 - 2008	10	0.16 (0.04)	-17.15 (-8.35 – -26.65)	-386.85 (-123.07 – -962.59)	-15.49 (-26.58 – -82.20)
Grand River	1989 - 2008	20	-0.19 (0.04)	17.84 (23.4 – 11.84)	98.03 (99.52 – 91.86)	96.33 (98.10 – 92.69)
	1994 - 2008	15	-0.23 (0.06)	20.80 (29.78 – 10.58)	96.95 (99.50 – 81.32)	90.64 (95.09 – 81.87
	1999 - 2008	10	-0.07 (0.12)	6.69 (26.27 – -18.08)	49.98 (95.15 – -427.31)	90.49 (94.49 – 81.87)
Clyburn River	1989 - 2008	20	-0.12 (0.02)	11.16 (14.85 – 7.31)	90.62 (95.98 – 78.11)	82.35 (90.88 – 66.24)
	1994 - 2008	15	-0.11 (0.04)	10.77 (16.80 – 4.30)	81.90 (93.67 – 48.27)	83.52 (87.27 – 78.26)
	1999 - 2008	10	0.00 (0.05)	-0.24 (9.73 – -11.33)	-2.48 (64.10 – -192.53)	62.72 (81.87 – 22.97)

Table 3.2.1. Sites electrofished in rivers throughout eastern Cape Breton in 2006 and 2007.

River	Site name	Index river	site #	Years sampled	Site location				
					Map	Grid Ref	Datum	Latitude (decimal degrees)	Longitude
Black Brook	Main channel	no	BlkB001	2007	11K16	016-826	NAD83	46.7666	60.3597
Clyburn	SP1	no	Cly001	2006	11K9	912-706	NAD83	46.6619	60.5009
	SP2	no	Cly002	2006	11K9	907-707	NAD83	46.6629	60.5070
		no	Cly003	2006	11K9	904-708	NAD84	46.6639	60.5110
	Franny Brook	no	Cly004	2006	11K9	941-699	NAD83	46.6554	60.4637
	Main channel	no	Cly005	2006-2007	11K9	700-977	NAD83	46.6545	60.4159
River Denys	Glen 27	no	Denys001	2006	11F14	345-822	NAD83	45.8822	61.2652
	Glen 8	no	Denys002	2006	11F14	350-819	NAD83	45.8796	61.2577
Grand	Mud Hole (above falls)	yes	Grand001	1996-2000, 2006	11F10	843-665	NAD83	45.7279	60.6309
	Fishway (above falls)	yes	Grand002	1996-2000, 2006	11F10	847-647	NAD83	45.7114	60.6267
	Crib Pool (below falls)	yes	Grand003	1996-2000, 2006	11F10	844-613	NAD83	45.6815	60.6319
	Frank MacDonald Rd. (below falls)	yes	Grand004	1996-2000, 2006	11F10	824-589	NAD83	45.6604	60.6583
Indian Bk (Eskazoni)		no	Indian001	2002, 2006-2007	11K2	858-918	NAD83	45.1232	60.1012
Ingonish		no	Ingon001	2001, 2006	11K9	956-664	NAD83	46.6230	60.4448
Middle	MacKenzie Bk	yes	Mid001	1996-2001, 2006	11K2	575-107	NAD83	46.1323	60.9599
	Finlayson	yes	Mid002	1996-2001, 2006	11K2	603-232	NAD83	46.2436	60.9195
	Twin Churches	yes	Mid003	1996-2001, 2006	11K2	601-134	NAD83	46.1559	60.9265
	MacLeods Bk	yes	Mid004	1996-1998, 2006	11K2	600-140	NAD83	46.1612	60.9265
Mira River	Gaspereaux River	no	Mira001	2007	11F16	073-884	NAD83	45.9181	60.3274
North Aspy	South branch	no	NAspe001	2006	11K15	810-871	NAD83	46.8129	60.6275
		no	NAspe002	2007	11K15	800-864	NAD83	46.8072	60.6400
North	Karr's	yes	NorCB001	1998-2001, 2006	11K7	829-312	NAD83	46.3100	60.6245
	MacLeans	yes	NorCB002	1997-2001, 2006	11K7	779-337	NAD83	46.3338	60.6882
	Narrows	yes	NorCB003	1999-2001, 2006	11K7	812-320	NAD83	46.3178	60.6460
	Benches	yes	NorCB004	1996, 1998-2000, 2006	11K7	774-343	NAD83	46.3397	60.6940
Sydney	Meadows Brook	no	Sydney001	1996-2000, 2006-2007	11K1	105-028	NAD83	46.0333	60.2792
	Woodbine Brook	no	Sydney002	2002, 2006-2007	11K1	084-995	NAD83	46.0210	60.1353

Table 3.2.2. Number of fish captured by species while electrofishing in rivers in eastern Cape Breton during 2006 and 2007. Contributions to data collection came from First Nations (FN), Parks Canada (Parks) and the Department of Fisheries and Oceans, including the Aquatic Resources Division (ARD) at the Gulf Fisheries Center, and the Population Ecology Division (PED) at the Bedford Institute of Oceanography. Alosa and chub were not identified to the species level.

			Number captured by species										
River	Crew	Site ID	Alosa unidentified	American eel	Atlantic salmon	Brook trout	Brown trout	Chub unidentified	Mummichog	Rainbow trout	Sea lamprey	Three-spined stickleback	Total
2006													
		Cly001		10	22	1							33
		Cly002				5							5
Clyburn	Parks, ARD, PED	Cly003											0
		Cly004		1	14								15
		Cly005		15	52	1							68
River Denys	FN, ARD, PED	Denys001			28	4							32
		Denys002			1	3							4
		Grand001	6	10	14				3				33
Grand	FN, ARD, PED	Grand002		8	16								24
		Grand003	1	15	23								39
		Grand004			9			1					10
Indian Brook	FN, PED	Indian001			20	4	2			6			32
Ingonish	Parks, ARD, PED	Ingon001		2	22								24
		Mid001			37	15							52
Middle	FN, ARD, PED	Mid002			101	5							106
		Mid003			100	1							101
		Mid004			164	5							169
North Aspy	Parks, ARD, PED	NAspe001		12	152	6							170
		NorCB001		9	84	2							95
North	Parks, ARD, PED	NorCB002			69								69
		NorCB003		4	76								80
		NorCB004			38	4							42
Sydney	FN, PED	Sydney001			29	2							31
		Sydney002				32							32
2007													
Black Brook	Parks, PED	BlkB001		1	2	3							6
Clyburn River	Parks, PED	Cly005		14	31								45
Indian Brook	FN, PED	Indian001			42	6				5			53
Mira River	FN, PED	Mira001		8	83	2	4	1			1		99
North Aspy	Parks, PED	NAspe001		1	43	4							48
		NAspe002		1	45								46
Sydney	FN, PED	Sydney001		1	11	2						1	15
		Sydney002				46							46

Table 3.2.3. Juvenile density by age of Atlantic salmon at electrofishing sites in eastern Cape Breton in 2006 and 2007. Total catch at each site is standardized by shocking time and scaled up to density using the catch-per-unit-effort (CPUE) - density relationship for fry and parr developed by Chaput et al. (2005). The catchability of age 1 and age 2 parr is assumed to be equal.

				No. of	Area	Shocking	Catch			CPUE (3 min.)			Density (per 100m^2)		
	River	Site ID	Method	Sweeps	(m^2)	Time	Age 0	Age 1	Age 2	Age 0	Age 1	Age 2	Age 0	Age 1	Age 2
2006	Clyburn	Cly001	one-pass	1	93.28	300	0	17	5	0	10	3	4	57	19
		Cly004	one-pass	1	201.08	385	3	4	7	1	2	3	11	14	21
		Cly005	one-pass	1	178.41		40	9	3						
	River Denys	Denys001	one-pass	1	69.27	301	28	0	0	17	0	0	92	4	4
		Denys002	one-pass	1	55.61	281	0	1	0	0	1	0	4	8	4
	Grand	Grand001	one-pass	1	249.73	967	11	3	0	2	1	0	14	7	4
		Grand002	one-pass	1	257.04	889	13	3	0	3	1	0	17	7	4
		Grand003	one-pass	1	372.49	1400	20	3	0	3	0	0	17	6	4
		Grand004	one-pass	1	199.81	567	5	4	0	2	1	0	12	11	4
	Indian Brook	Indian001	one-pass	1	223.44	534	5	6	9	2	2	3	13	14	19
	Ingonish	Ingon001	one-pass	1	222.07	545	7	15	0	2	5	0	16	29	4
	Middle	Mid001	one-pass	1	91.57	535	0	21	16	0	7	5	4	40	31
		Mid002	one-pass	1	230.15	723	40	49	12	10	12	3	56	68	19
		Mid003	one-pass	1	138.82	470	74	25	1	28	10	0	157	54	6
		Mid004	one-pass	1	214.37	1083	135	24	5	22	4	1	124	24	8
	North Aspy	NAspe001	Removal	4	352.63	735,743, 748,1056*	23,19, 10,10*	45,10, 11,0*	7,5, 9,3*	6	11	2	33	61	13
	North	NorCB001	one-pass	1	174.72	560	12	63	9	4	20	3	24	112	19
		NorCB002	one-pass	1	153.61	453	3	33	33	1	13	13	10	73	73
		NorCB003	one-pass	1	169.03	673	6	65	5	2	17	1	12	96	11
		NorCB004	one-pass	1	142.07	504	25	11	2	9	4	1	50	24	8
	Sydney	Sydney001	one-pass	1	192.27	434	25	3	1	10	1	0	58	10	6
2007	Clyburn	Cly005	one-pass	1	276	539	22	7	0	7	2	0	42	16	4
	Indian Brook	Indian001	one-pass	1	384	855	10	25	5	2	5	1	15	31	10
	North Aspy	NAspe001	one-pass	1	242	573	24	16	1	8	5	0	43	30	6
		NAspe002	one-pass	1	235	531	15	27	3	5	9	1	30	51	9
	Sydney	Sydney001	one-pass	1	251	629	9	2	0	3	1	0	17	7	4
	Mira River	Mira001	one-pass	1	449	786	72	2	1	16	0	0	91	7	6
	Black Brook	BlkB001	one-pass	1	357	517	0	0	2	0	0	1	4	4	4

*Numbers correspond to the shocking time and catch on each of the four passes.

Table 4.1: Area (m^2 x 100) by percent orthogradient for 17 rivers in eastern Cape Breton (adapted from Robichaud-LeBlanc and Amiro 2004).

		%Grade												
Group	River	0-0.12	0.121-0.249	0.25-0.49	0.5-0.99	1.0-1.49	1.5-1.99	2.0-2.49	2.5-2.99	3.0-3.49	3.5-5.0	>5.0	Total Area	Proportion of Habitat <1% grade
east	Mira	6422	2721	2210	1196	306	180	91	42	21	17	5	13211	0.950
east	Salmon	5824	1273	469	206	137	34	17	4	0	0	0	7964	0.976
east	Gaspereaux	0	1054	976	764	0	0	0	0	0	0	0	2794	1.000
east	Sydney	1135	1084	872	874	474	131	51	41	25	36	28	4751	0.835
east	Tillard	0	279	329	330	139	43	0	4	0	3	2	1129	0.831
east	Aconi	519	189	115	548	67	96	15	10	4	0	2	1565	0.876
east	Catalone	0	2614	785	596	121	84	45	13	24	22	6	4310	0.927
east	Framboise	0	2154	2537	1317	324	175	54	51	68	13	7	6700	0.897
east	Frenchvale	0	457	497	246	142	88	96	32	0	52	17	1627	0.738
east	Gerratt	0	0	247	386	86	51	36	16	10	4	7	843	0.751
east	Grand	873	2352	1329	443	187	154	72	27	11	32	10	5490	0.910
east	Lorraine	695	227	1215	957	138	27	27	8	3	3	5	3305	0.936
east	Marie Joseph	565	1160	1392	1297	262	63	9	24	13	10	0	4795	0.921
west	North	0	0	391	1413	859	201	419	121	220	161	43	3828	0.471
west	Baddeck	0	494	2321	3387	873	616	374	155	68	75	0	8363	0.742
west	Barachois	0	0	227	502	453	422	393	139	36	106	19	2297	0.317
west	Ingonish	0	0	157	268	373	505	198	124	119	134	57	1935	0.220
west	Middle	0	2538	1534	3530	539	331	85	62	27	0	0	8646	0.879

10.0 FIGURES

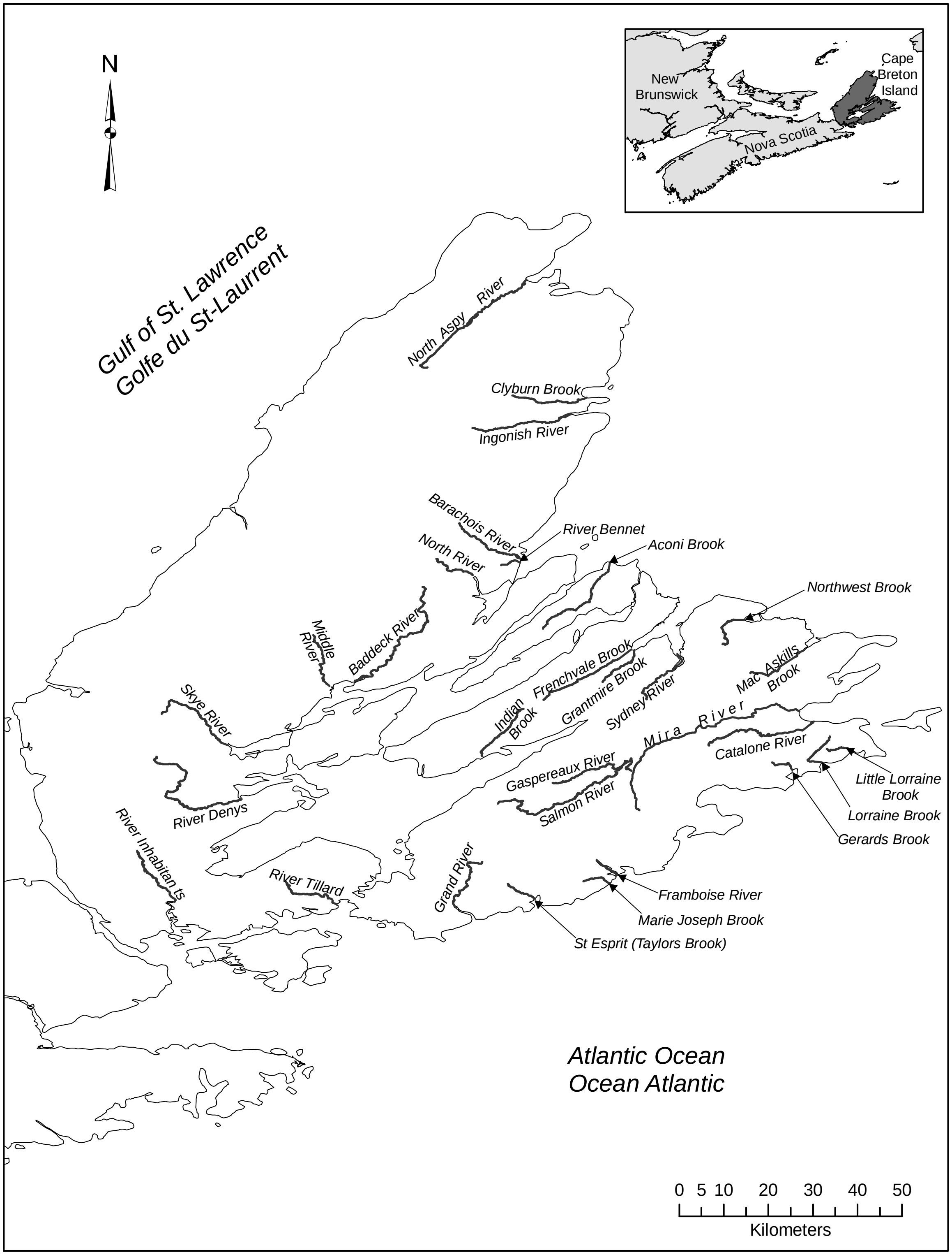


Figure 1.1. Rivers in Eastern Cape Breton with a reported recreational catch.

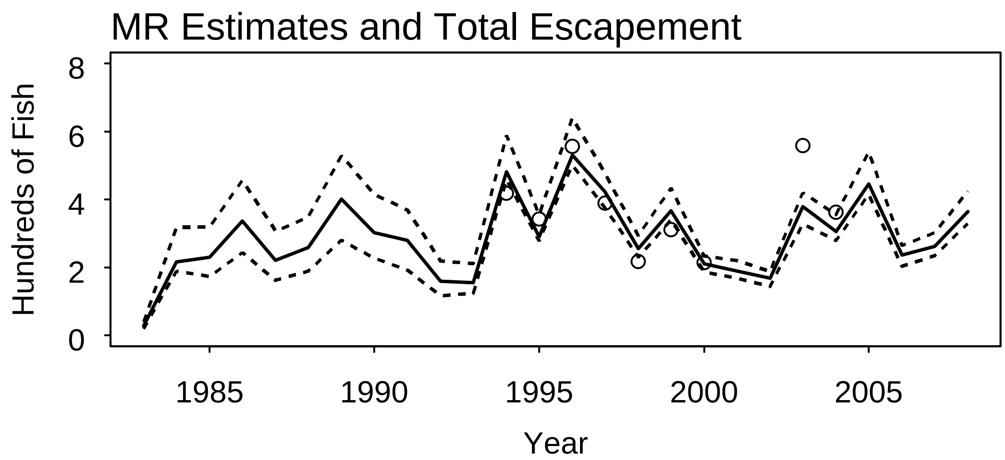


Figure 2.1.1. Estimated total number of salmon (solid lines) escaping the fishery in Middle River, NS, from 1983 to 2008. The points are the population estimates obtained by mark recapture during the dive surveys. The dashed lines are the 10th and 90th percentiles of the posterior probability densities for the total annual escapement. See Appendix 1 for the derivation of this figure.

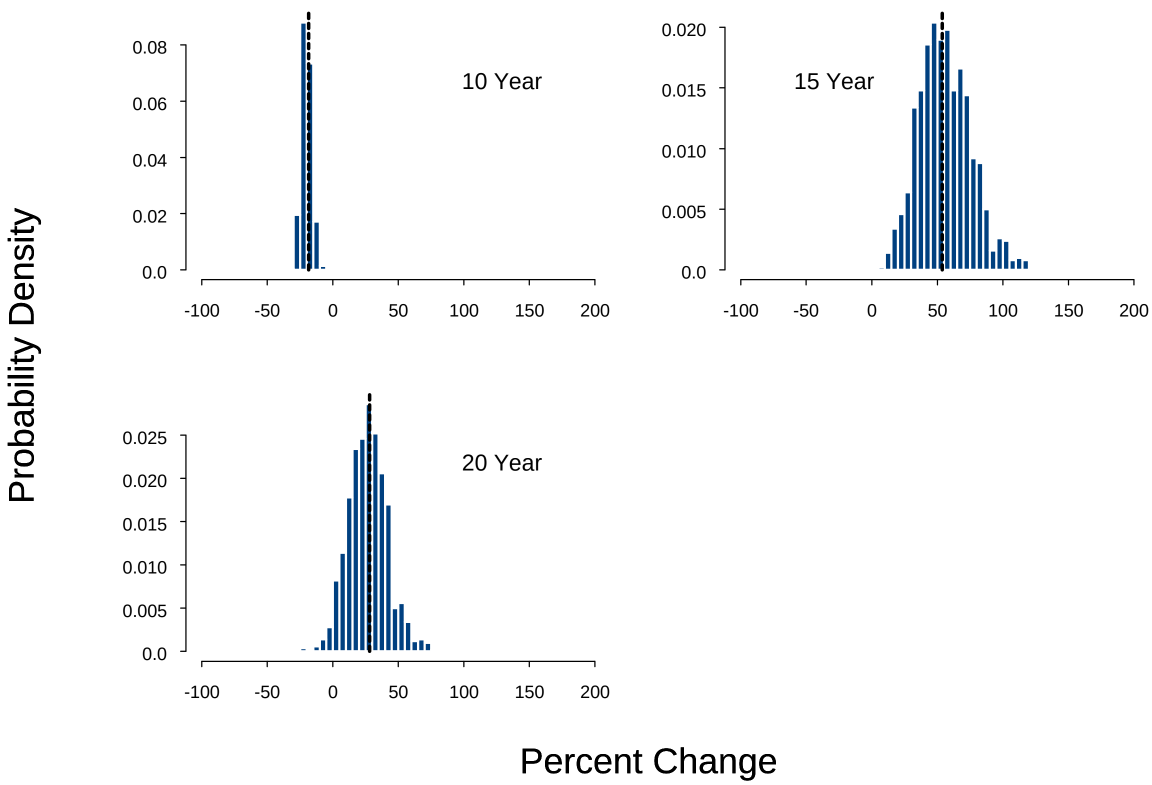


Figure 2.1.2. Posterior probability densities for the percent decline in the Atlantic salmon escapement in Middle River, NS over 10-, 15- and 20-year time periods. Percent decline was calculated by comparing the mean number of returning salmon for the 2004-2008 time period to means for the 1994-1998 time period (10-year comparison), the 1990-1994 time period (15-year comparison), and the 1984-1988 time period (20-year comparison). The dashed lines show the maximum likelihood estimates for the percent change in population size. See Appendix 1 for the derivation of this figure.

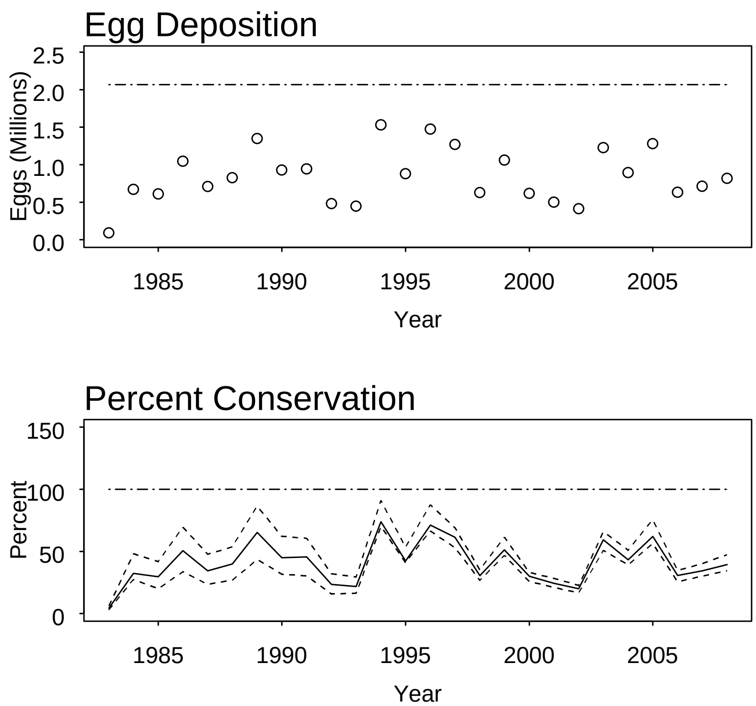


Figure 2.1.3. Estimated egg deposition and the percent of the conservation requirement achieved in Middle River, NS, from 1983 to 2008. The horizontal line is the conservation requirement. The 10th and 90th percentiles of the posterior probability densities for the percent of the conservation requirement achieved are shown. See Appendix 1 for the derivation of this figure.

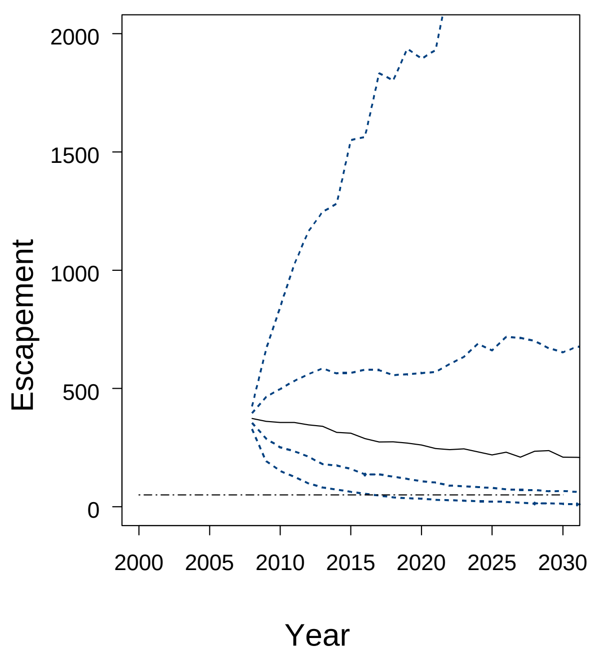


Figure 2.1.4. Results of the Bayesian version of a Dennis-type population viability analysis for Atlantic salmon in Middle River, NS. The solid line is the median population size and the dashed lines are the 10th, 30th, 70th and 90th percentiles of the posterior distributions for the projected annual population size. The horizontal dashed line shows an arbitrary quasi-extinction threshold of 50 salmon. See Appendix 1 for the derivation of this figure.

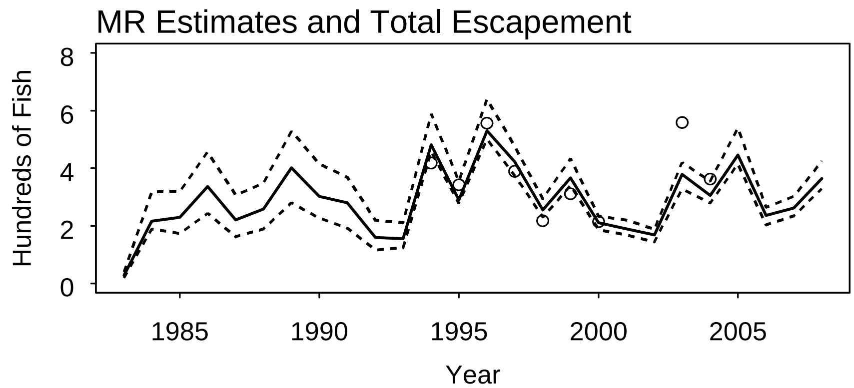


Figure 2.2.1. Estimated total number of salmon (solid lines) escaping the fishery in Baddeck River, NS, from 1983 to 2008. The points are the population estimates obtained by mark recapture during the dive surveys. The dashed lines are the 10th and 90th percentiles of the posterior probability densities for the total annual escapement. See Appendix 2 for the derivation of this figure.

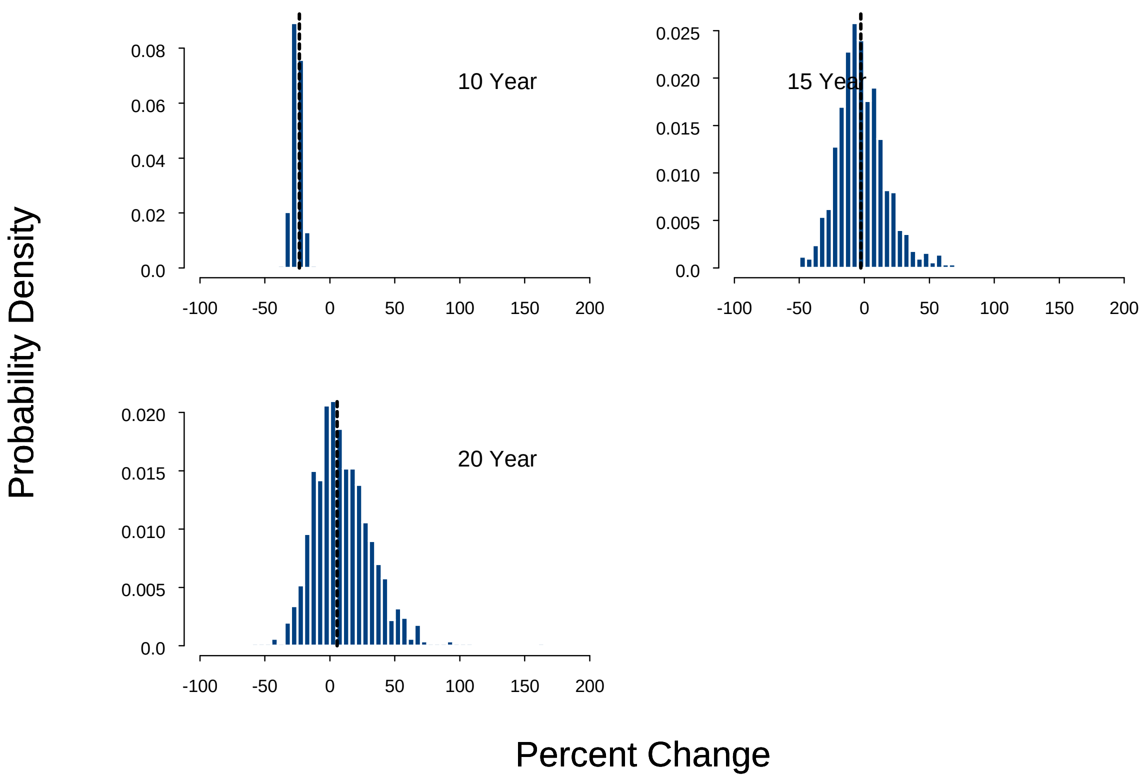


Figure 2.2.2. Posterior probability densities for the percent decline in Atlantic salmon escapement in Baddeck River, NS, over 10-, 15- and 20-year time periods. Percent decline was calculated by comparing the mean number of returning salmon for the 2004-2008 time period to means for the 1994-1998 time period (10-year comparison), the 1990-1994 time period (15-year comparison), and the 1984-1988 time period (20-year comparison). The dashed lines show the maximum likelihood estimates for the percent change in population size. See Appendix 2 for the derivation of this figure.

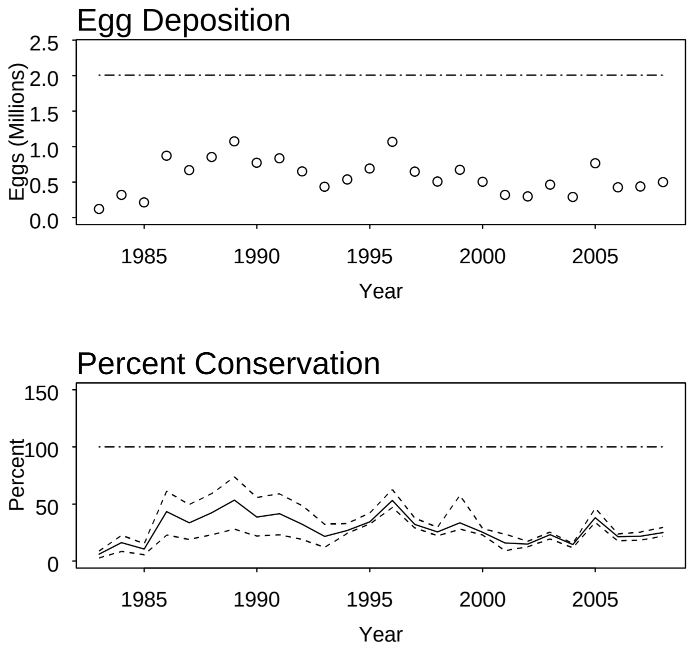


Figure 2.2.3. Estimated egg deposition and the percent of the conservation requirement achieved in Baddeck River, NS, from 1983 to 2008. The horizontal line is the conservation requirement. The 10th and 90th percentiles of the posterior probability densities for the percent of the conservation requirement achieved are shown. See Appendix 2 for the derivation of this figure.

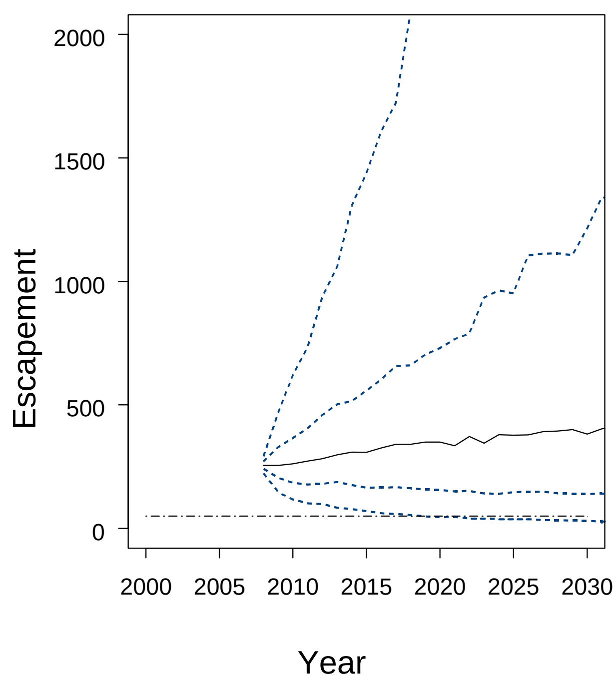


Figure 2.2.4. Results of the Bayesian version of a Dennis-type population viability analysis for Atlantic salmon in Baddeck River, NS. The solid line is the median population size and dashed lines are the 10th, 30th, 70th and 90th percentiles of the posterior distributions for the projected annual population size. The horizontal dashed line shows an arbitrary quasi-extinction threshold of 50 salmon. See Appendix 2 for the derivation of this figure.

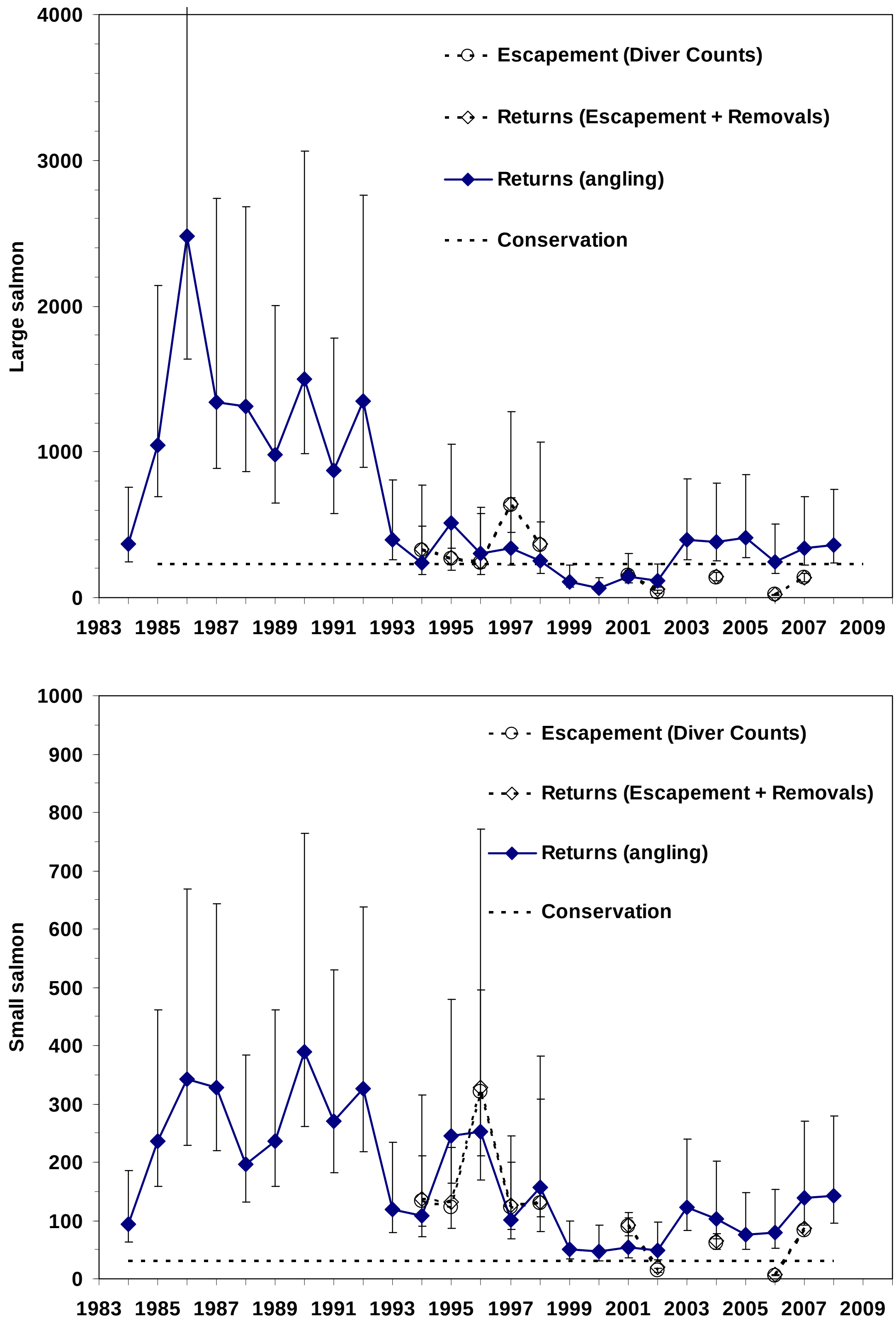


Figure 2.3.1. Estimates of the number of salmon returning to spawn and the spawning escapement for large and small salmon in the North River, NS, as derived from diver counts and from recreational catch data. The number of large or small salmon required to meet the conservation requirement is shown by the horizontal dashed line.

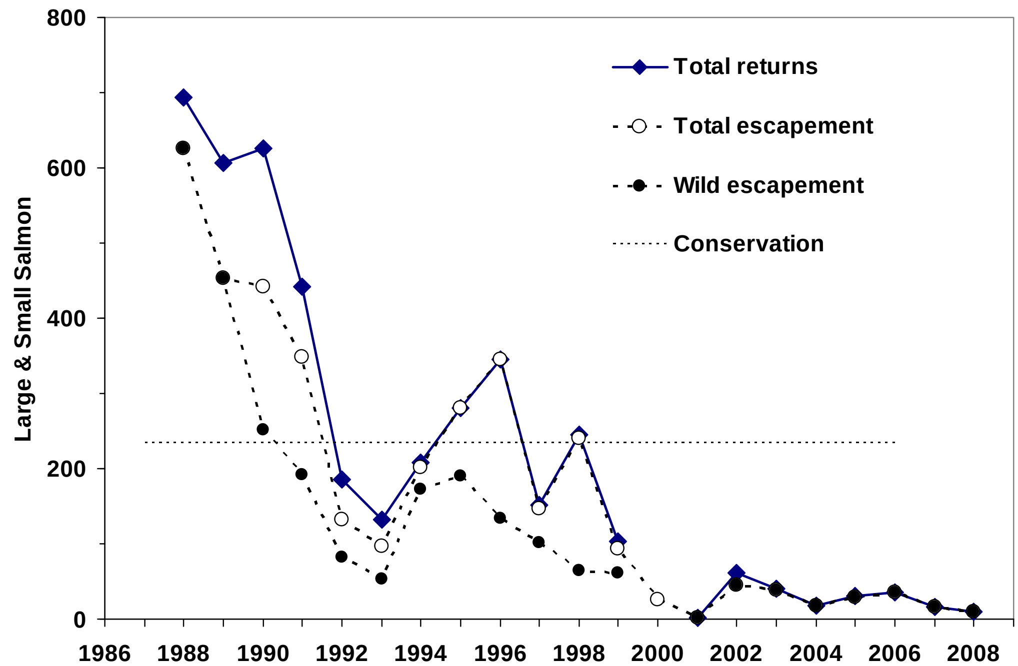


Figure 2.4.1. Returns and escapement to the Grand River, NS, for large and small salmon as derived from recreational catch data. The number of salmon (large and small combined) required to meet the conservation requirement is shown by the horizontal dashed line.

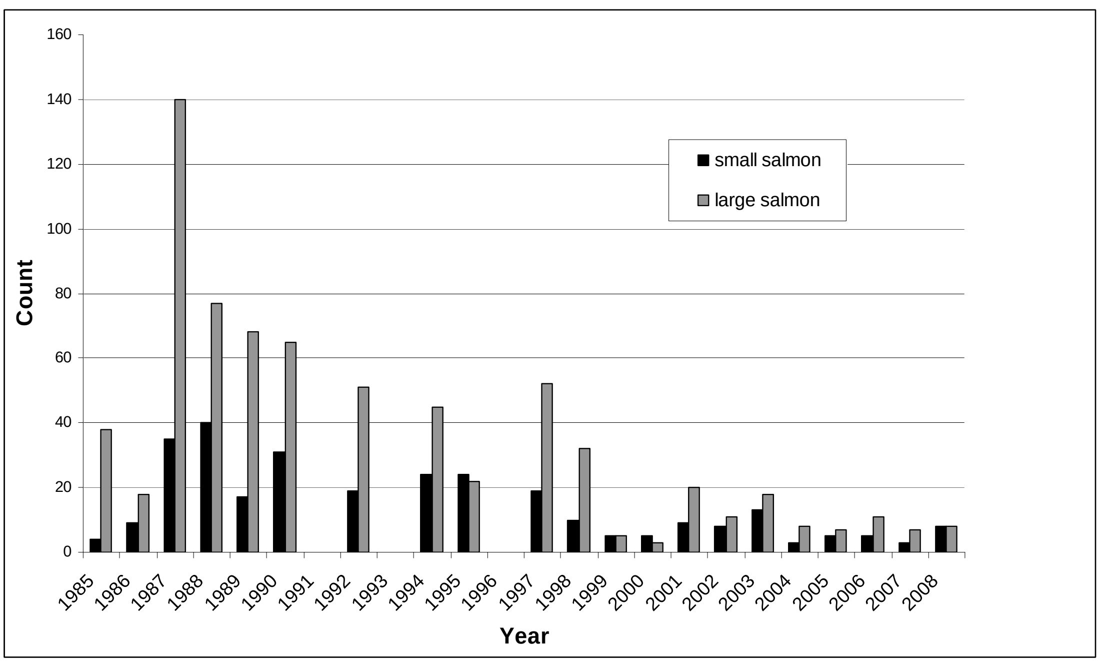


Figure 2.5.1. Counts of large and small salmon during dive surveys in Clyburn River, NS, from 1985 to 2008. Counts occur at the end of the fishing season.

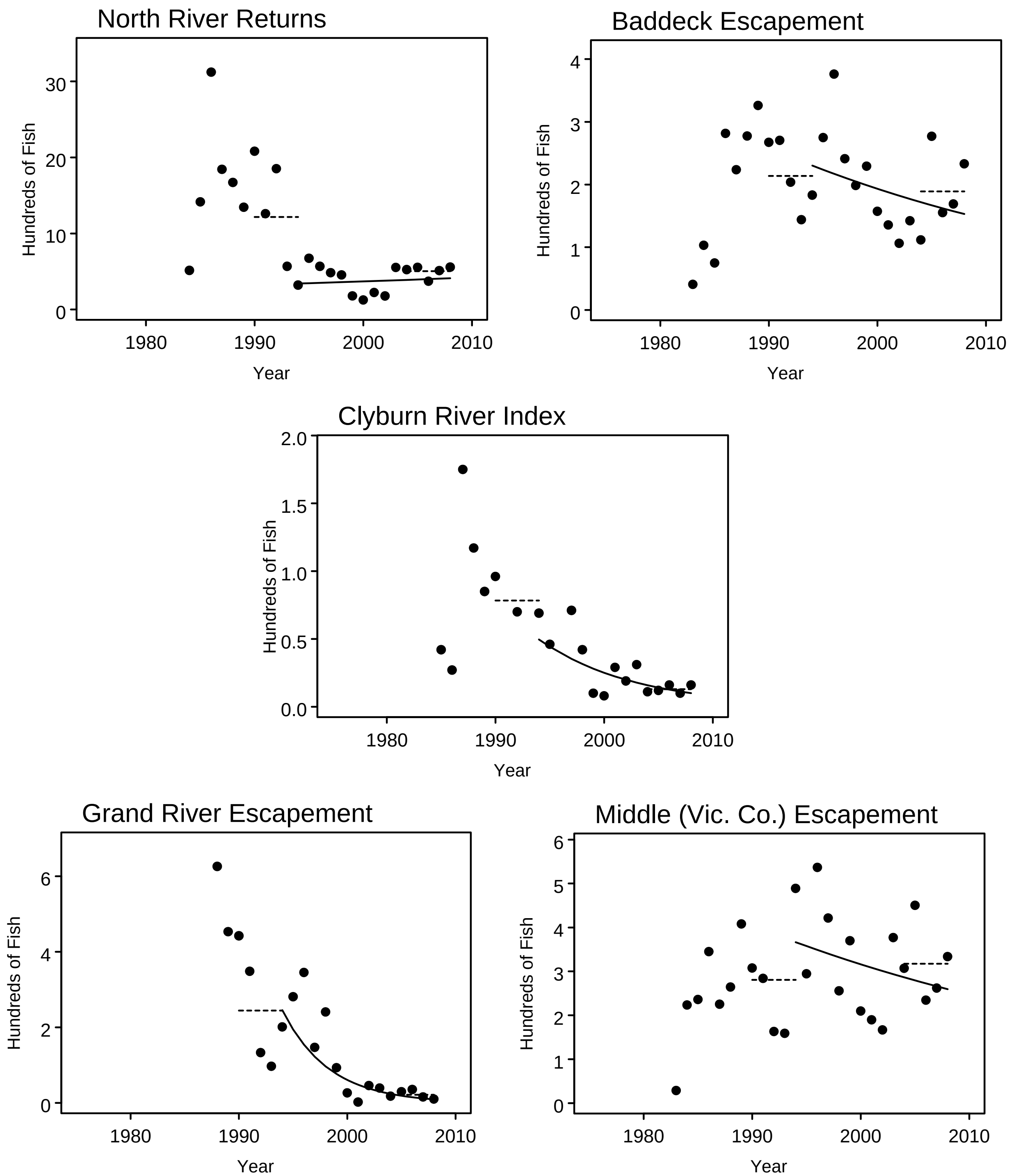


Figure 2.6.1. Trends in abundance of adult Atlantic salmon (size categories combined) in five eastern Cape Breton rivers during the last 15 years. The solid line is the predicted abundance from a log-linear model fit by least squares. The dashed line shows the five-year mean abundance for two time periods separated by 15 years. The points are the observed data. Model coefficients are provided in Table 2.6.2.

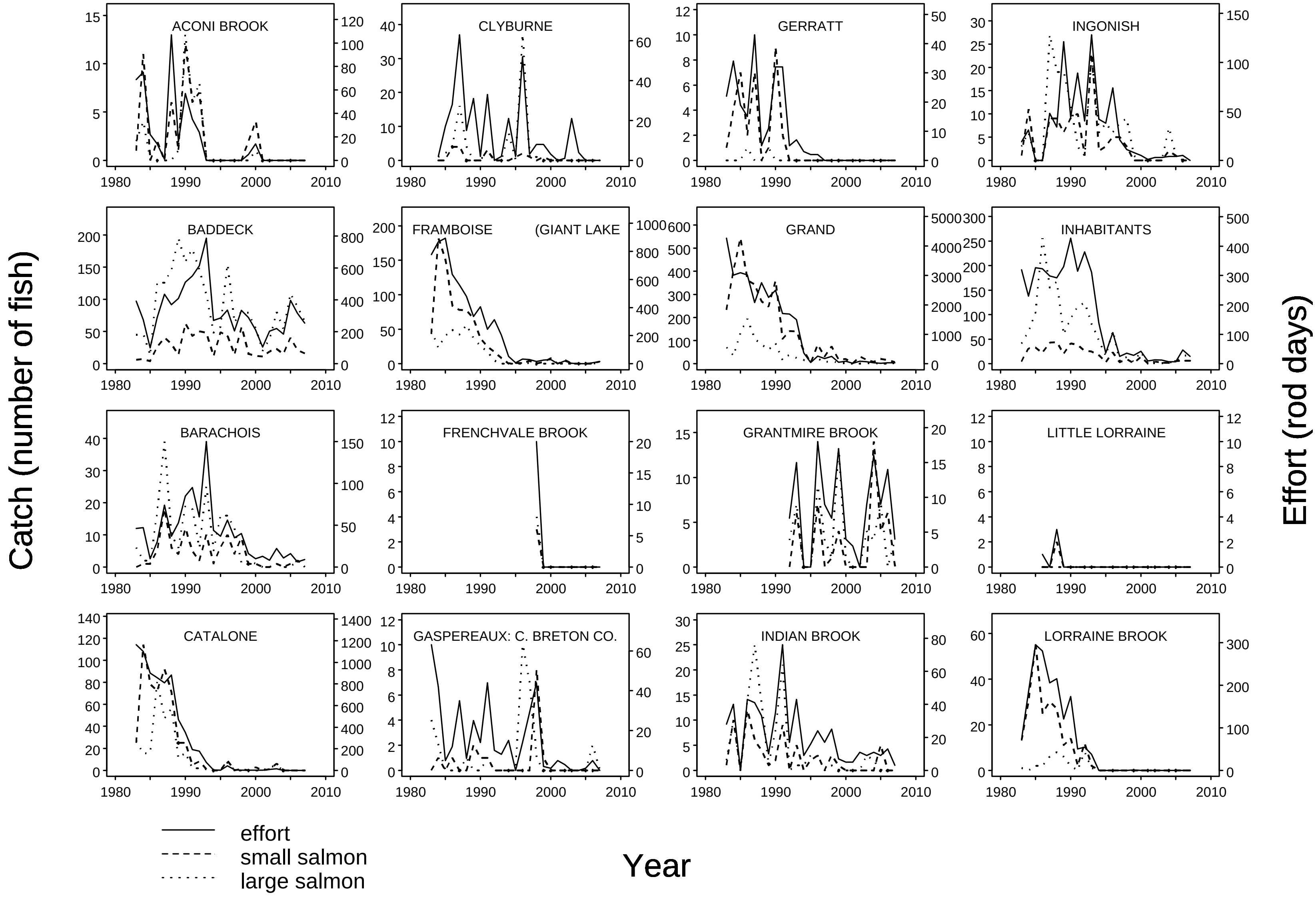


Figure 3.1.1. Estimated recreational catch of small and large Atlantic salmon and fishing effort for eastern Cape Breton rivers (SFA 19) from 1983 to 2007 based on salmon fishing license stub returns (continued next page).

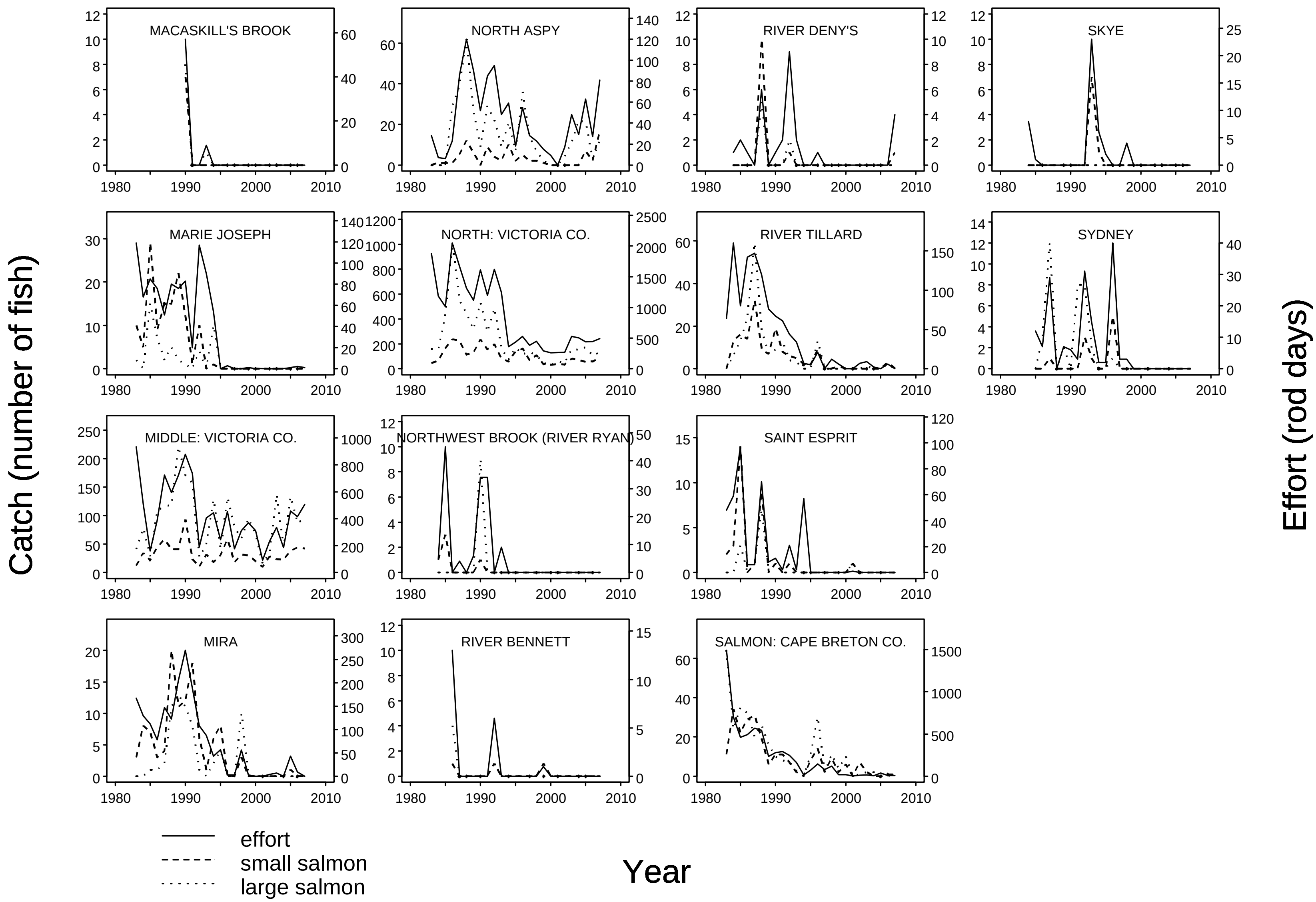


Figure 3.1.1. (continued).

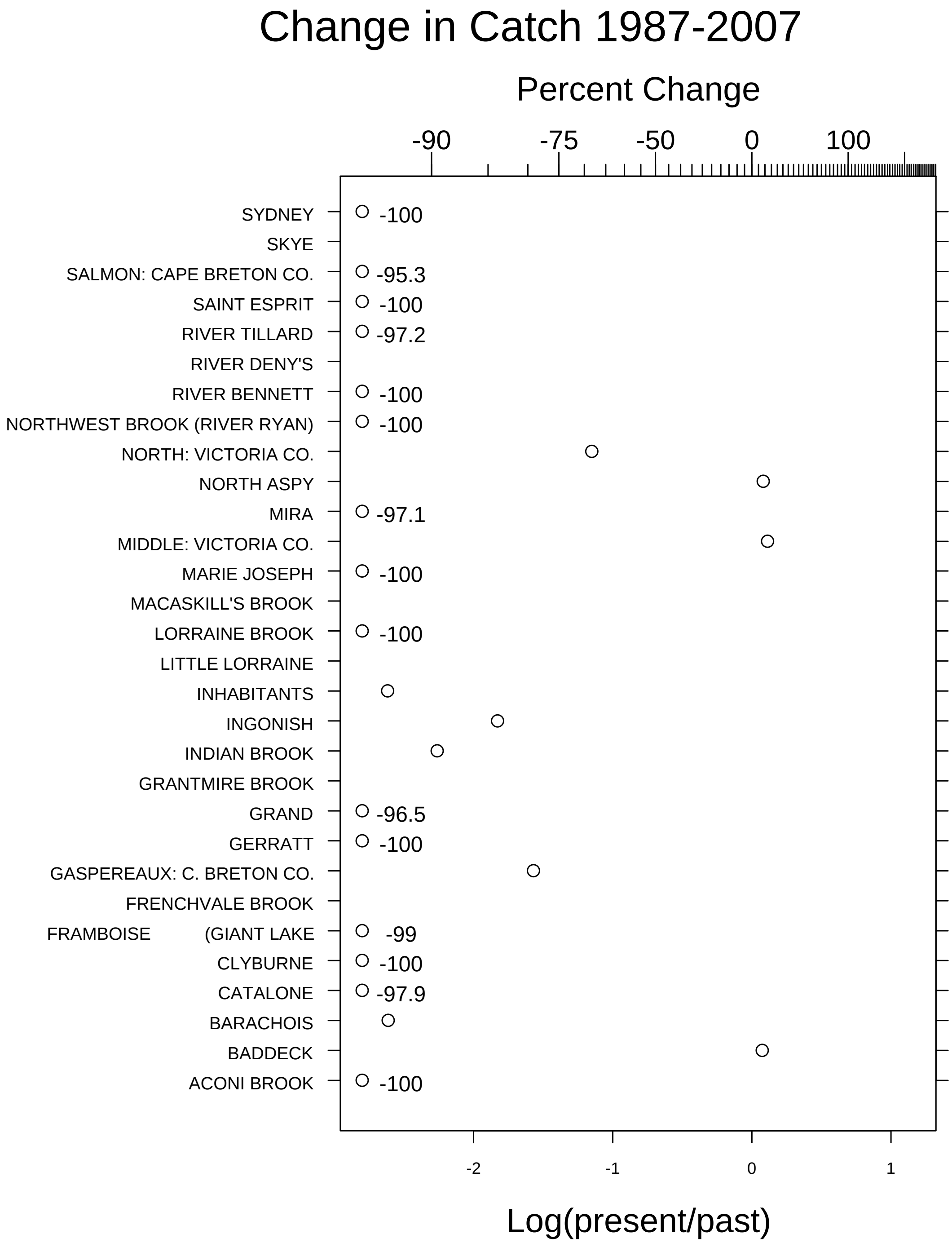


Figure 3.1.2. Change in the average estimated reported catch, of large and small salmon combined, between the five-year time periods ending on 1987 (years: 1983 to 1987) and 2007 (years: 2003 to 2007). Points with value labels are outside the range of the graph.

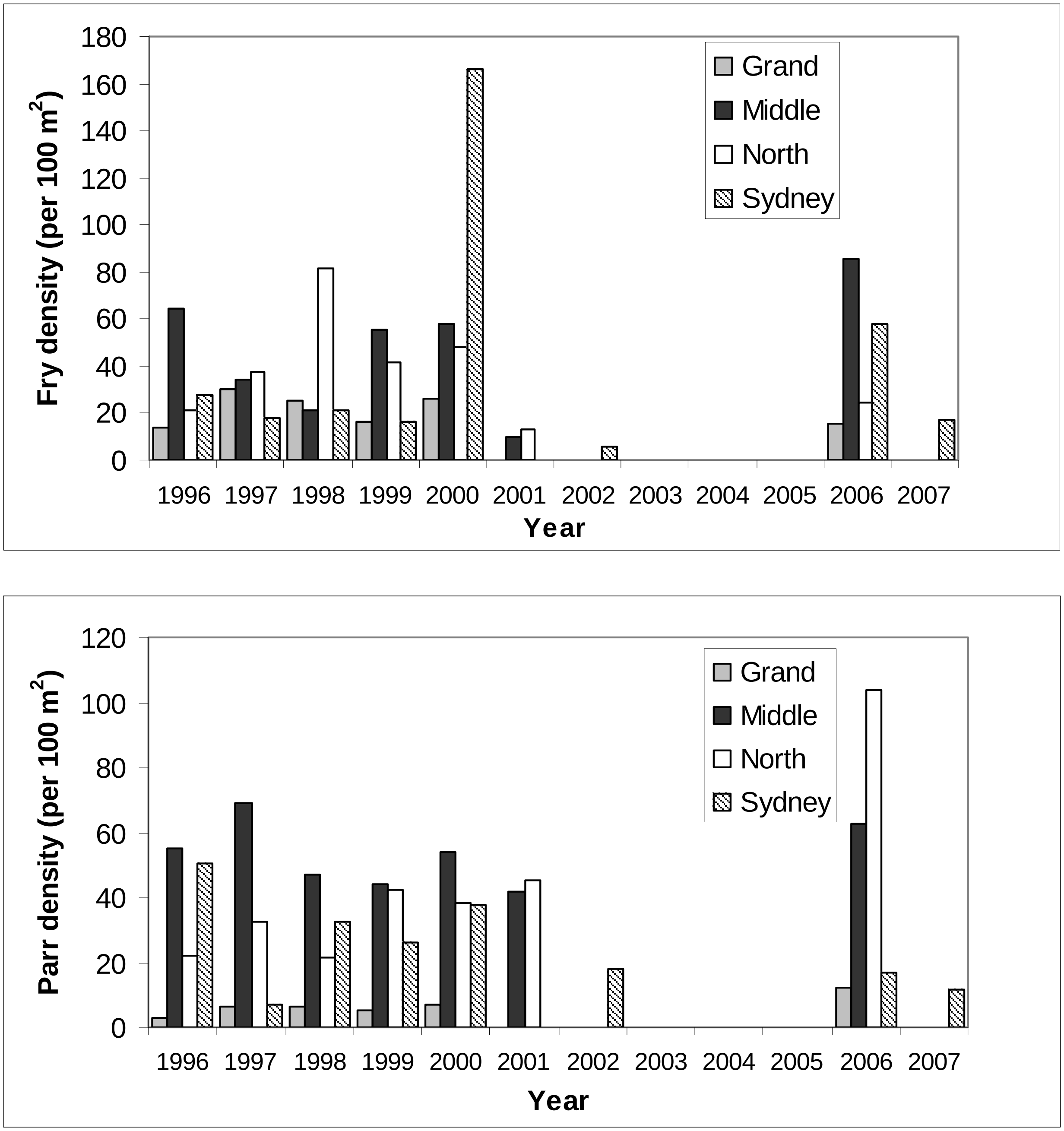
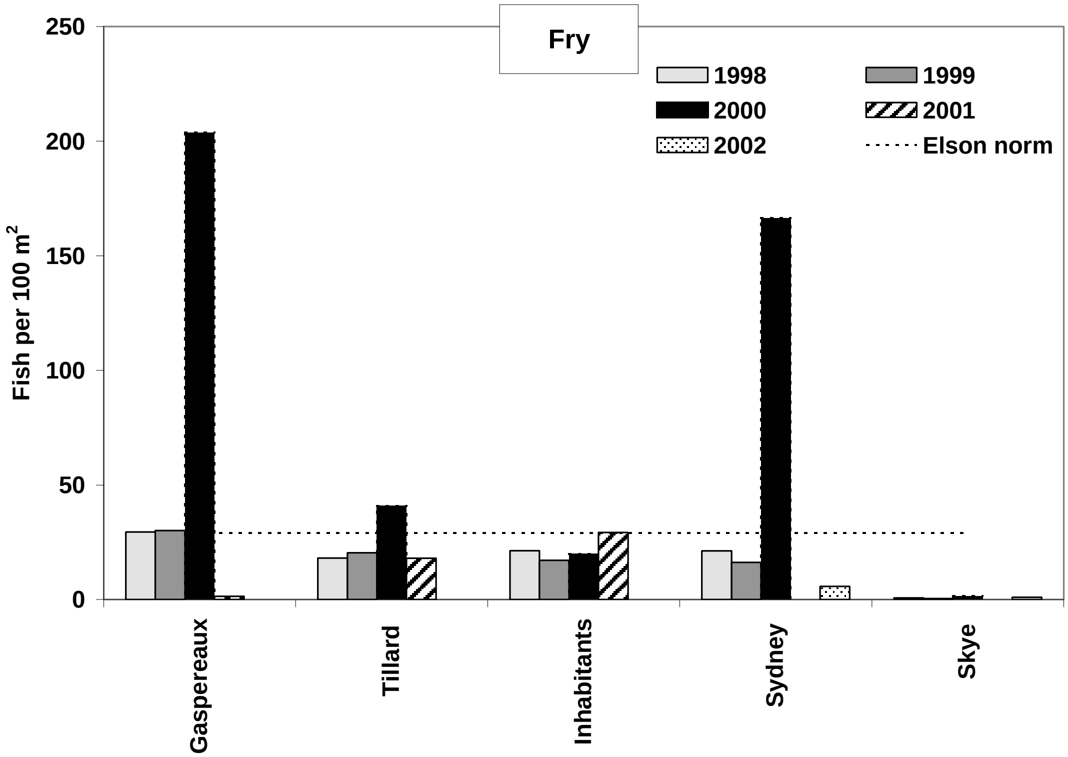


Figure 3.2.1. Mean fry (age 0) and parr (age 1 and age 2 combined) density in the Grand, Middle, North and Sydney rivers from 1996-2001, 2002, 2006 and 2007.



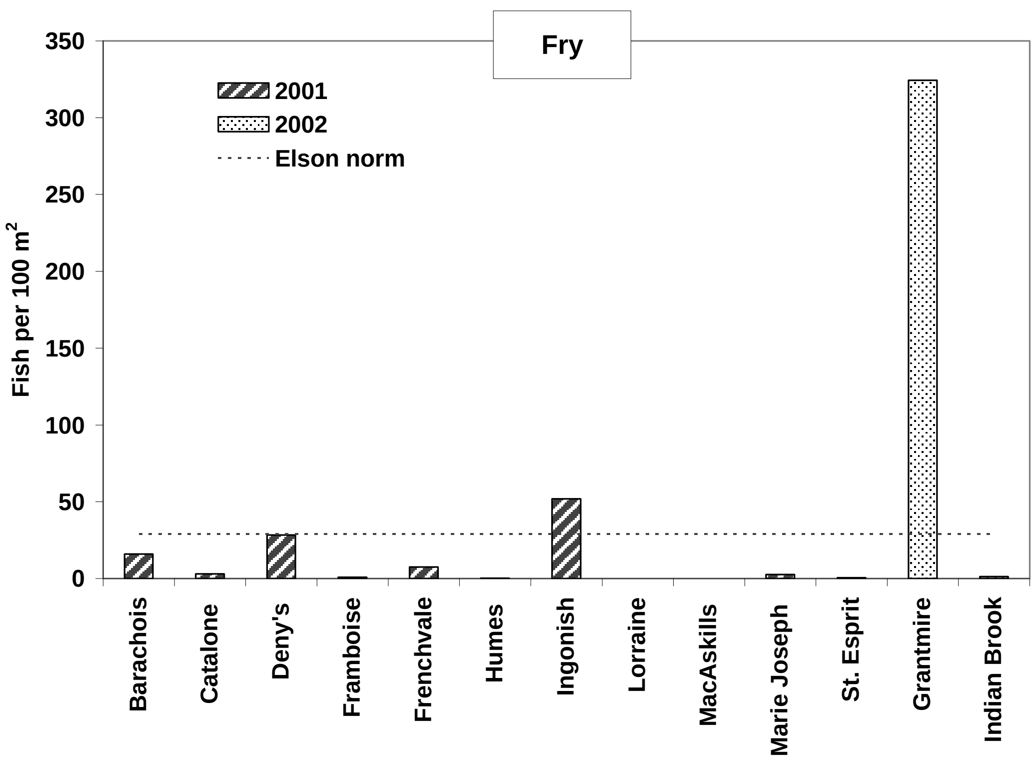
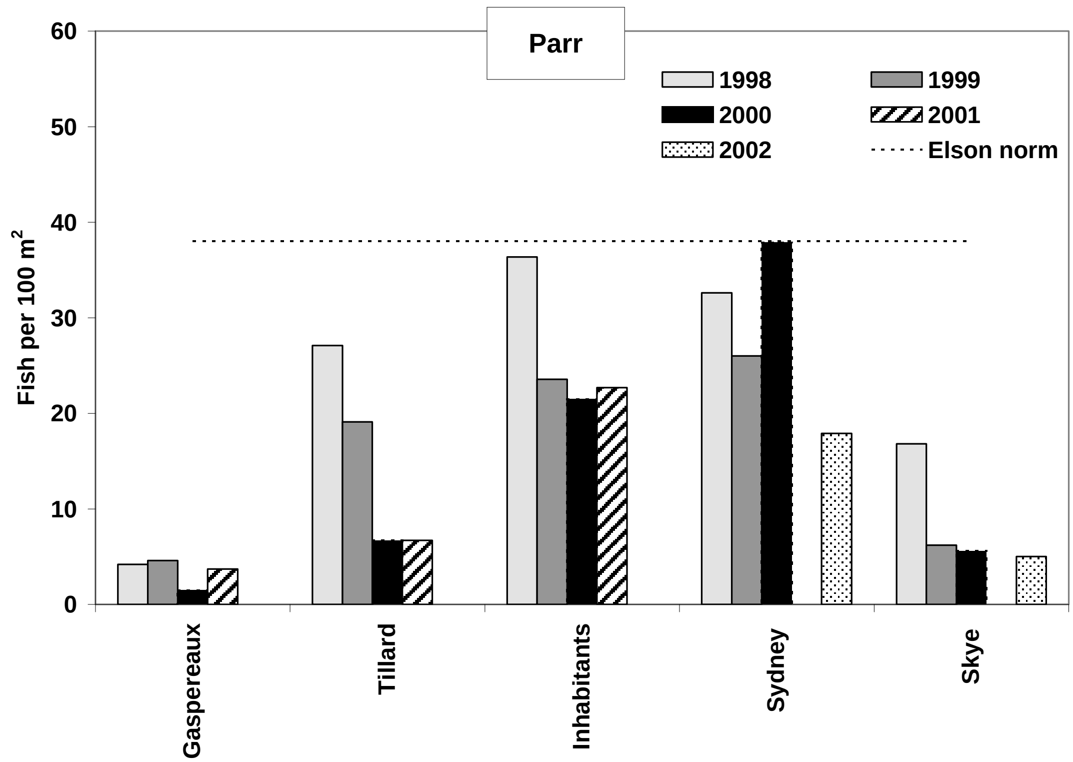


Figure 3.2.2. Mean densities of age 0 juvenile Atlantic salmon (fry) sampled at a single site on 'other' eastern Cape Breton rivers from 1998 to 2002 (from Robichaud-LeBlanc and Amiro 2004).



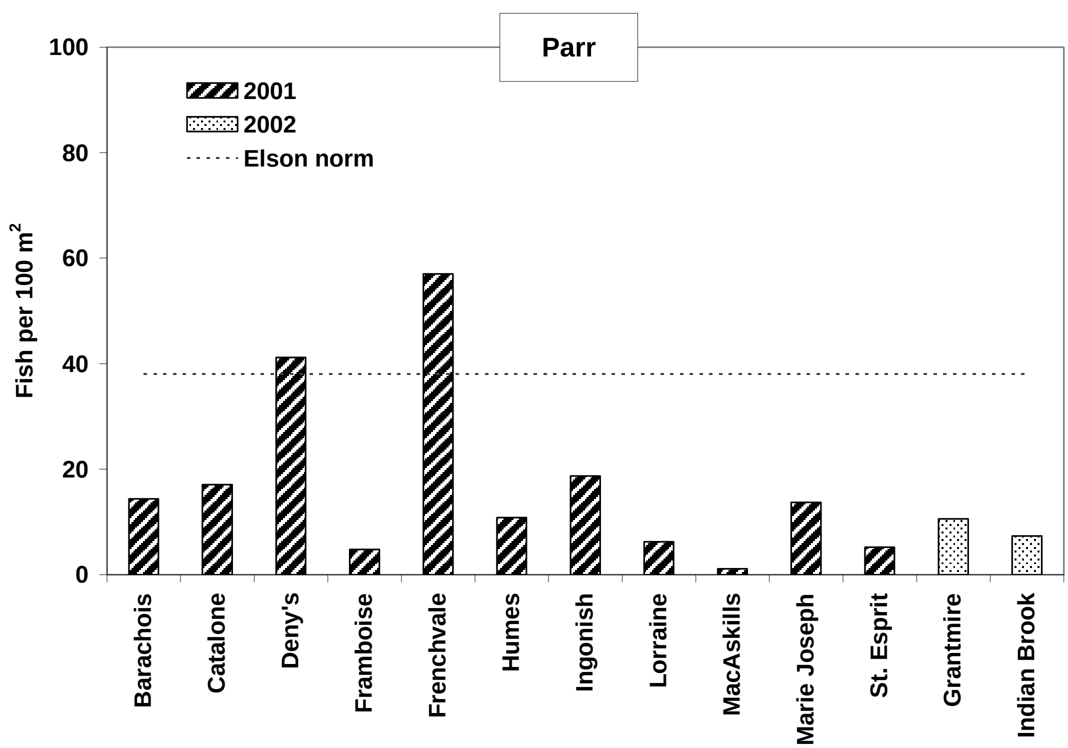


Figure 3.2.3. Mean densities of age 1 and older juvenile Atlantic salmon (parr) sampled at a single site on 'other' eastern Cape Breton rivers from 1998 to 2002 (from Robichaud-LeBlanc and Amiro 2004).

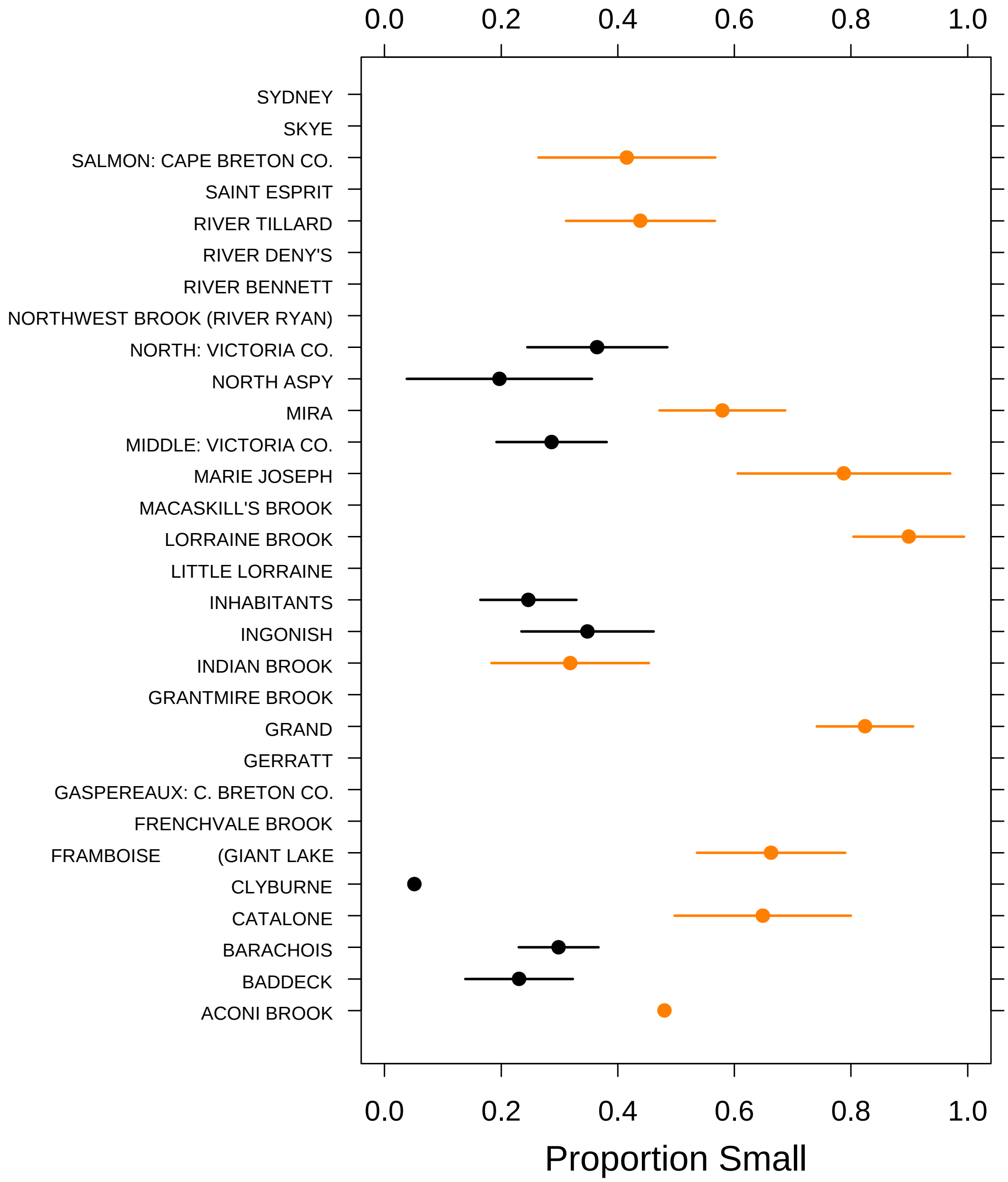


Figure 4.1. A comparison of the proportion of small salmon in the recreational catch (1983-2008) in rivers to the east (orange dots) and west (black dots) of the Bras d'Or Lakes. The points are the mean of the annual proportion of the catch which are small. Error bars are +/- one standard deviation. Years in which the river-specific catch was less than 20 salmon were excluded (missing error bars mean only one year of data met this criterion).

11.0 APPENDICES

Appendix 1. Estimation of Abundance and Trends for Atlantic Salmon in Middle River, Victoria County, Nova Scotia

We adapted the approach used by Gibson and Amiro (2003) for Stewiacke River salmon, and Gibson et al. (2003) for Big Salmon River salmon, to estimate abundance of Middle River salmon from all available indices. This is also similar to the approach described by Rago (2001). The method used follows the general theory developed by Fournier and Archibald (1982) and Deriso et al. (1985) for statistical catch-at-age models for stock assessment that allows auxiliary data to be incorporated. Although we are not using catch-at-age data, our approach is comparable in that we use multiple indices (auxiliary data) together with catch and effort data to estimate abundance and harvest rates for this population. The core of the model is the basic catch equation for a Type I fishery (Ricker 1975). Auxiliary data are in the form of counts of salmon by divers at the end of the recreational fishery, as well as estimates of juvenile salmon densities in fresh water obtained by electrofishing. The model is "anchored" using mark-recapture experiments carried out in some years during the snorkelling counts.

The Model

Of interest are the number of fish in each size category, s, returning to the river to spawn in year t, denoted $Esc_{t,s}$. Because the mark-recapture experiments provide estimates of the total escapement (size categories combined), it is convenient to parameterize the model in terms of the total escapement, Esc_t, and the proportion that are in the small size category each year, p_t, such that the annual escapement of small salmon is given by $Esc_t p_t$ and of large salmon is given by $Esc_t(1-p_t)$. The predicted catch in each year and size category, $C_{t,s}$, is related to the population size, $N_{t,s}$, through the instantaneous rate of fishing mortality for each size class and year, denoted $F_{t,s}$:

$$C_{t,s} = N_{t,s}(1-e^{-F_{t,s}}) .$$

We assumed that that $F_{t,s}$ is proportional to the fishing effort in year t, E_t, and is related through the size-specific catchability coefficients, q_s:

$$F_{t,s} = q_s E_t .$$

The reported recreational catch includes estimates of the number of salmon retained in the fishery. The predicted number of fish harvested in each size class in each year, $H_{t,s}$, was estimated using the ratio of the predicted to the reported catch as an estimate of the error in the reported number of salmon retained (based on an assumption that the errors in these two data series are the same as they are derived from the same source). A correction factor for hook and release mortality (assumed 4%) is included in the model at this point. The number of fish returning to the river in each year and size class, $N_{t,s}$, is then:

$$Esc_{t,s} = N_{t,s} - H_{t,s} .$$

The dive counts in year t, $swim_t$, are used as an index of escapement, and are related to $Esc_{t,s}$ through an "observability" coefficient for the dive counts, q_{swim}:

$$Swim_t = q_{\text{swim}} \sum_s Esc_{t,s} \text{ .}$$

Estimates of q_{swim} are obtained by incorporating a mark-recapture component into the model for those years when marked fish were released into the population (see below).

Egg deposition in year t, $Eggs_t$, was calculated as product of $Esc_{t,s}$ and the specific fecundity for each size class, fec_s, summed over size classes:

$$Eggs_t = \sum_s Esc_{t,s}\, fec_s$$

We used the same fecundities as were used to calculate the conservation requirement for salmon in Middle River (O'Connell et al. 1997), values that were weighted by the sex ratio in each size group. These values, 137 eggs per small salmon, and 3,547 eggs per large salmon, were used as constants in this analysis.

We use the notation $P_{t,a}$ to denote the mean density of juvenile salmon of age a in year t (we are using P for parr, and do not distinguish between age 0 parr and fry). Two ages of parr are included in the model: age 0 (fry) and age 1+ (ages 1 and older). For Atlantic salmon, density dependence is known to occur in fresh water (Gibson 2006; Chaput and Jones 2006; Gibson et al. 2008). In a comparison of nine populations, Gibson (2006) found that the timing of density dependence in fresh water varied among populations, and did not find evidence of overcompensation. We therefore incorporated density dependence into the model using a Beverton-Holt function (Hilborn and Walters 1992) to model survival in fresh water. For each age category, we estimated the asymptotic recruitment level, R_{0a}, and the slope at the origin, α_a , for this model:

$$P_{t,a} = \frac{\alpha_a Eggs_{t-a-1}}{1 + \dfrac{\alpha_a Eggs_{t-a-1}}{R_{0a}}} \text{ .}$$

Initial model runs indicated that R_0 was not well determined for age 0 fish. R_0 was always estimated as the upper bound placed on the parameter, as would occur if a linear function were more appropriate (a linear relationship between egg deposition and age 0 density would be appropriate if electrofishing occurred prior to density dependent processes within the cohort). In the final model, a linear function was used for age 0 fish:

$$P_{t,0} = \alpha_0 Eggs_{t-1}$$

Parameter estimates were obtained by minimizing an objective function ($O.B.V.$) that is the sum of the negative log likelihoods (Quinn and Deriso 1999) for the catch (ℓ_{catch}), the dive counts (ℓ_{dive}), the juvenile electrofishing data ($\ell_{electrofishing}$) and the mark-recapture experiments (ℓ_{m-r}) conducted during the dive surveys. The relative contribution of each likelihood to the objective function was controlled using a set of weighting values, w_i. These values may be selected to keep any one part of the objective function from dominating the fit, or alternatively, to reflect perceptions of data accuracy (Merritt and Quinn 2000). Here, we set all weights equal to one, an approach that has the advantage that the $O.B.V.$ can be interpreted as the likelihood. We used lognormal error structures for all likelihoods except the mark-recapture for which a hypergeometric distribution was used. Superscripting observed values with "obs", the log likelihoods are:

1. Recreational Catches:

$$\ell_{catch} = -n\ln(\sigma_{catch.s})\sqrt{2\pi} - \sum_{t,s}\ln(C_{t,s}^{obs}) - \frac{1}{2\sigma_{catch.s}^2}\sum_{t,s}(\ln C_{t,s}^{obs} - \ln C_{t,s})^2$$

2. Dive Counts:

$$\ell_{dive} = -n\ln\sigma\sqrt{2\pi} - \sum_{t,s}\ln(swim_t^{obs}) - \frac{1}{2\sigma^2}\sum_{t,s}(\ln swim_t^{obs} - \ln swim_t)^2$$

3. Electrofishing (log likelihoods were calculated separately for each age class and then summed):

$$\ell_a = -n\ln(\sigma_a)\sqrt{2\pi} - \sum_t \ln(P_{t,a}^{obs}) - \frac{1}{2\sigma_a^2}\sum_t(\ln P_{t,a}^{obs} - \ln P_{t,a})^2$$

$$\ell_{electrofishing} = \sum_a \ell_a$$

For the lognormal log-likelihoods, n is the sample size for the corresponding data set and σ_x is the corresponding shape parameter (for a lognormal distribution, σ is the standard deviation of a normal distribution prior to exponentiation).

4. Mark Recapture:

$$\ell_{mark-recap} = \ln\binom{m}{r} + \ln\binom{N-m}{c-r} - \ln\binom{N}{c} \quad ,$$

where N is the population size estimate, m is the number of marked fish in the population, c is the number of fish examined for marks and r is the number of fish that were examined for marks that were, in fact, marked.

Initial attempts to estimate the σ's for all model components, were unsuccessful. Therefore, we used σ's estimated for other Atlantic salmon populations for the juvenile electrofishing component of the model. Myers et al. (1995) published spawner-recruit relationships for 15 populations and recruitment age categories for Atlantic salmon. For a recruitment age of 1, σ averaged 0.330 (n = 4; range: 0.293 to 0.402). Models were fit to single data sets for recruitment ages of 0 and 2, for which σ was estimated as 0.334 and 0.581 respectively. These values were similar to the estimated σ's when smolt was used as the recruitment category (mean=0.329; n=5; range: 0.206 to 0.440). Based on their analyses, we set σ_a equal to 0.334 for a=0, and 0.330 for a=1. For the remaining model components (the recreational fishery and boat electrofishing), an estimate of σ was calculated within the model as:

$$\hat{\sigma} = \sqrt{\frac{1}{n}\sum \log\left(\frac{obs_i}{pred_i}\right)^2} \, ,$$

and substituted into the likelihood equation. Here, obs_i and $pred_i$ are the observed data and predicted values associated with each model component, and n is the sample size.

The objective function is:

$$O.B.V. = -(w_1\ell_{dive} + w_2\ell_{catch} + w_3\ell_{electrofishing} + w_4\ell_{m-r}).$$

We set up the model to estimate the log of the total escapement in each year from 1983 to 2008 (25 parameters), the proportion of the population that are small salmon in each year (25 parameters); the catchability coefficients for the recreational fisheries (two parameters estimated on the log scale) and dive surveys (one parameter); and the log of the slopes at the origins and the asymptotic level for the electrofishing data (one parameters). We programmed this model using AD Model Builder (Fournier 1996). AD Model Builder (ADMB) uses the C++ auto-differentiation library for rapid fitting of complex non-linear models, has Bayesian and profile likelihood capabilities, and is designed specifically for fitting these types of models.

Whenever minimization is used to estimate parameters in a nonlinear model, there is a possibility of convergence to a local minimum, rather than the global minimum. We ran multiple iterations of the model using several starting values. The estimates are robust with respect to the starting values. We also examined the sensitivity of the results to the weighting of model components and changes in model formulation. The results are robust with respect to these modifications.

Bayesian Analyses

Bayesian methods provide a powerful tool for assessing uncertainty in fisheries models (McAllister et al. 1994). Punt and Hilborn (1997) and McAllister and Kirkwood (1998) have reviewed their fisheries applications. The posterior probability distributions resulting from Bayesian analyses show the uncertainty in model or policy parameters including both estimation uncertainty, as well as prior information about their values (Walters and Ludwig 1993). AD Model Builder (ADMB) uses a Markov Chain Monte Carlo (MCMC) algorithm (Carlin and Louis 1996) to approximate the posterior distribution for parameters of interest. MCMC is a stochastic simulation method used to evaluate complex integrals in order to derive posterior distributions. ADMB uses the Metropolis Hastings algorithm (Chib and Greenberg 1995) to generate the Markov chain, using a multivariate normal distribution based on the variance-covariance matrix for the model parameters as the proposal function. If the chain is long enough, the posteriors will be reasonably well approximated.

We assumed uniform bounded priors for all model parameters. Bounds were wide enough so as not to influence the fit. We used 2,000,000 iterations after a burn in of 200,000 iterations, and sampled every 2,000th iteration to derive the posterior distribution. This level of thinning was sufficient to ensure that autocorrelation in the chain was not problematic. Convergence of the Markov chain was inferred informally by comparing the similarity of the 10th and 90th percentiles of the posterior densities based on the first 1,000,000 iterations with those based on the second 1,000,000 iterations, and by comparison of the posterior densities from several chains (Gamerman 2000).

Population Viability

Of interest when assessing status is whether or not populations are decreasing in size and if so, how long they will persist if the recent trends continue into the future. We used a Dennis-type Population Viability Analysis (PVA) model (Dennis et al. 1991), integrated into the Bayesian analysis, to address this question. The population was projected forward through time using the equation:

$$N_{t+1} = N_t e^{\log(\lambda_t)+\sigma\varepsilon_t}$$

where

$$\lambda_t = N_t / N_{t-1}$$

and

$$\varepsilon_t \sim N(0,1)$$

where λ is the ratio of the population size in one year to the population size in the previous year, σ is the standard deviation of λ, and ε_t is a random deviate with a standard normal distribution. The mean and standard deviation of λ were calculated from the escapement time series for each step in the Markov chain, and a single 30-year projection was then produced using these values. A different set of random values was used for each step in the chain.

Data Inputs

The data inputs for this model are described in Section 2.1 of the main body of this document. These are the recreational catch and effort from 1983 to 2008 (Table 2.1.1), the dive survey counts and mark-recapture experiments from 1994 to 2008 (Table 2.1.2) and juvenile density estimates obtained during intermittent electrofishing surveys from 1985 to 2006 (Table 2.1.3).

Results

Between 1983 and 2008, fishing effort for Atlantic salmon on the Middle River varied from a low of 92 rod days in 2001 to a high of 935 rod days in 1983 (Figure A1.1). During these years, observed catches of small salmon (corrected for non-reporting) varied between 10 (in 2001 and 1992) and 93 (in 1989) fish. Catches of large salmon varied between 15 fish in 2001 and 221 fish in 1990. The predicted catch tracks the observed catch of both small and large salmon very well (Figure A1.1), with a few exceptions. For example, in 2008, the preliminary estimate of the recreational catch is lower than that predicted by the model. During the 2008 dive survey, visibility was very good and it is possible that a higher proportion of the population was observed during that survey than it is on average, potentially explaining this difference.

Parameter estimates from the model are provided in Table A1.1. The log of the catchability coefficients for the recreational fishery were higher for small salmon (-6.227) than for large salmon (-6.782). These estimates suggest that at a fishing effort of 427 rod days (the average for the time series), 57.0% of the small salmon and 38.4% of large salmon would be captured by the recreational fishery. The catchability coefficients are well estimated, with a slight difference between the maximum likelihood estimate and the mode of the posterior density for the parameter for small salmon (Figure A1.2).

The dive survey observation coefficient was 0.597 (Table A1.1, Figure A1.3), with an 80% Bayesian credible interval (BCI) of 0.530 to 0.639 (Figure A1.3). Model fits to the dive count data are also very good (Figure A1.4), indicating high congruence between the recreational catch data and the dive survey data (both series are fit well by the model).

In contrast, the model fits to the densities of juvenile salmon in Middle River are not as good (Figure A1.5). The predicted densities of age 0 salmon loosely track the observed values, whereas the age 1 and older data are not informative about abundance. The functional relationships between egg deposition and subsequent juvenile densities (Figure A1.6) indicate that abundance of age 0 salmon increases with adult abundance, whereas there is no relationship between the densities of older parr and adult abundance over the range of observed values.

The posterior probability densities for the number of returning salmon annually are shown in Figure A1.7. The MLE’s and models of the posteriors agree reasonably. The 80% BCI’s are roughly +/- 40% of the abundance estimates.

The MLE’s of the recreational catch and harvest rates for large and small salmon, shown in Figure A1.8, show a slight downward trend. The MLE's of the catch rates range between 16.6% and 84.2% for small salmon and between 9.90 % and 63.4% for large salmon. The highest predicted values occurred in 1983, the year the highest exploitation occurred. The predicted harvest rates indicate that a significant proportion of salmon may have been removed from the river during the recreational fishery prior to the switch to catch and release. The BCI’s for the harvest rates are reasonably narrow (Figure A1.9).

A time series of the MLE's of the numbers of salmon available to spawn after the recreational fishery is shown in Figure A1.10. The series shows an increase until 1996, followed by a slight decrease. During the 1984 to 1988 time period, spawning escapement averaged 259 fish; from 1994 to 1998 it averaged 399 fish and from 2004 to 2008 it averaged 317 fish (Table A1.1). The five-year mean population size has likely decreased during the last 10 years, but increased over the previous 15- and 20-year time periods (Figure A1.11). Egg depositions (Figure A1.12) show a similar pattern with very little chance that the population has met its conservation requirement since 1983 (Figure A1.12). Estimates of the percent conservation achieved have been less than 37% for the last three years.

We examined the ratio of the population size in a given year to the size in the previous year (Figure A1.13). Since 1983, the population size has increased over the previous year on 12 occasions, and has decreased on 13 occasions. During the last three generations, the MLE for the log mean ratio is -0.0273 (Table A1.1, Figure A1.14), equating to a decline rate of 2.7% per year with little to no chance that the population increased during that time period (Figure A1.14). This is slightly greater than the decline rate obtained by log-linear regression of 2.4% per year (Table A1.1).

We used the Dennis-type PVA to project the population forward through time (Figure A1.15). The rapidly increasing trajectories obtained in some simulations are unrealistic because a carrying capacity is not included in the model. The results suggest that if the recent future is similar to the recent past, the population is expected to continue to decrease, although the trajectory is highly uncertain.

Table A1.1. Parameter estimates for Middle River, NS, Atlantic salmon obtained from the assessment model.

Name	Year	Value	Std. Dev.
Coefficients:			
Dive survey catchability		0.5974	0.0408
log recreational fishing q (small)		-6.2268	0.1268
log recreational fishing q (large)		-6.7820	0.0932
log alpha (age 0)		-1.0007	0.1260
log alpha (age 1)		12.5780	18470.0000
R0 (age1)		45.6590	4.7649
Abundance:			
log returns (small + large)	1983	4.3434	0.1519
log returns (small + large)	1984	5.5306	0.1467
log returns (small + large)	1985	5.5304	0.1594
log returns (small + large)	1986	5.9548	0.1581
log returns (small + large)	1987	5.6459	0.1483
log returns (small + large)	1988	5.7019	0.1553
log returns (small + large)	1989	6.1068	0.1617
log returns (small + large)	1990	5.9510	0.1451
log returns (small + large)	1991	5.7224	0.1644
log returns (small + large)	1992	5.1431	0.1650
log returns (small + large)	1993	5.2253	0.1433
log returns (small + large)	1994	6.2090	0.0940
log returns (small + large)	1995	5.6957	0.0938
log returns (small + large)	1996	6.3078	0.0848
log returns (small + large)	1997	6.0594	0.0909
log returns (small + large)	1998	5.5816	0.0860
log returns (small + large)	1999	5.9277	0.0902
log returns (small + large)	2000	5.3590	0.0863
log returns (small + large)	2001	5.2494	0.0972
log returns (small + large)	2002	5.1293	0.0956
log returns (small + large)	2003	5.9445	0.0909
log returns (small + large)	2004	5.7352	0.0887
log returns (small + large)	2005	6.1280	0.0956
log returns (small + large)	2006	5.4735	0.0963
log returns (small + large)	2007	5.5864	0.0944
log returns (small + large)	2008	5.8247	0.0941

(continued)

Table A1.1. Continued.

Name	Year	Value	Std. Dev.
proportion small	1983	0.1851	0.0435
proportion small	1984	0.2128	0.0478
proportion small	1985	0.3072	0.0638
proportion small	1986	0.2131	0.0494
proportion small	1987	0.2691	0.0571
proportion small	1988	0.1979	0.0463
proportion small	1989	0.1201	0.0307
proportion small	1990	0.2940	0.0600
proportion small	1991	0.0982	0.0257
proportion small	1992	0.1866	0.0454
proportion small	1993	0.3022	0.0600
proportion small	1994	0.1080	0.0124
proportion small	1995	0.1477	0.0166
proportion small	1996	0.2290	0.0223
proportion small	1997	0.1687	0.0175
proportion small	1998	0.3372	0.0280
proportion small	1999	0.1945	0.0195
proportion small	2000	0.1811	0.0185
proportion small	2001	0.2653	0.0249
proportion small	2002	0.3254	0.0287
proportion small	2003	0.0909	0.0104
proportion small	2004	0.1798	0.0187
proportion small	2005	0.1992	0.0202
proportion small	2006	0.2563	0.0247
proportion small	2007	0.2453	0.0234
proportion small	2008	0.3844	0.0310
Derived Values:			
Slope parameter (log-linear regression)		-2.4677	0.0043
a) mean N (2004-2008)		317.3300	22.8880
b) mean N (1994-1998)		399.3400	26.9460
c) mean N (1990-1994)		214.4000	21.8380
d) mean N (1984-1988)		258.7300	25.9970
ratio: a/b		0.7946	0.0356
ratio: a/c		1.4801	0.1276
ratio: a/d		1.2265	0.0984
mean(log (N_t/N_{t-1}))		-0.0273	0.0069
std. dev. (log (N_t/N_{t-1}))		0.4437	0.0315

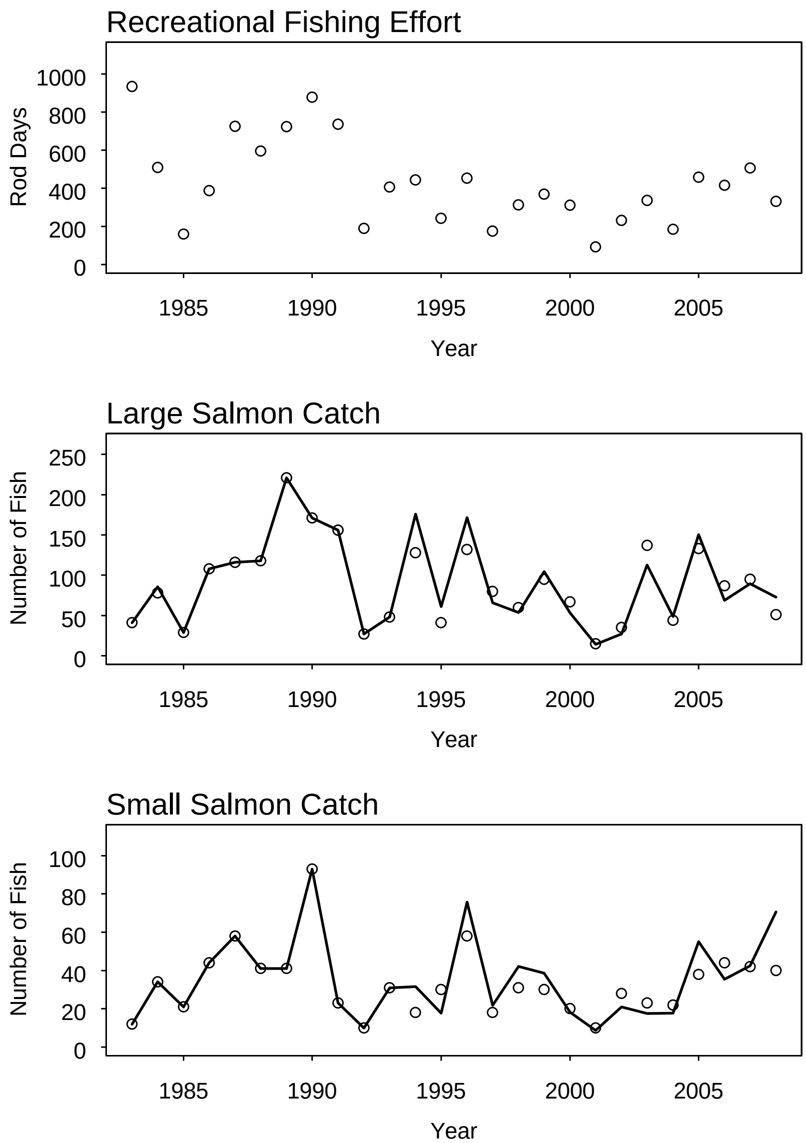


Figure A1.1. Fishing effort and observed (points) and predicted (lines) Atlantic salmon catches on the Middle River, NS, from 1983 to 2007.

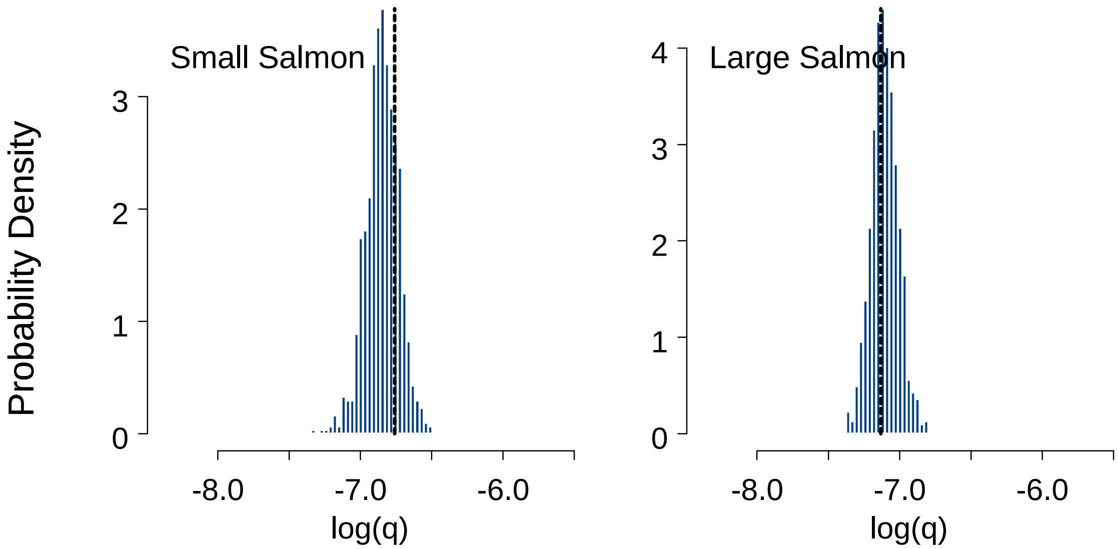


Figure A1.2. Posterior probability densities for the natural logarithms of the recreational fishery catchability coefficients for small and large salmon in Middle River, NS. The dashed lines show the maximum likelihood estimates.

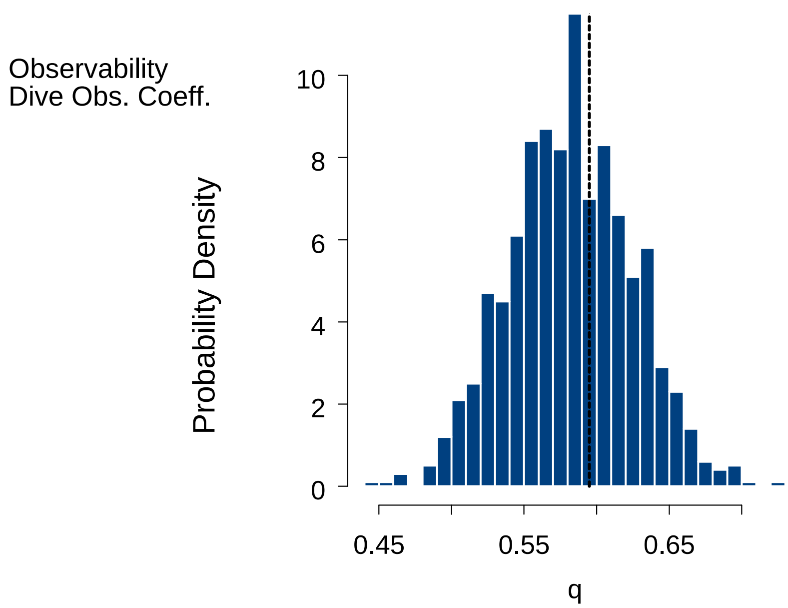


Figure A1.3. Posterior probability density for the diver observation coefficient (proportion of the population observed in a dive survey). The dashed line shows the maximum likelihood estimate.

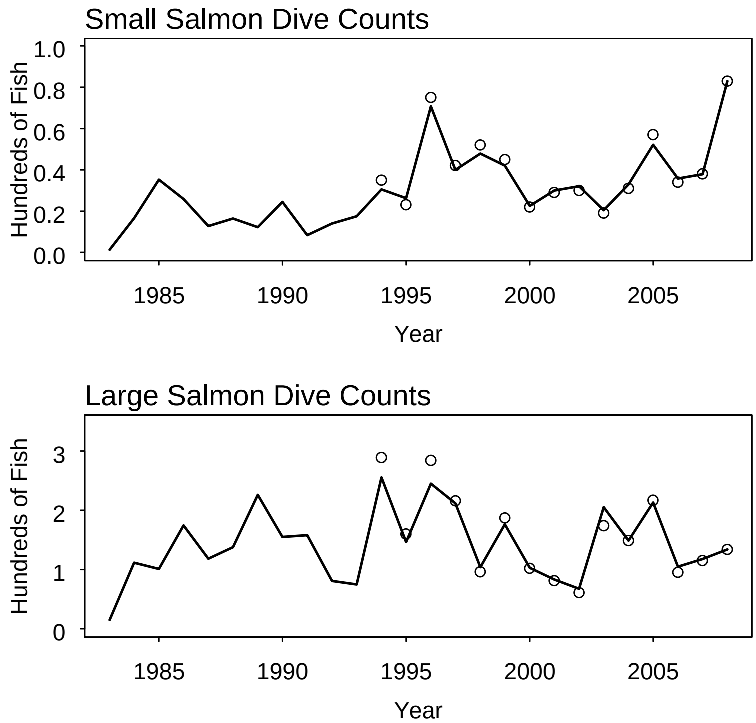


Figure A1.4. Predicted (lines) and observed (points) number of small (top panel) and large (bottom panel) Atlantic salmon seen during dive surveys in the Middle River, NS, from to 1994 to 2008. The predicted series is extrapolated back to 1983.

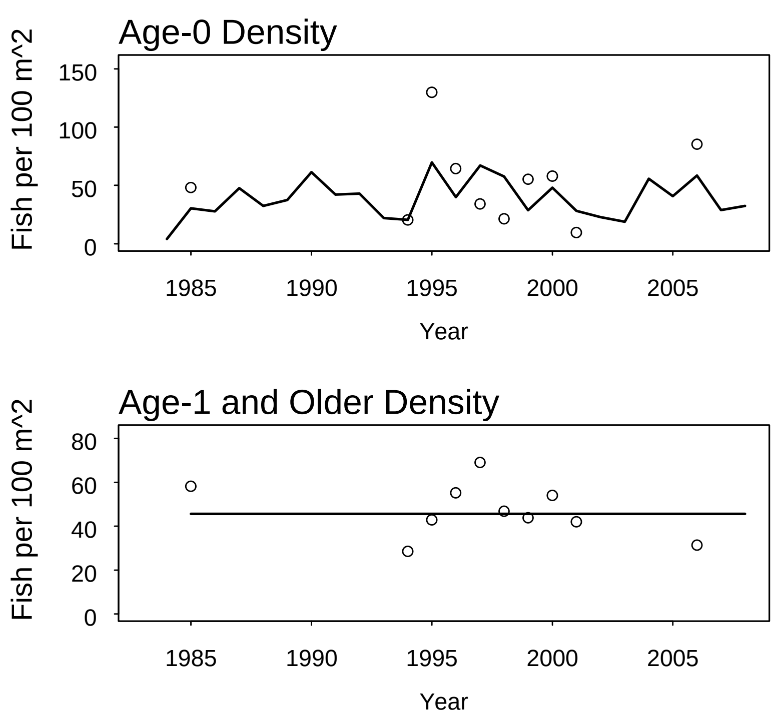


Figure A1.5 Mean density of juvenile Atlantic salmon in the Middle River, NS, from 1983 to 2007. The points are the observed densities determined by electrofishing. The lines are the predicted densities from the assessment model.

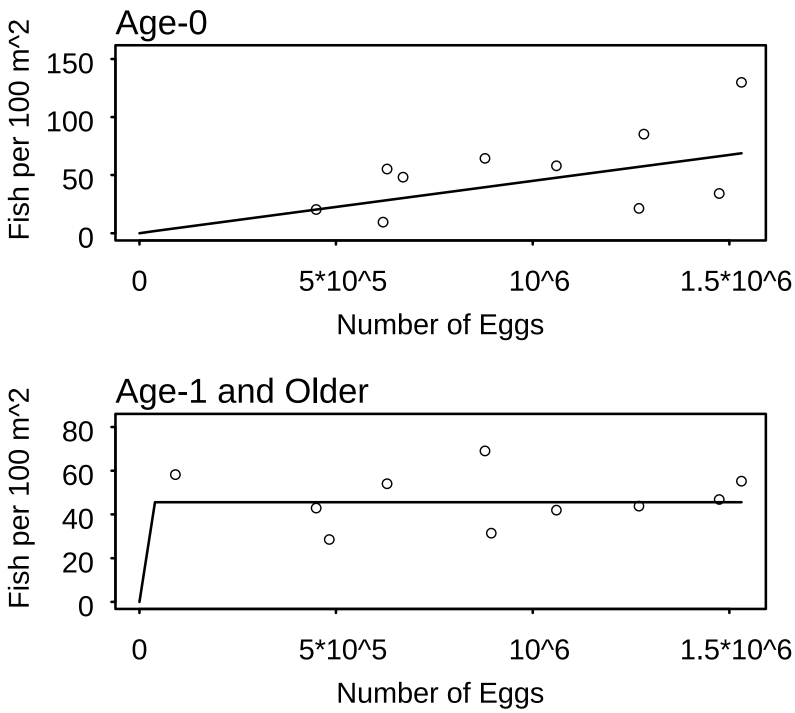


Figure A1.6. The relationship between egg deposition in year t and the number of juvenile Atlantic salmon in years t+1 (age 0) and t+2 (age 1 and older) in the Middle River, NS. Juvenile densities were determined by electrofishing between 1985 and 2006. Egg deposition was predicted using the assessment model.

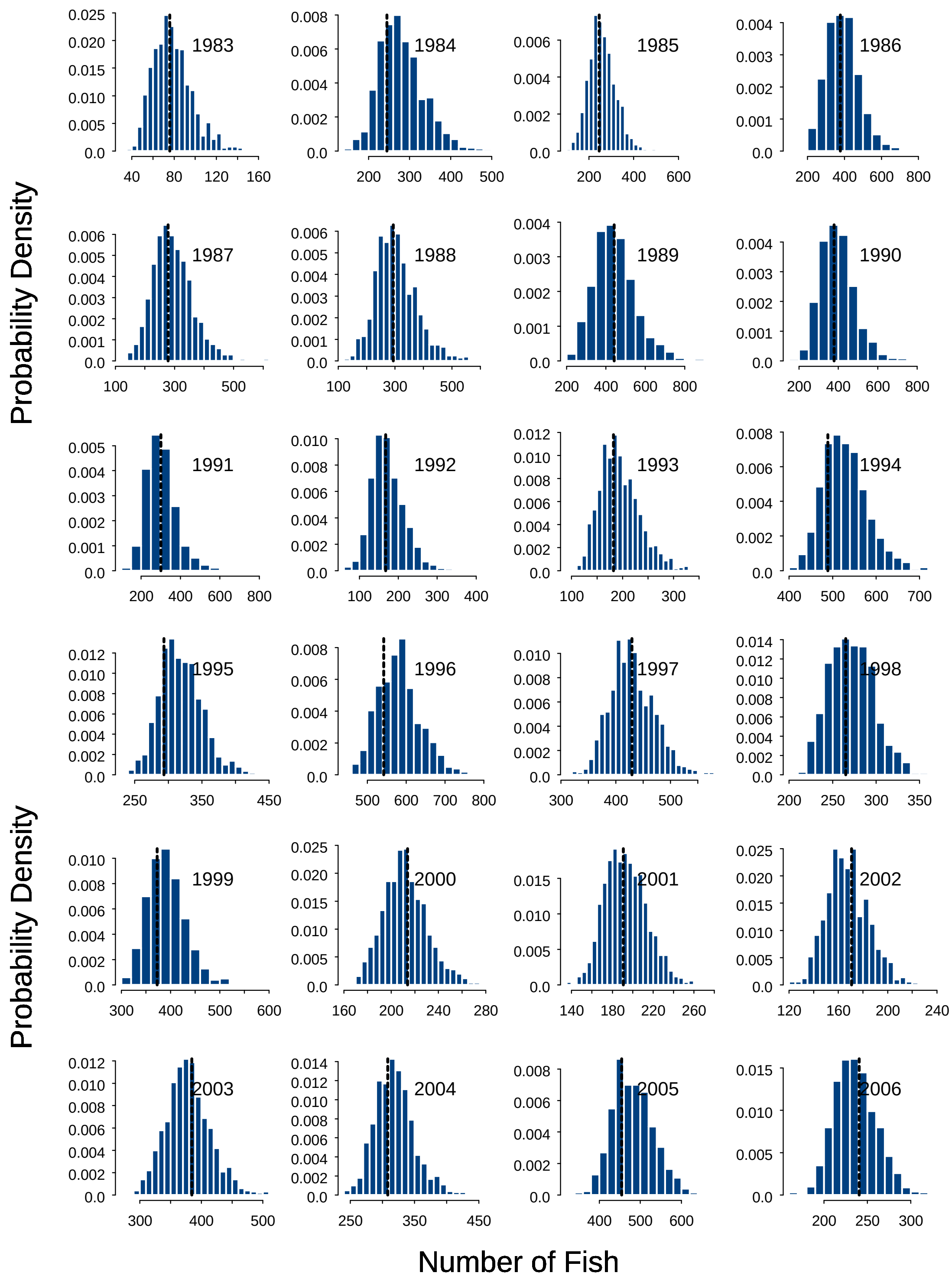


Figure A1.7. Posterior probability densities for the number of Atlantic salmon returning to the Middle River annually from 1983 to 2006. The dashed lines show the maximum likelihood estimates.

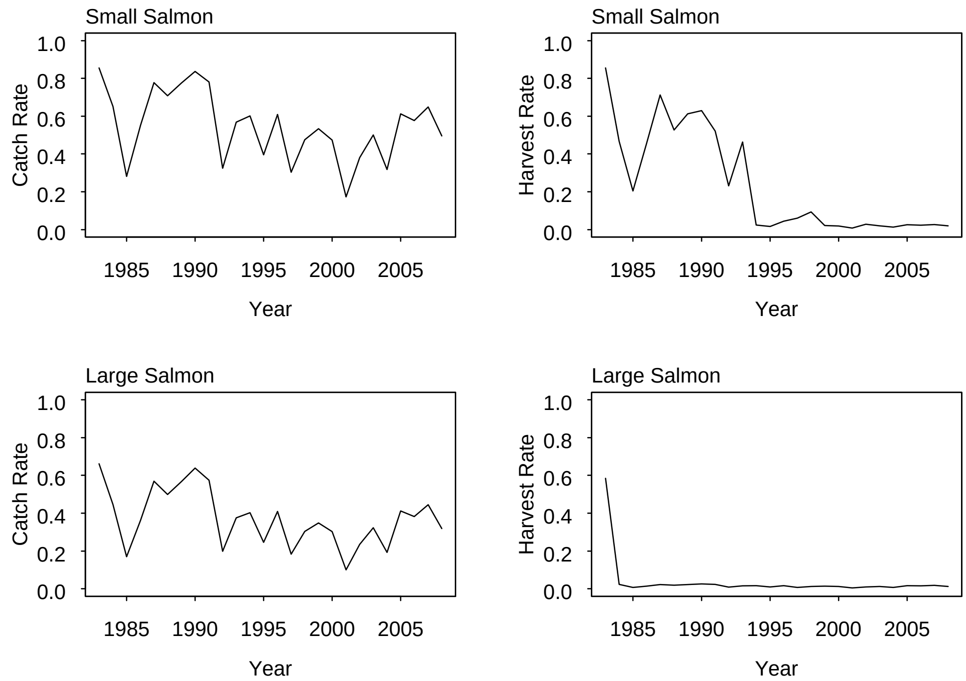


Figure A1.8. Estimated catch rates and harvest rates for small and large Atlantic salmon in the Middle River, NS, recreational fishery from 1983 to 2007. The recreational harvest fishery for large salmon was closed after 1984 and for small salmon in 1994. A 4% hook and release mortality is included in the harvest rate estimate.

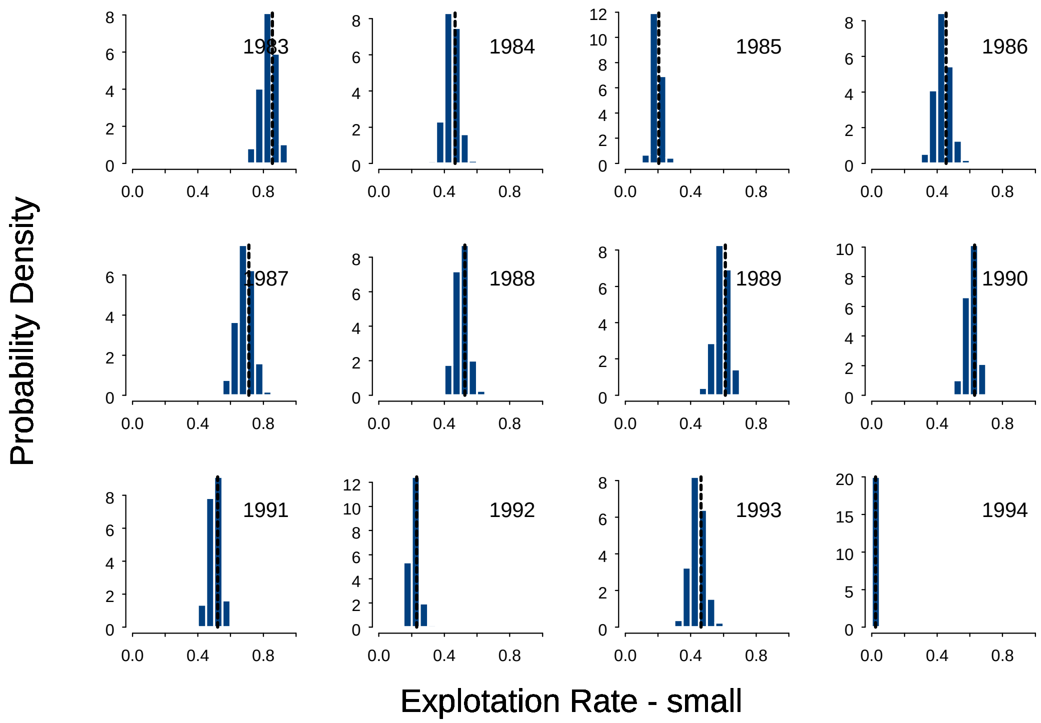


Figure A1.9. Posterior probability densities for the exploitation (harvest) rate for small salmon in Middle River, NS, from 1983 to 1994. The dashed line is the maximum likelihood estimate.

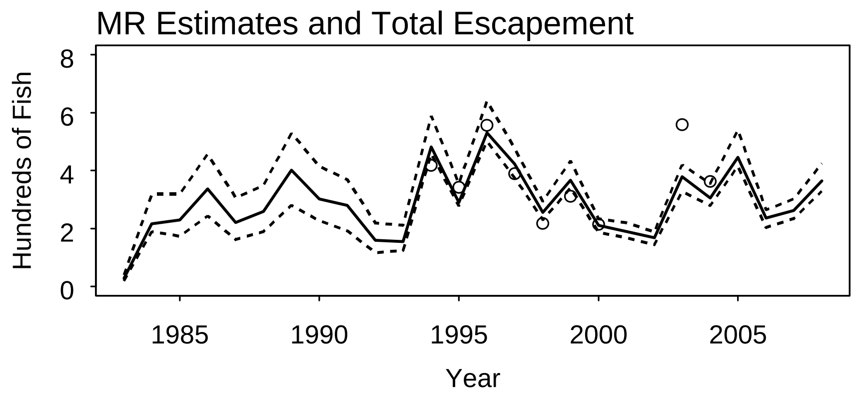


Figure A1.10. Estimated total number of salmon (solid lines) escaping the fishery in Middle River, NS, from 1983 to 2008. The points are the population estimates obtained by mark recapture during the dive surveys. The dashed lines are the 10th and 90th percentiles of the posterior probability densities for the total escapement annually.

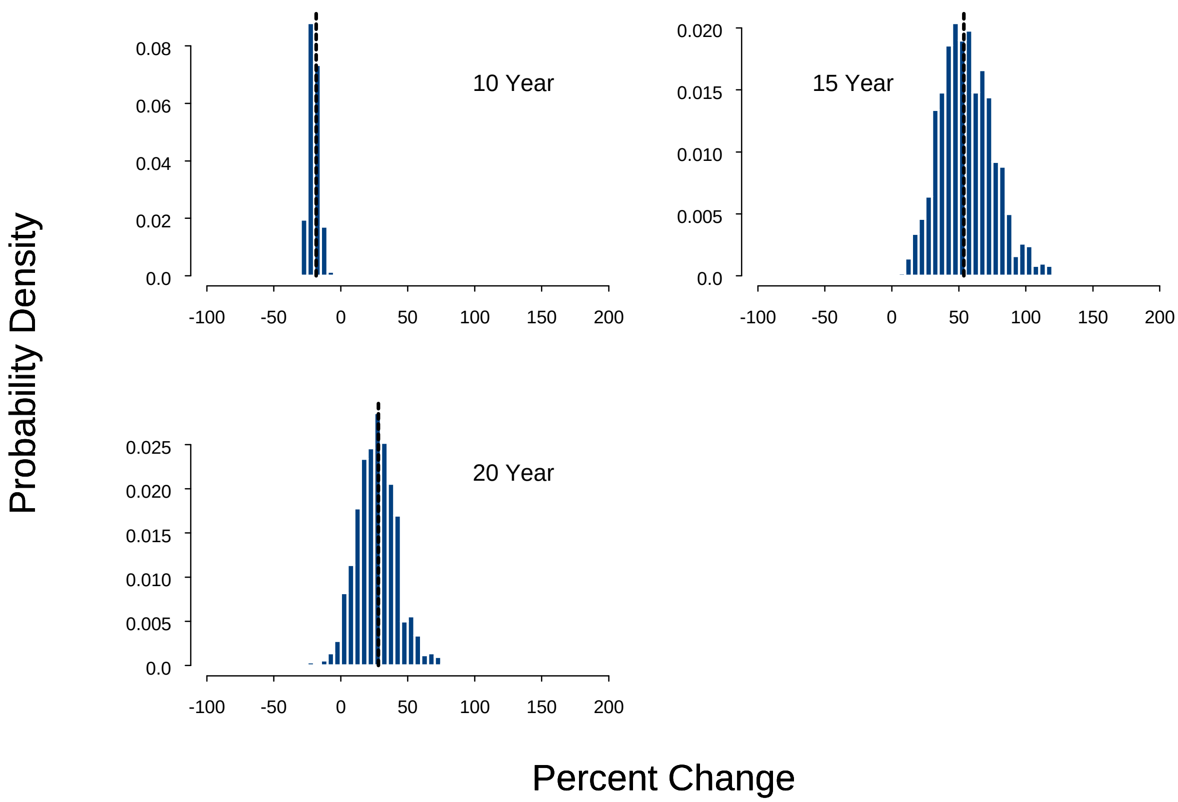


Figure A1.11. Posterior probability densities for the percent decline in Atlantic salmon escapement in Middle River, NS, over 10-, 15- and 20-year time periods. Percent decline was calculated by comparing the mean number of returning salmon for the 2004-2008 time period to means for the 1994-1998 time period (10-year comparison), the 1990-1994 time period (15-year comparison), and the 1984-1988 time period (20-year comparison). The dashed lines show the maximum likelihood estimates for the percent change in population size.

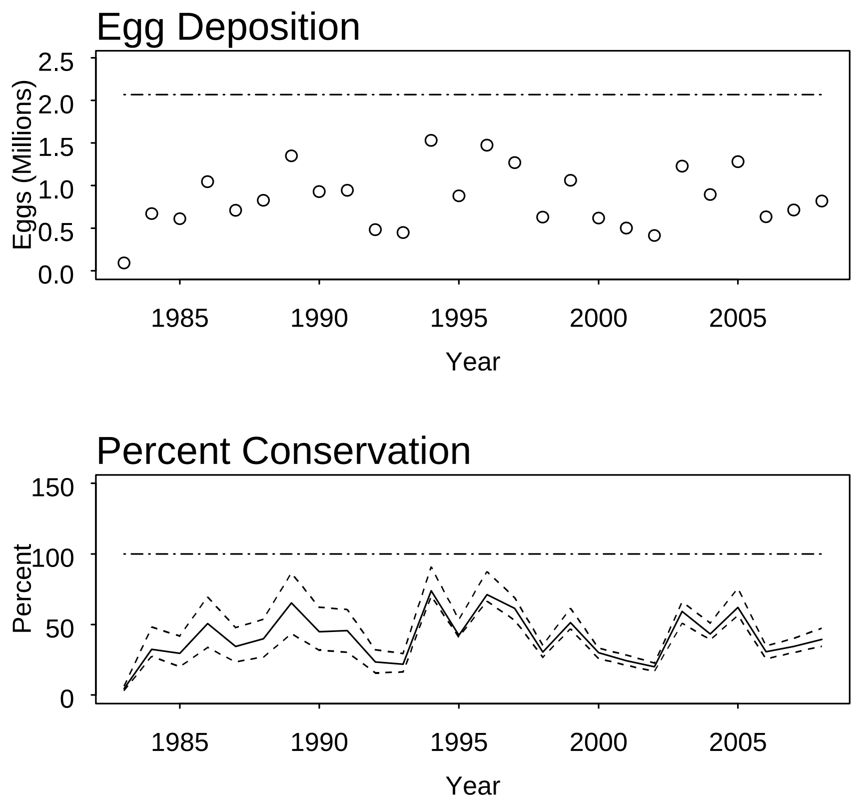


Figure A1.12. Estimated egg deposition and the percent of the conservation requirement achieved in Middle River, NS, from 1983 to 2008. The horizontal line is the conservation requirement. The 10th and 90th percentiles of the posterior probability densities for the percent of the conservation requirement achieved are shown.

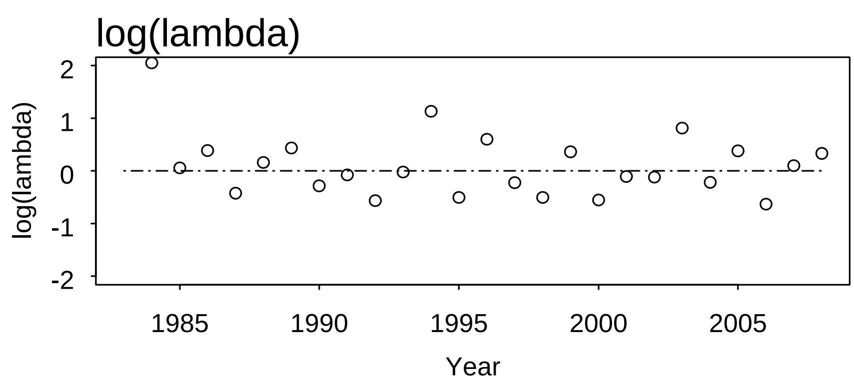


Figure A1.13. The ratio of N_t to N_{t-1} for Middle River salmon from 1984 to 2008. The dashed line is the level at which the population size does not change.

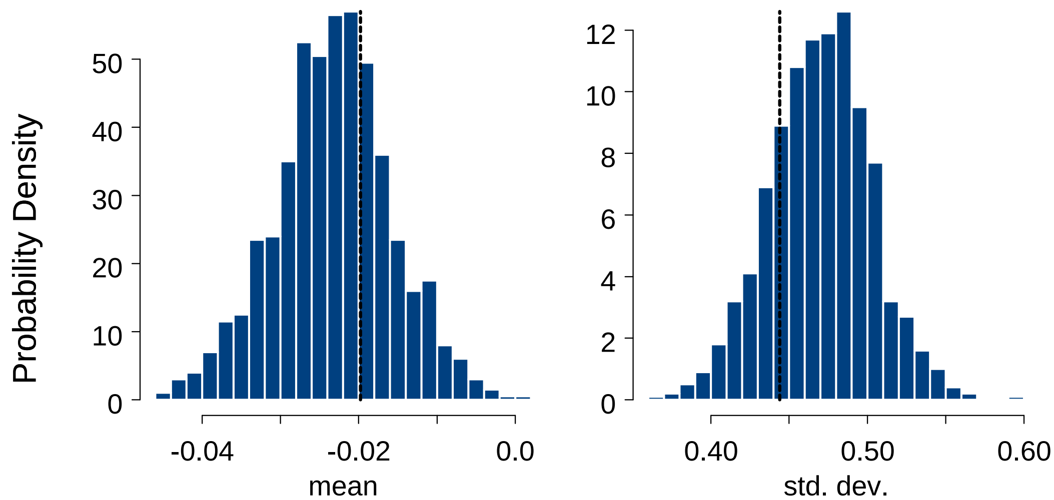


Figure A1.14. Posterior probability densities for the mean and standard deviation of log (lambda) used as inputs for a Bayesian version of a Dennis-type population viability analysis for Atlantic salmon in Middle River, NS. The dashed lines show the maximum likelihood estimates.

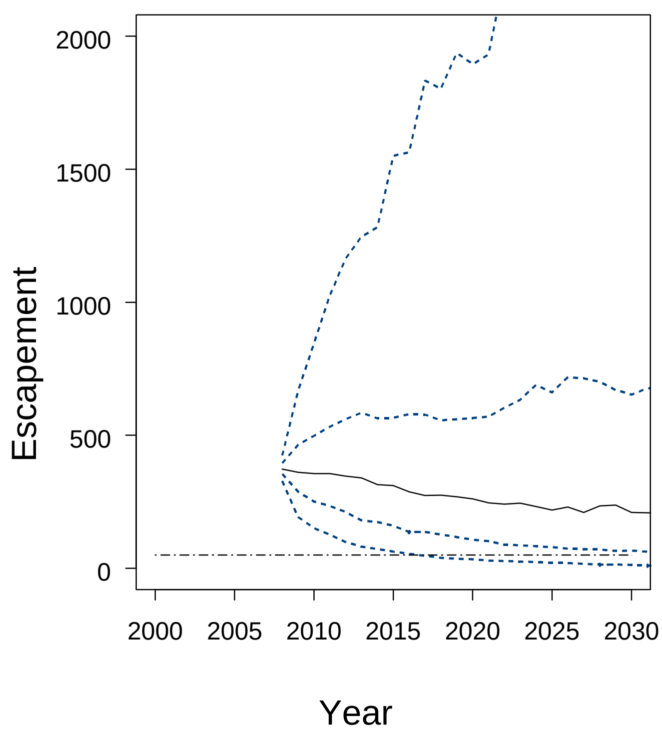


Figure A1.15. Results of the Bayesian version of a Dennis-type population viability analysis for Atlantic salmon in Middle River, NS. The solid line is the median population size and dashed lines are the 10th, 30th, 70th and 90th percentiles of the posterior distributions for the projected annual population size. The horizontal dashed line shows an arbitrary quasi-extinction threshold of 50 salmon.

Appendix 2. Estimation of Abundance and Trends for Atlantic Salmon in Baddeck River, Victoria County, Nova Scotia

The Model

The model structure is identical to that used for Middle River (Appendix 1).

Data Inputs

The data inputs for this model are described in Section 2.2 of the main body of this document. These are the recreational catch and effort from 1983 to 2008 (Table 2.2.1), the dive survey counts and mark-recapture experiments from 1994 to 2008 (Table 2.2.2) and juvenile density estimates obtained during intermittent electrofishing surveys from 1996 to 2001 (Table 2.2.3).

Results

Between 1983 and 2008, fishing effort for Atlantic salmon on the Baddeck River varied from a low of 100 rod days in 1985 to a high of 786 rod days in 1993 (Figure A2.1). During these years, observed catches of small salmon varied between four (in 1985) and 62 (in 1990) fish. Catches of large salmon varied between 13 fish in 1985 and 195 fish in 1989. As was the case for Middle River, the predicted catch tracks the observed catch of both small and large salmon very well (Figure A2.1), except for the last three years. Similar to Middle river, the preliminary estimate of the recreational catch in 2008 is lower than that predicted by the model. During the 2008 dive survey, visibility was very good and it is possible that a higher proportion of the population was observed during that survey than it is on average, potentially explaining this difference.

Parameter estimates from the model are provided in Table A2.1. The log of the catchability coefficients for the recreational fishery were higher for small salmon (-5.850) than for large salmon (-6.077). Both of these coefficients are higher than the values estimated for Middle River. These estimates suggest that at a fishing effort of 330 rod days (the average for the time series), 61.3% of the small salmon and 53.1% of large salmon would be captured by the recreational fishery. The catchability coefficients are well estimated, with a slight difference between the maximum likelihood estimate and the mode of the posterior density for the parameter for small salmon (Figure A2.2).

The dive survey observation coefficient was 0.545 (Table A2.1, Figure A2.3), with an 80% Bayesian credible interval of 0.487 to 0.592 (Figure A2.3). Model fits to the dive count data are also very good (Figure A2.4), indicating high congruence between the recreational catch data and the dive survey data (both series are fit well).

Again, similar to Middle River, the model fits to the densities of juvenile salmon in the Baddeck River are not as good as those to the recreational catch or dive surveys (Figure A2.5). The predicted densities of age 0 salmon loosely track the observed values, whereas the age 1 and older data are not informative about abundance. The functional relationships between egg deposition and subsequent juvenile densities (Figure A2.6) indicate that abundance of age 0 salmon increases with adult abundance, whereas there is no relationship between the densities of older parr and adult abundance over the range of observed values.

The posterior probability densities for the number of salmon returning annually are shown in Figure A2.7. The MLE’s and models of the posteriors agree reasonably. The 80% BCI’s are roughly +/- 30% of the abundance estimates.

The MLE's of the recreational catch and harvest rates for large and small salmon, shown in Figure A2.8, show a relatively stable trend. The MLE's of the catch rates range between 25.0% and 89.6% for small salmon and between 20.5 % and 83.5% for large salmon. The highest predicted values occurred in 1992, the year the highest exploitation occurred. The predicted harvest rates indicate that a significant proportion of salmon may have been removed from the river during the recreational fishery prior to the switch to catch and release. The BCI's for the harvest rates are reasonably narrow (Figure A2.9), although the harvest rates are not as precisely estimated as those from Middle River.

A time series of the MLE's of the numbers of salmon available to spawn after the recreational fishery is shown in Figure A2.10. The series shows an increase until 1996, followed by a slight decrease. During the 1984 to 1988 time period, spawning escapement averaged 192 fish. From 1994 to 1998, it average 255 fish and from 2004 to 2008 it averaged 189 fish (Table A2.1). The five-year mean population size has decreased during the last 10 years, but has been relatively stable over a 15-year time period and may have increased slightly over a 20-year time period (Figure A2.11). The data do not preclude the possibility of a decline over these longer time periods. Egg depositions show a similar pattern with very little chance that the population has met its conservation requirement since 1983 (Figure A2.12). Estimates of the percent of the conservation requirement achieved have been in the range of 21 to 23% for the last three years.

We examined the ratio of the population size in a given year to the size in the previous year (Figure A2.13). Since 1983, the population size has increased over the previous year on 13 occasions, and has decreased on 12 occasions. During the last three generations, the MLE for the log mean ratio is 0.0172 (Table A2.1, Figure A2.14), equating to a increase in population size of about 1.7% per year with little to no chance that the population decreased during that time period (Figure A2.14). However, an estimate of the decline rate obtained by log-linear regression indicates a decline of 2.9% per year (Table A2.1), more or less consistent with Middle River.

We used the Dennis-type PVA to project the population forward through time (Figure A2.15). The rapidly increasing trajectories obtained in some simulations are unrealistic because a carrying capacity is not included in the model. The results suggest that if the recent future is similar to the recent past, the population is expected to continue to slightly increase, although the trajectory is highly uncertain.

Table A2.1. Parameter estimates for Atlantic salmon in Baddeck River, Victoria Co., NS, obtained from the assessment model.

Name	Year	Value	Std. Dev.
Coefficients:			
Dive survey catchability		0.5455	0.0397
log recreational fishing q (small)		-5.8498	0.1841
log recreational fishing q (large)		-6.0771	0.1311
log alpha (age 0)		-9.0141	0.1567
log alpha (age 1)		9.6381	22969.0000
R0 (age1)		32.5300	4.3826
Abundance:			
log returns (small + large)	1983	4.4409	0.2340
log returns (small + large)	1984	4.7103	0.2366
log returns (small + large)	1985	4.3743	0.2349
log returns (small + large)	1986	5.7233	0.2307
log returns (small + large)	1987	5.5420	0.2178
log returns (small + large)	1988	5.7027	0.2272
log returns (small + large)	1989	5.8320	0.2420
log returns (small + large)	1990	5.7353	0.2132
log returns (small + large)	1991	5.7116	0.2186
log returns (small + large)	1992	5.5361	0.2120
log returns (small + large)	1993	5.2022	0.2073
log returns (small + large)	1994	5.2364	0.1013
log returns (small + large)	1995	5.6571	0.0829
log returns (small + large)	1996	5.9522	0.0944
log returns (small + large)	1997	5.5018	0.0864
log returns (small + large)	1998	5.3124	0.0935
log returns (small + large)	1999	5.4588	0.2067
log returns (small + large)	2000	5.0769	0.0829
log returns (small + large)	2001	4.9177	0.2304
log returns (small + large)	2002	4.6811	0.1044
log returns (small + large)	2003	4.9739	0.0998
log returns (small + large)	2004	4.7461	0.1007
log returns (small + large)	2005	5.6483	0.1024
log returns (small + large)	2006	5.0655	0.1027
log returns (small + large)	2007	5.1668	0.0999
log returns (small + large)	2008	5.4696	0.0987

(continued)

Table A2.1. Continued.

Name	Year	Value	Std. Dev.
Proportion small	1983	0.1046	0.0427
Proportion small	1984	0.1152	0.0470
Proportion small	1985	0.2013	0.0759
Proportion small	1986	0.1504	0.0588
Proportion small	1987	0.2192	0.0777
Proportion small	1988	0.1529	0.0591
Proportion small	1989	0.0594	0.0254
Proportion small	1990	0.2601	0.0870
Proportion small	1991	0.1789	0.0662
Proportion small	1992	0.2378	0.0815
Proportion small	1993	0.2949	0.0930
Proportion small	1994	0.1712	0.0189
Proportion small	1995	0.3031	0.0285
Proportion small	1996	0.2067	0.0214
Proportion small	1997	0.2524	0.0248
Proportion small	1998	0.2872	0.0270
Proportion small	1999	0.1131	0.0445
Proportion small	2000	0.0998	0.0113
Proportion small	2001	0.3109	0.1010
Proportion small	2002	0.2169	0.0229
Proportion small	2003	0.0997	0.0121
proportion small	2004	0.3094	0.0294
proportion small	2005	0.2244	0.0234
proportion small	2006	0.2470	0.0251
proportion small	2007	0.2964	0.0281
proportion small	2008	0.4636	0.0342
Derived Values:			
Slope parameter (log-linear regression)		-0.0292	0.0048
a) mean N (2004-2008)	189.0200	15.0070	22.8880
b) mean N (1994-1998)	254.6900	17.9040	26.9460
c) mean N (1990-1994)	205.7700	26.0620	21.8380
d) mean N (1984-1988)	192.1200	26.9950	25.9970
ratio: a/b	0.7422	0.0355	0.0356
ratio: a/c	0.9186	0.1127	0.1276
ratio: a/d	0.9839	0.1241	0.0984
mean(log (N_t/N_{t-1}))	0.0172	0.0073	0.0069
std. dev. (log (N_t/N_{t-1}))	0.3924	0.0388	0.0315

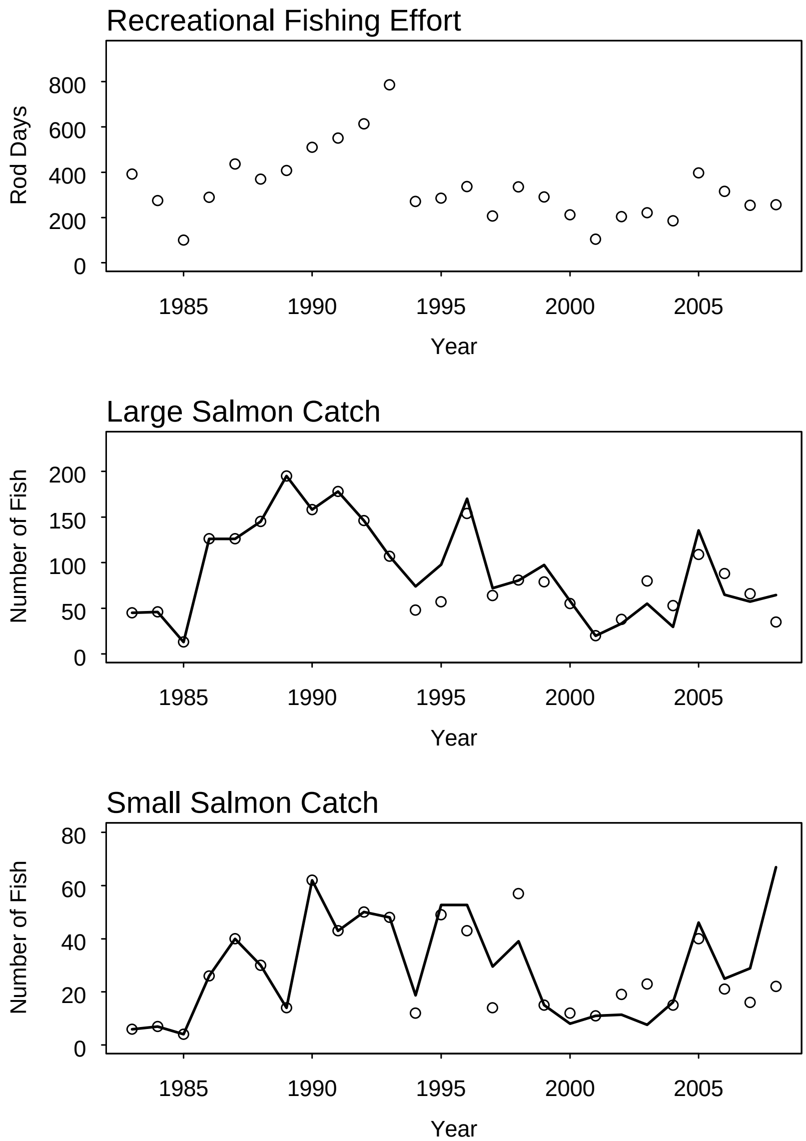


Figure A2.1. Fishing effort and observed (points) and predicted (lines) Atlantic salmon catches on the Baddeck River, NS, from 1983 to 2007.

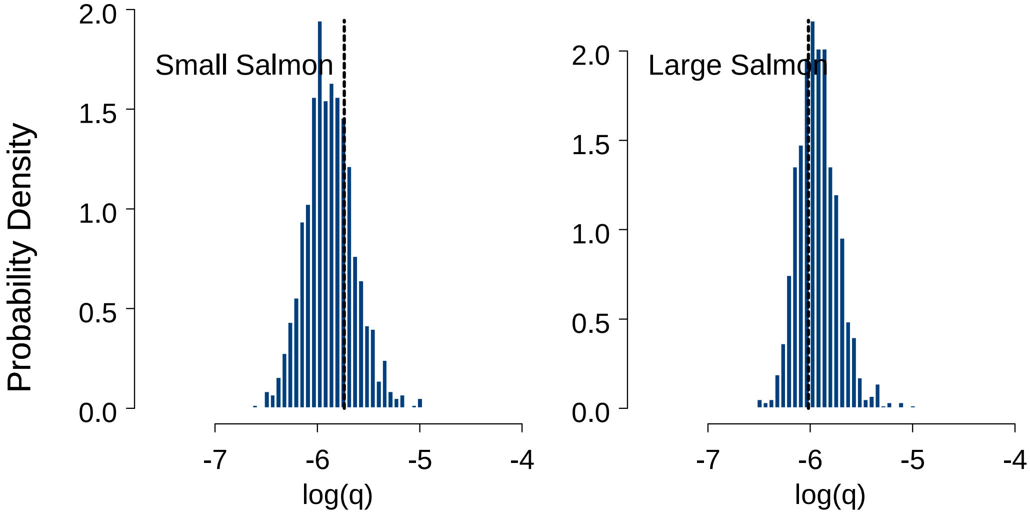


Figure A2.2. Posterior probability densities for the natural logarithms of the recreational fishery catchability coefficients for small and large salmon in Baddeck River, NS. The dashed lines show the maximum likelihood estimates.

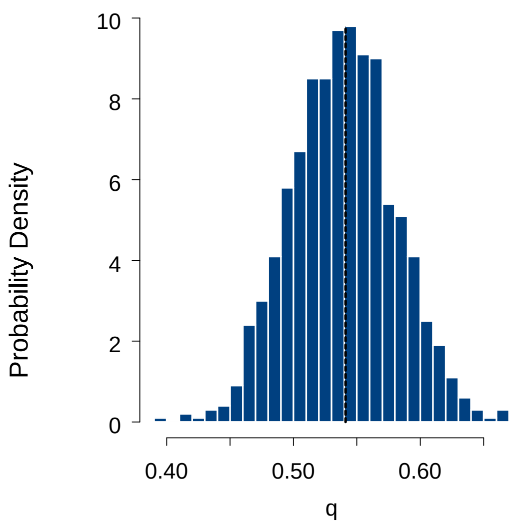


Figure A2.3. Posterior probability density for the diver observation coefficient (proportion of the population observed in a dive survey). The dashed line shows the maximum likelihood estimate.

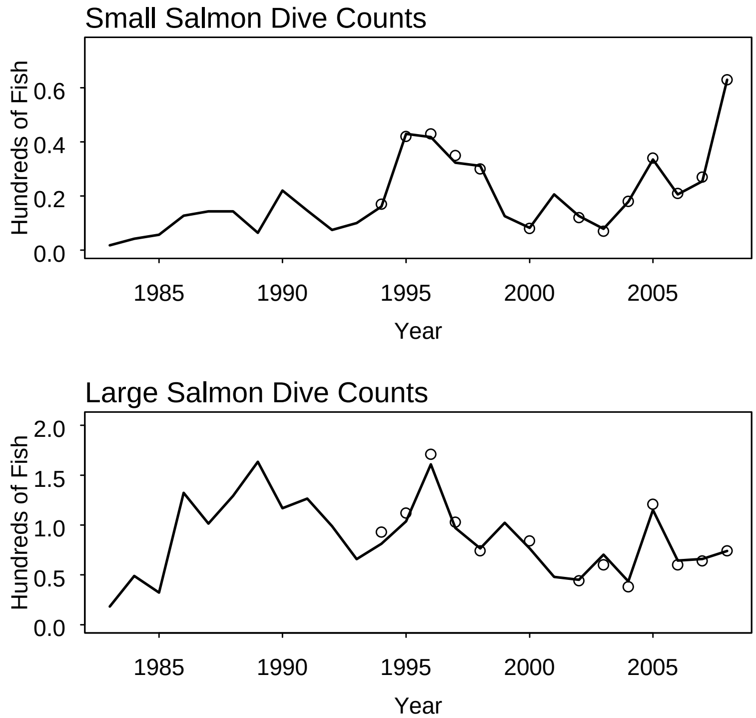


Figure A2.4. Predicted (lines) and observed (points) numbers of small (top panel) and large (bottom panel) Atlantic salmon observed during dive surveys in the Baddeck River, NS, from 1994 to 2008. The predicted series is extrapolated back to 1983.

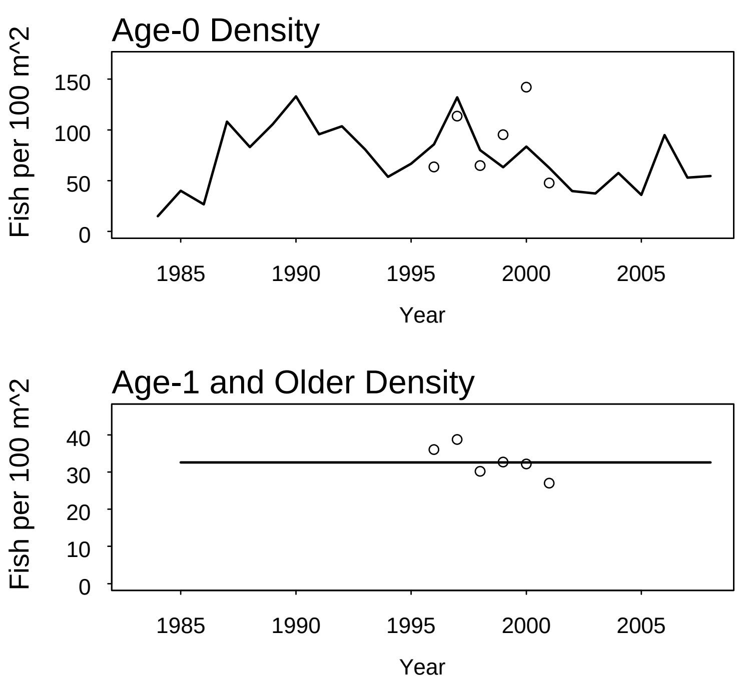


Figure A2.5. Mean density of juvenile Atlantic salmon in the Baddeck River, NS, from 1983 to 2007. The points are the observed densities determined by electrofishing. The lines are the predicted densities from the assessment model.

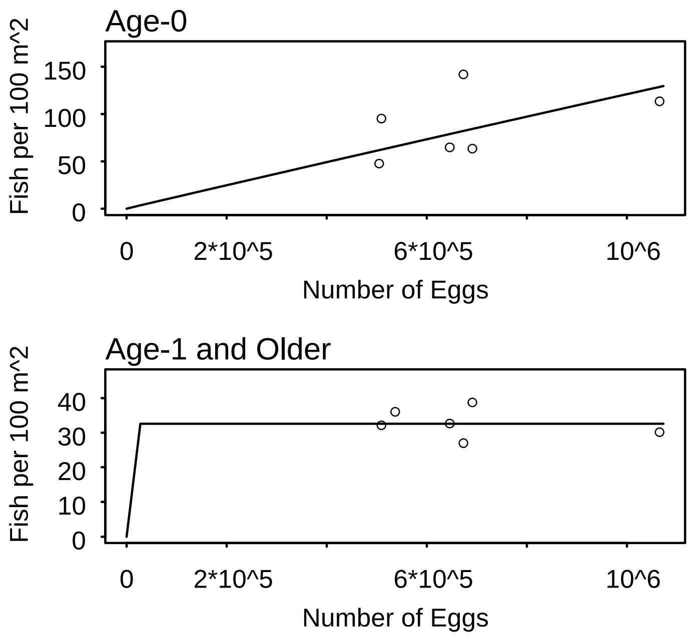


Figure A2.6. The relationship between egg deposition in year t and the number of juvenile Atlantic salmon in years t+1 (age 0) and t+2 (age 1 and older) in the Baddeck River, NS. Juvenile densities were determined by electrofishing between 1996 and 2001. Egg deposition was predicted using the assessment model.

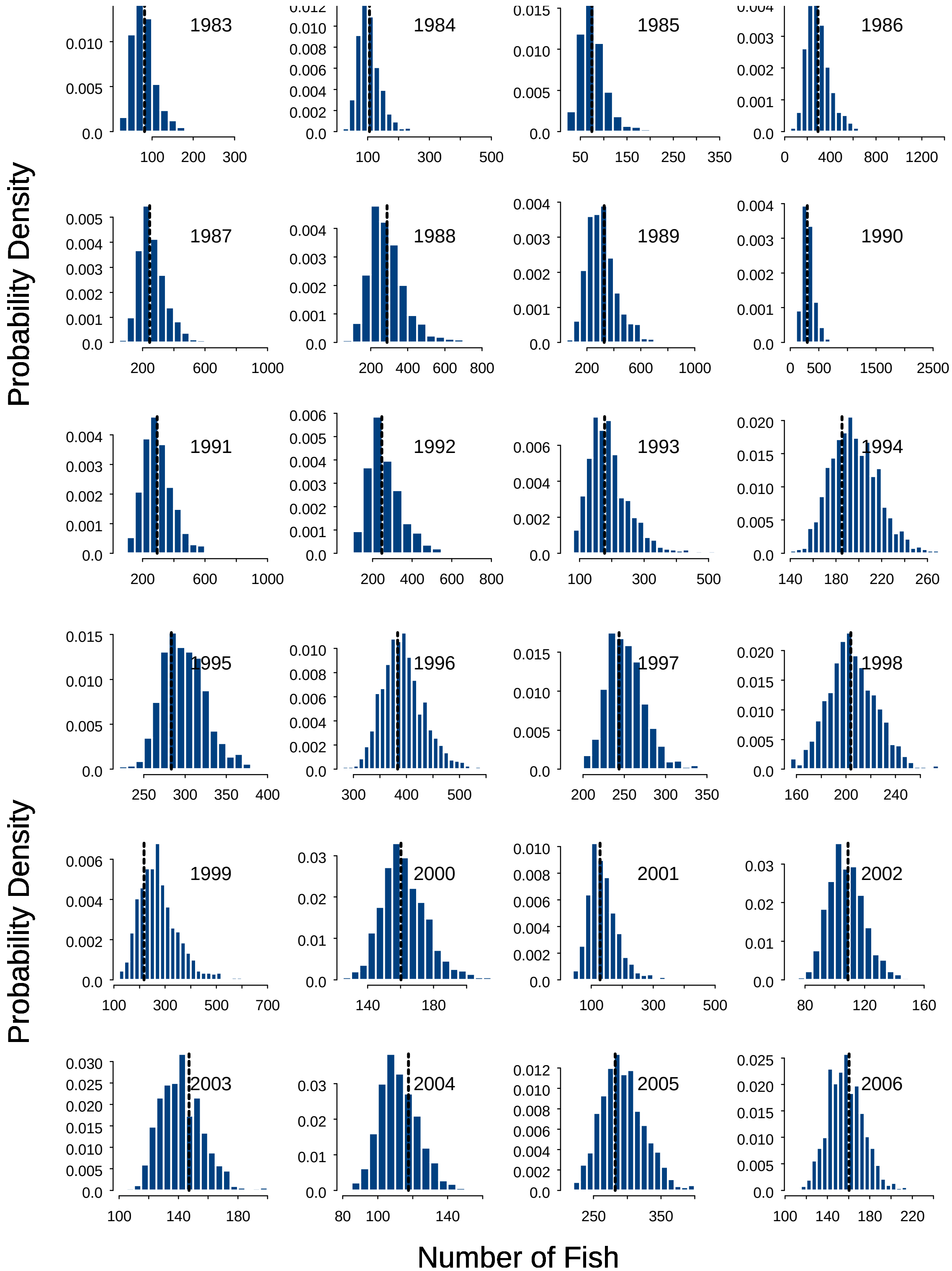


Figure A2.7. Posterior probability densities for the number of Atlantic salmon returning annually to the Baddeck River from 1983 to 2006. The dashed lines show the maximum likelihood estimates.

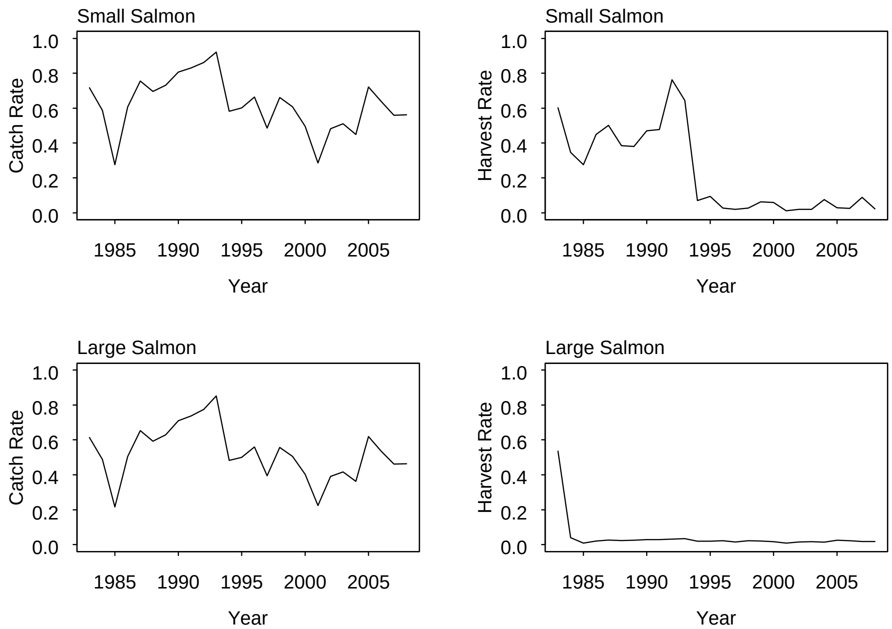


Figure A2.8. Estimated catch rates and harvest rates for small and large Atlantic salmon in the Baddeck River, NS, recreational fishery from 1983 to 2007. The recreational harvest fishery for large salmon was closed in 1984 and for small salmon in 1994. A 4% hook and release mortality is included in the harvest rate estimate.

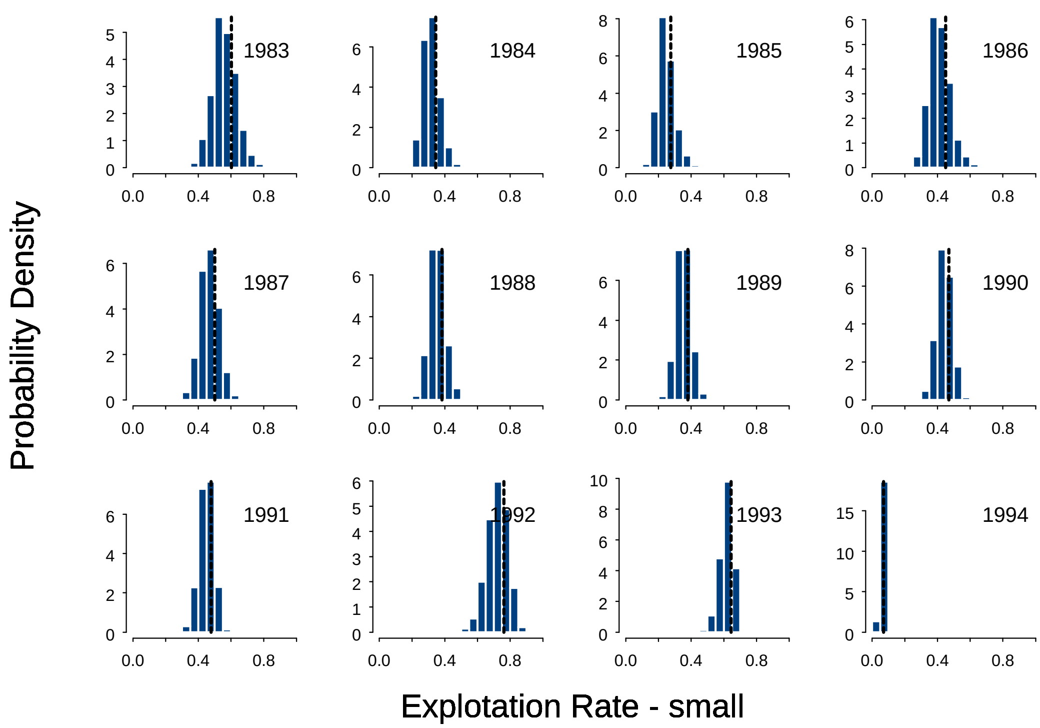


Figure A2.9. Posterior probability densities for the exploitation (harvest) rate for small salmon in Baddeck River, NS from 1983 to 1994. The dashed line is the maximum likelihood estimate.

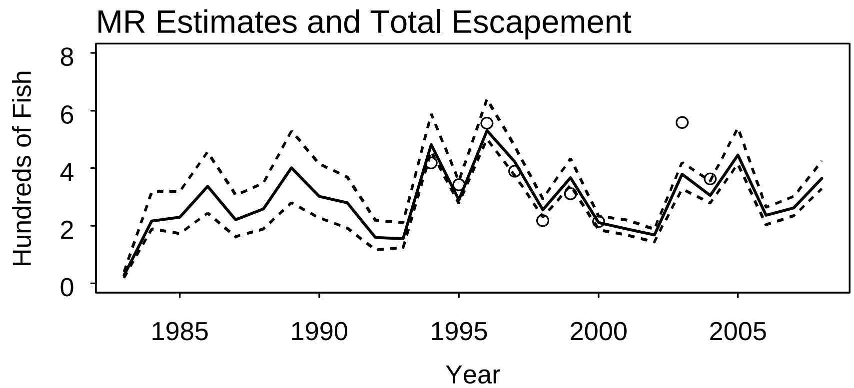


Figure A2.10. Estimated total number of salmon (solid lines) escaping the fishery in the Baddeck River, NS, from 1983 to 2008. The points are the population estimates obtained by mark-recapture during the dive surveys. The dashed lines are the 10th and 90th percentiles of the posterior probability densities for the total annual escapement.

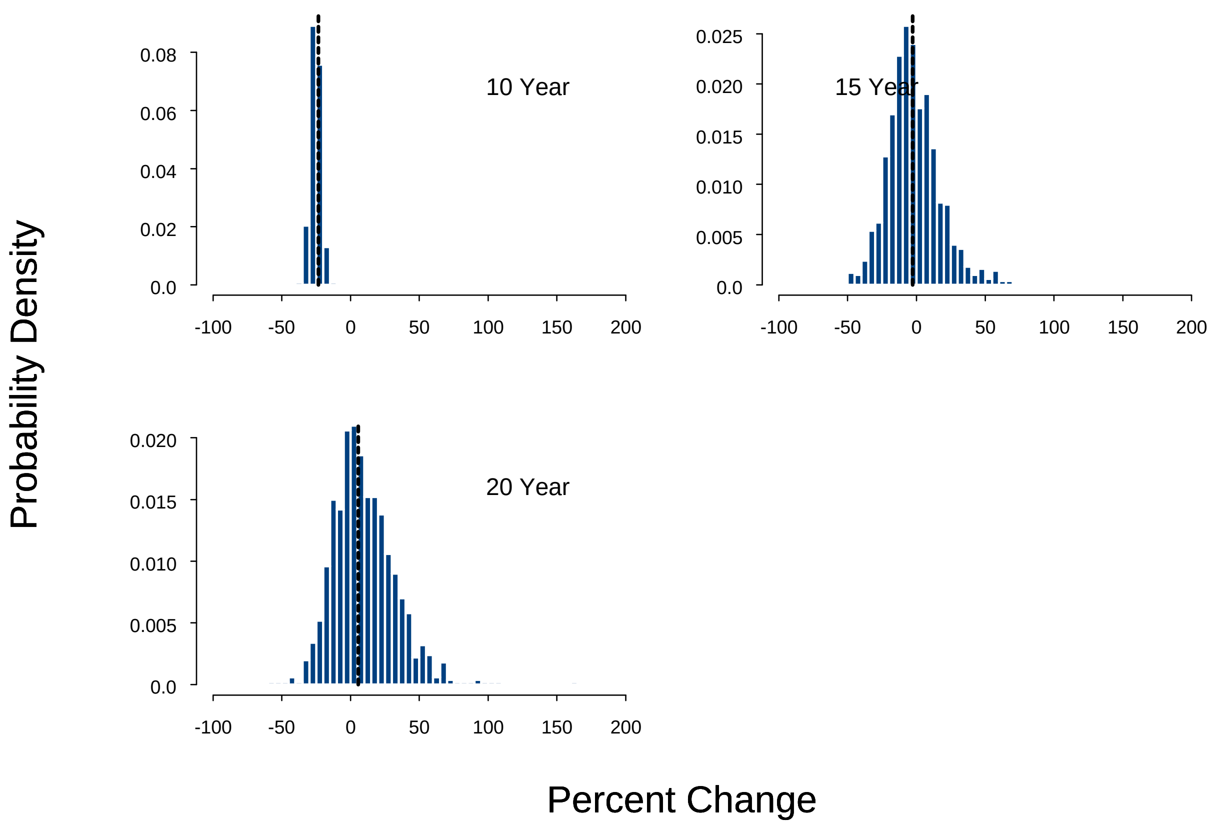


Figure A2.11. Posterior probability densities for the percent decline in Atlantic salmon escapement in Baddeck River, NS, over 10-, 15- and 20-year time periods. Percent decline was calculated by comparing the mean number of returning salmon for the 2004-2008 time period to means for the 1994-1998 time period (10-year comparison), the 1990-1994 time period (15-year comparison), and the 1984-1988 time period (20-year comparison). The dashed lines show the maximum likelihood estimates for the percent change in population size.

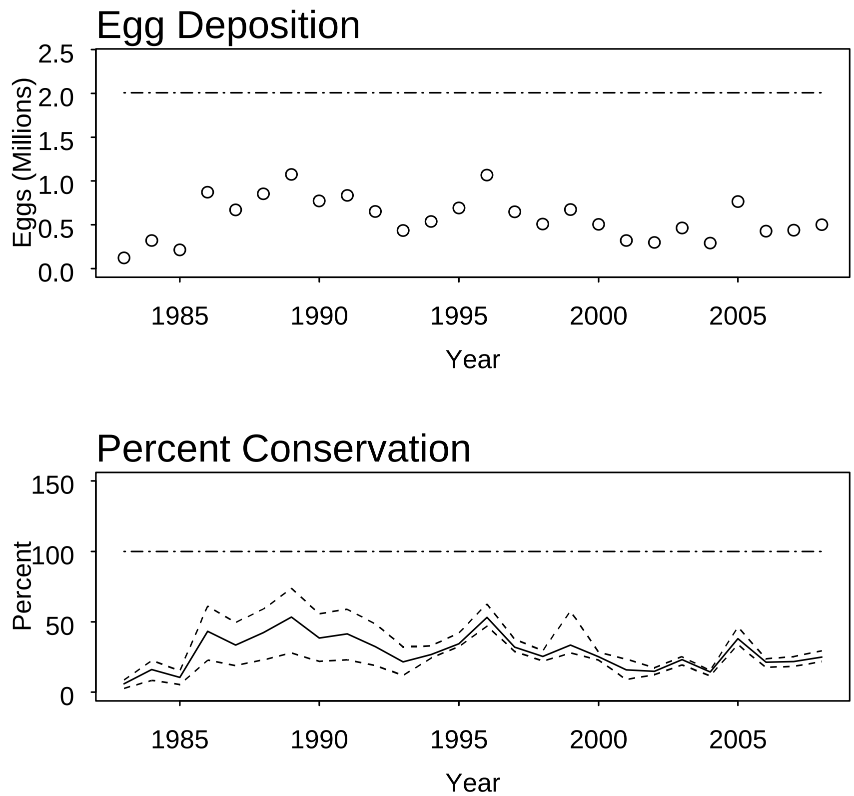


Figure A2.12. Estimated egg deposition and the percent of the conservation requirement achieved in Baddeck River, NS, from 1983 to 2008. The horizontal line is the conservation requirement. The 10th and 90th percentiles of the posterior probability densities for the percent of the conservation requirement achieved are shown.

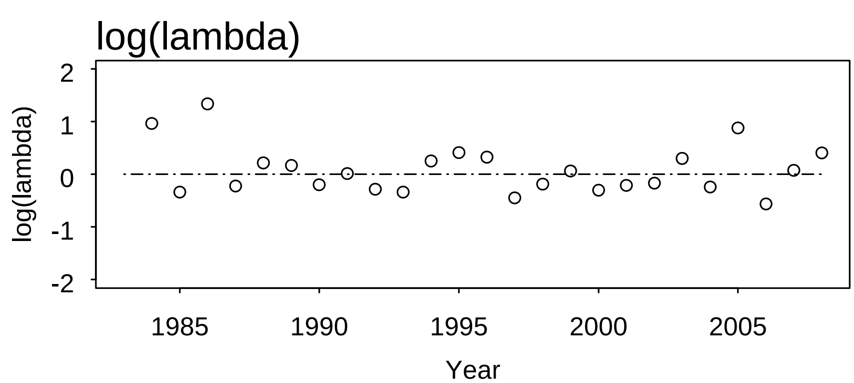


Figure A2.13. The ratio of N_t to N_{t-1} for Baddeck River salmon from 1984 to 2008. The dashed line is the level at which the population size does not change.

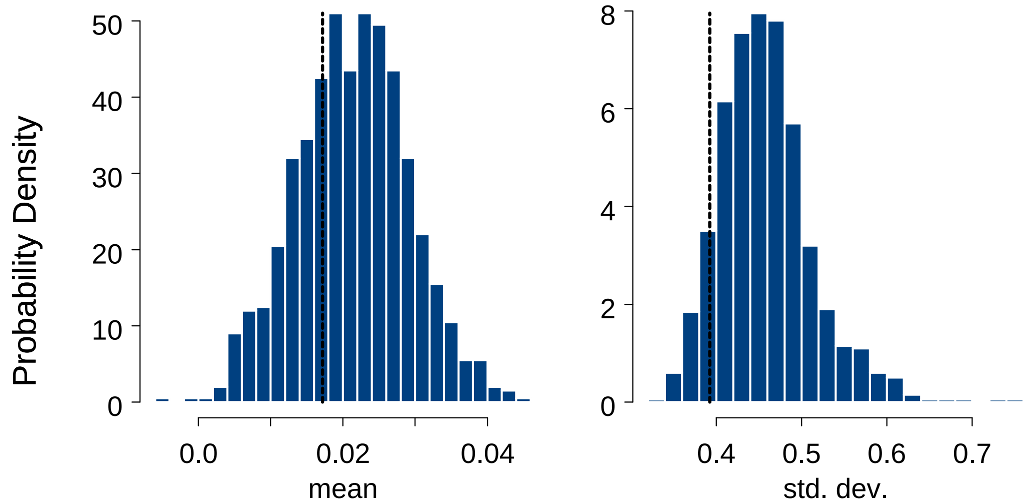


Figure A2.14. Posterior probability densities for the mean and standard deviation of log (lambda) used as inputs for a Bayesian version of a Dennis-type population viability analysis for Atlantic salmon in Baddeck River, NS. The dashed lines show the maximum likelihood estimates.

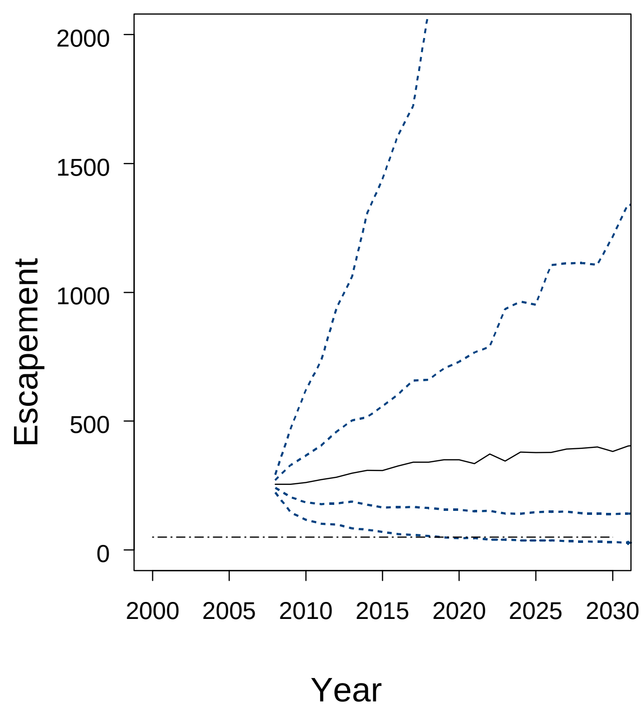


Figure A2.15. Results of the Bayesian version of a Dennis-type population viability analysis for Atlantic salmon in Baddeck River, NS. The solid line is the median population size and dashed lines are the 10th, 30th, 70th and 90th percentiles of the posterior distributions for the projected annual population size. The horizontal dashed line shows an arbitrary quasi-extinction threshold of 50 salmon.

Appendix 3. Recreational Catch and Effort Data for Salmon Fishing Area 19

		Year																								
River	Variable	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
ACONI BROOK	Catch Small	1	11	0	2	0	6	1	12	6	7	0	0	0	0	0	0	2	4	0	0	0	0	0	0	0
	Catch Large	2	4	0	0	0	0	1	13	6	8	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
	Retained Small	0	11	0	2	0	6	1	11	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	69	75	22	14	1	107	16	57	35	24	0	0	0	0	0	0	5	14	0	0	0	0	0	0	0
BADDECK	Catch Small	6	7	4	26	40	30	14	62	43	50	48	12	49	43	14	57	15	12	11	19	23	15	40	21	16
	Catch Large	45	46	13	126	126	145	195	158	178	146	107	48	57	154	64	81	79	55	20	38	80	53	109	88	66
	Retained Small	5	4	4	19	26	16	7	35	24	44	33	1	6	0	0	0	1	1	0	0	0	2	0	0	2
	Retained Large	39	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	391	275	100	289	436	369	408	510	550	613	786	271	285	337	206	335	290	212	104	204	221	185	397	316	254
BARACHOIS	Catch Small	0	1	1	5	18	6	4	12	5	2	10	1	6	10	4	9	1	1	0	0	1	0	1	2	0
	Catch Large	6	2	2	17	39	10	6	19	18	6	25	5	16	16	12	1	2	1	0	0	1	0	0	2	1
	Retained Small	0	1	1	4	12	4	3	5	3	2	8	0	0	0	0	1	0	0	0	0	0	0	0	0	0
	Retained Large	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	46	47	10	30	74	37	53	85	95	60	150	44	37	56	35	40	16	10	13	8	22	11	16	6	9
CATALONE	Catch Small	25	114	78	72	92	71	25	25	5	8	1	0	0	9	0	1	0	3	0	1	6	0	0	0	0
	Catch Large	27	15	16	81	47	56	11	16	2	2	1	0	0	7	0	0	0	0	0	3	4	0	0	0	0
	Retained Small	23	102	75	64	82	69	24	23	4	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large	19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	1162	1101	899	858	812	883	471	352	194	177	73	5	1	43	7	3	1	3	1	9	15	0	0	0	0
CLYBURNE	Catch Small		0	0	4	4	0	0	0	3	0	0	0	1	2	1	0	1	0	0	0	0	0	0	0	0
	Catch Large		1	2	4	16	4	0	0	3	0	0	8	0	37	1	1	0	0	0	0	0	0	0	0	0
	Retained Small		0	0	1	4	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)		2	17	28	63	15	31	2	33	0	2	21	2	52	3	8	8	3	0	1	21	4	0	0	0
FRAMBOISE (GIANT LAKE	Catch Small	43	182	151	84	78	77	65	36	25	17	8	0	1	1	4	0	2	8	0	5	0	0	0	0	3
	Catch Large	48	23	40	49	42	56	37	25	18	4	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
	Retained Small	39	156	143	84	72	71	60	29	20	14	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large	44	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	776	866	893	636	560	480	337	405	244	313	202	52	7	33	29	16	25	30	0	20	3	0	1	6	16

Note: Blank cells indicate fishing closures.

Appendix 3. Continued.

		Year																								
River	Variable	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
FRENCH-VALE BROOK	Catch Small																3	0	0	0	0	0	0	0	0	0
	Catch Large																4	0	0	0	0	0	0	0	0	0
	Retained Small																0	0	0	0	0	0	0	0	0	0
	Retained Large																0	0	0	0	0	0	0	0	0	0
	Effort (rod days)																20	0	0	0	0	0	0	0	0	0
GASPEREAUX: C. BRETON CO.	Catch Small	0	1	0	1	0	0	2	1	1	0	0	0	0	0	0	8	1	0	0	0	0	0	0	0	0
	Catch Large	4	2	0	0	0	1	0	0	1	0	0	0	0	10	7	1	0	0	0	0	0	0	0	2	0
	Retained Small	0	1	0	1	0	0	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	63	42	5	12	35	6	25	14	44	10	8	15	0	14	29	44	2	1	5	3	0	0	1	5	0
GERRATT	Catch Small	1	4	7	2	7	0	1	9	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Catch Large	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Small	1	2	4	0	3	0	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	22	34	19	15	43	5	11	32	32	5	7	3	2	2	0	0	0	0	0	0	0	0	0	0	0
GRAND	Catch Small	232	403	543	361	343	269	247	359	107	141	140	55	4	83	31	75	17	20	1	31	16	7	20	15	6
	Catch Large	71	34	132	194	107	84	59	88	15	39	25	15	10	23	6	12	3	1	0	0	3	2	0	0	2
	Retained Small	197	349	472	299	309	252	229	291	97	131	119	0	0	0	3	0	0	0	0	0	0	0	0	0	0
	Retained Large	31	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	4266	3009	3093	3019	2078	2754	2257	2497	1707	1689	1496	366	41	261	173	246	47	81	9	84	63	35	13	28	34
GRANTMIRE BROOK	Catch Small										0	6	0	0	7	0	1	4	0	0	0	0	14	4	6	0
	Catch Large										3	7	0	0	9	3	1	13	1	0	0	4	3	7	0	3
	Retained Small										0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large										0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)										7	15	0	0	18	9	7	17	4	3	0	9	16	9	14	4
INDIAN BROOK	Catch Small	1	10	0	12	6	4	1	2	9	0	5	0	2	3	0	3	1	0	0	0	0	0	5	0	0
	Catch Large	2	10	0	14	25	13	1	8	21	0	1	1	3	3	0	1	0	0	0	0	3	2	0	0	0
	Retained Small	0	9	0	6	4	2	1	1	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	28	40	0	43	41	33	10	35	76	17	43	9	16	24	17	25	7	5	5	11	9	11	9	13	3

Note: Blank cells indicate fishing closures.

Appendix 3. Continued.

		Year																								
River	Variable	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
INGONISH	Catch Small	1	11	0	0	9	9	6	9	10	1	23	2	3	5	5	3	0	0	0	0	0	2	1	0	0
	Catch Large	3	6	0	0	27	19	19	12	3	1	23	6	8	6	8	9	1	0	0	0	0	7	1	0	0
	Retained Small	1	6	0	0	5	4	6	9	9	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	19	31	0	0	48	34	121	44	89	40	128	42	38	74	21	11	8	5	1	3	3	4	4	5	0
INHABITANTS	Catch Small	4	31	33	22	43	44	20	41	38	26	25	17	3	23	3	9	1	14	0	4	2	2	5	6	6
	Catch Large	41	65	104	256	155	167	59	91	116	124	81	47	16	67	5	14	4	24	0	1	1	2	4	15	18
	Retained Small	4	27	28	21	41	36	19	32	32	26	25	0	0	2	0	0	0	0	0	0	0	0	0	0	0
	Retained Large	38	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	319	230	327	323	298	292	330	427	315	380	311	138	37	106	25	36	29	42	9	13	12	7	7	47	25
LITTLE LORRAINE	Catch Small				0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Catch Large				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Small				0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)				1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
LORRAINE BROOK	Catch Small	13	30	55	25	30	27	11	14	2	12	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Catch Large	1	0	2	2	6	8	6	2	0	8	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Small	10	30	53	24	28	26	10	13	0	10	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	73	184	295	281	206	215	121	174	50	55	38	0	0	0	0	0	1	0	0	0	0	0	0	0	0
MACASKILL'S BROOK	Catch Small								7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Catch Large								8	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Small								1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large								0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)								57	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
MARIE JOSEPH	Catch Small	10	5	29	9	15	15	22	12	1	10	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Catch Large	2	0	15	7	2	5	2	1	0	4	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Small	5	5	19	9	12	12	22	12	1	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	119	68	85	76	51	80	76	83	20	117	90	54	0	3	0	0	1	0	0	0	0	0	1	2	1

Note: Blank cells indicate fishing closures.

Appendix 3. Continued.

		Year																								
River	Variable	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
MIDDLE: VICTORIA CO.	Catch Small	12	34	21	44	58	41	41	93	23	10	31	18	30	58	18	31	30	20	10	28	23	22	38	44	42
	Catch Large	41	78	29	108	116	118	221	171	156	27	48	128	41	132	80	60	95	67	15	35	137	44	133	87	95
	Retained Small	12	24	15	36	53	30	32	69	15	7	25	0	0	2	3	5	0	0	0	1	0	0	0	0	0
	Retained Large	36	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	935	509	160	388	725	596	723	878	736	190	406	444	243	454	175	312	369	311	92	231	336	185	458	416	506
MIRA	Catch Small	3	8	7	3	4	20	11	12	18	6	1	6	8	0	0	3	0	0	0	0	0	0	1	0	0
	Catch Large	0	0	1	1	2	11	13	11	8	1	0	2	4	0	0	10	0	0	0	0	0	0	0	0	0
	Retained Small	3	6	6	3	3	19	11	12	17	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	167	129	112	78	147	122	205	269	188	108	87	43	57	3	3	56	3	0	0	4	7	0	43	9	0
NORTH ASPY	Catch Small	0	1	1	1	5	12	6	0	9	4	2	10	2	5	2	2	1	0	0	0	0	0	7	2	17
	Catch Large	0	0	0	29	39	62	26	9	29	22	9	21	7	36	14	7	2	0	0	4	11	22	21	3	12
	Retained Small	0	1	1	1	3	9	4	0	8	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	28	7	6	23	86	120	90	52	85	95	48	59	18	55	28	23	15	9	0	17	48	29	63	27	81
NORTH: VICTORIA CO.	Catch Small	44	66	162	235	226	112	128	233	156	198	83	57	136	162	70	108	35	32	37	34	81	70	55	56	92
	Catch Large	158	154	425	1010	546	445	316	531	297	486	164	75	169	115	137	104	45	27	60	45	156	152	171	104	134
	Retained Small	36	57	149	185	177	99	97	176	123	162	63	0	1	0	1	0	0	0	0	0	0	0	1	0	0
	Retained Large	150	96	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	1880	1182	1012	2050	1668	1316	1119	1612	1197	1619	1246	361	436	526	384	448	292	261	264	269	525	505	441	445	491
NORTHWEST BROOK (RIVER RYAN)	Catch Small		1	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Catch Large		0	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Small		1	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)		5	45	0	4	0	6	34	34	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0
RIVER BENNETT	Catch Small				1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
	Catch Large				4	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Small				1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)				13	0	0	0	0	0	6	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0

Note: Blank cells indicate fishing closures.

Appendix 3. Continued.

		Year																								
River	Variable	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
RIVER DENY'S	Catch Small		0	0	0	0	10	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Catch Large		0	0	0	0	5	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Small		0	0	0	0	8	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)		1	2	1	0	6	0	1	2	9	2	0	0	1	0	0	0	0	0	0	0	0	0	0	4
RIVER TILLARD	Catch Small	0	13	16	14	32	9	7	19	8	6	5	2	2	9	0	0	1	0	0	0	0	0	0	3	0
	Catch Large	0	6	13	24	59	18	7	9	13	4	3	0	0	13	0	0	0	0	0	0	1	0	0	2	0
	Retained Small	0	13	16	14	25	8	7	16	4	4	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	64	160	80	142	147	120	76	67	61	44	34	7	5	21	0	12	6	0	0	7	9	2	0	6	0
SAINT ESPRIT	Catch Small	2	3	14	0	1	9	0	1	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	Catch Large	0	0	3	0	1	7	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
	Retained Small	2	3	14	0	1	9	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	48	59	97	6	6	70	8	11	2	21	2	57	0	0	0	0	0	0	1	0	0	0	0	0	0
SALMON: CAPE BRETON CO.	Catch Small	11	34	22	29	31	19	6	11	11	7	2	0	8	14	2	9	2	6	0	7	2	0	0	1	1
	Catch Large	64	24	35	32	20	26	16	10	8	7	3	0	11	30	2	11	4	10	0	1	2	2	0	0	1
	Retained Small	10	32	18	29	30	16	6	10	6	6	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large	61	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)	1489	703	461	491	567	542	236	280	291	247	162	16	72	145	79	120	20	20	4	11	15	5	38	9	10
SKYE	Catch Small		0	0	0	0	0	0	0	0	0	7	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Catch Large		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Small		0	0	0	0	0	0	0	0	0	6	1	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)		8	1	0	0	0	0	0	0	0	23	6	2	0	0	4	0	0	0	0	0	0	0	0	0
SYDNEY	Catch Small			0	0	1	0	0	0	0	3	1	0	0	5	0	0	0	0	0	0	0	0	0	0	0
	Catch Large			0	3	12	0	2	0	8	8	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0
	Retained Small			0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Retained Large			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Effort (rod days)			12	7	29	0	7	6	3	31	15	2	2	40	3	3	0	0	0	0	0	0	0	0	0

Note: Blank cells indicate fishing closures.