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Assessment of Atlantic Salmon (*Salmo salar*) in Salmon Fishing Area 16 of the southern Gulf of St. Lawrence to 2013

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Foreword

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

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ABSTRACT

Of the 39 Atlantic salmon rivers in Salmon Fishing Area (SFA) 16, the Miramichi River is the largest and accounts for over 90% of the juvenile rearing habitat in SFA 16. Annual returns of adult salmon to the Miramichi River were monitored at estuarial trapnets and their abundance estimated with a mark and recapture experiment. The proportion of the conservation requirement attained was determined after accounting for the number of large (≥63 cm) and small (<63 cm) salmon harvested and lost from aboriginal and recreational fisheries. In 2013, returns of Atlantic salmon to the Miramichi River were estimated at 13,260 large salmon and 11,750 small salmon. The small salmon and large salmon returns in 2013 were among the lowest return estimates since 1970. Returns of large salmon and small salmon to the Southwest Miramichi River in 2013 were 10,780 (5^{th} and 95^{th} percentiles 6,804-18,250) and 7,537 (5,049-12,100) and insufficient to meet the egg conservation requirement before fisheries (83%) and after accounting for removals from fisheries (80%). Similarly for the Northwest Miramichi River, the returns of large salmon and small salmon were 2,342 (1,613-3,566) and 4,094 (3,241-5,546) and insufficient to meet the egg conservation requirement before (48%) and after removals from fisheries (39%). Catches and counts of large salmon at provincial barriers and crown reserve angling stretches in 2013 were improved over 2012 and above the previous 5-year averages. Small salmon catches and counts at provincial facilities in 2013 were also improved over 2012 levels but less than the previous 5-year means. The biological characteristics of adult salmon sampled at DFO index trapnets in the Miramichi River were updated for 2013. Juvenile salmon were sampled throughout the Miramichi watershed in 2012 and have remained at consistent levels since 1984 when significant changes in the management of the commercial and recreational salmon fisheries occurred. Reliable catch and harvest information from the recreational and aboriginal fisheries remain a significant constraint to the assessment of Atlantic salmon in SFA 16 and precludes any rigorous evaluation of current or potentially new management scenarios for these stocks.

Évaluation du saumon de l'Atlantique (*Salmo salar*) de la zone de pêche au saumon 16 du sud du golfe du Saint-Laurent, 2013

RÉSUMÉ

La zone de pêche au saumon (ZPS) 16 compte 39 rivières à saumon de l'Atlantique, dont la rivière Miramichi, qui est la plus grande et qui renferme plus de 90 % de l'habitat d'élevage des juvéniles de la ZPS 16. Les retours annuels de saumons adultes dans la rivière Miramichi ont fait l'objet d'un suivi au moyen de filets-trappes placés dans l'estuaire. De plus, on a évalué l'abondance de ces saumons par l'entremise d'une expérience de marquage et de recapture. La proportion de besoins en matière de conservation ayant été satisfaits a été établie après avoir compté le nombre de saumons de petite taille (< 63 cm) et de grande taille (≥ 63 cm) ayant été capturés et perdus dans le cadre des pêches autochtones et récréatives. En 2013, les retours de saumon de l'Atlantique dans la rivière Miramichi ont été estimés à 13 260 individus dans le cas des gros saumons et à 11 750 individus dans le cas des petits saumons. Les retours de petits et de gros saumons en 2013 figurent parmi les estimations les plus basses depuis 1970. En 2013, les retours de petits et de gros saumons dans la rivière Miramichi Sud-Ouest se chiffraient à 7 537 (5^e et 95^e centiles : 5 049, 12 100) et à 10 780 (5^e et 95^e centiles : 6 804, 18 250), ce qui ne permet pas de répondre à l'exigence de conservation (ponte) avant les pêches (83 %) ni après avoir pris en considération les prélèvements de la pêche (80 %). La rivière Miramichi Nord-Ouest connaît une situation similaire, ses retours de petits et de gros saumons étant de 4 094 (3 241, 5 546) et 2 342 (1 613, 3 566). Cela ne permet pas de répondre à cette même exigence, ni avant d'avoir pris en considération les prélèvements (48 %), ni après (39 %). Les prises de gros saumons capturées aux barrières provinciales et dans les zones de pêche des réserves de la Couronne en 2013 sont plus nombreuses qu'en 2012 et elles dépassent la moyenne des cinq années précédentes. La même année, les prises de petits saumons aux installations provinciales ont, elles aussi, dépassé celles de 2012. Elles sont toutefois inférieures à la moyenne des cinq années précédentes. Les caractéristiques biologiques des saumons adultes extraits des filets-trappes repères du MPO dans la rivière Miramichi ont été mises à jour pour 2013. En 2012, on a prélevé des saumons juvéniles dans l'ensemble du bassin hydrographique de la rivière Miramichi. Ceux-ci affichaient des niveaux constants depuis 1984, année où l'on a apporté des changements importants sur le plan de la gestion des pêches commerciales et récréatives du saumon. La fiabilité incertaine des renseignements sur les prises fournis par les pêches récréatives et autochtones continue d'être un problème majeur pour l'évaluation du saumon de l'Atlantique de la ZPS 16. De plus, elle empêche d'effectuer une évaluation rigoureuse des scénarios de gestion actuels ou éventuels pour ces stocks.

INTRODUCTION

The Atlantic Salmon Fishing Area (SFA) 16 is located along the east coast of New Brunswick and drains the province's rivers that flow east and into the Gulf of St. Lawrence (Fig. 1). Atlantic salmon inhabit 39 rivers of SFA 16 which combine for over 61 million m^2 of juvenile rearing habitat (Amiro 1983). The Miramichi River including its two branches, the Southwest (SW) and Northwest (NW) Miramichi rivers and their enormous network of tributaries account for approximately 91% (55 million m^2) of the juvenile rearing capacity in SFA 16. The remainder of the habitat is found in a number of smaller rivers located primarily in southeastern New Brunswick; sub-management unit SFA 16B (Fig. 1).

While commercial fisheries for Atlantic salmon have remained closed since 1984, Aboriginal peoples and anglers continue to exploit the resource for food and/or recreation. Aboriginal fisheries are managed by communal licenses for food, social, and ceremonial (FSC) purposes with restrictions on gear, season, and seasonal allocations of both small (fork length < 63 cm) and large (fork length ≥ 63 cm) salmon. The recreational fishery is regulated by season and both daily and seasonal bag limits for small salmon; all large salmon must be returned to the water. Due to low spawning escapements, rivers in southeastern NB (SFA 16B) have been closed to recreational angling and aboriginal access since 1998.

An annual monitoring program for adult Atlantic salmon in the Miramichi River has lent itself to regular assessments of the stock since 1982 (Randall and Chadwick 1983a, 1983b; Randall and Schofield 1987, 1988; Randall et al. 1985, 1986, 1989, 1990; Moore et al. 1991, 1992 Courtney et al. 1993; Chaput et al. 1994, 1995, 1996, 1997, 1998, 1999, 2000, 2001, 2006, 2010; Chaput 2010; Douglas et al. 2012; DFO 2013). Electrofishing surveys of the Miramichi watershed since 1968 (Moore and Chaput 2007) have helped inform the status of the stock and there has been recent interest to evaluate run sizes of emigrating Atlantic salmon smolts (Chaput et al. 2002). Programs that monitored adult Atlantic salmon in the smaller rivers of SFA 16 have been less frequent and irregular, however juvenile surveys have frequently been undertaken, although not annually in most cases, since the late 1990s.

The objective of the current assessment is to update the status of salmon stocks from SFA 16 with new information collected since their last collective review (Douglas et al. 2012).

FISHERIES

Due to low spawning escapements, rivers in southeastern New Brunswick (SFA 16B; Fig. 1) have been closed to all recreational and aboriginal salmon fisheries since 1998.

ABORIGINAL

Aboriginal fisheries for Atlantic salmon are managed under communal licenses with restrictions on gear, location, season, and allocations of both small and large salmon. The majority of aboriginal food, social and ceremonial (FSC) fisheries in SFA 16 occur in estuaries but also occur in Miramichi Bay and the crown open waters of the Miramichi, Bartibog, and Tabusintac rivers (Table 1). Estuarine trapnet programs with the objective of harvesting salmon for FSC purposes as well as marking and/or recapturing salmon for the purpose of estimating run size exist in the Tabusintac, and the Southwest and Northwest Miramichi rivers, and are conducted by Esgenoôpetitj, Eel Ground, and Metepenagiag First Nations, respectively. Trapnet catch information is provided in each of these cases and makes a valuable contribution to the overall salmon assessment of the Miramichi system. First Nation FSC gillnet fisheries and Native recreational fisheries for Atlantic salmon also occur in these rivers but catch information is incomplete.

RECREATIONAL

The recreational fishery is regulated by season and both daily and seasonal bag limits for small salmon. Angling seasons vary slightly throughout SFA 16 but typically open on April 15 and close on October 15. Only the retention of small salmon is permitted in the recreational fishery of SFA 16 and limited to one per day and a maximum of eight for the season. During the bright salmon season (generally May 16 to October 15), angling for Atlantic salmon must cease for the day once the daily bag limit has been filled or four salmon of any size have been captured and released. The same daily bag limit applies to the kelt fishery (April 15 to May 15) but 10 salmon of any size can be captured and released per day (Gulf Region Close Time and Quota Variation Order 2011-083). The upper portions of the Miramichi system close or switch to catch and release during the fall period. Recent concerns about low spawning escapements has prompted a change to catch and release of small salmon in the mid and upper sections of the Northwest Miramichi River for the 2011 to 2013 angling seasons.

A creel survey form is provided with the 15 to 20 thousand salmon angling licenses sold annually in the province of New Brunswick. The rate of return for the creel forms is low and has averaged 215 (range 115-411) in each year between 2008 and 2011, the equivalent of less than 1% of salmon licenses sold in the province for those years (C. Connell, NB DNR pers. comm.). The low return rates for creel survey forms makes meaningful analysis of catch statistics difficult.

Angling statistics from the Regular Crown Reserve Waters of the Northwest Miramichi River are compiled annually by the NB Department of Natural Resources (DNR) and have been used as an index of salmon abundance in the Northwest Miramichi since 1973 (discussed in detail below).

High river water temperatures in 2013 resulted in the closure of 22 salmon pools on July 17 and an additional four pools on July 19 (Gulf Region Variation Orders GVO-2013-054 and GVO-2013-058). All pools were re-opened to angling on July 25, 2013 (Gulf Region Variation Orders GVO-2013-059). Similar to previous years, three cold water pools in the estuary were closed between August 1, 2013 and the end of the season (Gulf Region Variation Orders GVO-2013-060).

ATLANTIC SALMON ADULT RETURNS TO SFA 16

MIRAMICHI RIVER

Indices of Abundance

Mark and recapture experiments

Small and large adult salmon returns to the Miramichi River and its two major branches have been estimated with mark-recapture experiments since 1992. Returning salmon are captured in estuarial trapnets, tagged with individually numbered dorsal tags and released for possible recapture in another trapnet higher in the estuary or one located in the other major branch. Tags are applied to returning grilse and salmon at four trapnet locations during the May to October spawning migration. The tagging locations are two trapnets operated by Eel Ground First Nation (one on the SW Miramichi River near its confluence with the NW Miramichi River and the other on the north bank of the Main Miramichi River adjacent to Beaubear’s Island), the DFO index trapnet at Millerton on the SW Miramichi River, and the DFO index trapnet at Cassilis on the

NW Miramichi River (Fig. 2). Both DFO index trapnets function as a recapture location for tags applied in the opposite branch, and the two trapnets operated by Red Bank First Nation function as a recapture location for tags applied anywhere. Information on biological characteristics is derived from samples taken at DFO index trapnets. Descriptions of trapnets, fish processing protocols and treatment of data have been detailed in Chaput (2010).

Protection barriers and Crown reserve angling

Other indices of abundance that have been regularly used to inform the status of Miramichi salmon are counts of large and small salmon at provincial and private headwater protection barriers, as well as, a creel survey from the Regular Crown Reserve waters of the Northwest Miramichi watershed. A headwater protection barrier has been operated by the province of New Brunswick on the NW Miramichi River since 1988 and on the Dungarvon River since 1981. The barrier on the north branch of the Southwest Miramichi River near Juniper has been operated since 1981 but only as a partial fence in recent years (2010 to 2013). Atlantic salmon and brook trout are counted through a lower fence and into a large holding pool until water levels increase in the fall and protection is no longer deemed necessary. Once the barriers are removed in the fall, salmon and trout seek suitable spawning locations in the area.

A creel survey including catch and effort of salmonids is required of anglers using the Regular Crown Reserve stretches of the Northwest Miramichi watershed. Most stretches are open to four rods during a 48 hour period that begins at 2 pm on day one and ends at 2 pm on day three. Crown reserve stretches are available to anglers between June 10 and September 15.

Estimated Returns

Mark and recapture experiments

Estimates of returns to the Miramichi River overall and to its Northwest and Southwest branches between 1998 and 2013 have been derived from a Bayesian hierarchical framework (Chaput and Douglas 2012).

Median estimates of returns of large and small salmon to the Miramichi River overall in 2013 were 13,260 (5th and 95th percentile: 9,770 to 19,180) and 11,750 (5th and 95th percentile 9,052 to 17,410), respectively (Table 2). The return of large salmon in 2013 was less than in 2012 and among the lowest return estimates since 1970. Small salmon returns in 2013 were improved over 2012 but estimates for these two years represent the lowest of the time series (Fig. 3).

The returns of large salmon to the Southwest Miramichi in 2013 were estimated at 10,780 (5th and 95th percentile 7,428 to 16,630) and similar to the returns in 2012 which were the lowest of the time series (Table 2). The return estimate of 7,537 (5th and 95th percentile 5,020 to 13,370) small salmon to the Southwest Miramichi in 2013 was higher than in 2012 but these estimates were the lowest of the time series (Fig. 3).

Northwest Miramichi returns of large salmon in 2013 were estimated at 2,342 fish (5th and 95th percentile 1,624 to 3,458), about the same as in 2012, and among the lowest return estimates of the time series (Table 2). The estimated return of small salmon to the NW Miramichi River in 2013 was 4,094 (5th and 95th percentile 3,238 to 5,538), an increase of 58% over 2012 but still among the lowest return estimates of the time series (Fig. 3).

Biological characteristics

The sex of large salmon can be determined from external features throughout the full spawning migration to the Miramichi River. Combined catches from both DFO index trapnets indicated that the majority (90%) of the large salmon return to the Miramichi River in 2013 was female. The proportion of large female salmon captured at Cassilis on the NW Miramichi was 92%, the highest proportion of the time series (1998-2013). Similarly, the female component of large salmon captured at Millerton on the SW Miramichi was 88% and among the highest proportions of the time series (Fig. 4).

It is more difficult to determine the sex of small salmon using external features during the early part of the run, before the kype (hooked lower jaw) develops on the males later in August and September. Internal examination of harvested small salmon from trapnets operated by Metepenagiag First Nation helped inform the sex ratio of small salmon returning to the NW Miramichi River. In 2013, the proportion of female small salmon returning to the NW Miramichi River was considered to be 23%. The proportion of female small salmon returning to the SW Miramichi River was considered to be 7% in 2013 (Fig. 4).

The interpretation of ages from scales collected from large salmon during the 2013 spawning migration identified two-sea-winter (2SW) maiden salmon as being the dominant component (69%), and similar to previous years (Fig. 5).

In 2013, the average fork length for small and large salmon was 56.2 cm and 78.2 cm respectively, and similar to previous years (Fig. 6).

Similar to previous assessments, the fecundity relationship for Miramichi salmon detailed in Randall (1989) was used to determine the number of eggs carried by large and small salmon to each of the main branches in 2013. Eggs carried by large salmon in 2013 were among the highest of the time series (Fig. 7).

The run timing of Atlantic salmon to the Miramichi River has been previously characterized as bimodal, with the first mode occurring in the summer (prior to August 31) and the second in the fall (after August 31) (Saunders 1967). Early and late runs of salmon to the Miramichi were obvious from DFO index trapnet catches in the early and mid-1990s but appears to have changed over time to a dominant summer mode. These changes in run timing have been consistent for both large and small salmon and on both major branches of the Miramichi River (Fig. 8). The proportion of salmon captured at DFO index trapnets by August 31 has increased on the SW Miramichi River since 1994, attaining levels of 75-90% in recent years. A similar pattern was observed for salmon on the NW Miramichi River but the trend was less pronounced (Fig. 9).

The reduced late run of salmon to the Miramichi River is not believed to be related to fish abundance but rather to a shift in behavior where the fish enter the river during the summer and no longer stage in Miramichi Bay until autumn. Decreases in the late run component have generally corresponded with increases in the early run component. Similarly, single-day peak catches at DFO index trapnets, particularly on the SW Miramichi River, have switched from previously occurring in the fall to occurring in July and at levels higher than those experienced in the 1990s (Fig. 10). Since 2008, there has been the perception of high salmon abundance in the river during the summer angling season but low abundance during the fall.

DFO Index trapnets

The catch of small and large salmon at the Millerton trapnet in 2013 was lower for both size groups than in 2012. The catch of small salmon at the Millerton trapnet in 2012 was the lowest of the time series (Fig. 11). The catch of large salmon was also lower at Cassilis in 2013 relative to 2012 but the catch of small salmon was improved over levels in 2012. Catches of both large and small salmon at both facilities in 2013 were lower than the previous 5-year means (Table 3).

Protection Barriers and Crown Reserve Angling

The headwater protection barrier on the north branch of the Southwest Miramichi River near Juniper has only operated during part of the salmon run since 2010 and counts are not comparable to the rest of the time series. Protection barriers on the Dungarvon and NW

Miramichi rivers operated from late May or early June to the end of October in 2012 and 2013 and there were no washout periods (Table 4). Small and large salmon counted through these facilities predominantly represent early-run fish.

The large salmon count (n=292) through the Dungarvon barrier in 2013 was 116% higher than in 2012 and 38% higher than the previous 5-year mean (Table 4). The small salmon count (n=244) was also up from 2012 levels (44%) but down 50% from the previous 5-year mean (Table 4; Fig. 12). The large salmon count (n=252) through the protection barrier on the NW Miramichi River in 2013 was improved from 2012 levels (55%) and the previous 5-year mean (13%). The small salmon count (n=240) at the NW barrier in 2013 was the same as in 2012 but 66% lower than the previous 5-year mean (Table 4; Fig.12).

Angling in the Crown reserve stretches was better in 2013 than in 2012 for both small (up 43%) and large (up 235%) salmon (MacEachern and Sullivan 2013). The small and large salmon catch in 2013 was 35% lower and 22% higher than the previous 5-year means (Table 5). Effort (rod days) has remained relatively constant through the time series (Fig. 13).

ATLANTIC SALMON ADULT REMOVALS IN SFA 16

HOME WATERS

Harvest levels of small salmon and catch and release statistics for large salmon in the recreational fishery of the Miramichi River have not been available since 1997. Similarly, harvest levels of small and large salmon are incomplete for aboriginal FSC gillnet fisheries but considered reliable from FSC trapnet fisheries. In the absence of fisheries' harvests statistics, assumptions about removals are required so an assessment of conservation attainment can be made. In recent assessments, the harvest of large salmon in aboriginal FSC fisheries of the Miramichi River has been assumed to be 600 fish which is about 90% of allocations in fishery agreements. It is also assumed that 30% of the large salmon return is angled in the recreational fishery and that 3% of those die as a consequence of being caught and released. Harvest of small salmon in the recreational fishery is assumed to be 25% of the small salmon return estimate while 1,500 fish or about 20% of the small salmon allocations are assumed to be removed from aboriginal FSC fisheries.

The local aboriginal FSC fishery exploits a mixed stock of SW and NW Miramichi origin salmon and their relative proportion in the harvest is unknown. In previous assessments, the majority of harvested fish in aboriginal FSC fisheries was allocated to the NW Miramichi and did not consider the important movement of salmon and grilse between the major branches (Fig. 14). For the period 1998 to 2013, the following method was used to estimate removals of large and small salmon in aboriginal FSC fisheries of the NW and SW Miramichi estuaries.

The information from the trapnets on the SW Miramichi operated by Eel Ground First Nation is considered reliable. There is virtually no harvest of large salmon from these trapnets and there are no gillnet fisheries on the SW Miramichi River for which harvest assumptions need to be made. The harvest of large SW Miramichi River origin salmon was calculated based on the estimated proportion of large salmon tagged at the Cassilis trapnet (NW Miramichi) that switched to the SW Miramichi River (35% in 2013). This proportion was applied to the reported harvest of large salmon in the Northwest Miramichi and considered to represent the harvest of large SW Miramichi salmon. The remainder of the assumed large salmon harvest was considered to have been of NW Miramichi origin fish, based on the proportion of large salmon tagged at the Cassilis trapnet that remained in the NW branch (65% in 2013) (Fig. 14).

The same approach was used to divide the FSC harvests of small salmon into NW and SW Miramichi origin fish. Tagging information from Eel Ground trapnets on the SW Miramichi River in 2013 indicated that 82% of small salmon remained in the SW branch while 18% moved to the Northwest branch. These proportions were considered to represent the contributions of SW and NW Miramichi origin fish in Eel Ground's trapnet harvest of small salmon. The tagging information at Cassilis was used to derive the rate of movement for small salmon from the Northwest branch to the Southwest branch. In 2013, 85% of the reported small salmon harvests in FSC fisheries on the Northwest Miramichi were considered to be NW Miramichi origin fish, while 15% were considered to be SW Miramichi origin fish.

There were no changes to the method of estimating removals of small or large salmon in the recreational fishery.

The harvest assumptions described above equate to the approximate loss of 519 large and 4,235 small salmon in 2013. The majority (69%) of small salmon losses occurred in the recreational fishery, while 78% of large salmon losses occurred in estuarine aboriginal FSC fisheries (Fig. 15).

During the 1998 to 2013 period, the harvest of small salmon (all fisheries) has generally accounted for the majority of the annual egg loss to the Miramichi River and its two branches. The proportion of the total loss of eggs due to large salmon harvests (all fisheries) has been trending upwards over the same time period (Fig. 16). In years of low small salmon returns, the proportion of eggs lost from the harvest of large salmon increases. The percentages of the total eggs in returns of small salmon lost due to small salmon harvests for the period 1998 to 2013 averaged 36% (30-57%) for the Miramichi River overall, 29% (27-33%) for the SW Miramichi River, and 44% (32-78%) for the Northwest Miramichi River (Fig. 17). Proportionally fewer eggs in the returns of large salmon were lost due to fisheries harvests, with average estimates between 1998 and 2013 at 4% (3-6%) for the Miramichi River, 2% (1-3%) for the SW Miramichi River, and 13% (6-28%) for the NW Miramichi River (Fig. 17).

ESCAPEMENT RELATIVE TO CONSERVATION REQUIREMENT

The conservation requirement for rivers in SFA 16 is the egg deposition rate of 2.4 eggs per m^2 (CAFSAC 1991; Chaput et al. 2001). Egg requirements for 77% of the rivers in SFA 16 are less than 1.5 million eggs or roughly less than 250 large salmon (see Table 1 in Chaput et al. 2010). Based on average biological characteristics, the conservation requirements are about 16,000 and 7,300 large salmon for the Southwest and Northwest Miramichi rivers respectively.

Considering the biological characteristics of salmon observed in 2013, eggs carried by returning large and small salmon were sufficient to attain 72% of the conservation requirement for the Miramichi as a whole, 83% for the SW Miramichi River, and 48% for the NW Miramichi River (Fig. 18). Considering the reported and assumed levels of exploitation on the resource, the salmon escapement to the river was sufficient to attain 68% of the conservation level for the Miramichi as a whole, 80% for the SW Miramichi River, and 39% for the NW Miramichi River (Fig. 18).

The escapement of salmon to the Miramichi River as a whole was sufficient to meet the egg deposition requirements repeatedly between 1992 and 1996 but only three times (2001, 2004, and 2011) during the period 1997 to 2013. The conservation requirement was attained on the Southwest Miramichi River between 1992 and 1996, and intermittently (7 times) between 1997 and 2013. The Northwest Miramichi achieved conservation levels between 1992 and 1997 but only twice (2001 and 2011) during the 1998 to 2013 period (Fig. 18).

FRESH WATER PRODUCTION

JUVENILE ATLANTIC SALMON

Miramichi watershed electrofishing surveys

Backpack electrofishing surveys of the freshwater sections of the Miramichi watershed have been completed annually since 1970 (Moore and Chaput 2007). A combination of open (n = 52) and barriered (also referred to as closed) sites (n=4) were sampled in 2012 between August 22 and September 28. Because of high water in 2013, only open sites (n=30) were sampled intermittently between August 26 and October 3 in the Northwest and Renous rivers.

As in previous assessments, abundance of fry and parr at closed sites was estimated by the depletion method described by Zippin (1956). The relationship between abundance estimates for fry and parr derived from the depletion method and those from the initial sweep of the catch-per-unit-of-effort method at closed sites provided the linear functions with which fry and parr abundance at open sites was estimated (Chaput et al. 2005). Calibration data collected between 2006 and 2012 (2008 omitted and none in 2013) were used to develop the linear function that predicted densities from CPUE information in 2012 and 2013 (Fig. 19). The large confidence intervals around the intercept and the prediction of negative abundances when catches were 0 or low necessitated forcing the line through the origin.

Similar to the previous assessment, densities of fry, small, and large parr were summarized according to the four major tributaries of the Miramichi River that are under tidal influence (the SW Miramichi, Renous, NW Miramichi and Little Southwest Miramichi rivers) (Chaput et al. 2010; Douglas et al. 2012). Average juvenile densities were included in the trend analysis only when four or more sites per large river system were surveyed in a given year. Juvenile densities were compared with average densities before and after significant management changes were implemented to the commercial and recreational salmon fisheries in 1984. Average densities before the closure of the fishery were calculated for the years 1970 to 1984 for fry, for 1970 to 1985 for small parr, and for 1970 to 1986 for large parr.

Salmon fry were captured at all but one of the 56 sites surveyed in 2012 and all of the 30 sites sampled in 2013 which indicates that adult salmon continue to spawn throughout the Miramichi watershed. Average fry levels in 2012 ranged between 45 (Little Southwest) and 132 (Northwest) per 100 m^2 and were above average for each river except the Little Southwest. Above average levels of fry in 2012 was likely a response to achieving conservation requirements in 2011. In 2013, average fry densities were 33 and 57 per 100 m^2 in the Renous and Northwest Miramichi rivers, respectively. With the exception of the Renous River in 2013, average fry densities were near the long term averages for the rivers since 1985 (Figs. 20 and 21).

Small parr abundance ranged between 8 (Little Southwest) and 23 (Northwest) per 100 m^2 in 2012 and was 21 and 41 per 100 m^2 in the Renous and Northwest Miramichi rivers, respectively, in 2013. With the exception of the Little Southwest, small parr abundance in 2012 and 2013 was near or above the long term averages for the rivers since 1986 (Figs. 20 and 21). Average large parr densities in 2012 were similar across rivers ranging from 2 (Renous) to 8 (Northwest) per 100 m^2 and similar again in 2013 (4/100m^2 on the Renous and 5/100m^2 on the Northwest). With the exception of the Northwest Miramichi, the average large parr densities in 2012 and 2013 were at or above the long term averages for the rivers since 1987 (Figs. 20 and 21).

The total biomass of all juvenile salmon has remained unchanged and equivalent to the long term average between 1986 and 2013 for each of the four major rivers. Highest estimates of juvenile salmon biomass in 2012 and 2013 were observed on the NW Miramichi River (510 g/100 m^2 in 2012 and 425 g/100 m^2 in 2013) (Fig. 22).

Southeast New Brunswick electrofishing surveys

In 2012, a total of 18 sites were surveyed between September 11 and 18 on the Richibucto, Coal Branch, Buctouche, and Kouchibouguac rivers. In 2013, 12 sites were surveyed between October 11 and 24 on the Richibucto, Buctouche, and Kouchibouguac rivers. As in the past for all southeast NB electrofishing surveys, all sites were open (not barriered) and sampled in an upstream direction. The method of deriving abundance estimates was the same as described above for the Miramichi watershed.

The average abundance of salmon fry in 2012 ranged between 26 and 58 per 100 m^2 and was above the long term average for each of the rivers since the management changes introduced in 1998 (Fig. 23). With the exception of the Kouchibouguac River, fry abundance dropped in 2013 to below the long term averages for the surveyed rivers. With the exception of the Kouchibouguac River in 2012, parr abundance was similar across rivers and across years (range 8 to15 parr per 100 m^2) and below the averages for the rivers since 1998 (Fig. 23).

Salmon fry densities of 40 per 100 m^2 were observed in the Buctouche River in 2000 following an adult salmon assessment the previous year that determined that conservation had been met (Atkinson and Peters 2001). Similar levels of fry were observed in the Buctouche, Cocagne, and Kouchibouguac rivers in 2005, suggesting that spawning requirements may have been achieved for those rivers in 2004. The density of salmon fry in the Kouchibouguac River was above 40 per 100 m^2 in 2012 and 2013; a possible indication that this river met its conservation requirement in 2011 and 2012.

UNCERTAINTIES AND KNOWLEDGE GAPS

There is no mechanism to reliably evaluate removals of small or large salmon from the aboriginal or recreational fishery so assumptions about harvest levels and catch and release mortality are required to assess spawning escapements. Depending on the accuracy of the assumed levels of removals, the level of conservation attainment may be under or over estimated. The lack of catch statistics precludes any evaluation of current or potentially new management measures.

The movement of small and large salmon between the Northwest and Southwest Miramichi estuaries decreases the confidence in the estimate of run sizes to the individual branches.

The hierarchical Bayesian model used to derive estimates of run size makes several assumptions that have not been validated. The potential differences in tagging and handling mortality over the season and at varying water temperatures should be explored. Similarly the catch efficiency of trapnets and exchange rates of large and small salmon between the branches may vary over the course of the season.

While electrofishing surveys provide an indication of the previous year’s spawning escapement, the level at which conservation was attained is difficult to validate with these data alone. Trends in juvenile abundance in individual rivers are considered to be relevant when an adequate number of sites and different habitats have been sampled. High water hampered electrofishing surveys in 2013 and may have affected catches due to sampling difficulty.

Atlantic salmon are known to inhabit 39 rivers in SFA 16. The majority of these are small rivers which have no monitoring programs in place to sample adult or juvenile salmon. The lack of information makes it difficult to explore management options for these smaller rivers.

CONCLUSIONS

Median return estimates of large and small Atlantic salmon to the Miramichi River in 2013 were 13,260 (5th and 95th percentile: 9,770-19,180) and 11,750 (5th and 95th percentile: 9,052-17,410), respectively. The large and small salmon returns in 2013 were among the lowest return estimates since 1970.

Returns of large and small salmon to the Southwest Miramichi River in 2013 were 10,780 (5th and 95th percentile: 7,428-16,630) and 7,537 (5th and 95th percentile: 5,020-13,370), respectively and enough to attain 83% of the egg conservation requirement before fisheries. After accounting for removals, 80% of the conservation level for the SW Miramichi River was attained.

Returns of large and small salmon to the Northwest Miramichi River in 2013 were 2,342 (5th and 95th percentile: 1,624-3,458) and 4,094 (5th and 95th percentile: 3,238-5,538), respectively and enough to attain 48% of the egg conservation requirement before fisheries. After accounting for removals, 39% of the conservation level for the NW Miramichi River was attained.

Catches and counts of large salmon at provincial barriers and crown reserve angling stretches in 2013 were improved over 2012 and the previous 5-year means. Catches and counts of small salmon at provincial facilities were better than 2012 but lower than the previous 5-year means.

The bimodal run timing of salmon to the Miramichi River (early and late runs) appears to have changed recently to a single dominant mode in the summer. The proportion of salmon captures at DFO index trapnets by August 31 has increased since 1994, attaining levels of 75-90% in recent years. The strength of the summer salmon run can inflate the perception of total abundance by user groups.

The low return of one-sea-winter (1SW) salmon in 2013 suggests the potential for a low return of 2SW salmon in 2014. The low grilse returns to SFA 16 in 2013 is consistent with the low returns of 1SW fish in 2013 to other Salmon Fishing Areas in the Gulf region, as well as, across most of the species range (ICES 2014).

Salmon continue to spawn throughout the Miramichi watershed. Juvenile abundance has remained relatively consistent at higher levels since the 1984 closure of the commercial fishery and the mandatory release of large salmon in the recreational fishery.

Salmon continue to spawn in rivers of southeastern New Brunswick but juvenile densities remain below levels that were observed in years when conservation was determined to have been met. It is inappropriate to compare juvenile salmon abundance directly among rivers when differences in habitat and carrying capacity have not been evaluated.

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TABLES

*Table 1. Allocations of small and large Atlantic salmon in SFA 16 to First Nations and aboriginal organizations according to agreements signed in 2013. Nrg refers to Native recreational gear.na = not applicable. * refers to kelts.*

				Allocation	
Aboriginal group	Location	Gear	Qty	Small	Large
Bouctouche FN	Crown open waters of Miramichi	angling	na	110	0
Eel Ground FN	NW Miramichi	trapnet	1	2,660	185
	NW Miramichi	gillnet	11		
	Crown open waters of Miramichi and Bartibog	Nrg	na		
	NW Miramichi	fence	1	240	5
	SW Miramichi	trapnet	2	2,100	10
	SW Miramichi	gillnet	1		
	Crown open waters of Miramichi and Bartibog	Nrg	na		
Elsipogtog FN	Crown open waters of Miramichi	angling	na	200	0
Esgenoôpetitj FN	Tabusintac River	angling	na	*100	*100
	Tabusintac River	gillnet	na		
	Tabusintac River	trapnet	2	112	304
	Tabusintac River	gillnet	13		
	Miramichi Bay	gillnet	25	2,000	200
	Crown open waters of Miramichi and Bartibog	Nrg	na		
Metepenagiag FN	NW Miramichi system	trapnet	3	4,000	500
	NW Miramichi system	gillnet	12		
	Crown open waters of Miramichi	Nrg	na		
New Brunswick Aboriginal Peoples Council (NBAPC)	Crown open waters of Miramichi	angling	na	280	0
	Crown open waters of Tabusintac	angling	na	30	0
SFA 16 total				11,832	1,304

Table 2. Small and large salmon return estimates to the Miramichi River (upper), the Southwest Miramichi River (middle), and Northwest Miramichi River (lower) between 1998 and 2013.

	Large salmon					Small salmon				
Year	2.5th	5th	Median	95th	97.5th	2.5th	5th	Median	95th	97.5th
Miramichi River										
1998	13,350	13,830	16,870	21,620	22,890	19,290	19,840	23,170	27,560	28,570
1999	12,790	13,370	16,190	19,400	20,210	18,870	19,310	21,940	25,360	26,090
2000	14,020	14,590	17,600	20,950	21,780	28,060	28,580	32,050	36,510	37,300
2001	19,410	19,870	22,630	25,650	26,260	23,290	23,900	27,210	31,240	32,220
2002	9,752	10,150	12,240	15,210	15,890	35,540	36,470	41,260	46,960	48,160
2003	16,510	17,110	20,260	24,280	25,270	23,320	24,090	28,390	33,790	34,960
2004	16,340	16,750	20,300	26,900	28,510	38,010	39,140	45,460	52,920	54,570
2005	14,950	15,420	18,870	25,160	26,420	25,000	25,910	31,700	39,650	41,480
2006	16,530	17,150	20,790	27,270	28,910	26,960	28,090	34,640	44,060	46,200
2007	14,080	14,720	17,790	21,550	22,620	20,250	20,930	26,940	36,320	38,690
2008	9,121	9,804	13,490	16,660	17,370	22,610	23,440	29,180	38,920	40,950
2009	15,000	15,500	18,630	22,870	24,210	9,510	10,030	13,040	17,550	18,860
2010	13,450	13,780	16,100	19,220	19,960	42,300	43,430	50,110	57,930	59,550
2011	21,940	22,980	31,060	44,660	50,230	34,730	35,950	43,880	56,850	59,670
2012	10,030	10,530	13,550	17,890	19,040	6,077	6,418	8,322	11,040	11,650
2013	9,306	9,770	13,260	19,180	21,090	8,682	9,052	11,750	17,410	18,880
Southwest Miramichi River										
1998	10,340	10,840	13,640	18,170	19,680	11,800	12,270	15,270	19,410	20,270
1999	9,123	9,667	12,540	15,850	16,610	10,440	10,840	13,290	16,540	17,260
2000	9,781	10,290	13,270	16,650	17,470	16,480	17,020	20,430	24,900	25,880
2001	11,810	12,290	15,070	18,070	18,690	15,290	15,800	18,950	22,960	23,880
2002	8,187	8,539	10,590	13,650	14,330	21,100	21,810	26,420	31,970	33,000
2003	13,820	14,420	17,600	21,660	22,550	17,520	18,150	22,350	27,610	28,830
2004	13,000	13,490	17,060	23,810	25,390	26,200	27,360	33,620	41,260	42,860
2005	11,240	11,670	14,810	21,100	22,250	15,930	16,750	21,950	29,310	31,020
2006	13,440	13,960	17,300	23,600	25,090	21,490	22,530	28,940	38,390	40,450
2007	10,750	11,380	14,420	18,210	19,260	14,010	14,730	20,590	29,870	32,440
2008	7,607	8,301	12,010	15,040	15,690	15,920	16,680	22,280	31,680	33,580
2009	12,850	13,410	16,480	20,660	22,090	6,929	7,388	10,320	14,850	16,150
2010	9,413	9,733	11,930	15,040	15,700	24,250	25,260	31,080	38,480	40,000
2011	16,590	17,720	25,460	39,190	44,710	21,870	22,810	30,320	43,190	45,960
2012	7,474	7,870	10,810	15,050	16,110	3,598	3,857	5,586	8,263	8,916
2013	6,978	7,428	10,780	16,630	18,850	4,690	5,020	7,537	13,370	15,140
Northwest Miramichi River										
1998	1,889	2,042	3,073	4,947	5,536	6,043	6,320	7,762	9,904	10,460
1999	2,581	2,733	3,589	4,821	5,081	7,289	7,474	8,599	9,991	10,250
2000	2,934	3,112	4,240	5,812	6,141	9,976	10,210	11,550	13,130	13,490
2001	5,456	5,765	7,486	9,685	10,170	6,709	6,926	8,186	9,715	10,070
2002	1,074	1,144	1,596	2,230	2,362	11,930	12,380	14,770	17,620	18,380
2003	1,791	1,908	2,634	3,623	3,843	4,663	4,851	5,949	7,433	7,780
2004	2,271	2,404	3,220	4,296	4,566	9,844	10,120	11,740	13,730	14,180
2005	2,422	2,627	3,863	5,766	6,312	6,914	7,274	9,458	13,290	14,330
2006	1,995	2,134	3,257	5,539	6,142	4,106	4,340	5,657	7,226	7,581
2007	2,169	2,334	3,283	4,643	4,970	4,856	5,049	6,269	7,820	8,145
2008	869	932	1,419	2,300	2,544	5,196	5,428	6,816	8,963	9,598
2009	1,368	1,473	2,079	3,098	3,361	1,949	2,053	2,654	3,544	3,778
2010	2,807	2,984	4,082	5,551	5,864	15,180	15,730	18,840	22,500	23,230
2011	3,531	3,745	5,293	7,781	8,366	10,140	10,500	13,200	17,020	17,800
2012	1,691	1,816	2,635	4,034	4,420	1,910	2,009	2,623	3,706	4,043
2013	1,528	1,624	2,342	3,458	3,714	3,110	3,238	4,094	5,538	5,922

Table 3. The time series of catches of large and small salmon at DFO index trapnets at Millerton on the Southwest Miramichi River and at Cassilis on the Northwest Miramichi River.

	Millerton		Cassilis	
Year	Large	Small	Large	Small
1994	881	2,386	-	-
1995	1,541	2,366	-	-
1996	710	2061	-	-
1997	753	860	-	-
1998	363	1,158	217	758
1999	436	924	280	835
2000	395	1,442	277	1,090
2001	1,352	2,153	983	893
2002	510	2,718	188	1,664
2003	1,080	2,182	339	617
2004	1,040	2,910	358	1,232
2005	750	2,447	417	932
2006	1,047	2,636	210	659
2007	613	1,353	365	893
2008	298	1,485	124	704
2009	824	949	204	270
2010	798	2,591	524	2,474
2011	732	2,000	464	1,170
2012	549	491	217	252
2013	373	448	189	379
2013 relative to 2012	-32%	-9%	-13%	50%
Average for time series up to 2012	772	1848	344	963
2013 relative to average	-52%	-76%	-45%	-61%
Average (2008-2012)	640	1503	307	974
2013 relative to average	-42%	-70%	-38%	-61%
Average (2003-2012)	773	1904	322	920
2013 relative to average	-52%	-76%	-41%	-59%

*Table 4. Counts of large and small Atlantic salmon at the headwater protection barrier on the Northwest Miramichi River, the Dungarvon River, and the North Branch of the Southwest Miramichi River near Juniper for years 1984 to 2013. Numbers preceded by an * represent information that was collected when the barrier facility was only partially operating.*

	Large salmon			Small salmon		
Year	Dungarvon	Northwest	Juniper	Dungarvon	Northwest	Juniper
1984	93	-	297	315	-	230
1985	162	-	604	536	-	492
1986	174	-	1,138	501	-	2,072
1987	202	-	1,266	744	-	1,175
1988	277	234	929	851	1,614	1,092
1989	315	287	731	579	966	969
1990	318	331	994	562	1,318	1,646
1991	204	224	476	296	765	495
1992	232	219	1,047	825	1,165	1,383
1993	223	216	1,145	659	1,034	1,349
1994	155	228	905	358	673	1,195
1995	95	252	1,019	329	548	811
1996	184	218	819	590	602	1,388
1997	115	152	519	391	501	566
1998	163	289	698	592	1,038	981
1999	185	387	698	378	708	566
2000	130	217	725	372	456	1,202
2001	111	202	904	295	344	729
2002	107	121	546	287	595	1,371
2003	158	186	920	389	478	912
2004	185	167	764	559	723	1,368
2005	300	262	673	441	735	853
2006	217	214	829	468	469	860
2007	88	166	783	195	460	945
2008	131	164	692	673	1,094	1,083
2009	234	206	770	207	315	245
2010	228	284	*563	660	852	*307
2011	327	298	*381	712	996	*268
2012 [1]	135	163	*361	169	238	*154
2013 [2]	292	252	*219	244	240	*136
2013 relative to:						
2012	116%	55%	-39%	44%	1%	-12%
Average (1984-2012)	188	227	765	480	747	921
Relative to average	55%	11%	-71%	-49%	-68%	-85%
Average (2008-2012)	211	223	553	484	699	411
Relative to average	38%	13%	-60%	-50%	-66%	-67%

[1]Operating dates for Dungarvon (May 29 to Oct. 18); Northwest (May 29 to Oct. 19); Juniper (May 29 to July 17, not operating June 26 to July 4)
[2]Operating dates for Dungarvon (May 30 to Oct. 16); Northwest (June 4 to Oct 18); Juniper (June 26 to July 14)

Table 5. Effort and angling catches of large and small Atlantic salmon from the Regular Crown Reserve waters of the Northwest Miramichi system, 1973 – 2013 (MacEachern and Sullivan 2013). CPUE refers to catch per unit of effort (fish per rod day).

	Effort	Small		Large		Combined	
Year	(rod days)	Catch	CPUE	Catch	CPUE	Catch	CPUE
1973	2,648	1,210	0.46	138	0.05	1,348	0.51
1974	2,940	1,259	0.43	121	0.04	1,380	0.47
1975	2,694	1,391	0.52	125	0.05	1,516	0.56
1976	2,791	1,280	0.46	157	0.06	1,437	0.51
1977	2,119	1,120	0.53	266	0.13	1,386	0.65
1978	2,557	594	0.23	170	0.07	764	0.30
1979	2,448	1,150	0.47	79	0.03	1,229	0.50
1980	2,835	1,306	0.46	159	0.06	1,465	0.52
1981	2,886	1,953	0.68	89	0.03	2,042	0.71
1982	2,203	1,816	0.82	134	0.06	1,950	0.89
1983	2,269	823	0.36	167	0.07	990	0.44
1984	2,179	1,240	0.57	229	0.11	1,469	0.67
1985	2,269	1,563	0.69	206	0.09	1,769	0.78
1986	2,456	1,676	0.68	156	0.06	1,832	0.75
1987	1,839	1,072	0.58	88	0.05	1,160	0.63
1988	2,432	1,860	0.76	102	0.04	1,962	0.81
1989	2,535	1,595	0.63	127	0.05	1,722	0.68
1990	2,502	1,587	0.63	144	0.06	1,731	0.69
1991	2,395	612	0.26	77	0.03	689	0.29
1992	2,364	1,423	0.60	94	0.04	1,517	0.64
1993	2,432	1,426	0.59	135	0.06	1,561	0.64
1994	2,342	1,234	0.53	130	0.06	1,364	0.58
1995	1,773	523	0.29	88	0.05	611	0.34
1996	2,607	1,301	0.50	131	0.05	1,432	0.55
1997	2,494	868	0.35	115	0.05	983	0.39
1998	2,488	1,044	0.42	125	0.05	1,169	0.47
1999	2,177	514	0.24	68	0.03	582	0.27
2000	2,619	949	0.36	93	0.04	1,042	0.40
2001	2,298	555	0.24	119	0.05	674	0.29
2002	2,566	836	0.33	66	0.03	902	0.35
2003	2,601	650	0.25	174	0.07	824	0.32
2004	2,565	569	0.22	74	0.03	643	0.25
2005	2,637	598	0.23	112	0.04	710	0.27
2006	2,579	767	0.30	99	0.04	866	0.34
2007	2,574	586	0.23	125	0.05	711	0.28
2008	2,558	1,685	0.66	135	0.05	1,820	0.71
2009	2,755	445	0.16	235	0.09	680	0.25
2010	2,208	1,077	0.49	158	0.07	1,235	0.56
2011	2,336	1,520	0.65	274	0.12	1,794	0.77
2012	1,919	474	0.25	63	0.03	537	0.28
2013	2,289	679	0.30	211	0.09	890	0.39
2013 relative to:							
2012	19%	43%	20%	235%	181%	66%	39%
Average (1973-2012)	2,447	1,104	0.45	134	0.06	1,237	0.51
Relative to average	-6%	-38%	-34%	58%	67%	-28%	-23%
Average (1984-2012)	2,397	1,043	0.44	129	0.05	1,172	0.49
Relative to average	-4%	-35%	-32%	64%	71%	-24%	-21%
Average (2008-2012)	2,355	1,040	0.44	173	0.07	1,213	0.51
Relative to average	-3%	-35%	-33%	22%	28%	-27%	-24%

FIGURES

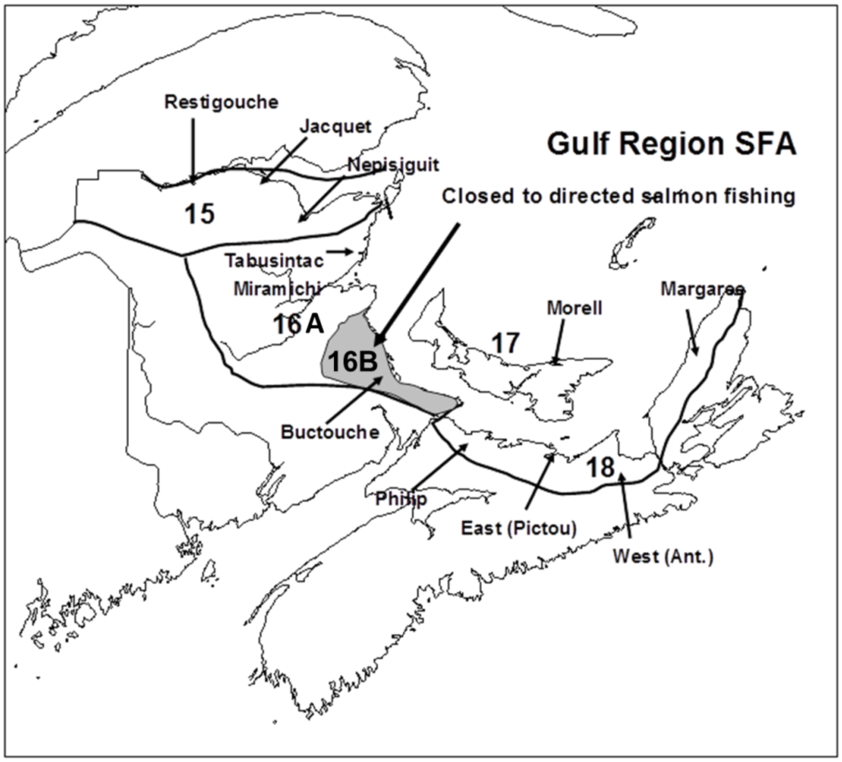


Figure 1. DFO Gulf region's Salmon Fishing Areas 15 to 18 and the locations of rivers referred to in the text.

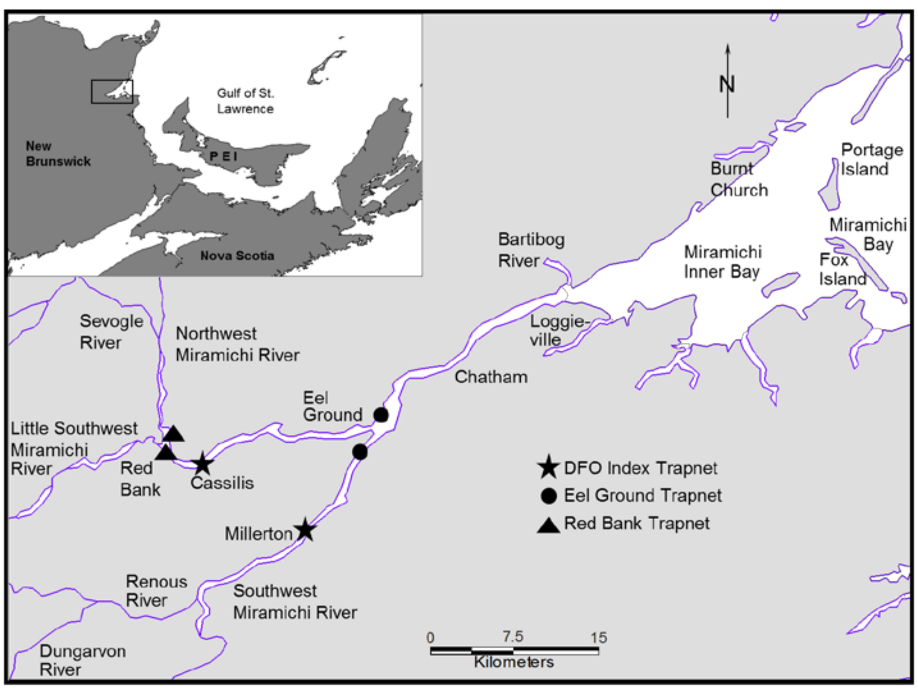


Figure 2. Locations of trapnets in the Miramichi estuary where salmon are tagged and recaptured.

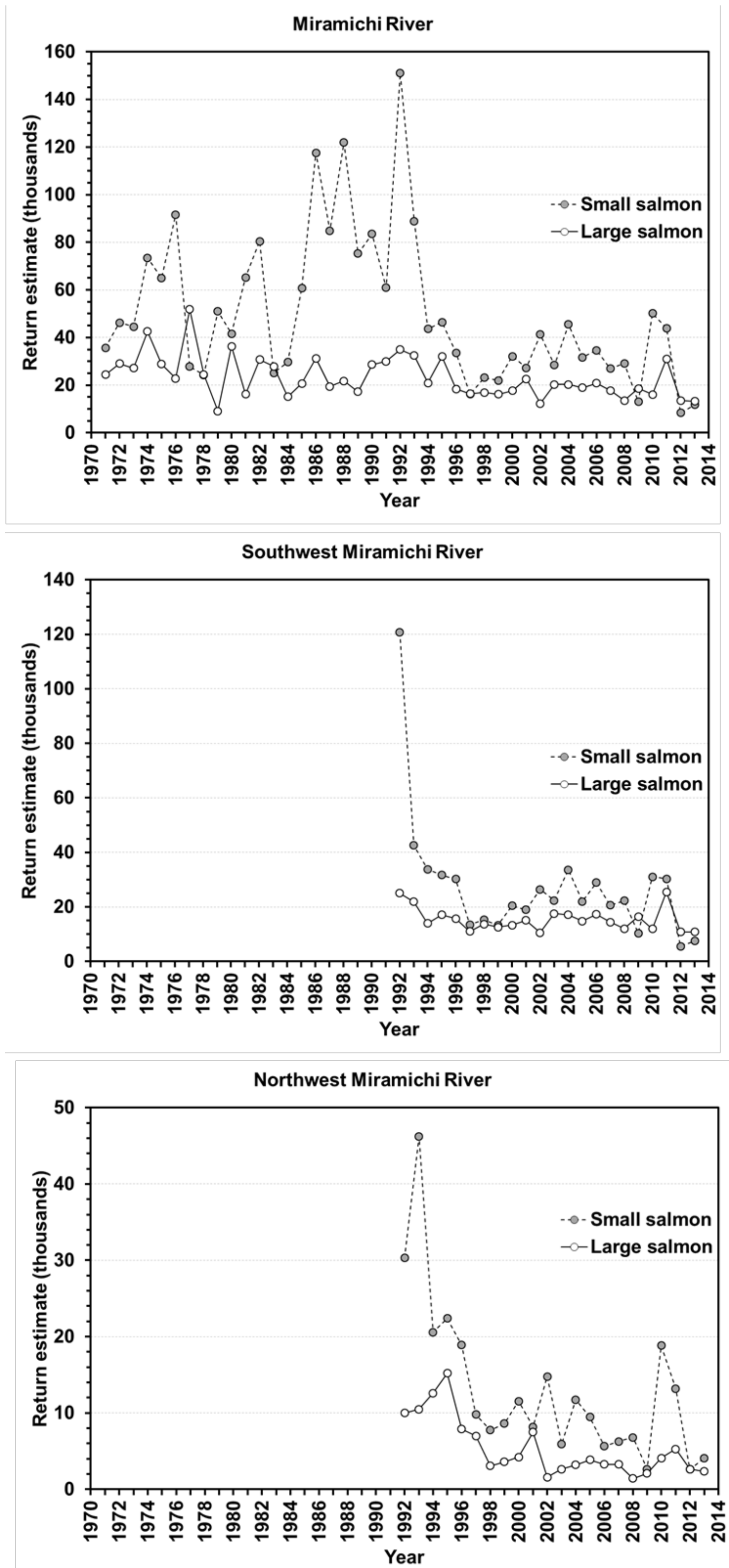


Figure 3. Median estimates of large and small salmon returns for the Miramichi River 1970-2013 (upper), the Southwest Miramichi River 1992-2013 (middle), and the Northwest Miramichi River 1992-2013 (lower).

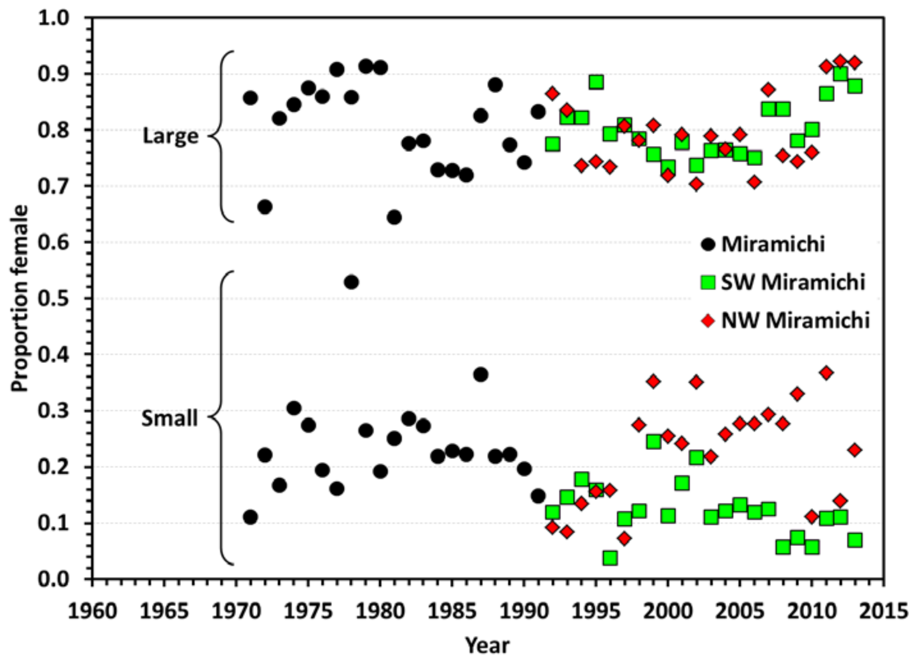


Figure 4. Proportion of female large and small salmon from the Miramichi River (1970-1991) and the Southwest and Northwest Miramichi rivers (1992-2013).

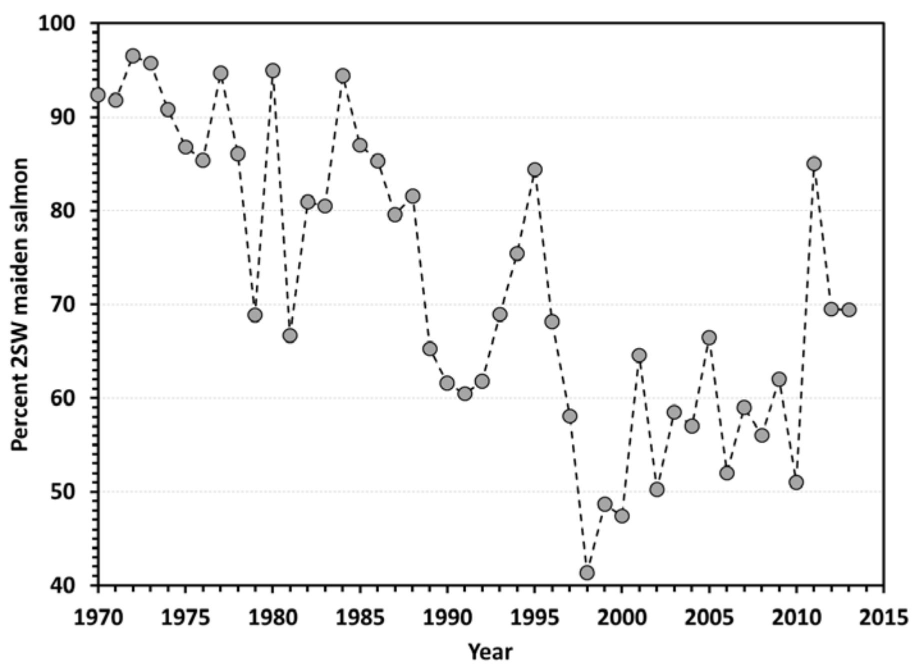


Figure 5. Percent 2SW maiden salmon from the large salmon category (≥ 63cm fork length) sampled at DFO index trapnets in the Miramichi estuary between 1970 and 2013.

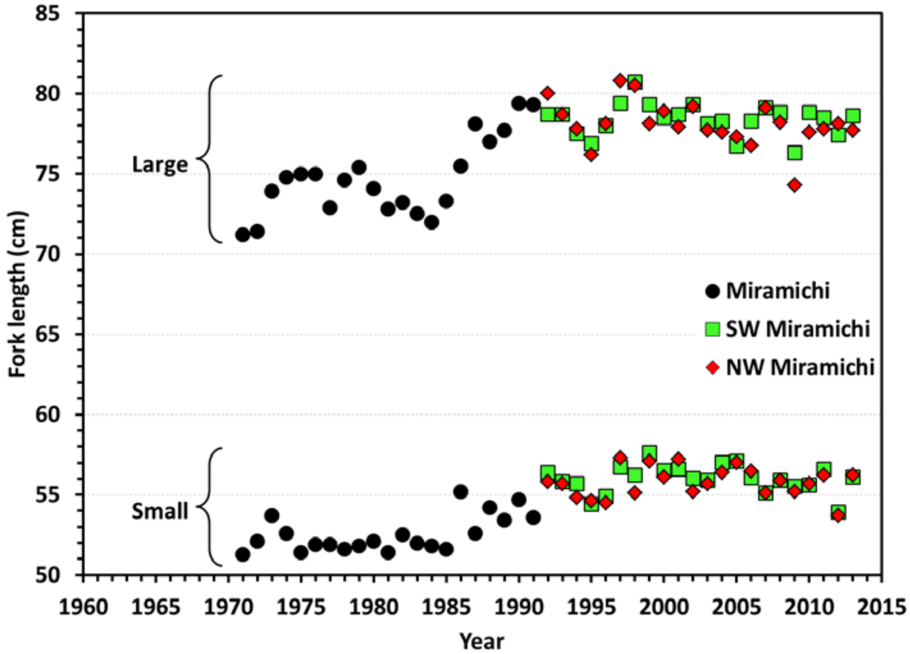


Figure 6. Mean fork length (cm) of small salmon and large salmon from the Miramichi River and the two main branches, 1970-2013.

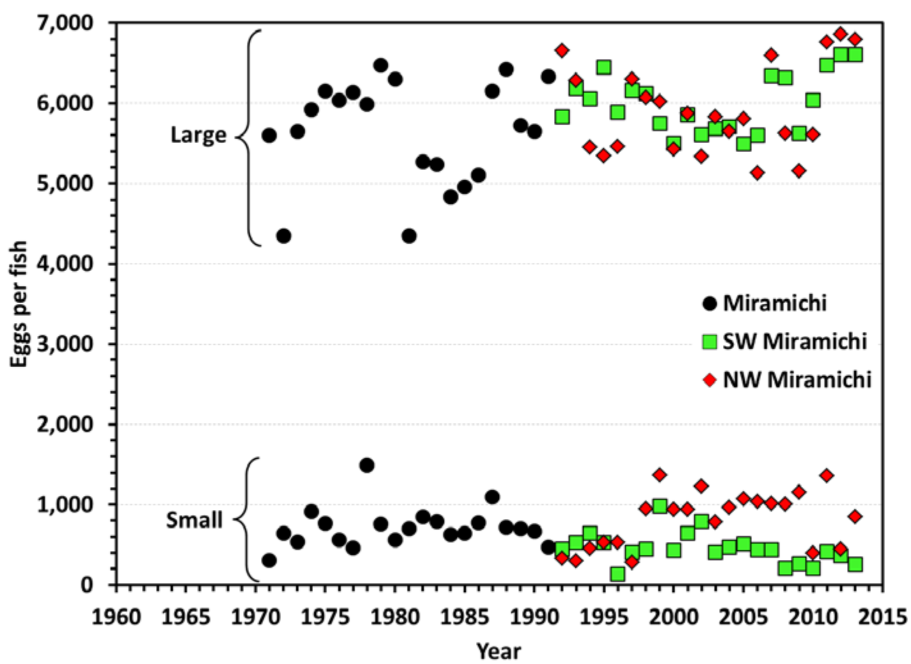


Figure 7. Number of eggs per large and small salmon from the Miramichi (1970-1991) and the Northwest and Southwest Miramichi rivers (1992-2013). Eggs were calculated from the annual average biological characteristics of small and large salmon in the Miramichi (Randall 1989).

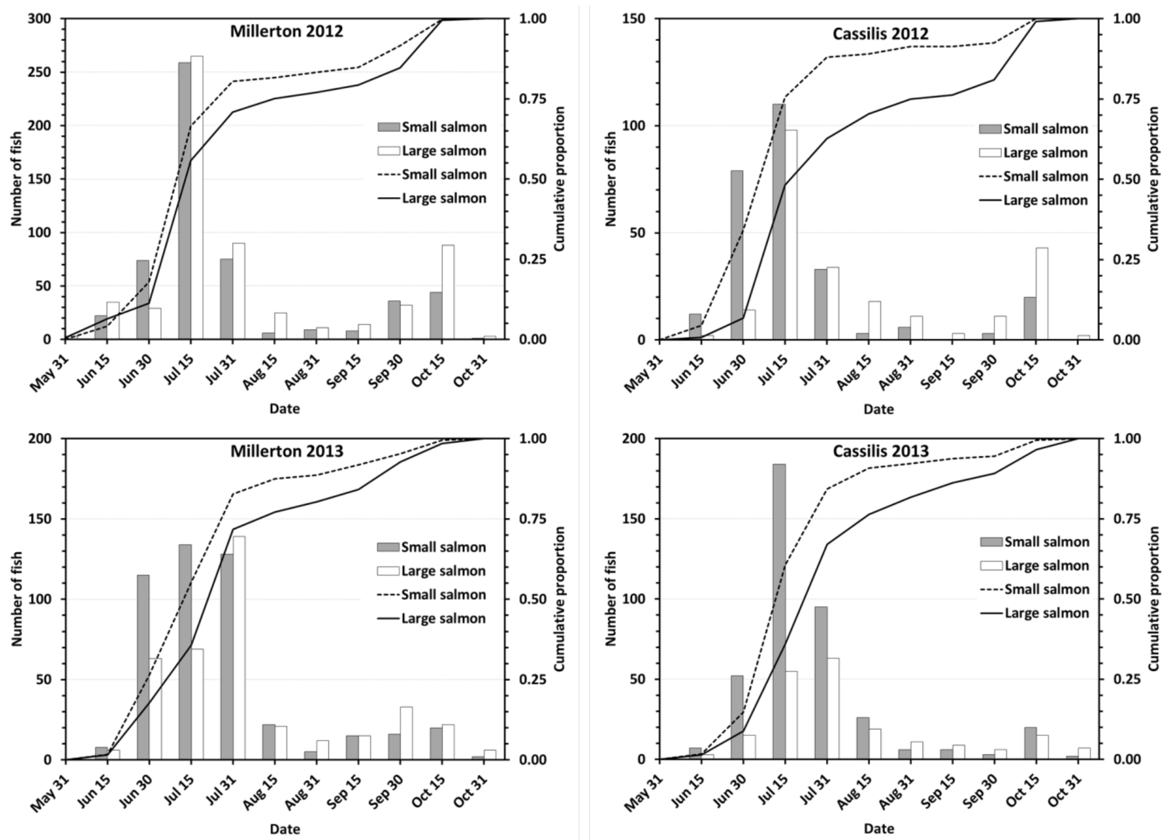


Figure 8. Timing and cumulative proportions of small and large salmon catches at DFO index trapnets at Millerton (left panels) on the Southwest Miramichi River and at Cassilis (right panels) on the Northwest Miramichi River in 2012 (upper panels) and 2013 (lower panels).

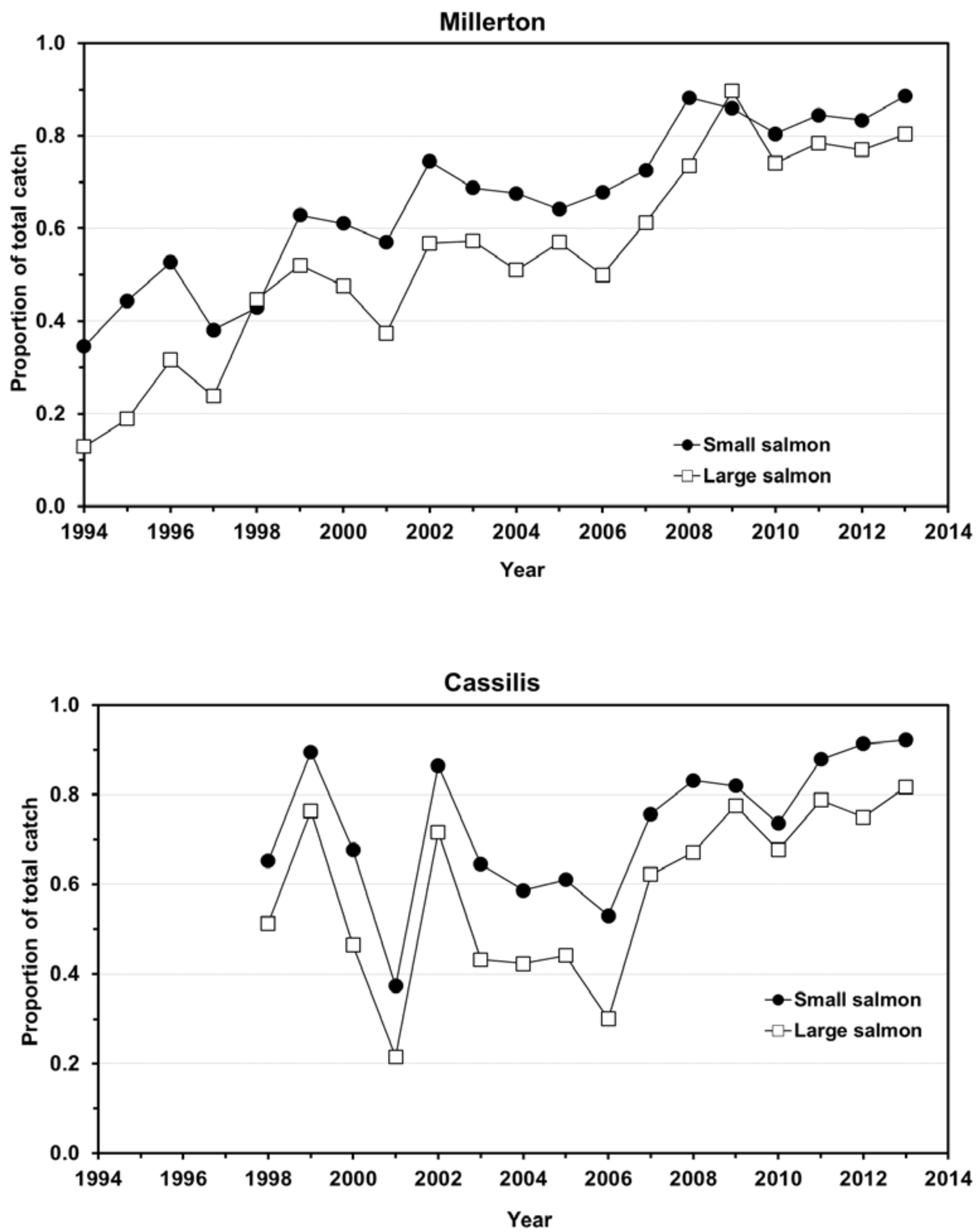
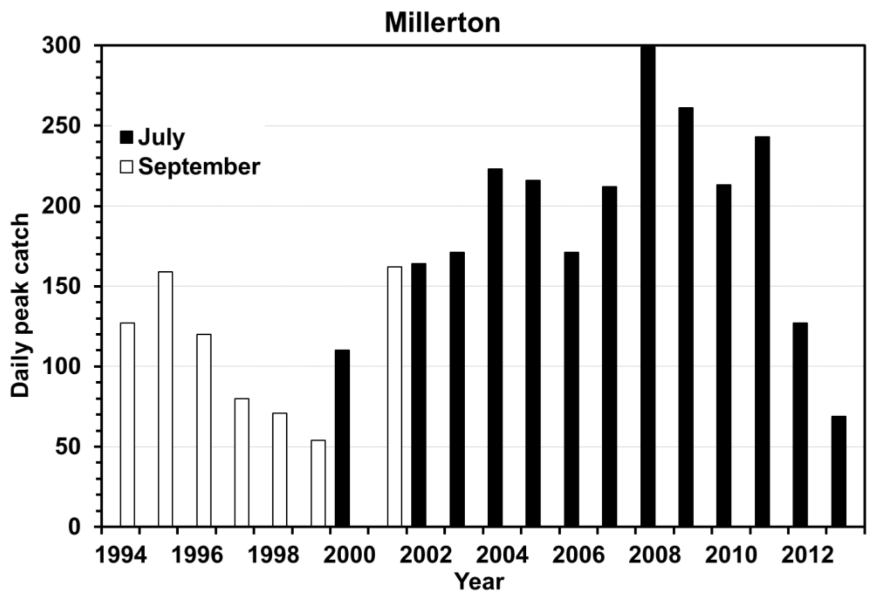


Figure 9. Proportion of large and small salmon catches by August 31 at DFO Index trapnets at Millerton on the Southwest Miramichi River (upper panel) and at Cassilis on the Northwest Miramichi River (lower panel) for 1998 to 2013.



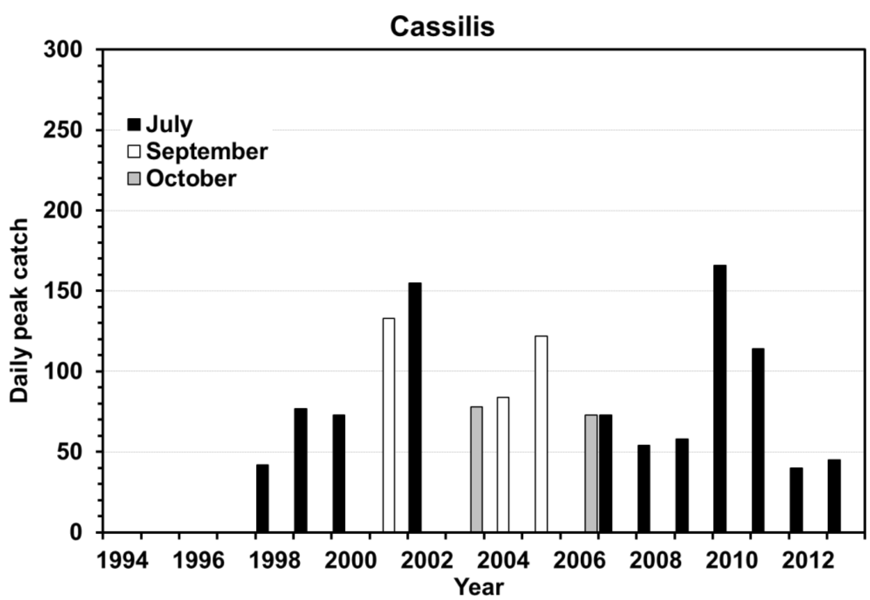
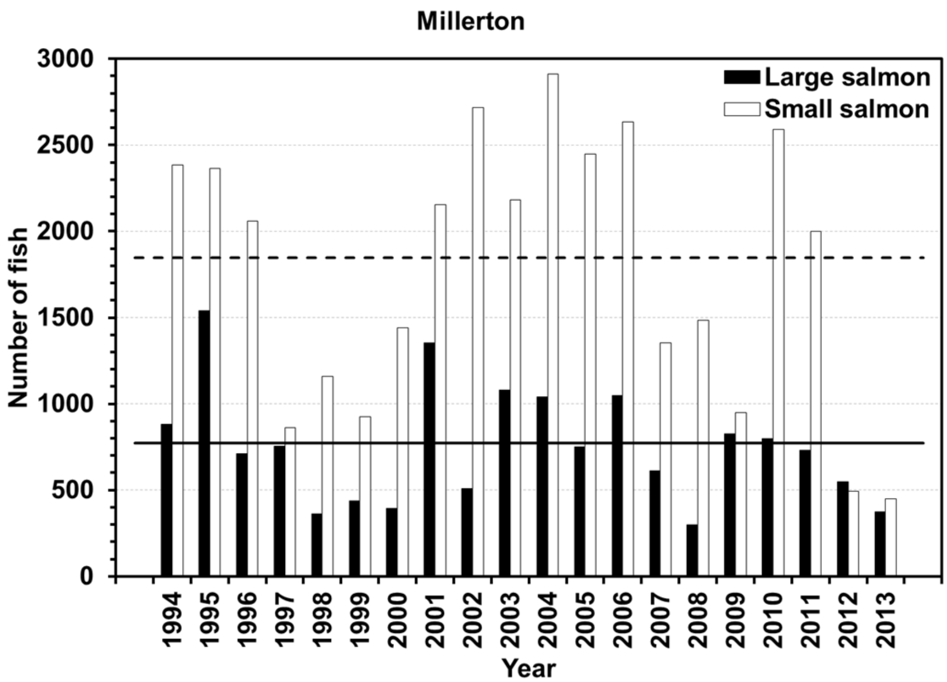


Figure 10. Month in which the single-day peak catch of small and large salmon combined was recorded at DFO Index trapnets at Millerton on the Southwest Miramichi River (upper panel) and at Cassilis on the Northwest Miramichi River (lower panel) for the time series of operation, 1994 to 2013.



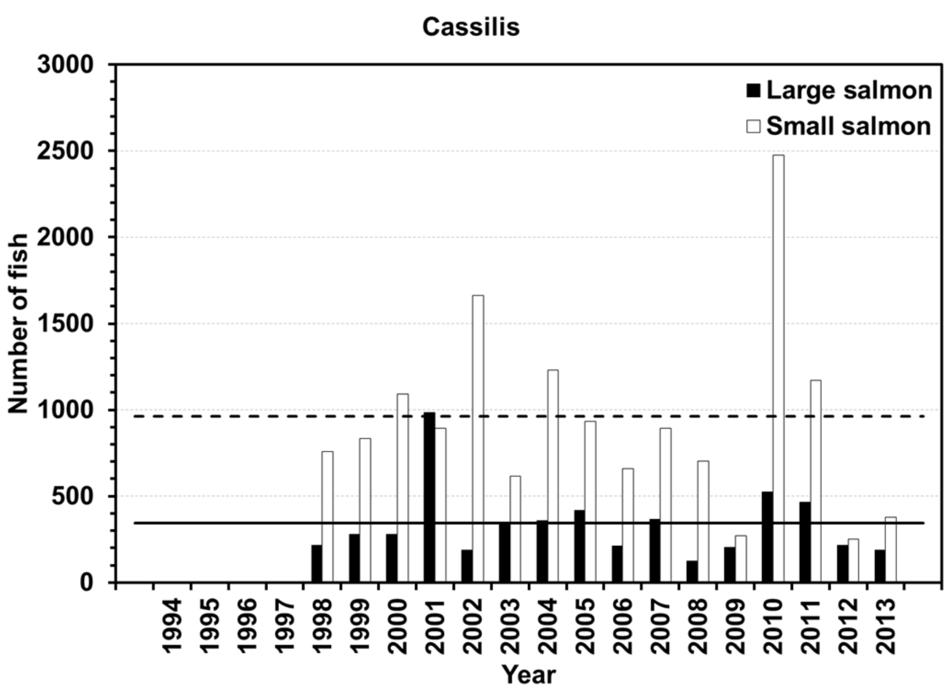


Figure 11. Catches of large and small salmon at DFO's index trapnet at Millerton on the Southwest Miramichi River (upper) and at Cassilis on the Northwest Miramichi River (lower). Solid horizontal lines represent the average number of large salmon for the index facility's time series (1994-2012 for Millerton and 1998-2012 for Cassilis). The dashed horizontal line represents the average catch for small salmon for the index facility's time series.

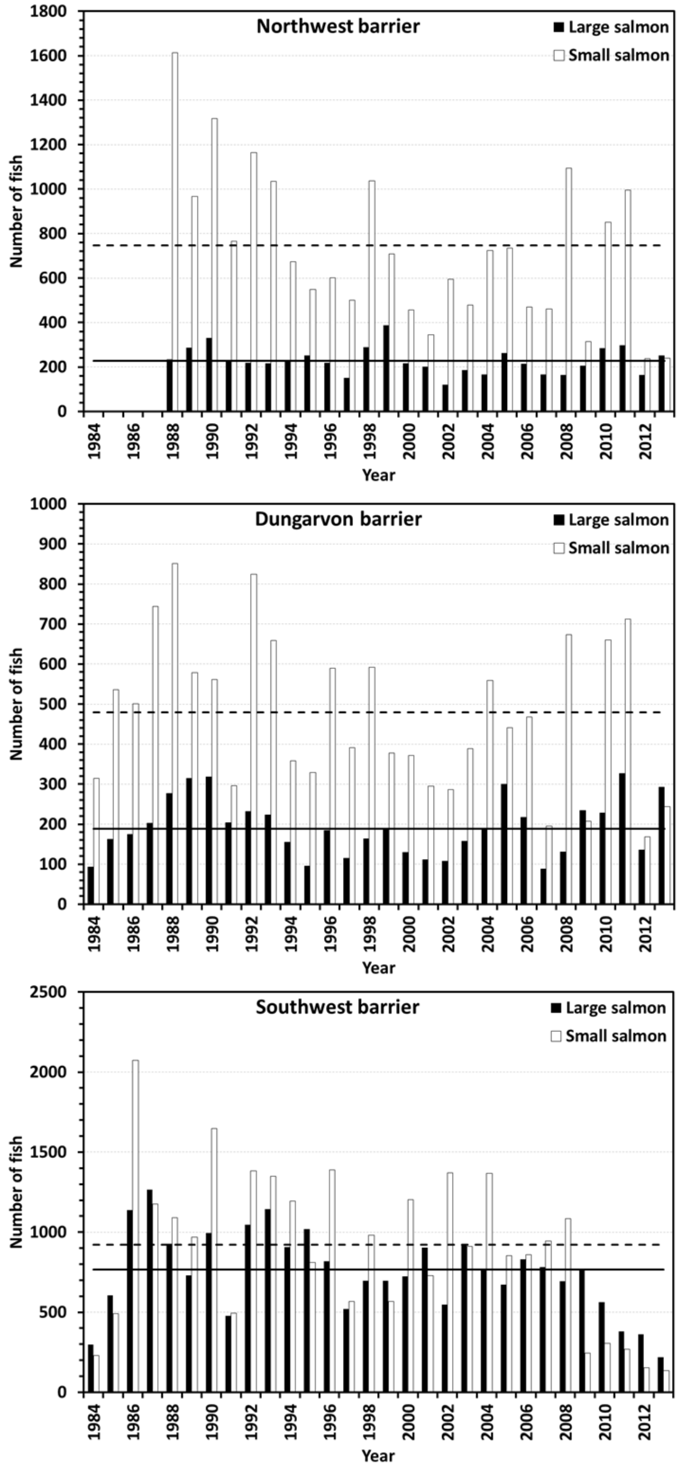


Figure 12. Counts of large and small Atlantic salmon at the headwater protection barrier on the Northwest Miramichi River (upper), the Dungarvon River (middle), and the north branch of the Southwest Miramichi River near Juniper (lower) between 1984 and 2013. Solid horizontal lines represent the average count of large salmon for the index facility's time series (1988-2012 for the Northwest barrier and 1984-2012 for the Dungarvon and Juniper barriers). The dashed horizontal line represents the average count for small salmon for the index facility's time series. Counts at Juniper were incomplete between 2010 and 2013.

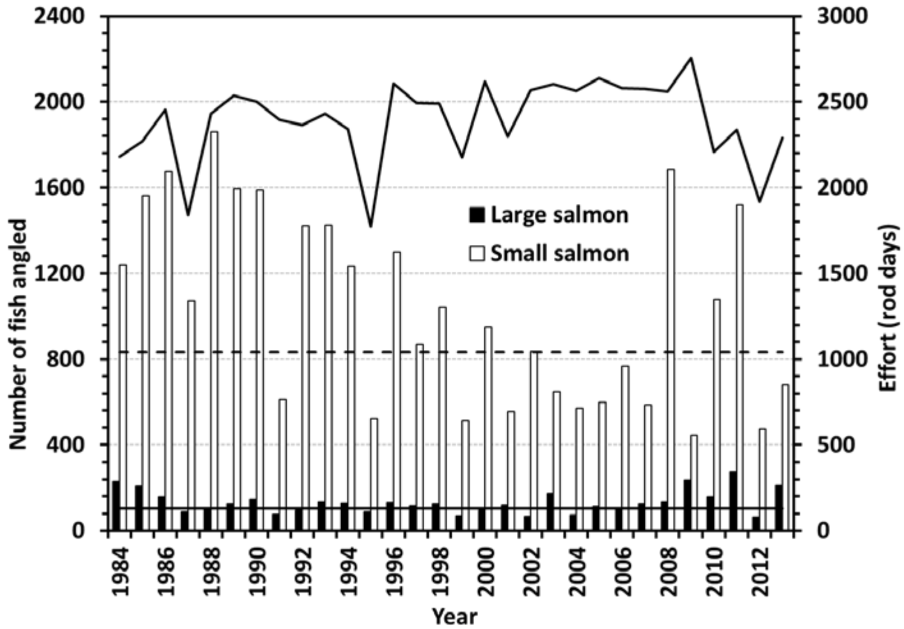


Figure 13. Effort and angling catches of large and small Atlantic salmon from the provincial Regular Crown Reserve stretches of the Northwest Miramichi watershed 1984 – 2013 (MacEachern and Sullivan 2013). The solid horizontal line represents the average catch of large salmon for the time series (1984-2012); the dashed horizontal line, the average catch of small salmon.

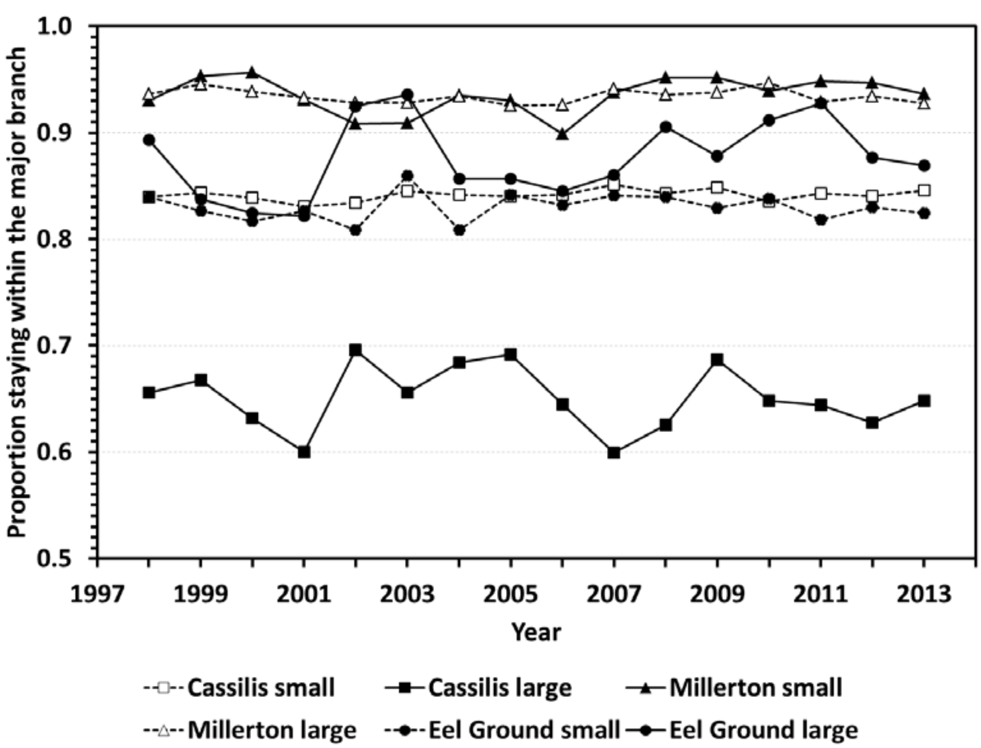


Figure 14. Median estimates of the proportion of large and small salmon staying within the major branch from which they were tagged 1998-2013.

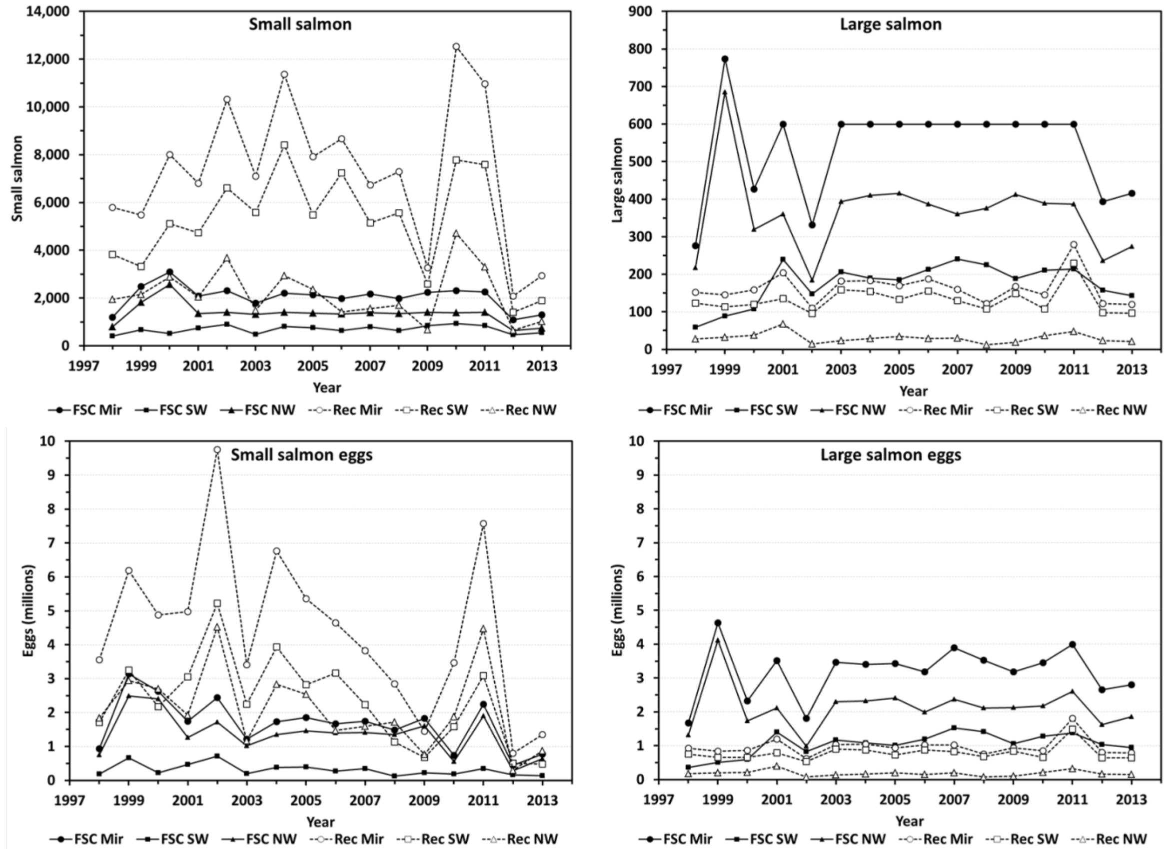


Figure 15. Assumed and estimated harvests of small and large salmon (upper panels) and the equivalent losses in eggs (bottom panels) from aboriginal fisheries for food, social and ceremonial purposes (FSC) and recreational (Rec) fisheries of the Miramichi (Mir), Southwest (SW) Miramichi, and Northwest (NW) Miramichi rivers, 1998 to 2013.

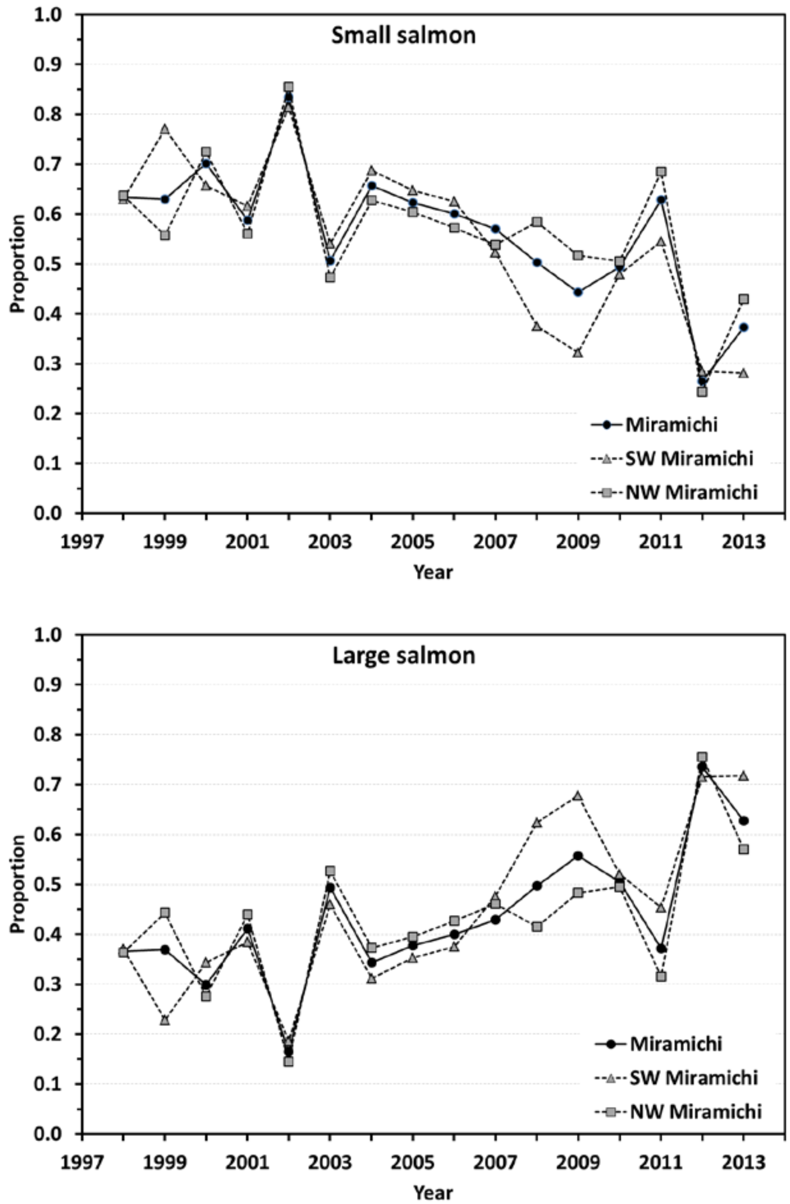


Figure 16. Proportions of the total annual egg loss from fisheries harvests due to small salmon harvests (upper panel) and large salmon harvests (lower panel) in the Miramichi River and each of its major branches for years 1998 to 2013.

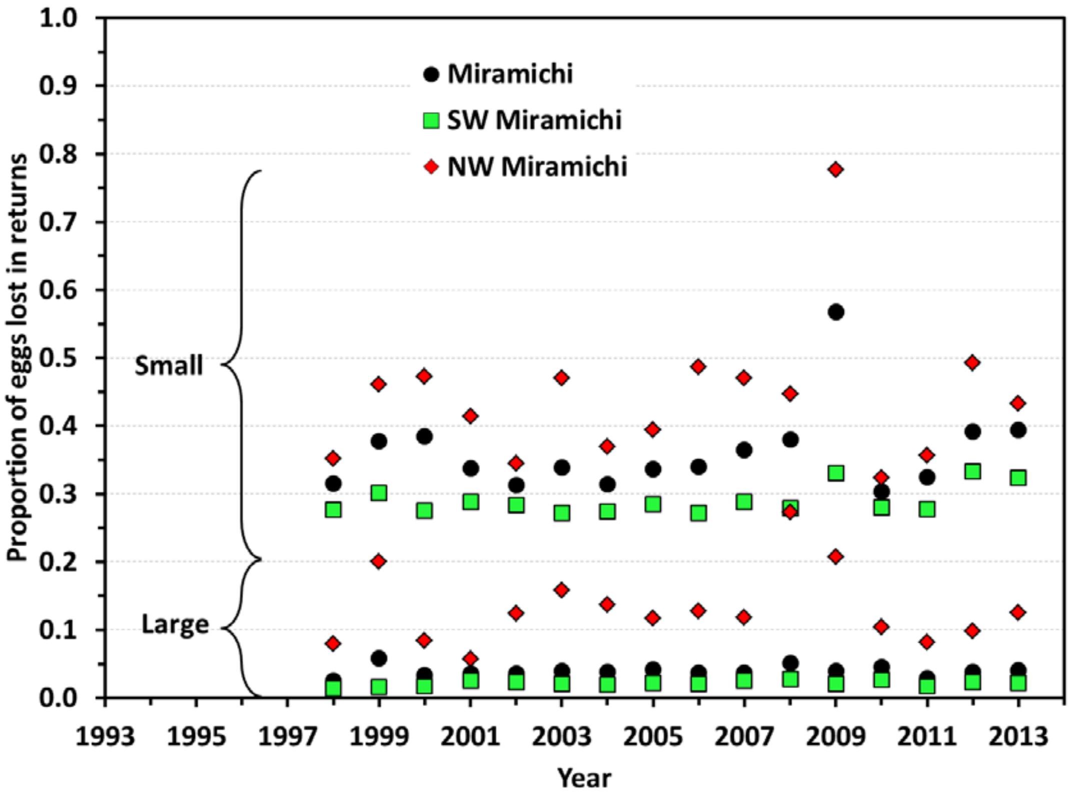


Figure 17. Proportions of total eggs in the returns by size group (small salmon and large salmon) which were lost to fisheries harvests for the Miramichi River and its two main branches, 1998 to 2013.

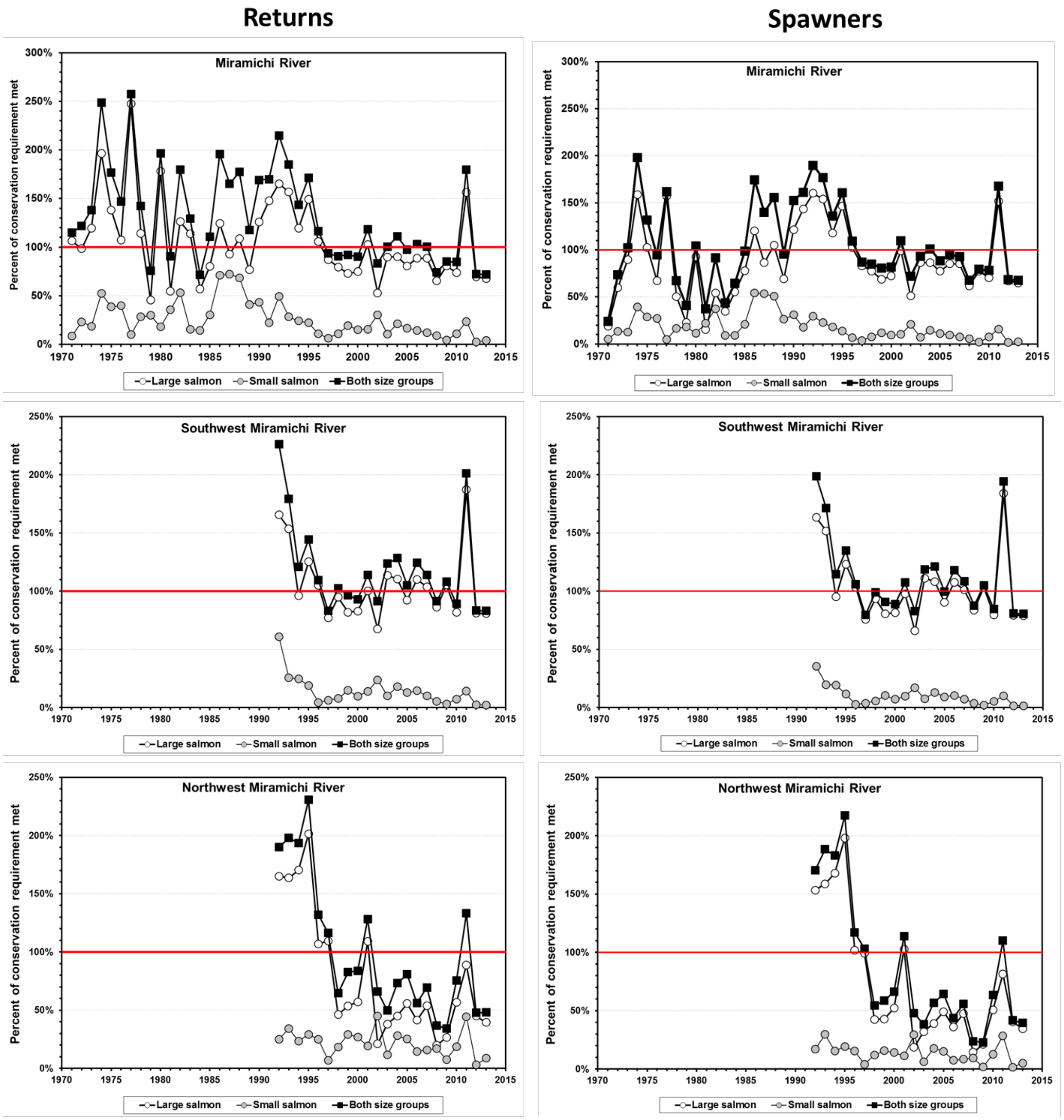


Figure 18. The estimated number of eggs, expressed as the percentage of the conservation requirement, in the returns (left panels) and escapement (right panels) of Atlantic salmon to the Miramichi (upper panels), the Southwest Miramichi (middle panels), and the Northwest Miramichi (lower panels) rivers, 1971 to 2013. The horizontal lines represent the 100% level of conservation attainment.

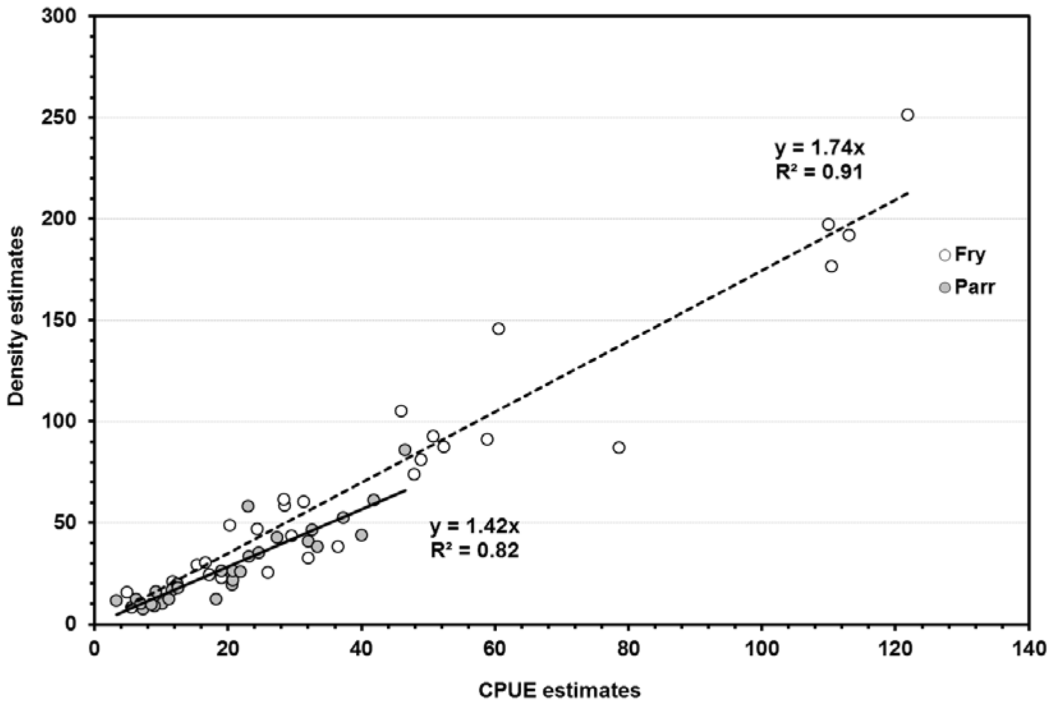


Figure 19. Linear relationship between estimates of density and abundance for juvenile salmon at closed sites in the Miramichi watershed 2006-2013. Densities of fry and parr at open sites in 2013 were predicted from these relationships.

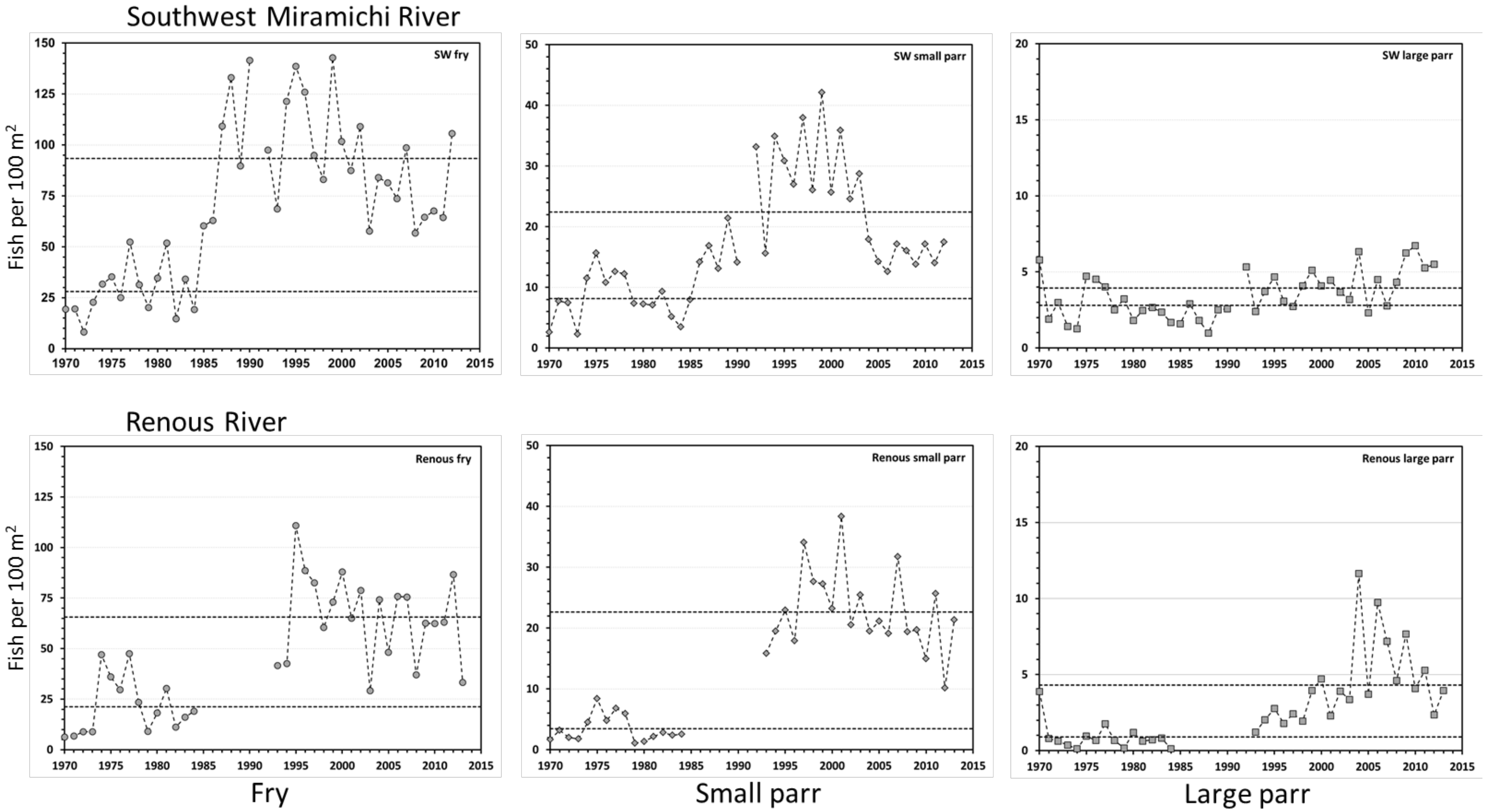


Figure 20. Average abundance (fish per 100 m²) of juvenile Atlantic salmon by size group in the Southwest Miramichi and Renous rivers, 1970 to 2013. The lower horizontal dashed line in each panel is the average abundance of fry (1970-1984), small parr (1970-1985), and large parr (1970-1986) whereas the top horizontal dashed line in each pamel is the average density of fry (1985-2013), small parr (1986-2013), and large parr (1987-2013) after significant management changes were implemented to the commercial and recreational salmon fisheries in 1984.

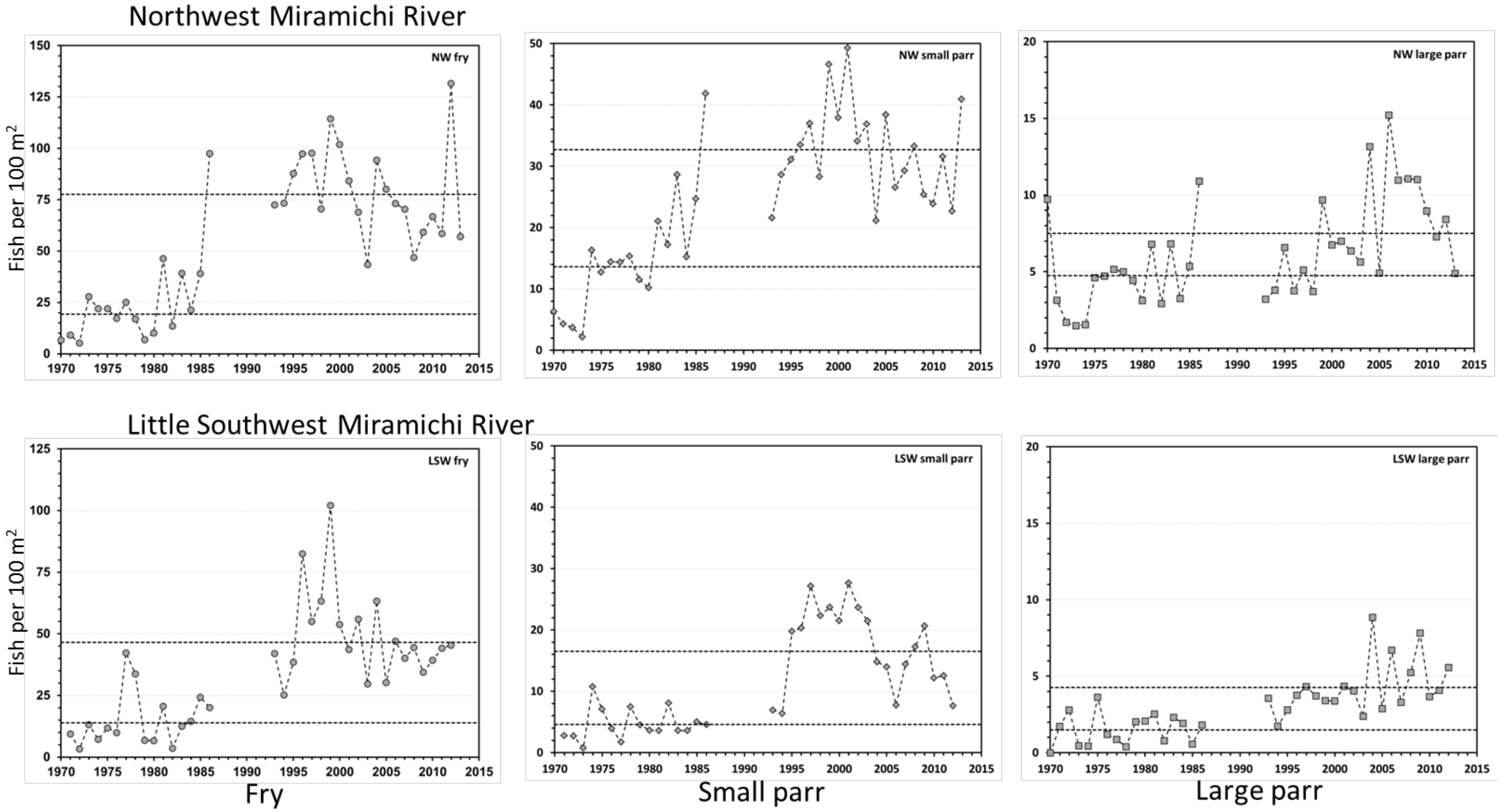


Figure 21. Average abundance of juvenile Atlantic salmon by size group in the Northwest and Little Southwest Miramichi rivers, 1970 to 2013. The lower horizontal dashed line in each panel is the average abundance of fry (1970-1984), small parr (1970-1985), and large parr (1970-1986) whereas the top horizontal dashed line in each pamel is the average density of fry (1985-2013), small parr (1986-2013), and large parr (1987-2013) after significant management changes were implemented to the commercial and recreational salmon fisheries in 1984.

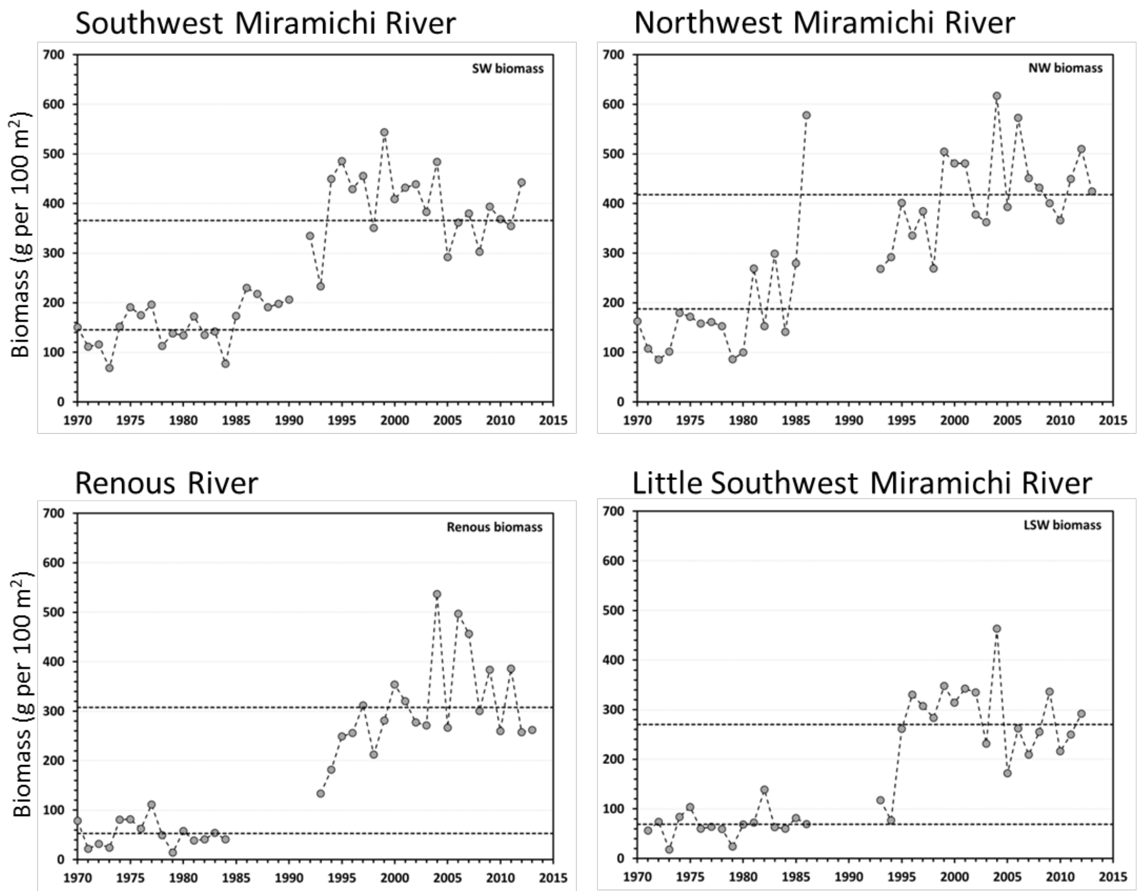


Figure 22. Total biomass of juvenile Atlantic salmon in the four major rivers of the Miramichi watershed, 1970-2013. Horizontal dashed lines in each panel are the average biomass values for the years 1970-1986 (lower line) and years 1987-2013 (upper line).

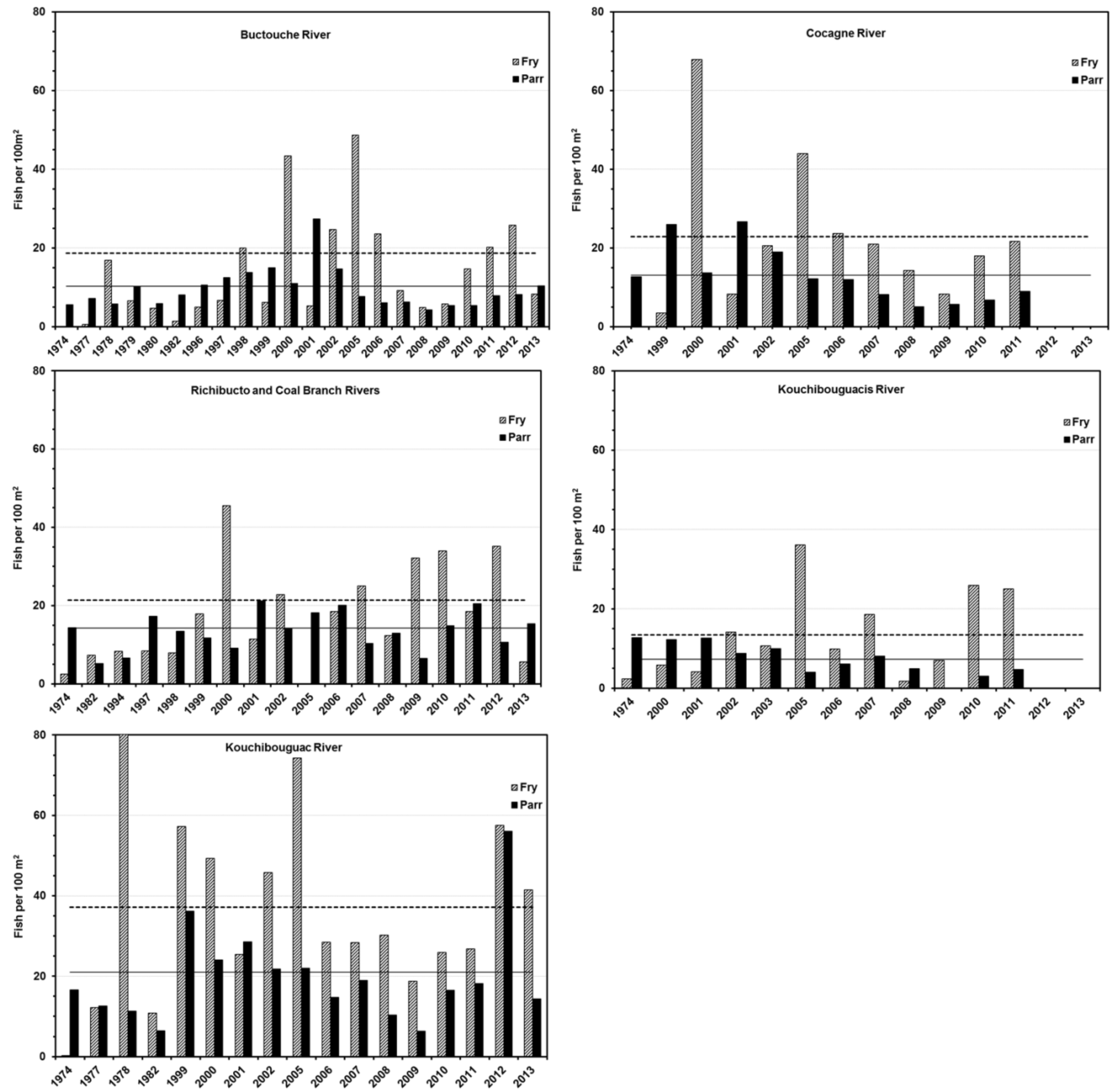


Figure 23. Average juvenile salmon densities by size group in rivers of southeastern New Brunswick for all years surveyed (1974 to 2013). The horizontal lines in each panel represent averages for fry (hatched) and parr (solid) in their respective rivers sicne the closure of the aboriginal and recreational fisheries in 1998.