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Information on Atlantic salmon (*Salmo salar*) from Salmon Fishing Area 16 (Gulf New Brunswick) of relevance to the development of a COSEWIC status report

Informations sur le Saumon atlantique (*Salmo salar*) de la Zone de Pêche du Saumon 16 (Golfe Nouveau-Brunswick) pertinents au développement du rapport de situation du COSÉPAC

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ABSTRACT

This document presents information on Atlantic salmon (*Salmo salar*) from Salmon Fishing Area (SFA) 16 of relevance to the development of the status report by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). SFA 16 includes 39 rivers and is located in DFO Gulf Region New Brunswick. Data are presented and interpreted relative to the following: biological characteristics, stocking of fish, area of occupancy based on juvenile surveys, indicators of adult abundance for monitored rivers, freshwater production based on juvenile surveys and smolt production, and factors which may be constraining Atlantic salmon abundance. Based on the data series from the Miramichi River, adult abundance was higher in the late 1980s and early 1990s than in the past decade. Juvenile salmon abundance indices rose to high levels as a result of changes in fisheries management in the 1980s which increased spawning escapements. Juvenile salmon abundance has started to decline as returns have declined but juveniles remain well dispersed in the Miramichi and densities are more than twice the abundances of the 1970s and early 1980s. The smaller southeast rivers have generally not met their conservation requirements and juvenile abundance remains low in these rivers reflecting lower adult abundance and possibly lower carrying capacity of the habitat.

RÉSUMÉ

Le présent document donne des renseignements sur le saumon de l'Atlantique (*Salmo salar*) de la zone de pêche du saumon (ZPS) 16 en vue de la préparation du rapport de situation par le Comité sur la situation des espèces en péril au Canada (COSEPAC). La ZPS 16 comporte 39 rivières au Nouveau-Brunswick région du Golfe du MPO. Les données présentées et interprétées se rapportent aux éléments suivants : caractéristiques biologiques, stock de poissons, superficie occupée en fonction des inventaires des juvéniles, indicateurs de l'abondance des adultes dans les rivières étudiées, production en eau douce en fonction des inventaires des juvéniles et de la production de saumoneaux et facteurs nuisant à l'abondance du saumon de l'Atlantique. Les indices d'abondance provenant de la rivière Miramichi démontrent que l'abondance était supérieur à la fin des années 80s et début 90s comparativement à la dernière décennie. Les changements apportés à la gestion des pêches dans les années 1980 ont entraîné une hausse d'abondance de saumons juvéniles en réponses aux augmentations de l'abondance des géniteurs. Malgré une tendance décroissante récente dans l'abondance des juvéniles suite aux diminutions d'abondance des adultes reproducteurs, les juvéniles sont répartis à la grandeur de la rivière Miramichi et leurs abondances demeurent à des niveaux deux fois supérieures à celles des années 70s et 80s. Les plus petites rivières de la région du sud-est n'ont généralement pas atteint leurs besoins de conservation et les abondances faibles de juvéniles reflètent les faibles niveaux de reproducteurs et possiblement une faible capacité d'accueil de l'habitat.

INTRODUCTION

This document presents information on Atlantic salmon (*Salmo salar*) which has been collected by Fisheries and Oceans Canada (DFO) and which is being made available in support of the preparation of a status report on Atlantic salmon in eastern Canada by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Information in this document pertains to Atlantic salmon in Salmon Fishing Area (SFA) 16 which consists of the rivers of the southeast portion of New Brunswick flowing into the Gulf of St. Lawrence (from 46ºN by 64.0ºW to 47.4ºN by 64.9ºW) (Fig. 1). There are 39 rivers (defined as the point where freshwater meets salt water) which are considered appropriate for Atlantic salmon production of which the Southwest Miramichi River is the largest with a drainage area of over 5,800 km^2 (Fig. 1; Table 1). Four rivers within this area have greater than 5 million m^2 of juvenile rearing area whereas 13 rivers are very small with less than 0.5 million m^2 of habitat area (Table 1). The conservation limit reference point for these rivers is an egg deposition rate of 2.4 eggs per m^2 of wetted area as defined in CAFSAC (1991). Egg requirements for 60% of these rivers are less than 1.5 million eggs or roughly less than 250 large salmon.

Reference is made in this document to various stages of Atlantic salmon:

- Small salmon: mature adult fish less than 63 cm fork length. This size group is comprised primarily of one-sea-winter maiden salmon and a small proportion of two-sea-winter maiden salmon and repeat spawners.
- Large salmon: mature adult fish greater than or equal to 63 cm fork length. This size group is comprised primarily of two-sea-winter maiden salmon but also includes three-sea-winter maiden salmon and repeat spawners.
- One-sea-winter salmon (1SW): mature adult salmon that have not spawned before and have spent one full year at sea.
- Two-sea-winter salmon (2SW): mature adult salmon that have not spawned before and have spent two full years at sea.
- Maiden spawner: a salmon which is on its first spawning migration.
- Repeat spawner: a salmon which is on a second or greater spawning migration.
- Smolt: juvenile Atlantic salmon migrating to the ocean for the first time.
- Parr: juvenile salmon, older than one year and which has not migrated to the ocean.
- Fry: juvenile salmon, less than one year found in fresh water.

BIOLOGICAL CHARACTERISTICS

The longest time series of information on Atlantic salmon from SFA 16 is available from the Miramichi River system. Biological characteristics data for salmon from this SFA are presented in Chaput et al. (2006) and O'Connell et al. (2006).

Small salmon make up less than 50% of the returns to the smaller rivers in this area but are on average two-thirds of the adult salmon returning to the Miramichi River. The small salmon are about 80% male in the Miramichi and 90% or higher in the other small rivers. There are a few 3SW maiden salmon in this SFA, most of the large salmon are maiden 2SW and repeat spawners. These older age groups are most often greater than 80% female.

Most salmon returning to the Miramichi River have spent two or three years in river, the oldest river age in the database is five years. In terms of maiden sea age, salmon can be one-sea-winter (1SW), two-sea-winter (2SW) or three-sea-winter (3SW). In terms of total age (river age plus sea age plus one for year of egg deposition), the oldest salmon sampled from the Miramichi is twelve years old (Fig. 2). Repeat spawners are also abundant in the Buctouche River (Atkinson 2001).

Proportionally more salmon of river age 3 years are found in the one-sea-winter (1SW) maiden salmon group compared with the two-sea-winter (2SW) salmon group (Fig. 3). Over all the years sampled, 1971 to 2007 (2008 ages not yet available), the proportions at river ages 2 to 5 for 1SW and 2SW are 0.40, 0.58, 0.02, <0.01 versus 0.47, 0.52, 0.01, <0.01, respectively.

The mean generation time, defined as the average age of salmon returns from a year class (egg deposition to egg deposition), has varied from 4.7 to 5.4 years (Fig. 4).

Exploitation rates decreased with the commercial fishery closure and the mandatory release of large salmon in the recreational fishery introduced in 1984. Following on these management measures, the proportion and ages of repeat spawning salmon in the Miramichi River have increased (Fig. 5). Salmon on a fifth spawning migration have been sampled annually since 1992 and salmon on a seventh spawning migration have frequently been sampled since 1995 (Table 2). Annual returns of salmon adults to the Miramichi now comprise 8 to 9 year classes (Table 3) (Chaput and Jones 2006).

Adult salmon in SFA 16 rivers range in length from 36 cm to 115 cm (based on sampling in Miramichi River, 1971 to 2007). By sea age history, 1SW salmon have an average fork length of 55 cm (95% Confidence Interval 48.8 to 61.8 cm), 2SW salmon have an average fork length of 75 cm (95% C.I. 69.0 to 80.8 cm), and 3SW salmon have an average fork length of 88 cm (95% C.I. 86.0 to 90.5 cm) (Fig. 6). Corresponding observed mean whole weights of 1SW, 2SW, and 3SW salmon are 1.7, 4.7, 6.9 kg, respectively (Fig. 7).

Fork length at maiden sea age for 1SW and 2SW salmon has increased over the period 1971 to 2007 (Fig. 8). The step increase in length post 1985 has been attributed to the closure of the size-selective commercial fishery from Miramichi Bay (Moore et al. 1995).

Fecundity at length relationships for Miramichi salmon were published by Randall (1989). Large salmon (sexes combined) have a fecundity of about 6,000 eggs per fish whereas small salmon, due to their small size and high proportion of male, contribute less than 1,000 eggs per fish (Fig. 9).

Most salmon return to the small rivers in this SFA during September to November. The return of salmon to the Miramichi estuary has a bimodal distribution with a first peak around early to mid-July (early run) and a second peak in late September to mid-October (late-run) (Fig. 10). Smolts migrate to the ocean from early May to mid-June.

INFORMATION RELEVANT TO THE DISCUSSION ON DU'S

DFO does not hold any genetic information on Atlantic salmon for this SFA to inform the discussion on designatable units (DU) as used by COSEWIC. Biological characteristics of salmon from some of the rivers in this SFA relative to other areas in eastern Canada have been summarized by Chaput et al. (2006) and O'Connell et al. (2006).

Hatcheries have been used to supplement wild production in several rivers of SFA 16. This procedure began in 1873 with the establishment of the first Atlantic salmon hatchery in Canada on the Miramichi River at South Esk. The South Esk hatchery has been in continuous operation since 1873 stocking a variety of juvenile Atlantic salmon life stages annually into the Miramichi watershed and occasionally into other SFA 16 rivers.

Between 1959 and 1970 experimental plantings of Restigouche origin stock (SFA 15) were distributed to the Tabusintac, Southwest Miramichi, Northwest Miramichi, and Little Southwest Miramichi rivers as well as to Rocky Brook (upper tributary of the Southwest Miramichi River).

Within the past 30 years, Miramichi origin stock were distributed in the Tabusintac and Buctouche rivers (Table 4). Otherwise, all recent enhancement activities have involved placing juvenile progeny back to tributaries from which the parents were collected. The southern rivers of SFA 16 from Shediac to the Nova Scotia border have not received hatchery supplementation.

Generally rivers in SFA 16 are reliant on natural production and within the Miramichi, on average, 99% of returning adults come from wild production (Chaput et al. 2001).

HABITAT REQUIREMENTS

Atlantic salmon from SFA 16 are anadromous, spawning in freshwater and migrating to the ocean to grow and mature. Extensive reviews of the habitat requirements for Atlantic salmon in freshwater are provided by Amiro (2006) and for the marine environment by Reddin (2006). These reviews document well the habitat requirements of Atlantic salmon for this SFA.

INFORMATION SOURCES SOUGHT/CONSIDERED

There is a large amount of data on the Atlantic salmon from the Miramichi River. Adult salmon have been enumerated and sampled at index estuarine trapnets since 1954 (Claytor 1996; Hayward 2001). Annual assessments were conducted between 1983 and 2000 and intermittently since. Annual juvenile electrofishing surveys have been conducted throughout the watershed since 1970 (Moore and Chaput 2006). Other abundance indicators include angling catch per unit effort (CPUE) from Crown Reserve Waters located in the Northwest Miramichi River (Table 5), and counts from three headwater barriers (Table 6). Smolt monitoring programs date to the 1950s and were re-initiated in 1998 in the Miramichi River.

Adult assessments have been conducted on three other rivers in this area, Tabusintac, Richibucto, and Buctouche rivers. Juvenile surveys are used to assess status in five other small rivers in the southeast area.

AREA OF OCCUPANCY

Atlantic salmon in SFA 16 are anadromous (spawn in freshwater, go to sea to grow and mature) and undertake long oceanic migrations. Salmon originating from the Miramichi River are annually intercepted in nearshore fisheries at West Greenland as non-maturing 1SW salmon (from smolts in their second year at sea) and as repeat spawning salmon (originally tagged as salmon on their spawning migration to the river). As well they have been reported from Labrador and Newfoundland coastal fisheries and from regional commercial fisheries throughout the Gulf of St. Lawrence (Saunders 1969; Claytor et al. 1987).

An extended juvenile monitoring program was conducted in 2008 to assess the present area of occupancy for Atlantic salmon. Area of occupancy for the fresh water portion of the life cycle is described in terms of the presence and abundance of the juvenile salmon life stages; the presence of juveniles was interpreted as evidence of successful spawning of adults.

For the northern section of SFA 16 (Tabunsintac River to Bay du Vin River Fig. 1; Table 1), juvenile Atlantic salmon were present at all sites in all rivers surveyed in 2008 (Fig. 11). In the middle portion of the SFA (Fig. 1; Table 1) juvenile Atlantic salmon were present in 8 of 10 rivers surveyed, the exceptions were Riviere au Portage and Ruisseau des Major, within Kouchibouguac National Park (Fig. 11); these rivers are small rivers, are characterized as stream orders 1 and 2 and would not normally be expected to have Atlantic salmon.

For the southern section of SFA 16 (Fig. 1; Table 1), from the Shediac River to the Nova Scotia border, juvenile Atlantic salmon were completely absent from two of six rivers surveyed and were absent from six of the twelve sites within the six rivers (Fig. 11). When salmon were present there was never more than one cohort found indicating intermittent spawning success in recent years.

Annual surveys measuring the relative abundance of juvenile salmon in the Miramichi watershed have been conducted since 1970 (Chaput et al. 2005; Moore and Chaput 2006). The percentage of sites in the annual surveys with fry densities < 1 per 100 m^2 decreased from an average of 15% during 1970 to 1985 to less than 5% during 1986 to 2008 indicating an increased distribution of spawning adults within the watershed (Fig. 12). The percentage of sites in annual surveys with parr densities < 1 per 100 m^2 also decreased from an average of 21% during 1970 to 1986 to an average of 3% for 1994 to 2004 indicating that parr were also distributed more broadly within the river over time (Fig 12). There is limited information from other rivers on temporal changes in the presence of Atlantic salmon (Atkinson 2004) but all indications are that the fresh water area of occupancy has not changed in the past three decades.

ABUNDANCE AND RECENT TRENDS

Abundance and trends are evaluated relative to the recent 15 years, 1994 to 2008 (or 1993 to 2007), when available. This time period has been chosen because it roughly represents three generations and also corresponds to the years since the moratorium on salmon commercial fishing in insular Newfoundland. Abundances are also put in context of the longer time period when available. Trend in an abundance index (Ln(Index)) is characterized as the instantaneous annual rate of change (Z) over the fifteen year period. Change in abundance for the most recent 15 year period is expressed as (exp^{Z*15}-1).

Adult Salmon in Individual Rivers

The abundance of adult salmon in the Miramichi River has decreased by 31% over the period 1993 to 2007 (Table 5; Fig. 13). The average abundance during 2003 to 2007 has been 54,200 fish representing about 33,300 small salmon and 20,800 large salmon (Table 5; Fig. 13). The decline in small salmon has been more important than for large salmon. Estimates of returns for 2008 to the Miramichi River were not available at the time of the meeting (Feb. 2009).

Eggs in the returns of adult salmon during 1993 to 2007 have been sufficient to meet or exceed the conservation requirements for the Miramichi in 7 of the 15 years although conservation requirements have only been met or exceeded in 3 of the last 10 years (Fig. 14). Losses of large salmon occur primarily in the First Nations fisheries with an additional assumed loss due to catch and release fishing. On average 105% of the conservation requirement was estimated to have been met by spawners in the past 5 years (Fig. 14).

Counts at headwater facilities in the Northwest and Southwest Miramichi have declined by 29% and 5% for large and small salmon respectively, since 1993. Counts of small salmon have increased by 6% and 8% in the Northwest and Southwest Miramichi, since 1993 (Tables 6,8; Fig 15).

Catch per unit effort (CPUE, expressed as catch per rod day of angling effort) in the crown reserve waters of the Northwest Miramichi has declined by 48% for small salmon and 33% for large salmon, respectively, since 1973. During 1994 to 2008, CPUE declined by 28% for small salmon and 13% for large salmon (Table 7,8; Fig. 16).

The intermittent assessments of salmon conducted on the Tabusintac River have indicated that returns of salmon were greater than 200% of the conservation requirement in all four years assessed between 1994 and 1999 (Douglas and Swasson 2000) (Table 8).

The smaller southeast rivers of this area have been closed to all directed salmon fishing since 1998. Assessments of adult returns to the Buctouche River, the index river for this group of southeast rivers, indicated that the conservation limit was met or exceeded once in eight years between 1993 and 2000 (Atkinson and Peters 2001) (Table 8). Returns to Richibucto River did not meet the conservation requirement in the years in which the river was assessed (Atkinson and Cormier 1998).

Adult Salmon in SFA 16

The total abundance of adult (by size group) Atlantic salmon in SFA 16 was estimated based on the abundance of salmon in the Miramichi River adjusted for the proportion of the freshwater habitat of Miramichi in SFA 16 (Table 1). The Miramichi River comprises 91% of total rearing area of rivers in SFA 16. Returns to the Miramichi have been assessed annually and are shown in Table 7. The ranges of the estimated returns are based on several assumptions:

- For 1971 to 1991, the minimum and maximum values are based on capture efficiencies of the Millbank trapnet representing a lower CI of -20% of estimate and upper CI of 33% of estimate. The point estimate of returns is in Table 7.
- For 1992 to 1993, the minimum and maximum are lower and upper CI are based on estimate bounds of -18.5% to +18.5%.
- For 1994 to 2007, the minimum and maximum values are 5th and 95th percentile ranges from the mark and recapture assessment models (Chaput et al. 2001).

The total adult abundance (returns) to SFA 16 are the Miramichi returns (Minimum, Maximum) divided by 0.91 (Tables 9 and 10).

Spawners are estimated as returns minus harvests. Harvests for 1971 to 1997 are from Chaput et al. 1998). For 1998 to 2007:

- The harvest of large salmon is estimated as 3% of the large salmon return which is the average rates for 1993 to 1997 as per the assessments (Chaput et al. 1998).
- The harvest of small salmon is estimated as 34% of the small salmon return which is the average rates for 1993 to 1997 as per the assessments (Chaput et al. 1998).

Estimated total adult abundance in SFA 16 has decreased by 33% for small salmon and decreased by 34% for large salmon over the past 15 years (Fig. 17). The average abundance of large salmon over the past 15 years (about 25,000 fish) is about 87% of the average abundance estimated over the 1970 to 1992 period (29,000; Fig. 17). The average abundance of small salmon during the past 15 years (44,000 fish) is 54% of the average abundance during the 1970 to 1992 period (Fig. 17).

Freshwater production

Juvenile surveys have been conducted annually throughout the Miramichi watershed since 1970 and abundance of all age groups of juvenile salmon increased after 1984 when management measures were introduced to increase spawning escapements (Moore and Chaput 2006). Abundance of all age groups has remained high relative to the 1970 to 1984 period, and average fry abundance during 2004 to 2008, which most directly reflect egg depositions, has averaged 194% of the abundance during 1970 to 1984 (Table 8).

Recent (15 year) trends in juvenile abundance by age/size group are described for the four major rivers of the Miramichi that empty into tidal waters: the Northwest Miramichi, Little Southwest Miramichi, Renous, and Southwest Miramichi rivers. Fry abundance reached a maximum during the 1990's, and has decreased by 13% to 48% since 1994 (Figs. 18 and 19). The recent declines are consistent with declines in returns and spawners to the Miramichi River (Table 8, Fig. 14).

Small parr (age-1 year) abundances also show a recent downward trend, decreasing by 5% to 63% since 1994 (Figs. 18 and 19). However, large parr (age-2 years and older) abundance has been stable or increasing over the last 15 years.

Total biomass of juvenile salmon has been estimated to provide a single measure for juvenile abundance over time (Fig. 20). Total biomass should be an indicator of spawning levels, habitat quality, and environmental conditions. All four major tributaries show large increases in biomass, from 161% to 690%, based on averages during 1970 to 1984 relative to the period 2004 to 2008. The trend over the last 15 years (1994 to 2008) is for increasing biomass in the Northwest Miramichi (+53%), Little Southwest Miramichi (+28%), and Renous (+94) rivers. A decreasing biomass trend is seen in the Southwest Miramichi River (-30%). All major tributaries have biomass levels that have fluctuated over the last five years at about 370 grams per 100 m^2.

The intermittent assessments of salmon conducted on the Tabusintac River indicate juvenile abundance is comparable to that of the Miramichi (Douglas and Swasson 2000) (Table 8).

In the smaller southeast rivers of this SFA which have been closed to all directed salmon fishing since 1998, juvenile abundances has generally been much lower than in the Miramichi River (Figs. 21 and 22). Adult assessments were carried out in the Buctouche River for 8 years (1993-2000) and only met conservation requirements in one year (1999). Fry abundances in 2000 increased to over 40 per 100 m^2 followed by small parr abundance in 2001 of over 25 per 100 m^2 (Fig. 21). Similar increases in fry were observed in 2000 in other southeast rivers suggesting that returns in 1999 to all these rivers had been much better than previously and that the Buctouche River and the juvenile sampling were sufficient indicators of adult abundance in these rivers. Based on the juvenile abundance index, the southeast rivers have likely been below conservation most years since 1993 with the exception of 1999 and 2004.

Smolt production

Estimated smolt production from the Miramichi River for 2001 to 2006 averaged 2.1 smolt per 100 m² (range 1.3 to 3.3) (Table 11). This compares to production for five years during the 1950's estimated to have averaged 2.9 smolts per 100 m^2 (range 1.6 to 4.9) (Kerswill 1971). Smolt production from the Southwest Miramichi River (including Southwest Miramichi and Renous rives) has been greater (average 2.6 smolts per 100 m²; range 1.3 to 4.4) than for the Northwest Miramichi River overall (average 1.8 smolts per 100 m²; range 1.0 to 2.6) and the Little Southwest Miramichi River (average 1.3 smolts per 100 m²; range 1.0 to 1.6). Smolt production has been increasing in the Miramichi in recent (2004 onwards) years (Table 11).

Trends in Marine Survival

Smolt enumeration programs began in 1999 in the Miramichi River. Return rates to 1SW salmon have varied between 2% and 6% whereas return rates to 2SW salmon have been between 0.5% and 2% (Table 11).

The adult salmon return rate to a second and subsequent spawning has been increasing since the 1970s. Return rates to a second spawning for 1SW maiden salmon exceeded 5% in the past five years while return rates for 2SW maiden salmon were greater than 10% and have been as high as 25% (Fig. 23). These return rates were uncorrected for inriver removals and fisheries in the high seas.

SUMMARY OF STATUS

Based on the data series from the Miramichi River, adult abundance was higher in the late 1980s and early 1990s than in the past decade. As a result of changes in fisheries management, particularly the closure of the Maritime provinces and Quebec commercial fisheries and the mandatory catch and release measures in the angling fishery since 1984, spawning escapement has increased which has resulted in increased abundance of juvenile salmon. Juvenile salmon abundance has declined as adult returns and spawners have declined but juvenile salmon remain well dispersed in the Miramichi and densities are more than twice the levels of the 1970s and early 1980s. Smolt production from the Miramichi averaged over 1.1 million smolts for 2001 to 2006. Freshwater production is not limiting for the Miramichi watershed. Returns to the Miramichi have been sufficient to meet the conservation requirements in 7 of the last 15 years.

The Tabusintac River has exceeded its conservation requirement in the four years it was assessed (Douglas and Swasson 2000). The smaller southeast rivers have generally not met their conservation requirements (Atkinson and Cormier 1998; Atkinson and Peters 2001). Juvenile abundance remains low in these rivers reflecting lower adult abundance and possibly lower carrying capacity of the habitat. These southeast rivers of SFA 16 have remained closed to all directed salmon fisheries since 1998.

The abundance of repeat spawners in the Miramichi has increased since the closure of the retention fisheries on large salmon. Repeat spawners represent between 30% and 50% of the large salmon and salmon on their fifth to seventh spawning migrations have been regularly sampled since 1992 (Table 2; Fig. 5). Annual returns to the Miramichi River are now derived from 8 to 9 year classes compared to the 5 to 6 year classes during the 1970s and 1980s (Chaput and Jones 2006).

Fork lengths of 1SW and 2SW salmon have also been increasing since the late 1980s (Fig. 8). There has been a 2% increase in fork length of 1SW salmon and a 3% increase in fork length of 2SW salmon since 1992 (Fig. 8).

THREATS

In the context of the identification and management for species at risk, a *threat*, is ‘an activity or process (both natural and anthropogenic) that has caused, is causing, or may cause harm, death, or behavioral changes to a species at risk or the destruction, degradation, and/or impairment of its habitat to the extent that population-level effects occur’ (Environment Canada 2006). In essence, it is an activity that imposes a *stress* on a species at risk population which contributes to or perpetuates its decline, or limits its recovery. In the case of Atlantic salmon, the elevated marine mortality and declining returns in recent years are stressors caused by unknown (but hypothesized) threats.

Cairns (2001) presents and describes 62 hypotheses which may explain the decline in abundance of Atlantic salmon. Any or all of the factors described may be acting to constrain present abundance of Atlantic salmon in the Gulf rivers. A few of these factors are discussed below (Table 12).

Fisheries

Losses of large salmon from fisheries are low, restricted to First Nations fisheries and from incidental mortalities associated with catch and release fisheries. Exploitation on egg bearing females is low throughout Gulf Region, the small salmon are generally less than 20% female whereas 75% of the large salmon are female. Although salmon from Gulf rivers continue to be intercepted in the West Greenland fishery, the rate of exploitation is presumed to be very low compared to levels during the peak of the fishery in the 1960s to 1980s (ICES 2008).

Environmental Constraints

Rivers of SFA 16 are subject to discharge and temperature events which can affect growth of juveniles and survival of juvenile and adult salmon (Swansburg et al. 2002, 2004). The summer water temperatures in portions of the Miramichi River can approach the upper lethal temperatures (25 to 28ºC) for Atlantic salmon. Water temperatures in excess of 25ºC for several hours were recorded at a major salmon holding pool in the Southwest Miramichi in 1999 and again in 2001. In 1999, a number of salmon mortalities were reported beginning in mid-July and extending into the first week of August in both branches of the Miramichi with most mortalities reported from the lower portion of the Southwest Miramichi. The recorded mortalities, 120 in total for the Southwest Miramichi, corresponded to a period when maximum daily water temperatures generally exceeded 24ºC. In 2001, the reports of salmon mortalities began on July 21 and several hundred adult salmon were reported to have died in the lower portion of the Southwest Miramichi in July and August (Chaput et al. 2001). Documented mortalities corresponded to days when the maximum water temperature was above 24ºC.

Climate change models predict a 2 to 6°C increase in air temperature in the Maritime provinces from which increased water temperatures and alterations in stream flows are expected, which may ultimately impact on juvenile production and adult survival (Swansburg et al. 2002). Overwinter survival of juveniles is also subject to variations in environmental conditions, particularly mid-winter freshets (Cunjak and Therrien 1998; Cunjak et al. 1998).

Disease

The bacterium *Aeromonas salmonicida,* the causative agent of a disease called furunculosis was first detected in the Miramichi in 1997. The bacterium has since been confirmed annually in some mortalities autopsied by DFO. It is not believed to be a major threat to adult salmon in this river although it is most frequently found on the early run components, especially those which have just recently migrated from the sea.

Bacterial kidney disease (BKD) is found in the Miramichi River but is not considered to pose any threat to either juvenile or adult salmon.

Land Use

Quality spawning and rearing habitat on most rivers of the southeast portion of SFA 16 appears to be limited. In general, the rearing habitat is marginal for Atlantic salmon, containing limited amounts of spawning substrate and rearing habitat that is too coarse for fry and more suitable for parr (Atkinson 2004). For the Buctouche River, egg-to-fry survival is generally low but high fry abundance has resulted from high egg depositions.
Forestry, agriculture, and rural development all impact in various ways on the fresh water habitat of Atlantic salmon. The forestry industry is a major contributor to the economy of the Maritime provinces and the impact of these activities are the subject of ongoing research (Cunjak 1995).

Recent studies have demonstrated an impairment of the parr-smolt transformation and subsequent sea water adaptability resulting from exposure of smolts to endocrine disrupting compounds (Madsen and Korsgaard 1989). Fairchild et al. (1999) suggested a link between past pesticide use and declines of some Atlantic salmon populations in eastern Canada. The estimated levels of 4 nonyl phenol (4-NP) present after forest spraying were similar to those currently found in industrial effluents, pulp mill discharges and municipal sewage outfalls (Bennie 1999). Sewage treatment facilities generally do not remove endocrine disrupting compounds. Research on this issue is ongoing.

Invasive Species

In July 2001, it was discovered that a population of chain pickerel (*Esox niger*) had become established in Despres Lake, a headwater lake of Salmon Brook, tributary to the Cains River in the Southwest Miramichi River. Chain pickerel in Despres Lake originated from an unsanctioned introduction. Management action consisted of eradication of chain pickerel from Despres Lake using rotenone. The eradication was considered to have been successful (Connell et al. 2002). Only two species of fish were recovered from the lake, 691 chain pickerel and greater than 3,200 yellow perch.

In late September 2008, smallmouth bass (*Micropterus dolomieu* L) was discovered in a lake in the upper portion of Southwest Miramichi River, the first known incident of the species in this watershed. In January 2009, DFO conducted a risk analysis of smallmouth bass impacts on Atlantic salmon in the Miramichi River, and to evaluate options for and the effectiveness of mitigation measures for minimizing the risks associated with range extension of smallmouth bass. The science review concluded that there is a high likelihood of widespread establishment of smallmouth bass in the Southwest Miramichi River and in Gulf Region rivers in general (DFO 2009). Also, the overall risk to the aquatic ecosystem is considered to be high in the lake environment and moderate in the riverine environment. Riverine habitat is used preferentially by Atlantic salmon. Although the overall risk to salmon is considered moderate, none of the consequences of bass introductions were considered to be positive for Atlantic salmon.

These two incidents of illegal introductions of predaceous fish species in the Miramichi watershed of SFA 16 are evidence that illegal introductions of non-native fish species in SFA are an ongoing and a potential threat to Atlantic salmon.

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Table 1. *Characteristics of Atlantic salmon rivers in Salmon Fishing Area (SFA) 16. Sources of evidence of salmon presence include adult sampling (Adult), juvenile surveys (Juvenile), or from angling catches (Angling). Habitat areas are from various published and unpublished sources. "X" means present. "A" means absent when sampled.*

Map Index Number	River	Longitude (W)	Latitude (N)	Egg requirement (million)	Drainage area (km²)	Fluvial area (million m²)	Adult	Juvenile	Angling
	Northern Section								
1	Tabusintac	-65.1034	47.3383	1.98	704	0.8243	X	X	X
2	Burnt Church	-65.1790	47.2036	0.72	135	0.2994		X	X
3	Oyster	-65.3043	47.1132					X	
4	Bartibog	-65.3723	47.1152	2.72	512	1.1353	X	X	X
5	Northwest Millstream	-65.6916	46.9737	1.20	210	0.4785	X	X	X
6	Northwest Miramichi	-65.8264	46.9633	20.10	2,307	8.2300	X	X	X
7	Little Southwest Miramichi	-65.8448	46.9531	19.70	1,345	8.0700	X	X	X
8	Renous	-65.7916	46.8164	14.00	1,429	5.8200	X	X	X
9	Southwest Miramichi	-65.7814	46.8164	70.90	5,840	29.5300	X	X	X
10	Barnaby	-65.6106	46.8961	3.10	490	1.3044		X	X
11	Napan	-65.3365	47.0496	0.28	115	0.1146		X	X
12	Black (Northumberland Co.)	-65.2798	46.9999	0.67	277	0.2774		X	X
13	Bay du Vin	-65.1167	47.0046	0.68	284	0.2837		X	X
14	Eel River	-65.0146	47.0189						
15	Portage River	-64.9737	47.0241					A	
	Middle Section								
16	Riviere au Portage	-64.9098	46.9277					X	
17	Black (Kent Co.)	-65.0039	46.8398	0.82	343	0.3433	X	X	
18	Rankin Brook	-64.9858	46.8311					X	
19	Kouchibouguac (Kent Co.)	-65.0200	46.7900	1.41	389	0.5880	X	X	X
20	Ruisseau des Major	-64.9290	46.8080					A	
21	Kouchibouguacis	-64.9796	46.7392	1.32	360	0.5490	X	X	X
22	Saint Charles	-64.9773	46.6668						
23	Molus River	-65.0732	46.5778					X	
24	Bass River	-65.0890	46.5453					X	
25	Richibucto	-65.1253	46.5079	2.94	1,292	1.2260	X	X	X
26	Coal Branch	-65.0934	46.5016					X	
27	Saint Nicholas	-64.9190	46.5509					X	

Table 1 *(continued).*

Map Index Number	River	Longitude (W)	Latitude (N)	Egg requirement (million)	Drainage area (km²)	Fluvial area (million m²)	Adult	Juvenile	Angling
	Middle Section (continued)								
28	Chockpish	-64.7554	46.5655	0.31	129	0.1294			X
29	Black	-64.7214	46.4964						
30	Buctouche	-64.8740	46.3726	1.59	628	0.6610	X	X	X
31	Cocagne	-64.7235	46.3135	0.68	333	0.2830		X	X
	Southern Section								
32	Shediac	-64.6048	46.2637	0.52	219	0.2160		X	X
33	Scoudouc	-64.5322	46.1944	0.35	159	0.1460		X	X
34	Aboujagane	-64.4149	46.1860	0.29	120	0.1198		X	X
35	Kinnear Brook	-64.3949	46.1817					A	
36	Kouchibouguac (Westmorland Co.)	-64.3530	46.1882					A	
37	Tedish River	-64.2980	46.2146						
38	Gaspereau (Westmorland Co.)	-64.0833	46.0500	0.41	170	0.1701		X	
39	Baie Verte	-64.0991	46.0257	0.14	38	0.0575			

Table 2. *Number of scale samples of Atlantic salmon interpreted by spawning migration history from the Miramichi River, 1971 to 2007. First spawning migration are maiden salmon.*

	Spawning migration						
Year	1	2	3	4	5	6	7
1971	550	17	1	.	.	.	.
1972	1180	17	.	.	.	.	.
1973	1451	15	.	.	.	.	.
1974	1904	39	3	.	.	.	.
1975	1317	40	2	.	.	.	.
1976	1159	21	1	.	.	.	.
1977	902	30	3	.	.	.	.
1978	638	38	.	.	.	.	.
1979	803	22	4	.	.	.	.
1980	851	14	5	.	.	.	.
1981	643	12	4	.	.	.	.
1982	594	17	2	.	.	.	.
1983	277	11	.	.	.	.	.
1984	323	9	.	1	.	.	.
1985	357	16	5	.	.	.	.
1986	667	38	3	.	.	.	.
1987	360	11	1	.	.	.	.
1988	530	37	6	2	.	.	.
1989	421	65	6	1	.	.	.
1990	494	109	33	7	.	.	.
1991	332	81	39	12	.	.	.
1992	1030	128	86	41	9	2	.
1993	636	79	47	24	3	.	.
1994	1728	127	34	19	4	3	.
1995	2068	172	40	19	3	2	1
1996	1275	211	61	20	2	3	.
1997	1292	308	123	51	6	2	1
1998	1339	210	91	36	5	1	1
1999	1261	168	76	36	9	2	.
2000	1837	274	108	61	21	2	1
2001	2805	499	125	66	31	6	2
2002	2669	208	71	31	27	4	1
2003	2366	293	73	31	8	7	1
2004	2539	320	94	32	8	1	1
2005	2057	193	52	18	5	.	.
2006	3240	459	64	15	6	.	.
2007	2409	247	95	24	5	.	1

Table 3. *Year class range and number of year classes in the returns of Atlantic salmon to the Miramichi River, 1971 to 2007.*

	Year classes in spawning run		
Year	First	Last	Total year classes
1971	1963	1967	5
1972	1964	1968	5
1973	1965	1969	5
1974	1966	1970	5
1975	1965	1971	7
1976	1967	1972	6
1977	1969	1973	5
1978	1970	1974	5
1979	1970	1975	6
1980	1971	1976	6
1981	1971	1977	7
1982	1973	1978	6
1983	1975	1979	5
1984	1976	1980	5
1985	1975	1981	7
1986	1976	1982	7
1987	1978	1983	6
1988	1976	1984	9
1989	1977	1985	9
1990	1979	1986	8
1991	1980	1987	8
1992	1981	1988	8
1993	1983	1989	7
1994	1983	1990	8
1995	1983	1991	9
1996	1985	1992	8
1997	1985	1993	9
1998	1987	1994	8
1999	1988	1995	8
2000	1989	1996	8
2001	1989	1997	9
2002	1990	1998	9
2003	1991	1999	9
2004	1993	2000	8
2005	1994	2001	8
2006	1995	2002	8
2007	1995	2003	9

Table 4. *Enhancement activities conducted in the rivers of SFA 16 in the past three decades. Rivers without enhancement activities have not been listed. UF = unfed fry, FF = feeding fry, FG = fall fingerlings, P = 1+ parr, Sm = smolts.*

River	Longitude (W)	Latitude (N)	Origin of fish stocked	Life stages of fish stocked	Range in annual numbers of fish stocked	Range of years when stocking occurred
Northern						
Tabusintac	-64.9667	47.3333	Miramichi	FG	10000	2003
Northwest Miramichi	-65.8333	46.9500	NW Miramichi	F, FG, P, Sm	13,000 - 133,000	1978 - 2007
Little Southwest Miramichi	-65.8333	46.9500	LSW Miramichi	F, FG, Sm	800 - 106,400	1978 - 2008
Renous & Tributaries	-65.7833	46.8167	SW Mir., Dungarvon	F, FG, P, Sm	2,200 - 118,000	1987 - 2007
Southwest Miramichi	-65.5833	46.9667	Tributary specific	F, FG, P, Sm	9,000 - 469,400	1978 - 2008
Middle						
Kouchibouguacis	-64.9000	46.7833	Kouchibouguacis	FG	1,500 - 4,300	2006 - 2007
Richibucto	-64.8500	46.7000	Richibucto	FG	39,300 – 122,000	2005 - 2007
Bouctouche	-64.7000	46.4667	Miramichi	FG	28,000, 9,000	1978, 1979
Southern						
No enhancement activities						

Table 5. *Estimates of returns and spawners for small salmon and large salmon to the Miramichi River, 1971 to 2007.*

	Small salmon					Large salmon				
Year	Returns	Lower	Upper	Removals	Spawners	Returns	Lower	Upper	Removals	Spawners
1971	35673			13727	21946	24407			20060	4347
1972	46275			19140	27135	29049			11378	17671
1973	44545			13857	30688	27192			6843	20349
1974	73418			18232	55186	42592			8147	34445
1975	64902			16433	48469	28817			7369	21448
1976	91580			29161	62419	22801			8469	14332
1977	27743			14468	13275	51842			18925	32917
1978	24287			9932	14355	24493			13664	10829
1979	50965			20115	30850	9054			4513	4541
1980	41588			14694	26894	36318			17445	18873
1981	65273			25048	40225	16182			11574	4608
1982	80379			24065	56314	30758			17500	13258
1983	25184			10106	15078	27924			19466	8458
1984	29707			10778	18929	15137			450	14687
1985	60800			18985	41815	20738			616	20122
1986	117549			28151	89398	31285			1069	30216
1987	84816			22039	62777	19421			1365	18056
1988	121919			31641	90278	21745			765	20980
1989	75231			26846	48385	17211			1671	15540
1990	83500	68000	113100	23624	59876	28574	21350	35583	986	27588
1991	60900	45700	76000	12411	48489	29949	22400	37333	860	29089
1992	152600	128000	184000	27443	125157	37000	31056	44643	1073	35927
1993	95000	61500	153800	15984	79016	35000	19732	76695	611	34389
1994	43571	36669	52592	14437	29134	20946	15870	28962	397	20549
1995	46458	38956	55741	20061	26397	32015	26643	38747	559	31456
1996	33610	28183	40425	19565	14045	18433	14294	24594	702	17731
1997	16139	12637	21203	9586	6553	16399	12931	21554	826	15573
1998	23143	18727	29015	6986	16157	14753	10039	24695	424	14329
1999	23121	19770	27194	8271	14850	14078	11329	18002	915	13163
2000	32031	27592	37272	11092	20939	15492	12058	20653	582	14910
2001	28160	24430	32690	9540	18620	22230	19420	25630	822	21408
2002	42290	36960	48830	13073	29218	11860	8495	18030	450	11410
2003	28830	24270	35030	9708	19123	20390	15980	27050	654	19736
2004	44760	38290	54350	13690	31070	26250	18980	38060	813	25438
2005	29990	21640	59770	9998	19993	16800	11940	26060	768	16032
2006	33250	25350	47490	9813	23438	20880	14440	33210	809	20071
2007	29840	18310	58020	8960	20880	19910	13970	30990	800	19110
%change in 2007 relative to										
2006	-5%					-8%				
02 -06	4%					-10%				
84 -92	-19%					-56%				
71 -83	-30%					-38%				
92 -06	-7%					-25%				
Means										
02 -06	19236					55060				
84 -92	24562					112009				
71 -83	28571					80249				
92 -06	21502					66365				

Table 6. *Counts of salmon by size group at the headwater protection barriers in the Miramichi River.*

	North Branch of Southwest Miramichi River			Southwest Miramichi Dungarvon Barrier			Northwest Miramichi Barrier		
Year	Large	Small	Total	Large	Small	Total	Large	Small	Total
1981	54	671	725	112	550	662			
1982	282	621	903	122	483	605			
1983	219	290	509	126	330	456			
1984	297	230	527	93	315	408			
1985	604	492	1096	162	536	698			
1986	1138	2072	3210	174	501	675			
1987	1266	1175	2441	202	744	946			
1988	929	1092	2021	277	851	1128	234	1614	1848
1989	731	969	1700	315	579	894	287	966	1253
1990	994	1646	2640	318	562	880	331	1318	1649
1991	476	495	971	204	296	500	224	765	989
1992	1047	1383	2430	232	825	1057	219	1165	1384
1993	1145	1349	2494	223	659	882	216	1034	1250
1994	905	1195	2100	155	358	511	228	673	901
1995	1019	811	1830	95	329	424	252	548	800
1996	819	1388	2207	184	590	804	218	602	820
1997	519	566	1085	115	391	506	152	501	653
1998	698	981	1679	163	592	755	289	1038	1327
1999	698	566	1264	185	378	563	387	708	1095
2000	725	1202	1927	130	372	502	217	456	673
2001	904	729	1633	111	295	406	202	344	546
2002	546	1371	1917	107	287	394	121	595	716
2003	920	912	1832	158	389	547	186	478	664
2004	764	1368	2132	185	559	744	167	723	890
2005	673	853	1526	300	441	741	262	735	997
2006	829	860	1689	217	468	685	214	469	683
2007	783	945	1728	88	195	283	166	460	626
2008	692	1083	1775	131	673	804			
Minimum	54	230	509	88	195	283	121	344	546
Maximum	1266	2072	3210	318	851	1128	387	1614	1848
Mean (2003 to 2007)	746	1073	1819	193	429	622	190	600	790
% change 2008 from 2003 to 2007	5%	-12%	-5%	-54%	-55%	-55%	-13%	-23%	-21%
Instantaneous rate of change annual	-0.0145	-0.0068	-0.0101	0.0031	-0.0264	-0.0183	-0.0174	-0.0272	-0.0248
% over 15 years	-19.5%	-9.7%	-14.1%	4.8%	-32.7%	-24.0%	-23.0%	-33.5%	-31.1%

Table 7. *Angling catch and effort from Crown Reserve Waters in the Northwest Miramichi watershed 1973-2008. Data are from Dubee (2008).*

Year	Effort (rod days)	Small salmon		Large salmon	
		Catch	CPUE	Catch	CPUE
1973	2648	1210	0.457	138	0.052
1974	2940	1259	0.428	121	0.041
1975	2694	1391	0.516	125	0.046
1976	2791	1280	0.459	157	0.056
1977	2119	1120	0.529	266	0.126
1978	2557	594	0.232	170	0.066
1979	2448	1150	0.470	79	0.032
1980	2835	1306	0.461	159	0.056
1981	2886	1953	0.677	89	0.031
1982	2203	1816	0.824	134	0.061
1983	2269	823	0.363	167	0.074
1984	2179	1240	0.569	229	0.105
1985	2269	1563	0.689	206	0.091
1986	2456	1676	0.682	156	0.064
1987	1839	1072	0.583	88	0.048
1988	2432	1860	0.765	102	0.042
1989	2535	1595	0.629	127	0.050
1990	2502	1587	0.634	144	0.058
1991	2395	612	0.256	77	0.032
1992	2364	1423	0.602	94	0.040
1993	2432	1426	0.586	135	0.056
1994	2342	1234	0.527	130	0.056
1995	1773	523	0.295	88	0.050
1996	2607	1301	0.499	131	0.050
1997	2494	868	0.348	115	0.046
1998	2488	1044	0.420	125	0.050
1999	2177	514	0.236	68	0.031
2000	2619	949	0.362	93	0.036
2001	2298	555	0.242	119	0.052
2002	2566	836	0.326	66	0.026
2003	2601	650	0.250	174	0.067
2004	2565	569	0.222	74	0.029
2005	2637	598	0.227	112	0.042
2006	2579	767	0.297	99	0.038
2007	2574	586	0.228	125	0.049
2008	2558	1685	0.659	135	0.053
Mean previous 5 years	2591	634	0.245	117	0.045
Change: 2008 relative to previous five-year mean	-1%	166%	169%	16%	17%
Maximum	2886	1953	0.824	266	0.126
Minimum	1773	514	0.222	66	0.026
Instantaneous rate of change	+0.0123	-0.0098	-0.0221	+0.0030	-0.0094
% change over 15 years (1996 to 2008)	+20%	-14%	-28%	+5%	-13%

Table 8. *Summary of status indicators and trends for rivers in SFA 16. Blank cells indicate no data or insufficient data for the estimate.*

Indicator	Life stage	Miramichi						
		Northwest Miramichi	Southwest Miramichi	Northwest Miramichi	Southwest Miramichi	Tabusintac	Buctouche	
		Mean level in past 5 years		Trend (1993 to 2007/2008)		Level (1993 to 1999)	Level (2005 to 2008)	Trend (1996 to 2008)
Returns	Small adult	33,300		-34%		976	90	
	Large adult	20,800		-24%		1,046	157	
	Total	54,000		-31%		2,023	247	
Relative to conservation requirements	Adults or Eggs	105% (92% for spawners)		-35% (conservation met in 7 of 15 years)		> 100% in four years assessed	33% to 100%	Met in 1 of 8 years
Barrier counts	Total adult	891	2,421	-31%	-16%			
Angling CPUE (crown reserve)	Small	0.32		-28%				
	Large	0.042		-13%				
Juvenile abundance (fish / 100 m²)	Fry	65	72	-29%	-46%	61	24	+40%
	Small parr	25	17	-10%	-51%	17	6	-70%
	Large parr	9	5	+176%	+50%	9	3	+41%
	Distribution of juveniles	Found at 100% of sites (N = 27 to 34 sites sampled)	Found at greater than 99% of sites (N = 37 to 44 sites sampled)	All sites remain occupied	All sites remain occupied	Salmon juveniles at 18 of 25 sites in 1999	Salmon juveniles at 26 of 27 sites	No trend
Large salmon in returns	Adult	37%		+8%		53%	63%	
Maiden salmon in returns	Adult	93%		-7%		90%	84%	
Maiden age structure 1SW, 2SW, 3SW	Adult	73%, 27%, 1%		+3% for 1SW -7% for 2SW			46%, 54%, 0%	
Smolt ages 2, 3, 4	Small	40%, 58%, 2%				18%, 78%, 4%	40%, 56%, 5%	
	Large	46%, 53%, 1%				35%-65%-0	66%-34%-0	
Percent female in 1SW, 2SW, 3SW	Adult	20%, 89%, 90%		No trend		6%, na, na	11%, 86%, ?	
Fork length (cm) of 1SW, 2SW, 3SW		54, 74, 88		+ 2% 1SW fork length + 3% 2SW fork length		57, na, na	56, 76, 101	

Table 9. *Estimation of total abundance of large salmon in SFA 16, 1970 to 2007.*

Year	Harvests: Commercial catch (large salmon) SD 67 to 73 Below Millbank	SD 75-80	Aboriginal fisheries: Below Index trapnet	Above Index trapnet	Miramichi River: Angling catch	Angling loss	Milbank count Large Salmon	Returns to index trap percentiles 5th	95th	SFA 16 inriver returns Large Salmon Min	Max	SFA 16 total returns Large Salmon Min	Midpoint	Max	Miramichi spawners Large salmon 5th	95th	SFA 16 spawners Large salmon 5th	Midpoint	95th
1970	34889	5783			3247	3247	245	3662	5724	4074	6367	44746	45893	47040	415	2477	462	1609	2756
1971	18264	790			1786	1786	394	5889	9206	6551	10240	25605	27449	29294	4103	7420	4564	6409	8253
1972	2439	129			8927	8927	1167	17444	27266	19404	30330	21972	27434	32897	8517	18339	9474	14937	20400
1973	742	254			5977	5977	1133	16936	26472	18838	29446	19835	25138	30442	10959	20495	12190	17494	22798
1974	866	58			7167	7167	1791	26771	41846	29779	46547	30703	39087	47471	19604	34679	21807	30191	38575
1975	697	559		200	6287	6287	1209	18072	28248	20102	31421	21357	27017	32677	11585	21761	12886	18546	24205
1976	851	807		200	7368	7368	943	14096	22033	15679	24508	17338	21752	26167	6528	14465	7261	11675	16090
1977	6513	456		400	11617	11617	1934	28909	45187	32157	50264	39126	48179	57233	16892	33170	18790	27843	36896
1978	8392	248		400	4891	4891	593	8864	13855	9860	15412	18499	21275	24051	3573	8564	3974	6750	9526
1979	1612	309		200	2641	2641	318	4753	7430	5287	8265	7208	8696	10185	1912	4589	2127	3616	5104
1980	10764	421			6502	6502	1093	16338	25537	18173	28406	29358	34475	39591	9836	19035	10941	16057	21174
1981	8575	400		500	3228	3228	199	6713	11595	7467	12897	16442	19157	21872	2985	7867	3320	6035	8750
1982	10096	553		291	4608	4608	408	14641	25289	16286	28130	26936	32858	38780	9742	20390	10837	16759	22681
1983	10185	602	2	169	2230	2230	245	8792	15186	9780	16892	20568	24124	27681	6393	12787	7111	10667	14224
1984	0	0	1	308	7685	231	333	11950	20640	13292	22959	13293	18127	22960	11411	20102	12693	17527	22360
1985	0	0	5	322	9620	289	311	16368	28273	18207	31449	18212	24833	31454	15758	27662	17528	24149	30770
1986	0	0	17	623	14215	426	469	24684	42636	27457	47426	27474	37459	47443	23635	41587	26290	36275	46259
1987	0	0	21	877	11932	358	291	15316	26455	17036	29427	17057	23253	29448	14081	25220	15663	21858	28053
1988	0	0	78	270	10068	302	325	17105	29545	19027	32865	19105	26024	32943	16533	28973	18391	25310	32228
1989	0	0	78	462	11928	358	257	13526	23364	15046	25988	15124	20595	26066	12706	22544	14134	19605	25077
1990	0	0	107	502	9258	278	427	22474	38818	24999	43179	25106	34196	43286	21694	38038	24131	33222	42312
1991	0	0	82	462	6147	184	448	23579	40727	26228	45303	26310	35847	45385	22933	40081	25509	35046	44584
1992	0	0	28	580	9476	284	202	31056	44643	34545	49658	34573	42129	49686	30191	43778	33583	41140	48697
1993	0	0	154	54	8131	244		19732	76695	22448	87253	22602	55004	87407	19434	76397	22109	54511	86914
1994	0	0	43	81	5129	154		15870	28962	18055	32949	18098	25545	32992	15635	28727	17787	25235	32682
1995	0	0	13	172	3146	94		26643	38747	30311	44081	30324	37209	44094	26377	38481	30007	36893	43778
1996	0	0	55	317		*175*		14294	24594	16262	27980	16317	22176	28035	13848	24056	15755	21561	27367
1997	0	0		548		*155*		12931	21554	14711	24521	14711	19616	24521	12267	20812	13955	18816	23677
1998	0	0	19	195		*156*		10039	24695	11421	28095	11440	19777	28114	9753	24278	11096	19358	27620
1999	0	0	34	655		*132*		11329	18002	12888	20480	12922	16718	20514	10572	17185	12027	15789	19551
2000	0	0		474		*147*		12058	20653	13718	23496	13718	18607	23496	11475	19993	13055	17900	22745
2001	0	0		503		*204*		19450	25800	22127	29352	22127	25739	29352	18772	25065	21356	24936	28515
2002	0	0		354		*112*		7994	16800	9094	19113	9094	14104	19113	7568	16295	8610	13574	18538
2003	0	0		259		*185*		15060	26140	17133	29738	17133	23436	29738	14665	25646	16684	22930	29176
2004	0	0		438		*227*		17080	33350	19431	37941	19431	28686	37941	16488	32612	18758	27930	37101
2005	0	0		*450*		*155*		11460	23030	13038	26200	13038	19619	26200	10907	22373	12408	18930	25452
2006	0	0		*460*		*188*		13340	28370	15176	32275	15176	23726	32275	12760	27655	14516	22989	31462
2007	0	0		*460*		*202*		13970	30990	15893	35256	15893	25575	35256	13384	30251	15227	24821	34415

Table 10. *Estimation of total abundance of small salmon in SFA 16, 1970 to 2007.*

Year	Harvests: Commercial catch (small salmon) SD 67 to 73 Below Millbank	Harvests: Commercial catch (small salmon) SD 75-80	Harvests: Aboriginal fisheries Below Index trapnet	Harvests: Aboriginal fisheries Above Index trapnet	Miramichi River Angling catch	Miramichi River Angling loss	Milbank count Small Salmon	Returns to index trapnet percentiles 5th	Returns to index trapnet percentiles 95th	SFA 16 inriver returns Small Salmon Min	SFA 16 inriver returns Small Salmon Max	SFA 16 total returns Small Salmon Min	SFA 16 total returns Small Salmon Midpoint	SFA 16 total returns Small Salmon Max	Miramichi spawners Small salmon 5th	Miramichi spawners Small salmon 95th	SFA 16 spawners Small salmon 5th	SFA 16 spawners Small salmon Midpoint	SFA 16 spawners Small salmon 95th
1970	7	1			19610	19610	2484	43810	62084	48731	69059	48739	58903	69067	24200	42474	26918	37082	47246
1971	40	616			13727	13727	1962	34603	49038	38491	54547	39147	47175	55203	20876	35311	23222	31250	39278
1972					19101	19101	2542	44832	63534	49869	70672	49869	60271	70672	25731	44433	28622	39024	49425
1973	66	7			13857	13857	2450	43210	61235	48064	68114	48137	58162	68187	29353	47378	32651	42676	52700
1974	354	80			18232	18232	4038	71217	100925	79218	112263	79652	96175	112698	52985	82693	58938	75460	91983
1975	1760			400	15598	15598	3548	62575	88678	69605	98641	71365	85883	100401	46577	72680	51810	66327	80845
1976	298	1222		200	27182	27182	4939	87108	123444	96894	137313	98413	118623	138832	59726	96062	66436	86645	106854
1977	1126	552		500	13590	13590	1505	26543	37616	29525	41842	31203	37361	43519	12453	23526	13852	20010	26169
1978	5290	165		400	8265	8265	1265	22310	31617	24817	35169	30273	35449	40625	13645	22952	15178	20355	25531
1979	2589			100	14508	14508	2500	44092	62484	49045	69504	51634	61863	72093	29484	47876	32796	43026	53255
1980	551				11997	11997	2139	37725	53462	41963	59468	42514	51267	60019	25728	41465	28618	37371	46123
1981	1475			1000	22716	22716	2174	49319	85188	54860	94759	56335	76285	96234	25603	61472	28480	48429	68378
1982	2311			567	21402	21402	2665	60458	104428	67251	116160	69562	94016	118471	38489	82459	42813	67268	91723
1983	1557		1	356	8390	8390	810	18376	31740	20440	35306	21998	29431	36864	9630	22994	10712	18144	25577
1984	0	0	1	380	18790	18790	1010	22913	39577	25487	44023	25488	34756	44024	3743	20407	4163	13431	22699
1985	0	0		546	18439	18439	912	48000	82909	53393	92224	53393	72808	92224	29015	63924	32275	51690	71106
1986	0	0	16	1972	26163	26163	1763	92789	160273	103214	178279	103230	140762	178295	64654	132138	71918	109451	146983
1987	0	0	16	1258	20765	20765	1272	66947	115636	74469	128628	74485	101564	128644	44924	93613	49971	77051	104131
1988	0	0	52	892	30620	30620	1828	96211	166182	107019	184852	107071	145988	184904	64699	134670	71967	110883	149800
1989	0	0	31	1054	24426	24426	1128	59368	102545	66038	114066	66069	90083	114097	33888	77065	37696	61710	85724
1990	0	0	15	2095	21372	21372	1247	65632	113364	73005	126100	73020	99567	126115	42165	89897	46902	73449	99996
1991	0	0	2	1109	11300	11300	913	48053	83000	53451	92325	53453	72890	92327	35644	70591	39648	59085	78522
1992	0	0	36	1616	21509	21509	971	128000	184000	142380	204672	142416	173562	204708	104875	160875	116657	147803	178949
1993	0	0	124	477	15271	15271		61500	153800	69966	174972	70090	122593	175096	45752	138052	52050	104553	157056
1994	0	0	56	2921	11203	11203		36669	52592	41717	59832	41773	50831	59888	22545	38468	25649	34706	43764
1995	0	0	39	2965	5533	5533		38956	55741	44318	63414	44357	53905	63453	30458	47243	34650	44198	53746
1996	0	0	5	2578				28183	40425	32062	45990	32067	39031	45995	16023	24103	18228	22824	27420
1997	0	0		1197	11492	11492		12637	21203	14377	24122	14377	19249	24122	7143	12797	8127	11343	14559
1998	0	0	20	1160				18727	29015	21305	33009	21325	27177	33029	11200	17990	12742	16604	20466
1999	0	0	26	2366				19770	27194	22491	30938	22517	26740	30964	10682	15582	12153	14940	17727
2000	0	0		2953				27592	37272	31390	42403	31390	36896	42403	15258	21647	17358	20992	24626
2001	0	0		1561				24770	31260	28180	35563	28180	31871	35563	14787	19071	16823	19259	21696
2002	0	0		2388				37310	46610	42446	53026	42446	47736	53026	22237	28375	25298	28789	32281
2003	0	0		1233				24100	31950	27418	36348	27418	31883	36348	14673	19854	16693	19640	22587
2004	0	0		2112				37520	50240	42685	57156	42685	49920	57156	22651	31046	25769	30545	35320
2005	0	0		1528				24540	36780	27918	41843	27918	34881	41843	14668	22747	16688	21283	25878
2006	0	0		1369				25920	40270	29488	45813	29488	37651	45813	15738	25209	17905	23292	28679
2007	0	0		*1500*				18310	58020	20830	66007	20830	43419	66007	10585	36793	12042	26950	41858

Table 11. *Results from smolt monitoring programs in the Miramichi River watershed for 1998 to 2008. Values in grey shading are underestimates or poor estimates.*

River	Smolt Year	Run size estimates Estimate	95% C.I.	Smolts per 100 m² Estimate	95% C.I.	Size (mean) Length (mm)	Weight (g)	Prop. Female	Proportion at freshwater age 2	3	4	Return rate to 1SW	to 2SW
Northwest Miramichi	1998					129	21.8	0.49	0.28	0.71	0.01		
	1999	390,500	315500 - 506000	2.3	1.9 - 3.0	132	22.4	0.63	0.36	0.62	0.02	4.1%	1.2%
	2000	162,000	118000 - 256000	1.0	0.7 - 1.5	131	21.2	0.58	0.34	0.63	0.03	4.7%	0.6%
	2001	220,000	169000 - 310000	1.3	1.0 - 1.8	130	21.1	0.53	0.38	0.60	0.01	6.2%	0.4%
	2002	241,000	198000 - 306000	1.4	1.2 - 1.8	128	20.7	0.57	0.52	0.48	0.00	2.2%	0.8%
	2003	286,000	224500 - 388000	1.7	1.3 - 2.3	128	21.2	0.53	0.50	0.49	0.01	4.3%	0.8%
	2004	368,000	290000 - 496000	2.2	1.7 - 3.0	131	22.1	0.57	0.41	0.58	0.01	2.7%	
	2005	*87,750*	86000 - 216000	0.9		130	21.4	0.52					
	2006	435,000		2.6									
Little Southwest Miram	2005	46,330	32710 - 68050			130		0.58	0.22	0.76	0.02		
	2006	87,500	42000 - 625000	1.0	0.5 - 7.6	130		0.51	0.51	0.49	0.00		
	2007	138,200	106000 - 186000	1.6	1.2 - 2.1	125		0.57	0.34	0.66	0.00		
	2008	124,100	96000 - 165000	1.4	1.1 - 1.9	130		0.50					
Southwest Miramichi	2001	470000	270000 - 670000	1.3	0.8 - 1.3	127	19.2	0.47	0.65	0.34	0.00	6.3%	
	2002	620000	506000 - 800000	1.7	1.4 - 2.3	126	18.8	0.54	0.55	0.44	0.01	3.6%	
	2003	450,000	390000 - 510000	1.6	1.1 - 1.8	128	19.6	0.58	0.49	0.51	0.00	6.4%	
	2004	1,110,000	770000 - 1144000	3.0	2.6 - 3.5	130	21.1	0.54	0.57	0.43	0.00	2.7%	
	2005												
	2006	1,330,000	980000 - 1810000	3.8	2.8 - 5.1	130	21.9	0.57	0.54	0.46	0.00	1.9%	
	2007	1,550,000	1050000 - 2050000	4.4	3.0 - 5.8	130	20.6	0.44	0.57	0.43	0.00		
	2008	880,000	670000 - 1190000	2.5	1.9 - 3.4	126							
Miramichi River	2001	690,000		1.3					0.56	0.42	0.00	7.8%	2.0%
	2002	861,000		1.6					0.54	0.45	0.01	3.5%	1.4%
	2003	878,000		1.6					0.49	0.50	0.00	5.6%	2.2%
	2004	1,478,000		2.8					0.53	0.47	0.00	2.1%	0.8%
	2005												
	2006	1,765,000		3.3					0.52	0.48	0.00	1.7%	

Table 12. *Summary of threats to, and rating of effects on recovery and/ or persistence of Atlantic salmon in SFA 16, Gulf Region NB (DFO and MNRF. In prep).*

Potential sources of mortality /harm Permitted and un-permitted activities	Source (with examples)	Proportion of salmon in SFA affected LOW < 5%, MEDIUM 5% to 30%, HIGH > 30%, UNCERTAIN	Cause/ Time Frame Historic (H) Current (C) Potential (P)	Effect on Population (LOW < 5% spawner loss, MEDIUM 5% to 30% spawner loss, HIGH > 30% spawner loss, UNCERTAIN)	Management Alternatives/ Mitigation (relative to existing actions)
Directed Salmon Fishing	Aboriginal	Low	H C	Low	Control harvest through agreements between DFO and First Nations
	Recreational: retention & release	Low	H C	**Low**–1SW retention only	Encourage the use of catch and release measures
	Commercial (domestic)	**Not Applicable –** all commercial fisheries closed			
	High Seas (West Greenland / St. Pierre – Miquelon)	Low	H C	Low	Reductions in internal use fisheries in those areas
	Illegal (poaching)	Low–	H C	**Low –** increased enforce-ment in conjunction with DFO and provincial enforcement officers; increased stewardship initiatives with local groups; changed enforcement strategies for more targeted efforts	Continue use of compliance monitors on selected watersheds, including Aboriginal guardians
	CUMULATIVE EFFECT	LOW – MEDIUM	C	**LOW–MEDIUM**– many initiatives in place in recent years to reduce mortality	.
Bycatch of Salmon in Fisheries for Other Species	Aboriginal	Low	C	**Low**– all bycatch mandatory release	
	Recreational	Low	C	**Low**– all bycatch mandatory release	

Potential sources of mortality /harm Permitted and un-permitted activities	Source (with examples)	Proportion of salmon in SFA affected LOW < 5%, MEDIUM 5% to 30%, HIGH > 30%, UNCERTAIN	Cause/ Time Frame Historic (H) Current (C) Potential (P)	Effect on Population (LOW < 5% spawner loss, MEDIUM 5% to 30% spawner loss, HIGH > 30% spawner loss, UNCERTAIN)	Management Alternatives/ Mitigation (relative to existing actions)
	Commercial near shore	Low	C	**Low**– all bycatch mandatory release	
	Commercial distant	Low	C	Low	None apparent
	CUMULATIVE EFFECT	LOW		LOW	None apparent
Salmon Fisheries Impacts on Salmon Habitat	Aboriginal	Low	H C	Low	None apparent
	Recreational	Low	H C	Low	None apparent
	Commercial	Not Applicable			
	Illegal	Low	H C	Low	None apparent
	CUMULATIVE EFFECT	LOW		LOW	None apparent
Mortality Associated with Water Use	Power generation at dams & tidal facilities (turbine mortalities, entrainment, stranding)	**Low–** very small number of dams	H C	Low	
Habitat Alterations	Municipal waste water treatment facilities	Low – Medium	H C P	**Low – s**ome system inadequate; occasional system failures	Ensure current projects and future developments meet standards
	Pulp & paper mills	Low	H C P	**Low –** pulp and paper mills comply with pulp and paper effluent regulations	
	Hydroelectric power generation (dams & reservoirs, tidal power): altered behavior & ecosystems	Low	H C P	Low	Very low number of facilities
	Water extractions	Low	H C P	Low	Must meet regulations in place; monitoring; develop regional guidelines
	Urbanization (altered hydrology)	Low	H C P	Low	Project redesign; existing regulation - monitoring

Potential sources of mortality /harm Permitted and un-permitted activities	Source (with examples)	Proportion of salmon in SFA affected LOW < 5%, MEDIUM 5% to 30%, HIGH > 30%, UNCERTAIN	Cause/ Time Frame Historic (H) Current (C) Potential (P)	Effect on Population (LOW < 5% spawner loss, MEDIUM 5% to 30% spawner loss, HIGH > 30% spawner loss, UNCERTAIN)	Management Alternatives/ Mitigation (relative to existing actions)
	Infrastructure (roads/culverts) (fish passage)	Medium	H C P	**Medium**– many non compliant culverts	Existing regulations; more monitoring/ enforcement
	Aquaculture siting	Not Applicable			
	Agriculture / Forestry / Mining, etc.	Low– Medium	H C P	**Low –** clear-cutting, sedimentation	Enforcement/ monitoring of existing suite of regulations, compensations where required
	Municipal, provincial & federal dredging	Low	H C P	Low	Follow regulations in place; mitigations and compensations as required; minimize amount
	CUMULATIVE EFFECT	MEDIUM	H C P	MEDIUM	None apparent
Shipping, Transport and Noise	Municipal, provincial, federal & private transport activities (inc. land and water based contaminants/ spills)	Uncertain	H C P	Uncertain	None apparent
Fisheries on Prey of Salmon (for ex. capelin, smelt, shrimp)	Commercial, Recreational, Aboriginal fisheries for species a, b, c etc.	Uncertain	H C P	Uncertain	None apparent
Aquaculture (Salmon and other species)	Escapes from fresh water, marine facilities, disease, parasites, competition, effects on behaviour and migration, genetic introgression	Low	H C P	Low	Fish Health regulations; Introduction and Transfer regulations
Fish culture / stocking (non-commercial, including	Impacts on effective population size, over representation of families, domestication	Low	H C P	Low	Must comply with Introduction and Transfer Guidelines

Potential sources of mortality /harm Permitted and un-permitted activities	Source (with examples)	Proportion of salmon in SFA affected LOW < 5%, MEDIUM 5% to 30%, HIGH > 30%, UNCERTAIN	Cause/ Time Frame Historic (H) Current (C) Potential (P)	Effect on Population (LOW < 5% spawner loss, MEDIUM 5% to 30% spawner loss, HIGH > 30% spawner loss, UNCERTAIN)	Management Alternatives/ Mitigation (relative to existing actions)
private, NGO, government)					
Scientific Research	Government, university, community and Aboriginal groups	Low	C	**Low** – minimal removals for scientific purposes.	None apparent
Military Activities	Field operations, shooting ranges	Not Applcable			
Air Pollutants	Acid rain	Low	H C P	Uncertain	None apparent
UN-PERMITTED					
Introductions of non-native / invasive species	Smallmouth bass, chain pickerel, muskellunge, rainbow trout, invertebrates, plants, algae	**High**- Smallmouth bass were found in Miramichi Lake in October 2008	C P	Uncertain	CSAS conducted risk analysis in Jan 2009 to provide advice to management Contain the invasive species if possible and conduct education programs
International High Seas Targeted	Flags of convenience?	Uncertain	H C P	Uncertain	None apparent
Ecotourism and Recreation	Private Co's & public at large (water crafts, swimming, etc) effects on salmon behaviour & survival	Low	H C P	Low	Increase enforcement activities Conduct education programs
Ecosystem change	Climate change, changes in relative predator / prey abundances, disease	Low–Uncertain	C P	**Low– Uncertain –** some rivers in this area are moderately impacted by low water levels and warm water temperatures; affect on salmon populations is unknown	None apparent

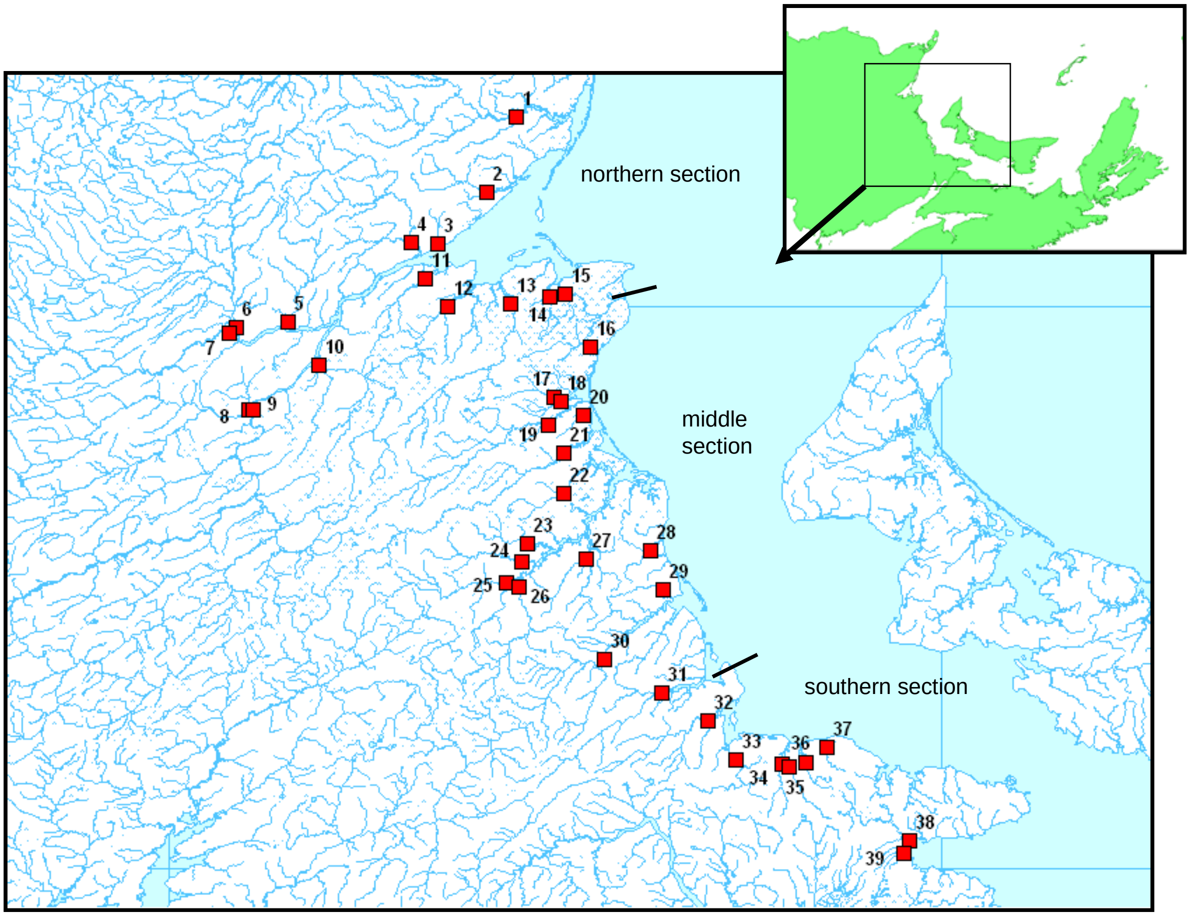

Figure 1. *Rivers within Salmon Fishing Area 16 of the southern Gulf of St. Lawrence. Index numbers refer to rivers in Table 1.*

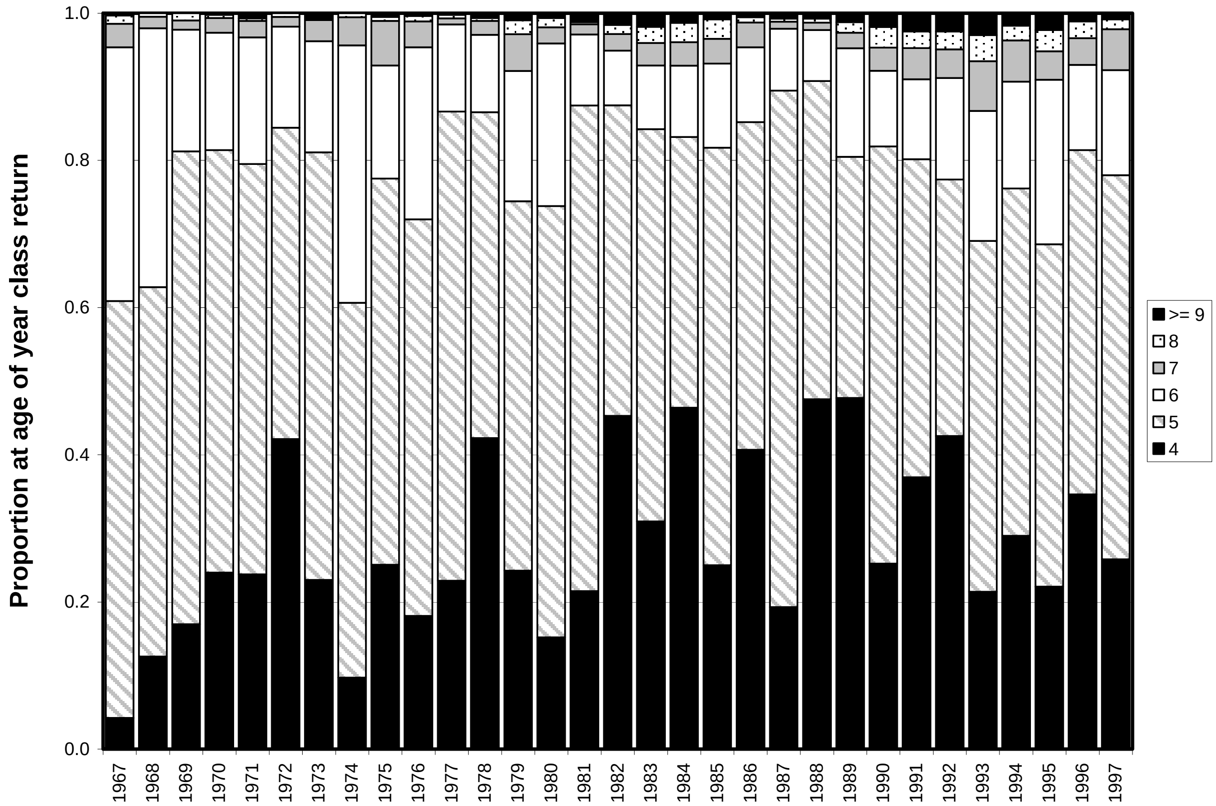

Figure 2. *Proportion at total age (river age plus sea age plus one for egg deposition year) of returns of Atlantic salmon by year class (year of spawning) from the Miramichi River. Abundance at age by year class is estimated from the returns by small and large salmon, proportion at age within the returns by size group, adjusted to year class based on total age. Only complete year classes are shown.*

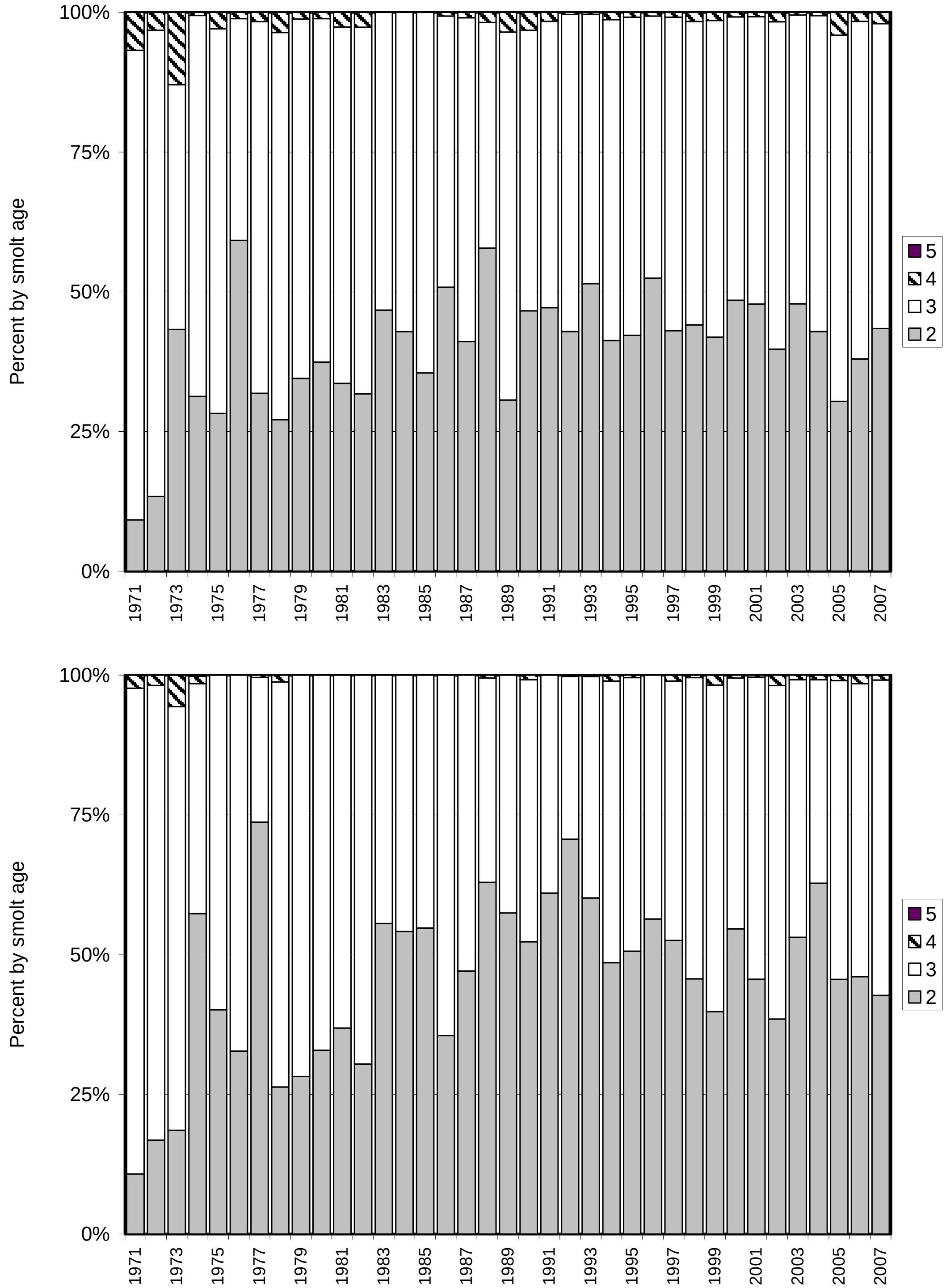

Figure 3. *Percent at smolt age in samples of 1SW (upper panel) and 2SW (lower panel) maiden salmon from the Miramichi River, by year of adult return, 1971 to 2007.*

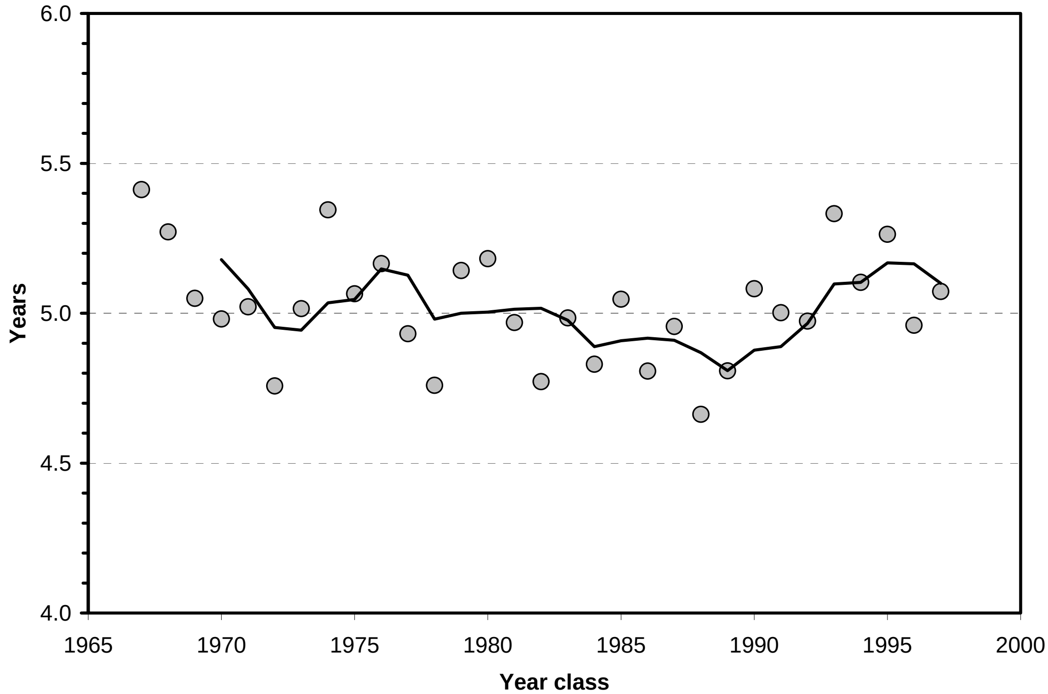

Figure 4. *Mean generation time (years; mean age of salmon returns from a year class, including repeat spawners) by year class of Atlantic salmon from the Miramichi River.*

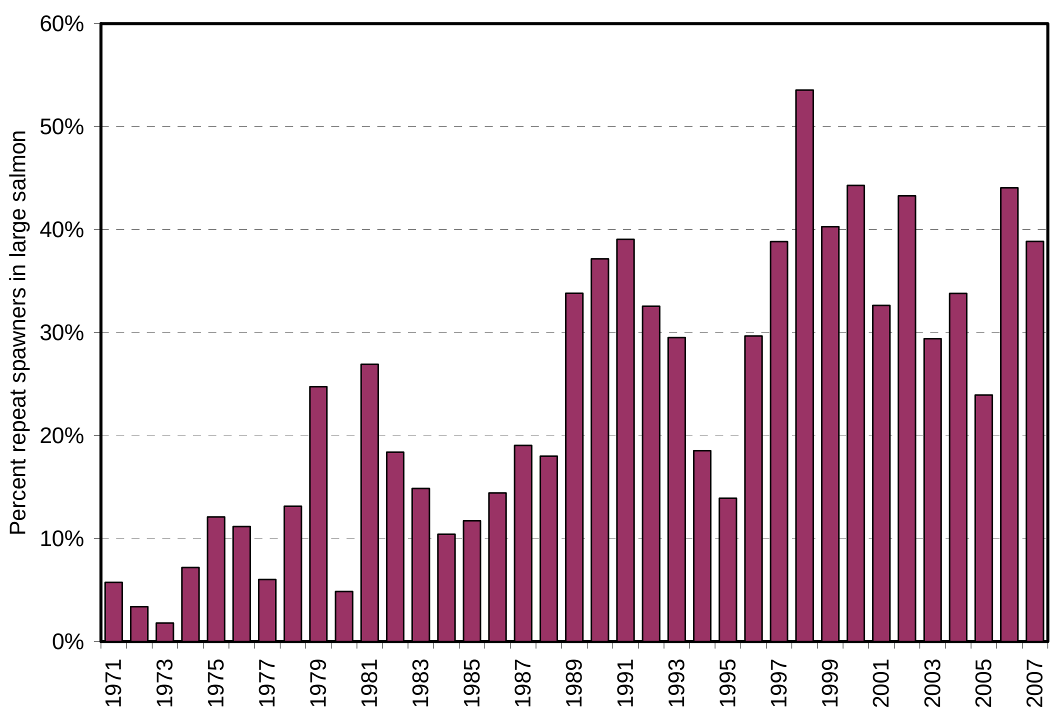

Figure 5. *Changes in relative abundance (percent) of repeat spawners in the returns of large salmon (>= 63 cm fork length) to the Miramichi River, 1971 to 2007.*

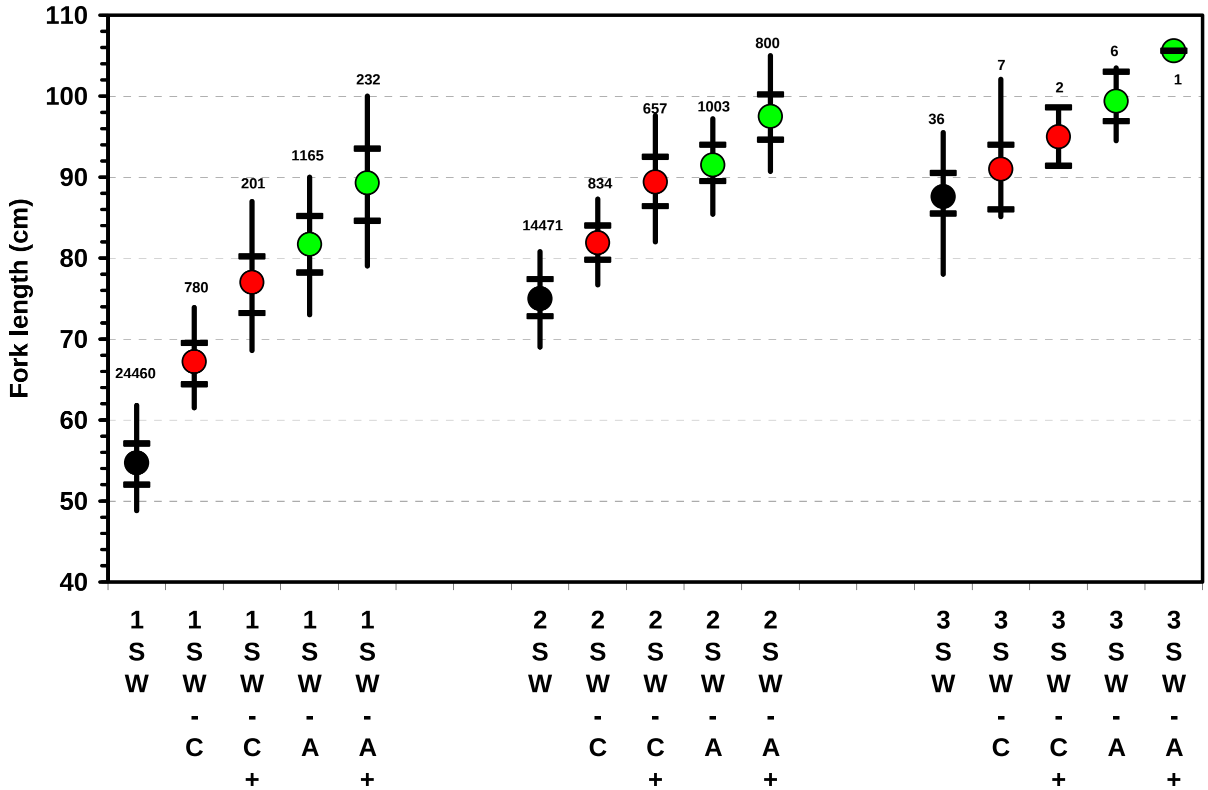

Figure 6. *Fork length (cm) by sea age history of Atlantic salmon from the Miramichi River, 1971 to 2006. The bullet is the median, horizontal hatches are interquartile range, and vertical bars are the 95% confidence interval range. The number above the plots is the sample size. Sea age histories are interpreted as follows: 1, 2, and 3 is sea age of respective maiden first time spawners; -C are consecutive second time spawners; -C+ are repeat spawners on a third or greater spawning migration which returned to a second spawning as consecutives; -A are alternate second time spawners; -A+ are repeat spawners on a third or greater spawning migration which returned to a second spawning as alternates. A consecutive spawner is a fish which returned to the river to spawn within the same year as it left the river in the spring as a kelt. An alternate spawner is a fish which spent more than twelve months at sea before returning to spawn after having left the river in the spring as a kelt.*

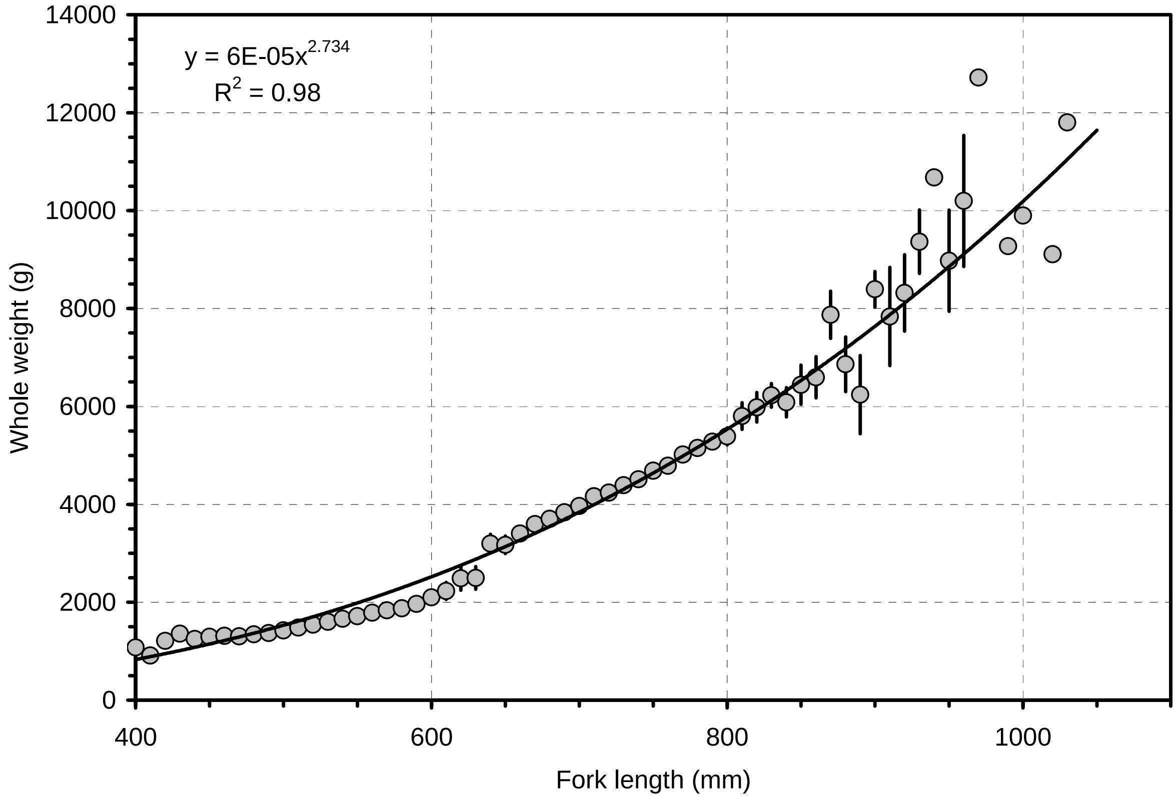

Figure 7. *Whole weight (g) to fork length (mm) relationship for adult Atlantic salmon from the Miramichi River. Means and two standard error ranges are shown. Data are based on samples from the estuarine trapnets for the period 1971 to 2007.*

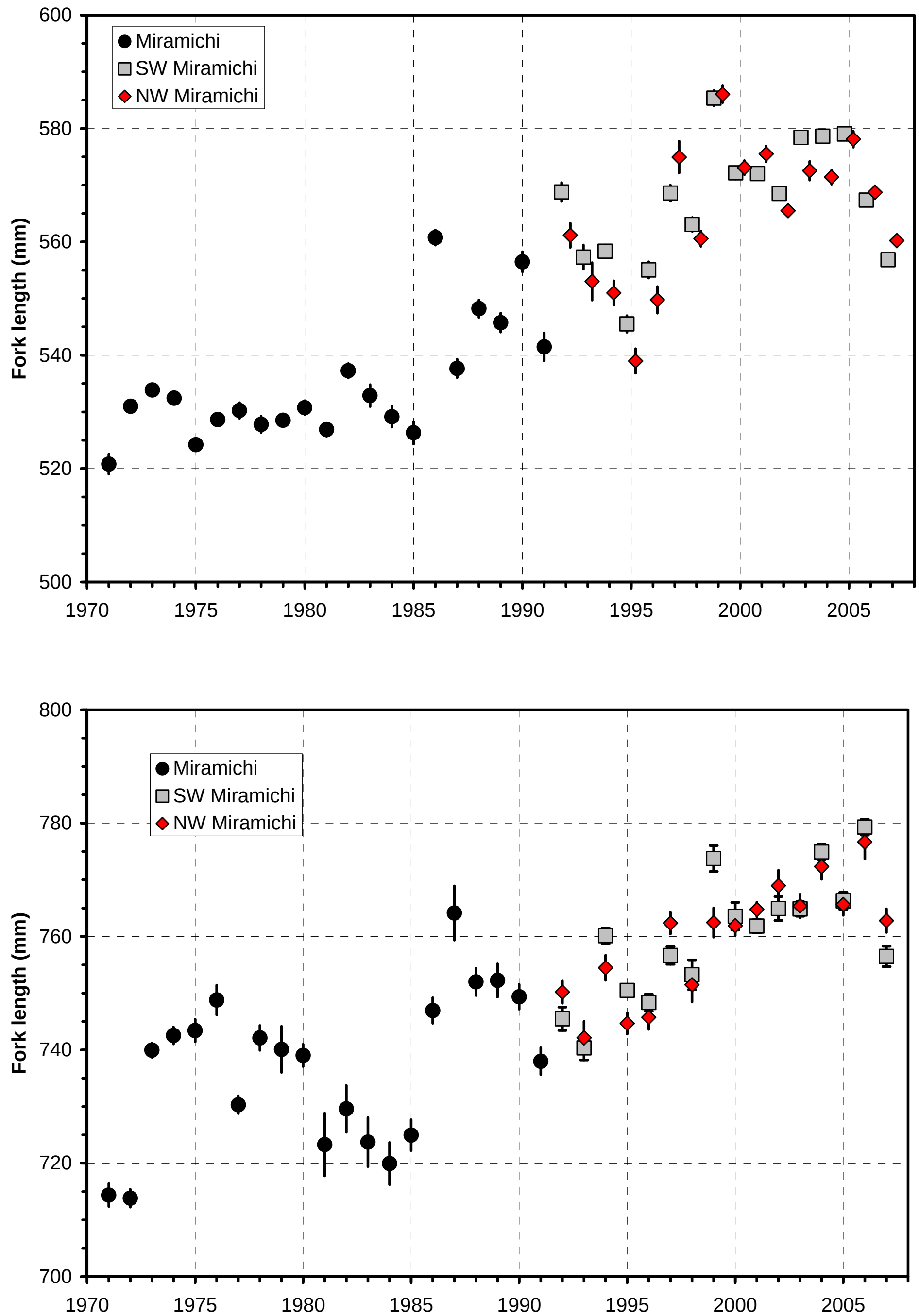

Figure 8. *Mean fork length (mm) (+/- 1 standard error) of one-sea-winter (1SW) (upper panel) and two-sea-winter (2SW) (lower panel) salmon from the Miramichi River, 1971 to 2007. Data are from fish sampled in May to August.*

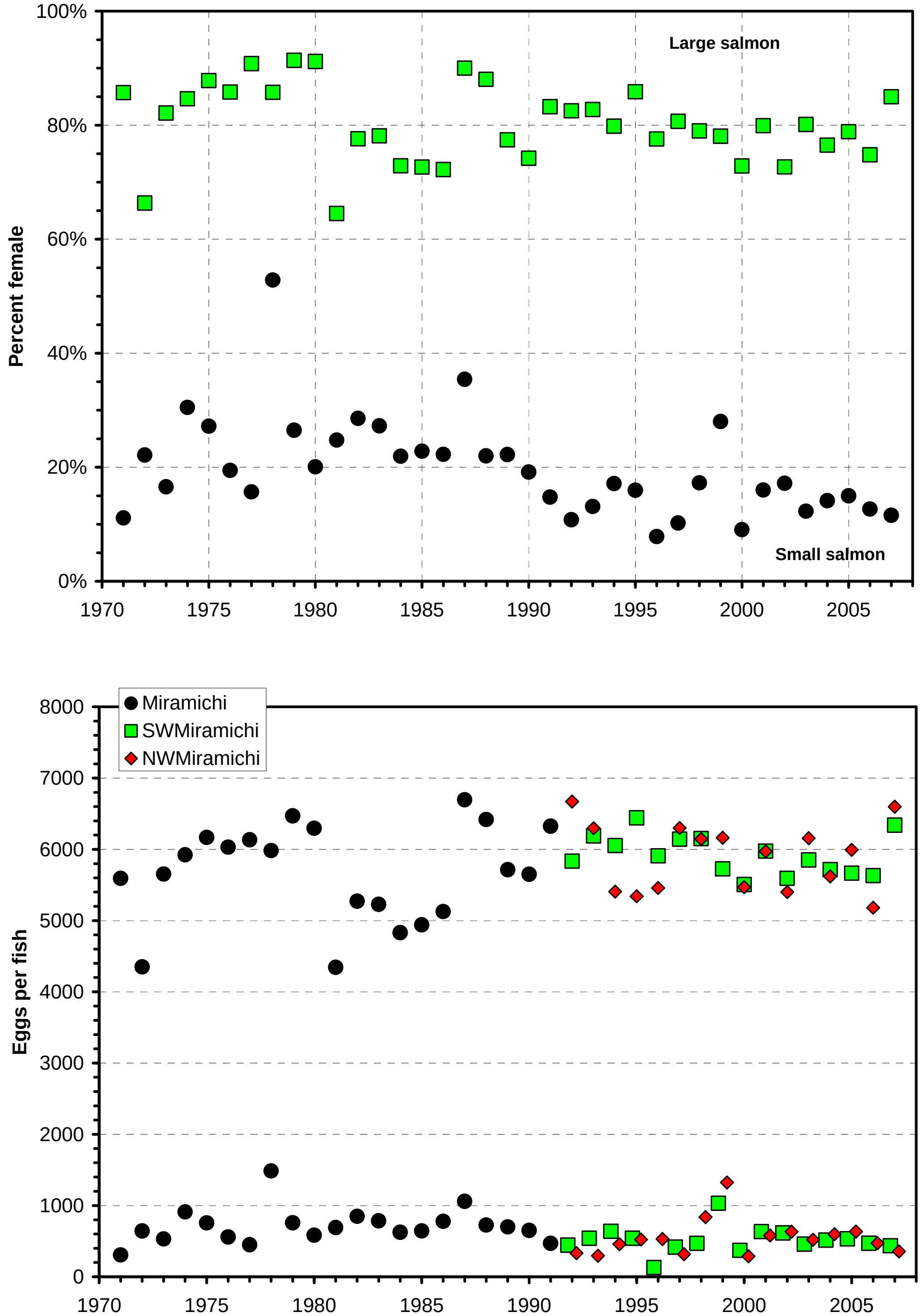

Figure 9. *Mean length (mm; upper panel) and mean eggs per fish (lower panel) of salmon by size group (small < 63 cm fork length; large >= 63 cm fork length) from the Miramichi River, 1971 to 2007. Eggs per fish are calculated using the mean length and the length to fecundity relationship of Randall (1989).*

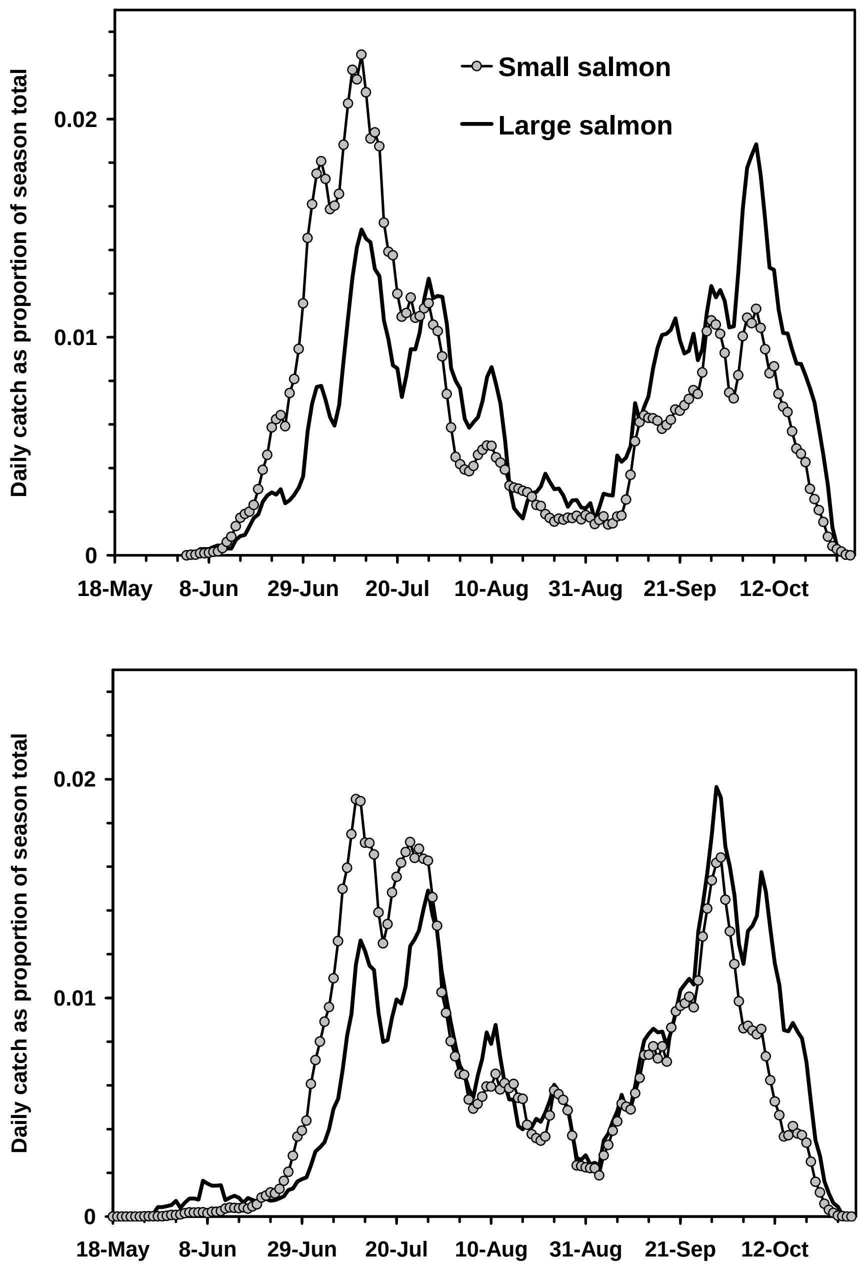

Figure 10. *Timing of catches at estuarine trapnets in the Northwest Miramichi (upper) and the Southwest Miramichi (lower). Plots are mean proportions of the total annual catch for the years 1998 to 2004.*

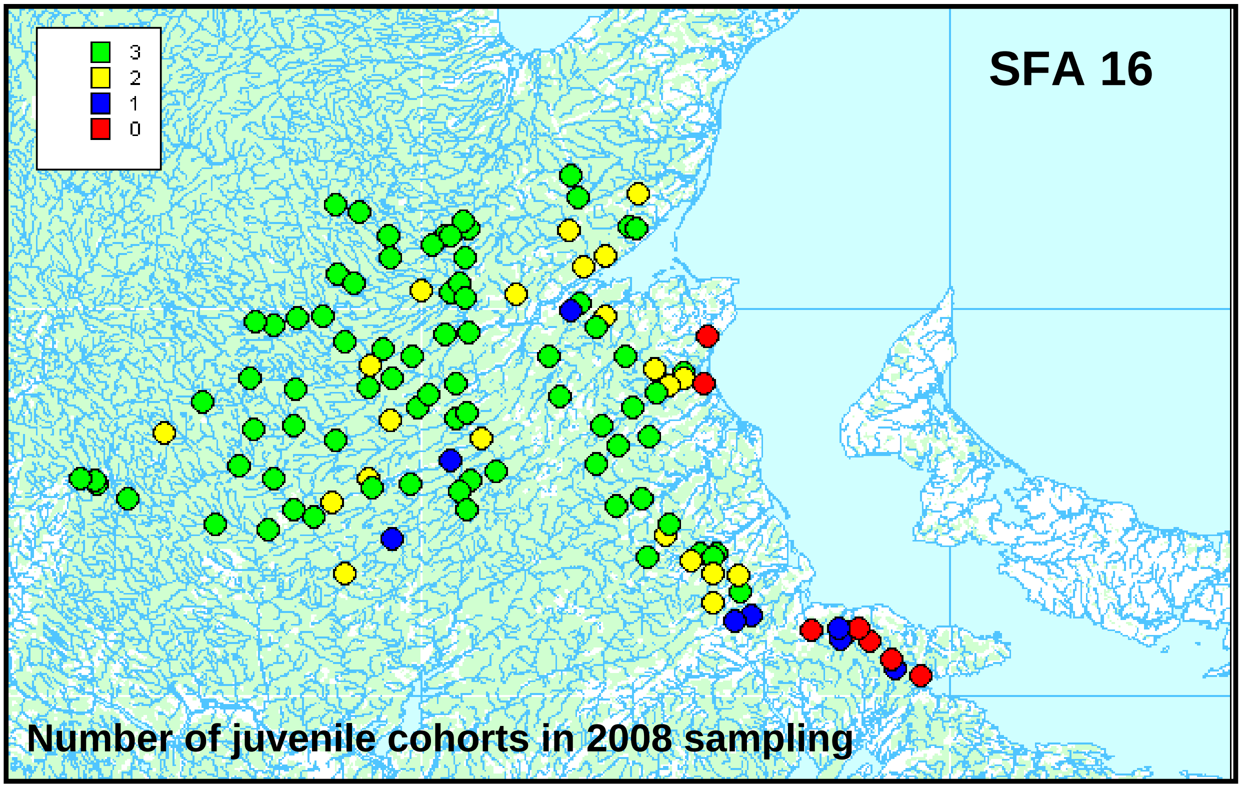

Figure 11. *Site specific presence/absence and number of cohorts (year classes) of juvenile Atlantic salmon present at sites in rivers of SFA 16 in 2008. The coloured symbols refer to the number of cohorts (fry, small parr ~ age-1, large parr ~ age 2+) observed at each site.*

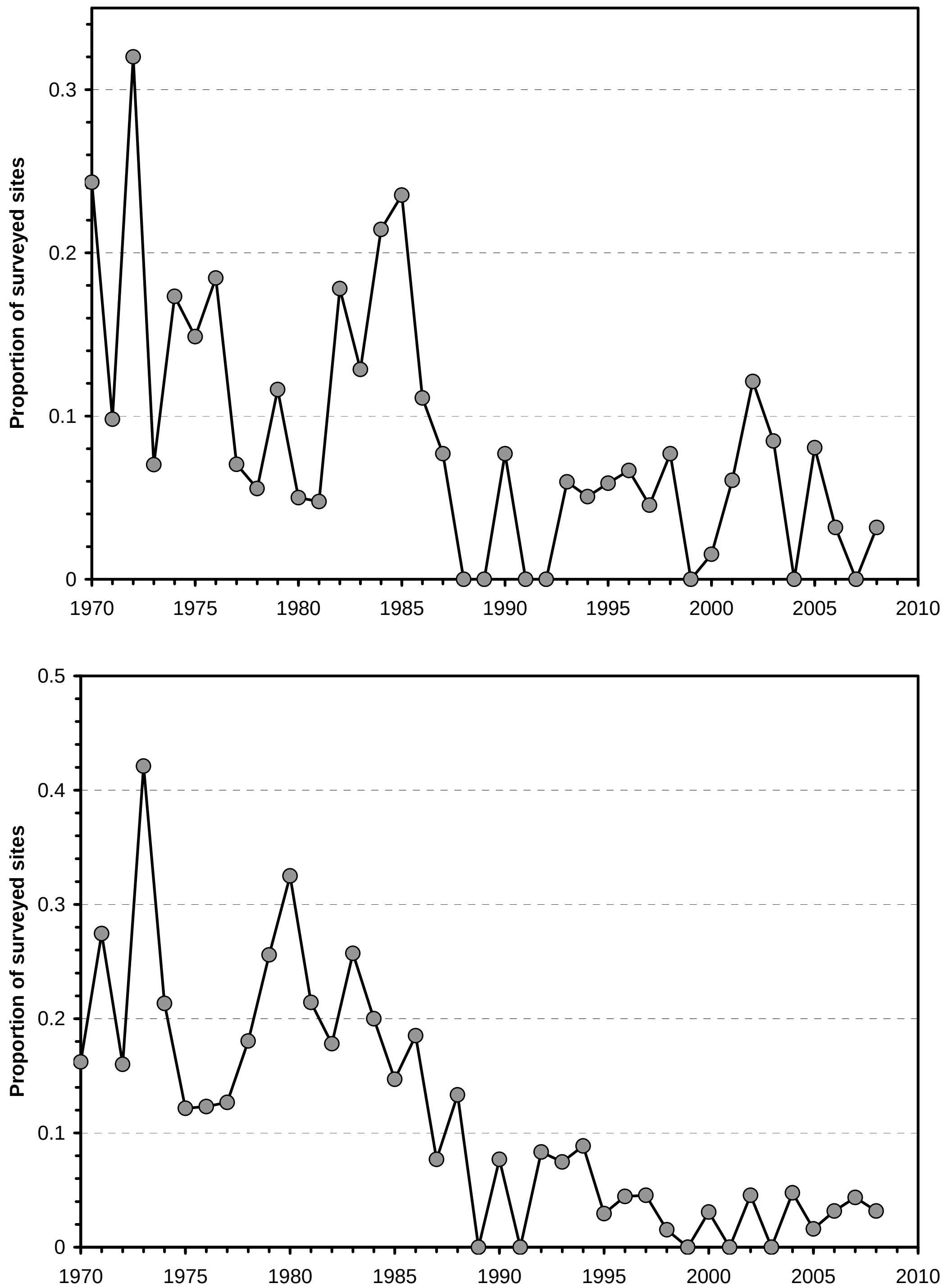

Figure 12. *Time series of the proportions of surveyed sites with Atlantic salmon juvenile abundances of less than 1 fish per 100 m*^{2} *for fry (upper) and parr (lower) in the Miramichi River, 1970 to 2008.*

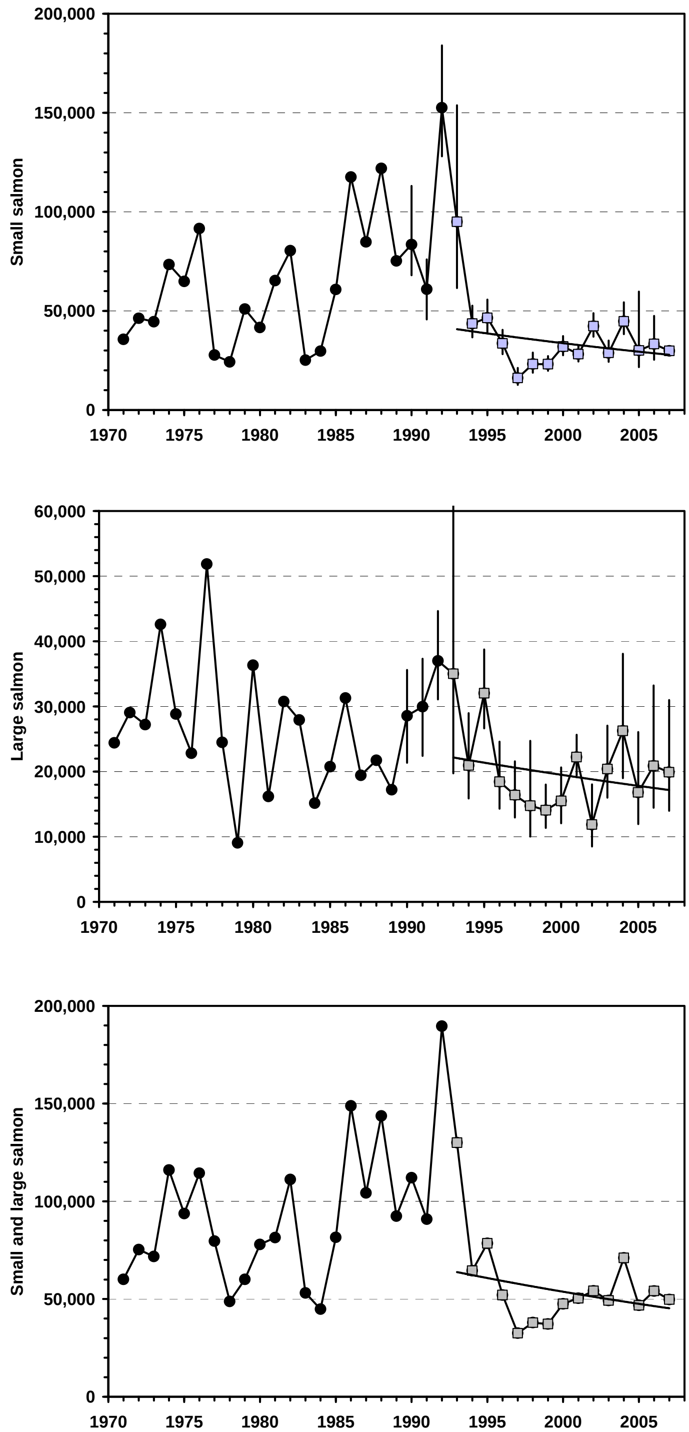

Figure 13. *Estimates of returns of small salmon (upper), large salmon (middle) and size groups combined (lower) to the Miramichi River, 1971 to 2007. Trend line (over the years with the square symbols with grey shading) is an exponential function for the most recent 15 years (1993 to 2007).*

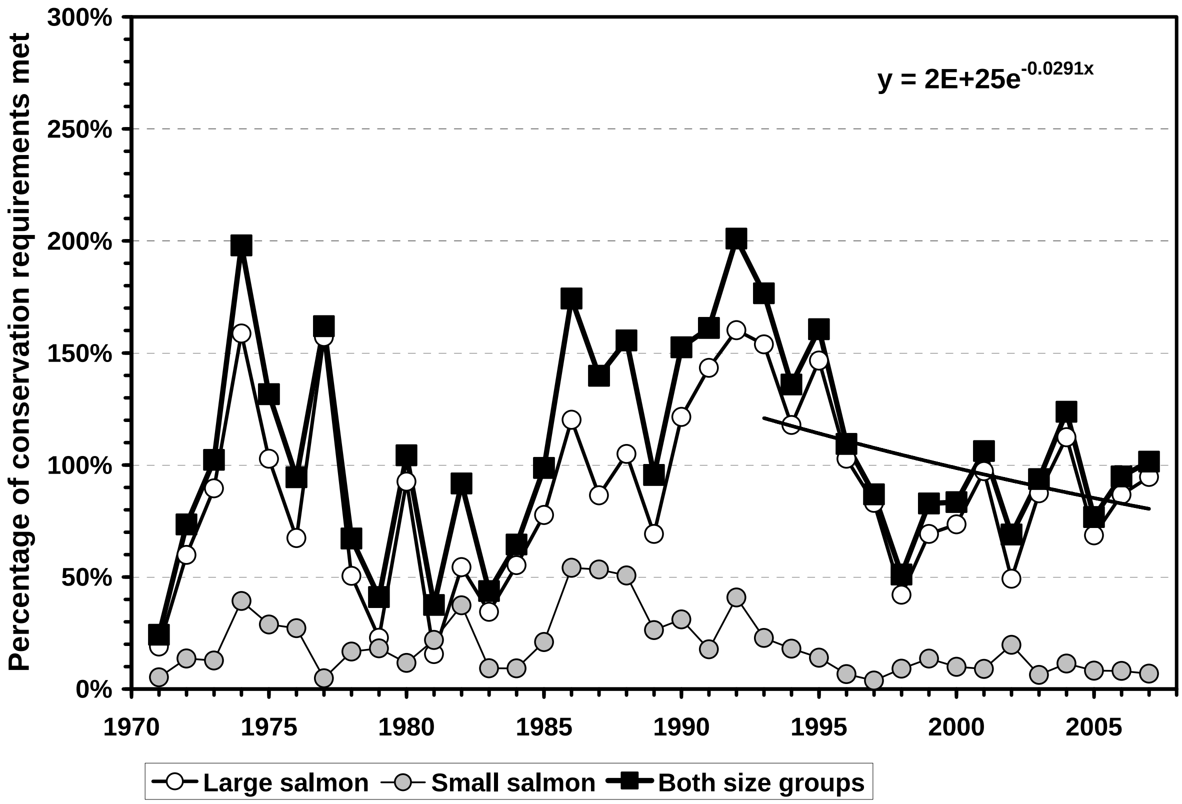

Figure 14. *Estimates of egg depositions relative to conservation requirement in the escapement of Atlantic salmon to the Miramichi River, 1971 to 2007. Trend line is shown for the period 1993 to 2007.*

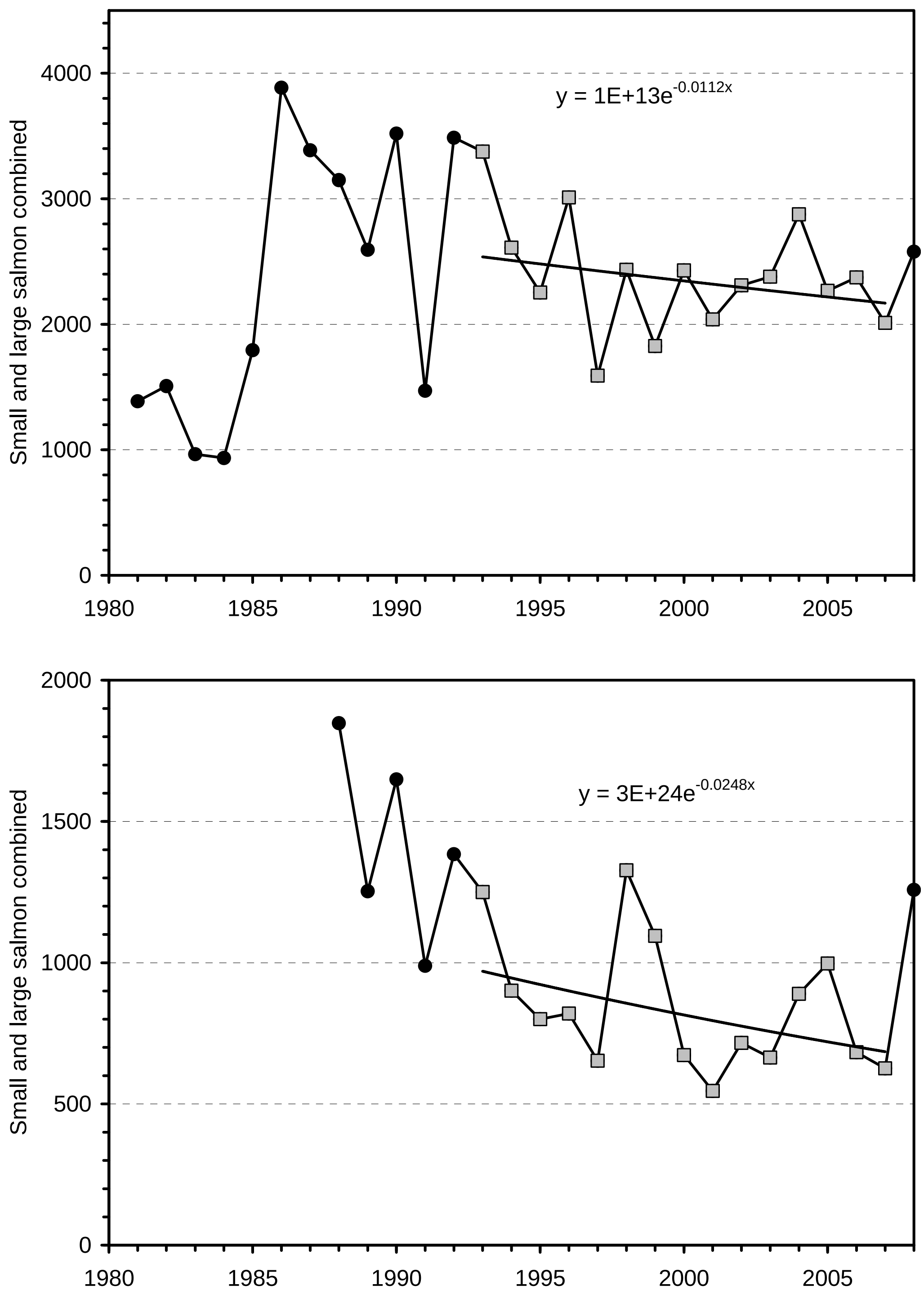

Figure 15. *Counts of salmon (size groups combined) at the two headwater barriers in the Southwest Miramichi (upper) and at the single headwater barrier in the Northwest Miramichi (lower). The trend line is for the years 1993 to 2007 (square symbols with grey shading).*

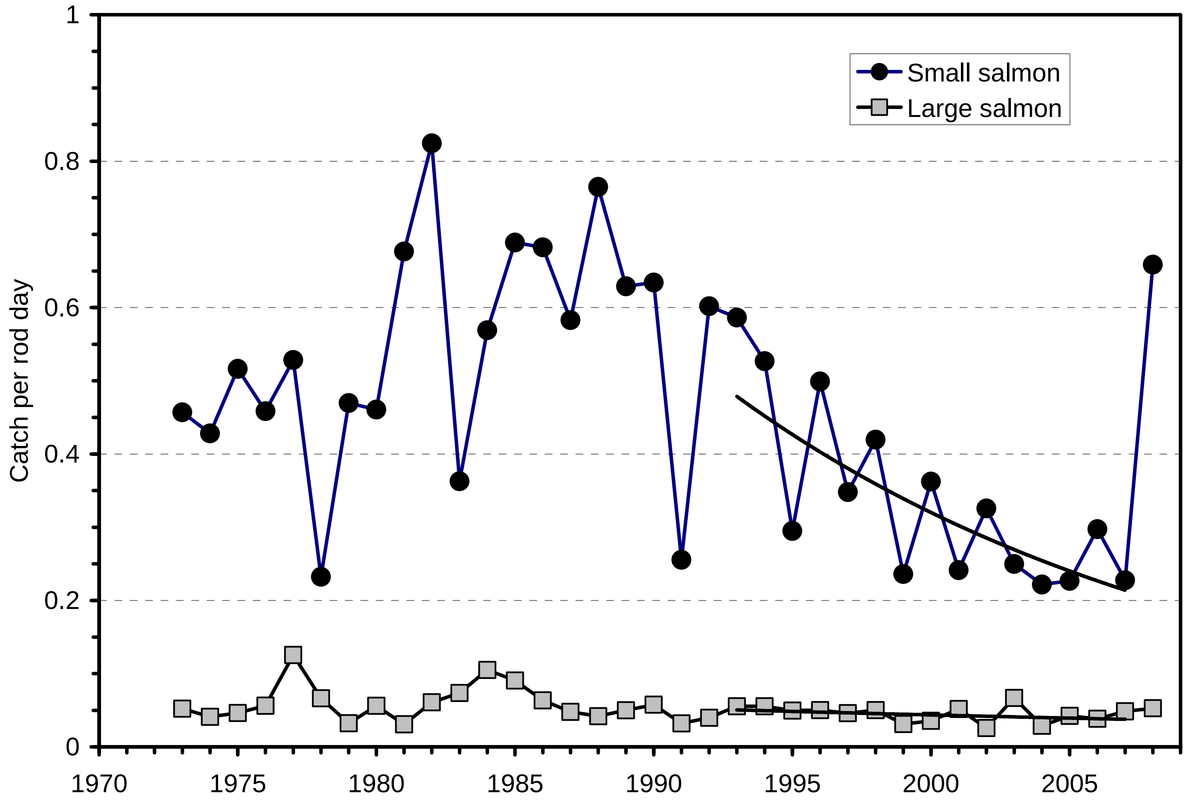

Figure 16. *Catch per unit effort (rod day) for large salmon and small salmon in the Crown Reserve angling waters of the Northwest Miramichi, 1973-2008. Trend lines are shown for 1993 to 2007.*

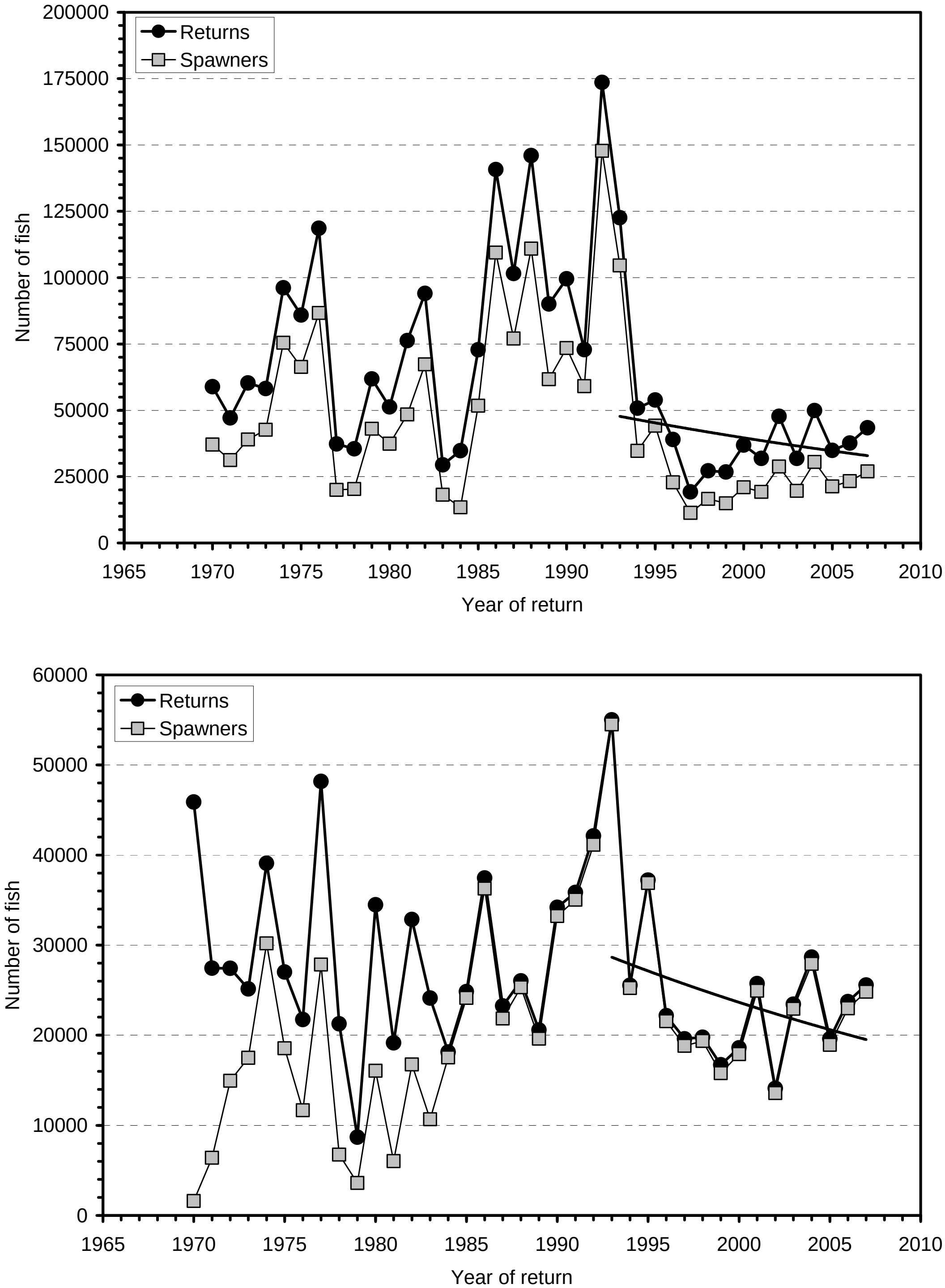

Figure 17. *Estimated abundance (number of fish; returns, spawners) of small salmon (upper) and large salmon (lower) to SFA 16, 1970 to 2007. Trend lines are shown for returns for the period 1993 to 2007.*

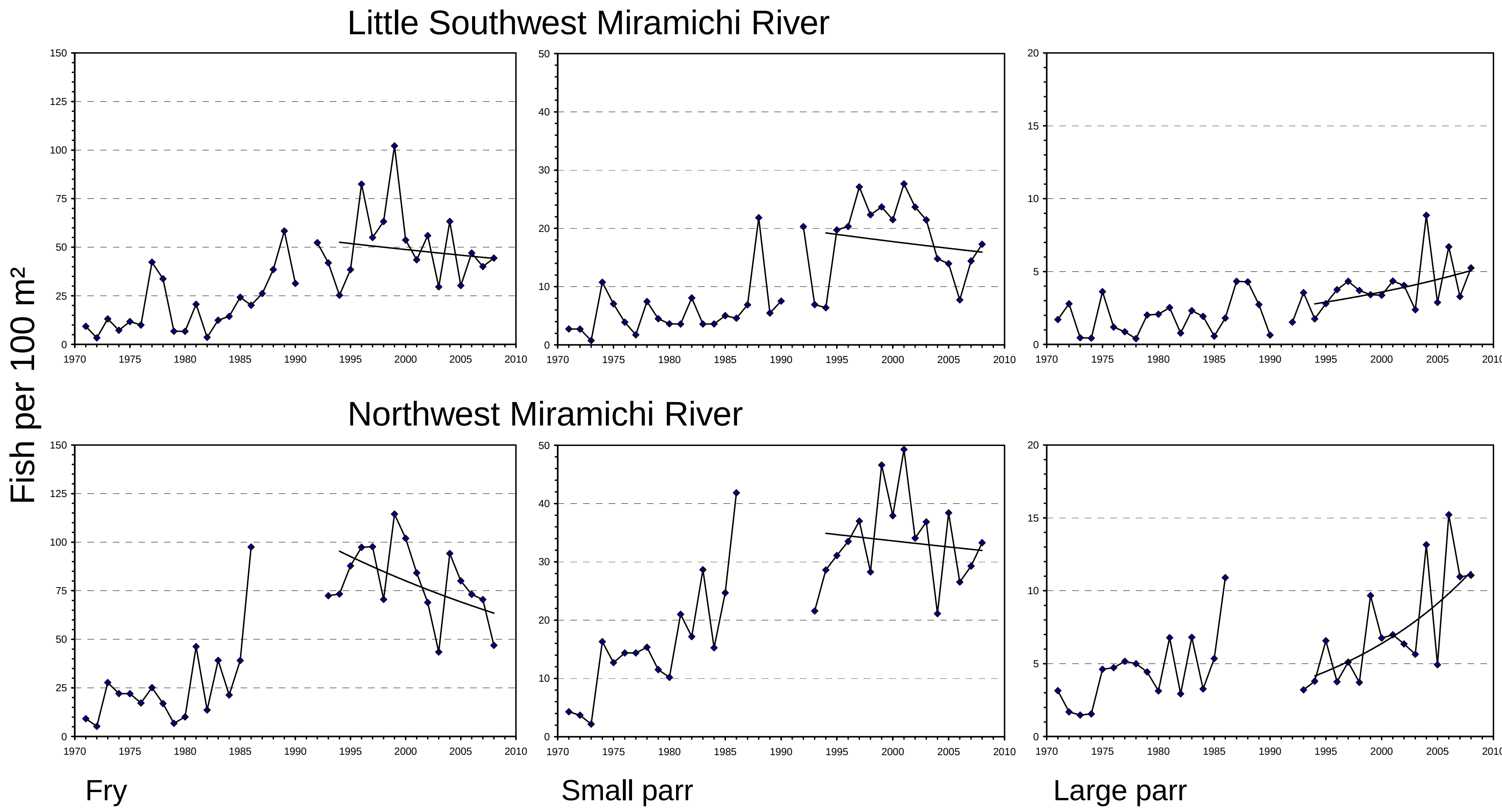

Figure 18. *Indices of abundance (average density, fish per 100 m²) of juvenile salmon by age/size groups in the Little Southwest Miramichi (upper panels) and the Northwest Miramichi rivers (lower panels), 1970 to 2008. Only years in which at least 3 sites per river were surveyed are included. The exponential trend line is for the years 1994 to 2008.*

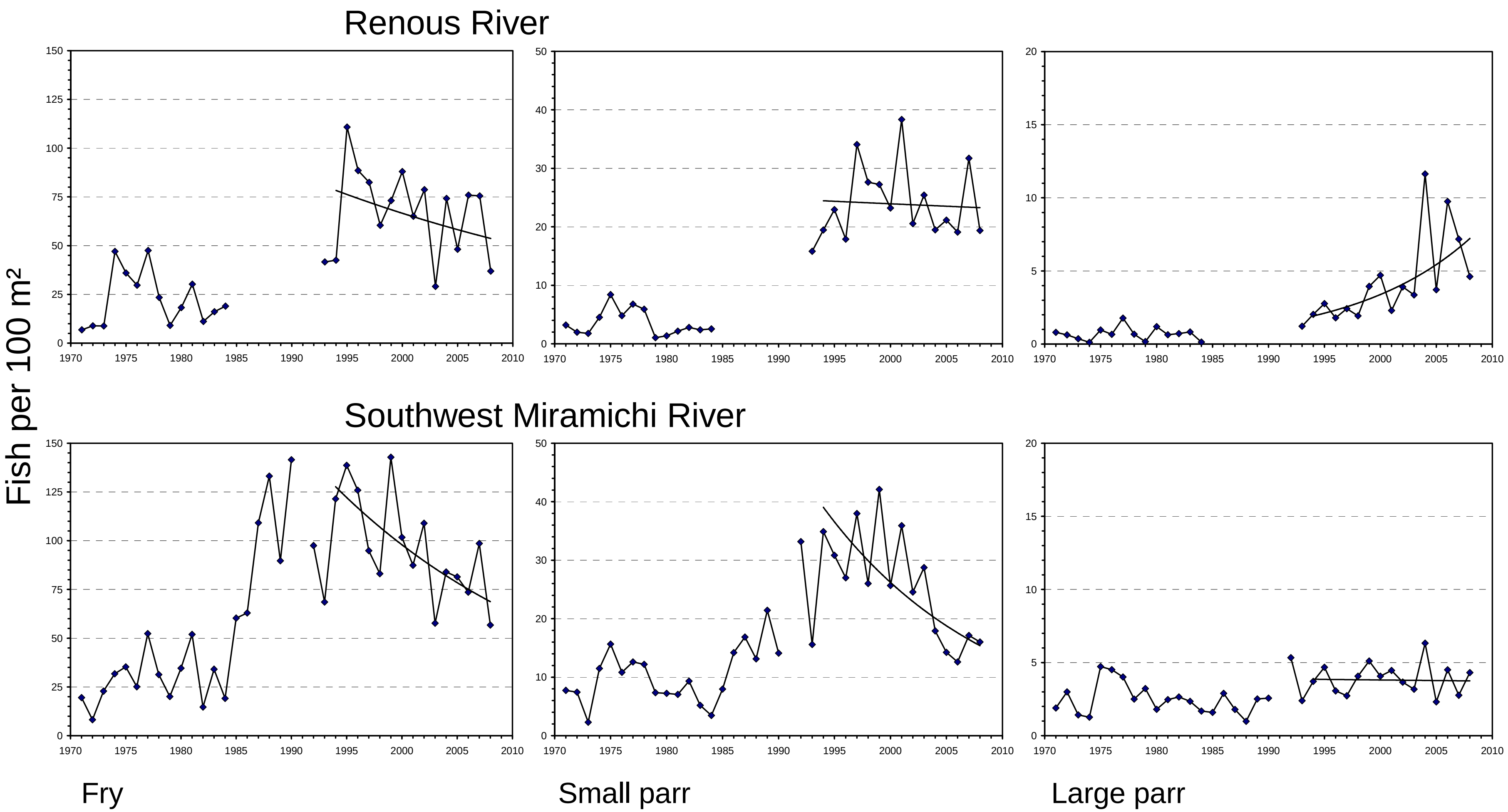

Figure 19. *Indices of abundance (average density, fish per 100 m²) of juvenile salmon by age/size groups in the Renous (upper panels) and the Southwest Miramichi rivers (lower panels), 1970 to 2008. Only years in which at least 3 sites per river were surveyed are included. The exponential trend line is for the years 1994 to 2008.*

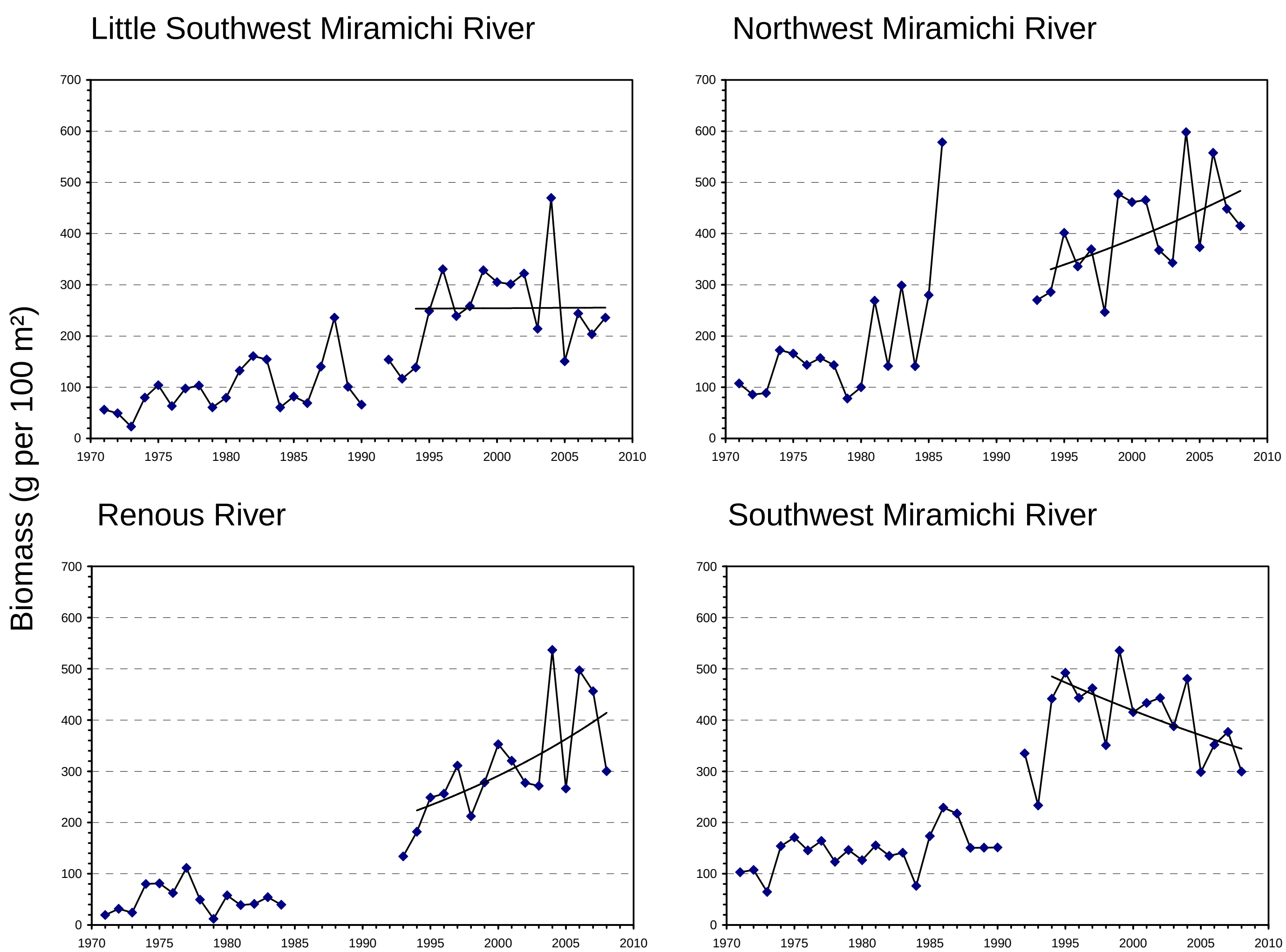

Figure 20. *Total juvenile salmon biomass (average, grams per 100 m²) in the four major rivers of the Miramichi watershed, 1970 to 2008. Only years in which at least 3 sites per river were surveyed are included. The exponential trend line is for the years 1994 to 2008.*

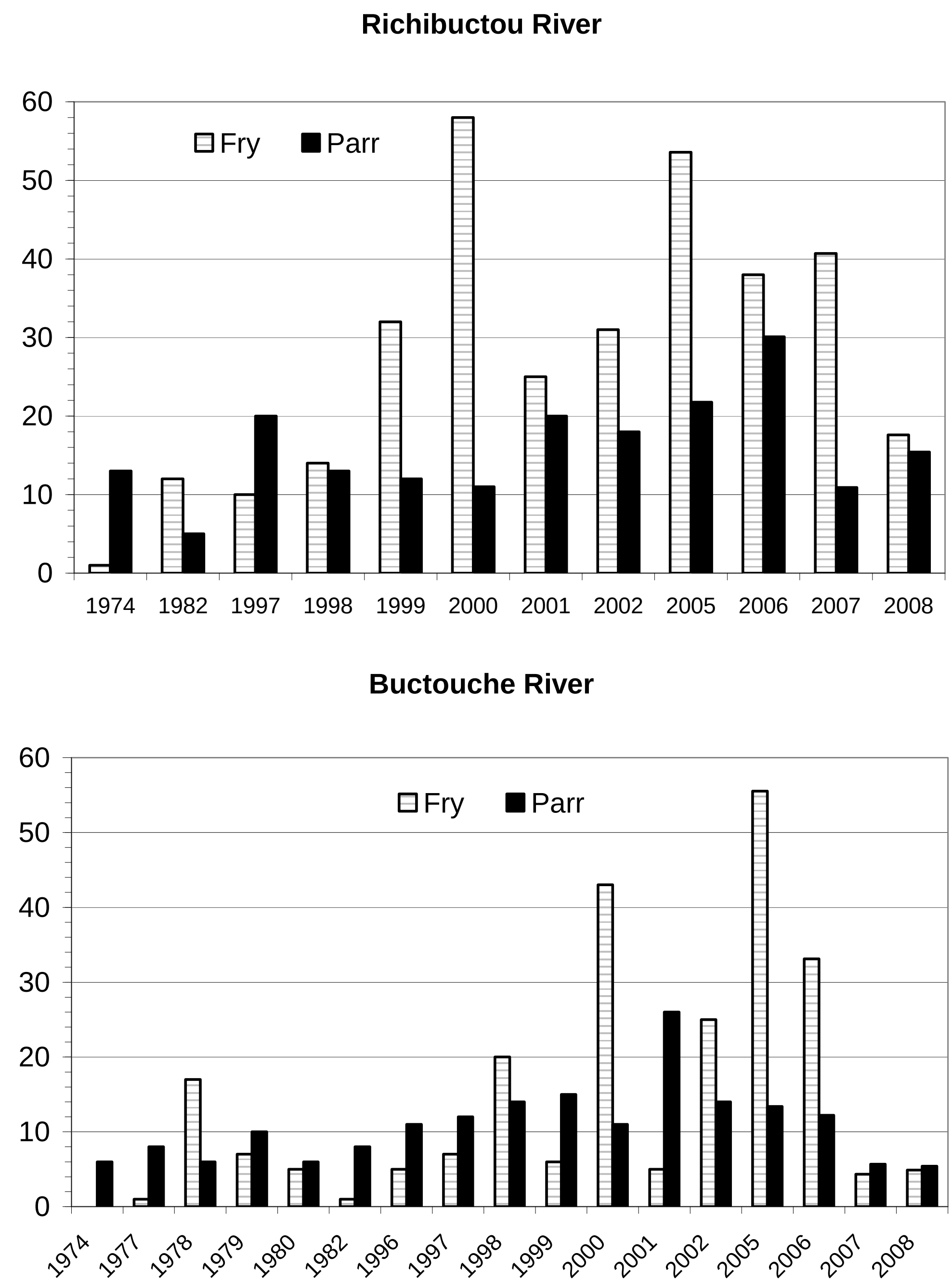

Figure 21. *Juvenile abundance (average density, fish per 100 m²) by age/size groups in the two largest rivers of southeastern New Brunswick.*

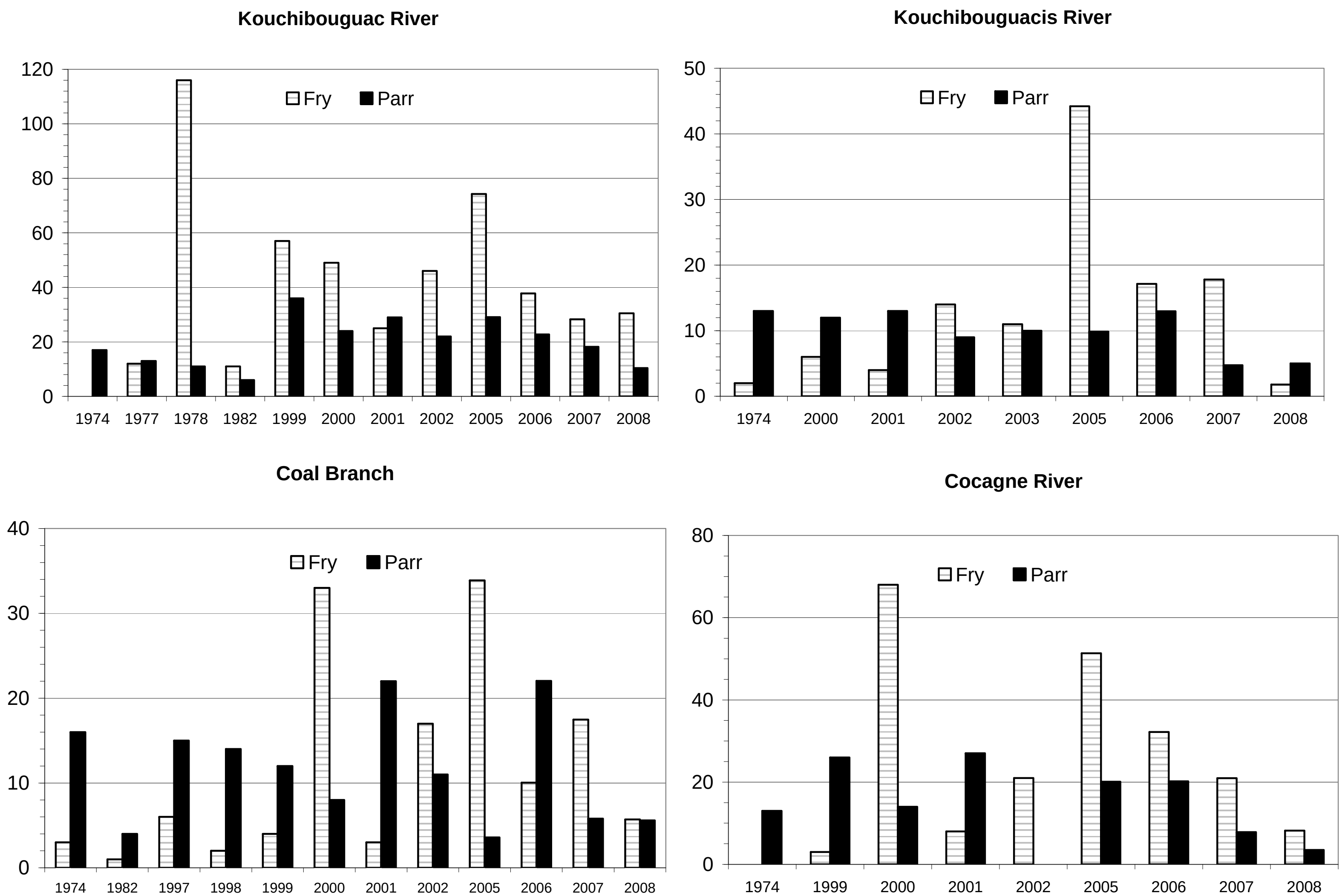

Figure 22. *Indices of abundance (average density, fish per 100 m²) of juvenile salmon by age/size groups in four of the smaller rivers of southeastern New Brunswick, for years between 1974 and 2008 when surveys were conducted.*

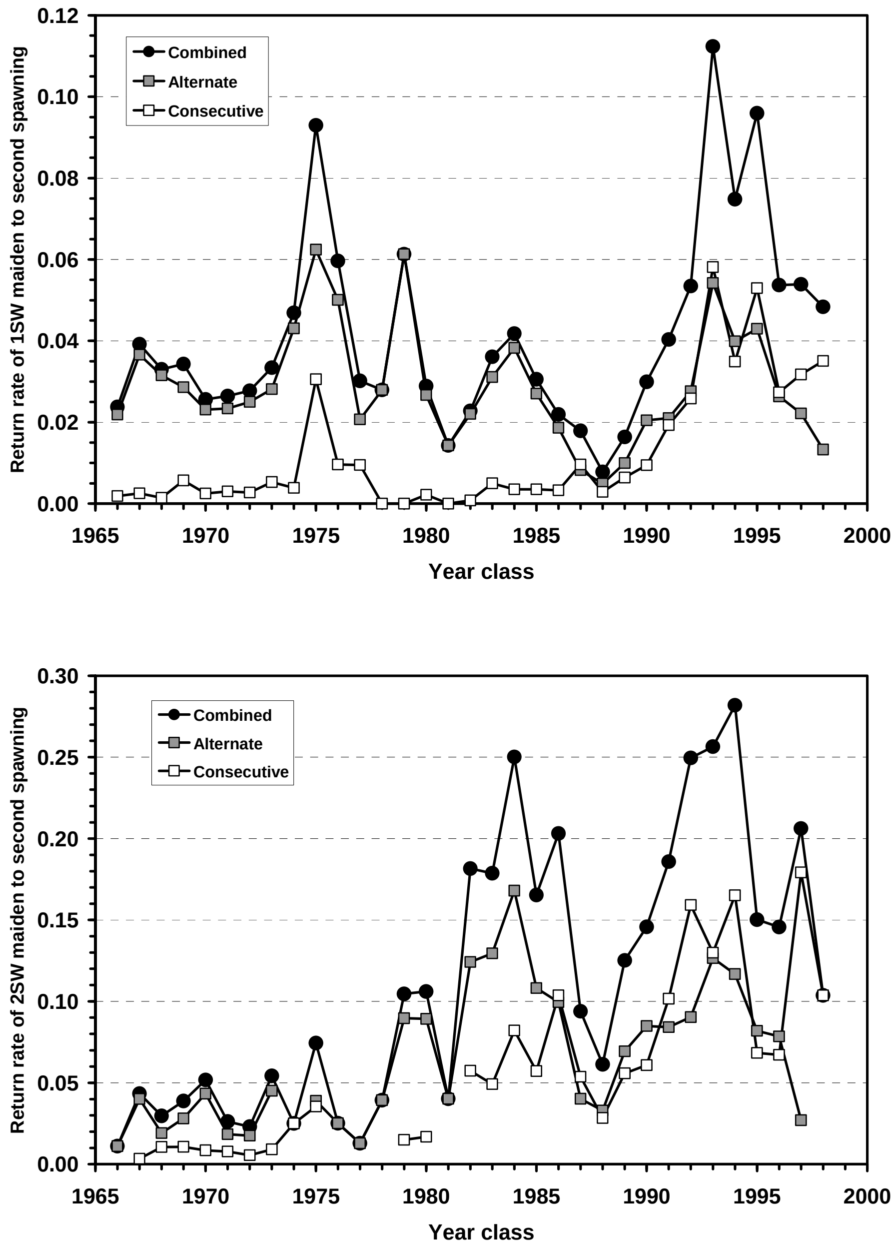

Figure 23. *Return rates to a second spawning of 1SW maiden (upper) and 2SW maiden (lower) salmon in the Miramichi River.*