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Stock status summary for Atlantic salmon from Newfoundland and Labrador

Résumé de l'état des stocks de saumon atlantique de Terre-Neuve-et-Labrador

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Foreword

This document is a product from a workshop that was not conducted under the Department of Fisheries Oceans (DFO) Science Advisory Process coordinated by the Canadian Science Advisory Secretariat (CSAS). However, it is being documented in the CSAS Research Document series as it presents some key scientific information related to the advisory process. It is one of a number of contributions first tabled at a DFO-SARCEP (Species at Risk Committee / *Comité sur les espèces en péril*) sponsored workshop in Moncton (February 2006) to begin the development of a 'Conservation Status Report' (CSR) for Atlantic salmon. When completed in 2007, the CSR could form the basis for a Committee on the Status of Endangered Wildlife in Canada (COSEWIC) status report, recovery potential assessment and recovery strategy, and most importantly, enable DFO to implement pre-emptive management measures prior to engagement in any listing process.

Avant-Propos

Le présent document est issu d'un atelier qui ne faisait pas partie du processus consultatif scientifique du ministère des Pêches et des Océans, coordonné par le Secrétariat canadien de consultation scientifique (SCCS). Cependant, il est intégré à la collection de documents de recherche du SCCS car il présente certains renseignements scientifiques clés, liés au processus consultatif. Il fait partie des nombreuses contributions présentées au départ lors d'un atelier parrainé par le MPO-SARCEP (*Species at Risk Committee* / Comité sur les espèces en péril) à Moncton (février 2006) en vue de commencer l'élaboration d'un rapport sur la situation de la conservation du saumon atlantique. Lorsqu'il sera terminé, en 2007, ce rapport pourrait servir de base à un rapport de situation du Comité sur la situation des espèces en péril au Canada (COSEPAC), à une évaluation du potentiel de rétablissement et à un programme de rétablissement mais, avant tout, il permettra au MPO de mettre en œuvre des mesures de gestion anticipées avant même de s'engager dans un processus d'inscription.

Abstract

The status of Atlantic salmon (*Salmo salar*) stocks in Newfoundland and Labrador is summarized focusing on longer term perspectives rather that the status of populations relative to events associated with the most recent year. Despite sporadic signs of improved salmon returns to some rivers in some years, for many populations total stock size is no higher now that it was prior to the closure of the Newfoundland commercial salmon fishery in 1992. Immediate improvements in spawning escapements during the first five years of the moratorium (1992-1996) to various Northeast and Northwest coast rivers did not result in any new productivity. Indeed, the number of recruits per spawner, used as an index of stock productivity, declined to levels where some populations were not replacing themselves. One region of particular concern is the South coast where the greatest declines in returns of both small and large salmon have occurred by comparison with their peak abundnaces. Trends in smolt production as well as freshwater and marine survival are also discussed.

Résumé

L’état des stocks de saumon atlantique (*Salmo salar*) à Terre-neuve-et-Labrador sont résumés en mettant l’accent sur les perspectives à long terme, plutôt que sur l’état des populations par rapport aux événements liés à l’année la plus récente. Malgré quelques signes sporadiques d’amélioration des retours de saumons dans certains cours d’eau au cours de certaines années, pour de nombreuses populations, l’effectif total du stock n’est pas plus important maintenant qu’avant la fermeture de la pêche commerciale du saumon à Terre-Neuve en 1992. Des améliorations immédiates des remontes de géniteurs ont suivi le moratoire, pendant les cinq premières années (1992-1996), dans diverses rivières des côtes nord-est et nord-ouest, mais elles n’ont pas entraîné de productivité nouvelle. De fait, le nombre de recrues par géniteur, qui sert d’indice de productivité du stock, a diminué au point où certaines populations ne se renouvellent pas elles-mêmes. La côte sud est une région particulièrement préoccupante, car c’est là que se sont produites les plus fortes baisses de retours, aussi bien de petits que de gros saumons, par rapport à leur sommet d’abondance. Le document aborde aussi les tendances de la production de saumoneaux, de même que le taux de survie de ceux-ci, en eau douce et en mer.

Introduction

As summarized recently by Klemetsen et al. (2003), Potter et al. (2003), Dempson et al. (2004a), and Niemelä et al. (2004), populations of Atlantic salmon (*Salmo salar*) in many areas of the north Atlantic are either in a state of decline or now extirpated such that concern over the continued survival of the species has been given more attention in recent years (Parrish et al. 1998; Potter and Crozier 2000; Hutchinson et al. 2002). Other stocks, while stable, have shown little or no improvement. In the past, high rates of exploitation in ocean fisheries were often associated with many stock declines and seen as a serious threat to the future conservation of salmon (Mills 1993, 2000). Marine exploitation rates ranged from 70 to 90% on multi-sea-winter (MSW) components, while one-sea-winter (1SW) stocks were harvested at 40 to 60% (e.g. Hansen 1988, 1990; Crozier and Kennedy 1994; Dempson et al. 2001a). Consequently, management measures were often introduced to reduce and later eliminate much of the directed ocean exploitation on salmon. Yet, Atlantic salmon abundance continues to decline in many areas, including some stocks in Newfoundland, despite the absence of, or great reduction in ocean fisheries (Ritter 1993; Parrish et al. 1998; Friedland et al. 2003; Dempson et al. 2004a).

Definitive reasons for the decline in salmon abundance remain unknown but are likely many and varied (e.g. Parrish et al. 1998; Cairns 2001; Jonsson and Jonsson 2004). Whether factors include, either in whole or in part, predation (e.g. Amiro 1998; Montevecchi et al. 2002; Middlemas et al. 2003), changes in ocean climate (e.g. Friedland et al. 1998; Drinkwater 2000; Jonsson and Jonsson 2004), impacts of escaped aquaculture salmonids (e.g. Hutchinson 1997 and papers therein), endocrine disrupting compounds or other chemical pollution (e.g. Zitko 1995; Fairchild et al. 1999), or the numerous factors that can affect processes in freshwater (e.g. Gibson 2002) or at sea, to name but a few, our ability to understand and predict fluctuations in abundance and survival remains challenged. One certainty, however, is that concern over the state of the resource has a long history. For example, in 1881, Kennedy wrote that salmon fishing in Newfoundland was a pronounced failure because,

> "*almost the whole of the noble salmon rivers are ruined, either by barring, sweeping with nets, traps, weirs or mill-dams in defiance of all laws and proclamations; so that very few salmon are able to ascend the rivers*" (Kennedy 1881).

More than 100 years later, five years into the Newfoundland commercial salmon fishery moratorium and following lower than expected returns to most rivers in Atlantic Canada in 1997, a detailed examination of possible factors contributing to the low returns was produced (DFO 1998). A synthesis for the Newfoundland-Labrador region (Dempson et al. 1998) provided a brief summary outlining historic trends in abundance as well as examples of past concern regarding the state of the salmon resource from the late 1800s and early 1900s.

The current paper is one of a group presented at a Fisheries and Oceans Canada workshop held in Moncton, New Brunswick, February 13-16, 2006 for the purpose pf presenting information and syntheses on the current status of Atlantic salmon stocks of eastern Canada. Output from the workshop will provide material for the preparation of a Conservation Status Report as background for a potential submission to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and for use in the current process of developing a Wild Atlantic Salmon Conservation Policy for Canada. Here a summary of the status of salmon stocks in Newfoundland and Labrador is presented focusing on longer term perspectives rather than status of populations relative to events associated with the most recent year. Individual overviews of each monitored river are avoided in favour of general trends in abundance but also highlighting particular rivers when appropriate. Total returns for individual rivers are, however, shown in Appendices 1a-1e. Detailed reviews of individual stock status are readily available via Fisheries and Oceans Canada Stock Status Reports (DFO 2004) or Research Documents (e.g. O'Connell et al. 2005), while evaluations of past management measures, namely the 1984 salmon management plan and the 1992 closure of the Newfoundland commercial salmon fishery are provided in O'Connell et al. (1992) and Dempson et al. (2004a), respectively.

Methods

Data sources

In Newfoundland, stocks of salmon assessed relative to conservation requirements are those for which abundance information is available. That is, stocks for which only angling data exist are not routinely evaluated although angling statistics by SFA are provided in annual status reports (e.g. O'Connell et al. 2005). This is because numerous changes have occurred to angling fisheries over the years that can compromise the consistent interpretation of the data. For example, daily and season angling bag limits have changed dramatically over the past several decades, while at other times split seasons or angling quotas have been introduced. A licence stub system was introduced in 1994 which changed the basis for how angling information are now compiled (O'Connell et al. 1996). With the licence stub system the onus is placed on the individual angler to return fishing logs at the end of the season from which catch and effort information are later compiled. The provision for catch-and-release angling has also added an additional dynamic in trying to track abundance using angling information, and catch-and-release continues to be a controversial issue in Newfoundland (Dempson et al. 2002). In addition, salmon rivers in Newfoundland are often closed to angling for environmental reasons, namely low water levels and warm water temperatures. In some years and regions, 35 to 65% of all potential fishing days have been unavailable for angling owing to environmental closures (Dempson et al. 2001b). Finally, where angling data have been used to infer salmon returns and compared against known salmon count information, major discrepancies were noted such that absolute use of these types of data have been declared as potentially "quite risky" (O'Connell 2003a).

With few exceptions, information on the abundance of adult Atlantic salmon included in this summary was obtained from actual counts at fishways or fish counting fences throughout Newfoundland (Fig. 1). Exceptions include Humber River where estimates were derived from mark-recapture surveys (Mullins & Caines 2000). At Gander River, complete counts were obtained from a fish counting fence, operated from 1989 to 1999. However, estimates of returns from 1984 to 1988 and for 2000-2005 followed procedures outlined by O'Connell (2003b), where counts of salmon returning to a tributary of the Gander River are used to derive full river estimates. Counts of salmon from five rivers located in southwest Newfoundland in Salmon Fishing Area (SFA) 13 were obtained visually from underwater snorkeling surveys (Porter et al. 2001). When required, recreational fishery removals below counting facilities were added to counts to determine total returns as described in Dempson et al. (2001b). Raw data on total returns by SFA and river up to 2004 are provided in O'Connell et al. (2005).

Table 1 provides a summary list and characteristics of rivers that have routinely been included in the annual evaluation of salmon stock status relative to conservation requirements. For some rivers, the time series of information has now ended (e.g. Biscay Bay River, Humber River). Rivers from which total return data were available vary in size from the 11272 km^2 Exploits River in SFA 4, to Northeast Brook, Trepassey, in SFA 9, with a drainage area of only 21 km^2 (Table 1). In the large rivers (e.g. Exploits, Gander) runs of 25 to 30 thousand salmon can occur (Table 1) while in smaller rivers runs in the hundreds (e.g., Rocky River), or low thousands (e.g., Terra Nova River) are common. It should be noted that the assessed salmon stocks do not necessarily represent a random distribution of the 158 scheduled rivers across the insular part of the Province. Indeed, some projects were initiated for various reasons including: an opportunistic basis owing to availability of funds; requests from various community watershed Development Groups; enhancement activities; Aboriginal Fisheries; or perceived stock conservation problems. Nevertheless, index rivers geographically cover many areas of the island. Also, during the period of time that data from the three largest rivers in Newfoundland were included (Exploits, Humber, and Gander; 1990-1999), collectively, the rivers shown in Table 1 represented almost 50% of the total scheduled salmon river drainage area for Newfoundland.

In Newfoundland, counts of adult salmon are separated into small (< 63 cm) and large (≥ 63 cm) life-history size components. Small salmon characterize the majority of runs (~90%) and are predominately maiden 1SW fish (Table 1). Large salmon represent a mix of life-history stages but are mostly various combinations of repeat spawning 1SW fish. In populations characterized by small salmon, returning adults are frequently female (~70% or more). Exceptions occur in some Bay St. George rivers (SFA 13) where maiden multi-sea-winter (MSW) characterize some of the runs. Here, small salmon are often 50-50% female.

Information on smolt abundance and hence marine survival was available from six rivers during the past decade or so (Campbellton River (SFA 4); Northeast Brook, Trepassey, and Rocky River (SFA9); Conne River (SFA 11); Highlands River (SFA 13) and Western Arm Brook (SFA 14A)). With the exception of Conne River, numbers of smolts were obtained from fish counting facilities. At Conne River, smolts were surveyed by mark-recapture (Dempson & Stansbury 1991; Schwarz & Dempson 1994).

Data analyses – adult salmon returns

Salmon abundance and hence stock status can be tracked by examining trends of individual stocks, or in a collective manner where information on salmon returns to all assessed rivers is combined to derive composite indices of abundance. As noted earlier, details for individual stocks can be found in Research Documents or Stock Status Reports. Information from individual rivers are used to highlight particular examples related to individual trends. Composite indices used to illustrate generalized trends in salmon abundance for different regions or combined for insular Newfoundland itself, follow the approach described in Dempson et al. (2004a).

Composite indices were obtained by fitting a general linear model separately to total returns of small and large salmon. Indices of abundance were derived from adjusted means of the response variables after standardizing for year and river effects. As each analysis (small or large salmon) was performed on the $\log_e$ values, the index is related to a geometric mean of the individual abundances. Individual rivers were grouped to produce separate indices for the Northeast (SFAs 3-8), South (SFAs 9-11), Southwest (SFA 13), and Northwest coasts (SFA 14A), as well as a composite index for all Newfoundland. Adjusted means and standard errors subsequently were back-transformed to construct regional plots of abundance trends as described in Dempson et al. (2004a). Previously, Dempson et al. (1998) showed a high degree of congruence in salmon counts from various regions of Newfoundland, particularly for the Northeast and Northwest coast areas.

Following Bradford and Irvine (2000) and Irvine (2002) we calculated an index of stock productivity (r) as r = ln(R/S), where S = spawners in year t and R = subsequent recruits produced from these spawners assigned to the respective river (smolt) age classes in years $t+4$, $t+5$ and $t+6$ for stocks characterized predominantely by ages 2, 3, and 4, or $t+5$, $t+6$ and $t+7$ with ages 3, 4, and 5. When $r < 0$, populations are unable to replace themselves. This was done on stocks where sufficient time series of returns were available and for which adequate biological characteristic data allowed partitioning of recruits back into their respective spawning brood classes.   The stocks examined and index/map location codes were: Gander River (3), Middle Brook (4), Northeast Brook, Trepassey (8), Conne River (11), Torrent River (22), and Western Arm Brook (23) (Table 1, Fig. 1). We have also provided an estimate of the productivity index based on anticipated returns in 2006 given that 2 of 3 year classes are already available. This was done by averaging the contribution of the oldest river age group and applying this to the recruits already determined for 2004 and 2005.

Total Returns and Trends

Historical trends in catch and abundance

Changes to the ways salmon stocks were managed in Newfoundland and Labrador have been around for many years. In the 1880s, salmon fishers who had completely blocked the mouths of rivers with dykes and weirs were forced to move away from rivers and their mouths to allow some salmon in to spawn. After Confederation with Canada in 1949, commercial salmon fishing was reduced from an all-year fishery to a seasonal fishery, 15 May to 30 December. In 1970, out of concern for mainland Canada salmon stocks, a driftnet fishery at Port aux Basques was closed (Pippy 1982). In 1978 a management plan was implemented to reduce harvests of Bay St. George salmon and increase spawning escapements. In spite of all these changes, salmon continued to decline (Chadwick et al. 1978).

From 1974 to 1983, the average harvest in the Newfoundland commercial salmon fishery was 905 t yr^{-1}. Owing to continued concern over depressed Atlantic salmon stocks in mainland Canada and southwest Newfoundland, another comprehensive management plan was introduced in 1984 to support rebuilding of stocks. Key elements of the 1984 plan involved catch restrictions in the recreational fishery, including the mandatory release of all large salmon (salmon $\geq$ 63 cm), with season changes and reductions in the number of fishers and amount of gear used in the commercial fishery (O'Connell et al. 1992). During the period of the 1984 management plan (1984-1991) commercial landings of salmon in Newfoundland declined to about 600 t yr^{-1} varying from a low of 355 t to a high of 925 t. This was equivalent to a harvest of 141 to 361 thousand salmon yr^{-1}. However, an evaluation of the 1984 plan showed that restrictions in the commercial fishery did not result in any consistent increase in salmon escapement to Newfoundland rivers (O'Connell et al. 1992). In fact, for the period ending in 1991 significant declines ($P < 0.05$) ranging from 50 to 70% or more in total returns of small salmon were noted in some stocks including Exploits River, Middle Brook, Biscay Bay River, and Conne River (Fig. 2), while returns of large salmon fell from 58 to 80%. Salmon returns also declined at other locations including Gander and Terra Nova rivers, or remained stationary with little or no consistent change (e.g. Lomond River, Torrent River, Western Arm Brook). Consequently, conservation concerns in these and other rivers of Atlantic Canada resulted in the most important change in the management of Newfoundland salmon stocks, namely the closure of the commercial salmon fishery beginning in 1992.

Expectations resulting from the closure were intuitively obvious: terminate a directed fishery with moderate to high rates of exploitation and escapements of salmon to rivers should increase immediately. It was also expected that improved spawning escapements beginning in 1992 would result in increased recruitment manifested as greater returns starting in 1997 (Dempson et al. 1998).

Newfoundland commercial salmon fishery moratorium

An analysis of the impact of the 1992 closure of the commercial salmon fishery (Dempson et al. 2004a) showed predictable results in terms of improved returns of small salmon for various rivers along the Northeast and Northwest coasts (Fig. 2), as well as dramatic improvements in returns of large salmon during the first five years of the moratorium (1992 to 1996). In some cases, runs doubled or tripled during the first few years of the fishery closure by comparison with the period immediately preceding the moratorium. At Gander River, for example, runs of small salmon varied from about 6700 to 7700 from 1989-1991 then rose to 18000 to 26000 fish during the next five years (1992-1996). A parallel situation occurred at Exploits River; counts of small salmon ranged from about 5600 to 7600 for the period 1989-1991, but rose to 13500 to 30000 for 1992 to 1996.

A comprehensive analysis of the 1992 moratorium showed that an abundance index for small salmon increased by over 70% for Northeast and Northwest coast rivers during the 1992-1996 period in contrast with 1984-1991 (Dempson et al. 2004a) (Fig. 3). Returns of large salmon to these regions increased by a factor of 4 or more. In contrast, returns to South coast monitored rivers showed no improvement coincident with the moratorium (Fig. 3) as individual stocks (e.g. Conne River, Northeast Brook, Trepassey, and Biscay Bay River) had lower returns of small salmon during the 1992-1996 period than they did prior to the closure of the commercial fishery. The most substantive decline was recorded at Conne River where returns of small salmon fell from 8- to 10000 in 1986-1988 to 1500 salmon by 1994. Indeed, total returns of both small and large salmon at Conne River have fallen by more than 75% as estimated by the change in predicted values from the initial year of monitoring (1986) to that in 2005 as derived from the slope of the regression across the time series. Even when data are smoothed by a five-year moving average, small and large salmon have declined by more than 50%. Conne River is located where a fin-fish aquaculture industry for salmonids (Atlantic salmon, steelhead trout) is situated. At Northeast Brook, Trepassey, returns of small salmon have fallen by 32% while large salmon had declined by 86% as predicted via regression analyses. Returns of small and large salmon smoothed by moving averages have shown declines of 24% and 70%, respectively. At Biscay Bay River, monitored from 1983 until 1996, returns of small salmon dropped by 58% (50% with smoothed data), although large salmon abundance increased by 10%.

Despite cautious optimism for increased recruitment beginning in 1997, albeit in those regions where significant increases in total returns occurred from 1992 to 1996, there was either no change (Northwest coast) or a significant decline (Northeast coast) in the abundance of small salmon for the 1997-2002 period by comparison with 1992-1996 (Fig. 3). With respect to large salmon, the only region that experienced a significant increase was the Northwest coast.

Total returns adjusted for marine exploitation – 1984 to 1991

The above discussion relates to information on salmon returning to monitored rivers. However, Crozier and Kennedy (1994, 1999) advocate that it is necessary to account for marine exploitation when examining total life cycle variation in salmon survival and return data. In doing so, more appropriate comparisons of trends in total stock size can be evaluated. This was the approach followed by O'Connell et al. (2005) in summarizing trends in composite abundance indices for Newfoundland. Thus, index values for the pre-moratorium period from 1984 to 1991 were adjusted to account for marine exploitation. In all cases, exploitation rates used were the average of the median values obtained from nine rivers as described in Dempson et al. (2001a), and were 45.3% for small salmon and 74.2% for large salmon.

In contrast to the perception obtained when examining data unadjusted for marine exploitation, the combined index of small salmon abundance show declining trends for the Northeast and South coasts, as well as for all Newfoundland (Fig. 4). South coast stocks have declined by 74% from the peak in 1986 to returns in 2005. There has been a small increase in abundance in recent years for Northeast coast rivers. Total stock size has remained essentially the same for the Northwest coast. Insufficient data existed for the Southwest coast pre-moratorium period. However, this is the only region that has shown a trend for increased returns since the early 1990s.

With respect to large salmon, which as noted earlier are predominately repeat spawning grilse, a dramatic decline (88%) in the abundance has occurred in South coast monitored stocks while total stock size for the Northeast coast and Newfoundland as a whole has remained relatively flat (Fig. 5). Abundance of large salmon has increased somewhat for Northeast coast rivers by comparison with the pre-moratorium period. As noted for small salmon, increased returns of large salmon have also occurred in the Southwest coast region. Collectively, in most regions with the exception of the Southwest coast, total stock size or abundance of salmon is either similar to or lower now (e.g. South coast) that it was prior to the closure of the Newfoundland commercial salmon fishery.

Productivity Index

The index of productivity (*r*) varies among stocks, and among years within stocks (Fig. 6). Western Arm Brook has shown the most consistent pattern with the population regularly replacing itself ($r \geq 0$). Except for south coast stocks (Conne River, Northeast Brook, Trepassey), the recruit per spawner ratios were generally high during the initial period of the commercial salmon fishery moratorium (1987 to 1990 spawner year classes yielding the first age 3:1 recruits in 1992). However, sharp declines in productivity occurred at Torrent River, Middle Brook and Gander River starting with the 1990 or 1991 spawner year classes with populations falling below the replacement line (Fig. 6). At Gander and Torrent rivers this trend has been reversed with both populations replacing themselves in recent years and as projected for 2006 returns. A different picture emerges for the two south coast stocks, Conne River and Northeast Brook, Trepassey. Here, both populations have failed to replace themselves at least 50% of the time, with return rates likely to be below the replacement line again in 2006.

Summary - Newfoundland

Despite sporadic signs of improved salmon returns to some Newfoundland rivers in some years, for many populations total stock size is no higher now that it was prior to the closure of the commercial fishery. Immediate improvements in spawning escapements during the first five years of the moratorium (1992-1996) to various Northeast and Northwest coast rivers did not result in any new productivity. Indeed, for some stocks the number of recruits per spawner declined to levels where some populations were not replacing themselves. One region of particular concern is the South coast where the greatest declines in returns of both small and large salmon have occurred by comparison with their peak abundances.

Labrador

By comparison with Newfoundland, salmon abundance data for Labrador rivers are limited. Currently, salmon returns are monitored at only four rivers: English River in SFA 1, along with Southwest Brook (Paradise River), Muddy Bay Brook (Dykes River), and Sand Hill River, in SFA 2. The longest consecutive time series is for English River (6 years) although historic information is available for Sand Hill River (1970 – 1973). With the exception of Sand Hill River, returns to the other three rivers are less than 1000 fish, while anywhere from 3500 to almost 8000 fish have returned to Sand Hill River. During the period 1970-1973, 2038 to 4761 small salmon and 138 to 504 large salmon returned to Sand Hill River. Returns of large salmon vary by river with English River and Sand Hill River having, on average, about 15% of the run composed of large fish. At Muddy Bay and Southwest brooks, large salmon represent less than 10% of the returns. In contrast with Newfoundland, most large fish in Labrador are MSW salmon. Aboriginal subsistence fisheries for salmon (as well as trout and Arctic charr) occur in Labrador. In recent years subsistence harvests have increased from about 16 t y^{-1} to about 30 t in 2004. This contrasts with the last year of the Labrador commercial fishery when about 47 t were harvested, versus an average of 111 t y^{-1} from 1990 to 1997.

In the absence of a long time series of information, it is difficult to infer changes in abundance over time, with the exception, perhaps, of Sand Hill River. From 1970-1973, from 2038 to 4761 small salmon (average = 3499) and 138 to 504 large salmon (average = 271) returned to the river. During the later stages of the Labrador commercial fishery, returns of small salmon varied from 2180-3319 (average = 2765) and from 414-730 (average = 568) large salmon. Clearly there were fewer small salmon but substantially more large salmon returning to the river when contrasting these two time intervals. Monitoring resumed at Sand Hill River in 2002 and continues to date. From 2002 to 2004, the run of small salmon averaged 3440 fish, thus similar to that of 1970-1973. Large salmon returns were much higher (561 to 627) than in the early 1970s. Record returns of both small and large salmon occurred in 2005 when 7007 small and 875 large salmon were recorded.

At the other monitored Labrador rivers, there is no corresponding premoratorium information on salmon abundance. Returns of small salmon to English River, have been variable varying by a factor of 6 from one year to another. However, prior to 2005, salmon returns to English River declined steadily from 367 small salmon in year 2000 to 56 fish by 2004.

Status Relative to Conservation

Monitored salmon populations are evaluated relative to conservation spawning requirements as a means by which the status of the resource can be quantified. For Newfoundland, conservation requirements are based on an egg deposition rate of 2.4 eggs per m^2 of fluvial habitat for juvenile production as well as 368 eggs per hectare of lacustrine habitat (O'Connell and Dempson 1995; O'Connell et al. 1997). This is because in Newfoundland, Atlantic salmon make extensive use of lacustrine habitat for juvenile rearing (e.g. O'Connell and Ash 1989, 1993; Dempson et al. 1996; O'Connell and Dempson 1996; Dempson et al. 2004b). Conservation requirements for Atlantic salmon were intended to be threshold levels below which no harvests or removals should occur (CAFSAC 1991; Chaput 1997; Potter 2001). However, in practice they are often used as management targets. The level of conservation achieved is strongly linked to the total number of salmon that survive and return to the respective rivers, as well as the level of in-river angling (or other) removals. Hence, conservation levels attained fluctuate markedly from one year to another. This necessitates looking at conservation achieved over a period of years rather than a single, point-in-time statistic that often forms the basis for annual stock status reviews (e.g. DFO 2004).

For discussion purposes, we consider conservation attained over the past 10 years (1996-2005) or during the last 10-year period stocks were monitored (e.g. Biscay Bay River, 1987-1996; Humber River, 1990-1999, etc.). As a first approach rivers are categorized into four groups based on the frequency by which conservation requirements have been attained:

a) stocks that consistently met or exceeded conservation requirements;
b) stocks meeting conservation between 50 and 100 % of the time;
c) stocks achieving conservation between 0 and 50% of the time; and
d) stocks where conservation requirements have never been attained.

Despite annual fluctuations in abundance, the following six rivers have consistently met or exceeded conservation spawning requirements:

SFA 4 -	Campbellton River
SFA 5 -	Middle Brook
SFA 9 -	Northeast Brook, Trepassey
SFA 10 -	Northeast River, Placentia
SFA 14A -	Torrent River and Western Arm Brook.

Rivers in the second category, those that have attained conservation better than 50% of the time during the past 10 years (or last 10 years of monitoring), with credit given for rivers at 95% or above, include the following seven rivers:

SFA 4 -	Gander River (6 times)
SFA 9 -	Biscay Bay River (7 times)
SFA 11 -	Conne River (7) and Little River (8 times)
SFA 13 -	Flat Bay Brook (6) and Humber River (7 times)
SFA 14A -	Lomond River (9 times)

Six stocks that have attained conservation less than half of the time (<50%) include the Bay St. George stocks:

SFA 13 -	Highlands River (3 times), Crabbes River (2 times), Middle Barachois River (2 times), Robinsons River (4 times), Fischells Brook (4 times), and Harry's River (1 time).

Finally, four monitored stocks have yet to attain conservation:

SFA 4 -	Exploits River
SFA 5 -	Terra Nova River and Northwest Brook, Port Blandford
SFA 9 -	Rocky River

Exploits River, Terra Nova River and Rocky River have been subject to enhancement activities (also Little River) and, traditionally, were not expected to achieve conservation levels in the near future. In the late 1940s, the area above Northwest Falls in Northwest Brook, Port Blandford was made accessible to anadromous salmon. Prior to this, only the first 3.2 km of the river were accessible. We note, however, that within the Exploits River system, the Lower Exploits section (downstream of Grand Falls) has attained conservation six times during the past 10 years. Torrent River was also subject to enhancement with the transfer of adult fish into the system from 1972-1976 (Mullins et al. 2003). In contrast with the other enhanced stocks, salmon returns increased rapidly to Torrent River such that conservation requirements have consistently been met or exceeded each year since 1977. To date, salmon returns to Rocky River and Exploits River are showing only modest increases in returns by comparison with Torrent River.

An alternate means by which stocks can be evaluated relative to conservation is with respect to the average percentage level of conservation attained (Table 1, Fig. 1). Exploits River, Terra Nova River, and Rocky River average less than 50% of conservation. Rivers with conservation levels that average between 50 and 75% include: Northwest Brook, Port Blandford, Highlands River, Middle Barachois Brook, Crabbes River, Fischells River, and Harry's River. For all other stocks, the average percentage level of conservation attained has been ≥ 100% (Table 1, Fig. 1). Ironically, with the exception of Rocky River, all other monitored South Coast stocks have average conservation levels that meet or exceed conservation requirements, but these are also the stocks that have shown the greatest declines over time with little or no evidence of any consistent improvement following the commercial salmon moratorium. On the other hand, the most consistent improvement in total returns since the moratorium in 1992 have occurred in Bay St. George stocks (SFA 13) even though most populations have attained conservation less than 50% of the time, with five stocks averaging between 50 and 75% of their conservation spawning requirement.

Conservation spawning levels provide reference points for managing the resource, or as stated by Chaput and Prévost (2001), a signpost to assess performance relative to an expected level. However, achieving conservation can give an artificial picture of the "status" of the resource. As noted above, the most dramatic declines in salmon abundance have occurred in South coast rivers, but for the most part these rivers are at or above required "conservation" levels. Attaining conservation may only help to ensure runs will persist, but provide no assurance that runs will increase or provide for maximum recruitment. Indeed, despite attaining conservation in most years, salmon abundance at Biscay Bay River, Conne River, and Northeast Brook, Trepassey, has been trending downward with the latter two populations failing to replace themselves at least 50% of the time.

To date, conservation requirements have not been defined for Labrador salmon stocks.

Smolt Production, Freshwater and Marine Survival

Smolt production

Trends in smolt production are summarized in Figure 7. Numbers of smolts vary among rivers and among years within rivers. Variation within rivers is moderately low with coefficients of variation ranging from 17% at Conne River to 36% at Rocky River. Peak smolt production occurred in 1997 at four of six monitored rivers (Fig. 7). In general, there have been no appreciable changes in smolt production over time with the exception of Campbellton River. There, numbers of smolts have declined precipitously falling from 62000 smolts in 1997 to 30000 in 2005, the lowest recorded for this river (Fig. 7). The decline occurred in spite of having exceeded conservation levels consistently on an annual basis. At Western Arm Brook, smolt production has gradually risen over time, but dropped sharply in 2005 to the lowest value in 26 years going back to 1979. Smolt monitoring ended at Highlands River in 2000.

The following text table summarizes the average production of smolts since 1996, except for Highlands River where data for all years was included. L/F represents the ratio of lacustrine (L) to fluvial (F) habitat expressed as m^2.

River	L/F ratio	Average Smolt production 1996-2005	Smolts per km² Drainage area	Smolts per 100 m² Fluvial habitat
Western Arm Brook	69.6	15072	101	5.2
Campbellton River	67.7	42150	142	7.1
Northeast Brook, Trepassey	5.2	1548	74	2.8
Rocky River	21.3	11244	38	1.0
Conne River	24.1	77539	129	5.9
Highlands River *	2.2	9567	61	1.8

* Using data for all years available

As an index of freshwater productivity, systems characterized by greater contributions of lacustrine habitat, namely Western Arm Brook, Campbellton River, and Conne River, produce substantially more smolts per unit area than predominately fluvial systems, an exception perhaps being Rocky River. These aforementioned rivers have smolt production rates expressed in terms of fluvial habitat varying from 5.2 to 7.1 per 100 m^2, with Campbellton River having the highest relative smolt production. Smolt production at Rocky River is anomalously low.

Numbers of smolts produced at monitored rivers appears to be constrained to certain carrying capacities of the respective systems. At Western Arm Brook, rarely has there been more than 18000 smolts produced regardless of the number of spawners entering the system as numbers typically fall with the range of 10- to 16000. Similarly, at Conne River, only twice have surveys shown more than 90000 smolts, with 65- to 80000 most common while at Northeast Brook, Trepassey, there appears to be an upper limit of about 2100 smolts for this system.

Freshwater survival

Survival in freshwater can be approximated from estimates of numbers of eggs deposited and subsequent production of migrating smolts. As noted by Hutchings and Jones (1998) there is considerable uncertainty about resulting egg-to-smolt survival rates owing to the error associated with each of the respective variables required to derive the estimates. Nevertheless, egg-to-smolt or freshwater survival can vary substantially both among rivers as well as within rivers over time to the extent that the variability often exceeds that observed among estimates of marine survival. Klemetsen et al. (2003) reported that salmon rearing in lacustrine habitat may have somewhat higher freshwater survival rates than corresponding stocks rearing predominately in fluvial environments. Indeed, egg-to-smolt survival averaged 0.52% (minimum = 0.36; maximum = 1.09%) for Northeast Brook, Trepassey, with an L/F value of 5.2 over 12 year-classes. In contrast, freshwater survival for Conne River (N = 14 year classes), with an L/F value of 24.1, averaged 1.24%, varying from 0.45 to 2.55% among individual year-classes. At Western Arm Brook, freshwater survival averaged 1.39% over 29 year-classes where the L/F value is 69.6. Freshwater survival has declined over the last decade at Western Arm Brook, such that there is now somewhat of a correspondence in survival among rivers in recent years (Fig. 8). There is also a tendency for egg-to-smolt survival to decrease with increasing egg deposition rates in some Newfoundland rivers (Fig. 9), and hence suggestive, perhaps, of possible density-dependent effects.

Marine survival

Counts of Atlantic salmon smolts and adults enable estimates of marine survival to be derived. Examination of survival trends over time can provide insight into the effects of management measures designed to reduce marine exploitation, or, in the absence of fisheries allow estimates of natural survival to be calculated. Counts of smolts also provide a direct measure of freshwater production, and in some cases as noted above, allow estimates of egg-to-smolt survival to be obtained and evaluated in relation to current conservation requirements attained.

Many factors act to influence the survival and production of Atlantic salmon (Saunders 1981; Dempson et al. 1998; McCormick et al. 1998; Parrish et al. 1998; Armstrong et al. 1998). Consequently, survival, and hence adult salmon abundance, is often highly variable, both in Atlantic (Chadwick 1988; Dempson et al. 1998) as well as in Pacific salmon populations (Noakes et al. 1990; Hargreaves 1994). Some factors, such as run timing and smolt size, can have a consistent influence on the subsequent survival to the adult life stage (e.g. Ward and Slaney 1988; Hansen and Jonsson 1989, 1991; Ritter 1989; McCormick et al. 1998; Salminen et al. 1995; Finstad and Jonsson 2001). In contrast, Hargreaves (1994) stated that many attempts have been made to relate marine survival rates to environmental parameters, and while observed patterns have often assisted in forecasting subsequent salmon abundance, frequently the resulting relationships showed little consistency among stocks, and among years within a stock.

A review of marine mortality of Atlantic salmon and its measurement concluded that contributory factors are complex and attempts to identify a single, dominant factor have been unfounded (Potter et al. 2003). Survival was found to vary substantially both among stocks and regions as well as within a stock over time. In populations for which multiple sea-age classes exist, estimates of survival tend to be underestimates because some of the fish are destined to remain at sea and either die or return as MSW fish (Hutchings and Jones 1998; Chaput 2003). No attempt has been made to adjust for this in the current synopsis.

Survival of smolts to small salmon (fish < 63 cm) in Newfoundland varies among rivers, among years within rivers, and is generally low (Fig. 10). Since the commercial salmon fishery moratorium began in 1992, and hence the opportunity to obtain 'natural' survival in the absence of directed marine fisheries, survival has exceeded 10% in less than 3% of all individual estimates available (N = 76). The majority of survival values for monitored Newfoundland stocks fall within the range of 2 to 7%, averaging around 5%. Indeed, for Newfoundland small salmon there is no difference in the distribution of survival values between the pre-moratorium and moratorium periods (G = 4.090, P = 0.665). In some South coast populations (e.g. Conne River and Northeast Brook, Trepassey) survival is lower since the Newfoundland commercial salmon fishery closed than it was prior to the moratorium in 1992 even in the absence of adjustments to account for marine exploitation prior to fishery closures (Fig. 10). This was largely unexpected given that estimates of the median marine exploitation rates during the period 1984 to 1991 were 45.3% (29.6 – 57.1%) on small salmon and 74.2% (57.7 – 83.7%) on large salmon (Dempson et al. 2001a).

A composite index of survival across all rivers (except Highlands) is shown in Figure 11. Here, index values represent standardized Z-scores averaged across all rivers where at least three values (stocks) were available for each year. Values shown are relative to the overall standardized average of the time series (zero) for all five rivers. In recent years, variability in survival has been reduced somewhat, but since 1988, survival has shown no particular increasing or decreasing trend despite major modifications to directed marine salmon fisheries. South coast rivers (Conne River, Rocky River, and Northeast Brook, Trepassey), by themselves, show a decline in survival over time (Fig. 11).

Variability in marine survival among and within rivers influences the subsequent pattern of adult salmon returns. For Newfoundland rivers, the emigration of greater numbers of smolts does not consistently result in more adults returning (Fig. 12). Scatter plots of numbers of smolts versus adult returns in the following year show a bewildering pattern for some rivers. There is somewhat of an increase in adult returns with smolt production at Rocky River and Western Arm Brook during the moratorium years, but at other rivers there is little correspondence between smolts and subsequent adult returns.

In addition to marine survival estimates of maiden salmon, survival of repeat spawners can also be determined for some stocks. Dempson et al. (2004a) used scale pattern analysis to identify first time consecutive spawners for six Newfoundland rivers. Survival was estimated by comparing the numbers of salmon returning to spawn a second time in year $i + 1$ with the corresponding number of maiden 1SW fish that spawned previously in year i. Similar to the situation in freshwater and that observed among maiden salmon, survival of repeat spawners also varied considerably among years within stocks. While survival of first time repeat spawners was commonly less than 20%, estimates of over 30% or greater survival occurred in some rivers in some years. Mean survival of repeat spawners was highest for Terra Nova River, Northeast River, Placentia and Middle Brook ($\bar{x} > 18\%$), and lowest for Exploits River, Gander River, and Conne River ($\bar{x} < 10\%$). In general, expectations for increased survival of repeat spawning salmon coincident with the commercial fishery closure in 1992 have not been fully realized as individual populations continue to be characterized by wide fluctuations in annual survival.

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Table 1. Characteristics of Newfoundland Atlantic salmon rivers conventionally assessed in the past or currently relative to conservation requirements. Data are derived from fish counting fences (F), fishways (Fw), snorkel counts (Sc), mark-recapture (MR) or estimated from tributary river counts (EFw). SFA = Salmon Fishing Area. Percent of run refers to the overall percentage of the entire run made up of small (< 63 cm) salmon, and of those, the % that are maiden 1SW fish. Min and Max refer to the lowest and highest total returns recorded within the interval 1984 to 2005. N = number of years of abundance data from 1984 onwards. Average % conservation is for the last 10 years (1996-2005) or the last 10 years a stock was monitored.

SFA	River	Map Location Code	Drainage Area km ^{2}	Data Source	Small salmon				Years			Average % Conservation
					% of run	% 1SW	Min	Max	N	First	Last	
Northeast Coast												
4	Exploits River	1	11272	Fw	94.7	94.0	5659	30425	22	1984	2005	41
	Campbellton River	2	296	F	91.3	86.7	1798	4001	13	1993	2005	229
	Gander River	3	6398	F, EFw	89.1	91.9	6745	26205	22	1984	2005	100
5	Middle Brook	4	276	Fw	94.1	91.8	626	2625	22	1984	2005	188
	Terra Nova River	5	1883	Fw	81.8	84.0	1127	3050	22	1984	2005	36
	Northwest Brook, Port Blanford	6	689	F	78.1	89.8	102	1210	11	1995	2005	51
South Coast												
9	Biscay Bay River	7	239	F	94.9	85.6	394	2688	13	1984	1996	106
	Northeast Brook, Trepassey	8	21	F	83.9	92.4	49	158	22	1984	2005	202
	Rocky River	9	296	F	82.2	84.2	80	435	19	1987	2005	45
10	Northeast River, Placentia	10	94	Fw	88.3	89.3	313	1532	19	1984	2002	424
11	Conne River	11	602	F	94.4	95.6	1503	10155	20	1986	2005	132
	Little River	12	183	F	89.2	94.0	55	674	19	1987	2005	185
Southwest Coast												
13	Highlands River	13	183	F	62.5	97.1	58	507	13	1993	2005	74
	Crabbes River	14	551	Sc	82.0	98.8	494	2150	10	1996	2005	72
	Middle Barachois River	15	241	Sc	87.8	92.2	563	1142	10	1996	2005	69
	Robinsons River	16	439	Sc	87.1	99.0	882	1976	10	1996	2005	100
	Fischells Brook	17	360	Sc	86.3		205	1800	9	1997	2005	72
	Flat Bay Brook	18	635	Sc	91.9	85.8	1150	2397	10	1996	2005	109
	Harrys River	19	816	EFw, F	84.8		888	2828	14	1992	2005	59
	Humber River	20	7679	MR	90.5	99.3	5724	30445	10	1990	1999	109
Northwest Coast												
14A	Lomond River	21	470	Fw	88.5	97.4	393	1529	19	1984	2002	143
	Torrent River	22	619	Fw	91.1	95.5	1510	7475	19	1984	2002	719
	Western Arm Brook	23	149	F	95.7	99.9	233	1718	19	1984	2002	412

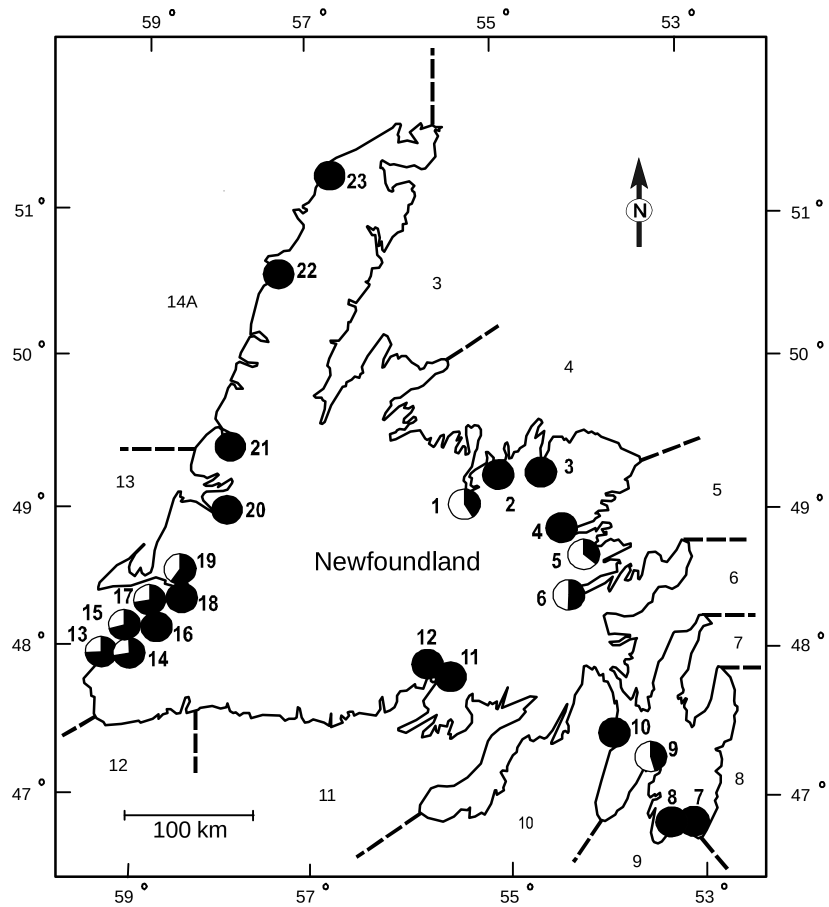


Figure 1. Map of Newfoundland showing Salmon Fishing Areas (SFAs) 3-14A, and the location of various fish counting facilities from which data were obtained for analyses of trends in abundance. Characteristics of individual rivers are provided in Table 1. Circles by each river indicate the average percentage conservation requirements met during the 10-year 1996-2005, or during the last decade a stock was monitored. Solid black circles imply 100% conservation, or more, was attained. See text for details.

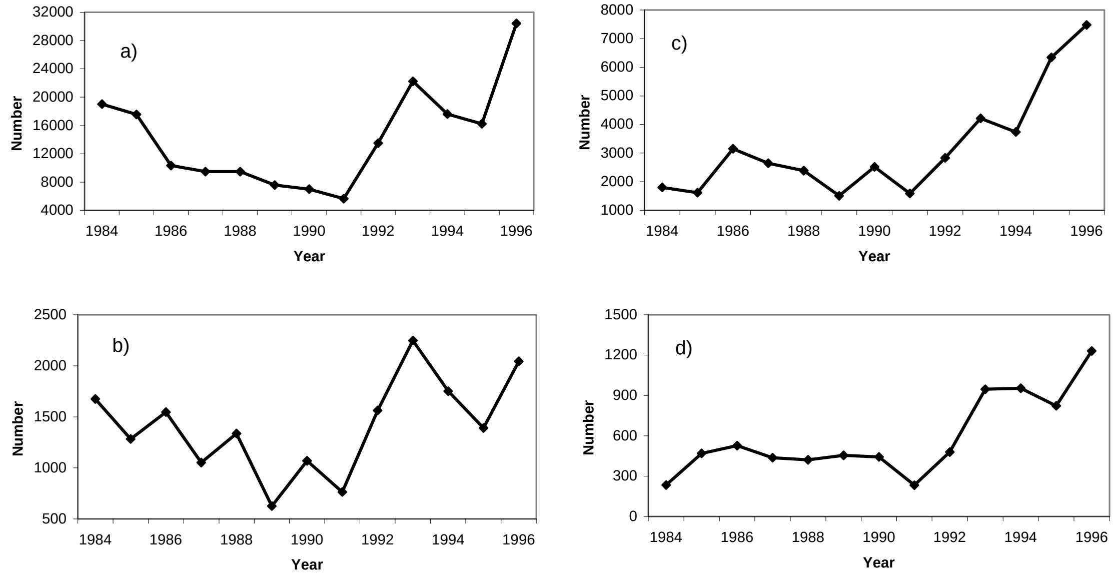


Figure 2. Trends in total returns of small Atlantic salmon to: a) Exploits River, b) Middle Brook, c) Torrent River, and d) Western Arm Brook, Newfoundland, 1984 - 1996. Number refers to numbers of small salmon.

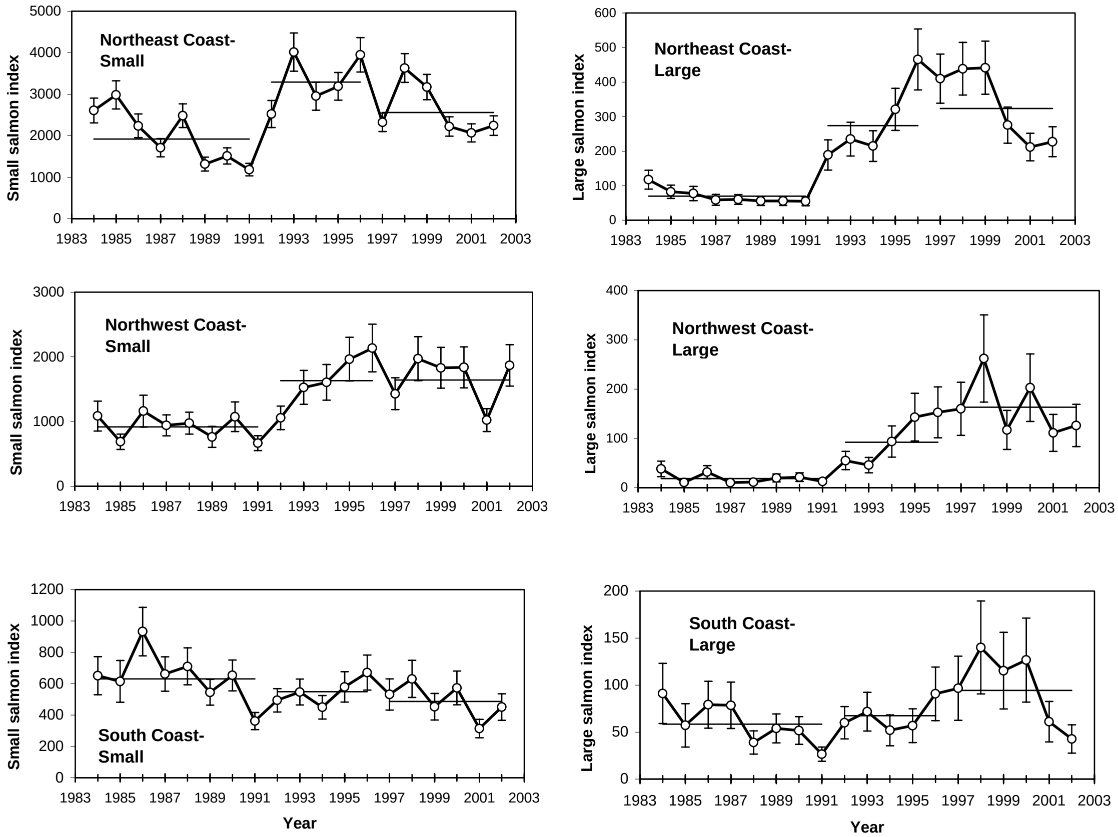


Figure 3. Trends in abundance of small and large salmon by region, 1984 - 2002. Vertical lines represent ± 1 standard error. Horizontal lines illustrate the mean abundance index for the periods 1984 - 1991, 1992 - 1996, and 1997 - 2002. From Dempson et al. 2004.

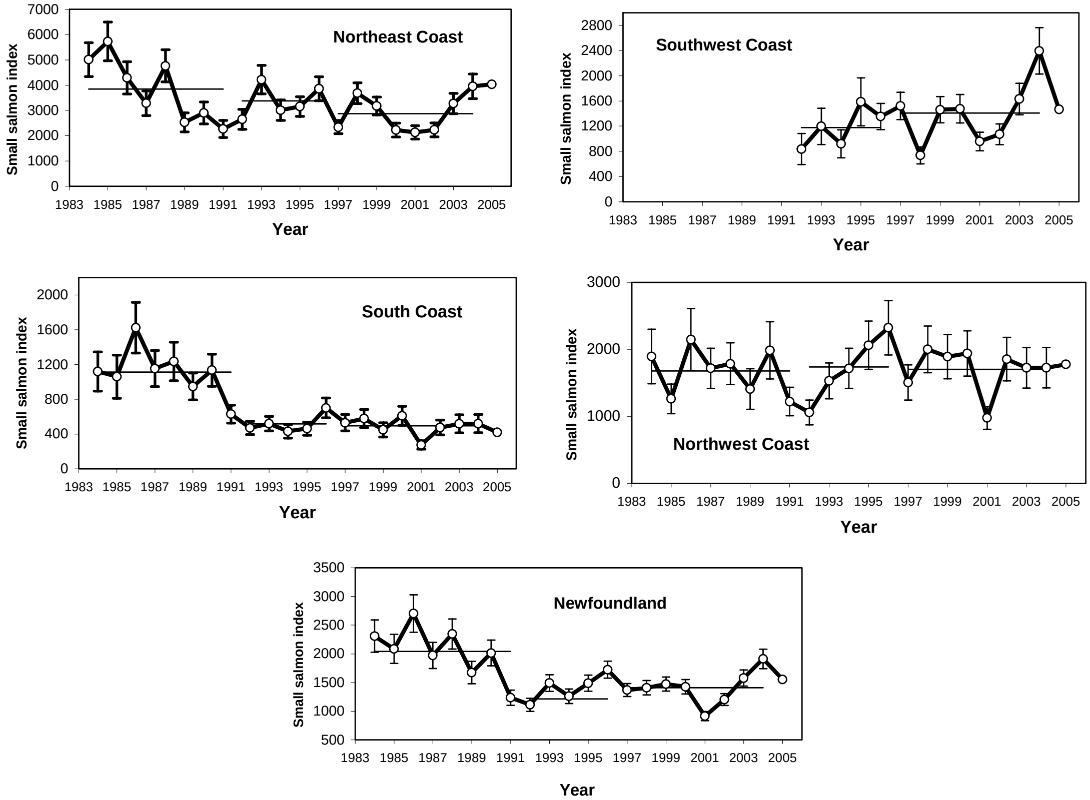


Figure 4. Trends in abundance of small Atlantic salmon by region and for all Newfoundland, 1984 - 2005. Vertical lines represent ± 1 standard error. Horizontal lines illustrate the mean abundance index for the periods 1984 - 1991, 1992 - 1996, and 1997 - 2004. Returns for 1984-1991 have been adjusted to account for marine exploitation.

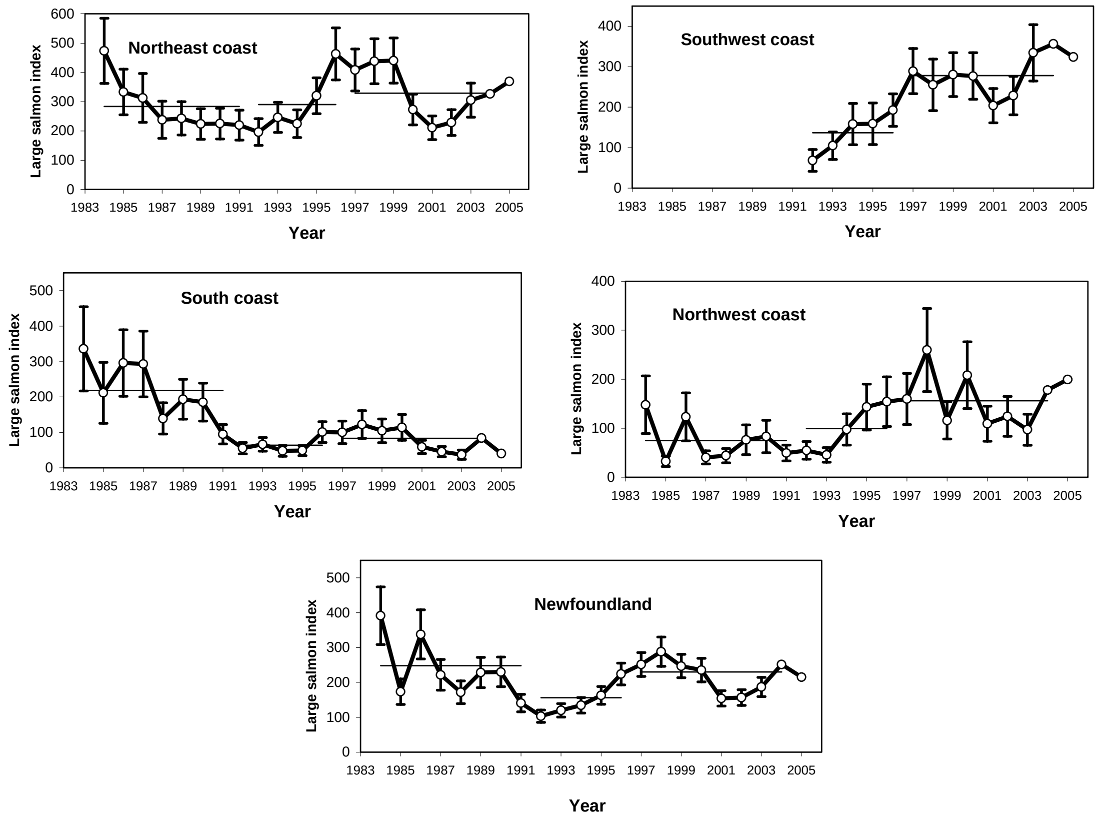


Figure 5. Trends in abundance of large Atlantic salmon by region and for all Newfoundland, 1984 - 2005. Vertical lines represent ± 1 standard error. Horizontal lines illustrate the mean abundance index for the periods 1984 - 1991, 1992 - 1996, and 1997 - 2004. Returns for 1984-1991 have been adjusted to account for marine exploitation.

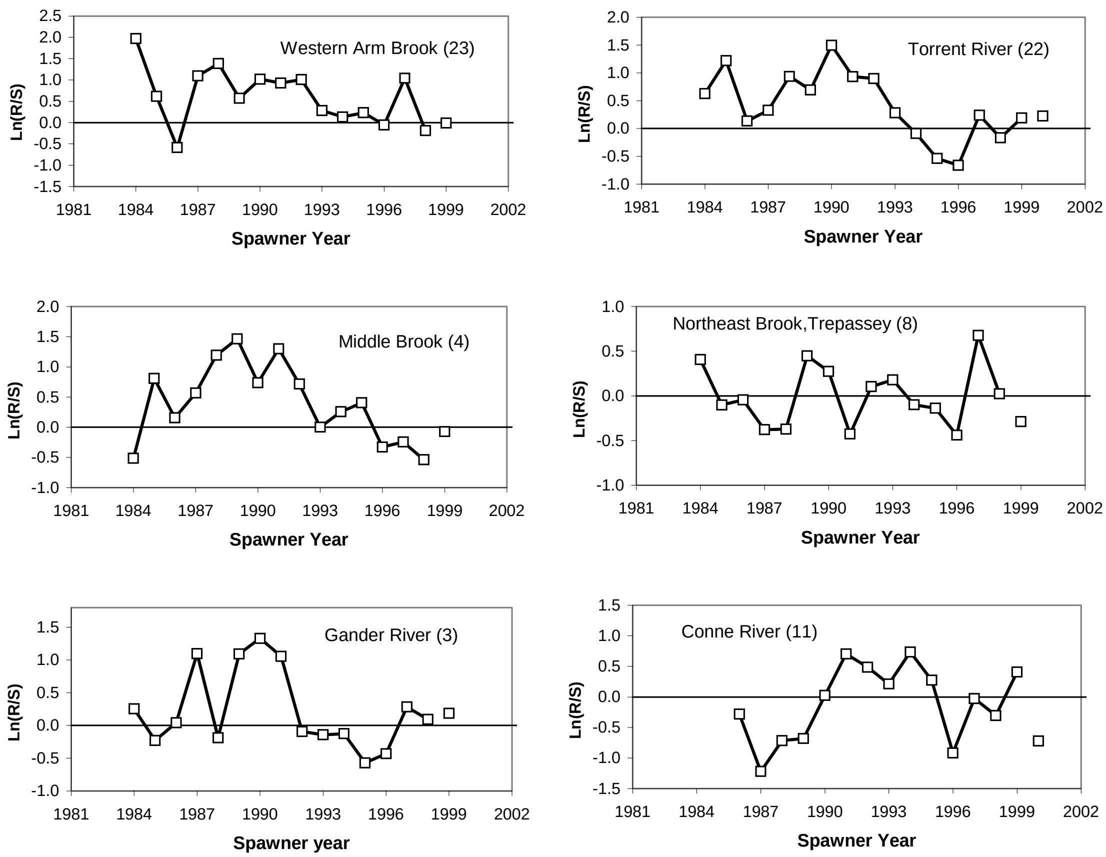


Figure 6. Productiy index of natural log of numbers of recruits per spawner for various Newfoundland salmon stocks. Index values equal to or above zero reflect years in which the population is replacing itself. Numbers beside river names refer to the map location code for Figure 1 and stock characteristics summarized in Table 1.

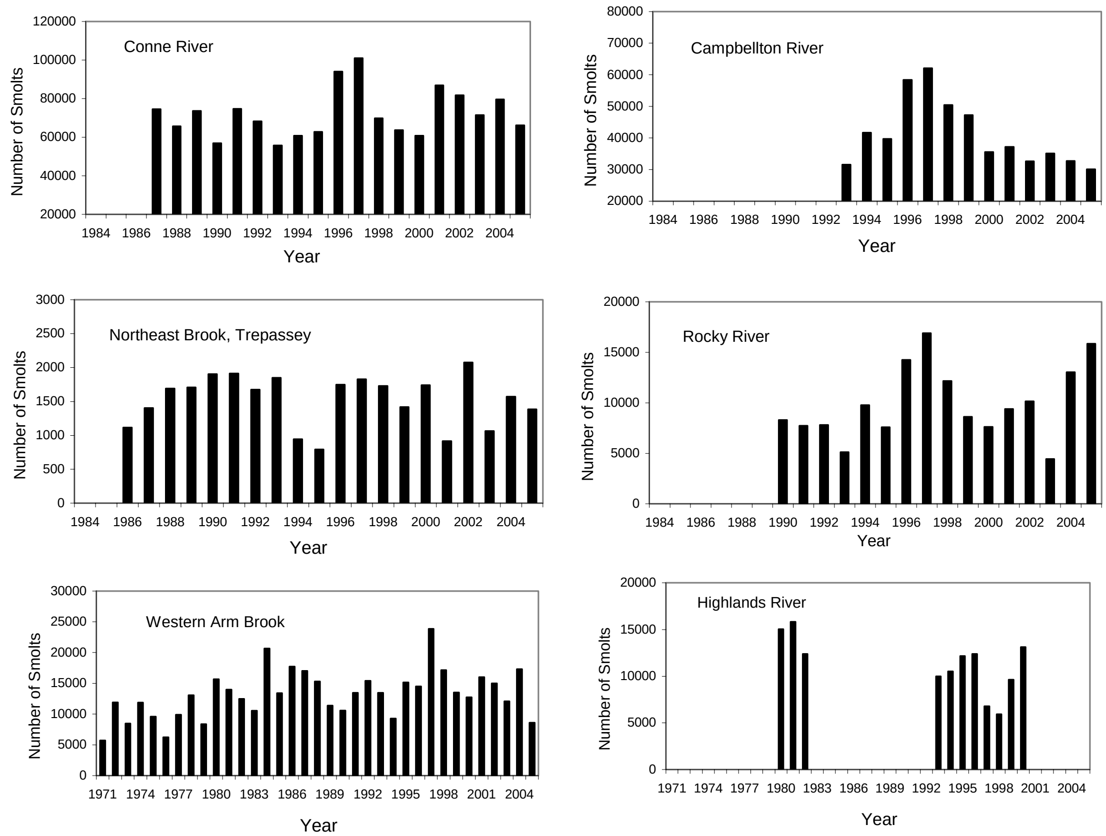


Figure 7. Trends in smolt production from various Newfoundland Atlantic salmon rivers.

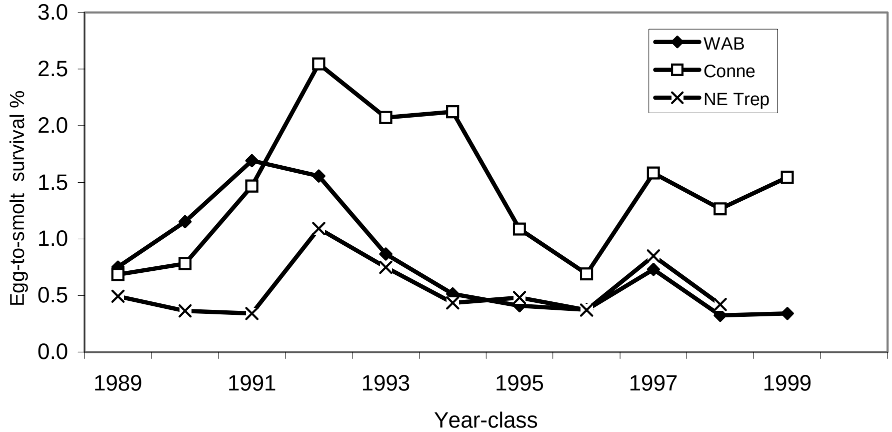


Figure 8. Egg-to-smolt survival at Western Arm Brook (WAB), Conne River, and Northeast Brook, Trepassey (NE Trep), Newfoundland.

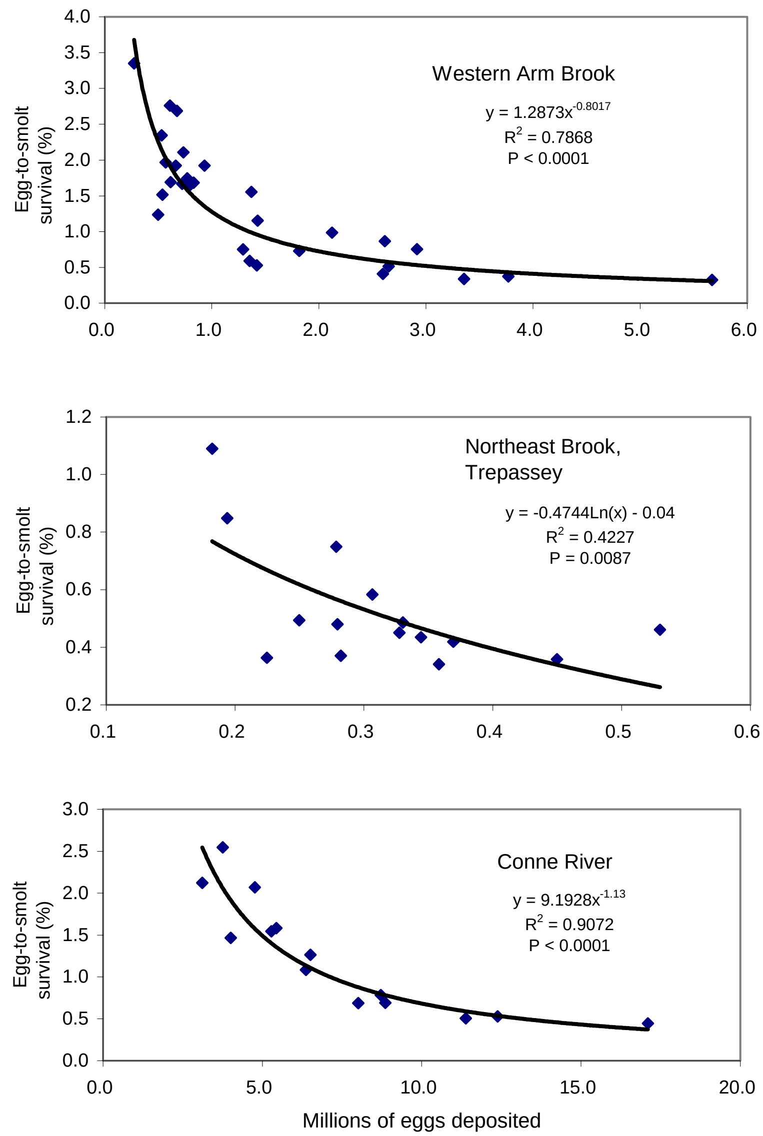


Figure 9. Estimated egg-to-smolt freshwater survival relative to egg deposition spawning levels for Western Arm Brook, Northeast Brook, Trepassey, and Conne River, Newfoundland.

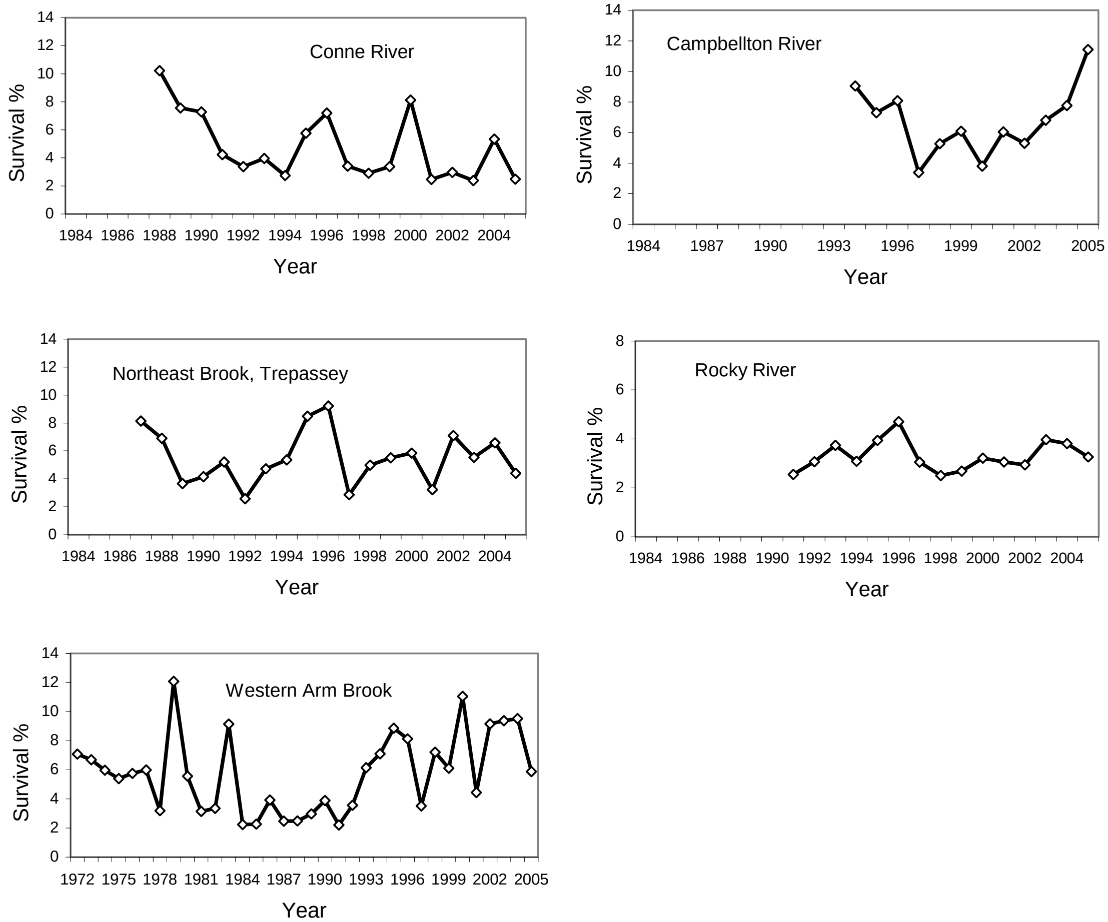


Figure 10. Marine survival rates for adult small salmon at various Newfoundland rivers. Survival rates have not been adjusted for marine exploitation in years prior to 1992 when commercial fisheries for salmon occurred. Thus, values represent actual survival of salmon back to the river or local home waters.

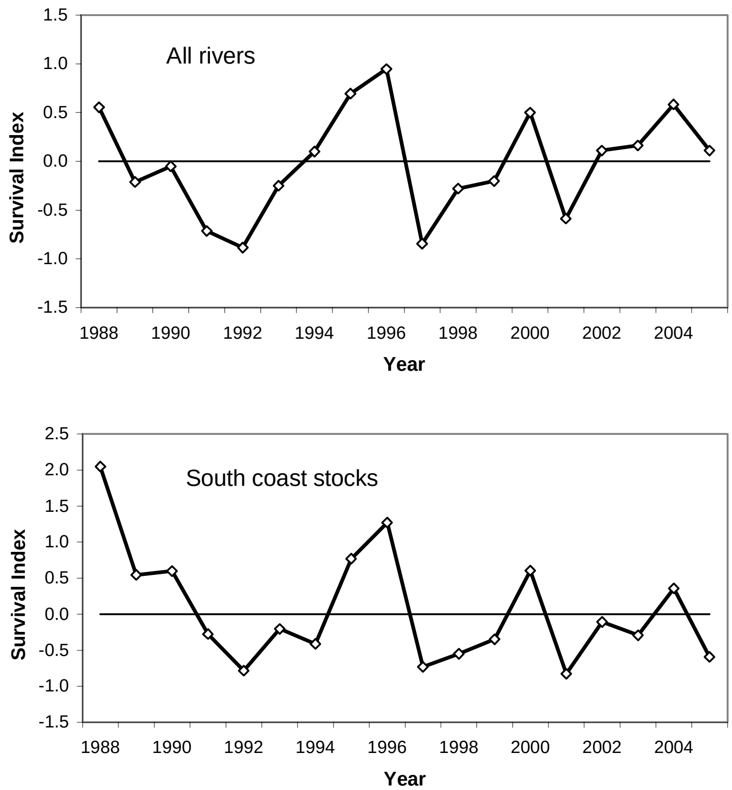


Figure 11. Overview of estimated marine survival of Newfoundland smolts to adult small salmon. Upper chart includes all five rivers, while the bottom chart is for three South coast stocks only. Index values represent averages of standardized (Z-score) survival values relative to the overall mean of the data series used.

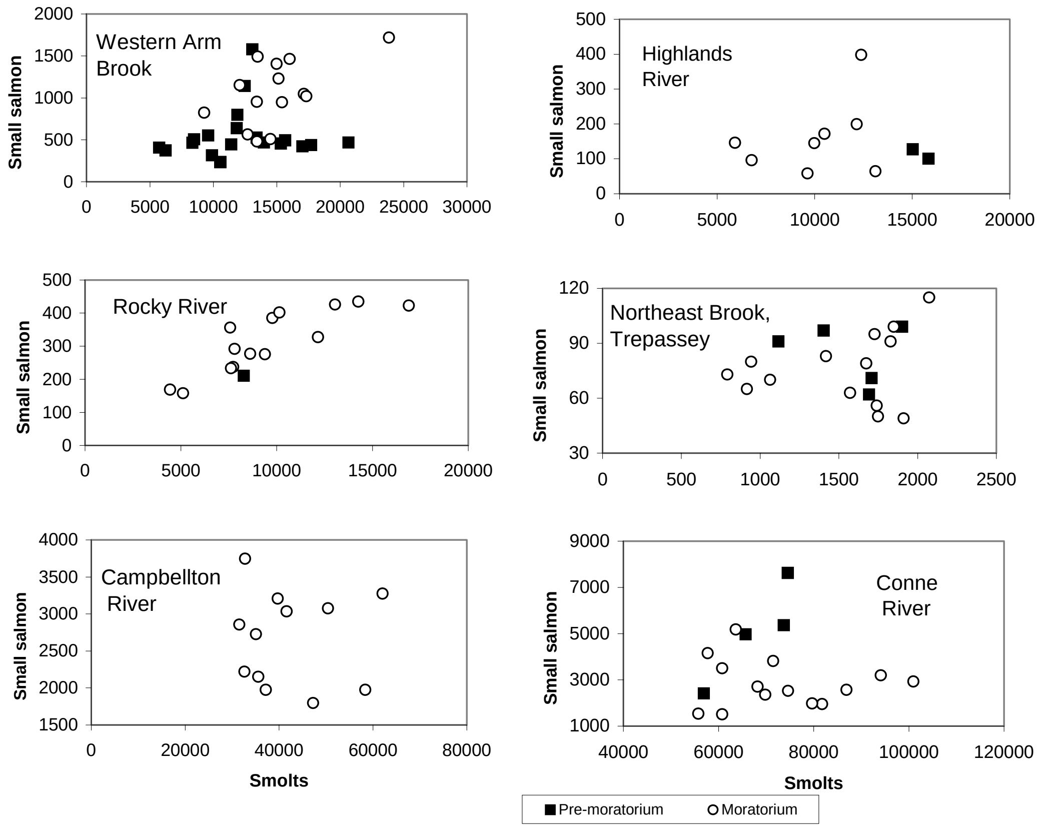
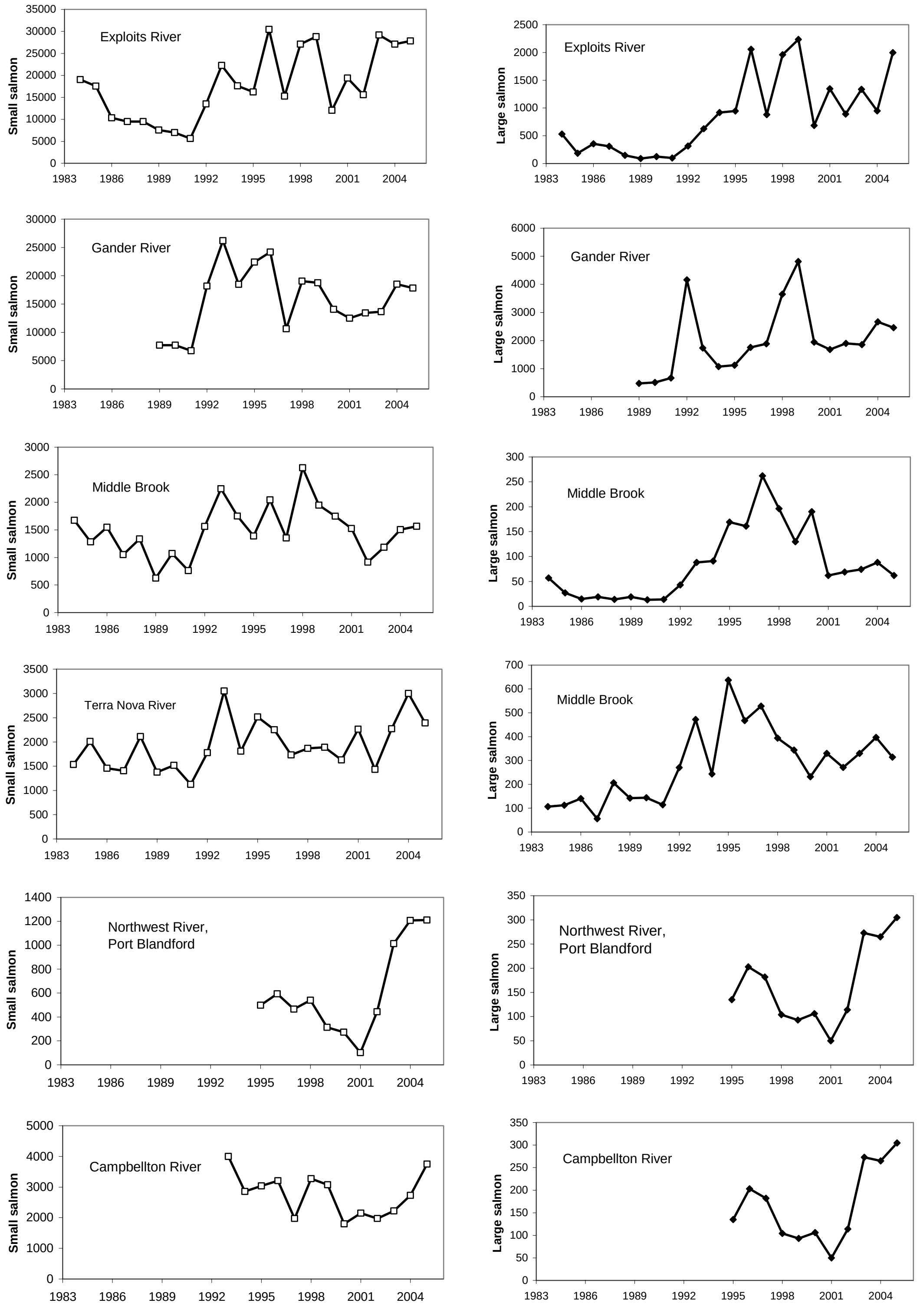
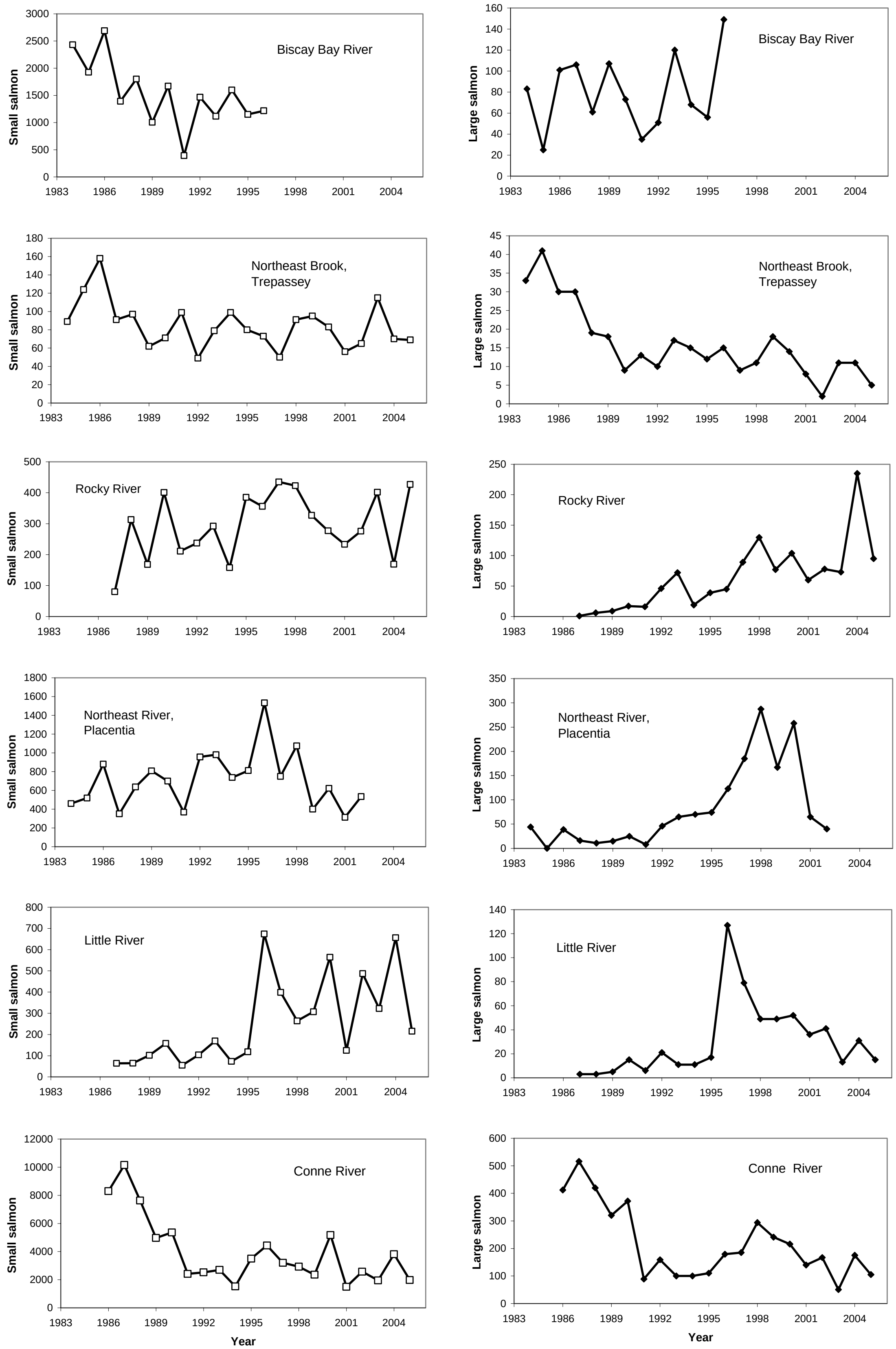


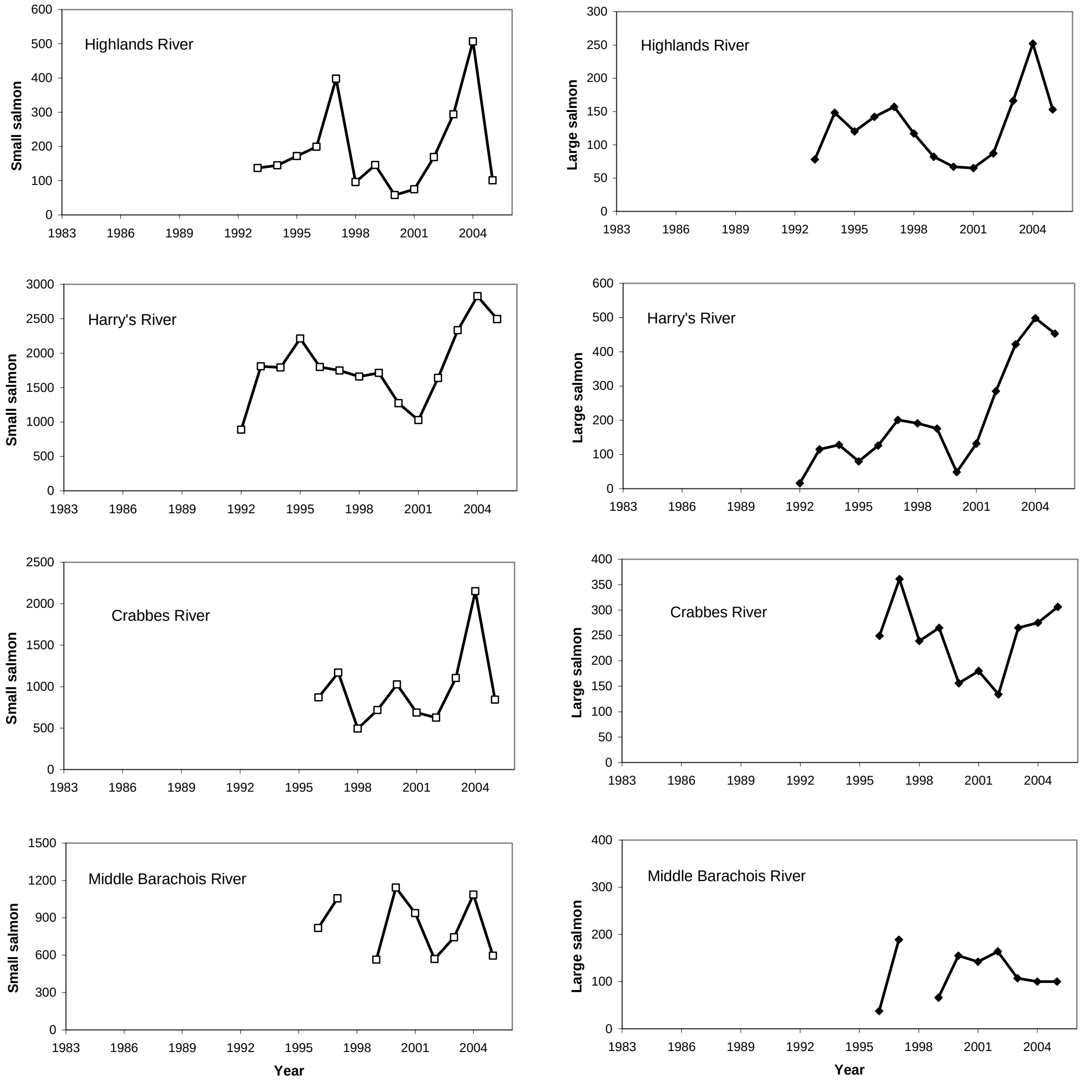
Figure 12. Relationship between smolt production and subsequent return of adult small salmon from various Newfoundland rivers. Moratorium years (1992 to 2005) are shown separately.



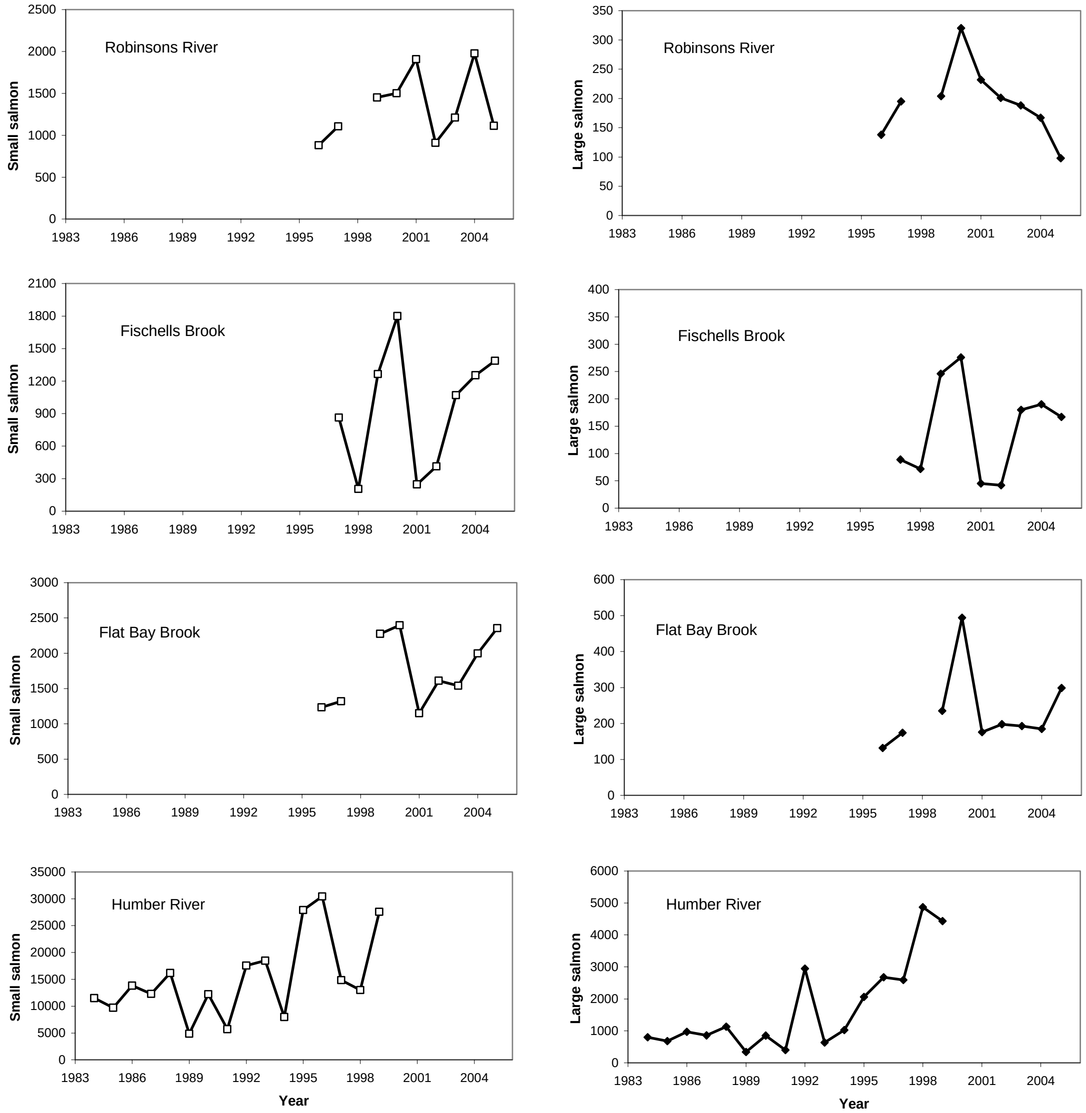
Appendix 1a. Total returns of small (left) and large (right) Atlantic salmon to various Northeast coast rivers in Newfoundland, 1984 - 2005.



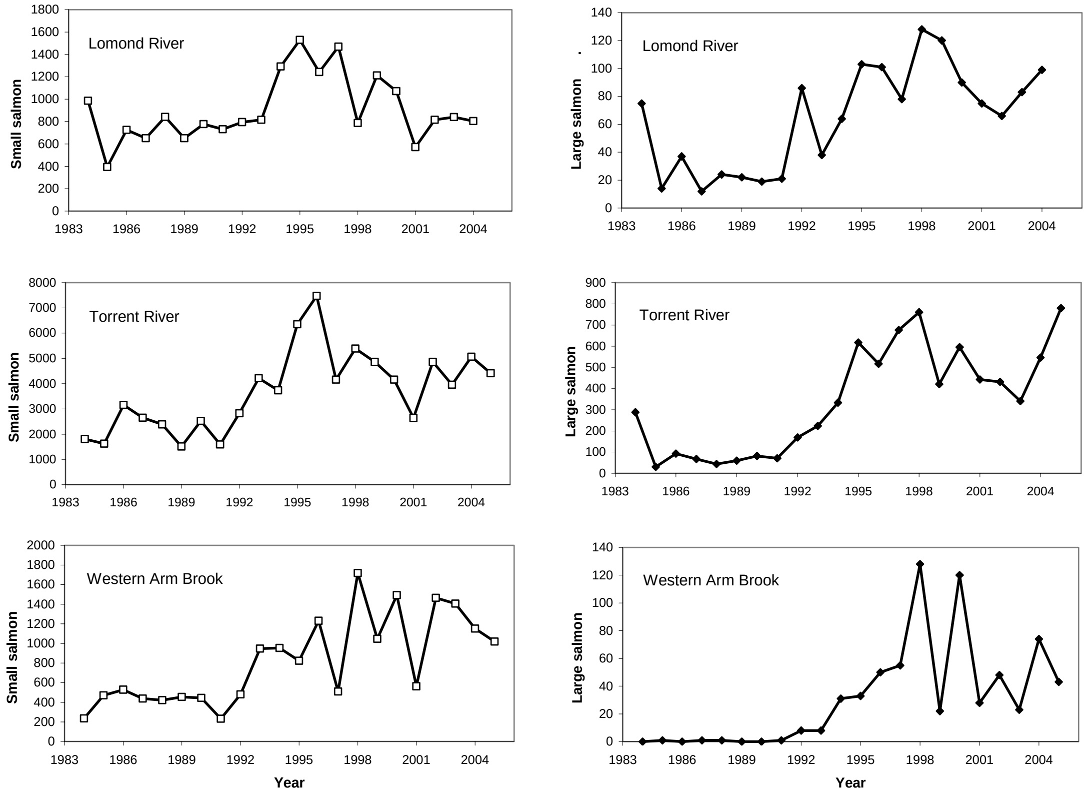
Appendix 1b.   Total returns of small (left) and large (right) Atlantic salmon to various South coast rivers in Newfoundland, 1984 - 2005.



Appendix 1c. Total returns of small (left) and large (right) Atlantic salmon to various Southwest coast rivers in Newfoundland, 1984 - 2005.



Appendix 1d. Total returns of small (left) and large (right) Atlantic salmon to various Southwest coast rivers in Newfoundland, 1984 - 2005.



Appendix 1e. Total returns of small (left) and large (right) Atlantic salmon to various Northwest coast rivers in Newfoundland, 1984 - 2005.