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Newfoundland and Labrador Atlantic salmon (*Salmo salar*) stock status summary for 1999, and methods to address possible causes for continuing low abundance and survival

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Abstract

The status of Atlantic salmon (*Salmo salar*) stocks of Newfoundland and Labrador was determined using information on annual returns to rivers and spawning escapements relative to conservation requirements, abundance of smolts, and trends in marine survival. Overall, of 22 rivers in insular Newfoundland assessed relative to conservation requirements, 14 stocks met or exceeded their requirements, one river was at 65% of conservation, while 7 rivers were at 50% or less than their spawning requirements. Of the latter rivers, three were located in Bay St. George (SFA 13), while three others were enhanced stocks that have been, or are undergoing colonization programs. Some salmon populations continue to remain at low levels of abundance, while others that have experienced increased spawning escapements, have shown no enhanced adult production resulting from this increase in the number of spawners. Marine survival remains low. Limited information from Labrador indicated that while salmon runs were generally low overall, numbers increased over previous years as evidenced by returns to two counting facilities. Factors potentially contributing to low abundance of some stocks and overall poor marine survival are identified along with suggestions as to how some of the factors could be further investigated.

Résumé

L'état des stocks de saumon de l'Atlantique (*Salmo salar*) de Terre-Neuve et du Labrador a été déterminé à l'aide d'information sur les remontées annuelles dans les cours d'eau et les échappées de géniteurs par rapport aux besoins de conservation, à l'abondance de saumoneaux et aux tendances de survie en mer. Des 22 cours d'eau de la zone insulaire de Terre-Neuve qui ont été évalués en fonction des besoins de conservation, 14 avaient atteint ou dépassé leurs besoins, un était à 65 % de ses besoins de conservation et 7 étaient à 50 % ou moins de leurs besoins en géniteurs. Pour ces derniers cours d'eau, trois étaient situés dans la baie St-Georges (SPS 13) et trois autres abritaient des stocks accrus grâce à des programmes de colonisation. Certaines populations de saumon enregistraient toujours de faibles niveaux d'abondance, tandis que d'autres ayant connu une augmentation des échappées de géniteurs ne montraient aucune hausse de la population d'adultes résultant de l'accroissement du nombre de géniteurs. Le taux de survie en mer demeure faible. Selon des données limitées du Labrador, les migrations de saumons étaient généralement basses, mais elles ont augmenté par rapport aux années précédentes comme l'a démontré le nombre de remontées enregistrées à deux postes de comptage. Les facteurs qui peuvent contribuer au faible niveau d'abondance de certains stocks et au faible taux global de survie en mer sont décrits et sont accompagnés de suggestions sur des façons d'étudier plus en détail certains de ces facteurs.

Introduction

Following the widespread decline in the abundance of Atlantic salmon returning to Newfoundland rivers in 1997, a review and analysis of various factors that could have contributed to the poor returns was carried out (Dempson et al. 1998). Although marine survival of the 1996 smolt class was among the lowest recorded, with six monitored stocks having smolt-to-adult small salmon return rates of less than 4%, the above report concluded that: "*No single factor, nor combinations of factors were identified that were clearly indicative of having been the direct cause of the lower than expected returns in 1997.*" Low returns have occurred in the past, and indeed, events similar to 1997 will likely occur in the future because salmon populations are characterized by being highly variable in abundance. The above report also highlighted that fact that there is evidence that the ecosystem of the northwest Atlantic has changed during the 1990's but acknowledged that in the absence of studies directed at the marine life stage of salmon, insight into identifying and quantifying impacts in the marine environment remains limited.

What makes the above situation one of concern however, is that despite large scale reductions in directed fishing exploitation on salmon, the average marine survival during the commercial salmon fishery moratorium (1992 to 1999) has been less than 7% (average survival range: 2.0 – 6.5%) whereas some populations experienced higher survival rates in some past years when directed fisheries were still in existence. In addition, the average survival during the past two years (1998 – 1999) is actually lower in five of six stocks than it was for the 1992 to 1997 period; that is, there is really no sign of improvement. Some populations continue to remain at low levels of abundance, while others that have experienced increased spawning escapements, have shown no enhanced adult production resulting from this increase in the number of spawners.

Smolt production peaked in 1996 and 1997 at four of six monitored stocks, while other stocks had smolt numbers similar to longer term averages (Dempson et al. 1998). This suggests that problems related to salmon abundance are likely happening in the marine environment. This does not necessarily imply that the problems associated with continued low marine survival could not be initiated in freshwater (e.g. Walters and Ward 1998; Fairchild et al. 1999), only that most evidence to date points to the marine area as the habitat in which, for most stocks, the survival is now lower than in the past especially when fisheries exploitation rates are accounted for.

The past decade has seen a number of anomalous abiotic and biotic events occurring in the northwest Atlantic. Colbourne et al. (1997) report that environmental conditions and water temperatures off Newfoundland were the severest recorded during the late 1980's and early 1990's. A number of aquatic marine species have shown distribution shifts coincident with environmental changes (e.g. northern cod: Rose et al. 2000; capelin: Frank et al. 1996; Carscadden and Nakashima 1997; Arctic cod and pandalid shrimp: Drinkwater and Mountain 1997), while American plaice (*Hippoglossoides platessoides*) declined in abundance in the absence of high rates of fishing (Bowering et al. 1997). Dietary changes have also been documented in seabird species (Montevecchi and Myers 1996; Bryant et al. 1999; Rowe et al. 2000) and collectively, these studies provide irrefutable evidence of major changes in the northwest Atlantic ecosystem. It is likely then, that Atlantic salmon have also been affected in some manner during the marine phase of their life-history.

As input to an interregional process to identify and develop testable hypotheses related to factors contributing to the low abundance of Atlantic salmon in the northwest Atlantic, many of which have already been described by Parrish et al. (1998), this paper: a) provides a brief update on the current status of Atlantic salmon in Newfoundland and Labrador in 1999; and b) presents a summary of various factors that could have contributed to the decline in salmon production in the northwest Atlantic, along with suggested approaches for testing various hypotheses associated with these factors. Specific details related to the status of Atlantic salmon stocks is contained in the most recent Stock Status Report (DFO 2000).

Methods

The status of Atlantic salmon stocks is determined from the annual returns to rivers and spawning escapements relative to conservation requirements, abundance of smolts, and trends in marine survival. During the commercial salmon fishery moratorium (1992-99), the numbers of small and large salmon returning to rivers in insular Newfoundland are considered to be the total number of salmon produced. Spawning escapements are determined by accounting for known removals of salmon, including recreational harvests, broodstock collections, in-river mortalities, or scientific samples. The status of stocks is assessed on the basis of the proportion of the conservation egg deposition achieved in a given year. For Atlantic salmon rivers, conservation requirements are customized for each river depending on the amount of parr-rearing habitat available for salmon, which is developed from a physical survey of the river. The conservation requirements are based on 2.4 eggs per m^2 of river rearing habitat and 368 or 105 eggs per hectare of lake habitat depending on the river system (105 eggs per hectare is used for some northwest coast and some Labrador rivers) (O'Connell and Dempson 1995). The conservation requirements are considered to be threshold reference points, but may not be appropriate for Labrador salmon stocks. In 1999, 26 rivers were assessed (Table 1).

Counts of smolts and small salmon 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, alternatively 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, allow estimates of egg-to-smolt survival to be derived and evaluated in relation to current conservation requirements. In Newfoundland, information on smolts and adult salmon counts is available from six rivers: Campbellton River (SFA 4); Northeast Brook, Trepassey (SFA 9); Rocky River (SFA 9); Conne River (SFA 11); Highlands River (SFA 13); and Western Arm Brook (SFA 14A). While the time series of available data varies among the rivers, each of the above have information that allows direct comparisons back to the 1993 smolt class. Often, biological characteristic data are used to remove repeat spawning fish from the population estimates for small salmon to derive values of survival to 1SW salmon. However, in the following discussions information on marine survival pertains to returns of small salmon only.

Section A - Resource Status

Labrador (SFAs 1-2, 14B)

There are 19 scheduled salmon rivers in SFAs 1 – 2 and 14B, although there are many more rivers that contain populations of Atlantic salmon. Prior to the closure of the Labrador commercial salmon fishery in 1998, landings (small and large salmon combined) averaged 369 t annually during the period from 1984 to 1989, and 111 t per year from 1990 to 1997, the period in which quotas and allowances were in effect. Commercial salmon landings during the last year of the commercial fishery (1997) were about 47 t. Specific rivers assessed in Labrador in 1999 include English River and Big Brook (Michaels River) (SFA 1), and Paradise River (SFA 2) (Fig. 1). The former two rivers were assessed using fish counting facilities while mark-recapture was used at Paradise River.

Status

Salmon returns to English River in 1999 were low totalling 107 small and large salmon combined. Salmon returns at Big Brook (N = 917), however, were 45% higher than in 1997, the only previous year that the river had been assessed. Conservation spawning requirements for Labrador rivers have not been defined and the use of 240 eggs per 100 metres squared of fluvial habitat and 105 eggs per hectare of pond habitat may not be appropriate. However, using the fluvial egg deposition rate as a reference level only, then Big Brook would have achieved

38% of the reference value. The habitat area of English River is not currently defined to allow for a similar comparison however, the number of spawners seems very low considering the river has a drainage area of about 300 square kilometres.

In contrast with the above SFA 1 rivers, 5,172 salmon were estimated to have returned to Paradise River, of which about 9.5% were large salmon. Using 240 eggs per 100 metres squared of fluvial habitat as a reference, then 96% of the reference value would have been met at Paradise River (Fig. 1).

Northeast and eastern Newfoundland (SFAs 3 – 8)

There are 60 scheduled rivers in SFAs 3 – 8. Prior to the closure of the Newfoundland commercial salmon fishery, landings (small and large salmon combined) averaged 422 t annually during the period from 1984 to 1991. The largest (Exploits) and third largest (Gander) rivers in Newfoundland occur in the area. Specific rivers assessed in this area include Exploits, Campbellton, and Gander rivers in SFA 4, and Middle Brook, Terra Nova River, Northwest River (Port Blandford), and Indian Bay Brook in SFA 5 (Fig. 2). All of the above stocks are assessed using fish counting facilities.

Status

Total returns of small and large salmon in 1999 were variable, with some rivers, including Exploits and Gander, having returns higher than in 1998 and the 1992 to 1998 mean, while others had lower returns. Returns of small salmon at Exploits River were the second highest since the moratorium began. Returns of large salmon in 1999 were the highest recorded at both Exploits and Gander rivers. With the exception of Exploits River, Terra Nova River and Northwest River (Port Blandford), other rivers assessed in these SFAs met or exceeded their conservation spawning requirements in 1999 (Fig. 2, Table 1). The opening up of additional habitat in 1985, as part of ongoing enhancement initiatives since the late 1980's, has more than doubled the amount of accessible rearing area on Terra Nova River and the river is essentially still in a colonization phase. Returns to this river were somewhat higher during the moratorium years compared to the pre-moratorium years, but it is not possible to determine the relative contribution of enhancement measures versus the closure of the commercial fishery in this regard. Most of the habitat in Northwest River (Port Blandford) was opened up to anadromous salmon in the late 1940s and enhancement programs (colonization) have been carried out on the Exploits River since the late 1950s.

Campbellton River, Middle Brook, and Indian Bay Brook have exceeded their conservation spawning requirements in each of the years that the rivers have been assessed during the moratorium (Table 1). Gander River has met or exceeded conservation in 5 of 8 years, while Terra Nova, Exploits and Northwest

River (Port Blandford) have yet to reach their conservation spawning requirements. There has been no apparent consistent change in the biological characteristics of either adult salmon returns or smolt migrants in recent years.

Marine survival

At Campbellton River (SFA 4), estimates of marine survival are available since the 1993 smolt class. During the 1993 - 1995 period, survival to subsequent small salmon returns averaged 8.1%. This fell to 3.4% with adult returns in 1997. Since then, survival has remained relatively low at 5.3% and 6.1% for small salmon returns in 1998 and 1999, respectively (Fig. 3).

Smolt production

Smolts produced at Campbellton River have ranged from a high of 62050 in 1997 to a low of 31577 in 1993. Smolt production in 1999 fell 6% from 1998, and was 24% lower than the peak run in 1997 (Fig. 4). Despite the decline in smolt production over the past two years, the 1999 run was similar to the mean production from 1993 – 1998 ($\bar{x}$ = 47303). Returns of adult small salmon in 2000 will be below that of 1999 unless there is an increase in marine survival to compensate for the decrease in smolt production.

South Newfoundland (SFAs 9 – 11)

There are 50 scheduled rivers in SFAs 9 – 11. Prior to the closure of the Newfoundland commercial salmon fishery, landings (small and large salmon combined) averaged 87 t annually during the period from 1984 to 1991. Owing to the proximity of the populated St. John's and Mount Pearl areas, some rivers in SFA 9 are often subject to substantial angling pressure. Bay d'Espoir (SFA 11) is the site of an aquaculture industry utilizing rainbow (steelhead) trout, Atlantic salmon, and at times brook trout. Numbers of each of these species have escaped sea cages and entered Conne River. In recent years, rainbow trout have also been confirmed in other south coast Newfoundland rivers including Biscay Bay River (SFA 9), Long Harbour River, Grand Bank Brook and Little River (SFA 11).

Specific rivers assessed in this area include Northeast Brook (Trepassey) and Rocky River in SFA 9, Northeast River (Placentia) in SFA 10, Little River and Conne River in SFA 11 (Fig. 2). Conne River has both a conservation spawning requirement and a management target. Spawning escapements of the above stocks are assessed using fish counting facilities while mark-recapture methods are used to survey smolt production at Conne River.

Status

Total returns of small salmon in 1999 declined relative to 1998 at all monitored rivers with the exception of Little River. The greatest decline was observed at Northeast River (Placentia), where small salmon returns fell about 60% from the previous year and the 1992-98 mean, and were the lowest recorded since 1987. Large salmon returns fell at three rivers, dropping 42% at Northeast River (Placentia), but were similar to or higher at Little River and Northeast Brook (Trepassey). However, at all monitored rivers returns of large salmon in 1999 were higher than the 1992-98 mean values. With the exception of Rocky River, all other monitored rivers met or exceed their conservation spawning requirements in 1999 (Fig. 2), while Conne River achieved 68% of its management target. Northeast Brook (Trepassey) and Northeast River (Placentia) have exceeded their conservation spawning requirements in each year during the moratorium (Table 1). Conne River has met its conservation requirement in 6 of 8 years, while Rocky River has yet to reach its conservation requirement. Enhancement initiatives (colonization) have been in progress on Rocky River and Little River since the 1980's, with Little River currently undergoing a fry stocking programs. Consequently, Little River was not evaluated relative to a specific conservation requirement. Note that some south coast rivers had average returns of small salmon during 1992 – 99 that are lower than returns prior to the closure of the commercial salmon fishery. There has been no apparent consistent change in the biological characteristics of either adult salmon returns or smolt migrants in recent years.

Marine survival

For Northeast Brook (Trepassey) (SFA 9), a late run river, marine survival has varied among years (Fig. 3). Peak survivals from the 1994 and 1995 smolt classes were in excess of 8 and 9%, respectively. Marine survival declined to 3% in 1997, and has remained at about 5% for adult small salmon returns in 1998 and 1999.

Rocky River (SFA 9) is an enhanced stock. Fry stocking occurred from 1984 - 1987, and again in 1995 and 1996. In 1987, 140 adult salmon were also stocked. Marine survival averaged 3.5% from the 1990 to 1995 smolt classes, about 23% lower than that reported for Conne River. Marine survival has remained low with values no higher than 3% during the past three years (Fig. 3).

For Conne River (SFA 11), estimates of marine survival have varied widely among years (Fig. 3). The highest survivals occurred with the 1987 - 1989 smolt classes (7-10%), and again with returns in 1996 from the 1995 smolt class (7.2%). Survival from the 1996 smolt class fell to 3.4% and declined to 2.9% with adult small salmon returns in 1998. Marine survival for adults returning in 1999 was 3.4%, similar to that observed from the 1996 smolt class. Note that an experiment using wild Conne River smolts reared in an aquaculture cage operation for one year achieved a survival rate four times greater than that obtained under natural conditions suggesting that fish have maintained the capacity to survive but events likely occurring at sea continue to affect overall marine survival (Dempson et al. 1999).

Smolt production

In each of the rivers where smolts were monitored, production in 1999 fell from 9% (Conne River) to 29% (Rocky River) relative to 1998, and was lower than the mean production during the 1992 – 1998 moratorium years (Fig. 4). The number of smolts leaving these rivers has declined in each of the past two years. Corresponding increases in marine survival will be required in order for adult small salmon returns in 2000 to meet or exceed 1999 values.

Southwest Newfoundland (SFAs 12 - 13)

There are 26 scheduled rivers in SFAs 12 and 13. SFA 12 was closed in 1984. Prior to the closure of the Newfoundland commercial salmon fishery, landings (small and large salmon combined) in SFA 13 averaged 52 t annually, during the period from 1984 to 1991. Humber River, the second largest river in Newfoundland, and several rivers in Bay St. George, produce significant numbers of large salmon, many of which are maiden multi-sea-winter fish. Historically, rivers in Bay St. George produced among the highest recreational catches of salmon in insular Newfoundland, although in recent years, a number of these stocks remain at low levels of abundance. Highlands River, Fischells Brook, and Cooks Brook were closed to recreational fishing in 1999. Rainbow trout, presumably from aquaculture escapees, have been observed or angled in La Poile River and Garia Brook (SFA 12), Flat Bay Brook, Robinsons River, and Humber River (SFA 13).

Specific rivers assessed in this area include Highlands River, Harry's (Pinchgut) River, Crabbes River, Middle Barachois Brook, Fischells Brook, Robinsons River, Flat Bay Brook, and Humber River (Fig. 2). Crabbes, Fischells, Robinsons, Middle Barachois and Flat Bay rivers were assessed by snorkelling surveys, Highlands and Pinchgut using fish counting facilities, and Humber River by mark-recapture.

Status

Total returns of small salmon showed marked improvements at all rivers except Middle Barachois Brook relative to recent years, and were similar to the previous year at Pinchgut Brook, a tributary of Harrys River. Total returns of large salmon were also generally higher, with the exception of Highlands River. All monitored rivers met or exceeded their conservation spawning requirements except for Highlands, Harrys, Crabbes, and Middle Barachois Brook (Fig. 2, Table 1). Highlands, Fischells, Middle Barachois, Robinsons and Flat Bay rivers have reached their conservation requirements only once since the moratorium began. Humber River has met or exceeded its conservation requirement in 5 of 8 years, while Crabbes and Harrys rivers have yet to reach their conservation spawning requirements.

Marine survival

For Highlands River, counts of smolts and adult salmon are available from two time periods: 1980 - 1982 and 1993 - 1999. Highlands River is characterized by a run of two-sea-winter (2SW) salmon as well as a few 3SW fish. Marine survival from smolts to small salmon was less than 1% in the early 1980's, but increased to 1.6% from the 1993 - 1995 smolt classes reaching a high of 3.2% for 1997 small salmon returns (Fig. 3). Returns of small salmon in 1998 coincided with the lowest marine survival rate obtained (1.42%) during the 1990's, but survival increased to 2.5% with salmon that returned in 1999. Survival to 2SW salmon returns in 1999 was the lowest in recent years which corresponds to the low survival rate of small salmon in 1998.

Smolt production

Smolt production at Highlands River increased by about 60% over the previous year, but was still lower than the mean production from 1993 to 1996 (Fig. 4). During 1997 and 1998, smolt numbers at Highlands River fell dramatically as a result of an extreme winter flood in February 1996. Higher numbers of smolts are expected in 2000.

Northwest Newfoundland (SFA 14A)

There are 22 scheduled rivers in SFA 14A. Prior to the closure of the Newfoundland commercial salmon fishery, landings (small and large salmon combined) averaged 37 t annually. Salmon returns and spawning escapements have improved the greatest in SFA 14A since 1992 compared with rivers in other SFAs in Newfoundland. Rainbow trout, presumably from aquaculture escapees, have been angled in and in Trout River, Parsons Pond. Portland Creek, and River of Ponds (SFA 14A) in recent years. Specific rivers assessed in this area include Lomond River, Torrent River, and Western Arm Brook (Fig. 2). All of these stocks are assessed using fish counting facilities.

Status

Total returns of small salmon were variable, with returns at Lomond River increasing over 1998, but with substantive declines at Torrent River and Western Arm Brook. Returns of large salmon declined at Lomond River and were the lowest in five years at Torrent River and Western Arm Brook. Despite the declines experienced in 1999, conservation spawning requirements at each of these rivers were greatly exceeded as in all years since the closure of the commercial salmon fishery (Fig. 2, Table 1). Lomond and Torrent rivers are enhanced (colonized) stocks. There has been no apparent consistent change in the biological characteristics of either adult salmon returns or smolt migrants in recent years.

Marine survival

For Western Arm Brook (SFA 14A), estimates of marine survival are available for 27 years. Survival has ranged from a low of 2.2% for small salmon returns in 1991, to a high of 12.1% in 1979. In general, higher marine survivals have occurred subsequent to the closure of the commercial fishery in 1992, but similar or even higher values were obtained prior to the closure of fisheries. Marine survival was 6.1% for small salmon returns in 1999, which is about 12% lower than the average survival during the previous five years (1994 - 1998) (Fig. 3). It must be kept in mind that the above referenced estimates of marine survival shown for years prior to 1992 have not been corrected for commercial exploitation. When corrected, the difference between marine survival rates in pre- and post-1992 periods are even greater (Fig. 3).

Smolt production

Since the moratorium began in 1992, smolts produced at Western Arm Brook have ranged from a high of 23,845 in 1997 to a low of 9,283 in 1994 (Fig. 4). Smolt production in 1999 fell 21% from 1998, and was 43% lower than the peak run in 1997. The decline in smolt production has occurred despite the high spawning escapements that have occurred coincident with the moratorium. Returns of adult small salmon in 2000 will be below that of 1999, unless there is an increase in marine survival to compensate for the decrease in smolt production.

Section B - Methods to address low abundance and survival

This section examines possible causes of the decline of North American salmon, outlining geographic scope, background and methods that could be used to test various hypotheses. It is not our intention here to begin with all potential causes but instead to build on what is already known and has been studied. We used as a beginning point for probable causes Dempson et al. (1998) and DFO (1998).

Factor accounts

Factors that potentially affect sea survival of salmon take place at various life-history stages and times prior to the onset of maturation and return to natal rivers. These factors could be associated with: 1) environmental conditions in freshwater and marine habitats; 2) removals by legal and illegal fisheries; 3) predation by avian, fish or mammalian sources; 4) diseases or parasites 5) changes to the biology of specific life stages; and 6) effects of escaped aquaculture salmon; and 7) physical effects such as pollution, etc. Dempson et al. (1998) were not able to completely eliminate density-dependent effects in freshwater affecting subsequent survival at sea but felt that current in-river programs (as they existed in 1999) were sufficient to explain freshwater causes as far as insular Newfoundland is concerned if they continue into 2000 and beyond. Consequently, they were not considered here.

We consider the following factors to be potentially but not exclusively causes of the low returns of Atlantic salmon to Newfoundland rivers in recent years.

1. Predation

Hypothesis – predation by marine birds, fish and/or mammals has increased, thereby reducing adult returns and survival rates from smolt to adult returns to rivers.

Background – the distribution and abundance of many prey species, i.e. capelin, has changed in recent years such that the diet of marine birds, fish such as cod, and seals may also have changed. Gannets, gulls, cod and seals are known to prey on salmon in estuaries and the open sea. Also, population distribution of some of these species seems to have shifted to areas suggestive of increased mortality on salmon. Of particular importance, may be estuaries and nearshore areas.

Life stage – smolt passage through estuaries and during ocean life

Geographic scope – covers Labrador Sea, inshore marine areas and many estuaries of Newfoundland and Labrador.

Probable change since 1984 –increased abundance of seals and some species of birds while overall cod abundance has declined there is a tendency to find them very close inshore over previous distributions.

Evidence – salmon postsmolts have been found in the stomachs of cod in estuaries of several rivers, several species of marine birds have been observed feeding on postsmolts in estuaries and at sea in the Newfoundland area. Seals have been observed in inshore areas feeding on salmon. Note: in the absence of historic information, it is unknown if these current feeding events represent a change in feeding behaviour, or rate of feeding by comparison with the past.

Tests – estuaries – mark-recapture estimates for cod in conjunction with stomach content analysis in the estuaries of rivers with smolt/adult enumeration facilities could determine the magnitude of predation and its impact on sea survival and adult returns. Examination of avian predators feeding in estuaries and their droppings at nesting sites could be used to quantify predation on salmon smolts. Seal behaviour could be monitored in estuaries with samples taken for stomach contents analyses to examine them for the presence of salmon postsmolts and adults. All of the above would be best done near rivers with enumeration facilities so that the effect on salmon abundance and survival rates can be quantified.

Tests – open sea –salmon distribution surveys at sea using trawls/acoustics can also monitor areas fished for presence of seals and avian predators. Archival tags could be applied at postsmolt stage that record depth, temperature and geoposition that when recovered can be used to compare to the marine distributions of seals and avian predators to detect areas of overlap.

2. Ocean climate

2.1. **Indirect impact on prey availability**

Hypothesis – altered ocean climate (oceanographic conditions) has changed migration routes/or lower marine temperature reduced survival through availability of prey.

Background –variable ocean climate seems to have changed the distribution and abundance of many marine species, i.e. capelin, cod, etc., in recent years shifting the marine regime in the northwest Atlantic. This may have altered productivity and availability of prey for salmon at sea to the extent that migration routes, maturity schedules and mortality rates have reduced the number of adult salmon returning to the coast and home rivers.

Life stage – postsmolt and adult during ocean life.

Geographic scope – covers Labrador Sea, Grand Banks and Greenland areas.

Probable change since 1984 – ocean climate in terms of temperature declined in the early 1990s but has since increased in 1998-99.

Evidence – lower abundance and sea survival of salmon returning to home rivers, lower proportion and abundance of salmon at Greenland, and higher incidence of North American salmon in the Norwegian Sea suggest that salmon distribution and abundance may have changed at sea. Distribution and abundance of cod and capelin and other marine species have not returned to what they were in the 1970s and 1980s. Recent paper by Tucker et al. (1999) on detecting pan-Atlantic migration in salmon using cesium suggests that salmon distribution is more panoceanic than previously thought or that the distribution has changed.

Tests – *open sea* –salmon distribution surveys at sea using trawls/acoustics including the application of archival tags. Comparison can be made to previous known distributions and research vessel catch rates.

Climate change can be monitored using satellite SST data and climate models can be applied to current SST data to discern magnitude and geographic areas of change. When coupled with models of the relationship of salmon catch rate and temperature the effects on salmon habitat can be quantified.

2.2 Direct impact on survival of smolts

Hypothesis – Marine survival of smolt differs among populations.

Background - Historic and current information on marine survival from smolt to returning small salmon shows that northeast and northwest coast Newfoundland populations have higher overall survival rates than south and southwest coast stocks. It is unknown whether this represents a true population difference, or a response to variable marine climate conditions experienced by smolts in different geographic areas.

Life stage – smolt and postsmolt

Geographic scope – northwest, east/northeast, south and southwest coast salmon populations

Probable change since 1984 – Marine survival has fallen in several south coast stocks, with continued declines or stable low rates experienced since the moratorium began.

Tests – To investigate whether there are true differences in survival among populations in the absence of different environmental conditions, salmon smolts from several populations could be reared in a common marine environment until the post-smolt or 1SW stage. The procedure would follow the procedures outlined in Dempson et al. (1999), where marine survival of cage-reared wild smolts increased by a factor of four over the average survival experienced by the same stock. The experimental design could also be modified to test the UV radiation theory, by treating different 'experimental cage-groups' differently.

3. Pollution

Hypothesis – smolts during out-migration from rivers through estuaries have lower survival rates due to the presence of endocrine disrupting chemicals and other pollutants and/or through increased solar radiation at sea.

Background – several authors have shown that parr-smolt transformation and adaptation to seawater are impaired by the exposure to gonadal steroids or endocrine disrupting chemicals. Fairchild et al. (1999) suggested a link between past pesticide use and declines of some Atlantic salmon populations. Chemical pollutants from pulp mill discharges, industrial effluents and municipal sewage also contain endocrine disrupting chemicals.

A recent paper by Walters and Ward (1998) suggested the possibility that exposure to solar radiation (UV-B) alters metabolic processes during stressful periods of transition to ocean entry which may in turn lower marine survival rates.

Life stage – smolt passage through estuaries and postsmolts and adults during ocean life.

Geographic scope – covers Labrador Sea, inshore marine areas and estuaries and rivers of Newfoundland and Labrador.

Probable change since 1984 –increased levels of pollution and exposure to UV radiation due to reductions in the ozone layer have occurred.

Tests – estuaries – investigate the mechanisms whereby chemical substances exert their influence on sea water adaptability. Measure estuaries and rivers with counting facilities for the presence of pollutants and endocrine disrupting chemicals.
Tests – open sea – investigate possibility of changes to food web in northwest Atlantic from UV radiation by analysis of plankton data from the Sir Alistair Hardy Institute.

Measure levels of UV radiation in Newfoundland and Labrador and their potential for reducing sea survival.

4. Impact of marine aquaculture operations

Hypothesis - Salmon populations are surviving at rates similar to those experience in past years, but returning adult salmon are confused by high concentrations of pheromones given off by salmon reared at aquaculture sea cage sites.

Background – Numbers of Atlantic salmon and marine survival rates at Conne River have declined since the late 1980's. Coincident with these declines, there has been an increase in the production of aquacultured fish (steelhead and Atlantic salmon) at Bay d' Espoir.

Life stage – returning adult salmon

Geographic scope – limited to areas with high concentrations of aquaculture operations

Probable change since 1984 – salmon populations have declined overall, while aquaculture operations have increased.

Evidence - Courtenay et al. (1997) have shown that coho salmon can discriminate among chemical emanations of salmon from their own and other populations, and that preference among populations was influenced by the quantity of odour produced. It was also shown that faeces are one source of olfactory stimulus. Wild Atlantic salmon smolts cage reared to the 1SW stage at Bay d'Espoir, experienced stray rates higher than many other natural populations (20%), with many surviving salmon failing to return to their home river.

Tests - Adult Atlantic salmon returning to areas such as the Bay d'Espoir fiord, have a gauntlet of aquaculture cage sites to by-pass when returning to their natal river. These cage sites represent potential sources of confusing odours owing to the very nature that large quantities of faeces are likely deposited beneath cage sites. Adult Atlantic salmon that have already returned to Conne River could be electronically tagged (acoustic tag), then transferred and released back into the Bay d'Espoir fiord at varying distances from their natal river. Movements of fish could be tracked to determine if there is an attraction to various cage site operations, and whether salmon are potentially 'lost' when trying to return to the river.

***Overall recommendation* – programs which monitor smolt and adult numbers in freshwater should be continued, and strengthened in areas where information is weak or lacking particularly in Labrador where there are currently no monitoring facilities. Labrador salmon stocks are at the northern end of the range of Atlantic salmon and information on these stocks may contain early clues as to the fate of North American salmon elsewhere. Studies designed to investigate potential causes of low abundance and survival should be initiated.**

Summary

- Limited information from **Labrador** (SFAs 1 – 2) indicated that while salmon runs were generally low overall, numbers increased over previous years as evidenced by returns to two counting facilities.

- In **Northeast and eastern Newfoundland** (SFAs 4 – 5), total returns of small (< 63 cm) and large (≥ 63 cm) salmon in 1999 varied, with some rivers, including Exploits and Gander, having returns higher than in 1998 and the 1992-98 mean, while others had lower returns. With the exception of Exploits River, Terra Nova River and Northwest River (Port Blandford), four other rivers assessed in these SFAs met or exceeded their conservation spawning requirements in 1999. Marine survival of smolts to returns of small salmon at Campbellton River increased from 5.3% to 6.1% over that observed in 1998, but survival was still less than the average survival of 8.1% from 1994 to 1996.

- In **Southern Newfoundland** (SFAs 9 – 11), total returns of small salmon in 1999 declined relative to 1998 at all monitored rivers with the exception of Little River. The greatest decline was observed at Northeast River Placentia, where returns of small salmon fell about 60% from the previous year and the 1992-98 mean, and were the lowest recorded since 1987. Returns of large salmon fell at three rivers, declining 42% at Northeast River Placentia, but were similar to or higher at Little River and Northeast Brook (Trepassey). However, at all monitored rivers returns of large salmon in 1999 were higher than the 1992-98 mean values. With the exception of Rocky River, four other monitored rivers met or exceed their conservation spawning requirements although the management target at Conne River was not attained. Some south coast rivers have average returns of small salmon during 1992 – 99 that are lower than returns prior to the closure of the commercial salmon fishery. Marine survival is monitored at three south coast rivers (Northeast Brook (Trepassey), Rocky River, and Conne River). While showing small increases over the previous year, survival remains low at or less than 5% for all rivers and below the 1992-98 means.

- In **Southwest Newfoundland** (SFAs 12 - 13), total returns of small salmon showed marked improvements at Highlands, Crabbes, Robinsons, Fischells, Flat Bay and Humber rivers and were similar to the previous year at Pinchgut Brook, a tributary of Harrys River. Salmon returns to Middle Barachois Brook seem to have declined. With the exception of Highlands River, total returns of large salmon were also generally higher. Except for Highlands, Harrys, Crabbes, and Middle Barachois brooks, all other monitored rivers met or exceeded their conservation spawning requirements. Marine survival of smolts to small salmon returns at Highlands River increased from 1.4% to 2.5% over that observed in 1998. Survival to 2SW salmon fell to the lowest value recorded during the 1990s (0.5%).

- In **Northwest Newfoundland** (SFA 14A), total returns of small salmon were also variable, with returns at Lomond River increasing over 1998, but with substantive declines at Torrent River and Western Arm Brook. Large salmon returns were the lowest in five years at Torrent River and Western Arm Brook, but also declined at Lomond River relative to 1998. Despite the declines experienced in 1999, conservation spawning requirements were greatly exceeded at each of these rivers, continuing the trend that began with the commercial salmon fishery moratorium. Marine survival of smolts to small salmon returns at Western Arm Brook fell from 7.2% to 6.1% in 1999, and was about 12% less than the average survival during the past five years (1994 – 98).

- Overall, of 22 rivers in insular Newfoundland assessed relative to conservation requirements, 14 stocks met or exceeded their requirements, 1 river was at 65% of conservation, while 7 rivers were at 50% or less than their spawning requirements. Of the latter rivers, three were located in Bay St. George (SFA 13), while three others were enhanced stocks that have been, or are undergoing colonization programs.

- With the exception of Highlands River, **smolt production** in 1999 decreased from 5% to 29% at five of six monitored rivers when compared with 1998, and was the lowest observed during the past four of five years. In contrast, smolt numbers were 60% higher at Highlands River, but still lower than the 1993 – 96 mean. For those rivers that have experienced overall declines in smolt production, returns of small salmon are expected to decline from 1999 levels unless there are corresponding increases in marine survival to compensate for the reduction in smolt numbers.

- Rainbow trout, presumably escapees from aquaculture marine cages, have been documented in a number of rivers along the south and west coasts of Newfoundland in 1998 and 1999.

- Various factors potentially contributing to continued low abundance and survival of Atlantic salmon stocks were identified, and suggestions provided as to how some of the factors could be further investigated.

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Table 1. Summary of Atlantic salmon stock status in the Newfoundland Region. Conservation met refers to the actual percentage of the conservation spawning requirement achieved, but is intended as a reference level only for Labrador stocks. Refer to footnotes for definition of characters and abbreviations.

Region / River	SFA	Map Index	Method	Total Returns in 1999 Small	Total Returns in 1999 Large	Conservation met (%) 1995	1996	1997	1998	1999	1992 - 1999	Status in 1999: Smolts Relative to 1998	Smolts Relative to 1992 - 98	Marine Survival Relative to 1998	Marine Survival Relative to 1992 - 98	Egg Deposition Relative to 1998	Egg Deposition Relative to 1992 - 98
Labrador																	
English *	1	3	Fe	59	48												
Big Brook *	1	2	Fe	737	180			24		38	0 of 2 yrs					-	⇧
Paradise *	2	1	MR	4681	491					96	0 of 1 yrs						
Newfoundland																	
Northeast Coast																	
Exploits	4	1	Fw	28303	2239	39	69	24	48	50	0 of 8 yrs					⇔	⇧
Lower	4		Fw			121	210	72	146	146	7 of 8 yrs					⇔	⇧
Middle	4		Fw			24	43	15	35	35	0 of 8 yrs					⇔	⇧
Upper	4		Fw			12	26	10	6	7	0 of 8 yrs					⇔	⬇
Campbellton	4	2	Fe	3076	493	279	304	200	311	326	7 of 7 yrs	⬇	⇔	⇧	⬇	⇔	⇧
Gander	4	3	Fe	18491	482	95	124	62	110	121	5 of 8 yrs					⇔	⇧
Indian Bay Brook	5	4	Fe	2248	365			113	183	161	3 of 3 yrs					⬇	⇔
Middle Brook	5	5	Fw	1950	130	114	250	196	306	227	8 of 8 yrs					⬇	⇧
Terra Nova River	5	6	Fw	1952	343	45	36	32	32	34	0 of 8 yrs					⇔	⇔
Northwest Brook (Port Blandford)	5	7	Fe	314	93	37	55	46	42	28	0 of 5 yrs					⬇	⬇

Assessment methods: Fe = counting fence; Fw = fishway count; Sc = snorkel count; MR = Mark-recapture

Trend symbols: ⬇ > 10% decrease; ⇧ > 10% increase; ⇔ no change = ± 10%

Map index numbers refer to text figure and legend

Marine survival is from smolts in year i to small salmon in year i + 1

* Use of 240 eggs/100 m2 as a conservation requirement for Labrador rivers may not be appropriate, and is used here only as a reference level

Table 1. Continued. Summary of Atlantic salmon stock status in the Newfoundland Region. Conservation met refers to the actual percentage of the conservation spawning requirement achieved, but is intended as a reference level only for Labrador stocks. Refer to footnotes for definition of characters and abbreviations.

Region / River	SFA	Map Index	Method	Total Returns in 1999 Small	Total Returns in 1999 Large	Conservation met (%) 1995	1996	1997	1998	1999	1992 - 1999	Status in 1999: Smolts Relative to 1998	Smolts Relative to 1992 - 98	Marine Survival Relative to 1998	Marine Survival Relative to 1992 - 98	Egg Deposition Relative to 1998	Egg Deposition Relative to 1992 - 98
Newfoundland																	
South Coast																	
Northeast Brook (Trepassey)	9	8	Fe	95	18	194	196	135	256	248	8 of 8 yrs	⬇	⬇	⬄	⬇	⬄	⇧
Rocky River	9	9	Fe	377	77	56	34	56	54	39	0 of 8 yrs	⬇	⬇	⇧	⬇	⬇	⬄
Northeast River (Placentia)	10	10	Fw	363	167	422	736	486	484	269	8 of 8 yrs					⬇	⬇
Little River	11	11	Fe	307	49												
Conne	11	12	Fe	2357	241	147	204	125	150	122	6 of 8 yrs	⬄	⬇	⇧	⬇	⬇	⬄
Southwest Coast																	
Highlands	13	13	Fe	141	72	67	79	105	59	49	1 of 7 yrs	⇧	⬄	⇧	⇧	⬇	⬇
Crabbes	13	14	Sc	686	264		68	95	44	65	0 of 7 yrs					⇧	⇧
Middle Barachois	13	15	Sc	565	67		52	97		44	0 of 6 yrs					-	⬇
Robinsons	13	16	Sc	1431	203		67	91		117	1 of 6 yrs					-	⇧
Fischells	13	17	Sc	1264	246			44	23	110	1 of 6 yrs					⇧	⇧
Flat Bay	13	18	Sc	2261	235	45	85	89		149	1 of 7 yrs					-	⇧
Harrys	13	19	Fe	1643	171	48	52	50	49	49	0 of 8 yrs					⬄	⇧
Humber	13	20	MR	27585	4433	128	186	115	120	201	6 of 8 yrs					⇧	⇧
Northwest Coast																	
Lomond	14A	21	Fw	1091	121	187	143	161	151	181	8 of 8 yrs					⇧	⇧
Torrent	14A	22	Fw	4330	411	1033	1279	797	924	680	8 of 8 yrs					⬇	⬇
Western Arm B rook	14A	23	Fe	1046	22	286	415	200	625	370	8 of 8 yrs	⬇	⬇	⬇	⬄	⬇	⇧

Assessment methods: Fe = counting fence; Fw = fishway count; Sc = snorkel count; MR = Mark-recapture

Trend symbols: ⬇ > 10% decrease; ⇧ > 10% increase; ⬄ no change = ± 10%

Map index numbers refer to text figure and legend

Marine survival is from smolts in year i to small salmon in year i + 1

* Use of 240 eggs/100 m2 as a conservation requirement for Labrador rivers may not be appropriate, and is used here only as a reference level

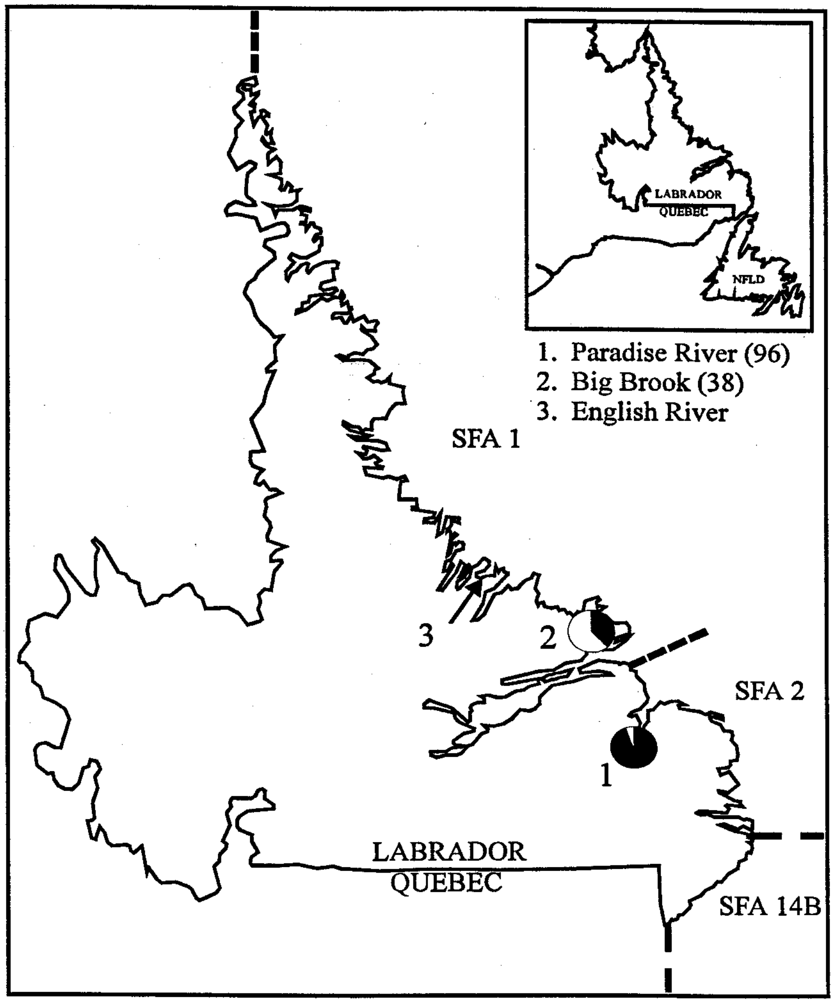

Figure 1. Map illustrating the location of the Salmon Fishing Areas of Labrador, along with salmon rivers assessed in 1999. The black portion of the circle and the numbers in parentheses indicate the percentage of the conservation reference level achieved in 1999. English River (map index 3) was not assessed relative to conservation spawning requirements.

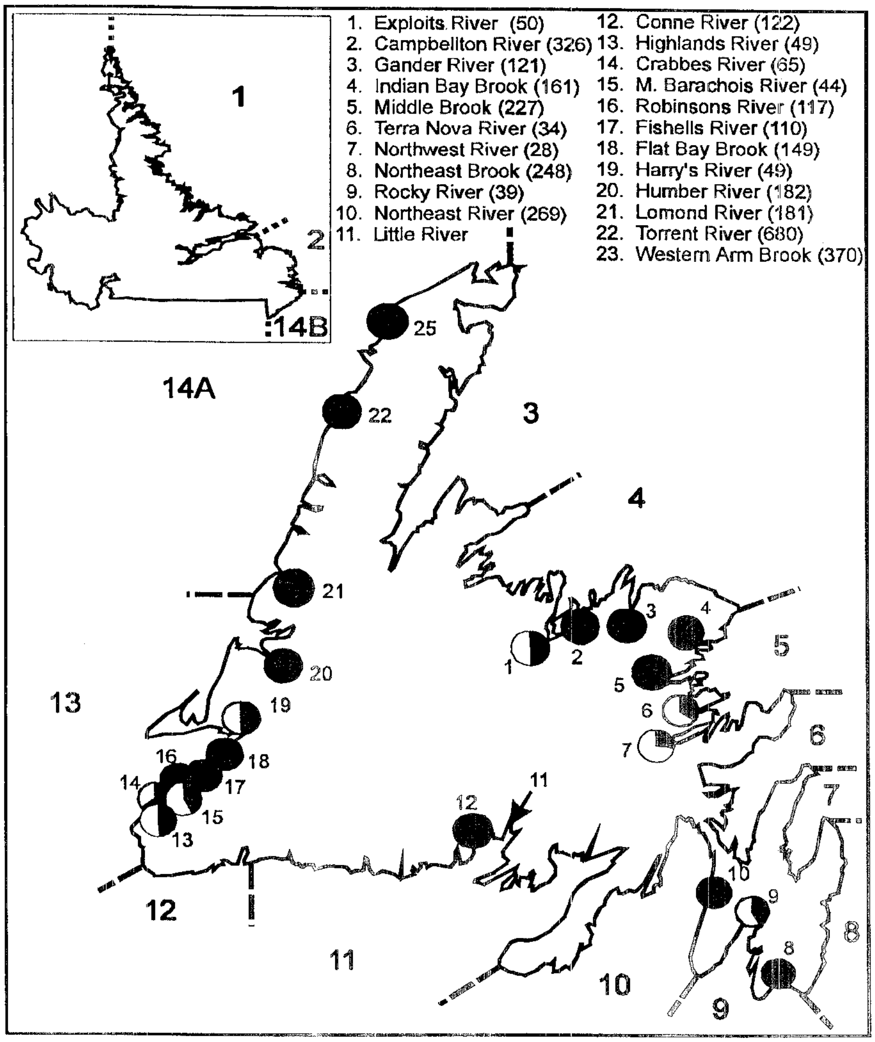

Figure 2. Map illustrating the location of the Salmon Fishing Areas of Newfoundland, along with the various salmon rivers assessed relative to their conservation requirements. The black portion of the circle and the numbers in parentheses indicate the percentage of the egg conservation requirement achieved for each river in 1999. Little River (map index 11) was not assessed relative to conservation spawning requirements.

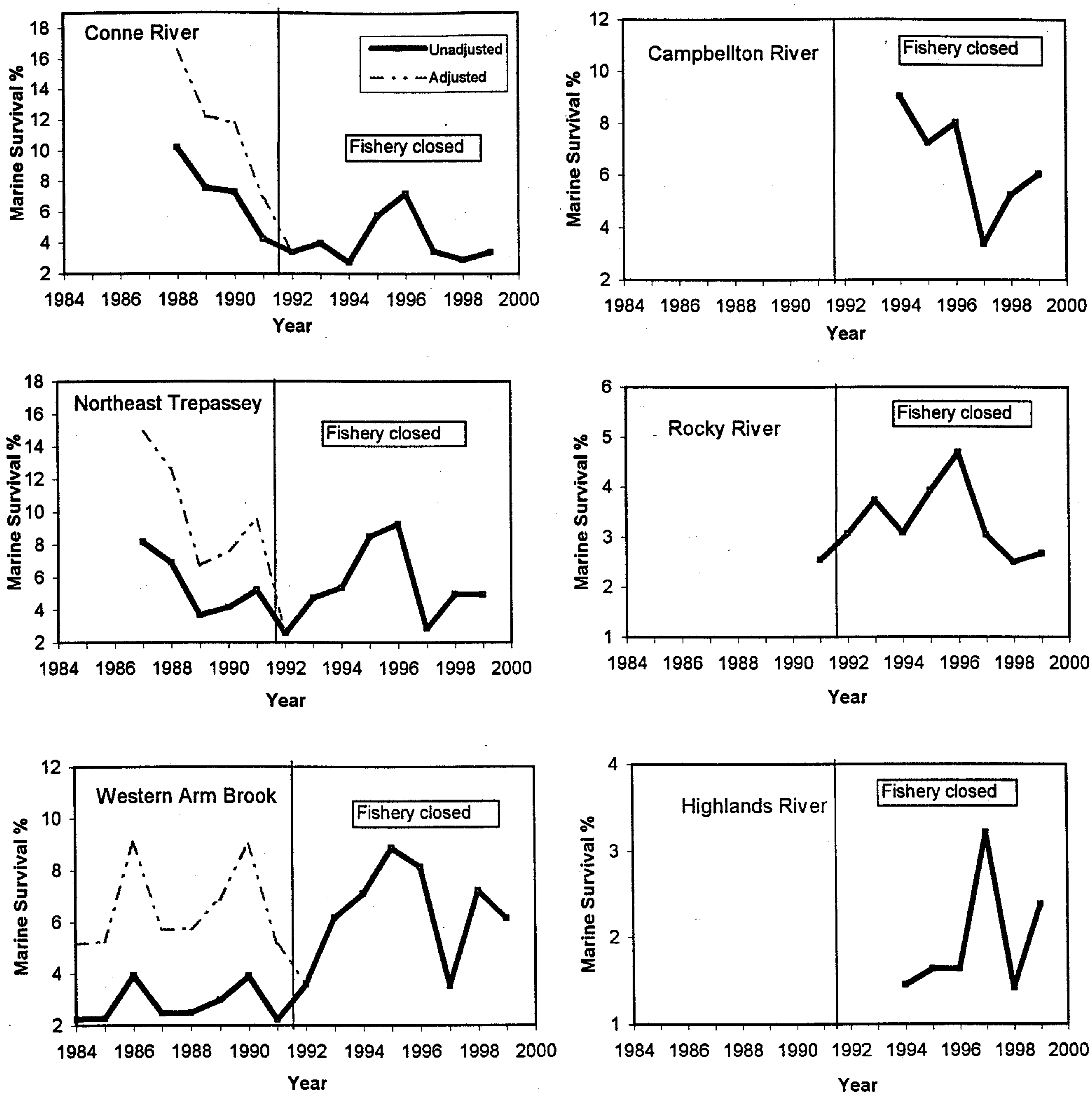

Fig. 3. Marine survival rates for small Atlantic salmon at Conne River, Campbellton River, Northeast Brook (Trepassey), Rocky River, Western Arm Brook, and Highlands River, Newfoundland. Dashed lines illustrate survival rates adjusted from marine exploitation.

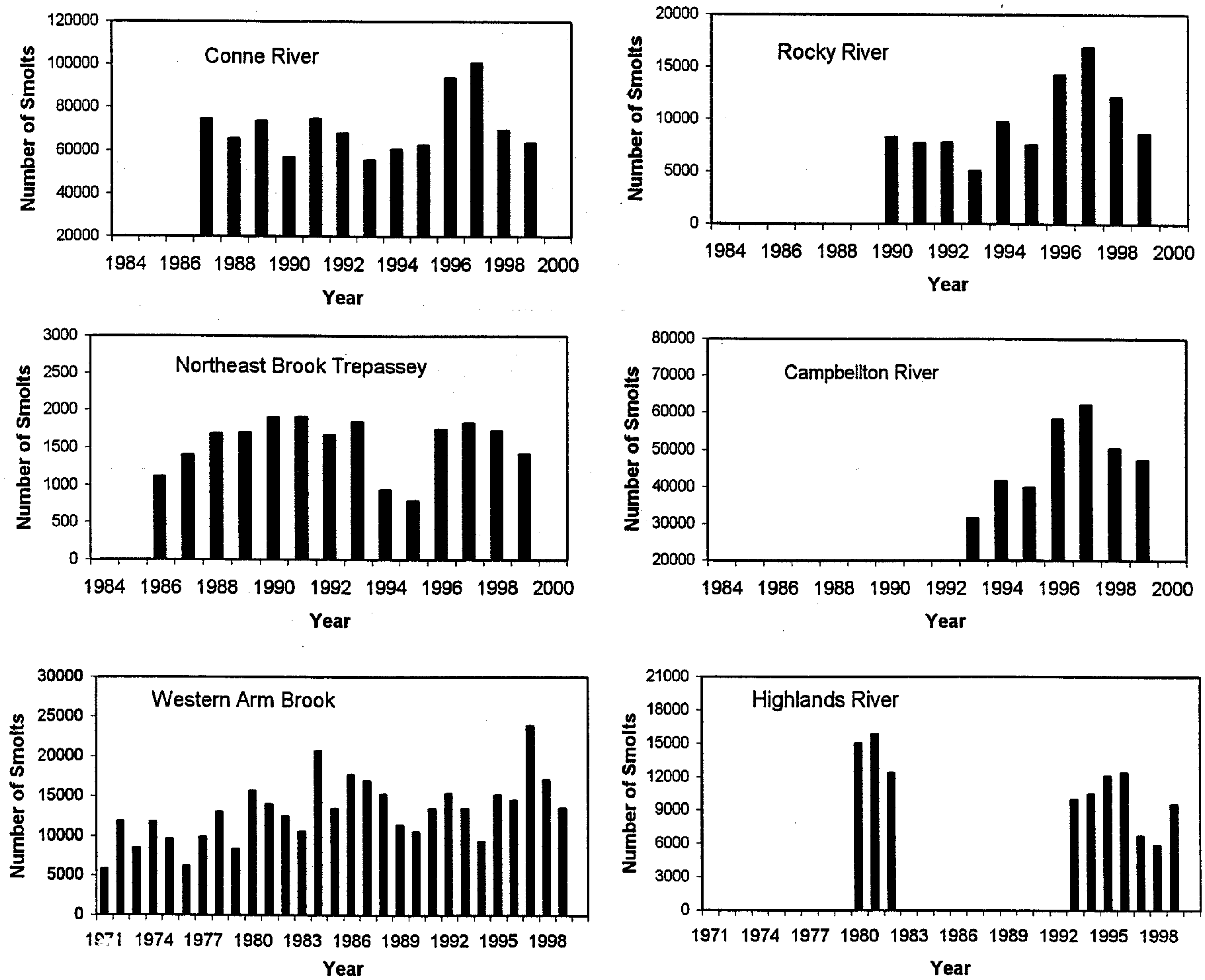

Fig. 4. Smolt counts at Conne River, Rocky River, Northeast Brook (Trepassey), Campbellton River, Western Arm Brook, and Highlands River, Newfoundland.