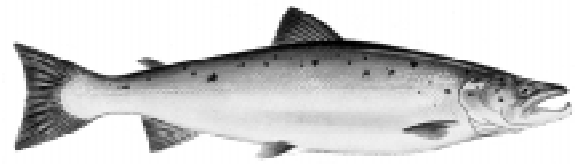


Atlantic Salmon Abundance Overview for 1997

Background

There are approximately 550 Atlantic salmon rivers in eastern Canada. Each river is assumed to consist of at least one stock with the larger rivers containing several stocks. There is a diverse life history structure including variations in freshwater residence time, age at maturity and the extent of ocean migrations. Spawning populations consist of varying proportions of small salmon (fork length <63 cm) and large salmon (fork length •63 cm). In the majority of rivers, small salmon are predominantly grilse (never spawned before) which have spent one year at sea before returning to spawn (one-sea-winter salmon, 1SW). The large salmon component contains a mixture of multi-sea-winter fish which have spent two (2SW) and occasionally three years at sea before spawning and previous spawners which are returning for a second or subsequent spawning.

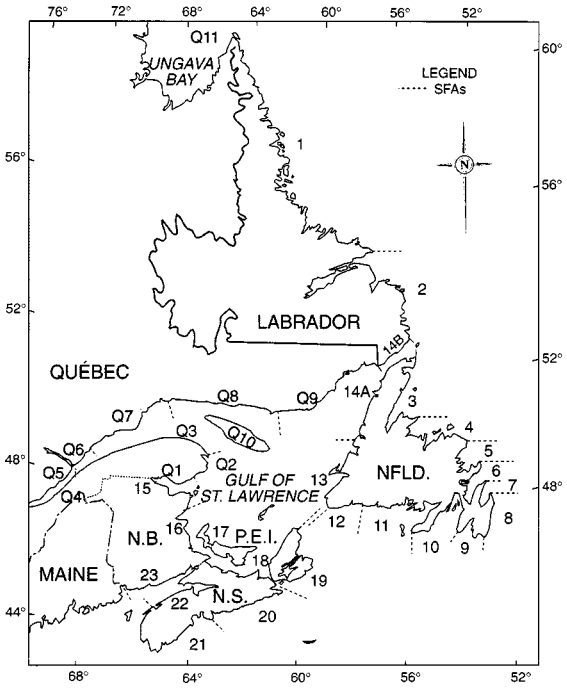
Inseason reviews of salmon returns in 1997 resulted in closure of some fisheries. Returns were low throughout most of eastern Canada.

Low returns in 1997 cannot be looked at in isolation of past events. Historic information suggests that salmon populations are characterized by fluctuations in abundance which can be quite severe and which can occur over wide geographic areas. Salmon populations have previously displayed a high resilience that has allowed them to survive and persist for subsequent generations. Exceptions are cases where the habitat has been eliminated or severely degraded.

The unexpected decline in abundance in 1997 prompted this review of the status of the resource, the trends in abundance, and examination of factors that could have contributed to low returns. Short-term and long-term expectations for the Atlantic salmon resource of eastern Canada are described.

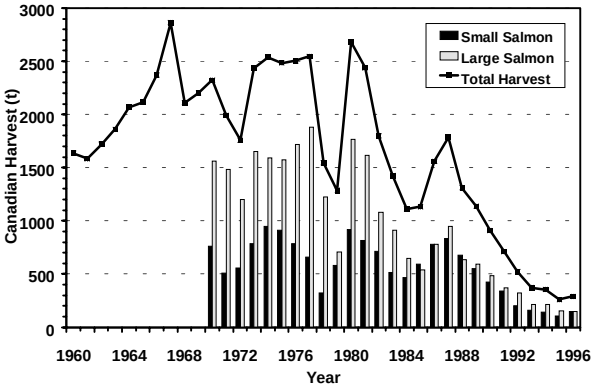
Conservation for Atlantic salmon, considered to be a threshold reference point, defines the level of egg deposition below which the consequences are likely to be deleterious.

Stock assessments of individual rivers will be available in spring 1998.

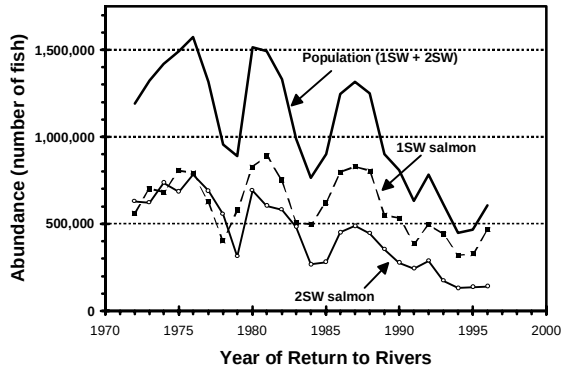


Historical Harvests and Production

Historical harvests in Canadian fisheries show wide fluctuations in abundance of Atlantic salmon. The sharp decline in harvested tonnage since 1988 is for the most part the result of reductions in commercial salmon fisheries effort and, since 1992, the closure of the insular Newfoundland commercial salmon fishery. Reduced harvests also correspond to declines in overall abundance of salmon.



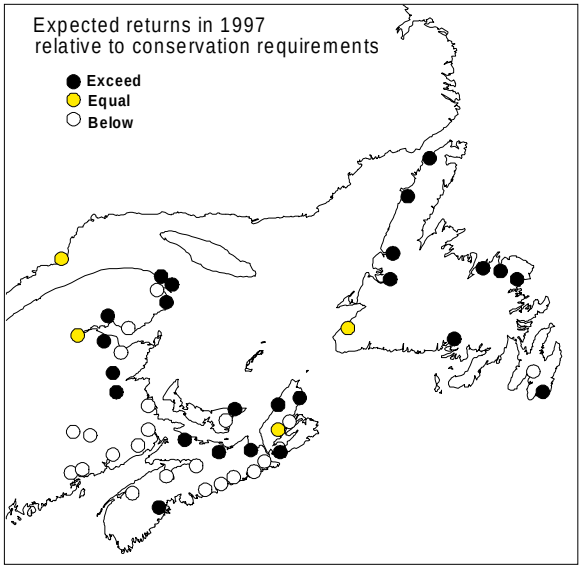
The estimated total abundance of North American origin Atlantic salmon (before any exploitation) was calculated from the total returns to rivers of eastern Canada and the US and the harvests in the Canadian and Greenland commercial fisheries. The total population of 1SW and 2SW Atlantic salmon in the northwest Atlantic has oscillated around a generally declining trend since the 1970s, and the abundance recorded in 1993-1996 was the lowest in the time series.



During 1993 to 1996, the total population of 1SW and 2SW Atlantic salmon was about one-half million fish, 45% of the average abundance during 1972 to 1990. The decline has been more severe for the 2SW salmon component than for the small salmon (maturing as 1SW salmon) age group.

Expectations for 1997

Substantive increases in spawning escapements in northeast coast Newfoundland rivers, high smolt and juvenile production in many rivers, and improved sea survivals in recent years in conjunction with suitable ocean climate indices were all suggestive of improved adult salmon returns for 1997. Forecasts of returns for 1997 were based on a combination of methods: i. use of the previous 5-year average returns; ii. forecast models based on small salmon returns in the current year to predict large salmon returns in the coming year; iii. stock-and-recruitment relationships; and iv. trends in survival rates of juveniles and smolts from hatchery stocking combined with stocking levels in previous years.



Returns to the Bay of Fundy and Atlantic coast of Nova Scotia were expected to be low, relative to conservation requirements, in 1997. Returns to Gulf of St. Lawrence rivers and generally throughout Newfoundland were expected to equal or exceed the conservation requirements. Most rivers which recently have been below conservation

requirements were expected to have returns again below conservation requirements in 1997.

Colder oceanic conditions both nearshore and in the Labrador Sea in the early 1990s are thought to have contributed to lower survival of salmon stocks in eastern Canada during that period. It was expected that increased marine water temperatures in 1994 to 1996 would have favoured higher marine survival and subsequent adult salmon production.

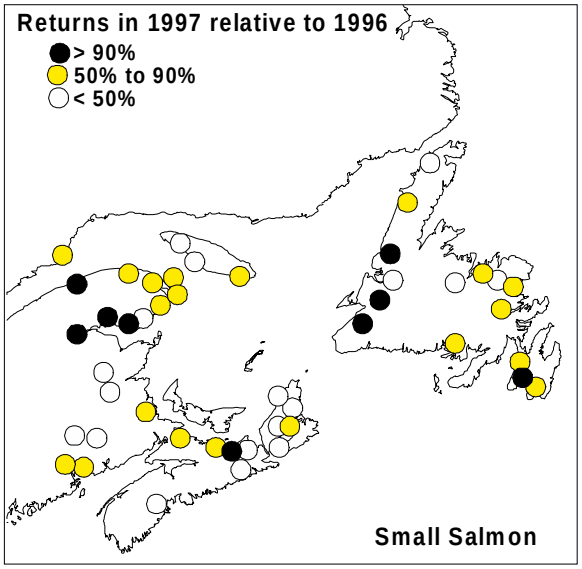
Status of Atlantic Salmon in 1997

Status was assessed in terms of returns to rivers which represent the size of the population before any in-river removals, but after any commercial marine harvests.

Returns to rivers since the closure of the commercial salmon fisheries in Newfoundland are an indication of the total population size. Prior to the commercial fisheries closure, returns to rivers represented but a portion of the river's stock (as small as 25% depending upon the river-specific marine exploitation rate on the stock). Returns to rivers are sometimes also used as a representation of the spawning stock size.

Information on returns was available for a total of 47 rivers in eastern Canada in 1997.

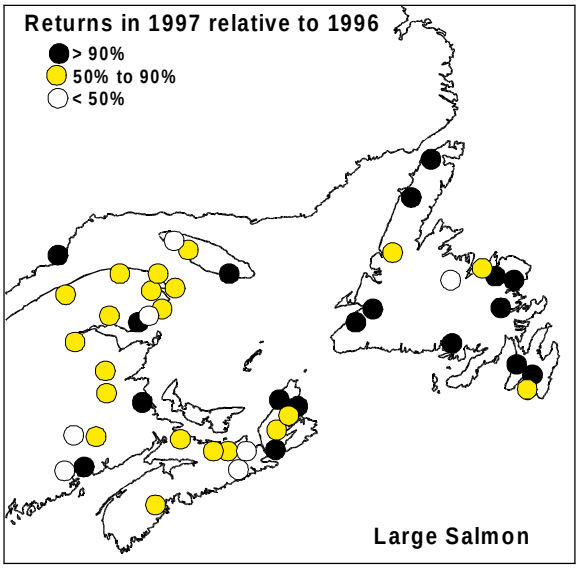
Small salmon returns in 1997 were similar or above 1996 levels in only 9 rivers (19% of rivers assessed). Returns were less than 50% of the previous year in 38% of rivers, spread through all regions of eastern Canada.



It is unlikely that the observed decline in 1997 relative to 1996 in the large number of rivers occurred by chance. The decline is probably indicative of a broad-scale phenomenon which affected returns to rivers in eastern Canada.

Relative to the recent five-year period, returns of small salmon in 1997 to the Maritimes and Québec were the lowest or second lowest in 75% of the rivers monitored. Returns of small salmon to Newfoundland rivers were the lowest or second lowest in 54% of the rivers.

Large salmon returns did not decline to the same extent as small salmon. Returns of large salmon to Newfoundland rivers in 1997 were similar to or improved relative to 1996. In most rivers of Newfoundland, large salmon are repeat spawners rather than maiden spawners.



Large salmon returns in 1997 declined throughout the Maritime provinces and Québec. In these Regions, large salmon are mostly 2SW salmon. It is unlikely that the observed decline in 1997 relative to 1996 in the large number of rivers occurred by chance. As with small salmon, the decline is probably indicative of a broad-scale phenomenon.

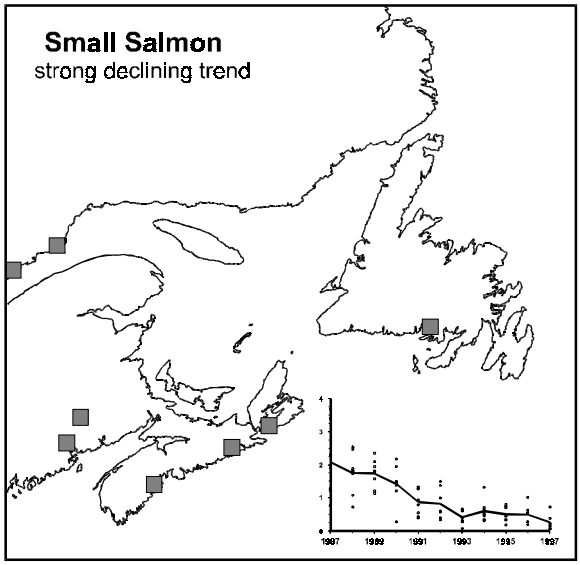
Large salmon returns in 1997 relative to the recent five years were the lowest or second lowest in 68% of the monitored rivers of the Maritimes and Québec. This contrasted with the returns of large salmon to Newfoundland which were the highest or second highest in the recent five-year period in 69% of the rivers.

Recent Trends (1987 to 1997)

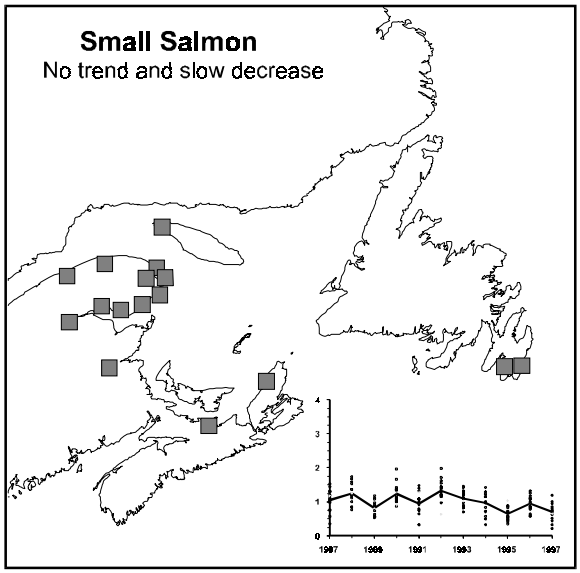
An analysis of the trends in returns to rivers of small salmon and large salmon for the period 1987 to 1997 provides an indication of the regional differences in status and prospects. There are however no data available for the Québec North Shore and Labrador due to lack of long-term monitoring facilities in these areas.

Analysis of the **small salmon** return trends for 37 rivers of eastern Canada revealed three major groups with different trend patterns over time. These three groups are shown below as returns to individual rivers on the same scale (1=the mean over 1987 to 1997); the line indicating the trend is plotted through the annual mean of the rivers in the group.

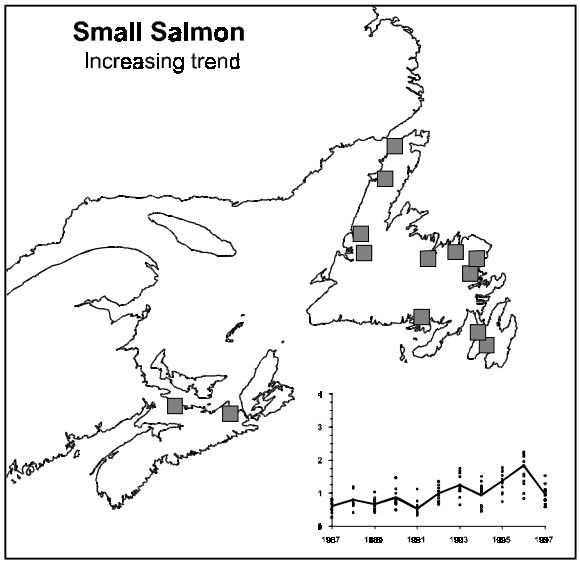
There was a strong declining trend in returns to eight rivers, mostly from the Bay of Fundy and Atlantic coast of Nova Scotia. These rivers are now at less than one-third of the average for the time series.



A second group of 16 rivers was characterized by stable returns up to 1993 followed by a declining trend. These rivers were clustered around the southern Gulf and Gaspé region of Québec and the southeast coast of Newfoundland.

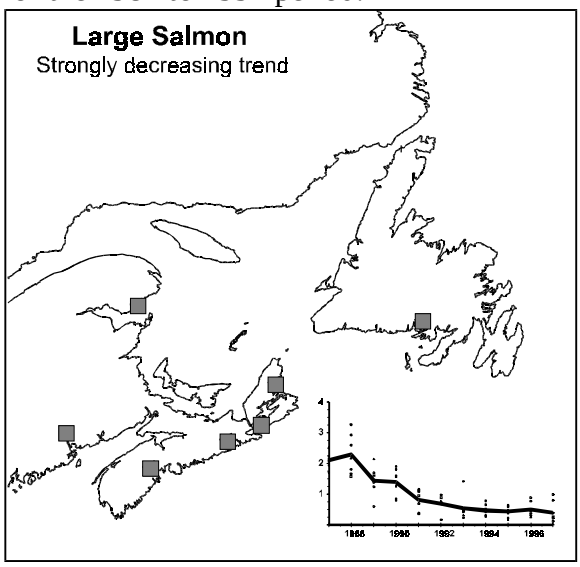


The third major group of 13 rivers was described by an increasing trend since 1992. Rivers characterized by this pattern were mostly from insular Newfoundland and these benefited most from the closure of the Newfoundland commercial salmon fisheries in 1992.

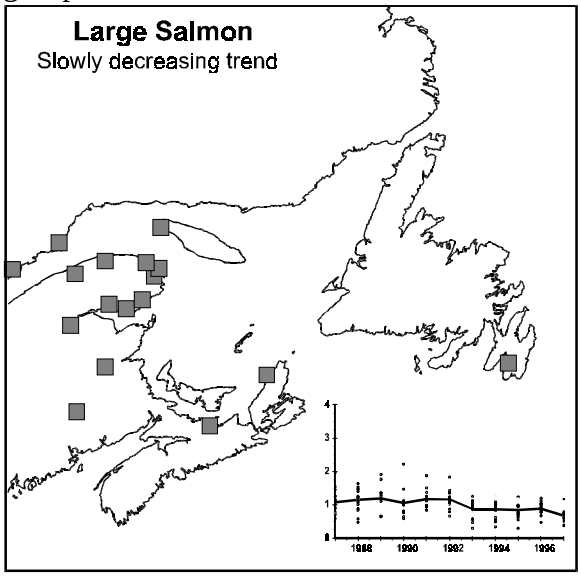


Large salmon returns over the same time series produced three groups as well, two with a decreasing trend and one with an increasing trend.

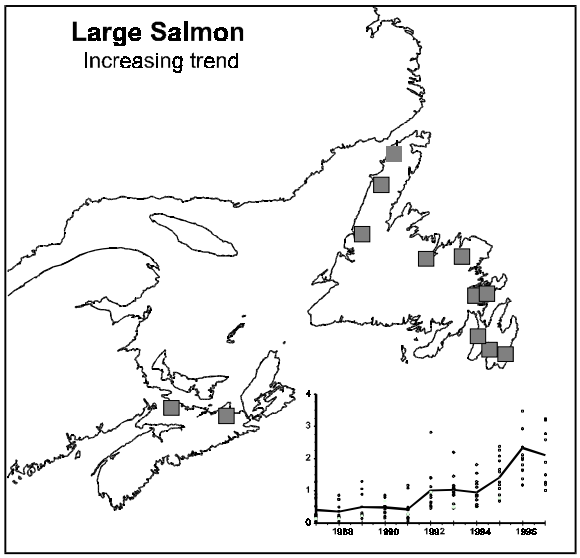
There was a strong decreasing trend in seven rivers, four of which were on the Atlantic coast of Nova Scotia. Large salmon abundance in these rivers since 1994 has leveled off at less than 50% of the average for the 1987 to 1997 period.



A slowly declining trend in returns to 17 rivers characterized the majority of rivers from Québec and the southern Gulf of St. Lawrence. The large salmon in these mainland rivers are comprised of maiden 2SW and 3SW salmon with varying proportions of repeat spawners of all age groups.



In a large number of Newfoundland rivers, returns of large salmon have increased since the closure of the commercial salmon fisheries in 1992. Increased returns have also been noted in some of the southern Gulf rivers which are primarily fall-run.



The analysis of trends for small salmon and large salmon returns to rivers illustrates a clear **geographic segregation**.

The Bay of Fundy and Atlantic coast of Nova Scotia are characterized by strong declines and returns since 1994 were considerably less than half the recent 10 year average. Rivers of Québec cover the entire range of slight declines through stable trend. The southern Gulf of St. Lawrence rivers ranged from slightly declining to some that are stable and others that are increasing. The majority of Newfoundland rivers have been characterized by increasing returns of both small and large salmon since the closure of the commercial salmon fisheries in 1992. The only exception was Conne River on the south coast of Newfoundland which exhibited a declining trend most similar to the southern Bay of Fundy and Atlantic coast of Nova Scotia group.

Returns pattern for small and large combined

Trend	Order of Decline	Fundy+NS	Québec	Gulf (NB+NS)	Nfld
Strong decline	1	Liscomb			Conne
Strong decline	1	St_Croix			
Strong decline	2	Grand			
Strong decline	2	LaHave			
Strong decline	3	North	Port_Daniel_Nord		
Decline	4	Saint_John	de_la_Trinité		
Decline	4		Sainte-Marguerite		
Decline	5		Bec-scie	East	
Decline	6		Bonaventure	Margaree	
Decline	6		Dartmouth	Miramichi	
Slight decline	7		Cascapédia	Restigouche	NETrepassey
Slight decline	7		Grande_Rivière		
Slight decline	7		Madeleine		
Slight decline	7		Matane		
Slight decline	7		Saint_Jean		
Slight decline	7		York		
Increase	8				BiscayBay
Increase	9			Philip	RockyR
Increase	9			West	
Increase	10				LittleR
Increase	11				Humber
Increase	11				Gander
Increase	11				Lomond
Increase	12				Terra Nova
Strong increase	13				Exploits
Strong increase	13				MiddleBr
Strong increase	13				Northeast
Strong increase	13				Torrent
Strong increase	13				Western_Arm_Br

Newfoundland Region

Status of salmon stocks in 1997 can be examined relative to past returns to rivers. Returns act as an indicator of potential spawning stock, but do not reflect true population size, particularly prior to the commercial salmon fishery closure in 1992. Spawning stock levels observed in 1997 are not unusual and are better than many of those observed in the years prior to the salmon fishery closure. The average minimum exploitation rates for marine fisheries (legal and illegal) for the period 1984 to 1991 and for all Newfoundland stocks combined are estimated to have been 44 % for small salmon and 75 % for large salmon.

Returns of small salmon to most Newfoundland rivers in 1997 declined in comparison with the previous year, or in relation to the 1992 - 1996 mean. Rivers in Salmon Fishing Areas (SFA) 4 (Exploits, Campbellton, Gander) and 14A (Torrent, Western Arm Brook) decreased from 38 % to 59 % in comparison with 1996, and from 19 % to 42 % in relation to the previous 5-year mean. In contrast, rivers in SFA 5 (Middle Brook, Terra Nova, Northwest Brook) and SFA 11 (Grand Bank and Conne) decreased proportionally less, ranging from 21 % to 33% relative to 1996, but only 2 % to 21% down from the mean. For many rivers, returns in 1997 were the lowest since the fishery closure began in 1992. Despite the general pattern of decreased small salmon returns throughout much of Newfoundland, there were some exceptions. Rocky River (SFA 9), rivers in Bay St. George (SFA 13; Highlands, Crabbes, Barachois, Robinson, Flat Bay), and Lomond River (SFA 14A) had returns in 1997 that were generally higher than the 1992 to 1996 mean.

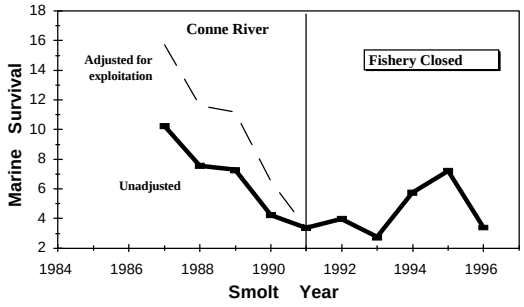
Although declines in small salmon returns were noted on many rivers, large salmon returns increased in most rivers to their highest levels since 1992. Where there were decreased returns of both small and large salmon (Exploits, Campbellton and Northeast Brook Trepassey rivers), the proportionate decline from 1996 was similar for both size groups.

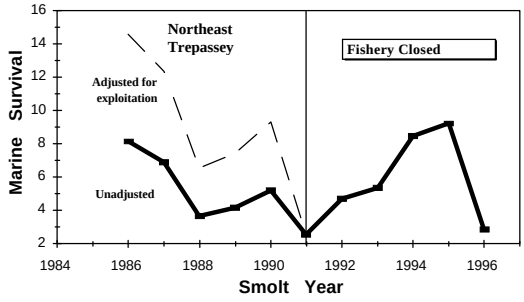
Atlantic salmon returns in the past have been lower than in 1997. The 1997 values although low, are still better than many other years prior to the fishery closure. However, when compared to returns prior to 1992 adjusted for commercial exploitation, 1997 levels were the lowest (Terra Nova and Gander rivers), or among the lowest (Middle Brook, Northeast Brook Trepassey, Northeast River Placentia, Conne, Humber, Lomond, and Western Arm Brook) recorded.

While much of the attention has been focused around the decline in 1997 returns of small salmon, little attention has been directed towards the lack of improvement of returns to the monitored rivers on the south coast after the closure of the commercial salmon fishery in 1992. There was a declining trend in total abundance to these rivers prior to 1992. It is only because of increased smolt production that stocks have not fallen to even lower levels.

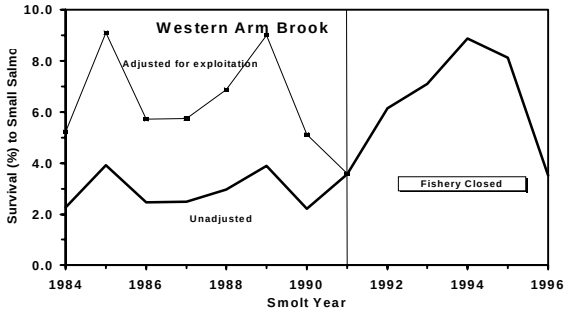
Since 1992, estimates of **marine survival** from smolts to adult small or 1SW salmon are believed to represent natural survival rates. Despite major changes to fisheries and corresponding reductions in marine exploitation, marine survival rates are still less than 10%. Marine survival rates for smolts from the Conne River and Northeast

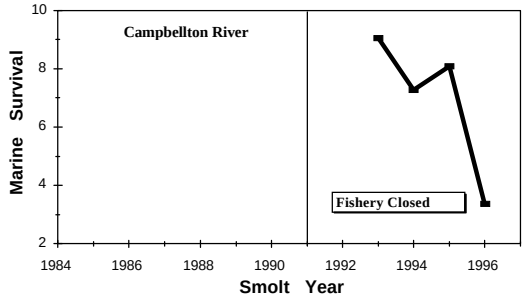
Brook Trepassey were the lowest observed in recent years.



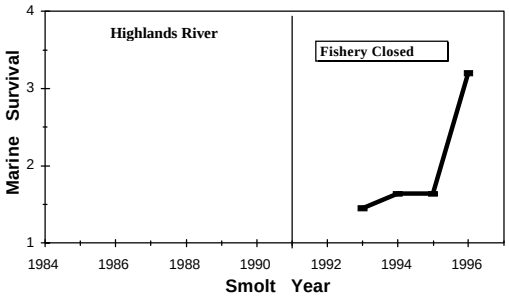


Following a brief period of increasing survival of smolts in recent years, the Conne River and Northeast Brook Trepassey stocks, along with Western Arm Brook, Rocky, and Campbellton rivers, smolt survival exhibited a substantive decline in 1996.





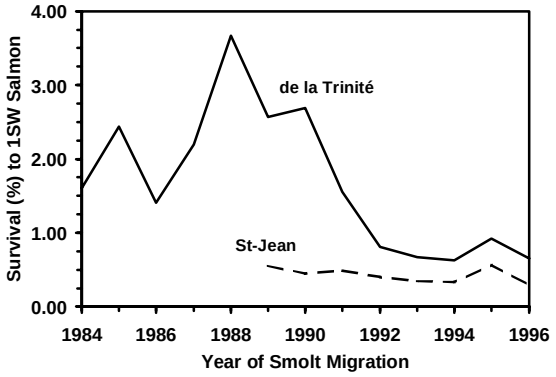
The Highlands River in Bay St. George was an exception as survival of the 1996 smolts to small salmon returns doubled over those of 1995 and was the highest observed to date.



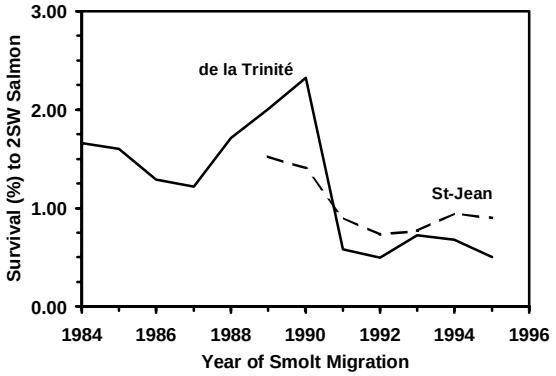
Québec

Recreational harvests of salmon generally declined in most rivers of Québec relative to the recent five-year mean. In total, harvests declined by 26% for small salmon and 34% for large salmon. Returns to rivers of Québec not subjected to enhancement are evaluated by direct counts at fishways or counting fences (5 rivers) and by visual counts (24 rivers). In total for these rivers, returns declined by 28%, equally for small salmon and large salmon. For the enhanced rivers, returns evaluated at counting facilities (6 rivers) and by visual counts (9 rivers) declined by 22% for both small salmon and large salmon.

Smolt survival was evaluated for the Saint Jean and de la Trinité rivers. In 1997, survivals to 1SW salmon were 69% and 39% of the means for the Saint Jean and de la Trinité rivers.

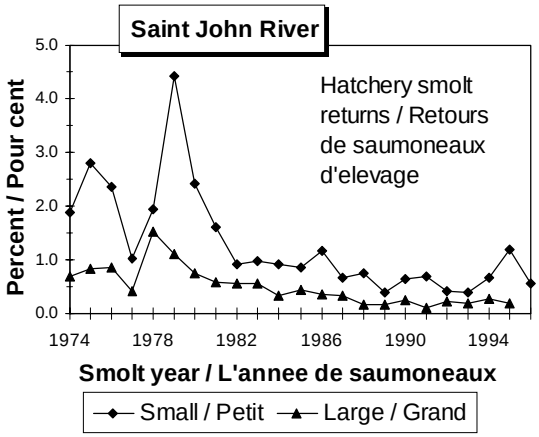


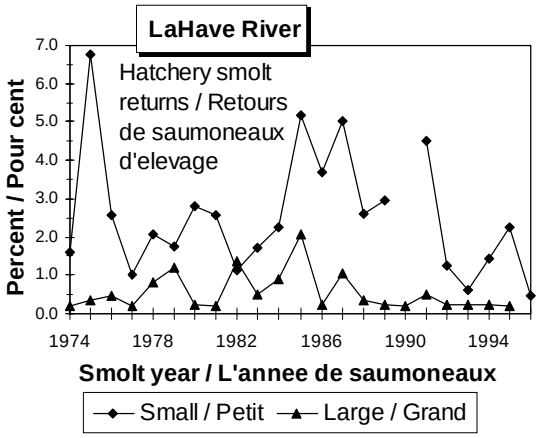
The survivals of smolts to 2SW salmon was 91% and 41% of the mean for these two rivers.

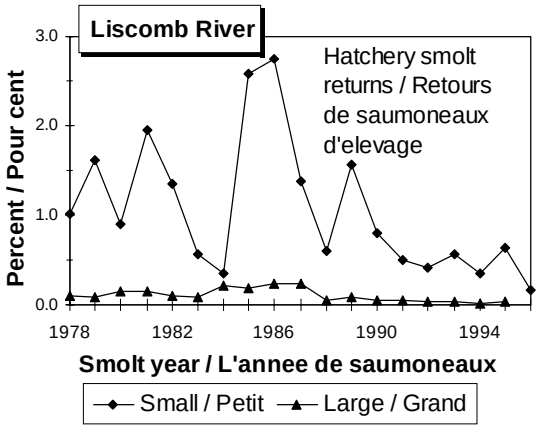


Maritimes Region

The returns of small and large salmon in 1997 from hatchery smolts released in the Saint John, LaHave and Liscomb rivers were the lowest noted since the commercial salmon fishery closure in Newfoundland in 1992 and among the lowest of their respective time series.







Salmon returns to the Atlantic coast of Nova Scotia and Southwestern New Brunswick at counting facilities, and as determined from population estimates using mark-and-recapture experiments or through estimates derived from angling catches, have declined over recent years. Estimated returns in 1997 were lower than anticipated when compared with the recent-year (1984-96) trends.

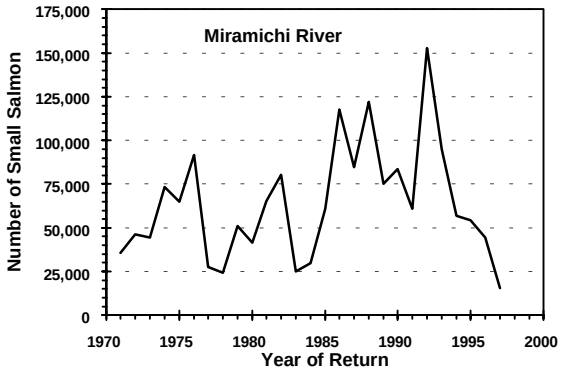
The wild large salmon returns in 1997 for both the LaHave and Saint John rivers were below the forecasts of returns based on the relationship between 1SW salmon returns in one year and large salmon returns the following year. On the Saint John River, the return of wild large salmon was very low (below the 90% confidence interval for the forecast number). Wild 1SW salmon returns to the Saint John River were forecast to be over 5,000 fish in 1997 based on egg depositions 5 and 6 years previous; the return in 1997 was less than 400 fish.

The numbers of 1SW and MSW hatchery salmon which returned to the Saint John River in 1997 were also below the 90% confidence interval for the forecast as were returns of 1SW hatchery fish to the LaHave River.

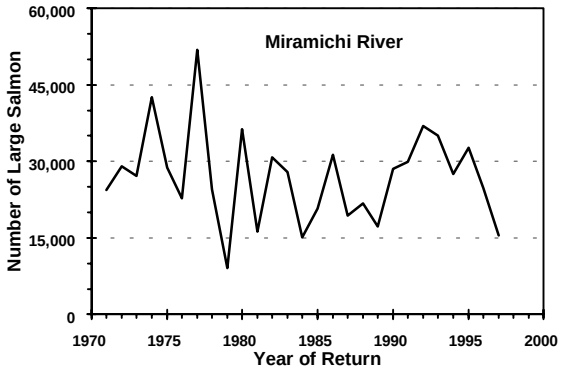
Numbers of Atlantic salmon which returned to rivers of the Gulf of St. Lawrence shore of Nova Scotia (SFA 18) in 1997 were similar to numbers observed in 1996 and recent returns to those rivers did not follow the trends noted in Atlantic coast and Bay of Fundy rivers.

The density of juveniles in rivers of the Atlantic coast or Outer Bay of Fundy which are not affected by acidification have remained stable over the past 10 or more years. Juveniles in streams on the Gulf of St. Lawrence shore of Nova Scotia have exhibited a significant increasing trend over the period 1992-97. In contrast, juvenile densities have declined over the 1984-97 period on the Stewiacke River, a stock representative of those in the Inner Bay of Fundy. This and other stocks inhabiting the Inner Bay of Fundy rivers do not migrate to the Labrador Sea like other stocks of eastern Canada.

Returns of small salmon to the Miramichi River in 1997 were estimated at 16,000 fish, the lowest level in the time series commencing in 1971. Average return of small salmon for 1994 to 1996 was 52,000 fish.



Large salmon returns in 1997 were estimated at 16,000 fish; average return for 1994 to 1996 was 28,000 fish. The estimated harvest rate on large salmon in homewaters was less than 5% in 1997, similar to recent years.



Returns of small salmon to the Restigouche were within 10% of those estimated for 1996. Large salmon returns were estimated at about 11,000 fish. Average returns to the Restigouche River for 1994 to 1996 were 13,000 small salmon and 15,000 large salmon. Returns of both small salmon and large salmon declined relative to 1996 in the Nepisiguit River and Jacquet River. Returns of large salmon to the Bouctouche River

improved slightly from 1996 (200 fish in 1997, 134 fish in 1996); small salmon returns declined slightly (97 fish in 1997; 127 fish in 1996) from the previous year.

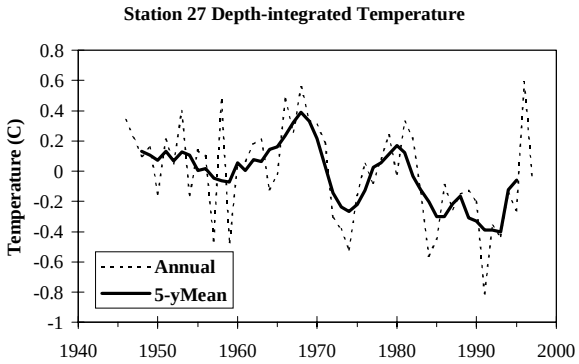
Juvenile densities in both the Miramichi and Restigouche rivers remain at high levels relative to the abundance in the 1970's to mid-1980's.

Eastern US Rivers

There are both wild and restoration runs of Atlantic salmon in New England rivers. Like salmon populations in neighboring areas of New Brunswick and Nova Scotia, the runs are comprised primarily of 1SW and 2SW fish. Previous spawners and 3SW salmon do occur in US rivers, but they are a minor component of the run. Runs of 1SW and 2SW fish in 1997 reflect the continued trend of low returns and return rate for both self-sustaining stocks and released fish. Minimum estimates of returns based primarily on rivers with counting facilities indicate that the 1SW and 2SW runs declined from 1996 levels by 44% and 33%, respectively. The only fishery allowed for sea-run salmon in US waters is catch-and-release angling in the state of Maine.

The Ocean Environment

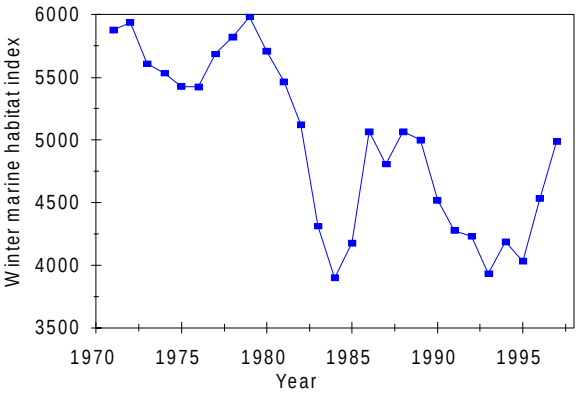
Studies have shown that oceanic variability influences both survival and growth of several salmon stocks as well as the timing and location of their migrations. During most of the 1990s temperatures of the waters off Newfoundland and Labrador have been relatively cold. The average water column temperature at a monitoring site off St. John's has varied cyclically with an approximate 10-year period. Minimum temperatures were observed in the early 1970s, the mid-1980s and the early 1990s. In addition, there has been a gradual decline in temperature over this period, so that the lowest values in the 50-year record occurred during 1991-1992. These cold conditions continued through 1995 before warming in 1996 to above normal values.



In 1997, temperatures remained well above the early 1990s values, but were lower than those observed in 1996.

Further south, the long-term trends have differed. In the Gulf of St. Lawrence, southern Newfoundland and on the northeastern Scotian Shelf, average water temperatures have been cold since the mid-1980s and although a slight warming has occurred during recent years, temperatures remain below normal. On the rest of the Scotian Shelf and in the Gulf of Maine, average water column temperatures have generally been warmer than or near normal.

Atlantic salmon at sea typically are found near the surface. Sea surface temperatures (SST) observed from satellites have been combined with research vessel salmon catch rates to establish a thermal habitat index for salmon. This index has been strongly associated with the total North American Atlantic salmon abundance, tending to be large when salmon abundance is high and small when abundance is low.



Its history has been similar to that of temperatures on the Newfoundland Shelf, and its increase from the extremely low 1995 value to near average values in 1996 and 1997 suggests that salmon returns in 1997 should have increased. However, as previously noted, this generally did not occur.

Associated with the ocean climate changes described above have been significant large-scale ecosystem changes. For example during the 1990s, Arctic cod increased in abundance on the Labrador Shelf and extended further southward onto the Grand Banks and into the Gulf of St. Lawrence. The distribution of Greenland halibut also extended further south at this time. During the late 1980s, capelin returned to the Scotian Shelf, and have increased in abundance there steadily. The distribution of capelin also spread eastward from the Grand Banks to Flemish Cap. Cold waters in the 1990s delayed the inshore spawning time of capelin by approximately 1 month, and they have continued to spawn late ever since. Large scale changes in the distribution and abundance of Atlantic herring also occurred in the early 1990s. On the northeastern Scotian Shelf, snow crab, which prefer temperatures colder than 3°C, have increased their distribution since the late 1980s. In addition, many important commercial species including cod and redfish declined to very low numbers, although the respective roles of fishing and the environment in this decline remain unclear.

Indirect evidence of ecosystem changes also comes from seabird diets. Since the late 1980s, there has been a marked shift in the diet of Funk Island gannets from warm-water species like mackerel to cold water species such as capelin as well as some salmon. While these significant and widespread ecosystem changes appear to be linked to cold water temperatures, there has been no rebound toward previous conditions during the last two years when surface waters have warmed.

Review of factors potentially influencing low salmon returns in 1997

Factors that affect sea survival of salmon take place at various times prior to the onset of maturation and return to natal rivers. These factors could be associated with: 1) environmental conditions (temperature, salinity, etc.); 2) removals in legal and illegal fisheries; 3) predation (cod, seals, seabirds etc.); 4) diseases or parasites (bacterial, viral, sea lice, etc.); or 5) a suite of other factors including changes in biological characteristics of stocks (e.g. delayed sea-age at maturation), and effects of escaped aquacultured salmon. The task of tracking the events affecting survival of Atlantic salmon for each of these factors becomes more complex after postsmolts leave fresh water and enter the marine environment. It is made especially difficult considering that there have been few studies of salmon in the sea in Canada since 1991. Also, to be a candidate for a cause of declines of adult 1SW salmon returning in 1997, the event must have occurred sometime between the entry of the smolts

into the sea during the spring-summer of 1996 up to their return in 1997.

The location of increased levels of mortality of 1SW salmon in 1996-97 can be inferred from an examination of the relative proportions of repeat-spawners compared to 1SW salmon spawning for the first time. The consecutive-year repeat spawners are at sea for only the spring and summer months of 1997 and the fact that repeat spawner survival was normal suggests that higher than usual mortality did not occur in the vicinity of homewaters in 1997.

Freshwater production

Could freshwater production cause the low returns of salmon in 1997?

The role of freshwater production in the low returns of 1SW salmon in 1997 was investigated by examining available information on abundance, size, and condition of smolts in 1996. Annual counts of wild smolts are available for eight rivers in Eastern Canada, six in Newfoundland and two in Québec. In Newfoundland, counts for 1996 were the highest recorded up to that year for four rivers and among the highest for the remaining two. In Newfoundland, although not in Québec, smolts departed rivers unusually early in the spring of 1996 compared to other years. Counts in 1996 for the two Québec rivers were average. In general, size and condition of smolts for these rivers in 1996 were average as were pre-smolt juveniles in two ponds located in the headwaters of a major river in Newfoundland. In some Maritime rivers, such as the Miramichi and Restigouche, the abundance of juvenile salmon measured in the summer and fall prior to smolting has been at the highest levels recorded in recent years.

Collectively, the above results suggest that the low returns in 1997 were not attributable to the abundance of the smolts. It is uncertain if the early run timing of smolts from some Newfoundland rivers influenced their survival.

Marine exploitation

Did harvests in legal and illegal fisheries increase sufficiently to explain the low returns of salmon in 1997?

Fisheries, both legal and illegal, reduce the number of salmon in the overall population, and where this happens prior to counting facilities, could be responsible for the lower returns in 1997. The determination of the effects of fishing on low returns of salmon in 1997 depends on showing a difference in landings between 1996 and 1997. In order to explain the low returns in 1997, landings in these fisheries would have had to have increased dramatically. Angling fisheries can be easily eliminated as a potential cause of the low returns because they occur after salmon have been enumerated.

There are commercial fisheries for salmon at west Greenland, Labrador, Québec and St. Pierre et Miquelon. Additionally, there is a small recreational marine net fishery for salmon in St. Pierre et Miquelon. All of these are mixed-stock fisheries and to various degrees exploit salmon from a variety of stocks and age classes. Fisheries at west Greenland and St. Pierre et Miquelon entirely exploit stocks from other countries while the fisheries in Labrador and Québec harvest salmon of which a high proportion originate in local rivers but some also come from other provinces or the US. The fishery at west Greenland harvests salmon that are non-maturing and will not return to North

American rivers until the following year as 2SW (or greater) fish. Fisheries at St. Pierre et Miquelon harvest maturing salmon on their homeward migration to spawn. The Labrador fishery catches salmon from both the maturing and non-maturing components of the North American stock complex.

Landings at Greenland have declined from a peak of 2,689 tonnes in 1971 to a low of 57 tonnes (quota was 57 tonnes) in 1997. The fishery did not operate in 1993 and 1994. In 1997, the coastal commercial fishery in Labrador (SFAs 1&2) was controlled by a quota of 50 tonnes with a catch of 46.4 tonnes, a decline of 1.3 tonnes from that in 1996. The fishery in SFA 14B (Labrador Straits) was closed in 1997 due to low stock levels. In Québec, the commercial fishery in Q9 has been controlled by quota for individual fishermen, the total of which was 12,068 salmon in 1997. The commercial and recreational marine fishery in St. Pierre et Miquelon is controlled by effort restrictions.

Recent landings recorded for these fisheries in numbers of salmon are shown in the following text table. Greenland harvests are for 1SW North American salmon only:

Fishery	1994	1995	1996	1997
Québec	13,800	13,653	11,718	10,581
Labrador	24,017	19,156	15,121	16,696
St. Pierre	1,656	364	670	est 670
Greenland	0	20,828	12,357	NA

Landings in the Québec fishery have been declining steadily over the period of 1994-97. Landings in Labrador have also declined over the period of 1994-97 although they increased by 10% in 1997 from 1996 by number (due to increases in smaller salmon) but this increased harvest is insufficient to explain the low returns. Newfoundland salmon from the northeast and northwest coasts are mainly maturing 1SW salmon (grilse) and Labrador harvests of grilse occur after this age class has already started returning to Newfoundland rivers. The migration of salmon returning to rivers in Newfoundland's south and southwest coast rivers takes them far from the Labrador coast and there is little likelihood of the Labrador fishery catching returning salmon from these stocks. Greenland does not harvest maturing 1SW salmon at all but harvests non-maturing 1SW, 2SW and repeat spawning salmon that would return home the following year. Landings of 1SW North American salmon at Greenland have declined from an average of about 111,000 (1985-1992) and declined further between 1995 and 1996 by 40% which should have reduced the impact on returns of 2SW salmon in 1997. The fishery at St. Pierre et Miquelon of 1.5 tonnes in 1996 remained the same in 1997.

Although it is acknowledged that salmon landed in these fisheries would have potentially reduced returns in rivers in eastern Canada, catches in these fisheries have generally declined and therefore they could not have been responsible for the decreased returns in 1997.

Bycatches of Atlantic salmon in offshore groundfish and shrimp fisheries are insignificant. Records of bycatches in offshore fisheries collected by observers placed aboard fishing vessels to examine catches on an individual set basis (1980 to present), reported by fisheries officer boardings for inspection of logbooks, catches and fishing gear (1987 to present), and kept by research vessels (1965 to present) indicate that in about one million observations of these catches at sea in the Newfoundland Region, a total of 49 salmon were reported taken.

Bycatches have also been recorded from inshore cod traps used in the Newfoundland sentinel (test) fishery. There was a small cod commercial fishery along the south coast in 1997. Catch rates of salmon in the sentinel fishery were low, with the highest value of 0.8 salmon caught per trap-day. The total catch of salmon was 345 fish in 1996 with only 274 salmon reported caught in 1997. The decrease in numbers from 1996 to 1997 was partially attributed to the use of deflectors on nets in 1997.

The low overall catches of Atlantic salmon in commercial fisheries and lack of evidence of increasing bycatches in some inshore and offshore fisheries indicate that fisheries are unlikely to have been the cause of the low returns in 1997.

Predation

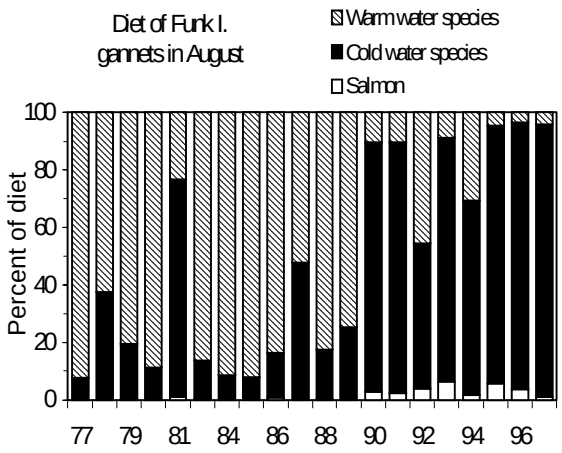
Did predators cause the low returns of salmon in 1997?

Atlantic salmon are known to be prey for many species in the sea. For most of these species, there are no estimates of their abundance and consumption rates of salmon. However, some information is available for a number of potential predators including birds, seals, and cod.

Birds: In fresh water, the main bird predators are common mergansers and belted kingfishers. Consumption calculations suggest that these birds take a substantial fraction of juvenile salmon in some Maritime rivers. However, repeated experiments in bird control have failed to demonstrate that bird culls increase juvenile salmon populations. For this reason, and because merganser numbers in the Maritimes have been stable in the years up to 1996, it is unlikely that bird predation in fresh water could have contributed to low salmon returns in 1997.

Smolts leaving rivers with nearby double-crested cormorant colonies pass through the foraging areas of these birds. In several Maritime rivers, cormorants could deplete smolt runs, even if salmon were only a small part of their diet. It is not known however if this occurs because data on comorant diets from colonies near rivers with major wild smolt runs are lacking.

Gannets are large seabirds which capture fish by plunge-diving from the air. Salmon were rare in gannet diets at Funk Island, Newfoundland, from 1977 to 1989, but increased during the 1990s to a sampled estimate of 3% of the diet (in August). At the same time the gannets' principal foods shifted from warm-water species (mackerel and others) to cold-water species (capelin and others including salmon), which reflected a significant change in the marine ecosystem.



Preliminary consumption estimates suggest that gannets at the Funk Island colony could have taken low percentages of North American postsmolt populations in the 1990s. The gannets' exploitation of

postsmolts is difficult to estimate because the duration of postsmolt predation by gannets has not been measured and because postsmolt populations and movements are poorly known.

Herring gulls and great black-backed gulls in Newfoundland markedly changed their feeding behaviour following the closure of ground fisheries in the early 1990s. Fisheries discards and plant offal, formerly a mainstay of gull diet, became unavailable. Major delays in arrival times of inshore spawning capelin have also reduced gulls' food supplies in the 1990s. Based on information from people living near salmon rivers, it is speculated that these gulls, deprived of their traditional food sources, may have increased predation on parr and on out-migrating smolts. There is no evidence that this activity was greater in 1996 than in other years since 1992.

Seals: There are 6 species of seals found in eastern Canada. Two species, ringed seals and bearded seals, are limited to the Labrador coast. Harp seals and hooded seals are both pelagic species, which spend roughly half of the year in the Arctic and Greenland waters, moving to Labrador, and Newfoundland waters and into the Gulf of St. Lawrence from about mid-November until mid-June. Harbour seals and grey seals are primarily coastal species that can be found along the Atlantic coast and in the Gulf of St. Lawrence throughout the year. There were an estimated 4.8 million harp seals, 500,000 hooded seals, 160,000 grey seals and <30,000 harbour seals in these areas in 1996. Fish consumption by seals has been estimated by combining information on seal abundance, distribution, energy requirements, and diet composition. Diet composition was determined by examining the contents of seal stomachs. Only a few salmon were found in about 10,000 stomachs examined. Even though the incidence of salmon in the diet of seals is very low, the high number of seals and abundance of salmon does not rule out that seals could be important to overall salmon mortality.

It is known that some seals establish themselves in or near salmon rivers, particularly on the Québec North Shore and in Labrador. At this more local level, the impact of seal predation has the potential to be an important source of mortality.

Salmon are protentially preyed upon by grey and harbour seals in or near river mouths and by harp and hooded seals along the coast of Newfoundland and in the Labrador Sea, respectively. This potential exposure to predation by seals and the diets of the four species of seals warrant further investigation.

Cod: In Norway, cod have been shown to consume about 20% of smolts as they enter the sea in some localized areas. A recent shift of cod distribution in Newfoundland and parts of the Gulf of St. Lawrence and possibly the eastern Scotian Shelf further inshore suggests that cod predation on smolts in 1996 may have been a factor in the low returns in 1997. No salmon have been found in the several thousand cod stomachs examined to date; however, cod have not been extensively sampled in the mouths of rivers at the same time as salmon smolts have been moving to sea. Thus, the potential importance of cod predation cannot be eliminated and should be further investigated.

Analysis of postsmolt population size in relation to food consumption of major predators suggests that post-smolts are likely to be extremely rare in predator diets, even if the predators are removing important

fractions of the postsmolt population. This means that conventional sampling programs, even those with very large sample sizes, are unlikely to clarify predator impact on postsmolt populations. An alternate method, based on assumed uniform exploitation rates among available prey species, may have potential in evaluating predator impact on postsmolt salmon.

The lack of evidence for 1996 of any sharp increase in population sizes or change in feeding habits of predators suggests that they are unlikely to have been the cause of the low returns in 1997. However, since the overall predation by birds, seals, and cod feeding on salmon is unknown, the impact of these predators can not be discounted.

Forage

The available evidence on salmon diet indicates that salmon are opportunistic feeders. Salmon prey on capelin, sand lance, squid, herring, mackerel, deepwater fish such as blacksmelts and barracudina, and many different types of crustaceans. They exploit different prey species in different feeding areas and the diet in a particular area may vary both between years and within years. Shrimp, *Pandalus* spp., is a relatively minor component of the diet and salmon growth and survival is unlikely to be altered by the commercial exploitation of shrimp. The ability to exploit a wide range of prey species, even at the postsmolt stage, suggests that the abundance of any one forage species will not greatly alter growth and therefore survival. However, forage abundance may affect growth rates of individual salmon. Furthermore, a year class composed of slow-growing individuals resulting from low prey abundance would, presumably, be more vulnerable to predators as it is thought that most natural mortality at sea takes place when salmon are small. Salmon would also be susceptible to any major climatic or oceanographic event that altered the abundance and/or distribution of entire assemblages of suitable prey.

There is no direct information on the availability of food for the 1996 smolt class in the marine environment. An indirect method of determining if there was a decrease in food resources is to examine returning adults in 1997 for a reduction in size and condition. Size and condition of maturing 1SW salmon in Newfoundland in 1997 was at or near the averages for the years corresponding to the commercial salmon fishery moratorium. Average size of this age class for Miramichi River, New Brunswick and Saint Jean River, Québec was the highest on record in 1997; LaHave River, Nova Scotia was average and de la Trinité River, Québec second highest. 2SW salmon returning to Miramichi River in 1997 were among the largest in size on record and were the largest recorded for de la Trinité River and Saint Jean River.

Reduced growth in the sea has been associated with a delay in age at maturity and it has been suggested that salmon not returning as expected as 1SW fish in 1997 might come back as 2SW fish in 1998. The above data suggest that this will not occur.

The size of the returning adults were equal to or greater in 1997 than in 1996 suggesting that availability of forage did not appear to cause the low returns in 1997.

Ocean climate

Atlantic salmon are known for their ability to migrate over long distances and are found widely distributed over the north Atlantic. Salmon from an individual stock are also

distributed widely as salmon from the same smolt class can be found simultaneously along the northeast coast of Newfoundland and at Greenland. Consideration of ocean climate variability as a possible cause of low returns of salmon in 1997 requires that we look for large-scale variations in the biological and physical environments in which the salmon lives. Salmon are found mainly near the surface although periodic trips to deeper depths are known to occur. Thus, an examination of ocean climate should concentrate on relationships with surface water conditions. Satellite sea surface temperature data are thus ideally suited for study of ocean climate and salmon.

A number of relationships were examined between thermal habitat and salmon abundance including those for total North American 1SW and 2SW and total recruits produced by several stocks in Newfoundland and Labrador. A significant positive correlation between ocean climate and salmon survival combined with an observed increase in thermal habitat in 1996-97 would lead to a higher rather than lower returns in 1997.

Other factors

A number of other factors were considered such as pollution, disease, poaching, age at maturity, and age of spawners. However, none were considered to be of a magnitude that could have caused the low returns of salmon in 1997.

Conclusions

A number of factors that could have contributed to the low returns in 1997 were examined including levels of freshwater production, legal and illegal fisheries, predation, forage availability, marine environmental conditions, disease, parasites, and others such as delayed maturation.

No single factor was identified that explained the cause of the lower than expected returns in 1997. For instance, smolt production from most rivers was higher it has been in many years. Commercial fisheries catches have been declining and are considerably lower than historical levels. There was no evidence of increasing by-catches or illegal fishing at sea. Salmon returning to rivers in 1997 were equal or larger in size than in recent years suggesting that there was no problem with the availability of food for the salmon. The magnitude of the decrease in salmon returns was not the same for all rivers. This suggests that the causes of low return in 1997 may be different from one river to another or, if a common factor caused the low returns, then it impacted stocks to varying degrees. For example, an outstanding feature in the life history of the cohort returning to insular Newfoundland rivers in unprecedented low numbers in 1997 is their exceptionally early entry to the sea as smolts in the spring of 1996.

There are however indications that the ecosystem of the northwest Atlantic has changed since the late 1980s as evidenced by oceanographic conditions and reflected in biological data on a number of species. Evidence for this comes from the shift in diet of marine birds, later spawning times for capelin, and changes in distribution of fish species other than salmon. This change in the marine ecosystem may also be responsible for the low return rates of salmon.

It is likely that postsmolt salmon mortality is primarily due to predation. It is clear that

the changes that have occurred in the marine environment of Atlantic salmon, particularly in the areas north of Newfoundland, could have influenced the susceptibility of salmon to predators and increased the magnitude of predation mortality. However, it is unlikely that any one species of predator accounts for the increase. Dietary records of thousands of cod in Newfoundland indicated salmon is not commonly a part of their normal diet. However, the samples were not generally collected in river estuaries at the time of smolt migration when cod are most likely to prey on salmon. Similarly, the stomach content data for seals indicates that salmon at best are a negligible part of the diet. Nevertheless, predation by seals may still have an influence on salmon abundance. Also, seals that remain close to or in salmon rivers may be of considerable importance to some individual stocks. Cormorants and gannets have been shown to consume salmon in estuaries and at sea, respectively, but we do not have sufficient diet information to estimate the magnitude of this source of mortality.

In the absence of adequate and directed research programs on salmon at sea, our knowledge of the life history of salmon at sea is insufficient to explain the low returns in 1997 as well as the significant decline in Atlantic salmon abundance (from 1.5 million to less than 0.5 million) since the late 1970s.

Expectations for salmon returns and attainment of conservation in 1998

Preliminary forecasts of returns are available for a few rivers in Atlantic Canada. 1SW returns in 1997 were used to forecast MSW returns in 1998 for the Saint John River (above Mactaquac, NB), LaHave and Liscomb rivers, (Atlantic coast, NS), Miramichi River, (Gulf, NB), Saint Jean River, (Gaspé, Québec) and Riviere de la Trinité, (North Shore, Québec). Forecasts for recent years have exceeded returns. Nevertheless, MSW returns to the four Maritime rivers are forecast to be equal to or fewer than those returning in 1997 and below conservation requirements. MSW returns forecasted to the two Québec rivers will equal or exceed returns in 1997 and are expected to meet conservation requirements.

No interim stock-specific forecasts of 1SW returns were available. Downward trends since 1989 in estimated abundance (before exploitation) of North American maturing (1SW) and, in particular, non-maturing (2SW) fish (see figure in Historical Harvests and Production section) suggest a low probability of significant increases in the total stock complex and returns in 1998.

One model of expectations of total North American 1SW and 2SW recruits to fisheries and returns in 1998 was based on simulations and regressions of recruits on an index of total North American smolt production, thermal habitat in the North Atlantic, and year (1972-1996). The model forecasts a 1SW salmon abundance in 1998 which is larger than the most recent prefishery abundance estimate of 1996 while 2SW salmon will be fewer than those of 1996 (see figure in Historical Harvests and Production section).

The 2SW component of the spawner requirements for North American rivers is estimated to be about 180,000 2SW salmon (151,000 in Canada). Estimates of total North American 2SW spawners, 1992-96, have ranged from 73,000-91,000 fish (about 97% Canadian). Deficits have contributed to increased restrictions on aboriginal,

recreational, and the few remaining commercial fisheries. The expectation of meeting these requirements in 1998 is low.

Management Recommendations

A cautious approach to managing Canada's Atlantic salmon resoure is recommended for 1998 because of great uncertainty about the returns of small salmon in 1998 and the expected low returns of large salmon to rivers where there were low grilse returns in 1997.

Management plans for 1998 should continue to be based on river-specific assessment advice and be flexible to allow for adjustments based on results of in-season monitoring.

Research Recommendations

Ecology of salmon at sea

The distribution, abundance, and ecology of salmon at sea is not well known, especially for the postsmolt stage. Investigations should be undertaken to clarify postsmolt biology through estuarine and marine sampling programs. The effects of the marine physical and biological environment on salmon should be further examined, especially as it pertains to large-scale shifts in northwest Atlantic fish communities since the beginning of the 1990s.

Predation

Predation on salmon, especially smolts and postsmolt salmon in the sea, should be further investigated Alternatives to conventional diet sampling to evaluate predation on salmon should be considered.

Salmon monitoring in freshwater

Programs which monitor smolt and adult numbers in fresh water should be continued, and strengthened in areas where information is presently weak or lacking, particularly in Labrador and Ungava Bay. In addition to quantitative measurements and ageing, monitoring programs should also record information on disease, parasites, and origin (wild, hatchery, aquaculture) in areas where these factors are issues.

Salmon life histories

Valuable information on movements of salmon at sea, maturity schedules, and factors affecting survival can be obtained by examination of salmon scales, especially when findings are integrated with information on physical and biological conditions in the ocean. Investigations of salmon life histories using this and other techniques should be continued and strengthened.

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ISSN 1480-4913

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