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Status of Wild Atlantic Salmon (*Salmo salar*) Stocks in the Maritime Provinces

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ABSTRACT

There are important geographic differences in the status of wild salmon populations in the Maritime provinces. Wild adult salmon abundance in the inner Bay of Fundy is critically low with juvenile abundance in these rivers currently at their lowest observed levels. The wild salmon returns to Mactaquac Dam in the Saint John River in 1997 were the lowest of record for both 1SW and MSW age groups. Total egg depositions in the Saint John River have been below conservation requirements since 1986 and in recent years have been below 50% of requirement. Abundance of wild adult salmon has also declined in the Atlantic coast of Nova Scotia rivers many of which are acid-impacted. The abundance of juveniles in these rivers is declining or low. The southern Gulf of St. Lawrence rivers have fared better; relative abundance in these rivers is currently at medium levels but declining in some rivers in recent years. Juvenile abundance is currently described as medium to high. Sea survivals of three hatchery stocks show a declining trend over time with the lowest survivals observed in recent years. Several factors including environmental conditions and predators are implicated in the reduced abundance of Atlantic salmon in the Maritime rivers.

RÉSUMÉ

Il existe des différences géographiques importantes dans l'état des populations de saumon atlantique sauvage dans les provinces maritimes. L'abondance du saumon sauvage adulte est à un niveau bas critique dans l'arrière Baie de Fundy et l'abondance des juvéniles est présentement au plus bas niveau historique observé. Au barrage de Mactaquac de la rivière Saint John, les retours de saumons sauvages unibermarins et pluribermarins en 1997 étaient aux plus bas niveau historique. Les dépositions d'oeufs dans la rivière Saint John ont été inférieures à 50% des besoins de conservation depuis 1986. L'abondance du saumon sauvage a aussi diminué sur la côte atlantique de la Nouvelle-Écosse dont plusieurs des rivières dans cette région sont affectées par les pluies acides. L'abondance de juvéniles dans ces rivières est basse ou en diminution. Les populations des rivières du sud du Golfe du Saint-Laurent sont en meilleur état. L'abondance des adultes est présentement moyenne mais en déclin dans quelques rivières durant les dernières années. L'abondance des juvéniles est présentement moyenne, soit-même haute. Les taux de survie en mer de trois stocks de saumonneaux d'élevages suivent une tendance en diminution avec les plus bas taux de survis observés durant les dernières années. Plusieurs facteurs, incluant les conditions environnementales et les prédateurs, sont impliqués dans la diminution d'abondance du saumon atlantique dans les rivières des maritimes.

INTRODUCTION

Atlantic salmon (*Salmo salar*) stocks are characterized by large fluctuations in abundance, frequently over wide geographic areas. Wide fluctuations in salmon abundance as inferred from landings were reported by Huntsman (1931) who explored the possibility of cycles of abundance, to no avail. Stocks in general have appeared resilient at least to fisheries exploitation and persisted even under periods of low abundance (Dempson et al. 1998). Although extensive research over several decades has elucidated the population dynamics of the freshwater stage of Atlantic salmon, the factors which ultimately determine the abundance of adults after completion of the marine phase can only be conjectured.

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. The term stock in this presentation refers to the definition used by Ricker (1972) which considers a stock to be an assemblage of fish which spawn in a particular location at a particular season and which to a substantial degree do not interbreed with other groups.

Within the Maritime Provinces, there are more than 150 rivers with reported Atlantic salmon catches (Fig. 1) (O'Neil et al. 1996). Direct measures of abundance based on counts of Atlantic salmon began in 1967 at the fish trap on the Saint John River (at Mactaquac; Fig. 1) (Marshall et al. 1998). Similar monitoring operations began at the Morgan Falls fishway of the LaHave River in 1970 (Amiro and Jefferson 1997) while counts at Liscomb River began in 1979 (O'Neil et al. 1997). Formal assessments of two rivers in New Brunswick (Miramichi and Saint John) were first conducted in 1977 (Anon. 1977). The number of individual rivers assessed has increased over the years in response to requests for fisheries management advice. For example in 1996, returns and spawning escapements of Atlantic salmon were assessed for 38 rivers of the Maritimes (DFO Science 1997).

In 1991, the Canadian Atlantic Fisheries Scientific Advisory Committee provided a formal definition of conservation of Atlantic salmon (CAFSAC 1991a) and quantified the conservation levels for 32 rivers of the Maritimes (CAFSAC 1991b). Conservation for Atlantic salmon is considered to be a threshold reference point and defines the level of egg deposition below which the consequences to the stock are likely to be deleterious. The conservation requirements are established for individual rivers based on 2.4 eggs per m^2 of river habitat with an additional egg requirement for the lacustrine habitat in Newfoundland and Labrador. In rivers impacted by airborne acid depositions, the conservation requirements are under review.

The status of the Atlantic salmon stock of a river is determined by evaluating the annual returns and spawning escapement of adults, the abundance of juveniles, the corresponding trends, and in a limited number of rivers, by considering measures of sea survival. As important as the annual measures of abundance are the trends in returns, escapements, and juveniles. Identification of constraints on production are also included in the assessment. This paper addresses the following issues specific to Atlantic salmon of the Maritime provinces:

- description of stocks in terms of numbers of stocks, genetic uniqueness, etc;
- current abundance of Atlantic salmon relative to conservation requirements;
- potential and/or recent production levels;

- comparison of stocks in areas of aquaculture concentration with stocks in other parts of the Region;
- factors which could potentially affect wild Atlantic salmon abundance.

MATERIALS AND METHODS

The majority of information on returns, escapement relative to conservation requirements, juvenile abundance and potential production levels was obtained from various stock status leaflets (for example DFO Science 1997) and supporting research documents.

The returns represent the size of the population before any in-river removals. Spawning escapement is determined by subtracting all the known removals, including food fisheries, recreational harvests, an allowance for hook-and-release mortality, broodstock collections, and scientific samples from the total returns.

Estimates of total returns are generally available by size group. Returns are obtained from counts at fishways and counting fences; using mark and recapture experiments; visual counts by snorkeling or from shore; and from angling catches with assumed or estimated catch rates. Biological characteristics, including fork length, sex, and less frequently weight, are obtained from fish at monitoring facilities. Scale samples are obtained to estimate the age of the fish including the age at smoltification (number of years spent in freshwater as a juvenile) and sea age. In some rivers, the absence of an adipose fin identifies the fish as being a product of enhancement programs. Only juveniles after the first summer of growth can be marked by removing the adipose fin. Depending upon resources, not all appropriately sized enhancement products are marked by this fin ablation technique.

Aboriginal food fishery removals are reported by the aboriginal communities. Recreational fishery removals are estimated from angler license stub returns in Nova Scotia and by mail-out survey in New Brunswick. An angler license stub was introduced in Prince Edward Island in 1995.

Juvenile abundance is estimated by electrofishing surveys. Abundance is generally reported as a density of fish per area of stream habitat surveyed.

Sea survival is estimated from the returns of adult salmon at age relative to the number of smolts which left the river. There are three long-term data sets of sea survival for hatchery stocked smolts from the Maritimes: Saint John River at Mactaquac, LaHave River at Morgans Falls, and the Liscomb River. A program to estimate wild smolt sea survival has been initiated on the LaHave River.

Temporal and geographic patterns of returns to rivers during 1987 to 1997 were examined using multivariate techniques (see Chaput and Prévost 1999). The returns of small and large salmon were analysed separately. Each river time series was adjusted by dividing by its corresponding mean (1987 to 1997). This produced a standard scale across rivers of different run sizes (i.e. the average of each river time series is equal to 1) but maintained differences between river time series regarding their variability.

The time series were first processed through correspondence analysis before being subjected to cluster analysis (see Chaput and Prévost 1999). The first five factors from the correspondence analysis were retained and used in the cluster analysis of the rivers. The factors of higher order were discarded because they were poorly informative (i.e. representing "white noise"). The cluster analysis was carried out following the Ascending Hierarchical Classification (AHC) technique. Several groups of the set of river-time series were deduced from the classification tree built by the AHC. Each partition is made of different river-time series that exhibit a common pattern of abundance over time within each class with contrasted patterns among classes.

STOCK CHARACTERISTICS

The most striking feature of Atlantic salmon populations in eastern Canada is the diversity of life history characteristics expressed through the broad latitudinal range of their distribution. These variations include freshwater residence time, age at maturity and the extent of ocean migrations. In this paper, the following terms are used:

1SW: refers to fish which have spent one year at sea before returning to the rivers to spawn

2SW: refers to fish which have spent two years at sea before returning for the first time to the rivers to spawn

MSW: refers to fish which have spent more than one year at sea. This includes 2SW, 3SW and previous spawner salmon.

Small salmon: defined as fish of fork length <63 cm. In the majority of rivers, small salmon are predominantly maiden fish (never spawned before) which have spent one year at sea before returning to spawn (one-sea-winter salmon).

Large salmon: fish of fork length 63 cm The large salmon component contains a mixture of maiden fish which have spent two and occasionally three years at sea before spawning and previous spawners which are returning for a second or subsequent spawning.

Wild salmon: progeny of fish where mate selection occurred naturally (eggs not stripped and fertilized artificially) and whose life cycle is completed in the natural environment.

Hatchery origin salmon: fish introduced into the rivers regardless of life stage. These are identified on the basis of a clipped adipose fin, from fin deformations, and/or from scale characteristics. Stocking of early life stages often precludes their later identification as hatchery origin fish.

Age structure of adults

The age at maturity of Atlantic salmon varies geographically. With the exception of the salmon from the inner Bay of Fundy (SFA 22 and northeast portion of SFA 23), returning adults are composed of several sea-ages classes including 1SW, 2SW, 3SW and previous spawners (Table 1). Salmon of the inner Bay of Fundy are composed of maiden and repeat-spawning 1SW salmon (Amiro 1998). The relative proportions of the age classes vary within the Maritimes with MSW salmon being more abundant than 1SW salmon in the southern Gulf of St. Lawrence rivers with the exception of the Miramichi River and in the Morell River (PEI, SFA 17). In these MSW salmon stocks, the proportion female tends to be low in the 1SW salmon and high in the MSW salmon age groups (Table 1). Along the Atlantic coast of Nova Scotia and in the Bay of Fundy, 1SW salmon are proportionally more abundant than the MSW salmon with a correspondingly higher female proportion in the 1SW salmon (Table 1).

Migration of adults at sea

MSW salmon from the Maritime rivers undertake ocean migrations into the Labrador Sea and off western Greenland. The 1SW salmon do not travel as far but migrate to feeding grounds off Labrador, Newfoundland, and the Grand Banks. The inner Bay of Fundy stocks differ from the other Maritime stocks in not undertaking migrations into the high seas and are believed to spend their entire time at sea ranging no farther than the Gulf of Maine (Amiro 1998).

Timing of adult returns

The season of return of adult salmon has been shown to have a genetic component (Saunders 1967). Atlantic salmon return to rivers of the Maritimes over an extended period, late May to late October. The proportion of the fish returning late (September and October) is highest in small rivers of the southern Gulf of St. Lawrence and the inner Bay of Fundy. Predominantly early-run (June to August) rivers are found throughout the Maritimes including the Restigouche River (SFA 15), the North River (SFA 19), and most of the rivers along the Atlantic coast of Nova Scotia (SFA 20 and 21) and the Saint John River (SFA 23). The Miramichi River (SFA 16) and the Margaree River have both early and late runs of salmon with the late runs being larger. The Saint John River at one time contained a particularly unique stock, the Serpentine stock, which spent almost twelve months in freshwater before spawning, having overwintered in the lower part of the river before continuing their upstream migration the following spring (Saunders 1981). There are still believed to be remnants of the Serpentine stock.

STOCK STATUS

The status of the Atlantic salmon stock of a river is assessed by:

- estimating annual returns and trends,
- estimating annual spawning escapement relative to conservation requirements and trends,
- assessing the trends in abundance of juveniles,
- assessing levels and trends of smolt production,
- considering measures of sea survival, and
- identifying and quantifying the impacts of production constraints unrelated to fisheries.

More details on the stocks of the inner Bay of Fundy are provided by Amiro (1998).

In many rivers of the Bay of Fundy and the Atlantic coast of Nova Scotia, hatchery origin fish make up important proportions of the total returns of adults (Fig. 2). In the Morell River (PEI), generally more than 95% of the returns are hatchery origin. In the Saint John River at Mactaquac, the proportion hatchery in the returns of small and large salmon has increased as the abundance of wild salmon has declined. In 1997, small salmon sampled at the Mactaquac facility were estimated to have represented 89% hatchery origin while large salmon were composed of 43% hatchery origin (Marshall et al. 1998).

Annual Returns and Trends

Commercial fisheries in the Maritimes were closed in 1984. With the introduction of the commercial fisheries moratorium in insular Newfoundland in 1992, the reduced fisheries in Labrador and Quebec and off West Greenland in subsequent years, the returns to rivers are essentially equivalent to total stock size. In spite of these major reductions in coastal and offshore harvests, the abundance of adult salmon in rivers has declined or generally remained unchanged. In terms of the historical abundance or the potential production level, the stocks of the southern Gulf of St. Lawrence are considered to be at medium levels of abundance with many declining. None are considered to be at high abundance. All the stocks of the Atlantic coast of Nova Scotia and Bay of Fundy are currently at low abundance.

Multivariate analyses of the returns of wild small salmon and wild large salmon to 37 rivers of eastern Canada since 1987 showed clear patterns of abundance over time and in particular geographic areas (Chaput and Prevost 1999). The data were returns to the rivers and were not representative of total population size for all rivers since no adjustments were made for commercial exploitation.

There was a strong declining trend in returns to eight rivers, mostly from the Bay of Fundy and Atlantic coast of Nova Scotia (Fig. 3). 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 (Fig. 3). This was characteristic of the southern Gulf and Gaspé region of Québec and the southeast coast of Newfoundland. The third major group rivers was described by an increasing trend since 1992 represented by only two rivers from the Maritimes, both in the southern Gulf (Fig. 3). The increasing trend was characteristic of stocks which benefited most from the commercial fishery moratorium in insular Newfoundland of 1992. Few of the Maritime rivers showed a positive response in returns following the commercial closure in 1992.

There was a strong decreasing trend in large salmon returns to seven rivers of eastern Canada, four of which were on the Atlantic coast of Nova Scotia (Fig. 4). 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 characterized the majority of rivers from Québec and the southern Gulf of St. Lawrence (Fig. 4). 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. Large salmon returns increased in the same two rivers of the Maritimes which had increased returns of small salmon (Fig. 4). Increased returns of large salmon were more characteristic of the Newfoundland rivers, where most large salmon are repeat spawning 1SW salmon whose abundance in rivers increased as a result of the commercial salmon moratorium.

The trends in returns of small salmon and large salmon provide a geographically segregated picture of abundance patterns for four geographic areas of eastern Canada:

1. Bay of Fundy and Atlantic coast of Nova Scotia characterized by a strong decline in abundance,
2. Québec rivers characterized by declining or relatively stable abundance,
3. Southern Gulf of St. Lawrence rivers with declining through stable abundance through slight increased abundance,

4. Insular Newfoundland with stable through increasing through strongly increasing abundance (with the exception of Conne River which had characteristics of the Bay of Fundy / Atlantic coast of Nova Scotia group).

Escapements Relative to Conservation

Since 1984, only small salmon can be retained (mandatory hook and release of large salmon) in the recreational fisheries of the Maritimes. Presently, large salmon can only be retained in aboriginal fisheries. Escapements relative to conservation are assessed annually in a large number of rivers of eastern Canada. In 1996, egg depositions exceeded or equaled the river specific conservation requirements in 32 of the 85 assessed rivers (Fig. 5). Large deficiencies in egg depositions were noted in the Bay of Fundy and Atlantic coast of Nova Scotia where 10 of the 20 rivers assessed had egg depositions which were less than 50% of conservation requirements. In 1997, egg depositions exceeded or equaled the river specific conservation requirements in only 26 of 89 assessed rivers (29%) and were less than 50% of conservation in 30 other rivers (34%) (Fig. 5). Large deficiencies in egg depositions were again noted in the Bay of Fundy and Atlantic coast of Nova Scotia where 14 of the 19 rivers assessed (74%) had egg depositions which were less than 50% of conservation requirements.

Escapements over time relative to conservation requirements have improved in some areas of eastern Canada but have declined in others. The status of three Bay of Fundy/Atlantic coast of Nova Scotia rivers has severely declined, especially since 1991 (Fig. 6). The proportion of the conservation requirements achieved were the lowest in all three rivers in 1997. The eight rivers of the southern Gulf have been the most consistent in equalling or exceeding the conservation requirements but the median escapements were below conservation requirements in the last four years and 1997 had the lowest median escapement since 1984 (Fig. 6).

The persistent failure of stocks in the Maritimes to achieve the conservation requirements has resulted in the progressive closures of Atlantic salmon fisheries beginning with the closure of the inner Bay of Fundy rivers in 1990. Further closures and the imposition of mandatory hook and release fisheries for all size groups in 1995 and 1996 culminated in 1998 with the most restrictive in-river fishery management to date (Fig. 7). Retention fisheries for small salmon were allowed only in the southern Gulf of St. Lawrence.

Juvenile Abundance

Increased escapements to rivers resulting from the 1984 management plan resulted in increased abundance of juveniles in some rivers of the Maritimes (Fig. 8). Juvenile densities increased through the 1980's and early 1990's in the southern Gulf of St. Lawrence with the recoveries most evident in the Miramichi and Restigouche rivers (Fig. 9). Juvenile abundance in the rivers of the southern Gulf rivers are at medium to high levels (Fig. 8). In the Atlantic coast of Nova Scotia and Bay of Fundy rivers, juvenile levels are low and in some cases continue to decline as evidenced in the Stewiacke River where densities in 1997 were lowest of record (Fig. 9). These juvenile abundance patterns parallel those of the adults. The time frame for recovery is increased and the recovery potential decreased when both adult and juvenile abundance become depressed.

Sea Survival

Decreased numbers of adults are in large part the result of low sea survival. There are no sea survival measurements for wild stocks in the Maritimes. Sea survivals of three hatchery stocks have been the lowest of record in the early 1990s with no apparent indications of recovery (Fig 10). The sea survivals of Saint John smolts declined in the early 1980's whereas the other hatchery stocks and the wild stocks of Quebec showed declines after 1988 to 1990 (Fig. 10, 11). In contrast to other Newfoundland stocks, low marine survival has persisted for the Conne River smolts of the south coast of Newfoundland (Fig. 11). These low survival rates have undoubtedly been the factor contributing the most to the lower abundance of adult salmon seen in the last decade in the Maritimes.

Habitat Constraints

Habitat degradation and fish passage constraints are most important in the Bay of Fundy and Atlantic coast of Nova Scotia. The Southern Upland (Atlantic Coast) area of Nova Scotia is impacted by acid rain because of a combination of hard rock geology, poor soils and prevailing weather patterns that cause much of the atmospheric pollution from the US industry to precipitate over the Maritimes (Watt 1997). Of the sixty Atlantic salmon rivers along the Atlantic coast of Nova Scotia, salmon runs have been extirpated in 14 rivers (mean annual pH <4.7), severely impacted in 20 rivers (mean annual pH 4.7 to 5.0) and lightly impacted in 16 rivers (mean annual pH 5.1 to 5.4) (Watt 1997) (Fig. 12). Thirteen rivers in this area do not have acid toxicity constraints (pH > 5.4) because of a higher acid neutralizing capacity. Sulphate levels showed a significant decline during the 1981 to 1995 period. The decline in sulphate emission/deposition is expected to become more pronounced over the next 5 to 10 years with the anticipation of a return to less toxic salmon habitat. In several of these rivers, returns of adult salmon are entirely dependent upon stocking of smolts (Fig. 2).

Other habitat constraints impacting on freshwater production include land use practices associated with intensive agricultural development especially in Prince Edward Island (Cairns 1997). Water use practices at both hydroelectric generating facilities and for municipal use impact on both freshwater production and adult migrations. Fish passage constraints impact on both smolts migrating to sea and adults returning in at least seven rivers of the Bay of Fundy and Atlantic coast of Nova Scotia (DFO Science 1997). The habitat constraints in the southern Gulf of St. Lawrence rivers are more generally associated with the impacts of forestry practices and with the industrial developments which discharge waste waters into the estuaries.

Factors affecting abundance

Numerous factors including those in freshwater are negatively affecting the present abundance of Atlantic salmon. The trends in sea survivals of both hatchery and wild salmon in eastern Canada suggest that the marine phase is a bottleneck regulating the abundance of salmon in the rivers of eastern Canada. Some of the contributing factors which have been examined include, but are not limited to, fisheries, predators, environmental conditions, and aquaculture production (DFO Science 1998).

In the 1960s to the 1980s, ocean **fisheries** substantially reduced the number of salmon returning to rivers of eastern Canada. Major closures in the commercial fisheries of the Maritimes in 1984 followed by the closure of the Newfoundland fishery in 1992 and the imposition of quotas which declined every year in the Labrador and Quebec north shore fisheries has resulted in the lowest commercial harvest of salmon of record in eastern Canada (Fig. 13). These fisheries are now so small that returns to rivers are considered to represent stock size.

Atlantic salmon are preyed upon by numerous **predators** in the sea including birds, seals and other marine mammals and other fish such as cod. Diet shifts in predator diets do occur as evidenced by the changes in relative abundance of warmwater prey such as mackerel and coldwater prey species such as capelin in the diet of gannets in a colony off Newfoundland (DFO Science 1998). Salmon were a small proportion of the overall diet. The most obvious predator which could account for the reduced abundance of Atlantic salmon is seals. Harp seals are the most abundant species in the northwest Atlantic and their numbers have increased monotonically since 1972 to reach the highest level in 1997 at just under 5 million animals (DFO Science 1998). The two decades of increasing seal populations in contrast to a decadal decline in many North American salmon stocks, and the low probability of observing salmon in harp seal stomachs even under extremely high predation rates suggest that seals could have a significant impact on salmon abundance (DFO Science 1998). Increased abundance of seals appears to correspond to the declines in sea survival of the hatchery stocks of the Maritimes.

Studies have shown that oceanic variability influences the growth, survival and distribution of salmon stocks (summarized in Dempson et al. 1998). The ocean **temperatures** have been hypothesized to be an important determinant of sea survival, especially conditions during the first winter at sea (Friedland et al. 1993). A marine habitat index of the northwest Atlantic during January to March has a strong positive association with the estimated abundance of 2SW salmon during their first winter at sea (ACFM 1998). Correlation analyses for the hatchery smolts of the Maritimes supported the previously reported positive association with the index of marine habitat during the first winter at sea. Other factors associated with sea survival include the annual variations in timing of the smolt migration; survivals of Conne River (Newfoundland) smolts were with one exception highest in early run years (Dempson et al. 1998).

Aquaculture production like seal abundance has increased continually since 1981 (Chang 1998, DFO Science 1998). It would be expected to have the greatest effect on the stocks in proximity to production areas. Coincidentally perhaps, the rivers which had strongly declining wild salmon returns were in the vicinity of the production areas (Fig. 14.

No factor can be singled out to explain the declines in abundance of Atlantic salmon in eastern Canada and the Maritimes. It is difficult to model the effects of predators and environment on salmon when neither variable can be controlled/varied independently of the other. Testing for the relative importance of predators and environment can be determined when contrasting conditions of habitat and predator abundance occur. One of these contrasting combinations should be testable in the coming years (high environment: low predator abundance in the 1970's; high environment: high predator abundance in the late 1990s).

Present abundance of Maritimes Atlantic Salmon

The abundance of Atlantic salmon by size group and SFA has been estimated for the period 1971 to 1997 (ACFM 1998). Between 1992 and 1997, the total stock size of wild and hatchery origin Atlantic salmon adults returning to rivers of the Maritimes was between 115,000 and 229,000 fish annually (Fig. 15). This contrasts with approximately 5.6 million market sized salmon harvested from cages in New Brunswick and Nova Scotia in 1997 (Chang 1998). The number of salmon escaping production facilities is generally unknown but in 1994, an estimated 20,000 to 40,000 salmon escaped from sites in southwestern New Brunswick (Anon. 1995). This escape was about twice the total number of wild and hatchery origin salmon returning to rivers of the entire Bay of Fundy (11,000 to 22,000) and equivalent to the average annual total returns (19,000 to 43,000 fish) to the Bay of Fundy and Atlantic coast of Nova Scotia between 1992 and 1997 (Fig. 15).

There are only three rivers in the Maritimes with total stock size in excess of 10,000 fish annually (Fig. 16). The many small rivers contain stocks whose annual returns are generally less than 500 fish. Individual rivers of the inner Bay of Fundy most probably receive less than 100 adult salmon annually. The stock size in most of the Atlantic coast rivers where populations are threatened by acid-deposition have not been estimated but are also believed to be very low.

CONCLUSION

There is a clear geographic distinction in stock status of Atlantic salmon in the Maritime provinces. Trends in returns, escapements relative to conservation requirements, juvenile abundance, and measured sea survivals of hatchery released smolts indicate that the stocks of the Bay of Fundy and Atlantic coast of Nova Scotia have declined to low levels with reduced recovery potential. Hatchery-origin fish have increased proportionally to wild salmon as the wild salmon abundance declines. Many of the stocks of the southern Gulf of St. Lawrence have also declined in recent years but juvenile abundances are at medium to high levels and most of the rivers are near or above conservation.

Freshwater constraints such as reduced survival of eggs and juveniles as a result of acid rain and barriers to migrations are most important in the Bay of Fundy and Atlantic coast of Nova Scotia rivers. When combined with the reduced sea survival observed in most stocks of eastern Canada, improved abundance in the short term is not expected. Several factors are potentially influencing the smolt to adult returns simultaneously including marine conditions, predators and perhaps in some areas human activities such as aquaculture.

The run-sizes of Atlantic salmon adults in many rivers of the Maritimes, especially in the Bay of Fundy are presently very small, numbering fewer than 500 fish annually. Such small populations are particularly vulnerable to "normal" fluctuations in the environment and the greatest threat to their existence tends to be related to environmental stochasticity (including catastrophes) and demographic stochasticity (chance survival of individuals) (Chaput 1997). The intrusion of aquaculture escaped fish can further threaten the viabiltiy of the wild salmon populations. The magnitude of the impacts would be related to the relative proportions of farm fish mixing with wild salmon (Lacroix et al. 1998; Verspoor 1998). Rivers with small run-sizes of wild salmon would be most susceptible to these intrusions.

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Table 1. Relative proportions of Atlantic salmon returns by age-at-maturity and by Salmon Fishing Area (SFA) in the Maritime provinces. Reference: O'Connell et al. 1997.

		1SW		2SW & 3SW		Repeat spawners	
SFA	River	% of stock	% female	% of stock	% female	% of stock	% female
15	Restigouche	39	2	49	54	12	?
16	Miramichi	78	24	18	84	4	57
	Other rivers	37	15	53	76	10	?
17	Morell	84	17	16	72		
18	Margaree	28	15	64	70	7	78
19	North, Middle, Baddeck	<30%	?	70%	?		
	Grand	>90%	?	10%	?		
20	Liscomb, St. Mary's	79	66	7	77	14	67
21	LaHave	81	37	13	88	6	57
23	Saint John	63	15	32	94	5	?

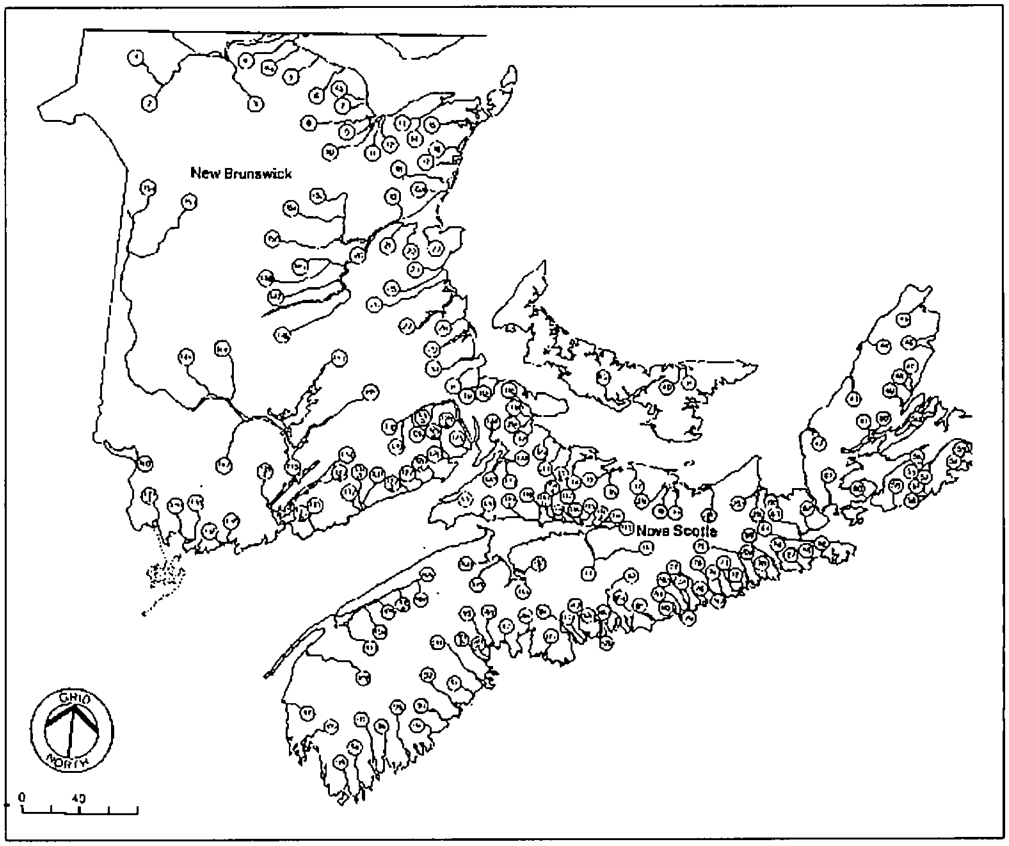


Figure 1. Atlantic salmon rivers of the Maritime provinces with reported angled catch. Map is from O'Neil et al. 1996.

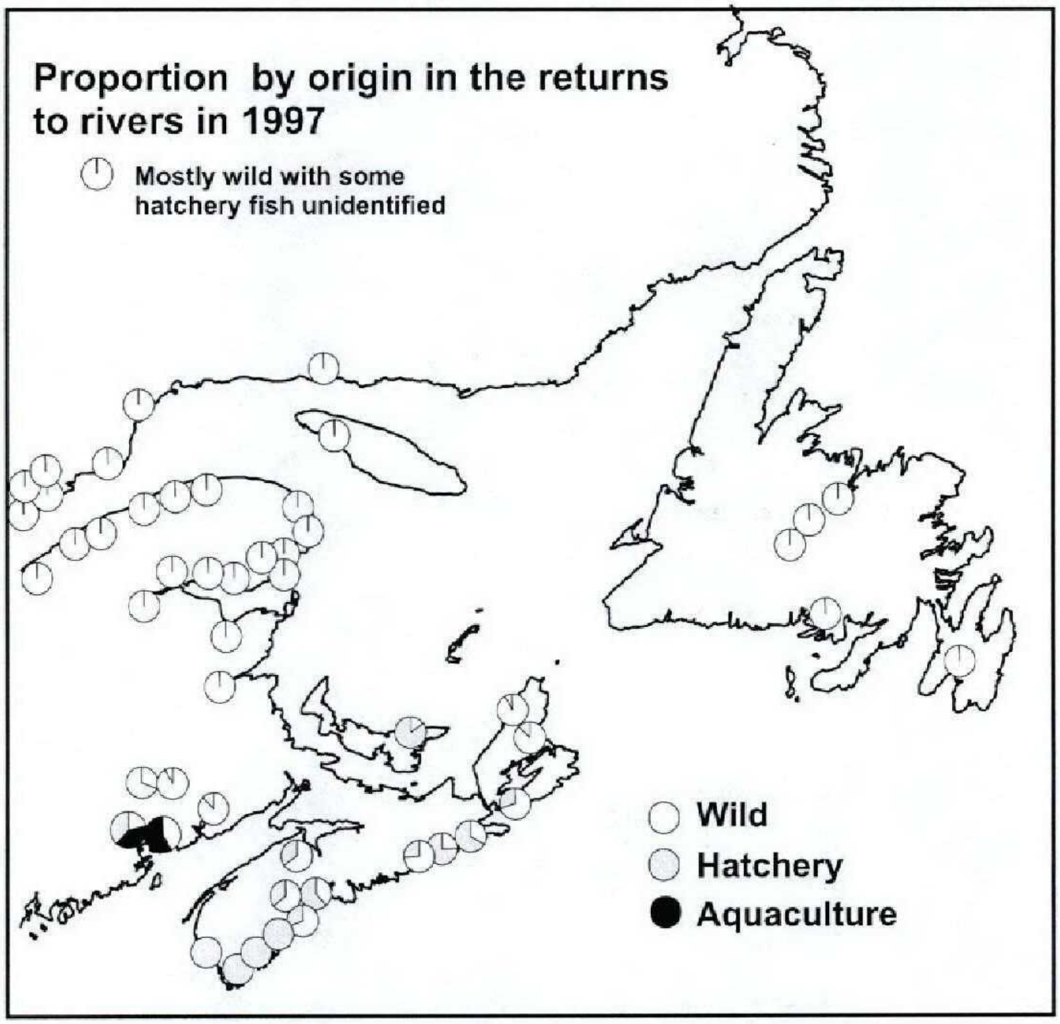


Figure 2. Proportion by origin in the returns of small and large salmon combined to rivers of eastern Canada in 1997.

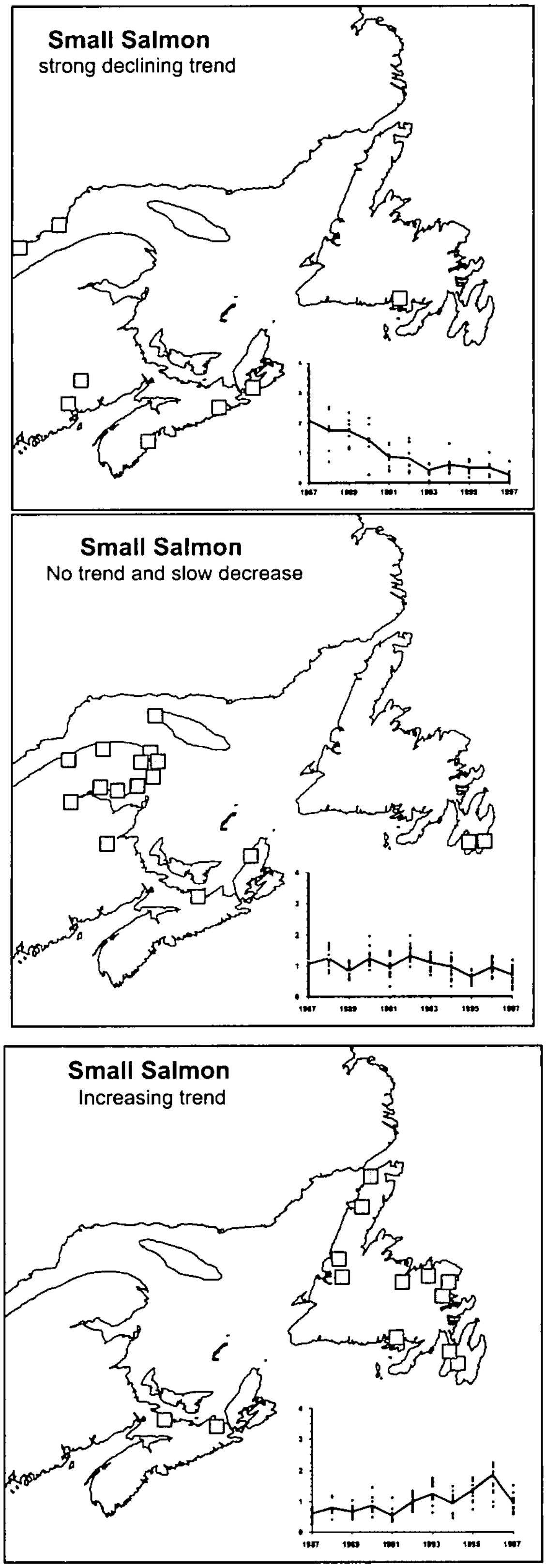


Figure 3. Geographical patterns of returns of small salmon to the rivers of eastern Canada, 1987 to 1997. Reference: Chaput and Prévost 1999; DFO Science 1998.

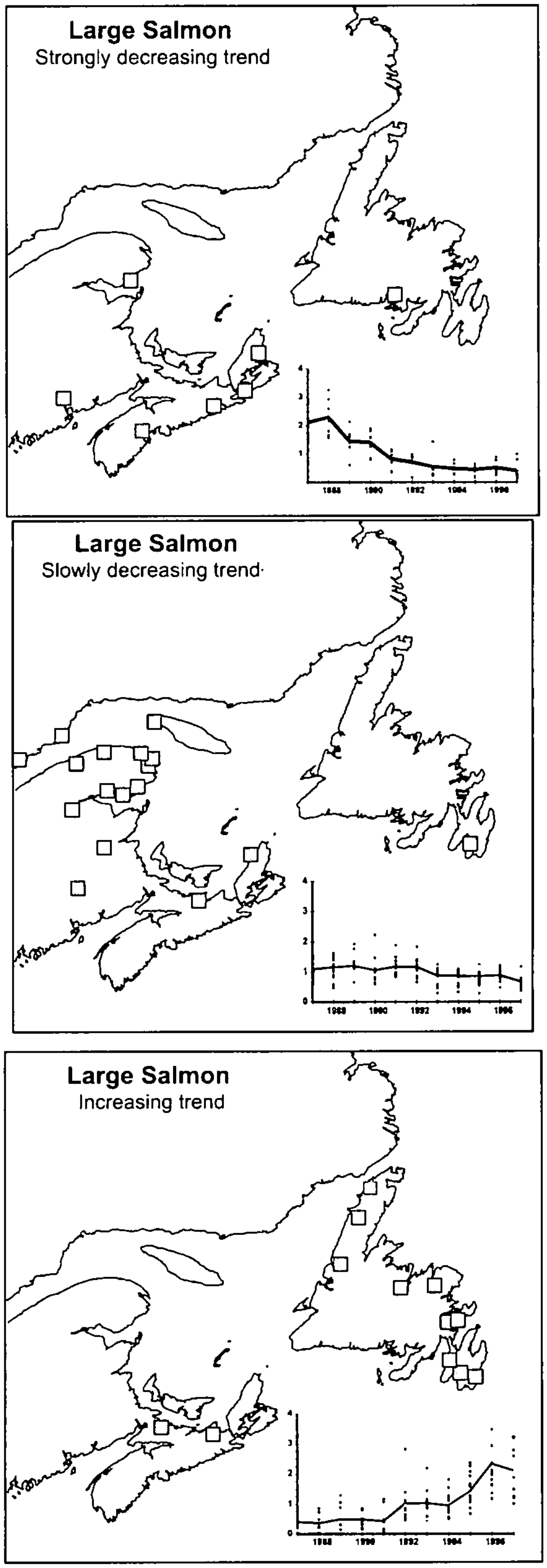


Figure 4. Trends in returns of large salmon to rivers of eastern Canada, 1987 to 1997. Reference: Chaput and Prévost 1999; DFO Science (1998).

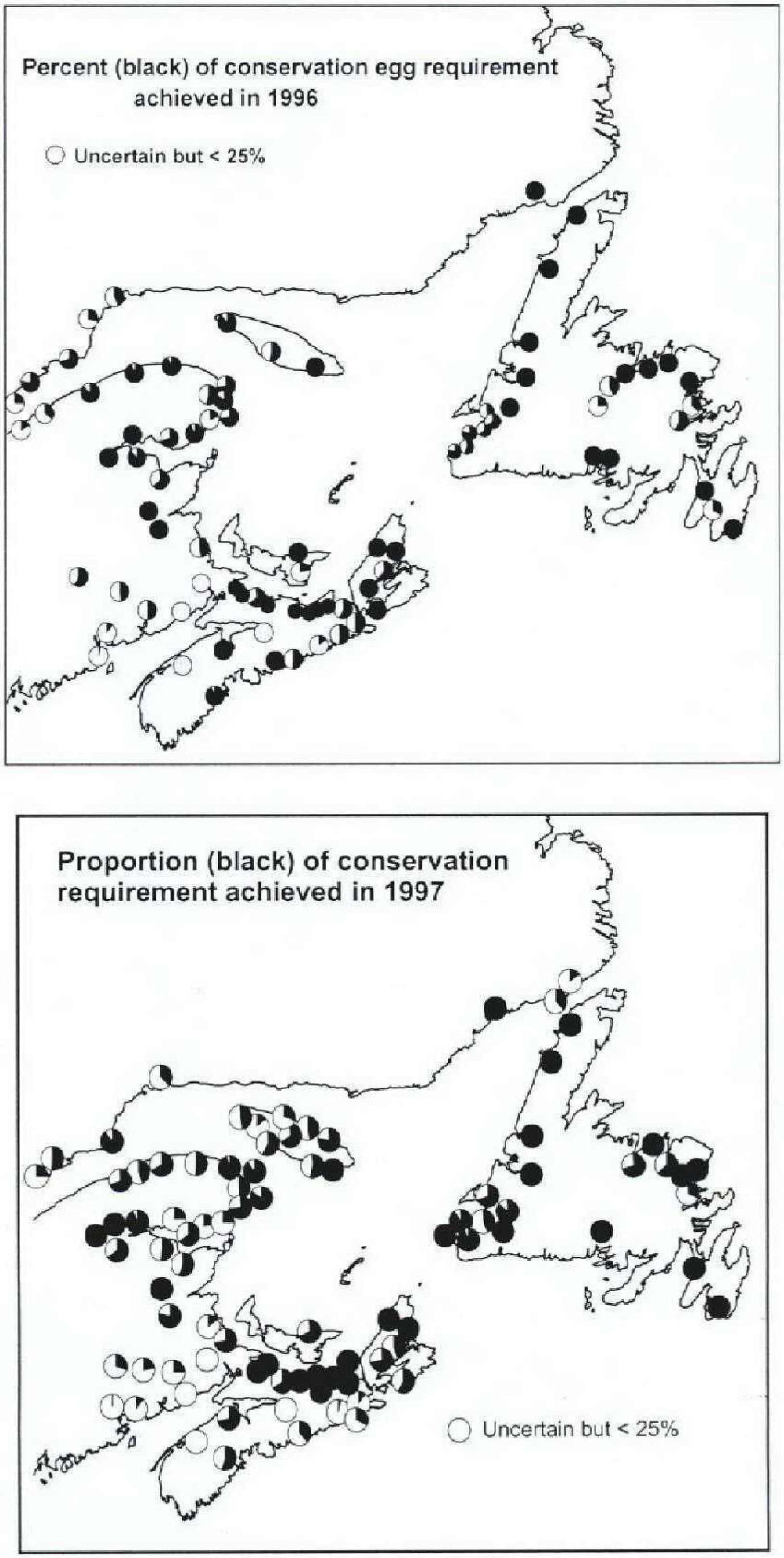
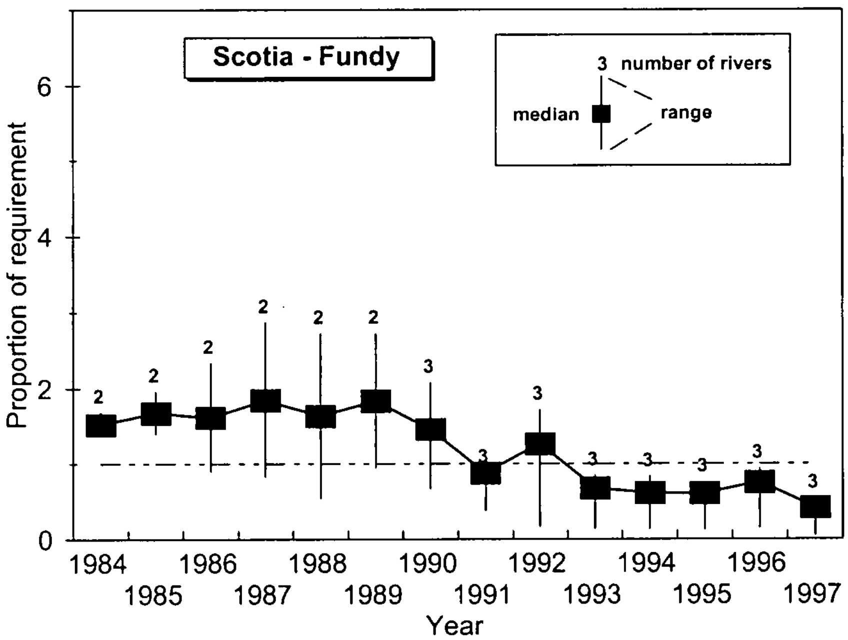


Figure 5. Proportion of conservation requirements achieved in 1996 (upper) and 1997 (lower) in rivers of eastern Canada. Reference DFO Science (1997, 1998).



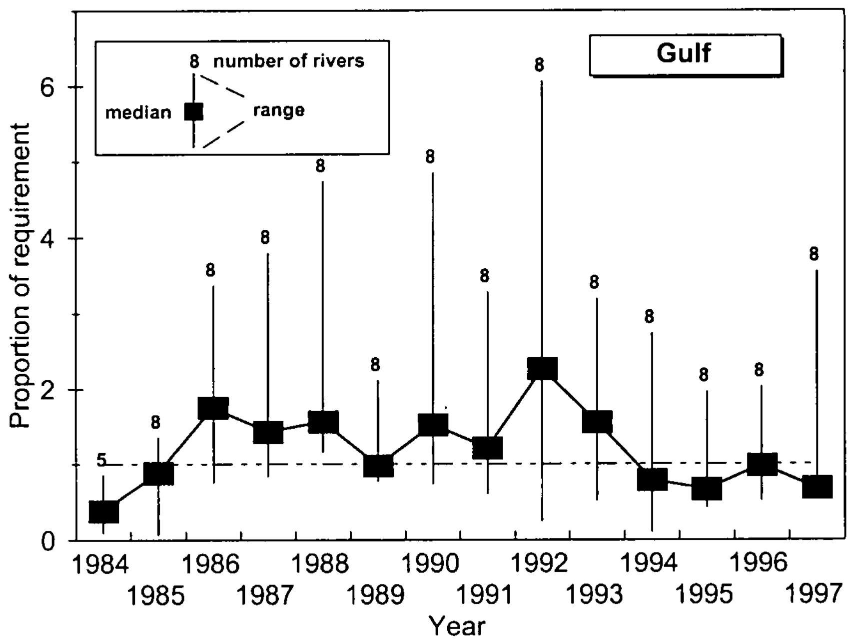


Figure 6. Proportion of the conservation requirements met in monitored rivers of the Maritimes region, 1984 to 1997. The vertical line represents the minimum and maximum proportion achieved in individual rives, the black square is the median proportion and the number above the vertical line is the number of rivers included in the annual summary. The horizontal line defines the location of 100% of conservation requirements. Reference: DFO Science (1998).

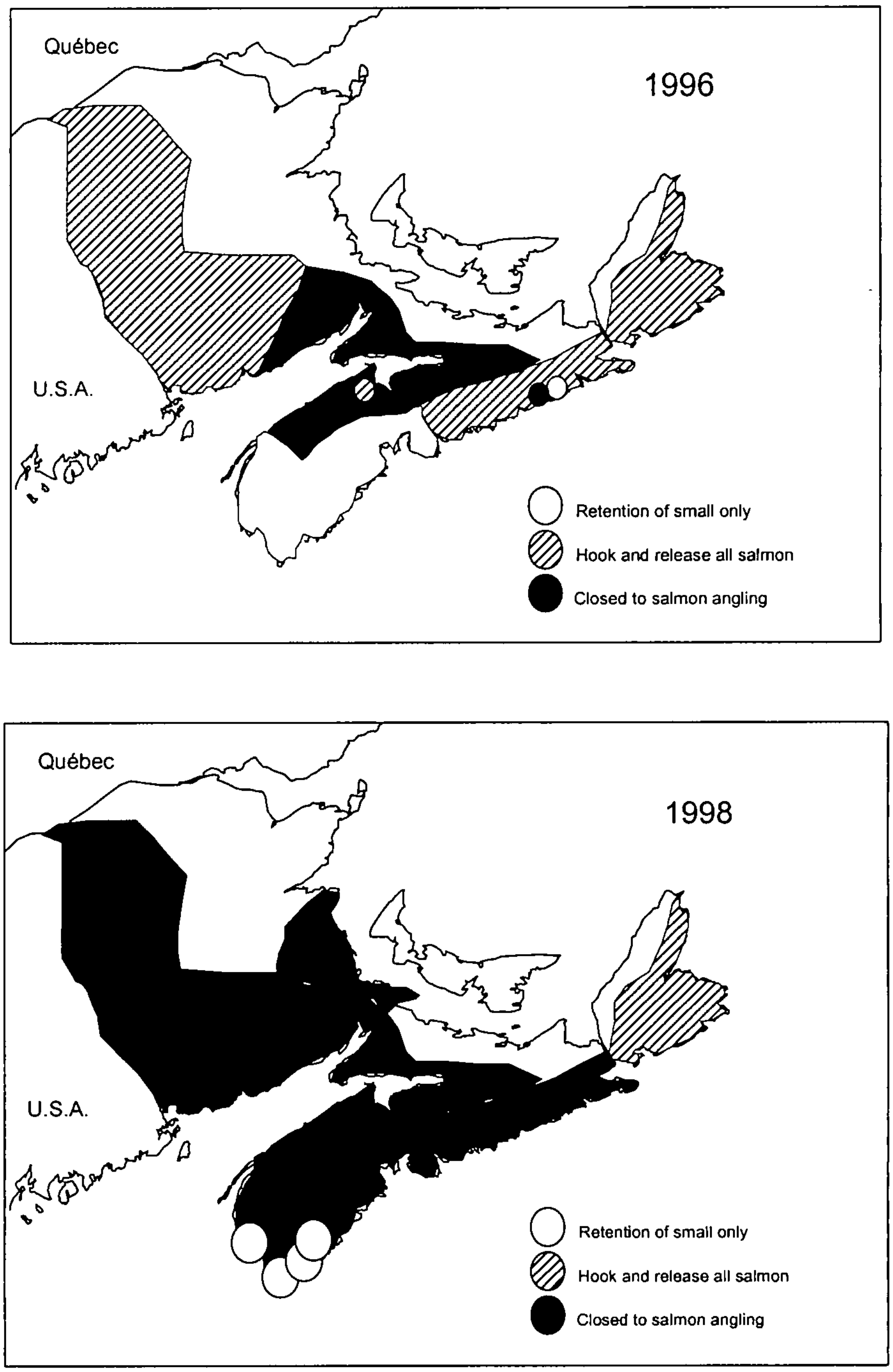


Figure 7. Changes in angling fishery management plans from 1996 (upper panel) to 1998 (lower panel) reflecting geographic differences and declines in abundance of Atlantic salmon in the Maritimes Region. Reference DFO Science (1998).

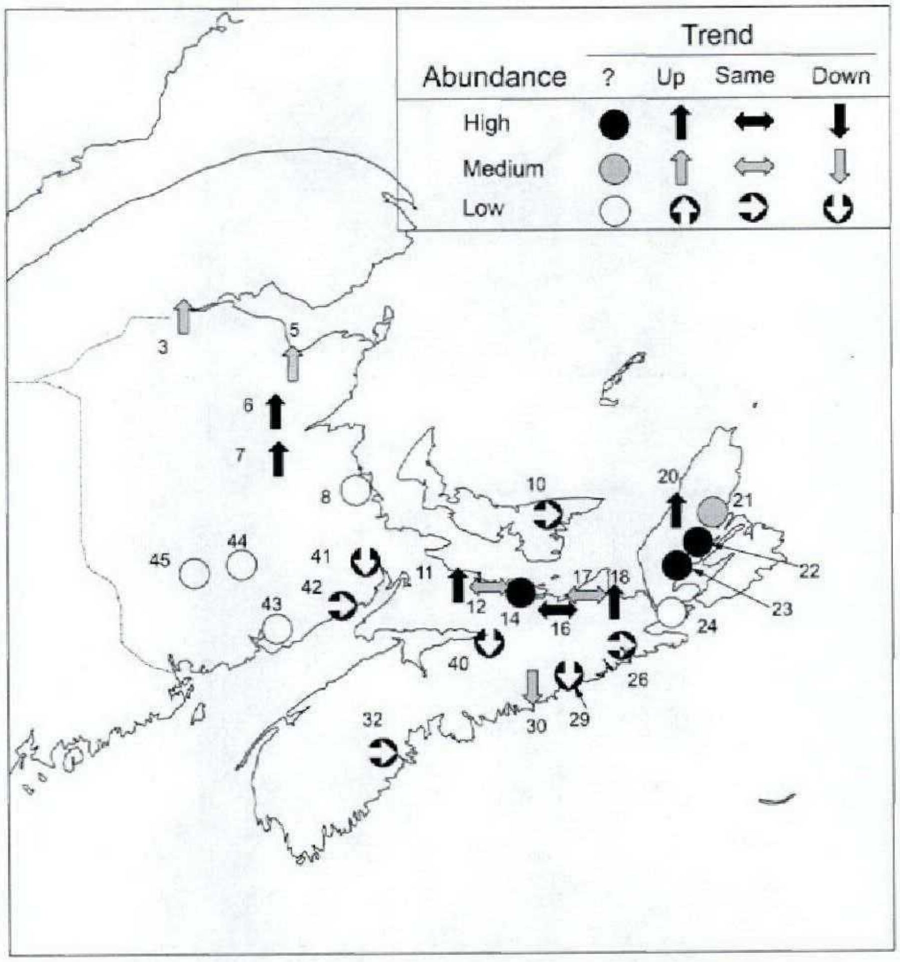
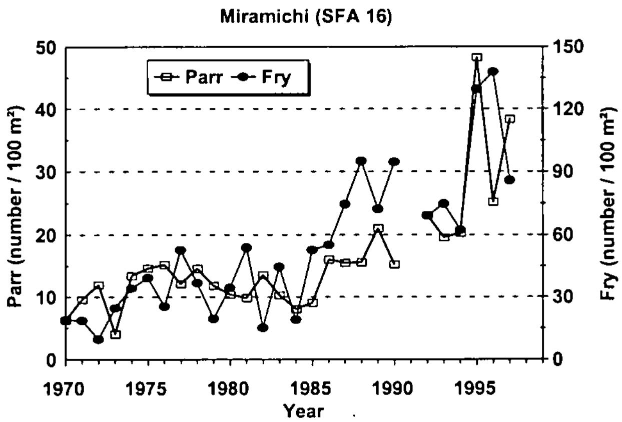
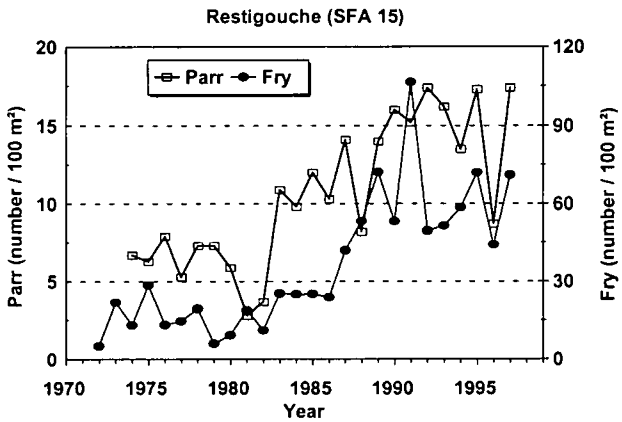


Figure 8. Relative abundance and trends in abundance of juvenile Atlantic salmon in the rivers of the Maritimes Region. Reference: DFO Science (1997).





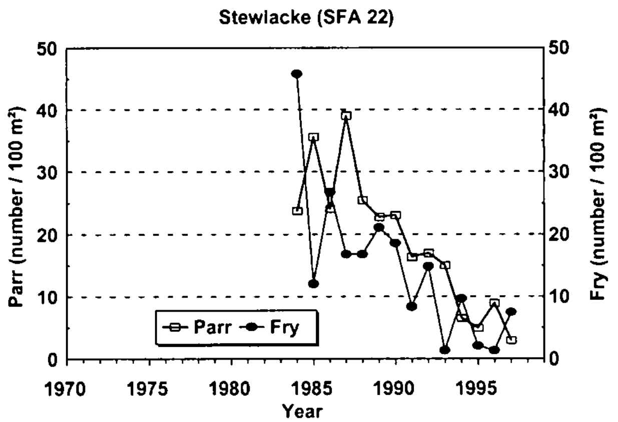


Figure 9. Mean juvenile Atlantic salmon densities in the Miramichi River and Restigouche River in the southern Gulf of St. Lawrence and the Stewiacke River in the inner Bay of Fundy. Reference: DFO Science (1998).

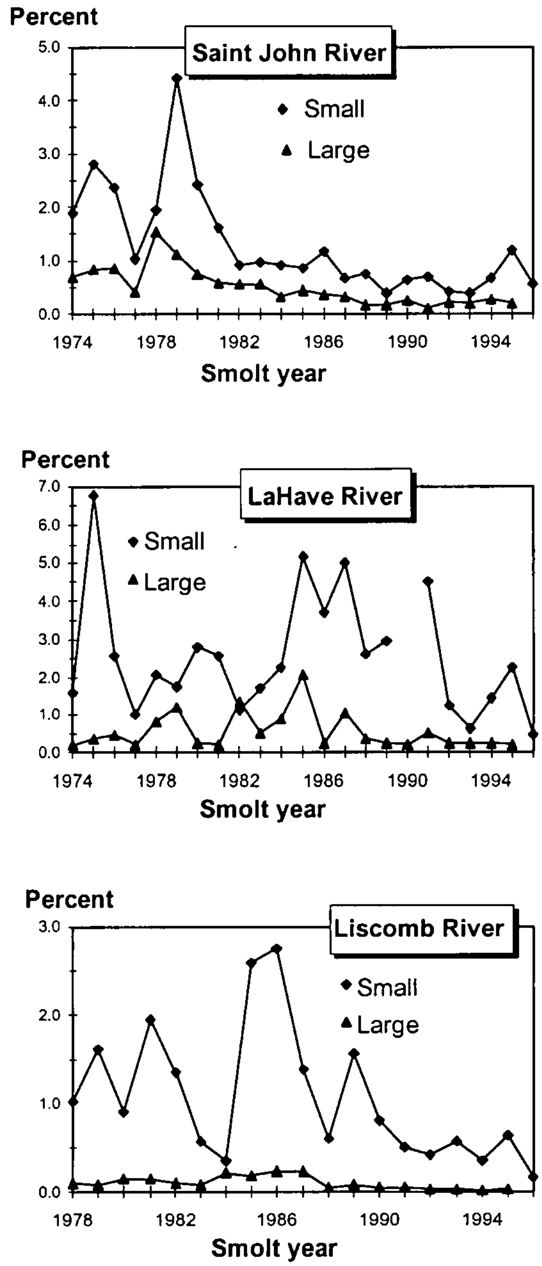


Figure 10. Hatchery smolt survival rates to small (mostly 1SW salmon) and large (mostly 2SW salmon) for three rivers of the Maritimes. Reference: DFO Science (1998).

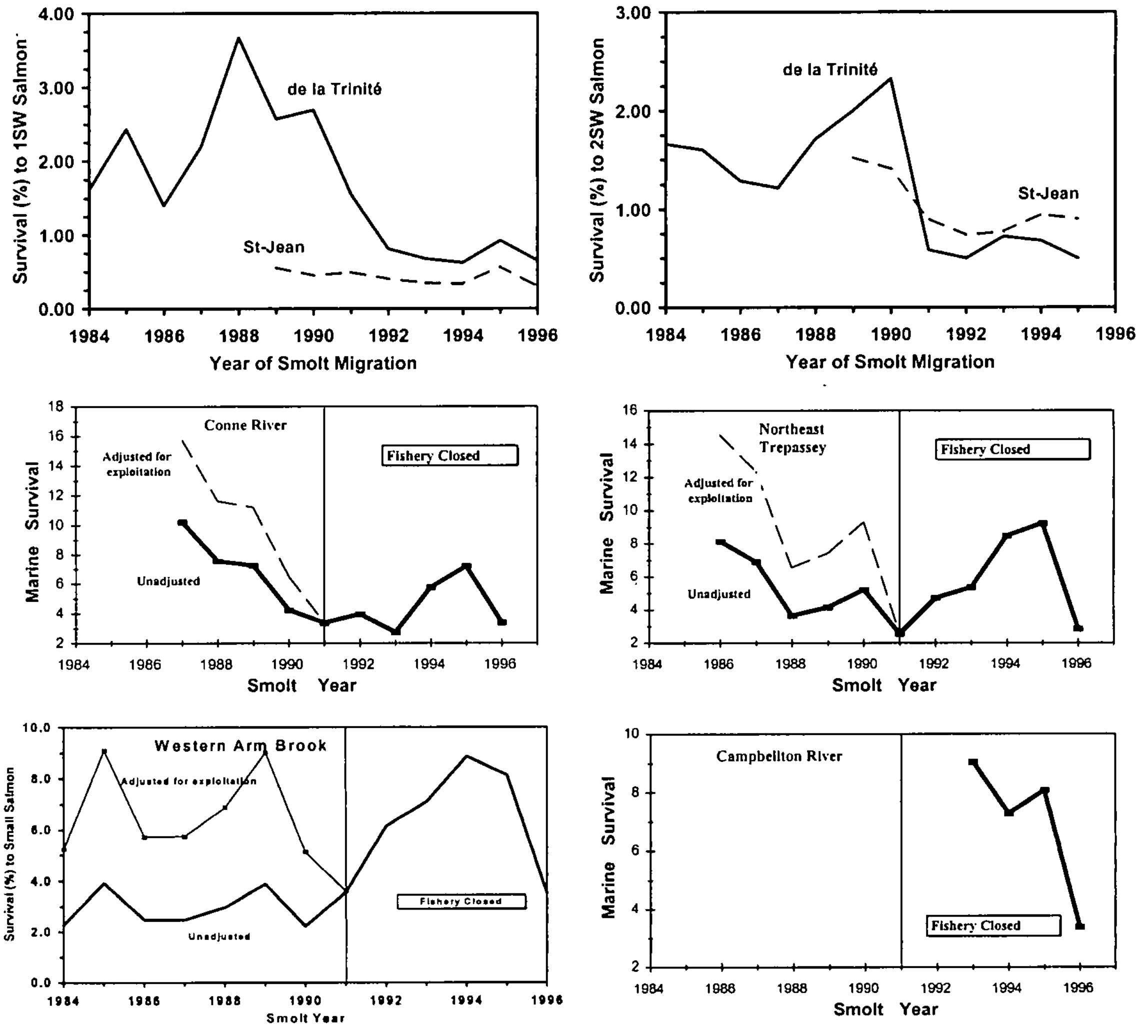


Figure 11. Wild Atlantic salmon smolt survival rates from Quebec and Newfoundland rivers. Smolt survival rates for the Newfoundland rivers (middle and lower panels) are to the 1SW salmon stage unless otherwise indicated. Reference: DFO Science (1998).

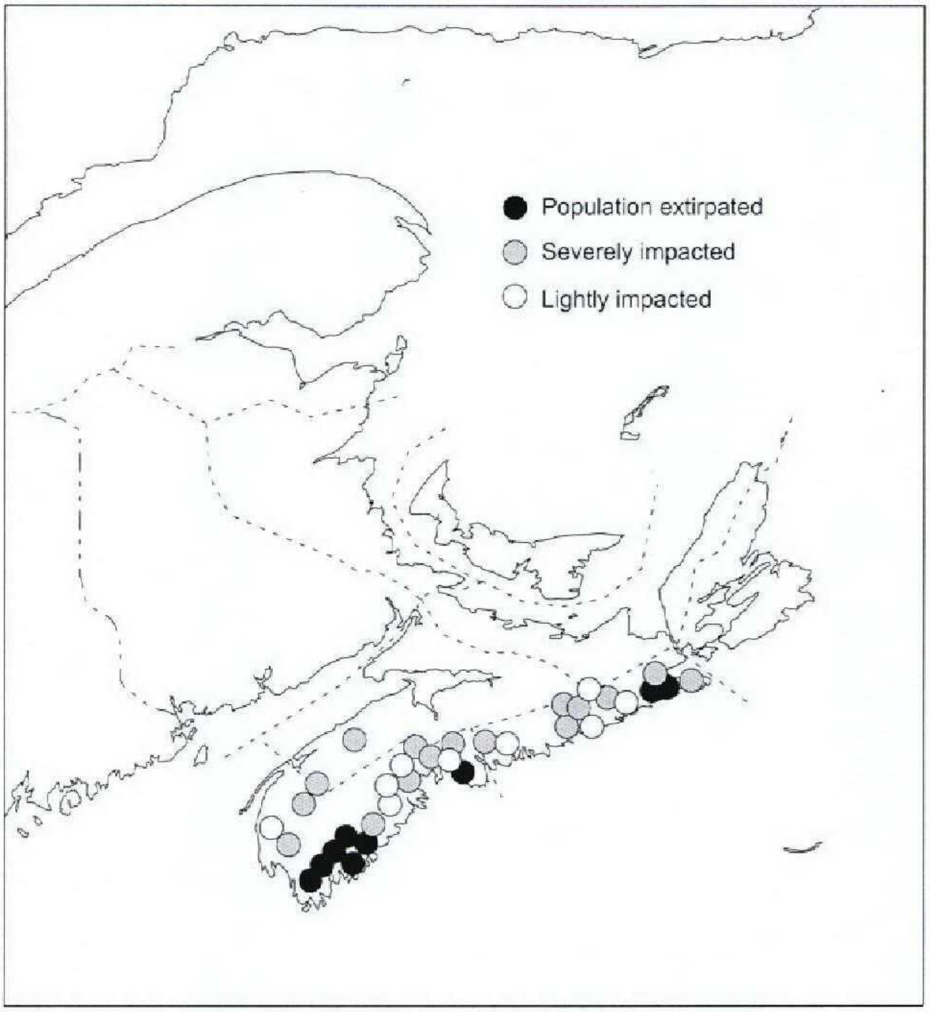


Figure 12. Distribution and population status of Atlantic salmon in acid-impacted rivers of Nova Scotia. Reference: DFO Science (1997), Watt (1997).

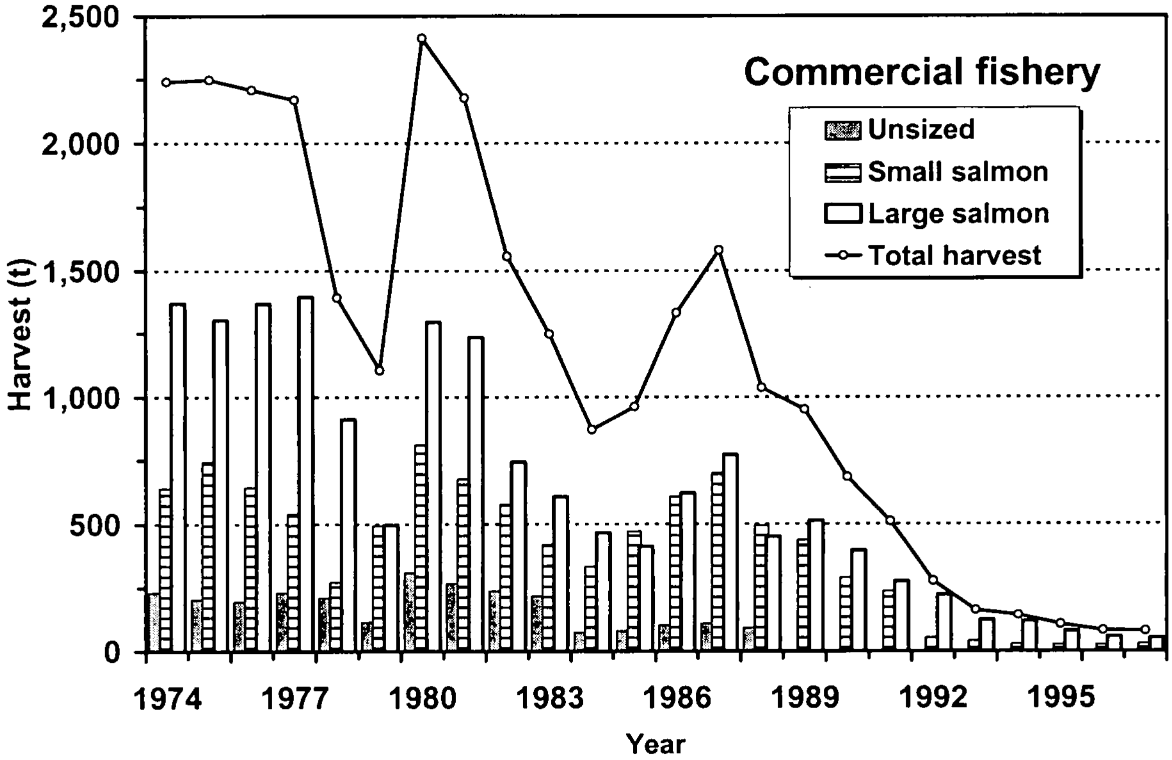


Figure 13. Harvest (t) of small salmon and large salmon and both size groups combined in the commercial fisheries of Canada, 1974 to 1997.

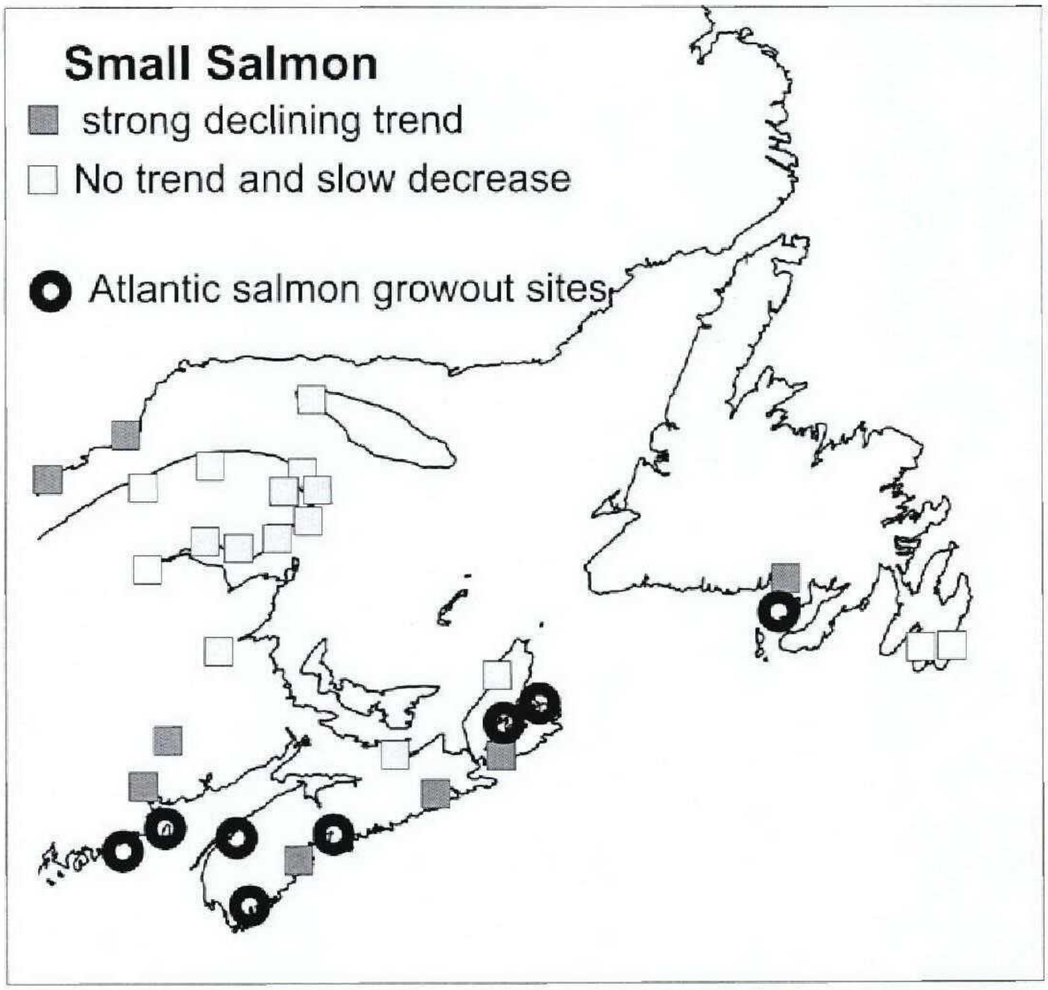


Figure 14. Summary of trends in returns to rivers of wild small salmon to eastern Canada during 1987 to 1997 overlaid by locations of Atlantic salmon growout sites.

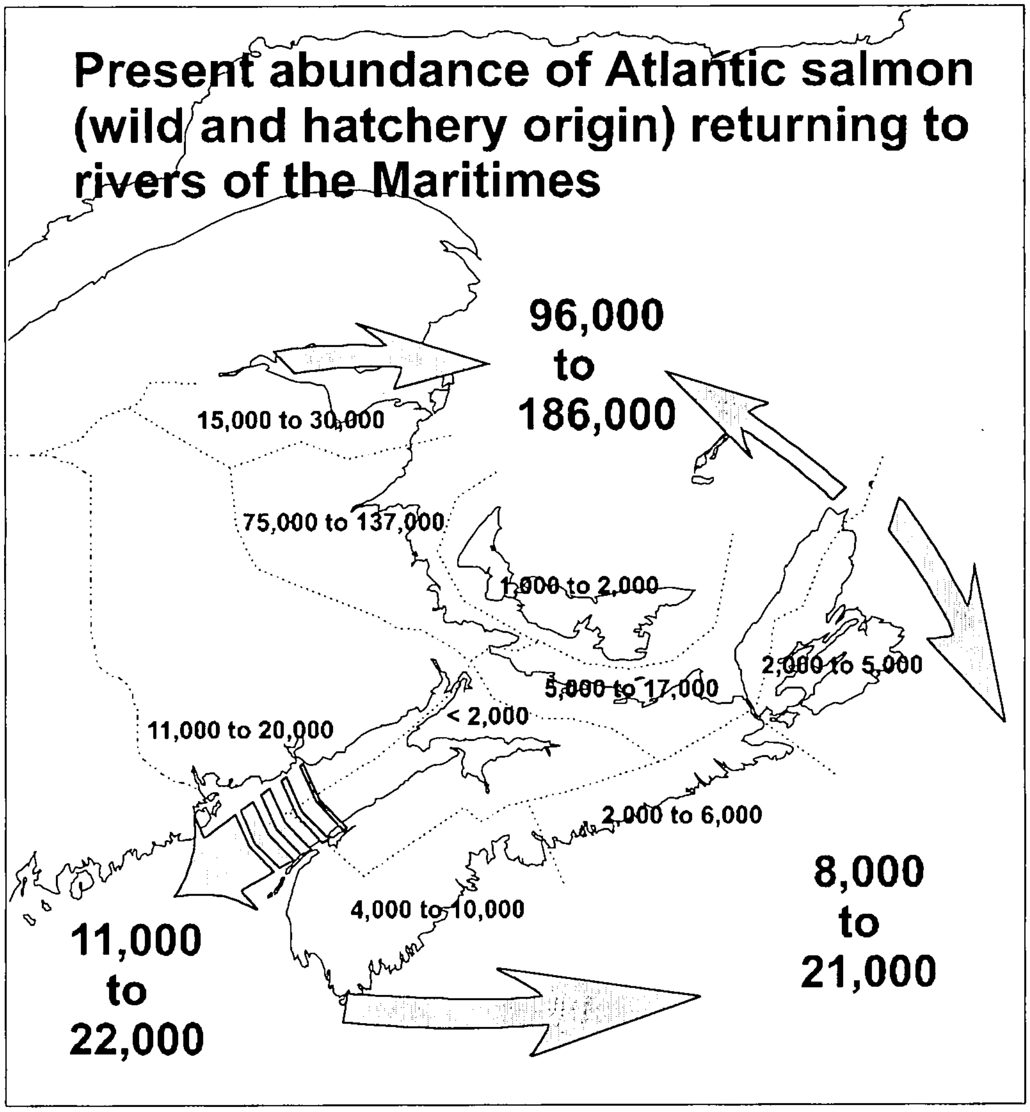


Figure 15. Estimates of abundance of wild and hatchery-origin Atlantic salmon by production area in the Maritime provinces. Estimates are minimum and maximum values for 1992 to 1997 as documented in ACFM (1998).

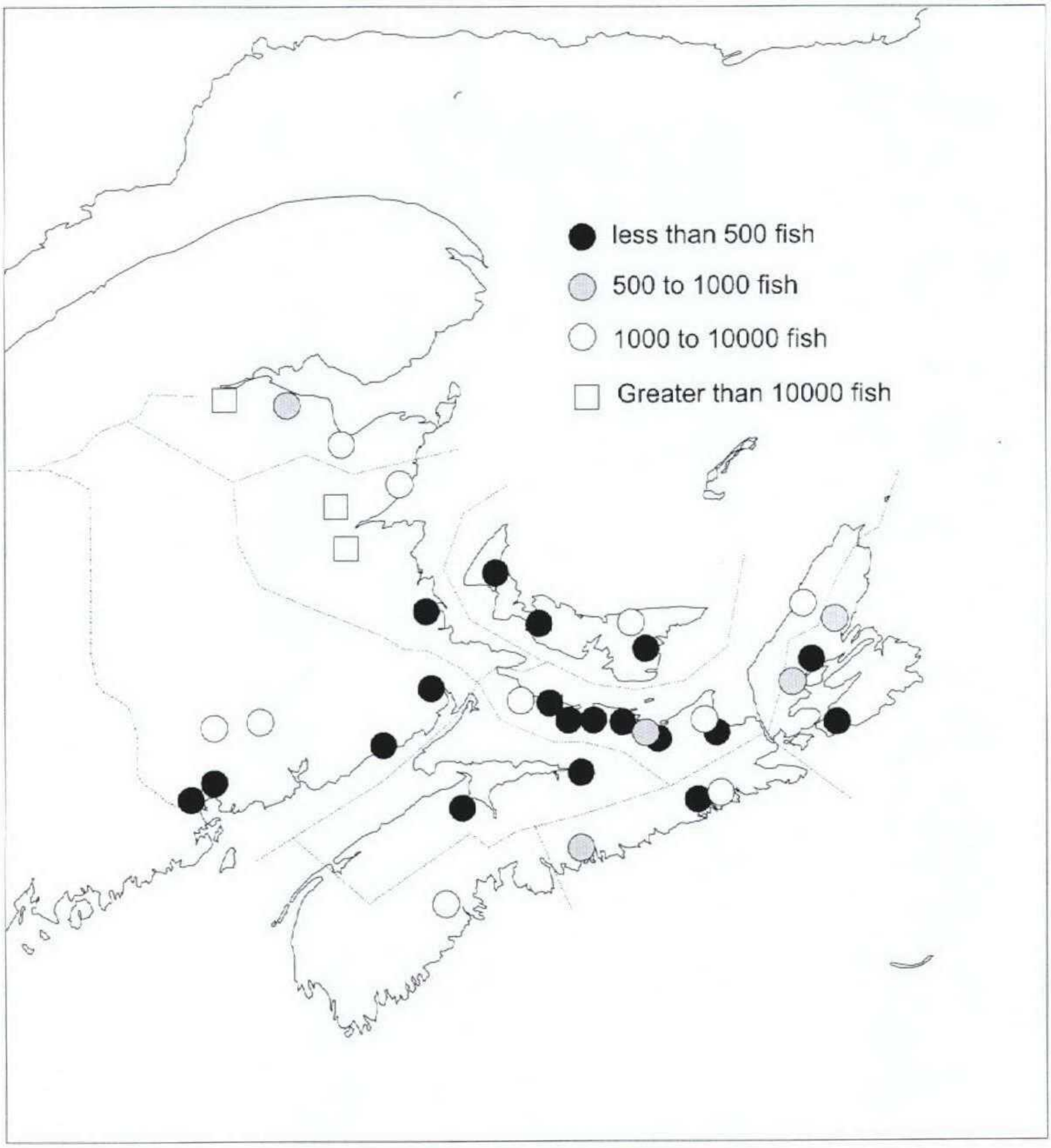


Figure 16. Approximate abundance of Atlantic salmon (small and large combined, wild and hatchery origin combined) by river in the Maritimes provinces during the last five years.