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Analyses of trends in returns of Atlantic salmon (*Salmo salar*) to rivers in Nova Scotia and Bay of Fundy, New Brunswick, and status of 1997 returns relative to forecasts.

by

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Abstract

This paper explores the spatial and temporal distribution of salmon return patterns among stocks of Nova Scotia and southern New Brunswick, the status of 1997 returns, the relative performance of wild and hatchery smolts and the condition of wild one-sea-winter returns to Morgan Falls, LaHave River. Temporal trends of small and large salmon returns were examined relative to time periods associated with the Salmon Management Plan of 1984 and the Newfoundland commercial salmon fishing moratorium of 1992. The analyses indicated a high degree of coherence among most Atlantic salmon stocks in the areas examined. Prior to the Salmon Management Plan (1970-1983), trends were generally increasing; trends over the years 1984-1997 were predominantly decreasing. Based on the 1984-1996 trends, 1997 returns were below expected returns in most data series. Low returns to the Liscomb, LaHave and Saint John fishways relative to forecasts, especially those based on 20-25 year forecast models, provide a strong indication of low recruitment in 1997 from both the 1995 and 1996 smolt classes. Estimated one-sea-winter and multi-sea-winter wild and hatchery returns to the Saint John and LaHave rivers were well below the forecast returns. Wild smolts migrating in 1996 from above Morgan Falls were 4.8 times more likely to survive to return than hatchery smolts. The condition of age 2.1 wild fish moving through the Morgan Falls fishway before August 1 over the years 1985-1997 increased significantly, while no temporal trends were detected in mean length or weight. The coefficient of skewness of the lengths of all age 2.1 wild fish increased significantly over the 1970-1997 period, indicating a decline in smaller fish of that age.

Résumé

Le document traite de la distribution spatiale et temporelle des remontées de saumon de divers stocks de la Nouvelle-Écosse et du sud du Nouveau-Brunswick, de l'état des remontées de 1997, du rendement relatif des saumoneaux sauvages et d'élevage et de la condition des remontées d'unibermarins sauvages à Morgan Falls, sur la rivière LaHave. Les allures temporelles des remontées de petits et de grands saumons ont été examinées dans le contexte des périodes prévues dans le plan de gestion du saumon de 1984 et du moratoire de la pêche commerciale du saumon de Terre-Neuve imposé en 1992. Les analyses ont montré l'existence d'un niveau élevé de cohérence entre la plupart des stocks de saumon de l'Atlantique des zones examinées. Avant l'adoption du plan de gestion du saumon (1970-1983), les allures étaient généralement à la hausse tandis que celles de 1984 à 1997 étaient généralement à la baisse. Selon les allures de 1984 à 1996, les remontées de 1997 de la plupart des séries de données ont été généralement inférieures aux valeurs prévues. Les faibles remontées aux passes à poissons de la Liscomb, de la LaHave et de la Saint John, par rapport aux prévisions, notamment celles fondées sur les modèles de prévision de 20 à 25 ans, constituent un indice important de faible recrutement en 1997 des classes de saumoneaux de 1995 et 1996. Les remontées estimées de saumons unibermarins et pluribermarins sauvages ou d'élevage dans les rivières Saint John et LaHave ont été bien en deçà des prévisions. Les saumoneaux sauvages en migration, en 1996, en amont de Morgan Falls présentaient une probabilité de survie 4,8 fois supérieure à celle des saumoneaux d'élevage. La condition des poissons sauvages d'âge 2,1 traversant la passe à poissons de Morgan Falls avant le 1^{er} août a augmenté de façon appréciable entre 1985 et 1997 mais aucune tendance temporelle n'a été décelée pour la longueur ou le poids moyens. Le coefficient de dissymétrie des longueurs de tous les poissons sauvages d'âge 2,1 a augmenté de façon significative au cours de la période 1970-1997, ce qui indique une baisse des plus petits poissons de cet âge.

Introduction

Returns of Atlantic salmon to rivers of southern New Brunswick and Nova Scotia (Figures 1 to 4) were low in 1997 and resulted in closures to harvest and to catch and release angling in many rivers. Only in the Gulf of St. Lawrence coast of Nova Scotia did fisheries remain open to retention of salmon <63.0 cm in 1997. Preliminary estimates of stocks status, gathered at consultation meetings during the salmon run and imediately following fall runs, indicate returns to many rivers were less than 50% of forecast values. Low returns of wild salmon in 1997 may be a continuation of an observed pattern of decreased survial of hatchery salmon stocked in many of these same rivers. This pattern of diminishing returns of salmon appears to be widespread throughout all areas.

This paper explores questions concerning the spatial and temporal distribution of salmon return patterns among stocks of Nova Scotia and southern New Brunswick, the status of 1997 returns, the relative performance of wild and hatchery smolts and the condition of wild one-sea-winter returns to Morgan Falls, LaHave River.

Trends in indices of marine survival of 1SW and MSW Atlantic salmon

In this section we examine the temporal trends of small and large salmon returns relative to temporal periods associated with the Salmon Management Plan of 1984 (DFO 1984) and the Newfoundland commercial salmon fishing moratorium of 1992 (DFO 1992). The continuance of the temporal trend in 1997 was also examined. Angling catches raised by annual catch rates, return rates of hatchery origin smolts, densities wild juvenile salmon, and lengths and weights of a single age class of wild small salmon are examined.

Methods

The data series span the years 1970 to 1997. Annual angling catches (retained and released) of small and large salmon on Nova Scotia and southern New Brunswick rivers were obtained from O'Neil and Swetnam (1984) and Swetnam and O'Neil (1984) for 1970 to 1982, S.F. O'Neil (unpublished data) for 1983, O'Neil et al. (1985, 1986, 1987, 1989, 1991, and 1996b) for 1984 to 1989, and S.F. O'Neil (unpublished data) for 1990 to 1997. Annual estimates of returns, including fence counts, of small and large salmon were obtained for rivers with sufficient data from various sources (Appendix 1). Annual returns for Atlantic coast rivers were estimated by dividing the annual angling catches by the annual LaHave River catch rate. Hatchery return rates, juvenile salmon densities, and wild small salmon lengths were obtained from various sources (Appendix 1).

Angling catches for 1970 to 1982 were adjusted by Salmon Fishing Area (SFA) to license stub equivalents (Amiro et al. 1989). Single missing data values were interpolated by averaging the data values of the previous year and subsequent year. The data series were grouped by SFA, salmon size, and type of data series (returns, angling catches, etc.). SFAs 19, 20 and 21 were analysed as one group to represent Atlantic coast rivers.

To test the hypothesis that the Salmon Management Plan of 1984 and the Newfoundland moratorium of 1992 affected the temporal trend direction (increasing or decreasing), analyses were performed on 5 intervals of years where data were available: 1970-1997, 1970-1983, 1984-1997, 1984-1991, and 1992-1997. A common trend (slope) was estimated for each data series group and each interval of years as a weighted mean of individual river trends in the group through route-regression analysis (Geissler and Sauer 1990). Randomization techniques were used to estimate the significance of the common trend.

Results

The results of the route-regression analysis for each data series grouping and interval of years is summarized in Table 1. The sign of the common slope (trend) is indicated with a directional arrow. Trends covering the time series 1970 to 1997 varied in direction and significance among SFAs. Trends were predominantly positive in direction for the pre-Salmon Management Plan years 1970 to 1983, with approximately half of these trends significant at the α=0.10 probability level. With the exception of SFA 18 and wild small salmon lengths in SFA 23, all data series groupings indicated negative trends over the post-Salmon Management Plan years 1984 to 1997. In all but 2 cases, these trends were significantly negative at the α=0.10 level of probability.

Fewer points in the time series were available for the division of the data of post-Salmon Management Plan years into pre- and post-Newfoundland commercial salmon fishing moratorium. Statistically this may have contributed to non-significant trends between pre- and post-moratorium. However, during the pre-moratorium years 1984 to 1991, 22 of the 37 data series indicated decreasing trends, with 15 of these decreasing trends significant at the α=0.10 level of probability. The significant decreasing trends included SFA 19 small salmon returns and angling catches and most of the data series in SFAs 21, 22, 23 and along the Atlantic coast. Eight data series indicated significant increasing trends, specifically those in SFA 18, large salmon returns in SFAs 19 and 20, large salmon angling catches in SFA 19, and wild small salmon lengths in SFA 23.

During the post-moratorium years 1992 to 1997, few groups indicated significant ($p<0.10$) trends. This was likely due to the few years included in this series which requires a high level of coherence to attain significance. An exception was SFA 23 returns and angling catches which had a significant negative trend. Atlantic coast hatchery return rates and small salmon returns, SFA 21 small salmon returns, and SFA 20 large salmon hatchery return rates showed significant decreasing trends. The only significant increasing trend observed during this time interval was juvenile densities in SFA 18.

Discussion

The data and analysis indicate a high degree of coherence among Atlantic salmon stocks in the areas examined. Prior to the Salmon Management Plan trends were generally increasing and after the Salmon Management Plan trends were generally decreasing. Juvenile data were not extensive enough to assess whether juvenile production (a surrogate for smolt production) contributed to the decline. Parr densities were up in SFA 20 during the pre-moratorium period and up in SFA 18 for the post-moratorium period. During the post-moratorium period angling catches of small salmon declined in all SFAs and return rates of small and large salmon declined in all SFAs except SFA 21. Both parr densities and angling catches declined in SFA 22 after the Salmon Management Plan. Outside of SFA 22, these data suggest that declines in returns and catches were not the result of lower production of smolts contributing to the post-moratorium period.

Survival Indices for 1997 relative to recent trends

To test whether 1997 continued to follow the recent trend, linear regression equations were estimated for each data series over the post-Salmon Management Plan years 1984 to 1996. A predicted value for 1997 was calculated for each series, with a 90% prediction interval (Snedecor and Cochran 1989), and compared with the actual 1997 data value. Actual values outside the 90% prediction interval were identified as significant.

Comparison of 1997 data values with predicted values based on the 1984 to 1996 time interval trends indicated that the majority of 1997 values were lower than those predicted from the trends (Table 2). Few 1997 values were significantly lower than the predicted values, and only one series in each of small salmon returns in SFA 20 and the Atlantic coast rivers indicated an actual 1997 value significantly higher than the predicted value.

Returns to fishways in 1997 relative to forecasts

Methods

Forecasts of salmon returns to the Liscomb, LaHave and Saint John (at Mactaquac) rivers have been made for more than a decade. Wild MSW returns to each river have been forecast from regressions of MSW returns in year i on wild 1SW returns in year i-1 (and in the case of the Saint John, mean length of 1SW fish in year i-1) (Table 3). Wild 1SW returns to the Saint John have been based on estimated egg depositions in year i-4 and i-5. Wild 1SW returns to the LaHave and hatchery 1SW and MSW returns have been based on average return rates for recent years (Table 3).

Returns to fishways on the Liscomb and LaHave rivers are counts; hatchery and wild fish are differentiated on the basis of a clipped adipose fin. Returns (and forecasts) to Mactaquac (Saint John) are counts (now 90-95% of estimated returns) raised by an estimate of downstream removals (5-10% of total). The hatchery/wild composition is based on fin deformity or erosion and interpretation of scales; i.e., methods are less definitive than presence/absence of an adipose fin.

Results

With the exception of the few observed and expected MSW returns to the Liscomb River, the 8 stock components of the LaHave and Saint John rivers (Table 3) averaged only 45% of forecast values (30% of 1SW and 61% of MSW) in 1997. One of the LaHave (1SW hatchery) and four of the Saint John observed values were outside the bounds provided in preseason forecasts. Bounds for the LaHave models were very wide.

Conclusion

Low returns relative to forecasts, especially, those based on 20-25 year forecast models provide a strong indication of anomalous low recruitment from both the 1995 and 1996 smolt classes.

Stock as an indicator of 1997 recruits

LaHave River

1SW "stock" in 1996 contributed to MSW forecasts from stock recruitment models of returns that were 300% higher than those observed in 1997 (Table 3). The return rate of hatchery 1SW fish in 1997 was the lowest of record. The MSW hatchery return rate was the second lowest of record; the 1SW return rate from the same smolt class was the highest of recent years. Both 1995 and 1996 hatchery smolt classes are independent of stock size and freshwater recruitment processes (quality/health of 1995-96 smolt releases was accounted) which suggests that the principal impact on survival was at sea.

Higher than usual mortality to both smolt classes is suggestive of events occurring in the sea at a common location. This hypothesis would diminish the probability of mortality in coastal waters to account for the consecutive substantial decline in marine survival and point to oceanic fall feeding(1996) / overwintering areas (1997).

Diminishing numbers of recruits per spawner to stream habitat above Morgan Falls (Figure 5) also appears to be continuing through the 1993 spawners. Decline in recruits per spawner is coincident with a general decline in marine winter habitat (thru 1993) and hatchery return rates observed since 1980 (Harvie and Amiro 1996). The low returns in 1997 and 27% increase from thermal habitat$_{\text{Jan, Feb and Mar}}$ values in 1993 suggest the existance of significant other factors influencing salmon marine mortality operating within fluctuating levels of marine habitat.

Saint John River

Estimated returns of wild 1SW and MSW returns in 1997 were outside the bounds of expected returns and the lowest in a 28-year time series. Both forecast models were based on "stock", i.e., 1SW returns on egg depositions, and MSW returns on 1SW returns and their mean length, from the same smolt class. Thus stock and freshwater recruits cannot easily be implicated in low returns of either sea-age group in 1997.

Estimated returns of hatchery-origin 1SW and MSW fish were less than expected but within/close to the bounds of 1995-1996 return rates used in the forecast. Nevertheless the return rate for 1SW fish was the fourth lowest in 23 years; that of MSW salmon was the third lowest in 21 years of record (Marshall *et al.*, In prep.a). Reduced recruitment is independent of "stock" or a recent increase in March winter habitat (Figure 6) and stock cannot be implicated in reduced recruitment from hatchery smolts.

Concern that some "hatchery" designated fish, especially 1SW returns, were in fact wild fish was examined by comparing return rates of the age-1 smolt contribution by tagged and estimate of untagged returns (Figure 7). The comparison suggests that hatchery designation in 1997 may not be problematic relative to that of 1996. The impact of overestimating hatchery 1SW returns in 1996 would have contributed to higher expected hatchery 1SW returns in 1997 (difference between observed and expected might be less than depicted) and lower expectations for wild 1SW returns (difference between observed and expected might be greater than depicted).

Returns of tagged broodstock released from the Mactaquac Fish Culture Station to the hatchery's smolt migration channel, Saint John River, 1978-1996 were also examined. Releases were principally of maiden and repeat-spawning 2SW fish and number from 39 to 426 annually (Figure 7). The mean total return rate for the release years 1979-1996 when releases exceeded 115 tagged fish was 8.6%; the mean of returns in year i+1 was 5.0% and that of returns in year i+2 was 3.6%. Trends over years were not significant (Figure 7); return rates (arc sine square root proportion) were not correlated with March winter habitat in either the year of return (p= 0.304; p= 0.342) or, in the case of year i+2 returns, on the year preceding (p=0.812).

Hatchery smolt return rates compared to wild smolt return rates, LaHave River

Estimates of both hatchery and wild smolts migrating from above Morgan Falls on the LaHave River were derived using known numbers of marked and tagged hatchery smolts and counts of wild and hatchery smolts in the by-pass assessment facility at the Morgan Falls Power station. Numbers of wild and hatchery salmon and grilse ascending Morgan Falls are counted at the Morgan Falls Fishway opposite to the power facility. These data enable concurrent assessments of the survival of LaHave River wild and hatchery origin smolts. The relative performance of wild and hatchery smolts may provide additional insight into the fate of salmon at sea.

Wild Smolt Migration Estimates from above Morgan Falls, LaHave River, 1996

The number of wild smolts migrating in 1996 was obtained from the following formula and observations:

Wild Smolt Migration = (total # of wild and marked counted /(# of marked smolts recaptured / # of marked smolts released))- # of marked smolts released above in 1997

= (4,453+11,323)/(11,323/52,139)-52,139
= (15,776 / .2172) -52,139
= 20,494

Wild Smolt Migration Estimates from above Morgan Falls, LaHave River, 1997

The number of wild smolts migrating in 1997 were obtained from the following formula and observations:

Wild Smolt Migration = (total # of wild and marked smolts counted /(# of marked smolts recaptured / # of marked smolts released))- # of marked smolts released above in 1997

= (8,616+8,915+2,085)/(11,000/22,763)-22,763
= (19,616/0.4832)-22,763
= 40,592-22,763
= 17,829

Comparison of marine survival rates of wild smolts vs. hatchery smolts to Morgan Falls, Lahave River

Origin Year	**Number of smolts year i**	**Returns year i+1**	**Survival**
Wild			
1996	20,494	303	0.0148
1997	17,829		
Hatchery			
1996	47,111	144	0.0031
1997	22,927		

These data indicate that for the 1996 smolt class a wild smolt was 4.8 times more likely to return than a hatchery smolt.

Morphometric changes in recruits measured at Morgan Falls, LaHave River

Length, weight and age of Atlantic salmon passing the Morgan Falls fishway have been collected since 1970 (Table 4). Data for the 1984 to 1997 period indicate no temporal trend in the mean length or weight. Condition of age 2.1 wild fish moving through the fishway before August 1 significantly increased ($p= 0.003$; Figure 8). There was no temporal trend in the length of all age 2.1 wild salmon (Figure 9) for the period 1976 to 1997. Skewness of the lengths of all age 2.1 wild fish significantly ($p=0.0007$) increased over the 1970 to 1997 period (Figure 10).

Conclusion

Data and analysis for the LaHave River suggest that marine survival has decreased since 1970 and is unrelated to spawning escapement. Recruits coincident with this decrease in marine survival have been more robust and the length-at-age distribution has been positively skewed over this same time period. These observations suggest size-dependent marine survival.

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Appendix 1

The following rivers were examined in these analyses:

SFA 18: East (Pictou), Margaree, River Philip, Wallace, West (Ant.)
SFA 19: Baddeck, Barachois, Framboise, Grand, Marie Joseph, Middle (Vic.), Mira, North (Vic.), River Tillard
SFA 20: Country Harbour, Ecum Secum, Gaspereau Brook, Guysborough, Isaac's Harbour, Kirby, Liscomb, Moser, Musquodoboit, New Harbour, Quoddy, St. Mary's, Salmon (Guys.), Salmon (P. Dufferin), Ship Harbour, Tangier, West (Sheet Harbour)
SFA 21: Gaspereau (Kings; reassigned from SFA 22), Gold, Ingram, LaHave, Medway, Middle (Lun.), Petite Riviere, Salmon (Digby), Tusket
SFA 22: Big Salmon (reassigned from SFA 23), Debert, Economy, Folly, Great Village, Maccan, North (Col.), Portapique, River Hebert, St. Croix (Hants), Salmon (Col.), Shubenacadie, Stewiacke
SFA 23: Alma, Hammond, Kennebecasis, Mactaquac (includes St. John, Tobique, Salmon (Vic.)), Nashwaak

Annual returns for Atlantic coast rivers were estimated by dividing the annual angling catches by the annual LaHave River catch rate (Amiro and Jefferson 1998). This catch rate was applied to the following rivers: Country Harbour, Ecum Secum, Framboise, Gaspereau Brook, Gaspereau (Kings), Gold, Grand, Guysborough, Ingram, Isaac's Harbour, Kirby, LaHave, Liscomb, Marie Joseph, Medway, Middle (Lun.), Mira, Moser, Musquodoboit, New Harbour, Petite Riviere, Quoddy, River Tillard, St. Mary's, Salmon (Digby), Salmon (Guys.), Salmon (P. Dufferin), Ship Harbour, Tangier, Tusket, West (Sheet Harbour).

Sources for estimates of large and small salmon returns, counts, and hatchery return rates; juvenile densities; and wild small salmon lengths are:

Baddeck wild returns 1994-1997 (Marshall et al., In prep.b)
East (Pictou) returns, 1985-1994 (Claytor et al. 1995)
East (Pictou) returns, 1995-1996 (O'Neil et al. 1997b)
East (Pictou) returns, 1997 - estimated from angling catch divided by 1997 River Philip catch rate.
Grand wild returns, 1988-1997 (Marshall et al., In prep.b)
LaHave wild and hatchery counts, 1970-1996 (Amiro and Jefferson 1997a)
LaHave wild and hatchery counts, 1997 (Amiro and Jefferson 1998)
LaHave hatchery return rates, 1973-1997 (Amiro and Jefferson 1998)
Liscomb wild and hatchery counts, 1979-1995 (O'Neil et al. 1997a)
Liscomb wild and hatchery counts, 1996-1997 (O'Neil et al., In prep.)
Liscomb hatchery return rates, 1979-1995 (O'Neil et al. 1997a)
Liscomb hatchery return rates, 1996-1997 (O'Neil et al., In prep.a)
Mactaquac (includes St. John, Tobique, Salmon (Vic.)) wild and hatchery returns, 1970-1997 (Marshall et al., In prep.a)
Mactaquac (includes St. John, Tobique, Salmon (Vic.)) hatchery return rates, 1975-1997 (Marshall et al., In prep.a)
Mactaquac (includes St. John, Tobique, Salmon (Vic.)) wild small lengths, 1970-1997 (Marshall et al., In prep.a)
Mactaquac (includes St. John, Tobique, Salmon (Vic.)) large salmon wild returns including Newfoundland and Greenland, 1972-1997 (Marshall et al., In prep.a)
Margaree returns, 1970-1997 (large) and 1984-1997 (small) (Marshall et al., In prep.b)
Margaree juvenile densities, 1991-1997 (Marshall et al., In prep.b)
Middle (Vic.) wild returns, 1989-1997 (Marshall et al., In prep.b)
North (Vic.) wild returns, 1974-1997 (large) and 1994-1997 (small) (Marshall et al., In prep.b)
River Philip returns, 1985-1994 (Claytor et al. 1995)
River Philip returns, 1995-1996 (O'Neil et al. 1997b)
River Philip returns, 1997 - estimated from angling catch divided by catch rate; catch rate based on mark and recapture experiment and angling catch.

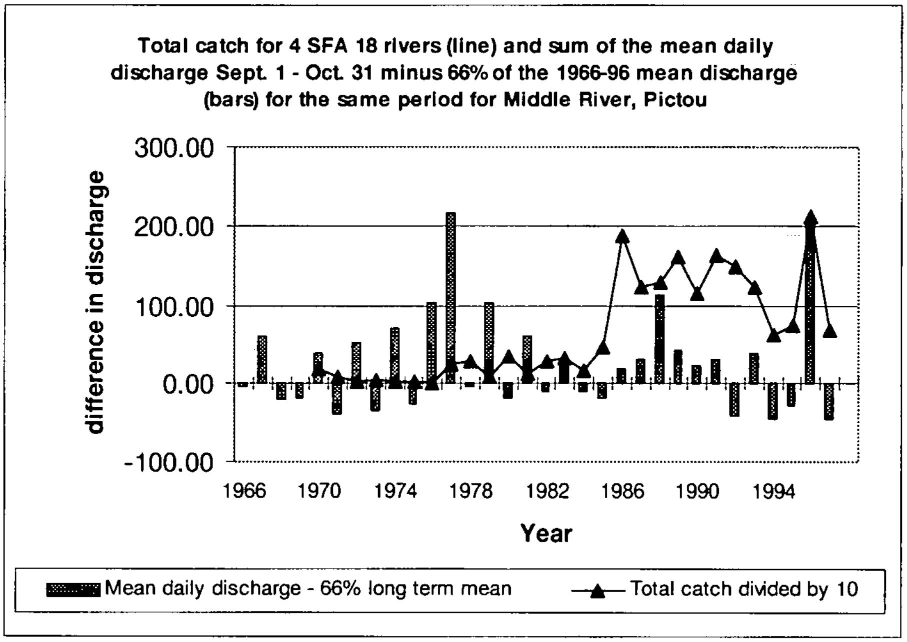
St. Mary's juvenile densities, 1985, 1986, 1990-1996 (O'Neil et al., In prep.c)
St. Mary's juvenile densities, 1997 (O'Neil et al., In prep.a)
Stewiacke juvenile densities, 1984-1995 (Amiro and Jefferson 1996)
Stewiacke juvenile densities, 1996 (Amiro and Jefferson 1997b)
West (Ant.) returns, 1985-1994 (Claytor et al. 1995)
West (Ant.) returns, 1995-1996 (O'Neil et al. 1997b)
West (Ant.) returns, 1997 - estimated from angling catch divided by 1997 River Philip catch rate.
West (Ant.) juvenile densities, 1978, 1991-1996 (O'Neil et al. 1997b)
West (Ant.) juvenile densities, 1997 (O'Neil et al., In prep.b)

The methodology for estimating large and small salmon returns to mainland Nova Scotia rivers (East (Pictou), River Philip, Wallace, and West (Ant.)) is described as follows:

Returns of Atlantic salmon to rivers along the northern coast of Nova Scotia's mainland (North NS) typically occur in late autumn (Chaput and Jones 1994; Claytor 1996). North NS river capture rates were used with catch data to estimate returns. Catch data were known not to be surrogates for returns in all years because of the influence of local environmental conditions which affected entry of fish into these late-run rivers. In some years, when discharge resulted in moderate to high levels of water flow which began as early as September or early October, fish entered the North NS rivers relatively early in the angling season and were accessible to angling. Evidence for the timing of access to fish by anglers has been described for several years with the reporting of angler diary data which provides the timing of catches of small and large salmon (Chaput and Jones 1991, Chaput and Jones 1994, O'Neil et al. 1996a, O'Neil et al. 1997b). The angling season on North NS rivers was open from September 1 until October 31 for the years 1983 and 1985-1997.

The index site chosen to indicate discharge on North NS rivers was the station on Middle River, Pictou, at Rocklin. The monitoring station is located approximately in the middle of the North NS area and has been operating for over 30 years.

The sum of Sept. 1 to Oct. 30 mean daily discharge for 1995 was the sixth lowest of the 1966-1997 data set. Low average discharge was observed to impact the angling fishery in some years, such as in 1995, when the first reported catch by an angler on East River, Pictou, occurred on October 23, 8 days before the angling season closed on October 31. In 1996, when the average discharge was the second highest at the discharge index site, the first angler-diary-reported catch on East River, Pictou, occurred on September 29, 32 days before the close of the season (see figure).



Discharge data for the years when angling catches were available (1983-1997) were examined for a relationship with total catch on four rivers within North NS: East, Pictou; River Philip; Wallace; and West, Antigonish. The effect of discharge on entry of fish into the rivers was viewed as an off-or-on effect so discharge data were classified into low or moderate to high values to look for a relationship with catch. The impact of discharge on catch was assumed to be a negative one if the discharge category was low (the bars below 0 in the figure), and assumed to have no impact if the discharge was moderate to high. A year was classified as a low discharge year when the sum of mean daily discharge for the Sept. 1 to Oct. 30 period was less than one-third (33%) of the long-term (1966-1996) mean daily discharge. The total catch on the four rivers was separated into two groups according to discharge category and tested for equality of means and found to be significantly different (t-value = -4.64; df=13; p=0.0002).

For the purposes of estimating returns, the capture rate estimated from mark-and-recapture population estimates and angling catch derived from angler license stubs for River Philip and East River, Pictou, in 1996, a high discharge year, was used to estimate returns using angling catch for other years where the discharge was not considered to be exceptionally low. Those years were 1983, 1986 to 1991, 1993, and 1996. Discharge in 1997 was considered a low discharge year so the capture rate calculated from a mark-and-recapture population estimate and license-stub derived angling catches for River Philip in 1997 was applied to the catch data to estimate returns for those years when the discharge was classified as low: 1985, 1994, 1995 and 1997. The relationship between discharge at Middle River and the 1992 catch value was not consistent with that noted for the other years; the 1992 catch was relatively high yet the Middle River discharge was low. In order to estimate returns for 1992, the mean of the catch rates for 1996 and 1997 was used. The catch data for the years 1970 to 1982 and for 1984 were not considered valid because the angling season during those years closed on October 15 rather than October 31. Consequently, no estimate of returns was attempted for those years.

Table 1. Trend direction (increasing or decreasing), significance of the trend, and number of data series examined for small and large salmon returns, angling catches, and hatchery return rates; juvenile densities; and wild small salmon lengths grouped by SFA, salmon size, and data series type across 5 intervals of years.

			Interval of years															
	Salmon		1970 - 1997			1970 - 1983			1984 - 1997			1984 - 1991			1992 - 1997			
SFA	size	Type of series	Slope	Prob.	# Series	Slope	Prob.	# Series	Slope	Prob.	# Series	Slope	Prob.	# Series	Slope	Prob.	# Series
18	Small	Returns[1]							↑	0.382	8	▲	0.039	8	↓	0.120	8
		Angling catches	▲	0.000	3	▲	0.009	3	↑	0.357	5	▲	0.018	5	↓	0.161	5
	Large	Returns[1]							↑	0.149	8	↑	0.219	8	↓	0.258	8
		Angling catches	▲	0.000	3	↑	0.334	3	↑	0.111	5	▲	0.018	5	↑	0.337	5
	Parr	Densities[2]													▲	0.054	2
19	Small	Returns[3]	↓	0.319	3	▲	0.028	3	▼	0.000	5	▼	0.005	5	↓	0.213	7
		Angling catches[3]	↑	0.330	7	▲	0.058	6	▼	0.000	9	▼	0.017	9	↓	0.341	9
	Large	Returns[3]	▲	0.001	3	↑	0.203	3	▼	0.074	6	▲	0.087	6	↓	0.486	8
		Angling catches[3]	▲	0.074	6	▼	0.017	6	▼	0.046	9	▲	0.061	9	↓	0.235	9
20	Small	Returns[3]	↑	0.262	16	▲	0.012	16	▼	0.000	18	↓	0.448	19	↓	0.334	17
		Angling catches[3]	↓	0.320	16	↑	0.184	16	▼	0.000	15	↓	0.338	16	↓	0.119	14
		Hatchery return rates							▼	0.031	1	↑	0.364	1	↓	0.183	1
	Large	Returns[3]	▲	0.000	16	↑	0.381	16	↓	0.400	19	▲	0.020	20	↓	0.176	13
		Angling catches[3]	▲	0.009	16	↑	0.307	16	▼	0.005	16	↓	0.211	17	↑	0.463	10
		Hatchery return rates							▼	0.001	1	↓	0.392	1	▼	0.013	1
	Parr	Densities[4]										↑	0.476	1	↓	0.416	1
21	Small	Returns	↑	0.212	9	▲	0.004	9	▼	0.000	11	▼	0.037	12	▼	0.004	11
		Angling catches	↓	0.347	7	↑	0.290	7	▼	0.000	8	▼	0.097	9	↓	0.298	8
		Hatchery return rates[5]	↓	0.115	1	↓	0.136	1	▼	0.012	1	↑	0.195	1	↓	0.125	1
	Large	Returns	▲	0.000	9	▲	0.029	10	▼	0.076	11	↑	0.290	12	↑	0.223	11
		Angling catches	↓	0.312	7	▲	0.018	8	▼	0.000	8	▼	0.079	9	↑	0.257	8
		Hatchery return rates[6]	↓	0.355	1	↑	0.220	1	▼	0.004	1	▼	0.087	1	↓	0.298	1
22	Small	Angling catches[7]	▼	0.004	10	↑	0.479	10				▼	0.002	13			
	Large	Angling catches[7]	▼	0.000	9	▲	0.028	10				▼	0.000	12			
	Parr	Densities[8]							▼	0.000	1	▼	0.048	1			
23	Small	Returns	↑	0.297	3	▲	0.000	3	▼	0.000	3	↑	0.510	3	▼	0.092	3
		Angling catches	▲	0.009	5[9]	▲	0.011	5	▼	0.000	1[3]	↓	0.403	5[9]	▼	0.000	1[3]
		Hatchery return rates[10]	▼	0.000	1	↓	0.227	1	▼	0.082	1	▼	0.017	1	↑	0.274	1
		Wild lengths	▲	0.000	1	↑	0.142	1	↑	0.140	1	▲	0.006	1	▼	0.056	1
	Large	Returns	▼	0.000	3	▲	0.069	3	▼	0.000	4	▼	0.002	4	▼	0.004	4
		Angling catches[11]	▼	0.001	1	↑	0.361	5	▼	0.050	1	▼	0.031	1			
		Hatchery return rates[12]	▼	0.000	1	↑	0.452	1	▼	0.000	1	▼	0.000	1	↑	0.356	1
19+ 20+ 21	Small	Returns[3]	▲	0.053	28	▲	0.001	28	▼	0.000	35	▼	0.023	36	▼	0.069	36
		Angling catches[3]	↓	0.447	30	▲	0.093	29	▼	0.000	33	▼	0.062	34	↓	0.203	32
		Hatchery return rates							▼	0.005	2	↑	0.186	2	▼	0.088	2
	Large	Returns[3]	▲	0.000	29	▲	0.029	29	↓	0.132	37	▲	0.030	38	↑	0.252	33
		Angling catches[3]	▲	0.039	30	↑	0.361	30	▼	0.000	34	↓	0.447	35	↑	0.461	28
		Hatchery return rates							▼	0.001	2	↓	0.120	2	▼	0.027	2

Notes:

(shaded) indicates significance at alpha=0.10

▲ and ↑ indicate positive trends.

▼ and ↓ indicate negative trends.

[1] Series do not include 1984.

[2] Series do not include 1996-1997.

[3] Series do not include 1997.

[4] Series does not include 1984-1987 and 1996-1997.

[5] Series does not include 1970-1972.

[6] Series does not include 1970-1973.

[7] Series do not include 1992-1997.

[8] Series does not include 1995-1997.

[9] Series do not include 1991-1997.

[10] Series does not include 1970-1974.

[11] Series do not include 1994-1997.

[12] Series does not include 1970-1975.

Table 2. Number of data series in which the actual 1997 data value is signficantly lower, non-significantly lower, non-significantly higher, and significantly higher than the predicted 1997 value (at alpha=0.10) grouped by SFA, salmon size and data series type.

			Trend years: 1984 - 1996				
	Salmon		1997 relative to prediction				
SFA	size	Type of series	↓ (shaded)	↓	↑	↑ (shaded)	Total # series
18	Small	Returns		1			1
		Angling catches	2	3			5
	Large	Returns			1		1
		Angling catches	1	2	2		5
19	Small	Returns		1	1		2
		Angling catches	1	3	2		6
	Large	Returns		2	1		3
		Angling catches		4	2		6
20	Small	Returns		13	1	1	15
		Angling catches		11			11
		Hatchery return rates		1			1
	Large	Returns	1	11	3		15
		Angling catches		12			12
		Hatchery return rates			1		1
21	Small	Returns	1	10			11
		Angling catches	1	5	2		8
		Hatchery return rates		1			1
	Large	Returns		8	3		11
		Angling catches		4	4		8
		Hatchery return rates			1		1
23	Small	Returns		3			3
		Hatchery return rates		1			1
		Wild lengths		1			1
	Large	Returns			4		4
		Hatchery return rates			1		1
19+ 20+ 21	Small	Returns	1	24	2	1	28
		Angling catches	2	19	4		25
		Hatchery return rates		2			2
	Large	Returns	1	21	7		29
		Angling catches		20	6		26
		Hatchery return rates			2		2
All SFAs			7	97	29	1	134

Notes:
(shaded) indicates signficance at alpha=0.10.
↓ indicates an actual 1997 data value lower than the predicted 1997 value.
↑ indicates an actual 1997 data value higher than the predicted 1997 value.

Table. 3. "Observed", and expected "counts" of small and large salmon at fishways on the Liscomb, LaHave and Saint John rivers, Scotia-Fundy Sector, Maritimes Region, 1997.

Stock (SFA)	*Sea-age and origin*	*Returns*				
		Observed	*Expected*	*Difference*	*Obs/Exp*	*Preseason forecast model; R^2; N; (bounds[a])*
Liscomb (SFA 20)						
	MSW	11	9	N	1.22	MSW = Const + 1SW; 0.70; 7; (0 - 26)
LaHave (SFA 21)	1SW W	303	938	N	0.32	1SW = Mean returns $_{1992\text{-}96}$; ; 5; (195 - 1,890)
	1SW H[b]	144	741	Y	0.19	1SW= Smolts * Rt'n rate $_{1SW - Smolts;n=24}$; ; (324 - 958)
	MSW W	68	179	N	0.38	MSW = Const + 1SW; 0.51; 23; (32 - 396)
	MSW H[b]	67	106	N	0.63	MSW = Const + 1SW; 0.50; 23; (18 - 232)
Saint John (SFA 23)	1SW W	343	5,183	Y	0.07	1SW = Const + Egg dep; 0.495; 21; (2,089 - 8,277)
	1SW H[c]	1,607	2,629	Y	0.61	1SW = Smolts * Rt'n rate $_{1995\text{-}96}$; : 2; (1,922 - 3,445)
	MSW W	1,123	2,051	Y	0.55	Log MSW = Const + 1SW + Length 1SW; 0.80; 25; (1,310 - 3,21
	MSW H[c]	485	565	Y	0.86	MSW = Smolts * Rt'n rate $_{1995\text{-}96}$; : 2; (493 - 692)

[a] 90% CL's with the exception of Saint John River hatchery fish.
[b] smolts released directly from hatchery + those estimated to have resulted from age 0+ and age- 1+ parr stocked in the previous years.
[c] smolts released directly from hatchery.

Table 4. Summary statistics and coefficient of skewness for lengths of wild age 2.1 Atlantic salmon sampled at Morgan Falls, LaHave River, Nova Scotia, 1970 to 1997.

	Length (cm)						
Year	N	Mean	Mode	Min	Max	Standard deviation	Coefficient of Skewness
1970	3	55.67		54.60	56.50	0.97	-1.019
1973	9	54.48		50.80	57.40	2.37	-0.211
1974	7	57.03		53.00	60.70	3.22	0.107
1975	4	56.43		54.60	58.50	1.83	0.210
1976	51	54.37	55.50	50.40	58.20	1.75	-0.006
1977	58	53.36	54.00	43.50	58.50	3.08	-0.968
1978	24	52.76	53.80	48.20	58.80	2.26	0.151
1979	116	52.40	52.50	45.50	57.60	2.32	-0.028
1980	139	54.04	53.40	46.90	60.70	2.42	0.415
1981	148	54.58	57.00	48.00	63.20	2.75	0.267
1982	116	54.57	54.20	48.60	63.20	2.67	0.350
1983	185	53.80	54.00	47.60	60.70	2.27	0.153
1984	216	54.14	55.40	47.00	61.50	2.89	-0.153
1985	187	53.11	53.00	45.00	63.00	2.92	0.077
1986	188	55.87	56.00	50.00	63.00	2.71	0.140
1987	457	54.86	54.20	48.60	63.50	2.47	0.629
1988	596	54.59	54.20	45.00	66.50	2.52	0.049
1989	634	53.99	53.20	48.20	63.60	2.43	0.333
1990	592	54.69	55.50	47.10	64.00	3.03	0.408
1991	162	53.86	53.70	47.70	61.50	2.43	0.256
1992	775	53.98	53.00	47.10	63.00	2.57	0.397
1993	258	53.67	53.50	47.70	64.30	2.59	0.704
1994	130	55.21	55.30	48.10	64.70	3.30	0.729
1995	133	53.22	54.50	48.00	59.00	2.27	0.205
1996	140	54.98	53.00	50.00	62.00	2.35	0.290
1997	124	55.21	56.50	49.60	60.50	2.43	0.139

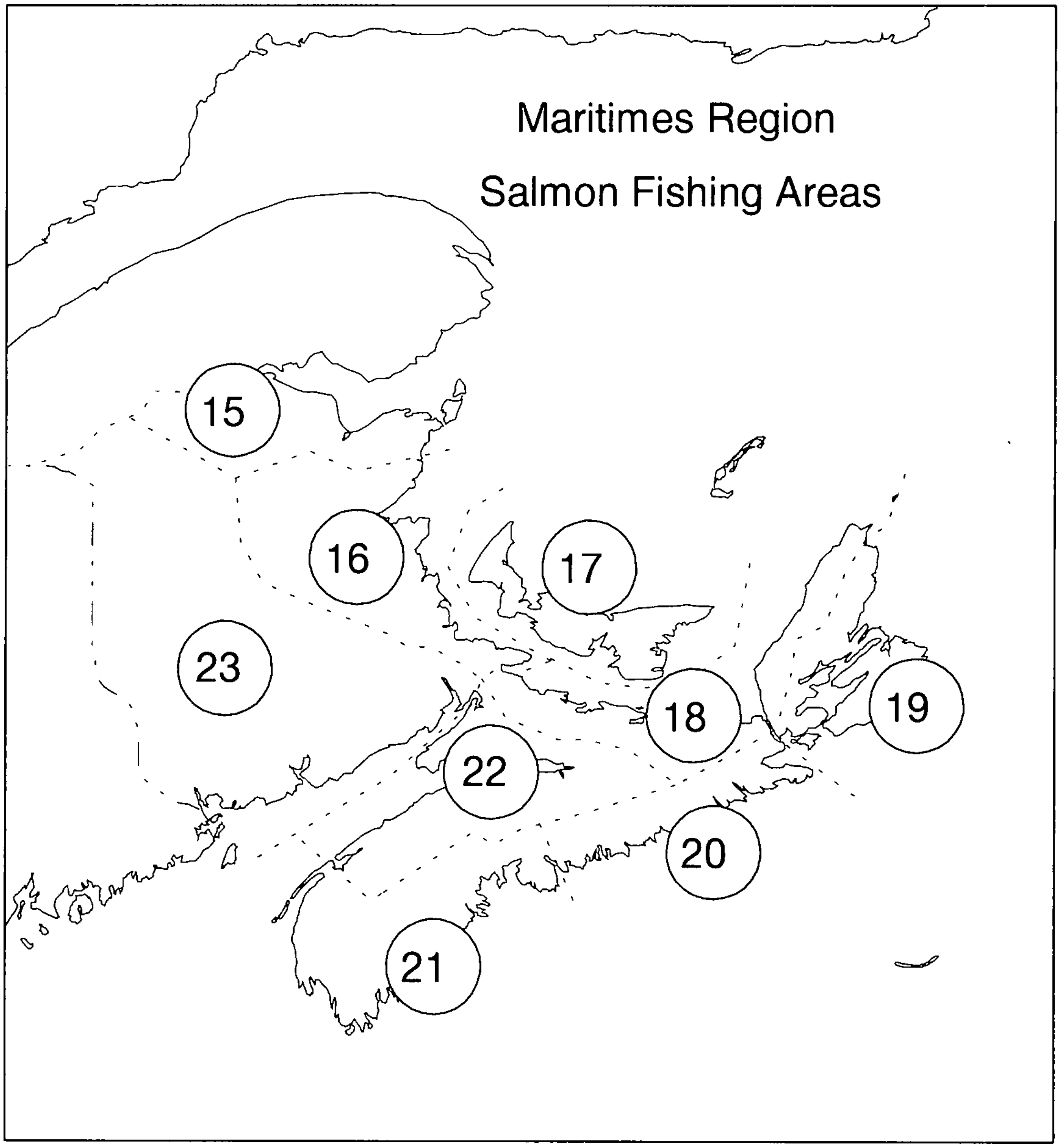
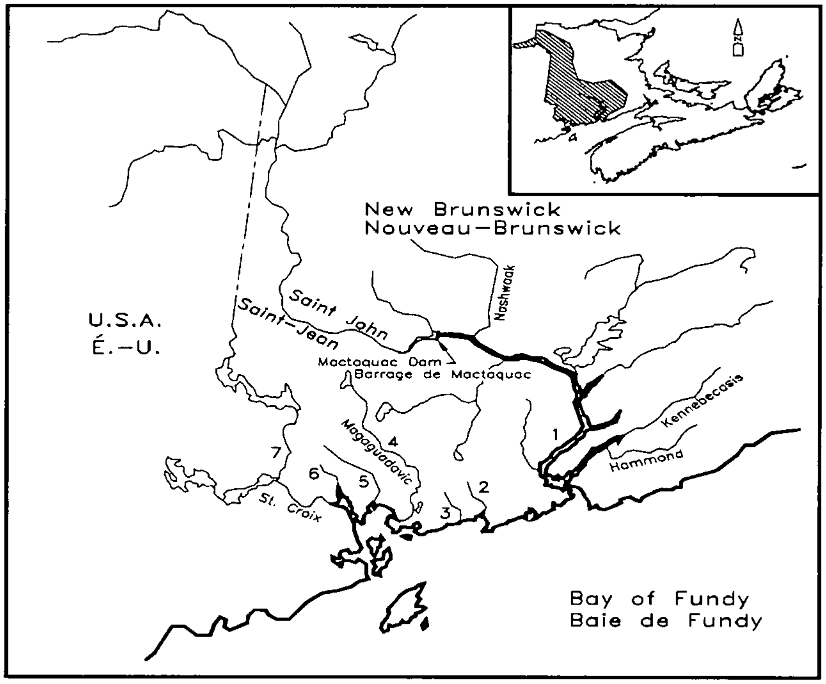


Figure 1. Map of Salmon Fishing Areas of the Maritimes Region of the Department of Fisheries and Oceans, Canada.



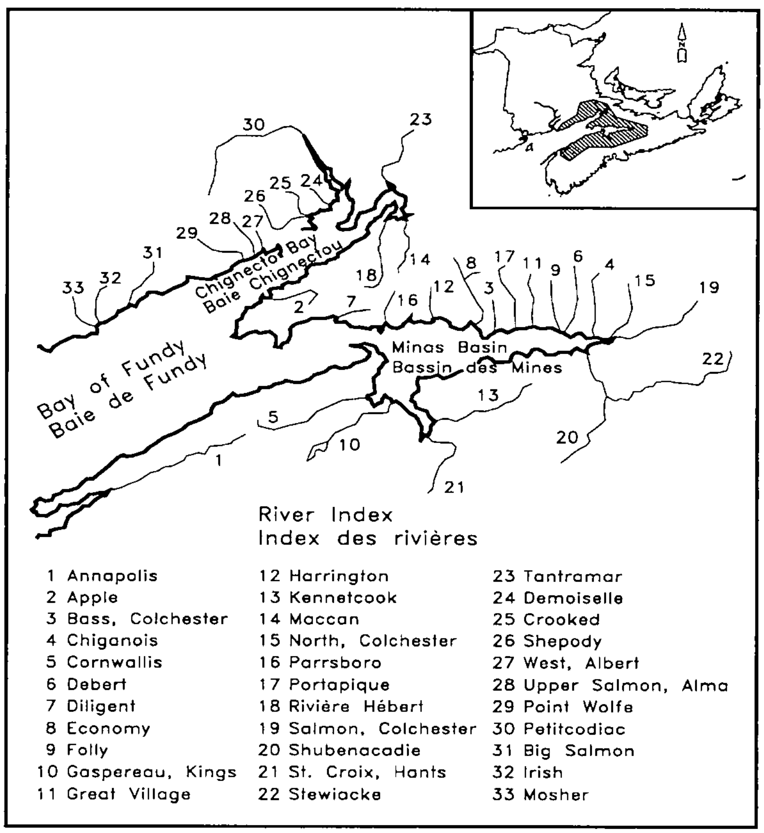
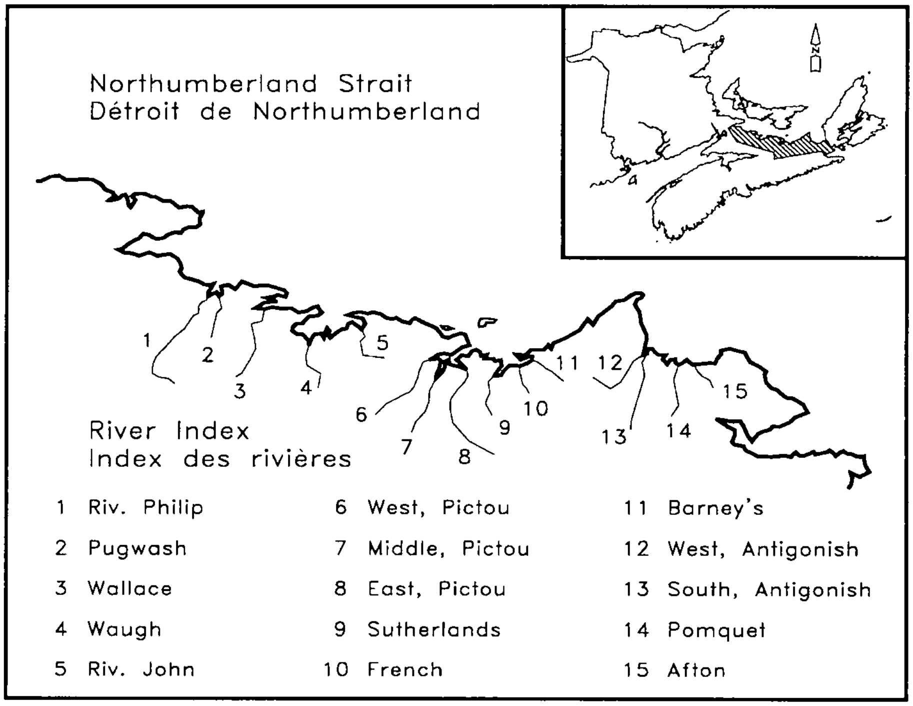


Figure 2. Map of the principal salmon rivers of south western New Brunswick, the outer Bay of Fundy portion of SFA 23, and inner Bay of Fundy of New Brunswick (eastern SFA 23), and Nova Scotia, SFA 22.



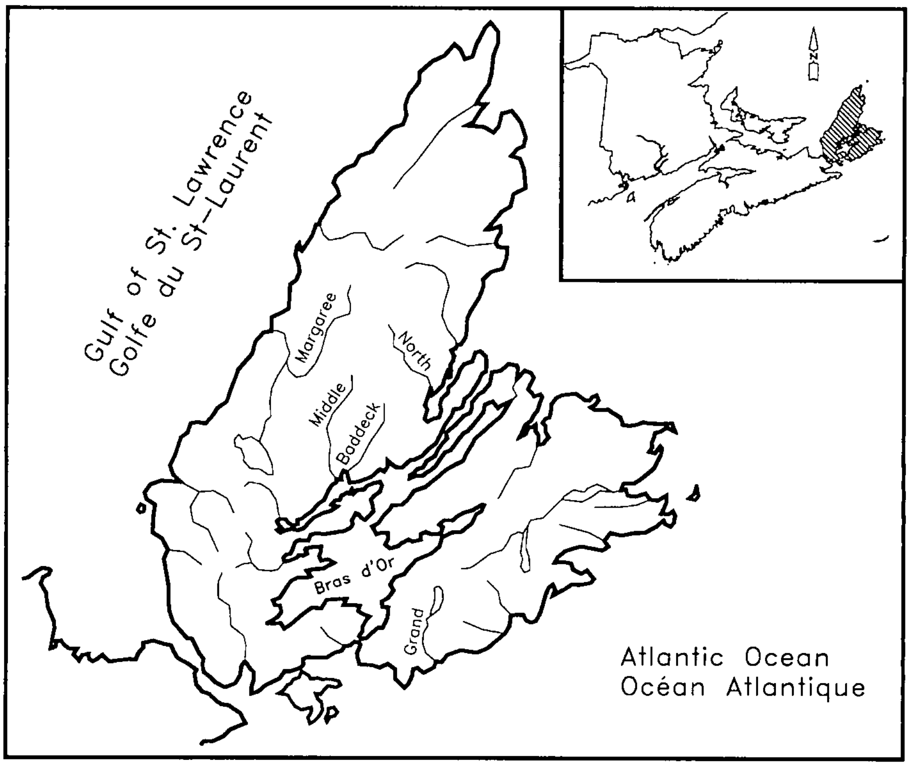
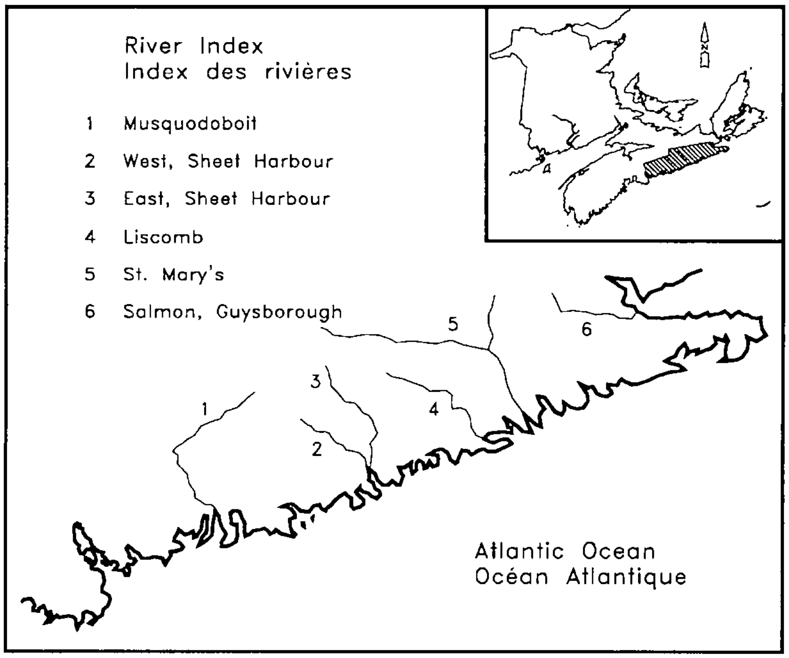


Figure 3. Map of the principal salmon rivers of the mainland portion of SFA 18 (top) and Cape Breton Island (Cape Breton portion of SFA 18 and SFA 19), Nova Scotia.



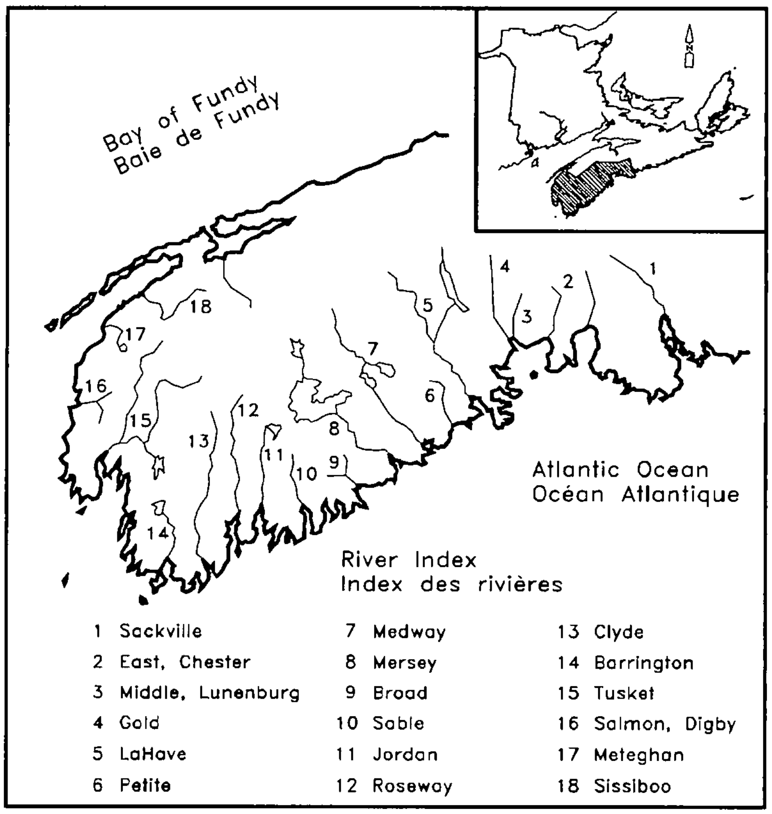


Figure 4. Map of the principal salmon rivers of SFA 20, eastern shore, and SFA 21, southwestern, Nova Scotia.

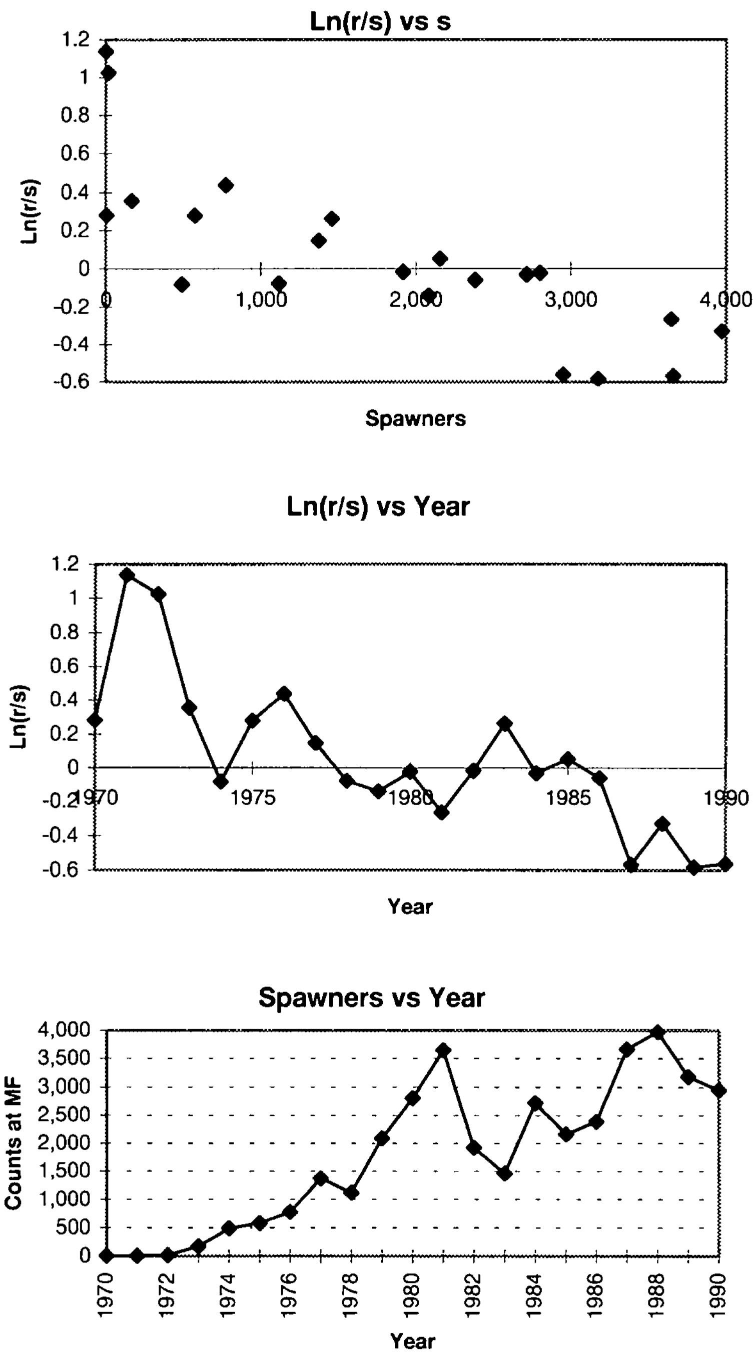
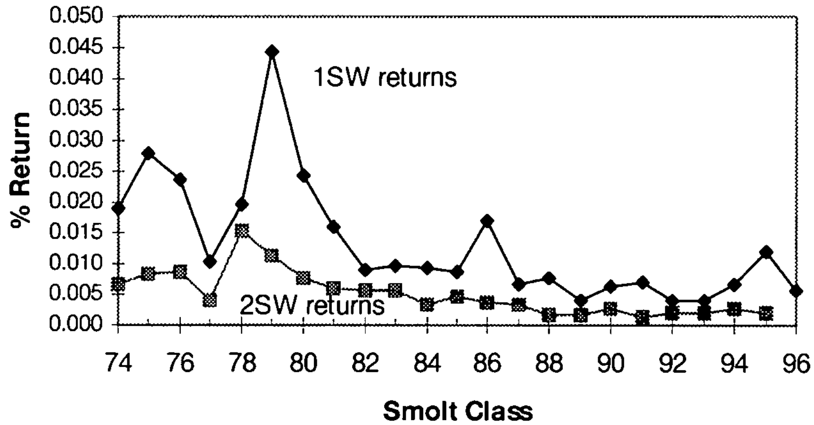
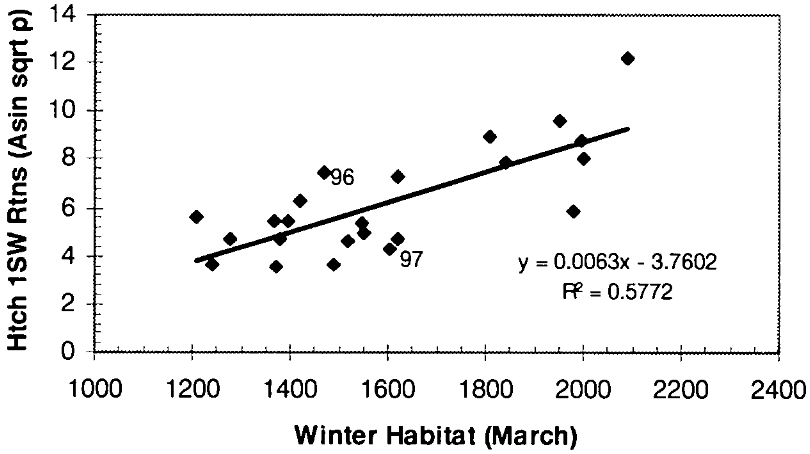


Figure 5. Plots of spawners (1SW and MSW salmon) above Morgan Falls, LaHave River, 1970-90 (lower), log of recruits per spawner on years (middle) and log of recruits per spawner on spawners.





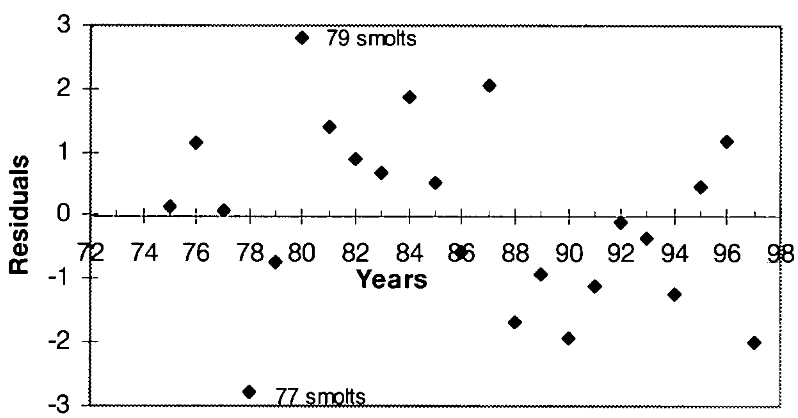


Figure 6. 1SW and 2SW return rates of 1974-96 age-1 smolts to Mactaquac, Saint John River (upper), plot of 1SW return rates and March winter habitat in the year of return (middle) and plot of residuals for the return rate:habitat relationship on years (lower).

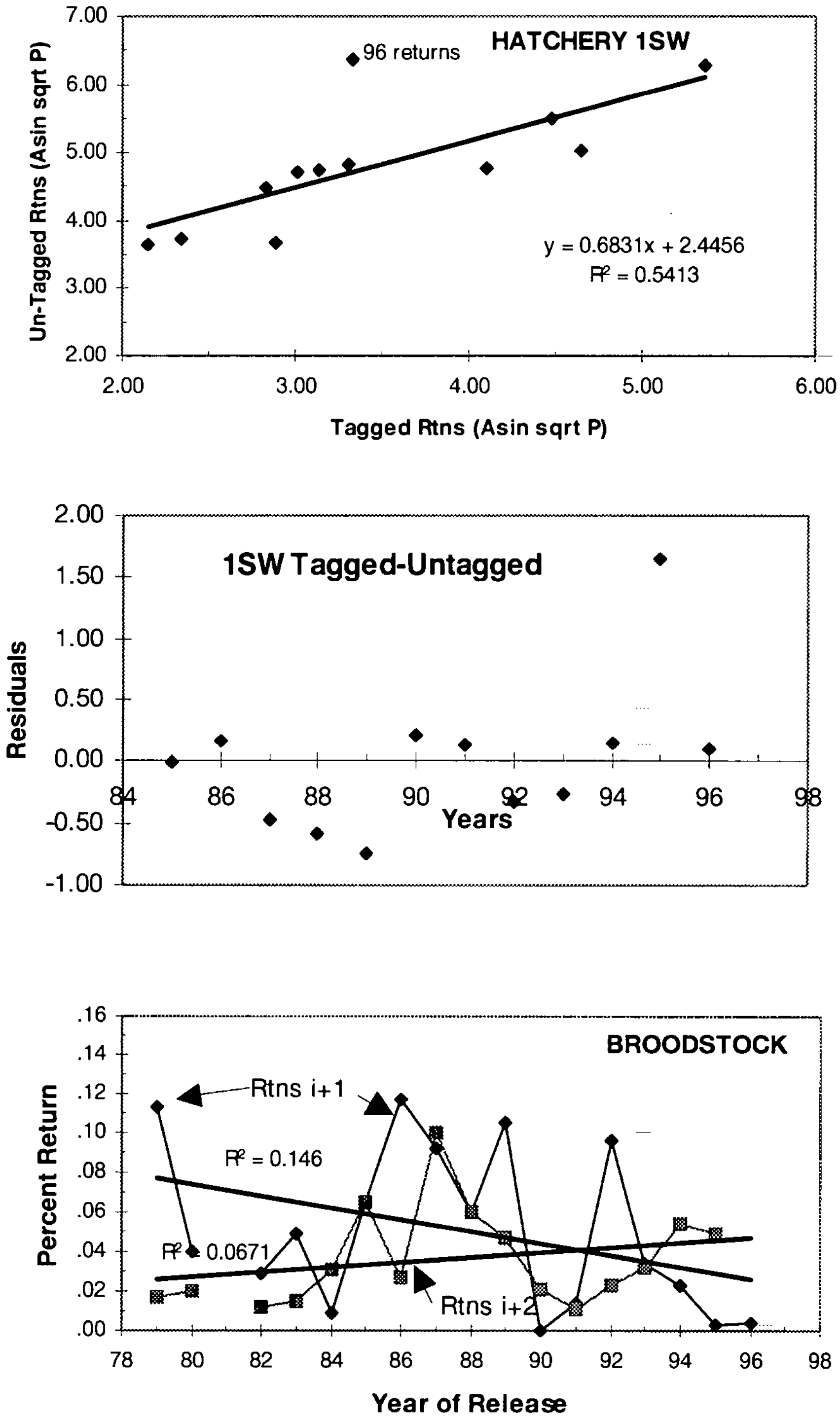


Figure 7. Relationship between return rates of tagged and untagged age 1.1 (1SW) fish at Mactaquac, Saint John River, 1985-97 (upper), the residuals (middle) and plots of return rates for tagged broodstock, 1979-96 (lower).

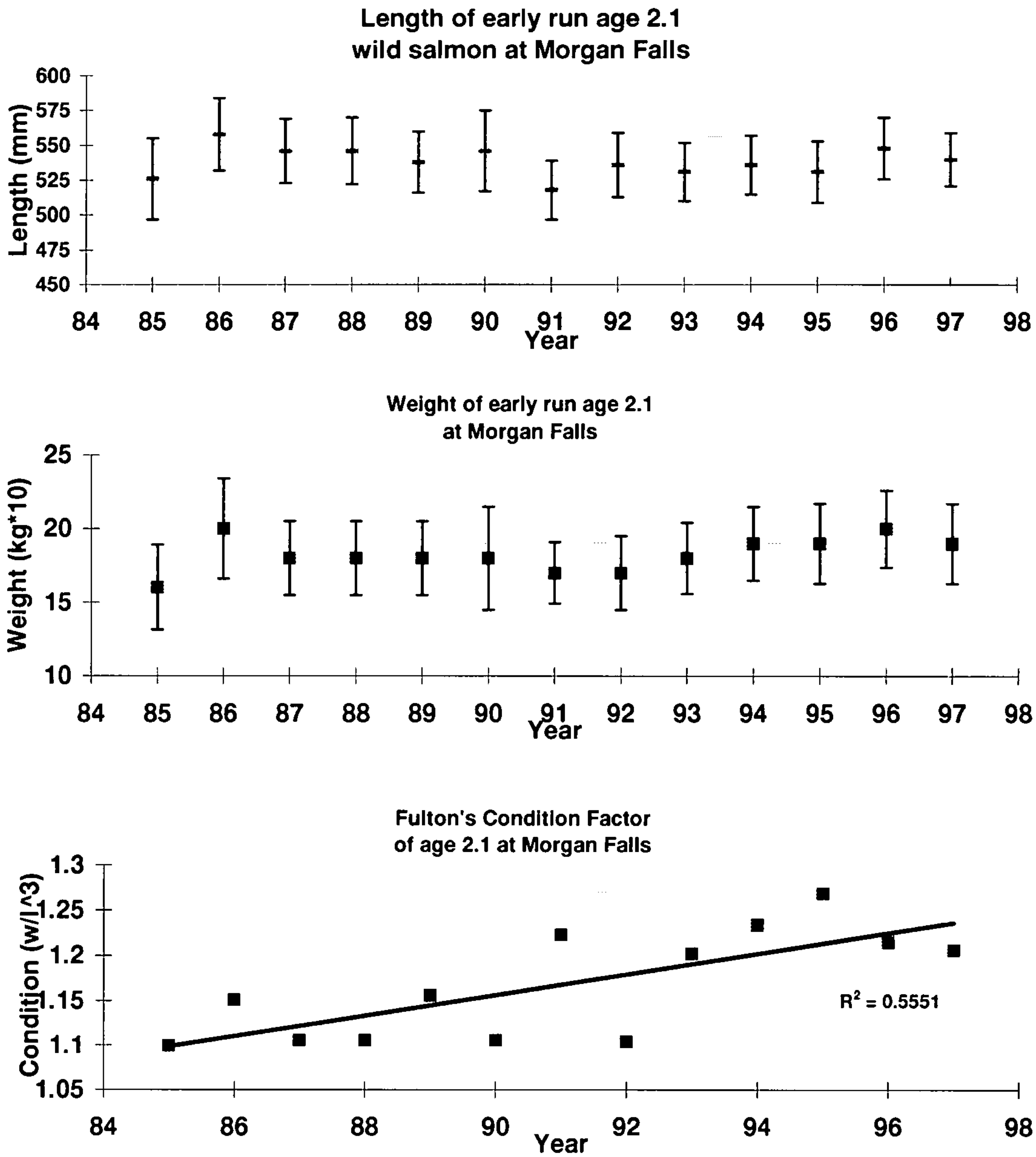


Figure 8. Length,standard deviation of length, weight, standard deviation of weight and Fulton's condition factor of early run age 2.1 (freshwater.sea winters) wild Atlantic salmon measured at Morgan Falls fishway, 1984 to 1997.

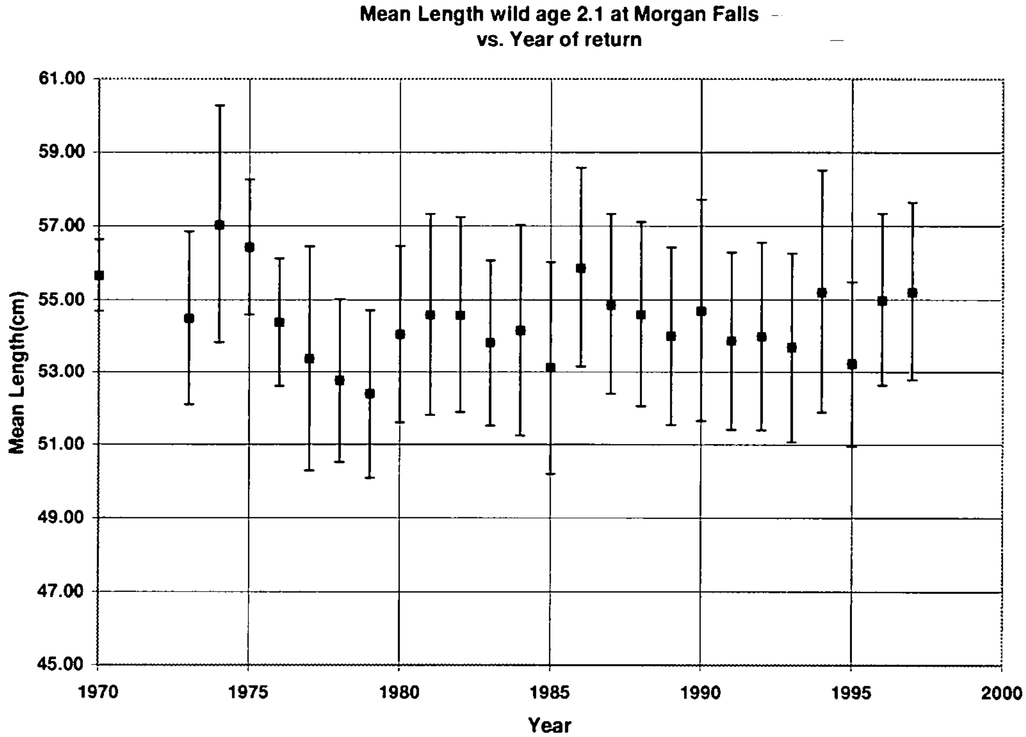


Figure 9. Length and standard deviation of age 2.1 wild Atlantic salmon measured at Morgan Falls fishway 1970 to1997.

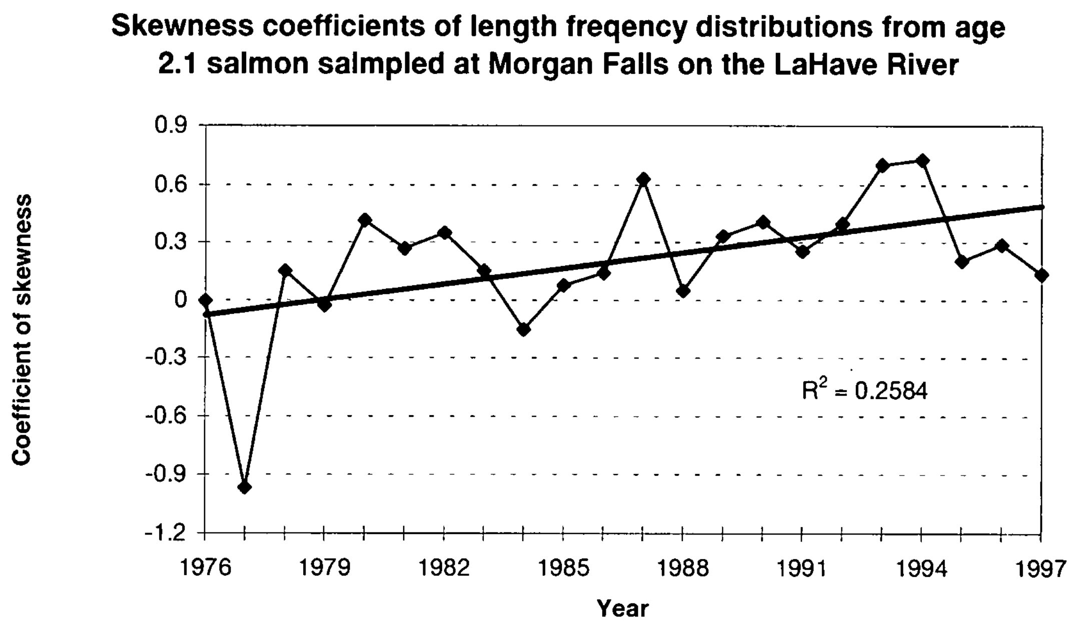


Figure 10. Coefficient of skewness of lengths of age 2.1 wild salmon passing Morgan Falls 1976 to 1997.