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Factors affecting the returns of adult Atlantic salmon, *Salmo salar*, with emphasis on Conne River

by

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Abstract

Various factors which may have contributed to, or impacted on the number of adult Atlantic salmon, Salmo salar, returning to Conne River, SFA 11, Newfoundland Region, are discussed. Of the various factors identified, few appear to have contributed to the overall pattern of decreased sea survival and decline in the number of adult salmon returning to Conne River. Those factors that have contributed include the impact of more severe spring climatic conditions on the 'condition' of outmigrating smolts, low survival of post-spawning salmon, possible losses due to legal and illegal interceptory fisheries, and perhaps changes in available marine habitat in the northwest Atlantic. One fact that is very apparent is that sea survival has declined dramatically and the impact of this has yet to be manifest in the production of smolts and their subsequent return as adult salmon.

Résumé

On discute ici de divers facteurs qui ont pu influer sur le nombre de saumons de l'Atlantique adultes, *Salmo salar*, qui sont revenus dans la rivière Conne (ZPS 11), dans la région de Terre-Neuve. Parmi ces facteurs, peu semblent avoir contribué au phénomène général de recul du taux de survie en mer et des remontées de saumons adultes dans la rivière Conne. Ont joué un rôle les conditions climatiques printanières plus rigoureuses, qui ont influé sur l'état des saumoneaux migrant vers la mer, le faible taux de survie des charognards, les pertes possibles dues à l'interception, légale ou illégale, par des pêcheurs et peut-être des changements dans l'habitat marin disponible dans l'Atlantique nord-ouest. De toute évidence, le taux de survie en mer a chuté considérablement et les répercussions de ce phénomène ne se sont pas encore manifestées dans la production de saumoneaux et dans leur montaison subséquente à l'état de saumon adulte.

Introduction

Conne River, SFA 11, flows into Bay d'Espoir on the south coast of Newfoundland (Fig. 1). It is a sixth-order river with a drainage area of 602 km^2, approximately 13000 rearing units of fluvial habitat (1 unit = 100 m^2) and more than 3000 ha of accessible lacustrine habitat. Adult salmon returns to Conne River have been in excess of 7000 fish in some years, while the recreational fishery had been the third most important in insular Newfoundland (Dempson and Stansbury 1991).

Similar to a number of other rivers in Newfoundland, Conne River also experienced a substantive decline in adult salmon returns in 1989 (Dempson 1989; O'Connell et al. 1990). While some rivers have shown increased salmon escapements in recent years as a direct result of the commercial salmon fishery moratorium, Conne River salmon abundance has continued to decline (Dempson et al. 1994a; O'Connell et al. 1994). Sea survival from smolt to small salmon (1SW) has dropped from 7-10% to less than 4%, and in 1993-94 was the lowest recorded (2.7%). To some degree this decline in survival parallels that on another south coast river (Northeast Brook, Trepassey) where smolt survival has been generally lower in the moratorium years than when commercial fisheries were still in existence.

The production of smolts at Conne River has been relatively stable (avg. 66000 from 1987-94, CV = 12%). Despite this, adult returns, enumerated at a fish counting fence, have continued to decline to the point that target spawning requirements have not been met since 1991. This suggests that part of the problem may lie in the marine environment. Alternatively, other factors impacting on life stages residing in freshwater, or associated either with the impact of the smolt estimation project, or with the enumeration of returning adult salmon at the fish counting fence may also be responsible.

This paper examines a number of potential factors that could influence and thus be responsible for the decline in the return of Atlantic salmon to Conne River.

Background

Since 1986, a fish counting fence has been operated on Conne River to enumerate the upstream run of Atlantic salmon. Returns of small salmon, including fish estimated to be of Conne River origin that were caught in the Conne River Indian Band food fishery, have ranged from 1533 in 1994 to a high of 10155 in 1987 (Table 1). Large salmon represent only about 5% of the total return and are thus omitted from much of the following discussion. Mark-recapture studies were initiated in 1987 to survey the number of migrating smolts. Details on the experimental design and model used are summarized in Dempson and Stansbury (1991) and Schwarz and Dempson (1994). Smolt estimates have ranged from approximately 56000 to 75000.

Potential factors influencing returns to Conne River

1- Drought conditions in 1987

During 1987, severe drought conditions affected Newfoundland (O'Connell et al. 1988). Many rivers experienced record high water temperatures (> 25 °C) and record low water flows. Conne River was no exception. Maximum water temperatures in excess of 25 °C occurred for much of July and parts of August. The highest temperatures recorded were 28 °C (Dempson 1990). As water abstraction also occurred, many places on the river were left with only isolated pools where fry were observed (occasionally dead) and where temperatures could have been even greater than that recorded at the fish counting fence.

According to Fry (1947), at an acclimation temperature of 20 °C, 50% mortality of salmon fingerlings can occur within six to seven hours at 28 °C. More recent studies by Elliott (1991) found similar results. The incipient lethal temperatures, defined as the mean temperatures for survival over 7 days, were 27.5-27.6 °C for fish acclimated at temperatures from 15 to 25 °C. The ultimate lethal temperatures (survival for 10 minutes) at these acclimation values were 32-33 °C. Normal feeding stopped at 22.5 °C, and no feeding occurred at acclimation temperatures of 25 °C or warmer (Elliott 1991).

Various age classes could have been affected by the conditions in 1987. For example, if age 2 parr had primarily been affected, survivors would have occurred as age 3 smolts in 1988 and age 3:1 adults (river age 3, sea age 1) returning in 1989. In comparison with 1987, the smolt run in 1988 declined by about 12% but sea survival of the subsequent adult salmon was still high (7.6%). Similarly, had age 0+ fry been impacted in a negative manner, these fish would have been apparent first as age 3+ smolts in 1990 with subsequent returns of age 3:1 adult salmon in 1991. It is noted that there was a 20% drop in the number of smolts migrating in 1990 from the average of the previous three years (1987-89). However, not only was there a decrease in the number of adult salmon returning in 1991, but the percent surviving to return decreased substantially to only 4.2%. The lowest returns of adult salmon recorded in 1994 were totally unrelated to 1987 drought conditions. We conclude that there appears to be no definitive association between the 1987 drought conditions and the continued decline in adult salmon returns, and the decreased survival that began in earnest with the smolt run in 1990 and which has continued to date.

2- Indian Band Food Fishery

Reported catches of small salmon by the Conne River Indian Band have ranged from a low of 18 fish in 1987 to a high of 959 in 1990 (Table 2). From 1986 to 1989 (omitting 1987) this represented an average harvest of only 7% of the total estimated returns of small salmon to home waters. In contrast, removals from the recreational fishery at Conne River for the same years took 22% of the total returns of salmon.

Over the following four years (1990-93), the native food fishery harvest increased to an average of 16% of the total returns, while the recreational fishery harvest dropped to 11%. It is noted that quota restrictions were also placed on the angling fishery beginning in 1991 and, as an added conservation measure, the river was closed to angling in 1993 and 1994. Similarly, the native food fishery was also closed in 1994. While the proportion of the total Conne River salmon stock harvested by the native food fishery increased in the years in which the sea survival had diminished, the reported landings in and by themselves were too small to have had any impact on the trend for declining adult salmon returns. Thus we conclude that there has not been a negative impact on the Conne River salmon stock as a direct result of the native food fishery.

3- Rainbow trout escapees and aquaculture production

Aquaculture production of rainbow (steelhead) trout in Bay d'Espoir has increased from 30 tonnes in 1991 to 328 tonnes in 1994. Rainbow trout escapees from cage operations have been captured in Conne River since 1990. Occurrences have been documented (Dempson et al. 1994a) and numbers observed have varied among years. No large numbers have been found and sizes have ranged from small, 13-20 cm fish, to large individuals (> 50 cm) weighing several kilograms. To date, there has been only one recorded finding of a rainbow trout feeding on a salmon parr in the river.

Eight rainbow trout (19.9-34.5 cm fork length) were caught with gill nets set next to the aquaculture cage site at Vyse Cove, Bay d'Espoir, May 18-19, 1994. No evidence of any predation on wild smolts was found. An additional survey was carried out July 6-7, 1994. Eighteen rainbow trout were sampled (27.5-45.6 cm) none of which was found to have been feeding on salmon.

Rainbow trout have also been found in three other streams that flow into upper Bay d'Espoir and their abundance in the bay itself could be increasing. Unless the rainbow trout are impacting via a transmission of disease or parasites, we cannot at present attribute to them the decline in sea survival of Conne River Atlantic salmon.

4- Atlantic salmon farmed escapees and aquaculture production

Aquaculture production of Atlantic salmon at Bay d'Espoir has increased from 31 tonnes in 1991 to 100 tonnes in 1993. Reported production dropped to 46 tonnes in 1994. Farmed Atlantic salmon were first discovered in Conne River in 1994. Both smolts and adult fish were obtained. Given the extremely low occurrences at present, it is doubtful that this has contributed in any way to the decline in sea survival. We note, however, the correspondence between total Atlantic salmon and steelhead production with sea survival estimates of wild Conne River smolts to adults:

Year	Aquaculture production (salmon and steelhead)	% survival to small salmon (yr of adult return)
1990	(no commercial production)	7.3
1991	61 t	4.2
1992	162 t	3.4
1993	213 t	4.0
1994	374 t	2.7

5- Decline in smolt production

Numbers of smolts migrating out of Conne River have ranged from a low of about 56000 in 1993 to a high of 74600 in 1991 (Table 3). The annual mark-recapture surveys of numbers of migrating smolts are estimated with a coefficient of variation of 3.9 to 9.0% (Warren and Dempson 1995). A 40% drop in the estimated potential number of eggs deposited in 1989 in comparison with the average from the previous three years (1986-88), could have been expected to result in decreased smolt production and subsequent declines in adult returns. Although the age 5 smolts from the 1989 cohort will not migrate until 1995, it appears that the overall production from the 1989 year class (year of spawning) will be 15-17% less than that produced from the earlier three year classes. The target egg deposition was, however, still met in 1989 but, in general, egg-to-smolt survivals have been much less than expected averaging 0.5% (Dempson et al. 1994a).

Overall, the smolt run at Conne River has been relatively stable with an average run of 66,324 and a coefficient of variation of 11.8%. The first substantive run of smolts from the low adult spawning escapement in 1991 will be apparent as age 3+ fish in 1995. There is a general pattern for increased adult returns from larger smolt runs (Fig. 2), but the relationship is not statistically significant. It is clear that had sea survival remained at 7% or higher, target spawning requirements would likely have been met or exceeded in all years. Thus we conclude that the continued decline in the number adult salmon returning to Conne River and falling sea survival rates cannot be attributed directly to decreased smolt production.

6- Spring environmental conditions

Dempson et al. (1994b) identified an association between condition of migrating smolts and spring environmental conditions that occurred during the initial period of the smolt run (first 25th percentile of the run) for two south coast rivers, one of which was Conne River. Years in which smolts had a higher condition were those that were generally associated with warmer spring temperatures (Fig. 3). These were also years in which the smolt run timing was also early. Similarly, it was also noted that the higher survival of salmon occurred in years when the condition of smolts was greater. As would be expected from the above, sea survival was also directly associated with the temperature index (Fig. 4) and with the median date of run timing (Fig. 4). Condition of Conne River smolts in 1993 was somewhat intermediate in comparison with other years. Thus sea survival would have expected to have been higher than in the immediate preceding years. This did not occur; survival decreased to the lowest value recorded. We note, however, that the temperature index for 1993 was among the lowest recorded. At Northeast Brook, Trepassey survival was within 3% of that 'predicted' based on condition of smolts migrating in 1993. Condition of Conne River smolts in 1994 was the second lowest recorded (Fig. 3) also with a low temperature index for the year. Thus we conclude that part of the reason for the decline in sea survival of Conne River salmon may be attributed to the lower condition of smolts that has largely occurred in recent years when spring environmental conditions have been particularly 'harsh' in comparison with earlier years.

7- Mortality of post-spawning salmon

Atlantic salmon are an iteroparous fish (Hutchings and Morris 1985). That is, they have the capacity to survive and spawn multiple times in contrast with the Pacific salmon (semelparous) which typically die after they reproduce. Thus while Conne River salmon have the potential to survive and become repeat spawners, in reality it appears that few fish actually do so.

Repeat spawners can be characterized as either consecutive or alternate year spawners. Consecutive spawners sampled from the river are typically less than 63 cm in fork length ($\overline{x}$ = 548 mm) while alternate spawners average around 682 mm. Although some virgin 2SW salmon do occur in Conne River, the majority of the large salmon are alternate (repeat) spawning fish. As stated earlier, over all years large salmon make up about 5% of the return of salmon to Conne River ($\overline{x}$ = 5.2%, 1986-1994). From 1986 to 1990 the average was 5.5% but dropped by 34% to 3.6% in 1991. Since then the contribution has varied from 3.6 to 6.1%. Clearly, 1SW salmon are not surviving in high numbers to return and contribute much as repeat spawners. This situation is not unique to Conne River. For example, at Gander River in 1992, over 4000 'large' salmon returned to the river. Since then this has declined by over 70% to approximately 1100 in 1994.

Not all size classes of salmon can be sampled representatively in that any large salmon angled had to have been released. However, with respect to fish less than 63 cm in size, only 73 (4.6%) fish out of 1591 samples were either consecutive (N = 72) or alternate (N = 1) spawners. We note that at the Miramichi River, since 1989 there has been a trend for increased proportions of previous spawning salmon in the 'large' salmon component varying as high as 40% or more in some years (Chaput et al. 1994).

We estimated the numbers of salmon of different life stages (virgin, consecutive or alternate spawners) that have entered Conne River since 1986. Salmon returning to the river are categorized as small (< 63 cm) or large (≥ 63 cm) fish. Biological characteristic information was similarly partitioned into these size categories and then applied to the number of returning fish. Data were available from 1591 small salmon, but only 41 large. For small salmon, year specific information was applied for 1986 to 1990. For years 1991-93, the average contribution for all years was applied. Data from all years combined were used for each year for the large salmon. The resulting numbers of salmon by life stage are summarized in Table 4. Survival of repeat spawning fish was determined by adding the subsequent estimates of consecutive spawners in year i+1 for both small and large salmon with the number of alternate spawners in year i+2. This value was then divided by the corresponding estimated number of 1SW fish from year i (Table 4).

As suggested above, the results indicate that less than 10% of the 1SW virgin fish survive to return to the river and spawn again. One exception was from 1986 when the estimated survival was 14%. We caution, however, that the contribution of repeat spawning small salmon may be underestimated. At Campbellton River, SFA 4, it has been shown that numbers of previous spawning salmon could be underestimated from biological characteristic data obtained from sampling the recreational fishery (D. G. Reddin, pers. comm).

We conclude that egg depositions at Conne River are lower in all years due to poor survival of post-spawning salmon. Spawning escapements in the years following the high numbers of small salmon returns (1986-1990) could have been greatly augmented and egg depositions substantially increased had greater proportions of salmon survived to spawn multiple times.

8- Smolt mark-recapture surveys

Estimates of smolt production at Conne River are obtained from mark-recapture surveys. Smolts are captured in a partial fish counting fence, tagged with an external streamer tag and released at an upstream site on the river (Fig. 1) (Dempson and Stansbury 1991). At a location approximately 10 km downstream, both tagged and untagged smolts are caught, again in a partial fence, counted, tag numbers recorded, and released.

Details on numbers of smolts tagged and released, and numbers of both tagged and untagged smolts caught at the lower partial fence facility are summarized in Table 5. Briefly, numbers of smolts tagged and released have varied from 2366 to 4975. Total numbers of tagged and untagged smolts caught at the lower site have ranged from 9581 to 19515. The percentage of the total estimated run tagged and released was 3.66-6.67, and the percentage of the run that was actually caught at the lower fence has been from 12.84 to 29.71% (Table 5).

Several hypotheses can be formulated to account for the decline in adult salmon returns to Conne River and the continued decrease in sea survival as a result of the smolt mark-recapture surveys:

1 - adult salmon returns are negatively associated with the numbers of smolts tagged and released;
2 - sea survival of Conne River salmon is negatively associated with the numbers of smolts tagged and released;
3 - adult salmon returns are negatively associated with the total numbers of smolts caught at the lower fence site;
4 - sea survival of Conne River salmon is negatively associated with the total numbers of smolts caught at the lower fence site;

The numbers of adult salmon returning are highly correlated with the sea survival estimates (Fig. 2; $r^2 = 0.980$) thus of the above hypotheses, statistical tests were carried out only on items 1 and 3. If the tagging and capture of smolts were having a detrimental impact, then the expectation would be a significant negative correlation. In figure 4, the upper right side panel illustrates the 'expected' relationship (small data points and trend line) *if* the data points had been ordered so that the higher numbers of returning adult small salmon were arranged with the lower numbers of smolts that were handled (counted) while the lower numbers of adult returns were arranged with the greater numbers of smolts handled.

We determined the significance of regressions of numbers of adult salmon returning in year i+1 with (1) numbers of smolts tagged and released in year i, and (2) total numbers of smolts caught at the lower fence site (year i) by randomization test following the method of Edgington (1987) for correlation analyses. A two-tailed test analysis was run with 2500 realizations of the data.

With respect to hypothesis 1, the observed data (Fig. 4, upper left panel) do not support a negative relationship. In fact, there is some indication that greater numbers of returns have occurred when more smolts were tagged. The probability for this relationship, however, was $P = 0.160$. Similarly, there was no significant relationship with the total numbers of smolts caught ($P = 0.399$). An alternate way to evaluate these hypotheses would be to conduct a one-tailed test. Here the data would be compared against the expectation of a negative relationship. For hypothesis 1, $P = 0.785$, while $P = 0.899$ for hypothesis 2.

For the mark-recapture program to have been directly responsible for trends in adult returns and survival, we would have expected to have seen the sea survival and overall number of adult salmon returns decreasing while the proportion of the total estimated smolt migration tagged, or captured at the lower fence site was increasing. This has not happened. High and low sea survival have occurred with both lower and higher proportions of the smolt run tagged (Fig. 4, lower left panel). Similarly, both high and low sea survival has occurred with both smaller and larger proportions of the total estimated smolt run captured at the lower fence site (Fig. 4, lower right panel). Even if each and every smolt that was counted at the lower partial counting fence trap had died (which does not occur), the same pattern of declining sea survival would have occurred; it would have only been scaled higher (i.e. ranging from 3.9 to 12.7%). In other rivers in other areas, for example Western Arm Brook, SFA 14, complete counts of smolts and adults have been obtained for over 20 years (Mullins and Caines 1994). The salmon population in this river would have gone extinct many years ago had the direct count of smolts been causing serious damage to the run. In fact, since the commercial moratorium, Western Arm Brook has seen substantive increases in the return of adult salmon. Thus we conclude that mark-recapture activities at Conne River in and by themselves have not contributed to the decline in sea survival of Conne River salmon.

9- Adult salmon fish counting fence operations

Fish counting fences have been used for over 35 years to enumerate upstream migrating salmon in the Newfoundland region (Moores and Ash 1984). They have been used on a number of rivers in the maritime provinces, Quebec, and in Europe and their usefulness in assessing the status of salmon populations has long been recognized (Allan 1965; Chadwick 1985, 1995). There has, however, periodically been concern that counting fences have contributed to the decline of salmon populations. This could be through preventing salmon from migrating upriver and causing salmon to seek alternate streams, or by directly contributing to the mortality of salmon in the river.

At Conne River, the highest sea survivals have occurred when the greatest numbers of salmon were counted through the fish counting fence (Fig. 2). In those years (1987, 1988) video camera systems were not in use but still 7000-10000 salmon managed to pass freely up-river and be counted. In any year on any number of days hundreds of salmon pass through the fence. On occasion, over 1000 fish have been counted migrating upstream on a single day.

Low water conditions can delay the upstream migration of salmon (Power, 1981; Chadwick 1988). This can occur in a river whether or not a fish counting facility is in place. Depending upon the water conditions, counting fences may delay the upstream passage for up to several days. Salmon, when they are ready, will, however, migrate on through. High numbers of salmon would not have been counted if the facilities prevented their migration. Similarly, it would have been readily apparent if many fish were 'stock-piling' in the lower sections of a stream or were dying.

Salmon tagged at Conne River have never been reported to have been caught at other brooks in the upper Bay d'Espoir area. In fact, in some ways this in itself is a surprise. Salmon do stray; they would not have colonized the rivers in which they now occur had straying not been an alternate part of their natural life history strategy (Quinn 1984; Thorpe 1994). Counting fences can delay salmon from migrating upstream. But, we conclude, based on their long standing use in many rivers where populations have fluctuated and increased over time, that the facility at Conne River has not contributed to the decline in sea survival and trend for lower adult returns.

10- Interceptory fisheries, legal or illegal, for salmon

Conne River had been generally considered to be an early run salmon stock. Until 1989, the majority of the run of salmon had been in the river by the end of June. Beginning in 1990, the run timing has been somewhat later, especially in 1991.

With the opening date of the former commercial fishery around June 5, Conne River salmon could have by-passed many directed salmon fisheries and been well within their homewater area by the time the fisheries began. In years of later timing (1990 and 1991), however, salmon could have been vulnerable to capture for longer periods of time. With the commercial salmon moratorium in effect since 1992, however, salmon returns should not have been influenced by any directed fishery on them. It is odd, then, that the numbers of salmon returning to the river with clear net-marks on them has not generally diminished. Based on direct observation of salmon at the fish counting fence trap from June 17-26, 1994, 18.6% of the fish were net scarred (total number examined = 253).

Some salmon can and do encounter gear set legally for other fish species (ex. herring). However, given the relatively high numbers of net-marked salmon returning to Conne River, the question arises as to the extent of any illegal fisheries for them. Even if the extent of the activities has remained constant over time, when salmon abundance was high, the impact may have been minimal. Now that overall abundance is low, the same amount of effort could have a much greater detrimental impact on salmon returns. In 1994, approximately 50 new capelin licences were issued for the Pool's Cove (Fortune Bay) to Hermitage area. There were no mesh size restrictions for these nets and a substantive by-catch of salmon was noted by local fisheries officers (L. Ryan, DFO, Grand Bank, NF.). Further discussion of this matter is included in Dempson et al. (1995).

11 - Influence of marine environment

Atlantic salmon are noted for their wide ocean migrations and undoubtedly Conne River salmon are no different. Other analyses in this paper have examined hypotheses relating decreased returns of adult salmon to Conne River to possible causes of mortality in freshwater or estuarine environments. In this section, we test the hypothesis that low returns of Conne River salmon in recent years are related to poor ocean conditions for survival.

Many studies (eg. Ritter 1989; Scarnecchia 1984a, 1984b; Friedland and Reddin 1993; Reddin & Friedland 1993) have related conditions in the marine environment to return rates of salmon. More recent studies have shown that production of North American 2SW salmon is related to an index of marine habitat in the Labrador Sea (Reddin et al. 1993). This relationship has been used to predict the number of potential 2SW salmon prior to the fishery at west Greenland (Anon. 1993 & 1994). Although it is unknown if Conne River salmon overwinter in the Labrador Sea and Grand Banks area, returns from 1SW salmon tagged during studies at sea have occurred along the south coast of Newfoundland. Also, river age distributions indicate that salmon with river ages 3+ and 4+ years, consistent with the known river ages of Conne River salmon, are found in the Labrador Sea and Grand Banks area (Reddin 1985).

In order to test hypotheses related to the marine environment, indices of marine condition and salmon survival are required. A measure of marine condition, termed thermal habitat, defined as a relative index of the area suitable for salmon overwintering, was developed by weighting salmon catch rates from experimental fishing by research vessels and sea surface temperature data from earth observation satellites and ships of opportunity obtained from the Comprehensive Ocean Atmospheric Data Set (COADS) issued by the National Centre for Atmospheric Research at Boulder, Colorado, USA. The area used to determine available salmon habitat encompasses the north-west Atlantic north of 41° N latitude and west of 29° W longitude and includes the Davis Strait, Labrador Sea, Irminger Sea, and the Grand Bank of Newfoundland (Reddin and Friedland, 1993; Reddin et al. 1993; Anon. 1994). Indices of salmon survival used for analysis include the percent survival from smolt to adult return for the smolt years 1987-93 and the number of adults returning to the Conne estuary for the years 1986-94. As described elsewhere in this paper, the significance of the relationships was derived using randomization tests.

Randomization tests between percent survival and thermal habitat indicate a strong positive relationship with $P = 0.004$ (Fig. 6A). There is also a strong positive relationship between the number of adult returns and thermal habitat, $P = 0.008$. Because survival is highly correlated with the number of adult returns, $r^2 = 0.98$ (Fig. 2), two more years of adult returns, viz. 1986 & 1987, can be added and tested. Now with a larger sample size ($N = 9$) with 5,000 realizations, $P = 0.039$, suggesting a strong correlation between adult returns and marine conditions in the Labrador Sea (Fig. 6B). We conclude that it is possible that reduced numbers of adult salmon returning to Conne River in recent years are related to changes in marine habitat in the northwest Atlantic area.

Conclusions

The factors discussed in this paper were not intended to reflect all causes that could potentially impact on adult salmon returns to Conne River. For example, it is known that one of the most critical stages in the life of the salmon is that period when smolts pass from freshwater into saltwater (Tytler et al. 1978). We do not have direct information to evaluate the performance of smolts at this time and whether their performance could have changed in more recent years.

Of the various factors identified and discussed in this paper, few appear to have contributed to the overall pattern of decreased sea survival and decline in the number of adult salmon returning to Conne River. Those factors that do include the impact of more severe spring climatic conditions on the timing and 'condition' of outmigrating smolts, low survival of repeat spawning salmon, possible losses due to legal and illegal interceptory fisheries, and perhaps changes in available marine habitat in the northwest Atlantic. One fact that is very apparent is that sea survival has declined dramatically and the impact of this has yet to be manifest in the production of smolts and their subsequent return as adult salmon.

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Table 1. Summary of counts of small salmon, estimates of total returns to home waters, percentage target spawning requirement met, and sea survival to 1SW salmon, for Conne River.

	Year								
	1986	1987	1988	1989	1990	1991	1992	1993	1994
Counts	7515	9287	7118	4469	4321	2086	1973	2355	1533
Returns	8302	10155	7627	4968	5368	2411	2523	2703	1533
% target met	145	214	159	103	112	51	51	61	39*
% survival to 1SW (related to year of smolt migration)		10.2	7.6	7.3	4.2	3.4	4	2.7	

* does not account for fish retained for subsequent stocking

(Large salmon ~ 5% of total count at fence)

Table 2. Summary of the Conne River Indian Band Council food fishery with the catch also expressed as a percentage of the total estimated returns to home waters.

Year	Catch	Catch as % of total returns	Total returns	% sea survival
1986	522	6	8302	
1987	18	0.2	10155	10.2
1988	609	8	7627	7.6
1989	382	8	4968	7.3
1990	959	18	5368	4.2
1991	284	12	2411	3.4
1992	488	19	2523	4.0
1993	420	16	2703	2.7
1994	0	0	1533	

Table 3. Estimates of Atlantic salmon smolts from Conne River, 1987 - 1994, along with subsequent survival to one-sea-winter salmon.

	Number of smolts			Population estimate			Survival	
	Upper site	Lower site						
Year	Tagged & released	Total number captured	Tag recoveries	N	Confidence interval	Coeffiicient of variation %	% survival to 1SW	Survival range
1987	4975	14314	990	74585	67597-81573	5.1	10.2	9.3-11.3
1988	3235	19515	1054	65962	59862-71522	4.8	7.6	6.9-8.3
1989	2699	16928	604	73724	66598-80850	5.1	7.3	6.7-8.1
1990	3719	13881	945	56943	52315-61571	4.4	4.2	3.9-4.6
1991	3753	9581	398	74645	62033-87527	9.0	3.4	2.9-4.1
1992	3758	10229	529	68208	61334-75052	5.4	4.0	3.6-4.4
1993	2456	15992	735	55765	51666-59864	3.9	2.7	2.6-3.0
1994	2366	11875	479	60762	53759-67765	6.2		

Table 4. Numbers of small and large Conne River Atlantic salmon partitioned by life stage, and subsequent percent survival of previous spawning fish.

	Small salmon			Large salmon			Percent survival of previous spawners
		Previous spawners			Previous spawners		
Year	1SW	Consecutive	Alternate	2SW	Consecutive	Alternate	
1986	8256	23	23	50	40	322	14.0
1987	9376	779	0	63	50	403	4.6
1988	7487	140	0	51	41	328	7.0
1989	4764	204	0	31	31	250	4.1
1990	5277	91	0	45	36	290	4.6
1991	2302	109	0	11	9	69	9.0
1992	2409	114	0	19	16	124	8.7
1993	2581	122	0	12	10	78	3.1
1994	1464	69	0	12	10	78	

* example of survival calculation from 8256 1SW salmon in 1986:

779 consecutive from 1987 + 50 (large) consecutive from 1987 + 328 (large) alternate salmon from 1988

= 1157/8256 (1SW) * 100 = 14.0%

Table 5. Percentage of estimated total smolt run that were tagged at the upper fence site and were caught at the lower fence site, 1987-1994

Year	N Tagged	Total number caught at lower fence	Number of untagged smolt at lower fence	Number of tag recaptures lower fence	Population Estimate	% of run tagged	% of run caught
1987	4975	14314	13324	990	74585	6.67	19.19
1988	3235	19515	18461	1054	65692	4.92	29.71
1989	2699	16928	16324	604	73724	3.66	22.96
1990	3719	13881	12936	945	56943	6.53	24.38
1991	2753	9581	9183	398	74645	3.69	12.84
1992	3758	10229	9700	529	68208	5.51	15.00
1993	2456	15992	15257	735	55765	4.40	28.68
1994	2366	11875	11396	479	58640	4.03	20.25

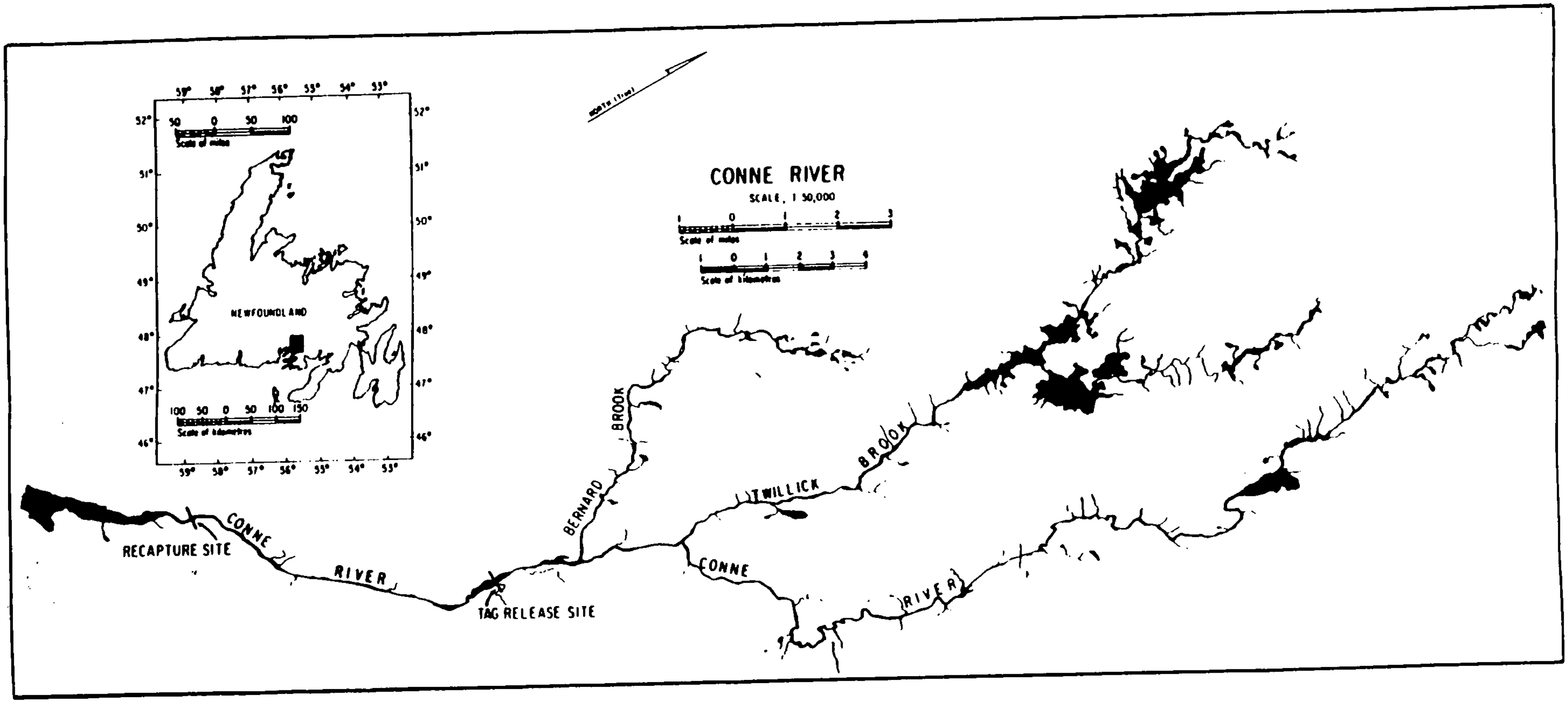


Fig. 1. Conne River, Newfoundland, SFA 11, illustrating the location of the fish counting fences used for the mark-recapture survey. The recapture site is also the location of the upstream adult salmon counting facility.

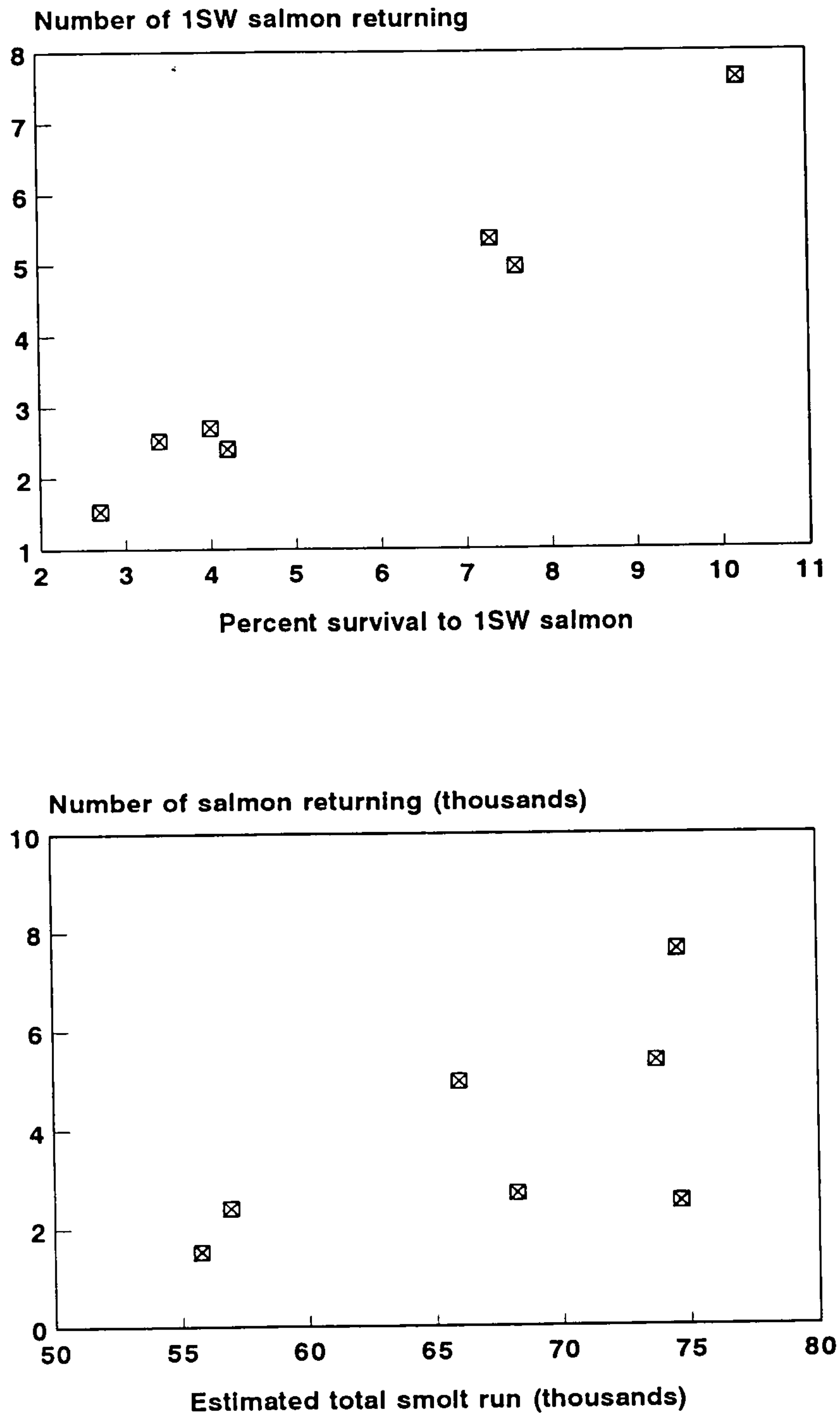


Fig. 2. Relationships between percent survival to small salmon and the coresponding number of adult small salmon returns to Conne River (upper graph), and the estimated smolt production and subsequent return of adult small salmon (lower panel).

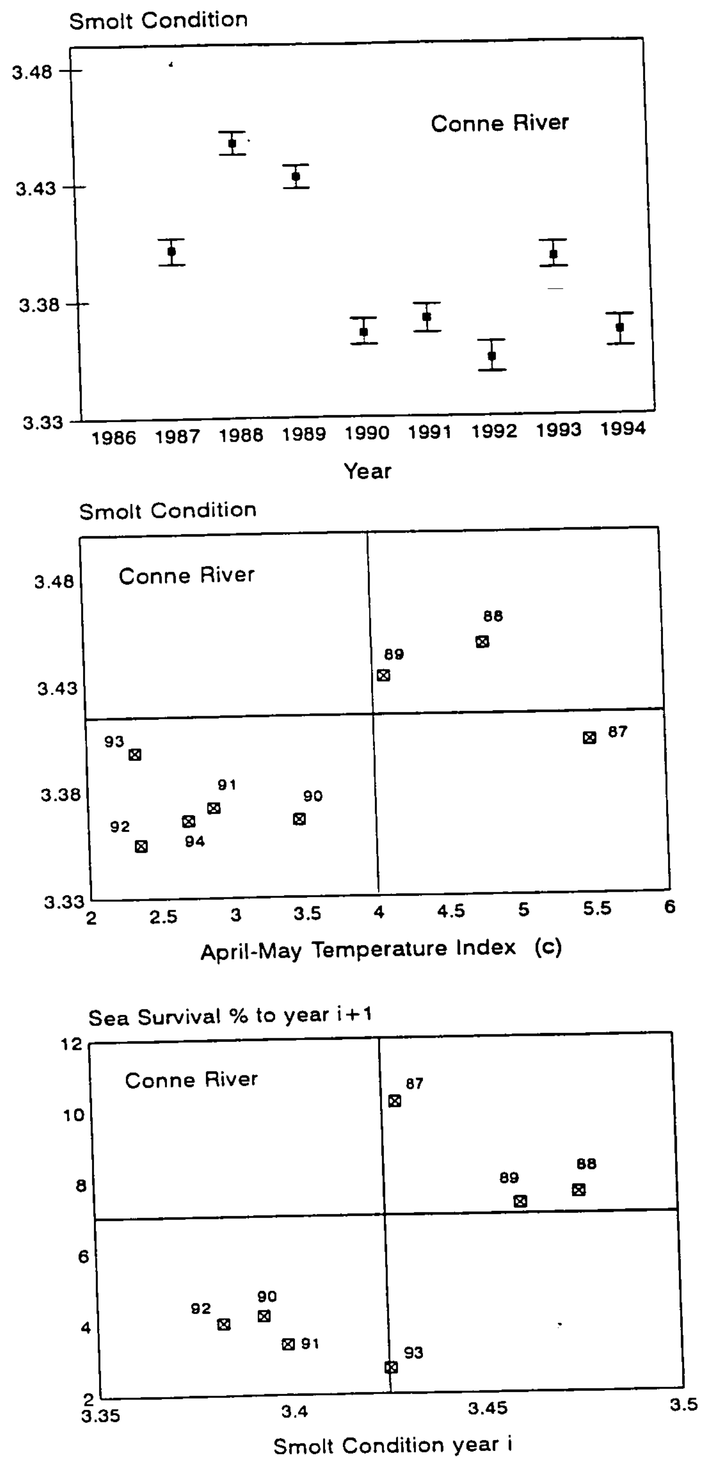


Fig. 3. Index of Conne River smolt condition varying over years (upper); in relation to the April-May air temperature index (middle); and as it relates to estimated sea survival of adult salmon returning in the following year. Vertical lines in the upper panel represent ± one standard error.

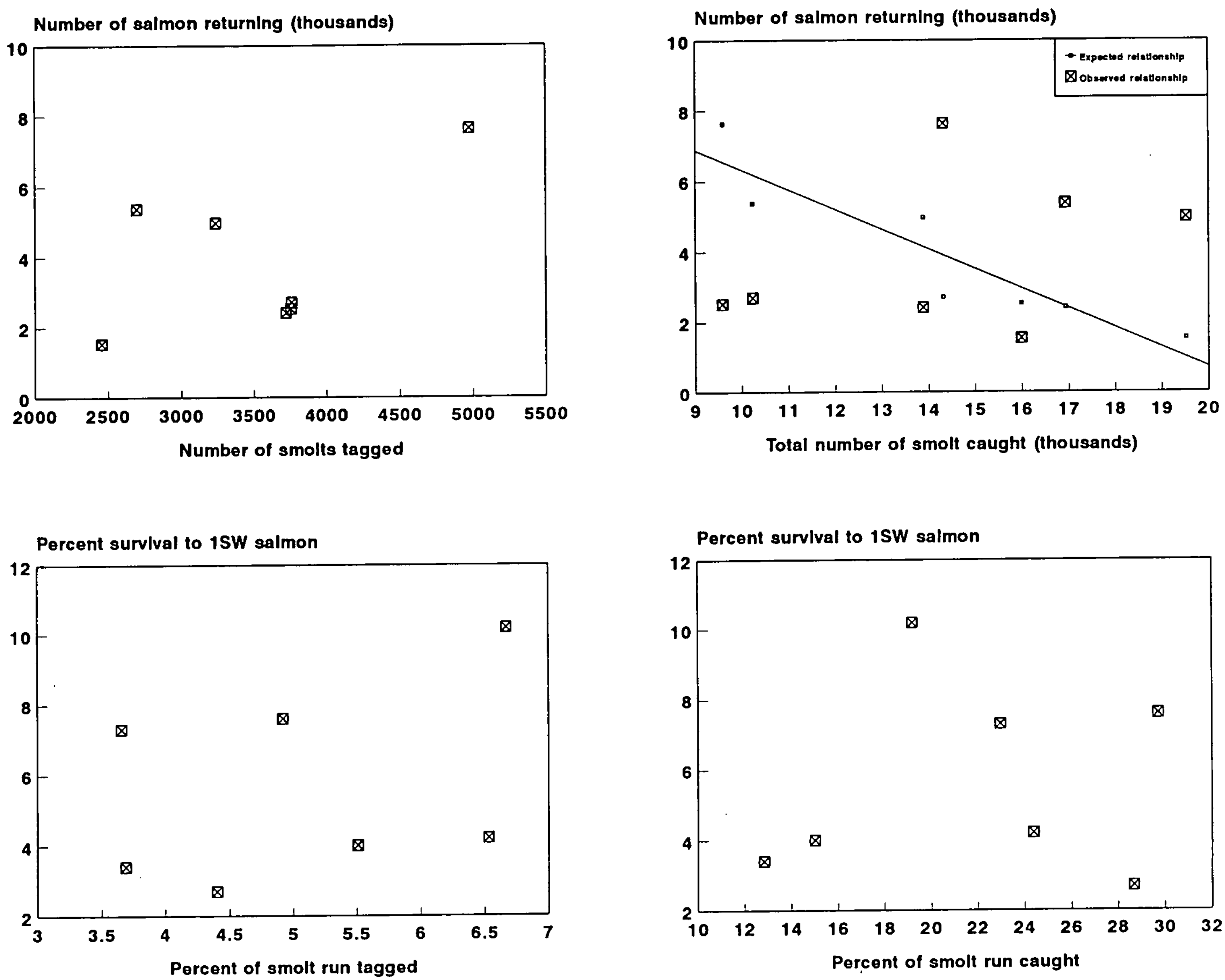
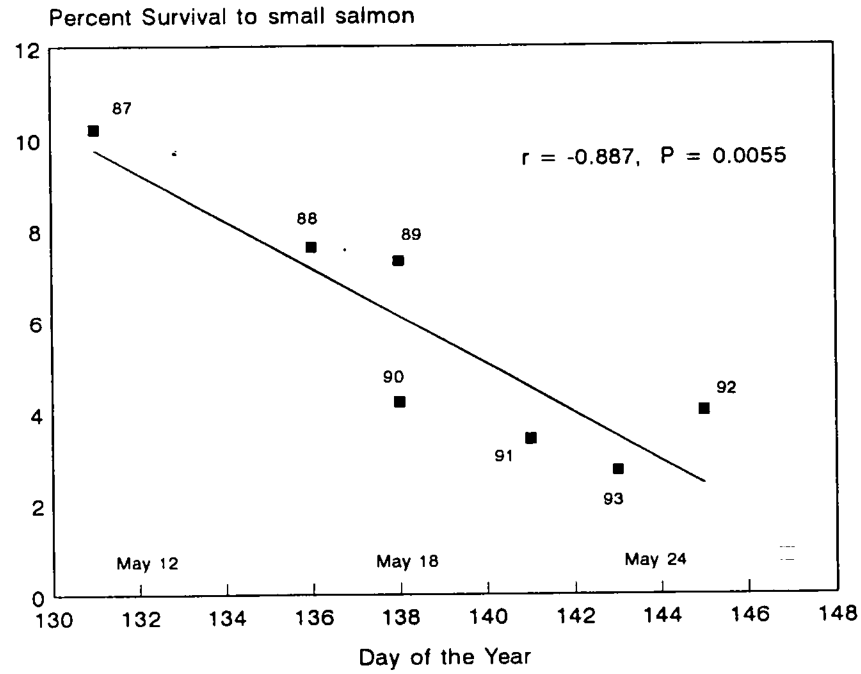


Fig. 4. Relationships between: numbers of smolts tagged and adult salmon returns; total numbers of smolts caught at the lower partial counting fence trap and adult salmon returns; the percentage of the smolt run tagged versus sea survival (%) to small salmon, and the percentage of the estimated total smolt run caught versus sea sea survival. The 'expected' trend line shown in the upper right panel illustrates the distribution of points had they been ordered so that higher adult salmon returns corresponded with fewer numbers of smolts that were handled (see text, section 8).



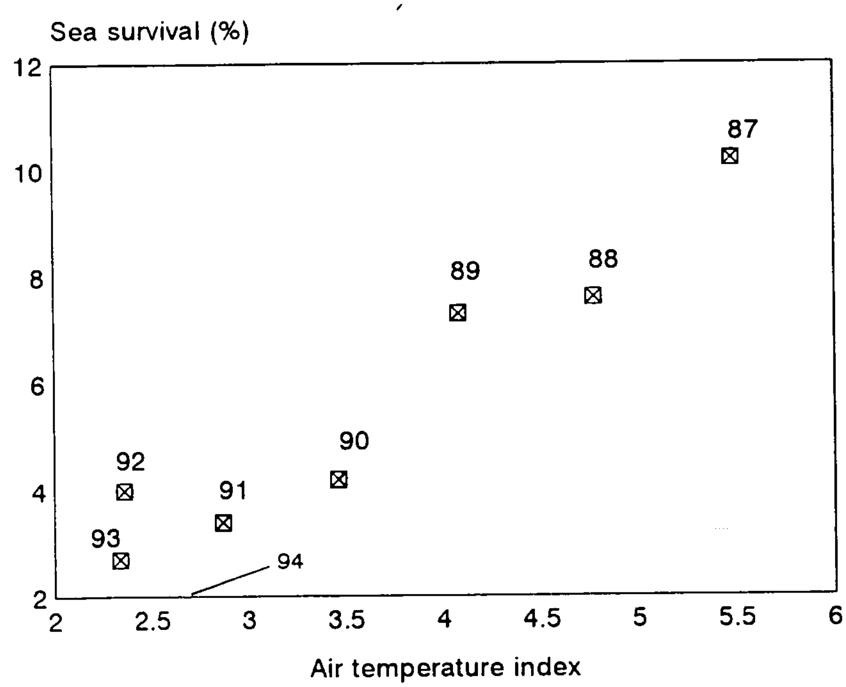


Fig. 5. Relationship between sea survival from smolt to adult small salmon and the median date of the smolt out migration (upper panel). Lower panel illustrates the sea survival (%) in relation to the spring air temperature index. Year of smolt run is indicated by the data points on both figures. In the lower panel, the 1994 air temperature position (2.69 °C) is indicated by the line. Note that the survival estimate corresponding to this temperature will not be available until the 1995 adult run of salmon has occurred.

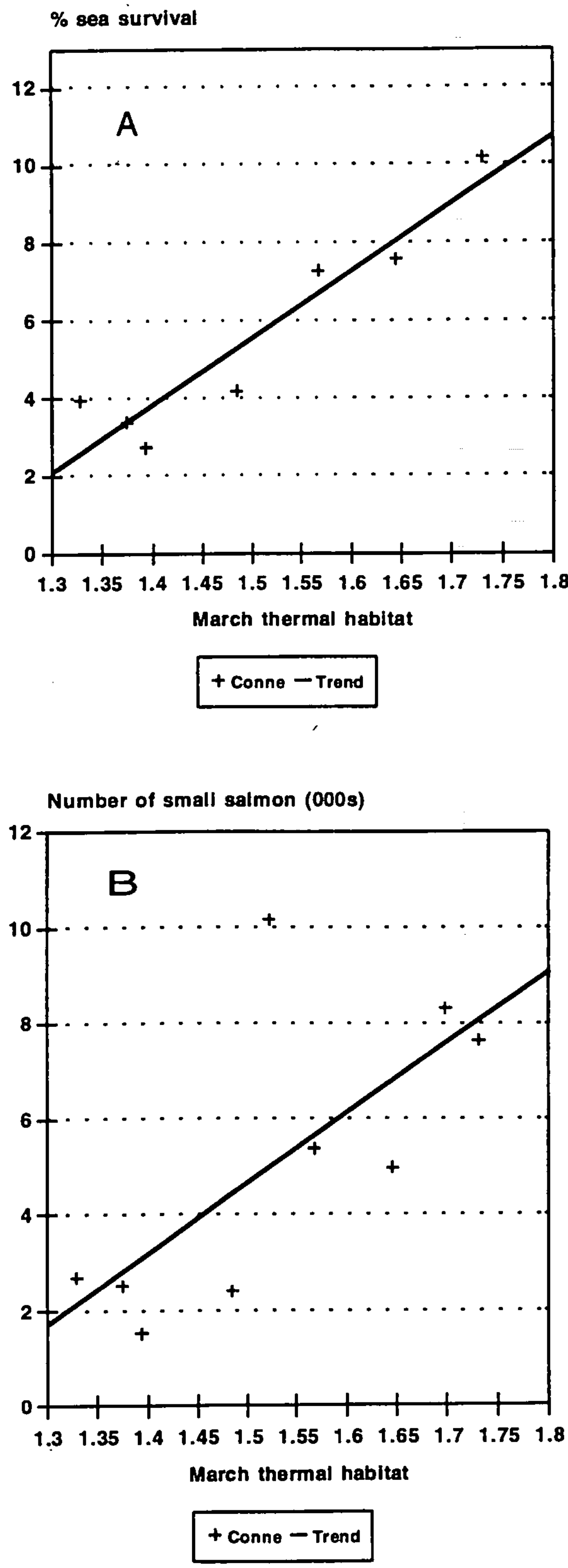


Fig. 6. Relationships between: (A) sea survival of Conne River small salmon and an index of March thermal habitat in the Labrador Sea, 1988-94, and (B), for numbers of small salmon returns versus the index of thermal habitat, 1986-94. Years refer to year in which the adult returns occur.