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Status of Atlantic salmon at Highlands River, Bay St. George, SFA 13, Newfoundland, 1998

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Abstract

The status of Atlantic salmon in Highlands River, 1998 was determined from the number of salmon counted through a fish counting fence located on the main stem of the river just above head of tide. Biological characteristics data were collected from kelt and updated summaries for past years are provided. Adult returns in 1998 were 96 small salmon and 117 large salmon. This represented a decrease of 76% for small salmon in comparison with 1997 while large salmon returns declined by 25% from the previous year. Sea survival was again low for both small and large salmon returns. The 1998 smolt count of 5922 is the lowest on record for 1980-82 and 1993-98. The proportion of the conservation requirement achieved for Highlands River in 1998 was 58.9% with the 5th and 95th percentiles of 46.1 to 73.7%. On average for the period of 1993-97, Highlands River has achieved 74.9% of its conservation requirement.

Population estimates of juvenile salmon were made at 5 sites. At 4 of the 5 stations, underyearlings were less than in 1995 and juvenile salmon biomass was also lower. An exceptionally high flood in February of 1996, prior to emergence of fry, moved massive amounts of substrate and was likely to have had a negative effect on the 1996 year class. The lower smolt production in 1997 and again in 1998 is believed to be a result of the flood. Smolt production is again expected to be low in 1999, and because of the poor runs in 1997 and 1998, the conservation requirement for Highlands River is not expected to be attained in 1999.

Résumé

L'état du saumon de l'Atlantique de la rivière Highlands en 1998 a été déterminé à partir du nombre de saumons dénombrés à une barrière de comptage située sur le cours principal de la rivière, juste en amont de la limite de la marée. Des données biologiques ont été recueillies pour les charognards. Des résumés à jour des données des années antérieures sont présentés. Les remontées d'adultes de 1998 comptaient 96 petits et 117 grands saumons. Cela correspond à une baisse de 76 % pour les petits saumons par rapport à 1997 et les remontées de grands saumons ont diminué de 25 % par rapport à l'année précédente. La survie en mer a encore été faible, tant pour les petits que pour les grands saumons. Le dénombrement de saumoneaux de 1998, de 5 922, est le plus faible enregistré par rapport aux périodes de 1980-1982 et de 1993-1998. La proportion des besoins de conservation atteinte pour la rivière Highlands en 1998 s'est élevée à 58,9 %, les 5^{e} et 95^{e} percentiles se situant entre 46,1 et 73,7 %. En moyenne, les besoins de conservation de la rivière Highlands ont été atteints à 74,9 % au cours de la période 1993-1997.

La population de saumons juvéniles a été estimée en cinq endroits. À quatre des cinq stations, les poissons de moins d'un an étaient moins nombreux qu'en 1995 et la biomasse des saumons juvéniles était inférieure. Une crue exceptionnellement forte survenue en février 1996, avant l'émergence des alevins, a déplacé d'importantes quantités de substrat et a sans doute été nuisible à la classe de 1996. La plus faible production de saumoneaux de 1997, et de 1998, s'explique probablement par les effets de cette crue. La production de saumoneaux devrait encore être faible en 1999 et, étant donné les remontées peu importantes de 1997 et 1998, les besoins de conservation de la rivière Highlands ne devraient pas être atteints en 1999.

Introduction

The Highlands River is a fourth order system located on the south west coast of Newfoundland (48° 11' 38'' N, 58° 53' 40" W), in Salmon Fishing Area (SFA) 13 (Fig. 1). The river drains westerly into Bay St. George from the southern part of the Long Range Mountains, with an average gradient of about 1.2%, over an axial length of 29.0 km. Area of the drainage basin is 183.1 km^2. The river has long been noted for a fall run of very large salmon, and in the past at least, for good trout fishing (Palmer 1928). Owing to the decline of angling success at the time, especially of the large salmon component, the river was closed to angling in 1978, and has remained so (Chadwick et al. 1978; Porter and Chadwick 1983; Gibson et al. 1987). In the 10-year period prior to the closure of the sport fishery (1968 - 77), angled catch of small salmon ranged from 16 to 105 fish per year ($\bar{x}$ = 39.0 $year^{-1}$) while large salmon catch varied from 4 to 25 ($\bar{x}$ = 11.8 $year^{-1}$). Prior to 1968, annual angled catches of 50 to 97 large salmon were reported (Moores et al. 1978).

Adult spawning escapement and smolt yields have been obtained from a counting fence that operated from 1980 to 1982, and again from 1993 to 1998. Adult returns have ranged from 82 to 398 small salmon ($\bar{x}$ = 162) and from 29 to 157 large salmon ($\bar{x}$ = 100). The highest runs occurred in 1997 (Reddin and Whalen 1998) while the lowest returns were in 1980. Smolt production has varied from 5922 to 15839 ($\bar{x}$ = 11220) with the fewest smolts occurring in 1997 and 1998. The low smolt runs were believed to have been the result of a severe flood that affected the river in February, 1996 (Reddin and Whalen 1998). Juvenile salmon population estimates were also made in 1980 and 1981, and from 1993 to 1998. Surveys carried out in 1997 and 1998 were based on a reduced subset (N = 5) of stations and thus were not as thorough as in previous years. Based on past assessments (Gibson et al. 1994, 1996; Reddin and Whalen 1998), it was determined that less than 40% of the conservation requirement was achieved at Highlands River from 1980 to 1982. With the closure of the Newfoundland commercial salmon fishery in 1992, the percentage of the conservation requirement attained has averaged about 75% (1993 - 1997) but in only one year, 1997, has the actual conservation level been obtained.

This paper summarizes smolt production and returns of adult Atlantic salmon to Highlands River in 1998 along with results of juvenile salmon population estimates from electrofishing surveys. In addition, information on environmental characteristics are provided, and biological characteristic data for Atlantic salmon are updated. Where possible, information on upstream and downstream runs and biological characteristics have been obtained from electronic data records. In some cases, information presented in the current document differs from that provided in the past. Owing to the impact of the 1996 flood event on subsequent smolt production, we also provide a summary of hydrological conditions at Highlands River for the period 1982 - 1998, in order to gain insight as to whether similar events may have impacted salmon production in this river in the past.

Methods

1. Environmental conditions

Water temperatures were obtained from a continuous recording Hugrun thermograph set 1 m from the surface at the fish counting fence site located in the lower river and operated from April 27 - November 6, 1998. Discharge information for the period 1982 - 1998 was obtained from Environment Canada records for the gauging station situated where the Trans Canada Highway crosses over the major stem of Highlands River ('River Brook'; Fig. 1). The drainage area above the water gauge is 72 km^2, which represents 39% of the reported total drainage area for the entire Highlands River watershed. Cloud cover, relative water levels, general weather conditions, air and water temperatures were also recorded at the fence site during successive fish trap checks each day.

2. Biological characteristics

Biological characteristic information on smolts, including fork length to the nearest millimeter, whole weight to the nearest one hundredth of a gram, sex, and scales were derived from samples captured at the fish counting fence. Samples of adult salmon, obtained from kelt emigrating in the spring, provided information on fork length to the nearest centimeter, scales and a visual inspection (external) to determine sex. Some returning adult salmon were also sampled for fork length to the nearest centimeter, scales and sex (external). Additional information on fork lengths (to the nearest 5 centimeters) has been obtained over the years from visually estimating lengths of returning adults when they were in the counting fence trap where a fish measuring stick was placed along side of salmon. These data are provided for reference but we caution that except for 1980 and 1981, the distributions should not be interpreted as reflecting the overall length distribution of the run in each year.

3. Smolt monitoring

Standard conduit smolt and adult counting fences were installed according to the description in Anderson and McDonald (1978). The smolt fence was installed on May 6 to catch downstream migrating fish and operated until June 13 (Table 1).

4. Kelt tagging

In 1998, a number of kelt counted at the downstream fence were tagged and released with either individually numbered temperature recording archival tags (N = 24) or Carlin tags (N = 32).

5. Avian predation

During the 1998 smolt run, observations were made to document potential predation on smolts by avian predators. Observations were made at a location approximately one-half km downstream of the fish counting fence by fish counting fence personnel. The observations were taken one half hour after the first release of smolts in the morning and continued for approximately one hour. Time of day, species and number of birds (flying, standing and swimming), number feeding and observed prey species were recorded. Observations were carried out from May 28 to June 11, 1998.

6. Juvenile salmon population estimates

Population estimates were conducted during July at five sites. As in 1997, stations were chosen to reflect different stretches and habitat types in Highlands River. The same stations were sampled in previous years, including 1997, with the exception of one station (Station 3 - Main Rainy Brook) which no longer existed due to physical changes in the river resulting from previous high water conditions. An additional site (Station 50 - Main Rainy Brook) was used from which previous data had been collected in other years (not including 1997). Densities of small salmonids were estimated by the depletion method in riffles and the flat with the use of an electrofisher. Four (4) sweeps done at each of the sites electrofishing in an upstream direction from the lower end of the study area. If no fish were caught in the first sweep, no further sweeps were made. Habitat variables were measured at each site according to the method described in Gibson et al. (1993).

7. Adult salmon returns, sea survival and egg deposition

The adult fence was installed on June 14 to catch upstream migrating adult salmon. The trap and fence were removed for the season on October 26, 1998 (Table 1). All fish were counted, and sizes of adult upstream migrating salmon were estimated. All fish were released alive. Since the river is closed to angling, no adult fish were killed for more detailed sampling.

The adult fence was fished with every second conduit removed; therefore, smaller fish counted migrating upstream could be an underestimate since some could pass through the fence and not be counted at the trap. The trap was checked and fish released on a regular 4-hour basis from 0800 hrs to 2000 hrs (during the peak of the runs and during high water levels the trap was checked more frequently). The adult salmon counted were sized in two categories; small salmon were those less than 63 cm in fork length while large salmon were fish 63 cm or greater.

Sea survival was determined from the number of small salmon returning in year i+1 or the number large salmon in year i+2 relative to the number of smolts that emigrated in year i. Adult salmon returning to Highlands River are characterized by several life-history types including virgin one sea-winter (1SW), two sea-winter (2SW), three sea-winter (3SW) and previous spawners of each of these life histories. Thus an estimate of survival to the 2SW life history stage is also provided.

Because Highlands River is closed to angling, total river returns or spawning escapement (SE) were simply the numbers of fish enumerated at the fish counting fence. Egg deposition (ED) was calculated separately for salmon $<$ 63 cm (small salmon) and salmon $\geq$ 63 cm (large salmon) and then totaled:

$$ED = SE \times PF \times F$$

where, PF = proportion of females
F = fecundity at size.

For this assessment, egg deposition for all years has been recalculated using the average biological characteristic information (proportion females and mean lengths) obtained from samples of kelts, separately for small and large salmon, for two time periods 1980 - 1982, and 1993 - 1998. Mean values were used because the numbers of samples obtained in any specific year are generally limited:

Size		1980 - 82	1994 - 98
Small	% female (N)	55.4 (74)	46.1 (191)
	mean length, cm (N)	52.0 (41)	53.1 (88)
Large	% female (N)	75.0 (80)	69.5 (203)
	mean length, cm (N)	85.2 (60)	81.6 (141)

Fecundity estimates were taken from Randall (1989):

Small salmon: Ln fecundity = -4.5636 + 3.1718 Ln (FL in cm); and,

Large salmon: Ln fecundity = -1.1862 + 2.3423 Ln (FL in cm).

The above equation for small salmon was originally derived for 1SW Miramichi River fish, while the equation used for large salmon was that derived from a composite of 2SW, 3SW and previous spawners from the Restigouche River.

Conservation egg deposition requirement

The conservation requirement for Highlands River is 1,498,475 eggs. This was derived from:

fluvial habitat	=	6219.26 units @ 240 eggs/unit
lacustrine habitat	=	15.9043 ha @ 368 eggs/ha

(Reddin and Whalen 1998).

Results and Discussion

1. Environmental conditions

Water temperatures

Daily mean water temperatures for the smolt fence ranged from a low of 4.6 °C in mid April to a peak of about 17.6 °C by the fence removal date of June 13. During operation of the adult salmon fence, temperatures continued to increase reaching a mean daily temperature of 20 °C for the first time on July 15 and remained over 20 °C for most of the next two weeks. There were 14 days in 1998 when the mean daily water temperature was 20 °C or warmer. Mean daily water temperatures peaked on August 8 and 9, reaching 26.0 and 27.9 °C, respectively. Over the entire summer, there were 31 days when maximum temperatures ≥ 22 °C were reached and 6 days when maximum temperatures ≥ 25 °C were obtained. The latter occurred between the dates July 16 to August 9. Mean daily water temperatures began to decline by mid-August. Mean daily water temperatures remained below 10 °C from October 3 onward with the lowest temperature during the adult salmon monitoring of 4.9 °C that was recorded on October 26. Water temperature during the smolt and adult counting fence operations are illustrated in Figures 2 and 3.

Water level and Discharge - 1998

Mean daily water levels recorded at the fish counting fence trap at Highlands River ranged from about 20 to 79 cm. In general, water levels were low throughout most of the time smolt and adult fish monitoring was carried out with values usually between 20 and 40 cm. There were 12 days when the maximum water level recorded was ≥ 50 cm, but only 6 days when the mean daily water level exceeded this value. Similarly, discharge information obtained from the Environment Canada station on Highlands River indicated moderately low water levels during the smolt run (0.72 - 2.84 m^3/sec) and much of the adult migration. On only 11 occasions did discharge values exceed 5 m^3/sec during the adult salmon run (from June 14- October 26). The peak mean daily discharge was recorded on July 10 (22.7 m^3/sec).

Discharge 1982 - 1998

Figure 4 illustrates the mean monthly discharge values along with monthly minimum and maximums from 1982 to 1998, for Highlands River. With very few exceptions (e.g. April and May, 1982), mean monthly discharge values were less than 10 m^3/sec. As a very rough guide, a maximum **instantaneous** discharge that is approximately equal to or exceeds 1 m^3/sec per square kilometer of basin drainage area can be classed as an '**extreme**' high water event (Calvin Baker, Environment Canada, pers. communication). In the Highlands River basin, the drainage area above the Environment Canada water gauge is 72 km^2. Thus, using the above approximation an extreme high water event would be one where the maximum **instantaneous** discharge is around 72 m^3/sec or higher. For the purpose of this assessment, we have also defined a '**high**' water event when the mean daily discharge equals or exceeds one-half of the above instantaneous value (≥ 36 m^3/sec).

Table 2 summarizes the values and dates of annual maximum instantaneous discharges at Highlands River. We have also included the annual frequency of 'high' water events. Using the above criteria, there have been at least five (5) 'extreme' discharge events at Highlands River since 1982: April 30, 1982 (71.6 m^3/sec) ; August 7, 1983 (119.0 m^3/sec); January 28, 1986 (122.0 m^3/sec); December 9, 1990 (77.7 m^3/sec); and the single highest instantaneous discharge recorded over the 16 year period that occurred February 18, 1996 when an instantaneous discharge of 127 m^3/sec was recorded. The 'extreme' events of 1983 and 1986, however, approximated that recorded in 1996. Since there was only a single maximum instantaneous discharge value were reported, there could have been other occasions where 'extreme' events have happened. 'High' water events (≥ 36 m^3/sec) have occurred on ten occasions over the years (Table 2).

The following summarizes the incremental forest harvest history of the Highlands River watershed aggregated in five-year intervals (Scruton et al. in prep.)

Year	Forest area harvested (km^2)	Cumulative forest area harvested (km^2)
1940-44	0.00	0.00
1945-49	1.81	1.81
1950-54	3.25	5.06
1955-59	12.21	17.27
1960-64	11.93	29.20
1965-69	6.84	36.04
1970-74	5.42	41.46
1975-79	9.09	50.55
1980-84	10.12	60.67
1985-89	4.63	65.30
1990-94	3.15	68.45
1995-98	0.55	69.00

According to these data, upwards of 40% of the forested area of the Highlands River drainage basin (183.1 km^2) has been harvested, with most activity occurring from 1955 to 1963, and again from 1980-84. We note that in a detailed analysis of forest harvesting activities in Bay St. George rivers, Scruton et al. (in prep.) state that it is difficult trying to link these activities with variation in river flow patterns.

2. Biological characteristics

Table 3 summarizes annual biological characteristic data of Atlantic salmon from Highlands River. Overall, smolts average 12.9 cm and 20.4 g. Data from 1998 are above average (Table 3). Adult salmon have been partitioned into small and large categories with small salmon averaging 54.3 cm and large salmon 81.7 cm. All adult salmon data reported were obtained from sampling kelts leaving the river during the spring of the year. The summary includes repeat spawners.

River age distribution of smolts is provided in Table 4. Smolts are predominately 3+ (72.4%) but there is considerable variation among the data ranging from 50.5% river age 3 smolts in 1995 to 90.5% in 1998 (Table 4). Information contained in Table 4 for the years 1980 - 1982 differ considerably from that reported in Reddin and Whalen (1998) and past Highlands River assessment documents including the Technical Report by Gibson et al. 1987). This discrepancy cannot be reconciled. Information contained in the current document has

been obtained from electronic records at DFO St. John's, Newfoundland, and interestingly, is consistent with that summarized for Highlands River by O'Connell and Ash (1993). In any event, owing to the wide variation in reported smolt ages in recent years, subsets of scale samples from past years should be reanalysed.

River age distributions of small and large adult salmon are summarized in Table 5. Small salmon are similarly characterized with a river age of 3+ years (73.4%) with 9% of the samples over all years having a river age of 2+ years. In contrast, 83% of the large salmon sampled had a river age of 3+ years while 15% smoltified as 2-year old smolts. As shown by O'Connell and Ash (1993) smaller and slower growing smolts in fluvial systems are often characterized by multi-sea winter large salmon.

Small salmon at Highlands River are predominantly 1SW fish (97.0%; N_{small} = 267) (Table 6). In contrast, of 284 large salmon kelt that have been sampled, 64.8% were 2SW salmon while 27.1% were previous spawners (Table 6). Twelve (4.2%) virgin 3SW salmon have been sampled at Highlands River since 1980. These fish ranged from 87.0 to 105.0 cm in fork length. The majority of the previous spawning large salmon samples had a virgin sea age of 2 years (85.7%) and 20 of the large salmon had spawned in 3 or 4 consecutive years.

Length-frequency distributions of adult salmon obtained from estimated lengths of fish in the fish counting fence trap are shown in Figure 5.

3. Smolt monitoring

Numbers of smolts migrating downstream each year are summarized in Table 7. The smolt run in 1998 (5922) was 12.6% lower than that of 1997 and was the lowest on record. It is believed that low smolt production during the past two years is a result of the extreme high water discharge events that affected Highlands River in February, 1996. Numbers of smolt migrating by day along with mean daily water temperatures for 1998 are summarized in Figure 2. Smolt run timing at Highlands River is illustrated in Figure 6. For the period 1993 - 1998, the median date of the smolt run averaged May 31, approximately two weeks later than the smolt run at Conne River (May 18). In 1998, the median date of the smolt run was May 28.

4. Kelt tagging

Kelts on which archival tags were applied in the spring of 1998 (N = 24) averaged 71.7 cm in fork length (range: 55.0 - 103.5 cm). Six (6) of these fish were subsequently recovered. One was captured in the commercial salmon fishery at Heberts Cove West, Quebec, 51 days following its release from Highlands River and another was caught at Port au Port, Newfoundland, in the Sentinel cod fishery, 34 days after it was released. The other four

fish were recovered as they returned to the Highlands River fish counting fence in August and September, 1998. Carlin tagged salmon (N = 32) averaged 65.0 cm in fork length (range: 46.5 - 95.0 cm). Of these fish, only three (3) were subsequently recovered. Two returned to Highlands River while the other fish was similarly caught in the commercial fishery at Baie de Rush, Quebec, about 45 days from the time it left Highlands River. Details pertaining to the archival tag temperature records are provided in Reddin et al. (1999).

5. Avian predation

Eleven groups or species of bird were identified at Highlands River in 1998. Of these, sea gulls were the most common (Table 8) and were usually observed while flying. In contrast, the common merganser was usually swimming and smolts were identified as a prey item. With the exception of a single tern that was observed to have been feeding on a small salmonid species (trout or salmon), no other definitive occurrences of birds feeding on smolts. In a number of cases, avian predators were observed feeding, but it was not possible to identify with certainty the prey organisms birds were selecting.

6. Juvenile salmon population estimates

The lower riffle station in River Brook (Station 20) showed exceptional increases in density of underyearlings (age 0+) after the moratorium compared with previous samples obtained in 1980 and 1981, but a considerable reduction in 1996 (Fig. 7). The increase was believed to have been a result of increased spawning escapement coincident with the commercial salmon fishery moratorium, but disturbance of spawning gravel during the exceptionally high flood in February 1996, prior to emergence of the fry, may have caused the subsequent decline in 1996. Over the past two years, density of 0+ fry has also remained low. Density of age 1+ parr in 1998 was similar to densities observed in 1981. In contrast with 0+ fry that appeared to have been negatively affected by the flood in 1996, 1+ parr density was moderately high in 1996 but declined in 1997 (Fig. 7).

Underyearling (0+) and 1+ parr densities increased at Stations 2 and 9 in 1998 (Figs. 8 and 9) in relation to the two previous years while age 0+ fry abundance declined substantially at Station 10 (Fig. 10). At Station 50, which was not surveyed in 1997, age 0+, 1+ and 2+ parr densities in 1998 were similar to those recorded in 1996 (Fig. 11) and generally lower than densities reported from the 1993 - 1995 years. In general, abundance of 2+ parr has not shown any increase, and in 4 of 5 cases densities have been declining over time (Stations 2, 9, 10, 50; Figs. 8 - 11). With the exception of age 0+ fry, it is difficult to ascertain any direct impact of the 1996 extreme high water flood event on densities of either 1+ or 2+ fish in that year (i.e. 1996). Similarly, densities of 0+ and 1+ fish obtained in the 1998 survey would not have been impacted by the 1996 flood. However, with the exception of Station 2 (Fig. 8) where the densities of these age classes were quite high in 1998, at other

stations the densities are either similar to, or lower than past values despite the increased spawning escapements that occurred in 1996 and 1997 relative to most other previous years.

Erkinaro and Gibson (1997) have shown that in at least one Newfoundland river system, juvenile salmon can undergo high rates of instream migration and thus poor site fidelity in fluvial habitats. Thus frequent habitat shifts by juvenile salmon can influence the reliability and interpretation of resulting densities obtained from electrofishing surveys. Considerable bias in abundance estimates may also result when surveys are carried out at a small number of sampling sites (Erkinaro and Gibson 1997). An additional confounding problem at Highlands River is related to high variability in stream discharge. Indeed periodic high discharge events have rendered some traditional electrofishing stations unusable while altering the habitat characteristics of others making comparisons among years for fixed stations problematic. The periodic high or extreme discharge events at Highlands River may contribute to this system being somewhat unstable in regards to the production of salmon. Recall that Highlands River has been closed to angling since 1978, and the commercial salmon fishery has been under a moratorium since 1992, yet escapement continues to remain at relatively low levels.

Appendix 1 summarizes the raw numbers of salmon fry and parr caught by sweep at each station for the period 1980 - 1981 and 1993 to 1998.

7. Adult salmon returns, sea survival and egg deposition

Adult salmon returns

There were 96 small salmon and 117 large salmon enumerated at the fish counting fence in 1998 (Table 9, Fig. 12). This represents a decrease of 76% in numbers of small salmon and 25% in numbers of large salmon in comparison with 1997. Small salmon returns were 54% lower than the previous 5-year average (1993 - 1997) of 210 fish while large salmon returns were down 9% from the 1993 - 1997 mean of 129 salmon. Over the 9 years for which salmon return information is available (Table 9), small salmon have made up 61.7% of the returns. In 1998, however, small salmon contributed 45% of the total run. We note that over 60 years ago Belding (1937) indicated that south west coast Newfoundland rivers (Great Codroy, Grand Bay, Crabb's, Middle Barachois, Robinson's, and Fishell's) were similarly characterized by a *"high proportion of grilse"* (24 - 46%), few 3SW salmon and a high proportion of repeat spawning fish. By comparison with current information, grilse (small salmon mostly 1SW fish) appear somewhat more numerous in recent years although some 3SW fish are still present and many large salmon are indeed previous spawners.

Sea survival

The low return of small salmon in 1998 appears to be a direct consequence of the reduced numbers of smolts that emigrated from Highlands River in 1997 (see Table 7) and a 56% reduction in marine survival to the 1SW stage over the previous year (Table 10). Given the high returns of small salmon in 1997, 2SW large salmon returns in 1998 were expected to have been higher than that which materialized. Estimates of the survival of the 1996 smolt class to large salmon returns and 2SW returns in 1998 were 0.94% and 0.52%, respectively. Both of these values are the lowest recorded during the 1990's (Table 10). Despite major reductions in directed marine fisheries for Atlantic salmon, marine survival rates remain at disturbingly low values.

Egg deposition

Potential egg deposition by small salmon was:

3088 eggs per fish x 96 small salmon x 0.461 proportion females = 136,663 eggs

Potential egg contribution from large salmon was:

9175 eggs per fish x 117 large salmon x 0.695 proportion females = 746,065 eggs

Total potential egg deposition was: 882,728 of which large salmon contributed 84.5%.

Thus 58.9% of the conservation spawning requirement was achieved in 1998 (882,728/1,498,475 = 58.9%), a decrease of 43.7% from that attained in 1997, and 21.3% below the average conservation requirement obtained over the previous 5 years (1993 - 1997: 74.9%). Table 11 and Figure 12 summarize updated information on egg depositions at Highlands River for all years in which fish counting fences have been operated.

In the above evaluation, only the numbers of small and large salmon returning to Highlands River in 1998 were known with certainty. To account for some of the uncertainty in the potential egg deposition that occurred, we assumed a coefficient of variation of 20% around the fecundity and percentage females of both small and large salmon components and recalculated the estimated egg depositions using 1000 realizations from a uniform distribution. Results are illustrated in Figure 13.

Based on this level of variation in fecundity and percentage females, the corresponding 5^{th} and 95^{th} percentiles of the percentage of the conservation requirement met varied from 46.1 to 73.8%.

8. Outlook for 1999

Based upon the low smolt production in 1998, returns of small salmon, which are predominantly 1SW fish, in 1999 will likely be low. Applying the range in survival rates from smolts to small salmon over the past 5 years (1.42 - 3.21%) to the number of smolts in 1998 (5922), small salmon returns in 1999 could vary anywhere from 84 to 190. Similarly, from the 6776 smolts that emigrated in 1996 and the range in marine survival to large salmon over the past four years (0.94 - 1.35%), 64 to 91 large salmon could return in 1999. The 'worst' and 'best' case scenarios from the above exercise would mean that 35 to 57% of the conservation requirement could be achieved.

To achieve 100% of the conservation requirement, based upon the average egg deposition contribution from small and large salmon respectively over the past 6 years (1993 - 1998), marine survival rates approximating 4.3% for small salmon returns from 1998 smolts and 2.6% for large salmon returns from the 1997 smolt class would be required. Neither of these values have been recorded at Highlands River during the years that the fish counting fence has been in operation.

Assuming that the 1996 flood event also affected underyearlings that year as suggested by the electrofishing surveys, then smolt production in 1999 would still be expected to be low. This is because the majority of smolts have a river age of 3+ years and this age class in 1999 were underyearlings back in 1996. In the absence of other larger scale environmental impacts, higher smolt production would be expected in the year 2000 resulting from spawners in 1996 when an estimated 79% of the conservation requirement was achieved.

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Table 1 Summary of fish counting fence operation dates at Highlands River, SFA 12, Labrador

Year	Smolt counts		Adult salmon counts	
	Start	Finish	Start	Finish
1990	May 1	June 20	May 1	Oct 13
1991	April 27			Sept 9
1992	May 22			Sept 20
1993	May 19	June 19	June 19	Sept 29
1994	May 19	June 21	June 22	Oct 13
1995	May 14	June 9	June 12	Oct 28
1996	April 29	June 14	June 14	Oct 22
1997	May 22	July 14	June 20	Dec 3
1998	May 9	June 13	June 14	Oct 29

Table 2. Summary of the annual maximum instantaneous discharge values and frequency of 'high' water events at Highlands River, Newfoundland, 1982 - 1998.

Year	Month	Day	Maximum Instantaneous Discharge m^3/sec	Number of times per year mean daily discharge exceeded 36 m^3/sec *
1982	Apr	30	71.6	3
1983	Aug	7	119.0	2
1984	Feb	6	28.8	0
1985	May	19	46.3	0
1986	Jan	28	122.0	1
1987	Nov	21	57.5	0
1988	Nov	29	58.0	0
1989	Nov	16	33.2	0
1990	Dec	9	77.7	1
1991	Oct	8	29.7	0
1992	May	14	36.0	0
1993	Apr	23	49.7	1
1994	Apr	8	53.5	0
1995	Nov	9	41.4	0
1996	Feb	18	127.0	1
1997	Jan	26	34.6	0
1998	Mar	11	56.8	1

* 36 m^3/sec is approximately one-half of an extreme high water event for the Highlands River drainage

Table 3. Summary of biological characteristics for Atlantic salmon samples from Highlands River, Newfoundland (SFA 13). Specimens of small and large salmon were obtained from sampling kelts when they were leaving the river in the spring of the year.

		Fork length (mm)					Whole weight (g)					River age (y)					Sex Ratio	
Lifestage	Year	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max	N	% female
Smolt	1980	343	132	12.5	100	173	344	22.0	5.9	8.7	44.4	337	2.80	0.47	2	4	330	66
	1981	265	127	9.8	94	159	252	19.5	4.2	9.3	38.0	261	2.89	0.54	2	5	234	75
	1982	329	131	16.5	83	180	329	21.1	7.2	5.4	48.0	324	2.92	0.51	2	5	287	70
	1994	168	123	16.9	96	291	167	16.5	4.5	7.9	31.8	164	3.21	0.52	2	4	167	63
	1995	181	129	12.7	102	189	180	20.3	6.1	10.7	54.0	178	3.44	0.64	2	5	181	64
	1996	240	127	12.8	85	171	237	19.3	5.7	5.3	43.7	239	2.88	0.51	2	4	209	67
	1997	138	129	11.6	102	165	138	20.2	5.5	11.3	39.9	138	2.92	0.44	2	4	138	63
	1998	127	136	10.8	108	169	127	23.0	5.3	13.0	41.0	126	3.03	0.31	2	4	69	62
TOTAL		1791	129	13.7	83	291	1774	20.4	6.0	5.3	54.0	1767	2.97	0.54	2	5	1615	67
Small	1980	34	536	48.6	390	595						34	2.97	0.39	2	4	34	41
	1981	14	552	37.4	490	620						14	2.86	0.36	2	3	14	57
	1982	28	527	33.8	450	600	28	1093	253.8	500	1700	29	3.24	0.51	2	4	26	73
	1994	18	541	45.4	445	600						18	3.17	0.38	3	4	18	28
	1995	8	563	31.1	515	600						8	3.00	0.00	3	3	8	63
	1996	54	529	36.2	400	600						54	3.15	0.49	2	4	54	48
	1997	84	556	46.5	420	625						84	3.07	0.60	2	4	84	39
	1998	27	544	39.5	465	625						27	3.07	0.55	2	4	27	70
TOTAL		267	543	43.2	390	625	28	1093	253.8	500	1700	268	3.09	0.51	2	4	265	49
Large	1980	26	896	111.6	710	1100						26	2.62	0.50	2	3	26	65
	1981	43	820	87.7	630	1050						43	2.84	0.37	2	3	43	86
	1982	12	845	102.3	650	1100	12	4100	1009.1	2200	6000	12	2.92	0.29	2	3	11	55
	1994	18	782	82.9	645	1000						18	3.06	0.24	3	4	18	56
	1995	31	782	78.9	630	1000						31	2.90	0.40	2	4	31	77
	1996	40	808	90.7	645	1030						40	2.98	0.28	2	4	40	70
	1997	87	811	90.4	635	1120						87	2.90	0.40	2	4	87	70
	1998	27	819	90.0	630	1035						27	2.74	0.45	2	3	27	67
TOTAL		284	817	94.5	630	1120	12	4100	1009.1	2200	6000	284	2.87	0.40	2	4	283	71

Table 4. Estimated total numbers of smolts in each age class at Highlands River, Bay St. George, Newfoundland. The percentage in each age class is shown in the lower part of the table. Information for 1993 was taken directly from Reddin and Whalen (1998) and could not be reconciled with electronic records.

Year	River age (y) 2	3	4	5	6	Total
1980	3426	11151	451	0	0	15028
1981	3152	11467	1093	127	0	15839
1982	2142	9174	1027	37	0	12380
1993	(2376)	(6661)	(789)	(80)	(80)	(9986)
1994	515	7236	2752	0	0	10503
1995	547	6141	5059	413	0	12160
1996	2440	8965	978	0	0	12383
1997	935	5448	393	0	0	6776
1998	190	5359	373	0	0	5922

Year	Percent in each age class 2	3	4	5	6	Number of samples
1980	22.8	74.2	3.0	0	0	337
1981	19.9	72.4	6.9	0.8	0	261
1982	17.3	74.1	8.3	0.3	0	324
1993	(23.8)	(66.7)	(7.9)	(0.8)	(0.8)	?
1994	4.9	68.9	26.2	0	0	164
1995	4.5	50.5	41.6	3.4	0	178
1996	19.7	72.4	7.9	0	0	239
1997	13.8	80.4	5.8	0	0	138
1998	3.2	90.5	6.3	0	0	126
Total *	15.3	72.4	11.7	0.5	-	1767

* excluding 1993

Table 5. River age distribution (%) of small and large salmon sampled as kelt leaving Highlands River, Bay St. George, Newfoundland.

Small salmon

Year	Percent in each age class 2	3	4	5	Number of samples
1980	8.8	85.3	5.9	0	34
1981	14.3	85.7	0	0	14
1982	3.6	67.9	28.6	0	28
1993	-	-	-	-	-
1994	0	83.3	16.7	0	18
1995	0	100.0	0	0	8
1996	5.6	74.1	20.4	0	54
1997	14.3	64.3	21.4	0	84
1998	11.1	70.4	18.5	0	27
Total	9.0	73.4	17.6	0	267

Large salmon

Year	Percent in each age class 2	3	4	5	Number of samples
1980	38.5	61.5	0	0	26
1981	16.3	83.7	0	0	43
1982	8.3	91.7	0	0	12
1993	-	-	-	-	-
1994	0	94.4	5.6	0	18
1995	13	83.9	3.2	0	31
1996	5.0	92.5	2.5	0	40
1997	13.8	82.8	3.5	0	87
1998	25.9	74.1	0	0	27
Total	15.1	82.8	2.1	0	284

Table 6. Sea age distribution of small and large salmon sampled as outmigrating kelt at Highlands River, Newfoundland, where 1SW, 2SW and 3SW refer to virgin sea ages.

	Small salmon (Fork length < 63 cm)				Large salmon (Fork length >= 63 cm)				
Year	Number	1SW	2SW	PS	Number	1SW	2SW	3SW	PS *
1980	34	34			26		13	5	8
1981	14	14			43	2	37	2	2
1982	28	28			12	1	10		1
1994	18	18			18		14		4
1995	8	8			31	5	24	1	1
1996	54	53	1		40		24		16
1997	84	77	1	6	87	1	47	3	36
1998	27	27			27	2	15	1	9
Total	267	259	2	6	284	11	184	12	77

* Of the 77 previous spawning large salmon sampled, 66 (85.7%) had a virgin sea age of 2, 10 (13.0%) had a virgin sea age of 1, while one (1.3%) had a virgin sea age of 3.

Table 7. Numbers of downstream migrating fish enumerated at the Highlands River fish counting fence.

	Numbers of fish migrating downstream							
	Atlantic salmon			Brook trout				
Year	Parr	Smolt	Kelt	Resident	Sea-run	Smelt	Eels	Killifish
1980	339	15028	73	796	814	35	1486	4
1981	199	15839	63	702	514	13	929	5
1982	375	12380	59	1293	0	19	439	0
1993	877	9986	90	731	0	43	162	0
1994	1345	10503	57	759	204	16	188	0
1995	152	12160*	43	33	503	13	7	0
1996	1111	12383	110	236	303	16	10	0
1997	196	6776	192	56	457	41	9	0
1998	133	5922	69	2	84	6	8	0

* The 1995 smolt count was adjusted to account for a washout that occurred during the latter part of the smolt run. The unadjusted count was 9009 smolts.

Smelt = *Osmerus mordax*
Killifish = *Fundulus diaphanus*

Table 8. Summary of observations made on potential avian predation at Highlands River, Bay St. George, Newfoundland, May 28 - June 11, 1998. Observations were made approximately one-half km downstream of the fish counting fence. When feeding activities were noted but actual food items could not be confirmed, the food column has been left blank.

Species/Group	Activities observed				
	Flying	Standing	Swimming	Feeding	Food
Sea gull	174	7	14	13	
Common merganser	19		44	37	smolt
Red breasted merganser			1		
Ring necked duck			1	1	
Mallard duck			2		
Kingfisher	20	1			
Tern	16			3	smolt/trout
Cormorant		1		2	
Crow	17	1		1	
Raven	1				
Hawk	3				

Table 9. Numbers of upstream migrating fish enumerated at the Highlands River fish counting fence.

Year	Numbers of fish migrating upstream				
	Atlantic salmon			Brook trout	
	Small	Large	% small	Resident	Sea-run
1980	82	55	59.9	0	10
1981	127	29	81.4	0	11
1982	100	56	64.1	0	15
1993	137	78	63.7	0	63
1994	145	148	49.5	74	208
1995	172	120	58.9	2	16
1996	199	142	58.4	0	10
1997	398	157	71.7	0	6
1998	96	117	45.1	0	0

Table 10. Estimated survival of smolts in year i to small salmon in year i + 1, and to large salmon or 2SW salmon in year i + 2, at Highlands River, Newfoundland.

Year (i)	Number of Smolts (year i)	% survival to small salmon (year i + 1)	% survival to large salmon (year i + 2)	% survival to 2SW salmon (year i + 2)
1980	15028	0.85	0.37	0.31
1981	15839	0.63	-	-
1993	9986	1.45	1.20	0.93
1994	10503	1.64	1.35	0.81
1995	12160	1.64	1.29	0.70
1996	12383	3.21	0.94	0.52
1997	6776	1.42	-	-

Table 11. Values used in the determination of the level of conservation requirements met at Highlands River, Bay St. George, Newfoundland, based upon an egg requirement of 1.498 million eggs.

	Small salmon				Large salmon						
Year	Number	% female	No. of eggs per fish	No. of eggs	Number	% female	No. of eggs per fish	No. of eggs	Total No. of eggs small and large salmon	% contribution from large salmon	% conservation level achieved
1980	82	0.554	2890	131287	55	0.75	10151	418729	550016	76.1	36.7
1981	127	0.554	2890	203335	29	0.75	10151	220784	424119	52.1	28.3
1982	100	0.554	2890	160106	56	0.75	10151	426342	586448	72.7	39.1
1993	137	0.461	3088	195029	78	0.695	9175	497377	692406	71.8	46.2
1994	145	0.461	3088	206417	148	0.695	9175	943741	1150158	82.1	76.8
1995	172	0.461	3088	244854	120	0.695	9175	765195	1010049	75.8	67.4
1996	199	0.461	3088	283290	142	0.695	9175	905481	1188771	76.2	79.3
1997	398	0.461	3088	566580	157	0.695	9175	1001130	1567710	63.9	104.6
1998	96	0.461	3088	136663	117	0.695	9175	746065	882728	84.5	58.9

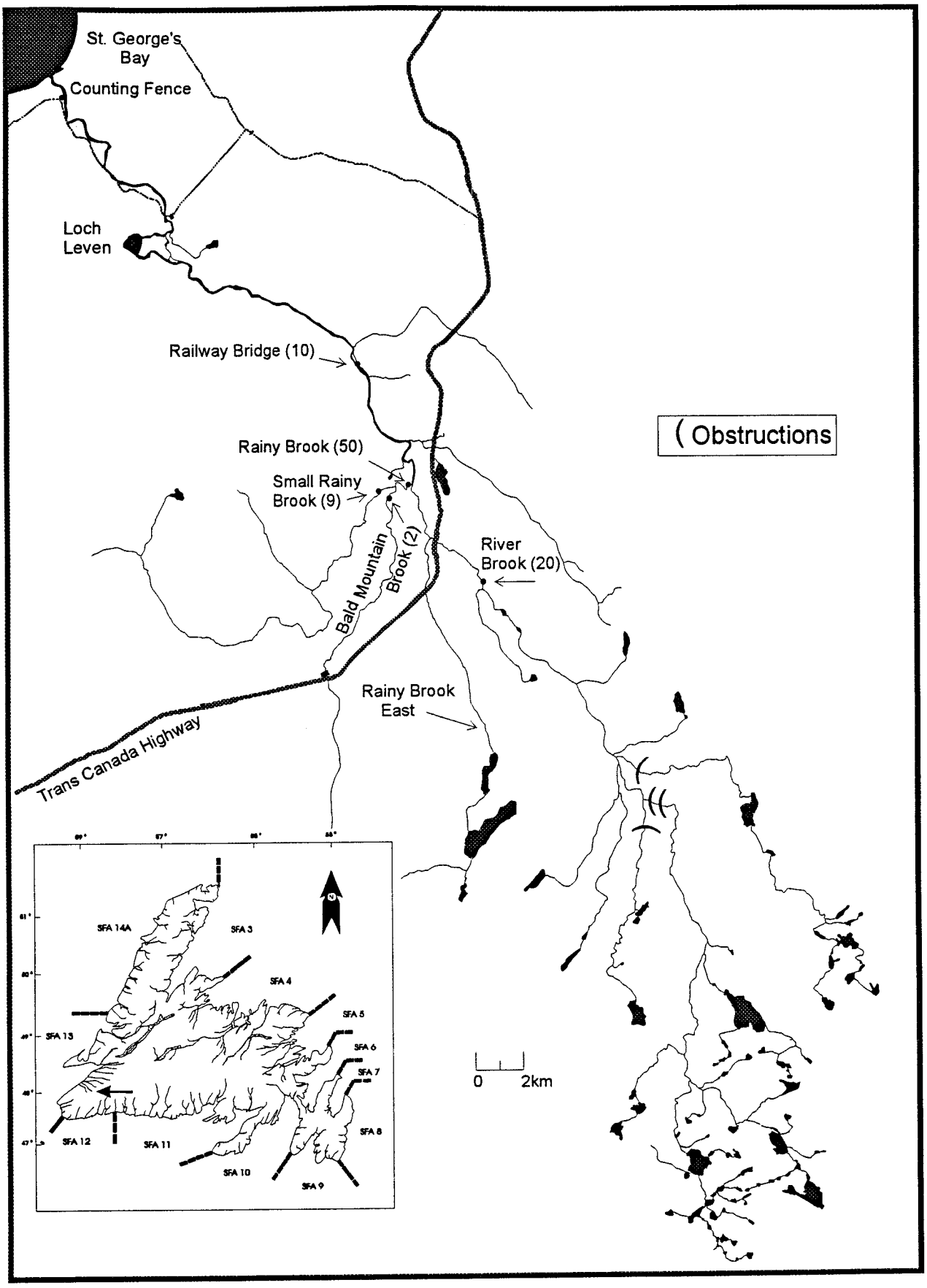

Fig. 1. Location of Highlands River, Samon Fishing Areas and electrofishing stations.

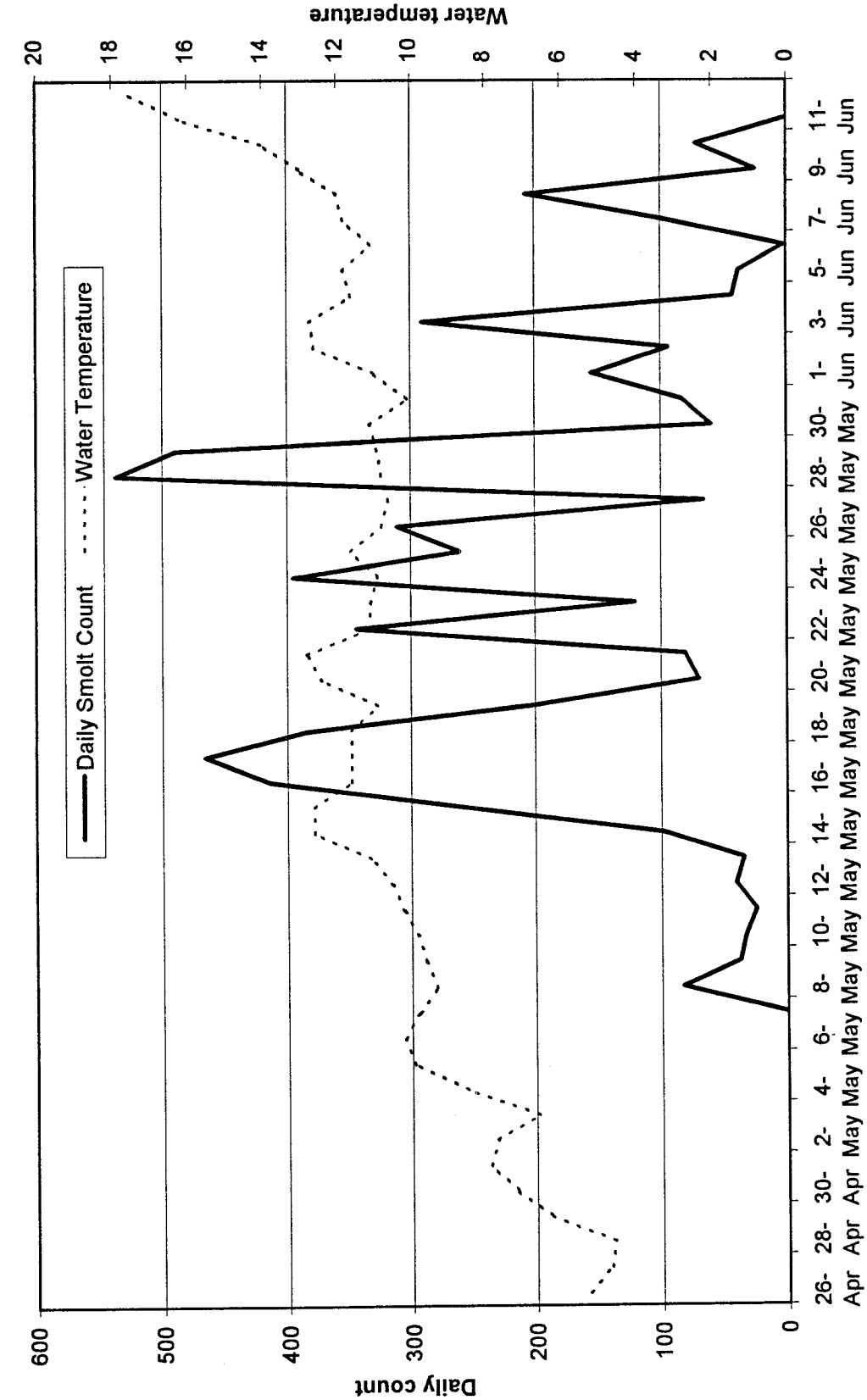

Fig. 2. Highlands River daily smolt counts and mean water temperature, 1998.

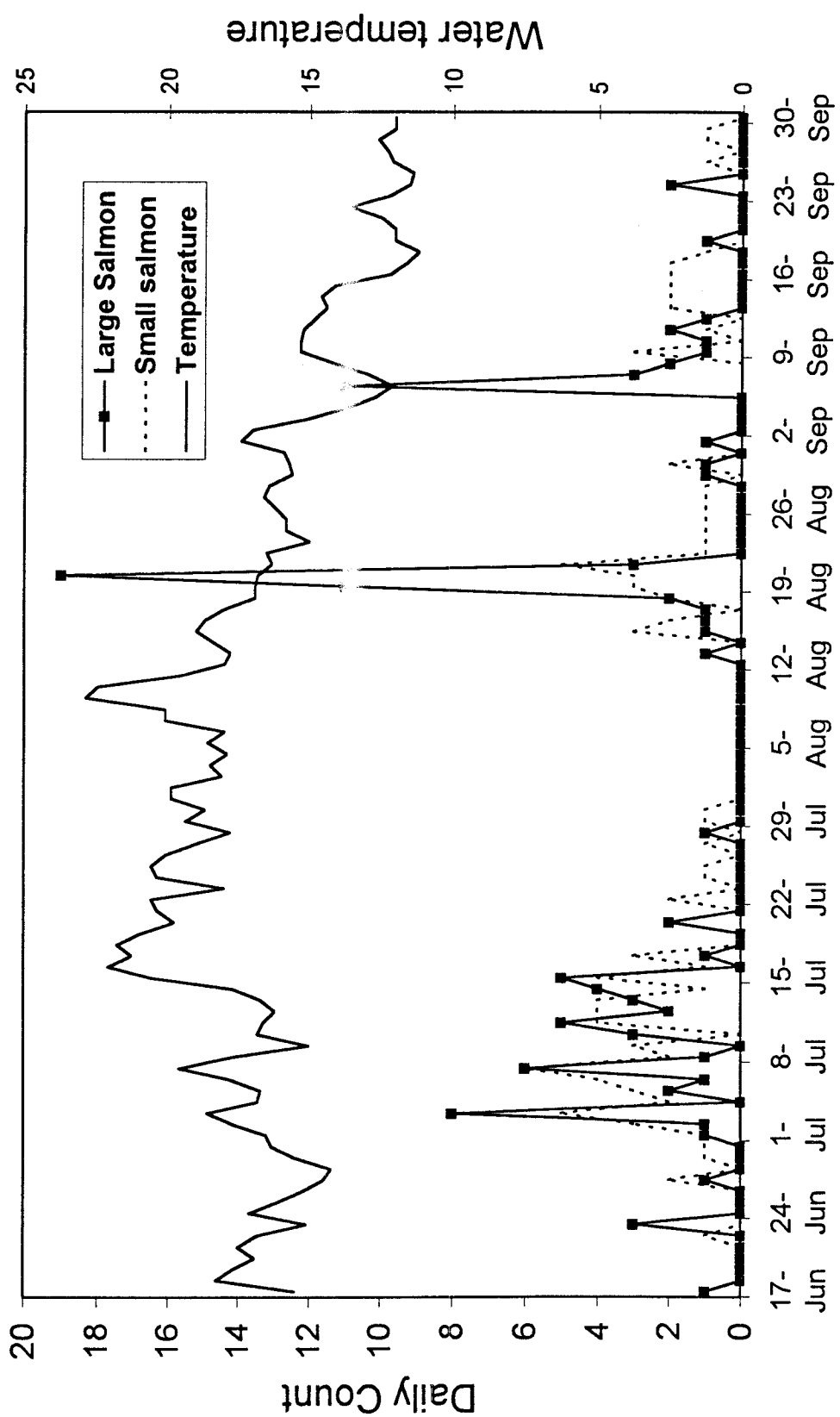

Fig. 3. Highlands River small and large salmon counts, by day, and mean water temperatures, 1998.

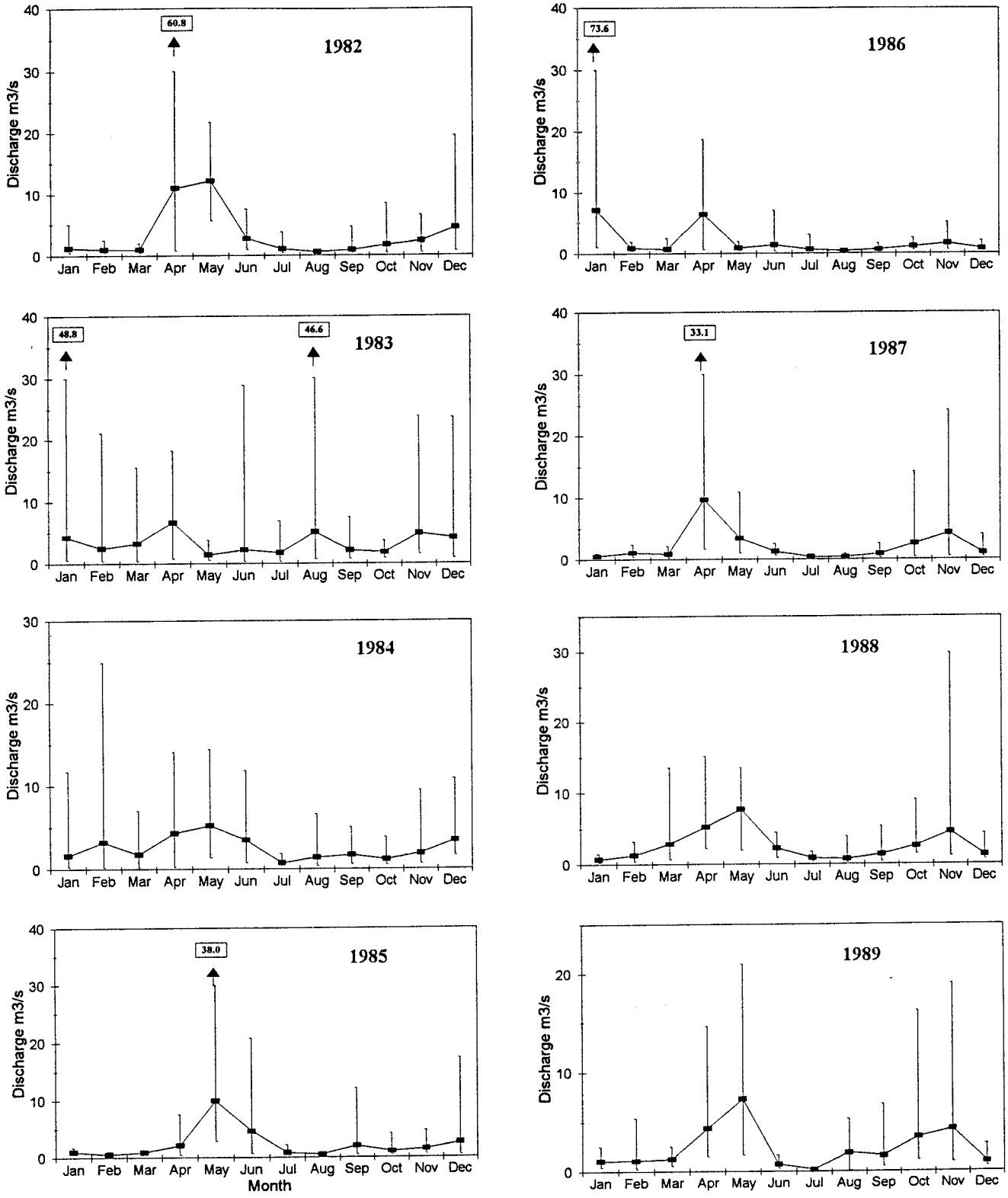

Fig. 4. Summary of maximum, minimum and mean daily discharge by month for Highlands River, Newfoundland, 1982 - 1989. Mean values are joined by a continuous line. Maximum values exceeding 30 m ^{3}/s are shown as a separate box for the respective months in which these high values occurred.

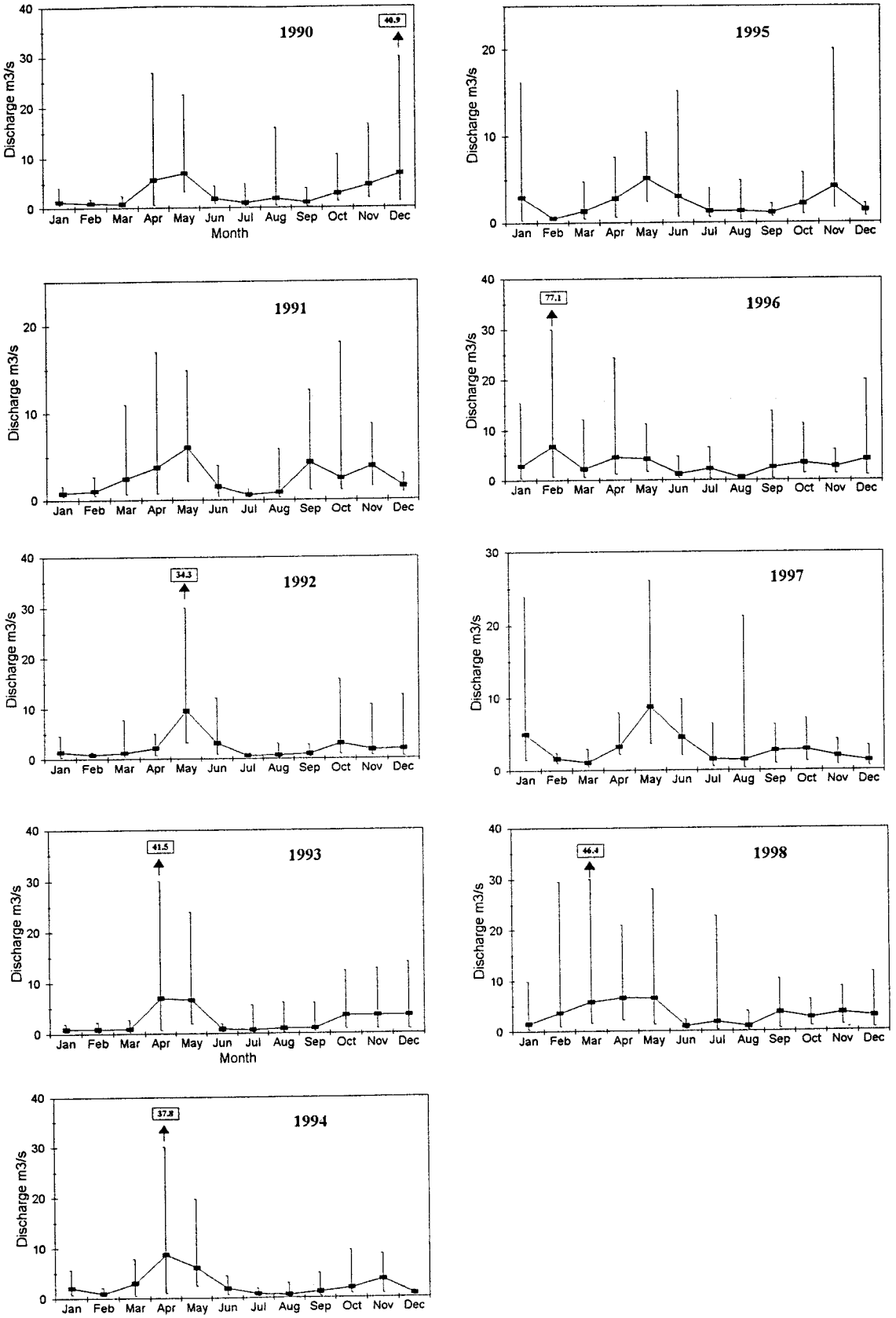

Fig. 4, continued. Summary of maximum, minimum and mean daily discharge by month for Highlands River, Newfoundland, 1990 - 1998. Mean values are joined by a continuous line. Maximum values exceeding 30 m^3/s are shown as a separate box for the respective months in which these extreme values occurred.

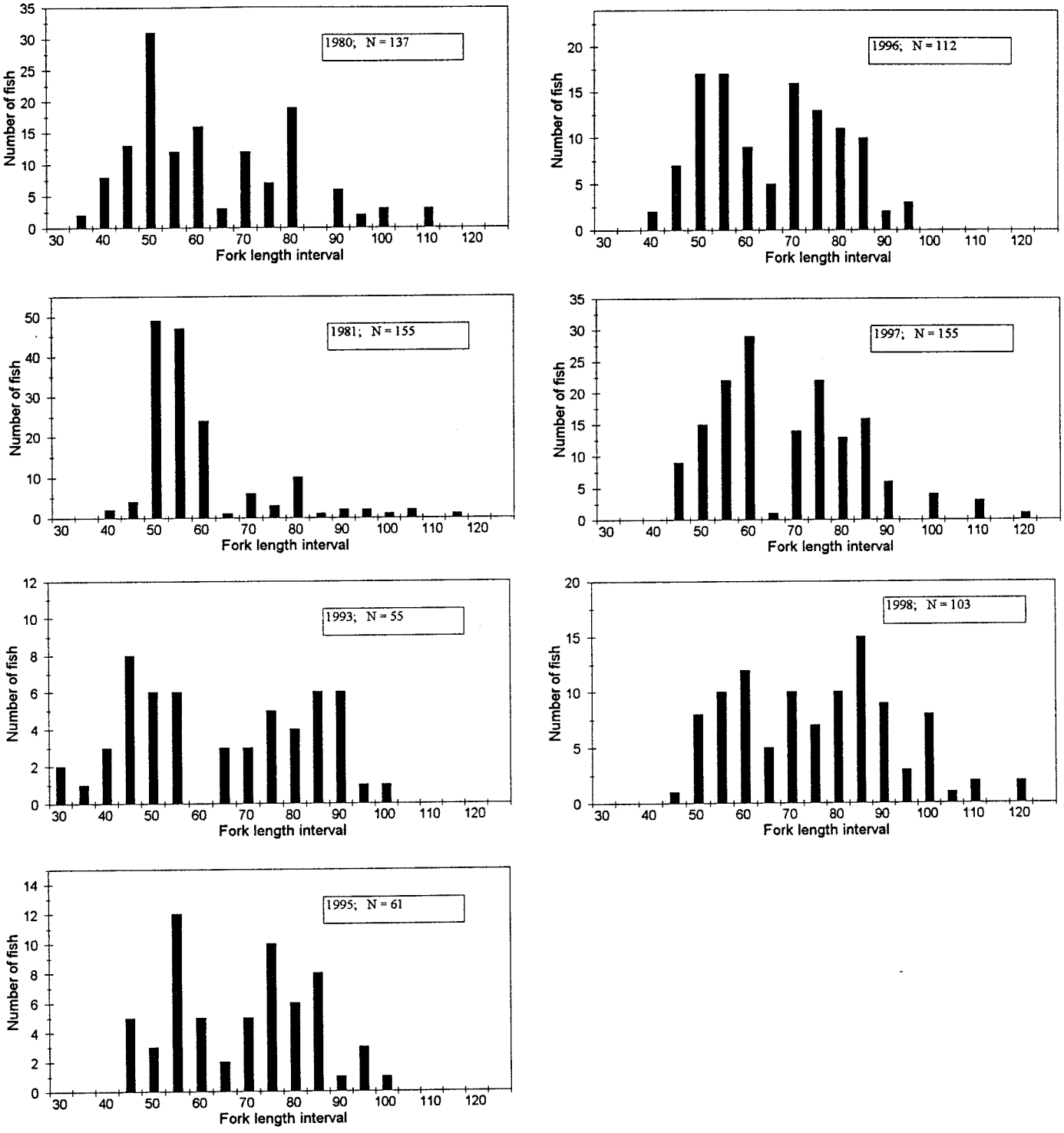

Fig. 5. Length distributions of adult Atlantic salmon estimated from fish in the fish counting fence trap at Highlands River, Newfoundland.

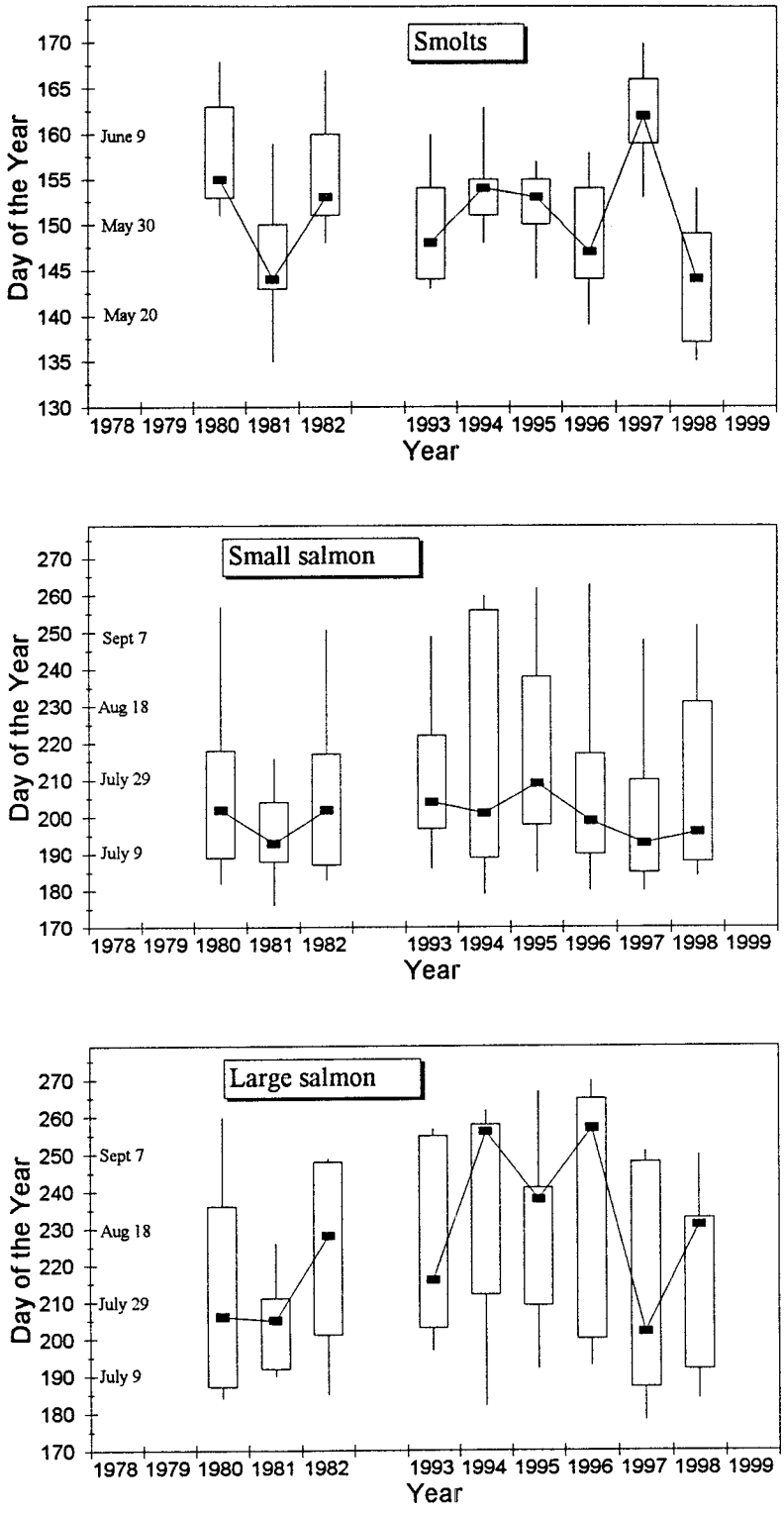

Fig. 6. Annual variation in run timing of Highlands River smolts, small and large salmon. Vertical lines represent the 10th and 90th percentiles of the day of the year of migration, the rectangle is the 25th and 75th percentiles, and the marker within the rectangle is the median run timing.

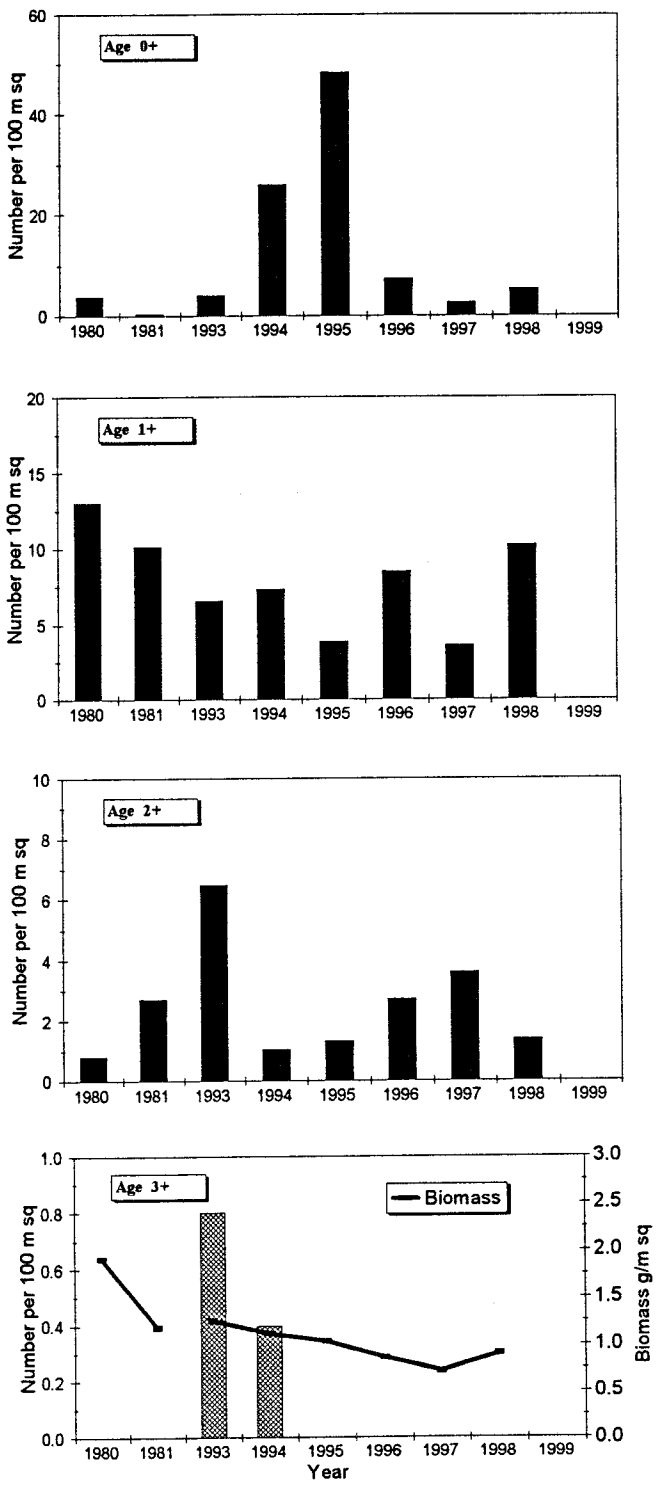

Fig. 7. Number of Atlantic salmon parr per 100 m square estimated by electrofishing at Station 20 (riffle habitat), lower River Brook, Highlands River.
The bottom panel also illustrates the overall estimated population biomass (solid line) for all age groups combined.

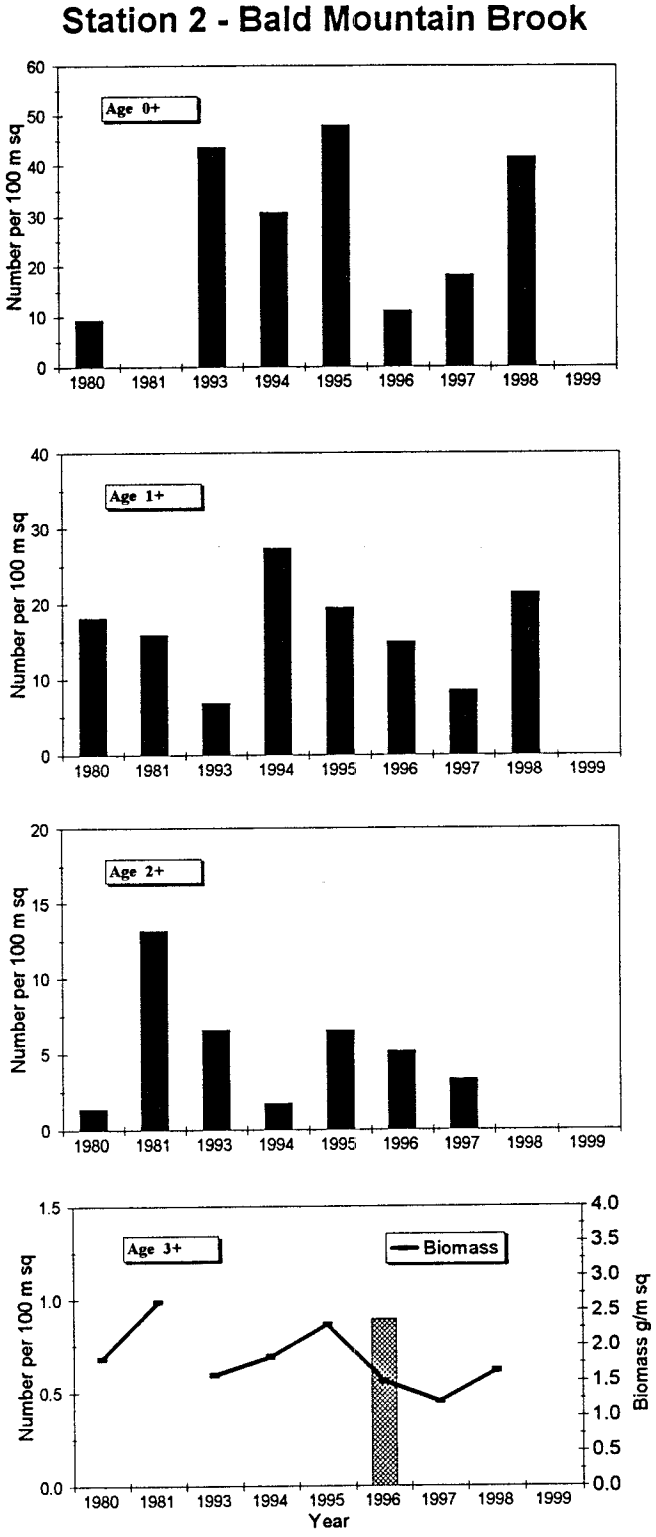

Fig. 8. Number of Atlantic salmon parr per 100 m square estimated by electrofishing at Station 2 (riffle habitat), Bald Mountain Brook, Highlands River. The bottom panel also illustrates the overall estimated population biomass (solid line) for all age groups combined.

Station 9 - Small Rainy Brook

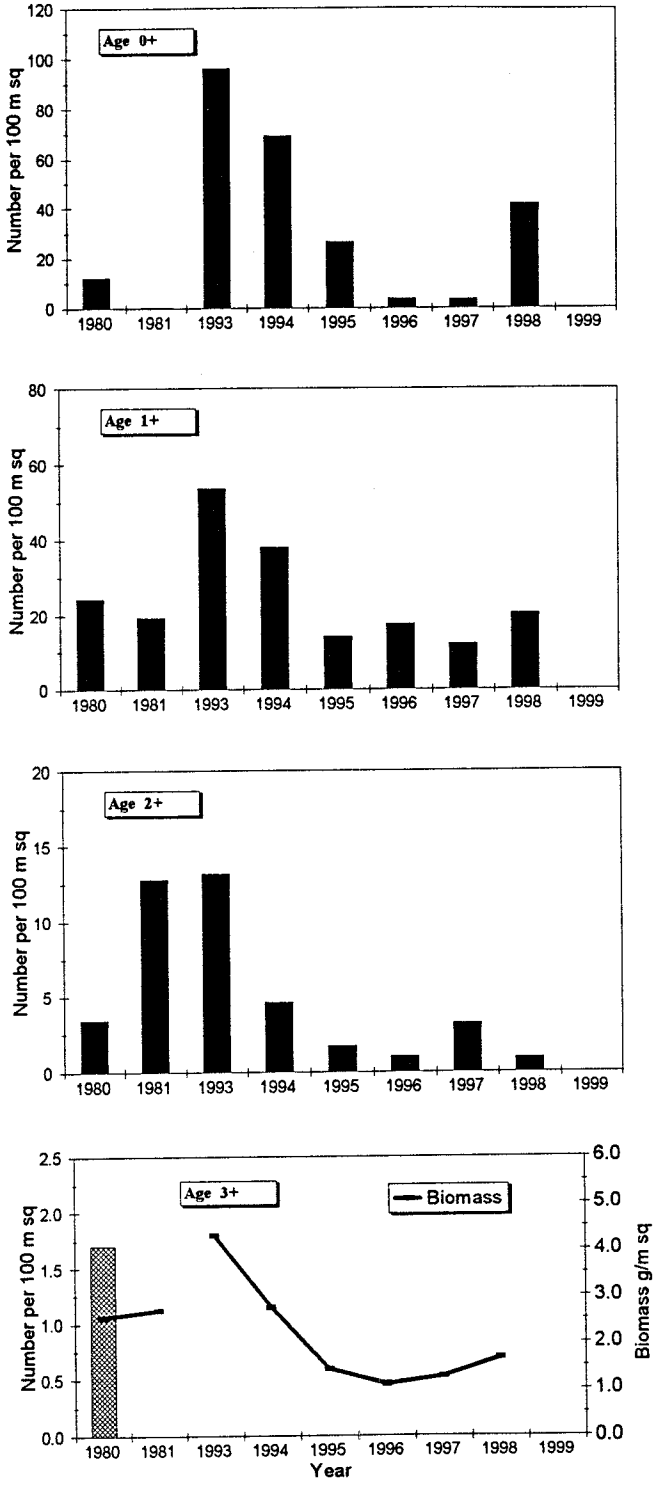

Fig. 9. Number of Atlantic salmon parr per 100 m square estimated by electrofishing at Station 9 (riffle habitat), Small Rainy Brook, Highlands River. The bottom panel also illustrates the overall estimated population biomass (solid line) for all age groups combined.

Station 10 - Railway Bridge Main River

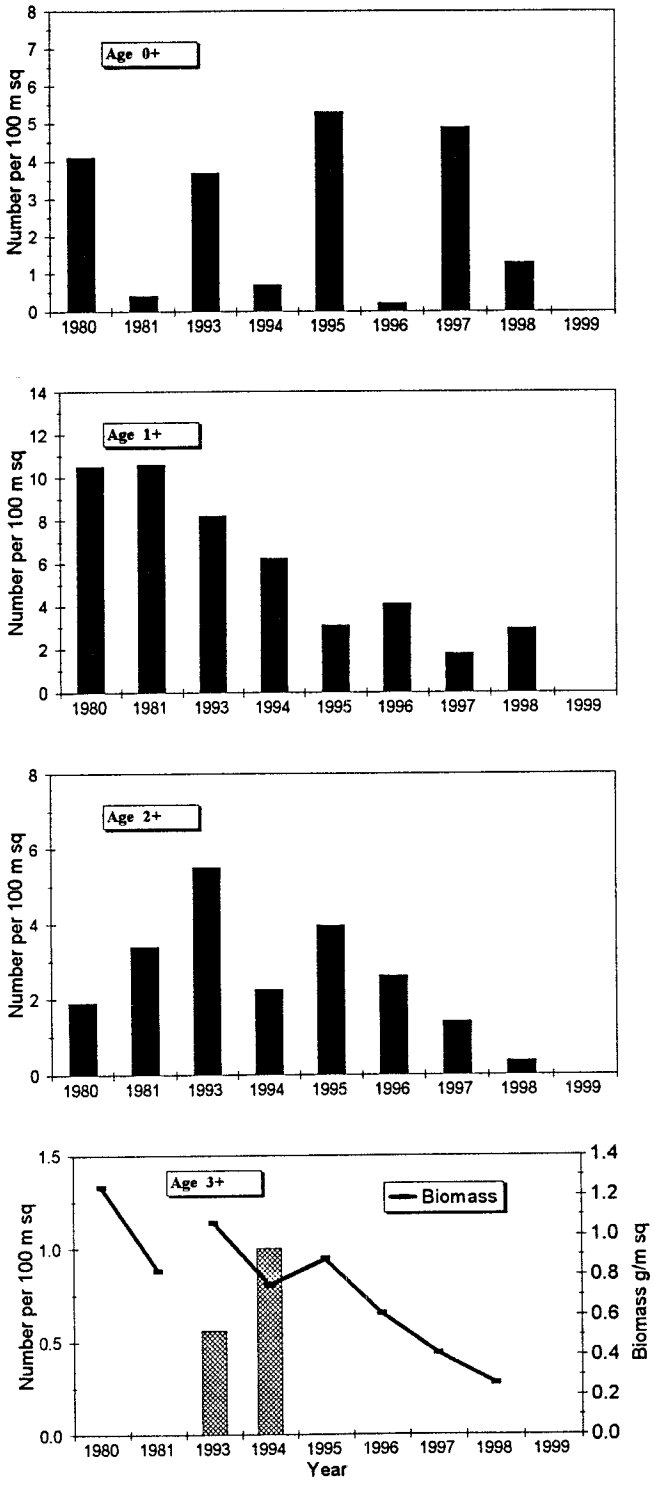

Fig. 10. Number of Atlantic salmon parr per 100 m square estimated by electrofishing at Station 10 (flat habitat), Railway Bridge, main stem Highlands River. The bottom panel also illustrates the overall estimated population biomass (solid line) for all age groups combined.

Station 50 - Main Rainy Brook

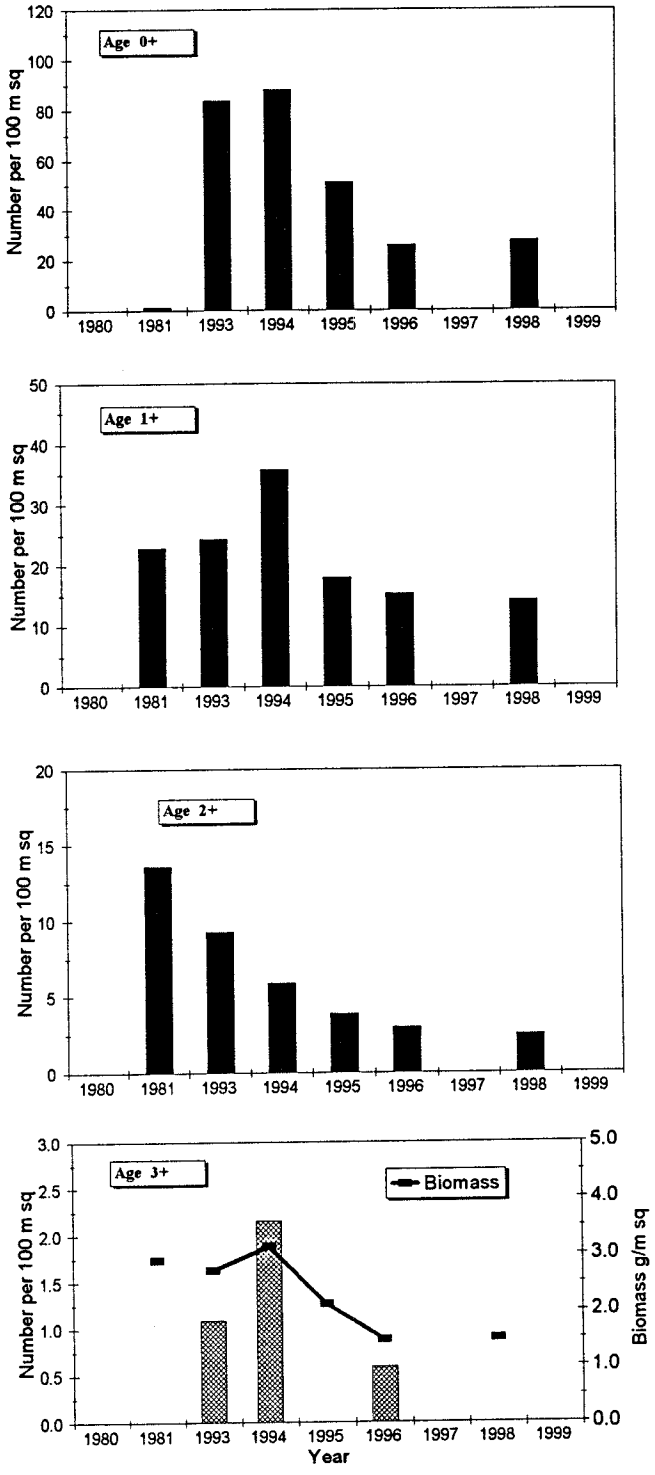

Fig. 11. Number of Atlantic salmon parr per 100 m square estimated by electrofishing at Station 50 (riffle habitat), main Rainy Brook, Highlands River.
The bottom panel also illustrates the overall estimated population biomass (solid line) for all age groups combined.

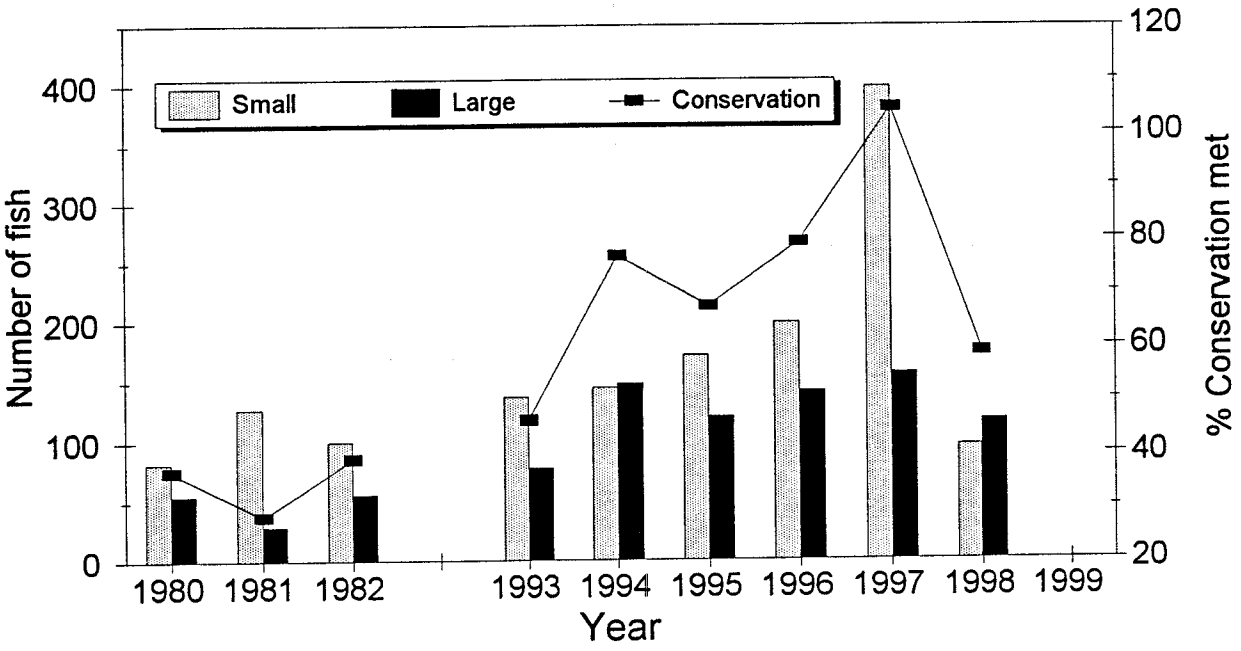

Fig. 12. Total numbers of small and large salmon returning to Highlands River, Newfoundland, along with the estimated percentage of the conservation requirement met.

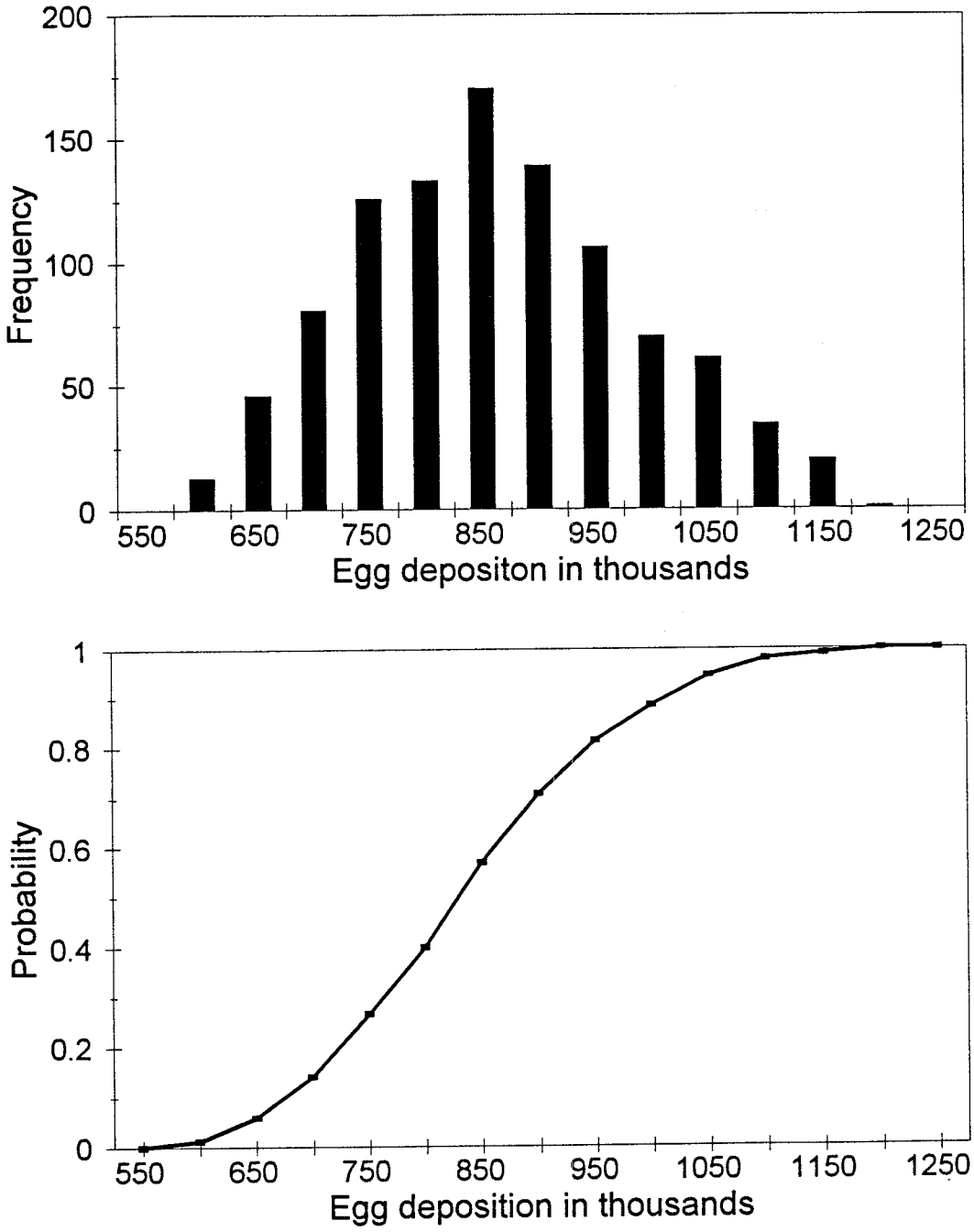

Fig. 13. Frequency distribution of the estimated egg depostion at Highlands River, 1998 (upper panel) and the corresponding probability distribution (lower panel). The analysis was done with 1000 realizations assuming a 20% coefficient of variation around both the fecundity and percentage females of the small and large salmon components. Egg depositions are in thousands showing the lower bounds of each interval.

Appendix 1. Summary of the raw numbers of juvenile Atlantic salmon parr caught during repeated electrofishing surveys at Highlands River, Newfoundland, 1980 - 81 and 1993 - 1998.

Station 2: Bald Mountain Brook

Sweep	1980	1981	1993	1994	1995	1996	1997	1998
1	65	49	25	37	43	26	16	40
2	51	19	18	15	18	12	6	29
3	22	11	12	12	12	5	13	11
4	25	7	5	2	4	0	2	9
5	-	-	-	-	-	-	3	-
Total	163	86	60	66	77	43	40	89

Station 20: Lower River Brook

Sweep	1980	1981	1993	1994	1995	1996	1997	1998
1	58	83	38	53	131	24	11	45
2	48	36	30	40	63	27	10	13
3	60	35	20	25	30	15	2	10
4	52	14	7	12	15	3	2	3
5			6	-	-	-	-	-
Total	218	168	101	130	239	69	25	71

Station 9: Small Rainy Brook

Sweep	1980	1981	1993	1994	1995	1996	1997	1998
1	127	50	98	122	56	30	25	68
2	96	21	56	70	17	16	19	44
3	59	11	48	40	15	10	7	28
4	41	14	40	23	6	5	2	21
Total	323	96	242	255	94	61	53	161

Station 50: Main Rainy Brook

Sweep	1980	1981	1993	1994	1995	1996	1997	1998
1	-	-	68	110	44	30	-	42
2	-	-	66	56	22	19	-	31
3	-	-	26	29	14	8	-	25
4	-	-	16	22	9	6	-	23
Total	-	-	176	217	89	63	-	121

Station 10: Railway Bridge Main River

Sweep	1980	1981	1993	1994	1995	1996	1997	1998
1	193	56	50	32	50	20	22	16
2	74	30	30	9	13	7	10	9
3	90	61	6	4	5	5	11	0
4	0	0	6	7	3	4	2	-
5	-	-	10	1	-	-	-	-
Total	357	147	102	53	71	36	45	25

STOCK: Highlands River (SFA 13) **Drainage area**: 183.1 km^2 (accessible)

CONSERVATION REQUIREMENT: 1.5 million eggs calculated as fluvial area x 2.4 eggs/m^2 and lacustrine area x 368 eggs hectare.

Year	1993	1994	1995	1996	1997	1998	Min[1]	Max[1]
Total returns to the river								
Small	137	145	172	199	398	96	82	398
Large	78	148	120	142	157	117	29	157
Recreational harvest (small salmon)				**CLOSED SINCE 1978**				
Retained	-	-	-	-	-	-	21	47
Released	-	-	-	-	-	-	-	-
Recreational harvest (large salmon)				**CLOSED SINCE 1978**				
Retained	-	-	-	-	-	-	8	18
Released	-	-	-	-	-	-	-	-
Spawners								
Small	137	145	172	199	398	96	82	398
Large	78	148	120	142	157	117	29	157
Egg conservation requirement								
% met	46	77	67	79	105	59	28	105
Smolt count	9986	10503	12160	12383	6776	5922	5922	15839
% Sea survival (adult return year)								
Small	-	1.5	1.6	1.6	3.2	1.4	0.6	3.2
Large	-	-	1.2	1.4	1.3	0.9	0.4	1.4

[1] Min and Max are for the period of record since 1974.

Data and methodology: Counts of smolt and adult salmon were obtained with a fish counting fence in 1980-82 and in 1993-98. Juvenile densities were measured at 5 stations in 1998 to determine changes in juvenile salmon production. Sea survival is calculated for small salmon returning in year i + 1 and large salmon returning in year i + 2 by dividing the number of returning adults by the number of smolts in year i.

State of the stock: The number of large salmon has increased since the closure of the commercial fishery although the number returning in 1998 was down considerably from 1997. Small salmon returns in 1998 were 76% lower than the previous year. Conservation requirements were achieved in 1997 but decreased to 59% (46% - 74%) in 1998. Juvenile densities had declined substantially in the summers of 1996-97 in association with a severe flood in the winter of 1996.

Forecast: The conservation requirement will likely not be met in 1999 owing to continued low production of smolts in 1998. Based upon the average egg deposition contribution from small and large salmon, respectively, over the past 6 years (1993 – 1998), marine survival rates approximating 4.3% for small salmon returns from the 1998 smolt class and 2.6% for large salmon returns from the 1997 smolt class would be required. To date, neither of these values have been recorded at Highlands River during the years in which the fish counting fence has been in operation.