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Status of Atlantic salmon (*Salmo salar* L.) in Highlands River, Bay St. George (SFA 13), Newfoundland in 1997.

by

D.G. Reddin and R.R. Whalen
Science Branch
Department of Fisheries and Oceans
P.O. Box 5667
St. John's NF A1C 5X1

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Abstract

The status of Atlantic salmon in Highlands River in 1997 was determined from the number of salmon counted through separate portable fish counting weirs (fences) for smolt and adult salmon. The two counting fences were located on the main stem just above head of tide. The assessment was conducted in response to major management changes that were first introduced in Bay St. George in 1978, further restrictions which were made in 1992 and continued in 1993-97 with the moratorium on commercial salmon fishing in insular Newfoundland. Adult returns in 1997 were 398 small salmon and 157 large salmon. The 1997 smolt count of 6,776 is the lowest on record for 1980-82 and 1993-97. The smolt and adult counts are complete and biological characteristics data were collected from downstream migrating kelt. Sea survival for the 1995 smolt class was 2.9% including the small salmon returning in 1996 and large salmon in 1997. Sea survival for the 1996 smolt class was 3.2% for the small salmon returning in 1997; the highest on record (large salmon will return in 1998). The proportion of the conservation requirement achieved for Highlands River in 1997 was 101%. This is the highest in the time series. On average for the period of 1980-82 and 1993-97, Highlands River achieved 59% of its conservation requirements.

Population estimates of juvenile salmon were made at 5 sites. At all stations, underyearlings were fewer than in 1995 and biomass was lower. An exceptionally high flood in February of 1996, prior to emergence of fry, moved massive amounts of substrate and was likely to have caused high mortalities on salmon parr and especially on the 1996-year class. Densities of the older parr were somewhat lower than previous values but were not affected to the same degree.

Résumé

L'état du saumon de l'Atlantique de la rivière Highlands en 1997 a été déterminé à partir de dénombrements de saumoneaux et d'adultes effectués à des barrières de comptage portables. Les deux barrières étaient situées sur le cours principal, tout juste en amont de la limite de marée. Cette évaluation a été réalisée en réaction aux importantes modifications apportées au régime de gestion de la baie St. George en 1978, à d'autres restrictions imposées en 1992 et au maintien, de 1993 à 1997, du moratoire sur la pêche commerciale du saumon de Terre-Neuve. Les remontées d'adultes ont atteint 398 petits saumons et 157 grands saumons en 1997. Le nombre de saumoneaux, de 6 776, est le plus faible jamais noté pour de 1980 à 1982 et de 1993 à 1997. Les dénombrements de saumoneaux et d'adultes sont complets et des données sur les caractéristiques biologiques ont été obtenues pour les saumons noirs retournant vers la mer. La survie en mer des saumoneaux de la classe de 1996 a été de 2,9 %; cela comprend les petits saumons qui sont revenus en 1996 et les grands qui sont revenus en 1997. La survie en mer des saumoneaux de la classe de 1996 a atteint 3,2 % pour les petits saumons qui sont revenus en 1997, soit la valeur la plus élevée jusqu'à maintenant (les grands saumons reviendront en 1998). Les besoins de conservation de la rivière Highlands ont été atteints à 101 % en 1997 et cette valeur est la plus élevée de la série chronologique. En moyenne, pendant les périodes de 1980 à 1982 et de 1993 à 1997, les besoins de conservation ont été atteints à 59 %.

La population de juvéniles a été estimée en 5 endroits. À toutes les stations, les poissons de moins d'un an étaient moins nombreux et la biomasse était plus faible qu'en 1995. Des hautes eaux exceptionnelles en février 1996, avant l'émergence des alevins, ont déplacé des quantités très importantes de substrat et cela a sans doute été la cause d'une mortalité élevée chez les tacons, surtout ceux de la classe de 1996. La densité des tacons plus âgés était quelque peu inférieure aux valeurs antérieures, mais elle n'a pas été affectée de façon aussi importante.

Introduction

The Highlands River is a fourth order system located on the southwest coast of Newfoundland (48° 11' 38'' N, 58° 53' 40" W), in Salmon Fishing Area (SFA) 13. 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 (Fig.1). Area of the drainage basin is 183.1 km^2 (Porter et al. 1974). The river has long been noted for a fall run of very large salmon (Palmer 1928). Due to the decline of angling success, especially of the large salmon component, the river was closed to angling in 1978, and has remained so up to the present time (Chadwick et al. 1978; Porter and Chadwick 1983; Gibson et al. 1987).

Adult spawners and smolt production have been estimated with a counting fence in 1980, 1981, 1982, and from 1993 to 1997. Juvenile salmon population estimates were made in 1980 and 1981, and from 1993 to 1997 (the 1997 study was not as thorough as in previous years as it included only five sites). The earlier studies, a decade and a half ago were undertaken partly to use the Highlands River as an index river for Bay St. George, and partly to study production of juvenile salmon related to habitat types and stock-recruit relationships. The background data have made the river useful to follow changes that have occurred since the moratorium was imposed on the salmon commercial fishery in 1992. The studies from 1993 to 1996 were undertaken under the auspices of the Cooperation Agreement for Salmonid Enhancement/Conservation (CASEC) program and Human Resources Development funded the 1997 study. The studies from 1993 to 1997 were sponsored through the Bay St. George South Area Development Association. In this paper, we examine the status of Atlantic salmon in Highlands River. Counts obtained from smolt and adult counting fences are used in conjunction with biological characteristics data to calculate total river returns and spawning escapements. Stock status is evaluated against a conservation requirement which includes salmon produced in fluvial and lacustrine habitats.

Management Measures

In 1992, a major change was introduced in the management of Atlantic salmon. A five-year moratorium was placed on the commercial fishery in insular Newfoundland, while in Labrador fishing continued under a quota. In addition, a commercial license retirement program went into effect in both insular Newfoundland and Labrador. All of these management measures were aimed at increasing spawners. Also, a moratorium on the Northern Cod Fishery was implemented in early July 1992 which should have resulted in the elimination of by-catch in cod fishing gear in SFAs 1-9. The cod fishery moratorium continued in 1997. A moratorium on cod fishing was introduced in SFAs 10-14A in 1993 and remained in effect in 1997.

Methods

UNRECORDED MORTALITIES

Complete understanding of all life history factors including mortalities is an important part of any stock assessment (Ricker 1975). Mortalities due to fishing but not recorded as part of the catch statistics have been defined as non-catch fishing mortalities (Ricker 1976). Non-catch fishing mortality should include those fish killed due to both illegal and legal fishing activities. Legal fishing mortalities of salmon in Newfoundland and Labrador include catches in food (First Peoples), recreational, sentinel, and commercial fisheries. Illegal mortalities include poaching in both the freshwater and marine environments. Illegal mortalities by their very nature are extremely difficult to quantify. An indirect method of observing the effects of illegal removals is by observation of net marks on salmon at enumeration facilities. In 1993-97, occurrences of fish with visible net marks were observed at Highlands River. These observations provide a minimum estimate of the incidence of net-marked fish. The incidence of net marks does not quantify unrecorded removals but does provide an indication that there were mortalities of Highlands River salmon prior to entering freshwater.

Due to the illegal nature of poaching no enumeration of the number of salmon caught illegally on Highlands River is possible. However, these additional removals potentially result in a lower than indicated number of spawners. Thus, the number of spawners should be regarded as potential.

SMOLT AND ADULT SALMON COUNTS

Standard smolt and adult counting fences were installed according to the description in Anderson and McDonald (1978). The smolt fence was installed on May 23 to catch downstream migrating fish and was operated until July 14 (fishing every second conduit after July 7) (Fig. 2). The adult fence was installed on June 20 to catch upstream migrating adult salmon and was removed for the season on November 2 (Fig. 3). Two percent of smolt and parr passing through the smolt counting fence were sampled. Most of the downstream migrating kelt were measured for fork length (FL) to the nearest cm, sex recorded, and a scale sample taken. Since the river is closed to angling, no adult fish were available for more detailed sampling. At the beginning of the upstream run, all adult salmon were counted and sizes of adult upstream migrating salmon were estimated, 10% being sampled for size, sex recorded from external characteristics, and a small scale sample removed for age determination. All fish were released alive. Due to high water temperatures and low water levels, it was decided to suspend sampling of live adult fish to avoid mortalities due to handling.

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). Adult salmon were sized visually into two categories (small salmon less than 63 cm and large salmon 63 cm or greater).

SEA SURVIVAL

Sea survival was determined from the number of returning small salmon in year n+1, the number of returning large in year n+2, and the number of smolt of year n. The adult salmon counted at the fence consisted of several year classes including salmon spawning for the first time as grilse, salmon spawning for the first time as large salmon and salmon that had previously spawned.

ENVIRONMENTAL DATA

During field operations, environmental data were collected at the fence. Water temperatures were recorded by Hugrun thermograph set at 1 m from the surface at the fence site. Cloud cover, relative water levels, weather conditions and air temperatures were also recorded at the fence site.

EXPLOITATION RATES

Exploitation rates in the commercial salmon fishery in 1980-82 were derived using a technique of 'differencing' average return rates in 1993-97 when there was no commercial fishery from those in 1980-82 when there was a commercial fishery. It is assumed that natural mortality rates remained the same on average during the two periods.

BIOLOGICAL CHARACTERISTICS

Biological characteristics data were collected from downstream migrating smolt and kelt as upstream migrating adult salmon. Standard techniques were used for mounting, preservation and age reading of scales. Adult salmon and kelts were measured for fork length to the nearest cm and whole weight (kg) to the nearest 0.1 kg. Smolts were also measured to the nearest mm and weighed to the nearest gram. Sex was also recorded. This information was used to derive stock status in terms of egg deposition.

TOTAL RIVER RETURNS, SPAWNING ESCAPEMENT, AND EGG DEPOSITION

In 1997, egg deposition was based on the number of spawning adult salmon, the sex ratio of kelt from the period 1994-1997, the mean fork length of female kelt in 1997 separated into large and small salmon, and fecundity estimates were from Randall (1989). Fecundity values from Randall (1989) were used due to an absence of fecundity information for Highlands River salmon and of fecundity information in insular Newfoundland on multi-sea winter salmon.

Total river returns

Total river returns (TRR) were calculated as follows:

(1) $$TRR = RC_b + HRM_b + C$$

where,

RC_b = recreational catch below counting fence

HRM_b = hook & release mortalities below counting fence (10% of the nunmber of hook & released salmon)

C = count of fish at counting fence

Spawning escapement

Spawning escapement (SE) was calculated as the difference between the number of fish released from the counting fence (FR), the recreational catch retained above the fence (RC_a) and hook & release mortalities above the fence (HRM_a).

(2) $$SE = FR - RC_a - HRM_a$$

Egg deposition

Egg deposition (ED) was calculated for small and large salmon as follows:

(3) $$ED = SE \times PF \times FV$$

SE = number of spawners
PF = proportion of females
FV = Mean fecundity values

Fecundity estimates were those reported by 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 proportion females and fork lengths were obtained from the biological characteristics information. Measurements from downstream migrating kelt in year i+1 were used instead of bright salmon in year i due to the small numbers of bright salmon measured.

CONSERVATION REQUIREMENTS

The accessible parr rearing habitat for Highlands River is 621,926 m^2 of fluvial habitat and 159,043 m^2 of pond habitat (Gibson et al. 1994). The egg deposition required for conservation is set at 240 eggs per 100 m^2 for fluvial habitats (Elson 1975) and 368 eggs per ha for lacustrine habitat (O'Connell et al. 1991; Anon. 1992; O'Connell and Dempson 1995). Although these values may be habitat and river specific for river systems from which they were derived, they are used to represent a threshold or danger zone to be avoided (O'Connell et al. 1991)

Conservation egg requirements are:

	Lacustrine	Fluvial
Accessible habitat	15.9043 ha	621,926 m^2

$$6219.26 \times 240 + 15.90 \times 368 = 1{,}498{,}475 \sim 1.5 \times 10^6 \text{ eggs}$$

JUVENILE SALMON POPULATION ESTIMATES

Population estimates were conducted during July and August at five sites. Stations were selected to give representation to each stretch of river and habitat type. The same stations were sampled in previous years. Densities of small salmonids were estimated by the depletion method in riffles and flats with the use of an electrofisher (Gibson et al. 1993). A beach seine and an electrofisher were used to catch fish for the mark and recapture estimates in pool habitats. Habitat variables were measured at each site according to the method described in Gibson et al. (1993). Juvenile salmon populations at each site were calculated according to the description in Gibson et al. (1993).

Results

UNRECORDED MORTALITIES

At the Highlands River adult counting fence in 1997, there were 0.5% or 3 of the 555 upstream migrating Atlantic salmon with visible net marks. The percentage of net marks on adult salmon has declined from 2.8% in 1993 to less than 1% in subsequent years (Table 1).

SMOLT AND ADULT SALMON COUNTS

Smolt and adult salmon counted moving through the fence in 1997 are detailed in Figs. 2 and 3, and are compared with previous years data in Figs. 4 and 5 (Table 2). Unlike most other rivers on the island the adult run continues through the summer and fall, with a substantial fall run of large adult salmon. The final salmon captured for the season was a large salmon on October 12 and a small salmon on October 13. The adult fence continued fishing until November 2. Complete counts of downstream migrating smolt and upstream migrating adult salmon were achieved. In 1997, the smolt count was the lowest on record (Fig. 4) while adult counts were the highest recorded (Fig. 5).

In addition, counted moving downstream were 196 parr, 56 resident brook trout, 457 silvery (sea) trout, 9 eels, and 41 smelt and upstream 6 sea trout. The adult fence was fished with every second conduit removed and therefore, the few trout counted migrating upstream are an underestimate since some could pass through the fence and not be counted in the trap.

SEA SURVIVAL

Smolt-to-adult survival for the 1995 smolt class was 2.9% including small salmon returning in 1996 and large salmon in 1997. Sea survival for the 1996 smolt class was 3.2% for the small salmon returning in 1997 (Fig. 6). The recorded survival will not be complete until large salmon returning in 1998 are included; however, it is higher than the survival rates for small and large salmon in all other years.

ENVIRONMENTAL DATA

Daily mean water temperatures for the smolt fence ranged from a low of 0 °C in mid April to a peak of about 19.7 °C in early July. The adult fence temperatures ranged from 4.5 to 20 °C (Figs. 2 and 3).

EXPLOITATION RATES

Since there has been no recreational fishery on Highlands River since 1978 angling exploitation rates are unavailable. However, commercial exploitation rates can be derived for the period 1980-82 by differencing survival rates experienced with commercial fishing (1980-82) from those without (1993-97) assuming that natural mortality has remained similar over the two periods. Exploitation rates derived by this method were approximately 60% for small salmon and 70% for large.

BIOLOGICAL CHARACTERISTICS

Age distribution of the smolt

From a sample of 138 smolt: 19 were 2+, 111 were 3+ and 8 were 4+. The proportions compared with previous years are given below:

Age Class of Smolt (%)

Year	2+	3+	4+	5+	6+	N
1980	35.5	63.4	1.2	0	0	
1981	34.4	64.5	1.1	0	0	
1982	16.2	69.8	12.5	0	0	
1993	23.8	66.7	7.9	0.8	0.8	
1994	3.6	70.7	25.7	0	0	168
1995	4.5	50.6	41.6	3.4	0	181
1996	19.5	72.5	8.0	0	0	240
1997	13.8	80.4	5.8	0	0	138

In 1997, the 2+ smolt were 47% female and 53% male, 3+ smolt were 60% female and 40% male, and 4+ smolt were 75% female and 25% male.

Age and size distribution of the bright adult salmon and kelt

Mean fork length of the small salmon sampled (1SW virgin fish, n=16) was 54.0 cm (range 46.5 - 59.0 cm). The females (n = 10) had a mean FL of 54.2 cm, and the males (n = 5) of 53.7 cm. One small salmon (51.0 cm) was not sexed. One 2SW virgin large salmon was sampled, a female of fork length 75.0 cm. One 1SW virgin large salmon was sampled, a male of fork length 64.0 cm.

The proportion of small salmon that were female was 0.67. Due to the small sample size of 16 small and 2 large salmon, we used data from the kelt for years 1993-1997 to calculate the proportion of female fish. This gave a proportion of female small salmon of 43/100 = 0.43, and of large salmon to be 63/90 = 0.70. To calculate the potential egg deposition, the sex ratios of all kelt from 1994 to 1997 were used due to the small sample sizes. A potential source of bias in determining the sex ratio of the adult population from kelts in the following year is differential mortality over winter between male and female kelt. Thus, data from 1994-97 was used to eliminate annual variability in survival as a source of bias.

Mean river age of the small female salmon was 3.1 (one 4+, nine 3+). Mean river age of the small male salmon was 3.2 (one 4+ and four 3+). An unsexed small salmon had a river age of 3+. The 2SW virgin female had a river age of 3+, the 1SW male 2+.

Mean fork length (FL) of small salmon kelts was 55.6 cm (n = 85; S.D. 4.63) with a range 42.0 - 62.5 cm, and mean FL of large kelts was 81.0 cm (n = 88; S.D. 9.04,) with a range 63.5 - 112.0 cm. The proportion of small kelts that were female was 33/85 = 0.39 with a mean FL of 52.7 cm and for large kelts, 62/88 = 0.70 were female with a mean FL of 82.4 cm. The small kelts (n = 85) had a mean river age of 3.1 years (21.4% of 4+, 65.3% of

3+, 14.3% of 2+). Large kelts (n = 88) had a mean river age of 2.9 years (3.4% of 4+, 82.8% of 3+ and 13.8% of 2+). Forty two of the 88 large salmon sampled (4 had spawned as 1SW) were repeat spawners. Thirty one of these (73.8%) were consecutive spawners that had spawned once, nine (21.4%) had spawned twice consecutively previous to having spawned in 1996 (three times altogether), and two (4.8%) of 103.0 cm and 107.0 cm had spawned consecutively three previous times. These latter two multi-winter repeat spawners as well as a 112.0 cm salmon that had spawned consecutively two previous times and a 101.0 cm salmon that had spawned consecutively one previous time were the largest fish sampled. The survival of small salmon kelts from river entry to their return to the sea in the following spring was about 47.8%, and large salmon kelts 69.4%.

The sea age distribution of upsteam migrating adult salmon indicates that most of the small salmon were grilse that had not previously spawned (Table 3). Large salmon mainly consisted of 2-sea winter salmon that had not previously spawned and previous spawners. The high number of virgin 2-sea winter salmon is unusual for rivers in Newfoundland of which the large salmon component mainly consists of previous spawners.

TOTAL RIVER RETURNS, SPAWNING ESCAPEMENT, AND EGG DEPOSITION

Total river returns and spawning escapement

There is no recreational fishery in Highlands River and thus, the total river returns and spawning escapement are equal to the count at the fence. This assumes that there were no removals of salmon due to poaching and disease. Therefore, total river returns and spawning escapment in 1997 were 398 small and 157 large salmon.

Egg deposition

The estimated egg deposition in 1997 for Highlands River in terms of eggs is as follows:

We combined the samples of kelt examined for sex from 1994-97, and used the proportion of females as 0.42 for small salmon, and 0.69 for large salmon. We used the mean fork length of the small and large female salmon kelt from 1997 samples of 52.7 cm and 82.4 cm, respectively to derive fecundity.

For 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).

Using mean fecundity values and proportion of females in the run:

Potential egg deposition by small salmon was:

3015.04 x 398 x 0.42 = 503,994

Potential egg contribution from large salmon was:

9386.77 x 157 x 0.69 = 1,016,869

In 1997, the total potential egg deposition was: 1,520,863

CONSERVATION REQUIREMENTS ACHIEVED

Conservation requirements in terms of eggs were calculated based on the available parr rearing area with contributions from both ponds and river habitat. The conservation requirement for Highlands River is 1.5 million eggs (Gibson et al. 1996). In 1997, the percentage of the conservation spawning requirement achieved was:

1,520,862.9/1,498,475 = 101 %

The 1997 value of 101% is an increase of 23% over the 1996 egg deposition of 78% (Fig.7). The post-moratorium years have all shown increased egg deposition rates over those of pre-moratorium years.

Juvenile salmon population estimates

The riffle station in the lower part of River Brook showed increased densities of underyearlings after the moratorium compared to samples collected in 1980-81, but then numbers declined considerably in 1996 and 1997 (Fig. 8). The increase was possibly due to the increase in spawning escapement in years since the moratorium; however, the disturbance of spawning gravel during the exceptionally high flood in February 1996, prior to emergence of the fry may have caused the decline observed in 1996 and 1997. The substrate is generally very coarse in River Brook and less suitable for grilse spawning. Earlier anecdotal observations from Palmer (1928) suggest that only large salmon migrate up River Brook, and it is possible that the restrictive availability of mainly coarse type of spawning substrate has imposed a selective pressure for spawning of large salmon over small in this section of the river. It is known that high velocities and large particle size for spawning favour larger fish (Hartman 1969). Parr were few relative to other riffle sites, possibly related to the shallow water depths, or relative productivity, and there may be migration of parr to habitats more suitable for the larger stages. At the other riffle stations (Figs. 9 & 10), in a flat station on the main stem (Fig. 11), and in a pool (Fig. 12), the underyearlings were reduced, and biomass was lower, relative to estimates in 1995, probably affected by the severe flood. Not only are some sections of river more productive than others, but distribution within sections is patchy, related to such variables as, substrate, mean depth, water velocity, etc.

Discussion

The juvenile population estimates demonstrate that prior to 1992, River Brook was underseeded, and emphasizes the importance of the large salmon component to the egg deposition in Highlands River. Also the juvenile salmon studies have shown that the flood in February 1996 probably has reduced the 1996 and 1997 year class and may cause reduced smolt production in subsequent years. Also, the flood probably had negative effects on older juveniles, since prior spawning escapements should have resulted in increased parr which is contrary to the observations of fewer parr at most stations. Additionally, we note that the number of smolts counted at the fence in 1997 was the lowest on record perhaps due to the flood. The 3-year smolts in 1997 would have come from 2+ parr in 1996. In addition, growth rates, biomass and production at most sites are less than in some other rivers of the island (Gibson et al. 1993). This may indicate that smolt production may increase little from present levels, although improvements in parr habitat in some areas and colonization in presently obstructed streams could result in higher juvenile populations. The biological processes influencing smolt production and predictions of smolt production are better understood with stream production studies which can provide some information that can lead to a better understanding of production. The general increase in underyearlings up to 1995 and increase in adult salmon compared with the previous studies in 1980 - 1982 suggests that the moratorium on the commercial fishery is increasing the number of juvenile salmon in the river. The decrease in underyearlings in 1996 was probably a consequence of the severe flood in February. Some studies have shown that fish can survive severe floods (Lobon-Cervia 1996). However, the flood in February occurred before fry had emerged, and massive amounts of substrate were moved, and undoubtedly affected spawning sites of the previous year.

The low smolt output from 1993 to 1995, compared to the studies a decade and a half ago suggest that spawning escapement prior to 1992 had been very low. However, the increased smolt run in 1996 indicates a higher spawning escapement in 1992 also observed in the high numbers of 0+ parr in 1993 during the juvenile survey. The decline in juvenile abundance in 1996 and 1997 and then smolts in 1997 suggests low adult returns may occur in the next couple of years depending on sea survival.

There has been an increase in grilse since the earlier studies which were before the moratorium on commercial salmon fishing, with a substantial increase in 1997, which may be related to the improvement in spawners in 1995 and increased sea survival. The increase of grilse in recent years compared to previous studies is also reflected in the increase of large salmon in the last three years, many of which are repeat spawners. The closure of the commercial fishery is most likely the cause for the relatively greater increase in the proportion of large salmon. The potential egg deposition is now 101% of the conservation requirements, higher than in the studies fifteen years ago. The attainment of conservation requirements will likely result in higher smolt outputs, although smolt output may be somewhat depressed in 1998 and 1999, but especially in 1999 due to the flood affecting the 1996 year class.

Continuation of the work would provide more information on stock and recruit which may ultimately be used to adjust the conservation requirements for Highlands River. The moderate increase in densities and biomass of juveniles at most stations suggests that carrying capacity may not be much higher than that presently being achieved. The exception is River Brook, which responded to an increase in large salmon by an increase in fry densities. If this tributary does indeed have a discrete stock, the large salmon component was depressed beyond its capacity to fully seed the river, and deserves special conservation.

Exploitation of Highlands River salmon in the Newfoundland commercial fishery can be derived by the technique of differencing used by Dempson et al. (1997). This technique compares the return rates of small and large salmon when the commercial fishery was operational prior to 1992 with return rates experienced since 1992. The technique assumes that survival has remained constant on average during the two periods of time. Downturns in survival are well documented in recent years (Dempson et al. 1997) but none-the-less the resulting calculation gives a value that is at least a minimum representation of exploitation in 1980-82. The calculated exploitation rates were 0.6 on small salmon and 0.7 on large salmon during the period of 1980-82. These values are similar to those reported by Reddin (1981) and Dempson et al. (1997). If natural mortality has increased as indicated by Dempson et al. (1997) then the actual exploitation rates would be higher than 0.6 on small and 0.7 on large salmon.

Sea survival of grilse and large salmon from the 1995 smolt class was 2.9%, similar to the previous year (2.8%), which is low compared to other Newfoundland rivers, but is more than double that of the survival to the river of smolt in 1980 (1.21%). Sea survival for the 1996 smolt class returning as small salmon in 1997 (note the large salmon will not return until 1998) at 3.2% is almost double that of previous years. If large salmon survive at a comparably increased rate then large salmon returning in 1998 could be higher than recent returns. The returns rates are lower for Highlands River compared to other insular Newfoundland stocks due to the large multi-sea winter component. Multi-sea winter salmon spend at least one additional year at sea which would include additional natural mortality and perhaps some fishing mortality at Greenland.

Smolt output remains relatively low, at about 2.0 per 100m^2 of fluvial habitat and decreased in 1997 probably due to flood in 1996. The modal smolt age is 3+ years. An angling season would allow more detailed collection of biological data on the adult fish. Anecdotal evidence suggests that Highlands River salmon have a stockier shape than salmon in other local rivers, if so then our fecundity estimates also may need revising especially. Although multi-sea winter salmon were included, fecundity values were derived for salmon in rivers of mainland Canada (Randall 1989). In addition the estimated proportion of females fish may need adjusting. We presently use kelt to derive the proportion of males and females in the population, but there is evidence that there is differential mortality of the sexes after spawning, with males having a relatively higher mortality (Fleming 1996). The Highlands River has the best background data over a critical period for salmon stocks in Bay St. George, for both the grilse and the large salmon components, and should be retained as an index river for the region.

Although not reported here, habitat characteristics were measured at all juvenile salmon sampling sites, so that models can be derived describing the potential production of juvenile salmon related to various types of habitat. In addition similar data were collected for brook trout. As densities increase a better estimate can be made of carrying capacity for juvenile salmon of various year classes in various habitat types and the potential smolt production from habitats throughout the system, and the effects of intra- and inter- specific competition. Density dependent growth models (Elliott 1993; Gibson 1995) will indicate the densities and production potentials in various habitat types. These data will be valuable for refining models related to carrying capacities of habitats, production, and interactions, and provide a more accurate target figure for spawning escapement in similar types of rivers in the region.

In summary, we provide an assessment of the salmon stock in Highlands River in 1997 which indicates that spawners were sufficient to reach conservation requirements for the first time in several years. This bodes well for the salmon population in Highlands River. Information contained herein adds to information presented on Highlands River by Gibson et al. (1987; 1994; 1996).

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Table 1. Net marks on adult salmon at the counting fence in Highlands River, 1993-97.

Year	Small			Large			Total
	Total Number	Number Marked	% Marked	Total Number	Number Marked	% Marked	% marked
1993	137	4	2.9	78	2	2.6	2.8
1994	145	0	0.0	148	0	0.0	0.0
1995	172	2	1.2	120	0	0.0	0.7
1996	199	3	1.5	142	0	0.0	0.9
1997	398	2	0.5	157	1	0.6	0.5
Mean	210	2.2	1.2	129	0.6	0.6	1.0

A number of other marks were noted on the salmon, not identified as net marks.

Table 2. Record of annual counts at counting fences on Highlands River.

	Downstream		Upstream	
Year	Smolt	Kelt	Small Salmon	Large Salmon
1980	15130	73	82	55
1981	15839	63	127	29
1982	12373	58	100	56
1993	9986	90	137	78
1994	10503	57	145	148
1995	12,160*	43	172	120
1996	12383	110	199	142
1997	6776	193	398	157

* The smolt count in 1995 was adjusted for a washout of the fence during the latter third of the smolt run. The unadjusted count was nine thousand and nine smolt migrants.

Table 3. Sea age distribution of salmon in upstream migrants as determined from downstream migrating kelt for Highlands River.

YEAR	NUMBER OF SMALL				NUMBER OF LARGE					NUMBER OF KELT SAMPLED (Year i+1)	
	V1SW	V2SW	PS	TOTAL	V1SW	V2SW	V3SW	PS	TOTAL	SMALL	LARGE
1980	82	0	0	82	3	47	3	3	55	14	43
1981	127	0	0	127	2	24	0	2	29	28	12
Mean	**105**	**0**	**0**	**105**	**2**	**36**	**1**	**2**	**42**	**21**	**28**
1993	137	0	0	137	0	54	0	24	78	19	26
1994	145	0	0	145	22	117	4	4	148	8	33
1995	169	3	0	172	0	72	0	48	120	55	40
1996	183	2	14	199	2	77	5	58	142	85	88
Mean	**158**	**1**	**4**	**163**	**6**	**80**	**2**	**34**	**122**	**42**	**47**

Percentage of kelt (year + 1) * Total Large or Small salmon through fence for each group

V1SW = Virgin One-Sea Winter (grilse), V2SW = Virgin Two-Sea Winter , V3SW = Virgin Three-Sea Winter, and PS = Previous Spawner.

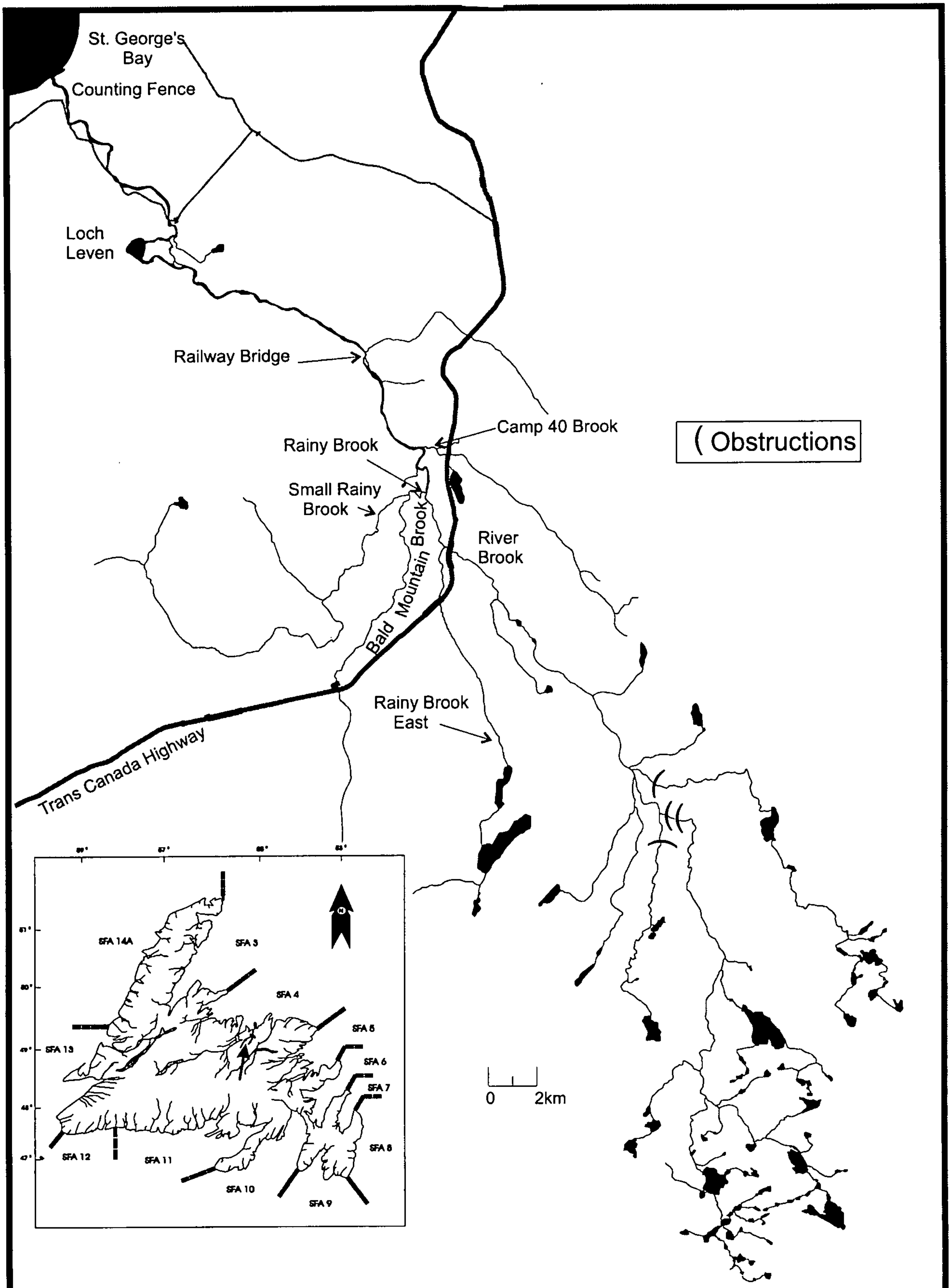


Fig. 1. Location of Highlands River, Salmon Fishing Areas and electrofishing stations.

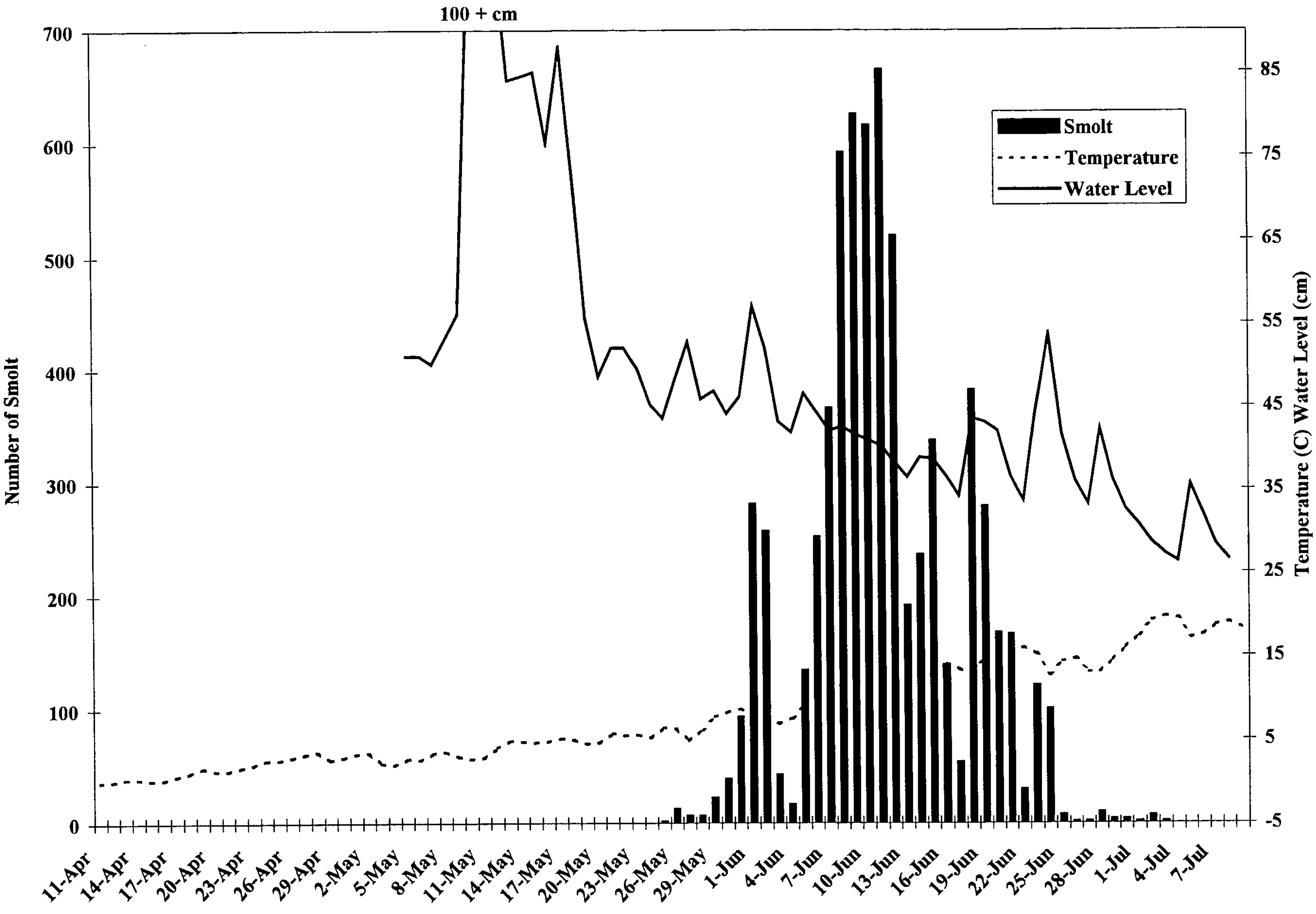


Figure 2. Smolt count on Highlands River 1997.

Fig. 3. Daily adult counts, water levels and temperatures for Highlands River, 1997.

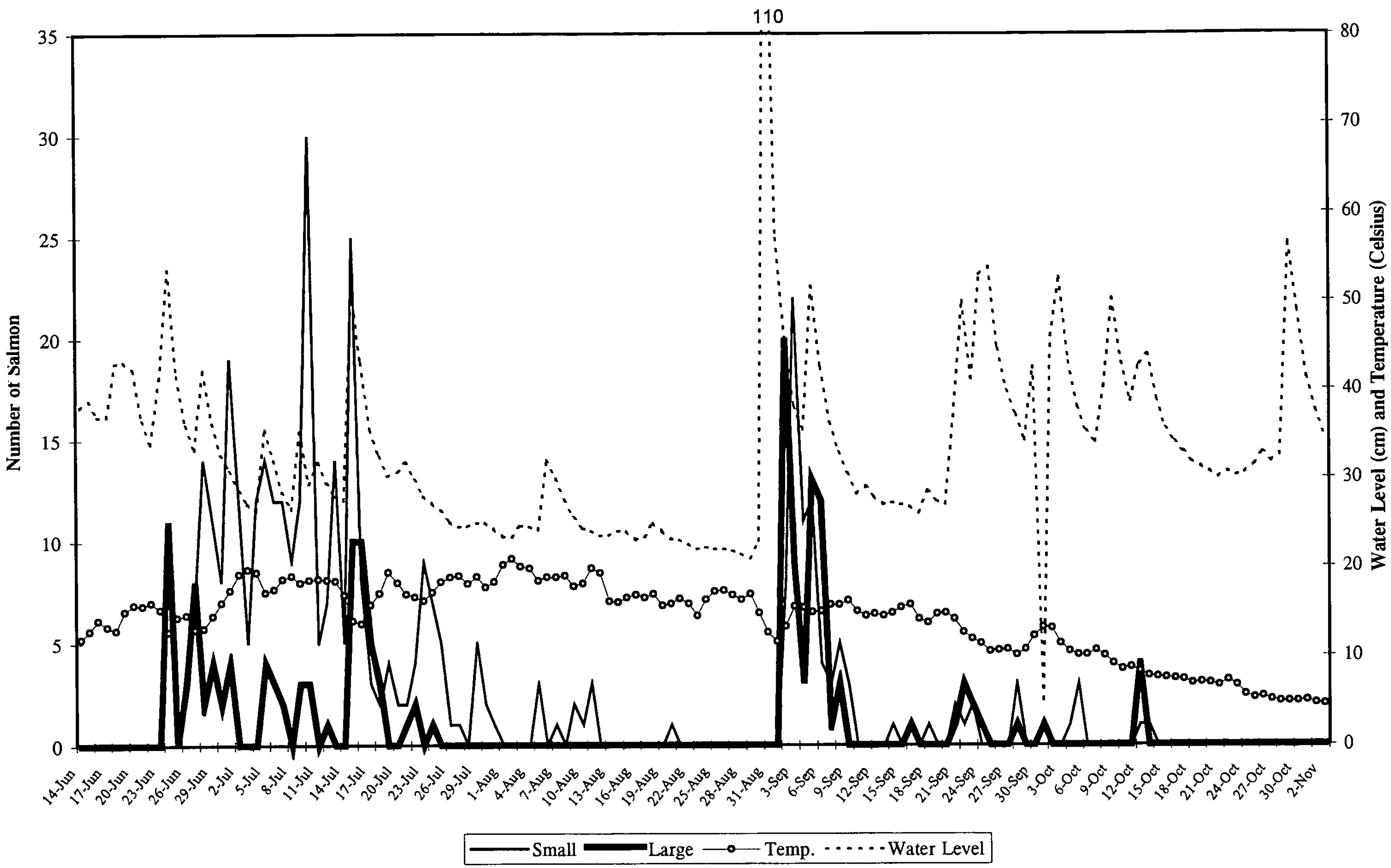


Fig. 4. Smolt counts from Highlands River.

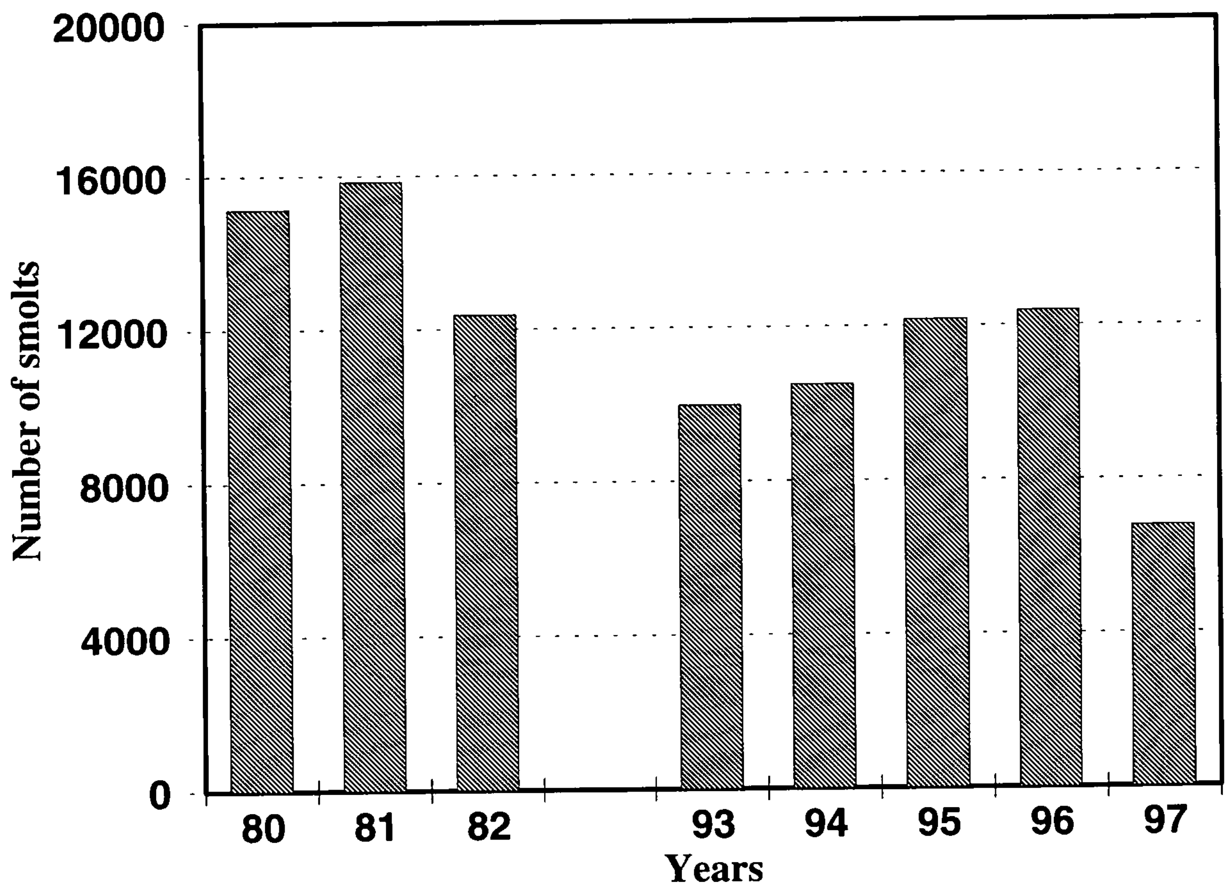


Fig. 5. Adult salmon counts from Highlands River.

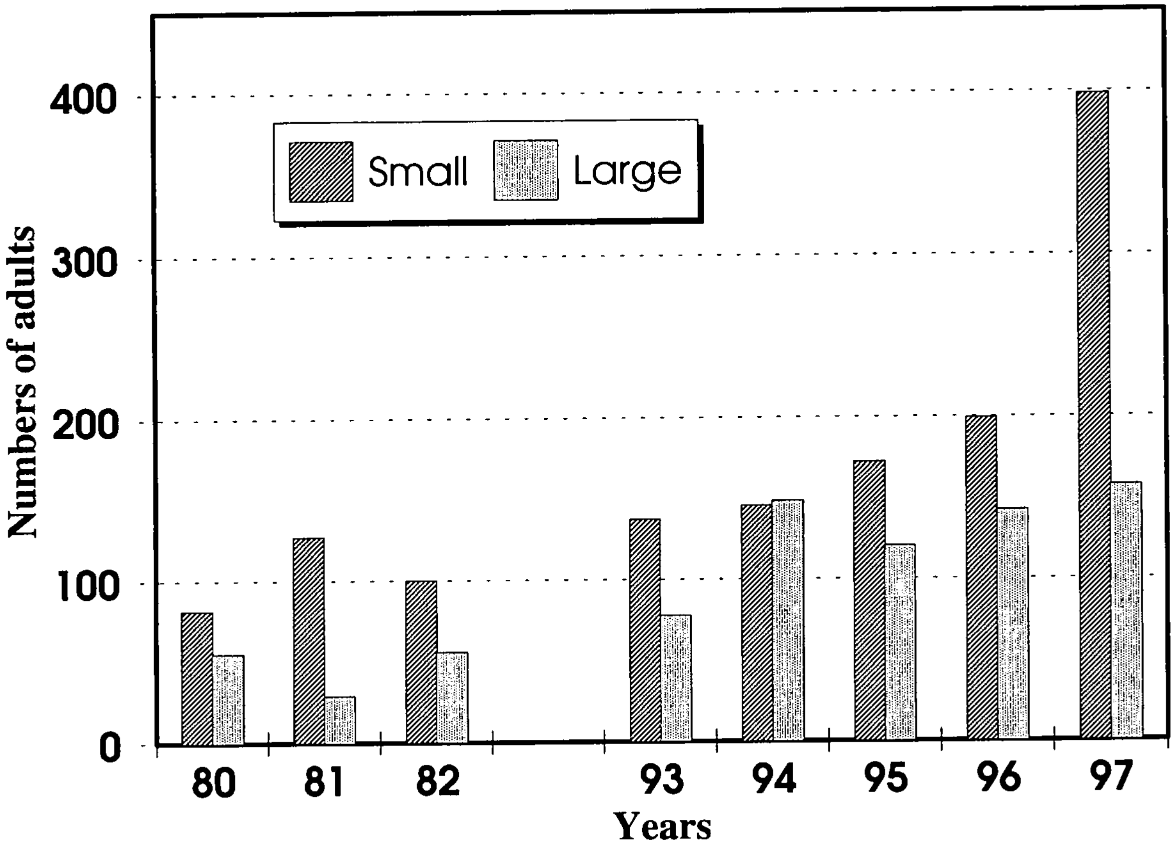


Fig. 6. Sea survival of salmon from Highlands River.

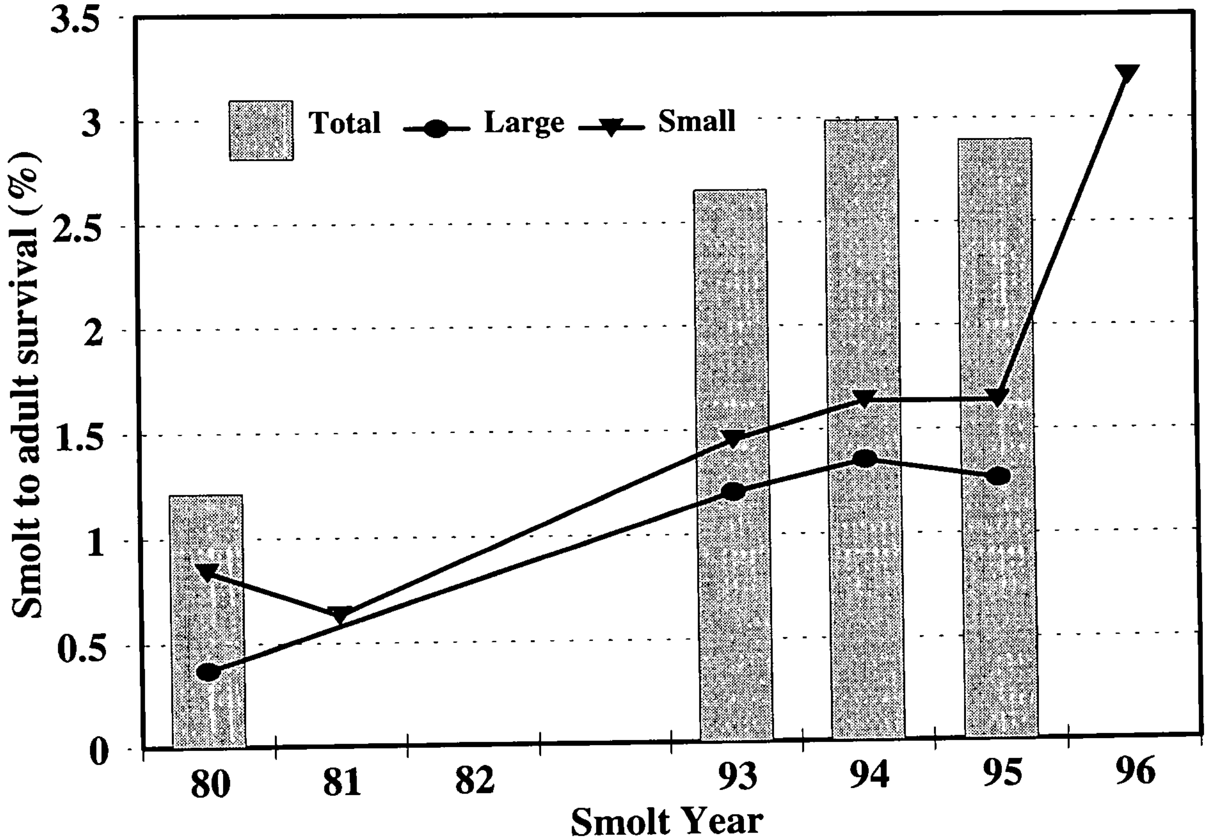
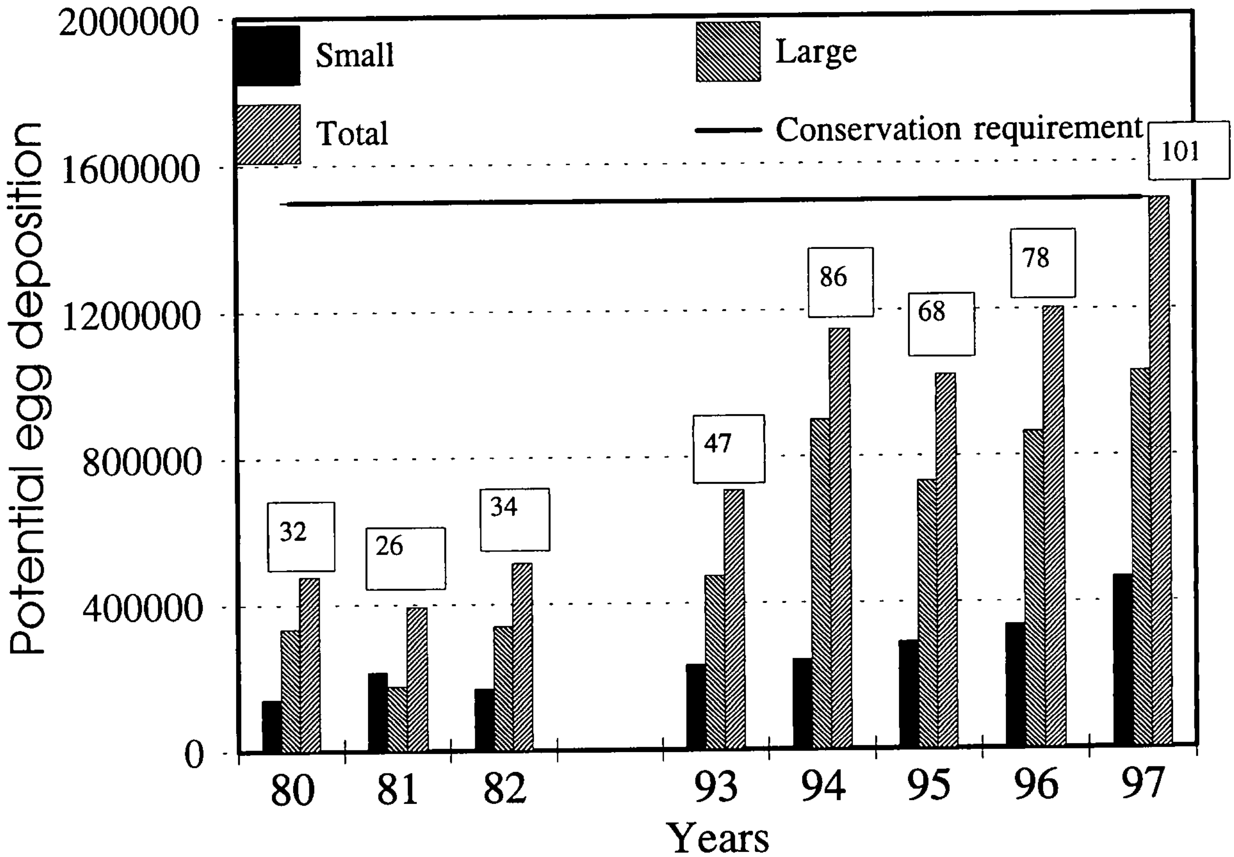


Fig. 7. Potential egg deposition and conservation requirements for salmon from Highlands River. Number in the box is the percent of conservation requirements met.



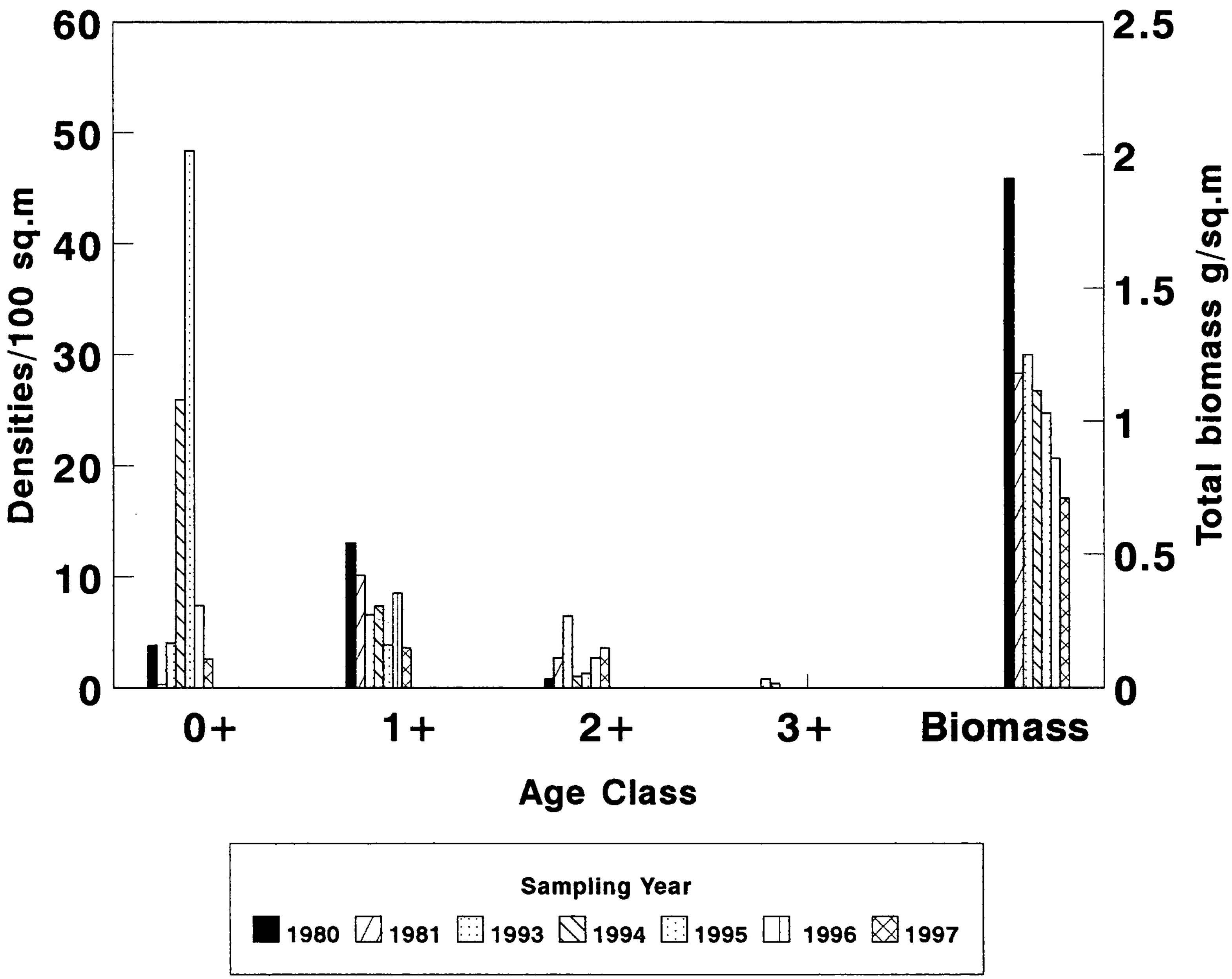


Figure 8. Number of juvenile salmon estimated by electrofishing in lower River Brook, an example of riffle habitat, Highlands River

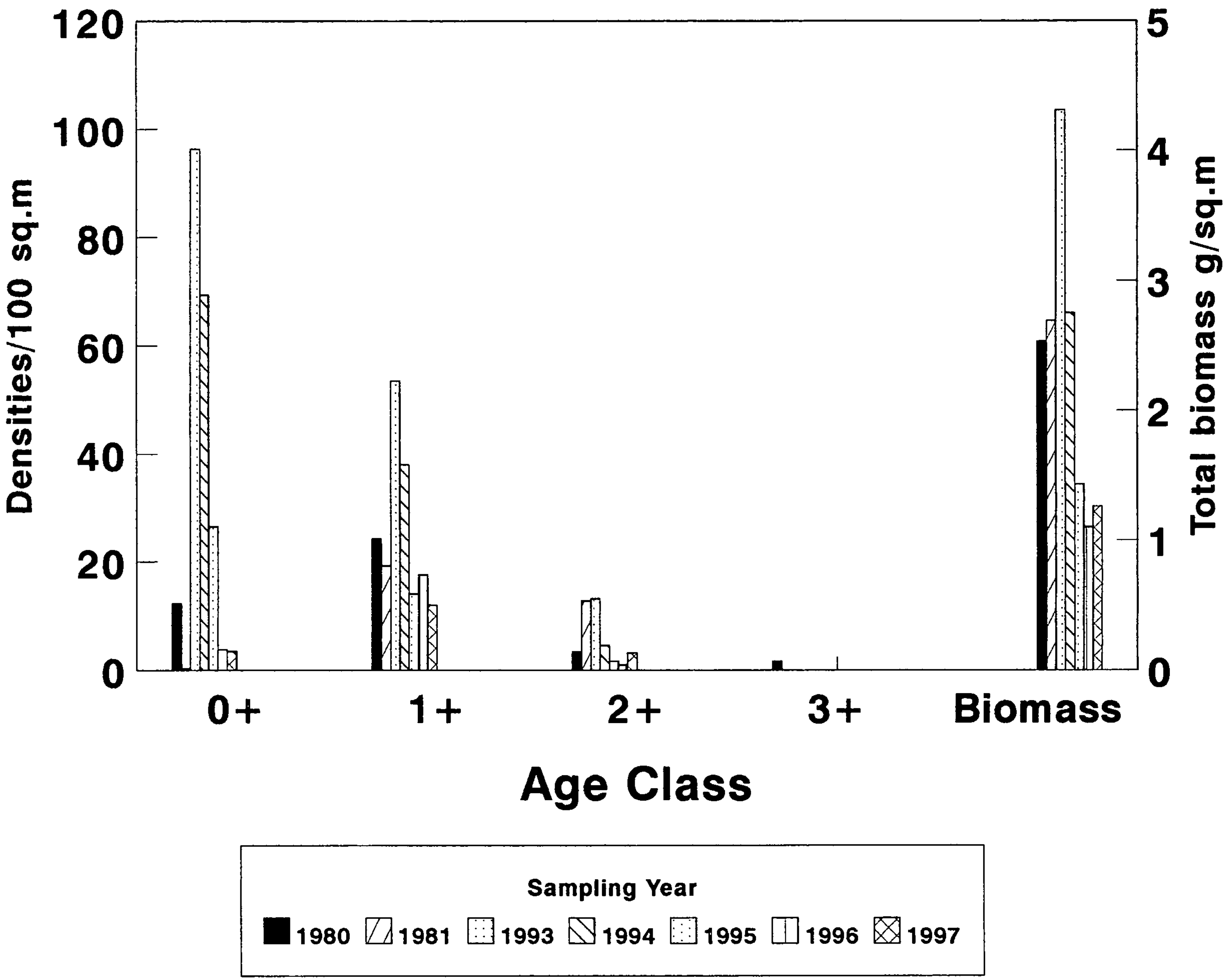


Figure 9. Number of juvenile salmon estimated by electrofishing in Rainy Brook, an example of riffle habitat, Highlands River

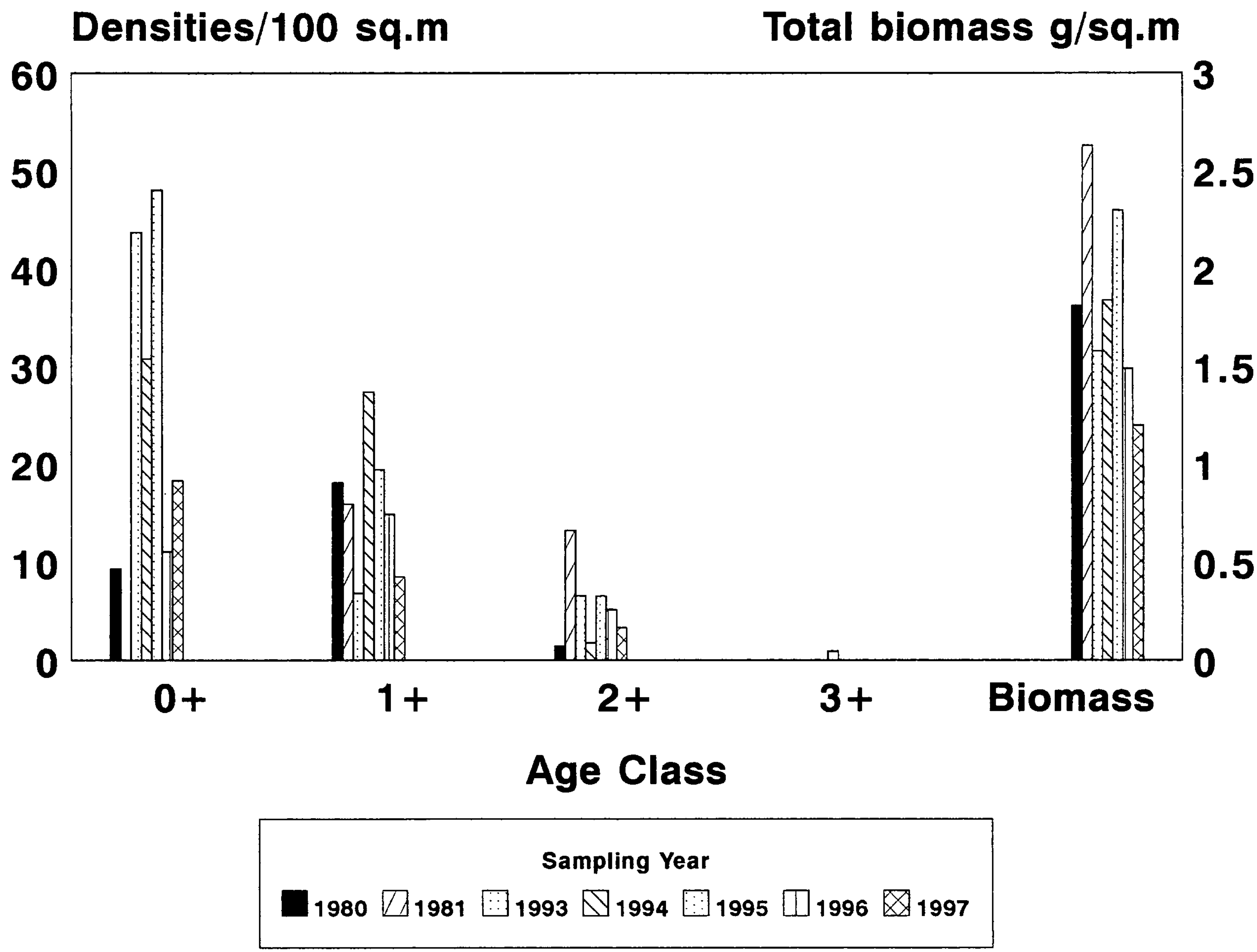


Figure 10. Number of juvenile salmon estimated by electrofishing in Bald Mountain Brook, an example of a riffle habitat, Highlands River

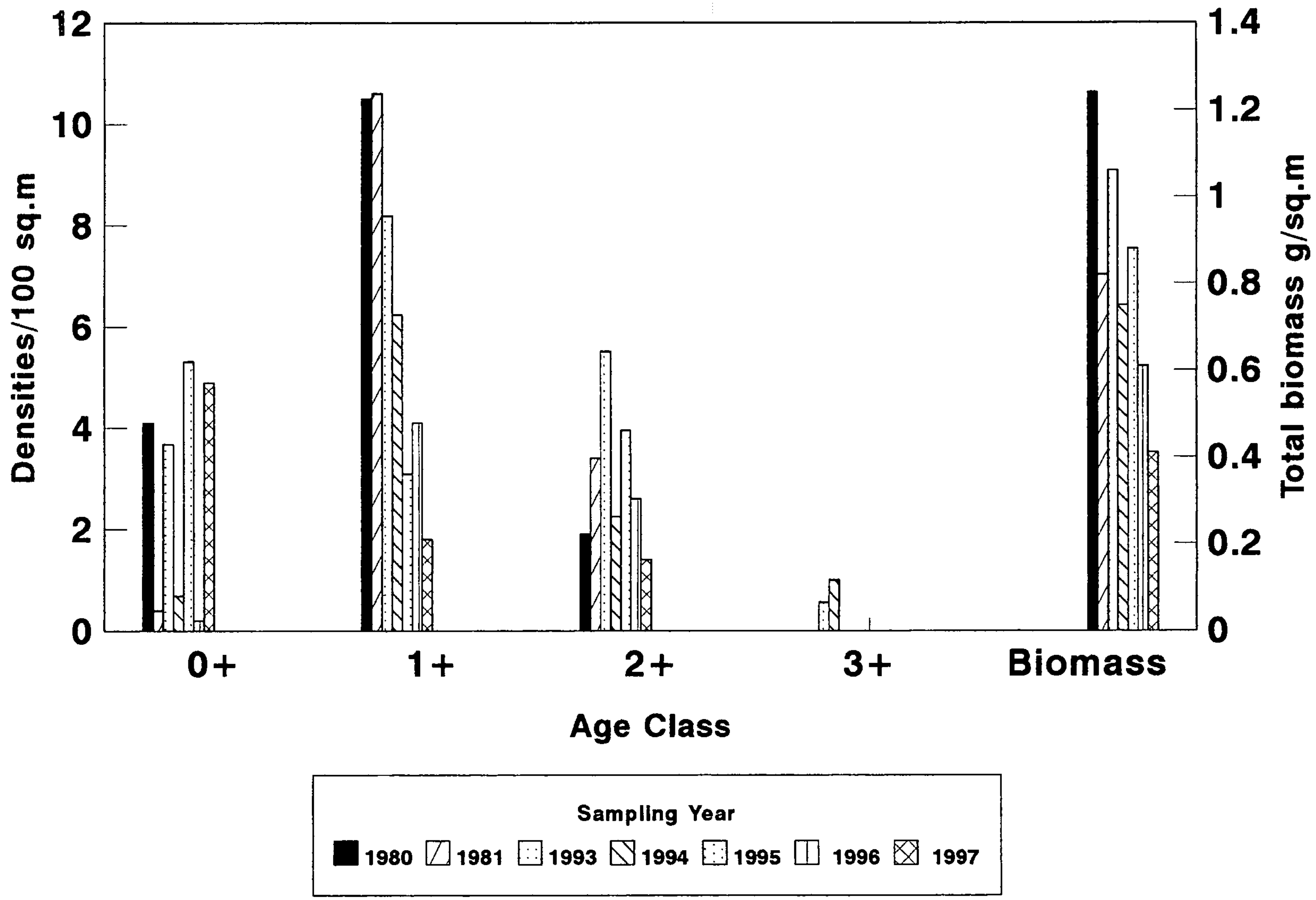


Figure 11. Number of juvenile salmon estimated by electrofishing at Railway Bridge main river, an example of a flat habitat, Highlands River

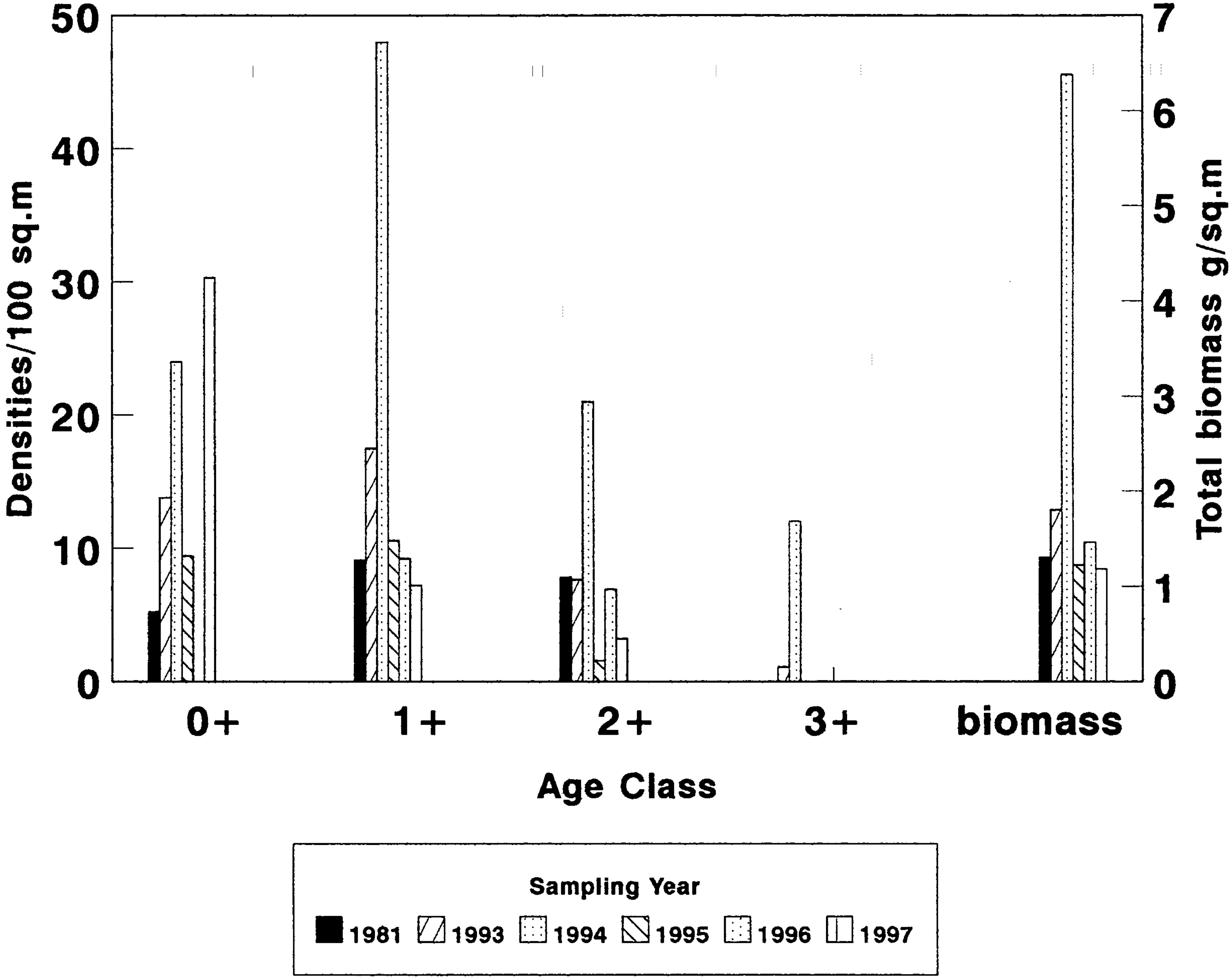


Figure 12. Number of juvenile salmon estimated by mark-recapture using a beach seine and electrofisher in Main Rainy Brook, an example of a pool habitat in Highlands River