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Juvenile Salmonid Production in the Highlands River, St. George's Bay, Newfoundland

R.J. Gibson, T.R. Porter, and K.G. Hillier

Science Branch
Department of Fisheries and Oceans
P.O. Box 5667
St. John's, Newfoundland A1C 5X1

March 1987

Canadian Technical Report of Fisheries and Aquatic Sciences No. 1538

Fisheries and Oceans | Pêches et Océans

Canada

364-638

Canadian Technical Report of Fisheries and Aquatic Sciences

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by

R. J. Gibson, T. R. Porter, and K. G. Hillier

Science Branch

Department of Fisheries and Oceans

P.O. Box 5667

St. John's, Newfoundland A1C 5X1

Cat. No. Fs 97-6/1538E ISSN 0706-6457

Correct citation for this publication:

Gibson, R. J., T. R. Porter, and K. G. Hillier. 1987. Juvenile salmonid production in the Highlands River, St. George's Bay, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 1538: v + 109 p.

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Production of Atlantic salmon (Salmo salar) and brook trout (Salvelinus fontinalis) was investigated in the Highlands River, a fourth order river, located in southwest Newfoundland, during 1980 and 1981. Commercial and recreational catches of the species had declined seriously in the area in the 1970s. In the spring of 1980 salmonid biomass (salmon and brook trout, varied from 0.8 g m^{-2} to 5.4 g m^{-2} at various sites, and in the autumn from 1.7 g m^{-2} to 6.3 g m^{-2}. Highest production was in second order tributaries and at a station below a lake in the main river. Lowest production was at two sites in the main river. In 1981, during the summer, salmonid biomass varied between sites from 1.18 g m^{-2} to 7.73 g m^{-2}, with greatest biomass in the second order streams, and lowest at sites in the main river. Biomass of salmon parr in a lake on the main stem was about 0.1 g m^{-2}. Eels (Anguilla rostrata) were abundant, with greatest biomass of 3.6 g m^{-2} found in a station below a lake in the spring of 1980. If three stations with poor salmon recruitment are excluded, the biomass of juvenile salmon was related positively to substrate rating, and negatively to width and cover. The biomass of brook trout was negatively correlated with stream width and with the height of ice scour marks (an indicator of the range of discharge), and positively correlated with the amount of cover. The growth rates of juvenile salmon varied between sites, and although probably related to density, was also related to differing productive capabilities between sites. Smolt production varied considerably between sites, and in 1981 was estimated to be from 1.0/100 m^2 in the upper part of the main river to 6.2/100 m^2 at the station below the lake, and about 0.2/100 m^2 from the lake. Major factors contributing to the decline of the salmon population in the Highlands River are the loss and physical degradation of the freshwater habitat. The system is not rearing salmon to its full potential, despite closure of the river to angling since 1978, due to insufficient number of spawners. The 1980 smolt class experienced a very high mortality at sea, with a mere 1.2% returning to the river as adults. Egg deposition was less than 40% of the recommended density.

RÉSUMÉ

Gibson, R. J., T. R. Porter, and K. G. Hillier. 1987. Juvenile salmonid production in the Highlands River, St. George's Bay, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 1538: v + 109 p.

En 1980 et 1981, les auteurs ont étudié la production de saumon de l'Atlantique (Salmo salar) et de truite arc-en-ciel (Salvelinus fontinalis) dans la rivière Highlands, une rivière de quatrième ordre située au sud-ouest de Terre-Neuve. Pendant les années 1970, les prises commerciales et sportives de ces espèces ont accusé une chute marquée dans cette région. Au printemps 1980, la biomasse de salmonidés (saumon et truite arc-en-ciel) variait de 0,8 g m^{-2} à 5,4 g m^{-2} à divers endroits tandis qu'à l'automne, elle oscillait entre 1,7 g m^{-2} et 6,3 g m^{-2}. La plus haute production a été observée dans les tributaires de deuxième ordre et à une station en aval d'un lac de la rivière principale, tandis que la plus faible a été notée à deux endroits de cette dernière. À l'été 1981, la biomasse de salmonidés variait de 1,18 g m^{-2} à 7,73 g m^{-2} entre les stations; la plus grande biomasse a été observée dans les cours d'eau de deuxième ordre et la plus faible, dans la rivière principale. La biomasse de tacons de saumon dans un lac du cours principal s'élevait à environ 0,1 g m^{-2}. L'anguille (Anguilla rostrata) était abondante; la plus grande biomasse (3,6 g m^{-2}) a été relevée au printemps 1980 à une station en aval d'un lac. Si l'on exclut trois stations où le recrutement en saumon était faible, on note une relation positive entre la biomasse de saumons juvéniles et le classement des substrats et une relation négative entre d'une part la biomasse et d'autre part, la largeur du cours d'eau et la couverture. La biomasse de truites arc-en-ciel était en corrélation négative avec la largeur du cours d'eau et l'emplacement des marques d'érosion des glaces (un indicateur de l'écart des débits) et en corrélation positive avec le degré de couverture. Les taux de croissance des saumons juvéniles variaient selon les endroits et quoiqu'ils soient densité, ils étaient aussi en relation avec les diverses capacités de production d'un endroit à l'autre. La production de saumoneaux variait fortement d'un endroit à l'autre en 1981, on a déterminé qu'elle variait de 1,0/100 m^2 dans la partie supérieure de la rivière principale à 6,2/100 m^2 à la station en aval du lac, tandis qu'elle s'élevait à environ 0,2/100 m^2 dans le lac-même. La perte d'habitat et la dégradation du milieu sont les principaux facteurs qui ont contribué au déclin de la population salmonicole de la rivère Highlands. Le potentiel que présente le système pour la croissance du saumon n'est pas pleinement réalisé malgré la fermeture de la pêche sportive dans cette rivière depuis 1978 à cause d'un nombre insuffisant de géniteurs. La classe de saumoneaux de 1980 a subi une mortalité très élevée en mer: seulement 1,2 % sont revenus à l'état d'adultes. La ponte était inférieure à 40 % de la densité recommandée.

INTRODUCTION

The rivers flowing into St. George's Bay on the west coast of Newfoundland are considered to be the most productive rivers in insular Newfoundland, with an estimated smolt production of 3.5 per 100 m^2 (Anon. 1978). However, in the late 1960s and 1970s the commercial catches in the bay and the angling catches in the rivers seriously declined (Chadwick et al. 1978). The decline in multi-sea-winter (MSW) salmon was most dramatic, showing a decline of about 70% in the angling catch (Anon 1978). In 1978 the seasons for the commercial and angling fisheries in St. George's Bay were made considerably shorter in an effort to improve spawning escapement. An egg deposition of 225/100 m^2 was recommended (Anon. 1978). In 1980, a study was initiated on the juvenile salmonid production of Highlands River, St. George's Bay. Emphasis was placed on Atlantic salmon. The Highlands River was selected because: it was believed to be similar to other rivers in St. George's Bay with a population of MSW salmon; the salmon population had declined; the river had been closed to angling since 1978; and the river was reasonably small, enabling a fish counting fence to be installed at its mouth, and fish could be easily sampled throughout the system. This report presents results of the juvenile salmonid production investigations in 1980 and 1981, and relates production to smolt output.

LOCATION AND STUDY AREA

The Highlands River is located at the southwest corner of the island, at 48°11'38"N, 58°53'40"W, draining into St. George's Bay. A general description of the river and the area is given in Porter et al. (1974). The system has a drainage basin of 183.1 km^2. The main stem rises from a number of ponds and streams in the southern part of the Long Range Mountains (Fig. 1). There are four major tributaries, the two largest of which are Rainy Brook East, and Rainy Brook. The latter drains from the Anguille Mountains, and is joined by Bald Mountain Brook. The main stem is called River Brook upstream from the confluence with Rainy Brook, and Highlands River downstream. There is a small lake in the main river, Loch Leven, 5.6 km from the mouth.

MATERIALS AND METHODS

Emigrating smolts were monitored in 1980, 1981, and 1982 and upstream migratory salmon were monitored in 1980 and 1981. Population estimates of juvenile salmonids were made at representative sites in the Highlands River in 1980 and 1981.

A number of stations were selected as representative of the major types of habitat in the system (Fig. 1). These were investigated in early and late summer in 1980 and in early summer of 1981 with some additional sites in 1981. At each site a population estimate was made of the fish fauna (Ricker 1975), and the following habitat parameters were measured.

<u>Physical</u>: Area of the sampling site;
Mean stream width;

Mean depth;
Mean water velocity;
Discharge;
Type of substrate;
Water temperature;
Height of ice scour marks (an indicator of range in discharge);
Amount of overhead cover.

Chemical: Nitrate nitrogen;
Total alkalinity;
Total phosphorus;
Total dissolved solids;
Hydrogen ion;
Total hardness;
Calcium;
Chloride;
Sulphate;
Color. Color was measured at the site with a U.S. Geological Surveys Hellige color comparator set (one color unit represents the color of a 1 mg per liter platinum solution when viewed in a depth of 200 mm).

Biological: Riparian vegetation;
Number and biomass of fish species;
Growth rate;
% of maturing or precocious male salmon parr;
Amount of invertebrates suitable as fish food.

Substrate: The relative percentage of the following types were visually assessed:

Boulders	(> 26 cm);
Rubble	(15-26 cm);
Cobble	(6-15 cm);
Pebble (coarse gravel)	(3-6 cm);
Gravel	(2-30 mm);
Sand	(0.06-2 mm);
Silt	(0.004-0.06 mm);
Clay	(< 0.0039 mm);
Organic detritus	(plant detritus including leaves and sticks, but does not refer to tree debris, which would be quantified under submerged and surface cover);
Convoluted bedrock:	bedrock, which has many pits, depressions, and projections. These can provide a fairly good substrate for some invertebrates and fish;
Smooth bedrock:	bedrock, which has only a few depressions and crevices. This generally provides a poor substrate for the fauna.

Except during water temperatures below 9°C, the type of substrate in low flows is thought to be less important than cover provided by depth, shade, or surface turbulence (Gibson and Power 1975; Gibson 1978). However, in fast water conditions salmon parr are generally associated with a coarse substrate, where parr hold station on the surfaces of cobble or rubble, or off the bottom in pockets of slower water. We therefore rated the type of substrate from 0 (worst) to 4 (best), according to what is generally considered good parr habitat (Elson 1975), as follows: 0 - plant detritus, clay, silt; 1 - sand, smooth bedrock, gravel; 2 - convoluted bedrock, pebble; 3 - boulders, cobble; 4 - rubble. Each proportion of substrate type in the station was multiplied by the rating, and the results summed for a general substrate rating.

Stream width was recorded as the wet perimeter. Usually three or four transects were taken to estimate mean stream width. More were measured if the area diverged from a regular rectangular shape, such as a narrow rectangular upstream section and a wider rectangular lower section.

The height of ice scour marks on the trunks of trees, above the present water level, was recorded as an indicator of range of water discharge. In the absence of water gauges this provided a useful general indicator.

Mean depth was measured from five depth measurements (n) taken at each transect width, divided by n+1. Water velocities were measured at each transect, at three locations, ¼, ½, and ¾ the width of the stream. Velocity was recorded at 0.6 of the depth, with a Hiroi acoustic current meter. Discharge was calculated from the formula:

$$D = \frac{WdVK}{t};$$

where, D = discharge ($m^3 s^{-1}$),

W = width (m), d = mean depth (m), $\frac{V}{t}$ = mean water velocity (ms^{-1}),

K = 0.8 if the stream bed is rough, 0.9 if the stream bed is smooth (mud, sand, hard-pan or smooth bedrock).

Overhanging cover referred to structures up to about 1 m above the surface and provided shade, and was recorded as the percentage covering the surface of the stream.

We also classified general water types related to depth and rate of flow, at each site, according to the method of Allen (1951). These were:

Pools, of two groups: pools, with current of less than 38 cm s^{-1}, and depth 46 cm to 68 cm; and deep pools, with current less than 38 cm s^{-1}, and depth over 68 cm.

The flow is smooth apart from a small turbulent area at the head of some pools.

Flats: Current under 38 cm s^{-1},
Depth under 46 cm
Flats are sections of relatively shallow water, but with a smooth surface.

Runs: Current over 38 cm s^{-1},
Depth over 23 cm.
The flow is usually turbulent. In such places the stream is usually of less than average width.

Riffles: Current over 38 cm s^{-1},
Depth under 23 cm.
These are shallow water areas with a rapid current and usually a broken flow.

Cascades: These are rapids in which a steep gradient, combined with a bed of stones or rocks large in proportion to the size of the stream, produces a very irregular rapid flow, often with some white water.

Invertebrates were collected at several sites by three methods in 1980, with kick and drift samples collected on the spring trip, and samples collected from colonization baskets in September. In 1981 colonization baskets only were used, and collected in September. Kick samples were collected in a net with opening of 24 cm x 24 cm, a handle 75 cm long, and the mesh of Nitex with mesh openings of 130 μm. The drift samplers were built on the reverse funnel plan, with the opening at the upstream end 2.5 cm wide x 20 cm high, and a 20 cm x 20 cm opening at the rear. The tapering net at the rear was 1 m long, with a receiving sample bottle, and was made from Nitex netting, pore size 130 μm. Drift samples were collected over 24 h. Colonization baskets were cylindrical and constructed of Vexar plastic screening, 1.9 cm diameter mesh size, and were 10 cm in height and 20 cm in diameter. They were filled with smooth stones, collected at an open ocean beach, and left in place over several weeks. In 1981, measurements from ten samplers had an average of 4.7 stones per basket (S.D. 0.67), with average diameter of 9.7 cm (S.D. 0.92). In 1980 baskets were similarly filled with cobble-sized stones, but unfortunately data on their size are mislaid.

At each site the salmonid population (species, numbers, population structure and biomass) was estimated either by a depletion method (Zippin 1958; Seber and Le Cren 1967; Braaten 1969) or by the adjusted Petersen's mark and recapture method (Ricker 1975). Biomass and densities were correlated with various habitat parameters by a stepwise regression model (Neter and Wasserman 1974). Fish were usually captured by means of a Coffelt Variable Voltage Pulsator electrofisher. The section was barricaded off with upstream and downstream nets of 0.6 cm square mesh, and usually four, but sometimes three successive sweeps were made, usually downstream. At two sites fish were captured with a beach seine, which was 15 m long, 1.8 m deep, with 0.6 cm square mesh and had a bunt 6 m long by 1.8 m deep. In the lake a fyke net was used of 3.7 m length and 1.1 m diameter mouth, with 0.6 cm square mesh. There were seven hoops, with throats on the second and fourth hoop. Wings were 0.6 cm mesh, 4.3 m long and 0.9 m deep. Some fish were collected by angling with small flies, and at two sites underwater observations were made using mask and snorkel. All fish collected were first anaesthetized with carbon dioxide, given off by dissolving Alka Seltzer tablets in the water. Fish lengths were measured to fork length for salmonids (salmon, Salmo salar, and brook trout, Salvelinus fontinalis), and total length for eels (Anguilla rostrata). Most fish were released, but samples were taken for weight, age, and sex. All eels were sampled. In the spring of 1980 released salmonids were given distinctive fin clips for each site, to give an indication of movements from the sites when sampled at later times. Highlands River from the estuary to the road below Loch Leven, and from the railway bridge upstream to just above the confluence with Camp 40 brook was mapped in 1980. In 1980 stations were sampled between May 27 and June 10, and again from September 17 to 30. In 1981 stations were sampled between June 21 and July 7.

RESULTS

INVESTIGATIONS, SPRING 1980

In 1980 seven sites were sampled (Fig. 1), four on second order streams (Camp 40 brook, Rainy Brook East, Bald Mountain Brook, Rainy Brook), one on a third order river (Lower River Brook), and two on fourth order rivers (the main river). Physical characteristics are shown in Table 1. Population estimates of salmonids are shown in Table 2, and mean fish sizes in Tables 6 and 7. The numbers of marked fish released and recaptured are given in Table 3. Results for the individual stations are as follows.

Camp 40 brook: This was a small, second order tributary, with mainly coarse gravel or pebble substrate, heavily shaded with alder. Roots and debris provided good holding areas for trout. The riparian vegetation was of alders, birch, spruce and balsam. The study site, just upstream from the confluence with the main river, contained two pools, one at the upstream end 2.5 m long, and 50 cm deep, and one near the lower end 2.8 m long and 50 cm deep. The remainder, 36.2 m, was riffle. In four sweeps 26 salmon parr were captured, 36 brook trout (excluding fry) and 13 brook trout fry. Salmon fry had not yet emerged. One eel was caught, 12.9 cm - 2.6 g. Results are shown in Tables 2, 6, and 7. These gave biomass estimates of 1.19 g m^{-2} for salmon, and 4.25 g m^{-2} for trout, with a total salmonid biomass of 5.44 g m^{-2}.

Rainy Brook East: The station was immediately downstream from a bridge where a logging road crossed the brook, and 4 km upstream from its confluence with River Brook. The valley had been logged a number of years previously but the banks were stable and well vegetated, although there was little overhanging cover. Riparian vegetation was mainly of balsam, spruce, birch, alders, and shrubs. There was a steep gradient. Less than 5% consisted of pools, mainly plunge pools, about 40 cm in depth. The deepest pool was of 70 cm. There were few undercut banks. The substrate was mainly of rubble and cobble, with some boulders. Although the habitat was primarily riffle, no salmon parr were caught. No suitable spawning areas were identified downstream from our sampling site and salmon would not be able to reach spawning sites upstream due to a collapsed bridge on an old logging road 0.6 km upstream from our station.

The trout biomass was estimated to be of 2.86 g m^{-2}.

In addition 17 eels were caught, with mean size of: 22.2 cm T.L. (S.D. 6.09) and 18.1 g (S.D. 13.59). Total weight was 306.9 g giving a minimum estimate of the eel biomass as 0.81 g m^{-2}.

Bald Mountain Brook: This station was 20 m upstream from the confluence with Rainy Brook. The stream was heavily overhung with alders, mature spruce, birch, etc. The substrate was mainly of cobble. The station could be described as mainly riffle, but there were three pools with a total length of 11.2 m, compared with 60.8 m of riffle. An upper pool had the deepest depth of 60 cm, the middle pool of 50 cm, and the downstream pool of 1 m. Catching success suggested that the middle pool was the most productive of the three pools for salmonids and the downstream deepest pool the least productive, although this is where we caught our eels. Altogether we caught 54 salmon parr, 6 smolt (mean F.L. 12.9 cm, S.D. 0.45), 30 trout, and 5 eels.

Biomass estimates of salmon, excluding smolts was, 1.15 g m^{-2}, and trout, 2.03 g m^{-2}, with total salmonid biomass of 3.18 g m^{-2}. Total biomass of the eels was 271.3 g (0.63 g m^{-2}).

Rainy Brook: This station was about 40 m upstream from the confluence with Bald Mountain Brook. The station was heavily overhung with alders. Mature trees of spruce and birch were along the banks. A pool at the upper end was 13.5 m long, and the remainder of the station was riffle (33.5 m). The deepest part of the pool was 75 cm. Substrate was mainly rubble. The main difference between stations in Rainy and Bald Mountain Brooks was a coarser substrate and browner colored water in Rainy Brook. A 1+ parr caught was a recapture, marked in the Bald Mountain Brook station 3 days earlier. Also two smolt (12.2 cm and 12.6 cm) were caught, and one eel (33 cm - 60 g). Salmonid biomass, other than smolt, was 5.04 g m^{-2} (3.47 g m^{-2} of salmon and 1.57 g m^{-2}) of trout.

River Brook (lower): The station was open with no overhanging vegetation and wide (24 m), with coarse substrate (60% boulders). The water was fairly deep and fast. In midstream depth was from 30 to 40 cm, and the water velocity 0.38 to 1.14 m s^{-1}. The electrofishing was inefficient in these conditions as an inconsistent proportion of the population was captured in each sweep, thus we could not make any population estimates. Altogether we caught 21 salmon parr, 6 smolt, and 6 trout (0.02 salmonids m^{-2}, excluding smolt). Mean F.L. of the smolt was 12.6 cm (S.D. 0.57).

Railway Bridge: This station was on the main river, a short distance upstream from a railway bridge, and immediately upstream from a gravel island. The substrate was mainly of cobble and gravel. Depth in midstream was 30 cm at the downstream end of the station, and 43 cm at the upstream end. The station was open, with thick alders along the banks. The station could be described as a flat.

Both a depletion (Zippin) and a mark and recapture (Petersen) method were used to estimate the density of salmon parr. After the first sweep, all fish were measured, and live salmonids, other than fry, were fin clipped and released within the enclosure. Two sweeps were made the following day.

Recaptured fish were used for a Petersen's population estimate, and unmarked fish were treated as the captures for an estimate by the depletion method. The two methods gave differing results. The Zippin method gave estimates of 182 yearling salmon, and 21 two-year-olds, whereas the Petersen's estimate gave 344 yearling parr and 39 two-year-olds. We suspect mortality of some of the marked fish, which would give us an overestimate of the population by the mark and recapture method. Our recovery tubs did not have screens on the sides to allow circulation of water (corrected in all our following work), and there was a high mortality from our first sweep, no doubt caused by the large numbers of fish and insufficient exchange of water (occasional additions of water). In this first sweep there were 132 salmon, 13 trout, 10 eels, and 2 sticklebacks. Of these 27 of the yearling salmon and 2 trout were mortalities. As the salmonids were returned to the area, one would expect to have similar numbers of them for the second sweep the following day, minus mortalities (i.e. 92 yearling salmon, 12 two-year-old salmon, 1 three-year-old salmon, and 11 trout). In fact this sweep yielded 49 yearling salmon, 10 two-year-old salmon, 0 three-year-old salmon, and 11 trout. It appears therefore that some of the released yearling salmon died shortly afterwards due to stress, or perhaps greater susceptibility to predation. A linear regression showing removal of the unmarked yearling salmon has a correlation coefficient of -0.9973, and gives a population estimate by the Leslie method of 211 yearlings. Catchability remained similar, and as a large proportion of the fish were caught, an estimate by the depletion method is probably the more accurate one in this case.

The figures for the mark and recapture data are: 92 yearling salmon marked and released, and 19 recaptured in a catch of 73; 12 two-year-old parr marked and released, and 3 recaptured in a catch of 11. Population estimates by this method were therefore: 344 (225-551) 1+; 39 (16-98) 2+.

Only six trout were marked, with one recapture, so an estimate only by the depletion method was made for this species.

Biomass estimates were 0.62 g m^{-2} of salmon, and 0.18 g m^{-2} of trout, with a total salmonid biomass of 0.80 g m^{-2}. If the population estimate of the salmon by the Petersen's method is used, salmon biomass would be, 1.16 g m^{-2}.

Mean length of the smolt (F.L.) was 13.3 (S.D. 1.63), and of the sticklebacks (T.L.) 4.1 cm (S.D. 0.58). Mean size of the eels was, 28.1 cm (S.D. 6.11) - 38.9 g (S.D. 23.88), and their biomass (estimated by the Leslie method), 886 g, or 0.53 g m^{-2}.

Gillam's Farm: This station was on the main river, below Loch Leven. The habitat was classified as a run, although a portion could have been classified as a flat, with a coarse substrate mainly of rubble, with some scattered boulders. The area was open, with spruce, balsam and birch along the banks. Depths in midstream were 50 cm at the downstream end to 46 cm at the upstream end with water velocities at these locations of 30 cm s^{-1} and 41 cm s^{-1}. Although relatively deep, electrofishing was more successful than at the River Brook site, possibly related to somewhat slower flows, and to higher conductivity (175 μmhos, compared to 32 μmhos at River Brook). The habitat appeared more productive than at upstream stations. Other than some *Chara* at the railway bridge station, this was the only station where we saw vascular aquatic plants (Ranunculus, Myriophyllum, and aquatic grasses, near the right bank). Also freshwater clams and gastropods were observed, unlike at other stations. Simuliidae also were observed on submerged leaves. Some white patches similar to Sphaerotilus were present, as though there were some organic enrichment. The bottom was more slippery than upstream, indicating that primary production may have been relatively more important at this station than at the others.

Salmon parr were abundant, with population estimates of 0.15 m^{-2} of yearling salmon, and 0.23 m^{-2} of 2+ salmon. Also abundant were eels, of which we caught in three sweeps: 63; 18; 10. Also caught were, 7 smolt and 14 trout, including a three-year-old sea trout of, 17.5 cm-49.7 g. Excluding the smolt and sea trout, there was therefore, 3.09 g m^{-2} of salmon, and 0.39 g m^{-2} of trout, with total salmonid biomass of 3.48 g m^{-2}.

Mean fork length of the smolt was 13.2 cm (S.D. 1.16).

Total weight of eels for each sweep was, 3177.7 g; 810.0 g; 465.3 g. By the Leslie method this gives an eel biomass estimate of 5275.67 g, or 4.05 g m^{-2}, and by the Zippin method, 3.60 g m^{-2}.

INVESTIGATIONS, FALL 1980

The same sites sampled in the spring were again sampled between September 19-27, 1980 (Tables 4 and 5). Population estimates were made by the Zippin (1958) method at all sites. In addition, at River Brook, Railway Bridge and Gillam's Farm sites population estimates were made by the modified Petersen's method. Mean sizes of the respective age groups at each site through the season are presented for salmon in Table 6 and trout in Table 7.

At some sites the numbers of fish of a species or of a year-class were few, and a significant decrease in numbers between sweeps did not occur, so that a population estimation by the depletion method could not be made. For example, at the Rainy River, River Brook, Railway Bridge, and Gillam's Farm sites, only a few trout of some year-classes could be caught, so the total weight of these was presented instead of an estimate of the biomass. These figures are therefore minimum estimates of the biomass. At the three sites where a Petersen estimate was also made, the unmarked fish plus the marked fish had similar numbers to the total numbers caught in the first sweep, so it was felt that undue mortality had not biased the Petersen's estimates (44 cf 42 on the first sweep at River Brook; 66 cf 60 on the first sweep at the Railway Bridge; 113 cf 132 on the first sweep at Gillam's Farm).

At Rainy Brook East four salmon were caught. Three of these were two-year-olds but had a mean fork length of 13.6 cm, compared with means between 10.8 cm and 12.3 cm for two-year-old parr at the other sites. One mature male parr of 12.7 cm was three years old. For purposes of estimating the biomass the four salmon were considered together. Although this station was typical of good salmon parr habitat salmon biomass was only 0.65 g m^{-2}, which was the lowest of the stations sampled. Trout densities were high, despite the riffle type of habitat, possibly related to the low density of salmon parr. Recruitment of trout from upstream would be possible as trout were abundant above the obstruction caused by the collapsed bridge 0.6 km upstream.

Eels were again abundant at the Gillam's Farm station, and 32 were captured, weighing 2157.4 g, with an estimated biomass of 2.34 g m^{-2}, although this is only about 58% of the biomass estimated in June. A nine-spine stickleback (4.1 cm) and a three-spine stickleback (4.1 cm) also were caught at this station.

Eels were also caught as follows: five at East Rainy, with total weight of 93.6 g; two at Bald Mountain Brook, total weight 151.7 g; two at River Brook, total weight 541.4 g; five at the Railway Bridge station, total weight 293.5 g. If these were close to the total populations their biomass would be between 0.25 g m^{-2} and 0.37 g m^{-2} at these stations. The biomass of eels at all stations appeared two to three times greater in the spring, indicating emigration, or lack of compensatory immigration to replace the eels removed in the spring, or possibly reduced activity may have made them less catchable.

The proportions of fish marked in the spring and recaptured in the fall are shown in Table 3. The Railway Bridge station is not comparable with the other stations as unfortunately a bulldozer had been active in the area sometime during the summer, including in the lower shallower half of the original station. The gravel bars downstream had been removed and some of the river bottom in the station had been gouged into furrows and banks, and the substrate generally disturbed. The lower boundary of the station was therefore moved up 22 m above the disturbance and the upper boundary moved up 13 m, so that only about 40% of the original station used in June was assessed. This possibly accounts for the low number of recaptures, although as mentioned previously, we also suspect a fairly high mortality of the yearling salmon in June, as the holding tubs were overcrowded and had poor circulation of water. For the same reason we suspect fairly high post release mortalities due to stress at the Gillam's Farm station. As there is such variation in percentage of recaptures between sites for each size class and species we can conclude little about this experiment, except that a proportion of both salmon and trout remains in the same area for the growing season, and that there is some movement between adjacent areas. The latter conclusion is an important consideration when the same site is to be sampled more than once, as if compensatory movement to replace missing fish did not occur, later estimates of biomass or density would be low.

Mean condition factors of salmon and trout are shown in Table 8. All were over 1.0, indicating 'good' condition. In the fall mature male parr show relatively higher condition factors (K) due to development of the testes. In September of 1980 the relative Ks were: mature male parr, 1.31 ($S_{\bar{x}}$ 0.03); immature male parr, 1.18 ($S_{\bar{x}}$ 0.02), immature female parr, 1.15 ($S_{\bar{x}}$ 0.02). The September sample was rather small, but of the males there were: 8 mature 1+; 9 immature 1+; 6 mature 2+; 2 immature 2+; 2 mature 3+; 1 mature 4+. There were 26 immature females (23, 1+ and 3, 2+), and 16 unsexed fry, with mean K of 1.12 ($S_{\bar{x}}$ 0.04).

Relative production at the study sites in 1980 is shown in Tables 9 and 10. Highest salmon production was in the second order tributaries and at the Gillam's Farm Station. However, the P/B ratio was least at the latter station, since most salmon were large parr. Production of brook trout was greatest in the smaller tributaries and least in the main river.

INVESTIGATIONS, SPRING 1981

In 1981 a preliminary trip was made from 5-7 June to select survey sites additional to the ones surveyed in 1980 (Fig. 1). Additional sites were required to supplement data on salmonid production from other sections of the system. In 1980 the survey in River Brook a short distance upstream from the Trans Canada Highway suggested that juvenile salmon were sparse in that section. Suitable spawning gravel appears to be lacking in these upstream reaches, and local opinion suggested few salmon migrated upstream above the TCH bridge. A new station with pool and riffle habitat was therefore selected in the upper reaches (River Brook upper), immediately upstream from the confluence with T3, to determine if juvenile salmon used the upstream section of River Brook. It was decided also to choose two additional sites in Rainy River below its confluence with Bald Mountain Brook, one with predominantly the pool type of habitat and one with predominantly a riffle habitat. This was to get better information on the value of salmon production from Rainy River, and to supplement data on the environmental variables that affect salmon production. An additional site representing the pool environment was also chosen in the main river (Main River Pool). Also Loch Leven was sampled to provide some indication of the contribution of this lake to production of salmon.

A section of River Brook was walked in the upper reaches above the major waterfall which constitutes a barrier to further upstream salmon migration. We walked about a mile downstream from a woods road. There was excellent potential parr habitat for at least the mile or so that was walked, and gravel suitable for spawning was present. Brook trout appeared to be abundant, and were easily caught by fly. Fry as well as the larger sizes were seen. The tributary T3, draining MacPherson's Pond, was also walked, to assess its potential as spawning and parr habitat. This was walked from a bridge on a woods road to the junction with River Brook. Small trout could be caught by fly all the way down, but were not abundant. Some gravel areas were present, but would be marginal for spawning. The gradient was steep, and the substrate was composed predominantly of bedrock and boulders. There were numerous small falls, which might not have constituted barriers to upstream migration, however a falls about 0.8 km from the confluence had a vertical drop of about 4.5 m. Angling in River Brook above the mouth of T3 yielded in half an hour, 11 trout and 1 salmon parr.

On 7 June, 1981 the upper areas of River Brook below the major obstruction were examined. It had been suggested that the falls downstream from the major falls might cause an obstruction. However, two large salmon parr, and four trout were caught in the pool below the main falls, and a further three salmon parr were caught between the two falls. It is most unlikely parr could surmount the smaller falls, so evidently salmon spawn in this upper section. A number of gravel patches were seen, but these appeared unsuitable for spawning.

The substrate consisted of boulder, bedrock, and some cobble. It is possible large salmon might use the latter for spawning. In a section below the smaller falls 6 parr and 22 trout were caught. The gradient was steep here with plunge pools and rapids. The substrate was predominantly of bedrock and boulders. Downstream from T3 a further 4 large salmon parr and 30 trout were caught and released. These upper sections therefore are seeded with salmon, although parr were relatively sparse. The angling success per hour was: between the two falls, 6 salmon and 4.8 trout; below, and downstream from the smaller falls, 3.6 salmon and 13.2 trout; at T3, and downstream in River Brook, 2.9 salmon and 23.4 trout.

The upper station on River Brook (near T3) was selected as generally representing the upper part of River Brook, with coarse substrate (30% cobble; 50% rubble; 10% boulder; 10% bedrock) and a riffle-run type of habitat. Riparian vegetation consisted of spruce trees and birch, with alders along the bank, although not providing overhanging cover. The mean depth was 26.8 cm, and maximum depth 80 cm. Ice scour marks were noted at 2.5 m above the water level, indicating a wide range in discharge.

The two pools selected for additional stations were in the main river, River Brook, and in the main stem of Rainy Brook. Main River pool had a mean depth of 65.0 cm and a maximum depth of 1.10 m. There was about 10% of overhanging cover, consisting of alders and tree debris in the lower left part of the pool. Rainy Brook pool had a mean depth of 51.0 cm, with a maximum depth of 92 cm at the lower right. Alder provided about 10% overhanging shade.

The riffle station on the main stem of Rainy Brook had a mean depth of 21.2 cm and a maximum depth of 41 cm. Alders and other shrubs provided overhanging shade of about 2%. Other riparian vegetation was of mature forest of spruce, white birch and maple.

Physical characteristics of the stations are given in Table 11, and capture data in Table 12, this field work being conducted between June 21 and July 7. Mean lengths, weights, and condition factors of salmon and trout are given in Tables 14 and 15.

Camp 40 Brook: A total of 18 salmon parr, 32 trout, and 2 eels were caught. Total salmonid biomass was estimated at 6.08 g m^{-2}, (salmon 1.43 g m^{-2}, trout 4.65 g m^{-2}) similar to estimates the previous year (5.4 g m^{-2} in the spring (Table 2) and 6.3 g m^{-2} in the fall (Table 5)). One 2+ trout was caught with the previous year's fin clip. Eight yearling trout had been marked.

Rainy Brook East: Seventy-nine trout, one salmon parr, and four eels were caught. Total salmonid biomasss was estimated as 5.38 g m^{-2}, (salmon 0.11 g m^{-2}, trout 5.27 g m^{-2}), compared to 2.86 g m^{-2} in the spring of 1980 and 2.82 g m^{-2} of trout and 0.65 g m^{-2} of salmon in the fall of 1980. This may be related to the mean water velocity (0.44 m s^{-1}) being somewhat slower in 1981, (compared with 0.59 m s^{-1} and 0.71 m s^{-1} in 1980).

Bald Mountain: Eighty-six salmon parr and 52 trout were caught, with an estimated salmonid biomass of 7.73 g m^{-2} (2.63 g m^{-2} salmon, 5.10 g m^{-2} trout) compared with salmonid biomass of 3.18 g m^{-2} and 4.75 g m^{-2} in the spring and fall respectively of 1980. There was a higher biomass both of salmon and trout in 1981. Mean water velocities were somewhat slower in 1981 than at the 1980 sampling times (0.23 m s^{-1} compared with 0.60 and 0.49 in 1980). Two 2+ salmon and two 2+ and one 3+ trout had fin clips of the previous year from this station (27 1+ salmon, and 8 1+ and 16 2+ trout had been marked).

Rainy: Ninety-six salmon, 45 trout, and 1 eel were captured, with an estimated salmonid biomass of 6.68 g m^{-2} (salmon 2.69 g m^{-2}; trout 3.99 g m^{-2}), compared to 5.04 g m^{-2} and 3.06 g m^{-2} in 1980. Eleven two-year-old salmon were captured which had been marked at this location the previous year. One hundred and forty-four yearlings had been marked. None of the trout was marked.

Main Rainy Brook, Riffle: One hundred and thirty-eight salmon, 49 trout, and 5 eels were caught. There were therefore about 37.7 salmon 100 m^{-2} and 12.8 trout 100 m^{-2}, with an estimated salmonid biomass of 3.92 g m^{-2} (salmon 2.90 g m^{-2}; trout 1.02 g m^{-2}). The difference in biomass compared with the upstream station was due mainly to fewer older trout. The depletion method did not work well for the yearling trout, possibly because they tended to hide under the bank in debris, and were only gradually drawn out. One 2+ salmon parr had a fin clip from being marked as a yearling upstream at the 'Rainy' station the previous year.

Main Rainy, Pool: Two methods of assessing the fish population were used, diving and the depletion method.

By direct underwater observation were counted: 12 large parr, 14 small parr, 4+ salmon fry, 25 trout, 8 trout fry.

As opposed to the pool in the wider main river, the electroshocker was relatively successful. However, in pool areas the fish tend to be driven or herded, and not to hide amongst rock, or in pockets of water, as they appear to do in riffles. The sweeps were made upstream, and in the first two sweeps fish were caught mainly not where the majority had been seen, at the downstream end, but at the upstream end. Both times a school of fish attempted to return downstream, but a number were stunned as they swam by.

The total fish caught in six sweeps was 18 salmon parr, 8 salmon fry, and 27 trout plus 7 trout fry. An eel about 30 cm long was seen during the third sweep, but it escaped. The depletion method appeared to be successful for trout, and gave an estimate of 28 trout plus 9 trout fry, with a biomass of about 4.5 g m^{-2}. The depletion method did not work for parr in this pool environment, but if the number observed by diving was correct, there would have been about 26 parr, with a salmon biomass of about 1.3 g m^{-2}, and a total salmonid biomass of 5.8 g m^{-2}. Under water visibility was good, greater than 3 m, and the number of trout estimated was close to the number counted underwater (28 vs 25). There was some debris at the downstream right-hand side, and possibly the extra trout were out of sight in this. Probably most of the salmon were counted, except for fry in the shallows, as salmon tend to be more in the open than trout, and the stream was clear and relatively narrow.

River Brook Upper: A total of 11 salmon (1 fry), 34 trout (28 fry), and 1 eel, was caught, with an estimated salmonid biomass of 1.18 g m^{-2} (0.78 g m^{-2} salmon; 0.40 g m^{-2} trout), and density of 3.5 salmon parr, 0.3 salmon fry, and 1.4 trout, 7.7 trout fry, per 100 m^2. This station had the lowest salmonid biomass of all the sites sampled, and in conjunction with the earlier angling success indicates that the upper part of River Brook, below the obstruction, is relatively unproductive.

River Brook, Lower: A total of 169 salmon (including 4 fry), 47 trout (including 22 fry), and 15 eels were caught, with an estimated density of 12.8 salmon parr, 0.3 salmon fry, 2.0 older trout and 1.6 trout fry per 100 m^2, and salmonid biomass of 1.62 g m^{-2} (1.18 g m^{-2} salmon; 0.44 g m^{-2} trout). A salmon fry was swept away in the current and lost during one sweep. The salmon fry were in relatively fast water and some may have been swept away from the electrofisher, whereas trout fry were in slow, shallow water and easier to catch. We therefore do not think the count of salmon fry was accurate here, although they were not numerous.

Eleven 2+ parr bore fin clips from being marked as yearlings (72 marked) at this station the previous autumn.

River Brook Pool: Three methods of estimating the relative densities and biomass of trout and salmon were attempted here; direct counts underwater, electroshocking for estimates by the depletion method, and the mark and recapture method.

Underwater counts were made on 30 June. By slowly moving upstream, fish were observed and recorded on a slate. The following fish were seen: 14 large salmon parr, 12 small salmon parr, 7 salmon fry, 29 brook trout, and no trout fry. Electrofishing was done afterwards on the same day, but proved to be ineffectual in this type of environment. In two sweeps only two brook trout, one trout fry, one salmon parr, three salmon fry, and one eel, were caught.

Captures for the Petersen estimate were made with a beach seine at night and by angling. Fish were measured, and marked and released over three days, 30 June-2 July.

The population estimate for all sizes above underyearlings was: 50 parr (28-96) and 60 trout (30-128) by the Petersen method, and 48 parr (33-74) and 69 trout (46-107) by the Schnabel multiple release and recapture method.

There was therefore a density of about 0.12 salmon/m^2 and 0.17 brook trout/m^2, with salmonid biomass of about 4.78 g m^{-2} (0.86 g m^{-2} salmon; 3.92 g m^{-2} trout).

The underwater observations considerably underestimated the actual population, by about a half (26 vs 50 parr, 29 vs 60 trout), although visibility was good, and greater than 3 m. There was much underwater debris at the lower left end of the pool, and it is possible that a number of fish were out of sight in this. Also the river was wide, and the approach was by moving upstream on the left deeper side, so that fish may have been missed on the shallow right side. A school of trout was seen upstream from the debris, but many were likely to be hiding in the brush. There is a greater tendency for trout to be in association with cover, whereas salmon occur commonly away from cover in relatively shallow water.

Railway Bridge: Two methods were used for population estimates at this site. Over two days three electrofishing sweeps were made. The first two were made on June 21st, and these fish were marked and released. The third sweep was made on June 22nd. Marked fish were used for a Petersen's estimate, and unmarked fish for the third sweep of the depletion method. Altogether, not counting recaptures, 116 salmon were caught (including 5 fry), 68 trout (including 38 fry), and 18 eels. Density estimates were, excluding fry, 11.7 (Petersen's), 14.0 (Zippin) of salmon parr, and 3.1 (Petersen's), 2.5 (Zippin) of trout, per 100 m^2, with an estimated salmonid biomass of 1.24 g m^{-2} (0.69 g m^{-2} salmon; 0.55 g m^{-2} trout) by the Petersen's method. This is 31% less than the salmonid biomass (1.81 g m^{-2}) observed in September 1980.

Eleven of the 32 2+ salmon parr were marked from fin clips as yearlings the previous year, 6 from 55 marked at this station in the fall, 4 from 118 marked here in the spring, and 1 from 144 marked in Rainy River the previous spring.

Gillam's Farm: Altogether 105 salmon parr, 3 brook trout plus 3 trout fry, 31 eels, 1 three-spine stickleback, and 1 grilse were caught. The grilse was sheltering in a depth of 43 cm, between two boulders. It was released downstream. A Petersen's estimate gave a population estimate of 155 (102-246) salmon parr. The depletion method was unsuccessful in the deeper water of this station. Two-year-old salmon parr were more numerous (7.5 per 100 m^2) than yearling parr (4.9 per 100 m^2), the reverse of stations with shallower water. Total salmonid biomass was about 1.34 g m^{-2}, (1.22 g m^{-2} salmon; 0.12 g m^{-2} trout).

Nine of the 2+ parr were marked as yearlings the previous year at this station, two (out of 103) marked in the spring, and seven (out of 90) marked in the fall.

Loch Leven: Loch Leven is approximately circular, with a diameter of 450 m, and circumference of 1414 m. It is basin-shaped with a maximum depth of 18.5 m. Much of the littoral areas were covered with *Scirpus* and *Equisetum*, so we chose to make our seine hauls on the northern shore, which was relatively open. This had a bottom of gravel and cobble, with some yellow lillies, *Nuphar*, and *Potomogeton* beds at the offshore parts of the seine hauls. The offshore area had a soft bottom, sloping to deep water.

A number of hauls were made here with the beach seine in the littoral area over a stretch of 210 m, and a fyke net was set overnight. The purpose was to discover if juvenile salmon used the pond, and to find some indication of their density.

We made 17 hauls altogether, all adjacent and overlapping, from east to west. This was done by one person wading out for nearly the distance of the net, wading parallel to shore for about the length of the net, and then hauling in the net the usual way. All fish were counted, and salmon parr were anaesthetized, measured, given a right ventral fin clip, and released.

Sweeps	Salmon parr	Banded killifish	Three-spine sticklebacks	Other
1	11	26	27	
2	10	6	39	
3	7	3	33	
4*	5	5	35	
5	1	1	36	
6**			6	
7	14	27	58	
8	15	12	90	1 brook trout (fry)
9	6	2	44	1 eel, 2 nine-spine sticklebacks (Pungitius pungitius
10	7	12	23	
11	19	7	35	
12	32	10	39	
13	16	9	27	
14	14	2	56	
15	30	24	43	
16	17	22	59	
17	13	5	23	

* A poor sweep, as submerged logs had to be removed from the net during the sweep.
**A spoiled sweep, as the net was riding over reeds.

The banded killifish (Fundulus diaphanus) were large, and there were many highly colored male and fat female sticklebacks (Gasterosteus aculeatus). Probably these two species were abundant in the littoral areas due to spawning activities.

The following day nine sweeps were made in the same area to sample for marked parr.

Sweeps	Salmon Recaptures	Salmon Unmarked	Banded killifish	Three-spine sticklebacks	Others
1	4	1		28	
2	5	4		17	
3	7	3	5	15	1 brook trout
4	7	12	1	15	2 brook trout
5	3	3		33	1 brook trout
6	6	0	4	46	
7	3	2	1	55	
8	5	3	8	31	1 brook trout
9	2	5		83	

We therefore sampled 42 marked parr (38, 1+ and 4, 2+) and 33 unmarked (29, 1+ and 4, 2+). We had released 213 the previous day (172, 1+ and 41, 2+; 4 of the total 217 caught were mortalities). This therefore gives the adjusted Petersen's estimate of 378 parr in this section (95% C.L. 286-525), or 302, 1+ (275-418) and 67, 2+ (30-168).

We continued with five additional sweeps, starting about 20 m away from the seining site. We caught 17 unmarked parr and 1 recapture.

Sweep 10: one unmarked parr; two three-spine sticklebacks.

Sweep 11: five unmarked parr; six three-spine sticklebacks; one brook trout (fry).

Sweep 12: 4 unmarked parr; 19 three-spine sticklebacks; 1 brook trout (fry).

Sweep 13: one unmarked parr, one salmon fry; four three-spine sticklebacks.

Sweep 14: 1 recaptured parr; 6 unmarked parr; 13 three-spine sticklebacks.

Although there was some migration of marked parr from the site, which would give an overestimate of the total number, there appears to have been very little movement around the lake. This corroborates findings of Pepper et al. (1985) who found in their lake studies that over 80% of their recaptures of parr were at the site of original capture. Although we did not estimate the density in other sections of the shoreline, we saw small fish rising at the surface in all littoral areas, probably salmon parr, so that density may have been similar. If this were so, the lake probably supported about 2500 parr (378 x 1414/210), or 2030 yearlings and 450 two-year-olds, with biomass of salmon of about 17.8 kg for the 15.9 ha lake, or about 0.11 g m^{-2}. Pepper et al. (1985) suggest that the littoral areas of lakes within the 2 m depth contour provide the principal lacustrine habitat of 1+ and 2+ parr. We estimated 12.6 g of young salmon per meter of shoreline, but we are unable to suggest a biomass for the littoral areas since depth contours were not carefully measured.

The greater catch of trout on July 7 may have been related to cooler temperatures. Overnight rain and cool temperatures brought the water temperature down to 16.7°C (measured at 1400 h) from 19.5°C at 1700 h the previous day. Air temperature was 13.8°C. Although densities of salmon were low, compared to the fluvial habitat, the lake provided significant rearing area, and would have produced about 15 smolt ha^{-1} in 1982.

The fyke net was set overnight at the west end of the seining site between 1800 h and 0930 h. It contained 36 eels, and no other species, although several *Fundulus* were regurgitated. The mean T.L. of the eels was 48.9 cm (S.D. 11.55), range 25.5-80.0 cm. A sample of six was taken for length weight relationships, and for food analyses.

T.L. (cm)	Wt (g)	Stomach contents (and length of fish prey in cm)
59.8	391.00	5 *Fundulus* - 10.0, 10.2, 8.5, 8.3, 10.2 1 *Gasterosteus* - 3.0
80.0	1300	1 eel - 28.5
50.3	246.73	2 *Fundulus* - 9.5, 9.5
52.0	258.80	3 *Fundulus* - 9.0, 9.0, 9.7 2 *Gasterosteus* - 3.5, 3.5
55.3	376.46	3 *Fundulus* - 10.5, 9.0, 10.0, and a head and a tail 1 salmon (unmarked) - 11.8
62.5	468.28	1 *Fundulus* - 10.0 1 salmon, of standard length 10.0

Five regurgitated *Fundulus* had T.L.s (cm) of 7.0, 11.7, 11.0, 10.5, and 8.0.

Eels in the lake therefore appear to be extremely abundant, although on the night of July 6-7 there was heavy rain, raising the water level about 30 cm, which may have increased the activity of the eels. Nevertheless the number in the net was surprisingly high. Other studies have shown that competition and predation by eels have negative effects on the biomass of salmonids, although the lake appears to be very productive, and the *Fundulus* may act as a buffer prey between eels and salmon.

The adjacent river basin (Crabbes) was sprayed twice with Matacil (June 30 and July 8). Starting 18 hours after spraying 1 liter water samples were poured through an absorbent collecting tube every 2 hours until 8 liters had been poured through the tube. These samples were analyzed by the Chemistry Department of Memorial University. No Matacil was detected (< 0.26 mg l^{-1}) in the Highlands River.

On July 8 and 9, 1981, parts of Bald Mountain Brook and Rainy River were walked and angled with fly to ascertain how far salmon migrated in these tributaries. About the lower 3 km of Bald Mountain Brook was walked. There were no serious obstructions, although there was some tree debris. At the upper end of the trek eight trout and two large parr were caught, so salmon were able to migrate at least that far. Salmon parr were also caught downstream from here. The stream became steeper upstream, with coarser substrate, and this may limit suitable spawning areas. Despite heavy rain and relatively high water, the stream remained clear. The upstream section of Bald Mountain Brook was walked the evening of July 5. At the Trans Canada Highway (TCH) the stream dropped from a culvert, which would be a barrier for migrating fish. Trout were abundant in the pool below the culvert. The water was clear and cold (estimated to be about 12°C). A short distance downstream the stream ran into a small lake. This was exceptionally clear and appeared deep. The outlet was very clear, and warm (about 20°C). Freshwater clams were abundant here. About 1½ km was walked downstream. The gradient was fairly steep, and the substrate coarse. It was heavily overgrown, and the traverse difficult. It was difficult to fish, but six trout were caught, although no salmon. Except for a gravel bar at the outlet of the lake, gravel suitable for spawning was probably limiting for salmon, and a number of tree debris dams probably would make this upper section impassable for salmon. It appears that below the TCH only the downstream half of Bald Mountain Brook is used by salmon.

On July 9 Rainy Brook was walked, mainly along the railway track. In an upstream section, above its crossing of the track, it was heavily overgrown, and difficult to fish, but five trout were caught. It had a fairly steep gradient, and coarse substrate. Some tributary streams were seen with fine gravel, which would provide good spawning substrate for brook trout. In contrast to Bald Mountain, Rainy Brook was cold (estimated to be about 12°C), and dark brown. Sections were angled all the way to about 1 km above the study area. Trout were abundant, and a further 37 were caught, ranging from about 10 cm to about 25 cm in length, but no salmon parr. Most trout were released alive, but three were sampled. These had their stomachs packed with insects and oligochaetes, the high water possibly increasing the amount of available food. There was no obstruction from the last place angled to our study area (M. Chadwick, pers. comm.) so that the lack of salmon upstream must be related to some other factor, such as density of spawning adults or lack of spawning substrate. It is unlikely that water chemistry or temperature would change sufficiently in such a short stretch to limit the distribution.

Final fish collections were made at each river site between September 9-12. An attempt was made at this time to collect Fundulus in Loch Leven, but in three sweeps only one small specimen was caught. Sticklebacks and small salmon were caught but released. Sizes of salmon and trout collected in September 1981 are reported in Tables 15 and 16.

INVERTEBRATES

Data from the invertebrate collections are shown for 1980 in Table 17, and for 1981 in Table 18.

In 1980 there was no apparent relationship between the relative abundance of invertebrates collected by three methods, or the relative amounts of invertebrates and the biomass of salmonids. However, differences may not have been sufficiently great for relationships to be detected. With the basket samplers the highest volumes of invertebrates in the fall were collected at the Gillam's Farm station, with mean volume of 1.58 ml, whereas other stations had mean amounts less than 1.0 ml. This was also the station with the highest biomass of salmon in the fall (3.54 g m^{-2}). However, the second lowest salmon biomass was in River Brook (1.47 g m^{-2}), and this station had the second highest mean volume of invertebrates collected on the basket samplers (0.81 ml). It appears, with possibly the exception of the Gillam's Farm station, that variables other than relative abundances of food had greater effects on salmonid biomass at the various stations. The correlation coefficient for mean volumes of invertebrates collected by basket samplers versus total biomass of salmonids at the various sites was -0.1662. There was a significant correlation ($P < 0.05$) between stream width and biomass of invertebrates on colonization baskets ($r = 0.779$) in the fall of 1980, but not in 1981 ($r = 0.49$; $P > 0.05$).

In 1981 the amounts of invertebrates collected on the basket samplers were again very much greater at the Gillam's Farm station than at the other sites. However, in 1981 salmon biomass was not highest at this station and there was no significant relationship between biomass of salmonids and collections of invertebrates. Correlation coefficients for comparing mean volumes of invertebrates with biomass of salmonids at the various sites were, for salmon, 0.0877, for trout, -0.2637, and for total salmonid biomass, -0.1704.

WATER CHEMISTRY

The differences in biomass of salmonids between stations were not correlated to differences in the water chemistry ($P > 0.05$) so that within this system the chemistry does not change sufficiently to affect fish production. There were considerable differences in conductivity down the river, and this may be related to the geology. We noticed a number of seepages and springs down the river, which colored the rocks a rusty color. We took a water sample from a pool by one of these, near the outflow of Camp 40 brook at Abraham's pool, on June 22, 1981. It was highly saline, and had a sulphate content of 1320 mg l^{-1}, calcium of 1860 mg l^{-1}, and ortho-phosphate of 0.191 mg l^{-1}. Changes through the season in 1980 and 1981 of acidity and concentrations of the major ions at locations in the main river are shown in Figures 2-9.

EELS

Biomass estimates and mean sizes of eels are given in Tables 19 and 20. At all three sampling times the greatest biomass of eels was found at the Gillam's Farm station. This station also had the highest invertebrate biomass as shown by basket samplers. It was below a lake, Loch Leven, which would tend to stabilize discharge and water temperature, and was the station closest to the estuary. There were considerable differences in biomass at different seasons. At Gillam's Farm the biomass in the spring of 1980 (3.60 g m^{-2}) was almost twice that found in the fall (1.96 g m^{-2}) and in the summer of 1981 (1.78 g m^{-2}). All eels were collected in 1980, so if there were restricted movements, this would have affected subsequent sampling. However, at other sites the biomass of eels increased, as for example at the lower River Brook station, where in the spring of 1980 no eels were caught, in the fall the biomass was about 0.37 g m^{-2}, and in the summer of 1981 the biomass of eels was about 1.16 g m^{-2}, indicating considerable movement, probably from downstream. The biomass of eels at a site may therefore be related to food and water conditions at the time. At the River Brook station, at the spring sampling time in 1980 the water was high (discharge = 4.2 m^3s^{-1}) and cold (9.5°C), and no eels were caught, whereas in the summer sampling period in 1981 discharge was lower (1.43 m^3s^{-1}) and the water temperature higher (21.3°C), and eels were fairly numerous (n = 15 and biomass estimate 1.16 g m^{-2}). Substrate and water velocity may have little effect on the distribution of eels. Baglinière (1979) found eels just as well distributed in habitats with running water and rocky substrate as in zones with no current and muddy bottom.

Judging by the catch of eels caught in the fyke net set in Loch Leven, and by our samples, eels were abundant in the system. They were abundant towards the estuary, and are exploited there by a small local commercial fishery. A pool a short distance upstream from the estuary is locally called the 'eel hole'. Some underwater observations were made there on the late afternoon of June 25, in 1981. It had been hot and sunny all day, and the water temperature was 20°C. Eels were numerous and were seen foraging. Some were very big, and appeared close to a meter in length. Several were seen in groups of half a dozen or so peering out of crevices. Elvers were migrating upriver at the time. Glass eels had been seen between the counting fence and the estuary on June 19 (T. Nicholls, Department of Fisheries and Oceans, P.O. Box 5667, St. John's, Newfoundland A1C 5X1, pers. comm.). Another underwater observation was made in the 'eel hole' on July 8. The water was cooler (17°C), and due to recent rains was higher and more murky than during the previous observation. No eels were seen, although underwater visibility was still good, so they had either moved or were under cover.

A log weight, g, (Y), log length, cm, (X) distribution gave a regression of Y = 3.1X - 3.0 (r^2 = 0.98) for eels in the spring of 1980 and, Y = 3.0X - 2.8 (r^2 = 0.99) in the fall (Fig. 10 and 11).

Reports of length-weight relationships for eels in Newfoundland are few. Button (1982) found for eels in Bay D'Espoir, on the south coast, a length (mm), weight (g) relationship of $W = 0.0000000413L^{3 \cdot 57}$, or logW = 3.57 logL - 7.38. Wood (1986) found in Indian Arm Brook, northeastern Newfoundland, a relationship of, logW = 3.50 logL - 6.63, where weight was in kg and length in cm.

Bouillon and Haedrich (1985) found that the mean length and weight of silver eels from Dog Bay, in northeast Newfoundland were significantly larger than those from Holyrood Bay, on the south coast. The growth of the eels was faster in the area with the largest watershed than in areas with smaller watersheds, which they thought probably reflected variation in competition for food and space. The relationships between weight, W (g) and length, L (cm) were: Dog Bay, $W = 0.00294\ L^{2 \cdot 91}$; Holyrood Bay, $W = 0.00340\ L^{2 \cdot 86}$, or logW = 2.91 logL - 2.53 and logW = 2.86 logL - 2.47, respectively.

RELATIONSHIPS OF SALMONID BIOMASS AND DENSITIES WITH HABITAT PARAMETERS

The relationships between salmonid biomass and densities and the major habitat variables are given by season in Table 21, and with all seasons combined in Table 22. The density of salmon 0+ was significantly ($P < 0.01$) correlated with mean water velocity ($r = 0.86$) in the summer of 1981. However, other correlations for salmon were insignificant ($P > 0.05$). Biomass of brook trout was found significantly ($P < 0.05$) and negatively correlated to the stream width in the spring of 1980 ($r = -0.83$) and in the summer of 1981 ($r = -0.755$) and when all seasons were combined ($r = -0.718$). Total trout density and trout 2+ density were negatively correlated ($P < 0.05$) with stream depth in the spring of 1980, but this was most likely due to a sampling problem, as pools were not sampled in 1980, and the preferred smaller streams had shallower water than at other sites. Trout biomass and densities were negatively correlated with ice scour height and positively with amount of overhanging cover. Trout biomass and density of 1+ were negatively correlated with substrate rating in the fall of 1980, and when all seasons were combined ($P < 0.05$). A curious correlation is the apparent negative correlation when seasons were combined between total trout densities and the amounts of invertebrates ($r = -0.52$; $P < 0.05$). However this correlation is confounded by a correlation between amounts of invertebrates and stream width ($r = 0.62$; $P < 0.01$). Width was also correlated with cover ($r = -0.65$; $P < 0.01$) and ice scour height ($r = 0.57$; $P < 0.01$). At the spring sampling sites in 1980 there was a significant ($P < 0.05$) correlation between width and depth ($r = 0.89$), but not at other times ($P > 0.05$).

With semi-logarithmic analyses (Table 23) some correlation coefficients were improved, such as width, amount of cover, and ice scour height. Substrate rating was an exception, and may therefore have a linear relationship where significantly correlated with biomass or densities. A logarithmic transformation of all variables (Table 24) improved correlations with width, ice scour height, amount of cover, and amount of invertebrates, although the latter was correlated with width ($r = 0.48$; $P < 0.05$). Width was also correlated to cover ($r = -0.878$; $P < 0.01$), ice scour height ($r = 0.675$; $P < 0.01$), and depth ($r = 0.41$; $P < 0.05$). Cover and ice scour height were also correlated ($r = -0.69$; $P < 0.01$).

Significant regressions ($P < 0.05$) of trout biomass and densities with variables of the habitat are given in Tables 25-27, arithmetically in Table 25, semi-logarithmically in Table 26, and logarithmically in Table 27.

Since in Rainy Brook East the traditional spawning beds for salmon were obstructed by a collapsed bridge upstream, and any parr in the station would have had to migrate upstream at least 4 km from River Brook, it is probably valid to exclude this station in the system from our calculations concerning salmon parr habitat. In Table 28 Rainy Brook East has been excluded. Both salmon biomass and density were then significantly ($P < 0.05$) correlated to substrate, but not to any of the other parameters ($P > 0.05$). Logarithmic transformations did not improve these correlations with substrate (Table 29).

Suitable spawning substrate was lacking in River Brook, and probably contributed to poor recruitment in this section. Therefore the two stations in

River Brook as well as the station in Rainy Brook East were excluded in Table 30. For all the other stations and seasons salmon biomass and density were significantly ($P < 0.05$) correlated to substrate, although not to other variables ($P > 0.05$). These correlations were not improved with logarithmic transformation (Table 31), but salmon 1+ parr density did then have a significant correlation with substrate ($P = 0.025$), although not with the untransformed data ($P = 0.053$).

STEPWISE REGRESSION PROCEDURE FOR DEPENDENT VARIABLES, BIOMASS, AND DENSITIES

Variables were entered in the stepwise regression only if biomass on variable was significant at $P < 0.15$ (Tables 32-43).

Salmon

With salmon biomass by season no variables met the 0.15 significance level for entry into the model. If seasons are combined, two variables met the criteria for entry into the model: width, X_1, and invertebrates, X_2. This gives the equation:

$$Y = 1.371 - 0.026X_1 + 1.186X_2;\ \text{with } r^2 = 0.2546.$$

With density of 2+ salmon, one variable only, invertebrates, met the 0.15 significance level for entry into the model:

$$Y = 3.320 + 4.416X;\ (r^2 = 0.1809).$$

If habitat variables were transformed (logX+1), substrate rating was retained in the model with salmon biomass: $Y = -2.191 + 6.202(\log X+1)$; ($r^2 = 0.149$); and with total salmon density: $Y = -31.454 + 86.981\ (\log X+1)$; ($r^2 = 0.093$).

With all variables transformed to log base 10, total salmon density could be related to ice scour height (X_1) and cover (X_2) as follows:

$$\log Y+1 = 0.373 + 1.760(\log X_1+1) + 0.385(\log X_2+1),\ \text{with } r^2 = 0.291.$$

The relationships with the Rainy Brook East station removed are shown in Table 33. Salmon biomass is related to substrate rating (X_1) and ice scour height (X_2) as follows:

$$Y = -0.757 + 1.063(X_1) - 0.643(X_2),\ \text{with } r^2 = 0.515;$$

and,

$$\log Y+1 = -0.528 + 1.792(\log X_1+1) - 0.449(\log X_2+1),\ \text{with } r^2 = 0.519.$$

With the logarithmic transformations total density and density of 1+ parr were related to cover and substrate (Table 33).

Some correlations were improved if the upper and lower stations in River Brook and the Rainy Brook East station were removed (Table 34). With total density of parr the following habitat variables were retained in the model, substrate rating (X_1), width (X_2), cover (X_3), and depth (X_4) to give the following relationships:

$$Y = 20.325 + 9.130(X_1) - 0.533\ (X_2) - 0.260(X_3) - 0.246(X_4);\ r^2 = 0.779.$$

With all variables transformed to log base 10, salmon biomass was related to substrate (X_1), width (X_2), and cover (X_3) as follows:

$$\log Y{+}1 = -0.464 + 1.503(\log X_1{+}1) - 0.576(\log X_2{+}1) - 0.268(\log X_3{+}1);\ r^2 = 0.741.$$

Brook trout

In the spring of 1980 trout biomass (Y) was related to cover (X_1) and ice scour height (X_2) as follows:

$$Y = 2.123 + 0.031X_1 - 1.132X_2;\ \text{with } r^2 = 0.925.$$

Transforming to log base 10 gave:

$$\log (Y{+}1) = 0.956 - 0.403(\log X_1{+}1) - 0.573(\log X_2{+}1);\ r^2 = 0.931,$$

where X_1 = width and X_2 = ice scour height.

In the fall of 1980 trout biomass was related to cover (X_1), and ice scour height (X_2) as follows:

$$Y = 1.927 + 0.039X_1 - 1.034X_2;\ \text{with } r^2 = 0.856$$

Transforming to log base 10 gave:

$$\log (Y{+}1) = 1.658 + 0.086(\log X_1{+}1) - 0.675(\log X_2{+}1) - 0.951(\log X_3{+}1);\ r^2 = 0.921,$$

where X_1 = cover, X_2 = ice scour height, and X_3 = depth.

In the summer of 1981 trout biomass was related to, width (X_1), cover (X_2), ice scour height (X_3), and mean water depth (X_4), as follows:

$$Y = 2.853 - 0.067X_1 + 0.028X_2 - 1.175X_3 + 0.055X_4;\ \text{with } r^2 = 0.905$$

Transforming to log base 10 gave:

$$\log (Y{+}1) = 0.433 + 0.281(\log X_1{+}1) - 0.593(\log X_2{+}1);\ r^2 = 0.844,$$

where X_1 = cover and X_2 = ice scour height.

With all seasons combined (Table 35), trout biomass was related to ice scour height (X_1), width (X_2), depth (X_3), and cover (X_4) as follows:

$$Y = 2.051 - 1.129(X_1) - 0.040(X_2) + 0.057(X_3) + 0.034(X_4);\ r^2 = 0.849.$$

Semi-log analyses did not improve the model (Table 36). The model was very slightly improved when all variables were transformed to log base 10 (Table 37), with the following variables: width (X_1), substrate rating (X_2), ice scour height (X_3), and depth (X_4):

$$\log Y{+}1 = 1.192 - 0.524(\log X_1{+}1) - 0.804(\log X_2{+}1) - 0.504(\log X_3{+}1) + 0.318(\log_4{+}1);\ r^2 = 0.860.$$

The total trout density was related to ice scour height (X_1), substrate rating (X_2), and width (X_3) as follows:

$$Y = 47.637 - 5.373(X_1) - 8.001(X_2) - 0.244(X_3);\ r^2 = 0.910.$$

The models with Rainy Brook East station removed are given in Tables 38-40, and also with the two River Brook stations removed in Tables 41-43. Although spawning substrate was limiting at these stations, unlike juvenile salmon populations, there would probably be adequate recruitment from upstream areas so that deleting these stations would not be valid in the case of brook trout analyses.

Salmon and trout

With all seasons combined, total salmonid biomass could be related to cover (X_1), ice scour height (X_2), and depth (X_3) as follows:

$$Y = 2.844 + 0.055X_1 - 1.158X_2 + 0.047X_3;\ r^2 = 0.786.$$

The model was not improved with log transformation.

If the Rainy Brook East station is removed, total salmonid biomass can be related to ice scour height (X_1), width (X_2), and invertebrate volumes (X_3) as follows:

$$Y = 6.558 - 1.645X_1 - 0.094X_2 + 1.660X_3;\ r^2 = 0.818.$$

This model was not improved with log transformation.

Competitive interactions

From the September samples of salmon in 1980, mean weights (Y) were plotted against density (X), (Fig. 12). With 0+ there was no significant correlation between mean weight and density ($r = -0.6376$; $P > 0.05$), and less correlation between log weight and log density ($r = -0.4375$; $P > 0.05$). With 1+ there was a significant correlation between weight and density ($r = -0.8414$; $P < 0.05$), and between log weight and log density ($r = -0.8489$; $P < 0.05$). There was no significant correlation for 2+ between weight and density ($r = -0.6007$; $P < 0.05$), but there was a significant correlation between log weight and log density ($r = -0.8295$; $P < 0.05$).

Regressions of specific growth rate and density were not significant ($P > 0.05$), but gave a larger correlation coefficient for 0+ ($r = -0.8030$) than weight and density ($r = -0.6376$). The growth rate of 0+ at the Gillam's Farm site is lower than might be predicted from the regression and is an obvious 'outlier' (Fig. 13), probably related to atypical habitat for fry. If this site is not included, the correlation is highly significant ($r = 0.9925$; $P < 0.01$).

There were no significant correlations ($P > 0.05$) in the 1980 samples of salmon between specific growth rate of 0+ with biomass of 0+ ($r = -0.4590$), biomass of 1+ ($r = -0.4816$), biomass of 2+ ($r = -0.4816$), or total biomass of salmon ($r = -0.4239$). With 1+ salmon there was a significant correlation between the specific growth rates and biomass of 1+ parr ($r = -0.8409$; $P < 0.05$), but not with biomass of 2+ salmon ($r = -0.6068$; $P > 0.05$), or with total biomass of salmon ($r = -0.1716$; $P > 0.05$). The specific growth rates of 2+ parr were not significantly correlated with biomass of 2+ parr ($r = -0.6068$; $P > 0.05$), or with total biomass of salmon, ($r = -0.7033$; $P > 0.05$).

In the summer samples of 1981 there was no significant correlation ($P > 0.05$) between the mean weights of 1+ parr and their densities ($r = -0.3833$), or between log weight and log density ($r = -0.4974$). There was no correlation between mean weights of 2+ parr and densities ($r = -0.1888$). With the latter regression there were three 'outliers', the two pool sites, and 'Railway Bridge'. If it is assumed that these three sites for some reason or other are not as productive as the others, and therefore not comparable, the remaining seven sites show a significant inverse correlation with mean weight of 2+ parr and densities ($r = -0.7790$; $P < 0.05$). A log weight (Y) versus log density (X) with these seven sites shows a better correlation, ($r = -0.8680$; $P < 0.05$), the regression equation being, $Y = 1.284 - 0.128X$ (Fig. 14). It is probably valid to omit the pool sites, as these provide different habitat and would not be as productive of aquatic food organisms as faster water habitat.

Considering instantaneous growth rates at sites sampled in both 1980 and 1981 there was a regression for 1+ parr of growth $(Y) = 0.583 + 0.013X$ density (X), with $r = 0.6566$ ($P > 0.05$), and for 2+ parr of, $Y = 0.193 + 0.044X$, with $r = 0.9157$ ($P < 0.05$) (Fig. 15). Although there was a significant correlation only with 2+ parr, what appears unusual is that the best growth rate was at the greater densities, and the least growth rate at the lower densities, whereas the opposite might be expected. The density dependent growth rates shown in Figures 13 and 15 therefore appear to be contradictory. With 1+ parr the best growth rates were in Rainy River and Bald Mountain Brook (1.237 and 1.109), at the higher densities (19.3 and 15.9 per 100 m^2 respectively) and the least at River Brook and Railway Bridge (0.874 and 0.516) at the lower densities (10.1 and 8.8 per 100 m^2). Similarly, with 2+ parr best growth rates were in Rainy River and Bald Mountain Brook (0.872 and 0.633) at densities respectively of 12.8 and 13.2 per 100 m^2, whereas least growth was in the River Brook and Railway Bridge sites (0.281 and 0.333) at densities of 2.7 and 2.9 per 100 m^2, respectively. The former sites were therefore more productive than the latter two, illustrating how density dependent growth may be masked by differing production between sites.

There appeared to be no relation between the biomass of salmon and trout, either at the sites in the fall of 1980 ($r = -0.3206$; $P > 0.05$) or in the summer of 1981 ($r = 0.0859$; $P > 0.05$).

Linear regressions were calculated for the trout populations at sampling sites in the fall of 1980 and in the summer of 1981 for the mean weight of each year-class present versus the density, for arithmetic and log-log plot, however none of these was significantly correlated ($P > 0.05$). However, in the fall of 1980, the specific growth rates of 1+ trout were significantly correlated with biomass of 1+ trout ($r = 0.9094$; $P < 0.05$), not showing density dependent effects, but reflecting better growth at the more productive sites. Specific growth rates of 0+ and 2+ trout were not correlated with their respective biomasses ($P > 0.05$).

Habitat mapping

Porter et al. (1974) reported from aerial observation that the substrate from the estuary up to Loch Leven was primarily boulder and rubble, and above Loch Leven up to Camp 40 brook was of rubble and gravel. Upstream from here, above the confluence of East Rainy, and up to 11.4 miles upstream from the estuary, the substrate consisted mainly of rubble, boulder, and gravel, and upstream from here to the impassable falls, the substrate was mainly of boulder and rubble.

In walking along the river our general observations of the substrate were similar to the ones described above. Coarse gravel suitable as a substrate for spawning appeared to be limiting upstream from the Trans Canada Highway to the impassable falls on River Brook. The substrate in this upstream stretch of the main river was coarser, consisting mainly of bedrock, boulders, and rubble, except for small pockets of gravel occasionally seen along the edge of the river, but which would be unsuitable as sites for spawning. Closer to the falls, or 'tunnel' as it is locally called, the substrate consisted predominantly of boulders and bedrock, with some rubble and cobble, but with no gravel suitable for spawning seen. Similarly all the tributary streams of River Brook had a coarse substrate of boulders, bedrock, and rubble. They were well shaded and provided habitat more typical for trout than salmon.

Upstream from the obstruction riffle areas were plentiful, suitable as good parr habitat, for at least the mile or so that we walked between a woods road and the falls, and abundant gravel areas, suitable for spawning, were present.

Details and data of the sections of Highland River mapped in 1980 are given by Nicholls (MS 1980). Physical characteristics of the river were measured every 100 m, including: wet width (m); depth (cm) at three equidistant points along a transect across the river; estimated maximum depth of pools; water velocity, measured as surface velocity of a floating object; relative proportions of types of riparian vegetation; height of river bank; and visual assessment of the type of substrate. Seventy-seven sites were measured in all. A summary of the mean values (and standard deviations) is as follows:

Mean wet width: 29.2 m (S.D. 9.50) (lower section, 29.5 m, S.D. 10.04; Upper section 28.4 m, S.D. 8.41).

Mean depth readings, excluding pools (> 50 cm), of lower section (87 readings, at 29 sites): 27.6 cm (S.D. 10.49).

Mean depth readings at sites with pools (57 readings at 19 sites): 64.4 cm (S.D. 41.37).

The first four sites had single readings, with depths between 1.2 m - 4 m.

Mean depth readings, excluding pools (> 50 cm), of the upper section, from the railway bridge, to above Camp 40 brook (58 readings, at 20 sites): 28.6 cm (S.D. 8.53).

Mean depth readings of sites with pools, in the upper section (15 readings at 5 sites): 51.8 cm (S.D. 41.88).

Mean percentages of substrate in the lower section (52 sites), S.D. in brackets:

Boulder, 29.1 (18.01);
Rubble, 11.5 (16.79);
Cobble, 22.4 (20.64);
Bedrock, 21.3 (31.84);
Gravel, 0.1 (5% at one site);
Sand, 1.3 (5-30% at four sites).

Mean percentages of substrate in the upper section (25 sites):

Boulder, 21.6 (12.48);
Rubble, 60.8 (21.54);
Bedrock, 4.4 (16.35);
Sand, 13.2 (12.90).
(Cobble was not mentioned, and may have been included with 'Rubble' in this upper stretch.)

Mean water velocity (cm s^{-1}): 68.3 (17.48) (n = 73).

Riparian vegetation (%): 42.9 (21.58) Coniferous; 39.1 (20.69) Deciduous; 17.6 (23.12) shrubs.

Mean bank height (m) = 4.6 (4.24).

Although stream mapping is important for estimates of the total area of habitat suitable for the various stages and species of salmonids, the results of the mapping here have limited application, as relatively small stretches of the river were measured, and insufficiently detailed data are available. However we can conclude that good rearing habitat for salmon parr is available for much of the river. The mean width of the river in the downstream section was wider than in the estimate by Porter et al. (1974), 29 m < cf 20 m, so was used in calculations of total area (Table 45). Therefore our figure of available habitat, 621,926 m^2, is larger than the previous estimate of 499,252 m^2. The discrepancy may be related to differences in water levels at the time of the surveys as well as the fact that the survey by Porter et al. (1984) only estimated widths by eye.

Available salmon habitat and the production of smolts

We have attempted to categorize the major sections of the river, and estimate the area available for salmon in Table 44. From our parr estimates in representative sections we have estimated total numbers of parr for these sections and extrapolated for the whole river. Using the counting fence records for total smolt counts, and the proportion of different age groups, we estimated the probable production of smolts from each section for 1981 and 1982. The estimates were made using 1+ and 2+ parr, as older parr were few, and totals of 2+ and 3+ smolt, as these were the predominant age groups.

Smolt counts at the fence were (T. R. Porter and E.M.P. Chadwick, pers. comm.):

Year	Number of smolts	Percent 2+	Percent 3+	Percent 4+
1980	15,130	35.5	63.4	1.2
1981	15,839	34.4	64.5	1.1
1982	12,373	16.2	69.8	12.5

Although we have extrapolated from relatively few sites, our estimates may not be too improbable. Using survival estimates of parr derived by Myers (1984) for the Little Codroy River, a comparable system in the southwest corner of the province, and proportions of mature parr from samples the previous September, we made estimates for juvenile salmon in the following year. Myers (1984) found survival was somewhat different in the four years he analyzed. One year (1961-62) had unusually high survival, possibly due to sampling error, so we used a mean survivorship derived from the other years. These were, (range in brackets):

Age	Survivorship
1+ (immature)	0.34 (0.30 - 0.40)
2+ (immature)	0.30 (0.24 - 0.40)
1+ (mature)	0.23 (0.12 - 0.32)
2+ (mature)	0.15 (0.095 - 0.19)

Our autumn samples were unfortunately rather few, but had the following numbers and proportions of mature (precocious) males:

	Age	Mature males (%)	Immature males	Females
1980	1+	8 (42.1%)	11	23
	2+	5 (71.4%)	2	2
	3+	1 (100%)	0	0
1981	1+	16 (72.7%)	6	18
	2+	26 (78.8%)	7	17
	3+	1 (100%)		

The small sample of autumn parr would tend to provide inaccurate estimates, and Myers (1984) has shown that in late summer and in autumn the proportion of mature male parr is higher near potential spawning sites, so that relative proportions change in the river. However, Myers (1984) found that approximately 80% of male parr were observed to mature precociously, a consequence of fast growth (Myers et al. 1986), and as our figures are close to this we have used our estimates for calculations.

If our 1980 estimates of parr are considered, estimates for 71,320 yearling parr would provide in 1981: 12,124 female 2+ (71,320 x 0.5 x 0.34), 3,452 previously mature (71,320 x 0.5 x 0.421 x 0.23), and 7,020 previously immature ((71,320 x 0.5) - (71,320 x 0.5 x 0.421)) x 0.34 male 2+ salmon, to give a total of 22,596 two-year-old juveniles. Of these 5,441 migrated as 2+ smolts, which would leave about 17,155 two-year-old parr in 1981. In fact about 27,034 were estimated, a difference of 9,880. The sex ratio from the calculations above suggest a male:female ratio of 2+ parr of 0.46:0.54; however, for estimates of 3+ parr they are considered as equal proportions since reliable figures are not available.

For 32,631 two-year-old parr estimated in 1980, estimates for 3+ in 1981 gave 4,895 females (32,631 x 0.5 x 0.3); 1,738 mature males (32,631 x 0.5 x 0.71 x 0.15); and 1,419 immature males (32,631 x 0.5 x 0.29 x 0.3)or a total of 8,052. Ten thousand two hundred and seventeen 3+ smolts were counted through the fence, an undetermined number of smolts would die from predation on their way down river, and a small number of 3+ parr remained in the river, so this estimate is low (-2,165).

Similarly, for 1981 parr, we might predict that from 49,255 yearlings there would be 15,608 two-year-olds in 1982. Fence records showed that 2,000 of these migrated as smolts, so survival estimates would suggest that 13,609 two-year-old parr remained in the river. A total of 6,513 three-year-old juvenile salmon in 1982 were estimated from our figures. In fact, 8,600 3+ smolts emigrated, again an underestimate (-2,088).

The fact that our estimates of 3+ smolt differed from counts by a similar figure in the two years (an underestimate by 0.79 in 1981 and by 0.76 in 1982) suggests that a similar error might be involved. This of course could be the survival estimate, but could also be due to inaccurate estimates of the available habitat, which has not yet been carefully measured. If, for example, the width of the lower river is estimated from the Railway Bridge and Gillam's Farm stations (41.5 m and 43.5 m), a larger area would be estimated for the lower river, and estimates for 3+ smolt would become 11,534 in 1981 (10,217 at the fence) and 8,100 in 1982 (8,600 counted at the fence). Better predictions of smolt numbers could be made with a greater number of representative stations and with accurate mapping of the available habitat. Survival from 2+ parr to 3+ smolts may have been similar in the two years. Using counts of 3+ smolts and estimates of 2+ parr, and not taking into account 3+ parr remaining in the river, there was a survival of 0.31 to 3+ smolts in 1981 and 0.32 to 3+ smolts in 1982. Few 3+ parr remain in the river (Tables 2, 5, and 13). However, the calculations above suggest that parr estimates for the river are somewhat low, so survival may be slightly lower.

If a total survival is calculated from the estimated numbers of 1+ parr in 1980 to 2+ parr and smolts in 1981, we get 0.46 [(27,034 + 5,441) ÷ 71,320]. If the number of smolt is reduced by a similar figure as the underestimate of 3+ smolt (5,441 x 0.79) the survival estimate becomes 0.44. This is close to the upper limits derived by Myers (1984) so may be a fair estimate. In fact if the density of parr in the Highlands River is relatively low, survival rates may be higher than at higher densities. Elson (1975) estimated a survival of 1+ parr to 2+ smolt of 0.44 in the Pollett River at low densities (an egg deposition of 45/100 m^2), similar to the survival and probable egg deposition in this study. If estimates for the total parr population are low due to inaccuracies in estimating the available habitat, this same error would be present in both years, so the survival estimate of the parr would not be affected by this error, if our sample sites were representative of the complete river. For each section there appear to be wide differences in survival (Table 46). These range from 0.27 in upper River Brook to 1.19 in Camp 40 Brook, the latter figure showing an increase in numbers from the previous year. Probably therefore the higher figures indicate immigration and lower figures emigration rather than real differences in mortality and survival. The main river sites show the lowest values, with the exception of below Loch Leven.

Table 45 suggests that smolt production varies considerably between sites. For example in 1981 over half the smolt production may have been derived from the river below Loch Leven, although the area has only about 25% of the available habitat. Relatively poorer smolt production is from the main river upstream from the lake. Smolt production from Loch Leven was estimated in only one year, but may produce about 2% of the smolts. Although relatively small, Loch Leven apparently has a positive effect on production downstream, probably in regulating discharge and water temperatures, and in providing food for invertebrates on which salmonids feed. Similar effects by lakes on production of salmonids in boreal areas have been measured at other locations (Gibson et al. 1984). Although production of smolts appears to be relatively low at some sites, such areas could be important for spawning and for rearing of fry and yearlings. Also the relative proportions of smolts from different age classes will differ between sites depending on the relative growth rates at various sites.

Symons (1979) points out that to reach 15 cm, smolts generally require approximately 500 days with water temperature at or above 7°C. Water temperatures are shown for 1980 and 1981 in Fig. 16 and 17, and were taken over the season in 1980. The latter indicate 142 growing days from mid-May to the beginning of October, which if similar for other years, should produce smolt of average age 3.5 years. In fact mean age was less, with a relatively high proportion of 2+ smolts. This could indicate better growth rates due to relatively higher production in the Highlands River, but since smolt age can fluctuate in response to density (Gibson and Côté 1982; Gibson and Dickson 1984), it may indicate also relatively low densities of parr.

Optimum egg deposition

For management purposes a target of 240 eggs per 100 m^2 of parr rearing area is used (Elson 1975). For the Highlands River therefore 1.5 x 10^6 eggs are required (6,219.26 x 240). If fecundity is taken as 1,540 eggs per kilogram (Anon. 1978), 969.2 kg of female salmon is required. Stock characteristics presented by Porter and Chadwick (1983) are 66% grilse, with mean weight 1.4 kg, and 14% females, and 34% large salmon, with mean weight 5.1 kg, and 67% females. Using these data the spawning requirement is 69 female grilse (494 grilse in total), and 171 female MSW salmon (255 MSW salmon), for a total of 749 salmon.

In fact spawning escapements in 1980, 1981, and 1982 were 55, 29, and 56 respectively of large salmon, and 82, 127, and 100 of grilse (Porter and Chadwick 1983). Unfortunately we do not have a long enough series of data to relate potential egg production to numbers of juvenile salmon in 1980 and 1981. The potential egg deposition was therefore 4.5 x 10^5 in 1980 (0.30 the required number); 1.9 x 10^5 in 1981 (0.13 the required number); and 3.2 x 10^5 in 1982 (0.22 the required number).

If a mean of these three years of 52 eggs per 100 m^2 is taken as a very rough approximation for egg deposition of a typical year recently, an underyearling density is estimated as 14/100 m^2 using Elson's (1975) model or 10/100 m^2 using Symons' (1979) calculations. This would result in five yearlings per 100 m^2 (Elson 1975) or six yearlings per 100 m^2 by Symons' (1979) model. In the present study we estimated that for the whole river there were for 1+ parr 11/100 m^2 in 1980 and 8/100 m^2 in 1981. Using Symons' (1979) estimated survival rates, there would have been egg depositions of about 104/100 m^2 in 1978, 72/100 m^2 in 1979, and using our estimates of 2+ parr and smolt, about 107 eggs/100 m^2 in 1977. Nevertheless, this represents only about 40% of the recommended density.

From our population estimates of parr at various sites, egg deposition may have varied considerably through the system. For example, using Symons's (1979) suggested survival rates, egg deposition per 100 m^2 may have been as shown in Table 46.

In fact these estimates for egg deposition probably illustrate better the migration and preferred parr habitat rather than actual areas of spawning. For example the estimate below Loch Leven suggests a deposition of 331 eggs per 100 m^2, calculated from a high density of 2+ parr. At this station fry were few and spawning habitat was lacking. Rainy Brook tributary and main stem appear to have had close to adequate seeding since yearling parr here were abundant and fry relatively numerous. Both the upper and lower sections of River Brook appear to have had very low egg deposition. This might be expected from the lack of substrate suitable for spawning in this section. In its present state it is unlikely River Brook would benefit from additional spawners.

Egg deposition for Lock Leven was not included in Table 46, as parr must have immigrated into these lentic waters, possibly both as 1+ and 2+ parr. However, if 2+ parr are considered (0.3/100 m^2), using Symons' (1979) suggested survival rates, about 5.3 eggs per 100 m^2 would have provided these parr, or 7.9 eggs per 100 m^2 using Elson's (1975) rates, for low deposition in 1978. Similarly for the 1+ parr (1.3/100 m^2), egg numbers in 1979 giving rise to these parr may have been 11.8/100 m^2 (Symons 1979), or about 14.3/100 m^2 (Elson 1975).

DISCUSSION

This investigation demonstrates that production of salmon varies considerably through the river system, and emphasizes the importance of studies of the stream ecology in conjunction with use of a counting fence. Conventional methods of estimating production of juvenile salmon have simply divided the total output of smolts by the total area of available fluvial rearing habitat in the system (e.g. Elson 1975). In general the principles of stream ecology (e.g. Hynes 1970; Vannote et al. 1980) have not been applied, and relative production of river systems is ascribed mainly to climate (e.g. Symons 1979), and water chemistry (e.g. Egglishaw 1967). A standard value of smolt production and egg deposition requirements per unit area may be useful on a general scale, but these methods do not allow accurate estimates or predictions for individual river systems and therefore their management. For example, an average smolt production for the river was 2.6/100 m^2 in 1981 and 2.0/100 m^2 in 1982 (taking all year-classes into consideration), whereas in 1981 we estimated a range of 1.0 to 6.2 smolts per 100 m^2, depending on habitat, and in 1982, 0.6 to 5.3 smolts per 100 m^2, with 0.2 smolts per 100 m^2 from the lake. Few studies have related salmonid production to stream ecology (Gibson and Côté 1982; Frenette et al. 1984; Gibson et al. 1984; Zalewski et al. 1985; Baglinière and Champigneulle 1986). Rather than treating a river system as a 'black box' by merely counting the output of smolts, more meaningful results can be obtained by analyzing representative sections of the river, related to stream order, hydrology, water chemistry, and suitable habitat related to the various stages of life history. Our available resources did not allow intensive studies, and long-term studies are necessary to determine carrying capacity and to analyze the effects of hydrology, climate and competitive interactions. Nevertheless, our results have determined the most important salmon producing areas, and indicate potential of the system.

Although we sampled only 0.94% of the available habitat in the spring of 1980, 0.83% in the autumn, and 1.07% in the summer of 1981, the smolt production was underestimated by only 21% in 1981 and 24% in 1982. The similar underestimate each year suggests a similar error, perhaps an underestimate of survival or of available habitat. However, the results indicate that smolt production could be estimated by relatively few study sites, if selected with the principles of stream ecology in mind, and to include reaches varying in productive capacity and representative of rearing habitat for different life stages.

Although in general the habitat requirements of salmonids are well known, and we did find relatively wide differences in salmonid production at various sites, it is perhaps surprising that we were able to suggest a model with several habitat variables for estimating the biomass of trout with r^2 = 0.860, but a less useful model for juvenile salmon (r^2 = 0.255). This is probably due to two reasons: 1) the wide range in types of habitat that juvenile salmon can successfully use in the absence of predators and severe competitors, and 2) poor recruitment at some sites in the absence of suitable spawning gravel. The latter case probably applies to Rainy Brook East and to River Brook upstream from the Trans Canada Highway. If the three stations in these tributaries are omitted, the model for juvenile salmon is considerably improved (r^2 = 0.741).

We can conclude, that within the bounds of the variables measured in this study, that relative trout biomass would increase with smaller order streams, an increase in overhanging cover, better stability in discharge, and an increase in mean depth or the number of pools. This is similar to the findings of Binns and Eiserman (1979), who derived a predictive multi-linear regression model for biomass of four salmonids in rivers of Wyoming, using these variables, plus a number of others.

Juvenile salmon, unlike brook trout, showed best correlations with a coarse substrate. The stepwise regression analyses in some of the models also retained the variables width and ice scour height, with negative relationships, and a positive relationship with amount of invertebrates. These conclusions are compatible with other observations that juvenile salmon are most abundant in association with riffle areas (Keenleyside 1962) and that there is in general higher production in stable streams than in ones with less stable flows and in lower order streams than in bigger rivers (Hynes 1970).

Although other authors (e.g. Elson 1975) have related preferred salmon parr habitat to a coarse substrate, in stream tank experiments salmon parr selected habitat in relation to water depth, and in shallow water in relation to cover, without regard to type of substrate (Gibson and Power 1975). Therefore salmon parr do not appear to select type of substrate *per se*. A coarse substrate in natural conditions may be related to other suitable conditions such as a broken water surface, preferred habitat of prey, pockets of reduced water velocity in fast water, smaller territories, etc.

Mr. G. Colbourne of Highlands, well experienced with the river, had never seen adult salmon upstream from the Trans Canada Highway, so they may not have been abundant in this section for many years. This latter section (River Brook) is subject to wide ranges in discharge. For example Environment Canada (1983) installed a water gauge near the TCH in 1982 and for that year they report a mean annual discharge of 3.35 m^3s^{-1}, a maximum daily discharge of 60.8 m^3s^{-1} on April 30, and a minimum daily discharge of 0.35 m^3s^{-1} on August 24. Similarly, in 1983 mean annual discharge was 3.37 m^3s^{-1}, maximum daily discharge 48.8 m^3s^{-1} on January 13, and minimum daily, 0.32 m^3s^{-1} on July 6 (Fig. 18 and 19). Besides the general lowering of stream production that is effected by unstable discharges (Binns and Eiserman 1979), the smaller pebble and gravel type of substrate that is necessary for spawning has been washed downstream. Although due partly to the steep gradient (Fig. 20), very high water velocities occur during spates, associated with high discharge. This has probably been aggravated by logging, which is known to increase the range in discharges (e.g. Anderson et al. 1976). The decrease in salmon production from rivers draining into St. George's Bay has been ascribed mainly to extensive logging operations and the construction of a network of forest access roads in the area (Anon. 1978). A local resident (Mr. Chaffey) remarked that during the '60s and '70s during the time of mechanized logging within the watershed, sediment colored the water badly after rains, indicating loss of surface vegetation and erosion of soil. There are areas of erosion to be seen at present where clear cutting had taken place. Water discharges were most stable where there had not been extensive logging, such as the drainage basin of Rainy River. It is possible the upper section of River Brook historically lacked good spawning gravel and that only very large fish could use the coarse substrate available, as described for large rainbow trout (Hartman 1969). The fact that the Highlands River was at one time known for its very large salmon (Porter et al. 1974) lends support to this hypothesis. These exceptionally large salmon were few in recent years (Porter and Chadwick 1983) and may have been reduced by heavy exploitation in the commercial fisheries.

The necessary amount of rearing area for underyearlings, or nursery area, has been estimated by Symons (1979) to be between 17 and 43%, and he suggests 25% of the total rearing grounds should usually provide sufficient nursery area. However, this estimate is based on the assumption that the habitat of underyearlings differs from that of larger juveniles, whereas there may be considerable overlap. Perhaps more essential is adequate spawning habitat.

In the most productive stations, downstream from Loch Leven, and in Rainy River, the substrate was dark green from periphyton, and more embedded than at other stations, indicators possibly of relatively stable flows. These conditions would be favorable for grazing invertebrates. Also below Loch Leven, unlike at other stations, aquatic macrophytes were abundant near shore, and filamentous algae were noticeable. The Rainy River watershed had not been logged, and Loch Leven would tend to stabilize discharges in the river downstream.

Biomass of brook trout may be more stable than that of salmon, possibly because of a wider population structure including older year-classes, and because of adequate recruitment, and therefore show a better correlation with variables in the habitat. For example, in the Matamek River, Québec, at one station sampled over five years, brook trout showed relatively little change in biomass, only by a factor of 1.4 (5.8 kg ha^{-1} to 8.1 kg ha^{-1}, mean 7.3, S.E. 0.41); whereas salmon showed considerable fluctuations in numbers and biomass, by a factor of 6.1 (4.6 kg ha^{-1} to 28.1 kg ha^{-1}, mean 15.5, S.E. 2.66) (Gibson and Dickson 1984). From the present study it is not clear whether it is valid to consider a total biomass of the salmonids present, or whether each species should be considered separately. The present study indicated no interactions, whereas previous studies have shown displacement of brook trout by salmon in fast water habitats (Gibson 1973). The severity of interactions no doubt are affected both by relative densities of the species, and variables in the habitat. Studies are presently being conducted on this problem.

Further studies also are required to derive a good general predictive model relating environmental parameters to carrying capacity of juvenile salmon. A wide range in types of habitats and their parameters should be measured, and since salmon have considerable fluctuations in recruitment, should be studied over a number of years, or with manipulated recruitment. In fact, such studies are presently underway in a number of rivers on the Avalon Peninsula. In order to apply such a predictive model more generally the variables of water chemistry and length of the growing season should be included. In conjunction with such data a useful model for assessment purposes can be derived relating numbers to density dependent growth. Studies in the Matamek River, Québec, showed that for salmon parr, but not for brook trout, there was a relationship between size and their numbers (Gibson and Dickson 1984). Within a habitat of a certain productive capacity a logarithmic linear regression can be derived. For example at one site in the Matamek River where eight years' data were available, the mean weights for 2+ parr varied between 14.5 g at 1,730 ha^{-1} and 28.8 g at 80 ha^{-1}, and for 1+ parr from 4.1 g at 460 ha^{-1} to 10.6 g at 160 ha^{-1}. The relationship between mean log weight (g), Y, and log density (nos ha^{-1}), X, for 2+ parr was: $Y = 1.886 - 0.229X$ ($r = -0.9508$; $P < 0.01$); and for 1+ parr: $Y = 1.519 - 0.307X$ ($r = -0.7193$; $P < 0.05$). There was in fact a better relationship with a simple linear plot of biomass, (kg ha^{-1}), Y, against density (nos ha^{-1}), X. For 2+ parr this was: $Y = 2.377 + 0.013X$ ($r = 0.977$; $P < 0.01$); and for 1+ parr: $Y = 0.026 + 0.005X$ ($r = 0.948$; $P < 0.05$). The gradient of the regression was steeper for more productive areas. The regression was limited for high densities at carrying capacity, and at exceptionally low densities for 2+ parr (below about 100 ha^{-1}).

This means that if an index for the productive capability of a habitat is available, so the gradient of the regression known, the numbers of parr present can be estimated by simply measuring a sample of fish, without making a population estimate. For example, a sample of salmon parr was taken in the Matamek River in 1967 (Schiefer 1969) in which the mean weight of the 2+ parr was 12.9 g and that of 1+ parr was 4.5 g but no population estimates were made. From the log weight log density regression for that site we can estimate that there were 2,430 ha^{-1} of 2+ parr, with biomass of 3.1 g m^{-2}, and 660 ha^{-1} 1+ parr, with biomass of 0.3 g m^{-2}. The habitat has remained unchanged since that time. Alternately, the size of the salmon, related to the density, provides an indication of the productive capability of the habitat. Brook trout on the other hand appear to control their biomass in relation to carrying capacity mainly with a response in density (and therefore survival, mainly at the fry and yearling stages), age at maturity, in weight and condition factor, but apparently within individual river systems, undetectably in length (Gibson and Dickson 1984; Gibson et al. 1976).

In the present study density dependent growth for young salmon was apparent (Fig. 12, 13, and 14) but as sites varied in productivity an accurate regression could not be derived from two years' data, and several regressions, applicable to the appropriate habitats, would have to be derived from several population levels over a number of years.

RECOMMENDATIONS

(1) A simple improvement to increase the amount of rearing habitat for juvenile salmon would be removal of the collapsed bridge on Rainy Brook East, which forms an obstruction 4.6 km upstream from River Brook, and 0.9 km downstream from a lake. The stream has a lower gradient upstream nearer the lake, where suitable spawning substrate is available. Rainy Brook East below the first lake has an area of 31,917 m^2, of excellent rearing habitat for salmon. Brook trout biomass was between 3 and 5 g m^{-2} during the two years of studies, indicating good production, which might be expected for a third order stream below a lake system, so that at least that sort of rearing capacity would be expected for salmon. If therefore the stream produced 4 smolt per 100 m^2, the contribution would be an extra 1,300 smolts. This does not take into account the lake system and inlet streams, which would be expected to have a significant contribution. A local resident, G. Colbourne, recalls that up to about 1970 salmon used to ascend Rainy Brook East. It might be necessary initially to introduce adult or juvenile salmon into this tributary system to allow imprinting of the smolt or to attract spawning adults (Solomon 1973), as an environmentally selected unique strain of salmon for this tributary may have been lost.

(2) River Brook appears to be underused by young salmon, probably because lack of good spawning substrate in this river and its tributary streams limits recruitment. The placing of suitable gravel would be unsuccessful with the wide range of discharge present. However, good spawning substrate is present above the main falls, or 'tunnel'. A fishway would not be economically feasible, but possibly adult salmon could be released in the upper reaches, with a retaining device until after spawning. Juveniles would naturally disperse downstream.

(3) The two smaller (second order) streams crossed by the Trans Canada Highway have poorly constructed culverts. Although we found young salmon in Camp 40 brook upstream from the highway, the culvert would be a barrier for upstream movement of small fish, and probably for adult salmon at some flows. This culvert should be made more conducive to fish migration. An adjacent lake (Abraham's Pond) drains into Camp 40 brook at the upstream end of the culvert, but the outlet is obstructed by a beaver dam. If the dam were removed young salmon could use this pond. Also there would be better recruitment of brook trout into the pond, which provides poor angling at present.

The culvert on Bald Mountain Brook is a complete obstruction to upstream migration of fish. However, salmon appear not to use the upper reaches of Bald Mountain Brook, possibly related to lack of density pressure of spawners. This may change, but nevertheless the small amount of habitat upstream of the TCH would not warrant the expensive remedial work which would be needed on this culvert. Further investigations may be warranted for placing coarse gravel, or the stocking of salmon fry, in the upper reaches of Bald Mountain Brook, at the outlet of the pond, and clearing tree debris dams in the upper reaches, which may be causing obstructions to migration. Similarly, the upper reaches of Rainy Brook were lacking salmon, and would benefit from the introduction of salmon fry.

(4) Since a deterioration in habitat appears to be a major reason for the decline of salmon in the Highlands River, even in the absence of industry, similar situations probably exist in other rivers where road building and logging have taken place. General habitat surveys in all present and potential salmonid rivers, followed by remedial measures would do much for restoring the resource. A common but simple problem seems to be incorrectly installed culverts. For example, during a preliminary survey in 1983 of 21 third and fourth order rivers between Frenchman's Cove and Burin in the southern third of the Burin Peninsula, we found 6 had badly constructed culverts, which would prevent upstream migration of anadromous fishes. Since culverts are so frequently installed poorly, and often later expensive to rectify, the pipe type culvert should not be allowed on any streams containing salmonids.

SUMMARY

In the St. George's Bay area in southwest Newfoundland, stocks of salmon (Salmo salar) have seriously declined. The Highlands River was therefore chosen as an experimental river representing a system draining into St. George's Bay. Seven stations were sampled in the spring and fall of 1980, and four additional stations in the summer of 1981. Four stations were on second order streams, four on third order streams, and three were on the main river (fourth order). The lake on the main stem (Loch Leven) was also sampled in 1981. Population estimates were made by the depletion method using an electroshocker at most locations, but mark and recapture methods had to be used in locations with deep water. Direct underwater observations appeared to be successful in a pool on a third order stream with clear water, but not in a larger pool in the main river. A marking experiment showed that a proportion of both salmon and trout (Salvelinus fontinalis) remain in the same area for the growing season, but that there is some movement between adjacent areas. In the spring of 1980 salmonid biomass varied from 0.8 g m^{-2} to 5.4 g m^{-2} at various sites, and in the fall from 1.7 g m^{-2} to 6.3 g m^{-2}. Best production was in the second order streams and at a station below the lake. Lowest production was at two sites in the main river. In 1981 during the summer salmonid biomass varied between sites from 1.18 g m^{-2} to 7.73 g m^{-2}, with greatest biomass in the second order streams, and lowest at sites in the main river. In Loch Leven there were about 2,500 parr in the littoral areas, or about 12.6 g m^{-1} of shoreline. This gave a rough estimate of a biomass of parr of about 0.1 g m^{-2} for the lake. Eels (Anguilla rostrata) were abundant in the lake, as well as in the river; the banded killifish (Fundulus diaphanus) and three-spine stickleback (Gasterosteus aculeatus) also were abundant in the lake. Trout and nine-spine stickleback (Pungitius pungitius) also were caught in the lake. Eels in the river were found to have their greatest biomass at a station below the lake, also the station nearest to the estuary. This station had the highest biomass of invertebrates. Eels showed considerable differences in biomass through the season at all stations, below the lake having 3.60 g m^{-2} in the spring of 1980, 1.96 g m^{-2} in the fall, and 1.78 g m^{-2} in the summer of 1981. There appeared to be migration to account for the differences, and relative biomass was probably related to food and to water conditions at the time.

The biomass and types of invertebrates differed with the method of collection, and time of year. If volumes are considered, in the spring of 1980 invertebrate collections from kick samples were dominated by Ephemeroptera at most sites, with Plecoptera dominating at a site in the upper part of the main river, whereas with drift samples Ephemeroptera and Diptera (Chironomidae) had greatest volumes. In September of both 1980 and 1981 net spinning trichopterans had the greatest volumes in collections from colonization baskets.

There was no significant relationship between the biomass of salmonids at the various sites with the biomass of invertebrate collections, although at the site below the lake, where invertebrate collections on colonization baskets were the highest in both years, the highest biomass of salmon was found in the fall of 1980. Apparently however, variables other than the relative abundance of food had greater effects on salmonid biomass at the various sites, possibly because the amounts of food available did not show wide differences.

There were significant correlations ($P < 0.05$) between the biomass of trout, negatively with stream width, negatively with the height of ice scour marks (an indicator of the range of discharge), and positively with the amount of cover. With all seasons combined and all variables transformed to log base 10, trout biomass (g m^{-2}) was related to width (m), X_1, substrate X_2, ice scour height (m) X_3, and mean depth (cm) X_4 as follows:

$$\log Y+1 = 1.192 - 0.524(\log X_1+1) - 0.804(\log X_2+1) - 0.504(\log X_3+1) + 0.318(\log X_4+1);\ r^2 = 0.860.$$

If the three stations with poor salmon recruitment are excluded, and all variables transformed to log base 10, the biomass of juvenile salmon was related to substrate (X1), width (X2), and cover (X3) as follows:

$$\log Y+1 = 0.464 + 1.503(\log X_1+1) - 0.576(\log X_2+1) - 0.268(\log X_3+1);\ r^2 = 0.741.$$

The growth rates of juvenile salmon varied between sites, and although probably related to density, was also related to differing productive capabilities between sites. Smolt production varied considerably between sites in 1981, from 1.0/100 m^2 in the upper part of the main river, to 6.2/100 m^2 at the station below the lake and in 1982 from 0.6/100 m^2 in the upper part of the main river, to 5.3/100 m^2 in a third order tributary. The lake contributed about 0.2/100 m^2. The survival of 1+ parr in 1980 to 2+ parr in 1981, for the whole river, was estimated to be 0.44, and was estimated for 2+ parr to 3+ smolts as 0.31 in 1981, and 0.32 in 1982, although a small number of 3+ parr remained in the river.

Coarse gravel suitable as a substrate for spawning was sparse in the main river upstream from the Trans Canada Highway (River Brook), and probably limited recruitment in this section. Steep gradients and high water velocities associated with a wide range in discharge, probably aggravated by logging, had probably displaced much of the gravel downstream. Water discharges were most stable in tributaries where there had not been extensive logging. Some remedial measures for increasing production of salmon are suggested. The removal of a collapsed bridge on a third order tributary, at present an obstruction to migration of adult salmon, would allow use of this stream and a headwater pond by juvenile salmon. Removal of tree debris dams on another stream, the improvement of a culvert, the removal of an old beaver dam, and the introduction of fry, are also suggested.

The system is underseeded, with egg deposition less than 40% of the recommended density, so that despite closure to angling since 1978, the river is not utilized to its full potential of producing salmon.

ACKNOWLEDGMENTS

T. J. Nicholls made the identifications and analyses of the invertebrates. T. H. Shears and T. J. Nicholls assisted with the field work. We are also very grateful to D. E. Stansbury for doing the statistical and computer analyses. The MS was typed by M. P. Bursey and K. A. Harding, and the figures were drafted by H. R. Mullett.

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Table 1. Physical parameters of study sites in the Highlands River, May 27 - June 11, 1980. Substrate is rated from 0 (poor-silt, clay, or plant detritus) to 4 (good-rubble).

Station	Mean width (m)	Length (m)	Area (m^2)	Mean depth (cm)	Mean water velocity ($m\ s^{-1}$)	Substrate* (%)	Substrate rating	Overhanging cover	Conductivity (μ mhos)	pH	Water color	Habitat
Camp 40	3.3	41.5	137	12.5	0.44	80 P 20 C	2.2	60	240	7.02	40	6.8:1 riffle:pool
Rainy Br. East	6.8	56.4	380.7	17.3	0.59	50 R 25 Bo 25 C	3.3	10	51	7.08	-	riffle
Bald Mountain	6.0	72	430	19.5	0.60	80 C 20 R	3.2	50	80	7.43	20	5.43:1 riffle:pool
Rainy	6.3	47	294	22.4	0.49	90 R 5 C 5 Bk	3.8	25	117	7.65	50	2.5:1 riffle:pool
River Brook (lower)	24.0	68.5	1644	22.2	0.66	50 Bo 40 R 10 C	3.4	0	32	7.2	40	riffle
Railway Bridge	45.3	37.1	1678.8	27.8	0.36	40 C 30 G 30 R	2.7	2	193	7.06	40	flat
Gillam's Farm	44.0	29.6	1302.4	33.0	0.40	75 R 15 C 10 Bo	3.7	0	175	7.05	50	flat

*G = gravel; P = pebble; C = cobble; R = rubble; Bo = boulders; Bk = bedrock.

Table 2. Captures of fish and population estimates, Spring, 1980.

Station	Date	Water temp. (°C)	Population estimates, as numbers per 100 m^2 (±S.E. or C.L. in brackets) Salmon 1+	Salmon 2+	Salmon 3+	Trout 0+	Trout 1+	Trout 2+	Trout 3+	Method	Salmonid biomass ($g\ m^{-2}$) Salmon	Trout	Total
Camp 40	5/VI	10.5	15.3 (±0.7)	4.4 (±0.7)		12.4 (±0.7)	7.3 (±0.7)	19.0 (±0.7)		Zippin	1.19	4.25	5.44
Rainy Br. East	27/V	7.5					6.0 (±0.8)	8.4 (±1.8)	0.8 (±0.3)	Seber & Le Cren		2.86	2.86
							6.6 (±1.2)	8.0 (±0.9)	0.8 (±0)	Zippin			
Bald Mountain	31/V	9.5	14.2 (±4.2)	2.8 (±0.9)	0.5		2.3 (±0.5)	4.4 (±0.7)	1.2 (±0.5)	Seber & LeCren	1.15	2.03	3.18
			18.1 (±0.5)	3.7 (±0.1)	0.5		2.8 (±0.7)	4.7 (±0.2)	0.9 (±0.2)	Zippin			
Rainy	3/VI	10	74.5 (±6.1)	9.5 (±2.0)			7.8 (±2.7)	3.7 (±0.7)	0.7 (±0.7)	Zippin	3.47	1.57	5.04
River Brook (lower)	29/V	9.5	-	-	-	-	-	-	-		-	-	-
Railway Bridge	7/VI	7.8	10.8 (±0.3)	1.3 (±0.1)	0.1	0.7 (±0.2)	1.7 (±3.2)	0.2 (±0.1)	0	Zippin	0.62	0.18	0.8
			20.5 (15.2-32.8)	2.3 (1.0-5.8)	0.1					Petersen's	1.16		
Gillam's Farm	10/VI	9.8	14.7 (±0.5)	22.7 (±3.4)		0.2	0.1	1.2 (±0.8)	0.3 (±0.1)	Zippin	3.09	0.39	3.48

Table 3. Number of salmon and trout marked (M) in the spring 1980 and the percentages recaptured (R) in September 1980 in the same stations. Recaptures are adjusted for population estimates.

	Salmon						Trout					
	1+		2+		3+		1+		2+		3+	
	M	R	M	R	M	R	M	R	M	R	M	R
Camp 40	16	7	3	100	-	-	8	63	25	4		
Rainy Bk E	-	-	-	-	-	-	18	18	25	13	3	0
Bald Mtn	27	33	7	17	1	0	8	14	16	38	4	58
Rainy Bk	144	23	20	43	-	-	9	13	7	29	1	0
River Bk	9	69	8	32	-	-	3	0	3	0	-	-
Railway Bridge	118	20	18	6	-	-	4	81	1	0	-	-
Gillam's Farm	103	12	93	46	-	-	1	0	-	-	-	-

Table 4. Physical parameters of study sites in the Highlands River, September 19-27, 1980. (VHR = velocity head rod method of estimating the water velocity.)

Station	Mean width (m)	Length (m)	Area (m^2)	Mean depth (cm)	Deepest spot (cm)	Mean Water velocity ($cm\ s^{-1}$) Surface	VHR	Height of ice scour (m)	Conductivity (μ mhos)	pH	Water color	Min-Max since Spring (°C)
Camp 40	4.8	43.3	209.1	13.0	55	62.8	69.3	0	180	7.55	110	7.0 - 20.5
Rainy Br. East	6.6	51.2	336.2	17.4	60	71.4	49.7	0	68	7.68	30	6.5 - 26.0
Bald Mountain	6.2	69.7	432.1	11.6	100	49.1	43.4	1.2	195	7.70	35	4.5 - 22.0
Rainy	7.8	52.3	407.9	22.5	78	74.7	68.3	1.0	122	7.88	210	3.5 - 20.0
River Brook (lower)	22.1	66.8	1476.3	20.7	50	58.1	-	2.2	52	7.47	110	7.0 - 23.5
Railway Bridge	41.8	28.4	1183.6	15.0	68	45.0	46.6	1.1	178	7.67	105	6.0 - 24.0
Gillam's Farm	43.7	25.8	1127.5	27.3	58	52.7	51.3	1.8	230	7.62	90	5.0 - 26.0

Table 5. Captures of fish and population estimates, September 1980. *Population estimates were made by the modified Petersen's method at these sites, and by the Zippin method at other sites. **2+ and 3+ salmon combined in Rainy Br. East.

Station	Date (Sept)	Water temp (°C)	Population estimates per 100 m^2 (±S.E., or C.L. in brackets) Salmon 0+	Salmon 1+	Salmon 2+	Salmon 3+	Trout 0+	Trout 1+	Trout 2+	Trout 3+	Salmonid Biomass (g m^{-2}) Salmon	Trout	Total
Camp 40	23	11.5	7.2(±0.8)	4.8(±1.0)	5.7(±2.3)	0	11.4(±3.6)	18.8(±14.0)	1.9(±0)	0	1.69	4.65	6.34
Rainy Br. East	19	11.3	0	0	2.1**(±0.5)		11.9(±0.9)	5.9(±0.4)	3.3(±0.6)		0.65	2.82	3.47
Bald Mountain	26	8.5	9.3(±0.8)	18.1(±4.5)	1.4(±0.8)	0	4.9(±1.2)	3.0(±0.4)	2.8(±0.2)	1.6(±0.6)	1.81	2.94	4.75
Rainy	27	9.4	12.3(±2.5)	24.3(±2.2)	3.4(±0.5)	1.7(±1.8)	>3.9	1.5(±0.4)	>1	0	2.53	0.53	3.06
River Br. Lower	24	10.0	*3.6(1.8-7.9)	9.3(5.8-15.8)	0.9(0.4-2.3)						*1.50		
	25		3.8((±1.0)	13.0(±1.3)	0.8		0.3	0.9(±0.3)	0.1	0	1.91	0.21	2.12
Railway Bridge	22	10.6	*4.1(2.0-8.8)	10.5(6.8-17.0)	1.9(0.8-4.7)	0	-	1.3	-	-	*1.24		
	23		>3.0	10.5(±1.9)	1.5(±0.3)		>0.8	1.1(±0.2)	>0.2	>0.2	1.23	0.58	1.81
Gillam's Farm	20	12.9	*1.1(0.4-2.0)	14.5(10.3-21.3)	16.2(11.2-24.4)	0.4(0.1-0.7)		-	-	-	*3.53		
	21		>0.6	14.9(±1.5)	14.8(±1.9)	>0.3	0.2(±0.1)	0	>0.2	0	3.29	0.09	3.38

Table 6. Mean sizes of age classes of salmon at sites in 1980. F.L. = fork length (cm); Wt = weight (g). The standard errors of the means are in brackets.

	Spring						Fall							
	1+		2+		3+		0+		1+		2+		3+	
Station	F.L.	Wt.	F.L.	Wt.	F.L.	Wt.	F.L.	Wt.	F.L.	Wt.	F.L.	Wt.	F.L.	Wt.
Camp 40	6.7	4.0	9.5	10.7			5.5	1.9	9.4	10.9	11.3	18.0		
	(0.14)		(0.30)				(0.16)		(0.17)		(0.24)			
Rainy Br. East											13.6	31.6	12.7	28.0
											(0.26)			
Bald Mountain	6.4	3.3	9.9	12.3	11.8	20.1	5.4	1.6	8.8	7.5	12.3	22.3		
	(0.10)		(0.25)				(0.05)		(0.11)		(0.25)			
Rainy	6.3	3.3	9.5	10.4			5.1	1.3	8.2	6.0	10.8	14.9	11.9	23.4
	(0.05)		(0.13)				(0.05)		(0.08)		(0.14)			
River Brook (lower)	7.9	6.0	10.4	12.7	12.8	24.7	6.4	3.0	10.0	12.3	12.4	23.8	*	
	(0.15)		(0.11)				(0.05)		(0.08)		(0.18)			
Railway Bridge	6.9	4.2	10.0	12.7	11.6	19.8	5.6	2.4	8.9	8.5	11.4	17.9		
	(0.06)		(0.11)				(0.07)		(0.07)		(0.15)			
Gillam's Farm	6.9	3.6	9.8	11.3			5.3	1.8	8.4	7.3	10.9	14.3	14.1	30.8
	(0.04)		(0.05)				(0.26)		(0.04)		(0.06)		(0.44)	

*A 4+ mature male parr, 14.8 cm-36.5 g, was caught. This was included in total biomass in Table 5.

Table 7. Mean sizes of age classes of brook trout at sites in 1980. F.L. = fork length (cm); Wt = weight (g). Figures in brackets are standard errors.

	Spring								Fall							
	0+		1+		2+		3+		0+		1+		2+		3+	
Station	F.L.	Wt.	F.L.	Wt.	F.L.	Wt.	F.L.	Wt.	F.L.	Wt.	F.L.	Wt.	F.L.	Wt.	F.L.	Wt.
Camp 40	3.2	0.5	8.5 (0.20)	6.1	11.8 (0.53)	19.7			7.2 (0.20)	4.6	11.4 (0.38)	16.2	17.1 (0.63)	55.6		
Rainy Br. East	-		8.3 (0.18)	8.3	12.4 (0.21)	21.4	16.4 (0.18)	50.4	7.2 (0.13)	4.3	11.6 (0.24)	17.3	14.8 (0.25)	39.1		
Bald Mountain	-		8.0 (0.27)	6.7	13.2 (0.29)	27.2	18.6	62.2	6.6 (0.18)	3.5	10.8 (0.30)	15.0	14.3 (0.36)	34.6	19.5 (1.59)	83.8
Rainy	-		7.8 (0.18)	6.5	12.0 (0.35)	19.4	16.9 (0.20)	48.8	6.3 (0.19)	2.5	10.1 (0.39)	11.8	13.3 (0.57)	26.8		
River Brook (lower)	5.1	1.6	7.9	5.4	11.8	19.2	14.5	35.7	7.5	4.6	11.4 (0.39)	16.3	15.8	43.4		
Railway Bridge	3.4 (0.12)	0.4	9.0 (0.31)	7.8	12.4 (0.75)	18.6	-		7.5 (0.19)	4.3	11.2 (0.42)	15.5	20.8	63.5	24.0	159.2
Gillam's Farm	3.6	0.4	8.8	7.8	12.6 (0.44)	22.4	15.4	39.9	8.1 (0.19)	6.3	-		16.0	47.2	-	

Table 8. Mean condition factors [(Weight) (Fork length)$^{-3}$.100] of all samples of salmon and brook trout in 1980 (S.D. in brackets).

Site	Salmon				Brook Trout			
	Spring	n	Fall	n	Spring	n	Fall	n
Camp 40	1.32 (0.15)	18	1.23 (0.19)	5	1.19 (0.09)	16	1.15 (0.09)	12
East Rainy	-		1.29 (0.17)	3	1.21 (0.35)	22	1.15 (0.10)	14
Bald Mountain	1.26 (0.13)	29	1.31 (0.12)	6	1.22 (0.14)	10	1.17 (0.11)	8
Rainy	1.32 (0.12)	23	1.08 (0.14)	16	1.26 (0.15)	11	1.07 (0.12)	6
River Brook	1.18 (0.04)	3	1.21 (0.12)	8	1.17 (0.04)	3	1.36	1
Railway Bridge	1.27 (0.14)	58	1.24 (0.10)	11	1.21 (0.15)	15	1.01 (0.25)	7
Gillam's Farm	1.14 (0.10)	85	1.18 (0.08)	24	1.11 (0.11)	11	1.16 (0.00)	2

Table 9. Relative biomass, specific growth rates, and estimated production of salmon at study sites in 1980. B = biomass, g m^{-2}; Gw = specific growth rate for weight; Gl = specific growth for length; P = production, g $m^{-2}yr^{-1}$.

	Spring				Autumn															
	1+	2+	3+	Total	0+				1+				2+				3+	Total	Total P	
Site	B	B	B	B	B	Gw	Gl	P	B	Gw	Gl	P	B	Gw	Gl	P	B	B	(Season)	P/$\bar{B}$
Camp 40	0.72	0.47	-	1.19	0.13	2.661	0.774	0.13	0.52	0.921	0.311	0.67	1.03	0.477	0.159	0.28	-	1.68	1.08	0.86
Bald Mountain	0.60	0.46	0.09	1.15	0.15	2.424	0.730	0.13	1.35	0.702	0.270	0.76	0.31	0.509	0.184	0.66	-	1.81	1.55	1.29
Rainy	2.48	0.99	-	3.47	0.16	2.160	0.656	0.14	1.46	0.515	0.227	1.15	0.51	0.310	0.111	0.26	0.40	2.53	1.64	0.56
River Brook (lower)	-	-	-	-	0.11	3.118	0.918	0.10	1.14	0.608	0.203	0.61	0.23	0.532	0.152	0.08	-	1.47	0.79	0.78
Railway Bridge	0.45	0.16	0.01	0.62	0.10	2.944	0.793	0.09	0.89	0.659	0.225	0.45	0.33	0.321	0.116	0.08	-	1.32	0.62	0.72
Gillam's Farm	0.53	2.56	-	3.09	0.02	2.689	0.749	0.02	1.06	0.693	0.193	0.54	2.32	0.231	0.104	0.57	0.14	3.54	1.20	0.37

Table 10. Relative biomass, specific growth rates, and estimated production of trout at study sites in 1980. B = biomass, g m^{-2}; Gw = specific growth rate for weight; Gl = specific growth for length; P = production, g $m^{-2}yr^{-1}$.

	Spring					Autumn																		
	0+	1+	2+	3+	Total	0+				1+				2+				3+				Total	Total P	
Site	B	B	B	B	B	B	Gw	Gl	P	B	Gw	Gl	P	B	Gw	Gl	P	B	Gw	Gl	P	B	(Season)	P/$\bar{B}$
Camp 40	0.06	0.45	3.74	-	4.25	0.35	2.034	0.744	0.35	3.05	0.898	0.269	1.34	1.07	0.952	0.340	2.20	-				4.47	3.89	1.07
E. Rainy	-	0.50	1.80	0.40	2.70	0.51	3.517	0.978	0.50	1.03	0.647	0.294	0.54	1.28	0.531	0.155	0.92	-				2.82	1.96	0.82
Bald Mountain	-	0.19	1.26	0.58	2.03	0.17	3.102	0.872	0.17	0.45	0.683	0.254	0.23	0.96	0.204	0.068	0.26	1.36	0.253	0.040	0.20	2.94	0.86	0.41
Rainy	-	0.51	0.73	0.33	1.57	0.10	2.817	0.832	0.09	0.17	0.514	0.219	0.19	0.26	0.279	0.087	0.15	-				0.53	0.43	1.02
River Brook (lower)	-	-	-	-	-	0.01	3.391	0.980	-	0.14	-	-	-	0.06	-	-	-	-				0.21	-	-
Railway Bridge	0.003	0.13	0.04	-	0.17	0.03	2.220	0.739	0.03	0.20	0.642	0.204	0.11	0.11	1.148	0.483	0.08	0.27	0.859	0.134	0.16	0.58	0.38	0.94
Gillam's Farm	0.001	0.006	0.26	0.12	0.39	0.01	2.703	0.795	-	-				0.08	0.693	0.216	-	-				0.09	-	-

Table 11. Physical parameters of study sites in the Highlands River, June 21 - July 7, 1981.

Station	Mean width (m)	Length (m)	Area (m^2)	Mean depth (cm)	Mean water velocity ($m\ s^{-1}$)	Substrate* (%)	Substrate rating	Overhanging cover	Conductivity (μ mhos)	pH	Water color	Habitat
Camp 40	4.1	40.6	166.5	24.2	0.51	50 P 50 C	2.5	60	1620		80	4.5:1 riffle:pool
Rainy Br. East	6.7	54.2	363.1	22.4	0.44	30 C 40 R 20 Bo; 10 Bk	3.2	20	78	7.92	35	riffle
Bald Mountain	4.2	75.1	315.4	18.9	0.23	10 P 50 C; 40 R	3.3	75	183		20	3.2:1
Rainy	6.9	49.5	341.6	26.2	0.30	5 P 40 C 50 R; 5 Bo	3.5	2	198		30	1.7:1 riffle:pool
Main Rainy Br. (riffle)	11.2	37.7	422.2	21.2	0.26	10 G 60 C 20 R; 10 Bo	3.0	2	183		30	riffle
Main Rainy Br. (pool)	7.4	20.7	153.2	51.0	0.18	50 G 50 C	2.0	10	195		30	pool
River Brook Upper	14.1	29.6	417.4	26.8	0.65	30 C 50 R 10 Bo; 10 Bk	3.3	> 1	70		60	riffle-run
River Brook Lower	22.4	65.1	1457.1	20.2	0.40	10 C 30 R; 60 Bo	3.3	0	125		40	riffle
Main River Pool	13.0	31.4	408.2	65.0	0.14	75 P 12 C; 13 R	2.4	13	248		40	pool
Railway Bridge	41.5	29.9	1240.3	36.7	0.37	40 G	2.3	1	650		30	flat
Gillam's Farm	43.5	31.1	1352.9	41.8	0.35	20 C	3.6	< 1	380		-	flat
Loch Leven	450	-	159043.1	-	-	-	-	-	700		30	lake

*G = gravel; P = pebble; C = cobble; R = rubble; Bo = boulders; Bk = bedrock.

Table 12. Captures of fish and population estimates, 1981. (Biomass estimates in brackets are derived from decreases rather than numbers.)

			Population estimates (100 m^{-2}) Salmon					(±S.E. or C.L. in brackets) Trout					Salmonid biomass ($g\ m^{-2}$)		
Station	Date	Water temp. (°C)	0+	1+	2+	3+	4+	0+	1+	2+	3+	Method	Salmon	Trout	Total
Camp 40	22/VI	14.2		10.9 (±5.0)	5.3 (±1.6)			3.0 (±0.8)	17.9 (±27.2)	4.3 (±0.2)	4.3 (±0.2)	Zippin	1.43	4.65 (4.67)	6.08 (6.10)
Rainy Bk. East	26/VI	13.0						2.0 (±0.2)	13.3 (±0.5)	4.8 (±0.8)	3.3 (±0.1)	Zippin	0.11	5.27	5.38
Bald Mountain	3/VII	18.5		15.9 (±0.8)	13.2 (±0.8)			2.5 (0)	7.3 (±0.4)	4.5 (±0.2)	3.1 (±0.7)	Zippin	2.63	5.10	7.73
Rainy	2/VII	16.0	0.3 (0)	19.3 (±1.5)	12.8 (±0.7)			2.0 (±0.3)	5.1 (±0.2)	4.0 (±0.3)	2.6 (0)	Zippin	2.69	3.99	6.68
Main Rainy Bk. Riffle	1/VII	17.1	1.2 (±0.1)	22.9 (±0.9)	13.6 (±1.5)			8.1 (±1.7)	>3.6	0.9 (0)	0.2 (0)	Zippin	2.90	1.00 (1.02)	3.90 (3.92)
Main Rainy Br. Pool	30/VI	19.8	5.2	9.1	7.8			5.2	10.4	5.2	2.0	Direct count	1.30	4.39	5.69
								5.8 (±0.3)	11.6 (±0.8)	4.9 (±0.3)	2.0 (0)	Leslie		4.52 (5.44)	
River Br. Upper Stn.	23/VI		0.3 (±0.2)	0.5 (0)	1.8 (±5.9)	1.0 (±0.2)	0.2 (0)	7.7 (±1.0)	0.2 (0)	0.7 (±0.1)	0.5 (0)	Zippin	0.78	0.40	1.18
River Br. Lower Stn.	4/VII	21.3	>0.3	10.1 (±0.8)	2.7 (±0.1)			1.6 (±0.1)	1.0 (±0.5)	>0.6	>0.3	Zippin	1.18	0.44	1.62
Main R. Pool			1.7	2.9	3.4					7.1 trout		Direct count			
			>1.7	7.9 (4.4-15.9)	4.2 (2.5-7.6)			≥0.7	7.3 (3.8-15.3)	4.2 (2.1-9.2)	3.1 (1.6-6.9)	Peterson	0.86	3.92	4.78
Railway Bridge	21-22 /VI	13.5	≥0.4	10.6 (±2.6)	3.4 (±0.7)			10.2 (±3.6)	1.5 (±0.1)	≥0.9	≥0.1	Zippin	0.82	0.46	1.28
				8.8 (5.2-12.6)	2.9 (1.6-5.3)				1.9 (0.9-4.2)	1.2 (0.4-2.7)		Petersen	0.69	0.55	1.24

Table 12 Cont'd.

Station	Date	Water temp. (°C)	Population estimates (100 m^{-2}) Salmon 0+	1+	2+	3+	4+	(±S.E. or C.L. in brackets) Trout 0+	1+	2+	3+	Method	Salmonid biomass (g m^{-2}) Salmon	Trout	Total
Gillam's Farm	24-25/ VI	18.8			5.5 (±1.0)							Zippin			
												Total catch		0.12	
				4.9 (2.6-7.8)	7.5 (3.7-15.2)							Petersen	1.22		1.34
Loch Leven	6-7/VII	19.5		1.3 (1.2-1.8)	(0.1-0.7)										

Table 13. Mean sizes of age classes of salmon at sites from June 21 to July 7, 1981. F.L. = fork length in cm; Wt = weight in grams; K = condition factor, Wt x F.L.$^{-3}$ x 100. (Standard errors of the means are in brackets.)

	0+			1+			2+			3+			4+		
Station	F.L.	Wt	K	F.L.	Wt	K	F.L.	Wt	K	F.L.	Wt	K	K.L.	Wt	K
Camp 40				7.8 (0.15)	5.26	1.12 (0.02)	11.0 (0.22)	16.1	1.20 (0.04)						
Bald Mountain				7.3 (0.07)	4.85	1.24 (0.02)	10.5 (0.15)	i4.12	1.22 (0.02)	12.2	22.9	1.26			
Rainy	2.8	0.3	1.23	7.2 (0.05)	4.48	1.18 (0.01)	10.5 (0.15)	14.35	1.24 (0.01)						
Main Rainy Br. Riffle	2.8 (0.09)	0.26 (0.08)	0.92 (0.12)	7.1 (0.05)	4.28	1.20 (0.02)	10.5 (0.08)	14.1	1.22 (0.03)						
Main Rainy Br. Pool	2.9 (0.06)	0.14	0.58 (0.08)	6.9 (0.24)	3.73	1.12 (0.05)	10.3 (0.07)	12.24	1.12 (0.03)						
River Br. Upper (T3)	2.7			8.1 (0.60)	6.45	1.25 (0.12)	11.7 (0.07)	18.74	1.18 (0.04)	13.1 (0.29)	28.67	1.29	17.2	45.1	0.95
River Br. Lower	3.4 (0.14)	0.5	1.20 (0.02)	8.3 (0.06)	7.19	1.25 (0.01)	10.7 (0.16)	16.29	1.33 (0.02)						
River Br. Pool	3.0 (0.03)			7.6 (0.07)	5.14	1.18	10.0 (0.13)	10.7	1.07 (0.01)						
Railway Bridge	2.8 (0.02)	0.19	0.85 (0.21)	7.1 (0.06)	3.93	1.11 (0.02)	10.1 (0.10)	11.86	1.16 (0.04)						
Gillam's Farm				7.4 (0.06)	4.64	1.15 (0.02)	10.2 (0.11)	13.21	1.23 (0.02)						
Loch Leven	3.2			7.6 (0.04)	5.47	1.25 (0.01)	10.9 (0.10)	14.97	1.15 (0.04)						

Table 14. Mean sizes of age classes of brook trout at sites in 1981, June 21 - July 7. F.L. = fork length in cm; Wt = weight in grams; K = condition factor, Wt x F.L.$^{-3}$ x 100. (Standard errors of the mean are in brackets). $\bar{K}$ = mean K for all cohorts.

	0+			1+			2+			3+			
Station	F.L.	Wt	K	F.L.	Wt	K	F.L.	Wt	K	F.L.	Wt	K	$\bar{K}$
Camp 40	4.7 (0.16)	1.10		10.6 (0.14)	14.6	1.22 (0.06)	12.8 (0.24)	25.2	1.19 (0.05)	17.3 (0.75)	53.8	1.04	1.19 (0.03)
East Rainy	4.2 (0.11)	0.96	1.33 (0.02)	10.5 (0.13)	14.5	1.26 (0.04)	13.5 (0.10)	31.1	1.26 (0.07)	16.5 (0.39)	55.09	1.23	1.27 (0.02)
Bald Mountain	4.4 (0.14)	1.04	1.22 (0.13)	9.7 (0.26)	10.62	1.18 (0.09)	13.9 (0.31)	32.69	1.21 (0.09)	20.0 (0.49)	89.94	1.12	1.19 (0.05)
Rainy	4.4 (0.20)	0.95	1.11 (0.09)	9.5 (0.22)	9.62	1.13 (0.03)	14.9 (0.37)	38.31	1.16	18.5 (0.46)	73.08	1.15 (0.03)	1.16 (0.05)
Main Rainy Br., Riffle	4.2 (0.10)	0.75	1.01 (0.13)	9.9 (0.34)	11.74	1.24	14.4 (0.38)	36.01	1.20	18.6	74.0	1.15	
Main Rainy Br., Pool	4.3 (0.24)	0.78	1.01	9.8 (0.26)	10.28	1.09	14.4 (0.38)	31.70	1.07	19.6 (0.91)	82.82	1.10	
River Br. Upper (T3)	3.8 (0.08)	0.66	1.16 (0.17)	9.5	9.77	1.14	11.2 (0.62)	15.31	1.10 (0.10)	16.0 (1.10)	46.26	1.14 (0.04)	
River Br. Lower	4.6 (0.09)	1.10	1.10 (0.09)	9.5 (0.06)	10.49	1.22 (0.02)	12.4 (0.25)	21.69	1.15 (0.04)	16.6 (0.75)	51.88	1.13 (0.04)	
River Br. Pool	4.0 (0.12)	0.68	1.10	9.5 (0.19)	10.43	1.22	12.7 (0.29)	22.67	1.10	18.5 (0.50)	69.96	1.10	
Railway Bridge	4.4 (0.07)	1.00	1.13 (0.07)	9.6 (0.23)	9.38	1.07 (0.02)	12.6 (0.40)	19.48	0.98	17.8	62.00	1.10	
Gillam's Farm	4.3 (0.24)	0.52	0.67 (0.13)	10.6	10.1	1.03				19.7 (2.02)	75.9		
Loch Leven	4.7 (0.26)	1.10					13.2 (0.75)	24.10	1.04				

Table 15. Mean sizes of samples of salmon taken September 9-12, 1981. F.L. = fork length (cm); Wt = weight (g); K = Wt x F.L.$^{-3}$ x 10^2; n = sample size. (S.D. in brackets.)

Station	Date (Sept)	0+				1+				2+				3+			
		F.L.	Wt	K	n	F.L.	Wt	K	n	F.L.	Wt	K	n	F.L.	Wt	K	n
Camp 40	12	4.60 (0.69)	0.92	0.97 (0.09)	5	8.20 (1.30)	5.73	1.04 (0.05)	2	10.60 (0.77)	12.95	1.10 (0.13)	5	12.20	20.90	1.15	1
East Rainy	10	-				-				10.30	13.40	1.23	1				
Bald Mountain	11	5.20 (0.10)	1.70	1.21 (0.10)	2	8.10 (0.90)	6.67	1.24 (0.07)	3	10.30 (0.52)	13.78	1.28 (0.08)	4				
Rainy	11	5.30 (0.86)	2.14	1.44 (0.26)	6	9.50 (1.42)	9.78	1.15 (0.07)	4	10.70 (1.25)	15.68	1.28 (0.10)	4	13.00 (0.30)	29.88	1.36 (0.07)	2
Main Rainy Br., Riffle	11	4.70 (0.38)	1.42	1.39 (0.15)	5	7.90 (0.23)	6.31	1.28 (0.11)	7	10.30 (1.35)	14.12	1.28 (0.11)	6				
Main Rainy Br., Pool	11	4.40 (0.38)	1.01	1.19 (0.10)	6	7.40 (0.16)	4.66	1.15 (0.05)	3	10.20 (0.65)	12.93	1.23 (0.14)	6				
River Br. Upper (T3)	10	6.30 (0.36)	2.42	0.99	4	9.70	10.5	1.15	1	11.80 (1.51)	21.69	1.32 (0.14)	8				
River Br. Lower	10	6.00 (0.28)	2.43	1.13 (0.11)	8	8.60 (0.44)	8.58	1.34 (0.22)	5	11.20 (0.73)	17.98	1.28 (0.14)	5				
River Br. Pool	11	4.70 (0.35)	1.16	1.12 (0.13)	15	8.30 (0.33)	6.38	1.13 (0.08)	3	10.20 (0.95)	12.83	1.20 (0.15)	4				
Railway Bridge	9	5.00 (0.36)	1.30	1.05 (0.06)	9	8.10 (0.55)	5.97	1.14 (0.08)	5	10.50 (0.71)	12.6	1.09 (0.13)	5				
Gillam's Farm	12	-				7.60 (0.89)	4.69	1.08 (0.07)	11	11.00 (0.48)	14.53	1.08 (0.05)	5				

Table 16. Mean sizes of samples of brook trout taken September 9-12, 1981. F.L. = fork length (cm); Wt = weight (g); K = Wt x $F.L.^{-3}$ x 10^2; n = sample size. (S.D. in brackets.)

	0+				1+				2+				3+				4+			
Station	F.L.	Wt	K	n	F.L.	Wt	K	n	F.L.	Wt	K	n	F.L.	Wt	K	n	F.L.	Wt	K	n
Camp 40	5.90	1.84	0.92	3	11.60	15.90	1.01	6	19.30	74.00	1.03	1								
	(0.35)		(0.22)		(1.36)		(0.04)													
East Rainy	6.10	2.18	0.96	4	10.70	13.10	1.07	7	14.50	32.89	1.09	4								
	(0.19)		(0.20)		(1.06)		(0.06)		(1.08)		(0.09)									
Bald Mountain	6.10	2.37	1.07	4	9.70	10.03	1.11	3	15.90	42.61	1.06	3*								
	(0.65)		(0.11)		(0.19)		(0.05)		(2.59)		(0.07)									
Rainy	6.50	3.24	1.18	3	10.90	14.10	1.10	2	12.70	20.89	1.02	2								
	(0.43)		(0.05)		(0.65)		(0.05)		(0.90)		(0.01)									
Main Rainy Br., Riffle	5.40	1.82	1.14	5	9.80	10.29	1.11	4	14.60	30.00	0.96	1								
	(0.62)		(0.05)		(0.50)															
Main Rainy Br., Pool	6.10	2.41	1.09	4	10.30	11.89	1.08	4	15.20	35.82	1.02	5								
	(0.67)		(0.05)		(1.12)		(0.08)		(1.04)		(0.03)									
River Br. Upper (T3)	6.30	2.46	0.99	7	10.40	12.04	1.07	4	12.50	21.00	1.08	1	20.30	93.69	1.12	2				
	(0.78)		(0.12)		(0.56)		(0.05)						(2.40)		(0.16)					
River Br. Lower	6.10	2.34	1.02	4	9.90	9.82	1.02	4	11.20	14.50	1.03	1	16.30	52.40	1.21	1				
	(0.33)		(0.18)		(0.95)		(0.07)													
River Br. Pool	4.80	0.99	0.90	1	11.50	14.80	0.97	1	17.50	56.41	1.05	7	20.40	90.50	1.07	1	25.30	177.50	1.10	1
									(2.55)		(0.06)								(sea trout)	
Railway Bridge	6.20	2.60	1.07	7	11.00	14.24	1.07	6	13.20	23.22	1.01	2								
	(0.59)		(0.07)		(0.57)		(0.03)		(0.30)		(0.05)									

*Also 4 (2+) sea trout, 19.4 cm (1.18) - 70.8 g (7.15), $\bar{K}$ = 0.98 (0.10).

Table 17. Mean volumes (ml) of the major taxa of invertebrates collected by three methods in 1980. K = kick samples, D = drift samples; B = Colonization basket samples; (n) = number of samples; (S.D.) = standard deviation. N = Net Spinners; C = Case Builders; R = Rhyacophilds; AC = Adult Chironomids; C = Chironomids; SI = Simuliids; F = Filipalpia; SE = Setipalpia; G = Gastropoda. Three kick samples and one drift sample were taken at each station.

		Trichoptera			Diptera			Plecoptera		Ephemeroptera	Others		Σ K (S.D.)	Σ D	Σ B (n) (S.D.)
		N	C	R	AC	C	SI	F	SE			G			
Camp 40	K	0.01	0	0.03		0.04	<0.01	<0.01	<0.01	0.05	0.01		0.15		
	D	0.02	<0.01	0		0.01	<0.01	0	<0.01	0.10	0.01		(0.08)	0.14	
	B	0.06	0.03	0.01		0.01	0	<0.01	0.03	0.05	0.01	0.10			0.31 (1)
East Rainy	K	<0.01	<0.01	<0.01		<0.01	<0.01	<0.01	<0.01	0.04	<0.01		0.06		
	D	0.02	0.03	0		0.12	0.02	0	0	0.06	0.02		(0.07)	0.27	
	B	0.14	<0.01	<0.01		<0.01	0	<0.01	0.01	0.05	<0.01				0.21 (3) (0.20)
Bald Mountain	K	<0.01	<0.01	0.01		0.01	<0.01	<0.01	0.01	0.06	0.03		0.13		
	D	<0.01	<0.01	0		0.04	<0.01	<0.01	<0.01	0.01	0.04		(0.03)	0.09	
	B	0.43	0.01	0.02		0.01	0	<0.01	0.03	0.15	0.03				0.68 (3) (0.13)
Rainy	K	<0.01	<0.01	0.02		<0.01	<0.01	<0.01	<0.01	0.05	0.02		0.09		
	D	<0.01	0.01	<0.01		0.08	0.01	<0.01	0.01	0.10	0.01		(0.02)	0.22	
	B	0.12	0.03	<0.01		<0.01	<0.01	<0.01	0.01	0.13	0.04				0.32 (2) (0.19)
River Br.	K	<0.01	<0.01	<0.01		0.02	<0.01	<0.01	0.07	<0.01	0.10		0.20		
	D	0.03	<0.01	0	0.08	0.05	<0.01	<0.01	<0.01	0.03	0.02		(0.14)	0.21	
	B	0.67	<0.01	<0.01		<0.01	<0.01	<0.01	0.02	0.12	<0.01				0.81 (3) (0.57)
Railway Bridge	K	<0.01	<0.01	<0.01		<0.01	<0.01	0	0	0.02	0.02		0.05		
	D	0.01	0	0		<0.01	0.01	0	0	0.08	<0.01		(0.02)	0.10	
	B	0.37	0.07	0		0.12	0	0	0	0.08	0.03	0.08			0.75 (1)
Gillam's Farm	K	<0.01	<0.01	0		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01		<0.01		
	D	<0.01	0	<0.01		0.02	0.04	0	0	0.18	0.01		(<0.01)	0.25	
	B	1.36	<0.01	0.02		0.02	<0.01	<0.01	0.02	0.15	0.01				1.58 (3) (1.28)

Table 18. Mean volumes (ml) and numbers of invertebrates collected from colonization baskets in 1981. S.D. = standard deviation; n = number of samples. N = Net Spinners; C = Case Builders; R = Rhyacophilids; C = Chironomids; Si = Simuliids; O = Other; F = Filipalpia; SE = Setipalpia.

		Trichoptera			Diptera			Plecoptera		Ephemeroptera	Others	Mean total volume (ml)	n	Mean water velocity (cm s^{-1}) (S.D.)	Mean depth (cm) (S.D.)
		N	C	R	C	Si	O	F	SE						
Camp 40	Vol.	0.28	0.07	0.03	0.01	0	<0.01	0.01	0.02	0.04	0.02	0.48	3	12.10	20.30
	nos.	30.00	20.30	12.30	339.00	0	10.30	3.70	6.70	107.00	28.70	(0.08)		(3.65)	(5.25)
East Rainy	Vol.	0.07	0	0.01	0.01	0	<0.01	<0.01	0.01	0.02	0.01	0.13	3	19.20	19.70
	nos.	5.30	0	1.00	14.70	0	2.00	0.70	6.00	45.70	4.00	(0.08)		(5.36)	(5.56)
Bald Mountain	Vol.	0.55	0.01	0.01	0.02	<0.01	<0.01	0	0.02	0.04	0.01	0.65	4	40.40	17.50
	nos.	56.00	4.00	6.50	310.30	0.75	29.80	0	7.50	131.80	31.50	(0.27)		(7.68)	(5.72)
Rainy	Vol.	0.18	0.03	0.03	0.01	0	<0.01	0.01	0.01	0.05	0.02	0.32	4	16.20	20.00
	nos.	33.50	6.30	16.30	276.50	0	18.30	1.00	4.30	291.00	20.80	(0.14)		(4.42)	(1.22)
Main Rainy Br. (Pool)	Vol.	0.38	0.05	0.02	0.02	<0.01	<0.01	<0.01	0.01	0.04	0.01	0.52	4	19.10	25.00
	nos.	93.80	4.30	4.30	360.80	2.30	3.50	0.50	5.30	193.50	5.80	(0.49)		(17.19)	(15.84)
River Br. Upper Stn. (T3)	Vol.	0.11	0.01	0.01	0.01	0	<0.01	<0.01	0.01	0.07	0.01	0.24	4	12.70	12.50
	nos.	8.80	25.30	4.50	110.30	0	2.50	0.50	10.00	66.50	41.30	(0.13)		(3.27)	(1.50)
River Br. Lower Stn.	Vol.	0.04	0.01	<0.01	0.01	0	<0.01	0.01	0.01	0.04	<0.01	0.13	3	15.00	20.00
	nos.	5.00	2.70	1.00	119.30	0	1.00	6.00	7.00	165.00	3.70	(0.06)		(1.04)	(2.16)
River Br. Pool	Vol.	0.01	<0.01	<0.01	0.01	0	<0.01	0	0.01	0.02	0.01	0.07	2	7.60	46.50
	nos.	3.50	1.50	1.50	180.50	0	2.50	0	11.00	44.00	3.00	(0.02)		(0.50)	(13.50)
Railway Bridge	Vol.	0.10	0.02	0.05	0.07	0	<0.01	0	0.01	0.05	0.01	0.29	4	4.70	17.00
	nos.	34.30	5.00	7.00	1126.00	0	5.00	0	19.80	52.50	9.00	(0.11)		(3.41)	(2.45)
Gillam's Farm	Vol.	0.94	0.02	0.01	0.06	<0.01	<0.01	0	0.03	0.20	0.61	1.87	2	22.20	31.00
	nos.	146.50	26.50	4.50	866.00	1.50	18.00	0	57.50	255.00	37.00	(0.27)		(10.75)	(9.00)

Table 19. Mean sizes and biomass estimates of eels at stations in the Highlands River, 1980. (S.D. is given in brackets.)

Station	Spring (May 25 - June 11) Mean size T. Lth (cm)	Spring Mean size Wt (g)	Spring Sample size	Spring Biomass (g m^{-2})	Fall (Sept 17 - 30) Mean size T. Lth (cm)	Fall Mean size Wt (g)	Fall Sample size	Fall Biomass (g m^{-2})
Camp 40	12.90	2.60	1	0.02			0	0
East Rainy	22.20 (5.91)	18.10 (13.59)	17	0.81	21.40 (6.28)	18.70 (12.94)	5	0.28
Bald Mountain Br.	30.40 (7.99)	54.26 (41.32)	5	0.63	35.50 (10.61)	75.90 (65.27)	2	0.35
Rainy River	33.00	60.00	1	0.20			0	0
River Brook			0	0	47.30 (22.20)	270.70 (304.34)	2	0.37
Railway Bridge	28.40 (1.80)	35.40 (6.44)	17	0.43* (0.01)	32.00 (6.56)	58.70 (37.89)	5	0.25
Gillam's Farm	29.60 (7.91)	48.90 (37.68)	91	3.60* (0.01)	30.70 (12.07)	69.10 (58.12)	32	1.96* (0.003)

*Biomass estimates by the Zippin method. Others are minimum estimates.

Table 20. Mean sizes and biomass estimates of eels at stations in the Highlands River, June 21 - July 7, 1981. (S.D. in brackets below sizes; S.E., where calculated, below biomass.)

Station	Mean size T.Lth (cm)	Mean size Wt (g)	Sample size	Biomass (g m^{-2})
Camp 40	28.30 (8.13)	35.80 (28.50)	2	0.43 (0)
East Rainy	19.30 (6.51)	12.20 (8.82)	5	$\geq$0.13
Bald Mountain Brook	30.76 (5.89)	44.60 (20.49)	6	0.75 ($\pm$0.02)
Rainy River	48.50	168.20	1	0.49 (0)
Main Rainy Riffle	29.40 (4.34)	37.50 (14.04)	5	0.42 (0)
Main Rainy Pool			0	0
River Brook Upper (T3)	32.00	46;.30	1	0.11
River Brook	24.70 (7.08)	25.90 (16.92)	15	1.16 (0)
River Brook Pool	37.50 (9.90)	84.40 (62.86)	2	$\geq$0.41
Railway Bridge	29.80 (3.33)	38.60 (12.50)	10	1.24 (0.09)
Gillam's Farm	30.50 (8.07)	48.70 (36.71)	31	1.78 (0.02)

Table 21. The significant correlation coefficients ($P < 0.05$) found with estimates of total trout or salmon biomass (g m^{-2}) and density (100 m^{-2}) by age class and total densities, with habitat variables from the three sampling periods.

	Variable	Correlation coefficient	Probability
1980 Spring			
Trout biomass	Ice	-0.0852	0.0310
	Depth	-0.948	0.0039
	Width	-0.832	0.0400
Trout 2+ density	Depth	-0.853	0.0306
Trout 3+ density	Velocity	0.902	0.0140
Total trout density	Depth	-0.841	0.0358
1980 Fall			
Trout biomass	Cover	0.828	0.0214
	Ice	-0.794	0.0331
	Substrate	-0.785	0.0365
Trout 0+ density	Ice	-0.925	0.0029
Trout 1+ density	Substrate	-0.887	0.0078
Trout 2+ density	Width	-0.767	0.0443
Total trout density	Ice	-0.871	0.0108
1981 Summer			
Salmon 0+ density	Velocity	0.857	0.0008
Trout biomass	Cover	0.679	0.0217
	Ice	-0.776	0.0050
	Width	-0.755	0.0072
Trout 1+ density	Cover	0.618	0.0429
	Ice	-0.789	0.0039
	Width	-0.654	0.0290
Trout 2+ density	Cover	0.646	0.0317
	Ice	-0.776	0.0050
	Width	-0.734	0.0101
Trout 3+ density	Cover	0.775	0.0051
	Ice	-0.718	0.0129
	Width	-0.723	0.0119
Total trout density	Ice	-0.805	0.0028
	Width	-0.681	0.0210

Table 22. The significant correlation coefficients ($P < 0.05$) found with estimates of trout biomass (g m^{-2}), age class density, and total density (100 m^{-2}), with habitat variables, for all seasons and stations.

	Variable	Correlation coefficient	Probability
Trout biomass	Cover	0.674	0.0003
	Ice	-0.745	0.0001
	Width	-0.718	0.0001
	Substrate	-0.502	0.0124
Trout 0+ density	Substrate	-0.498	0.0132
Trout 1+ density	Cover	0.588	0.0025
	Ice	-0.730	0.0001
	Substrate	-0.548	0.0056
	Width	-0.599	0.0020
Trout 2+ density	Cover	0.512	0.0105
	Ice	-0.571	0.0036
	Width	-0.517	0.0097
Trout 3+ density	Cover	0.457	0.0248
	Width	-0.468	0.0210
Total trout density	Cover	0.641	0.0008
	Ice	-0.780	0.0001
	Substrate	-0.649	0.0006
	Invertebrates	-0.517	0.0281
	Width	-0.685	0.0002

Table 23. The significant correlation coefficients ($P < 0.05$) of trout biomass (g m^{-2}) density (100 m^{-2}) by age class and total densities, with $\log_{10}$ transformation of variables in the habitat, for all seasons and stations.

Biomass or density	Variable (logX+1)	Correlation coefficient	Probability
Trout biomass	Cover	0.784	0.0001
	Ice	-0.743	0.0001
	Substrate	-0.504	0.0120
	Width	-0.782	0.0001
Trout 0+ density	Substrate	-0.507	0.0115
Trout 1+ density	Cover	0.671	0.0003
	Ice	-0.742	0.0001
	Substrate	-0.554	0.0050
	Width	-0.668	0.0004
Trout 2+ density	Cover	0.565	0.0041
	Ice	-0.589	0.0025
	Width	-0.611	0.0015
Trout 3+ density	Cover	0.532	0.0074
	Width	-0.483	0.0168
Total trout density	Cover	0.706	0.0001
	Ice	-0.802	0.0001
	Substrate	-0.656	0.0005
	Invertebrates	-0.495	0.0366
	Width	-0.769	0.0001

Table 24. The significant correlation coefficients ($P < 0.05$) of trout biomass (g m^{-2}), density (100 m^{-2}) by age class and total densities, with variables of the habitat, with all variables transformed ($\log_{10}$). All seasons and stations are included.

Biomass or density (logY+1)	Variable (logX+1)	Correlation coefficient	Probability
Trout biomass	Cover	0.836	0.0001
	Ice	-0.774	0.0001
	Substrate	-0.464	0.0223
	Width	-0.839	0.0001
Trout density:			
0+	Substrate	-0.504	0.0119
1+	Cover	0.791	0.0001
	Ice	-0.818	0.0001
	Substrate	-0.538	0.0066
	Invertebrates	-0.497	0.0358
	Width	-0.786	0.0001
2+	Cover	0.769	0.0001
	Ice	-0.710	0.0001
	Invertebrates	-0.539	0.0209
	Width	-0.806	0.0001
3+	Cover	0.530	0.0077
	Width	-0.496	0.0137
Total trout density	Cover	0.754	0.0001
	Ice	-0.753	0.0001
	Substrate	-0.553	0.0051
	Invertebrates	-0.698	0.0013
	Width	-0.839	0.0001

Table 25. Significant regressions ($P < 0.05$) of trout biomass (g m^{-2}) and densities (100 m^{-2}) with variables of the habitat.

Biomass or density	Habitat variable	Slope	Intercept	R^2	P
Trout biomass	Width	-0.101	4.096	0.483	0.0008
	Cover	0.058	1.235	0.433	0.0018
	Ice	-1.898	4.346	0.537	0.0003
	Substrate	-1.926	8.314	0.211	0.0316
Trout density:					
1+	Width	-0.243	9.751	0.325	0.0080
	Cover	0.157	2.507	0.378	0.0039
	Ice	-5.502	11.305	0.550	0.0003
	Substrate	-6.912	26.901	0.366	0.0046
2+	Width	-0.087	3.682	0.457	0.0012
	Cover	0.042	1.384	0.263	0.0171
	Ice	-1.558	3.818	0.457	0.0012
Total trout density	Width	-0.468	21.227	0.462	0.0011
	Cover	0.251	8.289	0.348	0.0059
	Ice	-9.617	23.203	0.622	0.0001
	Substrate	-11.896	49.892	0.401	0.0028
	Invertebrates	-10.697	19.083	0.221	0.0281

Table 26. Significant regressions ($P < 0.05$) of trout biomass (g m^{-2}) and densities (100 m^{-2}) with transformed ($\log_{10}$) habitat variables, for all seasons and stations.

Biomass or density	Habitat variable (logX+1)	Slope	Intercept	R^2	P
Trout biomass	Width	-4.941	7.941	0.612	0.0001
	Cover	2.416	0.255	0.655	0.0001
	Ice	-8.060	4.558	0.524	0.0004
	Substrate	-16.994	12.688	0.209	0.0324
Trout density:					
1+	Width	-12.448	19.614	0.458	0.0012
	Cover	6.004	0.321	0.476	0.0009
	Ice	-24.358	12.187	0.589	0.0001
	Substrate	-61.107	42.675	0.364	0.0048
2+	Width	-4.115	6.837	0.539	0.0003
	Cover	1.969	0.472	0.550	0.0003
	Ice	-6.511	3.964	0.430	0.0019
Total trout density	Width	-23.006	39.132	0.587	0.0001
	Cover	10.297	4.175	0.517	0.0005
	Ice	-41.951	24.575	0.644	0.0001
	Substrate	-105.069	76.979	0.398	0.0030
	Invertebrates	-42.482	20.593	0.198	0.0366

Table 27. Significant regressions ($P < 0.05$) of trout biomass (g m^{-2}) and densities (100 m^{-2}) with variables of the habitat, with all variables transformed ($\log_{10}$).

Biomass or density (logY+1)	Habitat variable (logX+1)	Slope	Intercept	R^2	P
Trout biomass	Width	-0.741	1.269	0.670	0.0001
	Cover	0.362	0.117	0.715	0.0001
	Ice	-1.207	0.761	0.573	0.0002
	Substrate	-2.392	1.886	0.197	0.0370
Trout density:					
1+	Width	-0.987	1.748	0.605	0.0001
	Cover	0.480	0.215	0.642	0.0001
	Ice	-1.832	1.133	0.690	0.0001
	Substrate	-4.123	3.139	0.334	0.0071
	Invertebrates	-1.801	0.950	0.200	0.0358
2+	Width	-0.669	1.178	0.630	0.0001
	Cover	0.317	0.147	0.630	0.0001
	Ice	-1.037	0.706	0.482	0.0008
	Invertebrates	-1.302	0.651	0.246	0.0209
Total trout density	Width	-1.102	2.228	0.656	0.0001
	Cover	0.471	0.574	0.523	0.0004
	Ice	-1.713	1.451	0.506	0.0006
	Substrate	-4.229	3.553	0.298	0.0112
	Invertebrates	-2.725	1.460	0.455	0.0013

Table 28. The significant correlation coefficients ($P < 0.05$) of salmon and trout biomass (g m^{-2}) and densities (100 m^{-2}), with habitat variables, but with the East Rainy station removed. All other stations, for all seasons, are included.

Biomass or density	Habitat variable	Correlation coefficient	Probability
Salmon biomass	Substrate	0.579	0.0060
Total salmon density	Substrate	0.460	0.0360
Trout biomass	Cover	0.745	0.0001
	Ice	-0.745	0.0001
	Substrate	-0.579	0.0060
	Width	-0.714	0.0003
Trout density:			
0+	Substrate	-0.618	0.0028
1+	Cover	0.638	0.0019
	Ice	-0.750	0.0001
	Substrate	-0.612	0.0032
	Width	-0.592	0.0047
2+	Cover	0.573	0.0067
	Ice	-0.554	0.0092
	Substrate	-0.438	0.0468
	Width	-0.498	0.0217
3+	Cover	0.487	0.0251
	Ice	-0.402	0.0712
	Width	-0.499	0.0213
Total trout density	Cover	0.696	0.0005
	Ice	-0.786	0.0001
	Substrate	-0.726	0.0002
	Width	-0.669	0.0009

Table 29. The significant correlation coefficients ($P < 0.05$) of salmon and trout biomass (g m^{-2}) and densities (100 m^{-2}), with habitat variables, all variables transformed ($\log_{10}$), but with the East Rainy station removed. All other stations, for all seasons, are included.

Biomass or density (logY+1)	Variable (logX+1)	Correlation coefficient	Probability
Salmon biomass	Substrate	0.548	0.0101
Trout biomass	Cover	0.848	0.0001
	Ice	-0.760	0.0001
	Substrate	-0.551	0.0096
	Width	-0.835	0.0001
Trout density:			
0+	Ice	-0.481	0.0271
	Substrate	-0.591	0.0048
	Invertebrates	-0.527	0.0361
1+	Cover	0.806	0.0001
	Ice	-0.822	0.0001
	Substrate	-0.630	0.0022
	Width	-0.778	0.0001
2+	Cover	0.793	0.0001
	Ice	-0.672	0.0009
	Substrate	-0.461	0.0354
	Width	-0.804	0.0001
3+	Cover	0.542	0.0111
	Width	-0.528	0.0138
Total trout density	Cover	0.759	0.0001
	Ice	-0.741	0.0001
	Substrate	-0.642	0.0017
	Width	-0.829	0.0001

Table 30. The significant correlation coefficients ($P < 0.05$) of salmon and trout biomass (g m^{-2}) and densities (100 m^{-2}), with habitat variables, for all seasons, but with East Rainy and the two River Brook stations removed.

Biomass or density	Variable	Correlation coefficient	Probability
Salmon biomass	Substrate	0.675	0.0021
Total salmon density	Substrate	0.574	0.0127
Trout biomass	Cover	0.708	0.0010
	Ice	-0.718	0.0008
	Substrate	-0.557	0.0164
	Width	-0.763	0.0002
Trout density:			
0+	Ice	-0.575	0.0125
	Substrate	-0.647	0.0037
1+	Cover	0.594	0.0093
	Ice	-0.748	0.0004
	Substrate	-0.594	0.0094
	Width	-0.623	0.0057
2+	Cover	0.536	0.0210
	Ice	-0.534	0.0225
	Width	-0.511	0.0303
3+	Cover	0.448	0.0621
	Width	-0.508	0.0315
Total trout density	Cover	0.669	0.0024
	Ice	-0.832	0.0001
	Substrate	-0.717	0.0008
	Invertebrates	-0.600	0.0303
	Width	-0.692	0.0015

Table 31. The significant correlation coefficients ($P < 0.05$) of salmon and trout biomass (g m^{-2}) and densities (100 m^{-2}), with habitat variables, all variables transformed ($\log_{10}$), for all seasons, but with stations in East Rainy and River Brook removed.

Biomass or density (logY+1)	Variable (logX+1)	Correlation coefficient	Probability
Salmon biomass	Substrate	0.649	0.0036
Salmon density:			
1+	Substrate	0.526	0.0249
Total salmon density	Substrate	0.582	0.0113
Trout biomass	Cover	0.821	0.0001
	Ice	-0.714	0.0091
	Substrate	-0.523	0.0261
	Invertebrates	-0.562	0.0456
	Width	-0.849	0.0001
Trout density:			
0+	Ice	-0.604	0.0079
	Substrate	-0.630	0.0051
	Invertebrates	-0.559	0.0470
1+	Cover	0.770	0.0002
	Ice	-0.786	0.0001
	Substrate	-0.615	0.0066
	Invertebrates	-0.664	0.0133
	Width	-0.800	0.0001
2+	Cover	0.763	0.0002
	Ice	-0.614	0.0067
	Invertebrates	-0.637	0.0193
	Width	-0.810	0.0001
3+	Cover	0.520	0.0269
	Width	-0.509	0.0310
Total trout density	Cover	0.778	0.0001
	Ice	-0.771	0.0002
	Substrate	-0.637	0.0045
	Invertebrates	-0.790	0.0013
	Width	-0.833	0.0001

Table 32. Stepwise multiple regression equations for salmon parr. All stations and seasons are included. Variables were entered in the stepwise regression only if biomass g m^{-2} or density (100 m^{-2}) on habitat variable was significant at $P < 0.15$. Regressions are given for arithmetic variables semi-logarithmically, and with all variables logarithmically transformed.

Independent variable	Intercept	Habitat variable	Regression coefficient	Partial r^2	Model r^2
Salmon biomass	1.3709	Invertebrates	1.1857	0.1400	0.1400
		Width	-0.0257	0.1146	0.2546
2+ Parr Density	3.3205	Invertebrates	4.4162	0.1809	0.1809
Salmon biomass	-2.1909	Substrate (logX+1)	6.2017	0.1490	0.1490
Total salmon density	-31.4543	Substrate (log X+1)	86.9814	0.0928	0.0928
Total salmon density (logY+1)	0.3730	Ice ($\log X_1+1$)	1.7599	0.1041	0.1041
		Cover ($\log X_2+1$)	0.3850	0.1871	0.2912

Table 33. Stepwise multiple regression equations for salmon, but with Rainy Brook East station removed. Variables were entered in the stepwise regression only if biomass or density variable on habitat variable was significant at $P < 0.15$. Regressions are given with variables arithmetically, semi-logarithmically, and with all variables logarithmically transformed.

Independent variable	Intercept	Habitat variable	Regression coefficient	Model r^2
Salmon biomass	-0.7574	Substrate	1.0630	
		Ice	-0.6431	0.5147
Density, 1+	-6.2886	Substrate	8.2079	
		Ice	-5.7823	0.5225
Total density	-5.4519	Substrate	12.5353	
		Ice	-9.7481	0.5156
Salmon biomass	-4.3884	Substrate ($\log X_1+1$)	11.5143	
		Ice ($\log X_2+1$)	-2.6716	0.4942
Density, 1+	-60.7288	Substrate ($\log X_1+1$)	113.1839	
		Cover ($\log X_2+1$)	8.4720	0.3080
Total density	-72.5328	Substrate ($\log X_1+1$)	145.9512	
		Cover ($\log X_2+1$)	9.7214	0.3538
Salmon biomass ($\log Y+1$)	-0.5278	Substrate ($\log X_1+1$)	1.7918	
		Ice ($\log X_2+1$)	-0.4485	0.5192
Density, 1+ ($\log Y+1$)	-0.3830	Cover ($\log X_1+1$)	0.2157	
		Substrate ($\log X_2+1$)	2.1391	0.3170
Total density ($\log Y+1$)	-0.0024	Cover ($\log X_1+1$)	0.1770	
		Substrate ($\log X_2+1$)	1.9414	0.3446

Table 34. Stepwise multiple regression equations for salmon, but with Rainy Brook East and the River Brook stations removed. Regressions are given arithmetically, semi-logarithmically, and with all variables logarithmically transformed.

Independent variable	Intercept	Habitat variable	Regression coefficient	Model r^2
Salmon biomass	-0.5914	Substrate	0.9361	
		Width	-0.0185	0.4994
Density, 1+	-9.0630	Substrate	9.1638	
		Invertebrates	-7.8752	0.6281
Total density	20.3253	Substrate	9.1301	
		Width	-0.5533	
		Cover	-0.2604	
		Depth	-0.2459	0.7787
Salmon biomass	1.8975	Substrate ($\log X_1+1$)	9.8065	
		Width ($\log X_2+1$)	-3.6099	
		Cover ($\log X_3+1$)	-1.7540	0.7109
Densities:				
1+	-38.3711	Substrate ($\log X_1+1$)	120.1152	
		Width ($\log X_2+1$)	-14.9861	0.3419
2+	-12.9740	Substrate ($\log X_1+1$)	34.3114	0.1608
Total density	13.3689	Substrate ($\log X_1+1$)	158.0076	
		Width ($\log X_2+1$)	-52.1810	
		Cover ($\log X_3+1$)	-21.5407	0.5269
Salmon biomass ($\log Y+1$)	0.4644	Substrate ($\log X_1+1$)	1.5034	
		Width ($\log X_2+1$)	-0.5763	
		Cover ($\log X_3+1$)	-0.2677	0.7408
Density, 1+ ($\log Y+1$)	0.0989	Substrate ($\log X_1+1$)	2.3185	
		Width ($\log X_2+1$)	-0.2886	0.4687
Total density ($\log Y+1$)	1.3829	Substrate ($\log X_1+1$)	2.1565	
		Width ($\log X_2+1$)	-0.8246	
		Cover ($\log X_3+1$)	-0.3454	0.6718

Table 35. Stepwise multiple regression equations for brook trout. All stations and all seasons are included. Variables were entered in the stepwise regression only if the independent variable on the habitat variable was significant at $P < 0.15$.

Independent variable	Intercept	Habitat variable	Regression coefficient	Partial r^2	Model r^2
Trout biomass	2.0512	Ice	-1.1287	0.5644	0.5644
		Width	-0.0396	0.1245	0.6888
		Depth	0.0567	0.0793	0.7682
		Cover	0.0335	0.0812	0.8494
Densities:					
1+	21.5633	Ice	-3.2871	0.5767	0.5767
		Substrate	-4.5638	0.1657	0.7424
		Cover	0.0771	0.0716	0.8140
2+	2.8969	Ice	-1.0967	0.4885	0.4885
		Depth	0.0553	0.1356	0.6241
		Width	-0.0607	0.1614	0.7854
Total density	47.6369	Ice	-5.3725	0.6438	0.6438
		Substrate	-8.0014	0.1757	0.8194
		Width	-0.2439	0.0909	0.9103

Table 36. Stepwise multiple regression equations for brook trout. All stations and all seasons with the habitat variables transformed to log base 10. Variables were entered in the stepwise regression only if the independent variable on the habitat variable was significant at P < 0.15.

Independent variable	Intercept	Habitat variable (logX+1)	Regression coefficient	Partial r^2	Model r^2
Trout biomass	5.0388	Cover	0.6784	0.6149	0.6149
		Substrate	-6.2869	0.0899	0.7049
		Ice	-3.1891	0.0480	0.7528
		Depth	2.7280	0.0356	0.7884
		Width	-2.2810	0.0373	0.8257
Densities:					
1+	32.0871	Ice	-11.6399	0.5508	0.5508
		Substrate	-30.1533	0.0996	0.6504
		Width	-4.8676	0.0563	0.7067
2+	20.6962	Width	-6.1522	0.3737	0.3737
		Substrate	-17.4595	0.0706	0.4444
Total density	78.9077	Ice	-19.9487	0.6429	0.6429
		Substrate	-75.5731	0.1617	0.8046
		Width	-12.9940	0.1040	0.9086

Table 37. Stepwise multiple regression equations for brook trout, with all variables transformed to log base 10. Variables were entered in the stepwise regression only if the independent variable on the habitat variable was significant at P < 0.15.

Independent variable (logY+1)	Intercept	Habitat variable (logX+1)	Regression coefficient	Partial r^2	Model r^2
Trout biomass	1.1922	Width	-0.5235	0.7046	0.7046
		Substrate	-0.8044	0.0857	0.7903
		Ice	-0.5041	0.0410	0.8313
		Depth	0.3179	0.0282	0.8595
Densities:					
1+	2.2309	Ice	-0.8135	0.6695	0.6695
		Cover	0.1103	0.1049	0.7744
		Substrate	-1.8464	0.0642	0.8386
		Width	-0.3261	0.0186	0.8572
2+	0.8249	Width	-0.6202	0.6501	0.6501
		Ice	-0.5832	0.0508	0.7010
		Depth	0.3681	0.0308	0.7318
Total density	3.4516	Width	-0.7596	0.7039	0.7039
		Substrate	-2.4455	0.1471	0.8510
		Ice	-0.4948	0.0228	0.8738

Table 38. Stepwise multiple regression equations for brook trout, but with Rainy Brook East station removed.

Independent variable	Intercept	Habitat variable	Regression coefficient	Model r^2
Trout biomass	1.3241	Ice	-0.8805	
		Width	-0.0345	
		Depth	0.0609	
		Cover	0.0408	0.8737
Densities:				
1+	21.6225	Ice	-2.1176	
		Substrate	-5.2459	
		Cover	0.0961	0.8477
2+	0.8422	Width	-0.0388	
		Depth	0.0702	
		Cover	0.0301	
		Ice	-0.6039	0.8464
Total trout density	45.6453	Ice	-2.6669	
		Substrate	-9.6935	
		Width	-0.1630	
		Cover	0.1051	0.9525

Table 39. Stepwise multiple regression equations for brook trout, but with Rainy Brook East station removed. Habitat variables transformed to log base 10.

Independent variable	Intercept	Habitat variable (logX+1)	Regression coefficient	Model r^2
Trout biomass	10.4474	Cover	0.9141	
		Substrate	-11.4694	
		Width	-1.9810	0.7948
Densities:				
1+	30.8856	Ice	-12.5262	
		Substrate	-27.9046	
		Width	-4.7527	0.7234
2+	21.1160	Width	-5.6837	
		Substrate	-19.3763	0.4513
Total density	89.8006	Ice	-23.0628	
		Substrate	-76.6112	
		Width	-18.3223	
		Cover	-3.6694	0.9274

Table 40. Stepwise multiple regression equations for brook trout, but with Rainy Brook East station removed. All variables transformed to log base 10.

Independent variable (logY+1)	Intercept	Habitat variable (logX+1)	Regression coefficient	Model r^2
Trout biomass	0.9698	Cover	0.1748	
		Substrate	-1.2205	
		Width	-0.3316	
		Depth	0.2763	0.8722
Densities:				
1+	2.6088	Ice	-0.8079	
		Width	-0.5013	
		Substrate	-1.9902	0.8472
2+	2.0133	Width	-0.6546	0.7109
		Substrate	-1.3349	
Total density	3.7956	Width	-0.8525	
		Substrate	-3.1043	0.8769

Table 41. Stepwise multiple regression equations for brook trout, but with Rainy Brook East and the River Brook stations removed.

Independent variable	Intercept	Habitat variable	Regression coefficient	Model r^2
Trout biomass	8.0126	Width	-0.0842	
		Substrate	-1.3066	0.7398
Densities:				
1+	23.6156	Ice	-5.2672	
		Substrate	-5.8358	
		Cover	0.0873	
		Invertebrates	4.0467	0.8998
2+	0.4395	Width	-0.0516	
		Depth	0.0689	
		Cover	0.0334	0.7851
Total density	47.2780	Ice	-5.5154	
		Substrate	-10.1262	
		Cover	0.0926	
		Width	-0.1632	
		Invertebrates	3.8988	0.9835

Table 42. Stepwise multiple regression equations for brook trout, but with Rainy Brook East and the River Brook stations removed. Habitat variables are transformed to log base 10.

Independent variable	Intercept	Habitat variable (logX+1)	Regression coefficient	Model r^2
Trout biomass	13.0100	Width	-3.4889	
		Substrate	-11.2601	0.7706
Densities:				
1+	31.0449	Ice	-12.4863	
		Substrate	-28.0772	
		Width	-4.8297	0.6951
2+	10.4196	Width	-6.3641	0.3448
Total density	78.8178	Ice	-21.8845	
		Substrate	-76.5132	
		Width	-12.1857	0.9176

Table 43. Stepwise multiple regression equations for brook trout, but with Rainy Brook East and the River Brook stations removed. All variables transformed to log base 10.

Independent variable (logY+1)	Intercept	Habitat variable (logX+1)	Regression coefficient	Model r^2
Trout biomass	1.9073	Width	-0.5592	
		Substrate	-1.4020	0.8273
Densities:				
1+	2.9830	Width	-0.6995	
		Substrate	-2.5808	0.8286
2+	1.9082	Width	-0.6346	
		Substrate	-1.1671	0.7107
Total density	3.7448	Width	-0.8318	
		Substrate	-3.0472	0.8944

Table 44. Estimates of the total habitat available for rearing of juvenile salmon in the Highlands River, the probable densities of parr, the estimated % production of smolt for various sections, and the possible production of smolt per 100 m^2. The figures for smolt are derived from the fence records, and the population estimates of parr at the various sites.

Section	Length (km) x width (m)	Area (m^2)	(% Area)	N of 1+ parr 1980	N of 1+ parr 1981	N of 2+ parr 1980	N of 2+ parr 1981	N smolt 1981 2+	N smolt 1981 3+	N smolt 1982 2+	N smolt 1982 3+	P% smolt ($N \cdot 100\ m^{-2}$) 1981	P% smolt ($N \cdot 100\ m^{-2}$) 1982
Estuary - L. Leven	5.3 x 29.5	156,456	(25.2)	22,686	7,666	25,346	11,734	1,731	7,936	311	3,750	61.7 (6.2)	38.2 (2.6)
L. Leven	-	(159,043)		-	2,068	-	477			84	152	-	2.2 (0.2)
L. Leven - Rainy Br.	9.3 x 28.4	264,120	(42.5)	27,733	23,243	5,018	7,660	2,116	1,571	943	2,448	23.6 (1.4)	31.9 (1.3)
River Br., lower section	5.2 x 22.4	116,480	(18.7)	10,825	11,764	1,048	3,145	826	328	477	1,005	7.4 (1.0)	13.9 (1.3)
River Br., upper section	4.3 x 14.1	60,630	(9.8)	5,639	303	546	1,091	430	171	12	349	3.8 (1.0)	3.4 (0.6)
Rainy Br., main stem	0.6 x 11.2	6,720	(1.1)	1,628	1,539	228	914	124	71	62	292	1.3 (2.9)	3.3 (5.3)
Rainy Br., tributary	0.3 x 6.9	2,070	(0.3)	503	400	70	265	38	22	16	85	0.4 (2.9)	1.0 (4.9)
Bald Mountain Br.	2.8 x 4.2	11,760	(1.9)	2,129	1,870	165	1,552	162	52	76	496	1.4 (1.8)	5.4 (4.9)
Camp 40 Br.	0.9 x 4.1	3,690	(0.6)	177	402	210	196	14	66	16	63	0.5 (2.2)	0.7 (2.1)
Total		621,926		71,320	49,255	32,631	27,034	5,441	10,217	1,999	8,639	100 (2.5)	100 (1.7)
Rainy Br. East (below first pond)	4.8 x 6.7	(31,917)	(4.9)										

Table 45. Estimates of survival of 1+ parr in 1980 to 2+ parr and smolts in 1981.

Section	Survival
Estuary - L. Leven	0.59
L. Levin - Rainy Br.	0.35
River Br., lower	0.37
River Br., upper	0.27
Rainy Br., main stem	0.64
Rainy Br., tributary	0.60
Bald Mountain Br.	0.81
Camp 40 Br.	1.19
Total river	0.46

Table 46. Possible egg depositions (100 m^{-2}) calculated from population estimates of 1+ parr in 1980 and 1981, and 2+ parr and smolts in 1980, using survival rates suggested by Symons (1979).

Section	1977	1978	1979
Estuary - L. Leven	331	132	45
L. Levin - Rainy Br.	39	95	80
River Br., lower	18	92	84
River Br., upper	18	85	5
Rainy Br., main stem	69	220	208
Rainy Br., tributary	69	221	176
Bald Mountain Br.	29	165	145
Camp 40 Br.	116	44	99
Whole river	107	104	72

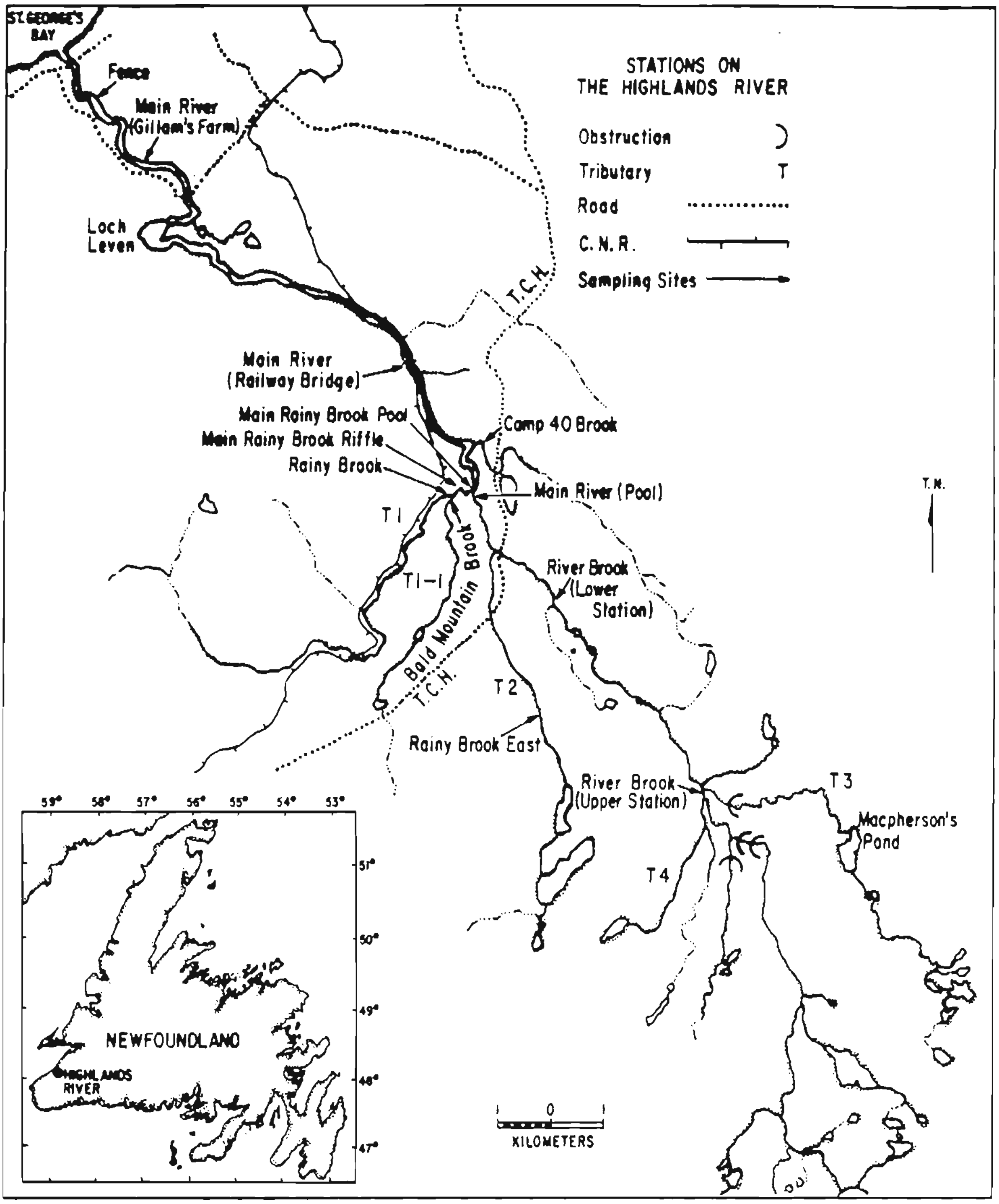

Fig. 1. The Highlands River system, showing the sampling sites, and the location of the river in Newfoundland (inset). Tributaries T1, T1-1, T3, and T4, are second order brooks. Tributary T2 is a third order brook, above which the river is called River Brook.

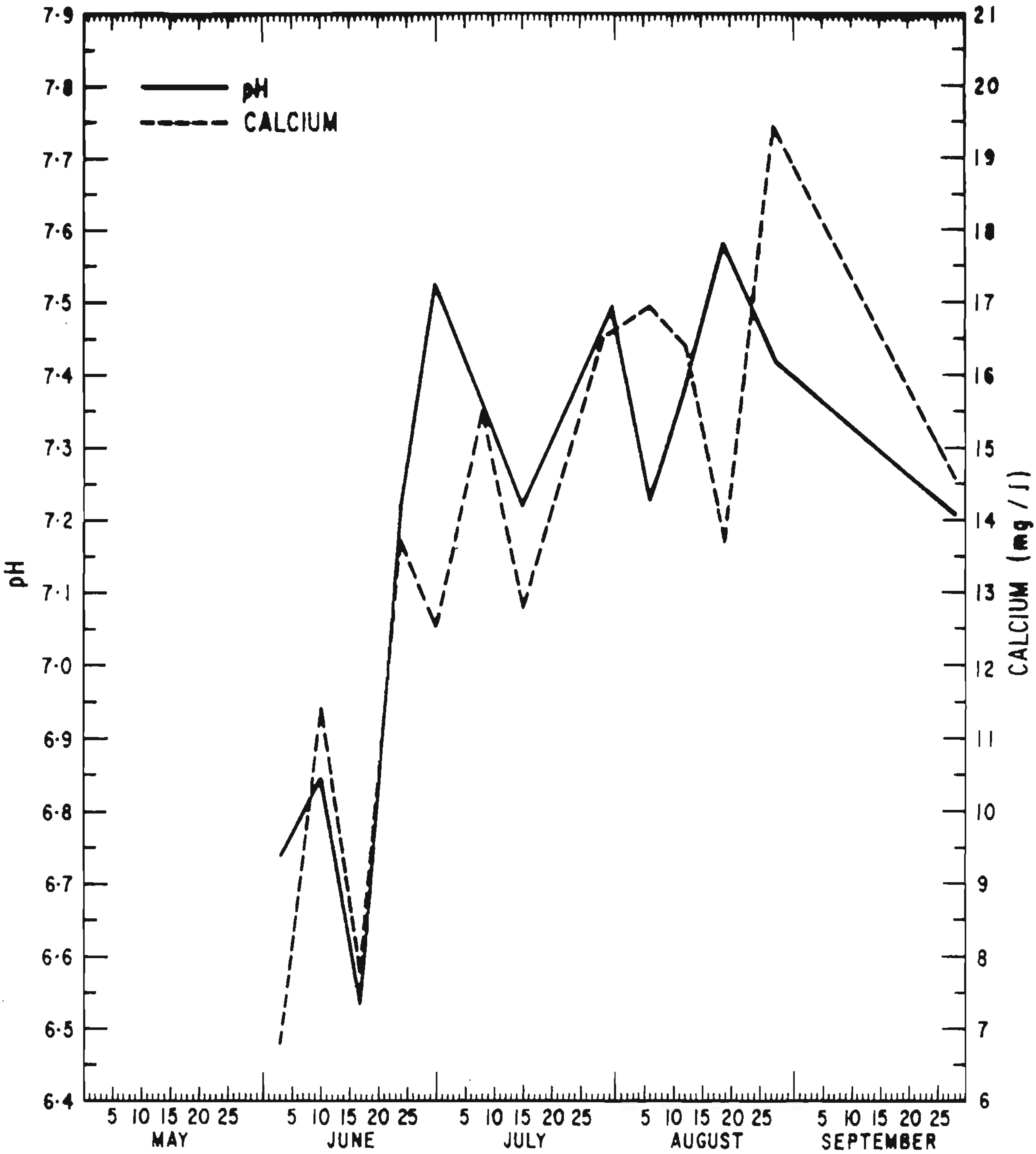

Fig. 2. Measurements of calcium and pH in water samples taken at the Highlands River counting fence in 1980.

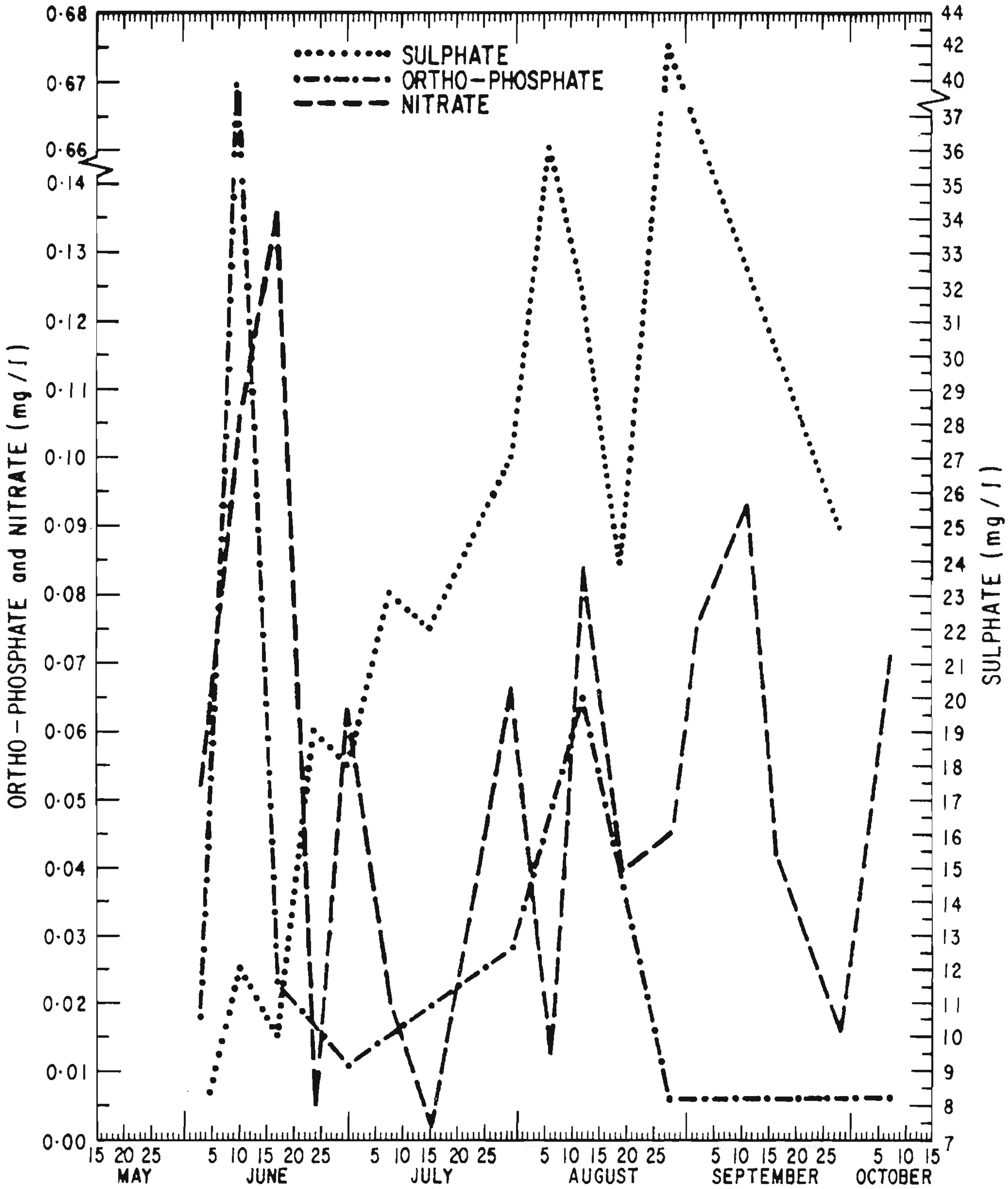

Fig. 3. Levels of sulphate, nitrate, and ortho-phosphate in water samples taken at the counting fence in 1980.

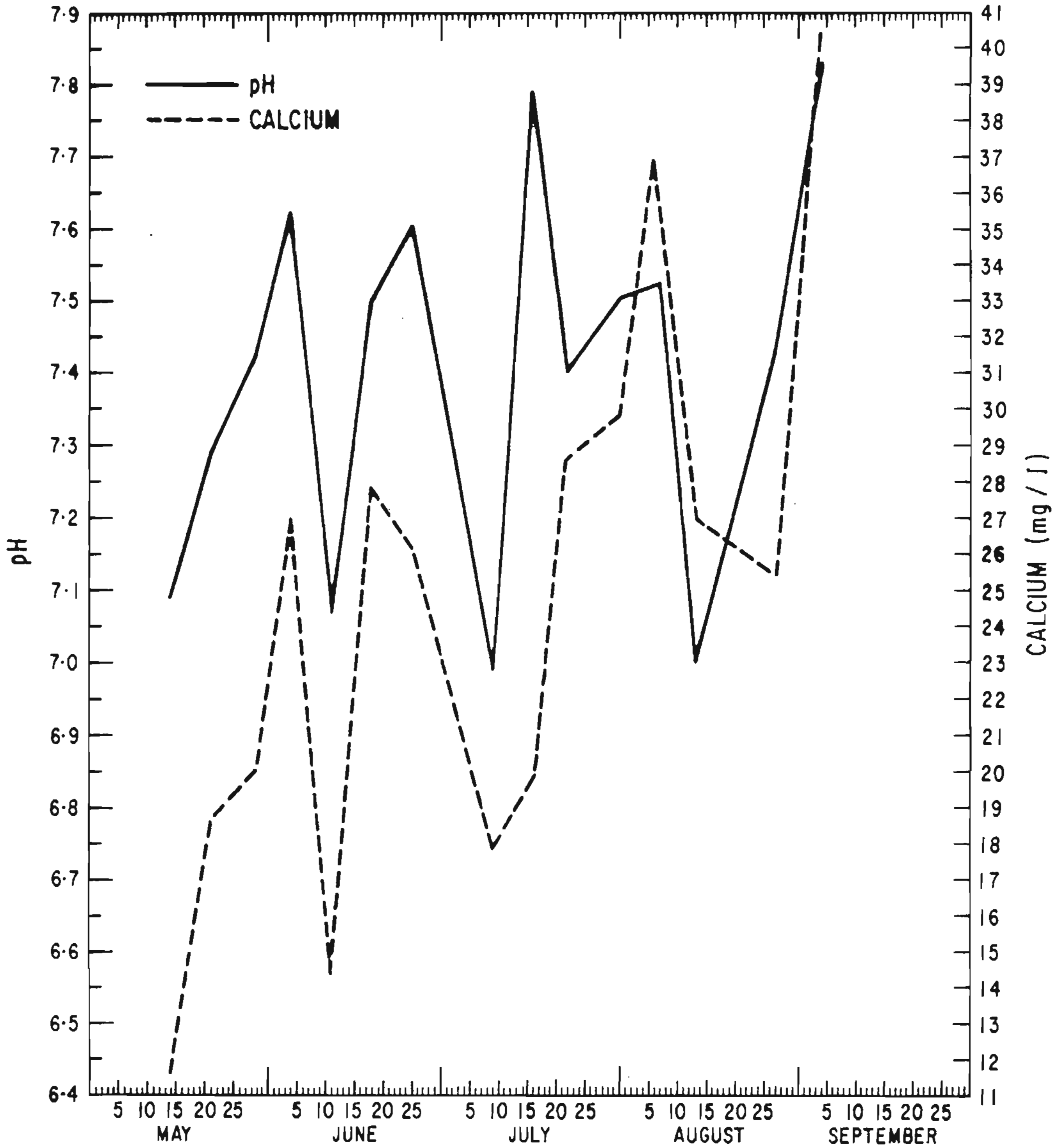

Fig. 4. Measurements of calcium and pH in water samples taken at the counting fence in 1981.

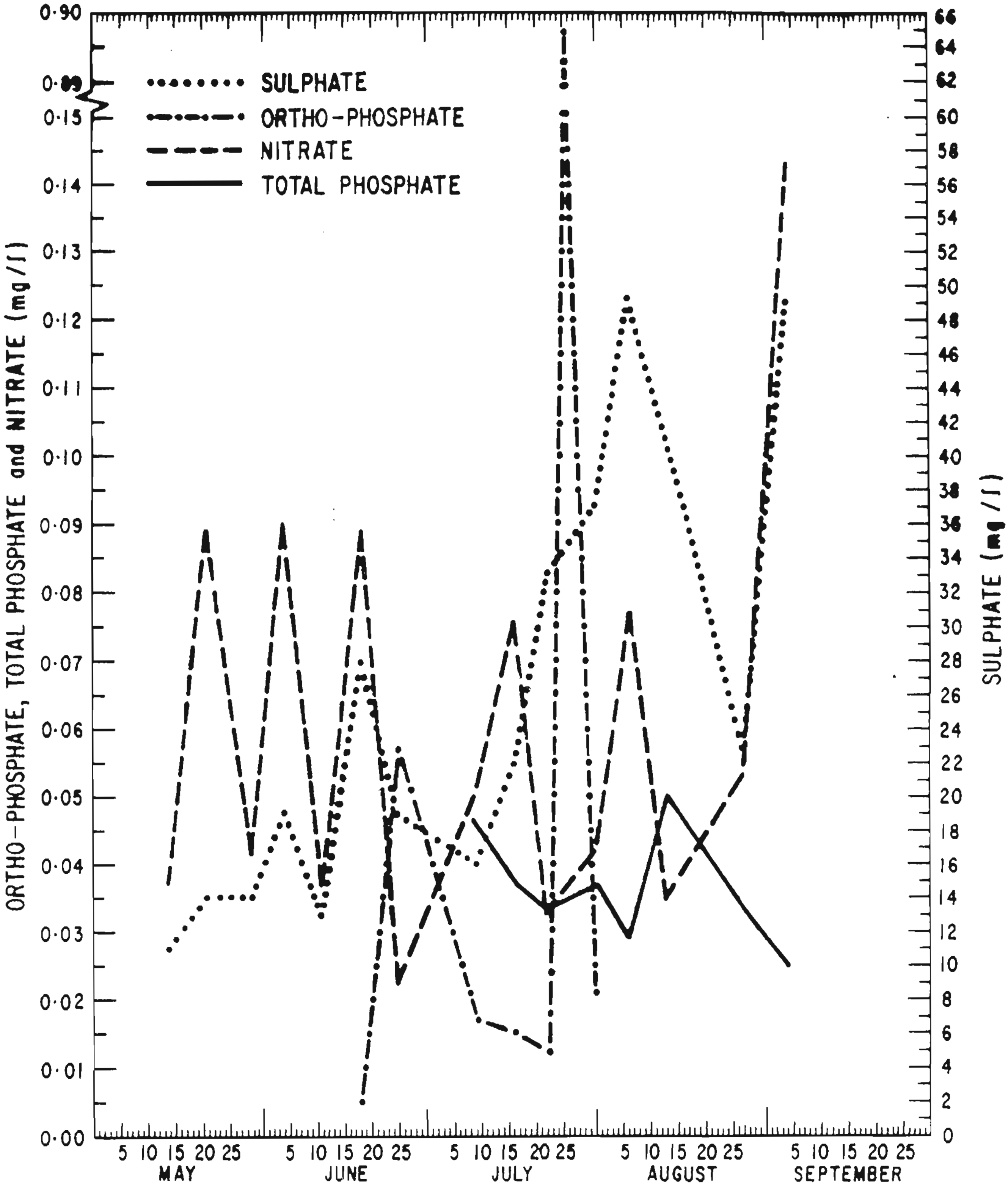

Fig. 5. Levels of sulphate, nitrate, ortho-phosphate, and total phosphate in water samples taken at the counting fence in 1981.

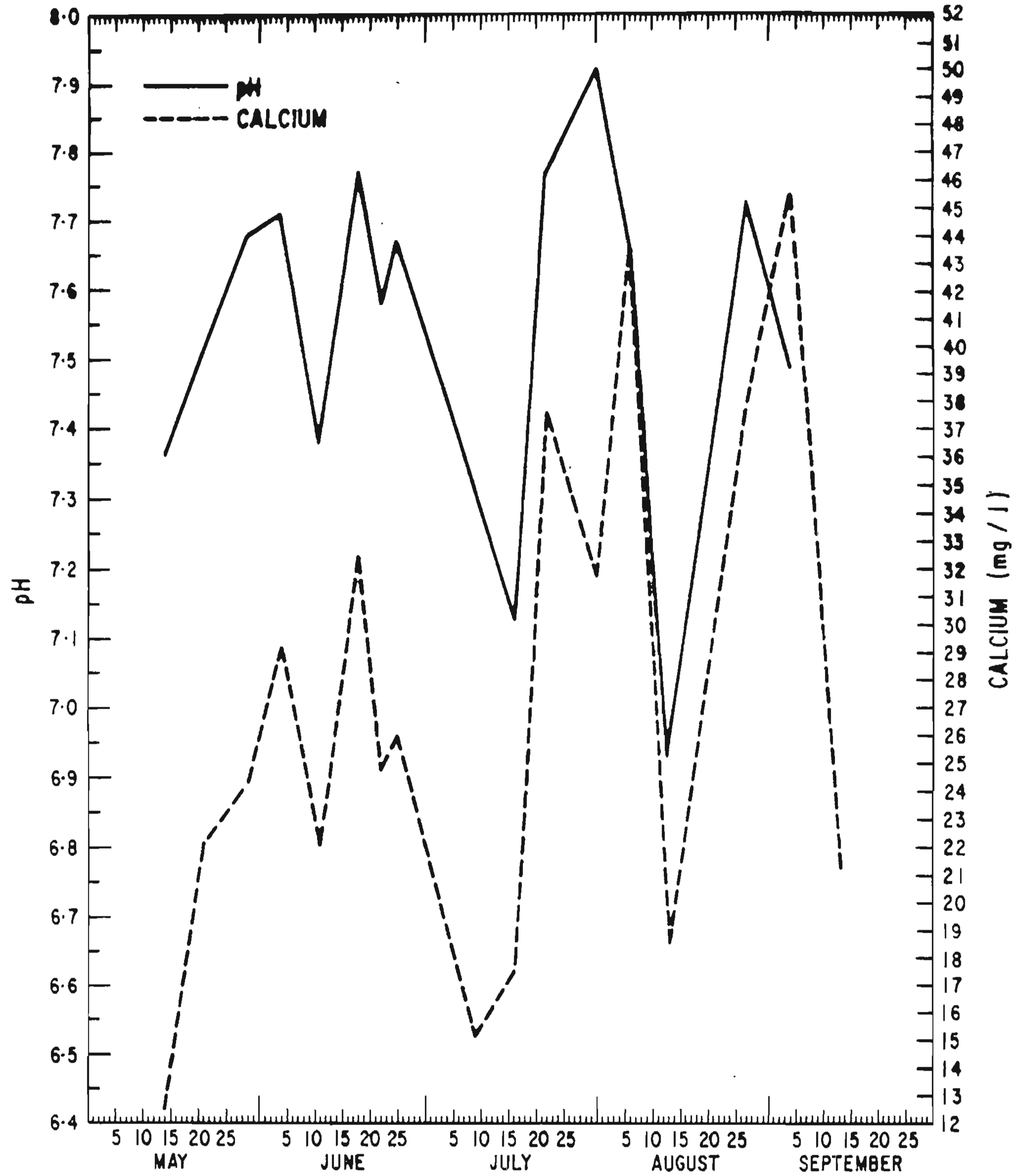

Fig. 6. Measurements of calcium and pH in water samples taken at the Railway Bridge station in 1981.

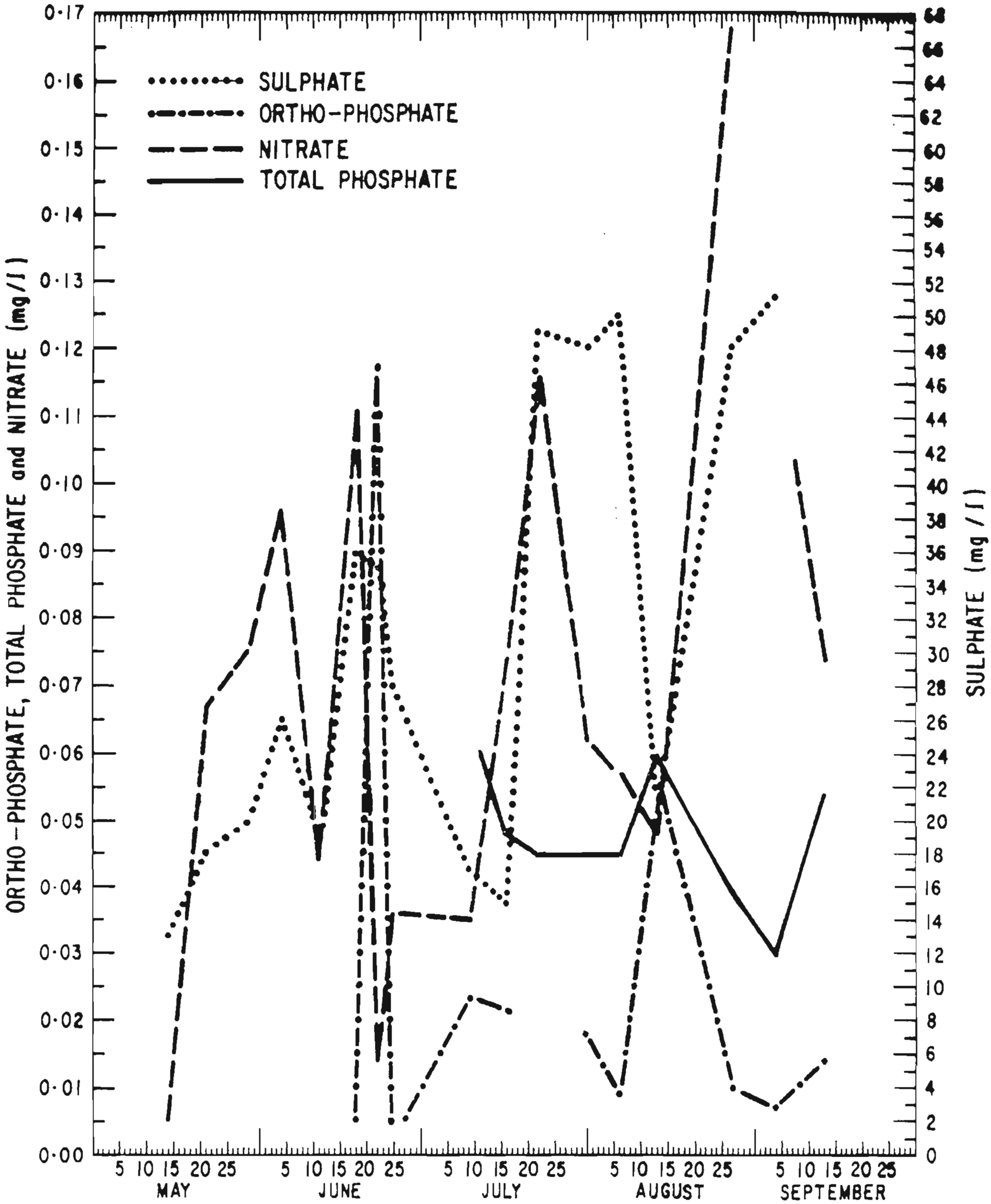

Fig. 7. Levels of sulphate, nitrate, ortho-phosphate, and total phosphate in water samples taken at the Railway Bridge station in 1981.

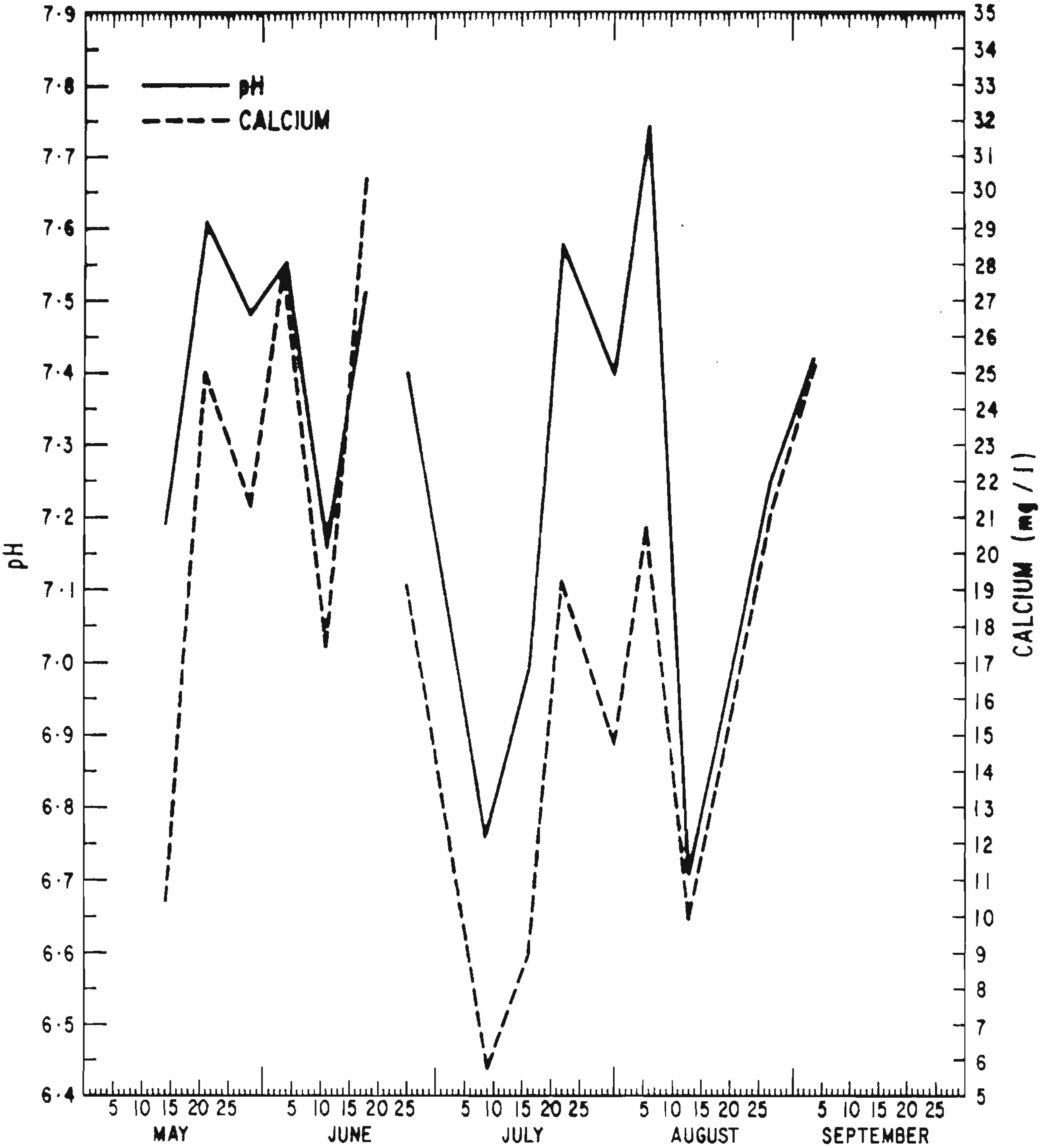

Fig. 8. Measurements of calcium and pH in 1981, taken in water samples up to June 18 in Highlands River at the confluence of Camp 40 brook (Abraham's Pool), and afterwards in River Brook at the TCH.

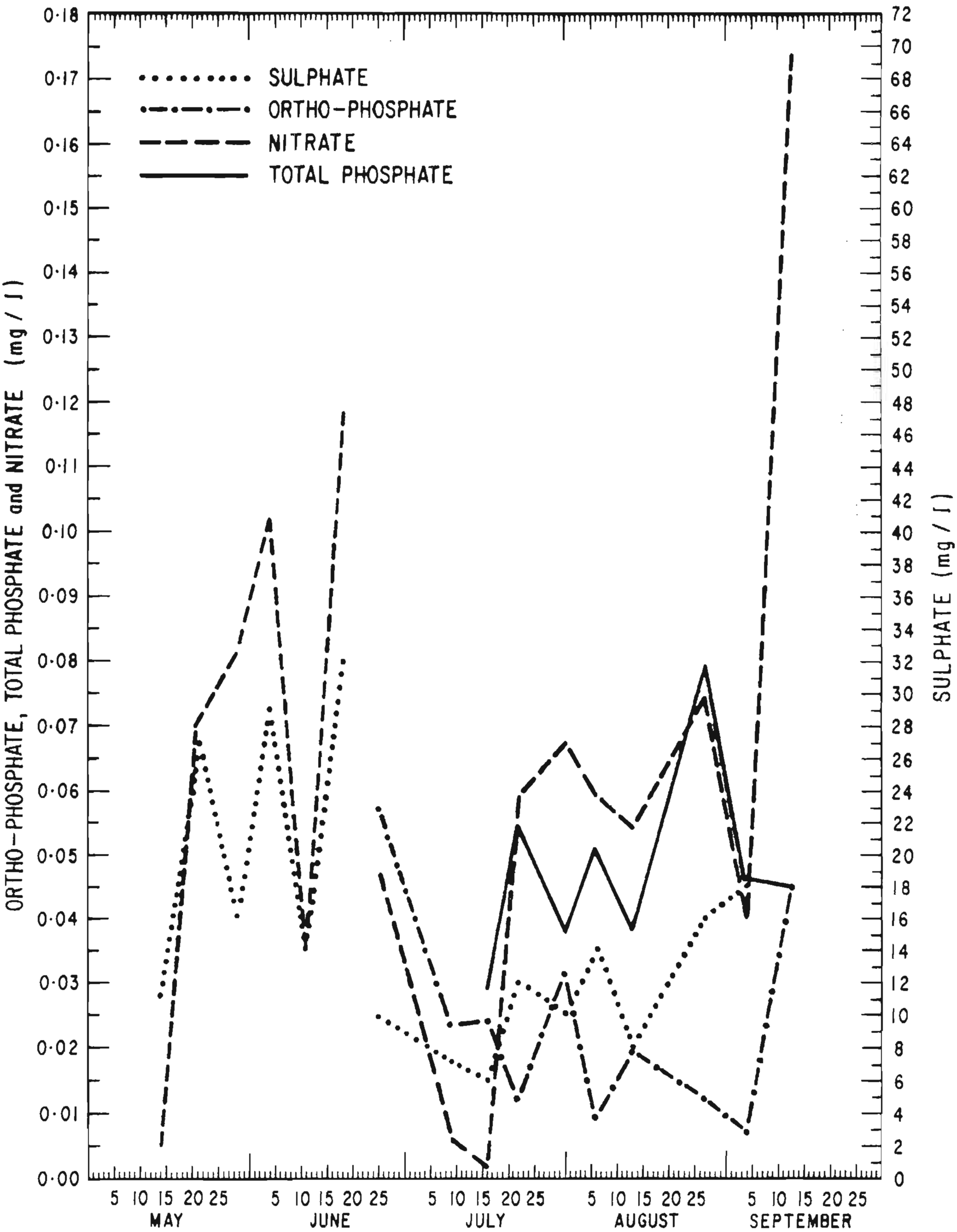

Fig. 9. Levels of sulphate, nitrate, ortho-phosphate, and total phosphate in water samples taken in 1981, up to June 18 in Highlands River at the confluence of Camp 40 brook (Abraham's Pool), and afterwards in River Brook at the TCH.

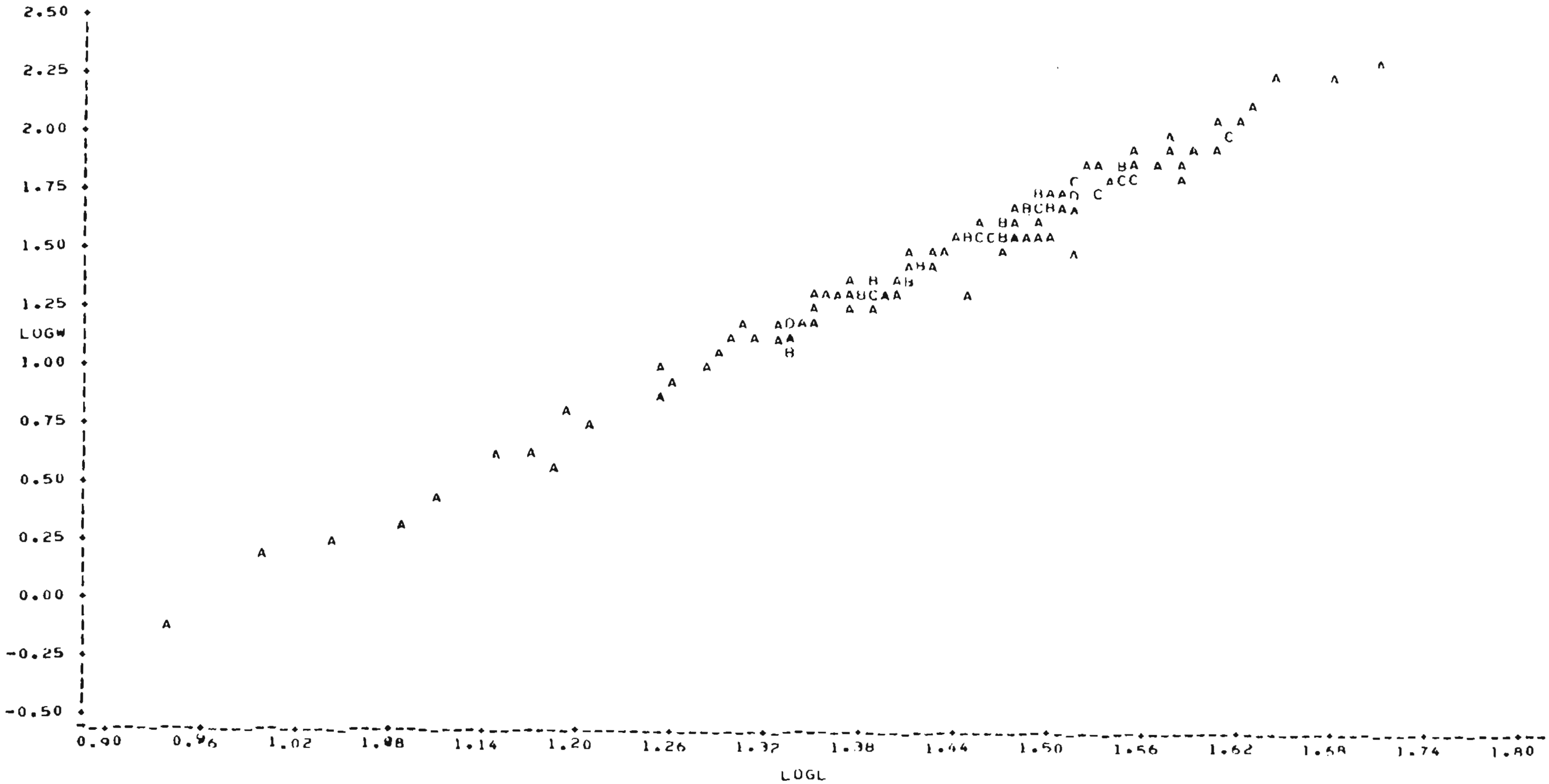

Fig. 10. The regression of log weight (g) versus log length (cm) of the eels sampled in the Spring of 1980 (Y = 3.1 x -3.0). A = 1 observation, B = 2 observations, etc.

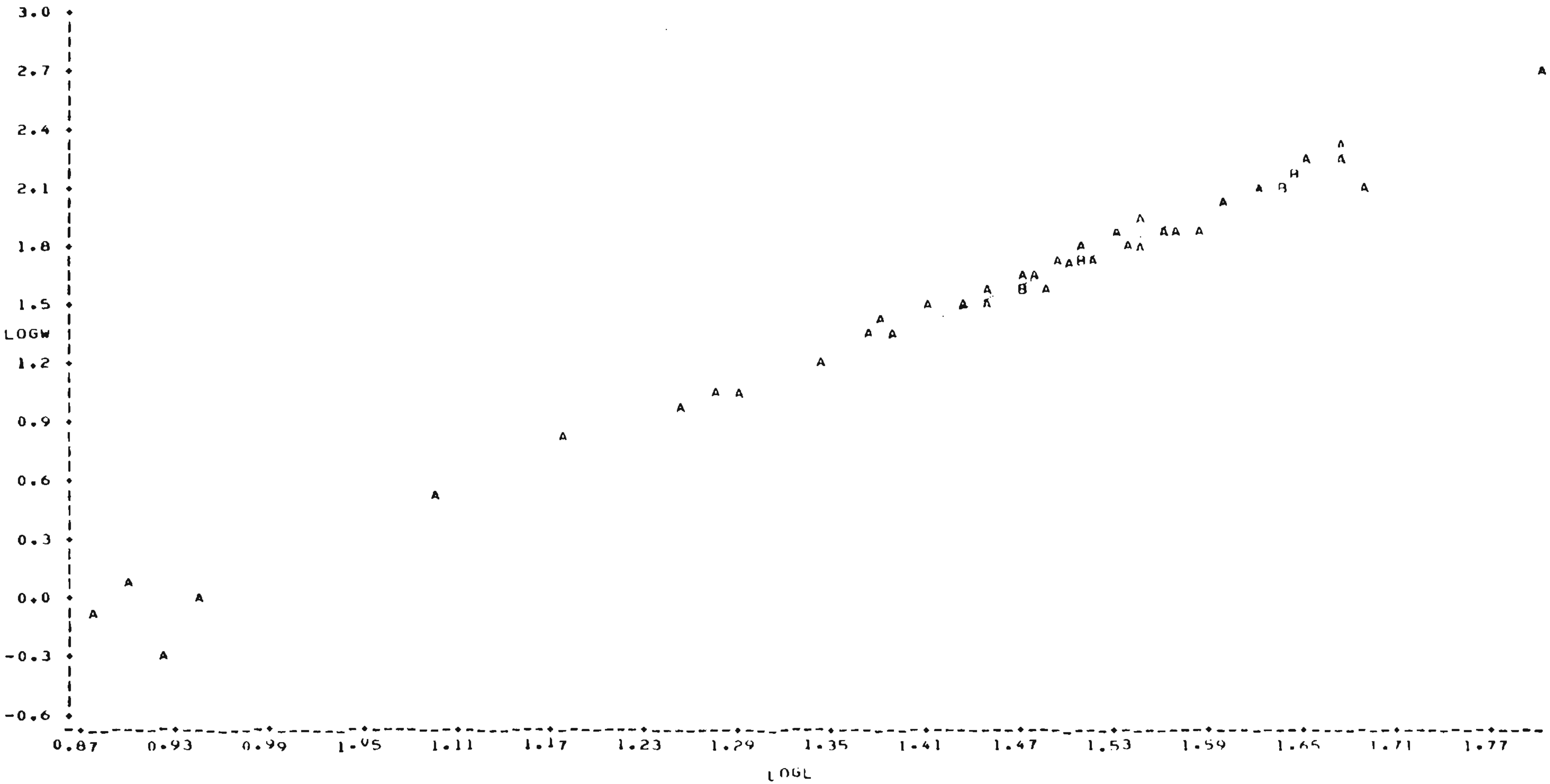

Fig. 11. The regression of log weight (g) and log length (cm) of the eels sampled in the Fall of 1980 (Y = 3.0X - 2.8). A = 1 observation, B = 2 observations.

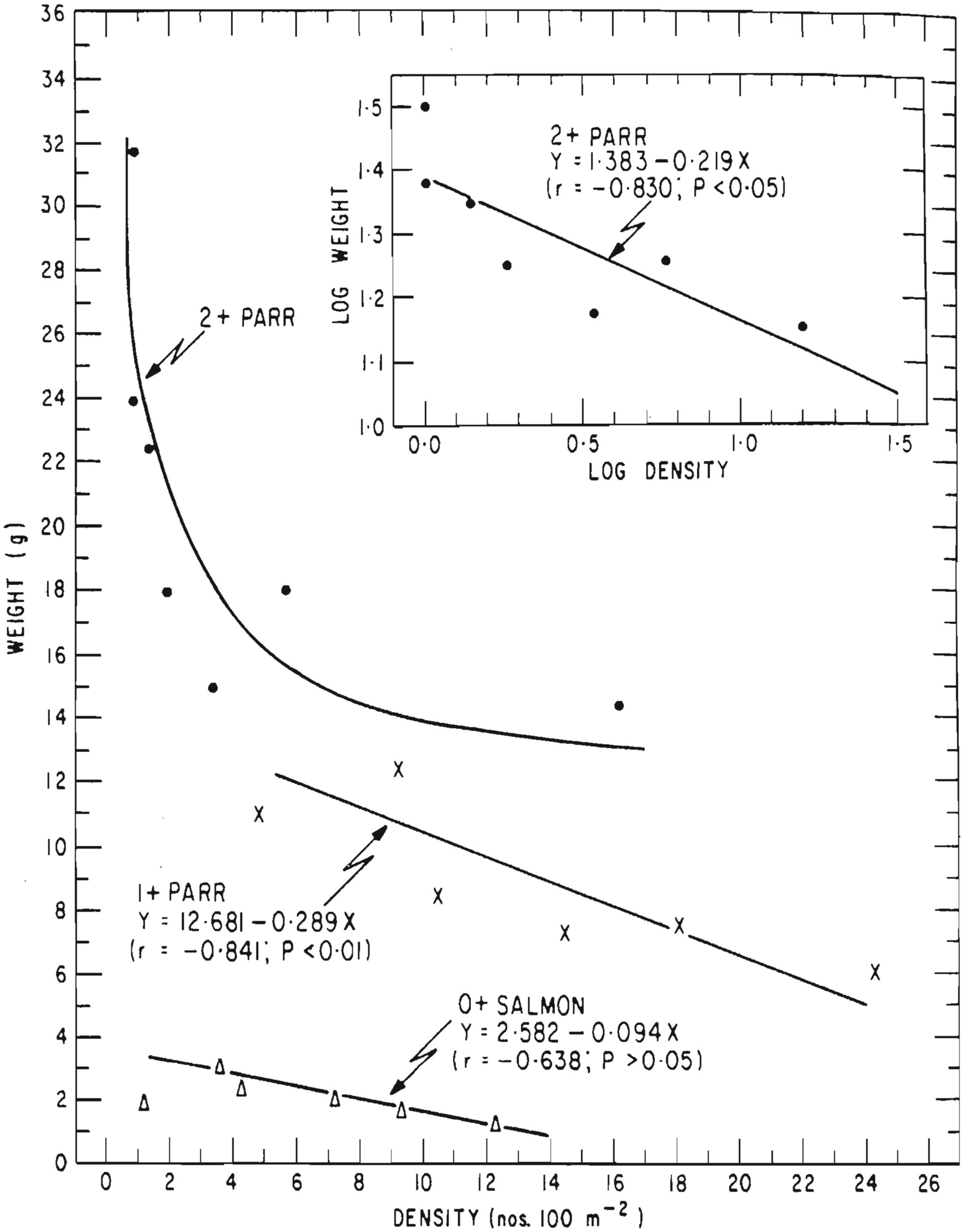

Fig. 12. Mean weights of the respective year-classes of juvenile salmon related to their densities at various sites, September 1980.

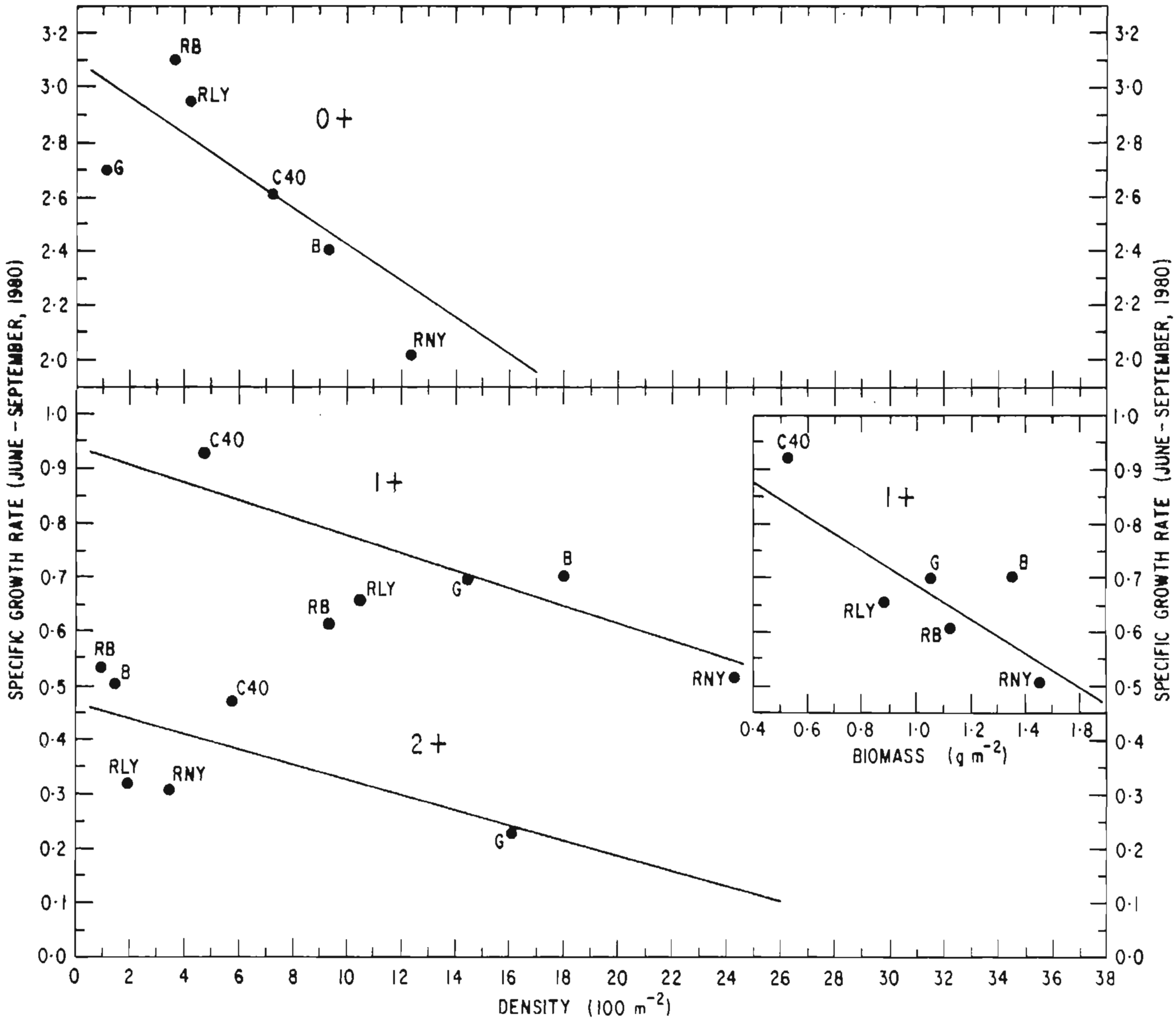

Fig. 13. Specific growth rates of salmon versus their density, 1980, for 0+ ($Y = 3.09 - 0.07X$; $r = -0.803$, $P > 0.05$); for 1+ ($Y = 0.88 - 0.01X$; $r = 0.72$; $P > 0.05$); and 2+ ($Y = 0.47 - 0.01X$; $r = -0.66$; $P > 0.05$); and versus biomass for 1+ ($Y = 1.04 - 0.34X$; $r = -0.84$; $P < 0.05$). RB = River Brook lower; B = Bald Mountain brook; RNY = Rainy Brook; C40 = Camp 40 brook; RLY = Railway Bridge; G = Gillam's Farm.

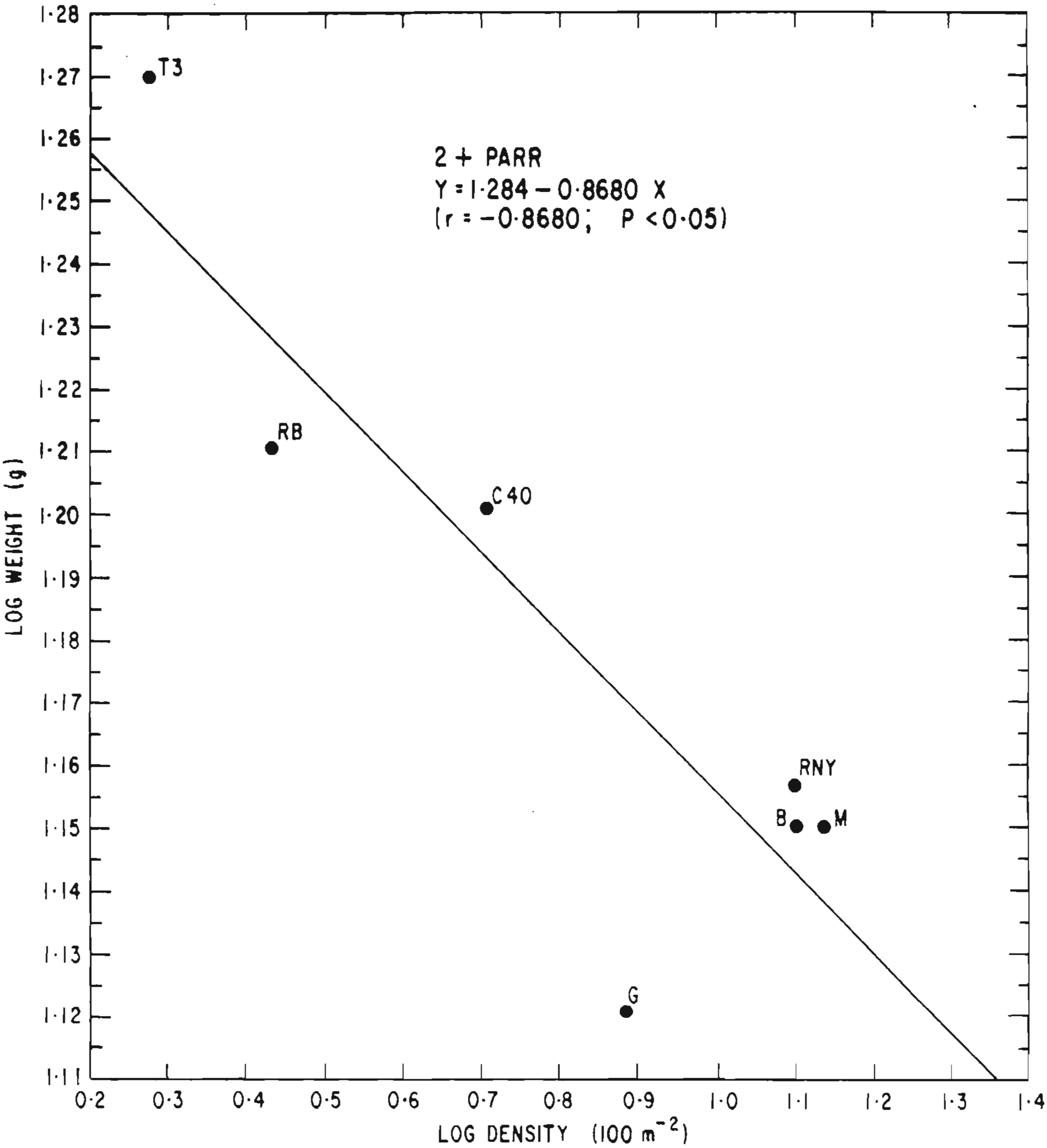

Fig. 14. Log weight versus log density of 2+ parr in 1981, with pool locations and the Railway Bridge omitted. T3 = River Brook upper; RB = River Brook lower; B = Bald Mountain Brook; RNY = Rainy Brook; M = Main Rainy Brook riffle; C40 = Camp 40 brook; G = Gillam's Farm.

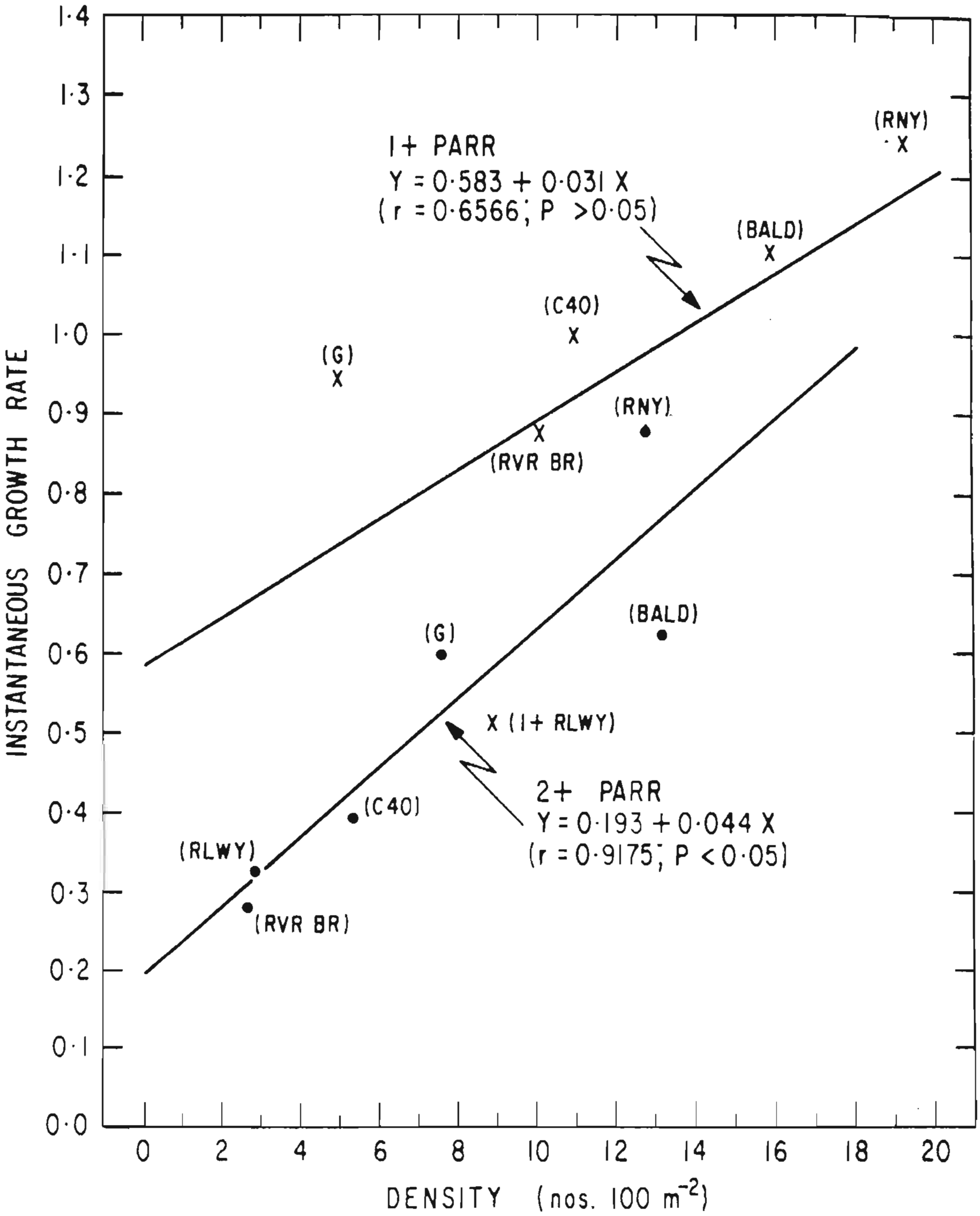

Fig. 15. Instantaneous growth rates of parr versus their densities, 1981. RVR BR = River Brook lower; BALD = Bald Mountain Brook; RNY = Rainy Brook; C40 = Camp 40 brook; RLWY = Railway Bridge; G = Gillam's Farm.

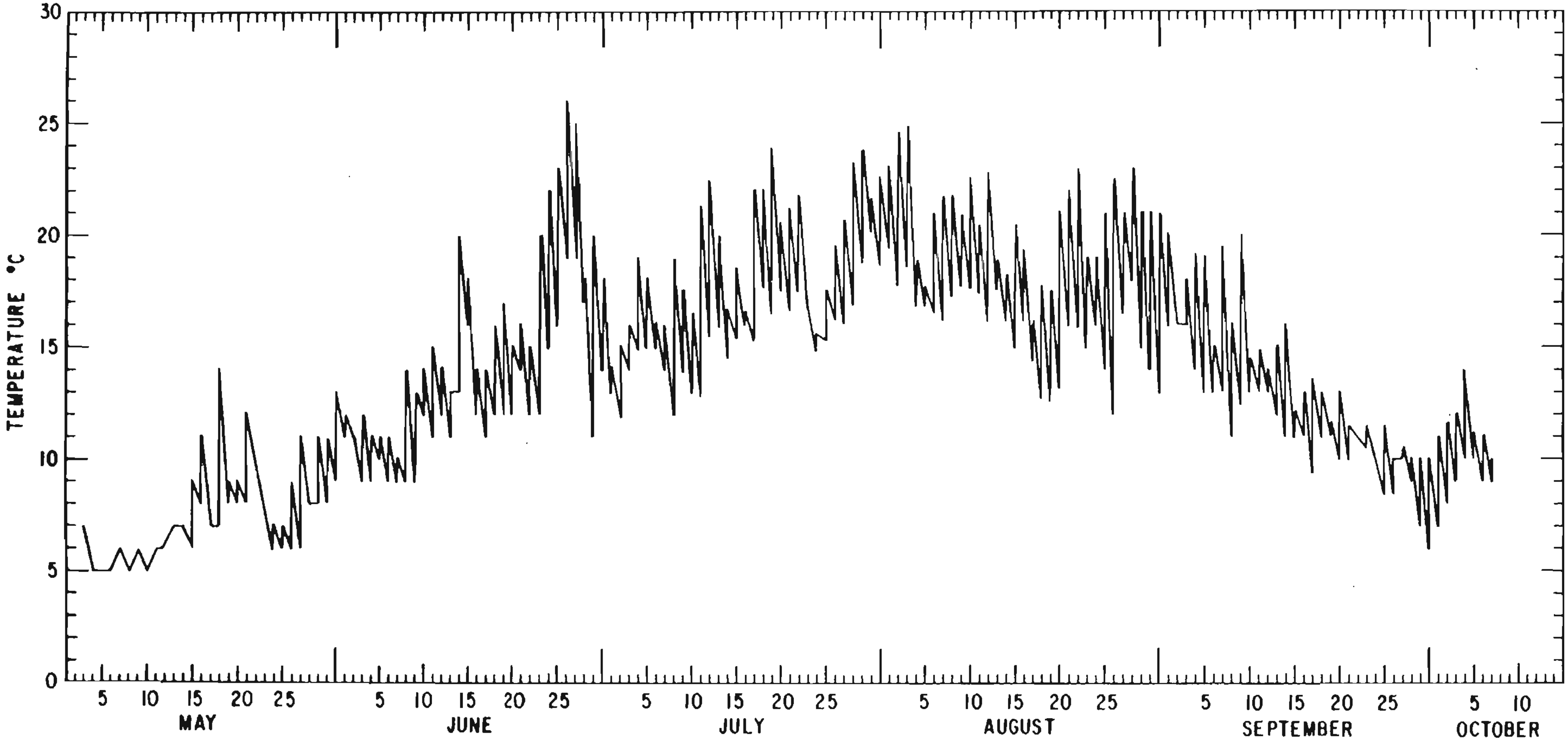

Fig. 16. Water temperatures for the Highlands River recorded at the counting fence in 1980.

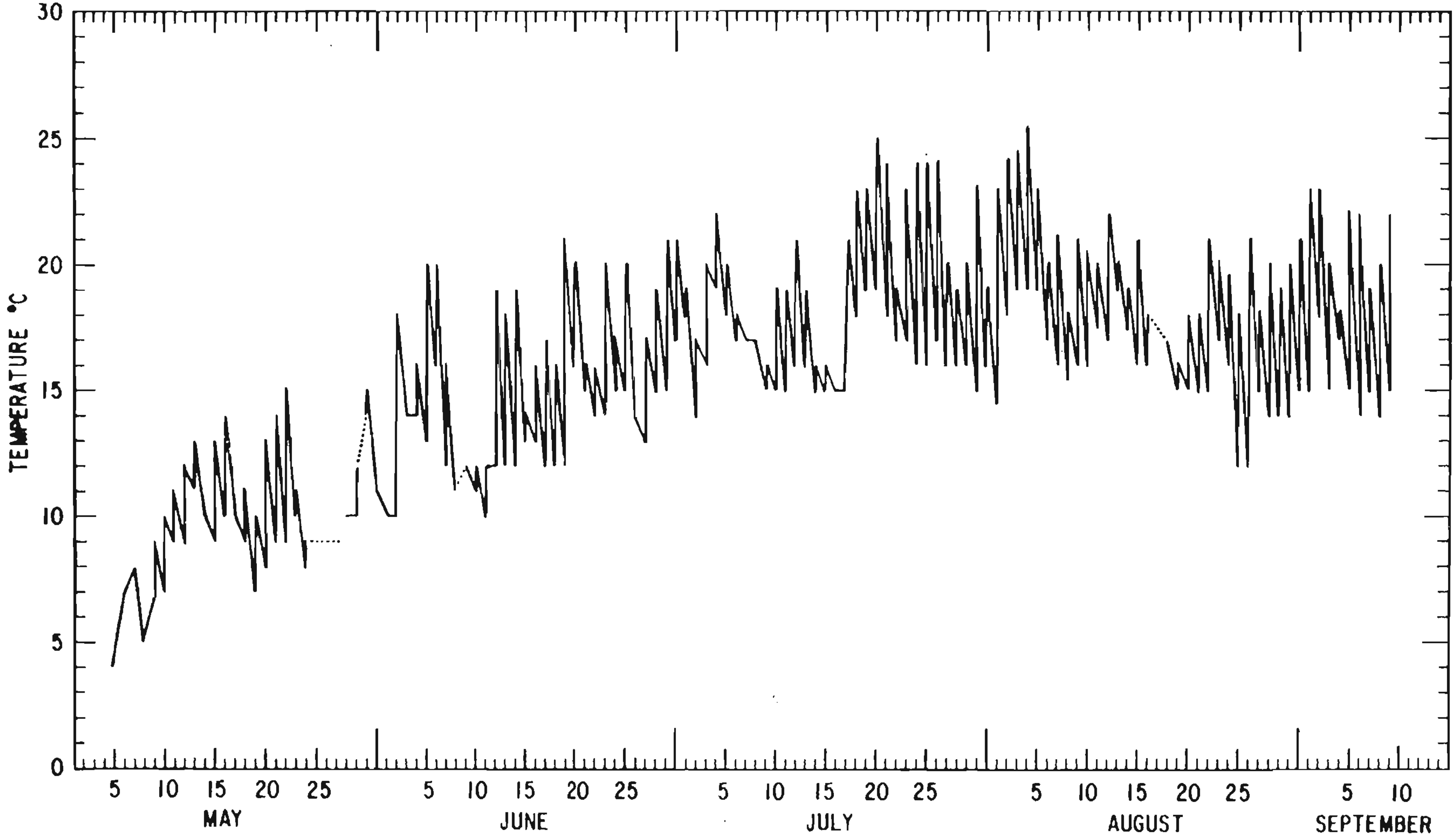

Fig. 17. Water temperatures for the Highlands River recorded at the counting fence in 1981.

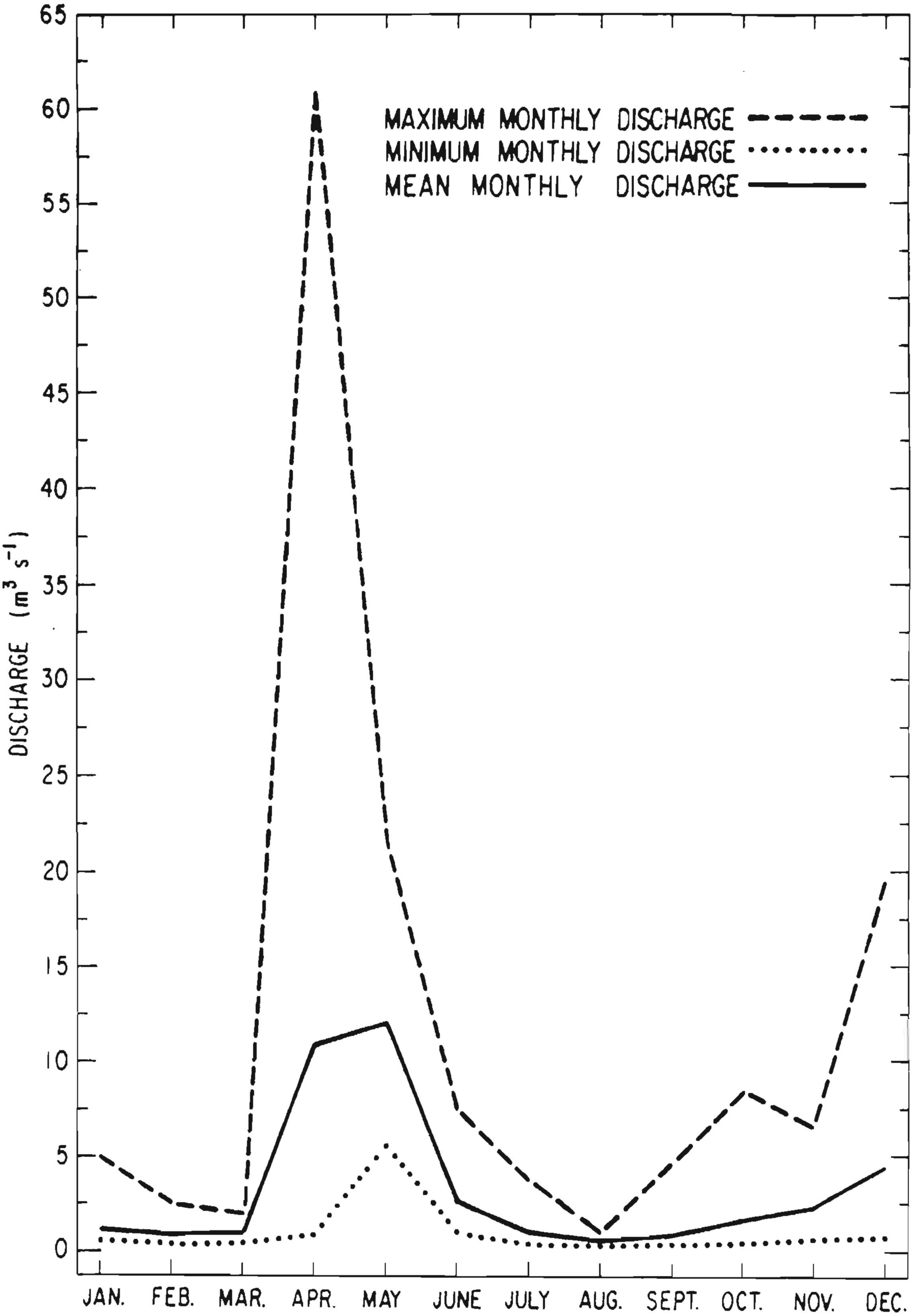

Fig. 18. River discharges recorded at River Brook (TCH) in 1982.

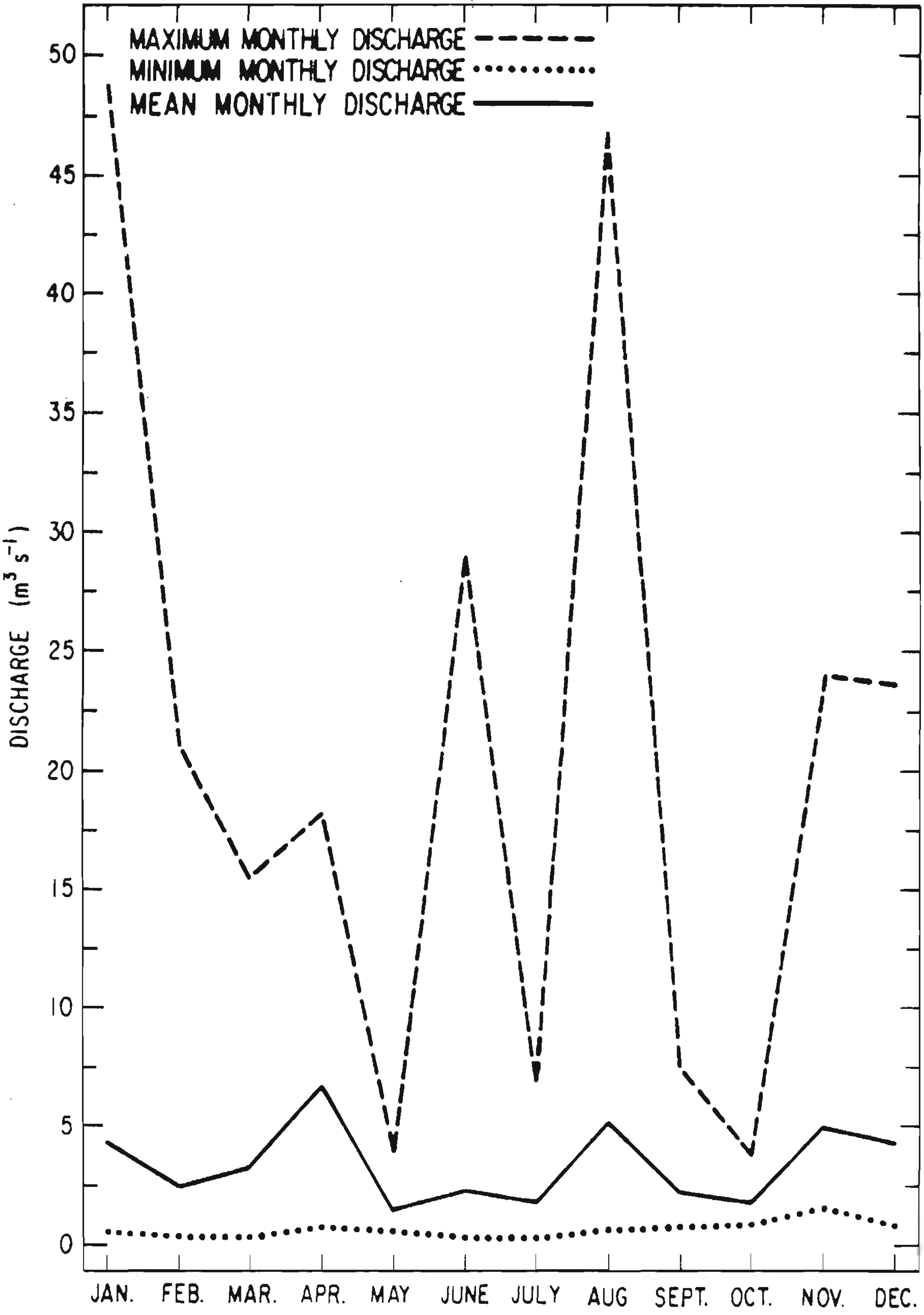

Fig. 19. River discharges recorded at River Brook (TCH) in 1983.

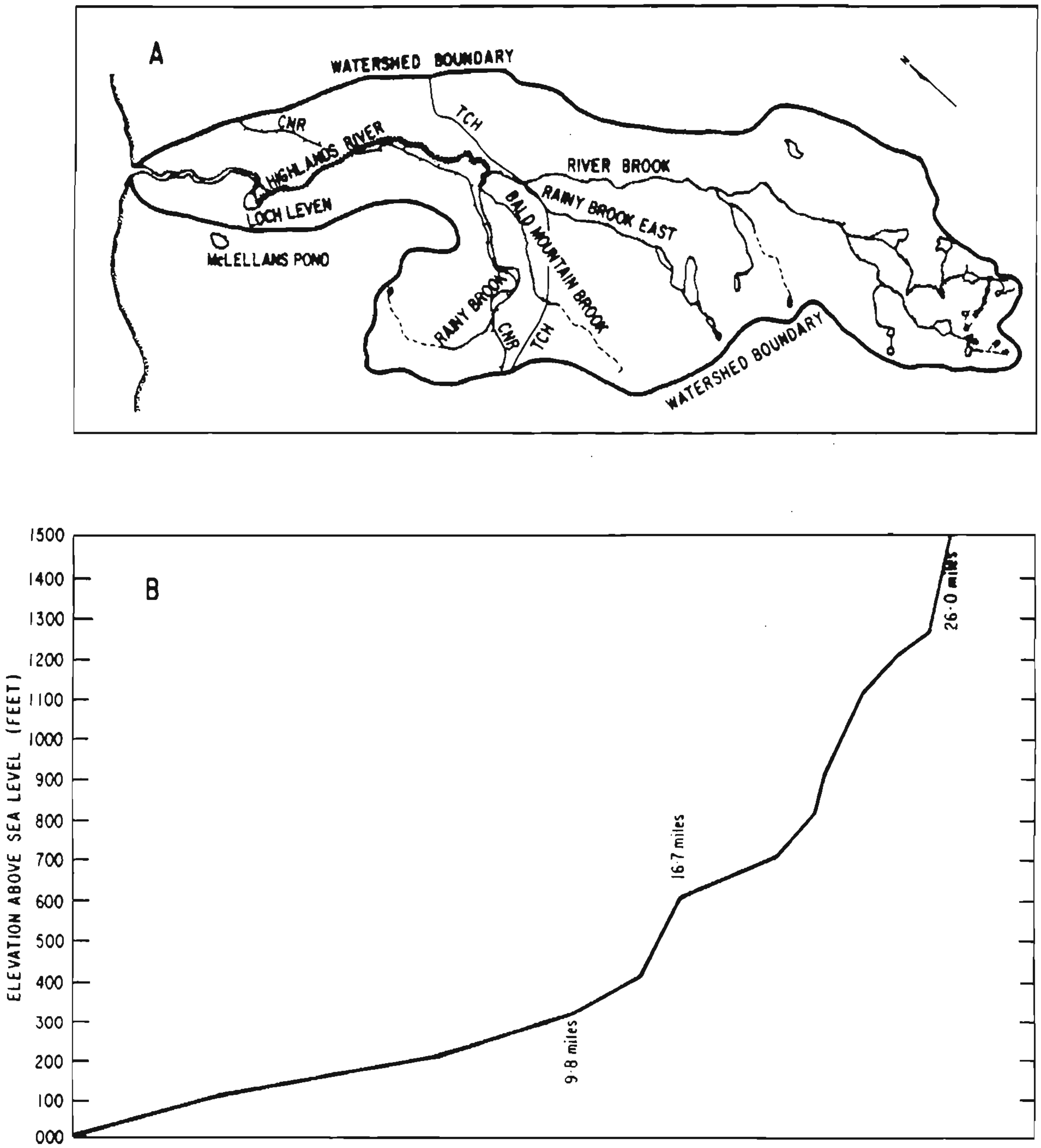

Fig. 20. The drainage basin of the Highlands River (A) and the gradient taken down the main stem (B). Taken from an original plan and profile by D. K. McComb on a 1:50,000 scale.