An Investigation of Competitive Interactions Between Brown Trout *(Salmo trutta* L.) and Juvenile Atlantic Salmon *(Salmo salar* L.) in Rivers of the Avalon Peninsula, Newfoundland

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AN INVESTIGATION OF COMPETITIVE INTERACTIONS BETWEEN BROWN TROUT (*SALMO TRUTTA* L.) AND JUVENILE ATLANTIC SALMON (*SALMO SALAR* L.) IN RIVERS OF THE AVALON PENINSULA, NEWFOUNDLAND

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Underwater observations were made at four sites in three rivers on the Avalon Peninsula, Newfoundland, three with both brown trout (Salmo trutta) and juvenile salmon (Salmo salar) present, and one with only brown trout. The two species were generally spatially segregated, with brown trout older than 0+ occurring in deeper slower water than salmon, although overhanging cover was a substitute for depth. The most obvious segregation of the two species was in the largest river, the Salmonier, where differences in habitat were greater than at other stations and abundance of food appeared least. The salmon:trout ratio was 45:1 in the riffle, and 1:3.2 in the pool. Holding stations between species with regard to depth and water velocity were significantly different ($P < 0.01$). There was considerable overlap of habitat distribution where the two species coexisted in the smaller stream investigated, the North Arm River. At an upstream station the ratio of salmon:brown trout was 5.7:1 in a riffle and flat, and 1.1:1 in a pool. There were no significant differences in preferences of depth and velocity ($P > 0.05$). At a downstream station the salmon:brown trout ratio was 4.3:1 in the riffle, and 3.6:1 in the pool. There was a significant difference in water velocity preference ($P < 0.05$), although not in depth ($P > 0.05$). There was considerable change in numbers of fish seen through the season, with least numbers seen during cold temperatures and high water in the early spring and late fall. Differences were found in feeding by the two species, with considerable overlap in diets. With fish older than 0+, salmon preyed more on ephemeropteran nymphs and simuliid larvae than did brown trout, which preyed more on terrestrial invertebrates in the surface drift than did salmon. The two species apparently are ecologically compatible and competition appears to be minimized by habitat segregation related mainly to water velocity and depth. Within the limitations of this study we found no evidence of negative effects of brown trout on juvenile salmon. It is suggested further extension of the range of brown trout in Newfoundland is limited by a combination of inter-specific interactions, habitat, and climate.

RÉSUMÉ

Gibson, R. J., and R. A. Cunjak. 1986. An investigation of competitive interactions between brown trout (Salmo trutta L.) and juvenile Atlantic salmon (Salmo salar L.) in rivers of the Avalon Peninsula, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 1472: iv + 82 p.

Des observations sous-marines ont été réalisées en quatre sites de trois cours d'eau de la presqu'île Avalon (Terre-Neuve). Des truites brunes (Salmo trutta) et des saumons de l'Atlantique juvéniles (Salmo salar) étaient présents à trois de ces sites, le quatrième n'abritant que des truites brunes. Les deux espèces étaient généralement spatialement isolées. Les truites brunes de plus de 0+ an se rencontraient généralement dans des eaux à écoulement plus lent et plus profondes que les saumons, mais la profondeur pouvait être remplacée par un couvert en surplomb. La ségrégation la plus apparente a été notée dans le plus important cours d'eau, la rivière Salmonier, où les différences d'habitat étaient plus marquées qu'aux autres endroits et où l'abondance de la nourriture semblait être la moindre. Le rapport d'abondance saumons-truites était de 45:1 dans le haut-fond et de 1:3,2 dans la fosse. Les zones d'attente utilisées par les deux espèces différaient de façon significative ($P < 0,01$) quant à la profondeur et à la vitesse d'écoulement des eaux. Dans le plus petit des cours d'eau étudiés, la rivière North Arm, il y avait un important recoupement de la distribution des habitats aux endroits où les deux espèces cohabitaient. A l'une des stations d'amont, le rapport saumons:truites brunes était de 5,7:1 dans un haut-fond et une zone surélevée et de 1,1:1 dans une fosse. Il n'y avait aucun écart significatif quant à la vitesse d'écoulement préférée et à la profondeur ($P > 0.05$). A l'une des stations en aval, le rapport saumons:truites brunes était de 4,3:1 dans un haut-fond et une zone surélevée et de 3,6:1 dans une fosse. Il y avait un écart significatif quant à la vitesse d'écoulement préférée ($P < 0,05$), mais non quant à la profondeur ($P > 0,05$). Le nombre de poissons noté au cours de la saison a varié de façon considérable; les poissons étaient les moins nombreaux au cours des périodes de température froide et de niveau d'eau élevé du début du printemps et de la fin de l'automne. Les deux espèces se nourrissaient de façon différente, mais il y avait un important recoupement des diètes. Chez les poissons de plus de 0+, les poissons de plus de 0+, les saumons se nourrissaient plus de nymphes d'éphéméroptères et de larves de simuliidés tandis que les truites brunes ingéraient plus d'invertébrés terrestres transportés par la dérive de surface. Les deux espèces semblent être écologiquement compatibles, la compétition étant minimisée par une ségrégation des habitats portant surtout sur la vitesse d'écoulement et la profondeur des eaux. Les auteurs n'ont noté, dans la cadre de leur étude, aucun indice d'effets nuisibles de la truite brune pour les saumons juvéniles et émettent l'hypothèse que l'accroissement de l'aire de répartition de la truite brune à Terre-Neuve est limitée par les effets combinés des interactions interspécifiques, de l'habitat et du climat.

INTRODUCTION

Brown trout (*Salmo trutta* L.) were first imported into Newfoundland from Scotland in 1886, with further importations from Germany and England in 1892 and in 1905 or 1906 (Andrews 1965). They have spread from the original plantings in ponds in the St. John's area, and at present are widely distributed on the Avalon Peninsula and around the adjacent bays (Scott and Crossman 1964; Andrews 1965). Many rivers of the Avalon Peninsula which support anadromous salmon (*Salmo salar* L.) now also have brown trout populations. Salmon have disappeared from some rivers on the Avalon Peninsula where brown trout persist, especially in the vicinity of St. John's. Also the brown trout, in present years, appears to be extending its range (O'Connell 1982). It is generally thought that brown trout are more aggressive than juvenile salmon and have the competitive advantage over salmon (Lindroth 1955; Kalleberg 1958; Le Cren 1965). If this is so, in Newfoundland the consequences on the future abundance of salmon stocks could be serious. However, few studies have been made on interactions between the two species, and none in North America. In North America, physical conditions and species compositions are different than in Europe, where the two species naturally coexist.

The present study was undertaken to investigate possible competitive interactions between brown trout and juvenile salmon, and if ecologically compatible to examine how the resource might be shared by the two species.

MATERIALS AND METHODS

Studies were made in three rivers, the Salmonier, the North Arm, and Broad Cove Brook (Fig. 1). Their locations and drainage areas are as follows (Porter et al. 1974):

- Salmonier River. Location: 47°10'40"N, 53°24'15"W (Salmonier, St. Mary's Bay); Basin area, 256.92 km^2.

- North Arm River. Location: 47°23'37"N, 53°09'30"W (Holyrood, Conception Bay); Basin area, 85.98 km^2.

- Broad Cove Brook. Location: 47°35'32"N, 52°53'10"W (Conception Bay); Basin area, 16.83 km^2.

Underwater observations were made using a 'wet suit', weights, mask, snorkel, and fins. Sometimes in shallow fast water fins were not used. A study area was approached from downstream. After carefully entering the water a slow approach was made upstream into the study area, and by looking ahead, the locations of fish were noted. This method of observing salmonids in shallow water has been used successfully in other studies (e.g. Keenleyside 1962a; Gibson 1966, 1973; Griffith 1980; Cunjak and Green 1983). Observations were made by placing colored stones in the exact location where a fish had been seen. These were carried in a plastic bag. A different color was used for each species. At the same time notes were made on a slate as to size of the fish and its height above the substrate.

The locations of fish could be observed over a wide area, for a distance of about 3 m, so the initial locations could be noted. A disturbed fish would usually retreat downstream and since the observer moved upstream the numbers seen were probably close to the numbers present. Water depth was measured at each fish's location. Water velocity was measured with a Gurley meter at approximately the depth the fish was seen, and type of substrate was noted. Types of habitat were defined according to Allen's method (Allen 1951). Water temperature, changes in water level, and weather were recorded. Some water chemistry measurements were made: pH, conductivity (measured with Hermes Electronics meters); and water hardness (measured with a Hach hardness kit).

Fish collections were made close to the study areas, but not adjacent to them. Usually a Dirigo 600B electrofisher (120 Hz, 100 V, with 12 V motorcycle battery) was used, but on two occasions the collections were supplemented by angling with small flies. Fish were immediately put into 10% formalin, and processed within 24 hours. Each fish was identified to species, fork length and weight measured, a scale sample for age estimate taken from between the dorsal fin and lateral line, gonads inspected for sex and as to whether the fish would spawn that fall, and the stomach removed between the oesophagus and pylorus. Significant differences related to fish collections and to holding stations of the two species were tested with the analysis of variance and the differences between means tested with the least significant difference test (Snedecor and Cochran 1967). The stomachs were analyzed for amount of fullness by Hynes' (1950) method, whereby an empty stomach would count for 0 points, a full stomach for 20 points, and a distended stomach up to 30 points. The food was identified if possible to family and grouped by percentage composition and by numbers of animals. The samples were taken in May, June, July, and October, 1979, with a further sample from the upstream station at North Arm River in June, 1981.

An index of diet overlap (α) for brown trout and Atlantic salmon for each of the four main prey groups (categories) was calculated using the equation developed by Schoener (1970) and utilizing the 'mean of the volume percentage' diet measure as suggested by Wallace (1981):

$$\alpha = 1 - 0.5 \left(\sum_{i=1}^{n} \left| P_{xi} - P_{yi} \right| \right)$$

where,
n = number of prey categories,
P_{xi} = proportion of prey category i in the diet of species x,
P_{yi} = proportion of prey category i in the diet of species y.

Zaret and Rand (1971) suggest that α values > 0.60 are assumed to indicate a significant dietary overlap.

Kick samples (Frost et al. 1971) were taken in May, June, July, and October, 1979. A triangular shaped net was used, with a bottom width of 48 cm and sides of length 48 cm. The netting was Nitex of pore size 308μ. Two kick samples were taken on a riffle area at each site, and six kicks were made for each sample. The sample was immediately preserved in 70% ethanol, the invertebrates later sorted and classified to order, with insects to family, and the displacement volumes determined for each invertebrate taxon in a sample.

An index of food selectivity was calculated using the Linear Food Selection Index (L) proposed by Strauss (1979) which is a modification of the Electivity Index (Ivlev 1961) and defined as:

$$L = r_i - p_i$$

where,
r_i = the percentage (by number of organisms from food category i in the diet,
p_i = the percentage (by number) or organisms from food category i in the fauna.
Values for this index range from -1 to +1 with positive values indicating preference and negative values indicating avoidance or inaccessibility. The expected value of this index for random feeding is 0.

STUDY SITES

SALMONIER RIVER

The site was immediately downstream from the junction of Black River, at approximately 47°11'N and 53°22'W. A riffle area was chosen on the right side of the river (looking downstream), to the right of an island dividing the stream. Initially, the riffle study area was 30.5 m long and 12.1-9.3 m wide (326 m^2). However, the upper part became too shallow for observations, so for the 20 June observations, and those following, the length was reduced to 14.1 m, giving an area of 150 m^2. The substrate was predominantly cobble. The banks were open with no cover and sloped from shallow water with low flow to depths (on 20 June) of 70 cm and highest mid-depth water velocities of 60 cm/s. On 24 May, in the main flow, the water velocity was 121 cm/s. The discharge of this portion of the river on 20 June was 1.5 m^3/s.

A second study area was located where the two riffle sections either side of the island joined to form a long flat section upstream from another island with riffles on either side. Only a section of this was used as a pool study area. This was a deep slow area by the left bank, which inclined steeply into the river, and was shaded by tall trees. A fallen tree at the upper end of this area, and another at the downstream end provided good submerged cover. Mud and sand formed the substrate next to the steep bank, with a cobble substrate towards the main flow. The length of this study area was 19.2 m, and the width of the river here was 23.8 m. However, the width chosen for study was 3.7 m, which extended the length of the submerged trees, so that it was possible to move in a straight line through the pool and see clearly across the area. The area of the pool section was therefore about 70 m^2. On 20 June the deepest part, in the center, was 86 cm. Depths at the upstream end were 78 cm towards midstream to 85 cm close to the bank. At the downstream end, depths were from 68-76 cm. Water velocities were about 17 cm/s towards mid-stream to about 14 cm/s towards the bank. Pockets of negligible flow occurred next to the bank. Discharge of the river on 20 June was 2.2 m^3/s.

NORTH ARM RIVER, DOWNSTREAM AREA

This station was on the eastern branch of the North Arm River, just west of where it is crossed by Route 6, at approximately 47°22'N and 53°11'W.

The original site chosen was unsuitable as it became too shallow, although one observation was made at this location. It had an upper riffle and lower pool, the former 5.5 m long with an area of 29 m^2, and the pool, 6.5 m long with an area of 50.7 m^2. The upper end of this study area was 5.3 m wide, and the lower end, 7.8 m wide. The substrate was of gravel, cobble, and boulder. On 29 May, the deepest part was 45 cm, and water velocity in the main flow of the pool area (depth 24-40 cm) about 38 cm/s. In the main flow of the riffle (20-25 cm), the water velocity was about 46 cm/s. All the remaining observations were made in the riffle and pool section immediately downstream. The total length of this area was 21 m. The riffle section was 10 m long, 9 m wide at the upstream end and 13 m wide at its downstream end. Substrate was of gravel, cobble, and rubble. On 12 June, average depth at the upstream end was 20 cm, and water velocity in mid-stream 37 cm/s. Depth at the downstream end of the riffle section averaged 26 cm, and water velocity averaged 13 cm/s. The pool was 11 m long and 13 m wide. Substrate was of cobble and rubble. There were two boulders at the downstream end in the deepest part of the pool (55 cm on 12 June). Average depth at the upstream end on 12 June was 39 cm, and average water velocity 5.6 cm/s, with 11.3 cm/s in the fastest flow. At the downstream end, mean depth was 42 cm and water velocity 4.7 cm/s. Discharge of the river on 12 June was about 0.2 m^3/s. Alder bushes along the left bank of both riffle and pool allowed some shade cover close to the bank, but otherwise overhanging shade was absent.

NORTH ARM RIVER, UPSTREAM AREA

This study area, in the upper reaches of the eastern branch of North Arm River, which drains Louis Pond, was located just north of the Trans Canada Highway, at approximately 47°21'N and 53°11'W.

The station chosen had an upper riffle, a lower flat, and a pool between the two. The pool was 5.4 m long, the riffle 5.6 m long, and the flat 4 m long. The total length of the study area was therefore 15 m. Width of the riffle was 4.5 m at the upstream end to 3.5 m at the downstream end. This widened to 6 m across at the deepest part of the pool and 7 m at the lower part of the study area. The riffle and flat areas had a cobble substrate. The pool had a rock and cobble substrate. On 11 June, the riffle had a mean depth of 16.7 cm at the upstream end, and a water velocity in the main current of 63 cm/s. The downstream part of this riffle was 45 cm deep in the centre, with mean depth of about 34 cm.

The pool had a rock outcrop with a steep wall forming the left side, with a depth at the edge of 59 cm. In the centre, at the deepest part, the depth was 63 cm. The depth a quarter of the width from the right bank was 24 cm. In the main flow, water velocity was 27.4 cm/s.

In the lower flat section, mean depth was 24 cm, and water velocity in the main flow was 17.4 cm/s. The whole study area was 85 m^2, and discharge on 11 June about 0.2 m^3/s. There was no overhanging cover.

BROAD COVE BROOK

The study areas on this stream were near St. Phillips, and were located at approximately 47°34'N, 52°52'W. The study areas were a short distance upstream from the 'benthobservatory' belonging to the Memorial University of Newfoundland.

The study areas consisted of a pool and an adjacent riffle and flats area upstream. The area of the pool was 29 m^2. Total length was 6.8 m. The upper part was 5.2 m wide. Above this, rocks centrally divided the stream. A gravel bank on the left side reduced the width at the downstream end to 3.8 m. Rocks, cobble and gravel formed the substrate. On 13 June, near the upper end of the pool, mean depth was 25 cm and water velocity in mid-stream was 18.3 cm/s. At the downstream end, mean depth was 47.7 cm, and mean water velocity was 5.3 cm/s. This varied from 0 near the left bank to 10 cm/s in the main flow. The deepest part was 61 cm. The pool had been artificially deepened somewhat by a dam of rocks at the downstream end.

The original riffle section was immediately upstream from the pool, but observations were made here only once, on May 31. After this the section became too shallow for observations. It had an area of 13.6 m^2. It was 1.7 m wide at the upstream end, 3.6 m wide at the downstream end, and was 5.0 m long. Deepest parts were 22-25 cm.

A shallow 'flat' area immediately upstream was used for all other observations instead of the riffle. This 'flat' had an area of 17.2 m^2, with length of 4.1 m, and width 4.2 m. Substrate was cobble and rock. On 13 June mean depth was 23 cm and mean water velocity 19.4 cm/s. The deepest part was 37 cm and water velocity here was 9.1 cm/s. Discharge of the stream was about 0.15 m^3/s. There was no overhanging cover.

Characteristics of these study areas are summarized in Table 1.

EXPERIMENTAL AREAS

Three experimental sections were chosen on the North Arm River, in which the fish inhabiting the sections were removed, and known numbers of salmon parr and brown trout were introduced. The experiment was not successful as some of the smaller fish escaped, and in a replicate experiment with marked fish high water again allowed escapes. However relative numbers and biomass related to the habitat of the fish removed prior to the experiment are presented in this report, as these data are relevant to the study. The sections were between the upper and lower diving stations on the North Arm River and were 900 m downstream from the Trans Canada Highway. They were located on both sides of an island which divided the stream. At this location the stream flowed through a meadow and marsh land type of terrain. The three sections differed somewhat in types of habitat. A 'control' section was selected in the right hand stream (looking downstream). This had both riffle and pool types of habitat, with a depth of 45 cm in the centre of the pool. The substrate was of cobble, rubble, and boulder. Downstream of this a riffle-like section was selected. Depths along the section were similar, of about 30 cm. Water velocity in mid-stream at the upper end was 43.9 cm/s, and 15.8 cm/s downstream. The substrate was of rubble, cobble, and boulder. In the left hand stream a pool-like section was selected. In the center the deepest part was 63 cm, and the velocity 17 cm/s, but there was zero velocity towards the banks. The substrate was cobble in the main flow, with mud and detritus in the slow flow, also with some emergent vegetation and filamentous algae near the bank. Shrubs and stunted trees occurred along the banks of the sections but overhanging shade was lacking.

The three sections were screened off with 1.27 cm square wire mesh. The mesh screening was 0.9 m high, of which about 20 cm was bent to form a lip at the bottom. The downstream screens were installed first by quietly approaching from downstream. Fish, when frightened, usually retreat downstream in preference to upstream; it was thought fish might more likely be frightened from a section if the upstream screen were installed first than they would if the downstream screen were installed first. The upstream screens were quietly installed by carefully crossing the stream at that point. After securing the screen across the stream, stones, gravel and rocks were put on the lip. The screens were also supported downstream by rocks and sticks. Size measurements of these study areas were made in July and are presented in Table 20. Depths and water velocities were measured in mid-stream and at intervals of one-quarter of the width of the stream. Water velocities were taken at mid-depth (approximately 0.6 depth). These depths and velocity measurements were taken at the upstream end, at the center, and at the downstream end.

The sections were set up, the original fish removed, and the first additions made, between 19 and 24 July. Successive upstream and downstream sweeps were made by electro-shocker. Fish were caught in a dip net, placed in a plastic pail, and at the end of each sweep, put into a retainer net. Electro-shocking was continued until no fish were caught in the last two sweeps (an upstream one and a downstream one) All fish were measured alive after anaesthetization with carbon dioxide.

RESULTS

SALMONIER RIVER

Observations were made in the Salmonier River on six occasions, 24 May, 4 June, 20 June, 27 June, 10 August and 6 October. These are summarized in Table 2.

On the first occasion the colored stones method, of placing the stone exactly where a fish had been seen, was not used. Instead, observations were recorded on a slate, and the water depth and mean stream velocity (0.6 of the depth) recorded. For this reason, water velocities are not tabulated for 24 May. On that date the water velocities recorded in the riffle area were 121.0 cm/s in the main flow where three of the salmon were seen and 85.3 cm/s where three others were seen. The velocity in mid-water where a brown trout was seen was 80.5 cm/s. In the pool the water velocity at the mid-depth reading was 30.2 cm/s. These distributions and velocities are comparable to those recorded later, as the velocity of flow in a channel decreases towards the bottom and is nearly inversely proportional to the logarithm of the depth (Grover and Harrington 1943).

In the first two observations, on 24 May and 4 June, a longer length of the riffle area was covered (30.5 m) than in the later observations (14.1 m). For this reason relative numbers are recorded as an abundance index of numbers/100 m^2.

In the Salmonier study area, because the river was larger than the others, a complete transect of the river was not covered, so that observations mainly record numbers of salmon and trout relative to the habitat, and only approximately represent the population of the area. The underwater visibility was usually about 3 m, although when it was most turbid on the 10 August and 10 October observations, visibility was reduced to about 2 m. During the first two observations a small backwater with foam cover at the upstream end of the riffle area was included in the observations. Here on 24 May one brown trout was seen, in 50 cm, in a flow too slow to measure. On 4 June three brown trout were in this pool in an average water velocity of 18.2 cm/s ($s_{\bar{x}}$ = 5.49) and depth of 51.0 cm ($s_{\bar{x}}$ = 7.12). As can be seen by Table 2, there was an obvious segregation of salmon parr and brown trout in these observations. In the fast shallow water of the riffle area, a total of 45 salmon were seen, but only one brown trout, whereas 29 brown trout were counted in the pool area, but only nine salmon parr. The brown trout observed appeared to be about 10-20 cm in length, except on 4 June, 27 June, and 10 August, when a brown trout larger than this was seen concealed amongst debris in the pool. Larger brown trout have a reputation of being nocturnal or crepuscular and remaining well concealed during the day. On two occasions (20 June and 27 June) a large brown trout, probably a sea trout, was seen in mid-stream, between the riffle and pool areas. Adult salmon were seen on two occasions. On 20 June, 12 grilse were counted below the riffle section. All were silvery as though they had recently entered from the sea. Some had sea lice and had green looking scars from sea lice. One grilse had white scars anterior to the dorsal fin, most likely from a gill net. Amongst the school of grilse was the large brown trout, only slightly smaller than the grilse.

On 10 August a number of adult salmon were again seen. It was difficult to count the actual number as the water was higher and more turbid than on the previous occasion. Only two grilse, holding station separately, were in the same location as seen previously, but about half a dozen, including two large salmon, were further downstream, in mid-stream, and to the side of the lower part of the pool area.

Two brook trout were seen in the riffle area (20 June and 26 June) and four were seen in the pool area (Table 2). The brook trout seen in the riffle on 20 June was a large one (about 30 cm). Another large brook trout (about 30 cm) was seen on 4 June close to the pool area but out of the study area.

Fry were first noted as a casual observation on 20 June. However, only the distributions of fish of 1+ and older have been recorded. Although usually in shallower water, some salmon fry were in mid-stream. As noted by Lindroth

(1955), brown trout fry were in shallower and slower water at the river's edge, in only a few centimeters of water.

Although an accurate estimate of the actual numbers was not made, there were obvious changes in the numbers of fish holding stations in the study areas through the season. In the riffle area the abundance index (numbers/100 m^2) of salmon parr changed from 1.85 and 0.92 on 24 May and 4 June to 8.0 and 10.0 on 20 June and 27 June respectively; it was 5.33 on 10 August and declined to 0.67 on 6 October. In the pool, the index for brown trout was 4.44 on 24 May, 4.29 on 4 June, 18.57 on 20 June, 10.0 on 27 June, 2.86 on 10 August, and was 0 on 6 October.

On the higher counts the water temperature was 16.0 and 15.0°C, close to the preferred temperature for parr, 17°C (Javaid and Anderson 1967), and brown trout, 7-19°C (Frost and Brown 1967). Salmon parr tend to go into hiding and into areas of slow water at 9°C (Gibson 1978; Rimmer et al. 1984). Observations were not made here at this low temperature, although in the first and last observations temperatures were 11.5 and 12.2°C, and some fish may have been in hiding, or still were remaining in pools, or had moved to deeper pools. The high water flows in the August and October observations may have allowed for a wider distribution of fish and displacement from the high velocity riffle area.

The late June observations were made when invertebrate food would likely be abundant (Gibson et al. 1984), and the fish actively feeding, thus more likely to be seen away from cover. As riffle areas are the most productive areas for the type of invertebrates eaten by salmonids, possibly fish are attracted more to these areas at that time, and would therefore be seen best on riffles, or close to riffles.

Fish were most numerous on the three sunny days. However even on cloudy days the visibility remained good enough to easily distinguish fish, so that visibility per se did not account for the changes in numbers of fish.

In conclusion, there was marked segregation of habitat in this part of the river between salmon and brown trout. For a total of all observations, in the riffle section the ratio of salmon:brown trout was 45:1, and in the pool section was 1:3.2. Mean water velocity of stations held by salmon was 34.2 cm/s (SD 14.70), and depth was 54.7 cm (SD 14.64). Mean velocity of stations of brown trout was 13.8 cm/s (SD 14.05) and depth was 72.1 cm (SD 14.40). Measurements of both depth and velocity held by the two species were significantly different ($P < 0.01$). Mean velocity in which brook trout were seen was 21.0 cm/s (SD 7.65), with depth of 72.8 cm (SD 17.0). The segregation of the species was more apparent in this study area than the others, possibly because the habitat areas were clearly distinguished, or food was scarce and therefore the boundaries of the niches better defined. The apparently low density and the relatively slower growth rate of the fish compared to the other study areas (Fig. 2 and 3) suggest that production was relatively low here.

NORTH ARM RIVER, DOWNSTREAM AREA

Results from underwater observations are shown in Table 3. Salmon were more numerous than brown trout in both the riffle and the pool sections, and the salmon were about as numerous in the pool section as they were in the riffle section. Some cover from alder bushes was present on the left bank, and this was usually where the brown trout were seen.

The first observation on 29 May (not recorded in Table 3) was made in a riffle (29 m^2) and pool (50.7 m^2) area immediately upstream from the area which was eventually chosen. The water temperature at this time was 12.2°C, it was overcast, and underwater visibility was about 4.6 m. Three salmon, two brown trout, and three brook trout were seen. The three salmon were in the main flow of the riffle, in water velocities of 45.7, 30.5, and 38.1 cm/s, and in depths of 24, 31, and 38 cm. One brown trout and two brook trout were in slower flow to the side of the riffle area (brown trout depth of 27 cm, velocity of 24 cm/s; brook trout in depths of 30 cm, 37 cm, and in velocities of 15 cm/s, 13 cm/s). One brown trout was in the slower flow to the edge of the pool (45 cm, 18 cm/s), and one brook trout at the downstream end of the pool in 35 cm and 30 cm/s. All fish were apart from each other. As this area later became shallow, subsequent observations were made in the pool and riffle sections immediately downstream.

The first observation in this latter area was on 12 June. Fry were not counted or locations recorded, but salmon fry were noted to be abundant, and brown trout fry to be present in the shallows. Fry were not noticed on 29 May, so probably they emerged in the interim. Six salmon were counted in the riffle section. Nine salmon and three small brown trout were counted in the pool. On 21 June five salmon and one small brown trout were counted in the riffle. In the pool 15 salmon were counted, four small brown trout (about 10 cm in length), and three brook trout, one of which was fairly large, about 25 cm. On 17 August, 11 salmon and one brown trout were seen in the riffle. In the pool were 11 salmon, most of them in the main current, and three brown trout, two close to overhanging alders near the left bank and one in water 73 cm deep at the end of the pool. The last observation was on 8 October. There were five salmon and four brown trout to be seen in the riffle section. The salmon were away from shade cover, but the four brown trout were each under shade from alder bushes on the left bank. In the pool were five salmon and one trout. Fish were more sparse than in previous observations, possibly due in part to higher water and dispersal of fish, or possibly they had migrated to deeper water with the onset of cooling temperatures or to spawning areas in the case of mature fish. The water level was 8 cm higher than in the previous observations. Barrier nets of 0.6 cm square mesh were placed across the upper part of the riffle and the downstream end of the pool, and the area electro-shocked. Three sweeps were made through the area, lasting in total 3/4 hr, but only one salmon was caught and this on the first sweep. Two hours were then spent electro-shocking for a general sample but only five salmon and one brown trout were caught. During lower water in the summer we experienced no difficulty in collecting fish. Diving observations suggested there were fewer fish per unit area, and they were probably more dispersed with the higher water, but the electro-shocker is not as effective in high water or in larger streams as it is in low water or in smaller streams, although conductivity may be similar. Care should therefore be taken in interpreting catch/unit effort by electro-shocker. The final sample was collected on 12 October by angling. In three hours, 15 salmon, three brown trout, and one brook trout were collected (6.3 fish/hr).

As a total of all observations there was a salmon:trout ratio of 4.3:1 in the riffle area and 3.6:1 in the pool. Mean depth and velocity measurements were: salmon 4.1 cm (SE 1.36), 13.7 cm s^{-1} (SE 1.10); trout 39.2 cm (SE 4.02), 8.8 cm s^{-1} (SE 1.98). Depth measurements were not significant ($P > 0.05$), but there was significant difference in water velocity measurements ($P < 0.05$).

In this study area brown trout were few. There was no brush cover, or pools with foam. This, plus the shallow water, may have presented an unfavorable habitat for brown trout. Much of the river in this lower section was similar to this study area, and deep pools, brush cover and overhanging shade cover were lacking. However, salmon were abundant in the slow water as well as in the riffle areas, which latter are usually regarded as preferred salmon habitat. This is due probably to lack of competitive interactions with other species of fish. The distribution of salmon in pools and in water of slow and moderate flow is similar to observations made in a river on the north shore of the Gulf of St. Lawrence, where there was also a depauperate fish fauna (Gibson 1973; Gibson and Côté 1982).

The sampling bias in assessing relative numbers of fish is interesting. Total numbers seen underwater were: 66 salmon, 17 brown trout, and one brook trout. This gives a salmon:brown trout ratio of 3.9:1. Samples from the electro-shocker gave 59 salmon and 30 brown trout, or about 2:1. The angling sample was 15 salmon, three brown trout, and one brook trout, or a ratio of 5:1 of salmon to brown trout.

NORTH ARM RIVER, UPSTREAM AREA

Results from the underwater observations in this study area are shown in Tables 4 and 5. Although brown trout were more numerous in the pool than the riffle and flat, salmon were also in the pool and overall were more numerous than brown trout. The pool section was downstream from the riffle, and a flat below the pool area was included in the study area. In the riffle and flat sections, for the total observations, the salmon:brown trout ratio was 5.7:1. In the pool section it was 1.1:1. Mean numbers (and numbers per 100 m^2) for all observations were: salmon, riffle 1.4 (6.4), pool 3.2 (9.1), flat 1.8 (6.4); brown trout, riffle 0.6 (2.7), pool 3.0 (8.6), flat 0; brook trout, riffle 0.8 (3.6), pool 0.8 (3.6), flat 0.2 (0.7).

The first observation was on 30 May, when 10 salmon, eight brown trout, and two brook trout were seen. Seven of the salmon were in the riffle and flat, in water depths from 27 cm to 18.5 cm, and in water velocity of 19.5 cm/s to 32.6 cm/s, but three were in the pool, in fairly close association with seven brown trout. The distribution on 11 June was similar. On 21 June, no brown trout were seen, but seven salmon were in the pool, in depths ranging from 26 cm to 66 cm, and in water velocities ranging from 6.1 cm/s to 12.2 cm/s and five in the riffle in depths of 22 cm to 47 cm, and water velocities of 44 cm/s to 20 cm/s. The water was at its lowest, so possibly there was insufficient cover to attract brown trout. It was also at its warmest (24°C). On 13 August only one salmon was seen in the riffle, although two salmon, three brown trout and two brook trout were in the pool. There had been recent rains and the water level was higher than in the earlier observations, although available food may have been less, causing the fish to be under cover or migrate to other areas.

The last observation was made on 5 October. The water level was higher than in any of the other observations, and the water temperature 12.4°C. Only two salmon and one brown trout were seen. The two salmon were in the pool, and the brown trout in the upper riffle section. However, the brown trout was in slow water beside the main current, in 12.5 cm/s, and a depth of 40 cm. The area was barricaded off at the upper and lower ends and electro-fished until no more fish could be caught. Seven salmon fry weighing 15.1 g, three salmon weighing 24.3 g, three brown trout weighing 58.4 g, and one brook trout weighing 15.3 g were caught. This was the equivalent salmonid biomass of 1.3 g/m^2, but there is no doubt fish were more sparse than during the summer. In attempts later the same day to collect a general sample of fish by electro-shocker, few were caught (two salmon and one brook trout) over our usual collection area, so that fish were genuinely sparse, and not merely under cover. The minimum water temperature since 28 September was 9°C. Probably many of the fish had emigrated to more suitable areas to spend the winter, possibly the pond a short distance upstream.

As a total of all observations depth and water velocity preferences were: salmon, 39.8 cm (SE 3.13), 18.0 cm s^{-1} (SE 1.84); trout, 49.4 cm (SE 2.61), 17.1 cm s^{-1} (SE 1.74). There was no significant difference between these measurements ($P > 0.05$).

BROAD COVE BROOK

In Broad Cove Brook brown trout was the only fish species seen during underwater observations. They were abundant, although the density changed through the season (Table 6).

The same pool area was used for all the observations. There was no overhanging cover, but boulders and rubble provided crevices where fish could hide. Immediately upstream was a riffle area, and this was the area used on the first observation. However, this became too shallow to observe fish later on, so an area upstream was used for the remaining observations. This new section was relatively shallow, but had only a slow to medium flow, so was better termed as a flat. Although fast water occurred in the stream, none suitable as a riffle area and suitable for observations could be found. There was no overhanging cover in either section.

The first observation was made on 31 May. The highest density of fish was seen on this day. Ephemeroptera were emerging, some trichopteran adults were seen, and biting simuliids were abundant. Six trout were seen in the shallow open riffle area in depths ranging from 19 cm to 25 cm, and holding station in water velocities from 5.8 to 24.1 cm/s. In the pool 16 trout were seen. One large trout was seen at the head of the pool, under a turbulent surface, but at the bottom in a slow pocket of water.

The second observation was made on 13 June. The stream water level was 6 cm less than the previous time. Ten trout were seen in the pool. Six trout were seen in the new observation area upstream. All the trout were small, about 10 cm long, except for a few larger ones in the pool (about 15-20 cm long). Fry were noticed in a depth of a few centimeters at the edges but were not counted. On 22 June the water level was down 1.6 cm from the previous time, but a similar number of trout were seen. In the flat area seven trout were seen, although there was no overhead cover; the average water depth was only about 30 cm, and the average water velocity 7.8 cm/s.

On 3 August the water level was 4.2 cm less than the previous observation period and in the flat section no trout were seen. The deepest part was 31 cm, and the water velocity about 5 cm/s. Only six trout were seen in the pool and they were all in the deepest part.

The final observation was made on 4 October. Eight trout were seen in the pool, and one in the flat. The areas were then barricaded off with seine nets and electro-shocked until no further fish were caught. More fish were caught than were seen. These may have been frightened into hiding, or more likely, as fish were seen in greater abundance in the earlier observations, they were naturally under cover. At these cooler temperatures (10.7°C), metabolism would be lowered and food may have been sparse, both reducing the search for food. However, during observations in October from the 'benthobservatory', an observation chamber a short distance downstream where free movement of fish was permitted, a number of brown trout, including large ones, were seen to be active. The large trout were probably mature fish which were involved in up and downstream movement associated with spawning.

The electro-fishing yielded 19 trout from the pool, weighing 585.8 g, equivalent to 20.2 g/m^2. They were mostly 1+, (8.0-12.2 cm), but three were 2+ (13.9-17.5 cm) and three were 3+ (17.9-20.4 cm). In the flat nine trout were caught, weighing 118.8 g, i.e. 6.9 g/m^2. These were all 1+.

Broad Cove Brook had the greatest density of trout of the four study areas. Also, unlike the other study areas, brown trout were seen in open shallow water, possibly due to high density of the brown trout population and lack of competitive interaction with salmon parr. During the lowest water they apparently left the shallow section, or were under cover. As a total of all observations, mean depth and water velocity measurements were: 46.5 cm (SE 2.53), 11.5 cm s^{-1} (SE 0.94).

Some physical and chemical parameters taken at the four study sites through the season are given in Tables 7-10. Conductivity was lowest in the Salmonier River (28-300 μ mhos), was 40-62 μ mhos in the North Arm River, and 42-58 μ mhos in Broad Cove Brook. The pH was highest in North Arm River (6.3-7.8), and between 5.3 and 7.2 in the Salmonier River and Broad Cove Brook.

AGE AND GROWTH

Sizes related to age of salmon and brown trout for the four study sections are given in Tables 11-14, and in Fig. 2 and 3.

Least growth of both species was in the Salmonier River. Greatest growth of either species was shown by brown trout in Broad Cove Brook. Growth of brown trout at both upstream and downstream locations in the North Arm River was more similar to growth in Broad Cove Brook than to growth in the Salmonier River.

Growth occurred through each season, however growth within the year is not linear, since fastest growth is in the spring and early summer, and then is less for the remainder of the year. We therefore plotted the linear regression only for the July samples, after the main growth period, for the rivers with the greatest differences. For salmon (Fig. 2), the regression for the Salmonier River was: $Y = 2.85 + 0.21X$ ($r^2 = 1.00$); and for the North Arm River upstream, $Y = 3.38 + 0.25X$ ($r^2 = 0.98$). If all sampling periods were included, the regressions would be: Salmonier River, $Y = 3.22 + 0.20X$ ($r^2 = 0.95$); North Arm River upstream, $Y = 2.45 + 0.27X$ ($r^2 = 0.97$). For brown trout (Fig. 3), the regression for July samples from the Salmonier River was $Y = 2.39 + 0.25X$ ($r^2 = 0.98$); and from Broad Cove Brook, $Y = 3.11 + 0.31X$ ($r^2 = 1.00$). If all sampling periods were included the respective regressions would be: Salmonier River, $Y = 2.68 + 0.22X$ ($r^2 = 0.94$); Broad Cove Brook, $Y = 2.39 + 0.36X$ ($r^2 = 0.96$).

An analysis of variance of the July samples of salmon from the different sites showed a significant difference in length ($P < 0.01$) with 2+ parr, but not with the other age groups ($P > 0.05$). The Salmonier River 2+ parr were significantly smaller ($P < 0.01$) than North Arm River 2+ parr at both sites, but parr from the upstream and downstream locations on the North Arm River were not significantly different ($P > 0.05$) in length. With samples of brown trout in July, there were significant differences in length with the four year-classes tested at the various sites (0+, $P < 0.01$; 1+, $P < 0.01$; 2+, $P < 0.01$; 3+, $P < 0.05$). The 0+ trout at Broad Cove Brook and the North Arm River upstream location were significantly bigger than those at the Salmonier River and North Arm River downstream sites ($P < 0.01$). However, there was no significant difference ($P > 0.05$) between mean length of 0+ trout at Broad Cove Brook and North Arm River upstream sites, or at Salmonier River and North Arm River downstream sites. With 1+ trout, the Salmonier River trout were significantly smaller ($P < 0.01$) than at the other sites, although there was no significant difference ($P > 0.05$) in mean lengths at the other three sites. Similarly, the 2+ trout were significantly smaller ($P < 0.01$) in the Salmonier River than at the other three sites, which showed no significant differences between sites ($P > 0.05$), although samples were small. There were few 3+ trout, but the Salmonier River fish were significantly smaller than those from the North Arm River upstream sites ($P < 0.05$).

An unusual situation compared to European rivers, where growth of brown trout is superior to that of salmon, was that in the Salmonier River the yearlings of both brown trout and salmon were about the same size, and the brown trout under-yearlings appeared to be slightly smaller than the salmon under-yearlings. Unfortunately salmon were difficult to capture at this station so their sample sizes were small. Juvenile salmon from the North Arm River were larger than brown trout of similar age from the Salmonier River. Salmon parr from the upstream station in the North Arm River appeared to be slightly larger than parr from the downstream station, although not significantly so. However, relatively more food would be available below a lake, which has been shown to affect growth rate of salmon parr in a similar situation in a northern Quebec river (Gibson 1978c; Gibson et al. 1984).

Condition factors of both species were above 1.04 at all stations throughout the sampling period (Tables 11-15). Condition factors were highest in the spring (late May and early June) and lowest in early October, except for the October samples for salmon in the Upper North Arm River. With the latter the mean was higher than the July sample, but the sample was small, of six fish, and included two mature parr with high K which may have biased the mean. An early April sample taken by K. McAuley and M. Branden (pers. comm.) in Black River immediately above its junction with the Salmonier River, had lower K factors for both species than later in the year, indicating that best feeding occurred somewhat later in the season than 10 April. All specimens in the April sample nevertheless had been feeding. Scales from our samples for both salmon and brown trout indicated that increased growth began earlier than in May and June, probably at the beginning of May. The growth rate appeared to have begun slowing down by the end of July. Narrow growth rings were well developed in the October samples. A sample of fish taken on 24 May in the Salmonier River showed slightly lower condition factors than the sample on 4 June, indicating that relatively greatest weight and probably heaviest feeding was at the end of May and beginning of June. Highest condition factors were shown by brown trout in Broad Cove Brook. These also had the greatest growth. Salmon had somewhat higher condition factors than brown trout in the North Arm River, but in the Salmonier River brown trout had slightly higher K factors than the salmon.

Brook trout caught in the Salmonier River, mainly in side channels, showed better growth than either salmon or brown trout from this river (Table 11). Samples of brook trout were too few at the other stations to make any conclusions. A large mature male brook trout was caught with the 4 October collection in Broad Cove Brook. It was 25.5 cm in length, 195.3 g in weight, and 3+ in age. This was larger for its age than any of the brown trout caught. This was the only brook trout encountered in this stream, except for one sighting of a large female from the Memorial University benthobservatory, also in the fall. They may have immigrated from a pond for spawning. The brook trout scales in general were more difficult to read than the other two species as they showed less obvious seasonal division between the circuli.

MATURITY

Age at maturity and proportion of mature fish can be indications of competition and river production of brook trout and salmon parr (Gibson et al. 1976, Gibson 1978c). The proportion of mature fish in the different age classes and at the four stations are shown in Table 16. Unfortunately samples are small but do indicate that the proportions of mature male parr were high. The proportion can increase with better growth, which can be due to reduced populations and reduced intra-specific competition, or to using parts of a river with higher production (Gibson 1978c). The proportion of male parr maturing also has a genetic basis (Saunders and Sreedharan 1978). The brown trout appear to mature earlier in Broad Cove Brook than they do in the Salmonier River, or in the North Arm River at the upstream location. This might be expected from the better growth shown by brown trout in Broad Cove Brook.

With the brook trout from the Salmonier River, four male yearlings, five male 2-yr-olds, and five male 3-yr-olds, were immature. One 2-yr-old female and one 3-yr-old female were mature.

The relative number of mature fish is also affected by proximity of the spawning beds near spawning time, although all the sampling areas were close to suitable spawning substrate.

Larger samples are needed to make firm conclusions, and may be warranted to compare with samples taken at later dates to follow possible changes in the ecosystem and in fish populations.

FEEDING STUDIES

Stream benthos

Total invertebrate abundance and biomass (volume) for each of the study sites and dates is shown in Table 17. The data suggest that the upstream site on the North Arm River and the Broad Cove Brook site were the most productive, in that order, followed by the downstream site on North Arm River, with the site on the Salmonier River being the least productive. However, caution is necessary in acceptance of productivity estimates based solely on benthos data (see review in Hynes 1970) and therefore such values can only be viewed as crude approximations.

Chironomid larvae and pupae were the most abundant invertebrates sampled at all sites, regardless of the season. Sphaeriidae clams were very common in the North Arm River collections but virtually absent from the other sites. Oligochaeta were a major component of the stream benthos at Salmonier River and the North Arm River (downstream).

Most of the insect fauna collected (other than chironomids) showed seasonal fluctuations in abundance as well as variation between stream sites. Ephemeroptera were moderately abundant in the spring, showed lowest occurrence in the July samples, and were most abundant in October. This pattern reflects the pre-emergence of sub-imagines, post-emergence, and early instar nymphal stages, respectively. Likewise, simuliid larvae were most abundant in the benthos during the spring prior to emergence of the majority of species. Philopotamidae (net-spinning Trichoptera) were very abundant at the upstream site on the North Arm River, but not elsewhere.

Diet analysis

The stomach contents were separated into four major prey groups (Fig. 4-7). Such a separation can influence data interpretation by combining species into units not necessarily distinguishable by the predator. Since we believed that a procedure separating stream site and sampling period was most appropriate for the study of these species' diets, the low sample sizes collected precluded any more detailed an investigation.

Where brown trout and salmon were sympatric, ephemeropteran nymphs constituted a greater proportion (by volume) of the diet of overyearling salmon than of overyearling trout. At Broad Cove Brook, brown trout, in the absence of salmon, preyed more heavily on Ephemeroptera suggesting a greater resource utilization in allopatry. Both species fed on them mainly in May, reflecting the period of pre-emergence for most of the local emphemeropterans.

Trichopteran larvae and pupae were important components of the diet of both species at all sites and at each sampling period. Overyearling salmon utilized this group with approximately equal frequency from May to October whereas overyearling trout showed a general decrease in the utilization (by stomach volume) of this prey group as the season progressed. However, at Broad Cove Brook, Trichoptera accounted for an increasing proportion of the diet of brown trout from May to October.

Aquatic Diptera made up a larger proportion of the diet of Atlantic salmon overyearlings than that for brown trout, especially at North Arm River (upstream) where dipterans comprised 25%, 17%, and 16% of the salmon's diet (by volume) for May, July, and October, respectively. Dipteran prey never accounted for more than 10% of the diet volume of brown trout at any site, even at Broad Cove Brook.

Surface invertebrates (both obligatory terrestrial species and aerial stages of aquatic insects) were a very important component in the diet of brown trout accounting for up to 55% of the mean stomach volume at the upstream North Arm River site in May. Generally, surface invertebrates formed an increasing percentage of the trout's diet at the Salmonier and North Arm rivers from May to October, but the reverse trend was observed for trout from Broad Cove Brook.

The results are shown in Table 18. Diet overlap was generally the case at each site and on all sampling dates, except at the North Arm River (upstream and downstream) in October, thereby indicating a significant similarity in the diets of the two species as overyearlings. The exception at North Arm River in October may indicate at this site greater species segregation through competition (Larkin 1956) as food resources become limiting in autumn (with respect to availability).

Data for fry feeding were not analyzed for diet comparisons between species for all study areas due to the small sample sizes procured for this group. Diet overlap values were calculated only at the Salmonier River and the North Arm River (downstream) for July, and in each case there was significant overlap (α = 0.67 and 0.80, respectively), indicating similarity in the diets of brown trout fry and Atlantic salmon fry at these sites in July. Generally, small sized invertebrates such as chironomid larvae and pupae, hydroptilid Trichoptera, and baetid Ephemeroptera were the most frequently ingested prey items. Frost (1950) and Egglishaw (1967) obtained similar results for the fry of these species in British rivers. Surface invertebrates were of minor significance in the diet of fry but where consumed, were eaten mainly by trout.

To relate the feeding habits of each fish species with the potential food availability in the stream, an index of food selectivity was calculated for each of four major food categories (Ephemeroptera, Trichoptera, Simuliidae, and Chironomidae). An estimate for surface invertebrates was not possible as this category was not sampled.

The calculated selectivity indices for trout and salmon overyearlings are given in Fig. 8-11. Both species showed a negative selectivity value for chironomids for all sites and sampling dates despite their abundance in the benthos. Rather than indicating an avoidance behavior, Chironomidae were likely inaccessible to predation because of their habitat within the substrate (Boerger et al. 1982) and also because they do not show drift periodicity (Waters 1969, 1972). Trichoptera were important to both species as evidenced by the positive selectivity values for most sites and dates. Only at the upstream site on North Arm River did both salmonid species show negative selectivity indices for this group, in May and July. This site was unique from the others in having large numbers of filter-feeding philopotamid Trichoptera present on these dates. Despite their abundance in the benthos, they were rarely an important component of the diets of trout or salmon at any of the study sites, except when emerging, and therefore were probably unavailable to predation as opposed to negatively selected for. Other trichopterans were highly selected for by trout early in the season and by salmon later in the season, where the fish were sympatric. This trend reflects the volumetric component changes for trichopteran prey in the stomachs of each species. As would be expected from the data of benthos abundance, Ephemeroptera were most selected for in the spring when they were abundant and of a larger mean individual size.

Both salmon and trout showed a positive selectivity for Simuliidae larvae, especially Atlantic salmon which showed the highest selectivity indices for this group, feeding on them much more than sympatric brown trout or where the latter was allopatric (Broad Cove Brook).

It is tempting to infer that differences in selectivity indicate differential species preferences for prey items. Such an inference would assume that prey such as simuliids were equally accessible to both trout and salmon, a difficult measure to quantify (Petraitis 1979). However, the observed discrepancy in selectivity indices may have been a function of microhabitat differences between trout and salmon and concomitant prey availability within these microhabitats. Maitland (1965) suggested that since Atlantic salmon preferred positions closer to the substrate, they were better able to exploit bottom foods whereas brown trout held more mid-water stations and therefore surface food items were consumed more. The habitat preferences found in our study could similarly explain the greater amounts of benthic invertebrates (e.g. simuliids) in the diets of salmon, and the greater amount of surface drift (e.g. terrestrials) in the diets of trout. Other research has also linked species' habitat and diet composition of stream salmonids (Cunjak 1982) and cyprinids (Mendelson 1975).

An index of stomach fullness for overyearlings of each species was determined and the results indicate some interesting differences (Table 19). At Broad Cove Brook, mean stomach fullness decreased from May to October. This may suggest increased competition for a limited resource as the season progressed, since fish density was highest here of all the sites and food availability (based on relative prey sizes) was lowest in the autumn.

At Salmonier River, trout showed higher stomach fullness values than salmon in May, after which both species had similar mean values of approximately 75% fullness. At North Arm River, salmon showed general declines in mean stomach fullness to less than 50% in October. Brown trout at the downstream site had values of less than 60% fullness throughout the season. The low values of both trout and salmon at the downstream site were not surprising since benthos abundance was low. At the upstream North Arm River site, brown trout mean stomach fullness was greater than that for salmon for all sampling dates except in May. The latter may be related to a more efficient utilization of ephemeropteran prey by salmon as this group was very abundant at this time of year and terrestrial invertebrates (favored by trout) were not.

EXPERIMENTAL AREAS

The physical characteristics of the experimental areas are shown in Table 20. Results from manipulating the relative numbers of salmon and brook trout were only partially successful (Gibson and Conover 1980), but the initial electro-fishing provides some interesting results. It was noticed that most fish were caught at the end of a sweep, at the upstream end, or the downstream end. This illustrates the necessity of having barrier nets or screens if quantitative estimates of biomass are required. This also shows that fish captured by the electro-shocker are not necessarily captured in their usual habitat, but possibly from areas to where they have been driven, so that conclusions about preferred habitat cannot always be made from samples taken with an electro-shocker unless the types of habitat are physically partitioned.

The sizes and numbers of fish caught are shown in Table 21 and the relative numbers and biomass in Table 22. The sizes corresponded to 1+, 2+, and 3+ salmon, and 1+ and 2+ brown trout.

In the control section was a total salmonid biomass of 437 g, or 9.0 g/m^2, and a ratio of salmon to brown trout biomass of 2.5:1. Also caught were two large eels (total lengths 73.5 cm and 75.0 cm and weights of 0.8 kg and 1.0 kg, respectively). The eel biomass was therefore 37.2 g/m^2. However, the eels may have been migrating and therefore only temporary residents.

The total salmonid biomass in the riffle section was 235.8 g or 5.7 g/m^2, and the ratio of salmon to brown trout biomass 9.1:1. The highest percentage (89.5%) of salmon biomass was in this section.

In the pool section was a total salmonid biomass of 309.5 g or 10.7 g/m^2. The ratio of salmon to brown trout biomass here was 2.8:1. An eel was also caught, of total length 67.3 cm and weight of 0.7 kg (24.1 g/m^2).

A few three-spine sticklebacks were seen in all three sections, but they responded poorly to the electro-shocker and few were caught, so were not recorded.

Further samples of fish were taken between 5 and 11 September. They were introduced to the experimental sections for a replicate experiment. Unfortunately the experiment was a failure, due to high water and debris. However, condition factors of these fish were:

Salmon: 1.13 (SD = 0.10)
Brown trout: 1.01 (SD = 0.060)

Although the experimental stocking was not a success, due to movements of fish, the results from the three types of habitat provide further evidence that riffle areas provide more suitable habitat for salmon than brown trout. The control section was more suitable as salmon habitat than brown trout habitat, as slow water pools with deep water or shade were lacking. The pool type section had the least biomass of salmon, but even in this habitat salmon had the major biomass (61.7%). There was no significant difference between the mean condition factor of salmon in July, August, or September ($P > 0.05$). There was a significant difference between the condition factors of salmon and brown trout in the natural density period in July ($P < 0.05$), in the partially successful experimentally stocked high density period in August, and in the natural density from the adjacent stream areas in September ($P < 0.01$). There was no significant difference between the condition factors of brown trout in the natural density conditions of July and September ($P > 0.05$). However, there was a highly significant difference between the condition factor of brown trout in July ($K = 1.05$) and at high density in August ($K = 0.95$) ($P < 0.01$), and a significant difference for brown trout between August and September ($P < 0.05$) (Fig. 12).

Two observations of adult or mature salmon bear mentioning. The day after we had set up the riffle section (24 July), a grilse was found in the section. It was released upriver. It had probably leaped over the downstream screen, but was unable to leap the upstream screen. This was the only anadromous adult we saw in our studies in the North Arm River. However, in the electro-fishing on 11 September a mature female ouananiche (24.4 cm fork length and weight of 159 g) was caught. Its age was 4+. Ouananiche are known to be present in the headwater ponds of both branches of the North Arm River.

DISCUSSION

The major findings of this study are that there generally was spatial segregation of brown trout and juvenile salmon, mainly with regard to water velocity and depth, and that the two species are ecologically compatible, with salmon being dominant as far as numbers and biomass are concerned in the study areas where they coexisted. Overall the average water velocity in which fish were seen was 34.2 cm/s for salmon and 13.8 cm/s for brown trout. Relative mean depths were 54.7 cm for salmon, and 72.1 cm for brown trout. As most salmon rivers on the Avalon Peninsula have abundant shallow riffle areas, there appears to be little danger that salmon will be displaced by brown trout.

The most distinct segregation was seen in the study area of the Salmonier River. Here the salmon:brown trout ratio, as a total of all observations, was 45:1 in the riffle, and 1:3.2 in the pool and differences in preference of depth and water velocity between species were highly significant ($P < 0.01$). This may have been due mainly to the distinct differences between the two types of habitat, with the pool providing better trout habitat than pools of the other study areas. However, the fish were relatively sparse here, and growth the least, indicating that food may have been in short supply, which would lead to sharper definition of the niche boundaries.

In the North Arm River at the downstream station, salmon were more numerous than brown trout in both the riffle and pool sections. Furthermore, salmon were as numerous in the pool section as in the riffle section. This latter finding is interesting because in New Brunswick the pool habitat is regarded as atypical for parr (Elson 1967), and is inhabited also by other species, mainly cyprinids. Symons (1976), in an experimental flume, could not find evidence that cyprinids competed with salmon; however a similar situation occurs in the Matamek River, Quebec, as in the North Arm River. There, although salmon parr were most abundant in riffle areas, the salmon parr were abundant in pools and slow water areas (Gibson 1978b and unpublished data), and in this river also many species found in New Brunswick, including all cyprinids, were missing. This demonstrates the importance of considering the biological community as well as the physical parameters when assessing the suitability of habitat for juvenile salmonids.

In the lower study area of the North Arm River the mean water velocity and depth of salmon in the riffle area was 20.5 cm/s and 32 cm, and for trout 12.2 cm/s and 27 cm. In the pool section it was: salmon, 9.2 cm/s, 47.1 cm; brown trout, 7.3 cm/s, 44 cm. The lack of brush cover, pools with foam, or deep water, probably accounted for the paucity of brown trout. The few that were seen were usually under the shade of alder branches. There was a significant difference in water velocity preference between species ($P < 0.05$), but not in depth ($P > 0.05$). During daylight salmon parr in shallow water with a smooth surface prefer shade, but in water deeper than about 45 cm, depth itself provides sufficient cover (Gibson and Power 1975). In this latter study salmon parr did not show any preference for types of substrate. Cover, in the form of shade, water depth, or a broken water surface, had more attraction than type of substrate in the relatively slow water of the experiments. However, a coarse substrate in fast water provides pockets of slower water and is generally associated with good parr habitat.

In the upstream area on the North Arm River there was closer association of salmon and brown trout. This may have been due to the less distinct differences in habitat, but invertebrates here were more abundant, so the niche boundaries would be more likely to overlap. Brown trout were more numerous in the pool than in the riffle and flat, but as at the downstream station, in both riffles and pools, salmon were the more numerous. As a total of all observations the ratio of salmon:brown trout was 5.7:1 in the riffle and flat, and 1.1:1 in the pool. The mean water velocities and depths at the stations where they were seen was: salmon, 18.0 cm/s, and 39.8 cm; brown trout, 17.1 cm/s, and 49.4 cm. However, there was no significant difference between preferences of the species ($P > 0.05$).

In a similar study in New Brunswick, salmon parr were found to be about twice as abundant as brook trout in riffle areas, but brook trout were almost four times as abundant as salmon parr in a pool (Gibson 1966), suggesting that both brook trout and brown trout may be ecological equivalents with regard to interactions with salmon parr.

Only brown trout were seen in Broad Cove Brook. An interesting observation here was that brown trout were seen in shallow open areas, in the type of habitat that would have been occupied by salmon in the other rivers. For example, on 31 May six trout were seen in the riffle study area in a mean water velocity of 18.2 cm/s and mean depth of 21.7 cm. Later this section became too shallow for diving so observations were then made in a shallow open section, as opposed to a deeper pool, but with relatively slow water. Here brown trout were also seen in the open. For example on 22 June seven trout were seen in an average water velocity of 8.3 cm/s, and depth of 30.4 cm. The fish left or were in hiding at lowest flows. On 3 August, no fish were seen, but the deepest part was 31 cm, and the water velocity about 5 cm/s. With the electro-shocker we caught brown trout in water shallower than this, but they were under thick bank cover, so evidently thick shade is as suitable for cover as deep water. The occurrence of brown trout in open shallow water here may have been due to high density of fish, or to lack of interaction with salmon. Butler and Hawthorne (1968) found that a large brown trout (402 mm; 525 g), in a water velocity of 8.2 to 10.1 cm/s and depth of 30.5 cm had a strong attraction to shade. However, smaller fish in somewhat deeper water may respond differently, and were seen to do so in this study, in the absence of salmon. Brook trout, also primarily a pool dweller, have strong responses to shade type of cover in shallow water under high illumination, although in nature can be seen in shallow water away from cover, in response to preferred water temperature, abundant food, or spawning activities. The feeding distribution of brook trout in shallow water can be changed in competition with salmon (Gibson 1973).

The changes in numbers of fish seen through the season may have been due to both movements away from the site and to hiding behavior. Juvenile salmon begin to hide at 10°C, and at 9°C the majority disappear amongst crevices in the substrate, or group in slow water pools (Gibson 1978a; Rimmer et al. 1984). In the October observations in the Salmonier River, the water was approaching these temperatures (12.2°C), and fish may have moved towards more suitable winter habitat.

In Broad Cove Brook fewer fish were seen on 4 October than on some of the previous occasions, but more fish were caught with the electro-fisher than were seen. However from the 'benthobservatory' some brown trout were seen feeding at 5°C, at temperatures at which the majority of salmon parr would have gone into hiding, so brown trout may continue to feed at lower temperatures than salmon parr, and this is suggested by Egglishaw and Shackley (1977). Some of the changes in numbers may have been due to migration from the area. There are local movements of salmon parr and brook trout in response to changing water conditions (Gibson 1966). Also the behavior may change with the season. In the Matamek River, Quebec, salmon are more mobile in the early spring, and again in the fall, and are then easier to catch in stationary gear set in pools. But in summer they are more common in riffles, and their movements are more restricted. Brook trout also showed this pattern, but had a more roaming type of behavior all summer (Gibson 1973).

Some salmonids are known to migrate to winter habitat before the onset of winter conditions. Bjornn (1971) working in two Idaho streams, studied the movements of rainbow trout, brook trout, Dolly Varden, chinook salmon, sculpin and dace. He found that many juvenile salmon and trout migrated from the Lemhi River drainage each fall-winter-spring period. Fish emigrated before the abundance of drift insects declined in the winter, and in spite of the relatively stable flows in both streams. The movements of non-smolt trout and salmon correlated best with the amount of cover provided by large rubble substrate. It is possible similar movements occur with east coast salmonids, related to movements towards suitable winter cover, whether this be a rubble substrate or deep pools or ponds. The time of year is therefore an important consideration to take into account when population estimates are made in streams.

An interesting finding was the bias in selectivity of the sampling methods. Frequently the relative occurrence of species is estimated from collections made by electrofishing. This may be valid in small streams, or where a section is enclosed. However, in large rivers, or where conductivity is low, the electro-shocker is less effective. Probably an electro-shocker tends to drive salmon, especially in large rivers with a smooth substrate. During underwater observations salmon rarely hid, unless actively frightened, but move further away as the diver approached. Brown trout on the other hand often hid amongst crevices, and due probably to a thigmotactic response would stay there almost until touched (With experience they can be lightly touched and removed from crevices - the poachers' method of catching brown trout by 'tickling'.). This behavior would make brown trout more susceptible than salmon to an electro-fisher. In the Salmonier River the electro-fisher was more successful along the banks and in side channels than in mid-stream, so one tended to spend proportionately more time in these areas, again selecting for trout.

The least growth of both species was in the Salmonier River, and the greatest growth of brown trout was in Broad Cove Brook. In all other reported studies where the two species coexist, brown trout grew faster than salmon. However, in the Salmonier River the one year olds were the same size and the underyearling trout appeared to be slightly smaller than underyearling salmon. This may shed further light on reasons for the differential growth. The prevailing theory is that because brown trout fry emerge earlier than salmon fry, this gives them a growth advantage which they maintain through all stages (Egglishaw and Shackley 1977). Egglishaw and Shackley (1973) have demonstrated that this mechanism is possible by stocking salmon fry larger than the brown trout fry, and showing that salmon then maintained a growth advantage. However, the fact that brown trout are not initially larger than salmon in the Salmonier River, yet become larger beyond the yearling stage, shows that other mechanisms are possible. Whether this is due to a growth hormone having an effect over a longer time period than in parr, if such is present at this stage, or whether the growing season is longer for brown trout, or whether the trout is metabolically more efficient than parr, or whether trout eat more, or find an extra food source at the large size, or become large enough to then dominate choicer feeding areas, etc., is unknown. Frost and Brown (1967) showed in a comparison of brown trout from different waters in the British Isles that there were striking differences in specific growth rates in the first year of life, but that growth rates later were fairly similar in all waters, although the fish were of varied sizes as a result of the differences in growth in the first year. Salmon parr on the other hand appear to be more plastic in their growth rates throughout their fluvial existence (Gibson and Dickson 1984). The trout growth rates may be a mechanism for determining density and survival at an early stage, since trout can adjust by increased growth to an abundant resource in later life, as for example when they go to sea.

A mechanism whereby an earlier emerging species, brook trout, was negatively affected by a later emerging species, rainbow trout (*Salmo gairdneri*), has been shown by Rose (1986). Although older fish of both species coexisted, densities of brook trout were reduced by competition at the fry stage with fry of rainbow trout, illustrating well that all life history stages should be studied in order to understand competitive effects.

Kennedy and Strange (1980) found in two streams in Northern Ireland with previously only brown trout, that by introducing salmon the total biomass was increased by 50.4% and 37.1%. They deduced that trout on their own did not occupy all the available habitat, and that both streams were apparently only carrying about two thirds of their salmonid standing crop capacity prior to the introduction of salmon. They also found that although salmon fry did not affect trout survival, the presence of salmon parr did cause a 23% reduction in mean trout fry density.

A parallel situation occurs with relative growth rates of brook trout and salmon as with brown trout. In some areas of the Matamek River, Quebec, the relative biomass and production of salmon and brook trout were similar, yet brook trout were fewer, but larger for their age than salmon (Gibson 1973). The adaptive advantage can be seen of juvenile salmon having their biomass in more 'bits' than resident trout, since they can grow to maturity at large size at sea, where density dependent factors probably are negligible and larger food items are abundant. Brook (and brown) trout on the other hand usually remain in the river, where a large size and early maturity is more advantageous, and biomass is controlled mainly by survival at underyearling and yearling stages (Gibson 1973). However, salmon stocked in fishless streams of the Matamek watershed, and sparsely stocked where there were only brook trout (Gibson and

Dickson 1984), grew faster than the brook trout in the same system, so the relatively slower growth of the salmon with brook trout in the usual situation is related to the salmon density, and their territorial behavior. Growth of brook trout in the same system did not appear to be density dependent, and as with brown trout (Frost and Brown 1967), future size in a particular river system may be determined as underyearlings. Another possible ecological reason for the differential growth is that a pool dweller must be larger than a more aggressive riffle dweller in order not to be displaced. Salmon for example have the competitive advantage over brook trout in riffles, and over smaller brook trout in pools (Gibson 1973), whereas growth rate and possibly numbers of salmon are negatively affected by larger brook trout in pools (Gibson and Dickson 1984). Possibly if the size advantage of brown trout were curtailed for example by climatic conditions, the brown trout would be displaced by competition. Quantitative studies of the relative aggression of salmon and brown trout have yet to be undertaken, but in studies of other fluvial salmonids the riffle dweller in flowing water is more aggressive than the pool dweller (Gibson 1981). In the Salmonier River brook trout grew better than brown trout, although in other studies brown trout have been shown to have the better growth of the two species (Cooper 1953; Marshall & MacCrimmon 1970). In general the Salvelinus genus is more successful than the Salmo genus in colder water, and vice versa (Fry 1947, 1948; Fisher and Elson 1950; Curry-Lindahl 1957). It appears that conditions for brown trout were marginal in this part of the Salmonier River, providing some evidence as to why the occurrence of brown trout is spotty in salmon rivers of the Avalon Peninsula. Large sea-run brown trout are common in this system, so that beyond a certain size the brown trout are very successful. However, if some factor such as late emergence of fry, or negative competitive effects due to habitat, gives rise to a smaller relative size, the species may not survive at the juvenile stages in competition with better adapted species. It has been suggested that brown trout in the 100 years that they have been in Newfoundland are successful only on the Avalon Peninsula since not all sea-run brown trout are mature, so that colonization is slow (O'Connell 1982). However, climate, habitat, and competition from salmon and brook trout, may have prevented brown trout from colonizing waters around the island.

The condition factor for both species at all stations was greater than 1.0, was highest in May and early June, and was lowest in early October. The highest condition factor of brown trout was in Broad Cove Brook. Brown trout in Broad Cove Brook and at the lower station of the North Arm River matured earlier than at the other two stations. The condition factors of fish in the collections were slightly higher than that of live fish measured in the experimental areas, probably because there is a slight shrinkage of fish in formalin (Wagner 1975). However the collections, for comparing age and size, were all treated in the same way, so comparisons are valid.

Some behavior experiments were made in a benthobservatory, an underwater viewing chamber owned by the Memorial University of Newfoundland. This facility is described in detail by Mokry (1975). The experiments were preliminary, and are not included in this report as it was not possible to test the aggression of either species in fast water, so few conclusions can be drawn. However, the following observations were made, reported in Gibson and Conover (1980). A brown trout was dominant over a slightly larger salmon and was territorial in slow water of about 5 cm/s and in temperatures between 16° to 24°C. Salmon in these slow flows were dominant over small trout but were not territorial and their aggression was low. This latter observation was to be expected, as salmon become less aggressive at low water velocities (Gibson 1978a). In the low water temperatures of two experiments the activity and aggression of both brown trout and salmon were low.

Kalleberg (1958) observed in his stream tank that brown trout were more aggressive that salmon. Lindroth (1955) noted that in rivers without brown trout, salmon fry could be found at the shallow edge, whereas with brown trout fry present, the trout fry occupied the margin of the river down to 2-3 dm and salmon fry lived in the deeper water. He concluded the trout fry were more aggressive than the salmon fry and that trout occupied the most suitable locations. However, this is similar to the riffle-pool distribution of the older fish, as the water at the edge of the river is slower than towards mid-stream. In other studies where more than one salmonid species coexist in the same stream, the habitat is generally shared by one of the species being more abundant in the riffle and fast water areas, and the other being more common in the pools and slow water areas, although there is considerable overlap, and both types of habitat are used by a species if the other species is absent (Gibson 1981). In the case of brown trout and juvenile salmon, the salmon are found predominantly in the riffles and fast water areas, and the trout predominantly in pools (Maitland 1965). Similarly Karlström (1977) found that in Swedish rivers during the summer salmon parr were never found in velocities below 0.1 m/s and seldom below 0.5 m/s, while brown trout parr were often found below 0.5 m/s. In allopatric populations he found the trout parr were in higher water velocities, but still showed a strong preference for a coarse bottom. Salmon on the other hand were found in small numbers in water velocities below 0.25 m/s when trout were absent. He found salmon and trout parr to be in lower water velocities in the autumn, when the water temperatures were low, than in the summer. Kennedy and Strange (1982) in Northern Ireland found that brown trout were limited in their distribution to areas of lower flow, whereas salmon were not, related to the apparent preference of trout for slightly deeper habitats than the equivalent year-classes of salmon. The relative abundance of salmon parr did not have any significant correlation with gradient, i.e. they did not exhibit preference for any flow-related habitat type. On the other hand, trout yearlings and older fish were very highly significantly more abundant in areas of low gradient, i.e. pools. Salmon apparently lived as readily in the sluggish low gradient areas, but also have the ability to occupy areas to which trout are not so well adapted. These observations were corroborated in the present study.

Keenleyside (1979) states that territoriality among stream living salmonids is probably related to the securing of food resources and of shelters in which to avoid predators, but that there is surprisingly little evidence bearing directly on the function of stream territories. However, if the resource is to be shared to achieve some optimum growth for the individuals present, holding territories when in fast water appears to be the most efficient method. The food consisting of organic drift is brought to the individual in moving water, so active searching and swimming is both unnecessary and inefficient in this type of habitat. Young Atlantic salmon can apply themselves to the substrate in fast water, using their pectoral and pelvic fins rather like suckers (Kalleberg 1958) and so can hold station using little energy, occasionally darting out for food or defense of the territory. It seems reasonable therefore, in this type of habitat, to defend a defined area rather than search for food. Recent work by Puckett and Dill (1985) has shown that for juvenile coho salmon that from an energetics viewpoint territorial fish are more efficient than those not defending territories. Kalleberg (1958) showed that the presence of large boulders or turbidity allowed more visual isolation and therefore smaller territories among Atlantic salmon underyearlings, and that faster water flows also brought about smaller territories by bringing the underyearlings closer to the substrate and reducing visual contact with neighbors. Dominant Atlantic salmon hold position higher above the substrate than subordinate salmon and have larger territories (Gibson 1981). In experimental conditions the distance to its nearest neighbor of a dominant Atlantic salmon parr is about 1.1 m at 15°C (Gibson 1981), although when food is abundant subordinates are allowed within the territory so that distances are reduced (Symons 1968, 1971). In the pool environment, food is more dispersed and settles to the bottom (McLay 1970), so that a more roaming type of behavior, reduced territoriality, and more feeding at the bottom and at the water surface, rather than in the water column, is prevalent. This is the situation with brook trout, brown trout and juvenile coho salmon, when occupying pools. It appears from the literature that salmonids can change their behavior to be aggressive in rapid water, but less aggressive and frequently schooling in pools, e.g. this applies with Atlantic salmon (Gibson 1978); brook trout (Keenleyside 1962a); coho (Ruggles 1966; Hartman 1965); steelhead trout (Hartman 1965); brown trout (Hartman 1963); and chinook salmon (Reimers 1968). A salmon-like fish in Japan, Plecoglossus altivelis is territorial in rapids, but schooling in pools (Kawanabe 1957). Even Atlantic salmon smolt, which are presumed to only school and to have lost their territorial behavior (Keenleyside and Yamamoto 1962) become territorial when obliged to hold station in a current (Gibson 1983). Probably Atlantic salmon smolt are usually seen in slow water, schooling, because they have become more buoyant than parr (Saunders 1965) and therefore find it more efficient to feed in pools, where the schooling type of response appears. This change of behavior in response to water current provides evidence towards the efficiency of territorial behavior for sharing the food resource in fast water.

The diet analyses support the contention that salmonids are opportunistic feeders (Tebo and Hassler 1963; Waters 1969). Considerable dietary overlap was observed between brown trout and Atlantic salmon where they were sympatric. However, certain differences in diet were revealed between the two species, reflecting their microhabitat preferences and the temporal abundance of the benthos. Atlantic salmon overyearlings preyed substantially more on ephemeropteran nymphs and simuliid larvae than did brown trout overyearlings, which preferred terrestrial invertebrates in the surface drift. Also a large brown trout sampled from the Salmonier River had eaten a fish, as had two brook trout. Other researchers (e.g. Frost 1950; Thomas 1962; Mills 1964; Frost and Brown 1967; Egglishaw 1967; McCarthy 1972) have also documented the greater utilization of benthic invertebrates such as dipteran larvae (especially simuliids) and ephemeropterans (in spring) by salmon whereas trout fed more often on surface organisms. Our data support the suggestion of Maitland (1965) that the position of salmon in the shallow riffles would provide them with better access to benthic prey whereas the preference of mid-water positions and pools close to cover by brown trout gave them better access to terrestrial species falling or lighting on the surface. However, benthic prey of pools or littoral areas of lakes, such as molluscs and Odonata, may also be the main food of some fish (Frost and Brown 1967; Tippets and Moyle 1979; Skinner 1985). In deep pools, say of more than 1 m or in lakes, it may therefore be more efficient to concentrate on either surface or bottom items rather than feed through the water column. The opportunistic feeding related to the habitat is illustrated by Egglishaw (1967) who found that in pools salmon took more surface food than did salmon from riffles. Similarly, in a Quebec river, Gibson et al. (1984) found in a deep slow section of the river that the diets of salmon parr and brook trout were more similar to each other's, than to the diet of either species in fast water below waterfalls upstream. Also, Pedley and Jones (1978) found in a lake which was stocked with salmon, but which had a natural population of brown trout, that the salmon ate surface food as much as the trout. It appears therefore that these salmonids can easily switch to the most available resource. Relative size and relative gape may generally allow brown trout to take larger food than salmon, and to become piscivorous as they grow older (Thomas 1962). Generally salmon migrate to sea or to a lake before becoming piscivorous. However, salmon parr will eat items normally unusual in their diet, such as gastropods, oligochaetes and small fish when aquatic insects are scarce (Keenleyside 1962b). Also Lillehammer (1973a, 1973b) and Elliot (1967) have shown that there are differences in feeding between the size groups of both salmon and brown trout, which reduces the competition for food between the year-classes.

Some species variation in feeding patterns between sites and seasons was apparent, indicating that stream size, fish density, invertebrate abundance, and habitat availability may play important roles in determining feeding, growth, and condition factor of individuals of each species where they occur sympatrically. In the Salmonier River, the large river size and relatively low fish density reduced the probability of interaction, as salmon and trout were mainly found in their respective preferred microhabitats. This may have contributed to the high condition factors displayed here, despite the low benthic invertebrate biomass, although growth of brown trout here was less than at other sites. At the North Arm River, brown trout had lower condition factors than salmon, possibly related to the lack of preferred trout habitat, specifically deep pools with associated cover. Likewise, the possibility of inter-specific interactions was greater here due to the higher density and smaller stream size relative to the Salmonier River. Since aggressive interaction is likely to increase during periods of resource limitation (Symons 1968) resulting in greater segregation (Nilsson 1967), this may explain the lack of significant dietary overlap at both North Arm River sites in October when competition would be expected to be greatest.

In the experimental areas, the riffle pool habitat was found to have a salmonid biomass of 9 g/m^2, the riffle area 5.7 g/m^2 and the pool area 10.7 g/m^2. These figures are less than in some other studies (e.g. LeCren 1969), but higher than found in some boreal regions (e.g. O'Connor and Power 1976) and as high as a river in Ontario (Marshall and MacCrimmon 1970). In all three types of habitat, salmon had a relatively greater biomass than brown trout (2.5:1 in the riffle-pool; 9.1:1 in the riffle; and 2.8:1 in the pool). Since ouananiche occur in the system, it is not known what proportion of these salmon were anadromous, and what proportion landlocked, although preliminary studies have suggested the landlocked or ouananiche form are associated primarily with the headwater lakes. Anadromous salmon occur in both the west and east branches of the North Arm River, although anadromous salmon in the west branch migrate no farther than the Trans Canada Highway, where a culvert, installed 20-30 years ago, creates an obstruction. Upstream from the Trans Canada Highway the ouananiche spawn in the lake (Sutterlin and Clark, MS in prep.). Also, brown trout occur downstream from the Trans Canada Highway, but apparently not upstream from the artificial obstruction, although a gene associated with the brown trout occurs in the ouananiche population upstream from the Trans Canada Highway (E. Verspoor, Department of Fisheries and Oceans, P.O. Box 5667, St. John's, Newfoundland A1C 5X1, pers. comm.), suggesting that brown trout were once present, but may have been eliminated by competition or some other cause. The Trans Canada Highway on the east branch, on which were our study areas, did not cause an obstruction. Nevertheless there is no evidence that juvenile landlocked salmon differ in behavior or in their ecological requirements from anadromous salmon.

Preliminary experiments involving artificially stocking high densities of salmon and brown trout in the experimental areas (Gibson and Conover 1980) indicated that the condition factors, and therefore ultimately the growth, of brown trout were depressed very much more than those of the salmon parr (Fig. 12). Replicate experiments should be made to test these findings. If it is true, it is contradictory to findings in the British Isles. Frost and Brown (1967) state that ". . . since young trout are much more aggressive than young salmon they may drive the salmon away from the better territories. Overcrowding in a river holding both salmon and trout may prevent salmon establishing themselves at all". They compared several waters containing brown trout, with or without salmon, and concluded that there was no relationship between growth of the trout and presence or absence of salmon. Similarly Thomas (1962) concluded that competition between salmon and brown trout was not expressed in the growth of the trout. Generally competition between the two species appears more severe in the British Isles than in Newfoundland. However, it is quite possible that density dependent growth is expressed in salmon, but less so, or growth effects were due to other factors, in brown trout. This has been shown to be the case with salmon and brook trout in a Quebec river (Gibson and Dickson 1984). LeCren (1965, 1973) found from an experiment in a stream in North West England (Black Brows Beck), that brown trout fry dominated salmon fry and the mortality rate of the trout was proportional to the density of trout alone, whereas the mortality of salmon depended upon the total number of trout and salmon. However, it has been shown from the present study that the relative success of a species depends very much on the habitat. These other studies have given the impression that brown trout displace salmon, although Berg (1965) found that opening new river stretches to salmon in North Norway diminished the numbers of both brown trout and arctic char (Salvelinus alpinus) inhabiting these waters. Similarly Heggbert and Hesthagen (1981) showed that stocked salmon fry survived in streams with dense brown trout populations. Also the recent studies of Kennedy and Strange (1980, 1981, 1982) have shown that brown trout and juvenile salmon are ecologically compatible and that in fact although salmon fry do not affect brown trout survival, the presence of salmon parr does cause a reduction in trout fry stocks. Similar findings have been found in a Quebec river with brook trout and salmon, where salmon reduced the numbers of yearling brook trout, possibly by negative effects on both fry and yearlings. The larger brook trout may not have been affected, but appeared to have negative effects on growth of large salmon parr (Gibson 1973; Gibson and Dickson 1984).

The growth of brown trout at all four stations in this study, including Broad Cove Brook, is considerably less than that found by Marshall and MacCrimmon (1970) in Ontario, and is at the low end of growth for its world wide distribution (Carlander 1969), possibly related to the relatively short growing season. Also, the growth of sea-run brown trout is poorer than in European rivers, probably related to our colder sea water in winter (O'Connell 1982). However, Wiseman (1971) found that in lakes on the Avalon Peninsula, brown trout had a faster growth rate than brook trout or ouananiche, where these species coexisted, and a higher biomass than either of the other two species (Wiseman and Whelan 1974). However, other than in streams in St. John's, which are enriched, and the cooler bogland areas with spring seepage, favored by brook trout, destroyed or degraded, the growth of brown trout in streams of Newfoundland is poor, and their success in streams here is probably marginal. The fact that they have not spread far from the Avalon Peninsula, which has the mildest climate of the island, suggests that the climate in Newfoundland may limit distribution of the species. It is unlikely that the geological facies would be important in limiting the habitat, as although the presence of calcium ions, and softness of the water may affect growth and production (e.g. Egglishaw 1967; Frost and Brown 1967; Kennedy and Fitzmaurice 1971), brown trout are successful in a wide range of streams (LeCren 1969). The gradient, and therefore average water velocity, appears to have limiting effects. Although present in adjacent streams, some salmon rivers on the Avalon Peninsula do not have brown trout, e.g. Branch River, Biscay Bay River, Northwest Brook Trepassey, Big Barachois River, South East River Placentia, and others. These rivers are characterized by extensive reaches of shallow riffles, which provide good salmon parr habitat, but have few pools, or areas of low water velocity with instream shade or cover, the sort of habitat preferred by brown trout. These rivers do however support brook trout, which may be derived mainly from cool side channels and streams or headwater ponds. On the other hand many rivers, especially in Conception Bay, Trinity Bay, and the Southern Shore, which have lost or have sparse salmon populations, have abundant brown trout populations. Many of these rivers have had their salmon populations reduced by habitat degradation, obstructions such as poor culverts and hydroelectric developments, and poaching. Although many of these rivers have runs of anadromous brown trout, the anadromous form may not be essential for success of the species, as resident trout would be successful without competitive pressures from salmon. However, the apparent loss of brown trout above an artificial obstruction (culvert) on the west branch of the North Arm River (E. Verspoor, pers. comm.) suggests that in this river, where salmon are abundant, whether ouananiche or anadromous, the anadromous form of brown trout, which occurs downstream, may be necessary for the continuation of the species (less competition at sea than in the river, and higher fecundity due to larger size at maturity). Several local good salmon rivers have good runs of anadromous brown trout (e.g. Salmonier, Colinet, Renews), which may have evolved partially for colonizing new river systems, but possibly in response to competition from salmon.

In other studies it has been found that where the two species coexist salmon are generally found in the wider parts of the river, and brown trout are more common in the smallest streams (Lindroth 1955; Power 1973). Lillehammer (1973b) noted in the river Suldalslagen in west Norway that the river biotope was optional for salmon as they dominated brown trout there in the ratio of 3:1, whereas in streams the biotopes seem to be optimal for trout as they dominated there in the ratio of 2:1. This situation appears not to hold in this study. The upper station of the North Arm River was a small stream (about 5 m wide), yet salmon dominated there. However, very small streams may be dominated by trout. E. Verspoor (pers. comm.) found in a first order brook draining into the west branch of the North Arm River that brown trout were very much more abundant than salmon (in a ratio of about 8:1), and brown trout were more abundant than the brook trout (in a ratio of about 3:1). Probably water velocity, water temperature and cover in the form of depth or shade are more important parameters of the habitat in regulating relative numbers rather than stream size per se (Fig. 14).

On the west coast of the Avalon Peninsula an interesting situation has been brought to our attention by M. O'Connell (Department of Fisheries and Oceans, P. O. Box 5667, St. John's, Newfoundland A1C 5X1, pers. comm.), where two very similar fourth order rivers (Northeast River and Southeast River) drain into the same estuary (Northeast and Southeast Arm, Placentia). Brown trout thrive in the main stem of the Northeast River, yet apparently are not present in the Southeast River. In the Northeast River the brown trout are abundant in the main lower river, yet have not been recorded through a fishway in the upper part of the main stem where salmon are counted migrating upriver. In the headwater lakes and tributary streams of Northeast River brook trout and salmon are abundant, but brown trout are rare. In the Southeast River, which appears to have the same types of habitat as the Northeast River, brown trout apparently are absent, although anadromous brown trout are caught in the Southeast Arm, a marine estuary. Salmon and brook trout are abundant in both systems. Subtle differences in habitat or fish communities must determine success of the brown trout in Newfoundland.

The physical parameters of microhabitats occupied by brown trout have been described by Baldes and Vincent (1969). They found that brown trout occupied resting microhabitats within a velocity range of 12.2 to 2.13 cm/sec., and that turbulence, light, water depth, spatial limits, direction of flow, and cover also influence selection. Areas were not used in an experimental flume because of one or combination of the following: (1) shallow water (< 5 cm); (2) too slow (< 12.2 cm/s); (3) too fast (> 21.3 cm/s); (4) time in direct sunlight; (5) turbulence; (6) lack of cover; and (7) spatial requirements. Lewis (1969) investigated physical factors influencing fish populations in a stream in Montana. He discovered that surface area, volume, depth, current velocity and cover accounted for 70 to 77% of the variation in numbers of trout over 6.9 inches T.L. Cover was the most important factor for brown trout, and current velocity for rainbow trout. Faster current velocities contributed to an increase in brown trout numbers above that expected on the basis of cover alone. Schuck and Kingsbury (1948) found a significantly greater number of brown trout present in fast-water sections than in slow-water sections. Also growth was greater in fast water.

It appears therefore that there is considerable overlap of habitat between brown trout and juvenile salmon, but that interactive segregation operates to spatially segregate the two species when food is in short supply, as has been found for other salmonids (Nilsson 1963, 1967). The mechanisms most likely involved are exploitation and interference, as defined by Brian (1956a, 1956b). Interference by aggression is a very likely cause between fish of similar sizes, but experimental evidence is lacking. It is also probable that exploitation is a likely cause, as the behavior and physical adaptations of each species favor one species over another in the appropriate habitat.

Findings from this study suggest that brown trout is not the serious competitor with salmon in Newfoundland that it is generally thought. It is not suggested that the brown trout has no effect. Salmon parr can inhabit pools and slow water areas if other fish species are sparse, and brown trout have the competitive advantage over salmon in deep water pools, especially with cover present. Also large brown trout are piscivorous, so that the occasional large trout in deep pools would probably reduce the salmon population in such habitats by predation. Also it is very likely that sea run brown trout prey on salmon smolts in the estuaries, as occurs in Ireland (Piggins 1958). The further distributions of brown trout should therefore not be encouraged, also on the grounds that under some circumstances the species does reduce brook trout populations (Nelson 1965; Nyman 1970; Fausch and White 1981; Waters 1983), especially in warmer waters (Brynildson et al. 1964). Anecdotal evidence suggests that in streams of St. John's channelizing of streams favors brown trout over brook trout (Gibson 1985; Hannaford 1985).

Climatic factors and associated habitat and inter-specific competition probably restrict the further distribution of brown trout in streams in Newfoundland. This may also apply to the Maritimes and to Quebec, as only rarely do brown trout appear in salmon rivers of these provinces, although brown trout occur in southern New Brunswick and rivers further south (Camile Pomerleau, pers. comm.).

It is unlikely that brown trout can be eradicated from the streams they now inhabit, without damaging these ecosystems. It is possible sea-run brown trout could be netted from estuaries of salmon rivers prior to each smolt run, although the density of the sea trout and their predation rate in Newfoundland rivers is unknown, so such a plan is not recommended. Brown trout in Newfoundland appear to be generally despised, but a logical step is to encourage acceptance of the species and the availability of the high quality angling that it provides. In Norway and Sweden the Arctic charr (Salvelinus alpinus) tends to displace brown trout (Schmidt-Nielson 1939; Svardson 1949; Curry-Lindahl 1957; Nilsson 1960). This is looked upon as an unsatisfactory situation there as brown trout is the preferred species. However, Arctic charr is a more desired species here, so an introduction of the desired strain into lakes with brown trout could improve the angling in Newfoundland waters. Evidently spring salmon (Oncorhynchus tshawytscha) has been introduced into lakes in New Hampshire where smelt negatively affected brook trout production. It preyed on and eliminated smelt, but did not reproduce itself, and provided good angling in the interim. The lakes were then re-stocked with brook trout after the salmon itself had died out (Scott and Crossman, 1973). This may possibly be a management tool to reduce unwanted brown trout populations in lakes, although the possible dangers of introducing another salmonid would have to be carefully assessed. However, brown trout is a highly desired species in Europe and in most of North America and several other countries where it has been introduced. Its acceptance or otherwise is therefore mainly conventional, and the best policy appears to be to encourage its exploitation as a desirable game fish, which may also attract a tourist industry related to angling for brown trout. In other parts of North America, because the species is somewhat more difficult to catch, it has been found to survive heavy angling pressure better than the native salmonids, and therefore to support continued angling better. As St. John's in the near future will experience increased growth in population, the brown trout will probably be accepted as a desirable fish to have in adjacent streams and ponds.

SUMMARY

Brown trout (*Salmo trutta* L.) are abundant in many rivers of the Avalon Peninsula, Newfoundland, including rivers producing Atlantic salmon (*Salmo salar* L.). Information from the literature regarding competitive interactions between brown trout and Atlantic salmon in Europe is conflicting. As brown trout is an introduced species in Newfoundland, and the indigenous fish communities have not evolved in coexistence with brown trout, it has been hypothesized that brown trout populations may be still expanding, with negative effects on Atlantic salmon. The present study was undertaken to investigate possible competitive interactions between brown trout and juvenile Atlantic salmon.

Underwater observations were made at four sites on the Avalon Peninsula, three with both salmon and brown trout present, and one with only brown trout. The two species were generally spatially segregated, with brown trout older than 0+ occurring in deeper slower water than salmon, although overhanging cover was a substitute for depth. The most obvious segregation of the two species was in the largest river, the Salmonier, where differences in habitat were greater than at other stations (Fig. 13). The salmon:trout ratio was 45:1 in the riffle, and 1:3.2 in the pool. The mean water velocity at which each species was seen were: salmon 34.2 cm/s (SE 1.10); brown trout 13.8 cm/s (SE 1.10); and mean depths, salmon 54.7 cm (SE 2.21), brown trout 72.1 cm (SE 2.59). Depth and velocity preferences were significantly different ($P < 0.01$). There was considerable overlap of habitat distribution where the two species coexisted in the smaller stream investigated, the North Arm River. At an upstream station the ratio of salmon:brown trout was 5.7:1 in a riffle and flat, and 1.1:1 in a pool. Mean water velocities in which each species was seen were: salmon 18.0 cm $^{-1}$ (SE 1.84), brown trout 17.1 cm s^{-1} (SE 1.74). Mean depths were: salmon 39.8 cm (SE 3.13), brown trout 49.4 cm (SE 2.61). These velocity and depth preferences were not significantly different ($P > 0.05$). At a downstream station on the North Arm River the salmon:trout ratio was 4.3:1 in the riffle, and 3.6:1 in the pool. The salmon at this station were common in relatively slow water velocities of the pool. Other studies suggest this would be unsuitable habitat for salmon parr if fish species diversity were higher. The mean water velocities where fish were seen were, for the riffle: salmon 20.5 cm s^{-1} (SE 0.23), brown trout 12.2 cm s^{-1} (SE 3.13); and for the pool: salmon 9.2 cm s^{-1} (SE 0.93), brown trout

7.3 cm s^{-1} (SE 2.15). Overall mean velocities (and SE) were: salmon 13.7 cm s^{-1} (1.10), trout 8.81 cm s^{-1} (1.98), which were significantly different ($P < 0.05$). The respective mean depths were, for the riffle: salmon 32.0 cm (SE 1.34), brown trout 27.0 cm (SE 1.78); and for the pool: salmon 47.1 cm (SE 1.37), brown trout 44.0 cm (SE 5.0). These depths were not significantly different ($P > 0.05$). In the stream where there were no salmon (Broad Cove Brook), brown trout were seen in shallow open water, of about 31 cm depth, as well as in deeper water. Mean depth of holding stations was 46.5 cm (SE 2.53), and mean velocity 11.5 cm s^{-1} (SE 0.94).

There was considerable change in numbers of fish seen through the season, with least numbers seen during cold temperatures and high water in the early spring and late fall. Least growth of both salmon and trout was at the station in the Salmonier River. Best growth of brown trout was in Broad Cove Brook. Compared with growth over its world distribution, growth of brown trout in Newfoundland is at the low end of the scale. Growth continued through the season, but condition factors decreased from spring to fall.

Invertebrate collections from kick samples showed differences both seasonally and between sites. Chironomid larvae and pupae were the most abundant invertebrates sampled at all sites, regardless of the season. Sphaerid clams were very common in North Arm River collections, but virtually absent from other sites. Oligochaeta were the major component in the stream benthos in the Salmonier River and at the downstream site in the North Arm River. Most of the insect fauna collected (other than chironomids) showed seasonal fluctuations in abundance as well as variation between stream sites.

Except for the North Arm River in October there was a significant similarity in diet of the two species analyzed for fish older than underyearlings. Differences were found in selectivity indices for the various taxa by the two species, but were probably a function of microhabitat differences between trout and salmon and the concomitant prey availability within these microhabitats. Juvenile Atlantic salmon preyed substantially more on ephemeropteran nymphs and simuliid larvae than did brown trout, which preyed on terrestrial invertebrates in the surface drift more than the salmon.

The two species apparently are ecologically compatible, and competition appears to be minimized by habitat segregation related mainly to water velocity and depth. There is some segregation also in time in that brown trout fry emerge earlier, and brown trout feed longer than salmon by also feeding at cooler temperatures, documented in other studies. In most situations this gives brown trout an advantage over juvenile salmon in size. Salmon appear to have the competitive advantage in riffles, and if similar to the situation with brook trout, probably the displacing mechanism in this habitat is by exploitation and aggression. Brown trout may displace salmon from the pool environment, possibly by exploitation, aggression and predation.

The present study shows no evidence that brown trout are more severe competitors of salmon than brook trout, or that brown trout are displacing salmon from their natural distribution. However, further experimental evidence is required, especially related to relative aggression and to inter-specific effects on growth in riffle and pool environments. Since brown trout have been in Newfoundland for the last 100 years, and yet occur only in river systems of the Avalon Peninsula and adjacent bays, it appears that climatic factors and habitat in conjunction with competition from salmon and brook trout is limiting their further distribution to other parts of the island. However, successful introductions above obstructions, by accident or otherwise, are possible. The anadromous form is common, although the resident strain of brown trout was initially introduced to Newfoundland. It is suggested the anadromous form has evolved as a strategy for colonizing new river systems and for successfully competing in river systems where there is strong competition from salmon.

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Table 1. Physical characteristics of the diving stations, measured during low flows in mid-June.

Location	Type of habitat	Predominant substrate	Length (m)	Width (m)	Mean depth (cm)	Maximum depth (cm)	Mean water velocity ($cm\ s^{-1}$)	Shade cover	Discharge at low flow ($m^3 s^{-1}$)
Salmonier River	riffle	cobble	14.1	10.6	45.3	70.0	36.3	0	
	pool	mud, sand, cobble	19.2	3.7*	68.8	86.0	15.3	canopy cover,	2.2
North Arm River, downstream	riffle	gravel, cobble rubble	10.0	11.0	23.0	42.0	25.0	< 5 % (alders, left side)	0.2
	pool	cobble, rubble	11.0	13.0	40.0	55.0	5.6		
North Arm River, upstream	riffle	cobble	5.6	4.0	16.7	45.0	50.0	0	0.2
	pool	bedrock, boulder, cobble	5.4	6.0	48.7	63.0	12.8	0	
	flat	cobble	4.0	7.0	24.0	28.0	17.4	0	
Broad Cove	pool	bedrock, boulder, cobble	6.8	4.5	36.4	61.0	7.4	0	0.15
	flat	cobble, bedrock	4.1	4.2	23.0	37.0	19.4	4	

*Whole river, 23.8 m.

Table 2. Underwater observations in the Salmonier River.

Date day/month	Weather	Temp. (°C)	Relative water level (cm)	Riffle: Species (no.)	Riffle: Depth (cm)	Riffle: Water velocity (cm/s)	Riffle: No./100 m²	Pool: Species (no.)	Pool: Depth (cm)	Pool: Water velocity (cm/s)	Pool: No./100 m²	Relative numbers Riffle:Pool S	T	C
24/5	Overcast	11.5	-	S (6)	46.7 (4.70)	-	1.85	T (4)	90.0 (0)	-	4.44	1.9:0	0.1:1.0	0:1.4
				T (1)	50.0	-	0.31	C (1)	90.0		1.43			
4/6	Overcast, Showers	12.7	3.8	S (3)	50.0 (4.97)	34.4 (8.84)	0.92	T (3)	77.7 (5.91)	9.1 (1.86)	4.29	1.0:0	0:4.3	0:1.4
								C (1)	76.0	14.9	1.43			
20/6	Sunny	16.0	0	S (12)	46.3 (10.90)	36.6 (11.09)	8.0	T (13)	77.3 (10.59)	11.0 (3.72)	18.57	2.8:1.0	0:18.6	0.2:1.0
				C (1)	63.0	30.8	0.67	S (2)	71.0 (0.71)	11.0 (1.83)	2.86			
								C (2)	84.0 (0)	6.7 (6.71)	2.86			
27/6	Sunny	15.0	0.1	S (15)	54.3 (10.25)	34.4 (6.71)	10.0	T (7)	74.4 (6.99)	10.7 (5.36)	10.0	2.3:1.0	0:10.0	0.7:0
				C (1)	40.0	24.1	0.67	S (3)	81.0 (6.38)	13.1 (1.16)	4.29			
10/8	Sunny, Cloudy intervals	18.2	15.0	S (8)	49.4 (11.03)	50.0 (13.41)	5.33	T (2)	67.0 (21.0)	10.7 (10.67)	2.86	1.9:1.0	0:2.9	-
								S (2)	85.5 (6.50)	22.9 (11.58)	2.86			
6/10	Overcast	12.2	17.3	S (1)	53.0	55.8	0.67	S (2)	76.0 (11.0)	11.3 (3.96)	2.86	0.2:1.0	-	-

S = salmon parr; T = brown trout; C = brook trout.

The relative water level is the level above the lowest recorded, on 20 June. (Standard deviation about the mean for water velocities and depths is given in brackets).

Table 3. The locations and numbers of salmonids observed in the North Arm River, downstream study area. S = salmon parr; T = brown trout; C = brook trout. Mean values are given for depths and velocities (SD in brackets).

			Riffle					Pool					Relative no. Riffle:Pool	
Date	Weather	Water temp. (°C)	Species	No.	No./100 m^2	Depth (cm)	Velocity (cm s^{-1})	Species	No.	No./100 m^2	Depth (cm)	Velocity (cm s^{-1})	S	T
12/6	Overcast	15.8	S	6	6.7	28.4 (6.50)	16.3 (5.69)	S	9	6.3	43.3 (5.48)	6.1 (3.14)	1.1:1	0.2:1
			T	0	0	-	-	T	3	2.1	34.2 (9.19)	4.5 (2.83)		
21/6*	Sunny	16.8	S	5	5.6	28.4 (3.44)	13.6 (2.86)	S	15	10.5	42.4 (8.65)	5.9 (1.33)	0.5:1	0.4:1
			T	1	1.1	19.0	-	T	4	2.8	36.3 (16.08)	1.9 (3.30)		
17/8	Cloudy	16.4	S	11	12.2	31.3 (5.12)	25.4 (8.86)	S	11	7.7	52.7 (5.56)	14.0 (6.81)	1.6:1	0.5:1
			T	1	1.1	25.0	25.0	T	3	2.1	58.7 (10.14)	13.2 (5.97)		
8/10	Overcast, rain	12.5	S	5	5.6	41.0 (5.51)	20.7 (4.12)	S	5	3.5	54.8 (5.19)	12.9 (5.49)	1.6:1	6.3:1
			T	4	4.4	29.5 (2.29)	9.0 (4.73)	T	1	0.7	60.0	19.2		

*Also 3 brook trout in the pool, at 48.7 cm (7.76) and 1.8 cm s^{-1} (2.59).

Table 4. Under-water observations in the upper study area of the North Arm River. (Figures in brackets are relative numbers/100 m^2).

Date (day/month)	Weather	Temperature (°C)	Relative water level (cm)	Species	Riffle	Flat	Pool	Relative numbers (100 m^{-2}) riffle and flat :pool	(No./100 m^2)
30/5	Sunny	17.0	8.5	S	1 (4.6)	6 (21.4)	3 (8.6)	1.6:1	11.77
				T	1 (4.6)	0 (0)	7(20.0)	0.1:1	9.41
				C	0 (0)	1 (3.6)	1 (2.9)	0.7:1	2.35
11/6	Overcast	14.6	1.6	S	2 (9.1)	2 (7.1)	2 (5.7)	0.7:1	7.06
				T	1 (4.6)	0 (0)	5(14.3)	0.1:1	7.06
				C	1 (4.6)	0 (0)	1 (2.9)	0.7:1	2.35
21/6	Sunny	24.0	0	S	5 (20.8)	0 (0)	7 (20.0)	0.5:1	14.12
				T	0 (0)	0 (0)	0 (0)	0	0
				C	3 (13.7)	0 (0)	0 (0)	6.0:0	3.53
13/8	Cloudy, showers	18.0	13.5	S	0 (0)	1 (3.6)	2 (5.7)	0:4.1	3.53
				T	0 (0)	0 (0)	3 (8.6)	0:8.6	3.53
				C	0 (0)	0 (0)	2 (5.7)	0:5.7	2.35
5/10	Overcast	12.4	24.5	S	0 (0)	0 (0)	2 (5.7)	0:5.7	2.35
				T	1 (4.6)	0 (0)	0 (0)	2:0	1.17
				C	0 (0)	0 (0)	0 (0)	0	0

S = salmon parr; T = brown trout; C = brook trout

The relative water level shows the changes related to the lowest recorded, on 21 June.

Table 5. The relative water velocities and depths chosen by salmonids seen in the upper study area of the North Arm River. Mean values are given (SD in brackets). Velocity is in cm/s and depth in cm.

Date (day/month)	Salmon		Brown trout		Brook trout	
	Velocity	Depth	Velocity	Depth	Velocity	Depth
30/5	22.1 (6.74)	32.6 (14.33)	22.7 (5.59)	45.8 (9.20)	14.5 (0.15)	48.0 (3.0)
11/6	13.4 (6.09)	39.0 (16.11)	10.7 (2.28)	51.5 (8.04)	5.4 (5.35)	27.5 (8.50)
21/6	18.7 (13.70)	38.0 (13.92)	-	-	22.06 (0.33)	35.7 (0.94)
13/8	12.3 (8.05)	47.0 (13.06)	16.5 (6.51)	58.0 (13.93)	21.3 (0)	50.0 (0)
5/10	16.2 (5.15)	78.0 (11.0)	12.5	40.0	-	-
Total:	18.0 (10.42)	39.8 (17.69)	17.1 (7.19)	49.4 (10.78)	16.5 (7.10)	39.8 (9.78)

Table 6. The numbers of brown trout observed in Broad Cove Brook and the depths and water velocities at their holding stations (SD in brackets).

			Upstream stations				Pool station			
Date (day/month)	Weather	Temp. (°C)	No.	No./ 100 m^2	Depth (cm)	Vel. (cm/s)	No.	No./ 100 m^2	Depth (cm)	Vel. (cm/s)
31/5	Sunny	18	6	44*	21.7 (1.97)	18.2 (7.61)	16	55	55.6 (17.59)	13.6 (7.50)
13/6	Overcast	16.2	6	34.8	31.7 (2.98)	9.9 (1.74)	10	34.5	53.4 (15.44)	11.1 (8.35)
22/6	Cloudy	16.6	7	40.7	30.4 (1.40)	8.3 (2.37)	10	34.5	61.8 (3.60)	8.1 (0.37)
3/8	Cloudy	18	0	0	-	-	6	20.7	50.1 (5.73)	2.6 (1.87)
4/10	Overcast	10.7	1	5.8**	38	11.9	8	27.6**	63.0 (9.97)	8.4 (6.50)

*The area for this observation was different from the area used in following observations.

**If the fish later caught by electro-shocker are included, the numbers/100 m^2 for October would be:

Flat, 52.3

Pool, 65.5

Table 7. Physical and chemical parameters measured at the time of underwater observations in the Salmonier River. (Water levels are relative to the lowest recorded, on 20 June.).

Date & time (day/month, time in hr)	Changes in water level (cm)	Temperature (°C)	pH	Conductivity (μ mhos)	Water hardness (mg/1 $CaCO_3$)
24/5 10.30	-	11.5	-	28	-
4/6 11.00	3.8	12.7	5.25	33	-
20/6 11.00	0	16.0	7.2	30	-
27/6 11.00	0.1	15.0	6.8	32	-
10/8 12.00	15.0	18.2	7.1	22	-
6/10 11.30	17.3	12.2	6.9	30	6

Table 8. Physical and chemical parameters measured at the time of underwater observations in the North Arm River, downstream station.

Date (day/month) and time (hr)	Temperature (°C)	pH	Conductivity (μ mhos)	Water hardness (mg/l $CaCo_3$
29/5 11.15	12.2	-	40	-
12/6 10.30	15.8	7.7	50	-
21/6 10.30	16.8	7.8	62	-
17/8 11.00	16.4	7.8	60	21
8/10 11.00	12.5	7.6	45	17

Table 9. Physical and chemical parameters measured in the North Arm River, upstream station. (Water levels are taken from the lowest recorded, on 21 June.).

Date (day/month) and time (hr)	Changes in water level (cm)	Temperature (°C) (Min - Max)	pH	Conductivity (μ mhos)	Water hardness (mg/l $CaCO_3$)
30/5 15.30	8.5	17.0			
11/6 10.30	1.6	14.6 (12.5 - 20.5)	7.8	42.0	
21/6 14.30	0	24.0 (14.2 - 25.2)	6.3	40.0	
13/8 12.00	13.5	18.0 (16.0 - 22.5)			
17/8 15.15	13.5	19.5 (9.5 - 19.5)			
5/9 14.00	19.5	17.5 (14.0 - 21.0)			
19/9 14.15	18.0	17.0 (10.0 - 17.0)			
28/9 a.m.	23.4	11.0 (10.0 - 17.0)			
5/10 16.00	24.5	12.4 (9.0 - 13.0)	7.6	40.0	13
8/10 17.00	23.5	13.5 (10.0 - 14.0)			

Table 10. Physical and chemical parameters measured at Broad Cove Brook. (Water levels are taken from the lowest recorded, on 3 August).

Date (day/month) and time (hr)	Changes in water level (cm)	Discharge (m^3s^{-1})	Temperature (°C) (min - max)	pH	Conductivity (μmhos)	Water hardness (mg/l $CACO_3$)
31/5 16.00	12.0	0.23	18.0		55	
13/6 09.30	6.0	0.14	16.2 (9.0 - 20.0)	6.9	42	
22/6 09.45	4.2	0.19	16.6 (10.7 - 22.2)	6.7	58	
30/7 15.00	2.0	0.05	23.2 (8.2 - 23.2)			
31/7 16.30	-	0.04	24.0 (17.0 - 24.0)			
1/8 12.20	-	0.03	20.0 (16.0 - 24.0)			
3/8 12.30	0	0.03	18.0 (15.0 - 22.0)			
6/8 12.00	3.0	0.08	20.0 (17.0 - 24.0)			
12/8 15.00			20.0 (13.0 - 20.0)			
27/8 15.00	4.0	0.06	18.5 (12.0 - 21.0)			
17/9 16.00	6.0	0.08	15.0 (8.5 - 19.5)			
1/10 16.00	9.0	0.10	10.0 (6.5 - 17.5)			
4/10 15.00	-		10.7		58	6
9/10 15.00	12.2	0.30	11.0 (7.0 - 13.0)			
2/11 14.00	-	1.14	5.0 (5.0 - 11.0)			

Table 11. Size related to age of salmon, brown trout, and brook trout in the Salmonier River. (Standard deviations in brackets).

Date:	24/5/79					4/6/79					26/7/79					6/10/79			
	n	F.L.	Wt.	K		n	F.L.	Wt.	K		n	F.L.	Wt.	K		n	F.L.	Wt.	K
Salmon Year-class					Salmon					Salmon					Salmon				
										0+	2	4.3	1.1						
												(0.20)	(0.05)						
1+	3	6.8	4.1	1.31						1+	1	7.0	5.8	1.69	1+	1	8.2	7.2	1.31
		(0.25)	(0.31)	(0.050)															
2+	1	9.6	11.3	1.28	2+	3	8.2	7.8	1.36	2+	4	9.2	9.8	1.25	2+	5	11.2	16.6	1.16
							(0.92)	(3.05)	(0.061)			(0.72)	(2.17)	(0.023)			(0.78)	(3.65)	(0.083)
					3+	2	11.9	21.3	1.28	3+	3	12.0	21.4	1.25	3+	7	12.0	20.0	1.10
							(0.25)	(0.50)	(0.50)			(0.76)	(2.50)	(0.091)			(1.40)	(7.22)	(0.10)
															4+	2	13.7	30.8	1.21
																	(0.60)	(1.05)	(0.12)
Brown trout Year-class					Brown Trout					Brown Trout					Brown Trout				
										0+	11	3.8	0.7		0+	3	4.3	0.9	
												(0.39)	(0.21)				(0.40)	(0.31)	
1+	6	6.13	3.17	1.29	1+	7	6.3	3.9	1.37	1+	14	7.3	5.4	1.36	1+	3	8.2	6.7	1.20
		(0.89)	(1.24)	(0.051)			(0.98)	(1.67)	(0.079)			(0.80)	(1.63)	(0.088)			(0.37)	(0.92)	(0.050)
2+	10	9.7	11.7	1.27	2+	6	10.2	15.5	1.41	2+	12	10.9	17.4	1.31	2+	6	10.1	13.7	1.28
		(0.83)	(2.82)	(0.083)			(0.96)	(4.57)	(0.052)			(0.89)	(4.62)	(0.12)			(0.94)	(3.64)	(0.056)
3+	1	10.7	16.4	1.34	3+	1	32.4	462.0	1.36	3+	4	12.6	23.9	1.18	3+	2	12.0	22.0	1.27
												(0.50)	(3.33)	(0.066)			(0)	(1.15)	(0.07)
Brook trout Year-class					Brook Trout					Brook Trout					Brook Trout				
															0+	5	5.5	2.0	
																	(0.26)	(0.18)	
1+	2	7.6	5.8	1.31	1+	1	7.3	5.5	1.41						1+	4	8.6	8.2	1.28
		(0.10)	(0.05)	(0.040)													(0.95)	(2.48)	(0.054)
2+	3	11.9	21.8	1.29	2+	1	11.1	19.0	1.39	2+	1	12.7	23.8	1.16	2+	5	14.0	34.2	1.22
		(0.57)	(2.36)	(0.045)													(1.45)	(10.24)	(0.015)
3+	2	14.3	38.6	1.32	3+	1	17.3	32.7	0.63	3+	2	13.2	28.1	1.22	3+	1	15.1	34.7	1.01
		(0.40)	(1.80)	(0.050)								(0.40)	(1.40)	(0.050)					
										4+	2	20.6	113.0	1.29					
												(2.1)	(25.8)	(0.095)					

F.L. = Fork Length in cm; Wt. = Weight in g; K = Condition factor, Wt. x 100 x $F.L.^{-3}$

Table 12. Size related to age of salmon, brown trout, and brook trout in the North Arm River, downstream section. (Standard deviations in brackets).

Date:	29/5 and 4/6					25/7					8/10			
	n	FL	Wt	K		n	FL	Wt	K		n	FL	Wt	K
Salmon Year-class					Salmon					Salmon				
0+	1	2.6	0.20		0+	5	4.6	1.2		0+	1	4.7	1.3	
							(0.30)	(0.22)						
1+	5	5.7	2.7	1.38	1+	5	7.9	6.3	1.29	1+	2	7.6	5.4	1.23
		(0.70)	(0.84)	(0.040)			(0.40)	(1.087)	(0.057)			(0.30)	(0.60)	(0.005)
2+	21	9.6	12.2	1.34	2+	6	10.5	15.0	1.28	2+	6	10.4	14.5	1.26
		(0.66)	(2.85)	(0.07)			(0.51)	(2.59)	(0.095)			(0.72)	(3.51)	(0.065)
3+	4	12.2	24.7	1.38	3+	4	12.8	26.6	1.25	3+	4	13.2	29.0	1.23
		(0.84)	(3.24)	(0.12)			(0.59)	(3.72)	(0.033)			(0.98)	(7.14)	(0.088)
					4+	1	15.0	48.4	1.43					
Brown trout Year-class					Brown trout					Brown trout				
					0+	5	4.1	0.9						
							(0.42)	(0.27)						
1+	11	6.9	4.5	1.37	1+	7	8.6	7.6	1.14					
		(0.61)	(1.11)	(0.05)			(0.96)	(3.12)	(0.069)					
2+	3	11.0	17.9	1.33	2+	1	13.6	32.4	1.29					
		(0.82)	(3.64)	(0.037)										
					5+	1	20.6	103.5	1.18	3+	4	17.4	62.9	1.19
												(1.52)	(14.36)	(0.055)

Table 12 (cont'd)

Date:	29/5 and 4/6					25/7					8/10			
	n	FL	Wt	K		n	FL	Wt	K		n	FL	Wt	K
Brook trout Year-class					Brook trout					Brook trout				
										2+	1	14.3	33.4	1.14

FL = fork length in cm; Wt = weight in g; K = condition factor, Wt x 100 x FL^{-3}.

Table 13. Size related to age of salmon, brown trout, and brook trout in the North Arm River, upstream section. (Standard deviations in brackets.)

Date:	30/5 and 4/6				26/7					5/10				
	n	FL	Wt	K		n	FL	Wt	K		n	FL	Wt	K
Salmon Year-class					**Salmon**					**Salmon**				
0+	2	2.8	0.25		0+	7	4.6 (0.27)	1.5 (0.21)		0+	7	5.3 (0.41)	1.9 (0.46)	
1+	19	7.3 (0.54)	5.6 (1.25)	1.40 (0.06)	1+	5	8.6 (0.61)	8.6 (1.85)	1.32 (0.048)	1+	5	8.3 (1.0)	7.9 (2.81)	1.33 (0.067)
2+	12	10.6 (1.20)	17.0 (5.23)	1.38 (0.088)	2+	4	11.4 (0.40)	18.4 (1.62)	1.23 (0.059)					
3+	6	13.4 (1.09)	32.3 (7.92)	1.32 (0.049)	3+	2	13.5 (1.05)	29.7 (6.75)	1.20 (0.005)					
Brown trout Year-class					**Brown trout**					**Brown trout**				
					0+	2	5.3 (0.15)	2.1 (0.15)						
1+	2	8.3 (0.30)	7.4 (0.95)	1.28 (0.025)	1+	3	9.6 (0.47)	11.0 (1.81)	1.22 (0.033)	1+	2	10.9 (0.75)	15.2 (3.08)	1.17 (0)
2+	4	11.7 (1.58)	18.5 (5.09)	1.16 (0.18)	2+	5	12.9 (0.72)	25.4 (3.11)	1.19 (0.057)	2+	1	13.4	28.0	1.16
3+	5	13.9 (0.65)	32.4 (3.54)	1.21 (0.10)	3+	1	14.8	37.5	1.16					

Table 13 (cont'd)

Date:	30/5 and 4/6					26/7					5/10			
	n	FL	Wt	K		n	FL	Wt	K		n	FL	Wt	K
Brook trout Year-class					Brook trout					Brook trout				
0+	1	2.7	0.2											
1+	1	8.9	9.3	1.32										
2+	1	10.8	17.7	1.41	2+	1	11.4	17.1	1.15					

FL = fork length in cm; Wt = weight in g; K = condition factor, Wt x 100 x FL^{-3}.

Table 14. Size related to age of brown trout in Broad Cove Brook. (Standard deviations in brackets.)

Date:	31/5				26/7				4/10			
Year-class	n	FL	Wt	K	n	FL	Wt	K	n	FL	Wt	K
0+	-	-	-	-	7	5.1 (0.16)	2.1 (0.24)	-	6	5.9 (0.41)	2.7 (0.54)	1.28 (0.045)
1+	16	7.7 (0.85)	7.0 (2.15)	1.51 (0.090)	10	9.3 (1.01)	12.3 (4.18)	1.47 (0.069)	34	10.5 (1.35)	15.7 (5.39)	1.29 (0.076)
2+	2	12.5 (0)	26.7 (1.35)	1.37 (0.065)	2	12.9 (1.35)	32.1 (9.05)	1.48 (0.035)	4	16.9 (2.09)	65.4 (25.29)	1.30 (0.042)
3+	3	17.1 (0.81)	71.5 (11.83)	1.41 (0.048)	1	16.4	55.2	1.25	4	19.2 (0.93)	86.4 (16.28)	1.22 (0.065)
4+	1	21.0	117.3	1.27								

FL = fork length in cm; Wt = weight in g; K = condition factor, Wt x 100 x FL^{-3}.

Table 15. Mean condition factors (K) of salmon and brown trout in the study areas during 1979. (Standard deviations in brackets.)

River	Species	April 10	May 29 - June 4	July 25-27	October 4-8
Salmonier	Salmon	1.05* (0.15)	1.33 (0.070)	1.31 (0.16)	1.15 (0.11)
	Trout	1.21* (0.38)	1.39 (0.069)	1.32 (0.11)	1.26 (0.68)
N. Arm (Upstream)	Salmon		1.38 (0.077)	1.27 (0.070)	1.34** (0.064)
	Trout		1.20 (0.13)	1.20 (0.050)	1.17 (0.0047)
N. Arm (Downstream)	Salmon		1.35 (0.074)	1.29 (0.079)	1.25 (0.071)
	Trout		1.36 (0.049)	1.16 (0.078)	1.19 (0.056)
Broad Cove	Trout		1.47 (0.11)	1.45 (0.085)	1.28 (0.075)

$K = Wt\ (g) \times 100 \times FL\ (cm)^{-3}$.

* These samples were taken by K. McAuley and M. Branden (pers. comm.)

**A small sample of six, with two mature salmon, one male with a K of 1.44, and the other a female with K of 1.38

Table 16. The percentages of mature brown trout and mature male salmon at the four locations, from samples in July and October. Numbers of mature and immature fish in the samples for brown trout are shown in brackets. M/F = total number of male/female salmon in the samples.

Location	Age class	Salmon Males	Salmon M/F	Brown trout Males	Brown trout Females
Salmonier	1+	100	1/1	0(11)	0(6)
	2+	75	4/5	0(6)	0(11)
	3+	100	4/6	0(3)	0(3)
	4+	100	2/0		
N. Arm (Upstream)	1+	50	4/6	0(3)	0(2)
	2+	0	2/2	0(2)	0(3)
	3+	100	2/0	0(1)	(0)
	4+		0/1 mat		
N. Arm Downstream	1+	100	1/6	25(4)	0(3)
	2+	87.5	8/4	100(1)	0(1)
	3+	100	6/2	100(1)	50(2)
	4+	100	1/0		
	5+			0(1)	
Broad Cove	1+			19(21)	0(23)
	2+			100(3)	0(3)
	3+			100(2)	100(3)

Table 17. Results of periodic benthic invertebrate collections from each of the study sites. Values are means of two samples.

Study site	Invertebrate abundance (# invertebrates/sample)				Invertebrate sample volume (cc)
	17/05/80	24-31/05/79	25-26/07/79	06-08/10/79	17/5/80
North Arm River Downstream	173	245	160	318	0.28
North Arm River Upstream	1084	1419	1295	-	1.96
Salmonier River	156	124	175	196	0.13
Broad Cove Brook	240	263	359	-	1.25

Table 18. Diet overlap indices (α) for overyearling brown trout and salmon at the three study sites. Values > 0.60 are assumed to indicate significant overlap.

Date (mo/yr)	Study site: North Arm River upstream	North Arm River downstream	Salmonier River
05/79	0.82	0.73	0.68
06/81	0.65	-	-
07/79	0.63	0.75	0.91
10/79	0.55	0.58	0.66

Table 19. Mean stomach fullness index (and std error) of brown trout and salmon for each site and sampling date.

	Study site						
	North Arm River upstream		North Arm River downstream		Salmonier River		Broad Cove Brook
Date	Trout	Salmon	Trout	Salmon	Trout	Salmon	Trout
24/05/79- 04/06/79	14.1 (1.1)	15.5 (1.3)	9.7 (1.3)	16.4 (1.1)	16.5 (1.2)	12.2 (1.2)	16.7 (1.2)
15/06/81	14.8 (0.8)	13.1 (0.9)	-	-	-	-	-
25/07/79- 26/07/79	14.4 (1.8)	11.6 (1.7)	11.1 (1.1)	7.2 (1.5)	15.0 (0.8)	16.9 (2.5)	12.9 (1.5)
04/10/79- 08/10/79	16.7 3.3	8.5 (2.2)	6.3 (3.2)	6.5 (1.6)	15.0 (2.2)	14.3 (1.6)	10.5 (0.9)

Table 20. Size and water velocity measurements of the experimental areas in the North Arm River. (Standard deviations are given in brackets following means.) Measurements were made in mid-July.

Section	Area (m^2)	Length (m)	Stream width (m)			Mean depth (cm)			Mean water velocity ($cm\ s^{-1}$)			Discharge ($m^3\ s^{-1}$)
			Upper	Mid	Lower	Upper	Mid	Lower	Upper	Mid	Lower	
Control	48.4	13.7	3.8	4.5	4.4	12.0(2.8)	34.0(8.29)	24.0(5.0)	46.9(5.0)	18.3(9.0)	18.9(5.0)	0.16
Riffle	46.0	10.0	4.5	3.9	5.5	30.0(5.0)	30.0(6.08)	31.3(12.92)	16.0	18.0	12.5(3.0)	0.17
Pool	29.0	7.8	1.5	4.3	2.7	18.5(1.5)	43.8(18.34)	24.0(2.4)	27.3(4.0)	5.7(9.85)	8.5(2.0)	0.05

Table 21. The sizes and condition factors, K [K = weight (g) x 100 x fork length $(cm)^{-3}$], of salmonids removed from the three experimental areas between 19 and 21 July 1979.

Control section			Riffle section			Pool section		
FL (cm)	Wt (g)	K	FL (cm)	Wt (g)	K	FL (cm)	Wt (g)	K
Salmon			Salmon			Salmon		
7.1	3.6	1.01	6.2	2.5	1.05	6.7	3.4	1.13
7.2	4.6	1.23	8.1	6.2	1.17	6.8	4.1	1.30
7.5	4.1	0.97	8.4	6.8	1.15	7.7	4.4	0.96
7.6	4.5	1.03	8.6	7.5	1.18	8.0	5.5	1.07
8.0	6.6	1.29	8.8	8.0	1.17	8.1	5.4	1.02
8.7	7.0	1.06	9.2	8.5	1.09	9.5	9.0	1.05
8.9	7.4	1.05	9.9	10.6	1.09	11.4	17.0	1.15
9.1	8.1	1.07	10.3	10.6	0.97	12.4	20.6	1.08
9.3	8.5	1.06	10.3	12.7	1.16	12.8	21.9	1.04
9.5	9.2	1.07	10.5	13.3	1.15	13.7	29.4	1.14
9.5	9.8	1.14	10.9	15.7	1.21	13.8	39.4	1.50
11.0	14.7	1.10	11.3	15.0	1.04	13.9	31.8	1.18
11.0	14.9	1.12	12.0	21.5	1.24			
11.3	15.1	1.05	13.4	29.0	1.21	Mean K (SD)		1.14(0.14)
12.0	19.0	1.10	13.8	32.9	1.25			
12.4	22.9	1.20	14.4	35.0	1.17			
13.1	23.5	1.05						
13.7	20.7	0.81	Mean K (SD)		1.14(0.07)			
13.7	25.0	0.97						
14.0	31.7	1.16						
14.1	34.1	1.22						
Mean K (SD)		1.08(0.10)						

Table 21 (cont'd)

Control section			Riffle section			Pool section		
FL (cm)	Wt (g)	K	FL (cm)	Wt (g)	K	FL (cm)	Wt (g)	K
Brown trout			Brown trout			Brown trout		
5.3	1.4	0.94	4.9	1.5	1.27	7.6	4.5	1.03
8.5	5.7	0.93	8.8	7.1	1.04	8.6	6.3	0.99
9.0	6.8	0.93	9.0	8.0	1.10	8.8	6.3	0.92
9.7	8.6	0.94	9.4	9.4	1.13	9.9	9.9	1.02
9.9	9.5	0.98				10.2	10.2	0.96
11.5	15.5	1.02	Mean K (SD)		1.14(0.08)	10.2	11.1	1.05
12.8	20.7	0.99				13.8	21.2	0.81
13.0	22.8	1.04						
14.0	29.0	1.06				Mean K (SD)		0.97(0.08)
Mean K (SD)		0.98(0.05)						
Brook trout			Brook trout			Brook trout		
12.7	22.0	1.07				10.2	11.0	1.04
						15.1	37.1	1.08

Table 22. Relative biomass of salmonids removed from the three experimental sections between 19 and 21 July 1979.

		Control	Riffle	Pool
Salmon (g)/m^2		6.1(67.8%)	5.1(89.5%)	6.6(61.7%)
Brown trout (g)/m^2		2.5(27.8%)	0.6(10.5%)	2.4(22.4%)
Brook trout (g)/m^2		0.5(5.6%)	0	1.7(15.9%)
Total salmonid biomass (g)/m^2		9.0	5.7	10.7
Ratio of salmon to brown trout	Numbers	2.3:1	4 :1	1.7:1
	Biomass	2.5:1	9.1:1	2.8:1

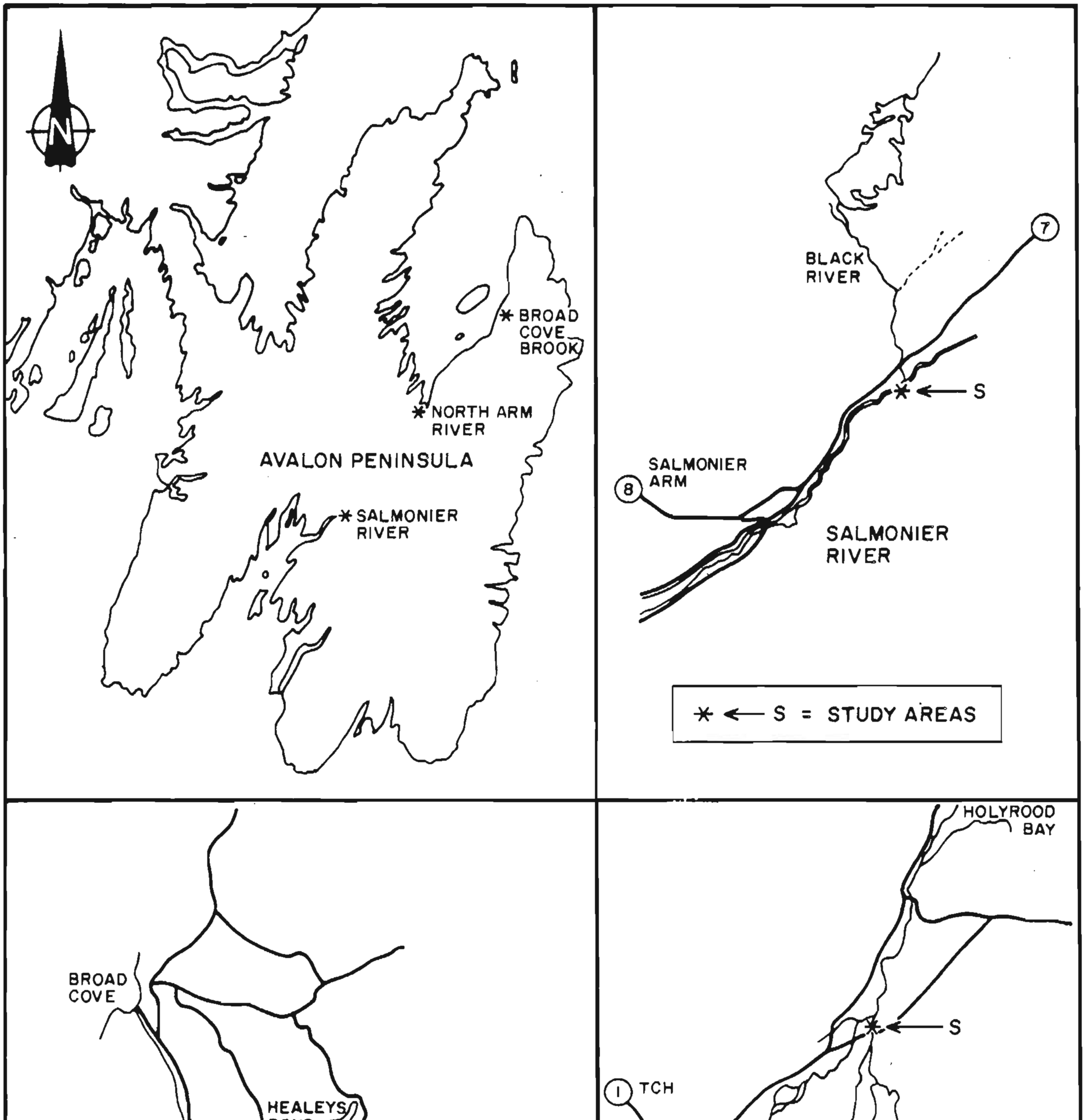

Fig. 1. The study areas and their locations on the Avalon Peninsula.

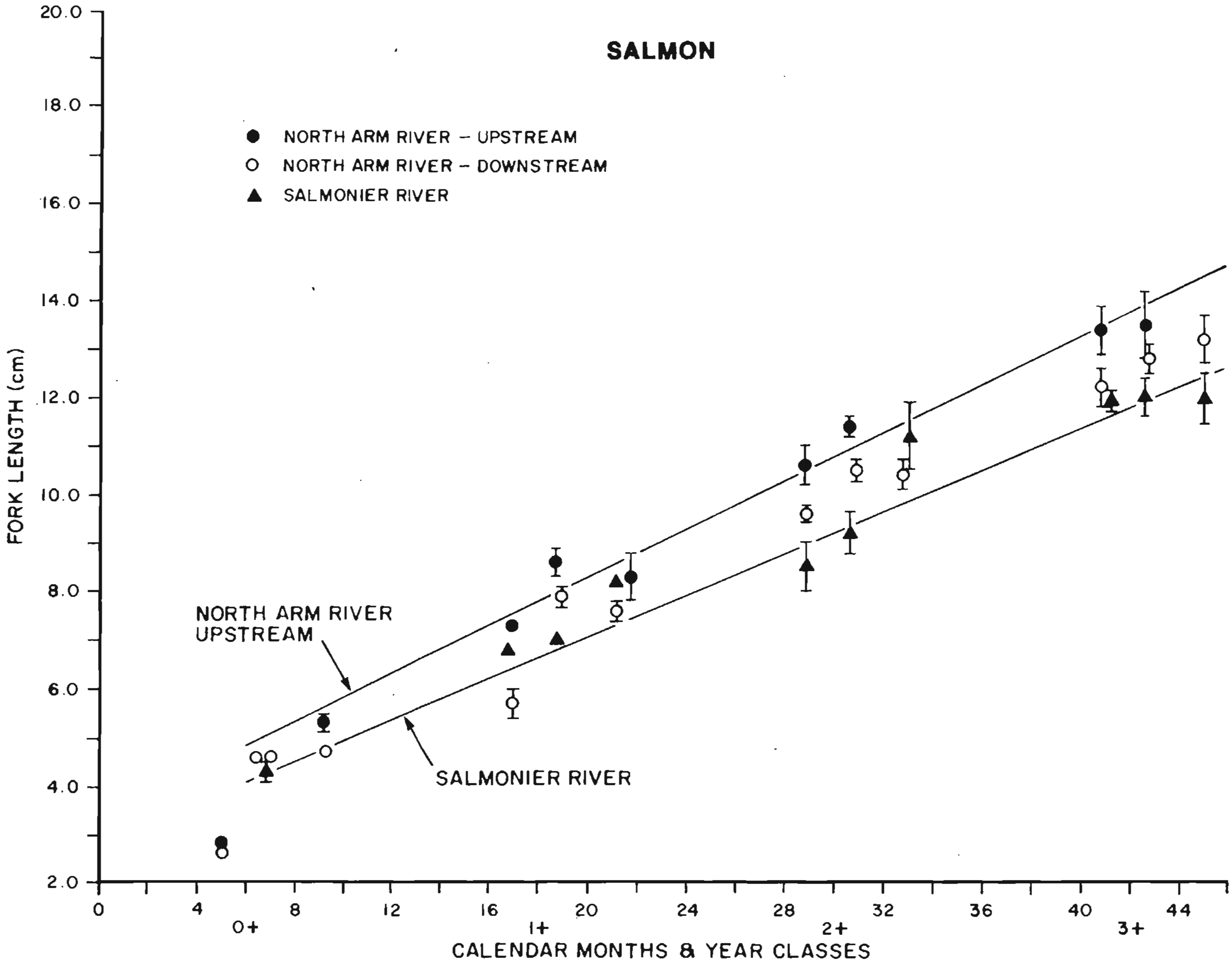

Fig. 2. The age and size relationships of young salmon sampled at the three study sites. Bars around the means are the standard errors. Regressions are plotted from the means of the July samples for the North Arm River upstream ($Y = 3.38 + 0.25X$; $r^2 = 0.98$), and the Salmonier River ($Y = 2.85 + 0.21X$; $r^2 = 1.00$).

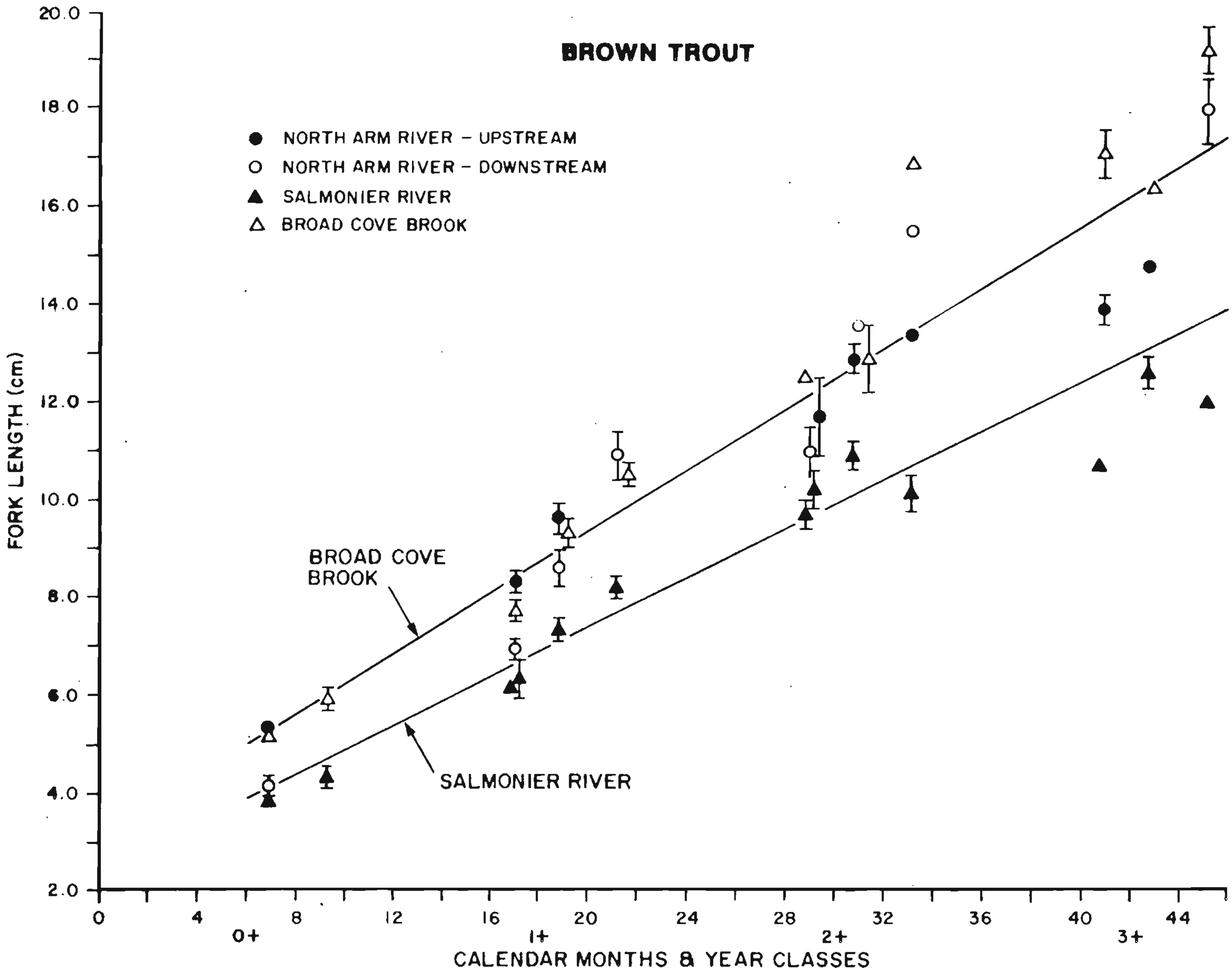

Fig. 3. The age and size relationships of brown trout sampled at the four study sites. Bars around the means represent the standard errors. Regressions are plotted for means of July samples for Broad Cove Brook ($Y = 3.11 + 0.231$; $r^2 = 1.00$), and for the Salmonier River ($Y = 2.39 + 0.25X$; $r^2 = 0.98$).

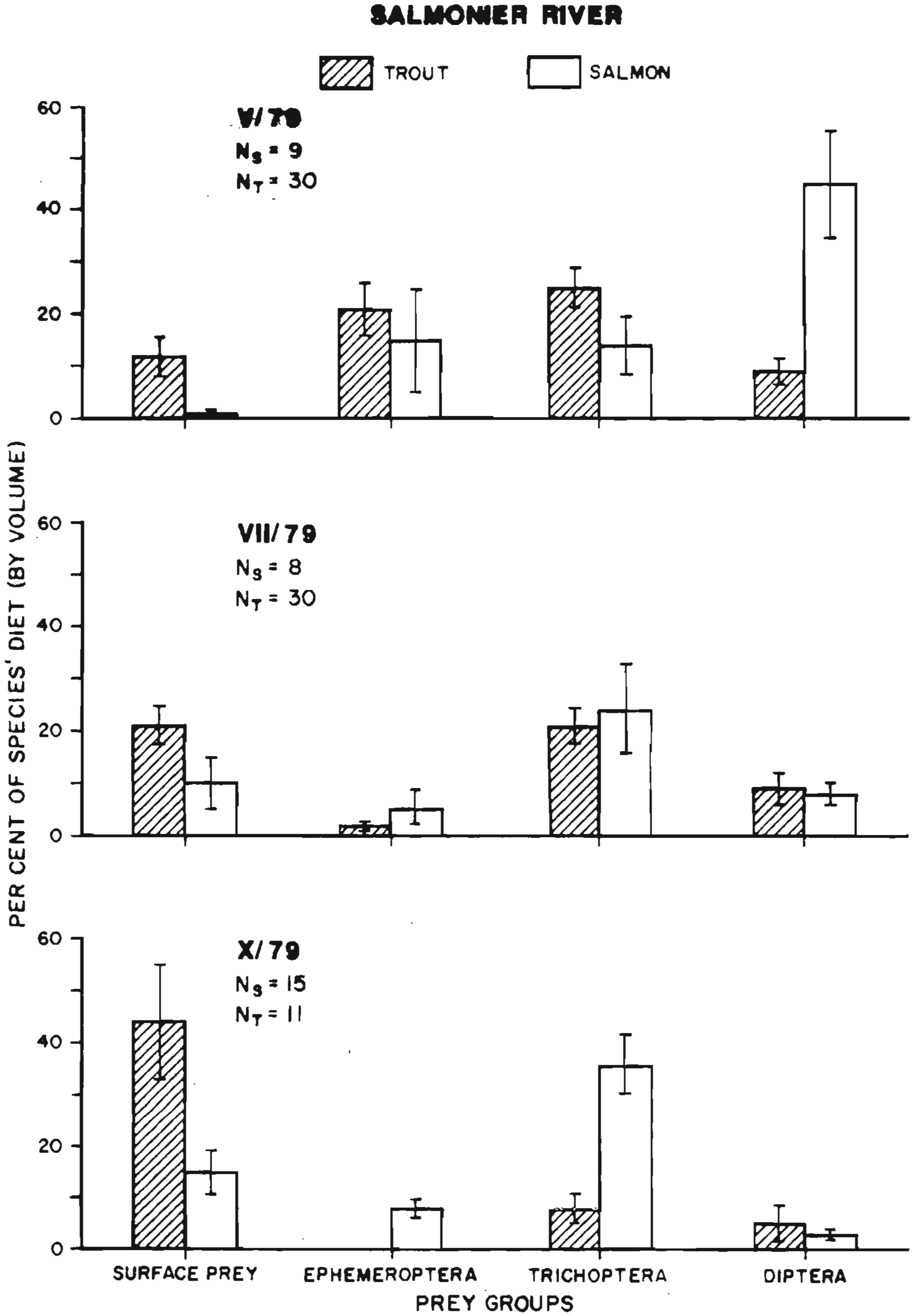

Fig. 4. Major prey groups consumed by overyearling Atlantic salmon (open bars) and brown trout (hatched bars) at Salmonier River during different times of the year. Vertical range bars indicate standard errors. N_S = sample size of salmon; N_T = sample size of trout.

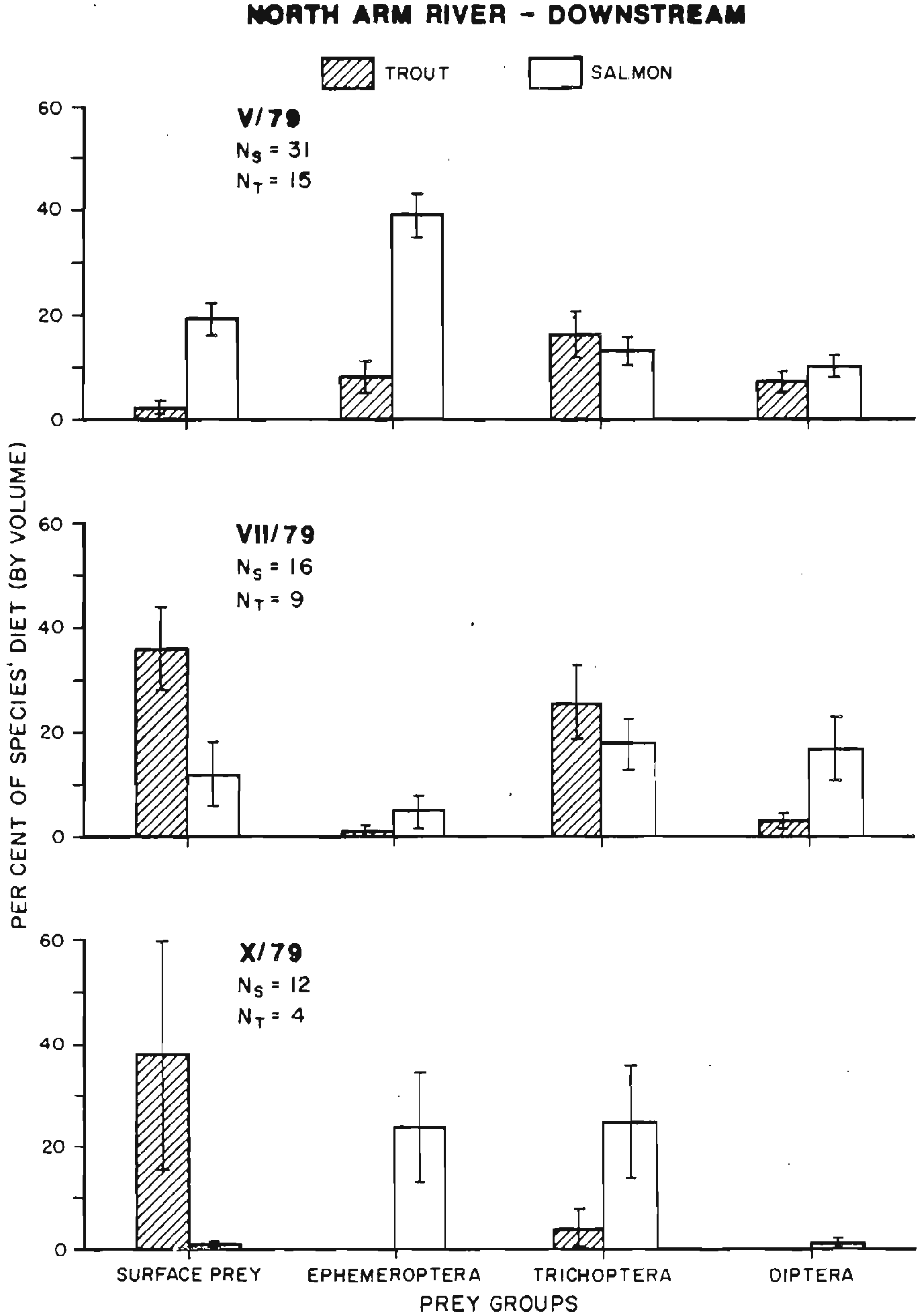

Fig. 5. Major prey groups consumed by overyearling Atlantic salmon (open bars) and brown trout (hatched bars) at the North Arm River downstream, during different times of year. Vertical range bars indicate standard errors. N_S = sample size of salmon; N_T = sample size of trout.

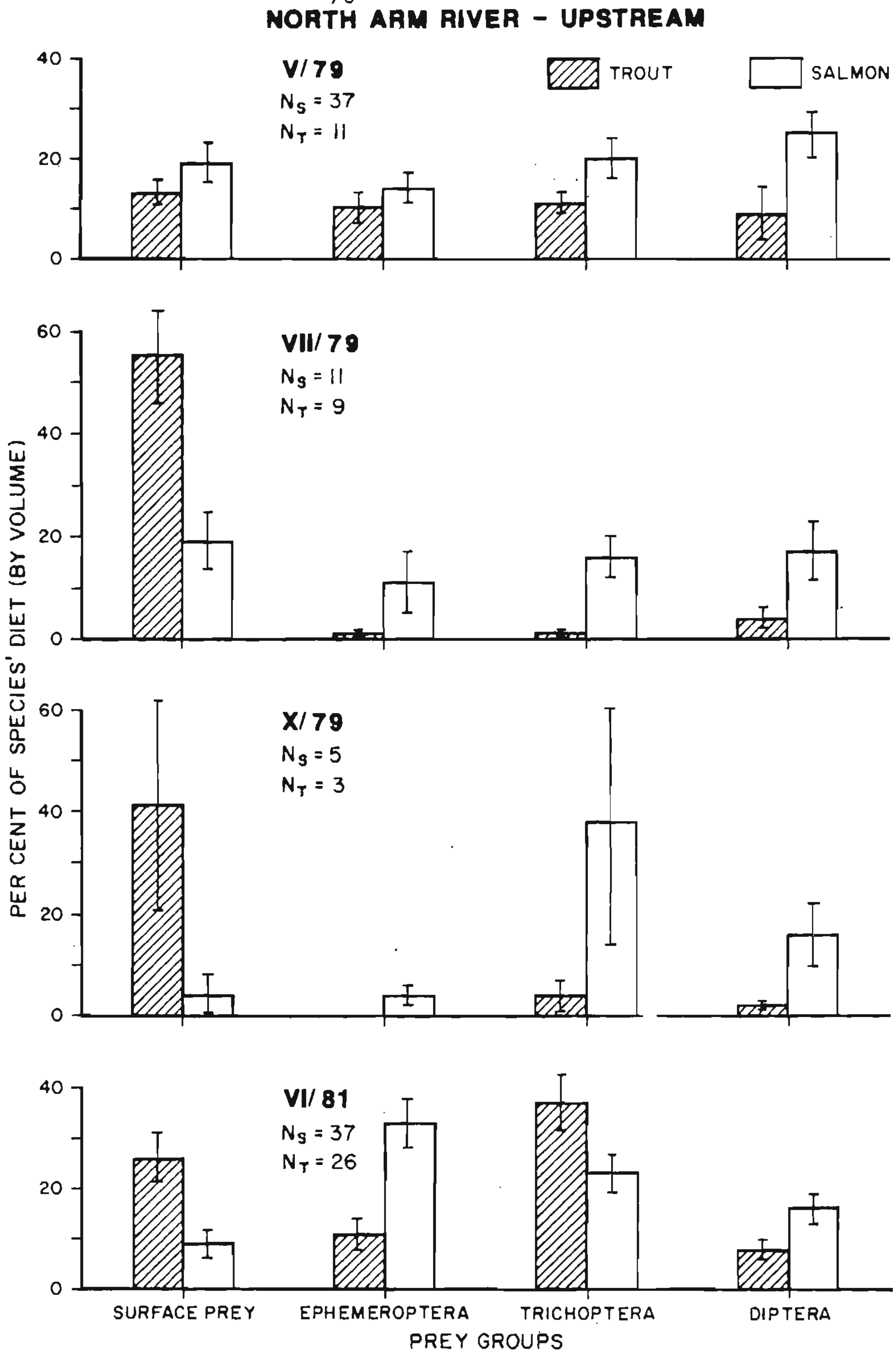

Fig. 6. Major prey groups consumed by overyearling Atlantic salmon (open bars) and brown trout (hatched bars) at the North Arm River upstream, during different times of the year in 1979 and in June 1981. Vertical range bars indicate the standard errors. N_S = sample size of salmon; N_T = sample size of trout.

BROAD COVE BROOK

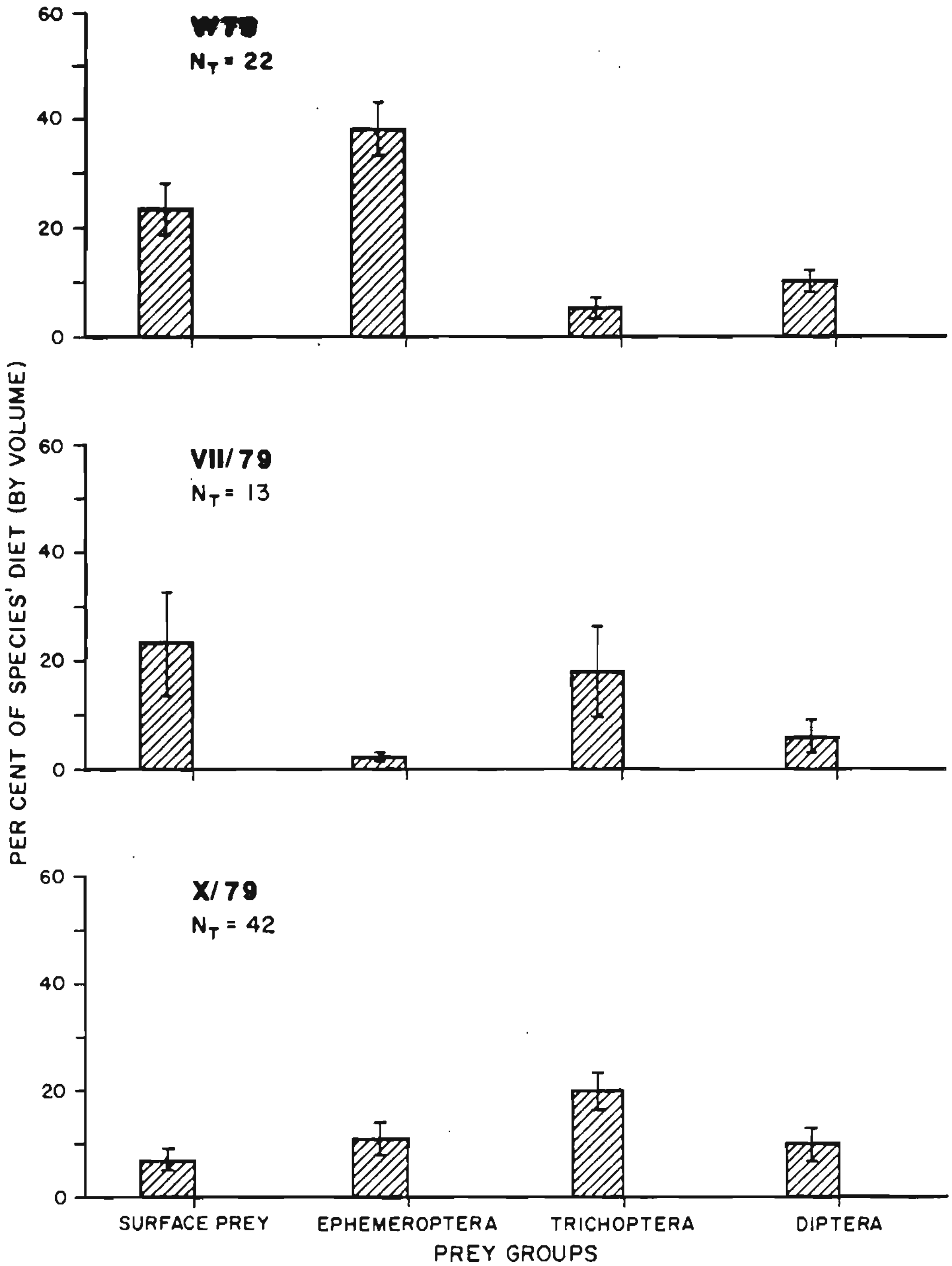

Fig. 7. Major prey groups consumed by brown trout in Broad Cove Brook. Vertical range bars represent standard errors. N_T = sample size.

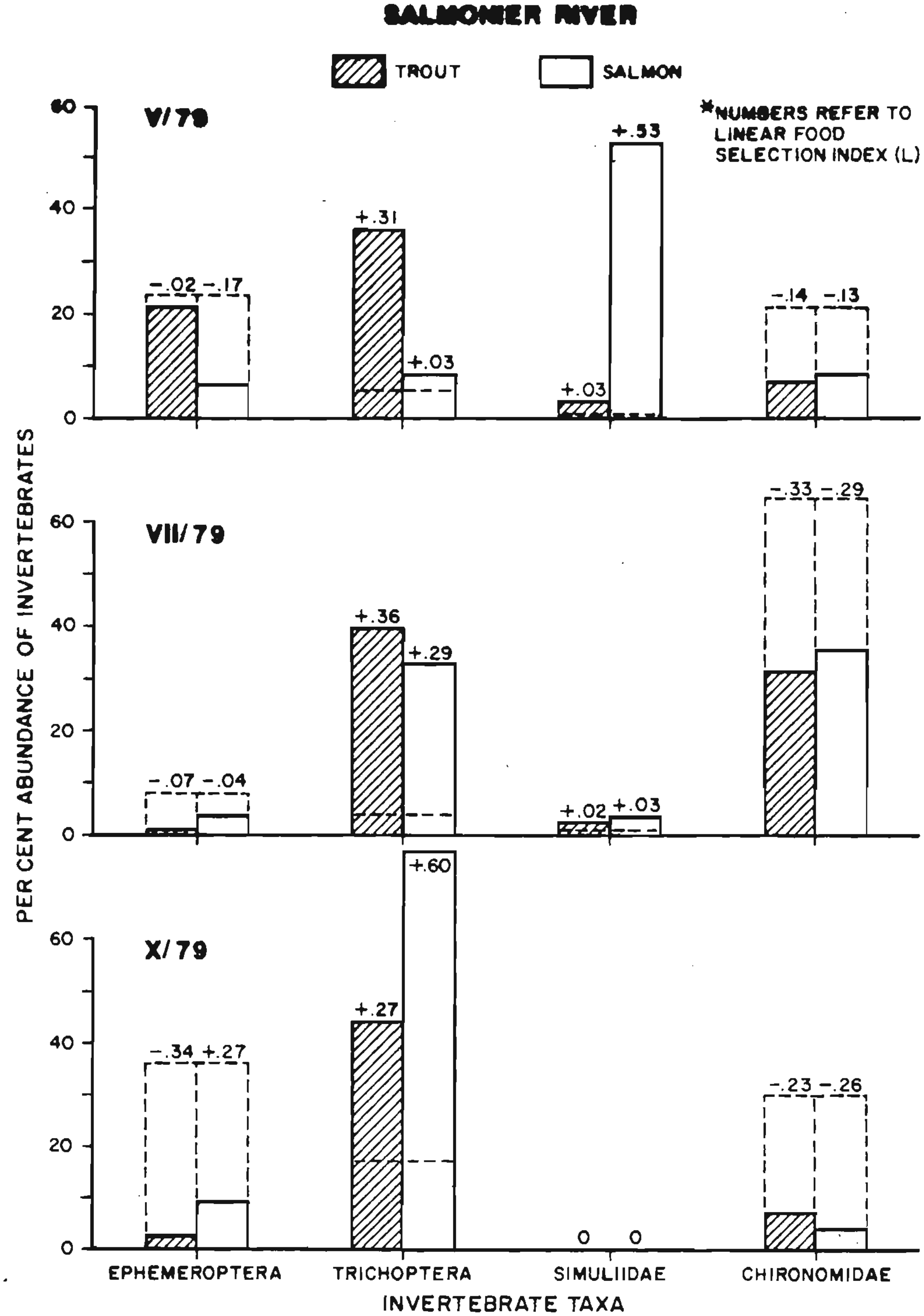

Fig. 8. Salmonier River. The percentage abundance of invertebrates found in the stomachs of overyearling brown trout (hatched bars) and Atlantic salmon (open bars) for different times of the year. Dashed histograms indicate percentage abundance of benthic invertebrates in the stream. Numbers refer to linear food selection index values of trout and salmon for each prey group.

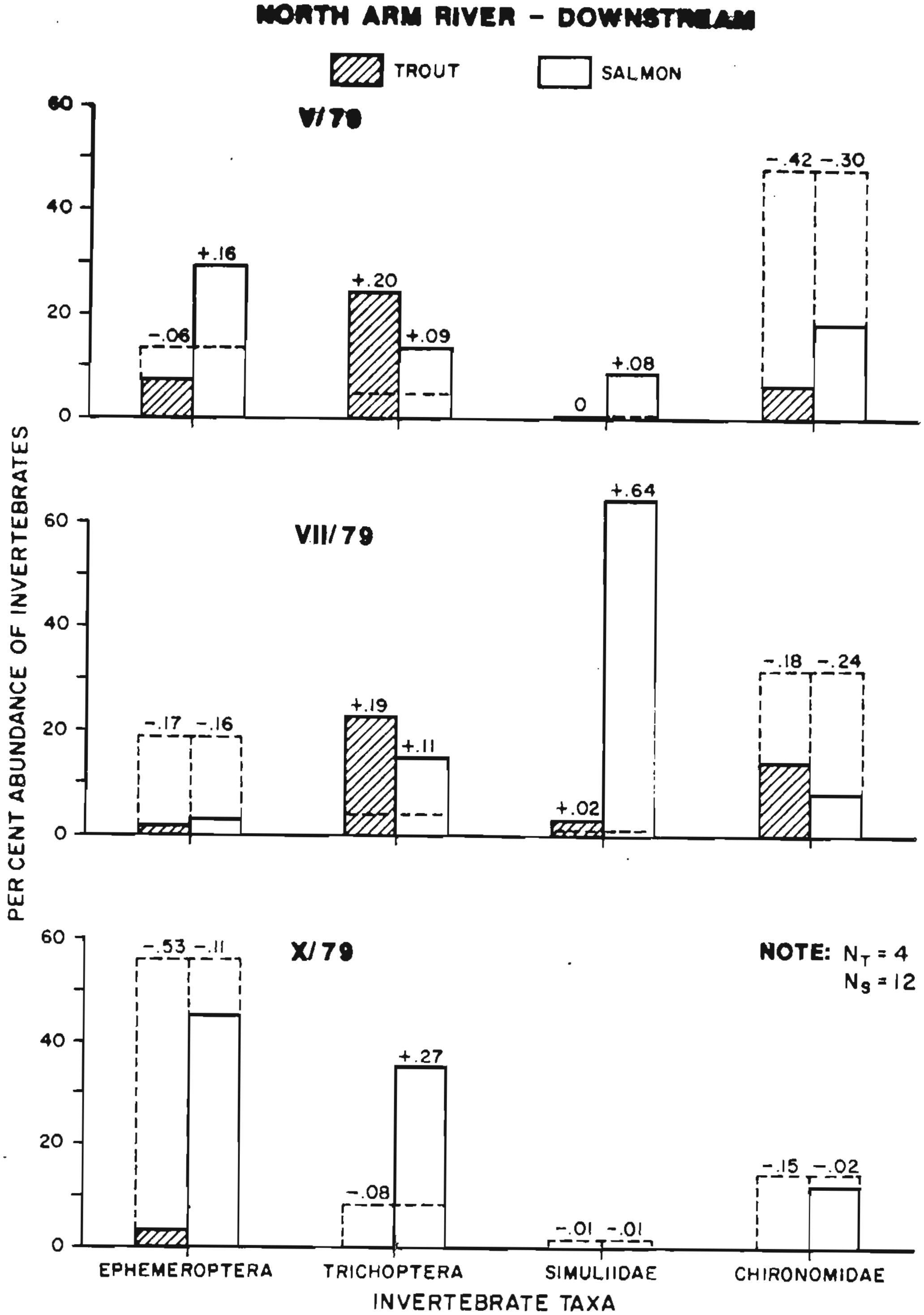

Fig. 9. North Arm River, downstream. The percentage abundance of invertebrates found in the stomachs of overyearling brown trout (hatched bars) and Atlantic salmon (open bars) for different times of the year. Dashed histograms indicate percentage abundance of benthic invertebrates in the stream. Numbers refer to linear food selection index values of trout and salmon for each prey group.

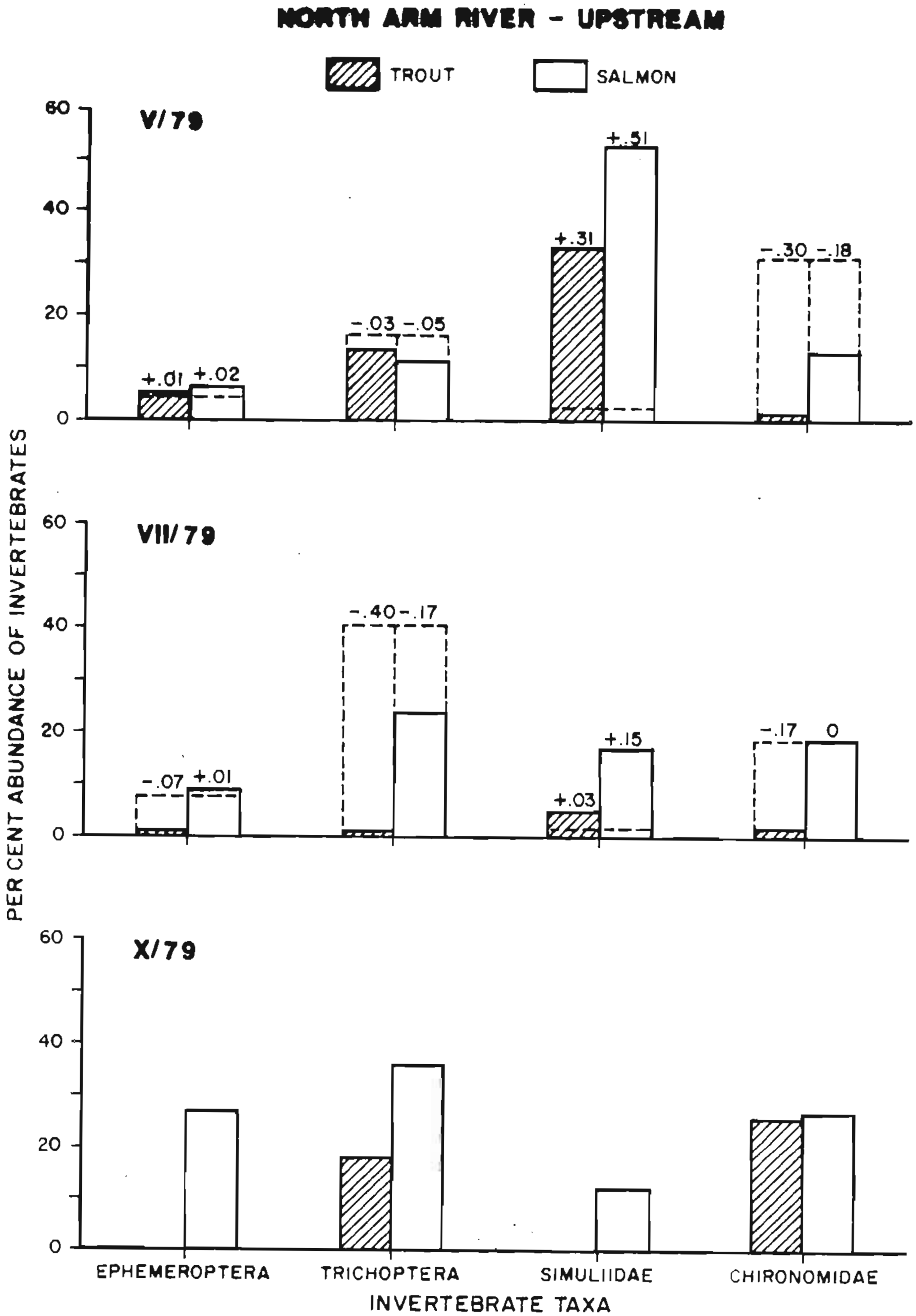

Fig. 10. North Arm River, upstream. The percentage abundance of invertebrates found in the stomachs of overyearling brown trout (hatched bars) and Atlantic salmon (open bars) for different times of the year. Dashed histograms indicate percentage abundance of benthic invertebrates in the stream. Numbers refer to linear food selection index values of trout and salmon for each prey group.

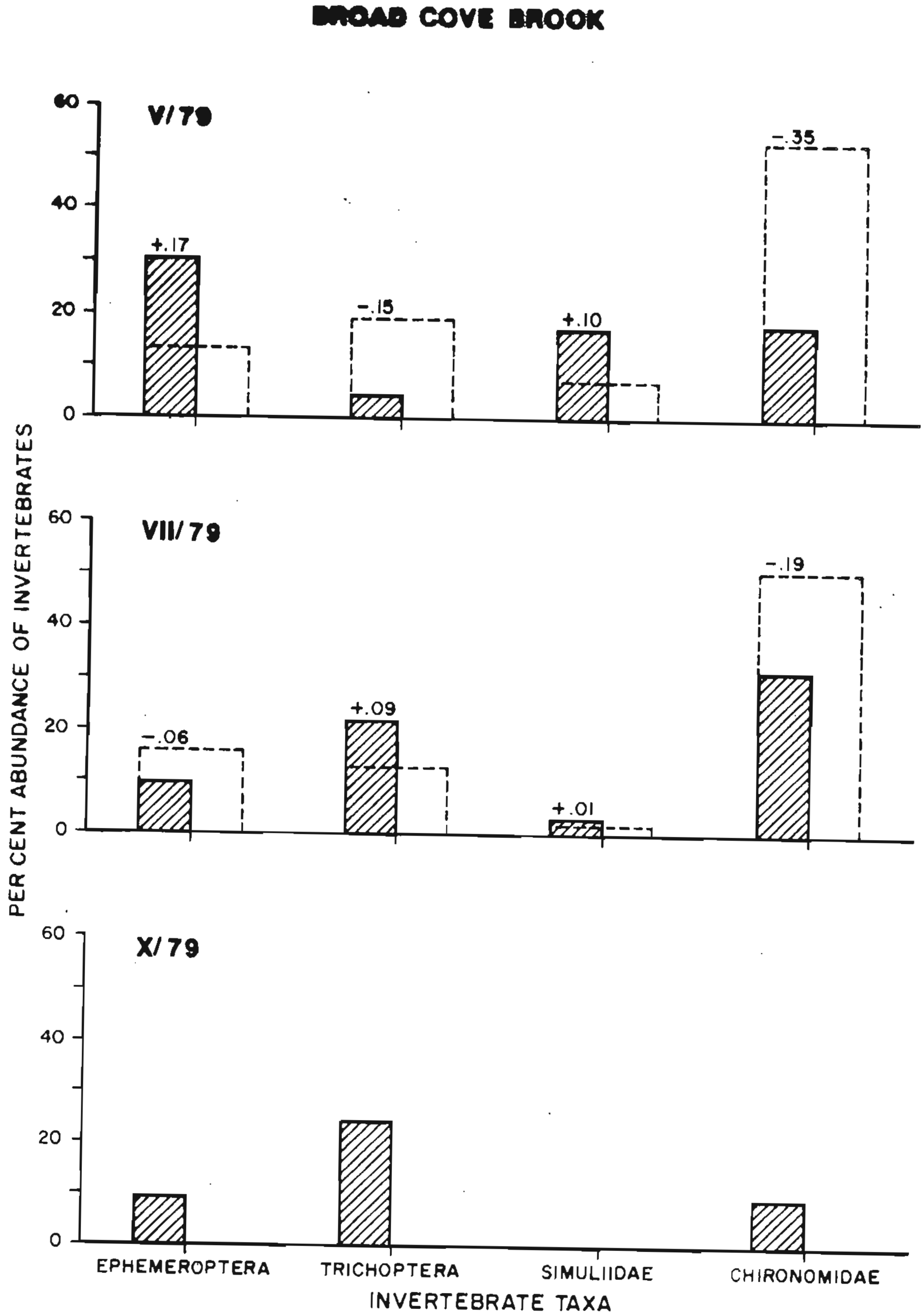

Fig. 11. Broad Cove Brook. The percentage abundance of invertebrates found in the stomachs of brown trout at Broad Cove Brook for different times of year. Dashed histograms indicate the percentage abundance of benthic invertebrates in the stream as determined from kick samples. Numbers above the columns refer to the linear food selection index.

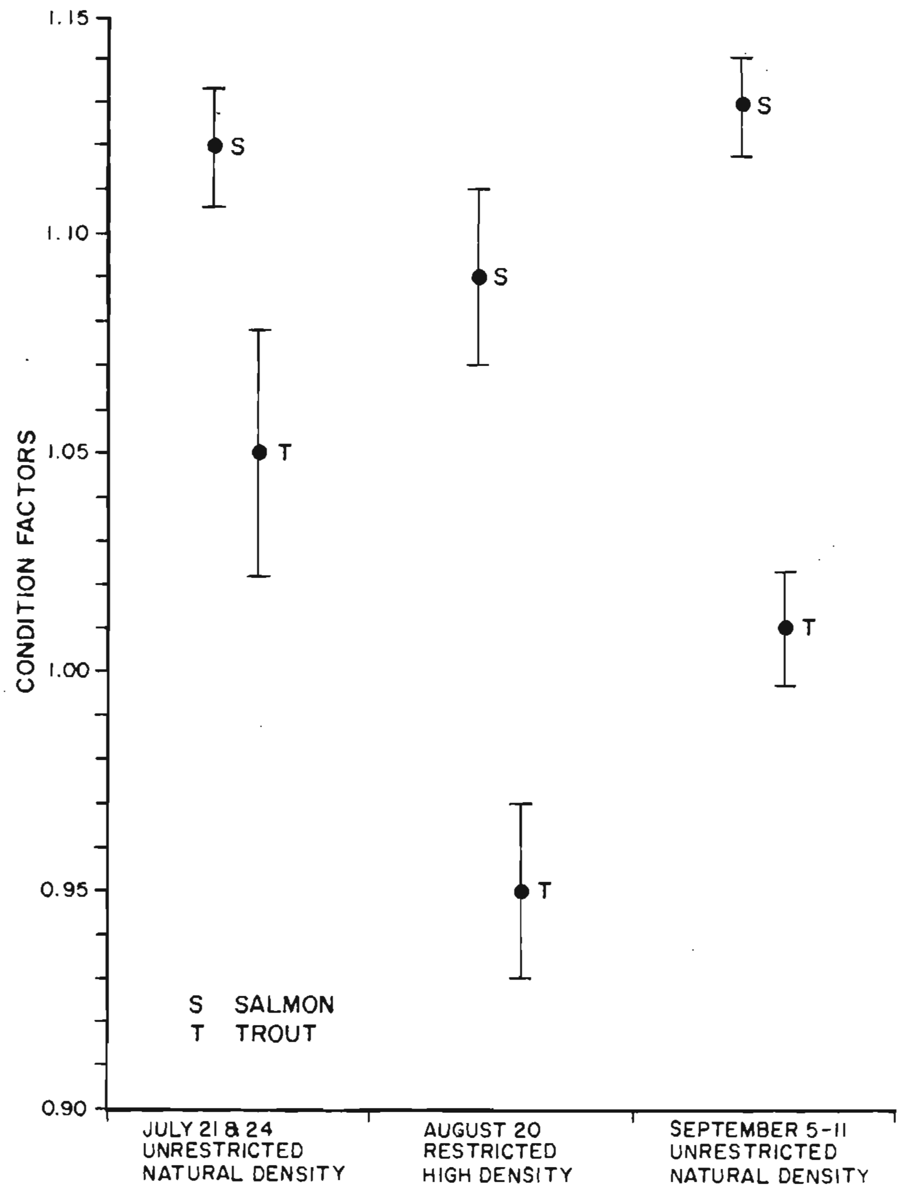

Fig. 12. The mean condition factors of salmon (S) and brown trout (T) in the control section of the experimental areas during natural density in July (S = 6.1 g m^{-2}; T = 2.5 g m^{-2}), in August after 27 days of high density (S $\geq$ 11.4 g m^{-2}; T $\geq$ 4.0 g m^{-2}), and in September in adjacent stream areas. The bars represent one standard error either side of the mean.

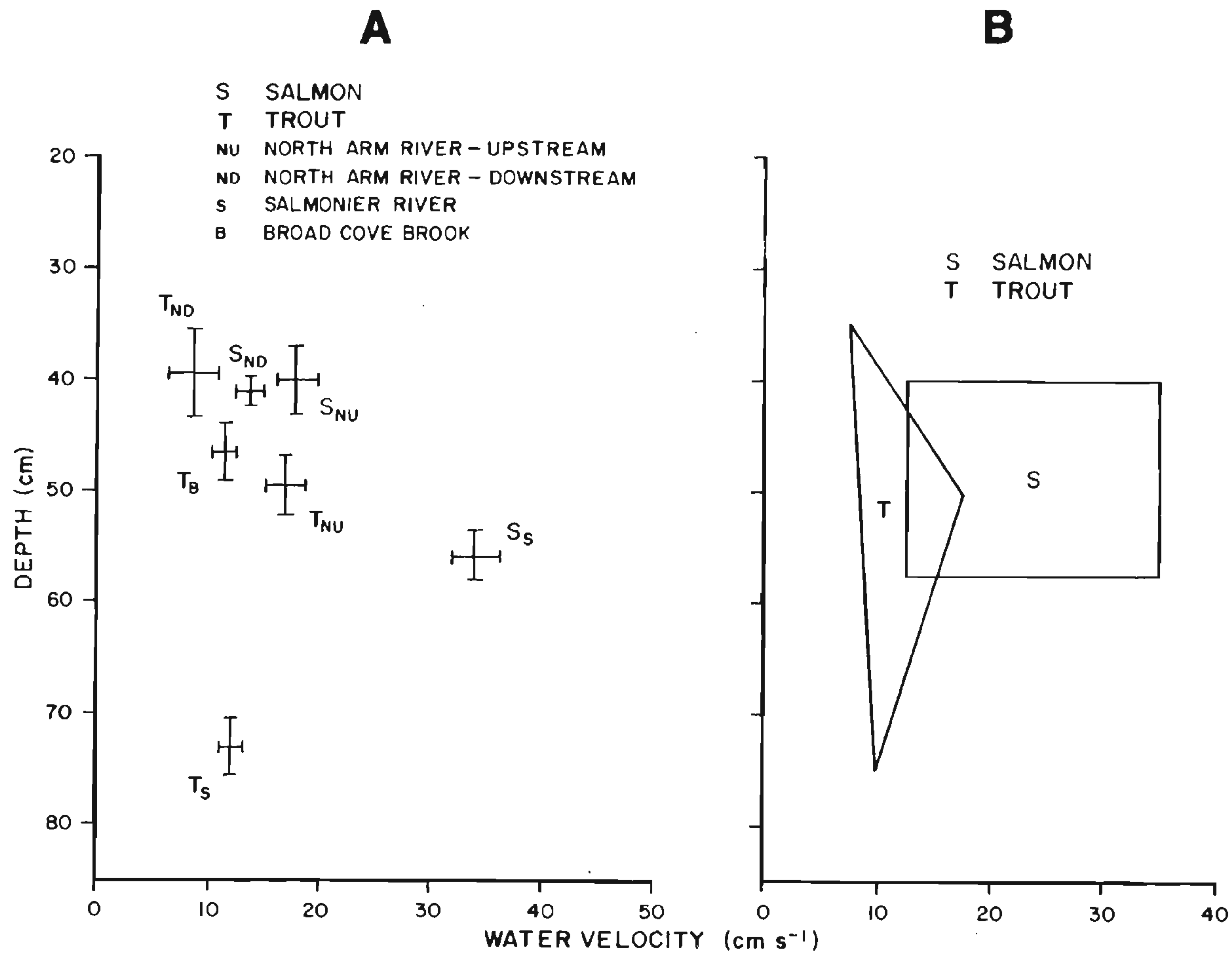

Fig. 13. The daytime feeding distributions of salmon parr and juvenile brown trout, older than underyearlings, as related to depth and to water velocity, other than during winter conditions. A = distributions observed in the present study. The bars represent one standard error either side of the mean. B = generalized distributions in preferred habitat. Distributions vary somewhat amongst the size classes and underyearlings in general are found in shallower, slower water than older fish. Also cover, in the form of overhanging shade, foam, or a broken water surface, allows fish to make use of shallower water than shown here.