A COMPARATIVE STUDY OF THE GROWTH AND FEEDING OF UNDERYEARLING (0+) BROWN TROUT (Salmo trutta Linn.) IN DISTURBED AND UNDISTURBED STREAM HABITATS IN THE AVALON PENINSULA, NEWFOUNDLAND

CHRISESTOM MWATETE MLEWA

A comparative study of the growth and feeding of underyearling (0+) Brown Trout (*Salmo trutta* Linn.) in disturbed and undisturbed stream habitats in the Avalon Peninsula, Newfoundland.

By

Mlewa, Chrisestom Mwatete B.Sc (Hons) (Moi)

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ABSTRACT

Although natural freshwater bodies on insular Newfoundland are oligotrophic, high growth and biomass of salmonids has been reported in streams within the city of St. John's. This study compared the growth and feeding of underyearling (0+) brown trout (*Salmo trutta* Linn.) from Juniper Brook, a headwater tributary of the Rennies River, which flows through the city; and a tributary of the Broad Cove River, outside the metropolitan area. Zero plus trout were obtained by electrofishing once every three weeks during the summer and fall of 1994 and 1995, with one sample collected in the intervening winter. In both years, fry in Juniper brook emerged later from the redds but grew at a faster rate and attained a slightly bigger size by the end of the growing season. Arithmetic growth curves for trout in each stream approximated the characteristic sigmoid curve. Within streams, growth rates were highest in early summer. Stream water temperatures showed consistent differences, with Juniper Brook warming up faster in the summer and cooling faster in the fall.

The composition of 0+ trout diet varied between streams and seasons and was related to changes in the food available both in the streams and adjacent terrestrial vegetation. Benthic samples from Juniper Brook had fewer taxa and were

dominated by chironomid larvae, whereas those from Broad Cove River had a higher taxonomic diversity but fewer numbers per taxon. Chironomids were consumed almost exclusively by 0+ trout in Juniper Brook during the summer but those in Broad Cove River had a much broader diet. Stomach contents were at times dominated by a single prey, suggesting opportunistic feeding, probably on the most abundant and available prey in the feeding environment. The higher abundance of chironomids in Juniper Brook was related to higher chemical richness resulting from the input of liquid and solid urban wastes. Thus the human disturbance that has occurred on Juniper Brook has altered the ecology of the stream resulting in higher stream temperatures in the summer and higher chemical richness which promoted the growth of 0+ trout in this stream.

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our first child, our lovely daughter, Faith Kadzo, while I was away on this study and for being a good mother to her while awaiting my return; and numerous relatives and friends back home in Kenya for their occasional letters of encouragement.

DEDICATION

I dedicate this work to three ladies in my life:

My Mother; Mrs Kadzo Mwatete (Nee Ngombo)

She alone will remember what it meant to have her only son so far away for so long.

My Wife; Mrs Margaret Wairimu Mlewa

She alone will remember what it meant to be parted from her husband soon after marriage, and bearing and raising our first child all by herself.

My Daughter; Miss Faith Kadzo Mlewa

She alone will want to know where her "Daddy" was (and why) when she was born.

To all three of you, this dedication is just but a token for all you have had to bear in the two years I have been away.

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1.0 INTRODUCTION

The brown trout (*Salmo trutta* Linn.) is one of the most widely distributed fish species in the world. Although its natural distribution range was restricted to Europe, some parts of western Asia and North Africa (Frost and Brown, 1967; MacCrimmon and Marshall, 1968; Scott and Crossman, 1973); it has, over the time, been introduced into freshwater habitats in many parts of the world. In his recent authoritative book on the species' ecology, Elliott (1994) stated that the brown trout has established populations in at least 24 countries outside its original distribution range. These introductions were largely as a result of the species popularity as a sport fish in the European recreational fishery (MacCrimmon and Marshall, 1968; Scott and Crossman, 1973); however, the successful expansion of its distribution range has been attributed to the species highly variable morphology, physiology, and behaviour (Elliott, 1994).

According to Andrews (1965), the brown trout was first introduced to insular Newfoundland in 1886 when the Loch Leven variety from Scotland was released into Long Pond, which is part of the Rennies River system that flows through the city of St. John's. Although this is without doubt the most cited date of introduction, other workers, notably Frost (1940) and, Scott and Crossman (1973), have

stated that the first introduction actually occurred earlier, in 1884. According to Steele (Pers. Comm.), this disagreement in the literature on the year when the species was first introduced is largely due to the destruction of records in the 1892 St. John's fire. Other introductions of the German Brown Trout and the English Brown Trout, into ponds and lakes around St. John's occurred later, in 1892 and 1905 respectively (Frost, 1940; Andrews, 1965). Although all initial introductions were in ponds and lakes on the Avalon Peninsula, the species expanded its range on the island and has been reported to be present in streams and rivers on the northern side of Trinity Bay and the eastern side of the Burin Peninsula (Andrews, 1965; MacCrimmon and Marshall, 1968). How the species achieved this dispersal on the island is not understood although Nyman (1970) has suggested that early sea run populations may have colonised new running waters.

The species is now naturalized (Liew, 1969; Gibson and Haedrich, 1988) in many freshwater streams, ponds and lakes on the Avalon Peninsula, and has replaced the indigenous Brook Trout (*Salvelinus fontinalis* Mitchill) in many of these habitats (Nyman, 1970; Cunjak and Green, 1983; Gibson and Cunjak 1986). Most of the streams and rivers flowing through the metropolitan area of the city of St. John's have populations of the brown trout. Gibson and Haedrich

(1988) found that the brown trout was the most common salmonid species and was especially abundant in disturbed sections of streams within the city. In their studies, Steele (1991), and Buchanan and Ringuis (1993) found the brown trout was the only salmonid in streams flowing through the metropolitan area of the city. Of the other salmonid species (Family: Salmonidae) known to exist in freshwater habitats on the island, only the Brook Trout still exists in city rivers but is restricted to the headwater streams (Gibson and Haedrich, 1988; Steele, 1991). The Rainbow Trout (*Oncorhynchus mykiss* Walbaum) is found in ponds and lakes in the northeastern part of the Avalon Peninsula (Cunjak and Green, 1983). Atlantic Salmon (*Salmo salar* Linn.) which have been extinct for years on the Avalon Peninsula, are currently being restocked in the city rivers (Gibson, Pers. Comm.).

However, the watershed areas of these city rivers have been subjected to considerable degradation in the course of the development and expansion of the city. Several workers in Newfoundland have documented the depreciation of the quality of aquatic habitats that has occurred in most freshwater habitats within the city. Porter et al. (1974), and Gibson *et al.* (1987) documented the loss of suitable salmonid habitat as a result of human activities such as channelization, diversion of streams and burying of some

sections underground, poor culverts, removal of riparian vegetation and dumping of urban wastes. These disturbances of aquatic habitats were probably responsible for the loss of the Atlantic Salmon from the city rivers (Gibson *et al.*, 1987). More recently, Steele (1991), and Buchanan and Ringuis (1993) reported that streams flowing through the city of St. John's continue to receive solid and liquid pollutants, and other effluent from storm sewers draining directly into them. Thus, although studies have indicated good populations of the brown trout in most streams and ponds in the metropolitan region, there is concern over the long term survival of the species and indeed that of other salmonid species. For example, Steele (1991) observed that "the survival of the brown trout (in city rivers) has so far occurred more by luck than by design". Clearly, there is need for more studies on the impact of these anthropogenic activities on the ecology of streams and their ichthyofauna, especially in view of the fact that with the expansion of the city, new urban developments (such as the bifurcation road; see Steele, 1991) continue to claim hitherto pristine areas thereby exposing them to potential degradation.

Like all other salmonids, the brown trout requires clear water that is well supplied with dissolved oxygen (Frost and Brown, 1967). Fry (1971) noted that salmonids

generally require waters that are close to oxygen-saturation for the full scope of their physiological activities. According to Mills (1971), free swimming brown trout can tolerate a minimum dissolved oxygen concentration of 5.0-5.5 mg l^{-1}; provided it is at least 80 per cent saturation. The species temperature requirements are well documented. According to Elliott (1981, 1982), the survival range for the species is 0-26 °C, although higher temperatures may be tolerated with acclimation. Within this range, Elliott (1994) has defined narrower thermal limits for various physiological processes, such as feeding (0.4-19.5 °C) and growth (4-19 °C), in his description of the thermal tolerance polygon for the species. Other important habitat requirements for the brown trout include the availability of cover and suitable spawning areas. According to Frost and Brown (1967), the best spawning habitat for the species is in riffle areas with coarse gravely substrate in headwater streams. Although the species can spawn in less favourable areas, Bottom *et al.* (1985) have stated that it is "particularly susceptible to reductions in streambed particle size" as this reduces the infiltration and flow of water through the substrate which is necessary for oxygenation of eggs in the redds.

The growth of fish has been extensively studied and variously defined by different workers. Carlander (1956)

noted that growth in fish is an extremely complex and highly variable process that readily responds to changes in the environment. Ricker (1975) defined growth in fish simply as "the elaboration of fish biomass". However, Weatherley and Gill (1987) and Busacker *et al.* (1990) have given a broader and more general definition. According to these authors, growth is "any change in the size or amount of body material, regardless of whether that change is positive or negative, temporary or long-lasting". Growth in fish is affected by a variety of abiotic and biotic factors in the natural environment (Weatherley and Gill 1987, Busacker *et al.*, 1990). However, according to Elliott (1975), food (energy) intake, water temperature and the size of the fish are the three most important factors affecting the growth of the brown trout.

Studies on food and feeding behaviour provide information that is valuable in understanding the growth dynamics of fish populations (Gerking, 1994). According to Elliott (1994), food availability is one of the major factors influencing the growth rates of brown trout in the natural environment. Although numerous investigations have been conducted on various aspects of the ecology of the brown trout in insular Newfoundland waters (Liew, 1969; Nyman, 1970; O'Connell, 1982; Gibson and Cunjak, 1986), Gibson and Haedrich (1988) noted a paucity of information

on its food and feeding habits. According to these authors, this lack of baseline information on the major food of brown trout constituted a serious knowledge gap in the species ecology in Newfoundland. Much less is known about the food and feeding ecology of the young of the year (0+) in Newfoundland waters. In the only study that has looked at the food and feeding of this age class in a Newfoundland stream, immature dipterans, ephemeropterans, and trichopterans were found to be the major food of 0+ brown trout in the Adams Octagon River (Tilley, 1984). The status of the study of 0+ brown trout in insular Newfoundland waters was aptly summarized in the statement by Steele (Pers. Comm.) that "little is known about the ecology of the young of the year as these little ones have been little studied".

In temperate regions, the size attained by young of the year salmonids at the end of the first growing season is critical and has been linked to overwintering mortality (Lindroth, 1965; Cunjak and Power, 1987). Thus, during their first summer, young of the year have to feed and grow to attain a size big enough for them to survive through the first winter. Went and Frost (1942) found that the size attained by brown trout during their first year determines the rate of growth in later years. Growth during the first summer of their life also affects the year class strength

and ultimately the stock-recruitment relationship of the population (Green, Pers. Comm.).

Gibson and Haedrich (1988) reported salmonid biomass of up to 48.9 g m^{-2} on some sections of rivers flowing through the city of St. John's, which was attributed to enrichment from a variety of anthropogenic activities within the city. According to these authors, the growth of brown trout in the city rivers ranked amongst the highest in the world. However, there has been no study that has specifically compared the growth of brown trout in city streams with those in relatively undisturbed streams outside the metropolitan area. The confounding effects of human activities on the ecology of streams and their ichthyofauna have not been well studied. For this reason and in view of the fact that the young of the year brown trout have so far received little attention, the present study was designed as a comparative investigation on the growth and feeding of underyearling (0+) brown trout from a disturbed stream within the city of St. John's, and a relatively undisturbed stream outside the metropolitan area. The main objective was to determine whether the growth of 0+ brown trout in streams flowing through city was different from that of 0+ brown trout in streams outside the city. The food and feeding habits of 0+ brown trout were also examined to determine if any difference in

growth could be related to type and quantity of food ingested by trout in these two streams. The specific objectives of the study were:

(i) to describe and analyze the taxonomic and quantitative composition of the diets of 0+ brown trout in the two streams;

(ii) to determine allometic and specific growth rates of 0+ brown trout in each of the two study streams;

(iii) to evaluate the impact of human activities on the feeding and growth of 0+ brown trout.

2.0 THE STUDY AREA AND STUDY STREAMS

2.1 Location of Study Streams

Studies were conducted on Juniper Brook, a second order tributary of the Rennies River, which flows through the city of St. John's and enters the Atlantic Ocean at Quidi Vidi; and on a second order tributary of the Broad Cove River which enters Conception Bay at St. Philips. Some samples for replication were also collected from a site on the Virginia River, which drains the northeastern part of the city (Figure 2.1); however, the site on Broad Cove River was the only undisturbed site sampled as it was not possible to find a comparable stream outside the metropolitan area that had populations solely of 0+ brown trout.

The study streams are found on the Avalon Peninsula, which experiences a cold continental climate that is characterized by short, warm summers (maximum air temperature is 28 °C), and mild winters (Hare and Thomas, 1979). According to Banfield (1983) these climatic conditions are generally "a function of the inter-related influences of the northern hemisphere mid-latitude circulation, the island's location with reference to the Canadian mainland, and the proximity of an extensive cold ocean surface". The maritime influence and insular topography have a profound effect on the nature and character of streams on the island (Larson and Colbo,

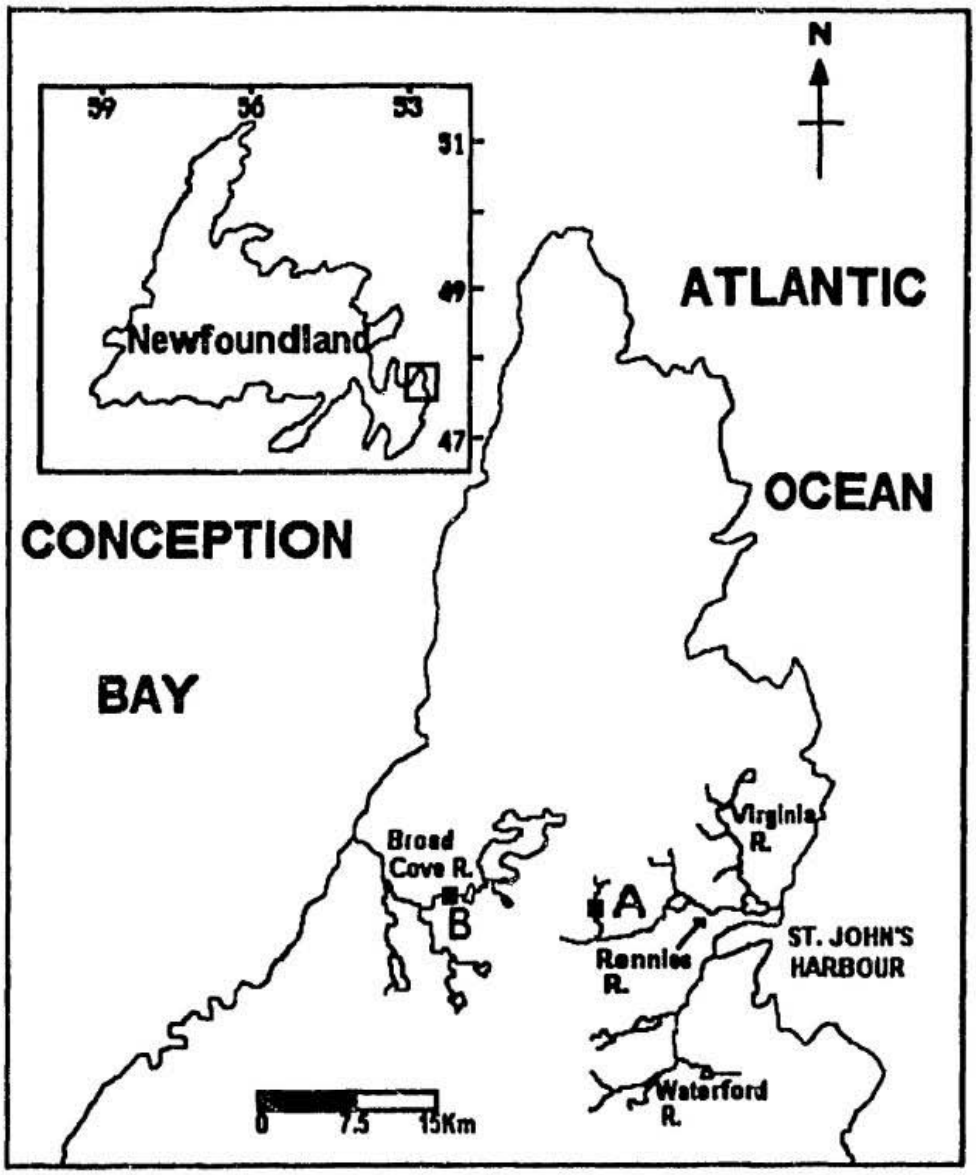


Figure 2.1 The location of the study sites, A and B, on the study streams. Also shown are the Rennies, Virginia, and Waterford Rivers which flow through the city of St. John's. Inset: Location of the study area on the Island of Newfoundland.

1983), which have been described by Colbo(1979) as being "unusually short, with low relief in the headwaters which drops rapidly near the sea".

The Rennies River is one of the major rivers that drain the metropolitan area of the city of St. John's (Gibson and Haedrich, 1988; Steele, 1991; Buchanan and Ringuis, 1993). It is part of the Quidi Vidi River system located at 47°34'59" N., 52°40'42" W. (Porter *et al.* 1974), which also includes the Virginia River that drains the northeastern parts of the city (Steele, 1991). The Rennies River flows eastward from the northwestern part of St. John's into Quidi Vidi Lake (Gibson and Haedrich, 1988). Like all other rivers draining the metropolitan area, the Rennies River and its tributaries have been subjected to degradation from various forms of human activities in its watershed in the course of the development of the city (Steele, 1991; Buchanan and Ringuis, 1993).

The Broad Cove River, on the other hand, is located at 47°35'32" N., 52°53'10" W. (Porter *et al.* 1974), outside the limits of the metropolitan area of the city of St John's and has received little human impact. Colbo (1979) noted that the Broad Cove River comprises a dendritic mix of numerous streams most of which originate as outflows from ponds, fens and bogs. The Broad Cove River flows westward draining into the Atlantic Ocean near St. Philips in

Conception Bay (Figure 2.1). This river system flows mostly through a natural forested region that has been subjected to minimal human influence. It is relatively undisturbed and in a more "natural" state (Steele, Pers Comm), and thus was chosen for study as a representative of a natural Newfoundland stream for comparison with the highly disturbed Rennies River.

2.2 Description of the Study Sites

Study sites were located on sections of the study streams known to have populations of 0+ brown trout. In insular Newfoundland, wild brown trout spawn in headwater streams of major rivers during late fall (October/November), with fry emerging from the gravel nests or redds in late spring (May/early June) of the following year (Liew, 1969; Gibson, personal communication). The young trout remain in these shallow riffle areas until the onset of the first winter when they move into deeper pools to overwinter (Elliott, 1994; Cunjak and Power, 1987). In these headwater streams, the young of the year brown trout prefer shallow marginal areas of the stream (Gibson and Cunjak, 1986; Steele, 1991; LaVoie IV and Hubert, 1994). These "lateral habitats" (Moore and Gregory, 1988) are characterized by low gradients, low water velocity,

heterogenous substrate rich in detrital material, and they support a high invertebrate fauna which makes them particularly suitable to the requirements of young of the year salmonids.

The physical characteristics of the study sites are summarised in Table 2.1. However, it should be noted that the stream channel characteristics presented in Table 2.1 reflect the conditions when samples were collected which was generally during low water when electrofishing was considered to be most effective and safe. Thus water levels and stream velocity were much greater in both streams during spates. The variations in water levels and stream velocity observed in the two streams during the study reflected the amount of precipitation that was received. Colbo (1985) observed similar fluctuations and stated that the current and stream discharge regimes of most streams on the island fluctuated greatly during the summer due to infrequent rains.

The study site on Juniper Brook was a 10 m long reach of riffle habitat extending about five metres above and below the bridge on Austin street upstream from the Avalon Mall shopping complex. This section of the brook was channelized in 1978 to allow the development of the O'Leary's Industrial Park. The channelization straightened the stream channel and resulted in the complete

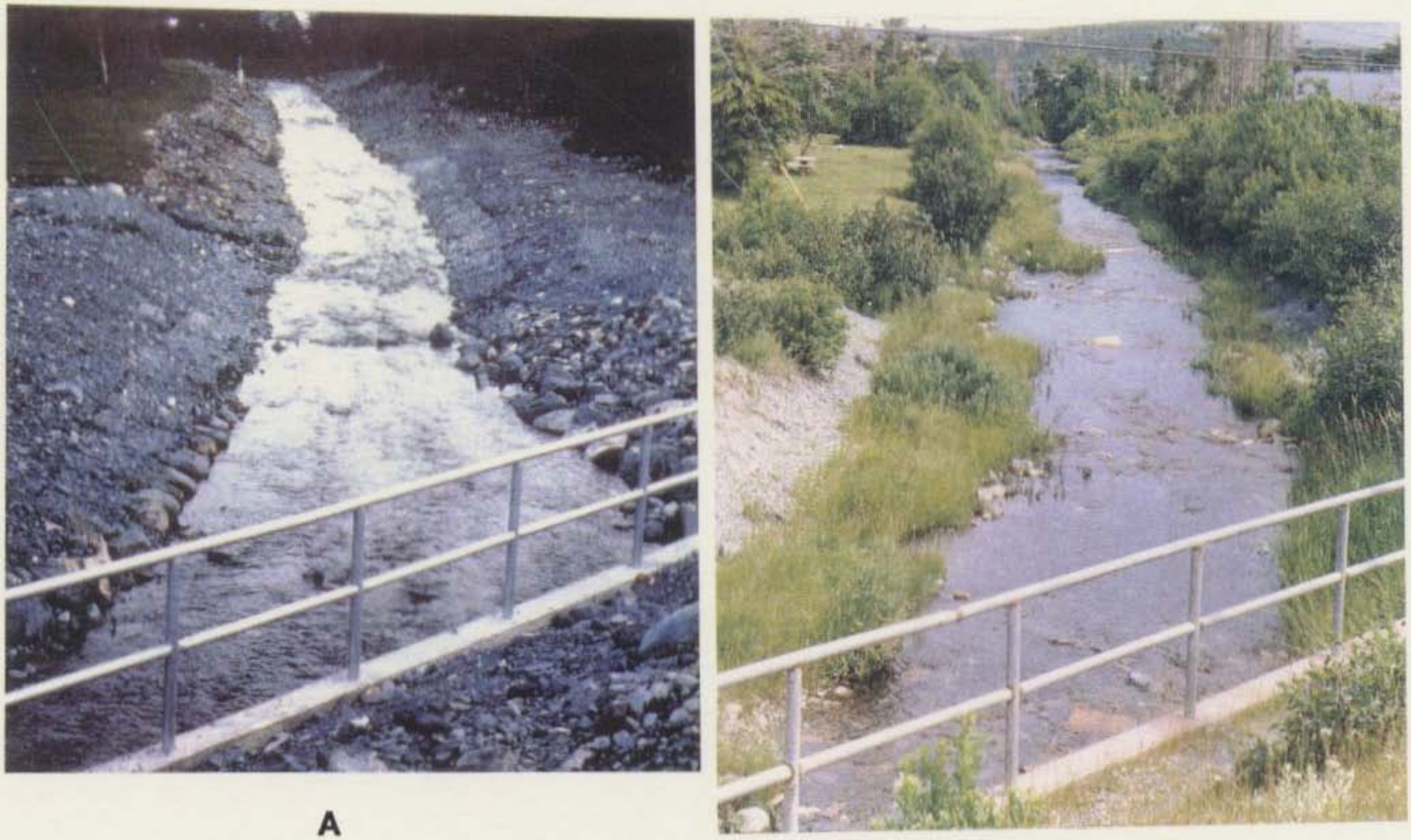
Table 2.1 Some physical characteristics of the study sites.

Characteristic	Juniper Brook	Broad Cove River
Stream Channel Profile	Straight 10 m reach, of uniform width due to channelization	Meandering 10 m reach of variable width.
Open channel width	Ranged between 1.5 - 2 m depending on volume of flow	Ranged between 0.5 - 2.5 m depending on volume of flow
Mean Depth	Ranged between 5 - 18 cm depending on volume of flow	Ranged between 5 - 20 cm depending on volume of flow
Stream Velocity	Ranged between 15 - 28.5 cm/s but varied greatly due to infrequent rains	Ranged between 15 - 25 cm/s but varied greatly due to infrequent rains
Bank Vegetation	Regenerated vegetation dominated by water mints (*Mentha ariensis*), willows (*Salix sp*), green alders (*Alnus sp*) and canary grass (*Phalix sp*).	Natural riverine vegetation fronted by sweet gale (*Myrica sp*) shrubs.
Substrate	Typical riffle area substrate dominated by gravel, cobbles, stones and small boulders.	Typical of riffle area; dominated by cobbles, stones and small boulders.
Aquatic Vegetation	Few submerged macrophytes, substrate covered with dense green algal blooms in summer.	Few submerged macrophytes; no algal mass on substrate.

disappearance of Wigmore Pond (Steele, Pers. Comm.) and change in the trout habitat (Figure 2.2a). In 1985, the Salmon Association of Eastern Newfoundland inserted deflectors on the channelized section thereby restoring meanders and the diversity of habitats (Steele, 1991). Recolonization by natural vegetation and further rehabilitation work using boulder clusters by the Natural History Society in 1994 have greatly enhanced the section of the stream as a trout habitat (Figure 2.2b). However, this section of the brook has been subjected to other forms of disturbance from a variety of human activities (Steele, 1991). The section receives considerable amount of liquid and solid effluent from the residential and industrial buildings in the newly urbanised O'Leary's Industrial Park area (Steele, 1991; Buchanan and Ringuis, 1993; personal observation). As a result, the stream at this section is highly enriched with dense green algal blooms covering the substrate throughout the summer (Table 2.1).

The study site on the Broad Cove River was on a tributary of the system which flows out of Healy's Pond (Figure 2.1). The study site on this river was located on a relatively undisturbed section extending about 10 metres downstream from the bridge on Thorburn road. The section on which the study was conducted had conspicuous meanders and natural vegetative overgrowth (Figure 2.3), although,

aquatic vegetation at the site was sparse with only a few submerged macrophytes (Table 2.1).



A

B

Figure 2.2 The study site on Juniper Brook within the metropolitan area of the city of St. John's; A: when it was channelized in 1978 (Picture by R.J. Gibson) and B: at the time the study was conducted [Notice the straight and more open channel].

Figure 2.3 The study site on Broad Cove River, outside the metropolitan area of the city of St. John's, when the study was conducted [Notice the natural meandering and vegetative overgrowth].

3.0 MATERIALS AND METHODS

3.1 Field Procedures

3.1.1 Measurement of Water Temperature and Conductivity

Water temperature at each study site was monitored using 30-day continuous water temperature recorders from June through November in 1994 and 1995. Mean daily temperatures were determined as the mean of the maximum and minimum temperature recorded over a 24-hour period (Kaeding and Kaya, 1978). The mean daily temperatures were then used to determine the average temperatures for the period between successive sampling dates. The number of degree-days was determined as difference between the average temperatures and the base temperature of 4 °C (the lower thermal limit for the growth of the species, Elliott, 1994), multiplied by the number of days within a sampling interval. In this way it was possible to compare the amount of heat energy available for growth of 0+ trout in the two streams for all sampling intervals with mean temperatures of above 4 °C.

After electrofishing on each date in 1995, water samples were collected in 500 ml plastic water sampling bottles and taken to the laboratory for determination of the conductivity of water at the study sites.

3.1.2 Collection of 0+ Brown Trout

Sampling of 0+ brown trout began after alevin (Balon, 1975) had emerged from the redds in late spring (early June) of 1994, and was continued, at approximately three-week intervals, through to November/early December when stream temperatures fell below 4.0 °C. This was repeated through the summer and fall of 1995. In the summer of 1994, samples were also collected from a site on the Virginia River on two occasions. However, restocking with Atlantic Salmon fry at the site by the Department of Fisheries and Oceans prevented the collection of samples from this river in 1995.

Although it was desirable to continue sampling through the intervening winter, this was not possible because of the presence of anchor ice at the study site on Juniper Brook. Only one moribund 0+ trout was collected from this site when sampling was attempted on 4th January 1995; and for this reason, winter sampling was discontinued in both streams. However, when sampled in spring (late May) of 1995, 1+ were collected from both study sites, indicating that individuals of the previous year class had survived through their first winter in both streams. No 0+ trout were collected at either site as these had apparently not yet emerged from the redds.

Underyearling brown trout were caught using a battery powered backpack Smith-Root Model-12 electrofisher. At each study site, electrofishing was restricted to the shallow marginal areas of the stream, the preferred habitats for 0+ brown trout (Gibson and Cunjak, 1986; Steele, 1991; LaVoie IV and Hubert, 1993). Electrofishing progressed upstream as recommended by Bohlin *et al.* (1989) and was carried out during the late morning to afternoon hours to coincide with a high incidence of full stomachs since underyearling (0+) brown trout are known to start feeding much later than the dawn feeding period reported for larger trout (Steele, 1991). Usually, samples were obtained from the two sites on the same day, within about 20-30 minutes of each other. However, whenever this was not possible (due to unexpected logistical problems), samples were collected from the other stream at similar times of the day. This allowed all 0+ trout sampled to have the same feeding opportunity before capture.

At each sampling occasion, electrofishing was continued only until ten 0+ brown trout were caught, this being in compliance with the limit of the collection permit issued by the Department of Fisheries and Oceans (see Appendix A). Stunned 0+ trout were collected from the stream using a dip net and transferred into a plastic bucket containing stream water for recovery and

transportation to the laboratory. Any larger brown trout (i.e. belonging to 1+ and older age classes) caught were immediately returned downstream as were threespine sticklebacks *(Gasterosteus aculeatus* Linn.) caught at the site on Broad Cove River. All 0+ brown trout were returned to their streams following the laboratory procedures described in section 3.2.1 and 3.2.2.

3.1.3 Sampling of Benthic and Drifting Invertebrates

During the second year of the study, benthic and drifting invertebrates were sampled at the two study sites. The purpose was to determine the type and amount of food resources available for 0+ trout in each of the two streams.

Benthic samples were collected from each study site during the summer and fall season of 1995 using the method of providing removable substrate for colonization (Radford and Hartland-Rowe, 1971). The sampling units consisted of perforated 10.5 cm (height) by 10.5 cm (diameter) containers cut from empty two litre plastic juice bottles. Five samplers were placed in holes randomly excavated into the substrate at each site. Each Sampler was filled with the excavated substrate material and left *in situ* for a period of one month. According to Coleman and Hynes (1970),

and Radford and Hartland-Rowe (1971) this period was more than ample for stabilization of the number of organisms in the disturbed substrate. After one month the samplers were retrieved and taken to the laboratory for sorting and identification of organisms.

Drift samples were collected from each study site on three occasions in late summer and early fall of 1995. Each daily collection of drift consisted of three samples taken consecutively about mid-way between the centre of the stream and the edge of the stream. The collecting apparatus was assembled in the laboratory according to the specifications described by Bell (1994). It consisted of a 0.7 m long cone-shaped 80 μm Nitex net glued to a collecting mouth-piece at the anterior end, and a removable collecting jar at the cod-end. The diameter of the mouth-piece at the anterior end was 9.5 cm, giving it an aperture area of 70.88 cm^2. The streams were shallow and therefore the drift sampler was secured in position using stones and small boulders. The sampler was set such that the upper surface of the collecting mouth-piece was just above the water surface to allow for collection of surface floating invertebrates. Collected invertebrates were retrieved when the nets showed initial signs of clogging. On average, this occurred after 25-30 minutes in Juniper Brook and 30-35 minutes in Broad Cove River. Each drift sample was

preserved separately in five percent formalin solution in the field for later analysis in the laboratory and the net reset until three samples were obtained. Surface velocity was estimated after the drift samples were collected using the floatation method (Wetzel and Likens, 1991).

3.2 Laboratory Procedures

3.2.1 Determination of Conductivity

In the laboratory, the conductivity of the water sample was determined with a conductivity meter. Chemical richness of the streams at the study sites was then determined as the total dissolved solids (T.D.S) estimated from the specific conductance of the water sample using the formula given in Steele (1991):

T.D.S = 7.02 + 0.72 X conductance in umhos, at 25 °C (and corrected for actual temperature of the sample).

3.2.2 Length and Weight Measurement

In the laboratory, fish were anaesthetized with carbon dioxide generated by dissolving Alka Seltzer in water. Each was measured for fork length, to the nearest 0.1 centimetre, on a standard fish length measuring board. The fish were then dried on absorbent tissue and weighed to

within 0.01 grams on a Mettler PC 4400 Delta Range electronic balance.

3.2.3 Stomach Contents of 0+ Trout

Stomach contents were obtained using the stomach flushing procedure described by Meehan and Miller (1978). The flushing apparatus consisted of a blunted hypodermic needle (2 cm long) attached to a 20 ml hypodermic syringe filled with water. The needle was inserted through the mouth and oesophagus of the anaesthetized fish into the stomach and a jet of water injected to flush its contents out through the mouth into a labelled Petri-dish. The fish were allowed to recover in oxygenated stream water and later returned to their streams. Any fish that died were placed in labelled Petri-dishes in a deep freezer for later processing. These were later thawed and their stomachs excised between the oesophagus and pyloric sphincter (Frost, 1950; Bowen, 1984) with the aid of a dissecting microscope. The stomachs were then transferred to clean Petri-dishes, opened up and their contents identified.

Identification of food items was done with the aid of a dissecting microscope. Food items, (or characteristic parts of partially digested items, Bowen, 1984), were generally identified to order (but where it was possible to

the family or lower taxa), using taxonomic keys and literature in texts (e.g. Pennak, 1978; McCafferty and Provonsha, 1981; Peckarsky *et al.*, 1990; and Clifford, 1991). Any prey organisms that could not be immediately identified were preserved in five percent formalin and later referred to Prof. D. Larson in the Department of Biology for their identification.

3.2.4 Processing of Benthic and Drift Samples

In the laboratory, each substrate sample was washed through a tier of four sieves of varying mesh sizes (0.5, 1, 2, and 6 millimetres) placed in a white enamelled tray. Organisms were hand-picked from substrate material on each sieve and also from the tray, using a pair of forceps, and preserved in five percent formalin solution in labelled vials. Invertebrates were later sorted under a dissecting microscope, identified and enumerated. Organisms in drift samples were similarly sorted and counted. To facilitate comparison with stomach contents of 0+ brown trout, invertebrates in both benthic and drift samples were identified to similar taxonomic resolution as that used for stomach contents (section 3.2.3).

3.3 Data Analysis

3.3.1 Growth and Condition of 0+ Trout

Mean fork length (FL) in cm and weight (Wt) in g, and their standard errors (SE) were computed for samples from each stream at each sampling occasion. Graphical plots of mean lengths and weights against time were used to study trends in the arithmetic growth of 0+ trout from the two streams. Specific growth rates (Ricker, 1975) were determined for each period between successive sampling dates from the respective mean sizes. Thus specific growth rate for weight (G_W, % d^{-1}) was calculated as:

$$G_w = \frac{100\,(lnWt_2 - lnWt_1)}{t}$$

where Wt_1 is the mean weight at one sampling date; Wt_2 is the mean weight at the next sampling date; and t is the time (in days) between sampling dates. The specific growth rate for length (G_L, % d^{-1}) was similarly computed, i.e. by substituting mean length for mean weight in the formula.

The condition (K) of each fish in a sample was first determined from their respective length and weight data using the Fulton's condition factor formula (Ricker, 1975):

$$K=100(Wt x L^{-3})$$

where K is the condition factor; Wt is the weight of fish; and L is the fork length. Thus computed, this results in unity K values for salmonid fishes in good condition (Ricker, 1975). The mean condition (and its SE) for all fish in a sample was then determined from the condition factors of the individuals in the sample.

3.3.2 Quantitative Analysis of 0+ Trout Diet

Feeding data were analyzed using the numerical method and frequency of occurrence method (Hynes, 1950; Berg, 1979; Hyslop, 1980; Bowen, 1984; and others). By the numerical method, individual prey belonging to each taxonomic category were enumerated. Their counts were recorded and summed up for all the fish in a sample. The total number of individuals in each particular food category was then expressed as a percentage (% N) (Berg, 1979) of the total number of individuals in all food categories for all the fish in a sample.

Frequency of occurrence was based on the occurrence of prey taxa among fish in a sample. Thus each time a particular prey taxon occurred in a fish was counted as one record for that taxon regardless of its numbers. The number of fish ingesting a given prey was expressed as a

percentage (% F) of the total number of all stomach examined (Berg, 1979).

The total number of taxa identified in the stomach contents of all fish gave a relative measure of the diversity of ingested food items. To determine the importance of terrestrial habitat to the diet of 0+ trout, organisms comprising the diet were classified into terrestrial or aquatic. However, adults of insects with obligatory aquatic immature stages (Williams and Feltmate, 1992), although essentially terrestrial, were considered to be aquatic due to their close association with water and also because it was possible that these were preyed upon when they were emerging.

To facilitate statistical examination of seasonal differences in food habits, feeding data for various sampling dates were pooled to broaden taxonomic groups so as to reduce the number of categories and the incidence of categories with less than five items (Crow, 1981). All samples collected between June and August (inclusive) were thus pooled to represent summer feeding whereas those between September and early December represented feeding in the fall season. The sample collected from Broad Cove River in the intervening winter was analyzed separately as representative of winter feeding.

3.3.3 Analysis of Benthic and Drift Invertebrates

For both benthic and drift collections, the total number of invertebrates was determined and the numerical counts of individuals in each taxonomic category used to determine their relative abundance. The total number of taxa identified in samples from a stream provided a relative measure of the taxonomic diversity of the benthic invertebrates in that stream. Similarity of invertebrate fauna between the two streams was estimated using the Jaccard index (Khmeleva *et al.* 1994):

$$p_{xy} = \frac{c}{a+b-c} \times 100\%$$

where p_{xy} is the faunal similarity between streams x and y, a is the number of taxa in stream x, b is the number of taxa in stream y, and c is the number of taxa common to stream x and y.

3.3.4 Determination of Food Selection by 0+ Trout.

To evaluate food preference, the linear electivity index proposed by Strauss (1979) was used:

$$L = p1 - p2;$$

where L is the index of electivity, p_1 is the proportion of the diet comprised by a given prey taxon, and p_2 is the proportion of the prey taxon in the environment.

Electivity values determined with this index have a possible range of -1 to +1 with values closer to +1 indicating preference whereas values closer to -1 indicating avoidance or inaccessibility of the prey item. Zero electivity values indicate prey were being eaten in proportion to their availability in the environment. The index was preferred to that developed by Ivlev (1961) because it results in extreme values only when the prey is rare but consumed almost exclusively, or is very abundant but rarely consumed.

Only the diet of fish sampled on the 18th August and 18th October were used to compute electivity values for the summer and fall respectively, as these were taken after the benthic samplers had been in the substrate for at least two weeks which allowed for the stabilization of the benthos (Coleman and Hynes, 1970). Electivity values were also computed for the drift samples collected at various dates in the fall.

3.3.5 Statistical Analyses

Observed differences in mean size (length and weight) between fish from the two streams, and seasonal, within and between stream differences, were tested for significance by the Student t-test procedure (Zar, 1984; Sokal and Rohlf, 1995), using a model based approach which allowed the examination of residuals (error term) for normality (Schneider, Pers. Comm.). Differences in mean condition were similarly tested. Statistical testing for quantitative differences in diet of fish in the two streams was carried out using the general linear model, based on a non-normal Poisson error structure, since the data were counts which are expected to generate non-normal errors (Schneider, Pers. Comm.). Thus, log likelihood ratios and the G-test (Crow, 1981; Sokal and Rohlf, 1995) were used to determine significance on the theoretical chi-square distribution. All statistical analyses were done using the Minitab Statistical Package on the Vax system at Memorial University of Newfoundland and significance was determined at the 0.05 level in all statistical tests.

4.0 RESULTS

4.1 Water Temperature and Conductivity

Water temperature profiles based on the mean daily temperatures for periods between sampling dates in 1994 and 1995 are presented in Figure 4.1. In both years, water temperatures in the two streams increased through early summer, peaked in late August and then progressively decreased in the fall. However, Juniper Brook warmed up much faster than Broad Cove River and was consistently warmer throughout the summer. In the first year of the study, the mean daily temperatures in Juniper Brook were higher than those in Broad Cove River by as much as 1.3 °C. Maximum temperatures in both streams fluctuated greatly but the fluctuations in Juniper Brook were more pronounced and closely related to the ambient air temperature. The highest maximum temperature in Juniper Brook over the two year period was 23.5 °C, recorded in late August of 1994; whereas in Broad Cove River the maximum temperature was 19.5 °C recorded in early September of the same year.

During the fall, temperatures in Juniper Brook decreased faster than in Broad Cove River and towards the end of the season mean temperatures in the two streams differed by as much as 5 °C. Although trends in the seasonal changes in the temperature profiles of the two streams were similar in the two years (Figure 4.1), early summer mean

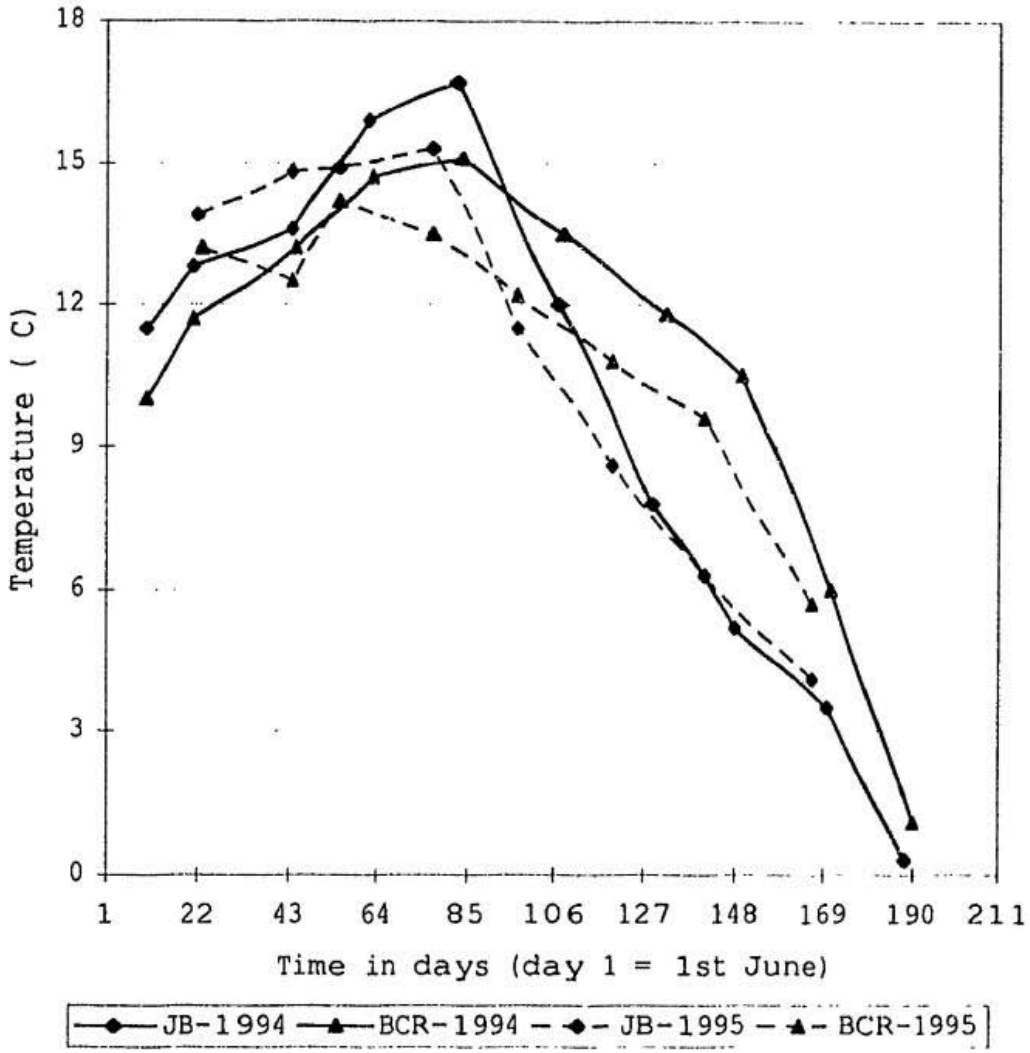


Figure 4.1: The mean water temperature of the two study streams during the summer and fall of 1994 (solid line) and 1995 (dashed line). [JB = Juniper Brook, BCR = Broad Cove River]

temperatures in both streams were higher in 1995. However, for the rest of the growing season, mean water temperatures in both streams were generally lower in 1995 (Figure 4.1).

The conductivity measurements for water samples collected from the study sites in 1995 are presented in Table 4.1. Also presented are estimates of the chemical richness of the streams at the study sites determined as the total dissolved solids (T.D.S). The mean total dissolved solids for the samples from Juniper Brook was 138.8 (±31.8 SE) whereas those from Broad Cove River were 107.9 (±20.0 SE). Specific conductance in both streams were high early in the season. However, at each sampling date, the conductivity of water samples from the site on Juniper Brook was higher than that of samples from Broad Cove River (Table 4.1).

4.2 Growth of 0+ Brown Trout

4.2.1 Mean Size (Fork Length and Weight) and Arithmetic Growth of 0+ Trout

The mean size [fork length (FL), and weight (W)] of 0+ brown trout from the two study sites at various sampling times during the first year of the study are presented in Table 4.2. When first sampled, 0+ trout in Broad Cove River were significantly longer ($t = -6.19$, $p = 0.0001$) and

Table 4.1 Specific conductance (Cond.), temperature (T °C), and total dissolved solids (T.D.S) of water samples collected from the study sites at various dates in 1995.

Date	Juniper Brook			Broad Cove River		
	Cond. uhmo/cm	T °C	T.D.S	Cond. uhmo/cm	T °C	T.D.S
13-Aug	300	20.0	174.4	225	20.0	135.2
17-Aug	340	22.0	221.6	275	20.0	164.0
06-Sep	375	20.0	221.6	275	18.0	147.6
27-Sep	275	13.0	106.0	225	14.5	98.0
18-Oct	240	8.5	61.1	180	10.0	54.6
13-Nov	225	8.0	48.3	175	9.0	47.9

Table 4.2 Mean fork length (FL), weight (Wt), and condition factor (K) of underyearling brown trout from the two study streams at each sampling date in 1994 (n = 10, ±SEM).

Sampling Date	Stream	Length (FL, cm)	Weight (g)	Condition Factor (K)
09/06/94	JB	2.43±0.03	0.098±0.002	0.691±0.035
	BCR	2.82±0.05	0.165±0.011	0.726±0.013
21/06/94	JB	2.69±0.08	0.158±0.017	0.782±0.027
	BCR	3.50±0.15	0.451±0.072	0.978±0.030
14/07/94	JB	3.59±0.09	0.488±0.044	1.029±0.033
15/07/94	BCR	4.70±0.19	1.139±0.123	1.046±0.014
01/08/94	JB	4.79±0.14	1.248±0.112	1.104±0.034
02/08/94	BCR	5.20±0.18	1.542±0.166	1.058±0.022
25/08/94	JB	5.72±0.10	2.044±0.130	1.082±0.031
26/08/94	BCR	5.85±0.09	2.234±0.169	1.098±0.036
15/09/94	JB	6.13±0.16	2.672±0.311	1.121±0.014
16/09/94	BCR	6.06±0.16	2.515±0.233	1.100±0.018
07/10/94	JB	6.33±0.16	2.704±0.245	1.043±0.015
10/10/94	BCR	6.21±0.15	2.523±0.182	1.038±0.021
26/10/94	JB	6.35±0.18	2.780±0.264	1.057±0.019
28/10/94	BCR	6.26±0.19	2.683±0.271	1.059±0.034
17/11/94	JB	6.42±0.24	2.986±0.310	1.095±0.027
18/11/94	BCR	6.31±0.18	2.672±0.232	1.043±0.013
07/12/94	JB	6.44±0.19	2.766±0.261	1.007±0.018
13/12/94	BCR	6.33±0.18	2.400±0.224	0.924±0.017

JB = Juniper Brook, BCR = Broad Cove River

Table 4.3 Mean fork length (FL), weight (Wt), and condition factor (K) of underyearling brown trout from the two study streams at each sampling date in 1995 (n = 10, ±SEM).

Sampling Date	Stream	Length (FL, cm)	Weight (g)	Condition Factor (K)
22/06/95	JB	2.49±0.05	0.130±0.030	0.829±0.048
23/06/95	BCR	3.25±0.12	0.352±0.043	0.975±0.027
14/07/95	JP	3.92±0.15	0.673±0.090	1.053±0.026
	BCR	4.11±0.16	0.764±0.098	1.041±0.025
25/07/95	JB	4.47±0.10	1.040±0.061	1.160±0.028
	BCR	4.50±0.10	0.937±0.059	1.018±0.014
17/08/95	JB	5.75±0.14	2.042±0.162	1.067±0.052
	BCR	5.30±0.14	1.622±0.119	1.074±0.015
06/09/95	JB	6.33±0.12	2.568±0.097	1.013±0.021
	BCR	5.67±0.17	1.920±0.152	1.040±0.026
27/09/95	JB	6.42±0.14	2.638±0.140	0.992±0.021
	BCR	5.85±0.17	2.033±0.187	0.987±0.014
18/10/95	JB	6.45±0.10	2.690±0.155	0.995±0.012
	BCR	5.94±0.24	2.046±0.245	0.933±0.019
13/11/95	JB	6.48±0.12	2.869±0.211	1.036±0.028
	BCR	5.97±0.19	2.062±0.211	0.939±0.020

JB = Juniper Brook, BCR = Broad Cove River

heavier ($t = -5.8$, $p = 0.0002$) than those in Juniper Brook. Although by mid-September 0+ trout in Juniper Brook had attained a slightly larger size, with a mean length of 6.13 cm (±0.21) and weight of 2.672 g (±0.311) compared to 6.06 cm (±0.16) and 2.515 g (±0.233) for those in Broad Cove River; these differences were not significant (t-test, $p > 0.05$). Similarly, at all subsequent sampling times 0+ trout in Juniper Brook were, on average, larger (both length and weight) than those in Broad Cove River, but the differences were not significant (t-test, $p > 0.05$).

Similar results were obtained on the first sampling date in the second year of the study (Table 4.3). 0+ brown trout in Broad Cove River were significantly larger in both length ($t = -5.75$, $p = 0.0001$) and weight ($t = -5.05$, $p = 0.0007$) than those in Juniper Brook. However, by early September, 0+ trout in Juniper Brook had attained a mean length of 6.33 cm (±0.12) and mean weight of 2.042 g (±0.162); and were significantly larger (t-test, $p < 0.005$) than those in Broad Cove River whose respective mean length and weight were 5.30 cm (±0.14) and 1.622 g (±0.119). At all subsequent sampling times during the second year of the study, 0+ trout in Juniper Brook were significantly larger than those from Broad Cove River (t-test, $p < 0.05$).

The 1+ brown trout parr (by convention, salmonids in the northern Hemisphere have a January 1st birthday) collected

from the site on the Broad Cove River during the winter (4th January) had a mean fork length of 6.35 cm (±0.17 SE) and weight of 2.34 g (0.±0.18 SE). Both length and weight were not significantly different (t-test, $p > 0.05$) from the mean length and weight at the previous sampling. Similarly, although the mean condition of the trout parr was 0.897 in January compared to 0.920 at the previous sampling in early December, the difference was not significant ($t = -1.33$, $p = 0.21$). The one parr that was collected at the site on Juniper Brook was 6.9 cm long and weighed 3.17 g, but appeared moribund. In late May, 1+ parr at the site on Juniper Brook had a mean fork length of 7.03 cm (±0.09 SE) and weight of 3.61 g (±1.47 SE) but were not significantly larger (t-test, $p > 0.05$) than those in Broad Cove River whose respective mean length and weight were 6.75 cm (±0.11 SE) and 2.98 g (±0.17 SE).

When mean lengths and weights were plotted against time, the resulting arithmetic growth curve for 0+ trout in both streams approximated an S-shape (Figures 4.2 - 4.5). Growth was slow at the start of the growing season, increased sharply to a peak in mid-August, and then gradually decreased from September onwards. The variation in individual size of 0+ trout was greater as the fish increased in size; although weights were more variable than lengths at each sampling date (cf Figure 4.2 and 4.3).

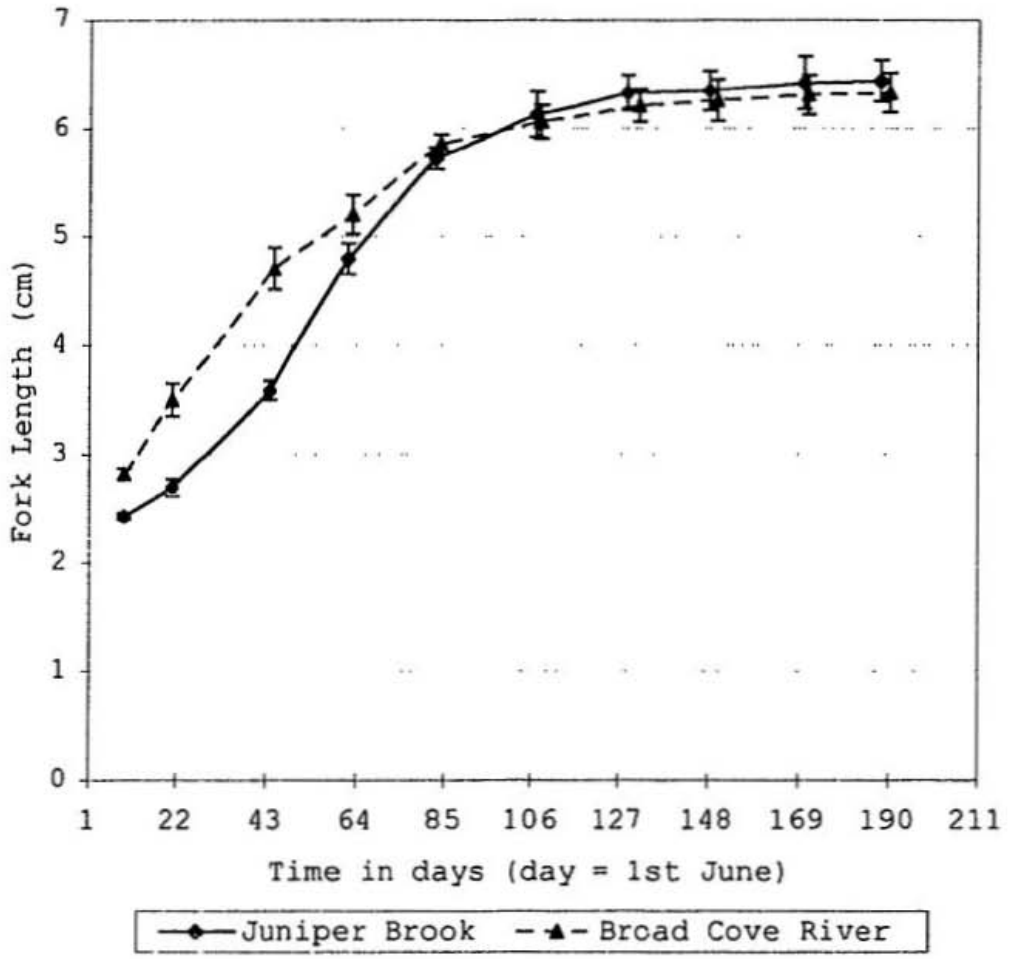


Figure 4.2: Arithmetic growth in length of 0+ brown trout collected from the two study sites in 1994 (vertical bars represent standard error of the mean).

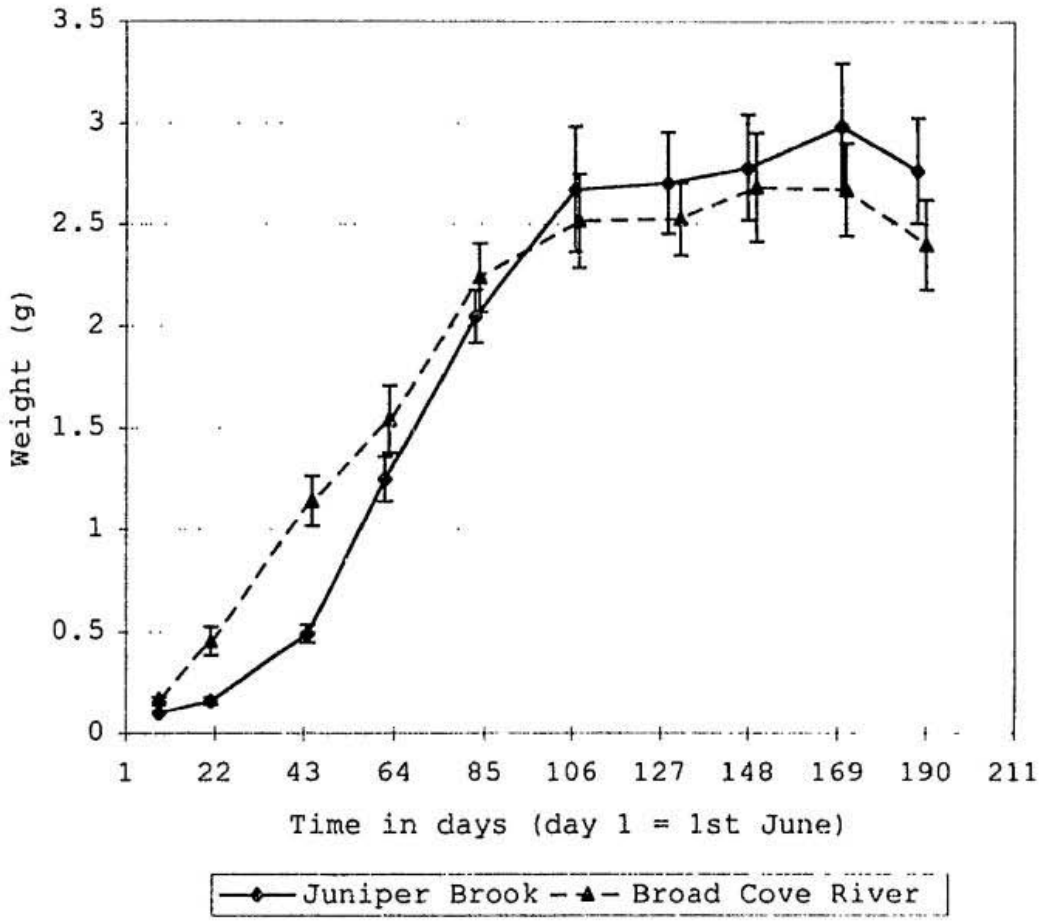


Figure 4.3: Arithmetic growth in weight of 0+ brown trout collected from the two study sites in 1994 (vertical bars represent standard error of the mean).

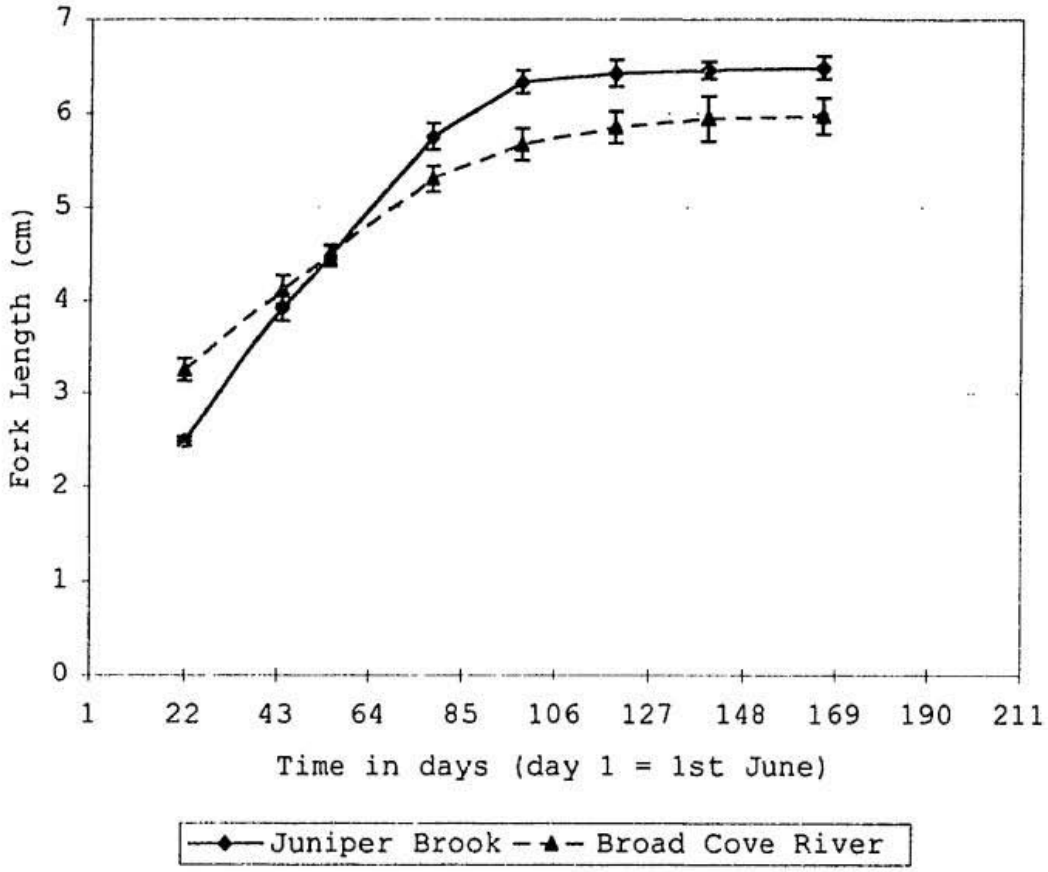


Figure 4.4: Arithmetic growth in length of 0+ brown trout collected from the two study sites in 1995 (vertical bars represent standard error of the mean).

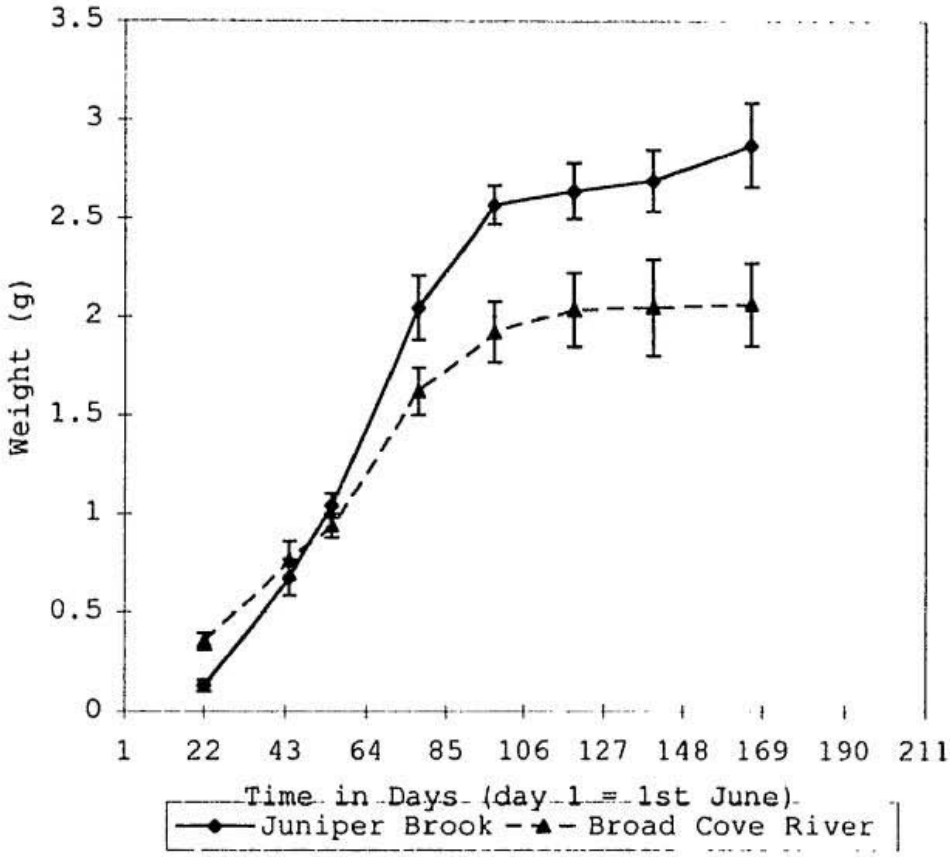


Figure 4.5: Arithmetic growth in weight of 0+ trout collected from the two study sites in 1995 (vertical bars represent standard error of the mean).

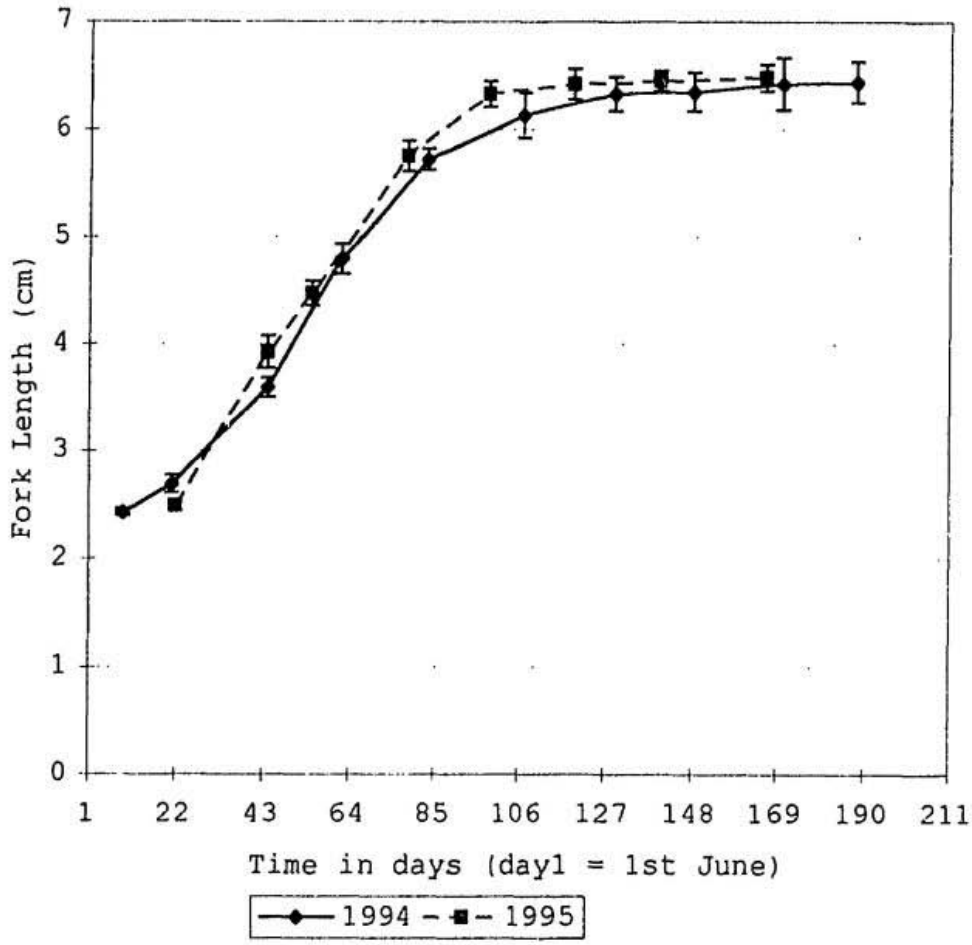


Figure 4.6: Comparison of the arithmetic growth in length of 0+ trout from Juniper Brook between the two years of the study (vertical bars represent standard error of the mean).

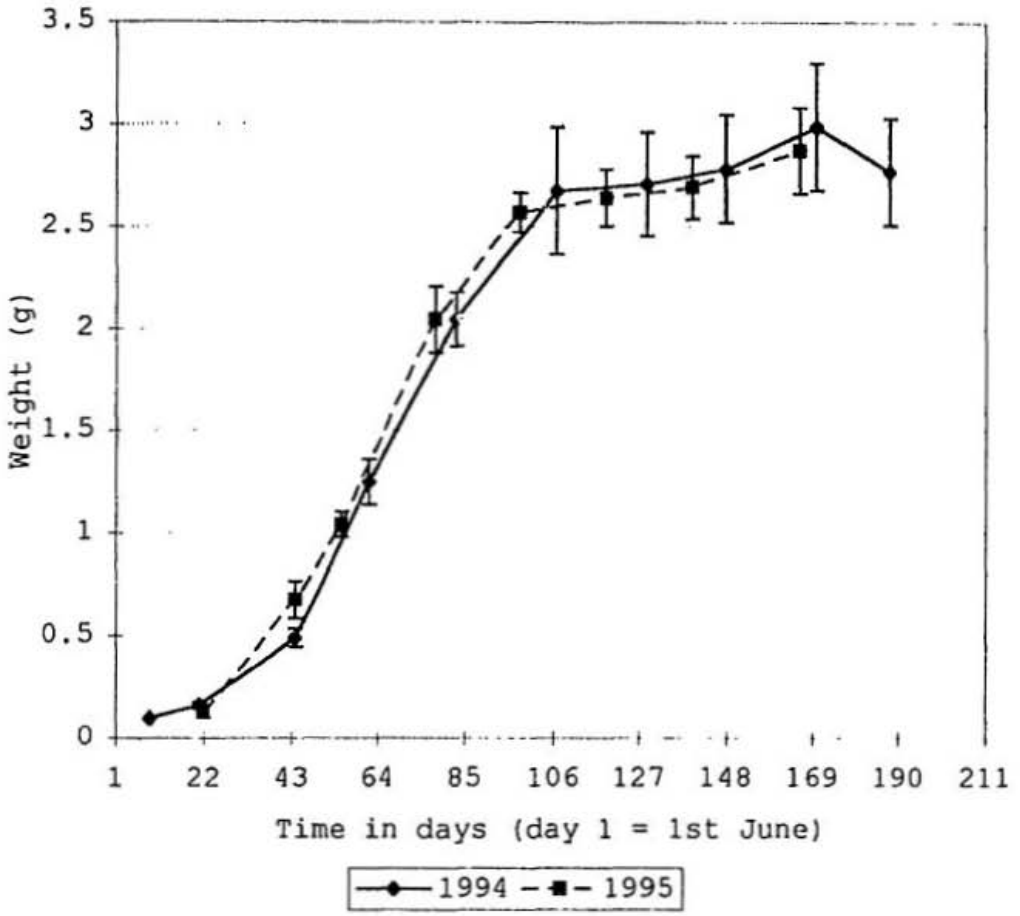


Figure 4.7: Comparison of the arithmetic growth in weight of 0+ trout in Juniper Brook between the two years of the study (vertical bars represent standard error of the mean).

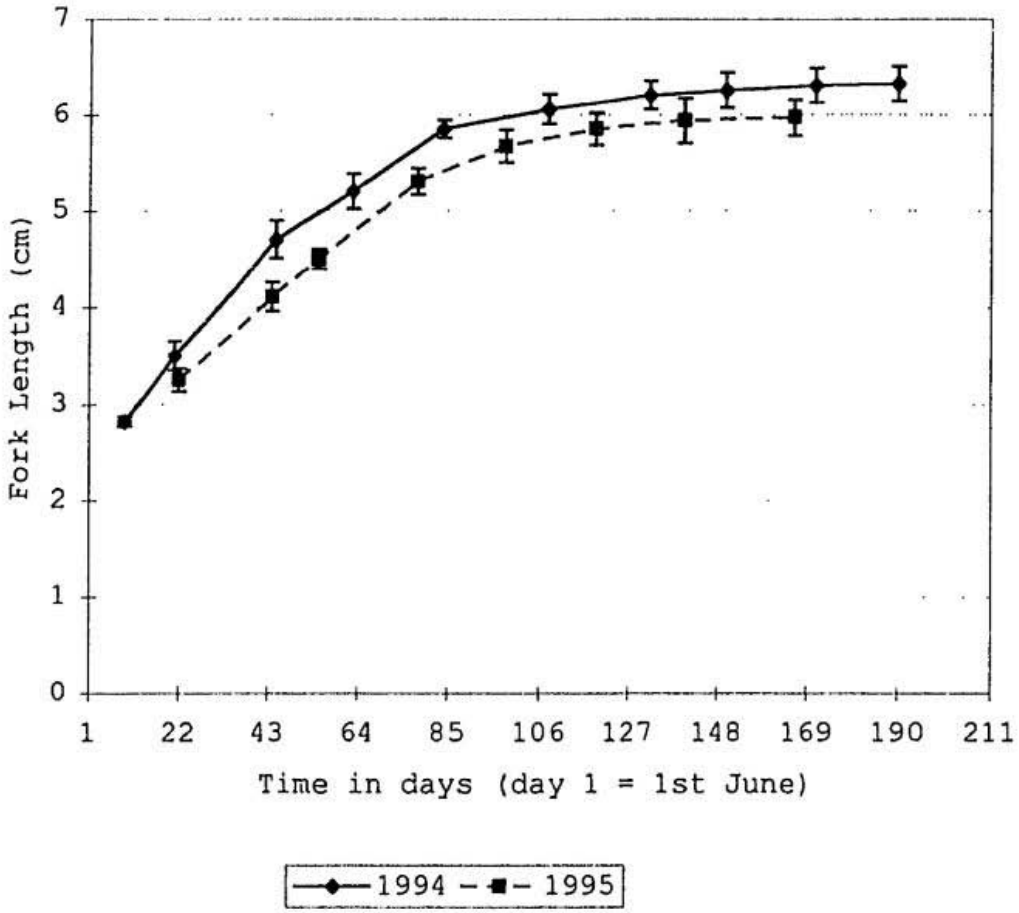


Figure 4.8: Comparison of the arithmetic growth in length of 0+ trout from Broad Cove River between the two years of the study (vertical bars represent standard error of the mean).

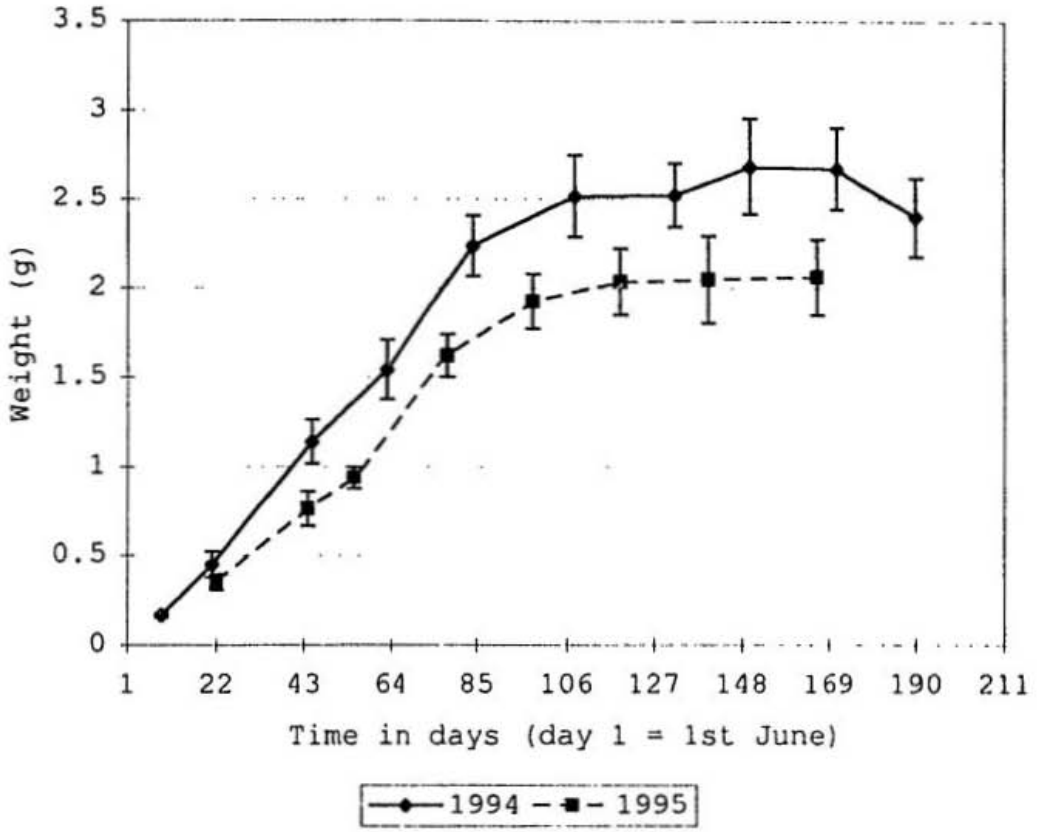


Figure 4.9: Comparison of the arithmetic growth in weight of 0+ trout in Broad Cove River between the two years of the study (vertical bars represent standard error of the mean).

Similar trends in the arithmetic growth of 0+ trout were obtained in the second year of the study (Figure 4.4 and 4.5). Within streams, arithmetic growth rates in length (Figure 4.6) and weight (Figure 4.7) were not significantly different for 0+ brown trout in Juniper Brook between the two years of the study but significantly different for those in Broad Cove River (Figure 4.8 and 4.9), with 0+ brown trout achieving better growth in 1994.

4.2.2 Condition of 0+ Trout

Table 4.1 and 4.2 also show the mean condition (K) (and standard errors) of 0+ brown trout at the various sampling dates in 1994 and 1995 respectively. When first sampled in each year, 0+ trout in both streams were generally in poor condition; with K values being below unity. However, those in Juniper Brook had lower condition than those in Broad Cove River. The differences in mean condition were significant for the second ($t = -3.95$, $p = 0.001$) but not for the first year ($t = -0.95$, $p = 0.36$) of the study. The mean condition of 0+ trout in both streams increased rapidly in the early part of the growing season (Figure 4.10 and 4.11) and were above unity for most of the summer. In the fall, the mean condition of trout in the two streams declined progressively to values of less than one

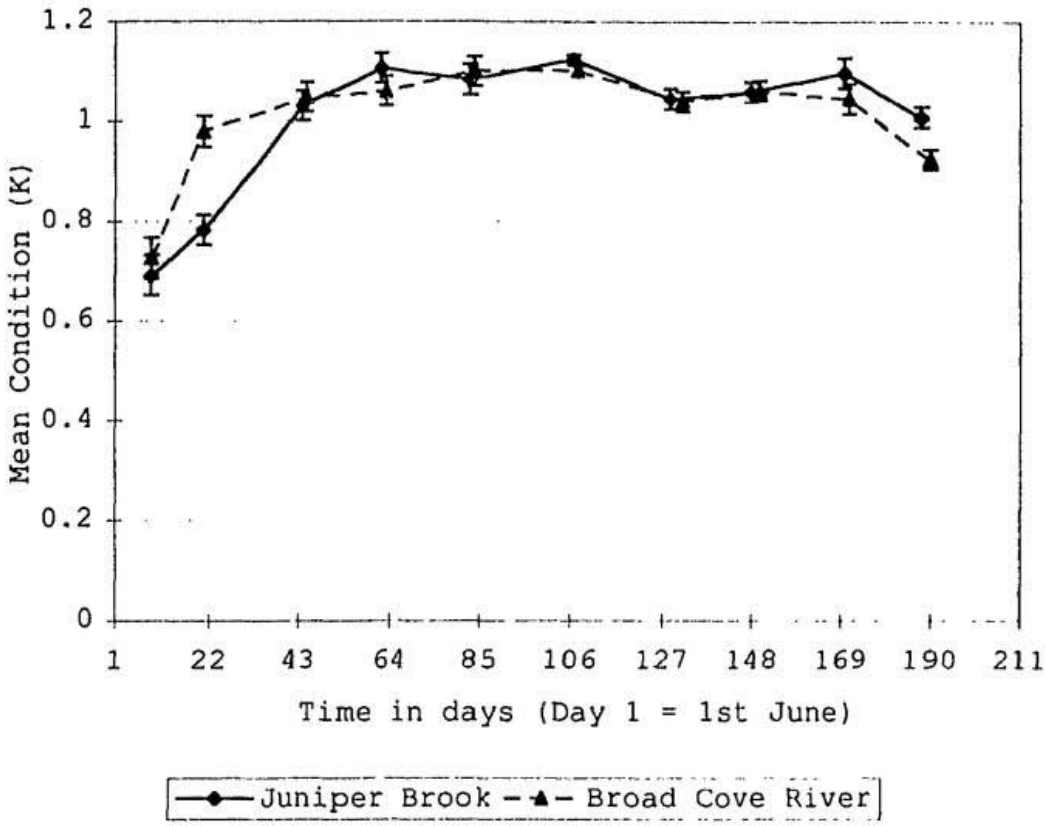


Figure 4.10: Seasonal variation in the mean condition of 0+ trout collected from the two study sites in 1994 (vertical bars represent standard error of the mean).

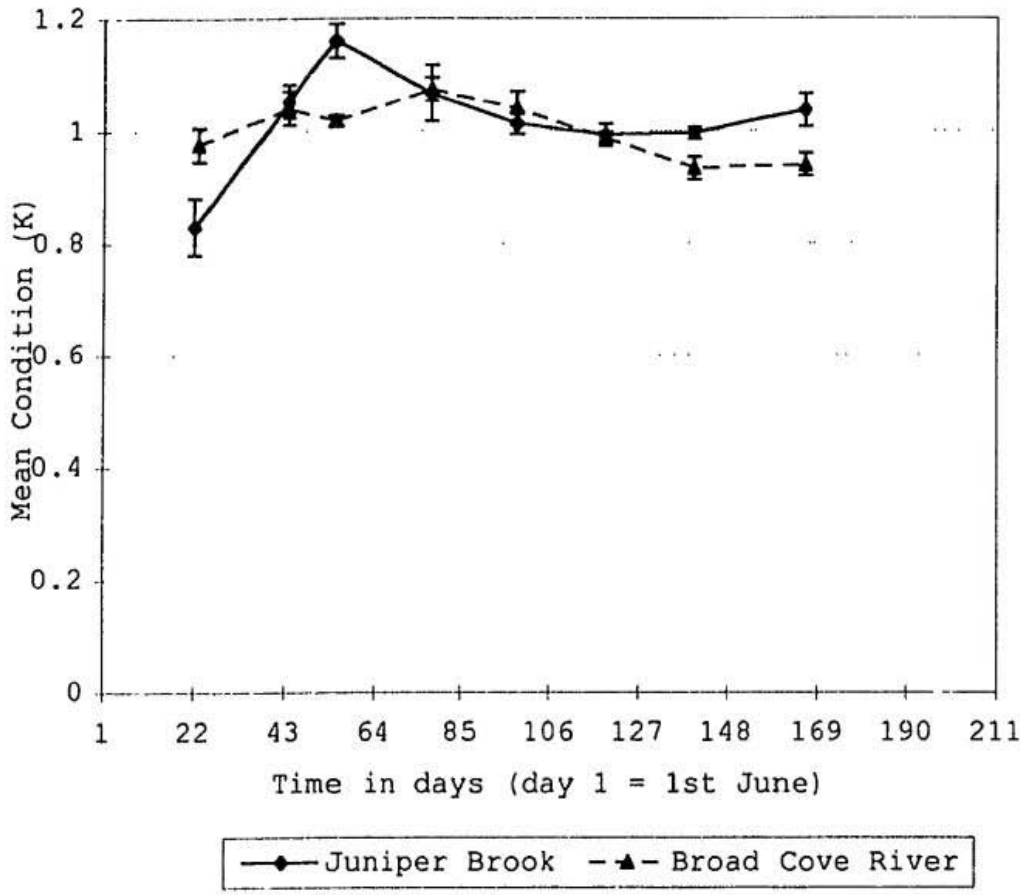


Figure 4.11: Seasonal variation in the mean condition of 0+ trout collected from the two study sites in 1995 (vertical bars represent standard error of the mean).

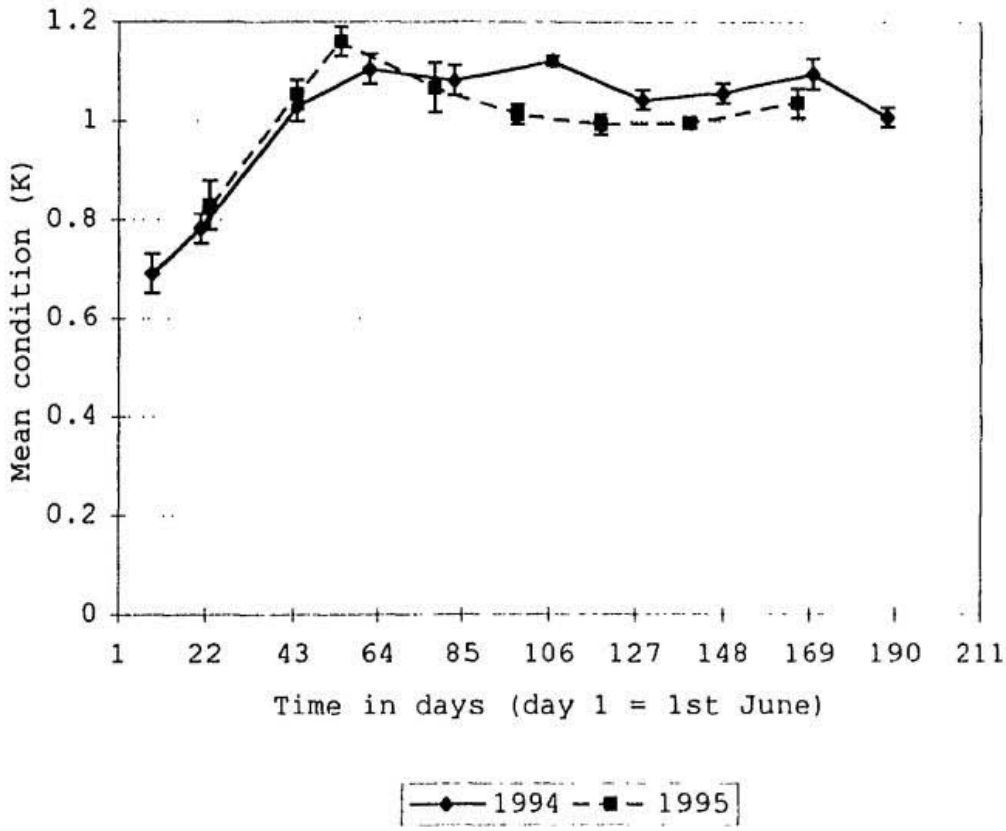


Figure 4.12: Comparison of the mean condition of 0+ trout from Juniper brook between the two years of the study (vertical bars represent standard error of the mean).

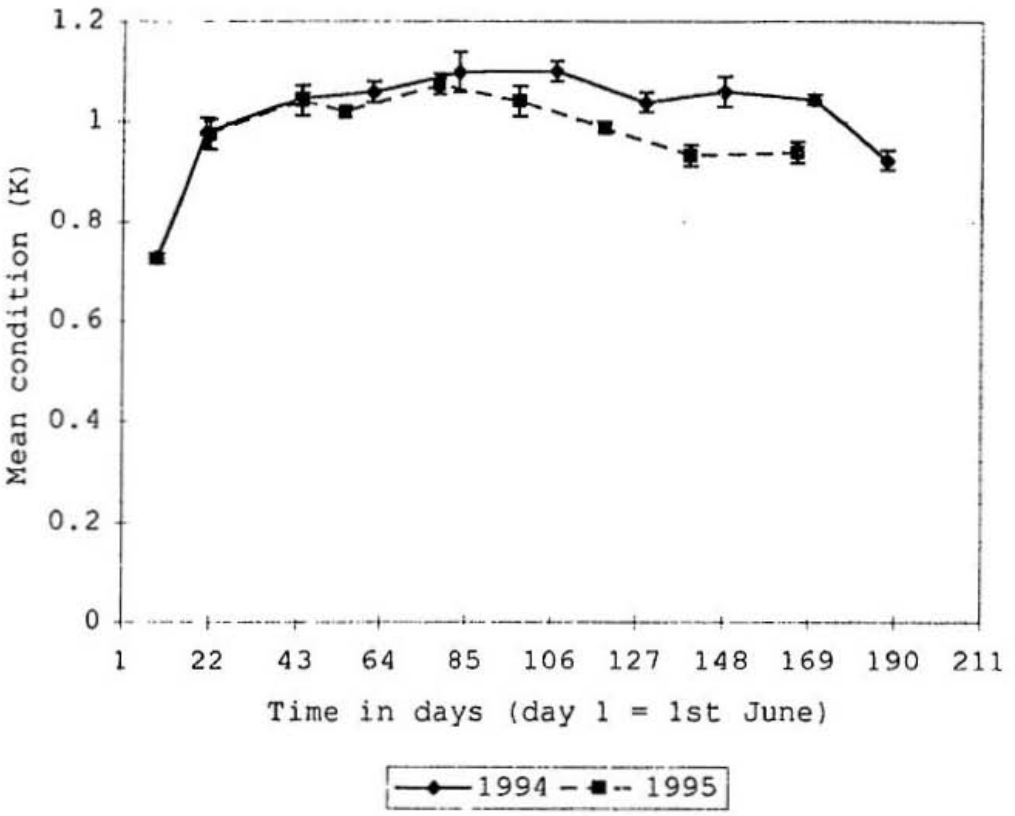


Figure 4.13: Comparison of the mean condition of 0+ trout from Broad Cove River between the two years of the study (vertical bars represent standard error of the mean).

by November, with those in Broad Cove River being the lower at each sampling date. Figure 4.12 shows that for 0+ brown trout in Juniper Brook, the 1995 year class were in better condition in the early part of summer but not for the rest of the growing season. In Broad Cove River, 1994 young of the year were generally in better condition than 1995 young of the year (Figure 4.13).

4.2.3 Specific Growth of 0+ Trout

Specific growth rates for length and weight of 0+ trout from the two streams in 1994 and 1995 are presented in Table 4.4a and 4.4b respectively. The tables also show the mean water temperatures recorded in the two streams at the various sampling times. Table 4.4a shows that specific growth rate in both length and weight increased with increasing temperature early in the growing season, but this relationship was not evident when temperatures rose above 15.9 °C in Juniper Brook and 13.2 °C in Broad Cove River. However, in the following year, there was no clear relationship between specific growth in weight and water temperature (Table 4.4b). In both years, specific growth rates tended to decrease with decreasing temperature during the fall. Between all sampling dates in both years, specific growth rates for weight were much higher than

Table 4.4 Water temperature (T), specific growth in length (G_L), and weight (G_W) of 0+ brown trout at each sampling date in (a) 1994 and (b) 1995.

(a)

Sampling Date	Juniper Brook			Broad Cove River		
	T (°C)	G_L (%d^{-1})	G_W (%d^{-1})	T (°C)	G_L (%d^{-1})	G_W (%d^{-1})
06 Jun	11.5	-	-	10.0	-	-
21 Jun	12.8	0.85	3.98	11.7	1.80	8.38
14 Jul	13.6	1.25	4.90	13.2	1.23	4.69
01 Aug	15.9	1.60	5.22	14.7	0.56	1.68
26 Aug	16.4	0.84	2.35	15.1	0.56	1.77
15 Sep	12.0	0.28	1.12	13.5	0.15	0.49
07 Oct	7.8	0.15	0.05	11.8	0.10	0.01
26 Oct	5.2	0.02	0.15	10.5	0.05	0.32
17 Nov	3.5	0.05	0.32	6.0	0.04	-0.02
07 Dec	0.3	0.00	-0.43	1.1	0.00	-0.52

(b)

Sampling Date	Juniper Brook			Broad Cove River		
	T (°C)	G_L (%d^{-1})	G_W (%d^{-1})	T (°C)	G_L (%d^{-1})	G_W (%d^{-1})
22 Jun	13.9	-	-	13.1	-	-
14 Jul	14.8	2.06	7.48	12.5	1.12	3.67
25 Jul	14.9	1.19	3.98	14.2	0.82	1.89
17 Aug	15.3	1.09	2.92	13.5	0.71	2.38
06 Sep	11.5	0.48	1.15	12.2	0.34	0.84
27 Sep	8.6	0.07	0.13	10.8	0.15	0.27
18 Oct	6.3	0.02	0.09	9.6	0.07	0.04
13 Nov	4.1	0.02	0.26	5.7	0.02	0.02

those for length for 0+ trout in the same stream (Table 4.4a and 4.4b).

Comparison of the amount of heat energy available for the growth of 0+ trout in each stream from the date of first sampling to when mean stream temperatures fell below 4 °C each year are presented in Figure 4.14. In each year the cumulative degree days were much higher in Juniper Brook than in Broad Cove River. However, between the two years degree-days were lower in 1995 compared to 1994.

Figures 4.15 and 4.16 show the seasonal variation in specific growth rates for length and weight of 0+ trout respectively over the 1994 growing season. Specific growth rates for length and weight in Broad Cove River were highest early in the summer (i.e. between the first and second sampling dates), but decreased thereafter and were lower than in Juniper Brook for the rest of the growing season. In Juniper Brook, specific growth rates for both length and weight were low initially but increased to a peak in early August and then progressively decreased to zero (for length) and negative values (for weight, Figure 4.16) towards the end of fall. The short phase of increasing specific growth rate with time early in the summer was not evident in the curves for 0+ trout in Broad Cove River which showed a continuous decrease with time from a peak in June.

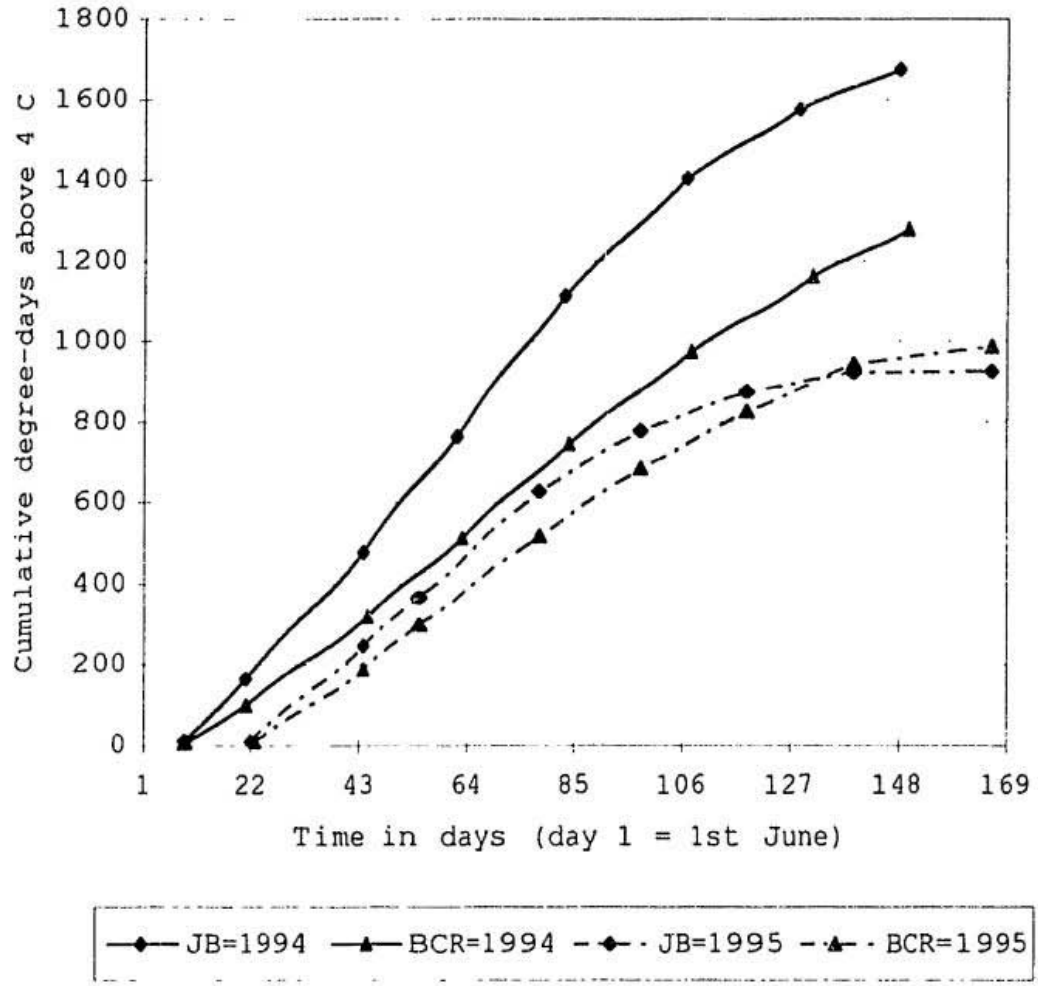


Figure 4.14: Comparison of the total amount of heat (degree-days) available for the growth of 0+ trout in the two study streams in 1994 and 1995

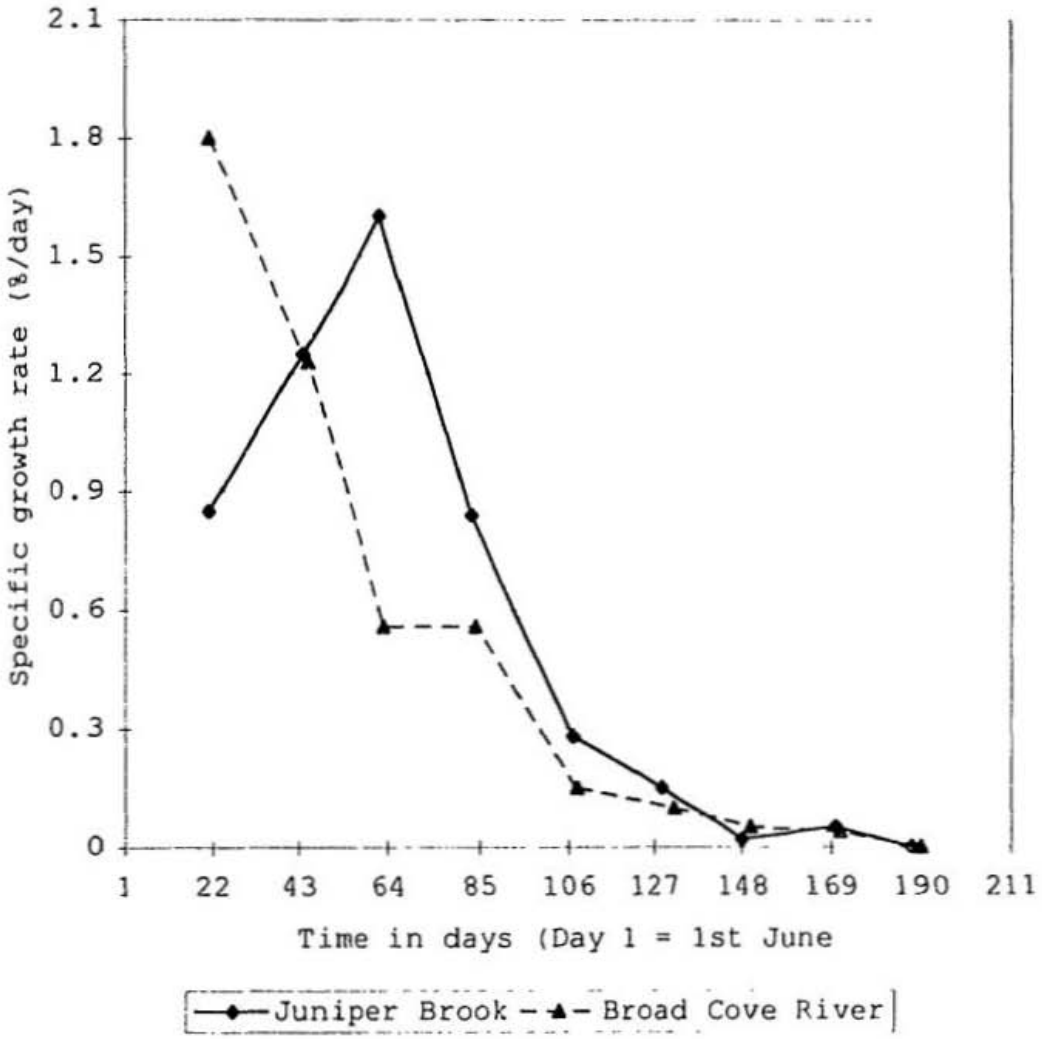


Figure 4.15: Comparison of the specific growth rates (in length) of 0+ trout sampled from the two study sites in 1994

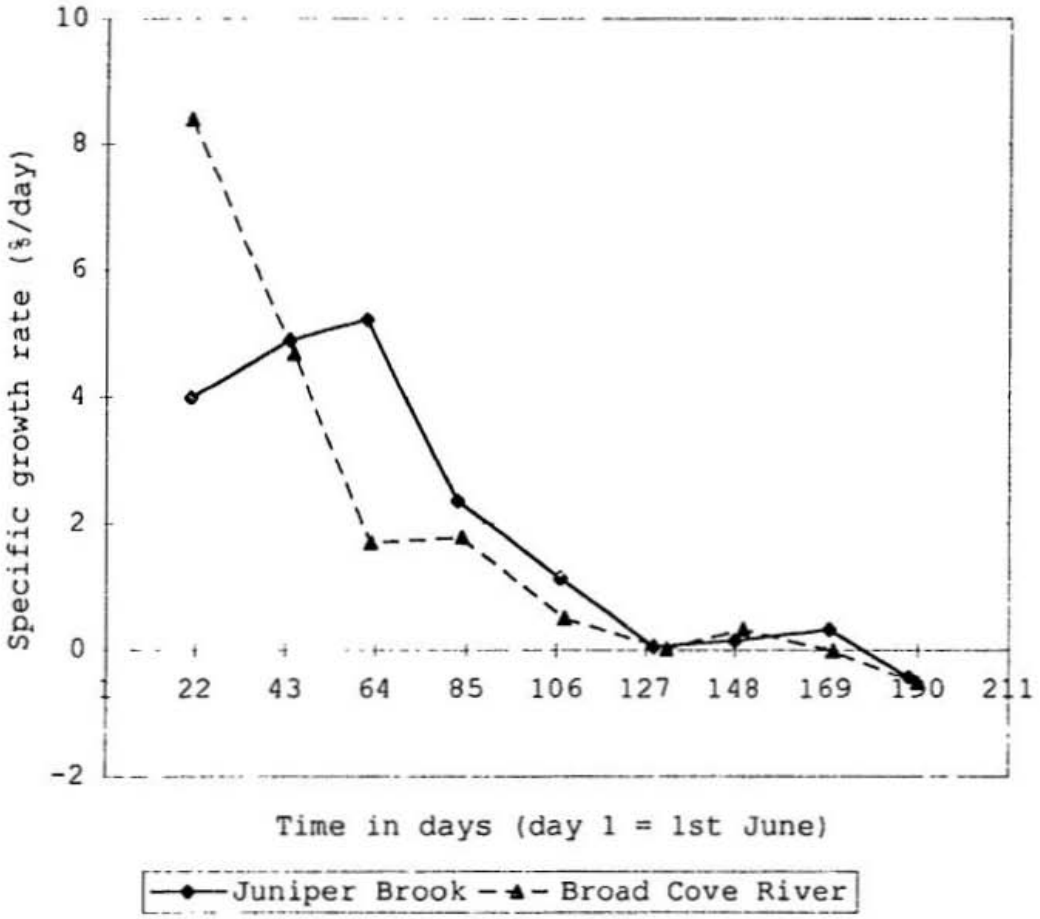


Figure 4.16: Comparison of the specific growth rates (in weight) of 0+ trout sampled from the two study sites in 1994

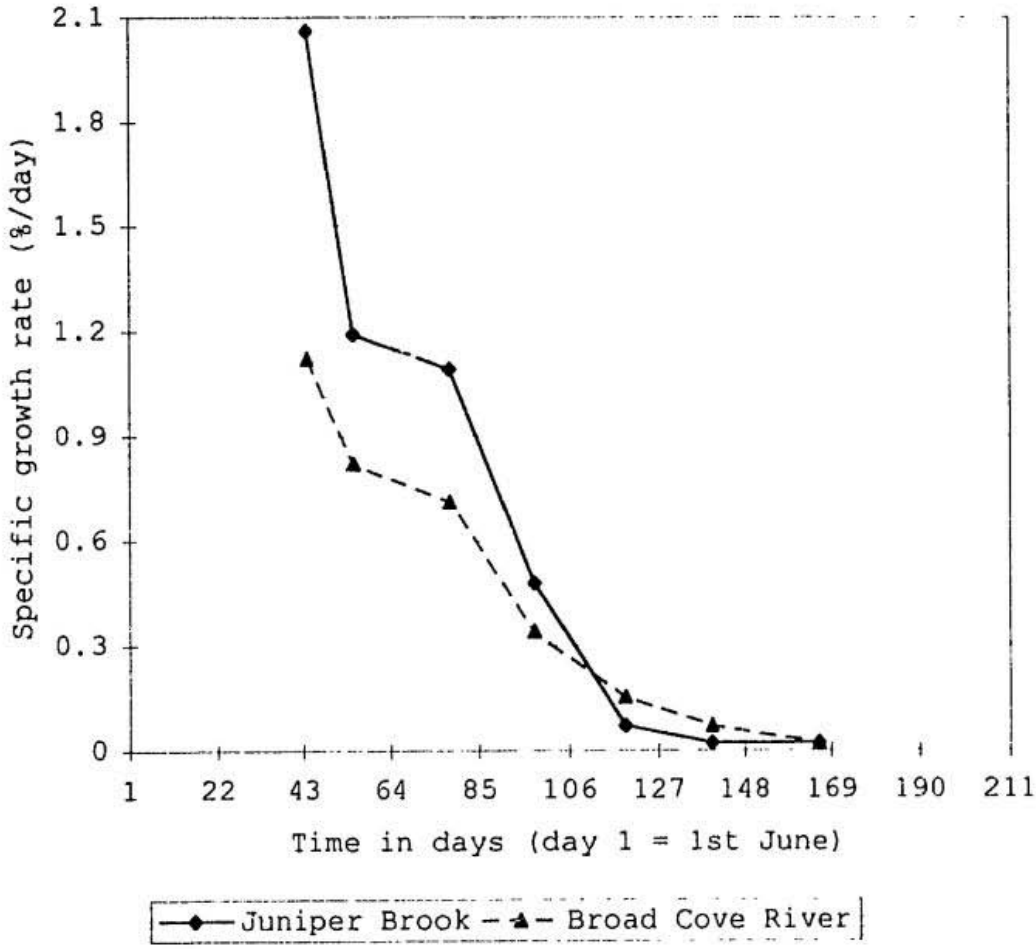


Figure 4.17: Comparison of the specific growth rates (in length) of 0+ trout sampled from the two study sites in 1995

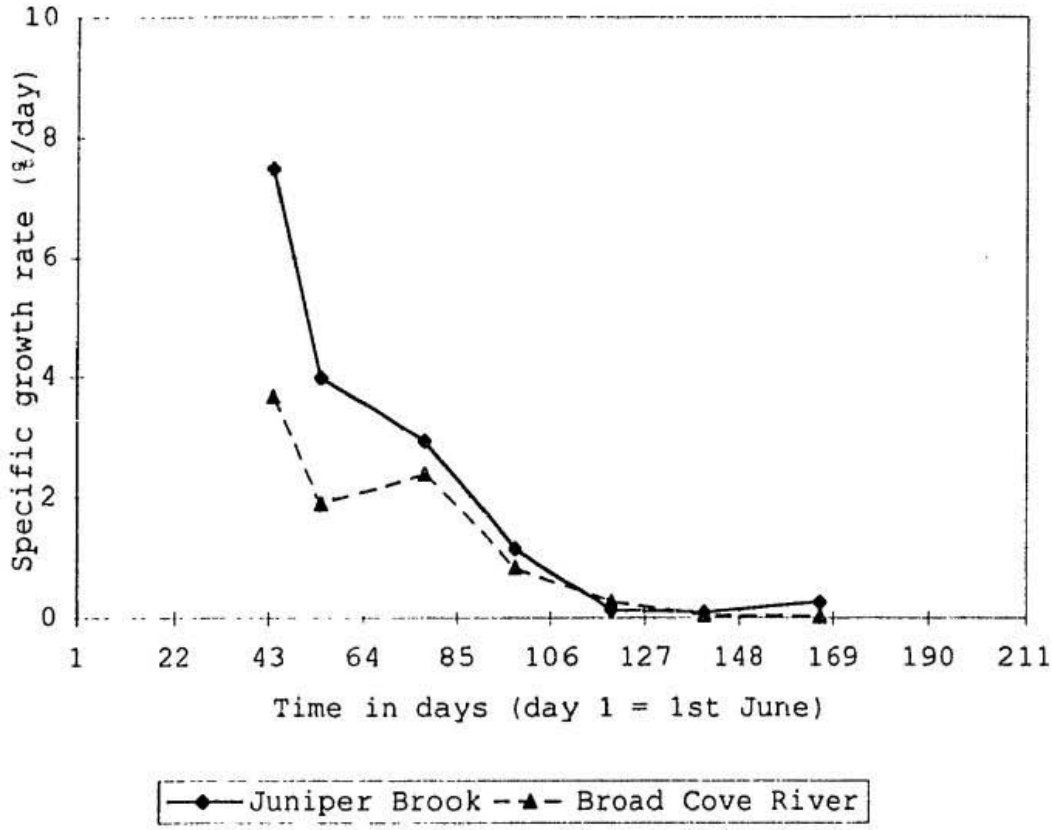


Figure 4.18: Comparison of the specific growth rates (in weight) of 0+ trout sampled from the two study sites in 1995

In the second year of the study, specific growth rate for both length (Figure 4.17) and weight (Figure 4.18) of 0+ trout were higher in Juniper Brook than in Broad Cove River throughout the summer season. Within streams, specific growth rates for weight were highest in early summer, decreasing to zero by mid fall. Specific growth rates for trout in the two streams were not very different in the fall. In the first year of the study, negative growth (in weight) was recorded for 0+ trout in both streams towards the onset of winter, although this was more pronounced, and occurred much earlier, for 0+ trout in Broad Cove River (Figure 4.18).

4.3 Food and Feeding Habits of 0+ Brown Trout

4.3.1 Diet of 0+ Trout in the two Streams

The total number, type of prey, their percent composition by number (% N) and frequency of occurrence (% F) in the diets of 0+ trout in Juniper Brook and Broad Cove River during the summer and fall of 1994 and 1995 are presented in Tables B1 - B8 in Appendix B. Also presented in Appendix B are the food of 0+ trout in the Virginia River (Table B9), the winter food of trout parr in Broad Cove River (Table B10), and that of 1+ parr sampled from the two study sites in late May, 1995 (Table B11).

When first sampled, most 0+ trout in Juniper Brook had not started exogenous feeding. However, the three which had food in their stomachs had only chironomid larvae (Table B1). Chironomid larvae (Family: Chironomidae) were the most important prey, both numerically and by frequency of occurrence, consumed by 0+ trout in Juniper Brook although immature baetid nymphs (Baetidae; Order: Ephemeroptera), and Trichoptera of the families Hydropsychidae and Hydroptilidae were increasingly important at subsequent sampling dates (Table B1).

All 0+ brown trout in Broad Cove River had food in their stomachs at the first sampling in 1994, and numerically chironomid larvae formed the largest proportion (74.6%) of the diet (Table B3). However, at subsequent sampling dates in the summer, the food of 0+ trout in Broad Cove River was dominated by either hydroptilid caddisfly larvae, baetid nymphs, or black fly larvae (Family: Simuliidae). Although immature aquatic stages of the Orders Diptera, Ephemeroptera and Trichoptera were the major food in both streams, individuals belonging to a larger number of families in each of these orders were found in the stomachs of 0+ trout in Broad Cove River than in Juniper Brook (cf Table B1 and B3).

In the fall, 0+ trout in both streams ingested a greater diversity of food items (Table B2 and B4). However,

chironomids decreased in importance in both streams, although they were still taken in greater number in Juniper Brook than in Broad Cove River. Other families of Ephemeroptera were consumed by trout in both streams, in addition to the baetid nymphs (Table B2 and B4).

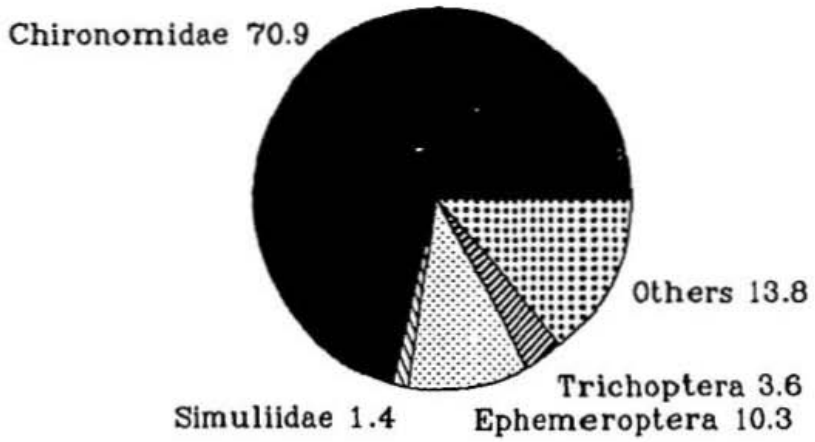
Non-insect aquatic invertebrates, although regularly consumed by 0+ trout in both streams, formed relatively small proportions (< 10% at most sampling dates) of the diet. Of these, water mites (Hydracarina) and crustaceans (both copepods and cladocerans) were the more frequently ingested. Although terrestrial insects were consumed only occasionally in the early part of the growing season (Table B1 and B3), they were ingested in greater numbers in the fall (Table B2 and B4). The highest incidence of terrestrial invertebrate prey occurred in September of 1994 when they formed as much as 35.5% of the total food items of 0+ trout in Juniper Brook (Table B2). Most of these were aphids (Order: Homoptera) and flying ants (Order: Hymenoptera), although terrestrial Coleoptera, Collembola, Lepidoptera and Psocoptera were also eaten.

Similar results were obtained during the summer (Table B5 and B7) and fall of 1995 (Table B6 and B8), although all trout in both streams had food in their stomachs at the first sampling date (Table B5 and B7). The other major difference between the two years was in the incidence of

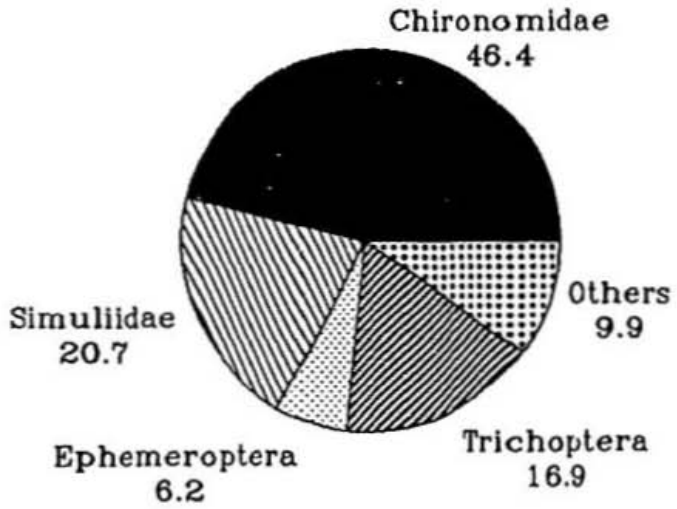
terrestrial insects in the diet; less taxa and fewer number of individuals were consumed in 1995. Pteromalid wasps (Family: Pteromalidae), and Collembola of the families Isotomidae and Poduridae were the only terrestrial taxa in stomach contents from the two study sites in the later part of the 1995 growing season (Table B6 and B8).

4.3.2 Seasonal Variation in Food Habits

The composition of the summer and fall diets for the two years are presented in Figures 4.19 - 4.22. In 1994, the food of 0+ trout in both streams during the summer consisted primarily of immature stages belonging to three orders of aquatic insects: Diptera (mainly Chironomidae and Simuliidae), Ephemeroptera, and Trichoptera (Figure 4.19). Numerically, chironomid larvae were the most important prey in both streams but they formed a greater proportion of the diet in Juniper Brook throughout the summer, comprising over 70.9% of all food items compared to 46.7% in Broad Cove River. Similarly chironomids dominated the summer food in 1995 forming 76.7% and 63.9% of all food items consumed in Juniper Brook and Broad Cove River respectively (Figure 4.21). Both black fly larvae and Trichoptera formed a higher proportions of the diet in Broad Cove River than in Juniper Brook. However, the proportions of Ephemeroptera

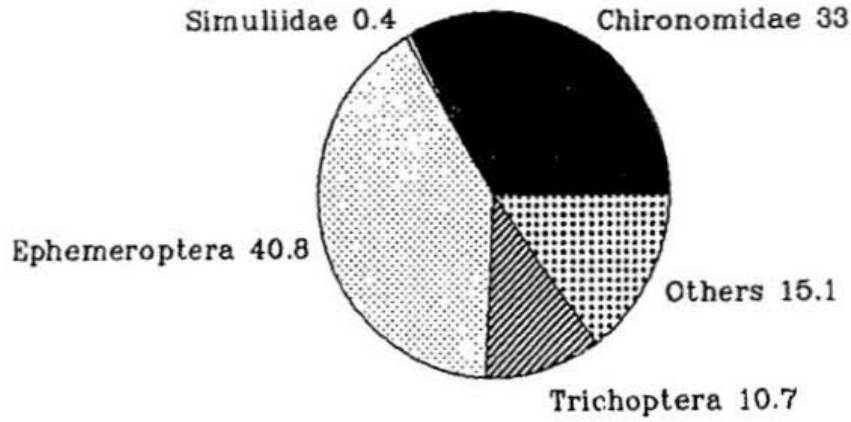


A. Juniper Brook

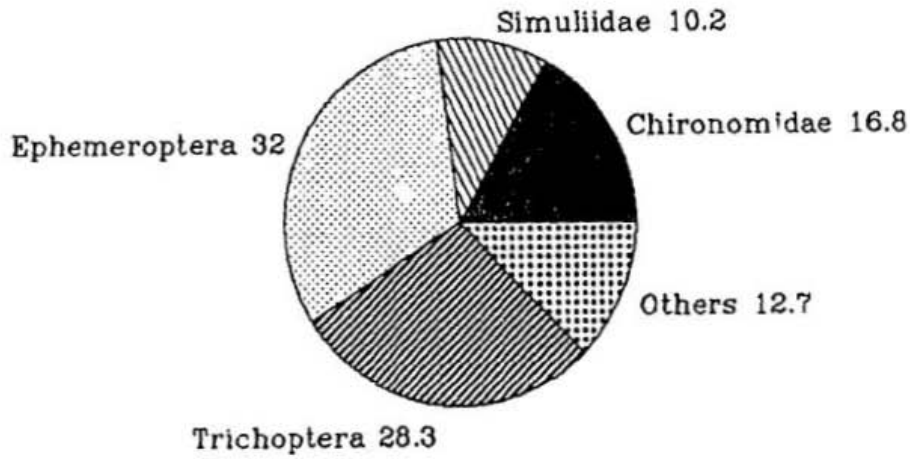


B. Broad Cove River

Figure 4.19 The summer diet of 0+ trout sampled from (a) Juniper Brook and (b) Broad Cove River in 1994 (Numbers represent percent of the total food items for the season).

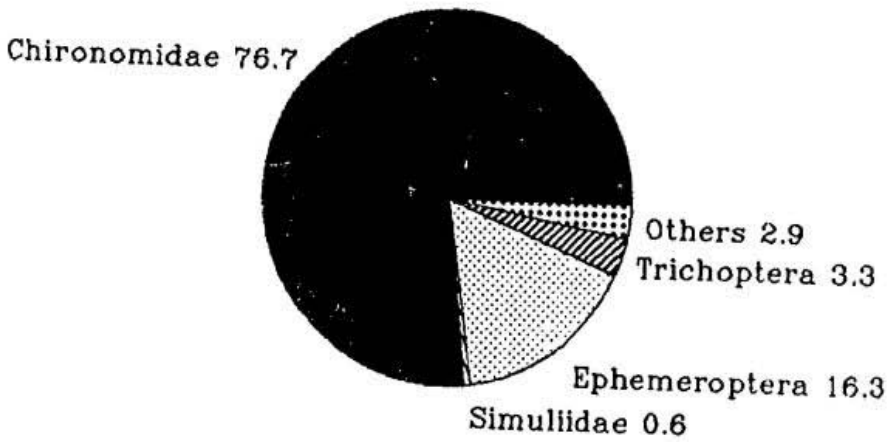


A. Juniper Brook

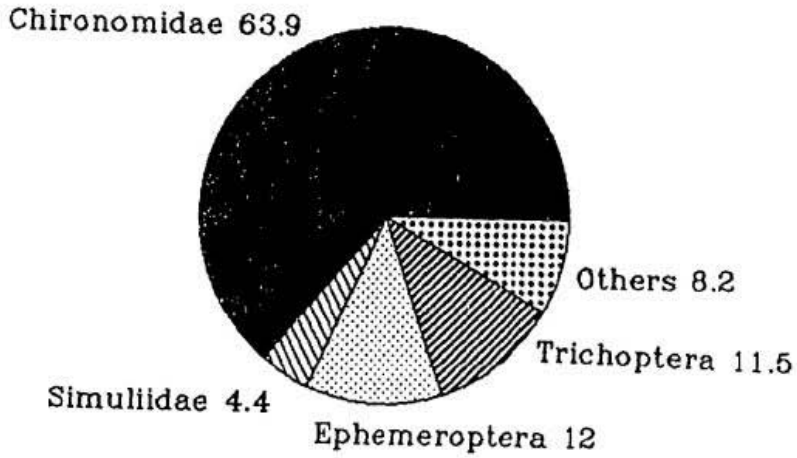


B. Broad Cove River

Figure 4.20 The fall diet of 0+ trout sampled from (a) Juniper Brook and (b) Broad Cove River in 1994 (Numbers represent percent of the total food items for the season).

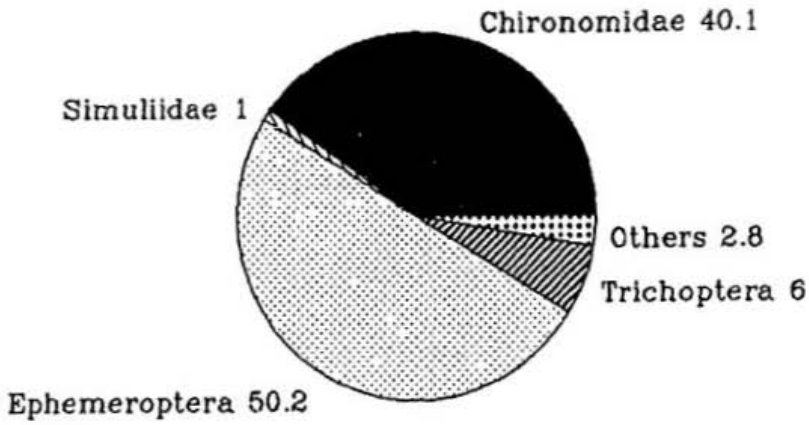


A. Juniper Brook

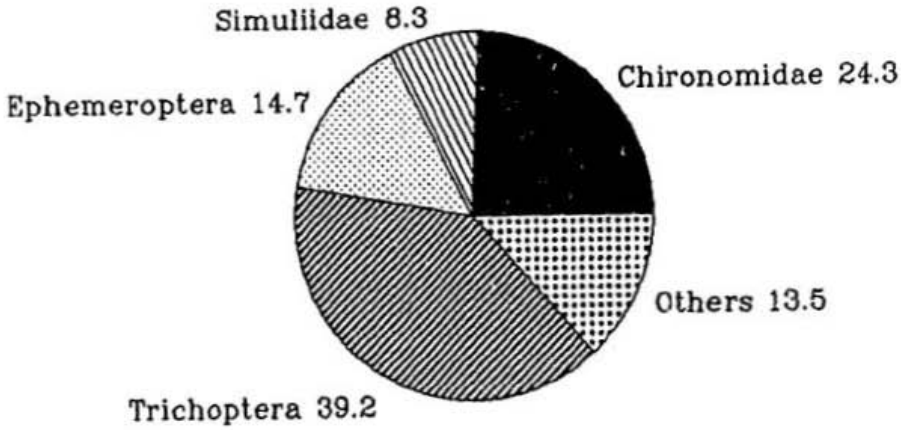


B. Broad Cove River

Figure 4.21 The summer diet of 0+ trout sampled from (a) Juniper Brook and (b) Broad Cove River in 1995 (Numbers represent percent of the total food items for the season).



A. Juniper Brook



B. Broad Cove River

Figure 4.22 The fall diet of 0+ trout sampled from (a) Juniper Brook and (b) Broad Cove River in 1995 (Numbers represent percent of the total food items for the season).

nymphs in the diet in both streams were relatively similar (Figure 4.19).

During the fall, a high number of taxa comprised the diet of 0+ trout in both streams; but in relatively low numbers per taxon. Chironomid larvae were still consumed regularly in both streams but were less important proportionately (Figure 4.20). Simuliid larvae were consumed in higher numbers in Broad Cove River in both years (Figure 4.20 and 4.22) than in Juniper Brook (Figure 4.20 and 4.22). Ephemeropteran nymphs and the larvae of caddis flies (Order Trichoptera) became more important, at least numerically, in the fall food of 0+ trout in both streams (Figure 4.20 and 4.22). Immature aquatic stages of the orders Odonata, Coleoptera, Hemiptera and Plecoptera were also consumed frequently but in relatively low numbers. Other invertebrates, dominated by crustaceans, also increased in importance in the early part of fall, forming over 13% of the diet in Broad Cove River in the fall of 1995 (Figure 4.22b).

Although the diets of 0+ trout in the two streams were taxonomically similar, they differed in the numerical proportions of the major food categories. When prey in the diets were pooled into major food categories and analyzed, the numerical composition of the summer diets of 0+ trout in the two streams in 1994 were found to be significantly

different ($G = 349.67$, $df = 7$, $p < 0.0001$) as were the fall diets ($G = 178.39$, $df = 7$, $p < 0.0001$). Similarly, the composition of the diets of 0+ trout in 1995 were significantly different ($G = 15.56$, $df = 7$, $p = 0.0001$) in the summer as well as in the fall ($G = 513.28$, $df = 7$, $p = 0.0001$).

Figures 4.23 and 4.24 show that the mean number of prey increased at each successive sampling date through the early part of the growing season but no similar relationship was evident in the later part of the growing season. Similarly, the mean number of chironomids ingested per individual fish was higher in Juniper Brook than for those in Broad Cove River (Figure 4.25 and Figure 4.26). Both the number of prey consumed and the number of chironomids in both streams showed considerable variation among fish in a sample (Figures 4.23 - 4.26).

The diet of 0+ trout sampled from the Virginia River on two occasions during the summer of 1994 are presented in Table B9. Chironomids were clearly the major prey consumed by 0+ trout in this river forming 91.3% and 97.3% of all ingested food items at the first and second sampling dates respectively. All fish had ingested chironomids. Both Ephemeroptera and Trichoptera were consumed in low proportions and by a few fish in a sample as were all other prey organisms in the diet (Table B9).

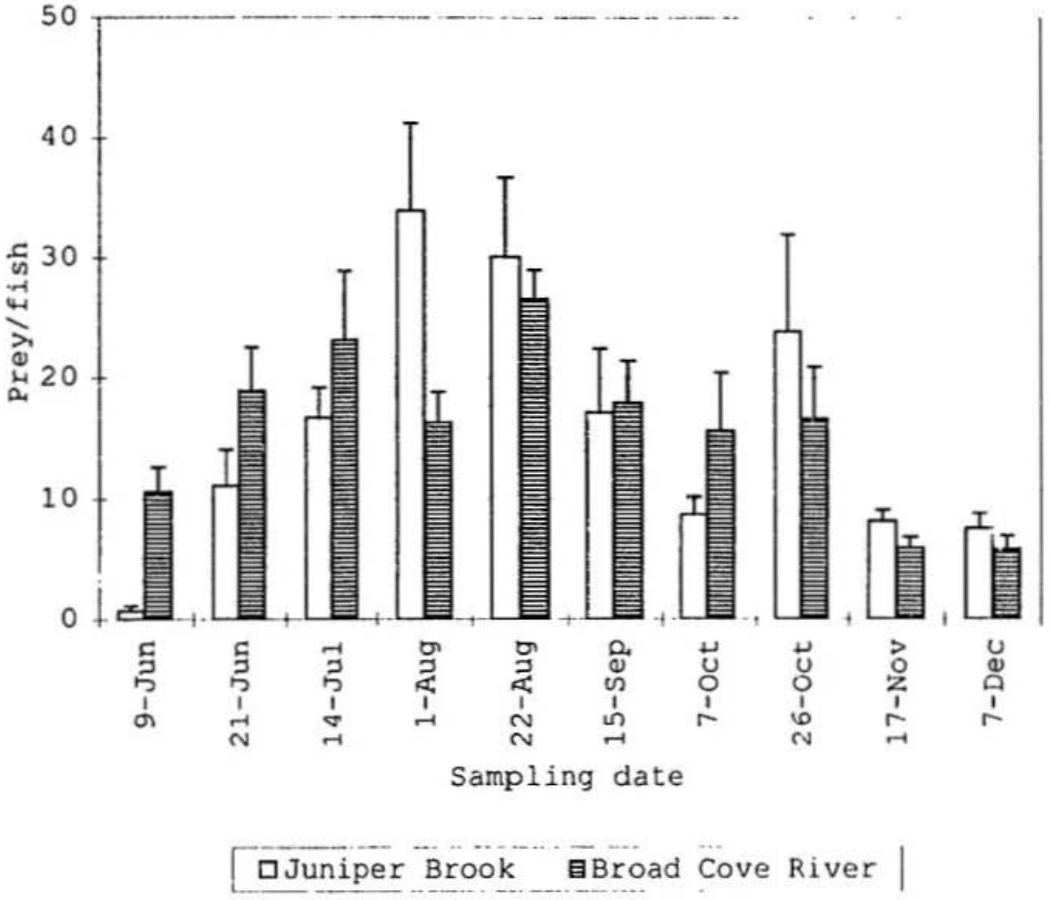


Figure 4.23: Mean number of prey (+Standard Error) in the stomachs of 0+ trout from the two study streams at various sampling dates in 1994.

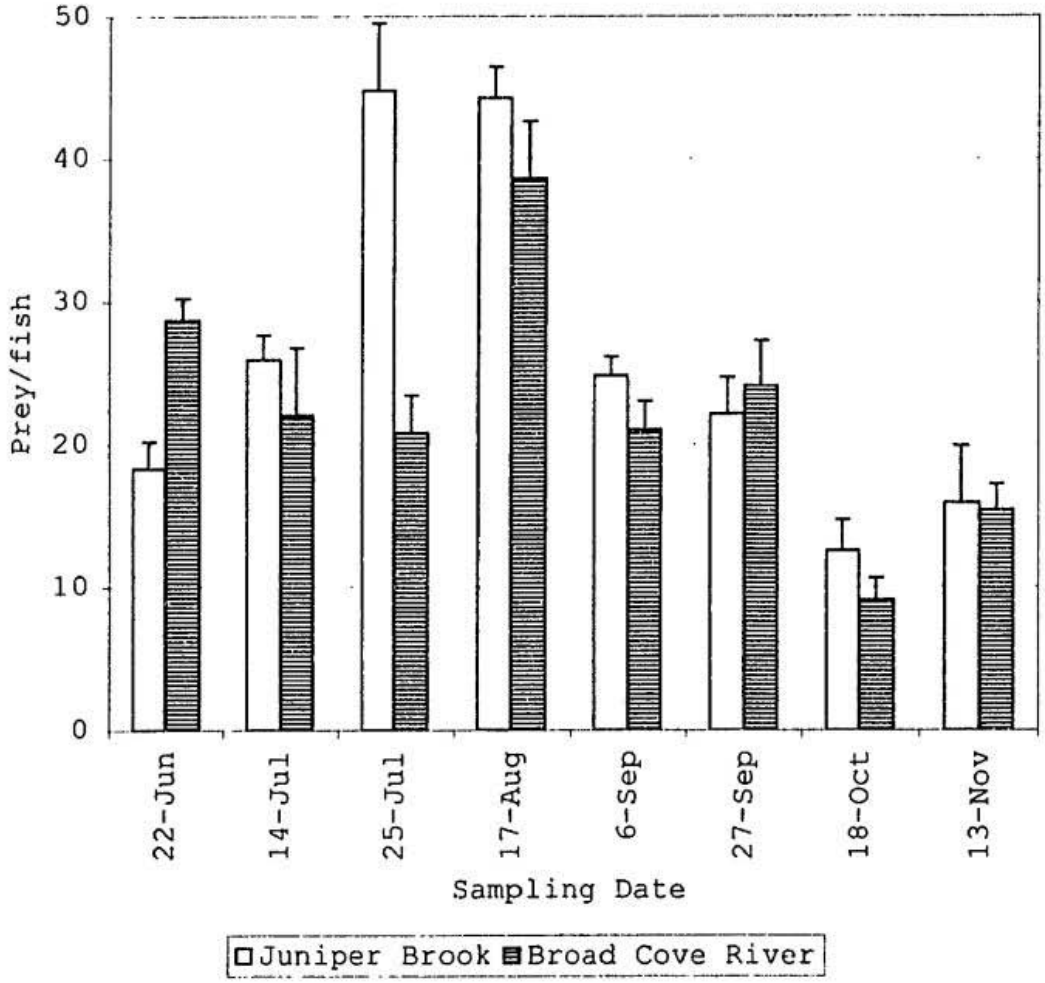


Figure 4.24: Mean number of prey (+Standard Error) in the stomachs of 0+ trout from the two study streams at various sampling dates in 1995.

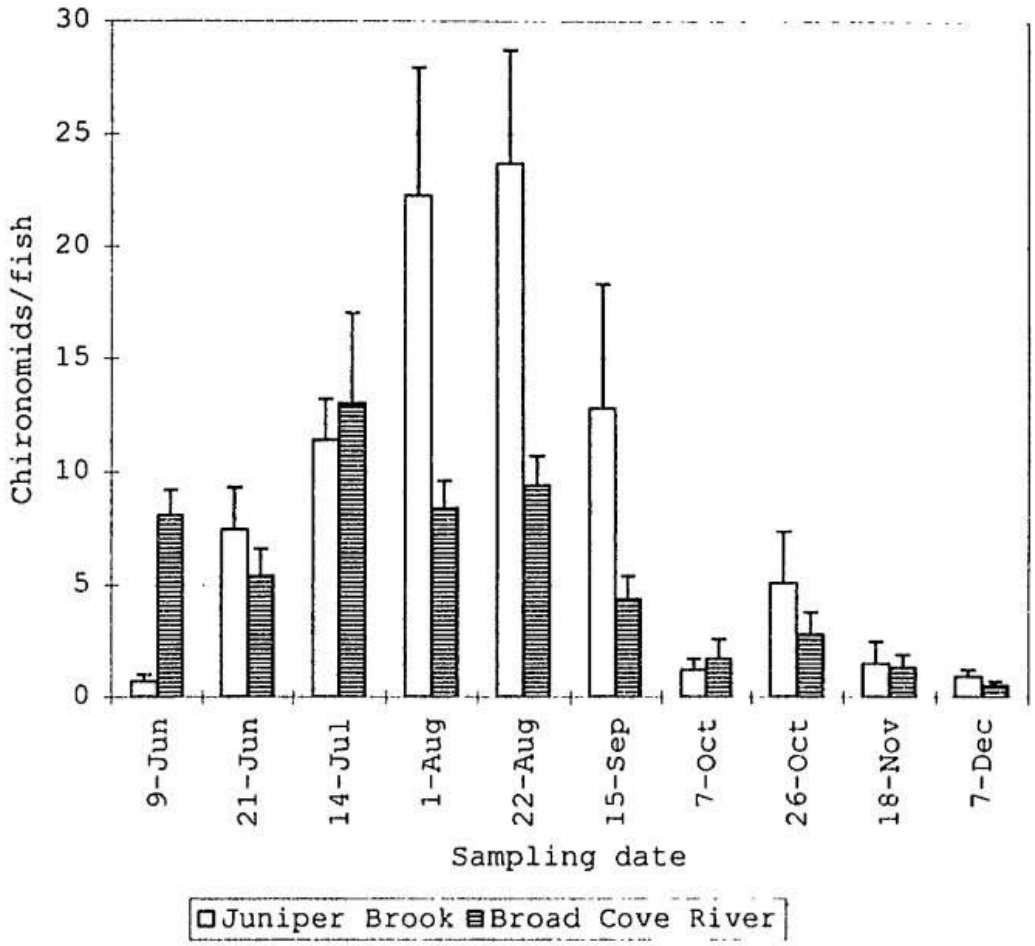


Figure 4.25: Mean number of chironomids (+Standard Error) in 0+ trout stomachs at various sampling dates in 1994

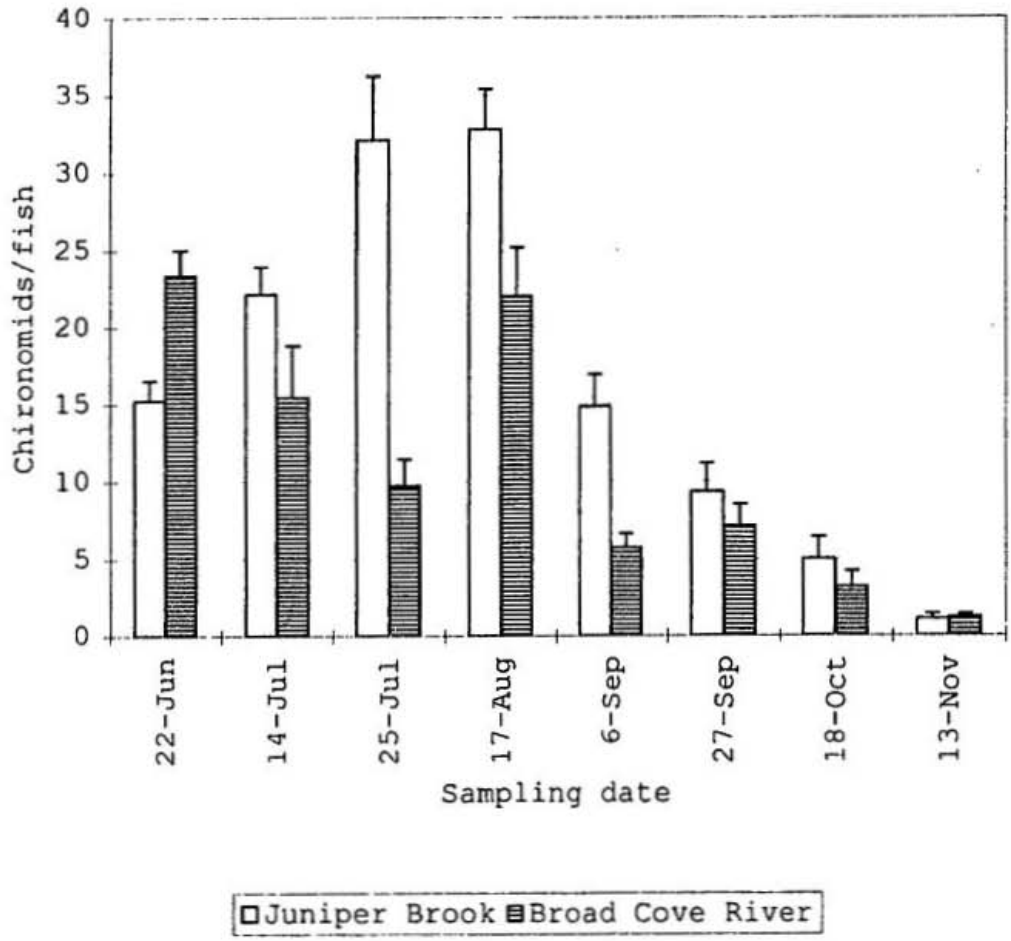


Figure 4.26: Mean number of chironomids (+Standard Error) in 0+ trout stomachs at various sampling dates in 1995

The winter food of trout parr collected from Broad Cove River is presented in Table B10. A total of only 47 prey organisms comprised the diet of the ten fish in the sample. These were dominated by aquatic insects which collectively formed 82.9% of the diet, the remaining 17.1% consisted of Nematoda (9.8%), Collembola (4.9%), and pelecypod clams (Family: Sphaeridae) (2.4%). Immature dipteran larvae (Chironomidae and Simuliidae) formed 41.5% of all food items and occurred in a higher number of individual fish in the sample. Ephemeroptera (mostly Leptophlebiidae) nymphs (26.8 %N) were next in importance whereas Trichoptera were consumed in lower numbers (Table B10). The single specimen obtained from Juniper Brook was moribund and had no food in its stomach.

Similarly, the diet of 1+ parr in both streams during spring was dominated by immature aquatic insects (> 97.5%), with dipteran larvae being the most important (Table B11). Chironomids were ingested by all trout but formed a greater proportion of the diet of 1+ parr in Juniper Brook than in Broad Cove River. Ephemeroptera and Trichoptera were consumed in lower proportions in both streams. A higher number of taxa comprised the diet of 1+ parr in Broad Cove River than in Juniper Brook. Non-insects were ingested in even lower proportions by 1+ parr in both streams (Table B11).

4.4 The Benthic and Drift Fauna of the two Streams

The taxonomic compositions of the benthic invertebrate fauna from the two study sites are presented in Table 4.5. A total of 964 and 1039 invertebrates were identified in the five benthic samples collected during the summer of 1995 from Juniper Brook and Broad Cove River respectively. Immature stages of aquatic insects were dominant in both streams, forming over 90% of the total invertebrates. The aquatic insect orders Diptera, Ephemeroptera, and Trichoptera were the most abundant in the benthic fauna of the two streams. All orders of aquatic insects found in Juniper Brook also occurred in Broad Cove River, however, the streams differed in both the number of families present and their numerical composition. Generally, more taxa belonging to the above orders of aquatic insects were found in the samples from Broad Cove River, but there were relatively fewer individuals per taxon compared to Juniper Brook.

Chironomidae was the most abundant taxon in Juniper Brook, comprising 69.6% of all invertebrates and 76.6% of the total insects. However, they formed only 25.0% of the total invertebrates in Broad Cove River (Table 4.5). The most numerous taxon in Broad Cove River, the Family Leptophlebiidae (Order Ephemeroptera) comprised 38.3% of

Table 4.5 Relative abundance (%) of benthic invertebrates in five samplers retrieved after one month from the substrate at study sites on Juniper Brook (JB) and Broad Cove River (BCR) in the summer and fall of 1995 (Total for the 5 samplers in parenthesis).

Taxa	Summer		Fall	
	JB (964)	BCR (1039)	JB (662)	BCR (726)
INSECTA				
Coleoptera				
Chrysomelidae	-	-	-	0.1
Dytiscidae	0.2	0.3	-	-
Elmidae	-	0.7	-	-
Haliplidae	-	0.4	-	-
Collembola				
Poduridae	0.1	0.1	-	-
Diptera				
Chironomidae	69.6	25.0	57.0	38.7
Empididae	-	1.0	-	0.6
Simuliidae	-	2.0	0.1	-
Tipulidae	-	0.5	0.4	-
Ephemeroptera				
Baetidae	1.4	5.3	27.6	5.6
Ephemerellidae	-	0.9	1.8	-
Heptageniidae	-	3.5	0.4	2.3
Leptophlebiidae	14.7	38.3	3.0	40.6
Lepidoptera	-	0.3	-	0.3
Odonata				
Gomphidae	-	-	-	0.3
Plecoptera				
Leuctridae	2.2	4.5	-	-
Perlidae	-	-	0.6	0.8
Trichoptera				
Hydropsychidae	-	4.6	-	0.7
Hydroptilidae	2.5	6.8	0.9	3.2
Limnephilidae	-	1.2	-	2.8
Polycentropodidae	-	1.8	-	0.4
Rhyacophilidae	-	0.1	-	-
Other Invertebrates				
Araneae	0.1	-	-	-
Crustacea				
Amphipoda	-	0.1	-	0.4
Cladocera	2.6	-	-	-
Copepoda	0.6	-	1.2	1.4

.../cont

Cont. Table 4.5

Taxa	Summer JB	Summer BCR	Fall JB	Fall BCR
Gastropoda				
Lymnaeidae	-	0.1	-	-
Hirudinea	0.1	-	-	-
Hydracarina	4.3	0.9	-	-
Nematoda	0.6	1.1	-	0.1
Oligochaeta	0.3	0.1	7.1	1.9
Pelecypoda				
Sphaeriidae	0.6	0.7	-	-

the invertebrates in this stream but formed less than 15% of the total invertebrates in Juniper Brook. Trichoptera larvae were less abundant in both streams.

Eight non-insect invertebrate taxa were identified in benthic samples from Juniper Brook and six in those from Broad Cove River. Collectively these comprised less than 10% of the total number of invertebrates in either stream. Non-insect invertebrates in Juniper Brook were dominated by water mites (Hydracarina) and crustaceans. In Broad Cove River, Nematoda (roundworms) and Hydracarina, in that order, were the most numerous, while crustaceans were represented by the amphipod family, Hyallelidae. The faunal similarity index between the summer samples from the two study sites was 37.9%.

In the fall samples, 662 invertebrates belonging to 11 taxa comprised the samples from Juniper Brook as compared to 726 in 17 taxa in the samples from Broad Cove River (Table 4.5). Aquatic insects dominated the benthic invertebrates in the fall as well; both in the number of taxonomic categories and the total number of individuals. Nine of the 11 taxa in the sample from Juniper Brook and 12 of the 17 taxa in the Broad Cove River sample were aquatic insects.

Chironomid larvae were again the most abundant taxon in Juniper Brook, comprising 57.0% of the invertebrates. In

Broad Cove River, Leptophlebiidae were the dominant taxon, comprising 40.6% of the invertebrates. However, baetid nymphs were the most numerous Ephemeroptera in Juniper Brook, forming 27.6% of invertebrates in this stream compared to only 5.6% in Broad Cove River. As was the case during the summer, there were more taxa in Broad Cove River and fewer individuals per taxon than in Juniper Brook. Four families of Trichoptera were present in the samples from Broad Cove River but only one of these; Hydroptilidae; also occurred in the samples from Juniper Brook.

Annelid worms of the family Naididae; and copepod crustaceans were the only non-insect taxa found in the fall sample from Juniper Brook. Together, these formed only 8.3% of the invertebrates in this stream. In Broad Cove River there were five non-insect categories which collectively comprised only 3.8% of the invertebrates. The faunal similarity index between the fall samples from the two study sites was 33.3%.

The invertebrates found in the drift samples collected from the study sites on Juniper Brook and Broad Cove River in September and October are presented in Table 4.6. The results show that there was a progressive decrease in both the total number and the number of individuals per taxa in samples from both streams at each subsequent sampling date. However, at all sampling dates, the total number of

Table 4.6 Total number of invertebrates in three drift samples collected from the study site on Juniper Brook (JB) and Broad Cove River (BCR) at various dates in 1995.

Taxa	07-Sept		29-Sept		20-Oct	
	JB	BCR	JB	BCR	JB	BCR
Insects						
Diptera						
Chironomidae	133	55	43	34	19	16
Simuliidae	0	3	0	1	0	0
Tipulidae	0	0	0	7	0	0
Ephemeroptera						
Baetidae	28	35	23	17	8	5
Leptophlebiidae	0	4	3	2	3	3
Trichoptera						
Hydropsychidae	0	0	7	6	0	0
Hydroptilidae	0	0	5	5	0	0
Collembola						
Poduridae	1	0	0	2	1	0
Hemiptera						
Corixidae	0	2	0	0	0	0
Other invertebrates						
Hydracarina	8	0	0	1	0	0
Oligochaeta	0	0	7	2	0	1
Nematomorpha	7	1	0	3	0	0
Total	177	100	88	80	31	25

invertebrates in Juniper Brook was higher compared to Broad Cove River. The total number of chironomid larvae was similarly higher in the samples from the site in Juniper Brook compared to those from Broad Cove River.

4.5 Food Selection by 0+ Trout.

Electivity values for common prey are presented in Table 4.7. During the summer, chironomids, simuliid larvae, baetid nymphs and hydroptilid caddis fly larvae, had positive electivity values. Leptophlebiid ephemeropterans, despite their higher abundance in the benthic samples, were under represented in the stomach contents of trout in both streams. Water mites and crustaceans had negative linearity indices in Juniper Brook but positive ones in Broad Cove River; whereas Hydropsychidae were selected for in Juniper Brook but avoided in Broad Cove River.

However, in the fall, chironomid and simuliid larvae had negative linearity indices in Juniper Brook but whereas chironomids were selected by trout in Broad Cove River, simuliids did not occur in both the diet and the benthic samples from this stream (Table 4.7). Ephemeropteran of the families Baetidae and Heptageniidae, and Trichoptera larvae of the families Hydroptilidae and Limnephilidae had positive indices in both streams. Leptophlebiidae had a

positive index value in Juniper Brook but negative one in Broad Cove River, whereas Hydropsychidae were avoided by trout in both streams. Water mites were selected for in Broad Cove River but avoided in Juniper Brook.

The electivity values for prey occurring in the drift are presented in Table 4.8. The results show that chironomidae, which was the most numerous taxa at all sampling dates (see Table 4.6), was avoided and had negative electivity values in both streams at all sampling dates. Most of the other prey had negative electivity values as well. Those that had positive values occurred in the stomach contents but not in the drift (Table 4.8).

Table 4.7 Electivity values for the common prey in the diet of 0+ trout and the benthos from Juniper Brook (JB) and Broad Cove River (BCR) in summer and fall of 1995.

Taxa	Summer		Fall	
	JB	BCR	JB	BCR
Chironomidae	0.044	0.310	-0.168	0.102
Simuliidae	0.002	0.003	-0.002	*
Baetidae	0.103	0.048	0.029	0.004
Heptageniidae	*	-0.035	0.086	*
Leptophlebiidae	-0.143	-0.377	0.085	-0.318
Hydropsychidae	0.009	-0.046	-0.014	-0.007
Hydroptilidae	0.054	0.061	0.024	0.100
Limnephilidae	*	0.056	0.023	0.093
Hydracarina	-0.002	0.045	-0.003	0.011
Crustacea	-0.032	0.001	*	0.004

* = Taxa not found in stomach nor benthos

Table 4.8 Electivity values for the common prey in the diet of 0+ trout and the drift from Juniper Brook (JB) and Broad Cove River (BCR) at various dates in the fall of 1995.

Taxa	7th Sept		29th Sept		19th Oct	
	JB	BCR	JB	BCR	JB	BCR
Chironcmidae	-0.155	-0.279	-0.067	-0.130	-0.213	-0.288
Simuliidae	0.004**	0.003	0.027	-0.001	*	*
Baetidae	0 03	-0.326	-0.080	-0.047	0.046	-0.178
Leptophlebiidae	0.093**	-0.021	0.097	-0.001	-0.009	0.143
Hydropsychidae	0.004**	0.010**	-0.052	-0.042	0.016**	*
Hydroptilidae	0.064**	0.533**	-0.039	0.186	0.024**	0.132
Hydracarina	-0.009	0.014**	*	-0.008	0.032**	0.011
Collembola	-0.006	*	*	0.008	-0.032	*
Nematomorpha	-0.040	-0.010	*	-0.038	*	*

* Taxa not found in diet nor drift
** Taxa found in diet but not in drift thus the positive value

5.0 DISCUSSION

5.1 Physical and Chemical Environment

Although the two river systems on which study sites were located occur in the same ecoclimatic region (Damman, 1983), their water temperature regimes showed consistent differences over the growing season (Figure 4.1), with Juniper Brook warming up faster in the summer and cooling more rapidly in the fall whereas Broad Cove River had a relatively more stable regime. The temperature fluctuations observed in Juniper Brook were consistent with those described for shallow streams lacking vegetation cover (Hynes, 1970; Crisp 1989). According to Hynes (1970), and Gordon *et al.* (1992), the lack of vegetation cover results in extreme temperatures especially in small headwater streams. Thus the rapid heating and cooling of Juniper Brook was mainly due to its shallowness and more open stream channel resulting from the removal of natural bank vegetation when the stream was channelized (Figure 2.2). In contrast, the presence of natural bank vegetation coupled with the influence of Healy's Pond upstream were contributory factors to the relatively more stable temperature regime at the site on Broad Cove River.

The values for specific conductance at both study sites were much higher than the 30-59 μmhos/cm range reported for natural fresh water bodies in insular

Newfoundland (Jameison, 1974; as cited in Steele, 1991) (Table 4.1). Steele (1991) found high values for specific conductance at the study site on Juniper Brook and attributed this to the winter use of salt to melt snow on adjacent roads. This also contributed to the high specific conductance at the study site on Broad Cove River since it was also a few metres downstream from a major road. However, the higher specific conductance in Juniper Brook at each sampling date suggests other factors, mainly the discharge of urban wastes from the residential and industrial buildings in the O'Leary's Industrial Park, had a significant effect on the chemical richness of the water at this site.

The mean total dissolved solids was 138.8 (±31.8 SE) in Juniper Brook compared to 107.9 (±20.0 SE) in Broad Cove River. The higher values for total dissolved solids (T.D.S) in Juniper Brook indicated that the stream was much richer chemically than Broad Cove River. Gibson and Haedrich (1988) noted that higher chemical richness due to addition of urban wastes to city rivers was associated with increases in the standing crop of macroinvertebrates in these rivers. Similarly, the results of benthic sampling in this study, showed higher numerical abundance of invertebrates, particularly chironomids (as is discussed in

section 5.4) at the site on Juniper Brook which was related to the high total dissolved solids in this stream.

5.2 Growth of 0+ Trout

Zero plus trout in Broad Cove River were both longer and heavier when first sampled each year (Table 4.2 and 4.3). Within streams, differences in fry size at the start of the growing season have been related to egg size which was in turn related to the size of the spawning female (Scott and Crossman, 1973; Elliott, 1994). However, between streams, such differences may well reflect differences in the time fry emerged from the redds in those streams. Most 0+ trout in Juniper Brook had no food in their stomachs when first sampled in the first year (Table B1), suggesting they had just completed "swim up" (Randall, 1982) and had not yet started exogenous feeding. Thus it appears that the smaller mean size of 0+ trout in Juniper Brook at the start of the growing season compared to those in Broad Cove River was related to their later emergence from the redds.

Elliott (1994) noted that the time from spawning to emergence varied between brown trout populations in different streams depending on the within-stream winter temperatures. Since adult brown trout were observed to spawn at about the same time at the two sites, the later

emergence of fry in Juniper Brook suggests longer egg incubation in this stream. Although within-stream winter temperatures were not determined at either site in this study, the observation of anchor ice at the site on Juniper Brook and none on Broad Cove River when sampling was conducted in the intervening winter, was indicative of lower winter temperatures at the site on Juniper Brook hence the later emergence of fry. The presence of Healy's Pond upstream from the study site on the Broad Cove River could have contributed to warmer temperatures at the site during winter.

The time when fry emerge from the redds has important implications on the size attained at the end of the first growing season; which is critical in temperate regions where smaller size has been linked to higher overwintering mortality (Lindroth, 1965; Cunjak and Power, 1987). First, early emerging fry have a relatively longer growing season during their first summer. Egglishaw and Shackley (1977) reported that fry that emerged early attained a bigger size at the end of the growing season due to the relatively longer feeding season. Secondly, early emerging fry can utilize the abundant stream invertebrates that usually occur in early summer as a result of the boost of stream productivity from the influx of nutrients from the spring melts (Larson and Colbo, 1983). In this study, 0+ trout in

Broad Cove River were smaller at the end of the growing season compared to those in Juniper Brook despite their early emergence, which was mainly because Broad Cove River, like all other natural streams on insular Newfoundland, is oligotrophic (Larson and Colbo, 1983; Gibson, Pers. Comm.). However, by emerging early 0+ trout in Broad Cove River were able to utilize the higher macroinvertebrate fauna in early summer resulting from increased spring production (Larson and Colbo, 1983), which enhanced their chances of attaining a large size, and therefore their survival through the first winter. This was supported by the finding in this study that 0+ trout in Broad Cove River had more food in their stomachs than those in Juniper Brook in early summer (Figure 4.23 and 4.24). Thus, for brown trout populations in oligotrophic environments such as the Broad Cove River, early emergence of fry was clearly advantageous. This finding suggests that early emergence could have evolved as a life history strategy by trout in this stream to enhance their chances of attaining a large size at the end of the growing season, however, experimental studies are needed to confirm this.

The arithmetic growth curves (Figure 4.2 and 4.3) show that growth in length and weight of 0+ trout in both streams over the first growing season approximated the characteristic sigmoid growth curve that describes the

yearly growth of fish in temperate regions (Weatherley and Gill, 1987). However, the early slow growth phase was only apparent in the 1994 length and weight curves for trout in Juniper Brook as these had just emerged when first sampled. The lack of the early slow growth phase in the 1994 curves for 0+ trout in Broad Cove River (Figures 4.2 and 4.3) and on those of 1995 (Figures 4.4 and 4.5) was because these were much bigger when first sampled hence the early slow growth phase was missed. In both streams, specific growth rates were highest during the early part of the growing season but decreased gradually as the summer progressed. The higher specific growth early in the growing season was related to the greater abundance of food resources in the stream following the spring boost in primary production (Larson and Colbo, 1983).

The mean length attained in mid-September by 0+ trout in Juniper Brook was 6.13 cm whereas those in Broad Cove River were 6.06 cm long in 1994 (Table 4.2). However, by early September of 1995, 0+ trout in Juniper Brook had attained a mean length of 6.33 cm and were significantly longer than those in Broad Cove River whose respective mean length was 5.30 cm (Table 4.3). These findings compare well with those reported by Randall (1982) for 0+ trout in Catamaran Brook and Little River in New Brunswick, which appeared to emerge at comparable times of the year to those

observed in this study. Egglishaw and Shackley (1977) found that the mean fork length attained by 0+ trout by September of each year in a productive Scottish stream section between 1966-1975 ranged from 5.66 - 6.80 cm. However, trout fry in their study emerged as early as April which gave them an early growth advantage and a longer growing season. In this study, trout fry in Juniper Brook, emerged as late as June, therefore the finding that these trout attained comparable mean fork lengths by September suggests much faster growth over a shorter growing season for trout in this stream.

Growth of 0+ trout in Juniper Brook was similar between the two years despite water temperatures being lower in 1995 than the previous year (Figures 4.6 and 4.7). Elliott, (1975) reported that the optimal temperature for the growth of trout on maximum ration ranged from 12.8 - 13.6 °C. Studies elsewhere (e.g. Allen, 1985; Forseth and Jonsson, 1994), have reported higher optimal temperatures for the species. The results of this study showed that specific growth rates for trout in Juniper Brook decreased when mean stream temperatures were above 15.9 °C, suggesting this temperature was above the optimal range for growth for trout in this stream. Thus higher growth was not realized in 1994 despite the higher temperatures because of the increased metabolic costs associated with increased

activity at higher temperatures (Forseth and Jonsson, 1994).

However, there was a considerable variation in the growth achieved by trout in Broad Cove River between the two years, being much lower in 1995 (Figures 4.6 - 4.9). This variation was partly explained by the fact that fry emerged from the redds later in 1995. The later emergence meant the loss of a growing opportunity early in the season when food resources were more abundant from the increased spring production (Larson and Colbo, 1983), which appeared to be critical for trout in this oligotrophic stream, hence the lower growth in the second year. However, water temperatures were lower in 1995 and the low growth could well reflect the lower heat energy available for growth (Elliott, 1981; Weatherley and Gill, 1987).

Differences in growth rates of salmonids in different streams have been attributed to many factors, including climate, especially temperature (Elliott, 1981; Weatherley and Gill, 1987), food supply (Elliott, 1967; 1973; Randall, 1982), and density (Liew, 1969; Egglishaw and Shackley, 1977; Gibson *et al.*, 1987). Although density is considered an important factor, Gibson and Haedrich (1988) found a "paradoxical association of high growth rates with high densities for salmonids in streams within the metropolitan area of the city of St. John's", which

suggests that density may sometimes be less important, especially where food resources are not limiting.

For the brown trout, the concept of density-dependent growth has been discounted by Elliott (1989) who found the mean sizes and growth rates of juvenile brown trout in two streams that were in close geographic proximity varied between years but were not density dependent. He concluded that; (i) the size of the fry at the start of the growth season was the chief factor responsible for the mean-size differences between the two populations for trout of the same age; and (ii) variation in temperatures were chiefly responsible for the differences in growth rates between year-classes. Growth trends for 0+ trout in Broad Cove River were in agreement with these conclusions but not for those in Juniper Brook, where human activities have altered both the physical and chemical characteristics of the stream. For example, fry in Juniper Brook were smaller at the start but attained a slightly bigger size by the end of the growing season. The faster growth observed for 0+ trout in Juniper Brook was related to the higher chemical richness in this stream (Table 4.1) which resulted in greater abundance of chironomids (Table 4.5). The finding of higher growth at the study site on Juniper Brook within the metropolitan area compares well with those in the study by Gibson and Haedrich (1988) who reported higher growth

and biomass production for salmonids in rivers flowing through the city of St. John's.

5.3 Condition of 0+ Trout

The condition factor of fish is a measure of their nutritional wellbeing or "fatness" and has been used widely as an indicator of the habitat suitability for the fish population (Ricker, 1975, Busacker *et al.*, 1990). The condition of 0+ trout in both streams was low when fish were first sampled each year (Table 4.2 and 4.3). Tilley (1984) also found that the condition of 0+ trout in the Adams Octagon River was low in late May soon after the trout had emerged. It appears that the low condition soon after emergence is associated with the transition from endogenous (yolk-sac) to exogenous feeding as the young trout learn how to identify food items from their environment.

However, the condition of 0+ trout in both streams improved rapidly early in the growing season to a peak in early July and remained high for the rest of the summer. Ellis and Gowing (1957) found that high condition was associated with periods of high growth. As expected, the change in mean condition over the growth season observed in this study reflected the respective increases in length and

weight of 0+ trout, thus improvement in mean condition was more rapid in Juniper Brook than in Broad Cove River. Within streams, the condition of fish was lower during the fall compared to summer. The gradual decrease of the mean condition in the fall reflected reduced feeding activity which was probably a function of either or of both reduced food supply and decreasing stream water temperatures.

Although the changes in condition of fish over the growing season appeared to be correlated with the seasonal availability of instream food resources, Morrison (1989) noted that for fish such as the brown trout whose diet often has a significant proportion of terrestrial insects, it is not possible to attribute realized growth to aquatic food supply *per se*. According to this author, the mean condition of fish therefore provides only an indirect relative measure of both the food supply and the feeding activity of fish. Thus the higher mean condition of fish in Juniper Brook is indicative of higher food supply (of both aquatic and terrestrial sources as discussed later on), and greater feeding activity, which was mainly as result of the higher summer temperatures (Forseth and Jonsson, 1994).

The mean condition of trout from Broad Cove River in winter was lower than at the previous sampling. Elliott (1985) stated that during winter 0+ parr obtained only enough food to maintain their weight. However, Cunjak and

Power (1987) found that brown trout in the Credit River in Ontario had lower condition in winter and concluded that the energy derived from winter feeding may not always be sufficient to meet the basic metabolic demands of the fish. The sample in this study was taken fairly early into the winter season and the lower condition, though not statistically significant, suggests that parr were utilizing energy reserves accumulated in the previous growing season, hence the importance of 0+ trout attaining a bigger size at the end of their first growing season.

5.4 Feeding

The food of 0+ trout in both streams was dominated by immature aquatic insects of families in the Orders Diptera, Ephemeroptera and Trichoptera. Several studies have reported these as the major prey of 0+ trout (McCormark, 1962; Hubert *et al.*, 1993; LaVoie IV and Hubert, 1994; and others), including the only other study that has looked at the food of young of the year trout in a Newfoundland stream (Tilley, 1984). However, there were some differences in both the number of taxa and their numerical proportions between the streams and also between seasons. For example, although dipteran larvae were the major food during the summer, chironomids were more important in Juniper Brook

whereas black fly larvae appeared to be the more important dipteran food item in Broad Cove River in both years (Figures 4.19 - 4.22).

The diet of 0+ trout in both streams when first sampled each year was dominated by chironomid larvae (Tables B1, B3, B5 and B7). This finding compares well with the study by McCormark (1962) who concluded that chironomids were the primary food of 0+ trout soon after emergence. Similarly, Hubert *et al.* (1993) found a dominance of chironomids in the diet of age-0 (0+) trout in a regulated mountain stream in Wyoming as did Tilley (1984) in the Adams Octagon River on the island of Newfoundland. In this study, the dominance by chironomids at the commencement of exogenous feeding appeared to be related to their higher availability in the feeding environment, although their relatively smaller size (Merrit and Cummins, 1984) may have been an important factor in rendering them suitable prey for the small trout.

In both years, the composition of the diet varied between sampling dates, with more taxa comprising the diet at each successive date. However, at times a single prey dominated or was the only food item found in the stomachs of most if not all trout in a sample. This was frequently observed and was more apparent when aquatic insects were emerging, as these appeared to be consumed almost

exclusively. This finding suggested that 0+ trout may be opportunistic in their feeding, taking the most abundant and available prey from the feeding environment.

The concept of opportunistic feeding is widely reported in the literature for larger trout as well as for the young of the year and has been referred to as "absent minded feeding" by some workers (see Tilley, 1984), which seems to be an unfortunate term to apply for a visual territorial predator such as the brown trout (Elliott, 1994). Dominance of a single prey may simply be a reflection of its higher abundance and availability in the feeding environment at the time of feeding relative to other prey hence making it more cost effective for the predator to feed on the abundant prey (Gerking, 1994). In this study, this was well exemplified by the findings on chironomids. During the summer, chironomids were consumed in large numbers by 0+ trout in Juniper Brook which was correlated with their higher numerical abundance in the summer benthic samples from this stream (Table 4.5).

However, the linear electivity values indicated that 0+ trout in both streams fed selectively to some extent, preferring different prey during the summer and fall seasons (Table 4.7). During the summer, chironomids, simuliids, baetid nymphs and hydroptilid caddis larvae were the preferred prey in both streams. These were also among

the most abundant taxa in the benthic samples (Table 4.5). Thus it appears that, during the summer, selection was related to prey abundance. However, leptophlebiid ephemeropterans were under-represented in the stomach contents, despite their higher abundance in the benthic samples during the summer (Table 4.5). According to Larson (Pers. Comm.), some genera of this family are hyporheic while others hide under stones, hence are less likely to be abundant in the drift, where 0+ trout mainly feed from during summer (Elliott, 1967; Hubert *et al.*, 1993; Sagar and Glova, 1995), hence their under representation in the summer diet.

In the fall, taxa which rarely leave the bottom such as ephemeropteran nymphs of the families Heptageniidae and Leptophlebiidae, and Trichoptera larvae of the family Limnephilidae were selected in Juniper Brook. All of these taxa (except Leptophlebiidae) had positive linearity indices in Broad Cove River as well. As these taxa are also relatively large in size (Merrit and Cummins, 1984), it is possible that selection was influenced by the size of the prey. Several studies (Elliott, 1967; Tilley, 1984; Hubert and Rhodes, 1992; and others) have reported a shift towards larger prey that was attributed to increasing fish size. Size dependent selection would also explain the avoidance of the relatively smaller sized chironomid larvae and

Hydracarina by the 0+ trout in Juniper Brook in the fall. However, both chironomids and Hydracarina were still selected by trout in Broad Cove River, possibly because of the smaller size of these fish compared to those in Juniper Brook (Figure 4.4 and 4.5). However, examination of the stomach contents of the 1+ parr collected from the two study sites in the spring of 1995 (Table B11) showed that even 1+ fish ingested chironomids in proportionately larger numbers when these were abundant in the streams early in the growing season; suggesting that, as was pointed out by Gerking (1994), increase in size may not necessarily mean exclusion of smaller food items and that prey abundance plays a greater role in the foraging dynamics of fish.

The preponderance of taxa that rarely leave the bottom in the fall diet suggested that 0+ trout were feeding from the benthos in the fall. The switch to benthic feeding in the fall would also explain the positive linearity index value for Leptophlebiidae in Juniper Brook in the fall, although an explanation could not be found for the under representation of this taxon in the stomach contents of trout in Broad Cove River despite its abundance. Nyman (1970) found that brown trout fed predominantly from the benthos from late summer onwards. In this study, few taxa and in low numbers were found in the drift samples collected in the fall of 1995 (Table 4.6), thus the switch

to benthic feeding could be related to the paucity of food items in the drift. Although some degree of selection of prey from the drift was apparent (Table 4.8), most taxa occurring in the drift also occurred in the fall benthic samples (cf Table 4.5 and 4.6), hence it was not possible to attribute feeding to the drift or substrate. However, the negative value for baetid nymphs in the drift sample of 18th October and a positive one in the benthic sample would suggest that these were taken from the benthos

The mean number of prey increased at each successive sampling date in the summer but not in the fall (Figures 4.23 and 4.24). The diversity of prey ingested at each successive sampling date also increased through the summer and to some extent in the fall (Table B1-B8). These findings suggested that 0+ trout were broadening their diet as they increased in size which, according to Gerking (1994), enhances feeding efficiency. McCormark (1962) also found that the diversity of aquatic invertebrates in the diet of brown trout in their first summer of life increased as the fish increased in size. The variation in the number of prey between individual fish in a sample was probably related to the fact that 0+ trout establish feeding territories soon after emergence (Elliott, 1986). Hence individuals with fuller stomachs most probably defended better feeding territories thus had better access to food

resources than others. Although brown trout are known to switch to piscine prey to increase feeding efficiency as they increase in size (Elliott, 1994), no fish were found in the food of 0+ trout over the two years of this study, suggesting that piscivory, which is well documented for bigger trout (Elliott, 1994), is a feeding strategy adopted later in life.

Non-insect aquatic invertebrates were ingested regularly in both streams, but formed relatively small proportions. These findings agree well with Tilley (1984) who similarly found low proportions of non-insect taxa in the diet of 0+ trout in the Adams Octagon River. However, in this study non-insect taxa also occurred in lower proportions both in the benthic (Table 4.5) and drift samples (Table 4.6) as well, and their low proportions in the diet may be related to their lower availability in the feeding environment.

Although terrestrial taxa (mostly insects) were consumed during the summer (Appendix B1 and B3), their numerical proportions in the diet of 0+ trout in the two streams increased during the fall (Appendix B2 and B4). Several workers including Elliott (1967), Hubert et al. (1993), and LaVoie IV and Hubert (1994) have also reported significant proportions of terrestrial insects in the diet of 0+ brown trout. An interesting finding was that the

highest incidence, both in the number of taxa and the number of individuals per taxa of terrestrial insects occurred in stomach contents of 0+ trout in Juniper Brook. According to Larson (Pers. Comm.), the lower incidence of terrestrial insects in the stomachs of 0+ trout in Broad Cove River reflects the paucity of insect fauna in the adjacent natural vegetation. The bank vegetation at the site on this river was dominated by *Myrica sp* (Table 2.1), whose "unpleasant smell" attracts few terrestrial insects. In contrast, herbaceous plants, which are generally associated with a richer terrestrial insect fauna, have colonised the banks at the site on Juniper Brook following the channelization of the stream (Figure 2.3), hence the higher incidence of terrestrial fauna in this stream.

All 0+ trout sampled from the study site on Broad Cove River during winter had food in their stomachs demonstrating that they continue feeding in winter. Cunjak and Power (1987) reported that brown trout in the Credit River in Ontario fed throughout the winter. However, in this study, a total of only 47 prey comprised the diet of the ten fish in the winter sample (Table B10), suggesting reduced feeding activity in winter. The reduced feeding activity was related to the reduced activity of trout at low temperatures and possibly a reduced availability of food resources as well. During winter, Collembola were the

only non-aquatic prey in the winter food of trout indicating a reduced terrestrial food supply. Although some aquatic taxa may be abundant in streams during winter, their availability to trout may be lower as most of these are known to hide under crevices in the harsh winter conditions (Larson, Pers. Comm.).

5.5 The Benthos and Drifting Invertebrates

The results of the benthic sampling showed that most invertebrates such as Diptera larvae, Ephemeroptera nymphs and Trichoptera larvae, which formed the major prey of 0+ brown trout were found in both streams, which partly explains the taxonomic similarity in the composition of the diet of 0+ brown trout from the two streams. However, the relative abundance of these taxa as reflected in the composition of the benthos differed (Table 4.5). A higher number of taxa were found in the benthic samples from Broad Cove River than from Juniper Brook. Thonney *et al.* (1987) found large differences in the type and relative proportions of invertebrate groups between ten rivers in Newfoundland and concluded that the type of organic nutrients entering a riffle may be the most important factor limiting the production of invertebrate fauna.

Huston (1979) stated that greater taxonomic diversity

in streams was associated with areas of low productivity resulting from low nutrients. Accordingly, the higher number of taxa in the benthic samples from Broad Cove River found in this study was correlated with the low total dissolved solids (and therefore lower chemical richness), found in water samples this stream (Table 4.1). Juniper Brook, on the other hand, was chemically richer (Table 4.1) due to the input of liquid and solid pollutants from a variety human activities described in section 2.2., thus had a lesser number of taxa but with relatively higher numbers of individuals per taxon.

The benthic fauna in Juniper Brook was dominated by chironomid larvae which were consumed in greater numbers by 0+ trout in this stream (Figures 4.25 and 4.26). The abundance of chironomids in aquatic environments has been regarded to be an indicator of nutrient enrichment (Hynes, 1960; 1970; William, 1964). Clarke (1995) found a six-fold increase in the density of chironomids following fertilization of oligotrophic ponds in Newfoundland. According to William (1964), the invertebrate fauna in disturbed aquatic systems is typically dominated by one or two taxa. Thus, the higher relative abundance of chironomids in the benthic fauna in Juniper Brook (Table 4.5), was correlated with the enrichment of the stream resulting from the input of organic and inorganic

urban wastes as described in section 2.2. It appears that the human disturbance that has occurred on Juniper Brook has contributed to the lower diversity of taxa found at the study site on this stream compared to the site on Broad Cove River which also explains the low faunal similarity between the two study sites, despite their close geographic proximity.

In conclusion, the study has demonstrated that the disturbances by human activities that occurred at the site on Juniper Brook have had a significant impact on its ecology. The removal of riparian vegetation when the stream was channelized and elimination of Wigmore Pond has resulted in an altered stream temperature regime. Thus, the stream heats up much faster in the summer and cooling more rapidly in the fall. This is in contrast with the more stable temperature regime in Broad Cove River where the presence of natural vegetation cover coupled with that of a large body of water (Healy's Pond) upstream contribute to the more gradual heating up in summer and cooling in fall. In addition, input of liquid and solid pollutants in form of urban wastes has increased the chemical richness at the study site on Juniper Brook, which has resulted in the greater numerical abundance of chironomids, which appears to be related to the faster growth of 0+ trout in this stream. The association of higher chironomid abundance with

the faster growth of trout can be explained in either or both of two ways. First, higher prey abundance reduces prey searching time which lowers the predators metabolic costs (Gerking, 1994). Secondly, soft bodied dipteran larvae are digested at a faster rate than those whose bodies had higher proportions of chitinized exoskeleton as was demonstrated by Hess and Rainwater (1932). In contrast, the lower abundance and availability of food resources in Broad Cove River increased feeding costs associated with searching for prey hence the growth realized by trout in this stream was lower (Gerking, 1994).

5.6 Summary of Major Findings

a) The two streams differed in both stream water temperatures and chemical richness (as indicated by the total dissolved solids), with Juniper Brook experiencing more extreme temperatures and having higher total dissolved solids than Broad Cove River. These were direct consequences of the human disturbance that has occurred on the Juniper Brook over time.

b) In both years of the study, young of the year trout in Juniper Brook emerged later than those in Broad Cove River, but grew at a much faster rate over the summer attaining a

slightly bigger size at the end of the growth season. The higher growth in Juniper Brook was attributed to the high abundance of chironomid larvae due to enrichment. The slow growth in Broad Cove River was largely due to lower availability of food resources in this stream resulting from low chemical richness.

(c) Stream temperature was an important factor that affected the growth of 0+ trout in the two streams. However, it appears differences in the type and abundance of food resources in the two streams were equally important. This was supported by the finding that growth realized by 0+ trout was lower in Broad Cove River although mean stream temperatures were within the range for the optimal growth of brown trout.

d) 0+ trout fed primarily on immature aquatic insects, mainly Diptera, Ephemeroptera and Trichoptera. Soon after emergence the diet of young trout in both streams was dominated by chironomid larvae. However, while chironomids were the most important food in Juniper Brook throughout the summer, 0+ trout in Broad Cove River consumed a greater diversity of taxa but in relatively lower numbers, as would be expected of fish when food resources are limiting in the feeding environment.

e) Electivity indices showed that 0+ trout fed selectively to some extent, preferring different prey during the summer and fall seasons. Selection appeared to be related to prey abundance during the summer, whereas in the fall larger prey were preferred.

(f) Benthic sampling revealed that Broad Cove River had a higher diversity of invertebrates than Juniper Brook. The taxonomic and numerical composition of the benthic fauna at the study site on Broad Cove River was characteristic of a stable community, which would be expected due to the lack of human disturbance. In Juniper Brook, there were fewer taxa but relatively higher numbers of individuals per taxon as would be expected of the fauna in a disturbed and enriched aquatic habitat.

(g) During the fall season, 0+ trout in both streams searched the benthos for food, as evidenced by the occurrence of taxa that rarely leave the bottom such as the dorso-ventrally flattened heptageniid and ephemerellid ephemeropterans, the larvae of *Tipula sp*, oligochaetes and gastropods which were often coated with benthic debris. However, the incidence of terrestrial prey suggested that 0+ trout still exploited the stream drift as well.

(h) 0+ trout parr continued feeding well into winter (fish collected in early January when water temperatures were 0.5 °C had food in their stomachs). However, their mean condition was lower than at the preceding sampling date. Since growth ceased in the late fall when temperatures fell below the 4 °C, lower thermal limit for the growth of this species (Elliott, 1994), the lower condition suggested that energy derived during the winter was below the basic metabolic demands of the fish.

(i) Terrestrial insects were consumed by trout in both streams, although more so in Juniper Brook. This showed the close interrelationship between the terrestrial and aquatic habitats and emphasizes the fact that changes in adjacent non-aquatic habitats may have indirect impact on freshwater bodies.

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Appendix A Copy of the Experimental Licence to catch Brown Trout issued by the Department of Fisheries and Oceans.

Fisheries and Oceans / Pêches et Océans

May 31, 1994

NF-465-94

EXPERIMENTAL LICENCE

Your file / Votre référence

Our file / Notre référence

Pursuant to Section 52 of the Fishery (General) Regulations, permission is hereby granted to D. E. Steele of the Memorial University of Newfoundland, or his designate, to catch Brown Trout for scientific purposes subject to the following conditions:

1. This licence is effective from May 31, 1994 to December 31, 1994.

2. Area to be fished: Rennies River System, Waterford River and Broad Cove River

3. Quantity to be caught: 10 fish per month from each stream

4. Gear to be used: Electrofisher

5. All precautions relating to prevention of inadvertent mortality such as not sampling during high water temperature (>=23°C) , etc, should be strictly adhered to. A record of all mortalites should be kept and if possible usual biological information collected from these specimens. (i.e., as per the attached form) of which a copy is to be sent to M. F. O'Connell, P. O. Box 5667, St. John's, NF A1C 5X1.

6. Prior to activities taking place, the local Area Chief must be notified verbally of your activities (Morley Knight - 772-5857, St. John's).

7. This licence must be carried at all times and must be produced for inspection upon request of a Fishery Officer.

Failure to comply with the above conditions will result in cancellation of the licence.

B.C. Rose
Regional Licencing Manager
Resource Management Division

Canada

Appendix B The total number, type of prey, and their percentage composition by number and frequency of occurrence in the diet of 0+ trout

Table B1 Percentage composition by number (%N) and frequency of occurrence (% F) of prey in the diet of 0+ trout sampled from Juniper Brook at various dates in the summer of 1994 (Total number of prey in parenthesis).

Taxa	09-Jun (7)		21-Jun (111)		14-Jul (167)		01-Aug (339)		25-Aug (301)	
	% N	% F	% N	% F	% N	% F	% N	% F	% N	% F
A. Aquatic Prey										
Insects										
Diptera										
Chironomidae	100	30	67.6	100	68.3	90	65.8	100	78.9	100
Simuliidae					5.4	30	0.3	10	1.0	30
Empididae									0.3	10
Ephemeroptera										
Baetidae			2.7	20	12.0	50	17.7	90	4.0	50
Trichoptera										
Hydropsychidae					0.6	10	3.8	50	1.3	30
Hydroptilidae			9.0	40	-	-	0.6	10	1.0	20
Odonata (Gomphidae)							0.3	10	-	-
Coleoptera (Curculionidae)							0.6	10	-	-
Plecoptera (Leuctridae)							0.3	10	-	-
Non-Insects										
Araneae									0.3	10
Cladocera									3.3	30
Copepoda			9.0	20	-	-	-	-	-	-
Hydracarina			11.7	50	13.8	50	9.1	60	10.0	40
B. Terrestrial Prey										
Collembola (Isotomidae)							1.5	10	-	-

Table B2 Percentage composition by number (%N) and frequency of occurrence (%F) of prey in the diet of 0+ brown trout sampled from Juniper Brook at various dates in the fall of 1994. (Total number of prey in parenthesis)

Taxa	15-Sep (171)		07-Oct (87)		26-Oct (238)		17-Nov (81)		07-Dec (75)	
	%N	%F	%N	%F	%N	%F	%N	%F	%N	%F
A. Aquatic Prey										
Insects										
Diptera										
Chironomidae	74.9	80	13.8	50	21.4	80	18.5	30	12.0	60
Simuliidae	0.6	10	-	-	0.4	10	-	-	-	-
Tipulidae			1.1	20	-	-	1.2	10	-	-
Ephemeroptera										
Baetidae	1.2	20	11.5	60	52.1	80	14.8	80	26.7	70
Ephemerellidae	0.6	10	2.3	10	1.7	40	4.9	20	12.0	50
Heptageniidae					1.3	10	3.7	10	2.7	10
Leptophlebiidae			2.3	20	3.8	30	40.7	90	34.6	80
Trichoptera										
Hydropsychidae	1.2	20	-	-	0.8	10	1.2	10	5.3	30
Hydroptilidae	4.1	40	4.6	50	11.3	80	3.7	20	1.3	10
Limnephilidae			2.3	10	0.8	10	2.5	20	1.3	10
Molannidae					2.1	10	2.5	20	1.3	10
Odonata										
Gomphidae	2.3	20	1.1	10	-	-	-	-	-	-
Coleoptera (Elmidae)	2.4	30	-	-	1.3	20	-	-	-	-
Hemiptera (Corixidae)							1.2	10	-	-
Plecoptera (Perlidae)							4.9	10	2.7	20
Non-Insects										
Araneae			2.3	10	-	-	-	-	-	-
Amphipoda			4.6	20	0.8	10	-	-	-	-
Cladocera	4.7	20	12.6	20	-	-	-	-	-	-

../cont

Cont/Table B2

Taxa	15-Sep %N	15-Sep %F	07-Oct %N	07-Oct %F	26-Oct %N	26-Oct %F	17-Nov %N	17-Nov %F	07-Dec %N	07-Dec %F
Hirudinea	3.5	10	-	-	-	-	-	-	-	-
Hydracarina	1.2	20	1.1	10	0.4	10	-	-	-	-
Oligochaeta	2.9	10	-	-	0.8	10	-	-	-	-
Gastropoda (Lymnaeidae)					0.4	10	-	-	-	-
B. Terrestrial Prey										
Coleoptera (Staphylinidae)			4.6	20	0.6	10	-	-	-	-
Collembola (Isotomidae)			2.3	20	-	-	-	-	-	-
Diptera (Tephritidae)			8.0	10	-	-	-	-	-	-
Hymenoptera (Pteromalidae)			5.7	30	-	-	-	-	-	-
Homoptera (Aphiidae)			14.9	10	-	-	-	-	-	-
Lepidoptera					0.4	10	-	-	-	-
Libithiformes	0.6	10	-	-	-	-	-	-	-	-

Table B3 Percentage composition by number (%N) and frequency of occurrence (% F) of prey in the diet of 0+ trout sampled from Broad Cove River at various dates in the summer of 1994 (Total number of prey in parenthesis).

Taxa	09-Jun (106)		21-Jun (189)		15-Jul (231)		02-Aug (163)		26-Aug (266)	
	% N	% F	% N	% F	% N	% F	% N	% F	% N	% F
A. Aquatic Prey										
Insects										
Diptera										
Chironomidae	76.4	100	28.6	100	56.3	100	51.5	100	35.5	100
Simuliidae	1.9	10	68.2	90	23.8	40	4.9	30	2.5	40
Empididae							0.6	10	-	-
Ephemeroptera										
Baetidae			1.1	10	6.1	80	16.6	80	5.6	60
Ephemeridae							0.6	10	-	-
Trichoptera										
Hydropsychidae			1.6	10	2.2	40	3.1	10	0.4	10
Hydroptilidae	8.5	20	-	-	1.3	20	6.1	30	46.5	100
Polycentropodidae							0.6	10	-	-
Odonata (Gomphidae)					2.2	20	0.6	10	0.4	10
Coleoptera (Dytiscidae)							0.6	10	0.4	40
Plecoptera (Perlidae)									0.4	40
Non-Insects										
Araneae							0.6	10	-	-
Hydracarina	13.2	50	-	-	7.8	40	12.0	60	0.8	20
Cladocera									7.9	30
Copepoda			0.5	10	-	-	-	-	-	-
B. Terrestrial Prey										
Coleoptera (Cantharidae)					0.4	10	-	-	-	-
Lepidoptera									0.8	10

Table B4 Percentage composition by number (%N) and frequency of occurrence (%F) of prey in the diet of 0+ brown trout sampled from Broad Cove River at various dates in the fall of 1994. (Total number of prey in parenthesis)

Taxa	16-Sep (179)		10-Oct (156)		28-Oct (166)		18-Nov (59)		13-Dec (58)	
	%N	%F	%N	%F	%N	%F	%N	%F	%N	%F
Aquatic Insects										
Diptera										
Chironomidae	24.6	100	10.9	50	16.9	50	16.9	30	8.6	40
Simuliidae	1.1	10	-	-	32.5	60	5.1	10	6.9	30
Ephemeroptera										
Baetidae	27.4	80	27.7	60	7.8	40	15.3	50	12.1	40
Ephemerellidae	1.1	10	8.3	20	7.2	70	5.1	20	3.4	20
Heptageniidae	1.1	20	1.3	10	-	-	-	-	-	-
Leptophlebiidae	0.6	10	8.3	40	-	-	18.6	50	27.6	60
Trichoptera										
Hydropsychidae	2.2	20	8.3	20	-	-	3.4	20	-	-
Hydroptilidae	27.4	60	17.9	80	5.4	20	16.9	60	1.7	10
Leptoceridae	1.1	10	-	-	1.8	20	-	-	-	-
Limnephilidae	1.7	10	5.1	10	7.2	50	15.3	40	5.2	30
Molannidae			9.0	40	-	-	-	-	-	-
Polycentropodidae					1.8	20	-	-	-	-
Rhyacophilidae					1.8	20	-	-	-	-
Odonata (Gomphidae)	1.1	20	0.6	10	-	-	-	-	-	-
Coleoptera (Elmidae)					1.2	20	1.7	10	-	-
Hemiptera (Corixidae)					0.6	10	-	-	-	-
Non-Insects										
Araneae					0.6	10	1.7	10	1.7	10
Hydracarina	2.2	20	-	-	1.2	10	-	-	-	-

../cont

Cont/ Table B4

Taxa	16-Sep %N	16-Sep %F	10-Oct %N	10-Oct %F	28-Oct %N	28-Oct %F	18-Nov %N	18-Nov %F	13-Dec %N	13-Dec %F
Cladocera	3.4	30	-	-	9.0	60	-	-	6.9	10
Hirudinea	0.6	10	-	-	-	-	-	-	-	-
Oligochaeta					0.6	10	-	-	6.9	20
Nematoda	1.1	10	-	-	-	-	-	-	15.5	30
Terrestrial Prey										
Collembola										
Isotomidae	2.8	30	-	-	3.0	20	-	-	-	-
Isopoda					0.6	10	-	-	-	-
Diplopoda					0.6	10	-	-	-	-
Hymenoptera (Formicidae)			0.6	10	-	-	-	-	-	-
Lepidoptera	0.6	10	-	-	0.6	10	-	-	-	-
Psocoptera			1.9	10	-	-	-	-	-	-

Table B5 Percentage composition by number (% N) and occurrence (% F) of prey in the diet of 0+ trout sampled from Juniper Brook at various dates in the summer of 1995 (Total prey in parenthesis).

Taxa	22-Jun (183) %N	%F	14-Jul (259) %N	%F	25-Jul (447) %N	%F	17-Aug (442) %N	%F
A. Aquatic Insects								
Diptera								
Chironomidae	83.1	100	85.3	100	71.8	100	74.2	100
Simuliidae			0.7	20	1.1	40	0.2	10
Tipulidae					0.7	30	-	-
Ephemeroptera								
Baetidae	9.2	70	12.7	60	24.8	90	11.8	80
Leptophlebiidae							0.5	10
Trichoptera								
Hydropschidae					0.7	30	0.9	30
Hydroptilidae	0.4	10	0.4	10	-	-	7.9	50
Limnephilidae					0.2	10	-	-
Plecoptera								
Leuctridae					0.2	10	-	-
Non-Insects								
Hydracarina	1.1	20	-	-	0.2	10	4.1	70
Crustacea								
Cladocera	1.6	20	-	-	-	-	-	-
Copepoda	3.8	30	-	-	-	-	-	-
Conchostraca			0.4	10	-	-	-	-
Nematoda	0.5	10	-	-	-	-	-	-
Oligochaeta					0.2	10	-	-
Pelecypoda								
Sphaeriidae							0.2	10
B. Terrestrial								
Collembola								
Isotomidae	0.5	10	-	-	-	-	-	-
Poduridae			0.4	10	-	-	-	-

Table B6 Percentage composition by number (% N) and occurrence (% F) of prey in the diet of 0+ trout in Juniper Brook at various dates in fall, 1995 (Total prey in parenthesis).

Taxa	06-Sep (248)		27-Sep (221)		18-Oct (125)		13-Nov (159)	
	%N	%F	%N	%F	%N	%F	%N	%F
A. Aquatic Insects								
Diptera								
Chironomidae	59.7	100	42.1	80	40.0	80	6.9	70
Simuliidae			2.7	30	-	-	-	-
Tipulidae	0.4	10	-	-	-	-	0.6	10
Ephemeroptera								
Baetidae	18.5	50	18.1	60	30.4	70	15.7	80
Ephemerellidae			3.2	40	-	-	12.5	30
Heptageniidae			12.2	30	10.4	30	-	-
Leptophlebiidae	9.3	30	13.1	70	8.8	30	62.3	90
Trichoptera								
Hydropsychidae	0.4	10	2.7	40	1.6	20	-	-
Hydroptilidae	6.5	50	1.8	20	2.4	20	0.6	10
Limnephilidae	0.8	10	2.7	30	3.2	30	-	-
Coleoptera								
Dytiscidae	0.4	10	-	-	-	-	-	-
Hydrophilidae					0.8	10	-	-
Plecoptera								
Leuctridae					0.8	10	-	-
Perlidae							0.6	10
Non-Insects								
Araneae							0.6	10
Hydracarina	3.6	30	-	-	0.8	10	-	-
Nematoda	0.4	10	0.5	10	-	-	-	-
Pelecypoda								
Sphaeriidae			0.9	10	-	-	-	-
B. Terrestrial								
Hymenoptera								
Pteromalidae					0.8	10	-	-

Table B7 Percentage composition by number (% N) and occurrence (% F) of prey in the diet of 0+ trout sampled from Broad Cove River at various dates in the summer of 1995 (Total prey in parenthesis).

Taxa	23-Jun (287)		14-Jul (220)		25-Jul (208)		18-Aug (386)	
	%N	%F	%N	%F	%N	%F	%N	%F
A. Aquatic Insects								
Diptera								
Chironomidae	81.2	100	70.0	90	46.6	90	57.9	100
Simuliidae			2.3	20	14.9	80	3.1	40
Dixidae					0.5	10	-	-
Tipulidae							0.8	20
Ephemeroptera								
Baetidae	5.9	70	8.6	60	18.8	90	10.1	90
Heptageniidae					3.8	40	-	-
Leptophlebiidae	1.7	30	1.4	30	-	-	0.5	20
Trichoptera								
Hydropsychidae			0.9	20	-	-	-	-
Hydroptilidae	2.8	50	9.0	50	8.7	70	13.0	-
Limnephilidae					1.4	20	6.7	70
Coleoptera								
Dytiscidae	0.7	10	-	-	0.5	10	1.0	30
Odonata								
Gomphidae	3.8	20	-	-	0.5	10	-	-
Plecoptera								
Leuctridae	1.0	20	-	-	0.2	10	-	-
Non-Insects								
Araneae							0.3	10
Hydracarina	0.7	20	4.1	60	4.3	20	5.4	50
Crustacea								
Cladocera			0.5	10	-	-	-	-
Conochostraca			1.4	30	-	-	-	-
Nematoda	0.7	10	1.8	20	-	-	0.5	10
B. Terrestrial								
Collembola								
Isotomidae	1.4	20	-	-	-	-	-	-
Poduridae							1.6	40

Table B8 Percentage composition by number (% N) and occurrence (% F) of prey in the diet of 0+ trout in Broad Cove River at various dates in fall, 1995 (Total prey in parenthesis).

Taxa	06-Sep (210) %N	%F	27-Sep (241) %N	%F	18-Oct (91) %N	%F	13-Nov (165) %N	%F
A. Aquatic Insects								
Diptera								
Chironomidae	27.1	100	29.5	80	35.2	80	7.3	100
Simuliidae	3.3	40	2.9	60	-	-	27.3	80
Dixidae			0.4	10	-	-	-	-
Empididae	0.4	10	0.4	10	-	-	-	-
Tipulidae	0.4	10	0.8	20	-	-	0.6	10
Ephemeroptera								
Baetidae	2.4	20	16.7	80	2.2	20	1.2	20
Ephemerellidae			1.3	30	-	-	-	-
Leptophlebiidae	1.9	40	2.5	30	26.4	50	10.9	70
Trichoptera								
Hydropsychidae	1.0	10	3.3	50	-	-	0.6	10
Hydoptilidae	53.3	80	24.8	80	13.2	30	24.8	40
Limnephilidae	1.4	30	3.3	60	12.1	70	7.3	60
Polycentropodidae	1.0	20	0.4	10	-	-	-	-
Rhyacophilidae			0.4	10	-	-	1.2	10
Coleoptera								
Dytiscidae	1.0	20	0.8	10	-	-	0.6	10
Elmidae	0.4	10	1.7	30	-	-	-	-
Psephenidae	0.4	10	-	-	-	-	0.6	10
Lepidoptera	0.4	10	-	-	-	-	-	-
Plecoptera (Perlidae)					1.1	10	-	-
Non-Insects								
Araneae	0.5	10	-	-	-	-	1.8	30
Hydracarina	1.4	20	0.4	10	1.1	10	2.4	30
Crustacea								
Isopoda			0.8	10	2.2	20	-	-
Nematoda	1.4	20	4.6	10	5.5	40	5.5	60
Oligochaeta	0.4	10	-	-	-	-	-	-
Sphaeriidae			0.4	10	-	-	0.6	10
B. Terrestrial								
Collembola								
Isotomidae							1.2	10
Poduridae			3.3	40	-	-	4.2	10
Diptera (Ephydridae)	0.4	10						
Hymenoptera	1.0	10	-	-	1.1	10	0.6	10

Table B9 The number (No), percent composition (% N) and frequency of occurrence (% F) of prey in the diet of 0+ brown trout sampled from Virginia River during the summer of 1994.

Food item	05-Aug No.	05-Aug % N	05-Aug % F	26-Aug No.	26-Aug % N	26-Aug % F
Aquatic Insects						
Coleoptera						
Amphizoidae	-	-	-	1	0.1	10
Elmidae	2	0.5	20	1	0.1	10
Diptera						
Chironomidae	381	91.3	100	718	97.3	100
Empididae	2	0.5	10	-	-	-
Simuliidae	2	0.5	20	-	-	-
Ephemeroptera						
Baetidae	1	2.4	50	1	0.1	10
Ephemeridae	4	1.0	20	1	0.1	10
Leptophlebiidae	-	-	-	1	0.1	10
Trichoptera						
Hydropsychidae	6	1.4	30	-	-	-
Polycentropodidae	1	0.2	10	-	-	-
Non-Insects						
Arachnida						
Hydracarina	1	1.4	30	5	0.7	40
Gastropoda						
Lymnaeidae	1	0.2	10	1	0.1	10
Oligochaeta						
Lumbriculidae	1	0.2	10	8	0.5	40
Terrestrial Prey						
Lepidoptera	1	0.2	10	1	0.1	10
Total	417	100		738	100	

Table B10 The composition of food of 0+ brown trout sampled from the study site on Broad Cove River during the winter.

Taxa	% N	% F
Diptera		
Chironomidae	24.4	50
Simuliidae	17.1	50
Ephemeroptera		
Baetidae	9.8	30
Ephemerellidae	2.4	10
Leptophlebiidae	14.6	30
Trichoptera		
Hydropsychidae	4.9	10
Limnephilidae	9.0	30
Collembola		
Isotomidae	4.9	10
Nematoda	9.8	30
Pelecypoda		
Sphaeriidae	2.4	10

Table B11 Percentage composition (% N) and frequency of occurrence (% F) of prey in the diet of 1+ brown trout parr sampled from Juniper Brook (n = 6) and Broad Cove River (n = 7) on 25th May 1995 (Total number of prey in parenthesis).

Food item	Juniper Brook (172)		Broad Cove River (163)	
	% N	%F	% N	% F
Aquatic Insects				
Diptera				
Chironomidae	75.0	100	57.7	100
Simuliidae	3.5	33.3	14.7	71.4
Tipulidae	-	-	1.2	28.6
Ephemeroptera				
Baetidae	8.7	66.7	5.5	71.4
Ephemerellidae	2.3	50.0	1.8	28.6
Heptageniidae	-	-	0.6	14.3
Leptophlebiidae	-	-	1.2	28.6
Trichoptera				
Hydropsychidae	3.5	66.7	3.1	57.1
Hydroptilidae	-	-	4.3	42.9
Limnephilidae	2.9	50.0	3.1	57.1
Polycentropodidae	-	-	1.8	28.6
Coleoptera				
Dytiscidae	-	-	0.6	14.3
Elmidae	-	-	0.6	14.3
Odonata				
Gomphidae	0.6	16.6	-	-
Plecoptera				
Perlidae	1.2	33.3	1.2	28.6
Non-Insects				
Araneae	1.2	33.3	-	-
Crustacea				
Conochostraca	1.2	33.2	0.6	14.3
Gammaridae	-	-	1.2	28.6
Gastropoda				
Lymnaeidae	-	-	0.6	14.3