Natural Fish Populations in Two Streams of the Nashwaak Experimental Watershed

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NATURAL FISH POPULATIONS IN TWO STREAMS OF THE NASHWAAK EXPERIMENTAL WATERSHED

by

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ABSTRACT

Martin, J. D. 1980. Natural fish populations in two streams of the Nashwaak Experimental Watershed. Can. Tech. Rep. Fish. Aquat. Sci. 982, iii + 17 p.

Fish sampling data are summarized from 1972-78, inclusive, prior to clearcutting on two streams of the Nashwaak Experimental Watershed Project. Hayden Brook was chosen to serve as the control and Narrows Mountain Brook as the experimental stream. The study area on Narrows Mountain Brook includes an upper (clearcut to the stream bank in winter 1978), and a lower site (with a 60-m wide riparian strip on either side, cut at the same time as the upper). Major species of fish caught include brook trout (*Salvelinus fontinalis*), Atlantic salmon (*Salmo salar*), American eel (*Anguilla rostrata*), slimy sculpin (*Cottus cognatus*), and blacknose dace (*Rhinichthys atratulus*).

Estimated annual numbers of brook trout fluctuated by over 100% (Hayden Brook 11.9-26.5, Narrows Mountain, lower site 7.3-19.2 and Narrows Mountain, upper site 46.4-97.8 per 100 m^2) under natural environmental conditions. Salmon parr and fry numbers fluctuated twentyfold. Upstream migrations of trout, salmon, and eels occurred in the study streams between May and July from the Nashwaak River. Subsequent downstream migrations occurred in the fall. These migrations were probably seasonally temperature related. At least the lower kilometer of each stream serves as a nursery area for juvenile Atlantic salmon from the Nashwaak River. Brook trout in the study streams seldom exceeded 3 yr of age or 15 cm fork length under natural environmental conditions and were closed to angling.

Key words: Population characteristics, brook trout, Atlantic salmon, American eel, slimy sculpin, blacknose dace, Nashwaak

RÉSUMÉ

Martin, J. D. 1980. Natural fish populations in two streams of the Nashwaak Experimental Watershed. Can. Tech. Rep. Fish. Aquat. Sci. 982, iii + 17 p.

On présente un résumé des données d'échantillonnage du poisson qui ont été recueillies de 1972 à 1978 inclusivement, avant la coupe rase effectuée aux abords de deux cours d'eau de bassin expérimental de Nashwaak. Le ruisseau Hayden a servi de cours d'eau témoin et le ruisseau Narrows Mountain de cours d'eau expérimental. Le secteur à l'étude du ruisseau Narrows Mountain comprend un emplacement élevé (coupe rase des rives du cours d'eau effectuée à l'hiver de 1978) et un emplacement moins élevé (comportant, de part et d'autre, une bande riveraine de 60 m de large qui a aussi fait l'objet d'une coupe à l'hiver de 1978). Parmi les principales espèces capturées, on note l'omble de fontaine (*Salvelinus fontinalis*), le saumon de l'Atlantique (*Salmo salar*), l'anguille d'Amérique (*Anguilla rostrata*), le chabot visqueux (*Cottus cognatus*) et le naseux noir (*Rhinichthys atratulus*).

On a constaté que, dans des conditions environnementales naturelles, le nombre annuel estimatif d'ombles de fontaine fluctue de plus de 100 pour cent (ruisseau Hayden, de 11,9 à 26,5; ruisseau Narrows Mountain, emplacement moins élevé, de 7,3 à 19,2; ruisseau Narrows Mountain, emplacement élevé, de 46,4 à 97,8 par 100 m^2). Le nombre d'alevins de saumon et de tacons est de vingt fois supérieur. Des truites, saumons et anguilles ont remonté de la rivière Nashwaak jusqu'aux cours d'eau à l'étude entre mai et juillet, puis sont redescendus à l'automne. Il existe probablement un lien entre ces migrations et les températures saisonnières. Le dernier kilomètre au moins de chaque cours d'eau constitue une zone d'alevinage pour les jeunes saumons de l'Atlantique de la rivière Nashwaak. Les ombles de fontaine des cours d'eau visés avaient rarement plus de 3 ans ou 15 cm de longueur à la fourche dans les conditions environnementales naturelles. La pêche à la ligne de cette espèce était d'ailleurs interdite.

INTRODUCTION

The Nashwaak Experimental Watershed Project, begun in 1970, was designed "to determine and understand the impacts of certain forest management practices on environmental quality, and to establish criteria for future forest management." The impact of clearcutting on numbers and growth of fish is the subject of the study on which this report is based. Other forest management practices, such as fertilization and spraying with insecticides for protection of trees against spruce budworm, may also affect freshwater streams. The impact of these treatments on the physical and on some biological aspects of the watershed are being investigated in a number of component studies by others within the Nashwaak Experimental Watershed Project.

The overall project includes three small watersheds (125-725 ha) in east central New Brunswick (Fig. 1) of which one, the control watershed (Hayden Brook), is to receive no special treatment, the second (Narrows Mountain Brook) will be clearcut, and the third (Lake Brook) was fertilized in 1976. The streams are tributaries to the Nashwaak River which joins the Saint John River below the Mactaquac Dam.

The Nashwaak River is accessible to sea-run Atlantic salmon (*Salmo salar*) with an average of 1,225 salmon and grilse angled yearly from 1973-78 (Dunfield 1973-76; Mitham and Bernard 1977-78). Atlantic salmon spawned in the Nashwaak River but not in the study streams from 1972-78, with the possible exception of lower Narrows Mountain Brook in 1977.

The 7-yr period of data collection prior to clearcutting represents baseline data. The clearcutting treatment is to be followed with at least 2 yr of post-treatment studies to determine any short-term effects. Results of these studies will determine the time interval for assessing long-term effects. Clearcutting of Narrows Mountain Brook watershed occurred between May 1978 and March 1979. This report covers fish studies in Hayden and Narrows Mountain Brooks during the pre-treatment period of 1972-78.

Fish population studies were initiated in 1972 and continued through 1973. During this period, the study constituted a mid-summer population census only. Fish were not measured, but trout were classified as "fry" (= underyearlings) and "small" (<15 cm) or "large" (>15 cm) yearlings or older. Data from 1972 and 1973 will not be reported in detail here.

In 1974 the study was expanded to include a new sampling site within the area to be clearcut to the stream edge in the headwaters of Narrows Mountain Brook, and by adding spring (May) and fall (Sept.-Oct.) sampling to the single mid-summer (July-August) fishing of 1972 and 1973. Fish were measured and weighed and many were also marked to provide information for growth-age determinations. Some of these data were previously reported in Nashwaak Experimental Watershed Project annual reports for 1973-78, and in project review documents for the same years. The present work includes an expanded analysis of these data with correction of some errors in previous reports.

STUDY SITES

Hayden Brook watershed (725 ha) has a predominantly southern aspect, with elevations of 200-475 m, and is covered with mixed hardwoods. The 4-km-long stream has eastern brook trout as the most common fish species, but eels and, in the lower reaches, juvenile Atlantic salmon, also occur. Fish studies were restricted to 420 m of stream (1420 m^2, wetted stream surface) near the mouth. The fishing site was divided into six study sections (Fig. 1) of approximately 70 m length each. The lowermost section had a steep gradient of 11% (Table 1) with sufficient falls and cascades to block upstream passage of young-of-the-year Atlantic salmon (Symons 1978), but yearlings could leap these falls and at certain seasons were found in all sections upstream.

Narrows Mountain watershed (400 ha) has a predominantly southeastern aspect, with elevations of 220-420 m, and is covered mostly with hardwoods in the headwaters grading to predominantly softwoods along the stream near the mouth. The stream is about 4.5 km long. Fish studies were carried out at two sites, an "upper" site in the headwaters, and a "lower" site near the mouth. Physical details of all study sites are given in Table 1.

The upper Narrows Mountain site, which was first fished in 1974, begins 70 m above the forks, and originally comprised two 70-m sections on each branch. The upstream section on the east branch was abandoned when it was found impossible to fish it effectively with electrofishing gear. The present area fished is 407 m^2. The streams are 1-2 m wide, and are inhabited by brook trout and slimy sculpins.

The lower site on Narrows Mountain Brook was originally comprised of four sections 40-70 m long within a 300-m length of stream, beginning about 50 m above a major logging road. The area of these sections was 498 m^2. Trout and juvenile Atlantic salmon commonly occur in these sections, and occasionally blacknose dace and creek chub are found which have probably moved down from an abandoned beaver pond approximately 100 m upstream from the study site. In 1975 a fifth section 71 m long (244 m^2) near the mouth of Narrows Mountain Brook was added to the lower site with the objective of making the lower Narrows Mountain Brook and Hayden Brook study sites more similar in area and in location relative to the mouth of the streams, and to provide additional information on movements of juvenile Atlantic salmon between Narrows Mountain Brook and the Nashwaak River. This fifth section is located about 600 m below the Nackawic-Napadogan haul road. The section is inhabited by trout, salmon, sculpins, eels, and blacknose dace. The fourth section was greatly disturbed in the fall of 1976 by construction of a hydrological weir and was eliminated in 1977. The area of the sections is now 645 m^2.

Clearcutting operations were carried out in the watershed surrounding the lower site above the main haul road between May 1978 and February 1979. A 60-m wide strip of trees was left along each bank.

Dates of fishing (number of days between fishings) and water temperatures at time of fishing are given in Table 2.

METHODS

FIELD

To obtain data on numbers of fish, each section was fished in turn progressively upstream using barrier nets at top and bottom of the section to prevent fish from moving in or out during the operation. Electrofishing was performed at 400-500 volts, with Smith-Root back-pack electrofishers (Mark IV and Mark VII) using uninterrupted direct current. In 1972-73 Elson (unpubl. data) made six sweeps of each section, but usually few fish (<5/sweep) were caught in the fourth and subsequent sweeps. Therefore, when the program was expanded to include new sites and sections, the number of sweeps per section was reduced and, during the mid-summer fishing, all sections were fished at least three times and sometimes four. Since the initial objective of the spring and fall fishings was only to provide information on growth, not all sections were fished at these seasons in 1974 and 1975. In fall and spring 1976 all sections were fished with two sweeps. This last practice proved to be the best compromise for providing useful migration and growth data with least effort and was continued in subsequent years.

Captured fish were anaesthetized with methane tricaine sulfonate (MS 222) or tertiary amyl alcohol, measured to the nearest millimeter (fork length), and weighed to the nearest gram. Each year all salmon and 90 yearling and older trout were hot-branded with individually coded numbers.[1] Young of the year trout were branded with the last digit of the year in which they were born. Branding was done with a small length of nichrome wire attached to a 12-volt battery. This brand was easy to apply in the field and remained visible for at least a year. After recovery from the anaesthetic, all fish were returned to the section from which they were captured.

ANALYTICAL

Fish ages were estimated by construction of length-frequency histograms of captured fish (Fig. 2-8). Scales from a number of trout were taken from the area between the lateral line and dorsal fin and read for age estimates under a dissection microscope. Otoliths from a few dead fish were also examined under a dissection microscope for age estimates. In 1976, 1977, and 1978 underyearling (0+) trout were branded with the last digit of the year in which they were hatched. Subsequent recaptures of these fish yielded accurate age-length information (Table 3; Fig. 9, 10).

Estimates of fish population densities were made by the depletion or DeLury (1951) method which utilizes the declining catch in repeated constant effort fishings. Population estimates for the years 1972 and 1973 were based on six fishings, 1974 and 1976 on four fishings and 1975, 1977 and 1978 on three fishings. All electrofishings for population estimates were conducted during the month of July each year.

Somatic growth was determined from recaptures of individually marked fish and marked, known, age-classes of fish. At least 90 yearling and older trout were individually marked each year beginning in 1974. All young-of-the-year trout caught were easily identifiable and were marked with the last digit of the year in which they were hatched, starting in 1976. All salmon, eels and dace were branded with individual codes.

RESULTS

AGEING

Histograms of trout and salmon lengths were usually bi- or tri-modal when grouped in 1-cm length-classes. Separation between the first and second modes was quite well defined as the frequencies fell to or near to zero. Separation among second, third, and later modes was poorly defined, indicating considerable growth variability.

Ageing by scales was difficult and considered no more reliable than ageing by length-frequency histograms. Otolith readings were highly successful on the few dead fish tried but could not be used routinely because killing the fish was not desirable.

The mean fork lengths of "known age" trout from recaptured branded fish were very close to mean fork lengths determined by the length-frequency histograms for age 0+. Ages of 1+ and older trout determined by length frequency from the upper site on Narrows Mountain Brook corresponded closely with fish of known age. However, length-frequency determined ages of 1+ and older trout from Hayden Brook were probably not accurate as much overlap occurred between lengths of age 1+ and 2+ fish. The mean fork lengths of recaptured fish of "known age" (Table 3) and the length-frequency histograms of numbers of recaptured known age fish, however, enabled an estimated division point between the majority of trout of each age class in 1977 and 1978. There appeared to be few trout age 3+ or older in these streams.

POPULATION ESTIMATES

Population density estimates fluctuated a great deal from year to year. Brook trout estimates varied two- to threefold and Atlantic salmon and eels varied up to tenfold over the 7-yr period. The accuracy of population estimates for the most abundant species of the Nashwaak for the years 1974-76 inclusive were examined in detail by Symons (unpubl. data). Inspection of the data suggests that catch efficiency did not differ significantly in the brooks in relation to size, gradient or seasonal differences.

Symons (unpubl. data) suggests that maximum likely errors for brook trout population estimates, estimated as the difference between total catch and estimate, and expressed as a percentage of the estimate, are 13 and 7% for three and four fishing estimates, respectively. The estimates for 1972 and 1973 provided by Elson (unpubl. data), based on six fishings, should be more accurate.

In July and September fishings in 1976, Symons (unpubl. data) compared the catchability of underyearling trout (0+) with that of older individuals (1+ and 2+) in Hayden Brook by means of two different estimates. The first estimate was made by

[1] In 1975 trout were branded according to length-class; this proved unsatisfactory.

dividing the catch according to age group and then by making separate regular population estimates for each age group. The second set of estimates (estimates as percent of total estimates) was made by deriving an estimate for the total population, and then by dividing this estimate into underyearlings or older trout in direct proportion to the numbers caught. The summarized data are:

July	0+	1+ and 2	Total
Separate estimates	106	243	349
Estimates as % of total estimates	105	243	346
Sept.			
Separate estimates	117	166	283
Estimates as % of total estimates	114	139	283

If catchability of underyearlings was lower than yearlings or older fish, then population estimates of underyearlings derived as a proportion of the catch should have been smaller than the separate estimates. Symons found this not to be the case in the particular streams of this study and the catchability of underyearlings has, therefore, been assumed to be the same as for older fish.

The numbers of fish of each species estimated from the mid-summer (July) fishing for the 7 yr are shown in Table 4. No relationship appeared to exist amongst species numbers changes (Fig. 11). A decrease of one species did not result in an increase in another. The only apparent relationship was the corresponding simultaneous change in numbers of brook trout and slimy sculpins in the upper site of Narrows Mountain Brook, suggestive of a common influential environmental factor.

A comparison of the biomass of the various species from actual catches in July of each year showed that all species increased or decreased in biomass within the same year in the upper and lower sites on Narrows Mountain Brook. No apparent interspecific relationship existed in Hayden Brook (Fig. 12). The biomass of all species was highest in 1975 and lowest in 1977 in both sites of Narrows Mountain Brook. Hayden Brook did not exhibit this pattern, and biomass values were more uniform with the exception of 1978 (Fig. 13). Actual numbers and weight of fish species caught from 1974-78, inclusive, in the three study sites are contained in Table 5.

MIGRATION

While no spawning Atlantic salmon were observed in Hayden or Narrows Mountain Brooks, large numbers of underyearling salmon were caught in all sections of the lower site of Narrows Mountain Brook for the first time in 1977 and fair numbers (36) were caught in the lowermost section in 1978 (Fig. 6). No salmon were caught in the upper site of Narrows Mountain Brook.

Yearling (1+ and 2+) salmon entered the lower site of Narrows Mountain Brook sometime between late May and early July each year from the Nashwaak River. Many marked yearling salmon apparently remained overwinter and emigrated the following summer and fall as 2-yr-olds, having remained in the brook for a year. Immigrating 2-yr-olds left again in the fall of the same year. Two-year-olds which had spent part or all of the summer in Narrows Mountain Brook presumably overwintered in the main river before migrating as 3-yr-old smolts.

Underyearling (0+) salmon were not caught in Hayden Brook during the study period except for three fish in 1974. Symons (unpubl. data) found that young salmon grew faster and remained a shorter time in Hayden Brook than they did in Narrows Mountain Brook: 1- and 2-yr-old salmon entered Hayden Brook between May and July, and with the exception of a few small yearlings all of them left again between fall and the next spring (Fig. 5). Most of the yearlings exceeded 10 cm fork length in the fall and therefore met the criterion of Elson (1957) for becoming smolts the following spring at age 2+.

Numbers of brook trout of all ages in all three study sites were lowest in the spring fishings conducted in late May, and these numbers probably represented fish that overwintered in the streams. Larger numbers of trout of all ages occurring in July fishings were the result of emergence of young-of-the-year fish in late May and early June and the immigration of yearling and older fish from possible overwintering sites in the stream or the Nashwaak River about late June. This immigration of fish from the main Nashwaak is believed to be the result of trout seeking cooler, preferred water temperatures in the shaded, smaller streams. Temperatures recorded at time of fishing seemed to verify this. Salmon anglers reported catching trout in the Nashwaak in the spring and early summer and noticed their absence after about the first of July. This generally coincided with seasonal, warm, low water conditions in the river. The upstream migration of trout was also noticed by the electrofishing crew on Hayden Brook in one particular instance when 10 of 33 trout branded June 29 in the lowermost section of Hayden Brook, less than 50 m from the Nashwaak River, were recaptured in the two uppermost sections 3 d later, a distance of about 600 m upstream. In the fall fishings of 1974, 1975, and 1976 in September and October, the numbers of trout decreased from the July fishings at all sites. However, in fall fishings conducted in late August of 1977 and 1978 (conducted early due to manpower difficulties) the numbers of trout were quite similar to the July fishings. This suggests a movement of trout sometime in September either upstream to spawning areas or downstream to the Nashwaak River. Some ripe males and gravid females were caught in late fall fishings at the upper site of Narrows Mountain Brook in 1975. Low numbers of trout at all sites in May, and the disappearance of some marked individuals which later reappeared, suggest that some trout of all sizes emigrated from all fishing sites. Two 1+ trout marked in upper Narrows Mountain Brook in 1975 were recaptured in lower Narrows Mountain Brook in May 1976. No other fish marked in upper or lower Narrows Mountain Brook were recaptured in the opposite site in subsequent years, probably because of the low probability of recapturing these fish.

American eels were found in all streams but were most numerous in Hayden Brook. Examination of the length-frequency histogram of eels (Fig. 7) shows eels to be scarce in May (0-6), good numbers were present in July (30-80), fewer in late August (18-34), and most of them left the stream by September and October. Most of the eels that left the streams were probably seeking overwintering sites in the Nashwaak River, and these movements may have been temperature-related. Eels were present in the study streams when the temperature was close to, or above, 14°C but few were present at lower temperatures. Smith and Saunders (1955) found the upstream movement of young eels into Crecy Lake to coincide with water temperatures above 12°C in that stream between mid May and September. Few eels over 30 cm were found in the Nashwaak streams.

Male eels have been found to mature as small as 27 cm (Katz 1954 cited in Carlander 1969), and some eel movements might be attributable to spawning migration but, for the most part, they were probably the result of temperature change.

GROWTH

Trout of all ages were larger in Hayden Brook than those of corresponding age in the upper site of Narrows Mountain Brook (Table 3). Too few trout were recaptured in the lower site of Narrows Mountain Brook for an accurate comparison; however, those caught were larger than those in the upper site. This agrees with Ricker (1932) that maximum size of brook trout seems correlated with the size of the body of water in which they live. The study site on Hayden is roughly twice the width and depth of the upper site on Narrows Mountain Brook. Larger bodies of water probably allow fish more mobility in foraging, enabling them to secure more food items resulting in faster growth and larger mean sizes of fish. Competition in the higher density trout population in upper Narrows Mountain Brook probably resulted in smaller trout due to competition for food items. Graphs constructed by Symons (unpubl. data) of the 1974 year-class of trout (Fig. 14) and graphs constructed of recaptures of 1976 and 1977 year-classes of trout (Fig. 15) show growth of trout, in terms of weight, to occur mainly in June and July of each year.

Mean growth where $G = (\log_e w_i - \log_e w_o)/n$ was 0.208 for Upper Narrows Mountain Brook, 0.250 for Lower Narrows Mountain Brook, and 0.262 for Hayden Brook. Mean condition factors, K, where $K = w/L^3$, were 1.010, 0.987, and 1.064 respectively (Table 6).

DISCUSSION

Logging may have several counter-balancing, conflicting consequences for fish production. Previous studies have found changes in stream water temperature regimes, discharge variability, nutrient input and sedimentation after clearcutting.

Territorial behavior is one mechanism for controlling the number of fish which can inhabit any particular area of stream. "The size of each territory is influenced by such factors as the species and size of fish, the velocity of the current, the irregularity of the bottom, and the temperature" (Allen 1968). One of the most serious detrimental effects that may affect a trout population is habitat alteration caused by sedimentation. The elimination of large interstitial spaces among rocks by filling in of sand and silt reduces the amount of cover available to fish. Reducing the irregularity of the bottom may result in larger territories and fewer fish or the conditions may not be suitable for large fish which may leave and be displaced by numbers of smaller fish. The need of larger fish for territories with suitable cover is the basis for much "stream improvement" which has been shown to produce desired results (Saunders and Smith 1962).

"In winter stream-living salmonids tend to become lethargic, drop into the pools, seek cover, and feed less actively" (Allen 1968). Atlantic salmon have been found to become inactive and penetrate particularly deeply into cover in winter (Allen 1940; Lindroth 1955; Saunders and Gee 1964). Sedimentation and change in the percent substrate as gravel-rock may affect salmon parr overwinter survival.

Studies by Welch et al. (1977) showed streams in clearcut watersheds to have 17% fewer trout, over 200% more sculpins, and 26% less benthos. Damage was attributed mainly to sedimentation, and road crossings were the main point source.

The collection of seven consecutive years of pre-clearcut data should provide an adequate baseline from which to detect effects of clearcutting on fish populations. The control stream should help separate environmental and clearcutting effects. The main areas to be examined for changes will be age and species composition and growth rates. Should changes occur, attempts will be made to relate them to environmental changes that are to be examined in component studies.

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Table 1. Location and physical characteristics of study sections.

Section no.	Location and length (m)	Av. width (m)	Area (m^2)	Gradient	Approx. water vel. (cm/s)	Bottom characteristics
				Hayden Brook		
Above road along Nashwaak River						
1	69	3.33	230	0.048	45	Cobble, boulders, gravel
2	69	2.72	180	0.049	-	Cobble, gravel, fallen trees
3	69	4.09	282	0.050	50	Cobble, boulders
4	69	3.64	251	0.052	-	Cobble, boulders, gravel
5	55	4.11	226	0.072	-	Cobble, boulders, gravel
6	73	3.35	245	0.109	95	Large boulders
				Narrows Mountain Brook (lower site)		
Above Napodogan Road						
1	69	2.11	146	0.041	45	Cobble, boulders
2	69	2.42	167	0.076	31	Cobble, boulders
3	41	2.15	88	0.098	70	Cobble, boulders
4	46	2.11	97	0.058	32	Cobble, boulders
Below Napodogan Road						
5	71	3.34	244	-	-	Boulders covered with fine sand and mud
				Narrows Mountain Brook (upper site)		
1 (Abandoned)		-	-	-	-	Sand, gravel, cobble, fallen logs
2 (West fork)	79	1.94	153	-	-	Sand, gravel, cobble, fallen logs
3 (East fork)	71	1.94	138	-	-	Sand, gravel, cobble, fallen logs
4 (East fork)	66	1.75	116	-	-	Sand, gravel, cobble, fallen logs

Table 2. Dates of fishing (number of days between fishings) and water temperatures at time of fishing.

Season and year	Hayden Brook Date (days between)	Hayden Brook Water temp. (°C)	Lower Narrows Mountain Brook Date (days between)	Lower Narrows Mountain Brook Water temp. (°C)	Upper Narrows Mountain Brook Date (days between)	Upper Narrows Mountain Brook Water temp. (°C)
Spring 1974	June 20 (34)		June 19 (27)		June 18 (29)	
Summer	July 23-25 (90)		July 16 (99)		July 17-18 (98)	
Fall	Oct. 22 (217)		Oct. 23 (213)		Oct. 24 (209)	
Spring 1975	May 27 (49)	6-9	May 20,28 (44)	7-12	May 21 (62)	10-13
Summer	July 11,15,17,18 (85)	15-18	July 7-10 (90)	15-18	July 22-23 (74)	9-11
Fall	Oct. 8 (223)	6	Oct. 6,7 (224)	7-8	Oct. 4 (228)	5
Spring 1976	May 18,21 (62)	6-9	May 17,19 (65)	9-10	May 20 (67)	7-9
Summer	July 18,20,21 (64)	15-19	July 22-23 (61)	14-17	July 26 (59)	13
Fall	Sept. 22 (287)	11-12	Sept. 21 (280)	14	Sept. 23 (294)	9-10
Summer 1977	July 5,6,7 (54)	12.1-15	July 12,19 (42)	13-17.5	July 14-15 (42)	13-13.5
Fall	Aug. 29,30 (311)	17.8-18	Aug. 23 (298)	12.3	Aug. 25 (309)	11.5-12
Summer 1978	July 5,6,7,11 (47)	12-16	June 29,July 11 (56)	13-16	July 12 (48)	12-14
Fall	Aug. 22,23	13-16	Aug. 24,30	12-14	Aug. 29,30	13

Table 3. Mean fork length (cm) of trout branded at age 0+ and recaptured. Brackets indicate number of fish recaptured.

Location	Date of recapture	Age 0+ $\bar{x}$ fork length ± SD	Age 1+ $\bar{x}$ fork length ± SD	Age 2+ $\bar{x}$ fork length ± SD
Hayden	Sept. 1976	7.02 ± 0.85(40)		
	July 1977		9.36 ± 1.09(27)	
	Aug. 1777	6.15 ± 0.17(4)	10.30 ± 1.15(25)	
	July 1978		9.78 ± 0.59(18)	12.75 ± 1.12(20)
	Aug. 1978	6.13 ± 0.54(15)	10.42 ± 1.42(20)	13.80 ± 1.41(4)
UNM	Sept. 1976	5.27 ± 0.50(22)		
	July 1977		8.30 ± 0.98(7)	
	Aug. 1977	5.67 ± 0.38(22)		
	July 1978		8.05 ± 0.76(24)	8.75 ± 1.06(2)
	Aug. 1978	4.94 ± 0.35(17)	9.00 ± 0.62(3)	
LNM	Sept. 1976	7.00 ± 0.00(1)		
	July 1977	7.00 ± 0.71(2)		
	Aug. 1977			
	July 1978			
	Aug. 1978			

Table 4. Fish species and comparisons of midsummer (July) population densities at three locations in Hayden and Narrows Mountain Brooks.

Stretch	Fish species	Estimated number/100 m^2 1972	1973	1974	1975	1976	1977	1978
Hayden (1422 m^2)	Brook trout (*Salvelinus fontinalis*)	25.7	19.0	11.9	22.2	26.5	15.1	23.0
	Atlantic salmon (*Salmo salar*)	0.5	2.3	3.7	5.9	2.2	1.3	1.8
	Eels (*Anguilla rostrata*)	2.7	4.1	3.2	4.7	3.9	2.4	6.0
Narrows Mountain Lower site (498 m^2 to 1974) (742 m^2 1975 & 1976) (645 m^2 1977 and after)	Brook trout	19.2	16.2	12.8	11.9	12.1	8.4	9.0
	Atlantic salmon	0.8	8.2	2.0	18.9	14.7	18.4	13.5
	Eels	6.6	9.1	0.8	5.1	3.3	1.6	1.2
	Blacknose dace (*Rhynichthys atratulus*)	5.9	4.6	0.7	0.7	7.1	6.4	0.9
	Creek chub (*Semotilus atromaculatus*)	0	0.6	0.2	0.1	0	0	0
	Slimy sculpin (*Cottus cognatus*)	0	0	0.2	0.4	1.2	0.2	0.8
Narrows Mountain Upper site (407 m^2)	Brook trout	-	-	68.3	97.8	67.3	46.4	55.5
	Slimy sculpin	-	-	28.7	41.3	28.3	13.7	26.4
	Eels	-	-	0.2	0	0.5	0	0.5

[a]The section added in 1975 was particularly rich in salmon. Separate salmon population estimates without this section are:

1975	1976	1977	1978
17.7	9.2	8.2	8.2

Table 5. Number of fish caught in the three brooks from 1974-78.

Brook	Month	No. of fishings	Number of fish and (wet weight (g))					Total weight (g)
			Trout	Salmon	Dace	Sculpin	Eel	
1974								
Hayden	July	4	176(3778)	50(1084)			37(458)	5320
Upper Narrows Mtn.	July	4	315(1723)			118(200)	1(19)	1942
Lower Narrows Mtn.	July	4	60(924)	9(198)	3(12)		5(79)	1213
1975								
Hayden	July	3	278(3369)	78(1293)			59(624)	5286
Upper Narrows Mtn.	July	3	349(1795)			140(530)		2325
Lower Narrows Mtn.	July	3	104(1654)	166(1948)	2(10)	3(10)	41(521)	4143
1976								
Hayden	May	2	110(504)	6(120)			1(42)	666
	July	4	357(3490)	20(438)			54(555)	4483
	Sept.	2	237(2511)	18(271)			0	2782
Upper Narrows Mtn.	May	2	77(425)			20(89)		514
	July	4	254(1447)			106(242)		1689
	Sept.	2	143(693)			22(63)		756
Lower Narrows Mtn.	May	2	40(354)	44(403)	5(5)	1(3)	0	765
	July	4	73(784)	144(1533)	54(290)	0	24(189)	2796
	Sept.	2	25(212)	70(924)	35(116)	4(10)	1(4)	1266
1977								
Hayden	July	3	207(3690)	16(418)			23(268)	4376
	Aug.	2	269(4254)	28(530)			19(376)	5160
Upper Narrows Mtn.	July	3	188(1153)			46(143)	0	1296
	Aug.	2	169(1038)			69(171)	1(3)	1212
Lower Narrows Mtn.	July	3	46(548)	112(661)	9(24)	2(9)	5(53)	1295
	Aug.	2	41(507)	145(665)	2(9)	0	6(41)	1222
1978								
Hayden	July	3	317(5720)	25(412)			140(665)	6797
	Aug.	2	404(5230)	33(516)			38(347)	6093
Upper Narrows Mtn.	July	3	222(1711)				2(193)	1904
	Aug.	2	195(1509)				1(4)	1513
Lower Narrows Mtn.	July	3	45(749)	86(617)	4(17)	7(31)	8(109)	1523
	Aug.	2	66(904)	116(943)	22(116)	5(20)	10(166)	2149

Table 6. Mean growth rates and condition factors of recaptured trout.

Location (no. of fish)	Time at large	Weight range at branding (g)	Length range at branding (cm)	Weight range at recapture (g)	Length range at recapture (cm)	$\bar{x}$ specific growth rate	SD	$\bar{x}$ condition factor (K)	SD
Upper Narrows Mtn. (32)	July 77-July 78 363-369 d	3-17	6.9-12.8	8-22	9.2-13.1	0.208	.248	1.010	.205
Lower Narrows Mtn. (7)	July 77-June 78 345-352 d	5-16	8.4-11.9	14-32	11.3-14.4	0.250	.149	0.987	.119
Hayden (21)	July 77-July 78 362-364 d	5-31	8.0-14.1	18-93	11.9-15.4	0.262	.080	1.064	.097

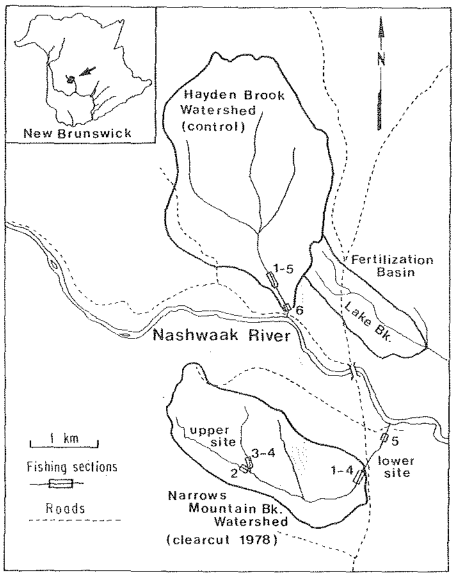

Fig. 1. Study sites.

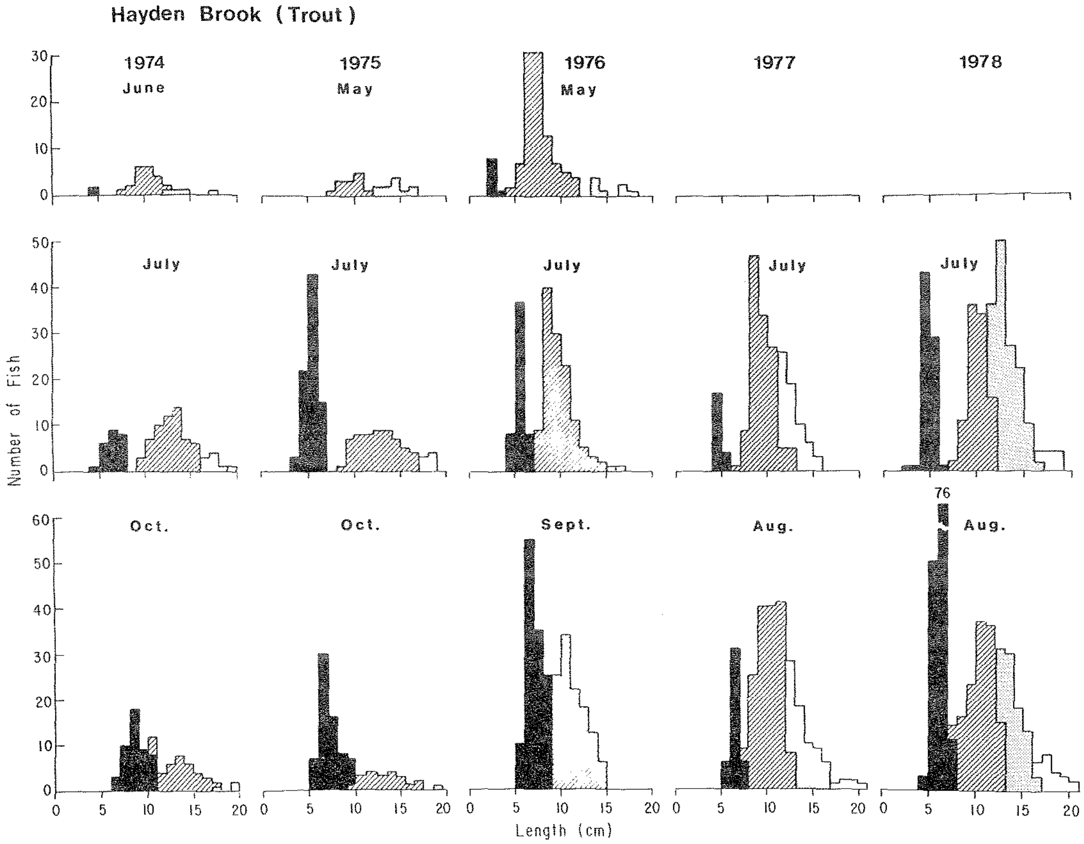

Fig. 2. Length frequency histogram of Hayden Brook trout.

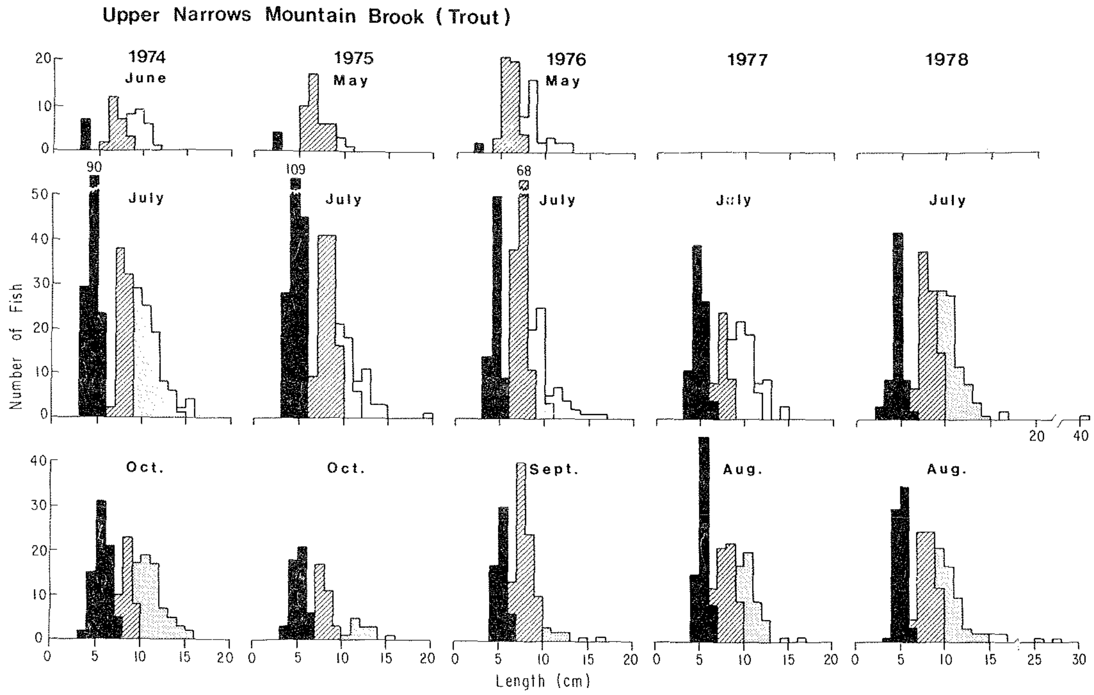

Fig. 3. Length frequency histogram of Upper Narrows Mountain Brook trout.

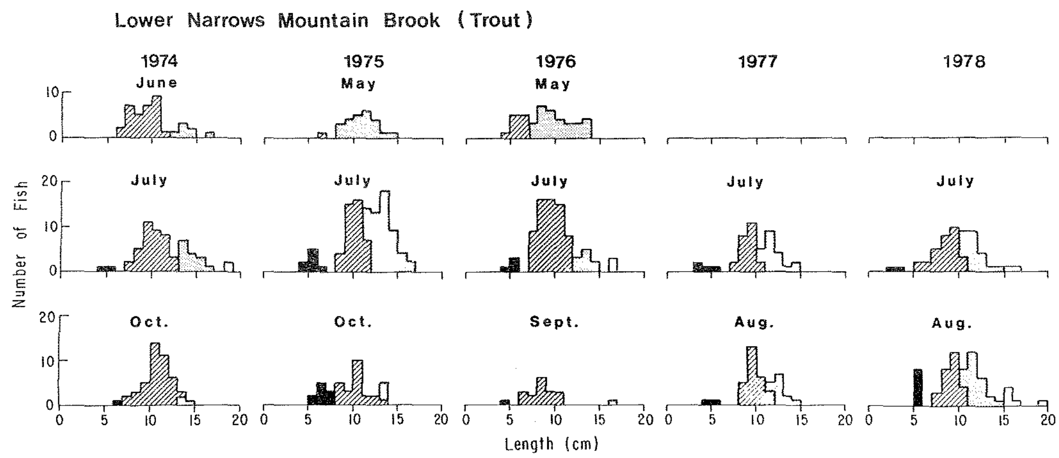

Fig. 4. Length frequency histogram of Lower Narrows Mountain Brook trout.

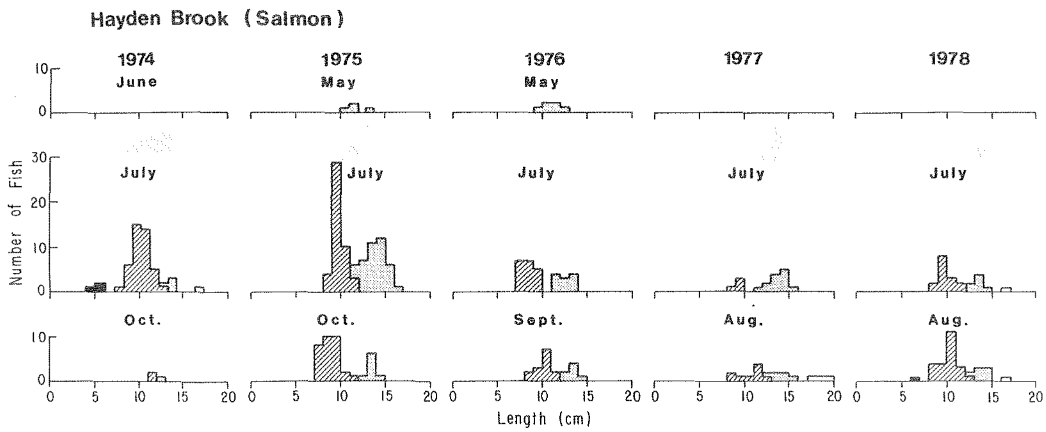

Fig. 5. Length frequency histogram of Hayden Brook salmon.

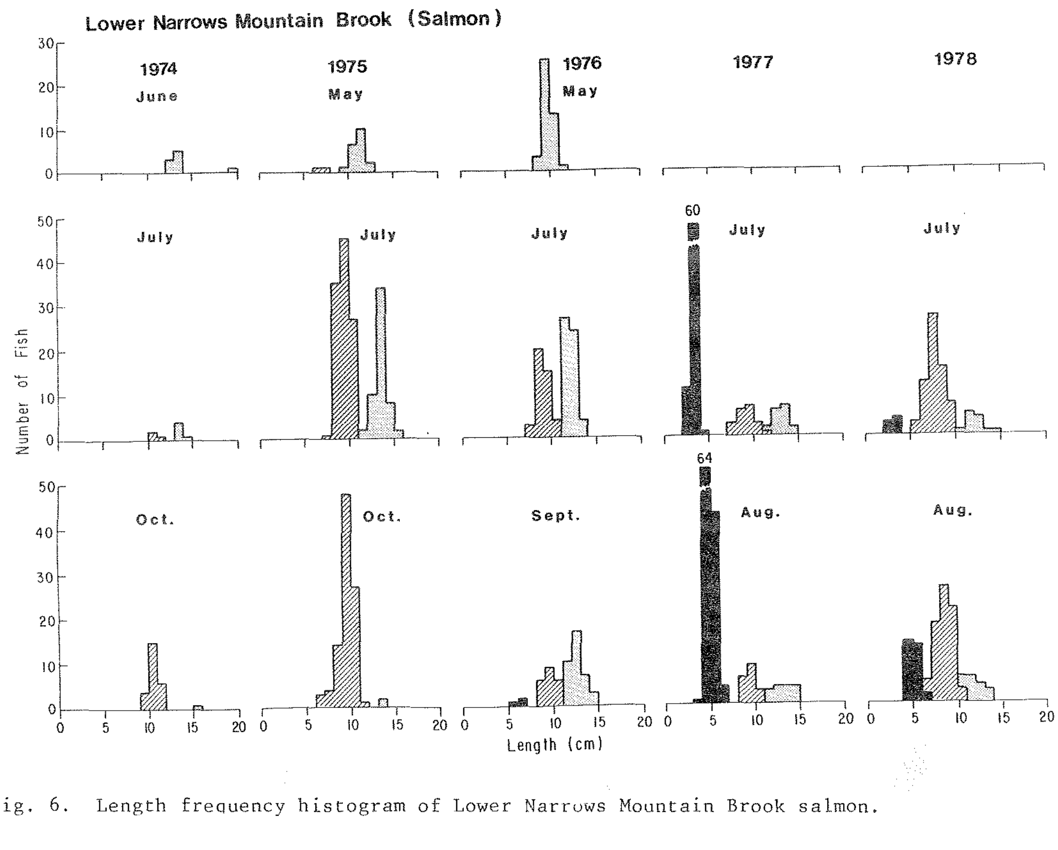

Fig. 6. Length frequency histogram of Lower Narrows Mountain Brook salmon.

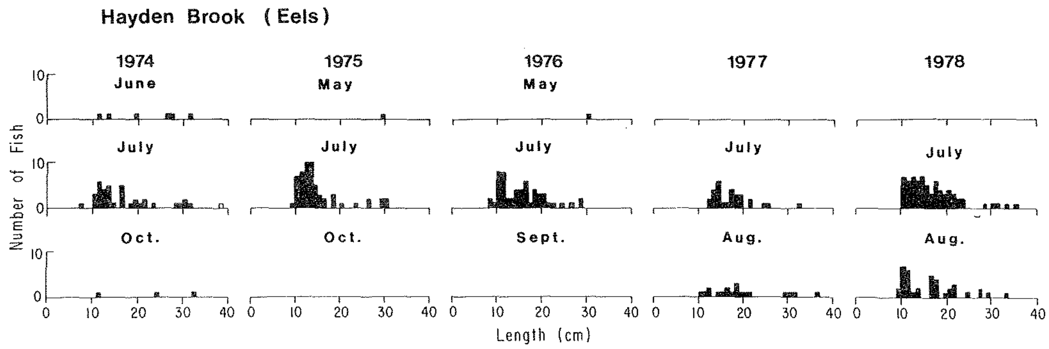

Fig. 7. Length frequency histogram of Hayden Brook eels.

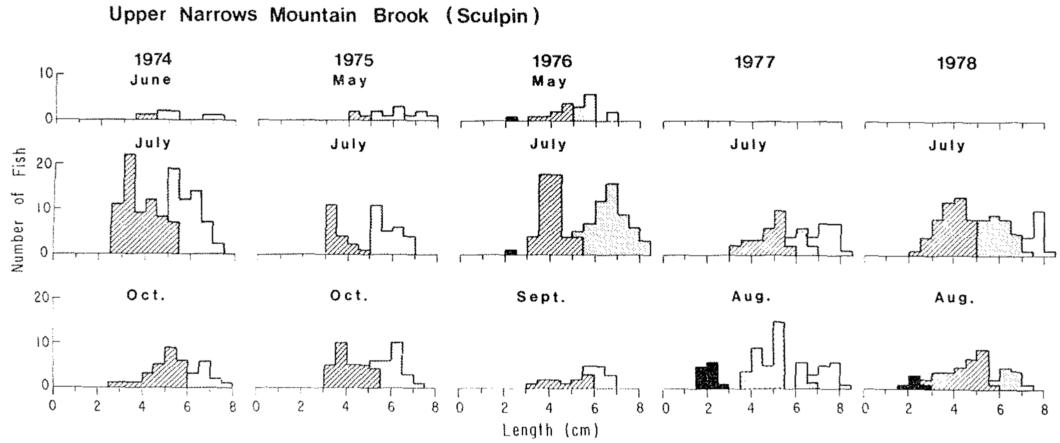

Fig. 8. Length frequency histogram of Upper Narrows Mountain Brook sculpin.

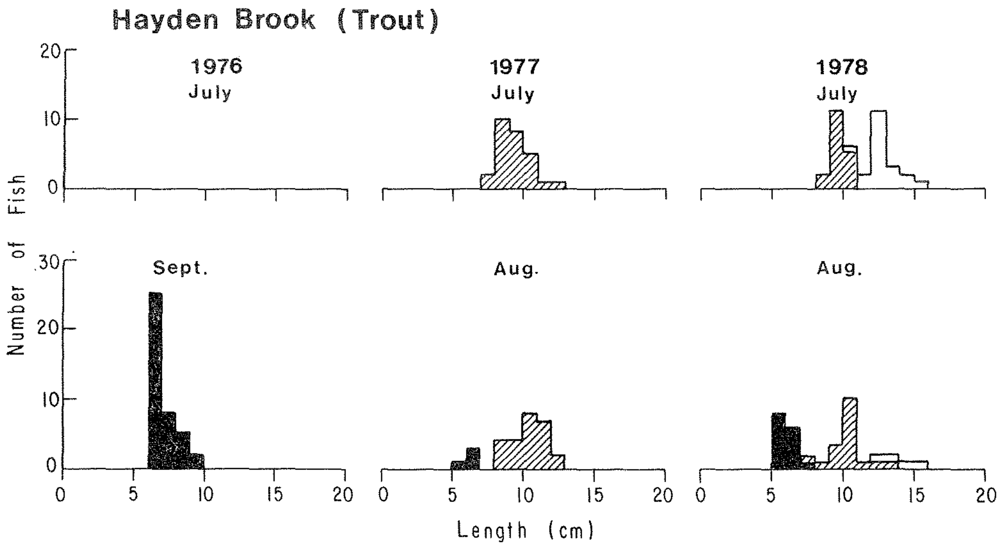

Fig. 9. Length frequency histogram of Hayden Brook recaptured trout marked at age 0+.

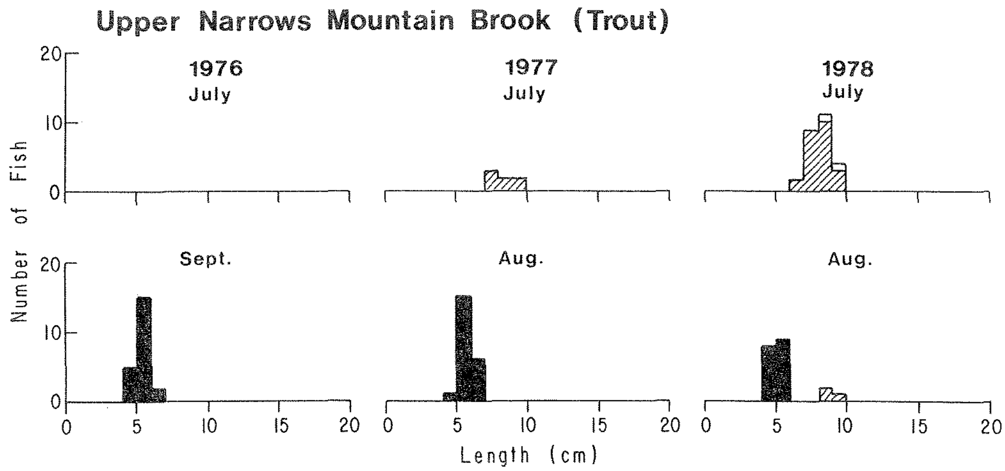

Fig. 10. Length frequency histogram of Upper Narrows Mountain Brook recaptured trout marked at age 0+.

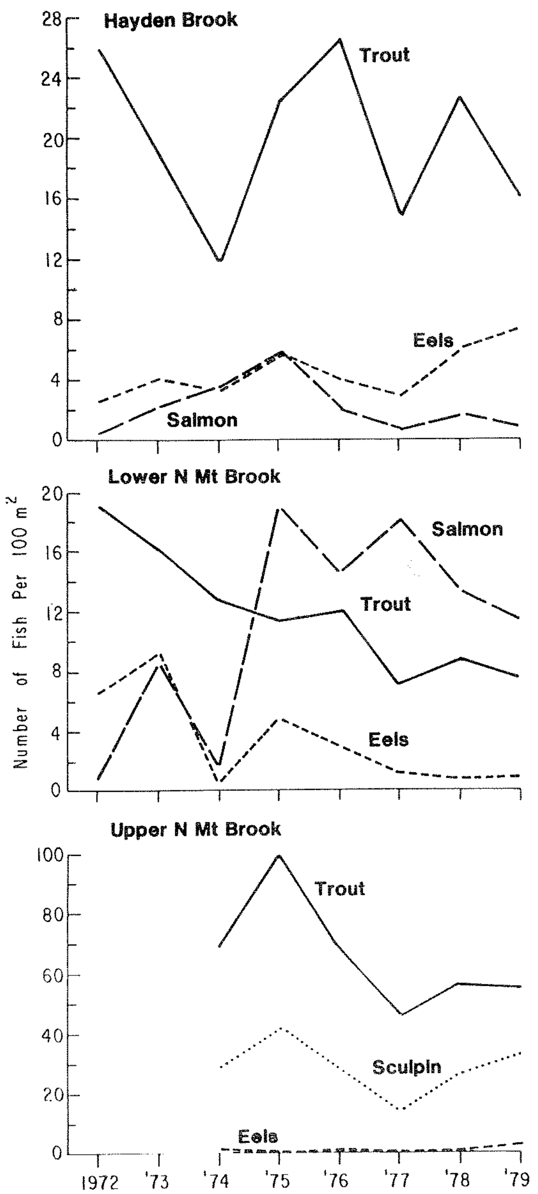

Fig. 11. Relative yearly numbers of fish of each species.

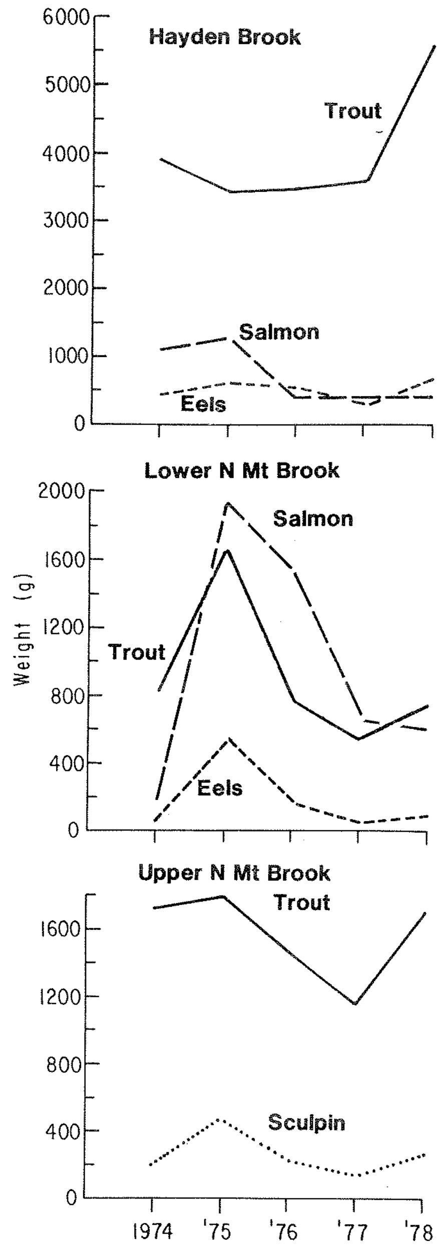

Fig. 12. Relative yearly biomass of fish of each species.

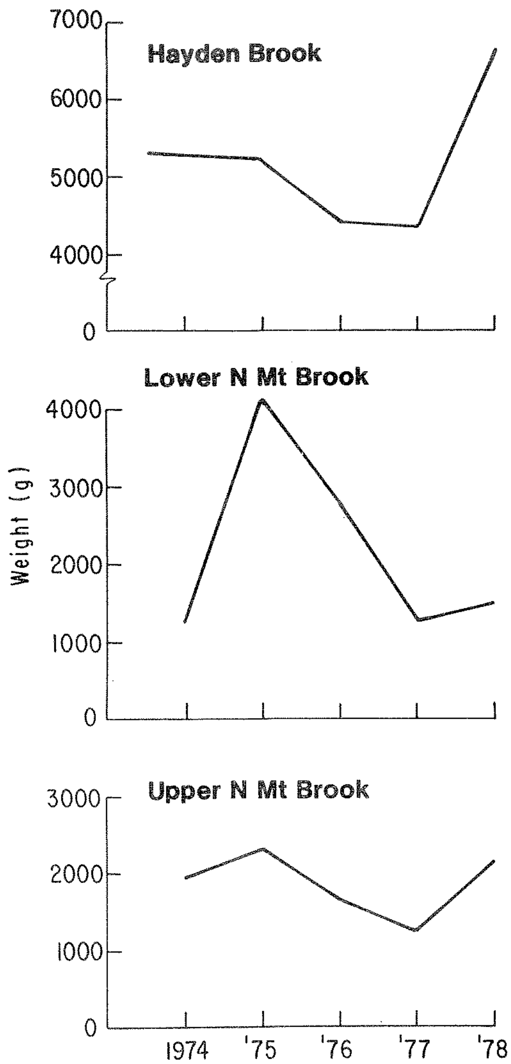

Fig. 13. Yearly total fish biomass.

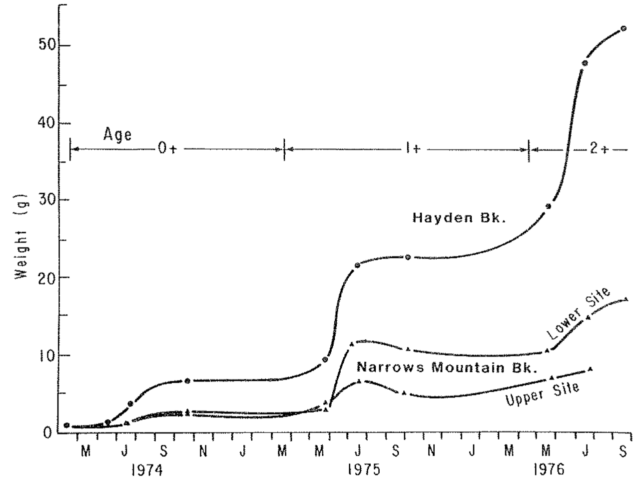

Fig. 14. Growth of 1974 year-class of trout.

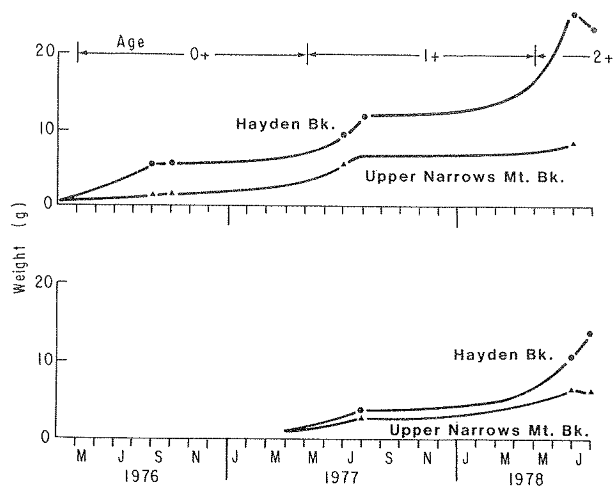

Fig. 15. Growth of 1976 and 1977 year-classes of trout (Table 3 data).