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Survival, Growth, and Food Habits of Brook Trout Introduced Into An Eastern South Dakota Stream

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SURVIVAL, GROWTH, AND FOOD HABITS OF BROOK TROUT INTRODUCED INTO AN EASTERN SOUTH DAKOTA STREAM

BY

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INTRODUCED INTO AN EASTERN SOUTH DAKOTA STREAM

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Thesis Adviser Date

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INTRODUCED INTO AN EASTERN SOUTH DAKOTA STREAM

Abstract

LARRY W. KALLEMEYN

Brook trout were introduced into the South Fork Yellow Bank River, an eastern South Dakota stream, on October 11, 1966. A supplemental brook trout plant was made on June 8, 1967. Survival for the initial plant from October, 1966 through October, 1967 was 2.4%. Survival for the supplemental plant from June, 1967 through October, 1967 was 21.0%. Trout from both plants took part in spawning activites during the fall of 1967. Average length of trout from the initial plant increased 9.8 cm during one year. Their average condition factor reached a peak in June, 1967 after being low throughout the winter. Average length and average condition factor of trout from the supplemental plant increased following stocking. Aquatic organisms made up most of the trout diet. Insects, both aquatic and terrestrial, were the most numerous organisms in trout stomachs while forage fish comprised the greatest volume of organisms in the stomachs. Trichoptera, Ephemeroptera, and Diptera were the predominate organisms found in benthos samples collected for forage ratio determinations. Forage ratios for the different orders varied throughout the study. Little relationship was found between the abundance of forage fish and the average number of fish in trout stomachs.

INTRODUCTION

Although stocking of brook trout, Salvelinus fontinalis (Mitchell)[1], in waters that had never contained trout was a common practice in early fisheries management in North America very few studies report the success of these plants. Rawson (1940) summarized 20 years of studies on brook trout introduced into the Maligne River system in Alberta. These trout exhibited excellent growth with some fish attaining weights of 2 pounds only 16 months after stocking. The population reproduced sufficiently to maintain itself. Brook trout introduced into a small mountain lake in California, reported by Reimers (1958), had poor growth during the first year after planting and negligible growth during the next two years. Bottom fauna and zooplankton populations were reduced by brook trout predation. No reproduction of trout was found.

Objectives of the present study were to determine the survival and growth of brook trout introduced into an eastern South Dakota stream and to determine the impact of the trout on the invertebrate fauna and indigenous forage fish population. Knowledge gained from the present study could aid in the evaluation and management of other streams in the area.

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[1]Scientific nomenclature of fish according to, A List of Common and Scientific Names of Fishes from the United States and Canada. American Fisheries Society Special Pub. 2, 2nd ed, 1960. Waverly Press, Inc., Baltimore, Maryland.

STUDY AREA DESCRIPTION

The South Fork Yellow Bank River is a spring stream that originates in Grant County, South Dakota. It flows northeasterly from the Prairie des Coteau across Grant County into Minnesota where it drains into the Minnesota River approximately 10 miles below Ortonville, Minnesota. Several similar streams exist in the area and two of them, Gary Creek and Sechi Hollow Creek, have been stocked with brook trout and rainbow trout, *Salmo gairdneri* Richardson, but no attempt has been made to evaluate these plants. The South Fork Yellow Bank River had never contained trout but appeared capable of supporting brook trout.

The study area was limited to the upper two miles of the stream where the average width is 11.3 feet and the gradient is 62.5 feet per mile. The stream flows through a mixed hardwood forest that is interspersed with small open patches of pastureland. One active farmstead and one cattle feedlot lie in the stream valley within the study area.

The riffles average three inches in depth and have substrates of small gravel and or rubble. Some sections of the study area contain long unbroken stretches of shallow riffles. Typical depth of the pools is 20 inches (range 12 to 50 inches). Pool substrates usually consist of either fine sand overlying clay-pan or exposed clay-pan. Leaves accumulate in the pools in the fall and remain there until the spring runoff.

Five sampling stations were established within the study area (Fig. 1). The stations were spaced approximately 0.3 miles apart with Station I located 0.1 miles from the source of the stream. Each station was 200 feet long and contained at least two riffles and two pools. Undercut banks, overhanging trees, large boulders, and pools offered cover in the sampling stations. All stations contained cattle watering and crossing areas.

Water temperatures averaged below 20°C during the summer. A 2 to 5°C difference existed during the summer between the average temperatures near the spring source (Station A) and two miles downstream (Station B) (Fig. 2). Air temperatures in the area often reached 30 to 35°C[2].

All except the upstream 0.5 mile of the study area was covered with ice from November, 1966 to March, 1967. Skim ice occurred in the upstream section when air temperatures reached -28.9°C. No anchor ice was observed. Heavy snow (52 inches) from November, 1966 to March, 1967 resulted in snow bridges over parts of the upstream section or an insulating cover on the ice-covered sections. The ice thickness decreased as the insulating snow cover increased.

The maximum and minimum temperatures observed at the two recording stations varied in time of occurrence and extremes (Fig. 2).

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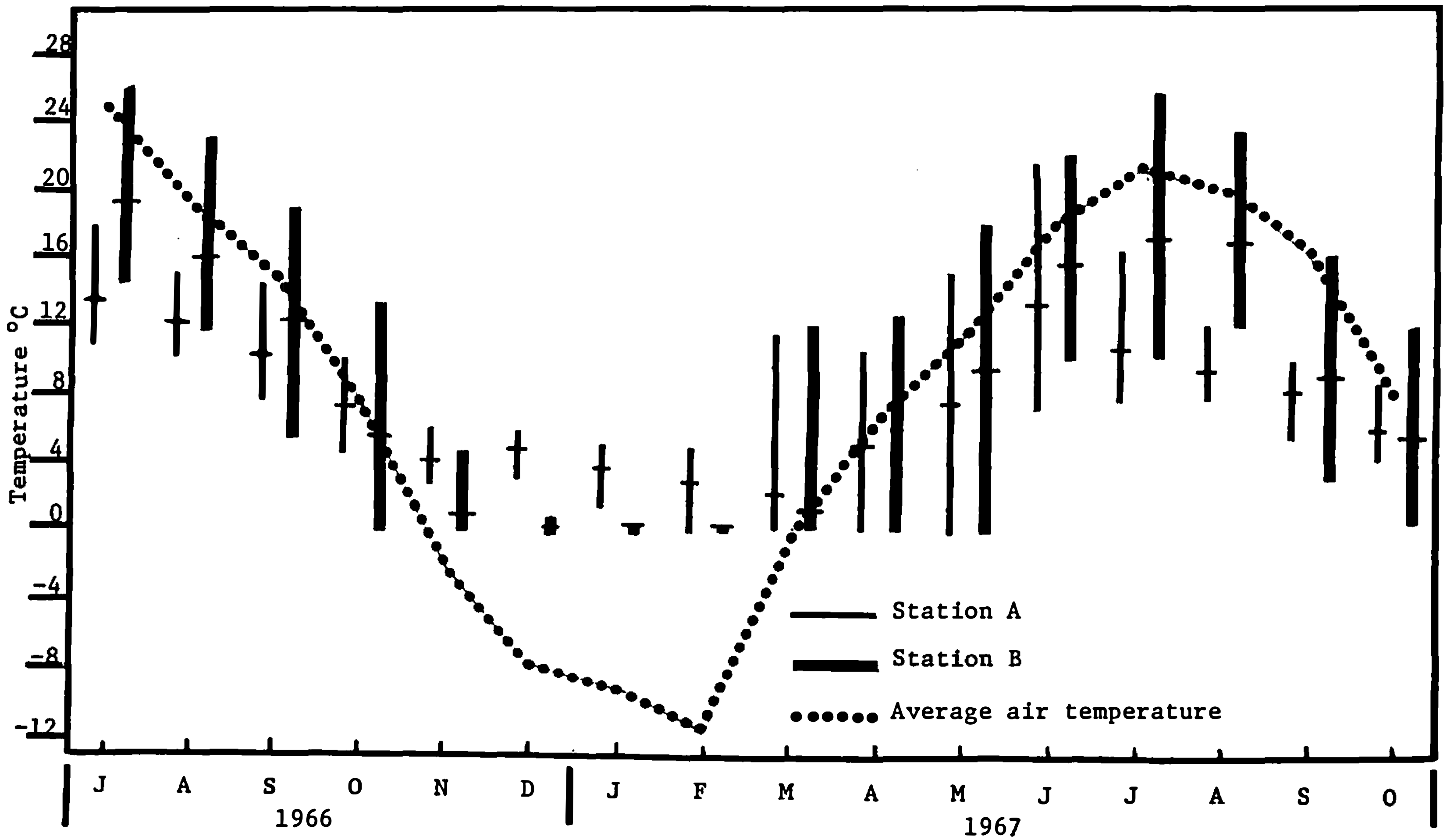
[2]Climatological data for Clear Lake, South Dakota, located 15.5 miles south of the study area. From U. S. Department of Commerce, U. S. Weather Bureau. Climatological Data, South Dakota. Vol. 71 and 72. 1966 and 1967.

Figure 1. Location of stations within study area.

Scale: 1 inch ≈ 0.20 mi.

Figure 2. Mean water temperature, water temperature range, and average air temperature at Stations A and B from July, 1966 through October, 1967 (Cross-bar indicates mean water temperature).



Minimum temperatures at Station A occurred between February and May of 1967 and were due to ice and snow melt overcoming the tempering effect of the spring source. The maximum temperatures at Station A occurred in June when the stream was exposed to high air temperatures and direct sunlight. Stream temperatures decreased as the overhead canopy developed. Station B, two miles from the source, exhibited minimum temperatures as soon as air temperatures were consistently below 0.0°C. Maximum temperatures at Station B coincided with air temperature peaks.

Water discharge measurements taken during the period July, 1966 to February, 1967 all gave readings of approximately 3.8 cubic feet per second. A discharge of 25 cfs was recorded in March, 1967 but water line marks along the stream indicated that discharge had been higher prior to this date. Discharge declined throughout the summer of 1967 until a low of 1.1 cfs was recorded on September 16. This discharge could be attributed entirely to spring outflow since no water was contributed by surface drainage above the spring source. Heavy rains produced temporary increases in discharge.

The effect of dilution by an increase in volume has been shown to have a definite effect upon the concentrations of many chemical ions in a small body of water (Moyle, 1956). This was quite evident in the study area as minimum values for most of the chemical ions occurred in March, 1967 when discharge was at its peak (Appendices A and B). Ionic concentrations remained fairly constant during the rest of the study. The chemical ion concentrations found were similar to those found by Schmidt (1967) for lakes in the area.

During periods of low discharge dissolved oxygen concentrations varied from 6 to 9 ppm at Station A and from 10 to 12 ppm at Station B. Oxygen concentrations at both stations varied from 9 to 13 ppm during periods of high discharge. No oxygen concentrations were recorded that would be detrimental to fish.

Bicarbonate alkalinity concentrations varied from 81 ppm to 334 ppm. The minimum concentration occurred in March, 1967 when discharge was at its peak while the maximum concentration was found in September, 1967 when the minimum discharge was recorded. The relatively high alkalinity values can be attributed to the calcareous nature of the soils in the drainage. The pH was always basic with a range of 7.2 to 8.0 being found. Iron precipitates in the hydroxide form at the spring source of the stream and where seep areas occur.

The indigenous fish population in the study area contained 14 species (Table 1). Northern pike, Esox lucius L., and blackside darter, Percina maculata (Girard), have been found in the upper four miles of the South Fork Yellow Bank River (Felix, 1967) but were not encountered in the present study.

Aquatic invertebrates found during the study are listed in Table 2. This list is not considered to contain all the aquatic invertebrates that occur in the study area since pools were not sampled. Identifications of most of the aquatic insects were made from immature stages.

Table 1. Indigenous fish species collected in the study area.

Blacknose dace, *Rhinichthys atratulus* (Hermann)
Stoneroller, *Campostoma anomalum* (Raf.)
Fathead minnow, *Pimephales promelas* Raf.
Creek chub, *Semotilus atromaculatus* (Mitchill)
Common shiner, *Notropis cornutus* (Mitchill)
White sucker, *Catostomus commersoni* (Lacepede)
Iowa darter, *Etheostoma exile* (Girard)
Emerald shiner, *Notropis atherinoides* Raf.
Sand shiner, *Notropis stramineus* (Cope)
Johnny darter, *Etheostoma nigrum* Raf.
Brook stickleback, *Eucalia inconstans* (Kirtland)
Black bullhead, *Ictalurus melas* (Raf.)
Hornyhead chub, *Hybopsis biguttata* (Kirtland)
Brassy minnow, *Hybognathus hankinsoni* Hubbs

Table 2. Aquatic invertebrates collected from the study area.

ORDER DIPTERA
- Family Rhagionidae
  - *Atherix variegata* Walker
- Family Chironomidae
  - *Chironomus* sp.
  - *Pentaneura* sp.
- Family Tipulidae
  - *Tipula* sp.
  - *Antocha* sp.
- Family Anthomyiidae
  - *Limnophora aequifrons* Stein
- Family Tabanidae
  - *Tabanus* sp.
- Family Simuliidae

ORDER TRICHOPTERA
- Family Hydropsychidae
  - *Hydropsyche slossonae* Banks
- Family Phryganeidae
  - *Agrypnia vestita* (Walker)
- Family Limnephilidae
  - *Hesperophylax* sp.

ORDER EPHEMEROPTERA
- Family Baetidae
  - *Centroptilum* sp.
- Family Heptageniidae
  - *Stenonema ithaca* (Clemens & Leonard)
- Family Siphlonuridae
  - *Isonychia* sp.

ORDER ODONATA
- Family Aeshnidae
  - *Anax junius* (Drury)

ORDER PLECOPTERA
- Family Nemouridae
  - *Nemoura* sp.
- Family Peltoperlidae
  - *Peltoperla* sp.

ORDER COLEOPTERA
- Family Dytiscidae
  - *Laccophilus* sp.
  - *Ilybius* sp.
- Family Elmidae
  - *Zaitzevia* sp.

ORDER HEMIPTERA
- Family Corixidae
  - *Hesperocorixa* sp.
- Family Gerridae
  - *Gerris remigis* Say

CLASS HIRUDINEA
- Family Glossiphoniidae
  - *Placobdella parasitica* (Say)
  - *Helobdella* sp.

ORDER PULMONATA
- Family Physidae
  - *Physa* sp.

ORDER AMPHIPODA
- Family Talitridae
  - *Hyalella azteca* (Saussure)

ORDER HYDRACARINA
- Genera and species undetermined

METHODS

The initial brook trout plant made on October 11, 1966 consisted of 2950 fish that were nine months old. A supplemental plant of 281 brook trout of unknown age was made on June 8, 1967. Trout in the second plant were marked with a right pectoral clip to distinguish them from the initial plant. The average length and weight of the trout for each plant were based on samples of 100 fish. All trout were measured to the nearest 0.3 cm and weighed to the nearest gram (range in parentheses). Trout in the initial plant had an average length of 14.0 cm (9.5 - 17.5) and an average weight of 29.5 grams (14.0 - 53.0). The average condition factor of these fish was 1.57 (1.28 - 2.04). Condition factors were computed using a formula developed by Cooper and Benson (1951), $R = \frac{W \times 10}{L^3}$, where W equals weight in grams and L equals total length in inches. Fish in the supplemental plant had an average length of 19.2 cm (16.2 - 26.0) and an average weight of 53.0 grams (27.0 - 121.0). Average condition factor was 1.21 (.98 - 1.44).

Fluorescent dyes were applied to most of the initial plant to determine if movement occurred within the study area. A marking method similar to that of Phinney, Miller, and Dahlberg (1967) was used with granular pigments applied by a low pressure spray gun at a pressure of 90 pounds per square inch produced by compressed nitrogen gas. Fish released in the areas of; Stations I and II were marked with red dye, Stations III and IV with green dye, and Station V with orange dye. The inability to differentiate between the red and orange fluorescent dyes after they were put on the fish made it impossible to use them to evaluate trout movement within the study area. This method of marking fish would still appear to have considerable merit if more readily distinguishable colors of dye were used. Dye was still evident on trout collected in July, 1967.

Trout were collected each month from November, 1966 through October, 1967 for length, weight, and food habits determinations. Trout collected from November, 1966 through April, 1967 were weighed and measured after preservation in 10% formalin. Parker (1963) found that preserving fish in formalin changed length and weight, therefore, correction factors were applied to the lengths and weights determined from preserved fish. The correction factors were derived from a sample of 51 trout collected during August, September, and October of 1967. Sampling difficulty due to snow and ice cover resulted in small collections of trout from January through April of 1967. Consequently, the growth, condition, and food habits determinations made during these months may not be as reliable as those from other months when larger samples of trout were taken. The study area was electrofished monthly from May, 1967 through October, 1967 to determine the trout population size.

All trout from the initial plant captured during this period received a caudal fin clip before release. The efficiency of electrofishing for trout was determined by making three passes through each of three sections of stream that had been blocked off with nets. The initial catch in all three sections contained better than 90% of the trout obtained and in one case contained all of the trout taken from a section. No trout were collected on the third pass in any of the sections.

Trout used for food habits determination had been preserved in 10% formalin. Food organisms found in trout stomachs were sorted to taxonomic groups and counted. The frequency of occurrence was determined. In some cases the numbers were too small to make individual volume determinations, therefore, volumes were determined for each taxonomic group from the pooled stomach contents of all trout collected each month. Aquatic invertebrates in the stomachs were identified using standard keys of Burks (1953), Ross (1944), Pennak (1953), Usinger (1963), Ward and Whipple (1959). Terrestrial invertebrates were identified using Borror and DeLong (1964).

The use of bottom samples to determine the composition and exact size of aquatic invertebrate populations in streams has been found to be severely lacking in reliability. Needham and Usinger (1956) concluded, from a study on Prosser Creek in California, that quantitative bottom sampling is impractical since an extremely large sample is required to get accurate estimates of the numbers and weights of aquatic invertebrates present in a riffle area. However, Needham, in a letter to H. D. Kennedy (Kennedy, 1967), stated that bottom sampling could be used to demonstrate changes in abundance of aquatic invertebrates and to help determine food ratios. These are the purposes for which bottom samples were collected during the present study.

Stream bottom fauna were collected with a sampler similar to that developed by Waters and Knapp (1961). Bottom organisms were collected monthly from three square feet of riffle bottom area at each sampling station. Pools were not sampled because their claypan substrate prevented the efficient use of an Ekman dredge. The presence of heavy ice cover, snow bridges, and extremely high water prevented sampling at some stations from December, 1966 through March, 1967. Bottom samples were preserved in 10% formalin until they could be sorted in a light table similar to that used by Minckley (1963). The sugar flotation technique developed by Anderson (1959) was used to aid in separating organisms from detritus. The organisms were separated into taxonomic groups and counted. Volume determinations were made to the nearest 0.1 cubic centimeter by the water displacement method. Trichoptera, Ephemeroptera, and Diptera were the major orders of aquatic insects found in the study area. Seasonal trends for these orders were determined for Station I since this was the only station that was sampled each month during the study.

The number of forage fish at each sampling station was determined monthly by electrofishing commencing October, 1966. Counts of forage fish were made to determine if there was any relationship between the occurrence of forage fish in trout stomachs and abundance of forage fish. Sampling was accomplished by three or four men using a D. C. shocker with a potential of 100 volts with an amperage varying from 1.0 to 3.0 amps. Block nets were placed at the upstream and downstream boundaries of each station to prevent escape of fish during sampling. Electrofishing was started at the downstream block net to avoid collecting in previously disturbed waters. After capture the fish were placed in live cars and allowed to recover. They were then identified to species, placed in size classes, and counted. Some stations were not sampled from December, 1966 through March, 1967 due to heavy ice cover, snow bridges, and high water.

Several difficulties are associated with collecting forage fish by electrofishing. Larimore (1961) stated that the ability of the shocker to stun fish and the behavorial habits of the fish are the two main factors affecting efficiency of electrofishing. The electrofishing unit used was not effective on fish less than 5 cm long. Therefore, the size of the population was underestimated due to the inability to measure recruitment of small fish into the population. Behavorial habits of the Iowa darter, Johnny darter, and black bullhead made them difficult to collect.

RESULTS AND DISCUSSION

Survival

Survival of hatchery-raised trout in streams and lakes has been the subject of intensive investigation (Smith, 1940; Shetter, 1944; and Schuck, 1948). In most of these studies survival was based on returns to the angler with little attention paid to fish that did not enter the creel. It was felt that by closing the study area to fishing and by sampling with electrofishing equipment a more comprehensive picture of the survival of a brook trout plant could be obtained.

Relatively low over-winter survival of 6.7% or 196 trout was found for the initial plant while survival for the entire study period was 2.4%. Adelman and Bingham (1955) found over-winter survival values of 28% and 64% for hatchery brook trout in two areas where migration was stopped. Over-winter survival values ranging from 32.4% to 49.8% were observed for fall planted hatchery brook trout in five streams in Wisconsin (Mason, Brynildson, and Degurse, 1967). The overall survival was lower than the 3.1% found by Cooper (1953a) for hatchery brook trout in the Pigeon River, Michigan, but higher than the 0.7% recorded by Mason et al. (1967) in Wisconsin.

Fish collected for food habits analysis accounted for a known mortality of 5.1%. Stocking more trout than recommended and movement out of the study area could have contributed to the relatively low survival. The actual plant of 2950 trout was approximately twice the number of fish recommended by a stocking table derived by Embody (1928). The number of trout captured in the areas that could be sampled decreased throughout the winter indicating that either considerable mortality had occurred or that there had been extensive movement out of the study area. Dead trout were observed in only two instances. Newell (1957) and Cooper (1952) observed downstream movement of hatchery brook trout when they were planted in water temperatures less than 10°C. At the time of the initial plant, water temperatures ranged from 5 to 8°C. Trout were found downstream from the study area in several instances. The presence of unmarked trout in all the summer samples except September indicated that upstream movement was occurring throughout the summer. The number of initially planted trout recovered increased from May through July and then started to decrease (Table 3).

Table 3. Brook trout catches by electrofishing from May, 1967 through October, 1967 (Trout removed for analysis in parentheses).

Date	Total Catch	October 11, 1966 Plant			June 8, 1967 Plant	
		Marked		Unmarked		
May, 1967	74	--	(0)	74	--	
June	333	51	(6)	82	198	(11)
July	296	109	(7)	27	158	(28)
August	245	111	(8)	5	129	(6)
September	185	97	(5)	0	88	(14)
October	129	62	(8)	8	59	(10)

Only 21.0% of the 281 trout planted in June, 1967 were present in the October, 1967 sample. Fish collected for food habits determination accounted for 26.1% of the 222 trout that were lost. Mortality or movement out of the study area could account for the rest of the lost trout. Of the unknown loss 50.6% occurred within the three week period following stocking while the remainder occurred from July through October (Table 3). Needham and Slater (1945) found that the survival of summer planted hatchery rainbow trout ranged from 33 to 56% while Miller (1955) found summer survival of 45.5% for hatchery cutthroat trout. Miller (1955) found that most mortality occurs within two weeks after stocking.

The weighing and measuring of trout resulted in the release of relatively large numbers of trout into small areas. In several instances concentrations of trout were still present in these areas when the next sample was taken. The greatest numbers of trout were found within a mile of the spring source during the summer.

Brook trout were observed spawning in the upper 0.5 miles of the study area in October and November of 1967. Trout from both plants took part in the spawning. The redds were constructed primarily in riffle areas or at the base of riffle areas. Success of spawning could not be determined in the present study.

Growth and Condition

Growth and the periodicity of growth have been determined for brook trout in many bodies of water (Cooper, 1949; Bishop, 1955; and Rupp, 1955). In most of these studies growth was determined by back calculation of lengths by the scale method. The initial brook trout plant offered the opportunity to study growth of known age trout by direct observation and seasonal variations in condition of introduced brook trout. The supplemental plant allowed observations to be made of the fluctuations in growth and condition of a summer plant of trout.

The hatchery origin of the planted fish made it impractical to compare their average length with those of wild brook trout. Growth increments of the planted trout were compared with those of trout of the same age from different populations. Trout in the initial plant had an average growth increment of 9.8 cm from October, 1966 through October, 1967. Hatchery brook trout stocked in three Wisconsin streams showed growth increments ranging from 8.6 to 10.9 cm over a similar period (Mason et al., 1967). Growth increments ranging from 7.1 to 23.6 cm were recorded for fall planted brook trout in six ponds in New York (Zilliox and Pfeiffer, 1956).

Seasonal fluctuations in growth were observed for the initial plant of brook trout (Table 4). The average length increased only 3.8 cm from October, 1966 through May, 1967. In June, 1967, the average length of the trout increased 4.2 cm. The average length increased 1.8 cm during the rest of the summer. By October the average length was 23.8 cm. Average water temperature in the study area during June ranged from 13.3°C at Station A to 15.6°C at Station B. Fry (1951) pointed out that brook trout exhibit optimum growth within a water temperature range of 13 to 16°C. This pattern of relatively slow growth during the summer and winter with rapid growth in the spring is similar to that found by Cooper (1953b) for wild brook trout in three streams in Michigan.

Table 4. Average lengths, weights, and condition factors for brook trout planted October 11, 1966.

Date	No. of Fish	Average Length (cm)	Average Weight (gm)	Average Condition Factor
Oct. 11, 1966	100	14.0(9.5-17.5)*	29.5(14-53)	1.57(1.28-2.04)
November	54	14.9(12.0-17.0)	30.7(13-50)	1.48(1.07-1.76)
December	34	15.0(12.3-16.7)	29.7(16-45)	1.45(1.21-1.70)
Jan., 1967	12	15.5(13.7-16.7)	32.0(20-44)	1.30(1.24-1.55)
February	8	16.8(15.3-18.4)	40.4(31-55)	1.37(1.29-1.50)
March	10	16.4(15.3-18.4)	39.7(32-59)	1.46(1.34-1.56)
April	8	17.5(16.0-19.4)	48.0(38-68)	1.46(1.36-1.58)
May	74	17.8(12.7-21.6)	61.5(20-106)	1.72(1.43-2.17)
June	133	22.0(16.2-25.4)	117.3(44-193)	1.75(1.22-2.17)
July	134	22.3(17.2-26.7)	122.4(50-208)	1.73(1.38-2.25)
August	116	23.1(17.8-27.3)	129.3(56-228)	1.68(1.34-2.32)
September	97	23.3(18.1-28.6)	143.3(64-248)	1.70(1.34-2.25)
October	70	23.8(18.4-29.2)	144.6(58-281)	1.69(1.20-2.18)

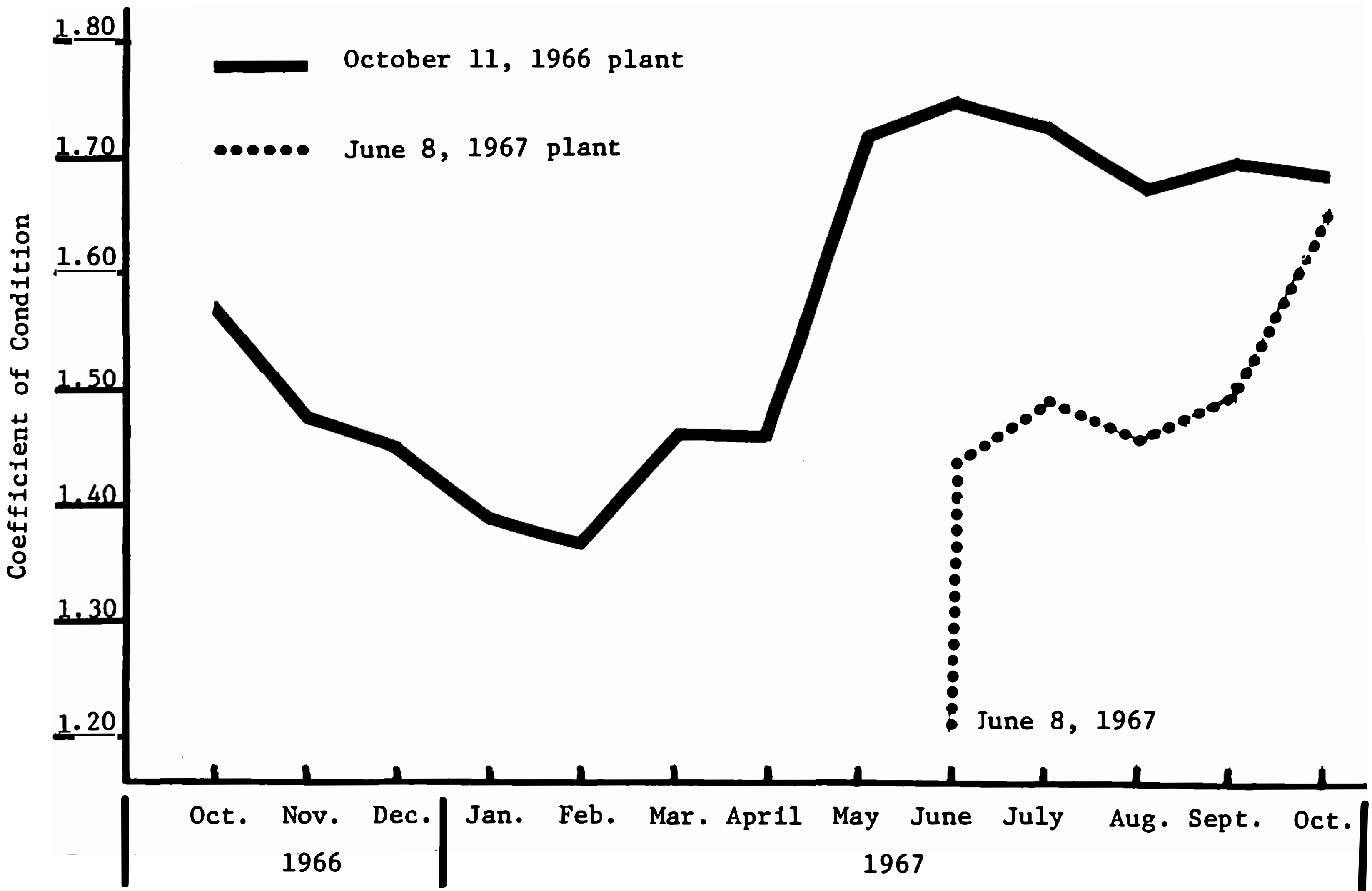
* Range in parentheses

The average condition of brook trout in the initial plant declined through the winter from 1.57 at the time of stocking to 1.37 in February (Fig. 3). Their condition started to improve in March and reached a peak in June when an average condition factor of 1.75 was determined. A slight decline in condition occurred during the summer and early fall. Seasonal fluctuations in condition were similar to those found by Cooper (1953b) in Michigan.

An increase in size and condition was observed for the brook trout planted June 8, 1967 (Table 5). Growth increment between sampling periods was relatively constant. The largest increment (1.2 cm) occurred in June and the smallest (0.6 cm) in July and October. Condition of the trout was poor at the time of planting but improved markedly during the summer and early fall (Fig. 3). The fact that some of the trout were considered to be stunted when they were planted may have had an affect on the growth and improvement in condition that occurred. Stunted brook trout have been observed to resume growth when put in a more favorable environment (Greene, 1955).

A comparison of the growth increment of the two trout plants from June through October shows that the average length of fish in the second plant increased 1.0 cm more than that of fish from the initial plant. During this same period the average condition factor of the second plant increased while that of the initial

Figure 3. Seasonal variation in condition of brook trout.



plant decreased. The greater growth and increase in condition of the second plant may be attributed to the stunted nature of the fish when they were planted. However, the fact that they were able to show improvement indicates that the initial plant was not utilizing all of the available habitat.

Table 5. Average lengths, weights, and condition factors for brook trout planted June 8, 1967.

Date	No. of Fish	Average Length (cm)	Average Weight (gm)	Average Condition Factor
June 8, 1967	100	19.2(16.2-26.0)*	53.0(27-121)	1.21(.98-1.44)
June	197	20.4(15.2-24.4)	75.9(30-151)	1.44(1.05-1.94)
July	156	21.0(14.6-25.4)	86.7(26-160)	1.49(.98-2.19)
August	127	21.9(17.8-26.4)	96.1(48-194)	1.46(1.14-2.11)
September	88	22.6(16.2-27.6)	108.7(35-239)	1.50(1.12-1.94)
October	59	23.2(17.1-27.6)	131.6(44-286)	1.66(1.29-2.22)

* Range in parentheses

Food Habits

Extreme variability in brook trout food habits has been demonstrated by Clemens (1928), Needham (1930), Ricker (1930), and Benson (1954). It is necessary, therefore, to determine the food habits of each individual trout population. The present study was undertaken to determine what organisms the trout used as food and what seasonal variations occurred in the trout diet. Food habits determinations were also made to help study the effect of brook trout predation on a large forage fish population.

Food habits were determined for 206 brook trout collected from November, 1966 to October, 1967. Food habits of trout from the two plants are not discussed separately since little difference existed between them. Frequency of occurrence, abundance (number), and volume for each food item are presented in Table 6. Stomachs contained 1398 organisms with a total volume of 196.3 cc. Aquatic organisms comprised 86.7% of the total number of organisms and 93.9% of the total volume of organisms with terrestrial organisms comprising the remainder. Needham (1938) showed that brook trout are dependent upon water-bred organisms for most of their food.

Insects have been found to be the major item in the brook trout's diet (Clemens, 1928; Benson, 1954). Insects, both aquatic and terrestrial, comprised 85.2% of the number of organisms found in the brook trout stomachs in the present study. The remainder of the trout diet was composed of various vertebrates and invertebrates with forage fish, snails, and millipedes the main contributors.

Trichoptera larvae, represented by *Agrypnia vestita*, *Hydropsyche slossonae*, and *Hesperophylax* sp., comprised the most abundant group of aquatic organisms in the trout diet. *Hesperocorixa* sp. ranked second and Diptera larvae represented by Chironomidae and *Tipula* sp. ranked third in abundance of aquatic organisms found in trout stomachs. Forage fish comprised the largest volume

Table 6. Stomach contents of 206 brook trout collected from November, 1966 through October, 1967.

Food Item	Frequency of Occurrence No.	Frequency of Occurrence %	Number of Organisms No.	Number of Organisms %	Volume of Organisms cc.	Volume of Organisms %
Aquatic Organisms						
Agrypnia vestita	101	49.0	350	25.0	18.0	9.1
Forage fish	69	33.5	97	6.9	125.1	63.7
Hydropsyche slossonae	67	32.5	133	9.5	1.5	.8
Hesperocorixa sp.	64	31.1	214	15.3	5.2	2.6
Chironomidae	28	13.6	142	10.2	.3	.2
Hesperophylax sp.	27	13.1	82	5.9	1.4	.7
Tipula sp.	21	10.2	32	2.3	4.4	2.2
Nemoura sp.	19	9.2	33	2.4	.5	.2
Physa sp.	17	8.2	50	3.6	1.6	.8
Centroptilum sp.	15	7.3	30	2.1	.1	.1
Hyalella azteca	6	2.9	7	.5	T	
Hirudinea	6	2.9	7	.5	.9	.4
Dytiscidae	5	2.4	15	1.1	.1	.1
Elmidae	5	2.4	6	.4	T	
Anax junius	5	2.4	5	.4	1.2	.6
Gerridae	3	1.4	6	.4	.2	.1
Rana sp.	1	.5	1	.1	24.0	12.2
Crayfish	1	.5	1	.1	.1	.1
Terrestrial Organisms						
Formicidae	16	7.8	37	2.6	.3	.2
Coccinellidae	11	5.3	30	2.1	.2	.1
Scarabaeidae	9	4.4	17	1.2	1.2	.6
Diplopoda	9	4.4	37	2.6	4.0	2.0
Diptera	9	4.4	17	1.2	.4	.2
Membracidae	8	3.9	18	1.3	.4	.2
Cerambycidae	6	2.9	7	.5	.3	.2
Acrididae	4	1.9	5	.4	.5	.2
Earthworm	2	1.0	6	.4	3.6	1.8
Chrysomelidae	2	1.0	2	.1	.1	.1
Cicadellidae	2	1.0	3	.2	T	
Carabidae	2	1.0	2	.1	.1	.1
Lepidoptera	2	1.0	3	.2	.6	.3
Gryllidae	1	.5	1	.1	T	
Elateridae	1	.5	1	.1	T	
Phalangida	1	.5	1	.1	T	
Total			1398	99.9	196.3	99.7

T trace

of the aquatic organisms in the trout diet with Rana sp. and Trichoptera larvae ranking second and third. Forage fish were treated as a group since in most cases the fish could not be identified to species following partial digestion.

Coleoptera represented by Coccinellidae, Scarabaeidae, Cerambycidae, Chrysomelidae, Carabidae, and Elateridae were the most abundant terrestrial organisms found in the trout stomachs. Formicidae and Diplopoda ranked second in abundance. Diplopoda and earthworms with total volumes of 4.0 cc and 3.6 cc made up the highest volumes of terrestrial organisms in the stomach contents.

Food organisms found in the trout stomachs varied considerably from one sampling date to the next (Tables 7 to 9). Agrypnia vestita was the most abundant organism found in the stomachs from November, 1966 to March, 1967. It also comprised the greatest volume during this period except in November when forage fish comprised the greatest volume. Forage fish, H. slossonae, Hesperocorixa sp., Hesperophylax sp., Tipula sp., and Nemoura sp. were the other principal organisms in the trout stomachs from November to March. Forage fish and A. vestita were the two most abundant organisms in the stomach contents in April, 1967 while earthworms and forage fish comprised most of the total volume. Relatively large numbers of terrestrial organisms occurred in the trout stomachs from June through September of 1967 but only in the

Table 7. Frequency of occurrence of major food organisms collected from brook trout stomachs each month (Number of stomachs analyzed in parentheses).

Food Item	Nov. 1966 (54)	Dec. (34)	Jan. 1967 (12)	Feb. (8)	Mar. (10)	April (5)	May (0)	June (8)	July (26)	Aug. (13)	Sept. (19)	Oct. (17)
Aquatic Organisms												
Agrypnia vestita	37	24	11	6	9	4					5	5
Forage fish	16	6	4	2	1	1		4	12	3	11	9
Hydropsyche slossonae	22	21	4	2	1	1		1	2	7	3	3
Hesperocorixa sp.	22	13	4	2	1	1			8	7		6
Chironomidae	6	16							3	1	1	
Hesperophylax sp.	17	4		2	1	1						2
Tipula sp.	5	10		2	3							1
Nemoura sp.	4	11	1	2	1							
Physa sp.	3	2		2					6	2	2	
Centroptilum sp.	2	4			3			1	1			4
Terrestrial Organisms												
Formicidae									7	5	3	1
Coccinellidae									4	1	6	
Scarabaeidae								3	3		3	
Diplopoda						1					8	
Diptera									7	2		
Membracidae								1	2	2	3	

Table 8. Total numbers of major food organisms collected from brook trout stomachs each month (Number of stomachs analyzed in parentheses).

Food Item	Nov. 1966 (54)	Dec. (34)	Jan. 1967 (12)	Feb. (8)	Mar. (10)	April (5)	May (0)	June (8)	July (26)	Aug. (13)	Sept. (19)	Oct. (17)
Aquatic Organisms												
Agrypnia vestita	127	95	37	12	46	8					6	19
Forage fish	19	6	4	2	2	12		7	16	3	13	13
Hydropsyche slossonae	41	36	4	6	4	1		2	2	22	4	11
Hesperocorixa sp.	54	27	9	3	2	1			19	16		83
Chironomidae	7	113				1			4	15	2	
Hesperophylax sp.	57	7		2	1	1						14
Tipula sp.	6	18		2	5							1
Nemoura sp.	4	22	2	3	2							
Physa sp.	3	8		6					21	7	5	
Centroptilum sp.	2	4			3			2	1			18
Terrestrial Organisms												
Formicidae									14	13	9	1
Coccinellidae									6	1	23	
Scarabaeidae								4	4		9	
Diplopoda						1					36	
Diptera									11	6		
Membracidae								1	5	2	10	

Table 9. Total volumes of major food organisms collected from brook trout stomachs each month (Number of stomachs analyzed in parentheses).

Food Item	Nov. 1966 (54)	Dec. (34)	Jan. 1967 (12)	Feb. (8)	Mar. (10)	April (5)	May (0)	June (8)	July (26)	Aug. (13)	Sept. (19)	Oct. (17)
Aquatic Organisms												
Agrypnia vestita	5.4	4.0	1.7	1.3	3.4	1.1					T	1.1
Forage fish	7.8	1.1	1.1	.1	.5	2.5		13.7	9.8	7.5	44.5	36.5
Hydropsyche slossonae	.7	.4	T	.1	.1	T		T	T	.2	T	T
Hesperocorixa sp.	.9	.7	.7	.1	.1	T			.1	.1		2.5
Chironomidae	T	.2				T			T	.1	T	
Hesperophylax sp.	1.0	.1		T	T	T						.3
Tipula sp.	.5	1.3		1.0	1.6							T
Nemoura sp.	T	.4	T	T	.1							
Physa sp.	T	.1		.3					.9	.2	.1	
Centroptilum sp.	T	T			T			T	T			.1
Terrestrial Organisms												
Formicidae									.1	.2	T	T
Coccinellidae									.1	T	.1	
Scarabaeidae								.6	.1		.5	
Diplopoda						T					4.0	
Diptera									.1	.3		
Membracidae								.1	.1	T	.2	

T trace

September sample were they more numerous than aquatic organisms. Aquatic organisms comprised most of the volume of the stomach contents at all sampling dates. Stomachs of the brook trout contained a wide variety of organisms during the summer with no one organism being dominant. Forage fish comprised the greatest volume from June through October of 1967. Hesperocorixa sp. was the most abundant organism in the trout stomachs collected in October, 1967.

Hess and Swartz (1941) used the term "forage ratio" to describe the relationship between the percentage a given organism comprises of the stomach contents and the percentage it comprises of the total population of food organisms in the fish's environment. A forage ratio of one indicates that the food item comprises the same percentage of the stomach contents as it does the total food organisms. If it is significantly different than one it can be the result of a difference in availability or a difference in preference. Before forage ratios could be determined it was necessary to determine the population of food organisms and what variations occurred in it.

It was determined, based on 201 bottom samples collected during the 16 month study period, that seasonal variations occurred in the aquatic invertebrate population. The greatest numbers of organisms ($249/ft^2$ to $532/ft^2$) were found from May through August (Table 10).

Trichoptera, Ephemeroptera, and Diptera were the major orders contributing to the summer peaks. The greatest number of organisms ($346/ft^2$) recorded in 1966 occurred in August. In 1967, the greatest number (532 organisms/ft^2) occurred in July. An exception to the summer high levels occurred in June, 1967 when 118 organisms/ft^2 was recorded. This could be attributed to the emergence of the three major orders of aquatic insects present in the study area. Kraft (1964), working on Berry Creek in Oregon, found that the peak emergence of aquatic insects occurred in May and June.

Table 10. Mean number and volume of bottom organisms collected from all sampling stations from July, 1966 to October, 1967.

Month	No. Samples	Total No. Organisms	Total Volume in cc.	Mean No. per Sq. Ft.	Mean Vol. per Sq. Ft.
July, 1966	15	3728	8.1	249	.54
August	15	5195	10.7	346	.71
September	15	3488	13.9	233	.93
October	15	2940	20.0	196	1.33
November	15	1860	17.5	124	1.17
December	9	2869	24.7	319	2.74
January, 1967	3	246	3.3	82	1.10
February	6	619	4.9	103	.82
March	3	256	1.9	85	.63
April	15	1401	11.0	93	.73
May	15	3926	26.6	262	1.77
June	15	1764	11.8	118	.79
July	15	7983	14.9	532	.99
August	15	6317	16.8	421	1.12
September	15	3808	15.9	254	1.06
October	15	2957	17.3	197	1.15

The number of organisms decreased from a September value of 233 organisms/ft^2 to a low in January of 82 organisms/ft^2. The disappearance of Ephemeroptera and the decrease in abundance of Trichoptera and Diptera caused this decline. A break in the decline occurred in December when a build up of Trichoptera and Diptera resulted in an increase to 319 organisms/ft^2. The increase from the low winter numbers to the May count of 262 organisms/ft^2 was an abrupt change brought about by a substantial increase in the number of Ephemeroptera.

In many streams in the United States the peak numbers of aquatic invertebrates occur in the spring and fall while the lowest numbers are present during the summer (Stehr and Branson, 1938; Heaton, 1966; Kennedy, 1967). Maximum numbers of aquatic invertebrates in the study area occurred during the summer and the minimum numbers during the winter. Surber (1937) and Minckley (1963) found that water discharge was the most important factor controlling fluctuations in aquatic invertebrate populations. This could account for the seasonal fluctuations in aquatic invertebrates in the South Fork Yellow Bank River since relatively high discharges in the spring cause considerable movement of the substrate materials.

Peak volumes of aquatic invertebrates occurred in the fall (1.06 cc/ft^2 to 2.74 cc/ft^2) and in May, 1967 (1.77 cc/ft^2) (Table 10). Fall peaks were primarily due to an increase in the volume of individual Trichoptera and Diptera while the May peak was the result of large numbers of these two orders and Ephemeroptera. Low volumes during the winter coincided with a decrease in abundance. Although aquatic invertebrates were present in high numbers in the summer, the small sizes of individual organisms caused the average volumes to be low. The seasonal fluctuations in volumes were similar to those found by Surber (1937), Needham (1938), and Allen (1951) for streams in Virginia, California, and New Zealand.

The numbers and volumes of organisms comprising the aquatic invertebrate population varied throughout the study (Tables 11 and 12). Trichoptera were predominant during most of the study but in February, March, and October of 1967 Diptera made up the largest percentage of the population. Ephemeroptera were predominant in May and June of 1967. Trichoptera, Ephemeroptera, and Diptera comprised 98.3% of the total number and 97.8% of the total volume of aquatic invertebrates collected. Coleoptera, Plecoptera, and a miscellaneous group containing *Physa* sp., *Hyalella azteca*, *Anax junius*, and Hirudinea comprised the remainder of the invertebrates. The occurrence of members of the miscellaneous group was quite irregular and measurable volumes were due to the presence of Hirudinea and *Anax junius*.

Trichoptera, represented only by *Hydropsyche slossonae* and *Hesperophylax* sp., was the most abundant order and comprised the

Table 11. Numbers of each major group of aquatic invertebrates collected monthly from July, 1966 to October, 1967 (Number of samples in parentheses).

Date		Trichoptera		Ephemeroptera		Diptera		Coleoptera		Plecoptera		Miscellaneous*	
		No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
July, 1966	(15)	2034	54.6	933	25.0	681	18.3	48	1.3			32	.9
Aug.	(15)	2845	54.8	1384	26.6	934	18.0	26	.5			6	.1
Sept.	(15)	2308	66.2	659	18.9	459	13.2	47	1.3			15	.4
Oct.	(15)	2233	76.0	123	4.2	508	17.3	60	2.0			16	.5
Nov.	(15)	1258	67.6	5	.3	556	29.9	6	.3	20	1.1	15	.8
Dec.	(9)	2210	77.0			619	21.6	15	.5	21	.7	4	.1
Jan., 1967	(3)	152	61.8	1	.4	75	30.4					18	7.3
Feb.	(6)	289	46.7			326	52.7			1	.2	3	.5
Mar.	(3)	104	40.6	1	.4	146	57.0					5	1.9
April	(15)	702	50.1	1	.1	681	48.6	4	.3	2	.1	11	.8
May	(15)	859	21.9	1979	50.4	1077	27.4					11	.3
June	(15)	348	19.7	694	39.3	671	38.0	32	1.8	3	.2	16	.9
July	(15)	3649	45.7	2750	34.4	1489	18.7	74	.9			21	.3
Aug.	(15)	3550	56.2	1636	25.9	1056	16.7	69	1.1			6	.1
Sept.	(15)	1965	51.6	868	22.8	816	21.4	148	3.9	1		10	.3
Oct.	(15)	2065	69.8	147	5.0	661	22.4	52	1.8	27	.9	5	.2

* Miscellaneous includes _Physa_ sp., _Hyalella azteca_, _Anax junius_, and Hirudinea.

Table 12. Volumes of each major group of aquatic invertebrates collected monthly from July, 1966 to October, 1967 (Number of samples in parentheses).

Date		Trichoptera		Ephemeroptera		Diptera		Coleoptera		Plecoptera		Miscellaneous*	
		cc.	%	cc.	%	cc.	%	cc.	%	cc.	%	cc.	%
July, 1966	(15)	3.4	42.0	.9	11.1	3.5	43.2	.2	2.5			.1	1.2
Aug.	(15)	6.0	56.1	2.0	18.7	2.7	25.2	T				T	
Sept.	(15)	10.7	77.0	1.3	9.4	1.6	11.5	.1	.7			.2	1.4
Oct.	(15)	14.7	73.5	.4	2.0	4.7	23.5	T				.2	1.0
Nov.	(15)	10.9	62.3	T		6.4	36.6	T		.1	.6	.1	.6
Dec.	(9)	21.3	86.2			3.2	13.0	T		.2	.8	T	
Jan., 1967	(3)	2.0	60.6	T		1.0	30.3					.3	9.0
Feb.	(6)	3.5	71.4			1.2	24.5			T		.2	4.1
Mar.	(3)	1.5	78.9	T		.4	21.0					T	
April	(15)	10.0	90.9	T		.7	6.4	T		T		.3	2.7
May	(15)	17.8	66.9	3.0	11.3	5.0	18.8					.8	3.0
June	(15)	7.7	65.2	1.8	15.3	1.8	15.3	T		.1	.8	.4	3.4
July	(15)	9.3	62.4	3.7	24.8	1.8	12.1	T				.1	.7
Aug.	(15)	10.8	64.3	2.8	16.7	3.0	17.9	T				.2	1.2
Sept.	(15)	8.8	55.3	2.1	13.2	4.3	27.0	.3	1.9	T		.4	2.5
Oct.	(15)	12.8	74.0	.5	2.9	3.7	21.4	.1	.6	T		.2	1.2

T trace

* Miscellaneous includes *Physa* sp., *Hyalella azteca*, *Anax junius*, and Hirudinea.

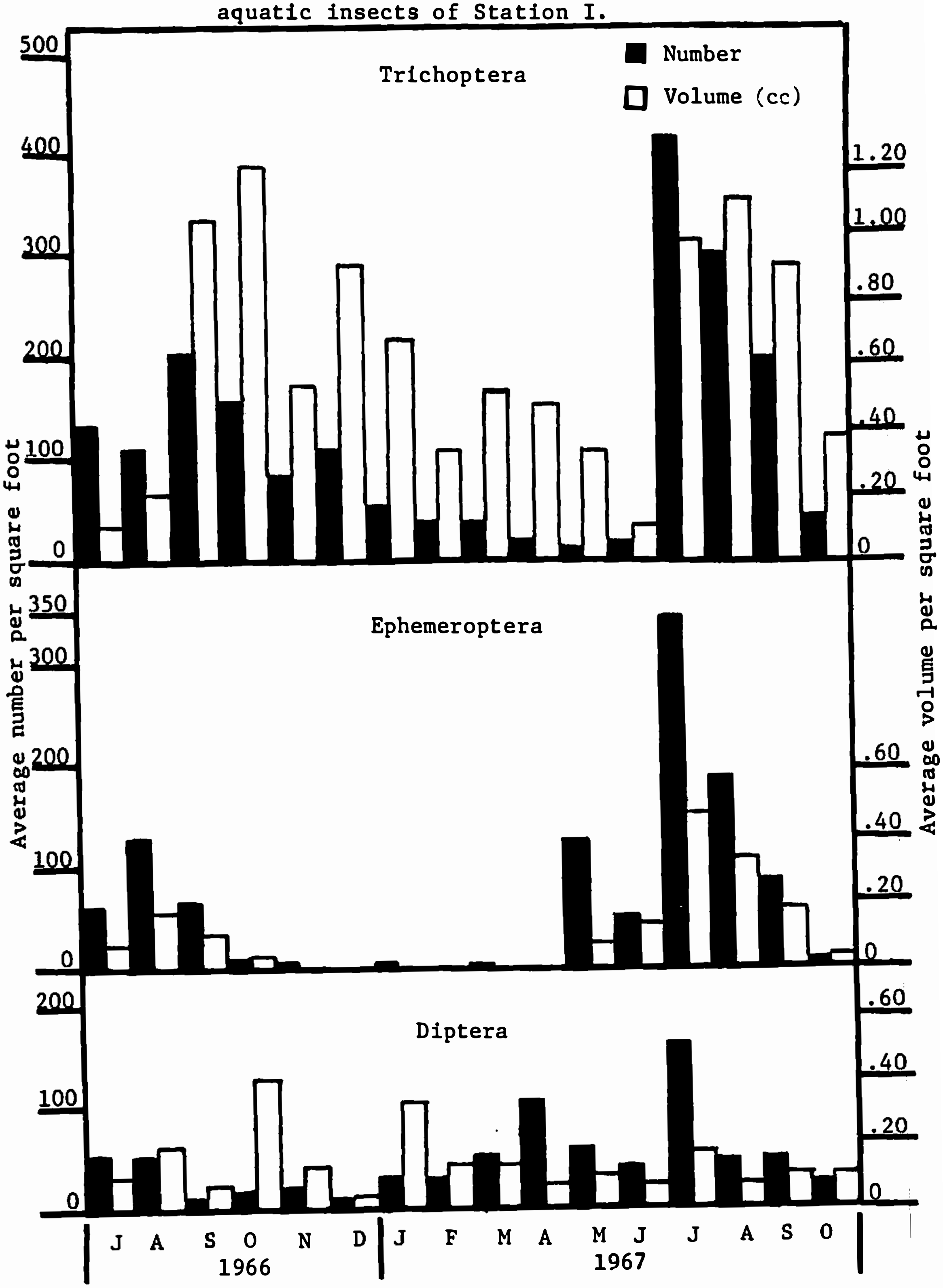
greatest volume of the aquatic invertebrates. Peaks in abundance of Trichoptera at Station I contained 200 larvae/ft^2 in September, 1966 and 412 larvae/ft^2 in July, 1967 (Fig. 4). The peak volumes for Trichoptera at Station I were 1.20 cc/ft^2 in October, 1966 and 1.10 cc/ft^2 in August, 1967 (Fig. 4). The number of Trichoptera declined after September, 1966 until a low of 10/ft^2 was recorded in May, 1967.

Ephemeroptera nymphs, represented by three species (Table 2), were the second most abundant aquatic invertebrate group but ranked third in total volume. Seasonal trends for Ephemeroptera at Station I were quite definite. Maximum numbers of Ephemeroptera occurred in August, 1966 (118 nymphs/ft^2) and in July, 1967 (320 nymphs/ft^2) (Fig. 4). No Ephemeroptera nymphs were found in December, 1966 and February, 1967 while only one nymph was found per month in all the samples in January, March, and April of 1967.

Diptera, represented by eight species (Table 2), ranked third in abundance and second in volume of aquatic invertebrates. The greatest numbers of Diptera larvae recorded at Station I were 100/ft^2 in April, 1967 and 154/ft^2 in July, 1967 (Fig. 4). The presence of a large Tipula sp. prevented detection of any seasonal trends in the volume of Diptera.

The numbers and volumes of the Coleoptera, Plecoptera, and miscellaneous organisms were quite small. The greatest numbers of

Figure 4. Number and volume of the dominant orders of aquatic insects of Station I.



Coleoptera occurred during the summer. Nemoura sp. was found in November and December of 1966 and in February and October of 1967. Peltoperla sp. was found in April and June of 1967.

The percentage composition by number and volume of aquatic invertebrates at the five sampling stations was quite similar (Tables 13 and 14). Exceptions to this occurred at Stations IV and V where relatively high numbers and volumes of Diptera caused a decrease in the percentage of Trichoptera. The increased percentage of Diptera appeared to be due to the composition of the riffle substrate. The mixed gravel and rubble substrate was apparently more suitable for Diptera than Trichoptera. The highest average number of organisms ($347/ft^2$) for the entire study occurred at Station III. Highest average volume of organisms ($1.70\ cc/ft^2$) for the entire study occurred at Stations II and III. The relatively low numbers and volumes for Stations I, IV, and V may have been due to extensive disturbance of the riffle substrate by cattle.

The average number of organisms was $250/ft^2$ and the average volume was $1.10\ cc/ft^2$. The greatest number of organisms in any sample was 893 at Station I in July, 1967. Trichoptera and Ephemeroptera comprised most of this sample. The smallest sample obtained was 23 organisms collected at Station V in November, 1966. The greatest volume of organisms in a sample was 4.2 cc collected at Station II in December, 1966. The sample was largely Trichoptera. The smallest volume in a sample was 0.1 cc collected in June, 1967 at Station IV.

Table 13. Total numbers of aquatic invertebrates collected at each sampling station (Number of samples in parentheses).

Group	Station I(48) Number	%	Station II(42) Number	%	Station III(39) Number	%	Station IV(36) Number	%	Station V(36) Number	%
Trichoptera	5570	51.5	8712	63.6	7790	57.5	2024	36.2	2475	43.4
Ephemeroptera	2940	27.2	2326	17.0	2993	22.1	1426	25.5	1496	26.2
Diptera	2160	20.0	2539	18.5	2431	17.9	1992	35.6	1633	28.6
Plecoptera	2		11	.1	44	.3	6	.1	12	.2
Coleoptera	14	.1	81	.6	267	2.0	136	2.4	83	1.5
Miscellaneous*	129	1.1	22	.1	24	.1	12	.2	7	.1
Total	10815	99.9	13691	99.9	13549	99.9	5596	100.0	5706	100.0

* Miscellaneous includes *Physa* sp., *Hyalella azteca*, *Anax junius*, and Hirudinea.

Table 14. Total volumes of aquatic invertebrates collected at each sampling station (Number of samples in parentheses).

Group	Station I(48) cc.	%	Station II(42) cc.	%	Station III(39) cc.	%	Station IV(36) cc.	%	Station V(36) cc.	%
Trichoptera	28.8	68.7	56.9	82.5	46.0	70.0	9.2	42.4	10.3	49.0
Ephemeroptera	4.7	11.2	4.7	6.8	5.1	7.8	1.7	7.8	2.3	11.0
Diptera	6.6	15.8	6.8	9.8	13.1	19.9	10.5	48.4	8.0	38.1
Plecoptera	T		T		.3	.5	T		.1	.5
Coleoptera	.1	.2	.1	.1	.4	.6	T		.1	.5
Miscellaneous*	1.7	4.0	.5	.7	.8	1.2	.3	1.4	.2	1.0
Total	41.9	99.9	69.0	99.9	65.7	100.0	21.7	100.0	21.0	100.1

T trace * Miscellaneous includes *Anax junius* and Hirudinea.

The average standing crop of aquatic invertebrates in riffles was high compared to other streams in the United States (Table 15). The average standing crop volumes during August and September of 1966 and 1967 were slightly smaller than those recorded by Waters (1961) for two streams in southern Minnesota.

Table 15. Riffle benthos standing crops for some streams in the United States.

Stream	Location	Number/m^2	Volume/m^2	Reference
S. Fork Yellow Bank River	So. Dakota	2,722	11.98 cc	Kallemeyn
Madison River	Montana	1,075	6.44 cc	Heaton (1966)
St. Vrain Creek	Colorado	610	2.50 cc	Pennak and Van Gerpen (1947)
Convict Creek	California	2,991	13.50 cc	Kennedy (1967)
Shope and Ball Creeks	No. Carolina	531	4.90 cc	Tebo and Hassler (1961)
Black River	Missouri	893	38.11 cc	O'Connell and Campbell (1953)

Since the benthos organisms were only sorted to order it was necessary to combine some food items before forage ratios could be determined. *H. slossonae* and *Hesperophylax* sp. were combined to determine the forage ratio for Trichoptera. The forage ratio for Diptera larvae was determined from the combination of Chironomidae and *Tipula* sp. *Centroptilum* sp. was used in determining the forage ratio for Ephemeroptera while Nemoura sp. was used for Plecoptera. The Coleoptera forage ratio was based entirely on the presence of Elmidae adults in the trout stomachs.

The forage ratios of the different orders varied considerably throughout the study (Table 16). The low forage ratios obtained for Trichoptera and Diptera indicate that either these organisms were not equally available to the sampler and the trout or that they were not a preferred food item. High forage ratios found in some months for Ephemeroptera, Coleoptera, and Plecoptera suggests that the trout preferred these organisms. Allen and Claussen (1960) found that Ephemeroptera and Coleoptera were the major items in the diet of brook trout in a Wyoming beaver pond.

Table 16. Forage ratios for consumption of five dominant insect orders by brook trout in the South Fork Yellow Bank River.

Date	Trichoptera	Ephemeroptera	Plecoptera	Coleoptera	Diptera
Nov., 1966	.43	2.00	1.09	4.00	.13
December	.16	*	9.14	.60	1.76
Jan., 1967	.11	X	*	--	X
February	.44	--	38.50	--	.09
March	.19	11.25	*	--	.13
April	.12	X	X	X	.06
May	--	--	--	--	--
June	.51	.25	--	X	X
July	.04	.02	--	.89	.17
August	.43	X	--	X	.99
September	.06	X	--	X	.07
October	.37	1.18	X	X	.01

* organisms present in stomach contents of brook trout but not in benthos samples.

X organisms present in benthos samples but not in stomach contents of brook trout.

Forage ratios could not be determined for A. vestita and Hesperocorixa sp. since they did not occur in the bottom samples. Hesperocorixa sp. absence from bottom samples could be attributed to the fact that it is a free-swimming insect. A. vestita was not collected due to it being found only in pools. Hesperocorixa sp. was found in the trout stomachs in all months except June and September of 1967. A. vestita, although being the most abundant organism in the trout diet for the entire study, did not occur in the stomach contents during June, July, and August of 1967. Its absence from the trout diet during the summer could be due to emergence of the insect or that in the presence of a larger variety of food items the brook trout stopped preying on it. Ross (1944), working in Illinois, found the peak emergence period for A. vestita to be May and June.

Forage fish have generally been found to play a minor role as food for brook trout that are less than 12 inches long (Needham, 1930; Clemens, 1928; and Doan, 1948). However, it was thought that the introduced brook trout might utilize the abundant forage fish as food. The relative frequency of occurrence of forage species is given in Table 17. Frequencies were determined from the total number of fish collected at all stations during the study. Relative frequencies were similar to those found by Felix (1967) (Table 17).

Table 17. Relative frequency of occurrence of fishes in study area.

Species	Frequency 1967 (in %)	Frequency+ 1966 (in %)
Blacknose dace, *Rhinichthys atratulus*	45.1	30.49
Stoneroller, *Campostoma anomalum*	19.3	22.62
Fathead minnow, *Pimephales promelas*	13.0	19.80
Creek chub, *Semotilus atromaculatus*	9.9	8.78
Common shiner, *Notropis cornutus*	5.5	8.65
White sucker, *Catostomus commersoni*	2.6	3.27
Iowa darter, *Etheostoma exile*	1.7	
Miscellaneous*	2.9	5.88#

+ Felix (1967)
* includes *Notropis atherinoides, Notropis stramineus, Etheostoma nigrum, Eucalia inconstans, Ictalurus melas, Hybopsis biguttata,* and *Hybognathus hankinsoni.*
# includes *Etheostoma exile* along with others listed as miscellaneous.

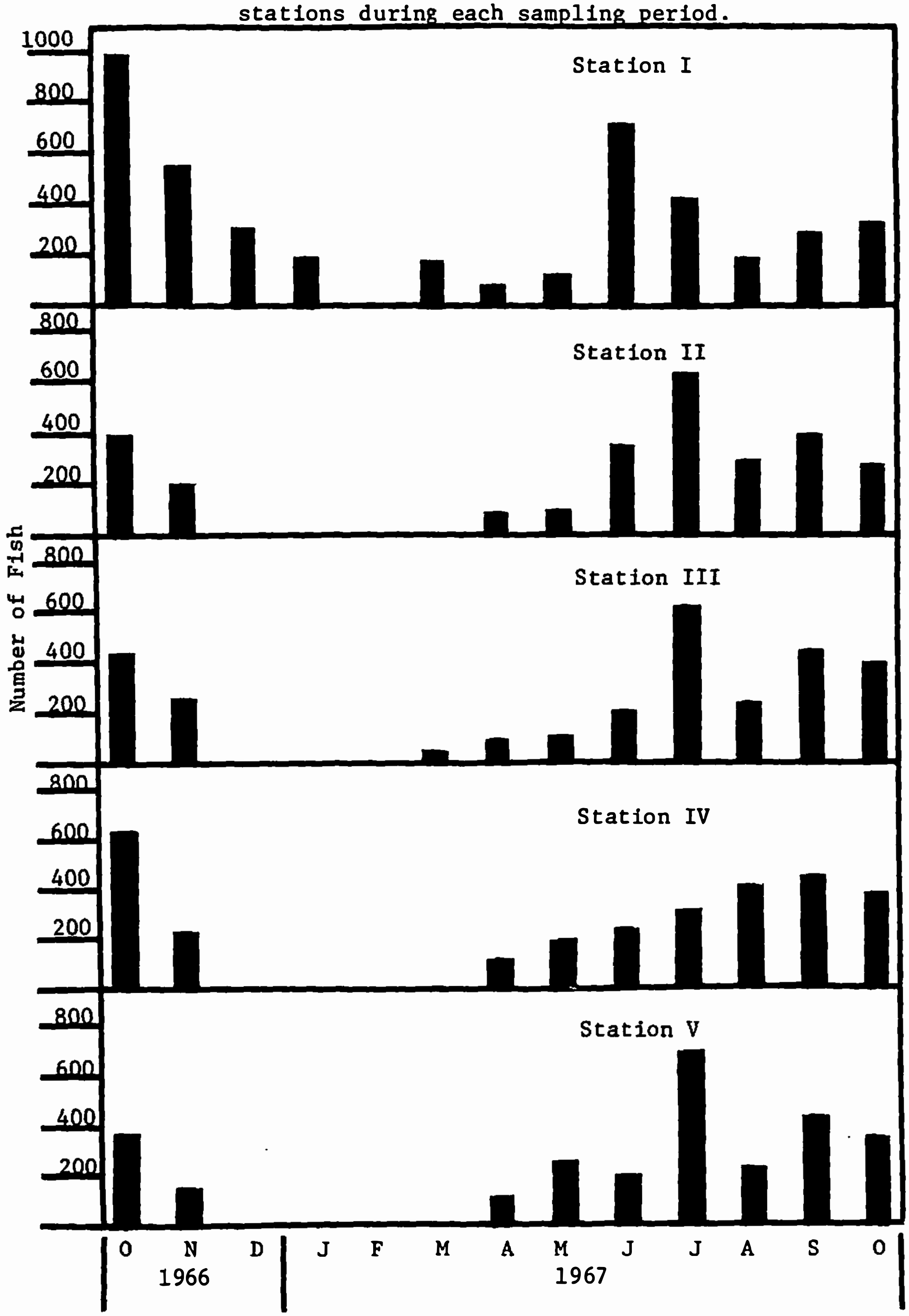
Larimore (1955) described an annual cycle of abundance for minnows in streams. This is characterized by the occurrence of low numbers in the spring, an increase during the summer as recruitment of young fish occurs, and a decrease during the fall and winter. Fluctuations in the forage fish population in the study area were similar to the abundance pattern described by Larimore (1955). Felix (1967) stated that the summer peak in the South Fork Yellow Bank River was due to upstream migration of some species during spring and summer and recruitment. Electrofishing at several locations downstream from the study area in April and May of 1967 indicated an upstream migration was taking place.

Similar seasonal trends in abundance of forage fish were recorded at all five sampling stations (Fig. 5). Two peaks in abundance of forage fish occurred at Station I. The first consisted of 991 fish in October, 1966 and was primarily due to a high concentration of blacknose dace. The second peak (710 fish) occurred in June, 1967 and was comprised primarily of fathead minnows, blacknose dace, stonerollers, and common shiners. The small number of fish recorded from November, 1966 to April, 1967 coincided with a decrease in the number of species. The relatively low number of fish (174) found in August, 1967 was due to a decrease in abundance of most species.

Peaks in abundance of forage fish occurred at Stations II, III, and V in October, 1966 and July, 1967. Blacknose dace and stonerollers were the main species contributing to the October peaks of 380 fish at Station II, 423 fish at Station III, and 370 fish at Station V. July peaks, comprised mainly of blacknose dace, fathead minnows, and stonerollers, consisted of 629 fish at Station II, 603 fish at Station III, and 751 fish at Station V. A decrease in abundance of most species of forage fish occurred in August, 1967 at the three stations.

Station IV was similar to the other stations in that the largest sample (621 forage fish) in 1966 occurred in October and was primarily

Figure 5. Total number of forage fish found at sampling stations during each sampling period.



composed of blacknose dace, creek chubs, and stonerollers. In 1967, the largest sample of fish (423) was collected in September. The installation of a stream improvement device two days prior to sampling in July may have caused extensive movement of fish out of the station. Without this movement the seasonal abundance of forage fish at Station IV might have been similar to those of the other stations.

The abundance of each forage fish species varied between stations and from one sampling period to the next but seasonal trends existed for some species (Tables 18 to 22). Blacknose dace occurred in relatively high numbers in October, 1966, July, 1967, and September, 1967. The October and September peaks were composed primarily of fish that had recently reached collectable size. Low numbers during the winter were attributed to downstream movement. Noble (1965), working on two streams in Iowa, found that blacknose dace moved downstream into deeper water during the winter.

Peaks in stoneroller abundance occurred in October, 1966 and June and July of 1967 while the lowest numbers occurred in the winter. Stonerollers have been found to migrate into moderate to high grade streams to spawn and then they move downstream to spend the winter (Trautman, 1957).

Fathead minnows were most abundant in June and July of 1967. This was attributed to fish from the previous year's reproduction

Table 18. Total numbers of forage fish collected at Station I.

Sampling Date	Blacknose dace	Stone-roller	Creek chub	Fathead minnow	Common shiner	White sucker	Iowa darter	Miscellaneous*
October, 1966	592	138	70	65	65	48		13
November	316	51	126	11	9	26		11
December	175	32	68	9	3	16		2
January, 1967	133	7	23	6	2	5		8
March	80	3	43	32	3	8		2
April	39	12	8	3	3	7		
May	42	8	22	12	4	14		6
June	133	115	27	273	91	41	9	30
July	102	83	17	33	100	41	12	43
August	38	32	16	48	5	21	10	14
September	107	76	22	51		9	15	23
October	150	27	18	81		1	26	36
Total	1907	584	460	624	285	237	72	188

* Includes sand shiner, emerald shiner, Johnny darter, brook stickleback, black bullhead, hornyhead chub, and brassy minnow.

Table 19. Total numbers of forage fish collected at Station II.

Sampling Date	Blacknose dace	Stone-roller	Creek chub	Fathead minnow	Common shiner	White sucker	Iowa darter	Miscellaneous*
October, 1966	236	76	30	19	21	6		3
November	28	66	56	12	19			9
April, 1967	50	2	19	2	1	3		
May	37	2	10	24		7		3
June	83	41	22	135	30	15	10	21
July	178	85	49	169	70	21	22	57
August	120	39	14	45	7	20	20	29
September	226	69	12	40	10	12	10	26
October	120	44	33	15	7	13	21	30
Total	1078	424	245	461	165	97	83	178

* Includes sand shiner, emerald shiner, Johnny darter, brook stickleback, black bullhead, hornyhead chub, and brassy minnow.

Table 20. Total numbers of forage fish collected at Station III.

Sampling Date	Blacknose dace	Stone-roller	Creek chub	Fathead minnow	Common shiner	White sucker	Iowa darter	Miscellaneous*
October, 1966	283	45	32	30	15	3		15
November	138	21	41	29	8			9
March, 1967	11	10	1			1		
April	62	4	14	7	1	1		1
May	47	3	6	15		3		6
June	61	21	18	68	22	2	2	5
July	179	115	27	154	58	19	30	51
August	90	28	15	41	5	9	14	26
September	286	51	19	29	26	6	11	26
October	195	55	40	22	30	13	17	25
Total	1352	353	213	395	165	57	74	164

* Includes sand shiner, emerald shiner, Johnny darter, brook stickleback, black bullhead, and hornyhead chub.

Table 21. Total numbers of forage fish collected at Station IV.

Sampling Date	Blacknose dace	Stone-roller	Creek chub	Fathead minnow	Common shiner	White sucker	Iowa darter	Miscellaneous*
October, 1966	313	107	119	19	34	10		19
November	166	30	16	7				1
April, 1967	97	2	9	1				
May	115	37	18	6	3	6	1	8
June	102	17	29	37	29	2	1	8
July	148	37	34	41	24		6	18
August	199	59	41	65	17	2	12	21
September	292	43	33	48	7	1	1	9
October	252	52	39	18			2	5
Total	1684	384	338	242	114	21	23	89

* Includes sand shiner, emerald shiner, Johnny darter, brook stickleback, black bullhead, and hornyhead chub.

Table 22. Total numbers of forage fish collected at Station V.

Sampling Date	Blacknose dace	Stone-roller	Creek chub	Fathead minnow	Common shiner	White sucker	Iowa darter	Miscellaneous*
October, 1966	103	117	79	23	11	12		25
November	83	22	30	18	1			1
April, 1967	92	11	6					2
May	113	93	20	4	3	7	1	11
June	81	8	30	7	55	5		12
July	239	124	77	208	67	2	6	34
August	130	45	15	19	6	3	12	18
September	231	58	53	57	16	3	15	28
October	122	40	100	66	4		6	23
Total	1194	518	410	402	163	32	40	154

* Includes sand shiner, emerald shiner, Johnny darter, brook stickleback, black bullhead, and hornyhead chub.

reaching collectable size. The decrease in numbers following the summer peak was attributed to post spawning mortality. Markus (1934) found in rearing ponds that most Age I fathead minnows die after spawning. A slight increase in numbers occurred in October, 1966 and October, 1967. This was attributed to young of the year entering the catch. Trautman (1957) recorded lengths in October of 6 cms for fathead minnows hatched in May and June of the same year.

The seasonal abundance of creek chubs was quite similar to that of blacknose dace in that peaks occurred in July and in the fall when young fish reached collectable size. Trautman (1957) found that creek chubs in Ohio migrated downstream in the fall. Creek chubs apparently followed the same pattern in the South Fork Yellow Bank River.

The build up in numbers of common shiners in June and July of 1967 was apparently due to upstream migration. Upstream migration of common shiners during spawning periods was observed by Raney (1940). A downstream movement after spawning of common shiners was observed by Trautman (1957) in Ohio. This movement could account for the late summer and fall decline in common shiner abundance in the study area. The other species of fish found did not occur in sufficient numbers to allow detection of seasonal trends in abundance.

Forage fish were found in the trout stomachs in each month. A correlation coefficient of .2094 determined by the method described by Steel and Torrie (1960) indicates that there was very little relationship between the abundance of forage fish and the average number of fish per trout stomach. However, when the decrease in forage fish abundance occurred in August, 1967 it was accompanied by a large decrease in the average number of fish per trout stomach. The frequency of occurrence of forage fish in the trout stomachs increased as the size of the trout increased. Ricker's (1930) findings for brook trout in Ontario indicated that as trout grow they feed on larger organisms.

CONCLUSIONS AND RECOMMENDATIONS

Significant information was obtained regarding the introduction of brook trout into an eastern South Dakota stream. The ability of brook trout to survive in the study area during all seasons of the year indicates that a limited trout fishery could be maintained by stocking. Trout from both plants showed an increase in size and condition, thereby, indicating that food was plentiful and conditions were favorable for growth. However, the final appraisal of the trout introduction should not be made until the results of spawning are evaluated. If the reproduction was successful then the life history of the hatched trout should be determined since a successful hatch, by introducing different size classes, would allow more complete use of the available habitat.

Several courses of action are still available whether reproduction is successful or not. The stream could be used strictly for experimental study of many aspects of the life history and ecology of brook trout. It was impossible to determine if the introduced trout had any effect on benthos and forage fish populations from the samples that were taken. Food habits of the trout only indicated that they were opportunists in feeding and took whatever was available. Therefore, the relationship between brook trout and forage fish should be studied more intensively. If forage fish were found to have a detrimental effect on trout then a fish barrier could be installed and the area could be completely eradicated. Then different types of stocking could be studied without interferance from forage fish.

If a trout fishery was maintained by stocking, the relatively high survival of the supplemental plant compared to that of the initial plant indicates that spring stocking would give better returns to the angler. Spring stocking also appears to be justified by the fact that the condition of trout from the supplemental plant increased during the summer while the condition of trout from the initial plant decreased. If the area is opened to fishing, considerable habitat improvement could be carried out to make the area more suitable for trout. Limiting the access of livestock to the stream would allow vegetative cover to develop and would prevent the banks of the stream from being broken down. Planting trees and shrubs along some sections of the stream would help maintain low water temperatures during the summer. The long unbroken stretches of riffles could be made into better trout habitat by installing stream improvement devices that would help create pools. Stream improvements could also be used to stabilize stream banks where the possibility of erosion exists. The location of the stream in an area dominated by a warm water fishery would appear to warrant the expense of stocking trout and making habitat improvements. A trout fishery would add to the variety of fishing offered the angler and at the same time would make use of a stream that previously had not produced any sport fishing.

SUMMARY

1. Brook trout were introduced into the South Fork Yellow Bank River, an eastern South Dakota stream, on October 11, 1966. A supplemental brook trout plant was made on June 8, 1967. Survival, growth, and food habits were determined for both trout plants.

2. The initial trout plant had over-winter survival of 6.7% and survival of 2.4% from October, 1966 through October, 1967. The low survival was attributed to the stocking of more trout than recommended and extensive movement out of the study area.

3. Survival of the supplemental plant was 21.0%. Approximately 50% of the trout loss from the supplemental plant occurred within three weeks after stocking.

4. Trout from both plants took part in spawning activities during the fall of 1967. Spawning occurred in the upstream .5 miles of the stream. Success of spawning could not be determined in the present study.

5. Trout from the initial plant had an average growth increment of 9.8 cm from October, 1966 through October, 1967. The greatest growth occurred in the spring when water temperatures ranged from 13.3 to 15.6 C. The average condition of the trout was low during the winter, increased in the spring until a peak was reached in June, 1967, and decreased throughout the summer.

6. The average length of trout from the supplemental plant increased 4.0 cm during the summer. The average condition factor increased from 1.21 at the time of planting to 1.66 in October.

7. Aquatic organisms comprised 86.7% of the total number and 93.9% of the total volume of organisms found in trout stomachs. Insects, both aquatic and terrestrial comprised 85.2% of the total number of organisms in trout stomachs while forage fish comprised 63.7% of the total volume of organisms. Considerable seasonal variation existed in the trout diet but only in September, 1967 were terrestrial organisms more numerous than aquatic organisms in trout stomachs.

8. Benthos samples collected for forage ratio determinations showed that the greatest number of bottom organisms were present during the summer. Trichoptera, Ephemeroptera, and Diptera were the predominate organisms in the bottom samples. The average standing crop of bottom organisms in riffles was high compared to other streams in the United States.

9. Forage ratios for the different orders varied throughout the study. Low forage ratios were found for Trichoptera and Diptera. High forage ratios were found in some months for Ephemeroptera, Coleoptera, and Plecoptera.

10. Forage fish populations reached a peak in the summer and then declined throughout the fall and winter. Little relationship was found between the abundance of forage fish and the average number of fish in trout stomachs. Frequency of occurrence of forage fish in the trout stomachs increased as the size of the trout increased.

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APPENDIX

Appendix A. Water Chemistry at Station A (Concentrations in parts per million).

Date	Specific conductance (micromhos at 25°C)	Sulfate (SO_4)	Total Hardness	Chloride (Cl)	Nitrate (NO_3)	Potassium (K)	Sodium (Na)	Silica (SiO_2)
July, 1966	400	55	204	2.5	.1	4.74	6.75	14.4
Aug.	590	105	216	1.5	.1	5.10	7.25	21.0
Sept.	500	135	234	1.0	.5	5.40	7.25	19.6
Oct.	560	90	219	2.5	.3	7.14	9.50	29.5
Nov.	570	95	204	1.5	.2	6.48	10.00	22.0
Dec.	550	80	212	1.5	.2	5.28	9.00	16.4
Jan., 1967	580	80	210	1.5	.1	5.16	7.75	16.8
Feb.	490	140	276	2.0	.2	3.90	7.80	16.4
Mar.	275	40	176	2.5	.4	5.10	4.00	12.4
April	580	132	318	3.0	.3	4.10	10.00	16.4
May	750	132	320	3.0	.3	4.30	9.00	18.3
June	710	122	398	2.0	.2	3.40	10.20	19.6
July	640	140	320	2.5	.2	4.10	8.50	18.3
Aug.	440	122	330	2.5	.2	3.10	6.00	16.4
Sept.	570	148	320	2.5	.3	4.00	7.50	17.3
Oct.	690	125	314	3.0	.3	3.40	6.40	19.6

Appendix B. Water Chemistry at Station B (Concentrations in parts per million).

Date	Specific conductance (micromhos at 25°C)	Sulfate (SO_4)	Total Hardness	Chloride (Cl)	Nitrate (NO_3)	Potassium (K)	Sodium (Na)	Silica (SiO_2)
July, 1966	580	115	302	3.0	.1	6.60	10.75	19.6
Aug.	540	117	248	2.0	.4	4.80	8.50	21.0
Sept.	520	110	240	1.0	.1	5.40	7.00	20.0
Oct.	540	82	218	3.0	.1	6.84	8.75	24.0
Nov.	550	95	208	1.5	.1	5.22	8.00	20.0
Dec.	610	110	226	1.5	.3	5.70	8.00	14.8
Jan., 1967	550	85	223	2.0	.4	5.40	7.50	17.2
Feb.	710	145	392	1.5	.2	3.40	6.50	18.3
Mar.	290	40	192	2.5	.5	5.70	4.80	12.0
April	660	142	350	3.0	.4	3.90	9.60	17.3
May	710	175	316	3.5	.2	4.20	8.50	19.6
June	740	152	430	2.0	.3	3.80	10.20	19.6
July	630	160	320	3.0	.2	4.10	7.40	15.7
Aug.	640	172	340	2.5	.2	4.10	7.70	17.3
Sept.	560	162	330	2.5	.3	4.15	8.00	17.3
Oct.	710	165	364	2.0	.3	3.90	7.00	16.4