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Feeding of Hatchery-reared Brown Trout (Salmo trutta L.) In Relation To The Diet In A South Dakota Stream

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FEEDING OF HATCHERY-REARED BROWN TROUT (*Salmo trutta* L.) IN RELATION TO THE DIEL DRIFT IN A SOUTH DAKOTA STREAM

BY

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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. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

FEEDING OF HATCHERY-REARED BROWN TROUT (*Salmo trutta* L.) IN RELATION TO THE DIEL DRIFT IN A SOUTH DAKOTA STREAM

Abstract

RICHARD W. MC COY

One thousand five hundred catchable brown trout (17-26 cm) were stocked into the South Fork of the Yellowbank River May 17, 1973. Samples were taken one month apart from May 22, 1973, through October 29, 1973. Fifteen-minute drift samples were collected every hour for 24 hours and trout were captured every 4 hours. Trout captured during the study varied in condition (R) from 1.34 to 2.55. Condition progressively decreased through August, rose in September, and decreased again by the October sample. The average weight of brown trout increased through the September sample and decreased in October. Two peaks in number of drifting invertebrates occurred at night in the samples for May through September and one peak occurred at night in the October sample. All nighttime peaks were a result of changes in the number of drifting benthic and emergent invertebrates; the presence of terrestrial invertebrates influenced the daytime drift patterns. Adult chironomids accounted for 60-90 percent of the emergent drift, and chironomid pupae and larvae constituted a large portion of the benthic drift in the June, July, and August samples. Ephemeroptera were the second most abundant order of invertebrates in the drift; Baetidae and Caenidae contributed 95 percent of all mayflies collected. Hydropsychidae and Hydroptilidae comprised 93 percent of all drifting Trichoptera.

Frogs and fishes were the primary food consumed by the brown trout examined. Trout ate a variety of invertebrates. Ephemeropterans

comprised 45 percent by numbers, 27 percent by weight, and 21 percent by volume of all invertebrates consumed. Trichopterans constituted 20 percent by numbers, 34 percent by weight, and 38 percent by volume of all invertebrates consumed. Dipterans comprised 17 percent by numbers, 28 percent by weight, and 28 percent by volume of all invertebrates consumed.

Correlation between mean drift rates (for the 4 hours prior to the trout sample) and mean stomach contents for all six sampling dates were not significant. Brown trout examined did not exploit the diel drift patterns of stream invertebrates. Hatchery-reared brown trout may require a longer acclimation time before full exploitation of invertebrate drift develops.

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INTRODUCTION

The primary objective of this study was to evaluate the exploitation of invertebrate drift by hatchery-reared brown trout Salmo trutta L., in a small South Dakota stream. Secondary objectives were to describe the condition and food habits of hatchery-reared brown trout collected during the study and to describe the diel drift patterns of stream invertebrates within the study area.

Stream drifting by many stream and terrestrial invertebrates is a result of their response to various stimuli. Waters (1972) divided the drift phenomena into three major classes: "constant drift" for those organisms appearing in low numbers at all times, "catostrophic drift" for organisms dislodged through physical disturbances such as flood, drought, pollution, etc., and "behavioral drift" for organisms which show behavioral patterns constant for each species. One of the first accounts of behavioral drift activity was reported by Tanakas (1960) in studying the diurnal periodicity of stream insects. Waters (1962a) reported marked increases in drift rates 1 hour after sunset with a gradual decrease during the night and a final sharp drop at sunrise. Bishop (1969) used an experimental stream to show that nighttime peaks observed by other investigators were due to increased activity of aquatic insects at low light levels.

Waters (1972) proposed several explanations for at least part of the drift activity by invertebrates. Since many drifting insects are of the larger and later instars, drift could be a result of intraspecific competition for living space, prepupation activity, or simply greater exposure to the current. He suggested that it would be advantageous for insects to have the ability to move into new habitats or recolonize denuded ones. Since drifting insects eventually move from riffle areas with low fish density into pools with high fish density, movement during periods of low predation would also be advantageous.

Many investigators have reported seeing brown trout, feeding on drift organisms during the day. Swift (1964) reported that brown trout held in cages suspended in a lake showed marked seasonal and diurnal activity patterns. Brown trout activity increased at dawn, rose during the day, and decreased at night during all months of the year except January, February, and March. Trout activity was random for the first three months of the year. Seasonal variations were due to changes in levels and duration of activity (Swift, 1964). Swift also altered feeding patterns but found no change in diurnal activity. He concluded that the trout were feeding during the day because they were more active then. Chaston (1968a), however, reported that brown trout held in tanks were most active from dusk until dawn even when the normal light regime was reversed. Chaston (1969) also noted greatest activity between dusk and dawn in a second study on a Dartmoor stream. Although brown trout were more active during the day in summer than in the spring and fall, peak activity was still at night (Chaston, 1969).

Chaston (1968b, 1969) tested the possibility of brown trout exploitation of diel drift. He held trout of age-group II+ in a wire tank in a stream and periodically recorded drift and stomach contents. He found that the fish fed on benthos and insects in the water column and not those in the drift. In a second experiment, Chaston took age-group II+ trout directly from the stream at three-hour intervals and observed a direct correlation between times of maximum terrestrial materials in the drift and maximum occurrence in stomachs but no correlation with emergent or benthic materials (Chaston, 1969). Chaston concluded that brown trout were not utilizing the stream drift patterns and any peaks in stomach contents of trout were coincidental to increased activity by the trout.

Tusa (1969) collected brown trout every 6 hours from a Russian stream and correlated the stomach contents with the drift. The food consumed corresponded qualitatively to the drift (except for caddisflies) but not quantitatively. Feeding activity was high in the morning and evening. Tusa, like Chaston, concluded that the brown trout were not utilizing the large increase of drift material at night.

Elliot (1970) studied brown trout in an English stream; stomach contents from three-year classes (0+, I+, II+) were taken every 4 hours and compared with mean drift rates. Food taken by trout was closely related to availability of benthic invertebrates; drifting benthic forms were more abundant in stomachs of younger trout. "Drift feeding" persisted throughout life but became less important to older trout. Elliot concluded that brown trout exploited the diurnal drift patterns of the stream invertebrates.

DESCRIPTION OF THE STUDY AREA

The South Fork of the Yellowbank River originates in Deuel County, South Dakota, flows northeast across Grant County, and drains into the Minnesota River 10 miles below Ortonville, Minnesota. The study area was limited to a one-mile section 3 miles from the origin of the stream. Average gradient within the study area was 13.3 m/km and average width was 4.8 m. The stream primarily drains open pastureland on the Coteau de Prairies and enters a forested ravine near the edge of the Coteau. The upper one-fourth of the study area was located in the forested ravine with the remaining three-fourths located in open pasture near the foot of the Coteau. Grasses, primarily *Elymus canadensis* L. and *Agrostis gigantea* Roth, and other plants overhung the stream in the open pasture. Aquatic vascular plants were present along the more exposed banks of riffles and pools. Filamentous algae, *Rhizoclonium* sp. and *Cladophora* sp., choked many riffle areas from July through the end of summer; *Batrachospermum* sp. was common in shallow runs during the spring. Aquatic insects found within the study area are listed in Table 1.

Short riffles, widely dispersed between large pools or long runs, were 1-2 m long, 2-4 m wide, and 15-30 cm deep and were composed of small to medium-sized rocks, gravel and sand. Pool area substrate was nearly all sandy-silt or fine gravel. Pool size was variable, ranging from 2-4 m wide, 4-10 m long, and 0.5-1.5 m deep. There were several long runs with sandy-silt bottoms that were 2-3 m wide and 1 m deep.

The warmest water temperature (21C) was recorded during the July sampling period and the coldest (5C) during the October sampling period.

Table 1. Aquatic insects present in the South Fork Yellowbank River, 1973.

- Collembola
  - Entomobryidae
  - Poduridae
  - Smynthuridae
- Ephemeroptera
  - Baetidae
    - *Baetis brunneicolor* McDunnough
    - *Baetis phoebus* McDunnough
    - *Baetis phyllis* Burk
    - *Baetis vagans* McDunnough
    - *Isonychia* spp.
    - *Leptophlebia* spp.
  - Caenidae
    - *Caenis* spp.
  - Ephemeridae
    - *Ephoron leukon* Williamson
    - *Hexagenia limbata* (Serville)
  - Heptageniidae
    - *Cinygma* spp.
    - *Heptagenia* spp.
    - *Stenonema* spp.
- Odonata
  - Aeschnidae
    - *Aeschna interrupta* Walker
  - Agrionidae
  - Coenagrionidae
    - *Ischnura* sp.
- Plecoptera
  - Perlidae
    - *Acroneuria arida* (Hagen)
    - *Neoperla clymene* (Newman)
    - *Perlesta placida* (Hagen)
  - Taeniopterygidae
    - *Taeniopteryx parvula* Banks
- Hemiptera
  - Belostomatidae
    - *Abedus* sp.
    - *Belostoma flumineum* Say
  - Corixidae
    - *Callicorixa audeni* Hungerford
    - *Corisella tarsalis* (Fieber)
    - *Hesperocorixa vulgaris* (Hungerford)
    - *Sigara* sp.
  - Gerridae
    - *Gerris* sp.
    - *Metrobates* sp.
  - Mesoveliidae
    - *Mesovelia* sp.
  - Nepidae
    - *Ranatra brevicollis* Montandon
  - Notonectidae
    - *Notonecta* sp.
  - Pleidae
  - Saldidae
  - Veliidae
    - *Rhagovelia* sp.
- Coleoptera
  - Carabidae
  - Curculionidae
    - *Endalus* spp.
  - Dryopidae
    - *Helichus* sp.
  - Dytiscidae
    - *Agabus* sp.
    - *Desmopachria* sp.
    - *Hydroporus* sp.
    - *Liodessus affinis* (Say)
  - Elmidae
    - *Dubiraphia* spp.
    - *Heterlimnius* spp.
    - *Optioservus* spp.
  - Gyrinidae
    - *Gyretes* sp.
  - Haliplidae
  - Heteroceridae
  - Hydrophilidae
    - *Laccobius agilis* Rand
  - Limnebiidae
    - *Ochthebius* sp.
  - Ptiliidae
    - *Smicrus* sp.
  - Ptilodactylidae
  - Staphylinidae
- Trichoptera
  - Helicopsychidae
    - *Helicopsyche* sp.
  - Hydropsychidae
    - *Cheumatopsyche* spp.
    - *Hydropsyche betteni* Ross
    - *Hydropsyche bifida* Banks

Table 1. (Continued)

Hydropsyche simulans Ross
Hydropsyche slossonae Banks
Hydroptilidae
Hydroptila spp.
Leptoceridae
Leptocella spp.
Limnephilidae
Glyphopsyche spp.
Hesperophylax spp.
Limnephilus spp.
Psychomyiidae
Polycentropus spp.

Diptera
Ceratopogonidae
Palpomyia sp.
Chironomidae
Anatopynia spp.
Brillia spp.
Cardiocladius spp.
Chironomus spp.
Diamesa spp.
Pentaneura sp.
Spaniotoma spp.
Tanytarsus spp.
Culicidae
Dixidae
Dolichopodidae
Empididae
Ephydridae
Liriopeidae
Muscidae
Limnophora sp.
Psychodidae
Rhagionidae
Atherix variegata Walker
Simuliidae
Eusimulium sp.
Simulium spp.
Syrphidae
Stratiomyidae
Eulalia sp.
Tabanidae
Chrysops spp.
Tabanus spp.
Tipulidae
Antocha saxicola Osten Sacken
Dicranota sp.
Holorusia sp.
Tipula spp.

Ranges of monthly water temperatures are presented in Table 12. Stream velocity varied from 0.67 m/sec in May to 0.27 m/sec in October. Water depths decreased progressively over the summer.

METHODS AND MATERIALS

One thousand five hundred catchable brown trout (17-26 cm) were stocked into the South Fork of the Yellowbank River May 17, 1973. Samples were taken one month apart from May, 1973, through October, 1973. Fifteen-minute drift samples were collected every hour for 24 hours and brown trout were collected once every 4 hours. Trout sampling periods each month were divided as follows:

Period I	1230-1530	Period IV	0030-0330
Period II	1630-1930	Period V	0430-0730
Period III	2030-2330	Period VI	0830-1130

All trout were collected within the first one-half hour of a trout sampling period. The study area was divided into approximately six equal sections; all trout for each 24-hour sample were taken from one of the six sections. Initial sampling began with the downstream portion of the study area, and sampling continued upstream with each succeeding period throughout the duration of the study. Brown trout were collected with D. C. electro-fishing gear.

Trout were weighed to the nearest 0.1 gm and total lengths were measured to the nearest 0.1 cm. Stomachs and intestines were placed in 10 percent formalin as soon after collection as possible. Stomach contents (from the esophagus to the pylorus) were analyzed separately from the intestine and only stomach contents were used for correlation with the drift. A dissecting microscope was used to analyze trout stomach contents. Relative fullness was determined using the following criteria:

F (full) - stomach greatly distended and lining smooth

3/4 - stomach full but not distended with rugae visible

1/2 - one-half to three-fourths of stomach having organisms

1/4 - one-fourth of stomach full

1/8 - 2 to 4 small invertebrates

T (trace) - one or part of one invertebrate

E (empty) - completely empty

Volume of organisms was determined to the nearest 0.1 ml by displacement of 20-50 representative invertebrates from each family in a graduated cylinder. Dry weight was determined to the nearest 0.1 mg by weighing 20-50 representative invertebrates from each family dried for four hours at 105 C (Allen, 195). Volume and weight for whole invertebrates were used to estimate stomach contents.

Frequency of occurrence for an organism is defined as the number of stomachs in which the food item occurred as a percent of the total number of stomachs examined each month (Hynes, 1950). Condition factors were computed using the formula: $R = \frac{\text{Weight (gm) X 10}}{\text{Total length (in)}}$ (Cooper and Benson, 1951).

The drift was collected with a net similar to the one described by Waters (1961) using 471 Nitex[1] screen. The net was placed at the downstream end of a riffle area where the greatest volume of water could be sampled. Each riffle area sampled was several hundred meters upstream from where the next trout collection would occur. One fifteen-minute drift sample each hour was collected from the same riffle during a

[1]Registered trademark of Tetko Inc., Des Plaines, Ill.

four-hour period. Sampling during the next four-hour period was conducted several hundred meters upstream. Drift sample contents were emptied into jars containing 80 percent ethyl alcohol and later separated to taxonomic groups in the laboratory. Stream velocity was recorded in front of the drift net using a Weather Instrument Corporation Model 583 Pygmy Water Current Meter. Counts were converted to number of invertebrates per 10,000 liters of water sampled. Spearman's nonparametric coefficient of rank correlation: $r_s = \frac{6 \sum d_i^2}{n(n^2-1)}$ (Steel and Torrie, 1960) was used to measure the degree of association between mean drift rate (four hours prior to sampling) and mean stomach content.

Analysis of water chemistry was done once each 24-hour period. Specific conductance was measured with a Beckman RB-3 meter; pH was determined with a Hellige pocket comparator; sodium and potassium were measured with a Coleman flame photometer; and all other chemistry was evaluated in the field using a Hach DR-EL engineer laboratory kit. The majority of vascular plants was taken while in bloom during the summer; non-aquatic plants include only those within a few feet from the edge of the water. Diatoms were taken from rocks in riffle areas and filamentous algae were collected in backwater areas and around springs. Benthic insects were taken in riffle areas during August with a Surber square foot sampler and their numbers expanded to show number per square meter. A fish population estimate was made by blocking off ninety meters of stream (to include one riffle and one pool) and removing fish with a D. C. electric shocker. A regression method outlined by Zippen (1956) was applied to the data.

Standard keys used for insect identification included: Borror and Delong (1964), Burks (1953), Frison (1935), Johannsen (1969), Ross (1972), Usinger (1956), and Edmondson (1959). Vascular plants were identified using the standard keys of Fassett (1972) and Muenscher (1967). Diatoms were identified using a key by Patrick and Reimer (1966), and algae were identified using a key by Smith (1933).

RESULTS AND DISCUSSION

Initial test shocking indicated that all brown trout were within 1 mile from the point of stocking with many pools containing 20-40 trout. Other investigators have noted similar restricted dispersion following the introduction of hatchery-reared brown trout (Cooper and Benson, 1951; Raney and Lachner, 1942; Schuck, 1943). Collection of sufficient numbers of trout became progressively more difficult in succeeding months, possibly due to natural mortality, angling, and emigration from the study area (Table 2). Schuck (1943) and Evans (1952) reported upstream movement of brown trout in October and November for spawning. Gonadal development progressed in the trout taken over the summer and several ripe males were captured in October. Trout were needed from every sampling period each month for correlation analysis. The difficulties encountered in obtaining the sample in October indicated further study with the collection method used would have been unproductive.

The range of condition factor (R) for brown trout captured during the study was 1.34 to 2.55. The monthly mean condition factors were found to be significantly different at the 0.01 level and all orthogonal comparisons of mean differences were highly significant (Table 3). Condition factor for trout collected during the study progressively decreased through August, rose in September, and decreased again by October (Table 4). Cooper and Benson (1951) in a study on the Pigeon River in Michigan reported slightly lower R values for hatchery-reared brown trout (1.25-1.92) from May through August and a different seasonal change of condition. Condition factors were highest in June and gradually decreased through winter. Cooper and Benson reported that hatchery brown trout

Table 2. Number and time of capture for brown trout taken from the South Fork Yellowbank River, 1973.

		Sample periods					
Date	Total # of trout	I 1230 - 1530	II 1630 - 1930	III 2030 - 2330	IV 0030 - 0330	V 0430 - 0730	VI 0830 - 1130
May	24	4	4	4	4	4	4
June	19	4	3	3	3	3	3
July	18	3	3	3	3	3	3
August	17	2	3	3	3	3	3
September	16	3	3	2	2	3	3
October	14	3	2	2	1	4	2

Table 3. Analysis of variance for monthly mean condition factors (R) of brown trout from the South Fork Yellowbank River, 1973.

Source	df	SS	MS	F
Total	107	6.94		
Among months	5	1.20	0.240	4.266**
Within months	102	5.74	0.056	

**Significant at the 0.01 level

were able to adjust quickly to stream feeding and exhibited only slight changes in condition factor after two weeks in the stream. Ellis and Gowing (1957) reported seasonal changes in condition more closely related to those in Table 4. The condition factor of brown trout in the study by Ellis and Gowing increased to a maximum in spring, declined during the summer, increased again in fall, and dropped to a minimum in mid-winter.

The average weight of the brown trout in the South Fork of the Yellowbank River increased through September and then decreased in October (Table 4). Allen (1938) observed that 76-100 percent of the brown trout he studied had rapid growth between May and August. He found a clear relation between average condition factor and rate at which brown trout were growing. Pentelow (1939), studying brown trout under controlled conditions, recorded maximum growth during the summer when water temperature was between 10-15.5 C. Between 4.4-10 C there was a direct relation between weight of food consumed and amount of growth, but no relation existed for other temperature ranges.

Table 4. Mean weight, total length, and condition factor (R) (with ranges in parentheses) for brown trout, South Fork Yellowbank River, 1973.

Date	# of Fish	Mean weight (gm)	Mean length (cm)	Mean condition factor (R)
May	24	146.4(69-214)	22.8(17.6-26.0)	2.00(1.66-2.36)
June	19	185.5(130-280)	25.0(22.9-27.3)	1.92(1.35-2.26)
July	18	205.9(98-415)	25.6(21.2-30.2)	1.88(1.45-2.47)
August	17	206.0(93-391)	26.3(22.5-30.2)	1.78(1.34-2.37)
September	16	270.3(113-420)	27.4(22.0-32.5)	2.07(1.39-2.55)
October	14	219.8(108-488)	26.8(21.6-34.5)	1.77(1.36-2.07)

Invertebrate Drift

Drifting invertebrates were collected hourly one day each month from May through October. Benthic drift included invertebrates that inhabit the aquatic environment; emergent drift included adult forms of aquatic insects; and terrestrial drift included all invertebrates that inhabit the terrestrial environment but found their way into the water.

Nearly all invertebrates collected were from the class Insecta (Figure 1). The miscellaneous category included Amphipoda, Thysanoptera, Orthoptera, and Arachnida. Diptera were the most important invertebrates collected from May through September (40-50 percent by numbers of all invertebrates drifting). Dipterans comprised only 9.3 percent of all invertebrates by numbers in the October sample. Diptera larvae, pupae, and adults were present each month but adult forms, especially chironomids, were most abundant. The number of mayfly (Ephemeroptera) nymphs

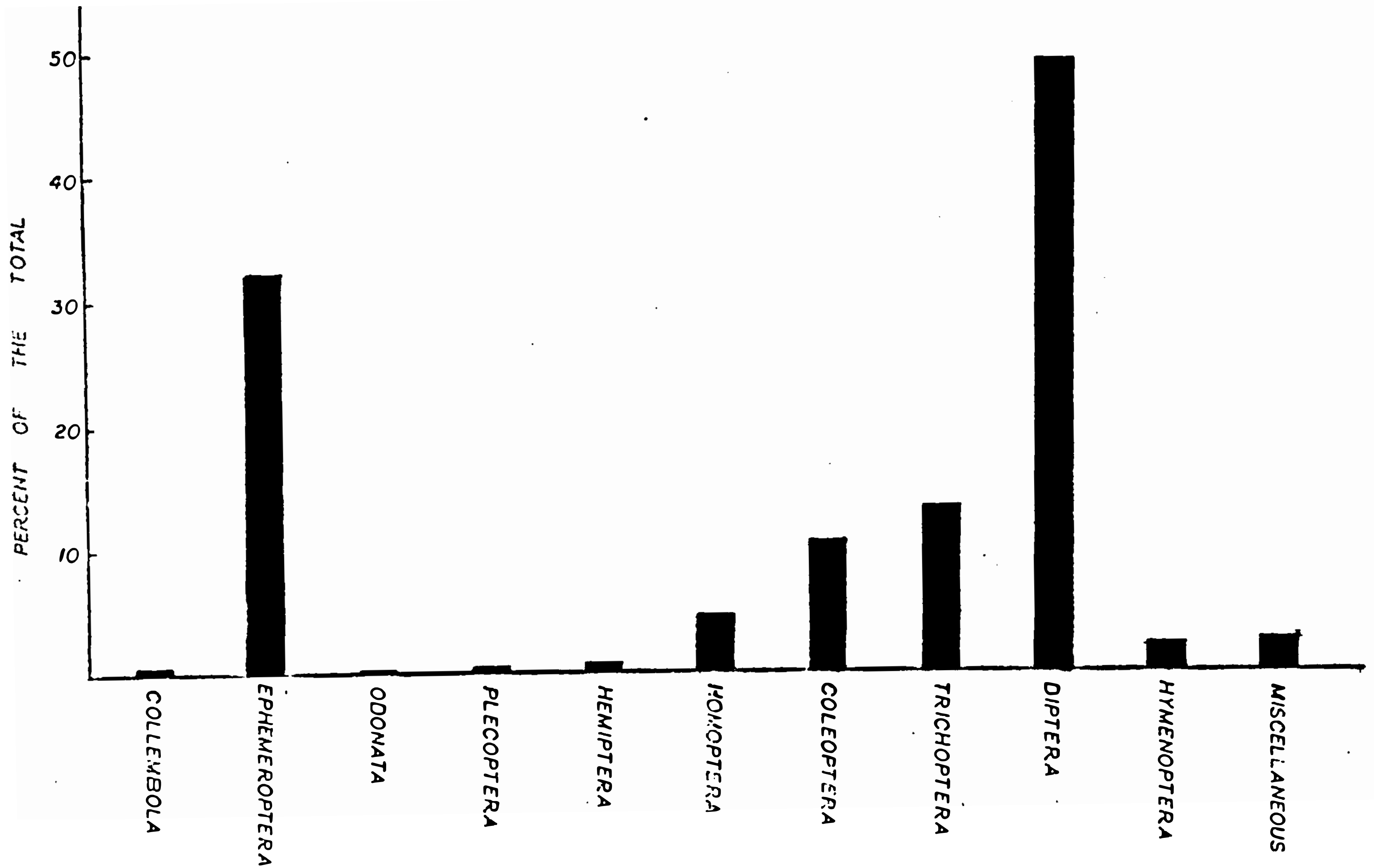

Figure 1. Drifting invertebrates expressed as percent of total numbers, May to October, 1973.

and adults varied considerably from month to month with a low of 13 percent in July to a high of 51 percent in the October sample. Baetid nymphs followed by caenid nymphs comprised the majority of drifting Ephemeroptera; adult baetids were important during spring. A few adults and nymphs of Heptageniidae and five Ephemeridae nymphs were the only other mayflies collected. Hydropsychidae larvae were the most abundant drifting caddisflies (Trichoptera) except in the October sample when larger numbers of limnephilid larvae were present. The second most abundant caddisfly species were Hydroptilidae. The number of elmid beetle larvae and adults collected in the drift samples for each month was nearly constant. An occasional dytiscid or dryopid was also collected in the drift. The bulk of the beetles (Coleoptera) in the drift were terrestrial forms; Orthoperidae were the most abundant beetles collected, and Carabidae were the second most abundant beetles collected. Large numbers of Aphididae and a few Cicadellidae were the only Homoptera collected in drift samples. Leafhoppers became more numerous than aphids in the September sample. A variety of small wasps constituted the majority of drifting Hymenoptera.

The number of drifting aquatic forms in the orders Ephemeroptera, Trichoptera, and Diptera decreased in the June sample, but the number of terrestrial forms increased. Increased numbers from all orders were collected in the July sample with dipterans doubling in abundance. The number of Ephemeroptera collected in the August sample was three times the number in July. The number of dipterans collected increased by half the number in July. All other orders collected in the August sample remained near July levels. Drift in the September sample declined in all orders with large decreases in terrestrial forms. Numbers for all orders were greatly reduced in the October drift sample except Hemiptera which showed a slight increase due to the increased occurrence of Corixidae.

The results of the hourly drift samples taken one day each month are shown graphically in Figures 2-13. Increased numbers of benthic and emergent insects were responsible for all peaks in drift after dark and nearly all peaks in drift during the day. Terrestrial invertebrates contributed more to the monthly drift rate during the day than at night except in October. The number of drifting invertebrates in May, July, and September was highest after dark and a second smaller peak occurred before dawn. The number of invertebrates drifting during the August sample reached a small peak after dark and a large peak occurred before dawn. June and October only had one peak in number of drifting invertebrates shortly after dark. Waters (1962a) reported a second peak in drift rates for May and August and attributed these peaks to the possible effects of moonlight. There was no moon on sampling days in May, August, or September and only a new moon during the sample in July. Apparently, some other mechanism was controlling the second peak in nighttime drift within the study area. The composition of drift became more complex throughout the duration of sampling, except in the October sample when few organisms were taken.

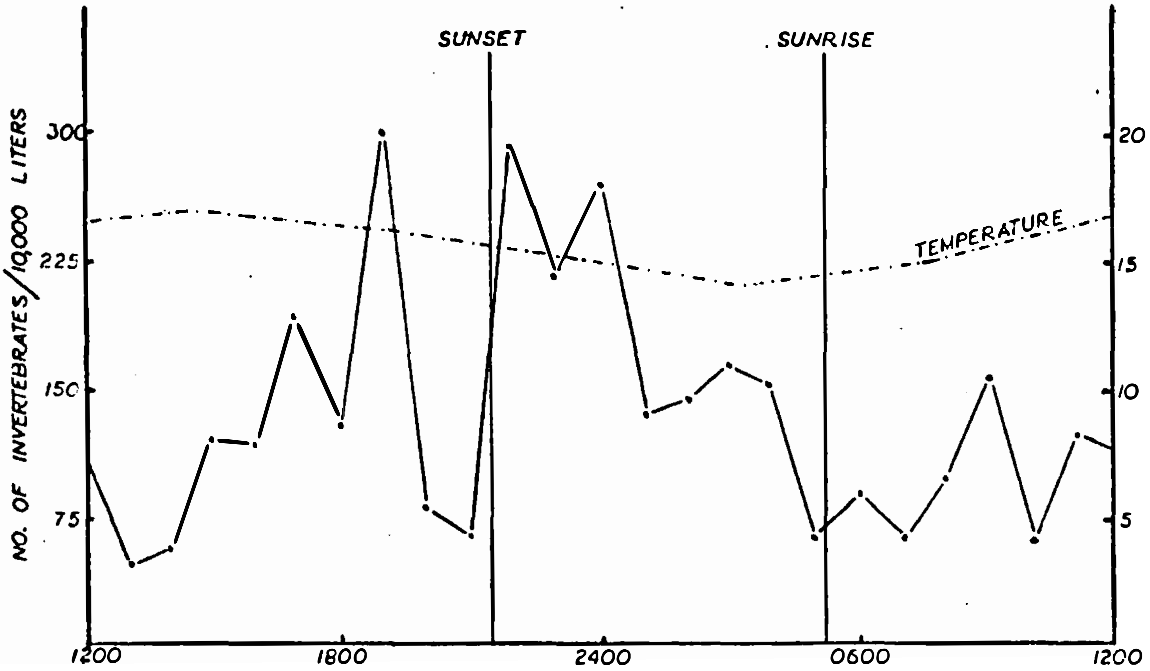

Figure 2. Water temperature and total number of drifting invertebrates, May, 1973.

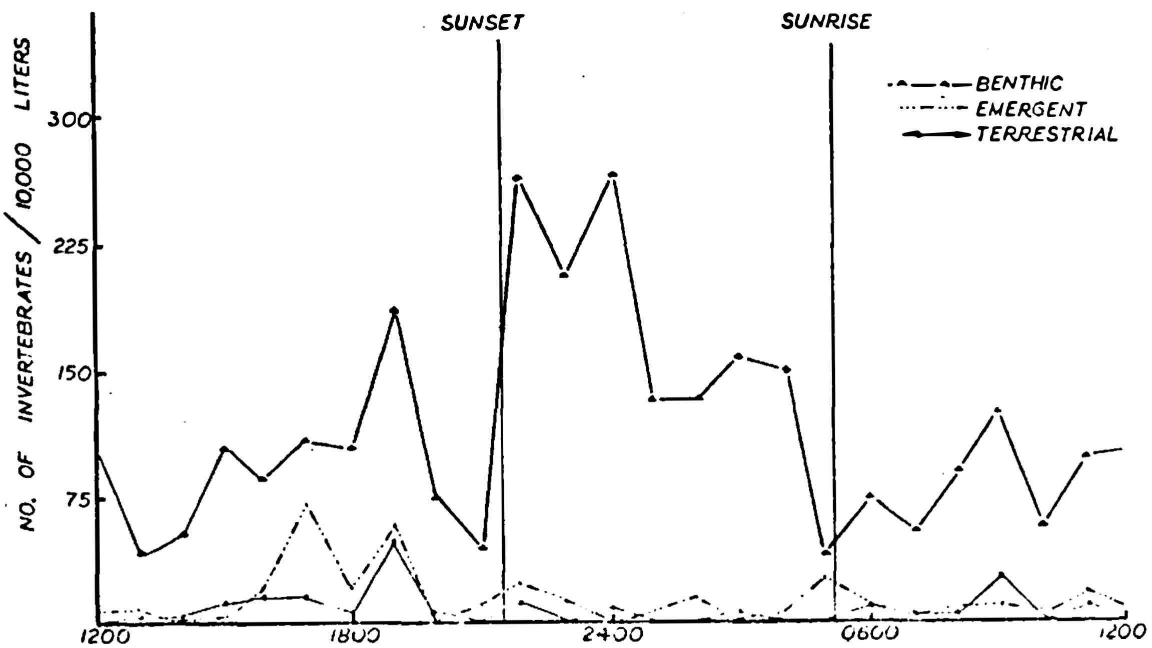

Figure 3. Number of drifting invertebrates by origin, May, 1973.

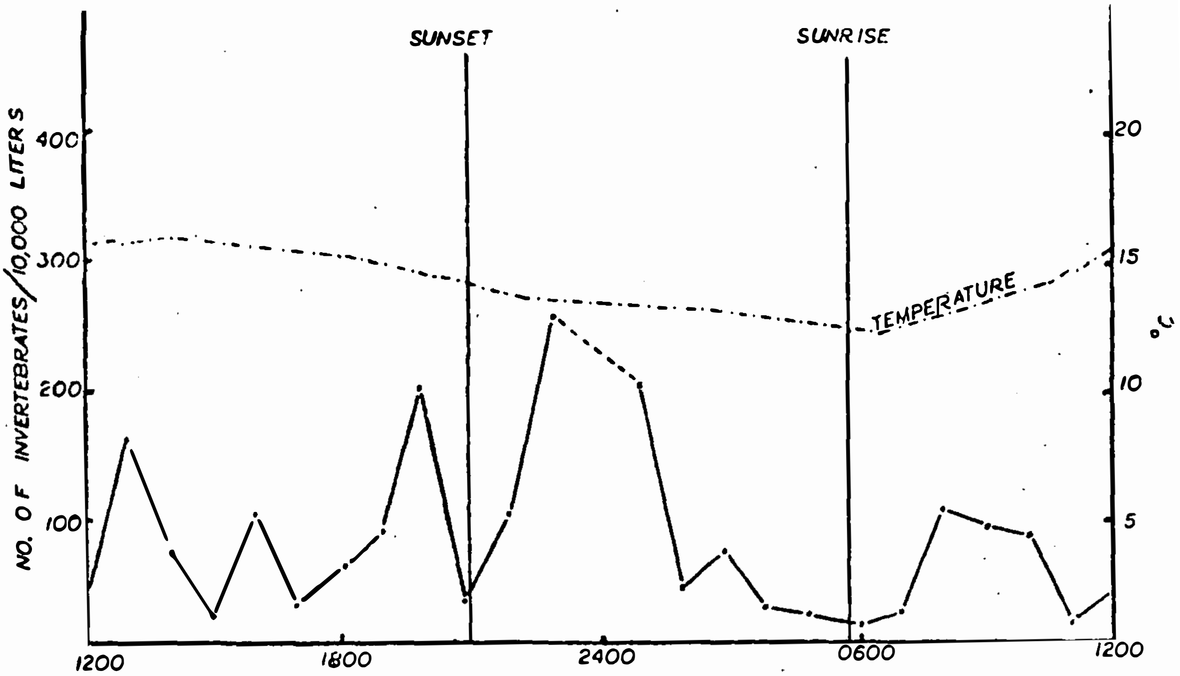

Figure 4. Water temperature and total number of drifting invertebrates, June, 1973.

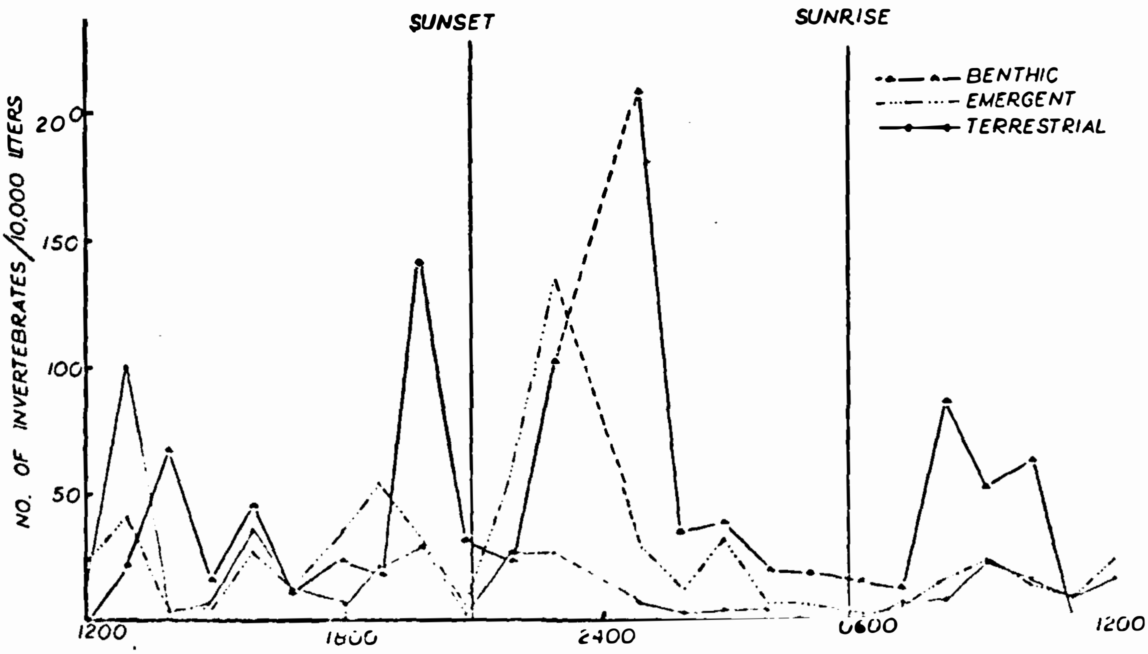

Figure 5. Number of drifting invertebrates by origin, June, 1973.

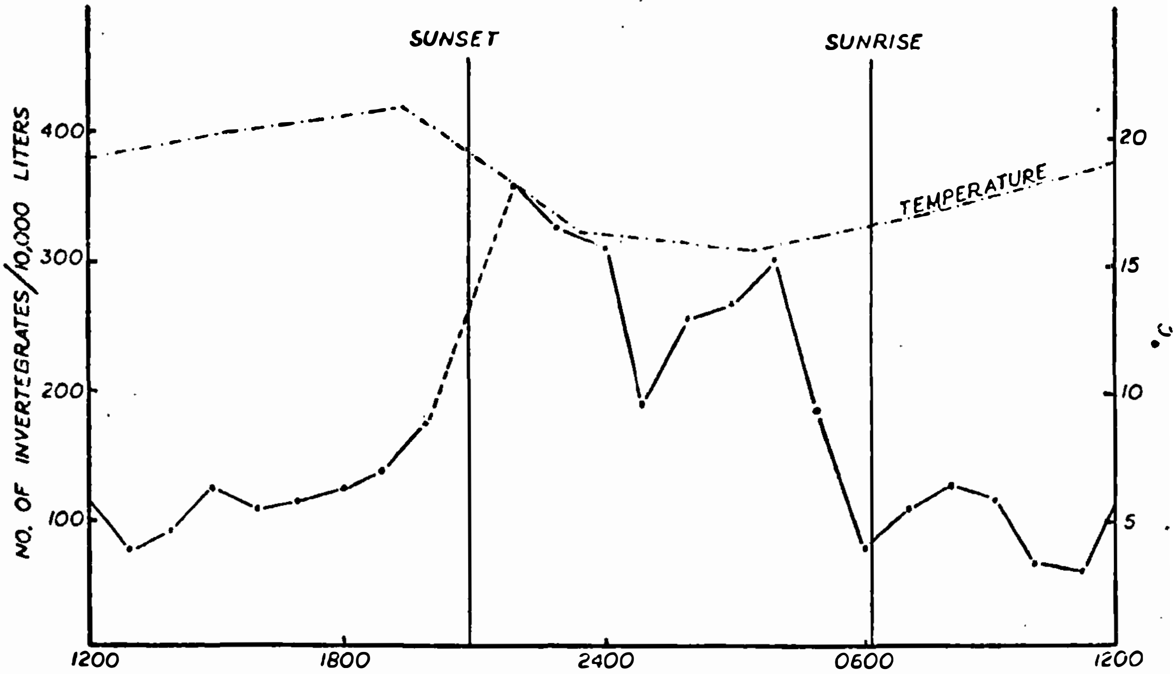

Figure 6. Water temperature and total number of drifting invertebrates, July, 1973.

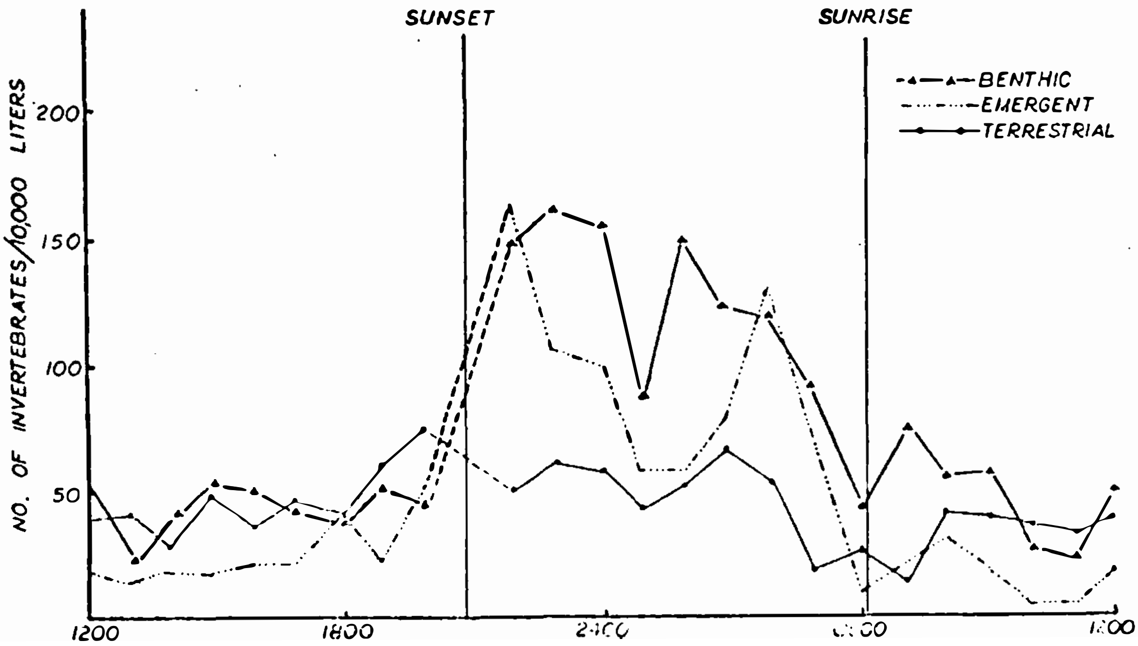

Figure 7. Number of drifting invertebrates by origin, July, 1973.

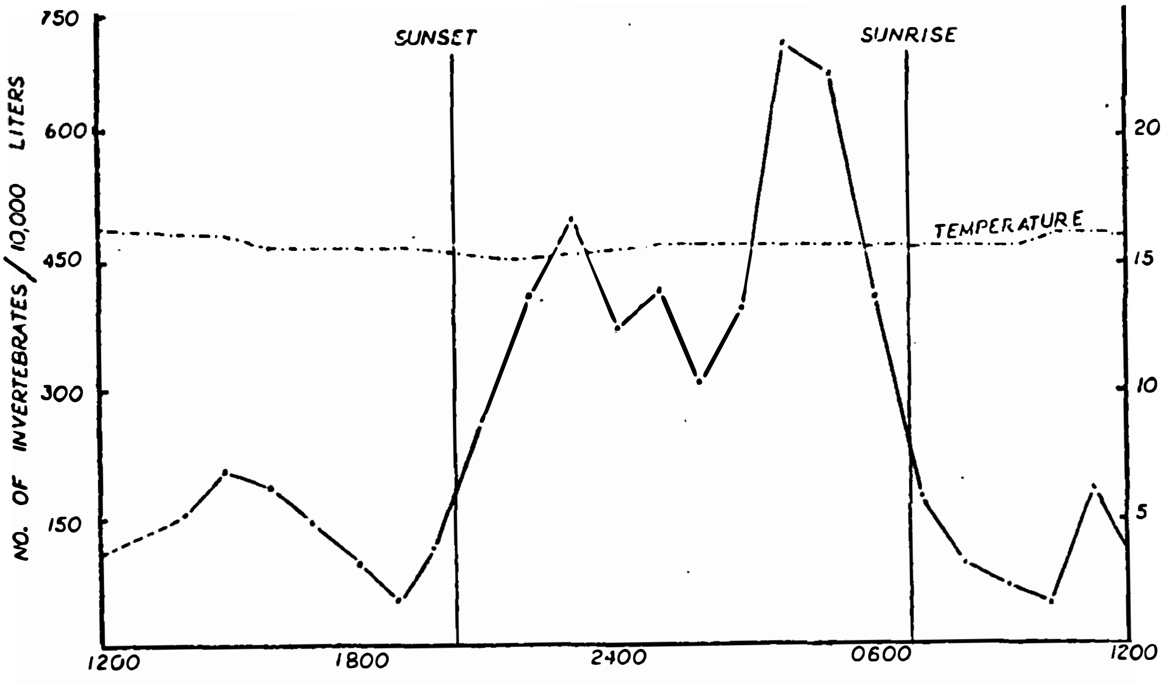

Figure 8. Water temperature and total number of drifting invertebrates, August, 1973.

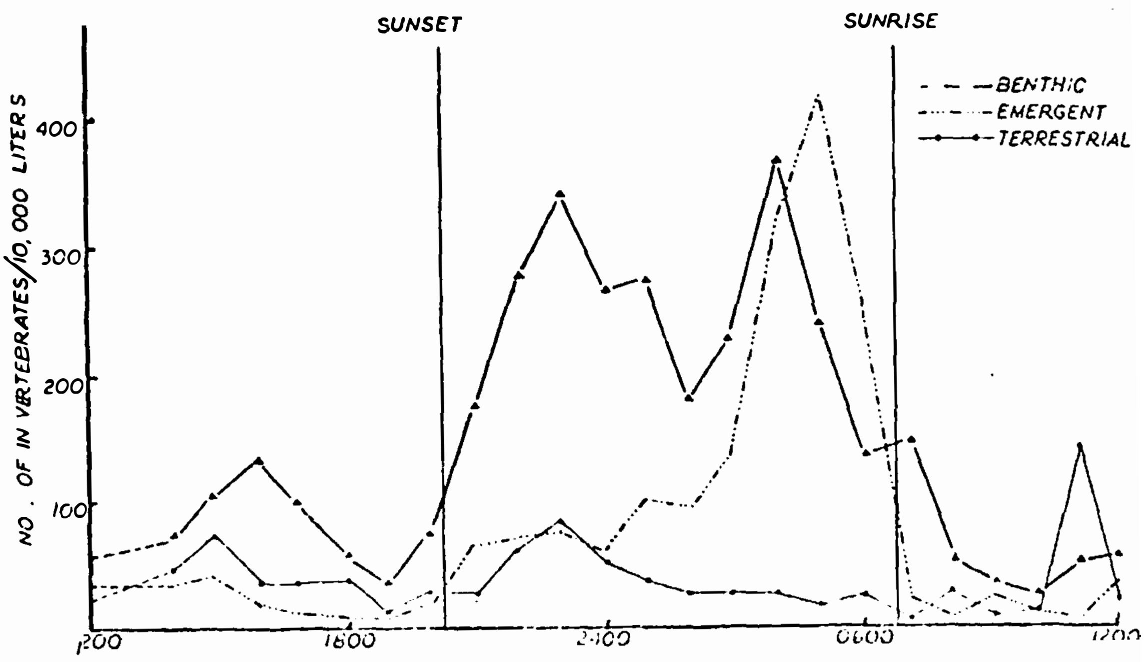

Figure 9. Number of drifting invertebrates by origin, August, 1973.

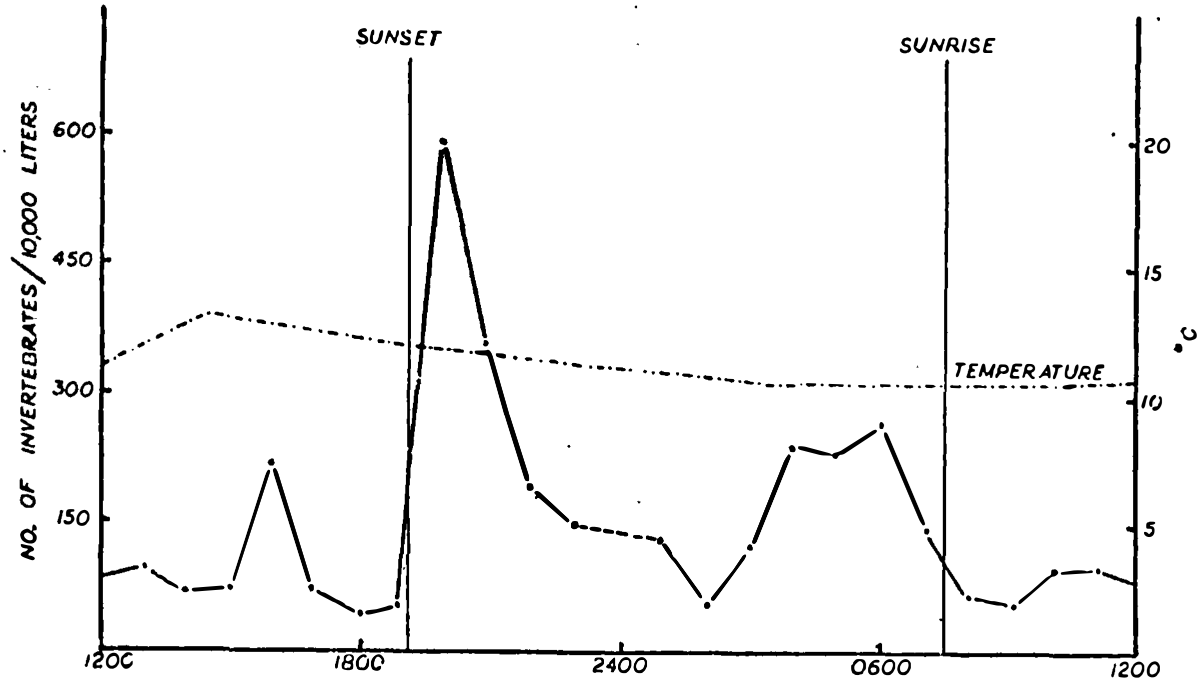

Figure 10. Water temperature and total number of drifting invertebrates, September, 1973.

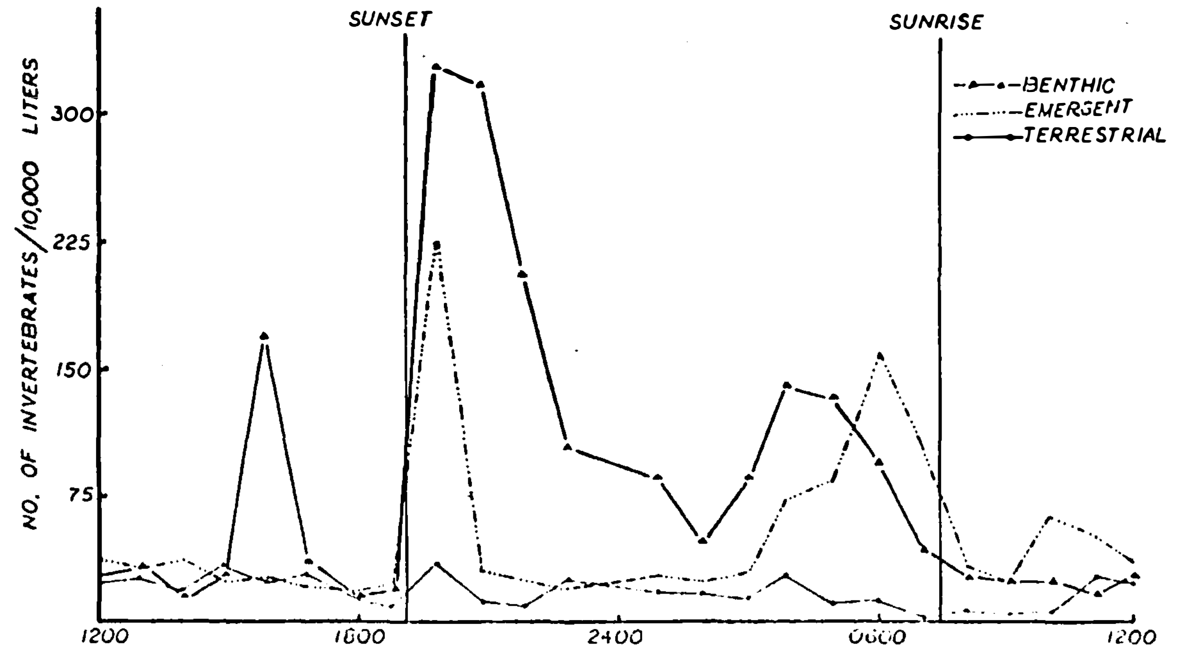

Figure 11. Number of drifting invertebrates by origin, September, 1973.

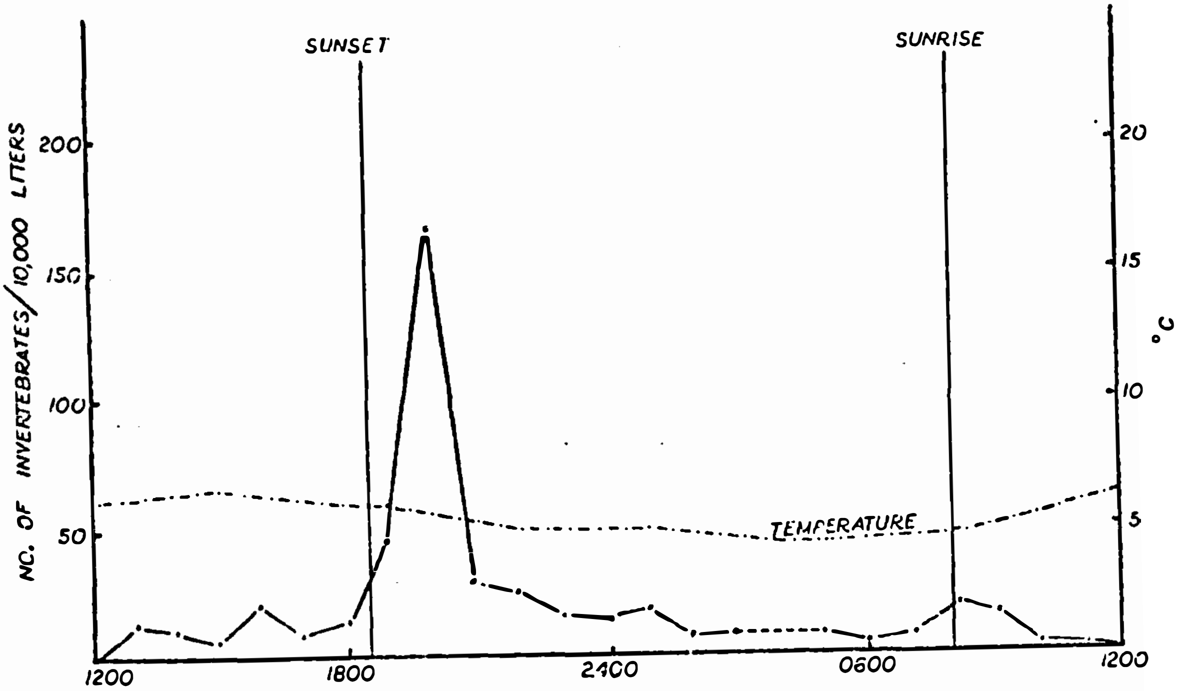

Figure 12. Water temperature and total number of drifting invertebrates, October, 1973.

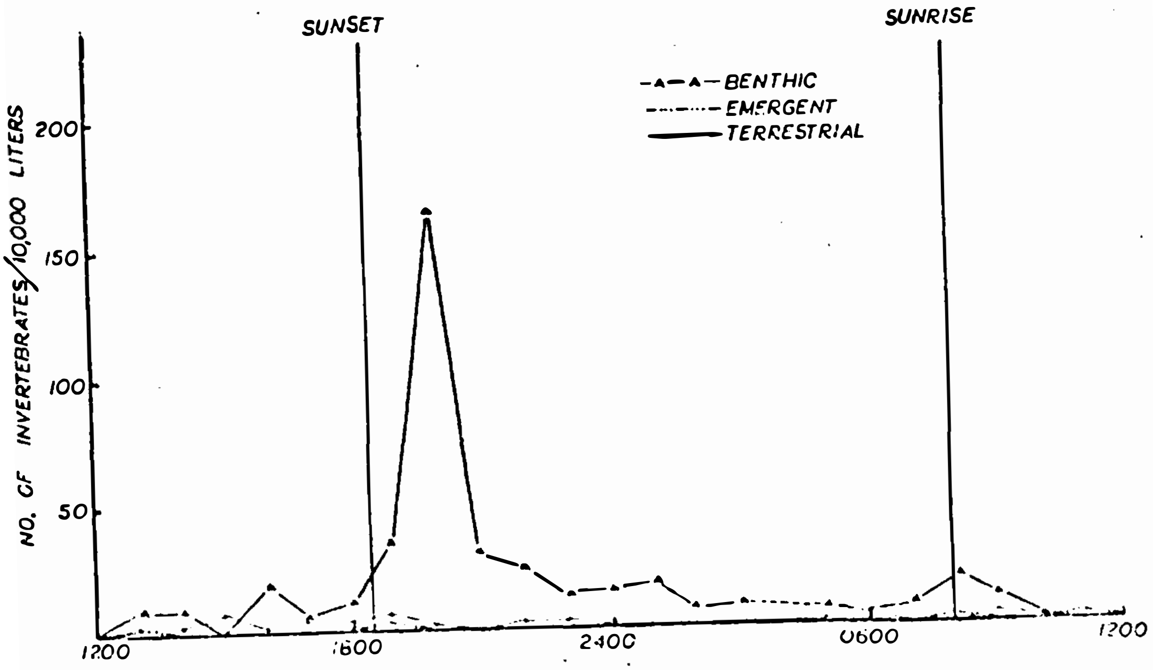

Figure 13. Number of drifting invertebrates by origin, October, 1973

Food Habits

Brook trout, Salvelinus fontinalis (Mitchill), were encountered throughout the study area but no attempt was made to assess their interaction with the brown trout. Kallemeyn (1968) studied the food habits of the initial stocking of brook trout in 1966. Insects constituted 85.2 percent by number of all organisms consumed by brook trout; the other 14.8 percent were mainly forage fishes and snails. By volume 93.9 percent of the insects eaten were benthic in origin, and the remainder were terrestrial. Trichoptera, Ephemeroptera, and Diptera made up 97.8 percent by volume of the aquatic insects ingested. By volume 86 percent of all invertebrates found in 108 brown trout stomachs was from the orders Trichoptera, Ephemeroptera, and Diptera. Some overlap, therefore, may have existed between the brown and brook trout for preferred food, but the extent to which this competition influenced their food habits was not assessed. Nyman (1971) studied the sympatric occurrence of brook and brown trout in Newfoundland and found that brook trout occupied the least favorable niches in pool or shallow rapid areas. No food segregation between the two species was apparent. Nyman observed low food selectivity for both brook and brown trout and no species specific food habits were noted.

The brown trout stocked into the South Fork of the Yellowbank River were reared on pelletized food in the McNenny National Fish Hatchery. The May collection was taken five days after stocking. Twenty-two trout taken in the May sample contained food and two stomachs were empty. The trout fed on a variety of benthic and terrestrial invertebrates, frogs, and fishes (Table 5). Robert (1960) studied hatchery-reared rainbow

Table 5. Number and frequency of occurrence (parentheses) of organisms in the stomachs and intestines of brown trout from the South Fork Yellowbank River, 1973.

	May		June		July		August		September		October	
	215		250		216		79		123		115	
Total organisms	24		19		18		17		16		14	
Number of trout	#	%	#	%	#	%	#	%	#	%	#	%
Rana pipiens	13	(33)	7	(26)	12	(44)	5	(24)	9	(38)	14	(57)
Unidentified minnows	12	(21)	16	(47)	5	(17)	2	(12)	10	(38)	6	(21)
Nematomorpha							3	(18)				
Decapoda	4	(21)	14	(32)	6	(33)	6	(35)	5	(25)		
Amphipoda			1	(5)								
Diplopoda							1	(6)	1	(6)		
Ephemeroptera adults	61	(17)	5	(21)	1	(6)						
Baetidae nymph	43	(46)	78	(63)	31	(67)	15	(41)	58	(81)	4	(21)
Heptageniidae nymph	15	(42)	50	(47)	13	(50)	1	(6)	4	(19)	2	(14)
Agrionidae nymph	2	(8)	4	(16)					1	(6)		
Orthoptera							1	(6)	4	(6)		
Hemiptera adult									1	(6)		
Corixidae adults	3	(13)			1	(5)			1	(6)	3	(21)

Table 5. (Continued)

	May		June		July		August		September		October	
Total organisms	215		250		216		79		123		115	
Number of trout	24		19		18		17		16		14	
	#	%	#	%	#	%	#	%	#	%	#	%
Notonectidae adult									1	(6)		
Cicadellidae adults					6	(22)	3	(12)	2	(6)		
Membracidae adult					1	(5)						
Coleoptera adults	13	(29)	5	(21)	12	(89)	1	(6)	2	(13)	1	(7)
Carabidae adults	7	(8)			8	(17)	1	(6)	1	(6)		
Dytiscidae adults					3	(11)						
Elmidae larvae			3	(5)								
Gerridae adult					1	(5)						
Gyrinidae adult			1	(5)								
Haliplidae adult							1	(6)				
Trichoptera adults	3	(8)	1	(5)	32	(72)	7	(35)				
Trichoptera pupae							1	(6)				
Helicopsychidae larvae									1	(6)		

Table 5. (Continued)

	May		June		July		August		September		October	
	215		250		216		79		123		115	
Total organisms	24		19		18		17		16		14	
Number of trout	#	%	#	%	#	%	#	%	#	%	#	%
Hydropsychidae larvae	5	(17)	41	(47)	12	(22)	3	(12)	14	(38)		
Limnephilidae larvae	2	(8)			1	(5)			1	(6)	77	(71)
Lepidoptera larvae	2	(4)					2	(12)				
Diptera adults	9	(21)	9	(26)	12	(38)	6	(29)	2	(13)	1	(7)
Chironomidae larvae	5	(21)			2	(11)					2	(7)
Tipulidae adults					7	(28)	9	(29)				
Tipulidae larvae	10	(21)	3	(11)	9	(28)					2	(7)
Hymenoptera adults					3	(22)	2	(6)				
Formicidae	1	(4)	3	(11)	32	(39)	5	(18)	3	(6)		
Arachnida adults	1	(4)	1	(5)	2	(11)	1	(6)	1	(6)		
Unidentified Gastropoda	3	(8)	8	(37)	5	(22)					2	(14)
Completely empty	1		1		1		1				1	
Intestinal parasite											1	
Number of organisms/trout	8.96		13.16		12.0		4.53		7.75		8.21	

trout, Salmo gairdneri Richardson, which were released into a river and found that newly introduced trout had fewer organisms in their stomachs than native trout. Raney and Lachner (1942) studied the stomachs of 26 brown trout two days after stocking and found that 10 were empty. Of the 16 trout which had eaten, 82 percent contained benthic insects from two orders, Diptera and Ephemeroptera. Additional stomachs were examined 16 days after stocking and all were found to contain organisms. Raney and Lachner reported positive correlation between the number of empty stomachs and abundance of food organisms for two separate streams. Webster and Little (1942) found empty stomachs in 2 out of 20 recently-stocked brown trout. One trout had eaten a frog; two contained fishes; and all had consumed a variety of invertebrates. Webster and Little (1944) in a second study examined the stomach contents of 40 brown trout caught by angling 20-27 hours after stocking and reported that all trout had fed on benthic organisms. Ninety percent of the insects consumed by trout in the second study were mayflies and the other 10 percent were dipteran and trichopteran larvae. Apparently hatchery-reared brown trout quickly learn to utilize natural food.

The relative fullness of trout stomachs was recorded in the present study using an arbitrary scale (empty, trace, 1/8, 1/4, 1/2, 3/4, and full). Numbers of stomachs were summed by sampling periods for each category of the scale. These sums were added together for all six months and expressed as frequency of occurrence (Figure 14). Empty, trace, and 1/8 full stomachs were considered to indicate little or no feeding activity and 1/2, 3/4, and full stomachs were taken to indicate active feeding. The most active feeding time was period VI, or early

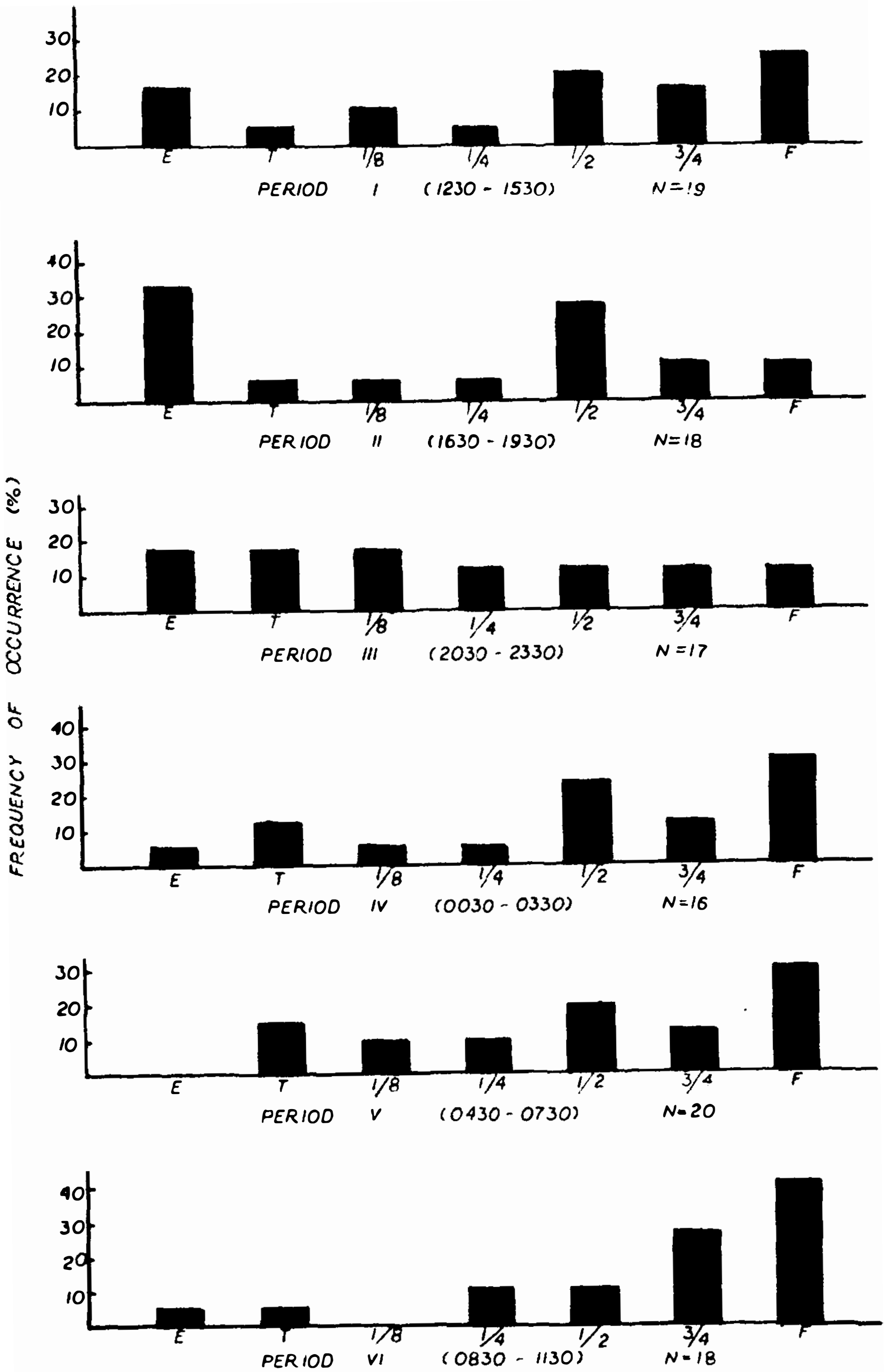

Figure 14. Relative fullness of brown trout stomachs for each period expressed as frequency of occurrence, May to October, 1973. (E - empty T - trace F - full)

morning, with 78 percent of the trout exhibiting active feeding and only 12 percent little or no feeding activity. Food items in stomachs collected at 1130 in the May sample were mostly aquatic insects. One trout contained terrestrial beetles and adult dipterans, and two trout had eaten fishes. Trout collected at 1030 in the June sample had eaten a large number of small crayfish and benthic insects plus a few emergent adults and terrestrial beetles. Trout collected at 1130 in the July sample had eaten mostly frogs. All trout had captured emergent adult insects and terrestrial beetles. Fishes were the most abundant forage organism for trout collected at 0930 in the August sample. The main invertebrates utilized were emergent adult and terrestrial beetles. Frogs, fishes, and nine baetid nymphs were the only items consumed by two trout collected at 1130 in the September sample. One trout collected at 1130 in the October sample had eaten nine limnephilid larvae and the other trout stomach contained a large frog.

The next two most active feeding times were periods IV and V respectively (69 percent and 65 percent of all trout taken at those periods were actively feeding and in both periods 25 percent exhibited little or no feeding activity). Feeding apparently occurred during the night and/or just before sunrise. Aquatic insects were the most abundant food items eaten during periods IV and V. Trout stomachs contained nearly equal numbers of benthic, emergent, and terrestrial insects in the July and August samples. Two fish also had eaten frogs. Fishes and some benthic insects were eaten during periods IV and V in the September sample and frogs and limnephilid larvae were the only items consumed in the October sample for these periods. Feeding activity was lowest near or just after sunset (period III) when 36 percent of the trout were actively feeding and 54 percent showed little or no feeding activity. In general, feeding activity increased after period III, reached a peak at period VI, and then gradually decreased to a low at period III. A similar feeding pattern was suggested by the mean biomass of invertebrates consumed (Table 6). The mean biomass of food increased from period III to a peak at period VI and decreased to a minimum at period II. These results are not in complete agreement with Chaston (1968a) who stated that feeding was purely coincidental with increased activity at night. Increased nighttime activity and increased feeding did coincide in the present study if the stomach contents were taken as representative of food consumed three or more hours prior to sampling. Elliot (1967), using 4 hours as a digestion and evacuation time for brown trout, found the presence of organisms in the stomach indicated most active feeding activity during the early hours of the night. It is also possible that daily changes in feeding activity may be linked with changes in water temperature. Pentelow (1939) conducted a controlled feeding experiment using Gammarus pulex L. and found that appetite of brown trout increased with rising temperature to 15.6 C and decreased above this temperature. The warmer daytime water temperature in the South Fork of the Yellowbank River may have caused the decline in feeding activity during the day.

The nighttime feeding implied through this discussion did coincide with the increased behavioral drift patterns of stream invertebrates in this study. Terrestrial organisms were most important in relation to all drifting invertebrates during the day and in general, were more frequent in the stomach samples representing daylight hours. The increased feeding

Table 6. Estimated mean biomass (mg dry weight) and number of invertebrates (parentheses) per brown trout stomach from the South Fork Yellowbank River, 1973.

Date	Total # of trout	Sample period I 1230 - 1530	II 1630 - 1930	III 2030 - 2330	IV 0030 - 0330	V 0430 - 0730	VI 0830 - 1130
May	24	6.9 (0.5)	22.5 (4.0)	40.8 (2.5)	15.0 (1.3)	79.8 (6.0)	61.7 (11.3)
June	19	4.5 (0.7)	50.5 (7.0)	4.7 (2.0)	96.7 (19.0)	66.0 (12.7)	213.7 (26.7)
July	18	68.0 (12.7)	40.3 (5.0)	36.2 (7.7)	94.6 (13.3)	83.3 (21.0)	20.0 (6.0)
August	17	34.6 (1.5)	36.6 (2.0)	28.6 (4.0)	18.0 (2.7)	45.1 (2.3)	8.9 (3.0)
September	16	26.4 (5.7)	0.9 (1.0)	9.6 (2.5)	2.4 (0.5)	38.0 (6.3)	18.8 (3.3)
October	14	17.6 (1.0)	0.0 (0.0)	50.4 (2.5)	0.0 (0.0)	33.6 (2.0)	119.1 (4.0)
Total	108	26.3 (3.7)	25.1 (2.8)	28.4 (2.9)	37.8 (6.1)	57.6 (8.4)	73.7 (9.1)

on terrestrial organisms during the day agreed with a study conducted by Jenkins (1969) on artificially fed brown trout. Ants were introduced through a tube into the stream and feeding behavior was observed from a tower. Brown trout took a smaller percent of available ants at night than during the day.

Frogs and then fishes were the most abundant food items by volume and weight in brown trout stomachs. Frogs were abundant alongside the stream during the summer, and by October, they had congregated in pools. Fishes were abundant throughout the study area all summer. Fishes still recognizable in stomach samples included the blacknose dace, Rhinichthys atratulus (Hermann), the common shiner, Notropis cornutus (Mitchill), and the johnny darter, Etheostoma nigrum Rafinesque. Two workers (Idyll, 1942; Thomas, 1962) reported that fishes were important items in brown trout stomachs and Evans (1952) also mentioned frogs in his findings. Idyll (1942) reported that brown trout fry and fingerlings fed exclusively on insects, and larger trout fed more on fishes than insects. Mann and Orr (1969) studied 557 brown trout (most were from the age-class 0+) taken between 1600 and 1700. Trout less than 10 cm ate more chironomids and simulids but fewer amphipods and trichopteran larvae than larger trout. Fishes were the major food items of the few larger trout examined.

Insects were the dominant food by numbers; a few horsehair worms, crayfish, snails, and spiders were the other invertebrates consumed (Table 5). Caution must be used in interpreting Table 5 since differential digestion rates may result in overemphasizing hard-bodied insects and underemphasizing soft-bodied insects. Trichoptera were the most abundant insects in the brown trout diet by dry weight and volume and were second in number (Figure 15). Hydropsychid larvae and adults were the most abundant caddisflies consumed, except in October when trout consumed more limniphilid larvae. Trichopterans increased in abundance through the July sample when large numbers of adults were taken, decreased through the September sample, and increased again in October when 67 percent of all items eaten by the trout were limnephilid larvae (Figure 16). Morofsky (1940) studied stomachs from 290 brown trout and found Trichoptera to be the most abundant item eaten followed by Ephemeroptera and Diptera; insects constituted 92.6 percent of all organisms consumed. Slack (1934) studied the winter food habits of II+ (28-38 cm) brown trout and listed Trichoptera as third in abundance of food items. Gammarus sp. and Asellus sp. were the most abundant food item in the trout stomachs. Horton (1961) found that the selection of food organisms by brown trout varied over the summer as well as between age classes. In May and June, Trichoptera were most important for II+ trout but third in importance for I+ trout behind dipterans and ephemeropterans. In July and August, caddisflies were ranked third for II+ and second for I+ trout while in September and October Trichoptera were first for II+ trout and second in importance for I+ brown trout. Elliot (1967) also reported a differentiation for food between age classes with II+ fish preferring limnephilids, I+ preferring oligochaetes, and 0+ trout preferring baetid nymphs.

By volume and weight, dipterans were the second most abundant invertebrate consumed by brown trout (Figure 15). Large numbers of larvae and adult Tipula spp. were eaten from May through August and constituted most of the total weight and volume of Diptera consumed. Horton (1961)

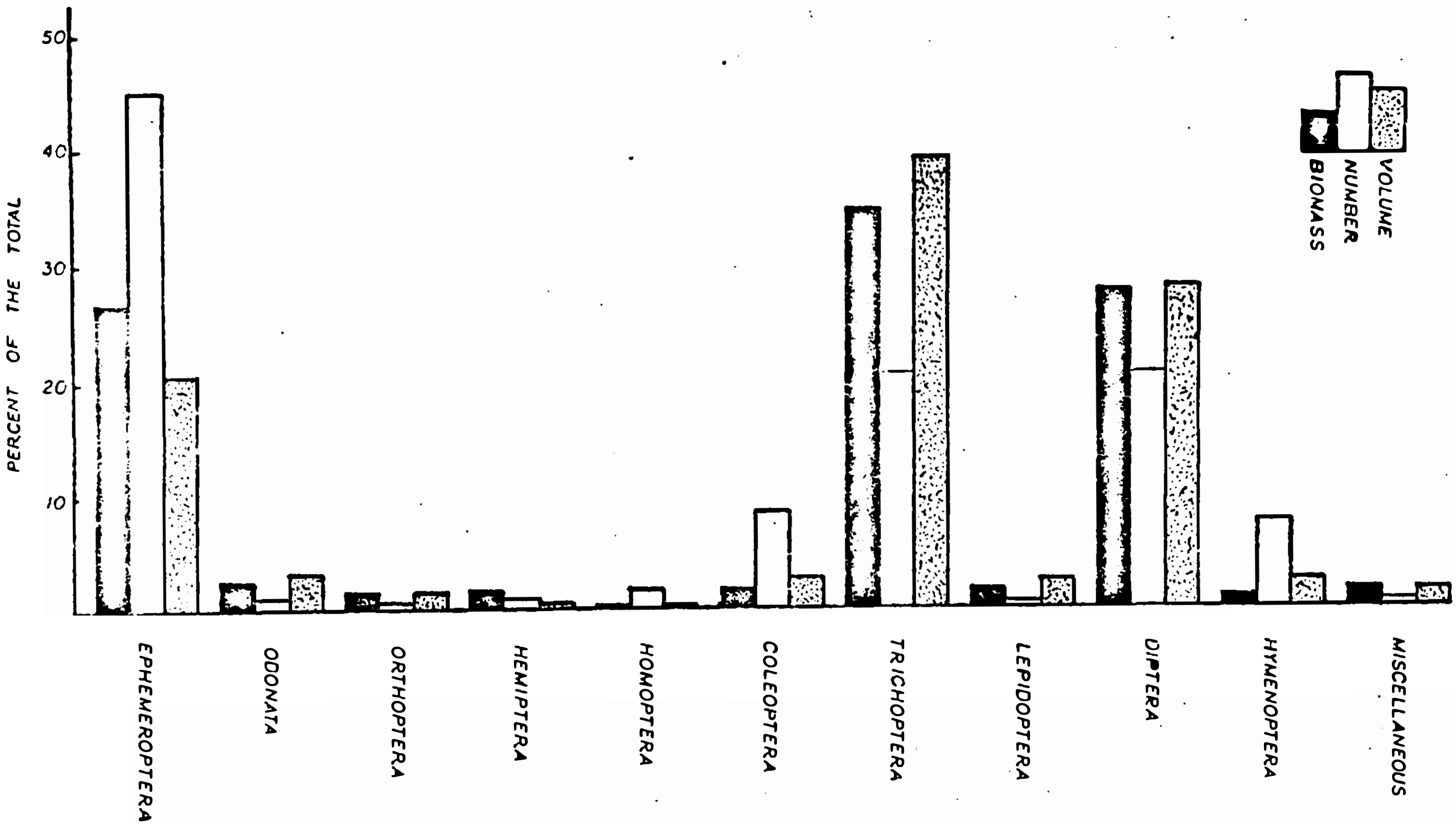

Figure 15. Biomass (mg dry weight), number, and volume (ml) of invertebrates in brown trout stomachs expressed as percent of total, May to October, 1973.

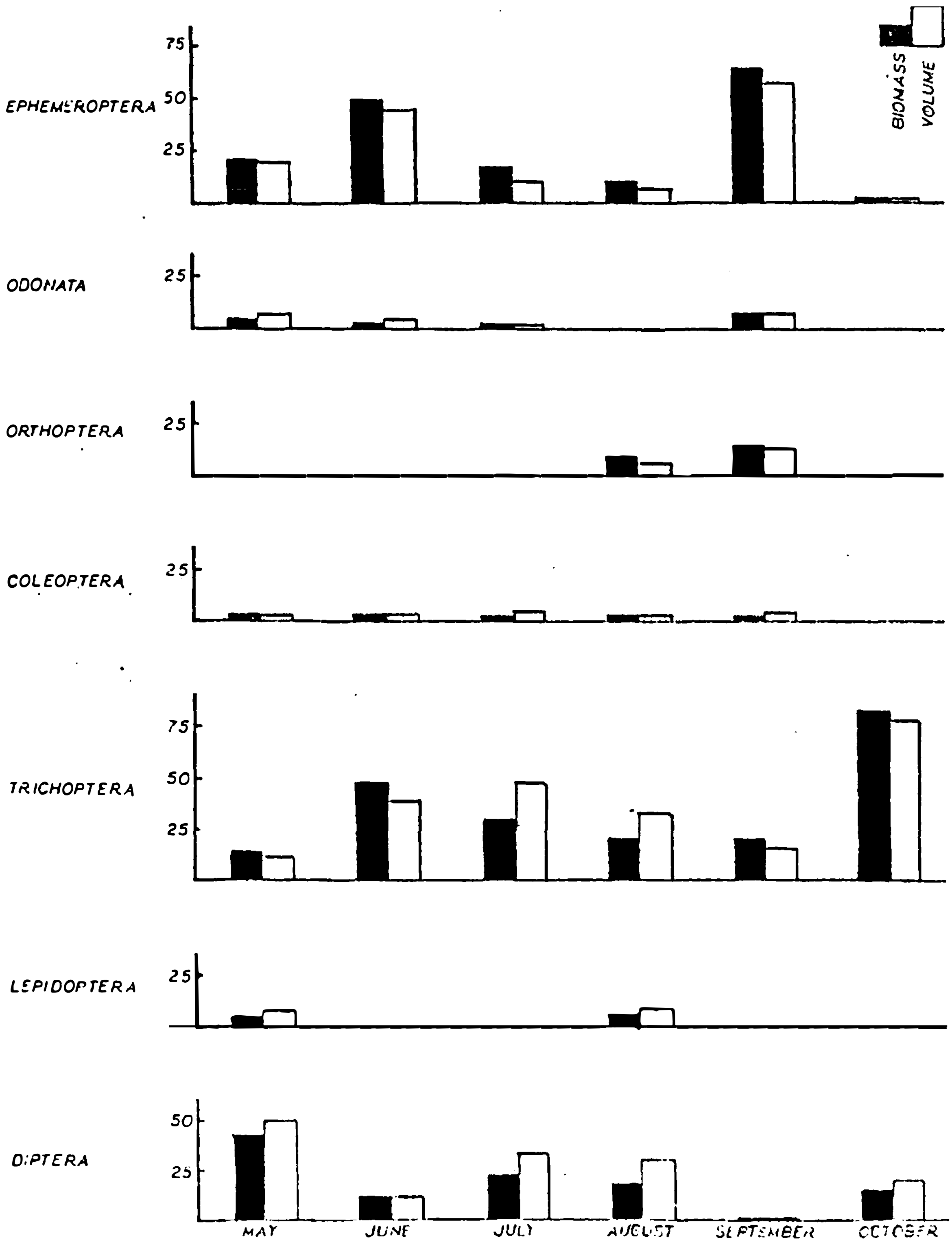

Figure 16. Biomass (mg dry weight) and volume (ml) expressed as percent of total for major insects in brown trout stomachs, 1973.

and Morofsky (1940) also listed dipterans as being most abundant in brown trout stomachs; ephemeropterans were slightly less abundant. Mayflies in the present study were most abundant by numbers and were from two families, Heptageniidae and Baetidae. A large number of heptageniid nymphs were eaten in June whereas large numbers of baetids were eaten in May, June, and August (Table 5). Adult Ephemeroptera were important only in the May sample. Coleoptera and Hymenoptera were abundant only in numbers with many small individuals ingested by the trout.

Frost and Brown (1967) concluded that trout were unspecialized carnivores and fed mainly by sight. These authors cited studies where trout ate a greater portion of those species which were easily captured and conspicuous than those which were concealed or difficult to capture. At times trout fed exclusively on one species even though other species were equally available. Bryan and Larkin (1972) studied specialization of feeding by brook, rainbow, and cutthroat trout (Salmo clarki Richardson) in a mark-recapture type experiment. Stomach contents from individual trout recaptured several times were more similar than stomach contents between trout taken at the same time. Degree of specialization was highest over short periods between capture and recapture. It was not necessary for a trout to feed in the same area to obtain food similar to that eaten previously. Bryan and Larkin reported that individual trout specialized on different prey from the same area with each trout eating only part of the entire list of prey taken by all members of the population. It is difficult to say whether this relation held true for brown trout in this study. Often a brown trout examined in the present study contained only frog or fish remains in its alimentary canal, and other brown trout contained only insect remains.

There seemed to be some degree of selection by brown trout with respect to the origin of food items (Table 7). The surface only category included trout which had eaten either terrestrial insects, emergent insects, or both; the combination category included trout which had eaten terrestrial and benthic insects, emergent and benthic insects, or all three types; and the subsurface only category included those trout which had eaten benthic insects exclusively. Brown trout fed more on the surface during June, July, and August and they fed more on benthic insects in May, September, and October, if the combination group is considered along with surface only.

Brown trout appeared to take a larger percent of the available terrestrial drift than available emergent drift during the summer (Table 8). There were few insects in the stomachs or drift in the October sample. In a study by Allen (1938), brown trout fed primarily on temporary bottom fauna (insect larvae and pupae) from March through July and primarily on terrestrial insects taken from the surface from May through September. When all classes of food were available, trout fed more on the surface. In the study by Allen, trout over 40 cm were largely piscivorous and trout less than 40 cm were predominately insectivorous. Pentelow (1932) examined 237 trout caught by dry flies and found 18.2 percent fed on the surface only, 52.9 percent had eaten a combination diet, and 26 percent fed on the subsurface only.

Overall, the number of invertebrates consumed by trout in the study area increased sharply in the June and July samples and then decreased to the October low (Figure 17). In another study of brown trout, the

Table 7. Frequency occurrence of insects from three possible origins in brown trout stomachs from the South Fork Yellowbank River, 1973.

Origin of insects	May # %	June # %	July # %	August # %	September # %	October # %
Surface only	2 (8)	2(11)		5(29)	1 (6)	1 (7)
Combination	6(25)	8(42)	17(94)	6(35)	2(13)	
Subsurface only	11(46)	6(32)		2(12)	7(44)	8(57)
No insects[a]	5(21)	3(16)	1 (6)	4(24)	6(38)	5(36)
Total stomachs	24	19	18	17	16	14

[a]All months except September had one completely empty stomach

consumption of invertebrates also reached a peak in June and July and decreased sharply thereafter (Mann and Orr, 1969). Caution should be used in applying importance to small differences between mean numbers consumed in different months during this study since sample size was small.

The contribution of terrestrial and emergent invertebrates to the total number of organisms consumed by trout was small in the present study. In two samples, May at 1930 and July at 1730, terrestrial forms became more abundant in the trout stomachs than aquatic forms. One trout ate several carabids and muscid-type flies in the May sample and in July two trout had taken large numbers of ants and adult dipterans. Brown trout took emergent insects in low numbers every month except July when nighttime feeding on emergent forms increased. All emergent insects taken in the July sample were tipulid and trichopteran adults. This coincided with the increased nighttime drift of emergents and a rise in

Table 8. Total number of invertebrates in the drift and stomachs (number per trout in parentheses) of brown trout, South Fork Yellowbank River, 1973.

Type	May		June		July		August		September		October	
	Drift	Stomach	Drift	Stomach	Drift	Stomach	Drift	Stomach	Drift	Stomach	Drift	Stomach
Terrestrial	174	29 (1.2)	381	18 (0.9)	1017	78 (4.3)	855	16 (0.9)	395	7 (0.4)	41	1 (0.1)
Emergent	335	0 (0.0)	576	6 (0.3)	1089	46 (2.6)	1838	11 (0.6)	1153	0 (0.0)	8	0 (0.0)
Benthic	2728	67 (2.8)	998	165 (8.7)	1577	73 (4.0)	3448	19 (1.1)	2009	47 (2.9)	425	25 (1.7)
Total stomachs		24		19		18		17		16		14

number of tipulid and trichopteran adults drifting (Figure 7). Benthic forms were the most abundant invertebrate food items taken by trout every month and followed the general pattern of increased feeding during the night and early morning. There was a trend throughout the summer for increased feeding before sunrise and early morning on Ephemeroptera (primarily baetid numphs) and Trichoptera (hydropsychid larvae from May through September samples and limniphilid larvae in the October sample). Trout had a more random feeding pattern on dipteran larvae. Elliot (1967) reported that benthic forms were the most abundant food taken by brown trout with emerging Plecoptera, Trichoptera, and Diptera becoming important only during the night.

Correlation Between Drift and Feeding

The results of this study indicated that hatchery-reared brown trout were not utilizing the diel drift patterns of stream invertebrates. Drifting invertebrates were grouped into benthic, emergent, and terrestrial categories similar to that described by Elliot (1970a) and mean numbers for the four hours prior to the trout sample were computed. The same groupings were used for invertebrates found in the trout stomachs and mean numbers per fish were calculated. These two mean values became the pair of numbers representing that sampling period. The data did not fit a bivariate normal distribution, therefore, use of linear correlation was not justified. Spearman's non-parametric coefficient of rank correlation (r_S) was computed for the six resulting pairs of means from each month (Table 9). No r_s values were found to be significant at the 0.05 level. No real correlation between food consumed by brown trout and available drift existed for any of the six sampling dates. Elliot

(1970a) used Spearman's r_s and found significant correlation with I+ trout for benthic invertebrates in April and benthic, emergent, and terrestrial invertebrates in August. Elliot correlated the contents of four stomachs per sample, but only the contents of three trout stomachs per sample were correlated in the present study. Chaston (1969) reported correlation of brown trout feeding with the terrestrial component of the drift but not with the emergent or benthic.

The mean number of invertebrates per brown trout stomach was low in May when the total number of drifting invertebrates was high (Figure 17). Brown trout fed most heavily on invertebrates during the June and July samples. Drifting invertebrates had decreased and subsequently increased in numbers in July. The number of invertebrates eaten by trout decreased in the August sample when the number of drifting invertebrates was at a peak. The only real correlation occurred during the September and October samples when both numbers of invertebrates in brown trout stomachs and the drift declined.

There were indications that brown trout were utilizing drifting organisms to some extent (Table 10). In May and August, ephemeropterans were taken by trout in proportion to their occurrence in the drift; these were also the peak months for mayfly activity. Trout were utilizing a greater percentage of mayflies than were collected in the drift during June and September samples. June and September followed months of peak mayfly activity and some degree of food specialization may have occurred. Homoptera were eaten in near equal proportion to the drift for samples in August and September. Trout were feeding almost entirely on Cicadellidae, but the majority of Homoptera drift was minute Aphididae

Table 9. Correlation coefficient (r_s) between mean drift rates (for the 4 hours prior to sampling) and mean stomach contents of brown trout from the South Fork Yellowbank River, 1973.

Origin	May	June	July	August	September	October
Benthic	0.13	0.14	0.63	0.24	-0.03	-0.04
Emergent	0.0	-0.77	0.24	-0.23	0.0	0.0
Terrestrial	0.43	-0.01	-0.79	-0.01	0.71	0.37

in August and adult Cicadellidae in September. The only similarity between drift and trout feeding for Coleoptera and Trichoptera occurred during the September sample. Brown trout had eaten only terrestrial forms of Coleoptera. There were slightly more terrestrial than benthic beetles drifting in September. Drifting Diptera did not correlate with brown trout feeding during the study except in October (numbers were too small to imply association).

A different correlation was implied when number of invertebrates were totaled for all six months with respect to drift and stomach samples (Figure 18). Ephemeroptera, Odonata, Orthoptera, Hemiptera, Coleoptera, Trichoptera, Lepidoptera, and Hymenoptera were taken in larger proportions than occurred in the drift. Underestimates in the drift for Odonata, Orthoptera, and Hemiptera may have resulted from their size and origin. Larger floating insects may not have passed through the pool area before they were taken by a fish, and subsequently, these insects would not have been sampled. Ephemeroptera, Coleoptera, and Trichoptera were more abundant in stomachs than in the drift. The large number of small chironomid adults in the drift may have accounted for the large difference in

Table 10. Total numbers and percent occurrence (parentheses) of major drift and food insects for brown trout in the South Fork Yellowbank River, 1973.

Order	May		June		July		August		September		October	
	Drift	Stomach	Drift	Stomach	Drift	Stomach	Drift	Stomach	Drift	Stomach	Drift	Stomach
Ephemeroptera	1555 (50.0)	60 (52.0)	364 (19.6)	117 (72.7)	510 (14.3)	45 (23.2)	1537 (23.2)	16 (25.8)	1283 (36.8)	42 (77.8)	242 (54.9)	2 (7.7)
Hemiptera	2 (T)[a]	3 (2.6)	2 (T)		7 (T)	1 (T)	8 (T)		18 (T)	2 (3.7)	55 (12.5)	1 (3.8)
Homoptera	22 (T)		145 (7.9)		297 (8.3)	8 (4.1)	296 (4.9)	3 (4.8)	102 (2.9)	2 (3.7)	23 (5.2)	
Coleoptera	86 (2.8)	15 (13.0)	107 (5.7)	7 (4.3)	81 (2.3)	27 (13.9)	424 (7.0)	5 (8.1)	175 (5.0)	3 (5.6)	38 (8.6)	
Trichoptera	110 (3.5)	9 (7.8)	147 (7.9)	22 (13.7)	463 (13.0)	50 (25.8)	555 (9.1)	12 (19.4)	220 (6.3)	3 (5.6	34 (7.7)	20 (76.9)
Diptera	1297 (41.7)	23 (20.0)	1012 (54.4)	12 (7.5)	2031 (57.0)	24 (12.4)	3146 (51.8)	14 (22.6)	1594 (45.7)	1 (1.9)	45 (10.2)	3 (11.5)
Terrestrial	36 (1.2)	5 (4.3)	84 (4.5)	3 (1.9)	177 (5.0)	39 (20.1)	113 (1.9)	12 (19.4)	97 (2.8)	1 (1.9)	4 (T)	
Total	3108	115	1861	161	3566	194	6079	62	3489	54	441	26
Number of trout		24		19		18		17		16		14

[a]Less than 1%

dipterans. Only in July and August were adult dipterans eaten in large numbers by trout. Most drifting Hymenoptera were small wasps.

Drift was taken above the area sampled for trout and undoubtedly some organisms were dislodged and could have been made available to trout captured in later periods. This effect was minimized by choosing areas far enough upstream. McLay (1970) estimated that all invertebrates physically dislodged dropped out of the drift within 46 m (mean distance of 10.7 m). The rate at which insects returned to the substrate was a function of their size, shape, density, center of gravity, and behavior. Waters (1962b) pointed out that the number of drifting invertebrates decreased through pools and increased through riffles, and that differences occurred in drift between riffles. Even though these changes occurred, Waters found that daily drift into and out of stream sections was about equal. It was impossible to say whether the drift actually available to the trout was identical to that collected in the drift nets, but studies by Waters implied that general changes in the drift would be nearly the same for both areas. The use of hourly drift sampling provided an accurate estimate of the actual number of invertebrates drifting. There was too much debris collecting in the nets in this study to leave the drift nets in the water over 15 minutes. It was also felt that sampling only 15 minutes every hour would minimize the effects on natural drift patterns. Waters (1965) evaluated the effects of blocking the downstream movement of invertebrates on normal drift patterns. The reduction in drift rates decreased downstream and did not reach normal drift rates 38 m below the blocking net. In the present study, nets were placed several hundred meters upstream in an attempt to minimize this blocking effect.

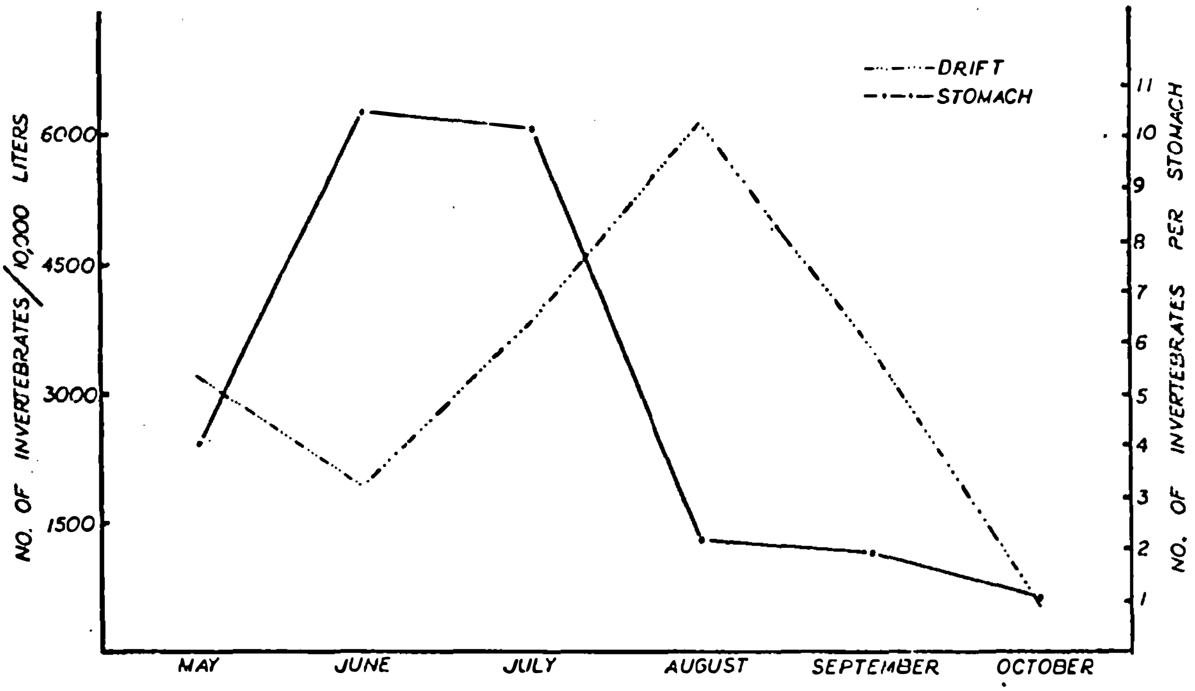

Figure 17. Total number of drifting invertebrates and mean number of invertebrates per brown trout stomach, 1973.

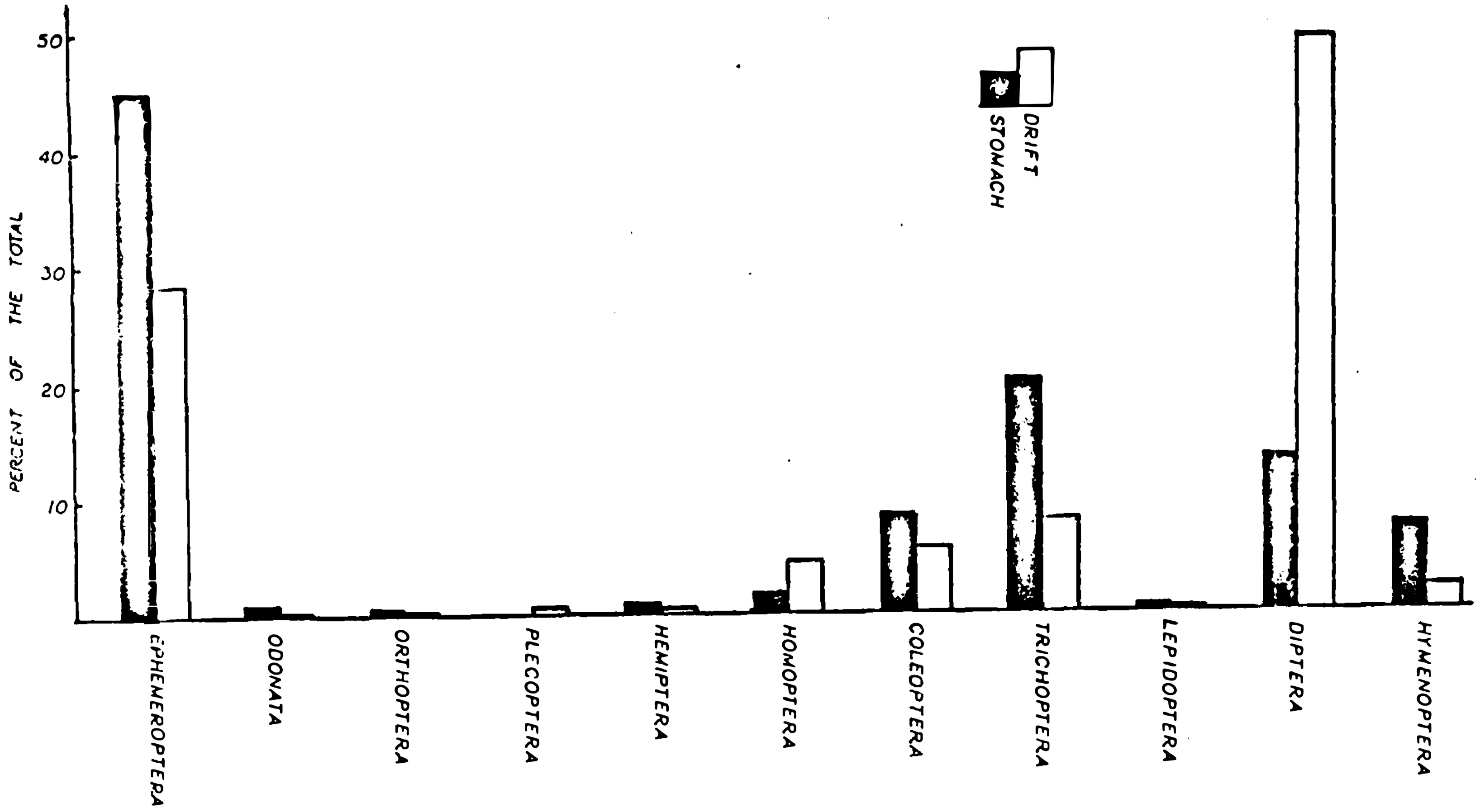

Figure 18. Major insects in brown trout stomachs and drift expressed as percent of total numbers, May to October, 1973.

The ability of insects to crawl or swim against a current created a problem. Several stoneflies were observed crawling out of the net and their numbers may have been underestimated.

There are inherent problems involved in working with stomach samples. Temperature can greatly affect the rate of digestion by fishes. Hewitt (1934) reported that trout required 24-36 hours to digest food at 10-13 C and one week at 4 C. Rainwater and Hess (1939) force-fed brook trout organisms with varying degree of chitinized material in their exoskeleton at different temperatures. Eighty percent of the hard-bodied insects were still in the stomach after 26 hours at 7.7 C and 60 percent were left after 45 hours at 5.6 C. Sixty percent of *Hydropsyche* sp. (medium amount of chitin) were present in the stomach after 17.5 hours at 11.3 C and 40 percent after 22 hours. Only 20 percent of *Chaoborus* sp., soft-bodied, remained in the stomach after 17.5 hours at 11.3 C. Remains of exoskeletons were found in the stomach up to 95 hours after feeding. Windell and Norris (1969), studying rainbow trout, also noted differential digestion rates between chitinized and unchitinized invertebrates. There was an initial four-hour lag period before digestion was noticeable on meal worms (chitinized), but no lag period was observed with oligochaetes (unchitinized). Both sets of trout were held at 15 C. Reimer (1957) force-fed rainbow trout stream invertebrates of various hardness and also noticed a differentiation in rate of digestion. Reimer calculated that all stomach contents were evacuated within four hours after consumption. No studies were found for digestion and evacuation of invertebrates by brown trout. Sharpe (1962) force-fed fathead minnows, *Pimephales promelas* Rafinesque, to brown trout and recorded complete digestion after 8 hours at 14 C. The variations in water temperature in the South Fork of the Yellowbank River could have affected the digestion rates of the brown trout taken during different months of the present study.

Rates of digestion and feeding activity may also be affected by time of last feeding. Windell (1967) studied bluegills, Lepomis macrochirus Rafinesque, which ate natural food at 20.8 C. All organisms tested (chironomids, crayfish, dragonflies, mayfly nymphs, mealworms, darters, and oligochaetes) were digested at the same rate. Chitinous material remained in the stomach longest. Windell postulated that debris in the stomach may serve as roughage to help break up material faster and allow quicker evacuation. Rates of digestion in bluegills starved for seven days was greatly reduced at each time interval. Starved fish also had a marked decrease in the size of the plyloric caeca (site of enzyme production and absorption). Bluegills that were allowed to eat until full rejected additional food. Brown trout may also require a longer digestion time if before feeding there was a long period when the stomach was empty. Invertebrates may remain in the stomach longer than the normal time for a given water temperature, and an overestimate may result. Likewise, trout having taken a large frog or fish may not feed on drifting invertebrates. On another day, this same fish may have readily taken drifting invertebrates.

Since no clear distinction could be made as to how long an organism had been in the stomach, all invertebrates were included in the counts. Elliot (1970) excluded from his stomach counts "non-drifting" invertebrates which were determined through a study of drift samples collected over 18 months. No determination of non-drifters was possible in this study and therefore, these organisms were also included in the stomach counts.

The problems mentioned with respect to evaluating digestion rates, feeding activity, and drift may all have contributed to the lack of correlation in the present study. The only positive association noted was the increased nighttime feeding activity and the increased numbers of drifting invertebrates at night. Newly-introduced hatchery trout may require a longer acclimation time before complete utilization of the diurnal drift patterns in the South Fork of the Yellowbank River develops.

SUMMARY

1. Hatchery-reared brown trout were stocked into the South Fork of the Yellowbank River May 17, 1973 and sampling began five days later. Drift data was taken for 15 minutes each hour and trout were collected every 4 hours with D.C. electric fishing gear. Sampling was limited to one 24-hour period each month from May through October.

2. There were two peaks in numbers of drifting stream invertebrates that occurred during the night in May, July, August, and September. There was only one peak in numbers drifting at night for the samples in June and October. Numbers of benthic and emergent insects were responsible for nighttime peaks; terrestrial invertebrates were more influential in daytime changes.

3. Dipterans were the most abundant organisms by numbers in the drift. Chironomid adults accounted for 60-90 percent of the emergent drift and chironomid larvae and pupae contributed to benthic drift in June, July, and August. Tipulid larvae and adults were abundant during June and July drift samples. Ephemeroptera were the second most abundant order of invertebrates in the drift with Baetidae and Caenidae contributing 95 percent of all mayflies collected. Trichoptera larvae and adults were the third most abundant drifting invertebrates. Hydropsychidae and Hydroptilidae comprised 93 percent of all caddisflies collected in the drift.

4. Mean brown trout condition factor R was 2.00 in the May sample, declined to a low of 1.78 in the August sample, increased to 2.07 in

the September sample, and declined again to 1.77 for the October sample. Mean length of brown trout increased from 22.8 cm to 26.8 cm, and mean weight increased from 147.4 gm to 219.8 gm between the May and October samples.

5. Frogs and fishes were the primary foods consumed during the study both by total volume and weight.

6. Brown trout feeding activity was high during the night, reached a peak in early morning, and declined during the day. Active night-time feeding correlated with the increased invertebrate drift during the night.

7. Brown trout ate a variety of invertebrates. Ephemeroptera (largely Baetidae) comprised 45 percent by numbers, 27 percent by weight, and 21 percent by volume of all invertebrates consumed. Trichoptera constituted 20 percent by numbers, 34 percent by weight, and 38 percent by volume of all invertebrates consumed. Diptera comprised 17 percent by numbers, 28 percent by weight, and 28 percent by volume of all invertebrates consumed.

8. Spearman's non-parametric coefficient of rank correlation (r_s) was used to measure the degree of association between mean drift rates and mean stomach contents of invertebrates. No correlation values were found to be significant for all six sampling dates. Brown trout examined in the present study were not exploiting the diel drift patterns of the stream invertebrates.

9. Problems in evaluating digestion rates, feeding habits, feeding activity and invertebrate drift may have contributed to the low correlation. Hatchery brown trout may require a longer acclimation time before full exploitation of invertebrate drift develops.

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APPENDIX

Table 11. Major vascular plants of the South Fork Yellowbank River, 1973.

Aquatic	Non-aquatic
Potamogeton zosteriformis Fernald	*Agrostis gigantea* Roth
Alisma Plantago-aquatica L.	*Elymus canadensis* L.
Glyceria sp.	*Rumex crispus* L.
Scirpus acutus Muhlenberg	*Polygonum ramosissimum* Michaux
Scirpus atrovirens Willdenow	*Aster simplex* Willdenow
Polygonum Hydropiper L.	*Nepeta Cataria* L.
Polygonum lapathifolium L.	*Oenothera biennis* L.
Lycopus asper Greene	*Verbena hastata* L.
Mentha arvensis var glabrata (Bentham) Fernald	*Lobelia siphilitica* L.
Veronica Anagallis-aquatica L.	
Bidens frondosa L.	

Table 12. Chemical and physical characteristics of the South Fork Yellowbank River, 1974.

	May	June	July	August	September	October
Specific conductance (micromho/cm at 25 C)	960	790	760	800	940	970
pH (units)	8.2	8.1	8.6	8.2	8.0	8.2
Turbidity (JTU)	23	3	0	12		
Total hardness (mg/L as $CaCO_3$)	480	420	390	380	440	480
Calcium hardness (mg/L as $CaCO_3$)	290	270	240	250	250	380
Total alkalinity (mg/L as $CaCO_3$)	290	275	250	270	290	290
Sodium (mg/L)	16	17		12	17	
Potassium (mg/L)	6.0	6.0		6.5	6.5	
Sulfates (mg/L as $SO_4^=$)	302	240	250	190		
Nitrates (mg/L as NO_3^-)	3.5	3.7	4.2	2.2		
Range of water temperature (C)	13-17	12-16	15-21	15-16	10-13	5-6

Table 13. Algae found within the study area, South Fork Yellowbank River, 1973.

CLASS CHLOROPHYCEAE
- Order Chlorococcales
  - Family Oocystaceae
    - *Ankistrodesmus* sp.
- Order Cladophorales
  - Family Cladophoraceae
    - *Cladophora* sp.
    - *Rhizoclonium* sp.
- Order Oedogoniales
  - Family Oedogoniaceae
    - *Oedogonium* sp.
- Order Ulotrichales
  - Family Ulotrichasceae
    - *Ulothrix* sp.
  - Family Chaetophoraceae
    - *Stigeoclonium* sp.
- Order Zygnematales
  - Family Zygnemataceae
    - *Spirogyra* sp.

CLASS XANTHOPHYCEAE
- Order Heterosiphonales
  - Family Vaucheriaceae
    - *Vaucheria* sp.

CLASS BACILLARIOPHYCEAE
- Order Bacillariales
  - Family Coscinodiscaceae
    - *Melosira* sp.
  - Family Cymbellaceae
    - *Cymbella* sp.
  - Family Fragilariaceae
    - *Fragilaria* sp.
    - *Meridion* sp.
    - *Synedra* sp.
  - Family Gomphonemaceae
    - *Gomphonema* sp.
  - Family Naviculaceae
    - *Gyrosigma* sp.
    - *Navicula* sp.
  - Family Nitzschiaceae
    - *Nitzschia* sp.

CLASS CRYPTOPHYCEAE
- Order Nemalionales
  - Family Batrachospermaceae
    - *Batrachospermum* sp.

CLASS MYXOPHYCEAE
- Order Oscillatoriales
  - Family Oscillatoriaceae
    - *Oscillatoria* sp.
    - *Pectonema* sp.

Table 14. Estimated number of fish in a 90 meter section of stream within the study area August 23, 1973.

Species	Estimate (N=728)
Salmo trutta L.	P[a]
Salvelinus fontinalis (Mitchill)	P
Esox lucius L.	P
Campostoma anomalum (Rafinesque)	186.4
Cyprinus carpio L.	P
Hybognathus hankinsoni Hubbs	135.0
Nocomis biguttas (Kirtland)	38.1
Notropis cornutus (Mitchill)	42.1
Notropis dorsalis (Agassiz)	35.5
Phoxinus eos (Cope)	P
Pimephales promelas Rafinesque	110.6
Rhinichthys atratulus (Hermann)	96.5
Semotilus atromaculatus (Mitchill)	152.9
Catostomus commersoni (Lacepede)	4.0
Ictalurus melas (Rafinesque)	P
Culaea inconstans (Kirtland)	1.0
Lepomis cyanellus Rafinesque	P
Lepomis humilis (Girard)	P
Etheostoma exile (Girard)	9.5
Etheostoma nigrum Rafinesque	16.5

[a]Present in the stream but not counted

Table 15. Mean number per square meter and percent composition (parentheses) of benthic insects from the South Fork Yellowbank River (August, 1973).

Number of samples	6		Number of samples	6	
Total organisms	2222	Percent	Total organisms	2222	Percent
EPHEMEROPTERA			Taeniopterygidae		
Baetidae			Taeniopteryx parvula	2.1	(T)
Baetis brunneicolor	75.3	(1.3)	COLEOPTERA		
Baetis phoebus	51.6	(3.3)	Dytiscidae		
Baetis phyllis	195.9	(4.9)	Agabus sp.	3.2	(T)
Baetis vagans	183.0	(4.6)	Loidessus affinis	3.2	(T)
Isonychia sp.	61.4	(1.5)	Elmidae		
Heptageniidae			Dubiraphia sp.	3.2	(T)
Stenonema sp.	75.3	(1.9)	Heterlimnius sp.	186.2	(4.8)
PLECOPTERA			Optioservus sp.	88.3	(2.3)
Perlidae			Ordobrevia sp.	26.9	(T)
Acroneuria arida	2.1	(T)[a]	Hydrophilidae		
Neoperla clymene	21.5	(T)	Laccobius agilis	2.1	(T)

[a]Less than 1%