1970

Productivity of Morrell Creek a mountain stream with an intermittant flow section Clark Fork drainage Montana

Robert Lee Newell
The University of Montana

PRODUCTIVITY OF MORRELL CREEK, A MOUNTAIN STREAM WITH AN INTERMITTENT FLOW SECTION, CLARK FORK DRAINAGE, MONTANA

by

ROBERT LEE NEWELL

B.S. Wildlife Technology, 1968
University of Montana

Presented in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN WILDLIFE BIOLOGY

UNIVERSITY OF MONTANA

1970

Approved by:

G. F. Weisel
Chairman, Board of Examiners

John M. Stewart
Dean, Graduate School

Date Aug 6, 1970

Montana
Newell,
R.L.

ACKNOWLEDGEMENTS

I appreciate the many hours of help given by my major professor, Dr. George F. Weisel. His suggestions, guidance, training, and encouragement were valued greatly. Monetary support supplied by him made this study possible.

My thanks are extended to Professors Reuben A. Diettert and John F. Tibbs for their critical reading of the manuscript, and to Mrs. Patricia Mitchell for her help in the identification of aquatic invertebrates.

I am also indebted to my fellow students, Mr. Burrell Buffington, Mr. Dale Burk, Mr. Jere Hightower, Mr. Lawrence Mitchell, and Mr. Harold Ramsey for their help in the collection of water and biological samples.

Finally, I would like to express my deep appreciation to my loving wife, Donna, and my daughter, Pamela, for their continued support, encouragement, patience, and understanding, and for their hours of assistance in the collection and analyses of samples.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF PLATES

CHAPTER I. INTRODUCTION

The assemblage of animals living on the bottom of a stream varies from time to time in number and variety for many reasons. Pollution has recently become a major cause of benthic variations and has stimulated the search for plant and animal indicators of water quality (Gaufin and Tarzwell, 1956; Hynes, 1962; Patrick, 1962). No single index species is as useful in revealing water conditions as the species composition of the stream community as a whole (Mackay, 1969). Present methods of evaluating water quality by indicator species rely mostly on aquatic insects, although other faunal and floral groups may prove to be more satisfactory indicators. One area of study which relates to organisms as indicators remains almost a void; that is, a knowledge of conditions in unpolluted waters.

For this investigation, a relatively untouched stream, Morrell Creek in western Montana, was chosen. The upper portion of this stream is in a pristine watershed.

The periphyton, algae, stream vegetation, water chemistry, benthos, adult insects, and mammals associated with Morrell Creek were studied in order to provide information on numbers, weights, species composition, and seasonal distribution. One of the sample sites was on a part of the stream with intermittent flow, which raised the question of repopulation and productivity relative to the other sampling sites.

Another intent of this investigation was to provide a base for future work on the stream relating to the effects of roading and logging on the water quality and benthos. The watershed is planned for clear-cutting with some selective logging in the next few years.

REVIEW OF THE LITERATURE

One of the most extensive investigations on stream ecology was conducted in Yellowstone National Park by Muttkowski (1925, 1929). He examined many streams in the park and considered all aspects of the biological, chemical, and physical relationships in these streams. Other benthic studies in Yellowstone Park have been conducted by Muttkowski and Smith (1929), Armitage (1958, 1961), and Heaton (1966). Some extensive stream ecology work was conducted by Minckley (1963) in a Kentucky stream.

Several workers have investigated stream benthos in other areas of the Rocky Mountains. In Montana, Linduska (1942) described mayfly distribution in relation to bottom type. Brown, et al. (1953) and Logan (1963) observed the effects of winter conditions on benthos. Knapp (1957) studied several benthic species in the Bitterroot River and Mitchell (1968) noted the insectivorous feeding habits of the water ouzel. Graham and Scott (1958, 1959), Schoenthal (1963), and Cope, et al. (1957) examined the effects of pesticides on benthos. In Utah, Moffett (1936) investigated the effect of flooding and measured repopulation due to drift, while Hazzard (1934) and Gaufin (1959) studied benthic productivity.

In Colorado, Dodds and Hisaw (1924a, b; 1925a, b) realized morphological adaptations occurred in stream dwelling insects. Knight (1965) and Nebeker (1968) investigated the distribution and adaptations of insects at high altitudes. Pennak and Van Gerpen (1947) correlated the relationship of invertebrates to various substrates. Tarzwell (1937, 1938) observed benthos in relation to substrate and alkilinity in several southwestern streams.

Various studies on coldwater streams have been done in other areas. Trout food relationships were studied by Needham (1928, 1933, 1934, 1938), Moore, et al. (1934), Surber (1936, 1951), Neill (1938), Mottley, et al. (1939), Allen (1940), Leonard (1941), Shockley (1949), Horton (1961), and Tebo and Hassler (1961).

The relationship of physical and chemical conditions to benthos has been investigated by Percival and Whitehead (1929), Ide (1935, 1940), Sprules (1940, 1947), Badcock (1954a, b), Needham and Usinger (1956), Scott (1958), Cordone, et al. (1961), and Jaag (1962). The effects of ice on benthos have received investigation from O'Donnell, et al. (1954), Maciolek and Needham (1951), and Benson (1955).

Observations on the drift of aquatic organisms are numerous; much of the earlier literature has been summarized by Müller (1954a, b), Waters (1961, 1965), and Elliott (1967). Additional references to drift as a natural and continuous phenomenon are Hunt (1965), Bailey (1966), Anderson (1967), Dimond (1967), Minshall (1967), and Bishop and Hynes (1969a, b). The magnitude of non-catastrophic drift in both biomass and numbers is often significant in respect to the standing crop (Waters, 1966) but fluctuates seasonally depending upon the life histories involved (Berner, 1951; Elliott, 1965, 1967).

Repopulation of eroded areas and colonization of new channels is often initiated by the drifting of an invertebrate fauna from upstream (Moffett, 1936; Surber, 1937; Leonard, 1942; Müller, 1954; Larimore, et al. 1959; Patrick, 1959). Recolonization of intermittent streams (Hynes, 1958; Harrison, 1966) occurs when the new fauna comes either from the subsurface in drought-resistant stages, or from adult immigration and oviposition. Other studies of intermittent streams and denuded areas have been done by Stehr, et al. (1939), Wene, et al. (1940), Larimore, et al. (1959), McWatters (1965), Clifford (1967), and Ulfstrand (1968a, b).

Water quality studies and water chemistry studies in the west have been carried out by Clarke (1924), Philipson (1954), Sylvester (1958), Livingstone (1963), Geological Survey (1965-67), Edington (1966), Harrel, et al. (1968), Kaushik, et al. (1968), Zimmerman (1968), Buscemi (1969), and Weisel and Newell (1970).

Periphyton studies are usually done in conjunction with other work. Gunitow (1955), however, conducted an extensive periphyton analysis on a Montana river and Whitford, et al. (1968) scrutinized several species of algae and found negative and positive responses to current.

CHAPTER II. MATERIALS AND METHODS

Weekly water samples were taken from midstream in one liter pyrex bottles after rinsing with creek water. Measurements completed immediately in the field included: oxygen, pH, carbon dioxide, alkalinity, and temperature. If the samples could not be analyzed upon returning to the lab, they were refrigerated and analyzed the next day. Samples were allowed to warm to room temperature for laboratory analysis.

The Hach Chemical Company portable engineer's laboratory, with additional pipettes and other glassware, were used for all chemical and physical determinations. The following analyses were made: temperature, carbon dioxide, chloride, chlorine, chromium, copper, fluoride, hydrogen sulfide, total iron, manganese, nitrate nitrogen, nitrite nitrogen, pH (wide range and thymol blue narrow range indicators), ortho phosphate, silica, sulfate, tannin and lignin, turbidity.

A Gurley Pygmy current meter (No. 625) was used for current determinations. The meter was placed in the center of the stream at approximately mid-depth. The velocity in feet/minute was then converted to feet/second. The volume of runoff was determined with the current meter and the formula devised by Robins and Crawford (1954):

$$R = \frac{W\ D\ a\ L}{T}$$

where R = stream flow in cubic feet per second
W = average width in feet over the section measured
D = average depth in feet over the section measured
L = length of section measured
T = time to traverse L
a = constant; 0.8 for rough bottom, 0.9 for smooth bottom.

The width of the stream was taken with a steel tape, and the depth with a yard stick to the nearest inch. The sampling site, chosen on the basis of parallel banks, even flow, and an even bottom, was used each time. Five depth recordings were taken each time and velocity was taken in three places.

Thirty-eight benthic samples were taken between June 27, 1967 and July 29, 1969, at intervals which varied from four to six weeks. These were taken with a Surber square foot bottom sampler. Each collection had three samples of stream bottom, taken along a transect across the creek, at each of the three stations. One sample was taken in the center and one between the center and each bank. This distribution was fairly representative of the various depths, velocities, and bottom types. All of the rocks within the sampler frame were rubbed to remove clinging organisms. Smaller rocks were stirred to ensure all organisms were removed. Each sample was placed in 70 percent alcohol. In the laboratory, the organisms were separated using a sugar flotation technique (Anderson, 1959), sorted into the lowest taxa, counted, and weighed. Volumes were determined by displacement in distilled water. Weights to the nearest milligram were determined on a Mettler balance after the organisms were placed on blotting paper for one minute at room temperature.

Samples from the station with the intermittent flow were removed from the dry creek bed by hand with a shovel, then flushed with water.

Adult insects were captured with an aerial net or swept from stream side vegetation. Adults were also picked from bridges and snow with forceps.

Weather data were obtained from the United States Forest Service weather station at Seely Lake, some three air miles from the stream.

Periphyton samples were collected by scraping rocks and by placing glass slides in the stream, for two to four week periods, and allowing periphyton to form. The live samples were examined under both dissecting and compound microscopes.

Immature and adult insects were keyed employing the following references: Needham, et al. (1935), Johannsen (1934, 1935, 1937a, b), Pennak (1953), Edmondson (1959), Jewett (1959), Usinger (1963), Gaufin, et al. (1966), Jensen (1966), and Nebeker (1966). Periphyton and algae were identified from: Smith (1950), Prescott (1954, 1968), Davis (1955), Palmer (1962), Kudo (1963), Garnet (1965), and Fassett (1966).

CHAPTER III. DESCRIPTION OF THE AREA

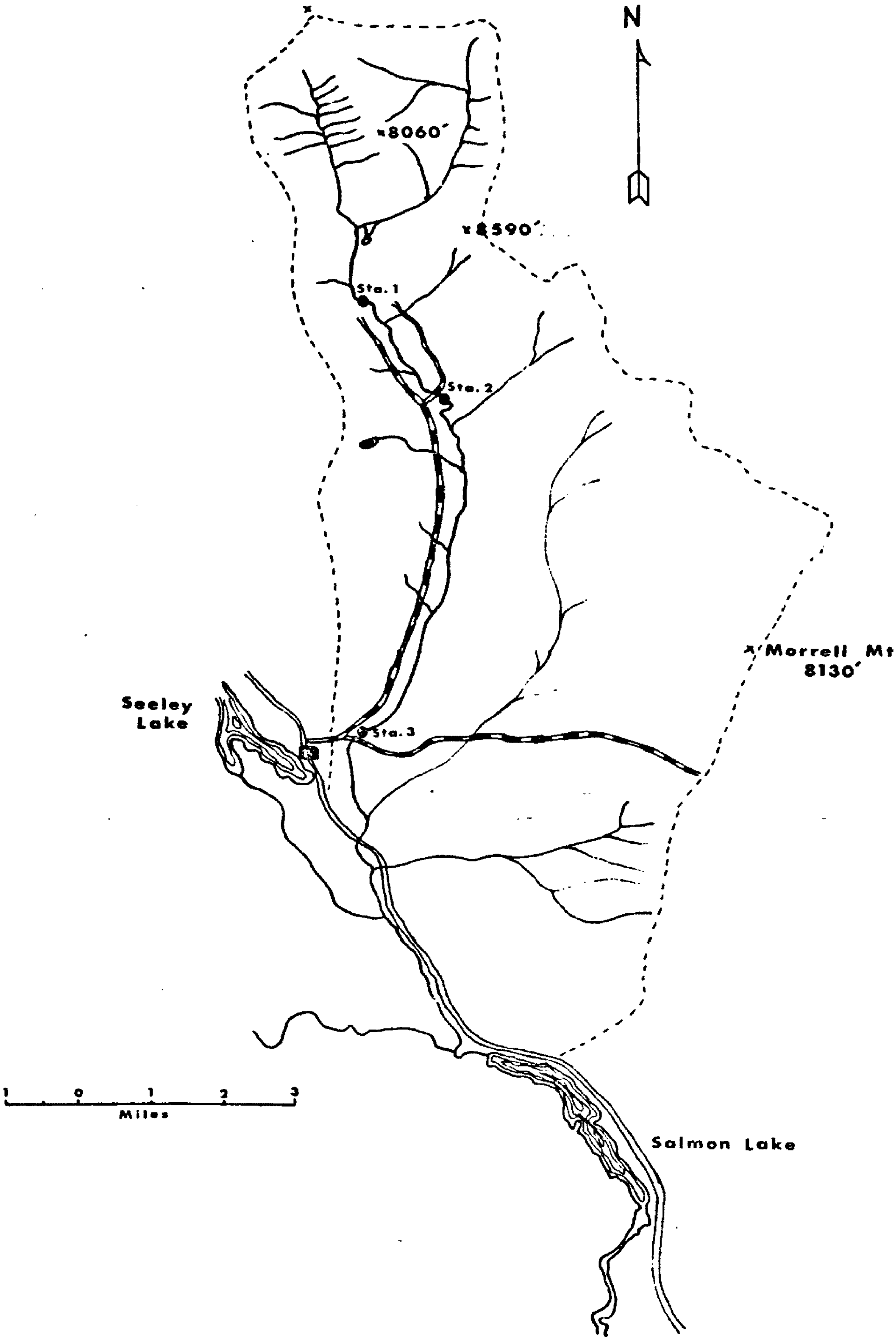
Morrell Creek drainage is within the Lolo National Forest of western Montana. It flows off the west slope of the Swan Range, which is the southwest boundary of the Bob Marshall Wilderness Area. The stream lies between 113° 30' - 20' West and 47° 30' - 10' North, T16-18N and R15 W. State highway 209 crosses Morrell Creek near the resort town of Seeley Lake, approximately 50 air miles NE of Missoula (Figure 1).

The creek originates from many small rivulets above timber line in the Swan Range. For its greatest part, Morrell Creek flows through spruce-fir climax zone. This zone is composed mostly of Engelmann Spruce (*Picea engelmannii*), sub-alpine fir (*Abies lasiocarpa*), and Douglas Fir (*Pseudotsuga menziesii*). Other conifers present include grand fir (*Abies grandis*), and lodgepole pine (*Pinus contorta*). Quaking aspen (*Populus tremuloides*) is also present close to the stream. Stream side willows include *Salix discolor*, *S. interior*, and probably other species. The understory is composed of various grasses, sedges, and bushes. In places, the willows and conifers form a canopy over the stream allowing very little light to reach the stream.

Morrell Creek is formed by the junction of two creeks that flow southwesterly out of the Swan Range. The eastern most fork flows from a hanging valley, disgorging in a waterfall of about 90 feet. A small lake of about five acres is present near the base of the falls. The outlet of this lake joins the northern fork and produces Morrell Creek proper.

The mountains in the drainage were formed in the Pre-Cambrian.

Figure 1.---Map of Morrell Creek showing the locations of sampling stations.


N
8060'
8590'
Sta. 1
Sta. 2
Sta. 3
Seeley Lake
Morrell Mt. 8130'
1 0 1 2 3
Miles
Salmon Lake

The Belt Series here is composed entirely of the Piegan group. These are mainly carbonate-bearing rocks, but the proportions and character of impurities in these rocks and the relations to non-carbonate rocks vary from place to place. They contain impure siliceous limestone, calcareous argillite, and quartzitic argillite.

From the meeting of the two forks downstream for approximately 12 miles, the stream flows through a valley of alluvial fill. For the remainder of its flow until joining the Clearwater River, Morrell Creek flows through morainal and outwash plain deposits of mountain glaciers, mainly ill-sorted and poorly rounded boulders, cobbles, pebbles, and sand with some alluvium (Ross, et al. 1955).

Three collecting stations were chosen. The station designated as station 1 is one and one-half miles upstream from station 2, at an elevation of 4700 feet. It is reached via a poor road that parallels the stream along the west bank. The station is at the end of the road. There were no roads beyond this point when the study began. At present there is a new road that proceeds further up the stream but it is about one-half mile from the stream along the west wall of the valley. The area around station 1 is pristine. The conifers and willows reach the banks and often form a canopy over the stream. The stream at this station averages 15 feet in width. The bottom is gravel and sand. The drought of 1968 was so severe that the creek was dry to station 1 for a period of two weeks.

Station 2 is six miles upstream from station 3 at an elevation of 4600 feet. The road that parallels the stream between stations 2 and 3 does not approach the creek until a spur road leaves the main road and crosses the creek at this station. The site is in a widened portion of the valley bottom. About six years ago this small flat was logged with almost all of the vegetation removed. The earth is gravel and sand. The stream from 200 yards upstream to 600 yards downstream from the bridge has an intermittent flow of water. Water is present in this section from May to July only (Plates 1 and 2).

Station 3 is approximately one and one-half miles east of the town of Seeley Lake, at an elevation of 4000 feet. It is near a Forest Service bridge. Here, the creek during the summer averages 20 feet in width and has a maximum velocity between 1.5 and 3.5 feet per second. There is a pool, with a maximum depth of 4 feet, and a shallow riffle. From the pool to about 50 feet below the bridge, the stream is a smooth run. The bottom is mostly gravel and sand with a few boulders which are about a foot in diameter. The gradient is 0.6 ft./100 feet. Except for a slight amount of fishing and picnicking, there has been little human disturbance. The timber is undisturbed along the banks and streamside willows are common (Plates 3 and 4).

The sampling sites are accessible by logging roads which are not always open in the winter. During the winter of 1967-68 the road to station 3 was open, but it was closed in the winter of 1968-69, necessitating a hike of one mile to reach it. Stations 1 and 2 are not accessible from December to April. Snow depth averages two to three feet for most of the winter. During both winters of the study, sheet ice formed over the creek for two or three weeks in January (Plate 5). This ice usually disappeared in late January and the stream remained open for the rest of the winter. Anchor ice, which seems to be more common to larger, more turbulent streams in northwestern Montana, never formed in Morrell Creek. Frazil ice also was never observed. Winter sampling

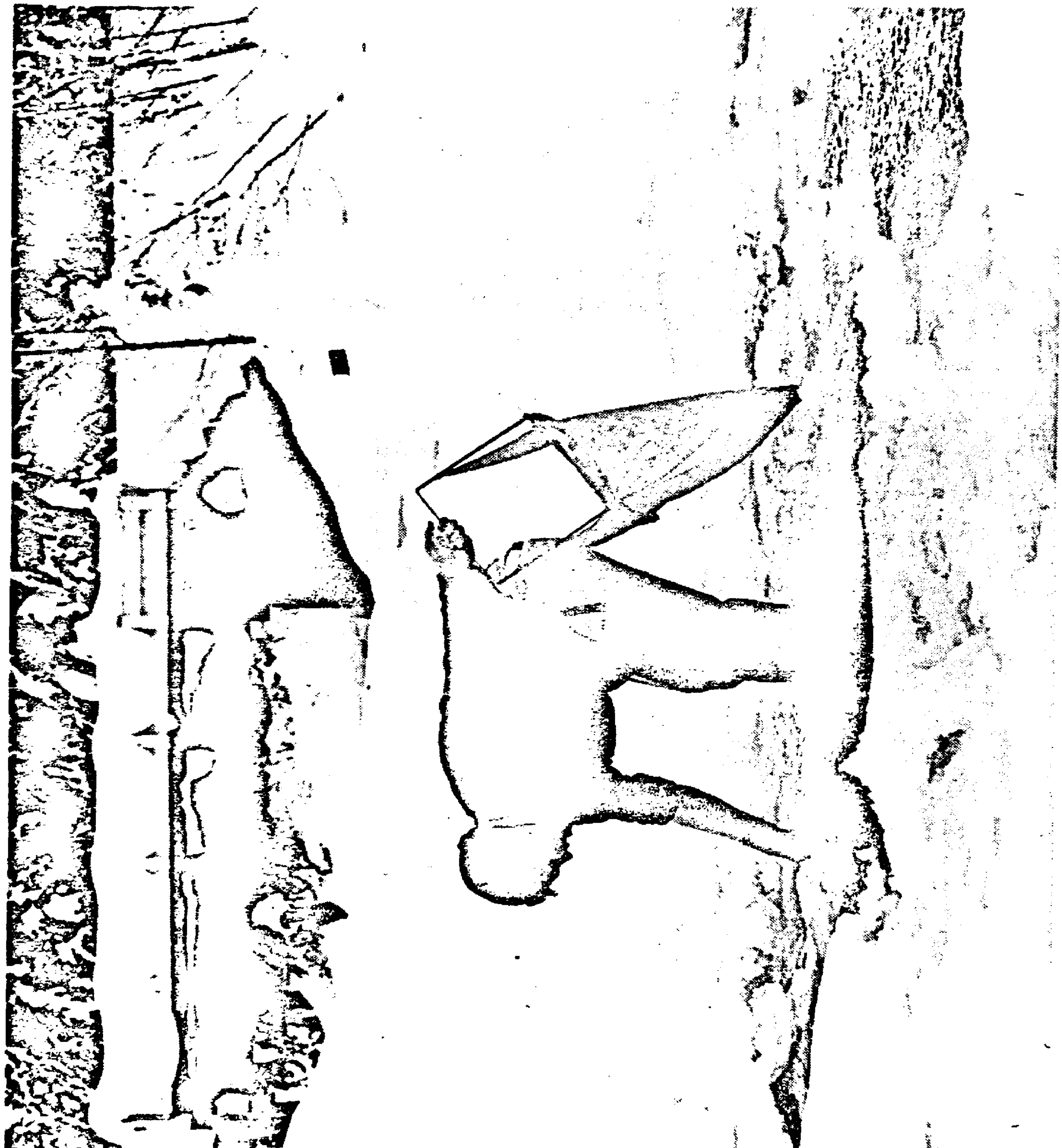
Plate 1.---Station 2 during the dry period, looking north.

Plate 2.---Station 2 during the dry period, looking south.

Plate 3.---Station 3 low water period (August),
looking north.

Plate 4.---Station 3 high water period (May),
looking north.

Plate 5.---Winter sampling, station 3 (January), looking south.



was more difficult than summer sampling. The sampler often froze and filled up with slush. The invertebrates usually had to be left in the sampler until the net could be thawed in the laboratory.

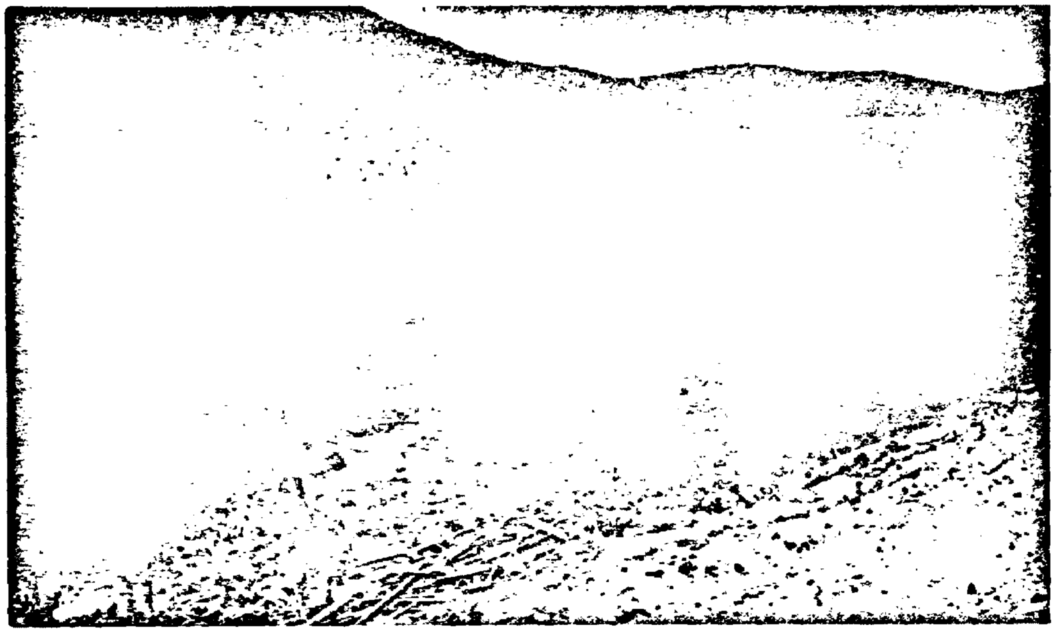
The volume of water in Morrell Creek varies considerably from season to season (Figure 13). At station 3, where the most complete data are available, the lowest flow occurred in March (11 cfs.), and the greatest occurred in June, 1969 (216 cfs.). Even during high water periods the creek never exceeded its banks. A flood plain is not present on Morrell Creek.

At station 2, which contains no water during most of the year, the greatest recorded flow was 41 cfs. in June, 1967. Underground flow occurs in this intermittent section. For a short period in November, 1967 and October to November, 1968, there was a slight flow at station 2. This is normally the dry period and flow at this time was caused by heavy rainfall. When water is present at station 2, the volume may or may not exceed the flow of station 1. Variations in underground flow and the presence of small streams and springs between stations 1 and 2 probably account for this.

Peak flow at station 1 was 107. cfs. in June, 1969. Low flow was 4 cfs. in October, 1967. This station was also dry for one sampling period in 1968.

Plate 6.---Station 2 from above, looking northwest.

Plate 7.---Highly turbid stream entering Morrell Creek below station 2, in August.



CHAPTER IV. RESULTS

CHEMICAL ANALYSES

The quality of water in Morrell Creek is excellent. Throughout the year the water is cool, clear, and most dissolved substances are present in amounts less than one milligram per liter. Generally, this is what would be expected from such an undisturbed stream in an area of almost insoluble bedrock.

Alkalinity - Methyl orange alkalinity varied between 43 and 80 mg/l. with a mean of 65 mg/l. The low occurred in July, the high in September. Station 3 had the highest values. The general trend was for alkalinity to increase as flow decreased in late summer and to decrease as runoff increased in the spring. There was no phenolphthalein alkalinity (Figure 2).

Carbon dioxide - This gas is present only in trace amounts, less than 2 mg/liter.

Chloride - This substance is present in trace amounts, less than 2.5 mg/liter.

Chlorine - All analyses were negative for chlorine.

Chromate - Values ranged from 0.03 to 0.07 mg/l. with a mean of 0.05 mg/liter.

Copper - Analyses with the Hach kit gave high values up to 0.27 mg/liter. The Delta Scientific analyzer revealed only trace amounts, less than 0.05 mg/liter.

Fluoride - Concentrations varied from 0 to 0.30 mg/l. with a mean of 0.10 mg/liter. About half of the samples recorded negative results.

No seasonal trends were observed.

Hardness - Total hardness varied from 45 to 90 mg/l. with a mean of 65 mg/liter. Calcium hardness was generally 10 mg/l. lower at each sampling date. Generally, the upstream stations recorded lower values. High stream flow coincides with reduced hardness. This situation is probably due to dilution from melting snow (Figure 3).

Hydrogen Sulfide - This gas was negative in all samples.

Iron, total - The low values recorded (0 to 0.10 mg/l.) could be analytical error.

Manganese - Values ranged from 0.01 to 0.75 mg/l. with a mean of 0.30 mg/liter. Highest values occurred from October to December, 1968. The lowest value recorded was at station 1 in November, 1967. No general trends were observed (Figure 4).

Nitrate nitrogen - Concentrations ranged from 0.03 to 0.12 mg/l. with a mean of 0.07 mg/liter. Highest values occurred during early summer. Although there are deer and elk in the drainage, there is no domestic grazing, which probably accounts for the low nitrate values.

Nitrite nitrogen - Recorded in trace amounts, less than 0.05 mg/l.

Oxygen - The oxygen concentration of Morrell Creek fluctuated between 7 and 13 mg/l. with a mean of 9 mg/liter. The high reading occurred in December and the low in August (Figure 6). The water had its greatest amount of dissolved oxygen in the winter when the water is coldest. Stations 1 and 2 were usually within 0.5 mg/l. of the values of station 3. The percent saturation varied similarly to the oxygen concentration. Highest saturation values occurred in February and December. The highest value recorded was in March when the saturation reached 112 percent. Figure 5 shows the mean of oxygen concentration. A 24-hour

Figure 2.---Alkalinity: monthly means at the three sampling stations.

Figure 3.---Hardness at the three stations.

Figure 4.---Manganese at the three stations.

Water Chemistry

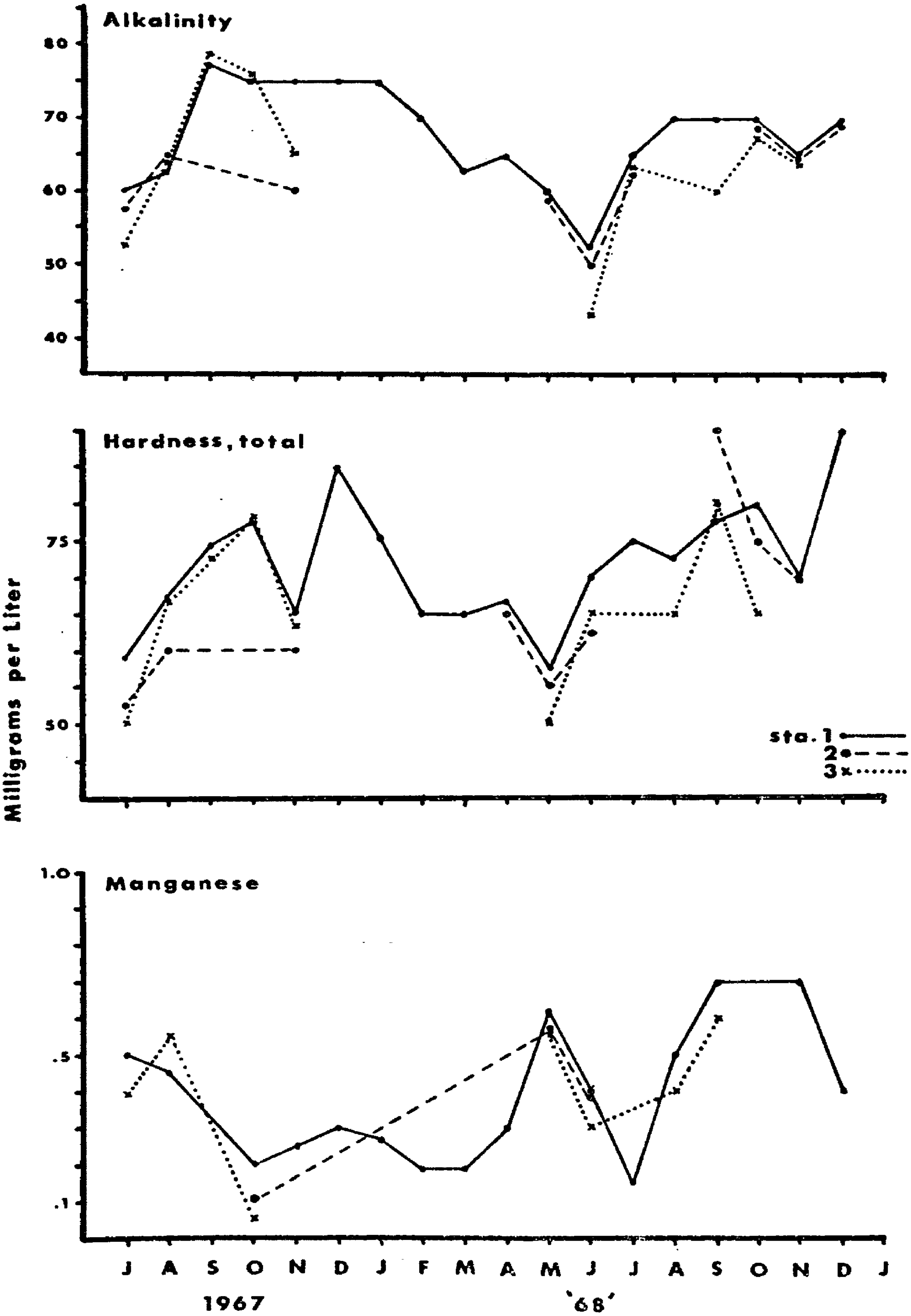
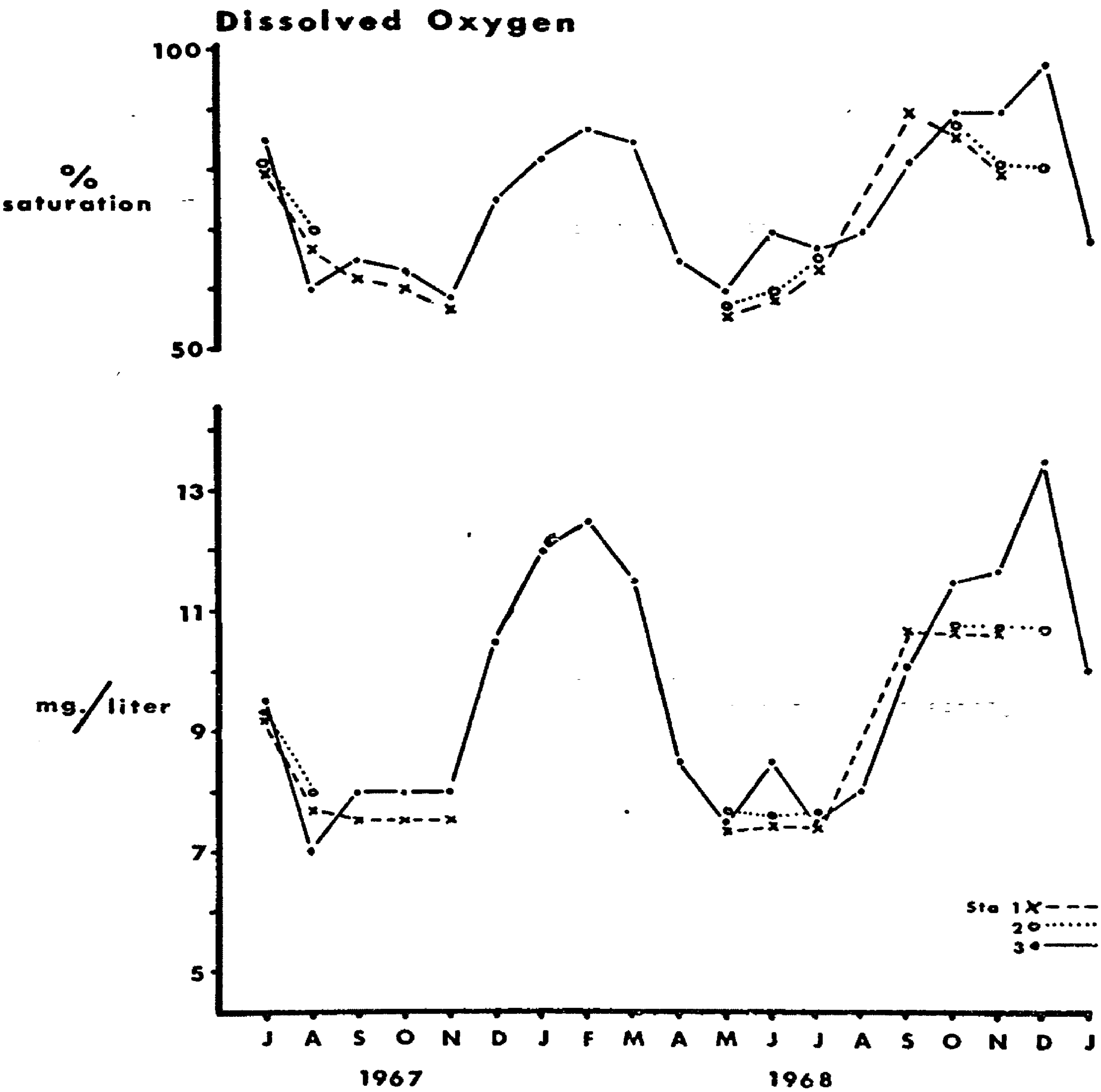


Figure 5.---Percent saturation of oxygen
at the three stations.

Figure 6.---Oxygen concentration at the
three stations.


Dissolved Oxygen
100
50
% saturation
13
11
9
7
5
mg./liter
Sta 1 X
2 o
3 •
J
A
S
O
N
D
J
F
M
A
M
J
J
A
S
O
N
D
J
1967
1968

sampling period in January and July, 1969, showed a change of no more than 0.5 mg/liter. This indicates that aquatic plants are not important to variations in dissolved oxygen.

pH - The pH of the stream was stable (Figure 7). It varied only from 7.5 to 8.6 in the two year period. No seasonal trends were observed.

Phosphate, ortho - Values ranged from 0.05 to 0.30 mg/l. with a mean of 0.15 mg/liter. Phosphate values at station 3 were stable except in the fall of 1967 and 1968 when high readings occurred. Station 3 had higher readings than the other stations.

Silica - Silica values for all stations were rather erratic and difficult to explain. The low values and differences could be due to analytical difficulties. The range was from 2.0 to 5.0 mg/l. with a mean of 4.0 mg/liter (Figure 8).

Sulfate - Sulfates were low (Figure 9). The highest value was 12 mg/l. at station 3 in March; the low was 3 mg/l. at station 3 in January. The mean was 7 mg/liter. Sulfate values were erratic.

Tannin and lignin - These were negative in Morrell Creek.

Turbidity - Turbidity never rose above 10 Jackson Units, a degree of turbidity undetectable to the human eye. The stream was very clear even during periods of high water. Neighboring streams in logged watersheds are never this clear during high runoff.

Water temperature - Stream temperature varied from a high of 52°F. to a low of 32°F. Figures 10 and 11 show the relationship between air and water temperature.

Table I shows a comparison between several streams of western Montana. Deer Creek and Pattee Creek were monitored from July, 1967 to July, 1968. Deer Creek is a few miles west of Morrell Creek and its

Figure 7.---pH for the three stations.

Figure 8.---Silica for the three stations.

Figure 9.---Sulfate for the three stations.

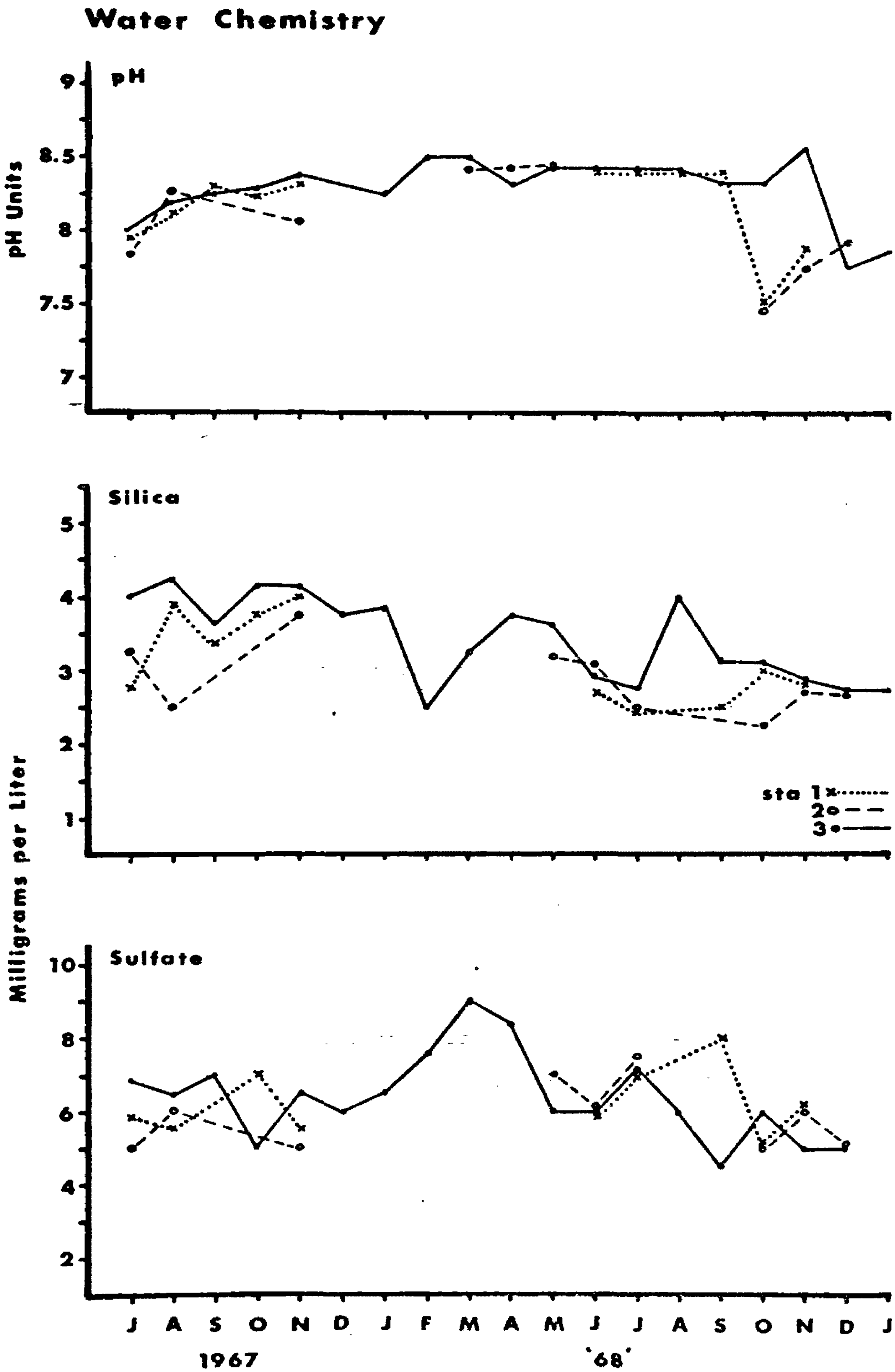

Water Chemistry
pH
pH Units
9
8.5
8
7.5
7
Silica
Milligrams per Liter
5
4
3
2
1
sta 1 x
2 o
3 •
Sulfate
10
8
6
4
2
J A S O N D J F M A M J J A S O N D J
1967
'68'

Figure 10.---Air temperature at the
Seeley Lake Ranger Station.

Figure 11.---Water temperature at station 3.

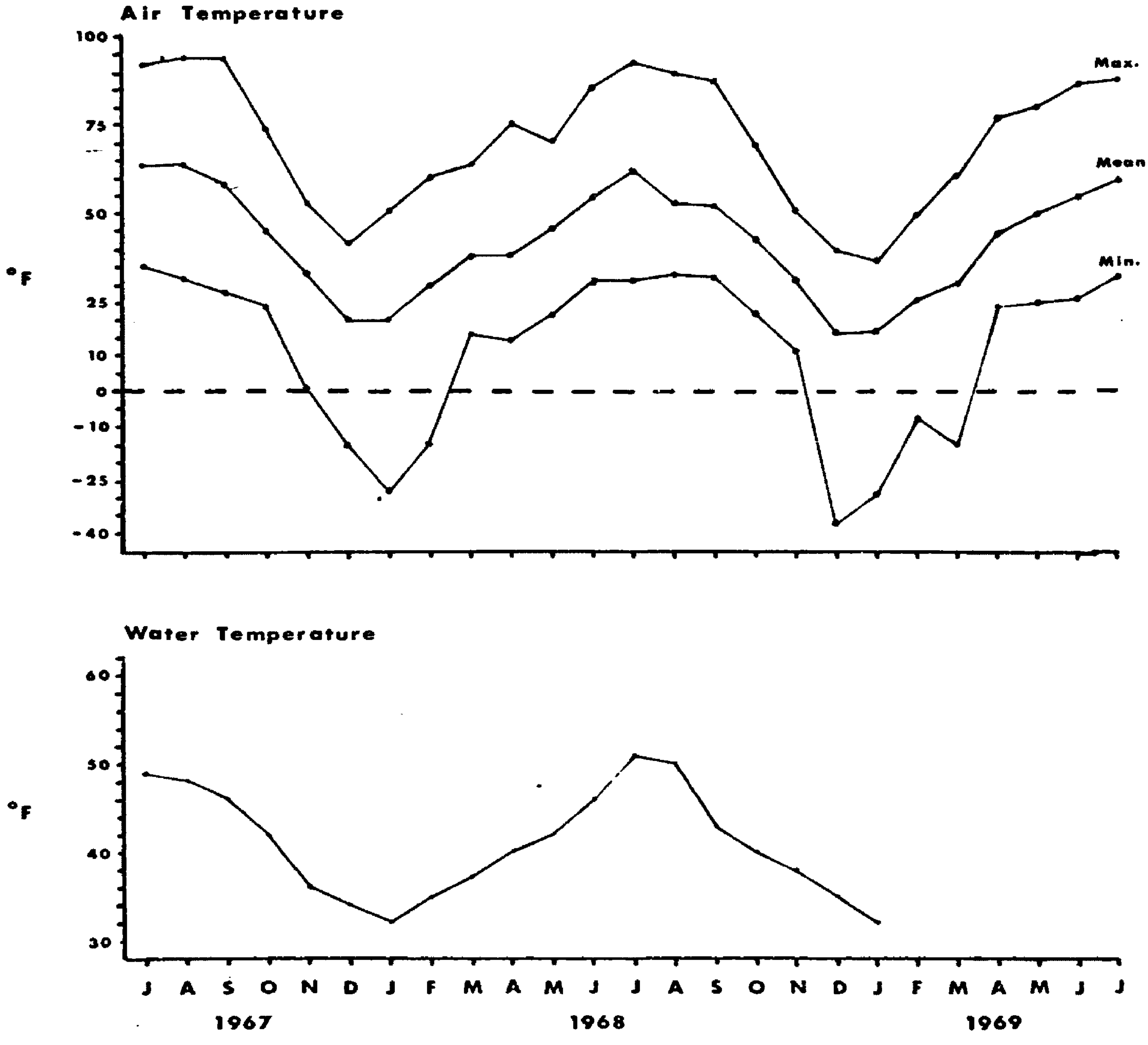
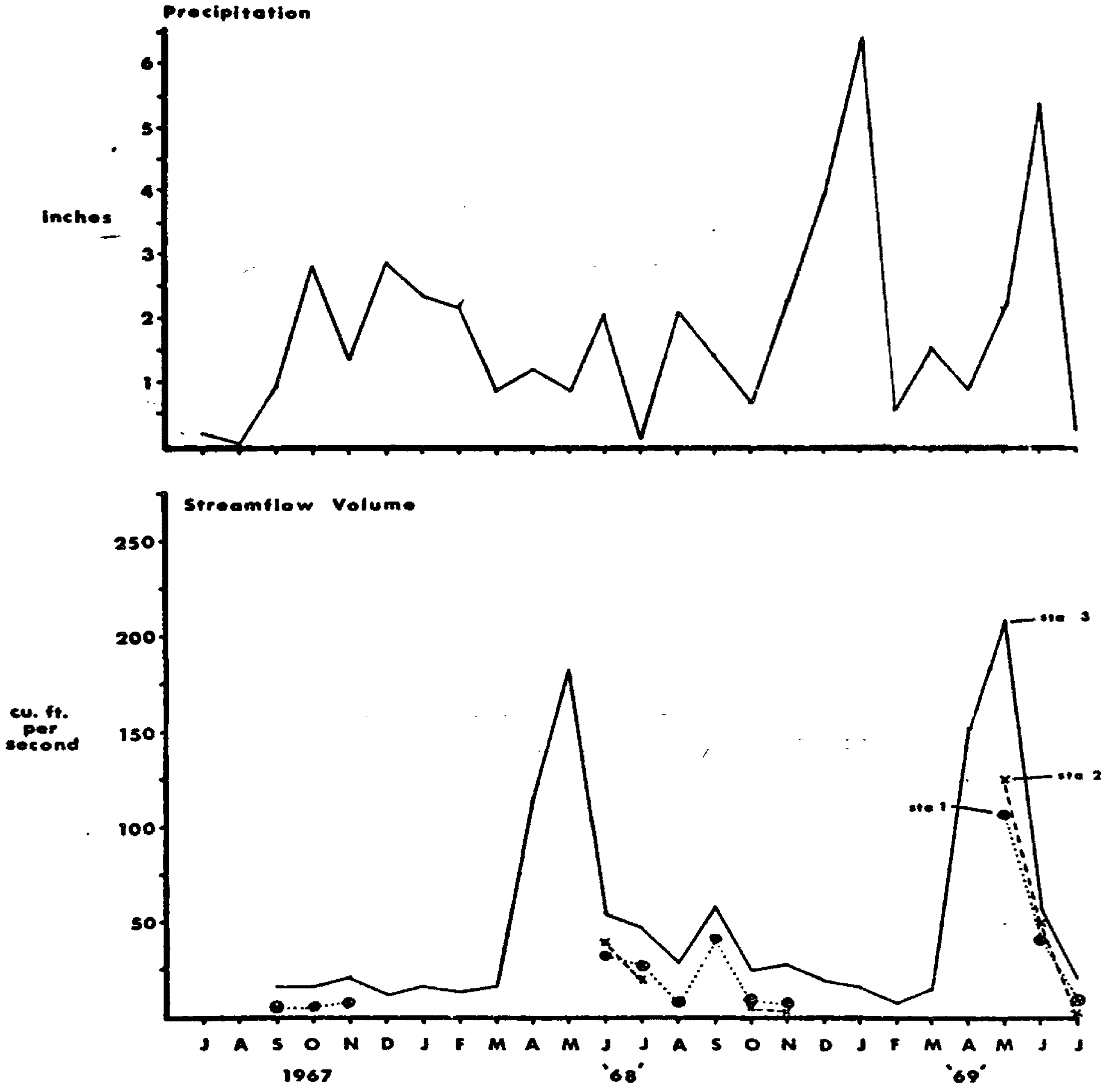

Air Temperature
100
75
50
25
10
0
-10
-25
-40
°F
Max.
Mean
Min.
Water Temperature
60
50
40
30
°F
J A S O N D J F M A M J J A S O N D J F M A M J J
1967
1968
1969

Figure 12.---Precipitation in inches at the
Seeley Lake Ranger Station.

Figure 13.---Volume of flow for the three stations.



Precipitation
inches
6
5
4
3
2
1
Streamflow Volume
cu. ft. per second
250
200
150
100
50
sta 3
sta 2
sta 1
J A S O N D J F M A M J J A S O N D J F M A M J J
1967
'68'
'69'

headwaters have been heavily logged. Pattee Creek is smaller than Morrell Creek and is only a mile from the University of Montana campus. It receives some wastes from humans and livestock. Pattee Creek and the Blackfoot River tributaries are generally higher in dissolved materials than Morrell Creek.

The Blackfoot River and 23 of its tributaries were analyzed from February, 1968 to February, 1969 (Weisel and Newell, 1970). These streams represent a variety of situations. Some, such as Montour Creek, are relatively untouched. Others receive domestic sewage, cattle wastes, mine wastes, logging caused siltation, and agricultural runoff.

TABLE I.---Data summary of water analyses in Morrell Creek, Deer Creek, and Pattee Creek, and 23 tributaries of the Blackfoot River. Average values in parentheses are given below the ranges. Turbidity expressed as J.T.U., other values as mg/liter.

	Morrell Cr.	Deer Cr.	Pattee Cr.	Tributaries
Iron	0-0.10 (0.04)	0.04-0.30 (0.12)	0-0.01 (0.01)	0-0.62 (0.11)
Copper	tr	tr	tr	0-0.12
Manganese	0.01-0.75 (0.30)	0.03-0.5 (0.29)	--	--
Silica	2-5 (4)	3-7 (5)	16-25 (19)	--
Chromate	0.03-0.07 (0.05)	0.04-0.1 (0.06)	--	--
Fluoride	0-0.30 (0.10)	0-0.25 (0.10)	0.05	--
Sulfate	3-12 (7)	4-11 (7)	4-15 (10)	0-79 (7)
Chloride	0-2.5 (2.5)	0-2.5 (2.5)	2.5-7.5 (3)	--
Phosphate	0.05-0.3 (0.15)	0.05-0.3 (0.15)	0.3-0.6 (0.43)	--
Nitrate	0.03-0.12 (0.07)	0.01-0.24 (0.08)	0.02-0.6 (0.2)	0-0.9 (0.12)
Nitrite	tr	tr	tr	--
Temperature °F	32-50 (41)	32-68 (48)	32-70 (48)	32-63 (43)
Turbidity	0-10 (3)	0-70 (15)	10-110 (31)	0-65 (4.3)
Oxygen	7-13 (9)	5-14 (8)	8-13 (10)	7-14 (10)
pH	7.5-8.6 (8.2)	7.6-8.6 (8.1)	7.5-8.6 (8.3)	6.6-8.4 (8.0)

TABLE I.---Continued.

	Morrell Cr.	Deer Cr.	Pattee Cr.	Tributaries
Alkalinity	50-80 (65)	20-70 (45)	30-100 (65)	--
Hardness Total	45-90 (65)	25-70 (45)	30-90 (58)	7-210 (116)
Hardness Calcium	35-70 (53)	10-55 (32)	20-50 (34)	--

Chlorine negative at all stations.
Hydrogen sulfide tests negative at all stations.
Tannin-lignin-like substances not above: 1mg/liter at all stations.
Phenolphthalein alkalinity zero at all stations.
CO_2 concentration usually zero at all stations, never greater than 2 mg/liter.

BENTHIC DATA AND THEIR INTERPRETATION

Measures of the density and biomass of the macroinvertebrate benthic population were estimated from 38 samples comprising an area of 114 square feet. Samples were taken over a period of 24 months. Each sample consisted of three square feet of bottom, insuring intensive sampling. The samples revealed 63 taxa of aquatic invertebrates, of which 57 were aquatic insects. A total of 16,083 invertebrates were sorted, counted, identified, and weighed. Extending these findings shows biomass to be 38.3 lbs/acre. Most data were obtained from the most accessible station 3.

Standing Crop. During the first year of the study no winter samples were taken. The 12 month period of July, 1968 to July, 1969 is the most complete. At station 3, the greatest number of organisms per square foot (500) occurred in November. The smallest number occurred in May, June, and July. This is reasonable, as many forms hatch in the spring. This is substantiated by the lower weights that occurred in the summer. The greatest weight from station 3 was 1.3 gm/sq.ft. in July; the lowest was 0.1 gm/sq.ft. in September. Station 2 had its greatest weight in July, 0.6 gm/sq.ft.; the lowest was 0.1 gm/sq.ft. in September (Figure 28). Station 1 had a high of 0.7 gm/sq.ft. in July and a low of 0.1 gm/sq.ft. in September (Figure 17).

The average number of organisms was 184/sq.ft. Their combined weights were 0.699 gm/sq.ft. at station 3; at station 2 70/sq.ft. weighing 0.18 gm.; at station 1 89/sq.ft. with a weight of 0.343 gm/sq.ft. The mean for the entire creek was 143 organisms/sq.ft. weighing 0.408 grams. Sampling error is probably greater in the spring when fast water washes some organisms from the net.

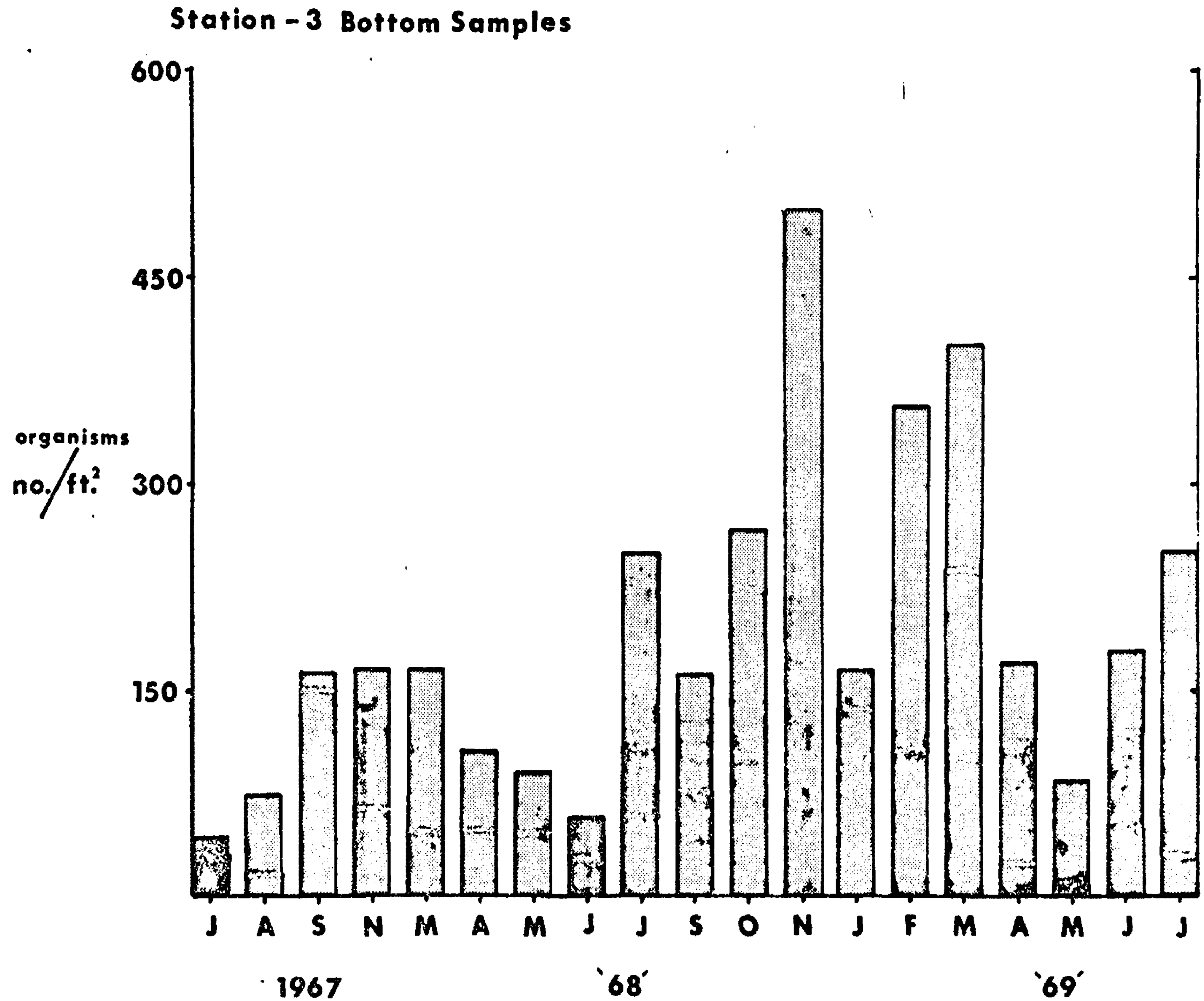
The benthic fauna of the study area is typical of unpolluted waters and similar to those described by Heaton (1966) and Gaufin and Tarzwell (1956). As previously mentioned, there were 63 taxa found with many identified only to genus and a few only to family. The five insect orders dominated the samples. The contribution of each taxon is discussed in the next section.

Although benthic organisms have definite distribution patterns in relation to velocity and/or substratum, this factor was not determined in Morrell Creek.

For the period from July, 1967 to July, 1968, the standing crop at station 3 was less than for following months, but the bulk was comparable. This was probably due to a change in technique. For the first year the bottom samples were field sorted. In doing this, the smaller invertebrates were excluded from the standing crop data. In the second year the samples were sorted in the laboratory. No bottom samples were taken during the winter of 1967-68, August, 1968, and the December, 1968 sample was lost by accident.

Benthic Invertebrates. The mayflies dominated all other groups comprising 65 percent of all invertebrates collected. Biomass comparisons were not made between the different orders, but one of the larger insects found was the mayfly, Ephemerella doddsi. For example, a bottom sample taken in July, 1969 showed 13 E. doddsi. They represented 1.7 percent of the numbers but 33 percent of the total weight. Baetis was the dominant genus. It comprised 20.8 percent of all Ephemeroptera and 13.5 percent of all invertebrates from the entire stream. This is 36.6 Baetis per square foot. Figure 18 shows standing crop of Baetis at station 3. The

Figure 14.---Organisms per square foot at station 3.



Station - 3 Bottom Samples
organisms
no./ft.²
600
450
300
150
J
A
S
N
M
A
M
J
J
S
O
N
J
F
M
A
M
J
J
1967
'68'
'69'

Figure 15.---Number of species and grams per square foot, station 3.

Bottom Samples

Station - 3

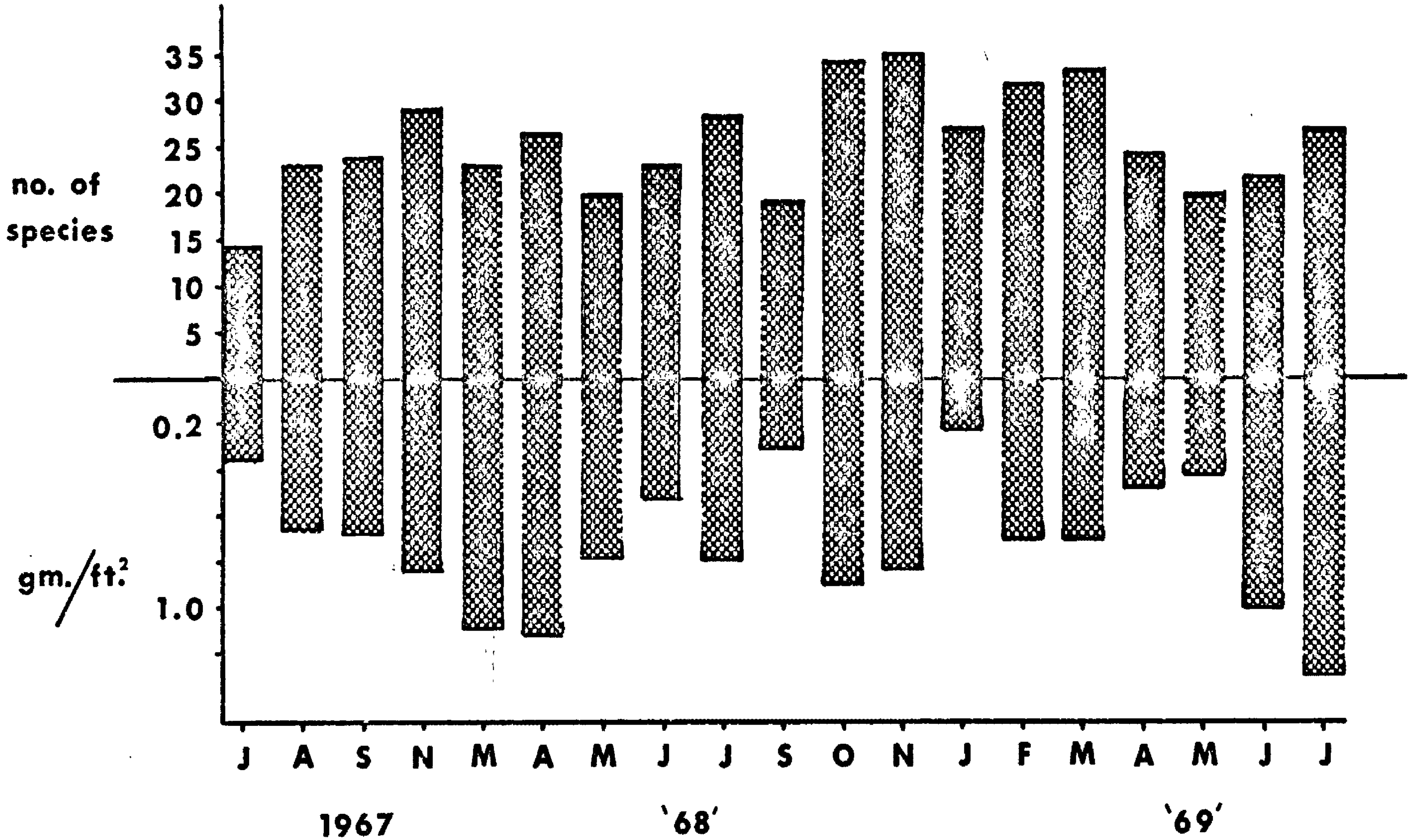


Figure 16.---Organisms per square foot at station 1.

Station -1 Bottom Samples

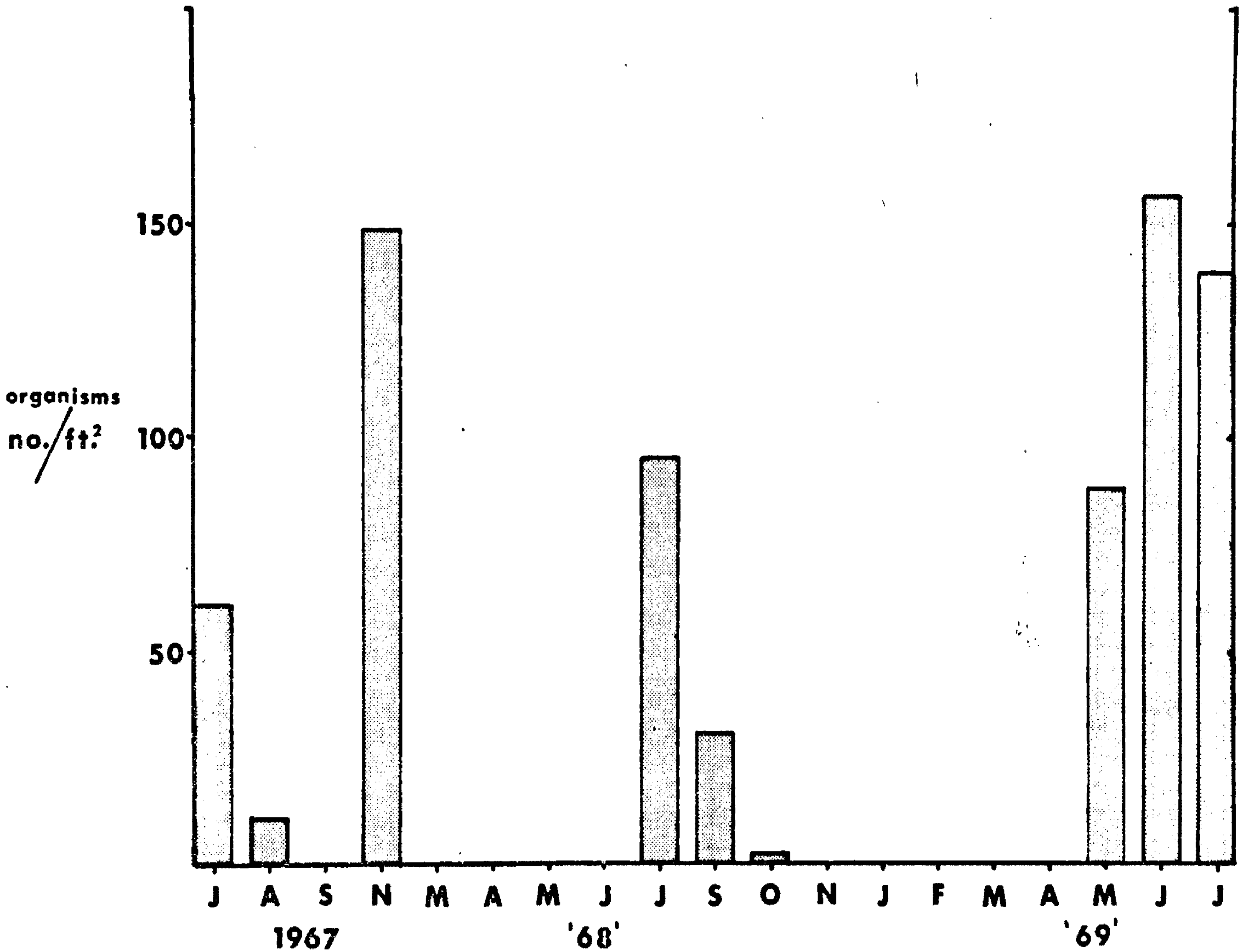


Figure 17.---Number of species and grams per square foot, station 1.

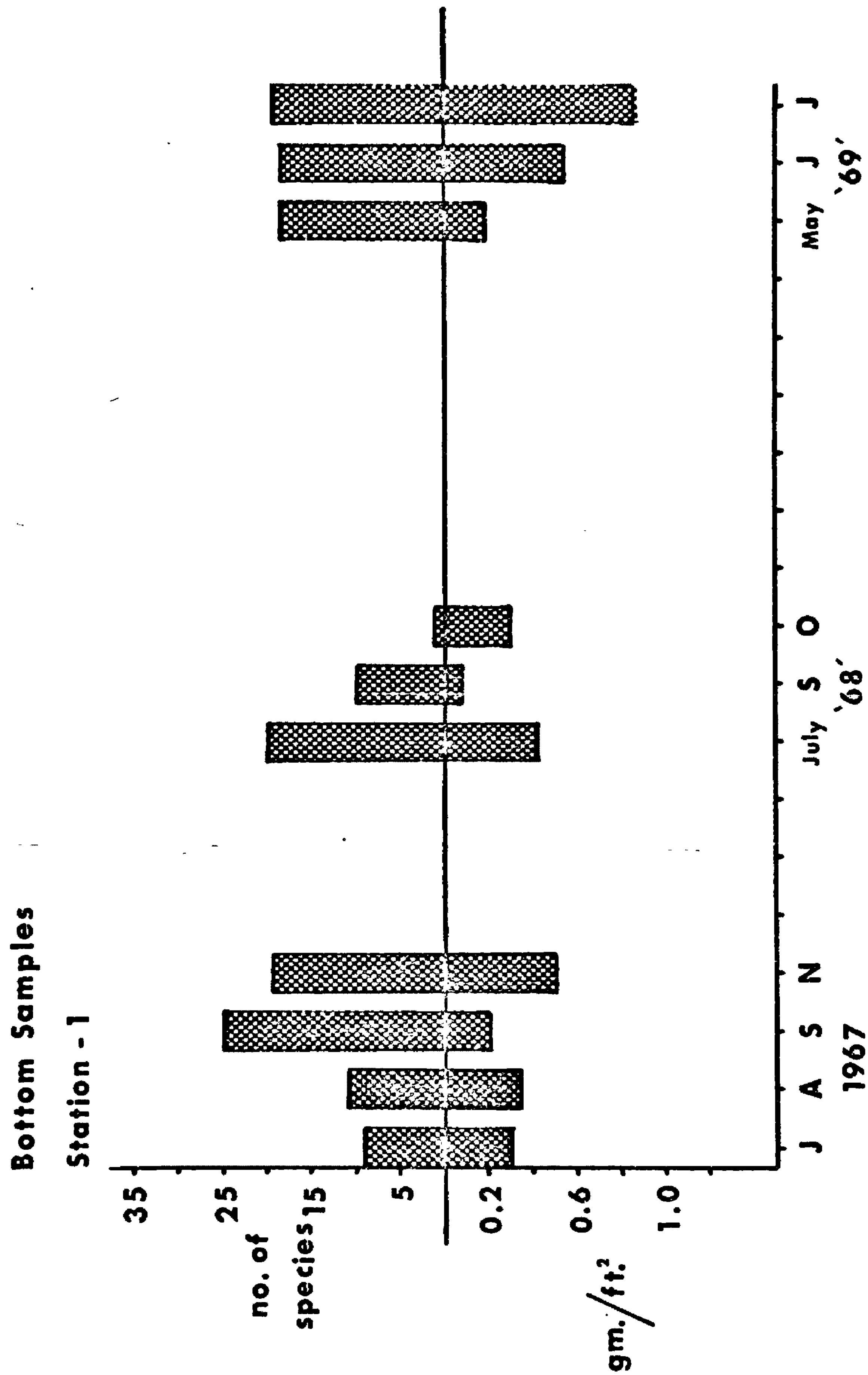
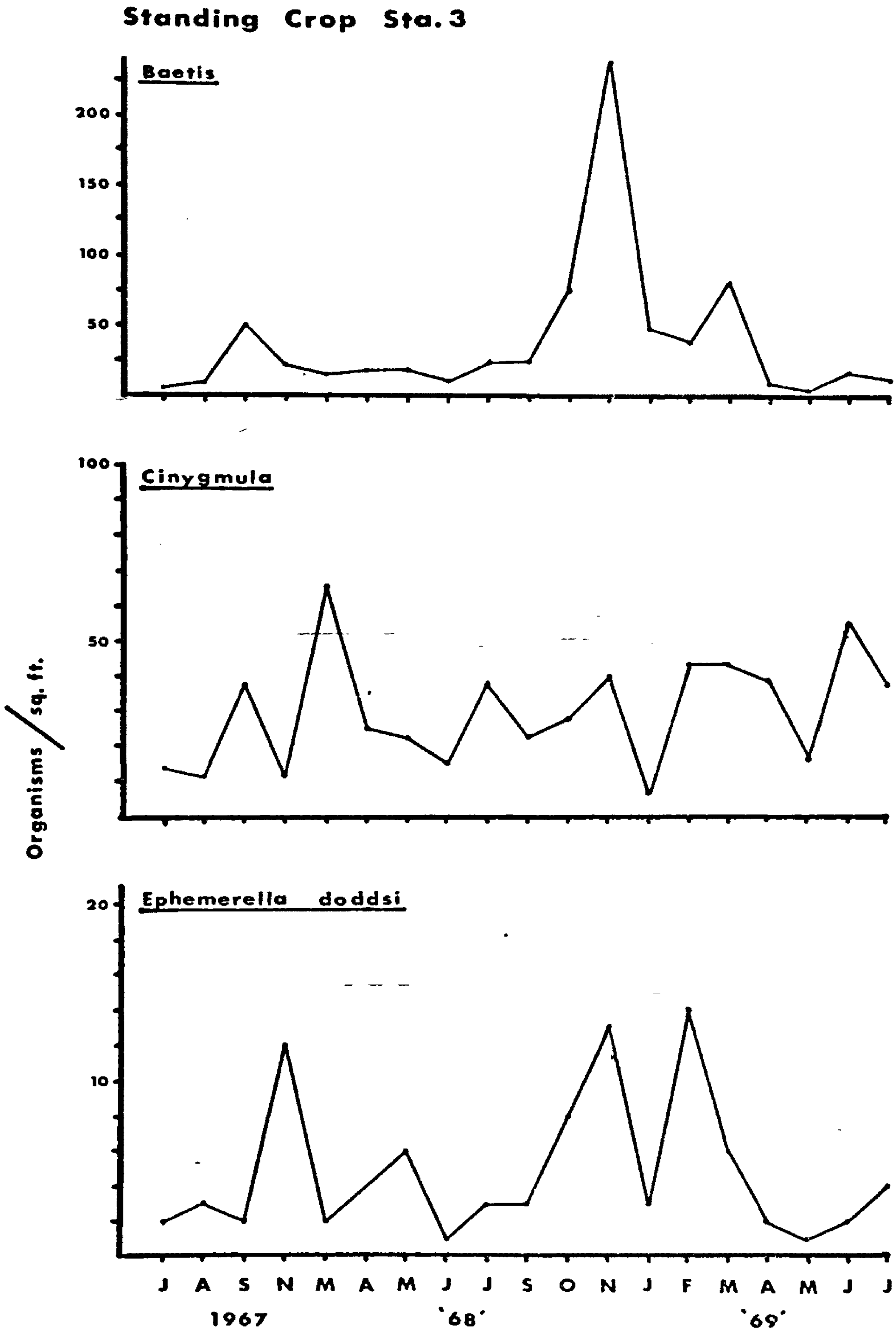

Bottom Samples
Station - 1
no. of species
gm./ft.²
35
25
15
5
0.2
0.6
1.0
J
A
S
N
1967
O
July
S
'68'
May
J
J
'69'

Figure 18.---Standing crop of Baetis at station 3.

Figure 19.---Standing crop of Cinygmula at station 3.

Figure 20.---Standing crop of Ephemerella doddsi at station 3.



Standing Crop Sta. 3
Baetis
200
150
100
50
Cinygmula
100
50
Organisms / sq. ft.
Ephemerella doddsi
20
10
J A S N M A M J J S O N J F M A M J J
1967
'68'
'69'

population was stable until November, 1968 when a large increase was evident. It is difficult to explain the fluctuations in numbers of representatives of this genus. There are at least three species involved which adds to the confusion. The genus Cinygmula made up 16.8 percent of all Ephemeroptera and 11 percent of all invertebrates which is 29.4/sq.ft. Figure 19 shows the standing crop of this organism at station 3. The results are erratic. There are probably several different species involved here, each hatching at a different time of the year. The two genera above comprised 24.5 percent of all invertebrates collected. Ephemerella tibialis made up 6.9 percent of the Ephemeroptera and 4.5 percent of all invertebrates (12.1/sq.ft., see Figure 22.). Rhithrogena comprised 5.6 percent of all mayflies (9.7/sq.ft.) and 3.6 percent of the total. Figure 24 shows the numbers of this mayfly over the study period at station 3. Ephemerella doddsi comprised 2.5 percent (4.4/sq.ft.) of the mayflies and 1.6 percent of the total. Their standing crop is shown in Figure 20. In all, 18 genera and species of mayflies were identified (Table V). A total of 10,470 mayflies were collected from the benthos. Many more were collected as adults. Station 2 contained the greatest percentage of mayflies, 74.2 percent. Station 3 had 64.7 percent and station 1 had 59.6 percent Ephemeroptera. Mayflies were the dominant order in 32 of 38 bottom samples.

Stoneflies comprised 14.5 percent of all insects collected. Alloperla was the dominant genus (Figure 21) comprising 27 percent of the Plecoptera but 3.9 percent of all invertebrates, and Brachyptera 6 percent and 0.9 percent respectively. The large predacious stoneflies, Acroneuria and Arcynopteryx were not numerous but contributed greatly to biomass. Nemoura comprised 13.6 percent of all stoneflies and 2.0 percent of all invertebrates. In all, 2,332 Plecoptera were captured and identified. At station 3, Plecoptera averaged 16.1 percent of the benthos, 6.3 percent at station 2, and 14.2 percent at station 1. The greatest numbers were captured in November and February.

The caddisflies were not numerous in the benthic samples. They comprised 4.4 percent of all invertebrates. Rhyacophila spp. made up 34.6 percent of all caddisflies but only 1.5 percent of all invertebrates (Figure 24). Conclusions about the standing crop of this genus are difficult to draw. Rhyacophila averaged 4.1/sq.ft. Glossosoma spp. comprised 18.6 percent of the Trichoptera and averaged 2.2/sq.ft. Trichoptera were common at station 3, making up 5.1 percent of the total; they made up 5.1 percent of the total also at station 1, and 1.3 percent at station 2. The greatest numbers were captured in July at stations 2 and 3, and in November at station 1. Some of the largest organisms collected were Trichoptera and included Arctopsyche, Hydropsyche, Parapsyche, and Psychoronia.

The true flies were grouped together with the remaining orders of aquatic insects. Together this combined group formed 16 percent of all the invertebrates. The dipteran present in greatest numbers was the family Tendepedidae, the midges (Figure 26). They averaged 14.7/sq.ft., but because of their small size they contributed little to the biomass. Others present are listed in Table V.

The aquatic beetles were the most obscure group on the stream. Larvae of the genus Heterlimnius were most dominant, averaging 3.6/sq. ft. (Figure 23).

Tables II and III show a comparison between several Rocky Mountain

Figure 21.---Standing crop of Alloperla (Plecoptera) at station 3.

Figure 22.---Standing crop of Ephemerella tibialis (Ephemeroptera) at station 3.

Figure 23.---Standing crop of Heterlimnius (Coleoptera) at station 3.

Standing Crop Sta. 3

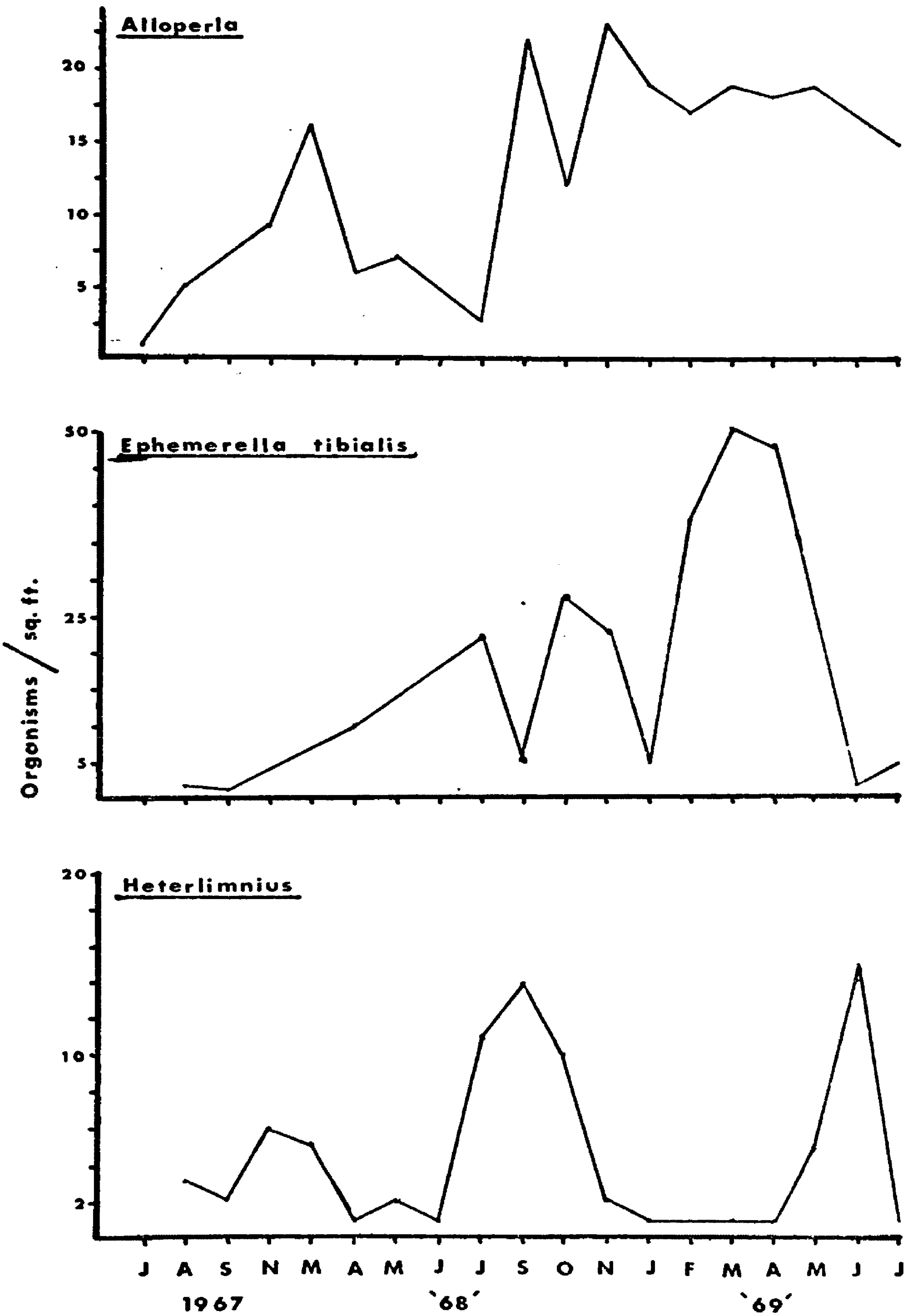
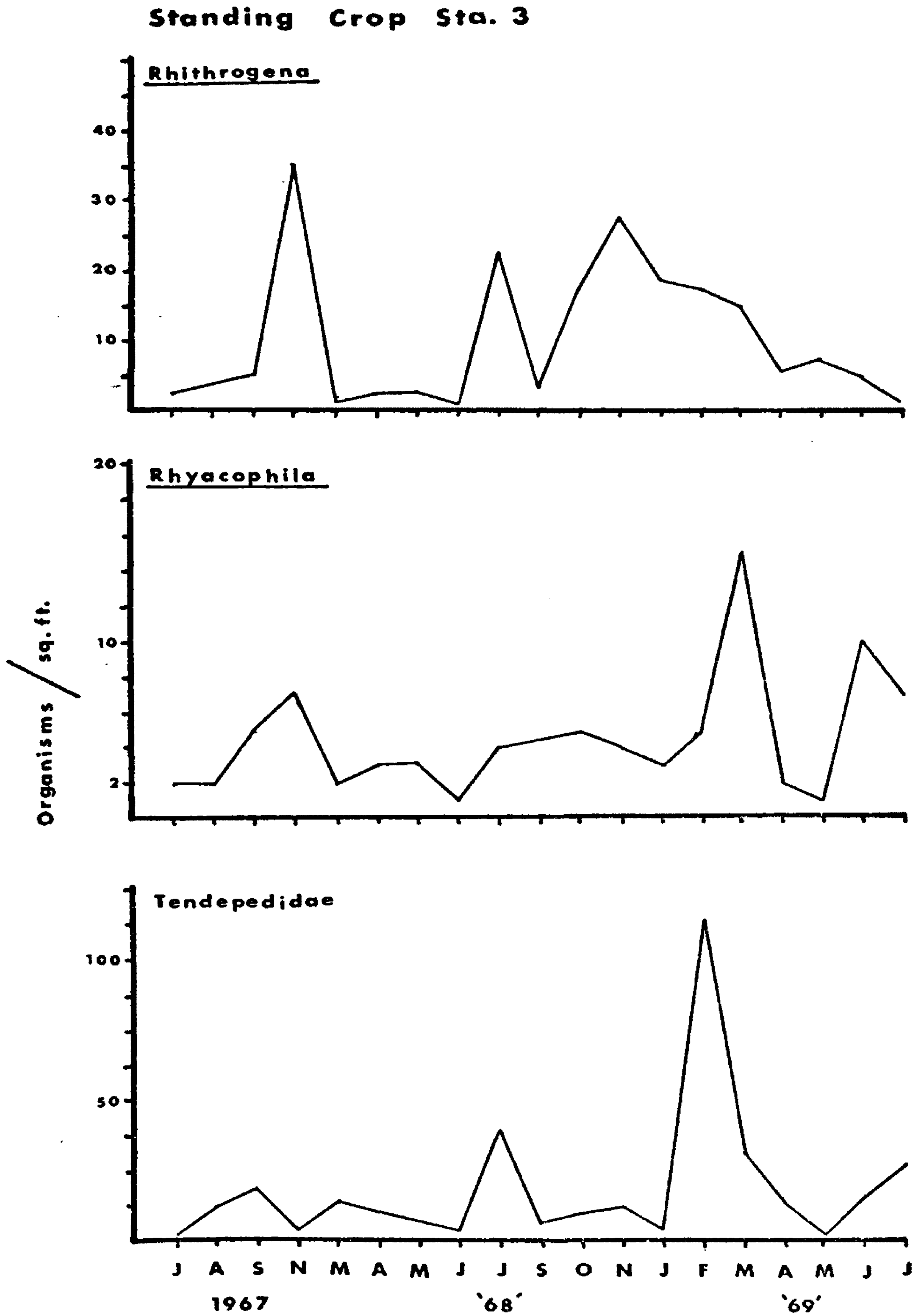


Figure 24.---Standing crop of Rhithrogena (Ephemeroptera) at station 3.

Figure 25.---Standing crop of Rhyacophila (Trichoptera) at station 3.

Figure 26.---Standing crop of Tendepedidae (Diptera) at station 3.


Standing Crop Sta. 3
Rhithrogena
40
30
20
10
Rhyacophila
20
10
2
Organisms / sq. ft.
Tendepedidae
100
50
J A S N M A M J J S O N J F M A M J J
1967
`68´
`69´

streams, various other North American streams, and Morrell Creek. The benthos of Morrell Creek is comparable to other Montana streams. Numbers, however, can be misleading, and volumes and weights are probably the better indicator of productivity. The volume:weight ratio in Morrell Creek is almost 1:1, so the 410 mg/sq.ft. average is comparable to 0.4 cc/sq.ft. This is lower than most streams shown. The Madison River was not much higher, showing 0.58 cc/sq.ft., while the Ruby River was higher with 3.6 cc/sq.ft. Almost all previous benthic studies in Montana were conducted in southwestern Montana, an area reknown for its productive streams. These streams are all part of the Missouri River system while the streams of western Montana are part of the Columbia River system. It is more difficult to compare the streams of the eastern United States. These streams seem to have greater weights and volumes than Morrell Creek; a few have fewer organisms.

TABLE II.---Benthos standing crop estimates for several Rocky Mountain streams.

Name of Stream	Location	Number/ ft.^{2}	Vol. or wt/ft.^{2}	Reference
Madison River	Yellowstone Park	107	0.58 cc.	Heaton, 1966
Madison River	Montana	76	1.47 cc.	Graham and Scott, 1959
Ruby River	Montana	112	3.58 cc.	Graham and Scott, 1959
Firehole River	Yellowstone Park	113	920 mg.	Armitage, 1958
Gardiner River	Yellowstone Park	303	2980 mg.	Armitage, 1958
Willow Creek	Utah	800	1.79 cc.	Moffett, 1936
Provo River	Utah	187	2.68 cc.	Gaufin, 1959
Horton Creek	Arizona	1650	3.23 cc.	Tarzwell, 1937
St. Vrain Creek	Colorado	56.7	0.23 cc.	Pennak and Van Gerpen, 1947
Morrell Creek	Montana	143	410 mg.	Newell, 1970

TABLE III.---Benthos standing crop estimates for several North American streams.

Name of Stream	Location	Number/ft.^{2}	Weight/ft.^{2}	Reference
Missouri River	Missouri	1.8	--	Berner, 1951
Central Ohio Streams		18-93	--	Roach, 1933
Colorado Streams		51	0.1 gm.	Pennak, *et al.*, 1947
Tennessee River	Tennessee	48	0.6 gm.	Lyman, 1943
Black River	Missouri	82	3.5 gm.	O'Connell and Campbell, 1953
Lake Superior Streams	Minnesota	58-150	1.0 gm.	Smith, *et al.*, 1944
New Hampshire Streams		0-580	0.34-0.58 gm.	Behney, 1937
New York Streams		--	1.02 gm.	Needham, 1934
Waddell Creek	California	604	2.05 gm.	Needham, 1934
Holston River	Tennessee	767	3.87 gm.	Lyman, *et al.*, 1945
Utah Streams		152-1673	1.3-2.99 gm.	Moffett, 1936
Michigan Streams		29-4016	1.5-13.6 gm.	Tarzwell, 1937
Big Spring Creek	West Virginia	--	5-6.7 gm.	Surber, 1937

THE INTERMITTENT SECTION

The intermittent section of Morrell Creek (station 2) was examined to determine the duration of drought and its effect on the benthos. The topography of the creek bed differs from that of the other stations which perhaps accounts for its intermittent nature. In other portions of Morrell Creek the stream bed is roughly "V" shaped. On either side of the intermittent section the valley widens and flattens out.

Stream Flow Volume. Volumes were not recorded from June to August, 1967 (Figure 13). The stream was full when the study began on June 27, 1967. From June 27 until August 1 the volume steadily decreased until the week of August 1-8, when the stream became completely dry. Although there is no stream side vegetation, the water temperature did not increase even during low flow in July.

When first visited in May, 1968, water was flowing. Although this station was not visited during the winter, I believe that this station is dry all winter and contains water only during spring runoff.

In June, 1968, the discharge was 41 cubic feet per second (cfs), while at station 1 it was 34 cfs. By July the volume at station 2 was 20 cfs. while it was 27 cfs. at station 1. By early August station 2 was dry and station 1 had a flow of 11 cfs. This means that at least 11 cfs. flow underground through station 2 in August. Probably 11 cfs. is an underestimate because several small feeder streams enter Morrell Creek between stations 1 and 2. Station 2 was dry during the summer of 1968 until October when a flow of 6 cfs. was recorded. This was caused by heavy rains. By November 2, flow was 1 cfs. and by December it was dry again.

In May, 1969, the greatest volume was recorded at station 2, 124 cfs. By June it was 50 cfs. and at station 1 it was 45 cfs. In July station 2 was 2.5 cfs. and station 1 was 8 cfs. From May to August, 1969, the area above and below station 2 was watched to see when surface flow ceased (Plate 6).

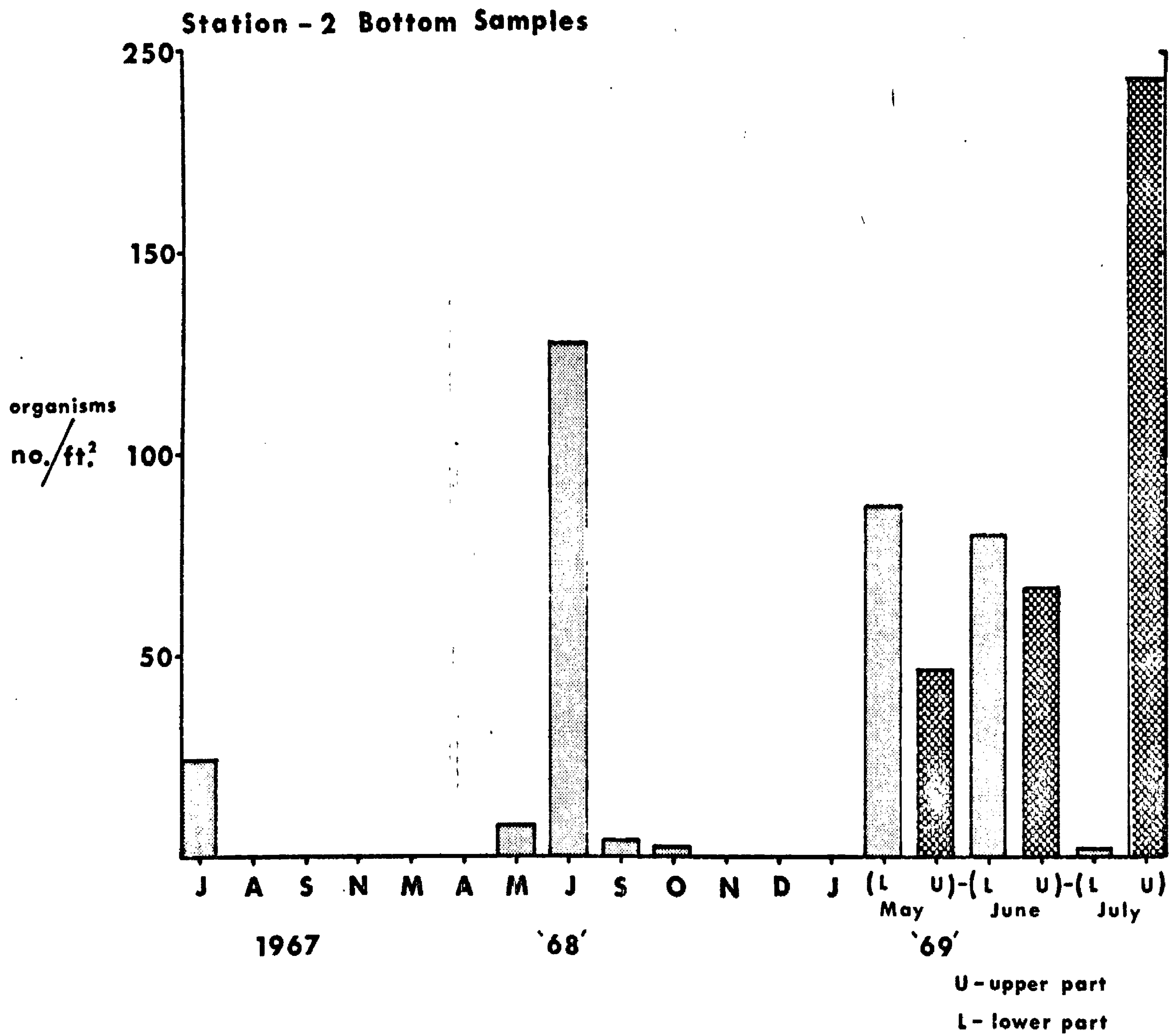
Flow gradually decreased over the entire area from May to August. On July 29, there was a slight flow at the bridge and to about 100 yards downstream, where the flow stopped. From this point downstream for several hundred yards no water was flowing and the water stood in pools. By August 7 the entire section was dry. The dry bed extended from 200 yards above the bridge to about 600 yards below the bridge. Down the stream bed water is first encountered as small pools, then as flowing water. This flow gradually increases until complete flow is regained within about 200 feet.

Where full flow is regained there is a luxuriant growth of moss, perhaps in response to the added carbon dioxide the water picks up in its underground flow.

Benthos. The benthos of station 2 consisted almost entirely of mayflies. The following percentages of numbers were recorded: Ephemeroptera, 74.2; Plecoptera, 6.3; Trichoptera, 1.3; others, 18.2. The mean number of organisms (as small as 1 mm. in length) per square foot was 69.8, only one-third that of station 3 (Figure 27). Ephemeroptera averaged 51.8 organisms per square foot, Plecoptera 4.4/sq.ft., Trichoptera 0.9/sq.ft., and others 12.7/sq.ft. The smallest bottom sample weighed less than 0.1 gram and contained one organism. The largest sample weighed 0.63 grams and had 235 organisms per square foot (Figure 28).

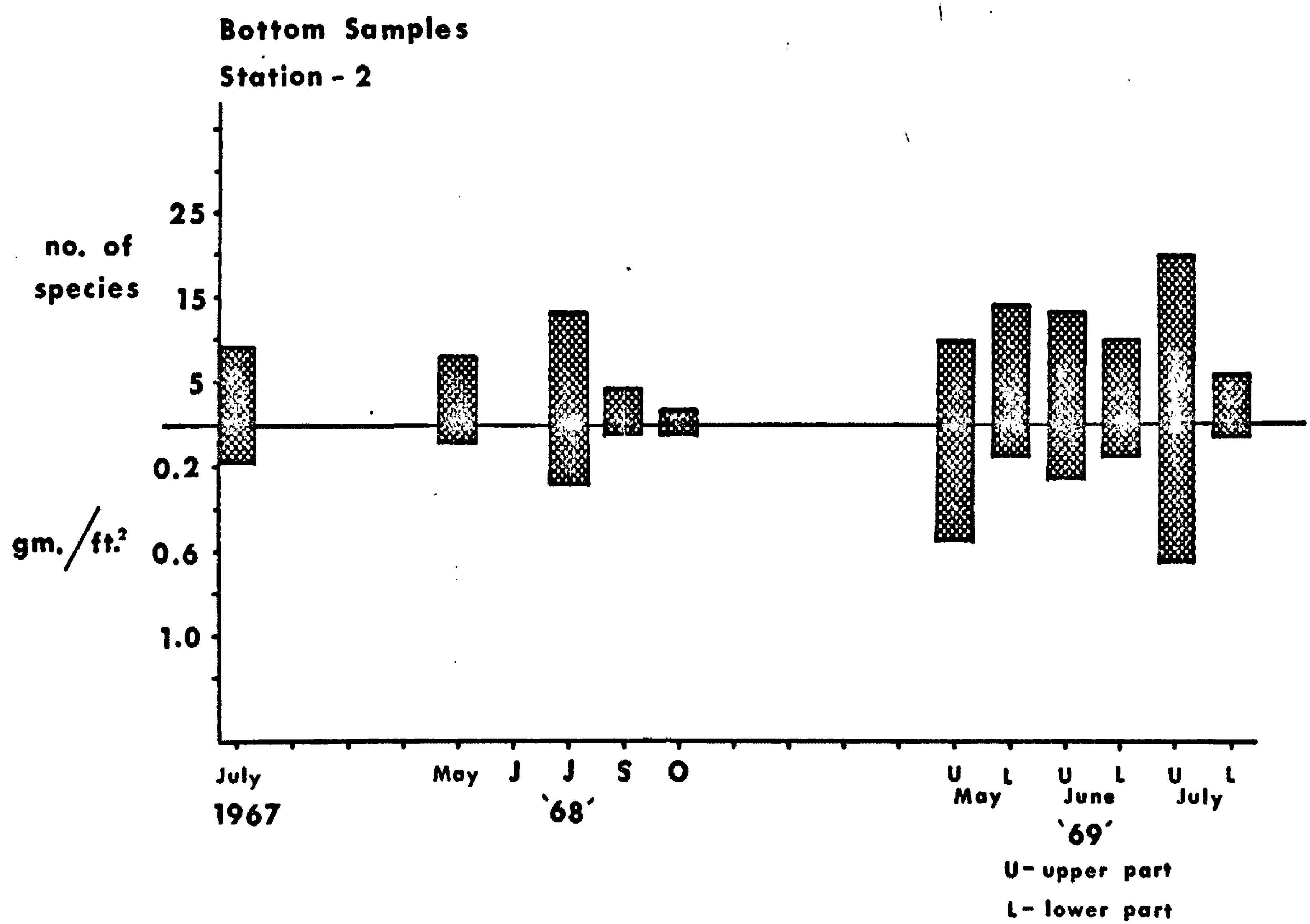
Standing Crop. The mayflies found at station 2 were Ephemeroptera doddsi,

Figure 27.---Organisms per square foot at station 2.



Station - 2 Bottom Samples
250
150
100
50
organisms
no./ft.²
J
A
S
N
M
A
M
J
S
O
N
D
J
(L U)-(L U)-(L U)
May
June
July
1967
`68'
`69'
U - upper part
L - lower part

Figure 28.---Number of species and grams per square foot at station 2.


Bottom Samples
Station - 2
no. of species
25
15
5
0.2
0.6
1.0
gm./ft.²
July
1967
May
J
J
S
O
'68'
U
L
May
U
L
June
U
L
July
'69'
U - upper part
L - lower part

Cinygmula, Baetis, Epeorus (Ironopsis), Epeorus (Iron), E. tibialis, Rhithrogena, Paraleptophlebia, E. coloradensis. The most common forms were Baetis, Cinygmula, and Epeorus (Iron). Six species recorded from stations 1 and 3 were never recorded from station 2 (Table V).

Stoneflies were never very common at station 2. Six species were found here while nine species were present at station 3 and eight at station 1. The large Acroneuria was never found at station 2. The largest number of stoneflies captured in one sample was 15 specimens per square foot in July, 1969.

Caddisflies were less numerous than Plecoptera at station 2. Of the 12 species found in the stream, only four species were taken at station 2. The greatest number captured was 6 organisms per square foot in July, 1969.

Diptera were represented by the midges, family Tendepedidae, and a few Simuliidae, Tipulidae, and Pericoma. Coleoptera were never found. A few Oligochaeta and Turbellaria were recorded.

During May to July, 1969, bottom samples were taken at the upper and lower ends of station 2 to determine whether differences in biomass exist and whether repopulation occurred mostly by drift or upstream migration. Samples taken from the middle of the section in 1968 were compared with these (Table IV).

As previously noted, in July the upper part of station 2 still had flowing water while the lower part had only standing pools. As Figures 27 and 28 show, the number of invertebrates increased over the period as did the biomass. The lower stretch remained relatively stable. The upper section had a decrease. This may be explained by the drifting of new species into the area from upstream. Upstream migration does not seem to increase the fauna of the lower section.

TABLE IV.---Number, weight, and number of species per square foot.

Month	Upper	Middle	Lower
May	45 550 mg. 10 spp.	8 53 mg. 6 spp.	87 140 mg. 14 spp.
June	68 250 mg. 13 spp.	- - -	75 150 mg. 10 spp.
July	235 630 mg. 20 spp.	128 288 mg. 13 spp.	- Trace 6 spp.

TABLE V.---Distribution of benthic organisms in the three segments of Morrell Creek.

Invertebrate	Station 1	Station 2	Station 3
Coleoptera			
Dytiscidae			x
Heterlimnius	x		x
Lara			x
Narpus			x
Optioservus			x
Zaitzevia		x	x
Diptera			
Antocha			x
Atherix variagata	x		x
Ceratopogonidae			x
Dicranota			x
Erioptera			x
Hexatoma	x		x
Heleidae			x
Pericoma	x	x	x
Prionocera			x
Rhabdomastix	x		x
Simuliidae	x	x	x
Tendepedidae	x	x	x
Tipulidae	x	x	x
Ephemeroptera			
Ameletus	x	x	x
Baetis	x	x	x
Cinygmula	x	x	x
Epeorus (*Iron*)	x	x	x
Epeorus (*Ironopsis*)	x	x	x
Ephemerella coloradensis	x	x	x
E. tibialis	x	x	x
E. doddsi	x	x	x
E. inermis		x	x
E. spinifera			x
E. proserpina			x
E. grandis	x		x
E. hystrix			x
E. spp.			x
Heptagenia	x		x
Paraleptophlebia	x	x	x
Rhithrogena	x	x	x

TABLE V.---continued.

Invertebrate	Station 1	2	3
Plecoptera			
Acroneuria	x		x
Alloperla	x	x	x
Arcynopteryx	x	x	x
Brachyptera	x	x	x
Chloroperlidae			x
Nemoura	x	x	x
Nemouridae	x	x	x
Isogenus	x	x	x
Paraperla	x		x
Trichoptera			
Arctopsyche			x
Brachycentrus			x
Glossosoma	x	x	x
Hydropsyche			x
Lepidostoma			x
Limnephilidae	x	x	x
Limnephilus	x		x
Platycentropus			x
Psychoronia			x
Parapsyche	x	x	x
Rhyacophila	x	x	x
Sortosa	x		x
Others			
Hydra	x		x
Oligochaeta	x	x	x
Ostracoda	x		x
Turbellaria	x	x	x
Hydracarina	x	x	x

TABLE VI.---List of adult insects taken at Morrell Creek, stations combined.

Diptera:	*Aedes idahoensis* (Theobald)
Ephemeroptera:	*Ameletus oregonensis* McDunnough
	Cinygmula ramaleyi (Dodds)
	C. uniformis McDunnough
	Epeorus(Iron) deceptivus (McDunnough)
	Rhithrogena robusta Dodds
Odonata:	*Aeshna eremita* Scudder
	Coenagrion resolutum (Hagen)
	Somatochlora semicircularis (Selys)
Plecoptera:	*Acroneuria californica* (Banks)
	A. pacifica Banks
	A. theodora Needham & Claassen
	Alloperla borealis (Banks)
	A. coloradensis (Banks)
	A. delicata Frison
	A. fidelis Banks
	Arcynopteryx signata (Hagen)
	Brachyptera nigripennis (Banks)
	Capnia distincta Frison
	C. gracilaria Claassen
	C. oenone Neave
	Eucapnopsis brevicauda (Claassen)
	Isoperla fulva Claassen
	Nemoura cinctipes Banks
	N. columbiana Claassen
	N. decepta Frison
	N. flexura Claassen
	N. oregonensis Claassen
	Leuctra augusta Banks
	Paraleuctra sara (Claassen)
	Paraperla frontalis Banks
	Peltoperla brevis Banks
Trichoptera:	*Arctopsyche grandis* Banks
	Dicosmoecus canax Banks
	Ecclisomyia conspersa Banks
	Glossosoma penitum Banks
	Hydropsyche bifida Banks
	Lepidostoma veleda Denning
	Rhyacophila acropedes Banks
	R. vepulsa Milne
	R. verrula Milne
	Sortosa aequalis Banks

ORGANISMS OTHER THAN INSECTS

The vertebrate fauna present in Morrell Creek includes three species of fishes of which the cutthroat trout is by far the most numerous. The Dolly Varden, or bulltrout, is also present and consists of two populations. There are the small individuals that live in the creek for a year or two, and the large individuals that come up into the creek to spawn. The largest Dolly Varden seen was about 24 inches long. The slimy sculpin was seen only occasionally. Kokanee salmon were present below the study area as were brown trout and mountain whitefish.

Two species of amphibians are present in the creek, the tailed frog, or bell toad, and the western leopard frog.

Fish eating birds occurring on the stream are the water ouzel, or dipper, and the belted kingfisher. The dipper is very common and aquatic insects make up a large part of its diet.

Beaver and mink are rarely encountered (Table VII).

Protozoa were numerous on glass slides placed in the stream and on natural rock surfaces. The periphyton of Morrell Creek has a rich and varied protozoan fauna (Table VIII). The protozoa and other invertebrates are held on the rocks in the current by a matrix made up of algae and detritus attached to the rocks.

The Coelenterata were represented by Hydra oligactis, which was present in detrital material of bottom samples.

One or two flatworms (Platyhelminthes), between 5 and 10 mm. in length, were found in most bottom samples.

Small nematodes were common in rock scrapings and on slides.

Aquatic earthworms (Annelida) occurred often in bottom samples. They generally resemble terrestrial earthworms and were about 30 to 80 mm. in length, and reddish-brown in color.

Small Ostracods, red water mites (Hydracarina), and Collembola comprised the arthropod fauna.

TABLE VII.---Vertebrates.

Cutthroat trout	Salmo clarki
Dolly Varden trout	Salvelinus malma
Slimy sculpin	Cottus cognatus
Leopard Frog	Rana pipiens
Tailed frog	Ascaphus truei
Water ouzel	Clinclus mexicanus
Belted kingfisher	Megaceryle alcyon
Beaver	Castor canadensis
Mink	Mustela vison

TABLE VIII.---Invertebrates other than insects

PROTOZOA
- Amoebidae
- Chlamydomonadidae
- Euglenidae
- Heliozoa
- Holotricha
- Oxytrichidae
- Testacea

COELENTERATA
- Hydrazoa
    - Hydridae
        - _Hydra_ _oligactis_ (Pallos)

PLATYHELMINTHES
- Turbellaria
    - Tricladida

ROTATORIA
- Monogononta
    - _Encentrum_

NEMATODA

ANNELIDA
- Oligochaeta
    - Opisthopora
        - Lumbricidae

ARTHROPODA
- Crustacea
    - Ostracoda
        - Podocopa
- Arachnoidea
    - Hydracarina

CHAPTER V. DISCUSSION

Seasonal variations in dissolved materials in Morrell Creek are more the exception than the rule. Alkalinity, total hardness, and calcium hardness have high values in late fall, low values in the spring. This situation can be explained by the diluting effect of melting snow. These materials are released slowly by the soil, with little or none being added by the snow water. As the water level drops in the late summer, the concentration of these materials increases. The remaining chemical components show no seasonal trends and must be released continually from their sources.

Soils in upper Morrell Creek appear to be very stable as turbidity in the stream was consistently very low. Even during high run off from steep slopes turbidity does not increase. The only extreme turbidity was from a small stream that enters the main creek below station 2 (Plate 7). Logging operations on this tributary accounted for the increased turbidity. This increase was not evident at station 3, six miles downstream.

The substratum of Morrell Creek is composed mainly of gravel and sand with little silt. The stream is quite stable, both physically and chemically, a reflection of its relatively undisturbed nature and its geology. Some logging has taken place within the drainage basin, but most has occurred some distance from the stream. The riparian vegetation near the stream has been disturbed only near station 2. The road that parallels the stream is from one-quarter to one-half mile from the bed on gentle slopes, and therefore silt problems from it do not occur.

Higher aquatic plants are totally absent from the stream. Little work has been done on stream algae. The work by Gunitow (1955), Prescott (1968), and Whitford (1968) list several genera of stream algae. Tiffany (1938) feels that the characteristic algae of swift streams are those possessing the so-called holdfast cells or other means of adhering to rocks in swift streams. There is a varied algal population in Morrell Creek. This appears as a coating on rocks and a few species are abundant enough to recognize grossly. Lemanea is present in the faster currents and Hydrurus foetidus is very common at times. Diatoms are abundant and make up a large part of the periphyton. They may be the most numerous organisms in the stream. There is little scouring action in the stream and the periphyton communities are relatively undisturbed.

The periphyton was examined qualitatively rather than quanitatively. Eight orders of organisms were present in the periphyton. The most numerous were the Protozoa and the Bacillariophycae or diatoms. Incidental forms included the Hydrozoa, Turbellaria, Rotatoria, Nematoda, Annelida, Ostracoda, and Collembola.

Various schemes have been devised to predict the quantity and quality of stream benthos, most with limited success. Needham (1938) indicated that stream width controlled the benthos while Tarzwell (1938) and Armitage (1958) showed that increasing alkalinity caused an increase in benthos. So many factors are involved in benthic productivitythat it is doubtful if one scheme will work in all areas. Needham (1938) felt that type of bottom, velocity, depth, temperature, and materials in suspension determine the distribution of aquatic organisms. Most ecologists agree that no two environmental situations are exactly alike.

Ephemeroptera are the most abundant invertebrates in Morrell Creek. They are especially abundant at station 2. Three genera dominated the Ephemeroptera: Baetis, Cinygmula, and Epeorus(Iron). There were as many as 393 mayflies per square foot in November, 1968, and they made up as much as 100 percent of some of the samples. Many of the species are small and contributed little to the biomass, except Ephemerella doddsi, specimens of which are comparatively large. Mayflies contributed the greatest numbers in June and July.

Plecoptera are a rather minor portion of the benthos. The greatest number found was 69 specimens per square foot. Most are of the genus Alloperla. They are, however, a diverse group. Adults of 23 species were collected.

The Trichoptera are the least numerous insect group. This order includes some of the largest insects in the stream. They are extremely scarce at station 2, making up only 1.3 percent of the benthos. Adults of ten species were collected. The mean number collected from station 1 was 3.5 per square foot and 9.4 per square foot at station 3.

Coleoptera, Diptera, and other orders were lumped together into one category that makes up 16 percent of all invertebrates. Mean values for each station follow: station 1, 19.6/sq.ft.; station 2, 12.7/sq.ft.; station 3, 25.7/sq.ft. The most common organisms in this group are the Tendepedidae, or midges. I was unable to identify these small worm-like larvae below the familial level. They are at times the most numerous organism collected. Coleoptera larvae of Heterlimnius are also common. Other forms include Lumbricidae, Hydracarina, and Turbellaria.

The standing crop variations are evident in Figures 14 and 15. The variations are most apparent at station 3. Here a few things are obvious. First, fluctuations in organisms per square foot do not always agree with an increase in biomass. Second, an increase in biomass always means an increase in the number of species present. Third, fluctuations in standing crop, biomass, and number of species do not agree for the two year period. Biomass showed a peak in March and April, 1968, and other peaks in July, October, November, 1968, and February, March, and July, 1969. The number of organisms present at station 3 generally increases from October to March. This may be accounted for by the hatching of many immature forms. They reach their peak of numbers in November and generally decrease all winter as predation and other forces act to reduce their numbers. This can be substantiated by the absence of concommitant increase in biomass with the large increase in numbers, e.g., in November, 1968. Biomass for this period shows a gradual decrease but not as great as the decrease in numbers.

The number of organisms caught in April and May during high runoff periods is probably biased by the loss of organisms from the net caused by increased current velocity. Badcock (1954a, b), reporting on work done in Sweden, showed from 4 to 20 percent of the organisms were lost from the net during high water periods. She found the greatest number of organisms in June and July, and the lowest in the period from December to March. She felt that migration shoreward to moss communities might account for the low winter values. She also stated that total volume of organisms is more accurate and more consistent than numbers. She found that some insects were able to burrow up to 12 cm. into the stream bed and these may be missed from the samples. She believes that the various physical and chemical factors interact in determining the nature of the plant growth, and this, by providing food and shelter, largely determines the nature and density of the fauna.

One must be cautious in the interpretation of these kinds of data. There are many variables such as microhabitat, sampling technique, velocity, net mwsh size, and substratum. Needham, et al. (1956) have explored the variability inherent in stream surveys using the Surber sampler.

The intermittency of water flow at station 2 of Morrell Creek must influence the productivity of the stream. Many thousands of insects die there each year as the streambed becomes dry. Data from June, 1969, indicate that about 2.3 million insects representing 5.8 kg. of biomass were present in this 800 yard intermittent section. Since this area becomes dry from the downstream area first, none escape the August dry period. This represents a substantial loss to the stream.

Clifford (1966) in his investigation of intermittent streams of Indiana, Illinois, and Ohio, found living invertebrates in the dry sections. In Indiana the intermittency is caused by the composition of the stream bed, mainly non-angular sandstone fragments. These fragments promoted the formation of numerous and relatively large interstitial spaces. However, the stream in Indiana was protected by riparian vegetation which kept the stream bed relatively cool in the summer. In the intermittent section of Morrell Creek this vegetation is gone allowing sunlight to dry the stream bed. The freezing winter also assures complete removal of the living forms. The creek bed at station 2 is composed of rounded gravel and rubble unlikely to entrap water.

I was never present in the spring when water first began to flow at station 2, so I do not know how rapidly recolonization occurred. However, heavy rains in the fall of 1968 brought a short resumption of flow at this station. In September, only three organisms per square foot were found. In October, this happened again, but only one organism was found.

Waters (1962) found that daily drift over a unit area is often several times greater than the standing crop of that area. Waters (1961) also found that drift was composed principally of organisms which are free-ranging and relatively weak swimmers (Baetidae) and a few strongly sedentary forms such as Hydropsyche spp. MacWaters (1965) confirmed the work of Waters and felt that upstream migration of some forms occurs. Unfortunately, drift studies were not undertaken on Morrell Creek.

The "colonization cycle" concept expounded by Müller (1954) to explain the lack of depopulation of upstream reaches by the drifting of nymphal forms, assumes that adults consistently migrate upstream and oviposit in the headwaters (Roos, 1957; Dorris, et al., 1962; Thomas, 1966, Waters, 1968). Waters (1961) theorized that the drift of immature forms was the result of an excess of population over the carrying capacity of the stream bed, resulting in displacement through physical competition for food and space. He used this (1962 a, 1966) as a basis for estimating productivity from the rate of drift. The direct relationship between benthic density and volume of the drift (Dimond, 1967; Pearson, et al., 1968) and the dependence of drift on the absolute volume of water and the rate of flow are clear (Maciolek, et al., 1951; Logan, 1963; Bailey, 1966; Elliott, 1967 a). Non-catastrophic drift exhibits a diurnal pattern, first documented by Tanaka (1960).

In the Speed River, Ontario, Bishop and Hynes (1969a) found 17.5 kg. of biomass drifted past the sampling point which was equivelant to a loss of 70 $gm/m^2/year$ from a hypothetical 50 meter upstream section supplying the drift. Estimated population for 1966 for a riffle was 620 gm/m^2. About 85 percent of production per year was lost to the terrestrial habitat, invertebrate predation, flood standing, and natural mortality.

Müller (1954) scoured a 450 m^2 section of stream. After 11 days the area had been repopulated by 4,158,000 organisms weighing 4.55 kg. Drift during this same period was 3,656,620 insects. This is an example of what Müller calls a traveling benthos. With such a tremendous amount of drift it would seem that upstream areas would become depleted, but such is not the case.

Drift seems to be a link in the chain that, starting from an overabundance of progeny in the upper reaches, regulates and maintains the population with the help of the current. Denuded areas are the recipients of these drifting organisms.

Dendy (1944) reviewed the literature on drift and reached several conclusions. He found in three Michigan streams that 71 different kinds of macroscopic animals representing seven phyla occurred in the drift during the summer. Further, he found that the presence of macroscopic animals, although highly variable in kind and quality, was a constant feature, and that in one stream all species represented in benthic samples were sooner or later found in the drift.

The distribution of some forms at station 2 may occur as a result of movement along the substratum. It is known that many benthic organisms possess some form of rheotaxis or stream bottom orientation. The work of Neave (1930) and MacWaters (1965) clearly shows the ability of aquatic organisms to move actively upstream against the current.

MacWaters (1965) discovered that the large net making caddisflies and Turbellaria were able to colonize bottom substratum in a manner which was not dependent upon stream drift. These forms are missing from station 2 in Morrell Creek. These species recolonized denuded substratum yet were never captured in the drift nets. It would appear that these invertebrates were able to move about on the stream bottom.

Neave (1930) showed further evidence of upstream migration. He noted that the nymph of the mayfly, Blasturus cupidus, moved upstream at a rate of 600 feet per day against a current. Ide (1935) discovered that mayfly nymphs will move downstream over the stream bottom. This movement is not gradual, but occurs rapidly at a time when the nymphs are about half-grown. Dodds, et al. (1924) also described the movements of insects. They described the movements of the mayfly, Baetis bicaudatus, which inhabits fast flowing streams. This species crawls about over the bottom while keeping its head toward the current.

MacWaters (1965) reached the following conclusions with respect to stream drift as a possible source for the colonization of denuded stream bottoms: (1) Invertebrates occurring in downstream drift in quantities adequate to serve as a source for recolonization are almost always smaller organisms, such as Baetis and Simulium species. This indicates that they are easily dislodged from the substratum and carried passively downstream by the current. (2) These smaller species were also the first invertebrates to recolonize a denuded stream area, suggesting that downstream drift acts as a rapid source for substratum colonization. (3) The large macro-invertebrates, such as Hydropsyche and others, appear occasionally in the drift.

This theory proposed by MacWaters seems to be pertinent in Morrell Creek. The intermittent area around station 2 contains many small forms such as Baetis, Cinygmula, Iron, and Tendepedidae. Large Trichoptera and Plecoptera are absent.

Several conclusions regarding repopulation of the intermittent section on Morrell Creek seem possible: (1) The intermittent portion of Morrell Creek contains no permanent inhabitants; (2) benthic productivity reaches a high value in a few weeks; (3) invertebrate drift plays an important role; (4) upstream migration appears to be a minor factor.

It is hoped that future studies on Morrell Creek can be conducted now that this preliminary study has been completed. More logging will undoubtedly occur on the stream and that offers an opportunity to examine any harmful effects it might have on the stream. Drift studies in the intermittent section would be of value as would winter studies in the upstream portions. More work on adult insects would help explain benthic variations.

SUMMARY

Morrell Creek is a pristine mountain stream in northwestern Montana. It is 16 miles long and drains a basin of about 68 square miles in the Swan Range of Lolo National Forest. The maximum width of the stream is 20 feet with a maximum depth of 4 feet. Faster riffles reach a velocity of 4 feet per second. The water is cool, clear, and relatively low in dissolved mineral nutrients.

The stream is slightly basic (pH 7.5-8.6), and of 20 chemical components analyzed, most are present only in trace amounts. Temperature of the water does not exceed 12° Centigrade. Total hardness varies between 45-90 mg/l., and alkalinity varies from 43-80 mg/l.

The periphyton is rich in protozoan and algal populations. Diatoms are the most numerous organism.

Monthly bottom samples contained 63 taxa of invertebrates of which 57 were aquatic insects. Mayflies are the dominant group comprising 65 percent of all invertebrates collected. Two genera, Baetis and Cinygmula alone make up 25 percent of all invertebrates. Plecoptera is the next most numerous group; Trichopterans are the least numerous.

Of the three sampling stations examined, the upstream section averaged 89 organisms per square foot, weighing 0.34 grams. Mayflies dominated the bottom samples, comprising 65 percent of the benthos in this section.

The second station is two miles downstream. The mean number of organisms here was 70 organisms per square foot, weighing 0.18 grams. This station has intermittent flow and contains water only during the spring and early summer. The benthos is 75 percent mayflies that

probably originate from downstream drift. When this one-mile section dries up in August, approximately two million invertebrates are killed.

The third section is six miles downstream from the intermittent section. The volume of water at this station is greater and there are more diverse habitats here than at the other stations. The benthos in this section averaged 184 organisms per square foot, weighing 0.69 grams.

Morrell Creek is typical of many mountain streams in western Montana. It has moderate flow with a rock and gravel bottom. It is cool, clear, and although it contains a breeding population of cutthroat trout, it is rather unproductive. The main threat to Morrell Creek is probably logging operations. Further studies may be conducted on Morrell Creek to determine if logging is altering the flora and fauna.

Allen, K.R. 1940. Studies on the biology of early stages of the salmon (Salmo salar). 2. Feeding habits. J. Anim. Ecol. 10: 46-76.

Anderson, R.C. 1959. A modified flotation technique for sorting bottom samples. Limnol. Oceanogr. 4: 223-225.

Anderson, N.H. 1967. Biology and downstream drift of some Oregon Trichoptera. Can. Ent. 99: 507-521.

Armitage, K.B. 1958. Ecology of the riffle insects of the Firehole River, Wyoming. Ecology 39: 571-580.

__________. 1961. Distribution of the riffle insects of the Firehole River, Wyoming. Hydrobiologia 17: 152-174.

Badcock, R.M. 1954a. Studies of the benthic fauna in tributaries of the Kavlinge River, southern Sweden. Inst. Freshwater Res., Drottningholm, Report 35: 21-37.

__________. 1954b. Comparative studies in the populations of streams. Ibid.: 38-50.

Bailey, R.G. 1966. Observations on the nature and importance of organic drift in a Devon river. Hydrobiologia 27: 353-367.

Behney, W.H. 1937. Food organisms of some New Hampshire trout streams. Biological survey of the Androscoggin, Saco, and coastal watersheds. N.H. Fish and Game Dept., Surv. Rept. 2: 77-80.

Benson, N.G. 1955. Observations on anchor ice in a Michigan stream. Ecology 36: 529-530.

Berner, L.M. 1951. Limnology of the lower Missouri River. Ecology 32: 1-12.

Bishop, J.E. and H.B.N. Hynes. 1969a. Downstream drift of the invertebrate fauna in a stream ecosystem. Arch. Hydrobiol. 66: 56-90.

__________ and __________. 1969b. Upstream movements of the benthic invertebrates in the Speed River, Ontario. J. Fish. Res. Bd. Canada 26: 279-298.

Brown, C.J.D., W.D. Clothier, and W. Alvord. 1953. Observations on ice conditions and bottom organisms in the West Gallatin River, Montana. Proc. Mont. Acad. Sci. 13: 13-27.

Buscemi, P.A. 1969. Chemical and detrital features of the Palouse River, Idaho, runoff flowage. Oikos 20: 119-127.

Clarke, F.W. 1924. The composition of river and lake waters of the United States. U.S. Geol. Surv., Profess. Paper No. 135.

Clifford, H.F. 1966. The ecology of invertebrates in an intermittent stream. Invest. Indiana Lakes and Streams. Vol. VII: 57-98.

Cope, O.B. and B.C. Park. 1957. Effects of forest insect spraying on trout and aquatic insects in some Montana streams. Mont. Fish and Game Dept., Job Compl. Rept. F-21-R-1.

Cordone, A.J. and D.W. Kelly. 1961. The influence of inorganic sediment on the aquatic life in streams. Calif. Fish and Game 47: 189-228.

Davis, C.C. 1955. The marine and fresh-water plankton. Michigan State Univ. Press. 562pp.

Dendy, J.S. 1944. The fate of animals in stream drift when carried into lakes. Ecol. Monogr. 14: 333-357.

Dimond, J. 1967. Pesticides and stream insects. Maine For. Serv. and Conser. Foundation Bull. No. 23.

Dodds, G.S. and F.L. Hisaw. 1924a. Ecological studies of aquatic insects II. Ecology 5: 262-271.

__________ and __________. 1924b. Ecological studies of aquatic insects I. Adaptations of mayfly nymphs to swift streams. Ibid.: 137-148.

__________ and __________. 1925a. Ecological studies on aquatic insects IV. Altitudinal range and zonation of mayflies, stoneflies, and caddisflies in the Colorado Rockies. Ecology 6: 380-390.

__________ and __________. 1925b. Ecological studies on aquatic insects. III. Adaptations of caddisfly larvae to swift streams. Ibid.: 123-137.

Dorris, T.C. and B.J. Copeland. 1962. Limnology of the middle Mississippi River. III. Mayfly populations in relation to navigation water-level control. Limnol. Oceanogr. 7: 240-247.

Edington, J.M. 1966. Some observations on stream temperature. Oikos 15: 265-273.

Edmondson, W.T. (ed.) 1959. Fresh-water biology. John Wiley and Sons. New York. 1248pp.

Elliott, J.M. 1965. Daily fluctuations of drift invertebrates in a Dartmoor stream. Nature 205: 1127-1129.

__________. 1967. The life histories and drifting of the Plecoptera and Ephemeroptera in a Dartmoor stream. J. Anim. Ecol. 36: 343-362.

Fassett, N.C. 1966. Manual of aquatic plants. Univ. of Wisconsin Press. 405pp.

Garnett, W.J. 1965. Freshwater microscopy. Constable and Company, London. 376pp.

Gaufin, A.R. and G.M. Tarzwell. 1956. Aquatic macroinvertebrate communities as indicators of organic pollution in Lytle Creek. Sewage and Ind. Wastes 28: 906-924.

__________. 1959. Production of bottom fauna in the Provo River, Utah. Iowa State Coll. J. Sci. 33: 395-419.

__________., A.V. Nebeker, and Joan Sessions. 1966. The stoneflies (Plecoptera) of Utah. Univ. of Utah, Biol. Ser. Vol. XIV, No. 1.

Geological Survey 1965. Water resources data for Montana. Part 2. Water quality records. U.S. Dept. Int., Geol. Surv., Water Resour. Div., Helena, Montana. 130pp.

__________ 1966. Water resources data for Montana. Part 2. Water quality records. Ibid.

__________ 1967. Water resources data for Montana. Part 2. Water quality records. Ibid.

Graham, R.J. and D.O. Scott. 1958. Effects of forest insect spraying on trout and aquatic insects in some Montana streams. U.S. Fish and Wildlife Serv., Montana Fish and Game Dept., U.S. Forest Serv., mimeo. 50pp.

__________ and __________. 1959. Effects of aerial application of DDT on fish and aquatic insects in Montana. Ibid. 35pp.

Gunitow, R.B. 1955. An investigation of the periphyton on a riffle of the West Gallatin River. Trans. Am. Micros. Soc. 74: 278-292.

Harrel, R.C. and T.C. Dorris. 1968. Stream order, morphometry, physical-chemical conditions, and community structure of benthic macroinvertebrates in an intermittent stream system. Amer. Midl. Nat. 80: 220-251.

Harrison, A.D. 1966. Recolonization of a Rhodesian stream after drought. Arch. Hydrobiol. 62: 405-421.

Hazzard, A.S. 1934. Quantitative studies of trout food in some Utah streams. Proc. Utah Acad. Sci. 11: 271-330.

Heaton, R.J. 1966. The benthos and drift fauna of a riffle in the Madison River, Yellowstone National Park. Unpubl. Ph.D. thesis, Montana State University. 59pp.

Horton, P.A. 1961. The bionomics of brown trout in a Dartmoor stream. J. Anim. Ecol. 30: 311-338.

Hunt, R.L. 1965. Surface-drift insects as trout food in the Brule River. Trans. Wis. Acad. Sci., Arts Letters. 54: 51-61.

Hynes, H.B.N. 1958. A key to the adults and nymphs of British stoneflies (Plecoptera). Sci. Publs. Freshwater Biol. Assoc. 17: 1-86.

__________. 1961. The invertebrate fauna of a Welsh mountain stream. Arch. Hydrobiol. 57: 344-388.

Ide, F.P. 1935. The effect of temperature on the distribution of the mayfly fauna of a stream. Publ. Ontario Fish. Res. Lab. No. 50. 102p

__________. 1940. Quantitative determination of the insect fauna of rapid water. Univ. Toronto Stud., Biol. Serv.47: 1-20

Jaag, O. and H. Ambuhl. 1962. The effect of the current on the composition of biocoenoses in flowing water streams. In Advances in Water Pollution Research. Vol. I. B.A. Southgate, ed. Pergamon Press. New York.

Jensen, S.L. 1966. The mayflies of Idaho. Unpubl. Master's thesis, Univ. of Utah, Salt Lake City, Utah.

Jewett, S.G., Jr. 1959. The stoneflies (Plecoptera) of the Pacific Northwest. College Press, Oregon State University. Monogr. No. 3.

Johannsen, O.A. 1934. Aquatic Diptera. Part I. Cornell Univ., Agric. Exper. Sta., Memoir 164.

__________. 1935. Aquatic Diptera. Part II. Ibid. Memoir 177.

__________. 1937a. Aquatic Diptera. Part III. Ibid. Memoir 205.

__________. 1937b. Aquatic Diptera. Parts IV-V. Ibid. Memoir 210.

Kaushik, N.K. and H.B.N. Hynes. 1968. Experimental study of the role of autumn-shed leaves in aquatic environments. J. Ecol. 56: 229-243.

Knapp, H. 1957. Aspects of insect populations of the Bitterroot River, Montana. Unpubl. Master's thesis, University of Montana, Missoula, Montana. 157pp.

Knight, A.W. 1965. Studies on the stoneflies (Plecoptera) of the Gunnison River drainage in Colorado. Unpubl. Ph.D. thesis, Univ. of Utah, Salt Lake City, Utah. 155pp.

Kudo, R.R. 1963. Protozoology. C.C. Thomas and Company. 966pp.

Larimore, R.W., W.F. Childers, and C. Heckrotte. 1959. Destruction and re-establishment of stream fish and invertebrates affected by drought. Trans. Amer. Fish. Soc. 88: 261-285.

Leonard, J.W. 1942. Some observations on the winter feeding habits of brook trout fingerlings in relation to the natural food organisms present. Trans. Amer. Fish. Soc. 71: 219-227.

Linduska, J.P. 1942. Bottom type as a factor influencing the local distribution of mayfly nymphs. Can. Ent. 74: 26-30.

Livingstone, D.A. 1963. Chemical composition of rivers and lakes. In Data of Geochemistry. Chapt. G. Geol. Survey, Prof. Paper 440-G.

Logan, S.M. 1963. Winter observations on bottom organisms and trout in Bridger Creek, Montana. Trans. Amer. Fish. Soc. 92: 140-145.

Lyman, F.E. 1943. A pre-impoundment bottom-fauna study of Watts Bar Reservoir area (Tennessee). Trans. Amer. Fish. Soc. 72: 52-62.

__________. and J.S. Dendy. 1945. A pre-impoundment bottom-fauna study of Cherokee Reservoir area (Tennessee). Trans. Amer. Fish. Soc. 73: 194-208.

Maciolek, J. and P.R. Needham. 1951. Ecological effects of winter conditions on trout and trout foods in Convict Creek, California. Trans. Amer. Fish. Soc. 81: 202-217.

Mackay, R.J. 1969. Aquatic insect communities of a small stream on Mont. St. Hilaire, Quebec. J. Fish. Res. Bd. Canada. 26: 1157-1183.

MacWatters, R.C. 1965. The cclonization of artificially denuded stream bottoms by aquatic macro-invertebrates. Unpubl. Ph.D. thesis, Penn State University. 56pp.

Minckley, W.L. 1963. The ecology of a spring stream, Doe Run, Meade County, Kentucky. Wildlife Monogr., No. 11.

Minshall, J.N. 1967. Life history and ecology of Epeorus pleuralis Banks (Ephemeroptera: Heptageniidae). Amer. Midl. Nat. 78: 369-388.

Mitchell, P. 1968. The food of the dipper (Cinclus mexicanus) Swainson on two western Montana streams. Unpubl. Master's thesis, University of Montana, Missoula, Montana. 73pp.

Moffett, J.W. 1936. A quantitative study of the bottom fauna in some Utah streams variously affected by erosion. Bull. Univ. Utah, Biol. Ser. 3: 1-33.

Moore, E., J.R. Greeley, C.W. Greene, H.M. Fargenbaum, F.R. Nevin, and H.K. Townes. 1934. A problem in trout stream management. Trans. Amer. Fish. Soc. 64: 68-86.

Mottley, C.McC., H.J. Rayner, and J.H. Rainwater. 1939. The determination of the food grade of streams. Trans. Amer. Fish. Soc. 68: 336-343.

Müller, K. 1954. Investigations on the organic drift in north Swedish streams. Rep. Inst. Freshwater Res., Drottningholm 35: 133-148.

Muttkowski, R.A. 1925. The food of trout in Yellowstone National Park. Roosevelt Wild Life Ann. 2: 470-497.

__________. 1929. Ecology of trout streams in Yellowstone National Park. Ibid.: 147-240.

__________. and G.M. Smith. 1929. The food of trout stream insects in Yellowstone National Park. Ibid.: 241-263.

Neave, F. 1930. Migratory habits of the mayfly, *Blasturus cupidus* Say. Ecology 11: 568-576.

Nebeker, A. 1966. The taxonomy and ecology of the family Capniidae (Plecoptera) of the western United States. Unpubl. Ph.D. thesis, University of Utah, Salt Lake City, Utah.

Needham, P.R. 1928. A net for the capture of stream drift organisms. Ecology 9: 339-342.

__________. 1933. Mayflies, a staple food of fishes in hill streams. Trans. Amer. Fish. Soc. 63: 178-181.

__________. 1934. Quantitative studies of stream bottom foods. Trans. Amer. Fish. Soc. 64: 238-247.

__________., J.R. Traver, and Yin-chi Hsu. 1935. The biology of mayflies. Comstock Publishing Company. Ithaca, New York.

__________. 1938. Trout Streams. Comstock Publishing Company. Ithaca, New York. 233pp.

__________. and R.L. Usinger. 1956. Variability in the macrofauna of a single riffle in Prosser Creek, California, as indicated by the Surber sampler. Hilgardia 24: 383-410.

Neill, R.M. 1938. The food and feeding of the brown trout (*Salmo trutta*) in relation to the organic environment. Trans. Roy. Soc. Edin. 59: 481-520.

O'Connell, T.R., Jr., and R.S. Campbell. 1953. The benthos of Black River and Clearwater Lake, Missouri. Univ. Missouri Stud. 26: 25-41.

O'Donnell, D.J. and W.S. Churchill. 1954. Certain physical, chemical, and biological aspects of the Brule River, Douglas Co., Wisconsin. Trans. Wisc. Acad. Sci., Arts and Letters 43: 201-255.

Palmer, C.M. 1962. Algae in water supplies. U.S. Public Health Serv. Publ. No. 657.

Patrick, R. 1959. Aquatic life in a new stream. Wat. Sewage Wks. December. 5pp.

__________. 1962. Algae as indicators of pollution, 225-230. In Third Seminar in Biological Problems in Water Pollution. C.M. Tarzwell (ed.) U.S. Publ. Health Serv. Publ. 999-WP-25. 424pp.

Pearson, W.D. and D.R. Franklin. 1968. Some factors affecting drift rates of Baetis and Simuliidae in a large river. Ecology 49: 75-81.

Pennak, R.W. and E.D. VanGerpen. 1947. Bottom fauna production and physical nature of the substrate in a northern Colorado trout stream. Ecology 28: 42-48.

__________. 1953. Fresh-water invertebrates of the United States. Ronald Press, New York. 769pp.

Percival, E. and H.W. Whitehead. 1929. A quantitative study of the fauna of some types of stream beds. J. Ecology 17: 282-314.

Philipson, G.N. 1954. The effect of water flow and oxygen concentration on six species of caddisflies (Trichoptera) larvae. Proc. Zool. Soc. London. 124: 547-564.

Prescott, G.W. 1964. How to know the fresh-water algae. W.C. Brown and Company. 272pp.

__________. 1968. The algae: a review. Houghton Mifflin Company. 436pp.

Roach, L.S. 1933. Some physical, chemical, and biological studies of impounded waters in Ohio. Trans. Amer. Fish. Soc. 63: 265-270.

Roos, T. 1957. Studies on upstream migration in adult stream-dwelling insects. I. Rep. Inst. Freshwater Res. Drottningholm 38: 167-192.

Ross, C.P., D.A. Andrews, and I.J. Witkind. 1955. Geologic map of Montana. Mont. Bureau of Mines and Geology.

Schoenthal, N.D. 1963. Some effects of DDT on cold water fish-food organisms. Proc. Mont. Acad. Sci. 23: 63-94.

Scott, D. 1958. Ecological studies on the Trichoptera of River Dean, Cheshire. Arch. Hydrobiol. 54: 340-392.

Shockley, C.H. 1949. Fish and invertebrate populations of an Indiana bass stream. Invest. Indiana Lakes and Streams. 3: 247-270.

Smith, G.M. 1950. The fresh water algae of the United States. McGraw-Hill Company. 719pp.

Smith, L.L. and J.B. Moyle. 1944. A biological survey and fishery management plan for the streams of the Lake Superior north shore watershed. Minn. Dept. Conserv. Tech. Bull. No. 1. 288pp.

Sprules, W.M. 1940. Effects of a beaver dam on the insect fauna of a trout stream. Trans. Amer. Fish. Soc. 70: 236-248.

__________. 1947. An ecological investigation of stream insects in Algonquin Park, Ontario. Univ. Toronto Stud., Biol. Ser. 56: 1-81.

Stehr, W.C. and J.W. Branson. 1939. An ecological study of an intermittent stream. Ecology 19: 294-310.

Surber, E.W. 1936. Rainbow trout and bottom fauna production in one mile of stream. Trans. Amer. Fish. Soc. 66: 193-202.

__________. 1951. Bottom fauna and temperature conditions in relation to trout management in St. Mary's River, Augusta County, Virginia. Virginia J. Sci. 2: 190-202.

Sylvester, R.O. 1958. Water quality studies in the Columbia River basin. U.S. Fish and Wildlife Serv. Spec. Sci. Rept. No. 239. 134pp.

Tanaka, H. 1960. On the daily change of the drifting of benthic animals in a stream, especially on the type of daily change observed in taxonomic groups of insects. Bull. Freshwater Fish. Res. Lab., Tokyo. 9: 13-24.

Tarzwell, C.M. 1937. Factors influencing fish food and fish food production in southwestern streams. Trans. Amer. Fish. Soc. 67: 246-255.

Tebo, L.B. and W.W. Hassler. 1961. Seasonal abundance of aquatic insects in western North Carolina trout streams. J. Elisha Mitchell Sci. Soc. 77: 249-259.

Thomas, N.A. and R.L. O'Connell. 1966. A method for measuring primary productivity by stream benthos. Limnol. Oceanogr. 11: 386-392.

Ulfstrand, S. 1968a. Life cycles of benthic insects in Lapland streams (Ephemeroptera, Plecoptera, Trichoptera, Diptera Simuliidae). Oikos 19: 167-190.

__________. 1968b. Benthic animal communities in Lapland streams. Oikos-Suppl. 10: 1-116.

Usinger, R.L. (ed.) 1963. Aquatic insects of California. Univ. of Calif. Press.

Waters, T.F. 1961. Standing crop and drift of stream bottom organisms. Ecology 42: 532-537.

Waters, T.F. 1962. Diurnal periodicity in the drift of stream invertebrates. Ecology 43: 316-320.

__________. 1965. Interpretation of invertebrate drift in streams. Ibid. 46: 327-334.

__________. 1966. Production rate, population density, and drift of a stream invertebrate. Ibid. 47: 595-605.

__________. 1968. Diurnal periodicity in the drift of a day-active invertebrate. Ibid. 49: 152-153.

Weisel, G.F. and R.L. Newell. 1970. Quality and seasonal fluctuation of headwater streams in western Montana. Mont. Forest and Conserv. Expt. Sta., Bull. (in press)

Wene, G. and E.L. Wickliff. 1940. Modification of a stream bottom and its effects on the insect fauna. Can. Ent. 72: 131-135.

Whitford, L.A. and G.J. Schumacher. 1968. Notes on the ecology of some species of fresh-water algae. Hydrobiologia 32: 225-236.

Zimmerman, J.W. 1968. Water quality of streams tributary to Lakes Superior and Michigan. U.S. Fish and Wildlife Serv., Spec. Sci. Rept.-Fish., No. 559.

APPENDIX

BOTTOM SAMPLES, STATION 1.

(3 sq. ft. samples)

	July 4 1967	July 18 1967	Aug. 8 1967	Sept. 11 1967	Nov. 4 1967	July 17 1968	Sept. 24 1968	Oct. 20 1968	May 23 1969	June 20 1969	July 29 1969
COLEOPTERA											
Heterlimnius	4		1	3	35	1	1			1	34
DIPTERA											
Atherix variagata						2			1		
Hexatoma			2		3						
Pericoma					32						
Rhabdomastix	10										
Simuliidae				18	1	4			2	2	
Tendepedidae	101	5	7	70	4	30	25		14	65	103
Tipulidae			1	1						1	
Unknown			1		3		8				3
EPHEMEROPTERA											
Ameletus				2	10				3		3
Baetis	34	8	1	104	4	52	27	2	24	100	37
Cinygmula	66	56	9	160	166	28			96	103	50
Epeorus (*Iron*)				2		1			46	107	14
Epeorus (*Ironopsis*)	7	4									
Ephemerella											
coloradensis	1	4	1			1			1	5	28
doddsi	1	9		36	44	7			4	7	11
grandis										1	
tibialis						5			3		11
Heptagenia						8	1		1		

BOTTOM SAMPLES, STATION 1. (continued)

	July 4 1967	July 18 1967	Aug. 8 1967	Sept. 11 1967	Nov. 4 1967	July 17 1968	Sept. 24 1968	Oct. 20 1968	May 23 1969	June 20 1969	July 29 1969
Paraleptophlebia							8				
Rhithrogena				17	16	75			3	2	
Unknown						25			20	30	18
PLECOPTERA											
Acroneuria			7	2	12						1
Alloperla	20		2	61	51	7			8	12	47
Arcynopteryx			1	2			2				
Brachyptera					10	2					
Isogenus	3	17		13					1	8	5
Nemoura				5	2	3	11		2	1	2
Nemouridae	6	4	2	13	12	2			1	2	7
Paraperla				1							
Unknown						1	10		16	10	9
TRICHOPTERA											
Glossosoma				2	3						5
Limnephilidae							1				
Limnephilus			2			1					
Parapsyche	2			19	3					2	5
Rhyacophila	3			6	29		1		1	3	17
Sortosa						3					
Unknown											3

BOTTOM SAMPLES, STATION 1. (continued)

	July 4 1967	July 18 1967	Aug. 8 1967	Sept. 11 1967	Nov. 4 1967	July 17 1968	Sept. 24 1968	Oct. 20 1968	May 23 1969	June 20 1969	July 29 1969
OTHERS											
Hydra				1							
Hydracarina				1							
Oligochaeta		4			4	11			16	5	
Turbellaria		5		5							5
TOTAL WEIGHT, GRAMS	0.5	0.9	0.8	0.6	1.6	1.3	0.1	0.01	0.5	1.7	2.6
TOTAL NUMBER	258	116	37	544	444	286	95	2	263	467	418

BOTTOM SAMPLES, STATION 2.

(3 sq. ft. samples)

	July 5 1967	July 18 1967	May 24 1968	July 17 1968	Sept. 24 1968	Oct. 7 1968	May* 23 1969	May** 23 1969	June* 20 1969	June** 20 1969	July* 29 1969	July** 29 1969
COLEOPTERA												
Zaitzevia											1	
DIPTERA												
Pericoma								2				
Simuliidae	1			2			1			1	3	
Tendepedidae	10	18	4	145			9	8	44	33	40	T
Tipulidae								1				
EPHEMEROPTERA												
Ameletus												10
Baetis	11	13	2	69	4	2	9	39	44	65	134	
Cinygmula	21	36	10	25			21	74	48	30	62	
Epeorus (*Iron*)							8	18	36	53	310	
Epeorus (*Ironopsis*)	6	5	5									
Ephemerella												
coloradensis									1		8	T
doddsi	1	6	1	2					6	1	1	
inermis											1	
tibialis				13				2	1		15	T
Paraleptophlebia					1							
Rhithrogena				66			2		1	1	7	
Unknown				46			70	60	6	36	38	

* = upper sample
** = lower sample

BOTTOM SAMPLES, STATION 2. (continued)

	July 5 1967	July 18 1967	May 24 1968	July 17 1968	Sept. 24 1968	Oct. 7 1968	May* 23 1969	May** 23 1969	June* 20 1969	June** 20 1969	July* 29 1969	July** 29 1969
PLECOPTERA												
Alloperla		1						3	4		18	
Arcynopteryx				4							1	
Brachyptera							2	40				
Nemoura			2	2	2	1	3	1		3	3	
Nemouridae		3										T
Isogenus		2						2	1		3	
Unknown				5			5				21	
TRICHOPTERA												
Glossosoma											1	
Limnephilidae		1										
Parapsyche											3	
Rhyacophila				1	1			2	1		4	
Unknown											10	
OTHERS												
Hydracarina				1								
Oligochaeta	5			3			6	4	8		1	
Turbellaria				1			1		2		4	
Unknown											15	
TOTAL WEIGHT, GRAMS	0.3	0.8	0.2	0.9	0.002	0.002	0.2	0.4	0.9	0.5	1.9	
TOTAL NUMBER	55	86	24	385	8	3	137	261	203	226	704	

BOTTOM SAMPLES, STATION 3.

(3 sq. ft. samples)

	Jul 4 '67	Jul 18 '67	Aug 8 '67	Sep 11 '67	Nov 4 '67	Mar 15 '68	Apr 19 '68	May 10 '68	Jun 4 '68	Jul 17 '68	Sep 24 '68	Oct 20 '68	Nov 27 '68	Jan 5 '69	Feb 2 '69	Mar 28 '69	Apr 19 '69	May 23 '69	Jun 20 '69	Jul 29 '69
COLEOPTERA																				
Dytiscidae			1								3									
Heterlimnius			8	7	17	9	2	7	4	34	41	31	7	3	3	1	4	14	38	3
Lara														1						
Narpus															2					
Optioservus												2	3	1						
Zaitzevia												10			1	9				1
DIPTERA																				
Antocha												2		2	2	2				
Atherix variagata							3			8			3			3	3	1	1	1
Ceratopogonidae										1		5				6	1	1		3
Dicranota					1	3		3	1											
Erioptera															3					
Hexatoma						1	1		2	3			4				1		1	
Pericoma				1	8	8	3	8	3			8	2		5	8	4			
Prionocera															1					
Simuliidae							1	7	1			1	2	1		3	1	6		4
Tendepedidae	1	4	31	49	7	34	25		9	122	15	22	30	12	334	79	37	8	44	63
Tipulidae			2		1				1		2									
Unknown					1	2	1		1					2						
EPHEMEROPTERA																				
Ameletus			1		13	7	32		2			6	1	18	4	2	4			4
Baetis	5	12	15	147	67	47	50	19	26	57	78	222	807	142	109	239	21	9	48	31
Cinygmula	6	76	35	110	43	191	76	68	48	112	65	85	122	21	131	132	115	49	166	115
Epeorus (Iron)			35	10												57	12	9	88	149
Epeorus (Ironopsis)	2	30			17	41	16	46	9				2							6
Ephemerella																				
coloradensis	14	9	14	1				27	31	34	4							16	64	22
doddsi	2	6	9	7	36	6		17	1	8	10	25	38	8	42	18	5	2	6	13
grandis												1				4				
hystrix												1		1		1		1		
inermis	1	7			16	33	10	7	1	1			3							14

BOTTOM SAMPLES, STATION 3. (continued)

	Jul 4 '67	Jul 18 '67	Aug 8 '67	Sep 11 '67	Nov 4 '67	Mar 15 '68	Apr 19 '68	May 10 '68	Jun 4 '68	Jul 17 '68	Sep 24 '68	Oct 20 '68	Nov 27 '68	Jan 5 '69	Feb 2 '69	Mar 28 '69	Apr 19 '69	May 23 '69	Jun 20 '69	Jul 29 '69
EPHEMEROPTERA																				
Ephemerella																				
proserpina								1												
spinifera			1		2	1							3							
tibialis			5							69	16	82	67	16	114	115	148		6	16
species				2	1	23	29													
Heptagenia	12									15	10	19	35	30	42	63	10	3		
Paraleptophlebia				13	4	7	4		1		4	2	4	1	3	3			1	
Rhithrogena	23	7		16	105	2	8	10	5	66	8	52	81	57	52	45	17	23	14	
Unknown										22	23	48	16	36	44	90	25	2	22	48
PLECOPTERA																				
Acroneuria	2	1	1	17	2	6	1	4	2	6	8	6	4	1	10	2		2	2	1
Alloperla	2	3	14		28	48	17			8		37	68	59	50	56	55	58		45
Arcynopteryx			3	20	2		3			19	60	2	4		3	4	4	1	2	
Brachyptera					2		1	1		15		5	61	21	14	15				
Chloroperlidae								22												
Isogenus					3	3	1		1			8	6	2	5	15	2	9		11
Nemoura			3	5	45		7		1	35	43	21	35	9	24	57	2		7	20
Nemouridae			1	3	9	3	5	1		12		10	18	6	19	15	16	2		9
Paraperla	1	3			6		6					3	3		2					
Unknown										40		42	8	8	32	32	12	26	17	24
TRICHOPTERA																				
Arctopsyche												2								
Glossosoma			14	10	6	2	1					12		9	8	5	3		2	53
Hydropsyche																				
Lepidostoma						6														
Limnephilidae				1	2	1			6		1	5								
Limnephilus			4																	
Psychoronia			4	3																
Parapsyche	1		2	3	14			4		2		5	15	3	13	8				3
Rhyacophila	6	3	6	15	20	5	9	9	2	12	14	14	13	9	15	44	7	3	31	20
Sortosa										3			5							2
Brachycentrus										6		8	7			2			1	13
Unknown															1	6				20

BOTTOM SAMPLES, STATION 3. (continued)

	Jul 4 '67	Jul 18 '67	Aug 8 '67	Sep 11 '67	Nov 4 '67	Mar 15 '68	Apr 19 '68	May 10 '68	Jun 4 '68	Jul 17 '68	Sep 24 '68	Oct 20 '68	Nov 27 '68	Jan 5 '69	Feb 2 '69	Mar 28 '69	Apr 19 '69	May 23 '69	Jun 20 '69	Jul 29 '69
OTHERS																				
Hydracarina										4			3		2	1				
Ostracoda												1	1		1					
Oligochaeta					1				1			2		1	1	3	3	4		3
Turbellaria		1		10			1	10	1	2	3	7	13	10	3	16	4			
Unknown				30																10
TOTAL WEIGHT, GRAMS	.74	1.4	1.9	2.1	2.6	3.2	3.3	2.3	1.6	2.2	0.9	2.7	2.5	0.7	2.1	2.1	1.4	1.3	3.0	4.0
TOTAL NUMBER	78	162	210	481	493	489	313	272	161	716	472	814	1494	490	1095	1201	516	249	561	750

CHEMISTRY, STATION 1.

All values are in mg/liter except Turbidity (JTU), Temperature (°C), and pH.

	July 5/67	July 11/67	July 18/67	July 25/67	Aug 1/67	Aug 8/67	Aug 16/67	Aug 22/67	Sept 4/67	Sept 11/67	Sept 18/67	Sept 23/67	Oct 6/67	Oct 20/67
Temperature	7	7	9	10	9.5	9	9.5	8	8	7	8.5	8	8	4
Oxygen	10	9	10	9	6	8	8	7	8	8	7	7	7	8
pH	7.8	7.5	7.7	8.2	8	8	8	8.3	8.1	8.4	8.3	8.4	8.4	7.9
Alkalinity	40	50	55	65	65	55	60	70	80	75	85	70	70	80
Turbidity	3	5	3	5	5	5	0	5	3	5	0	5	5	5
Hardness-Total	40	50	50	60	60	-	70	70	-	70	70	75	80	75
Hardness-Calcium	30	30	40	50	50	-	50	55	-	60	60	65	65	65
Nitrate	.08	.08	.12	.07	.10	-	.10	-	-	.06	-	-	.07	.08
Silica	3.3	2.2	3.7	2	3.5	-	4.2	-	2.8	4.8	2.3	-	4.8	2.8
Sulfate	6	5	5	5	6	-	6	5	6	7	6	-	7	7
Phosphate	.1	.2	.15	.1	.2	-	.05	.1	-	.2	.1	-	.05	.08
Chromate	-	-	-	-	-	.025	.05	-	-	.05	.05	-	-	-
Fluoride	-	-	-	-	-	.10	.15	-	-	.2	-	-	-	-
Iron	-	-	-	-	-	.05	0	-	-	.03	.01	-	-	-
Manganese	-	-	-	-	-	.35	.40	-	-	.60	.50	-	-	-

CHEMISTRY, STATION 1. (continued)

	Nov 4/67	Nov 17/67	June 19/68	June 27/68	July 10/68	July 17/68	July 25/68	Sept 24/68	Oct 6/68	Oct 20/68	Nov 1/68
Temperature	2	3	7	6	11	10	9	7	6	4	3
Oxygen	8	7	8	7	6	8	9	11	11	11	11
pH	8.2	8.4	8.4	8.4	8.4	8.4	8.4	8.4	7.4	7.4	7.8
Alkalinity	70	60	45	40	50	60	75	60	70	70	65
Turbidity	5	5	0	0	0	0	0	0	0	0	0
Hardness-Total	65	60	55	45	60	65	70	65	80	80	65
Hardness-Calcium	50	40	45	35	40	45	50	50	50	50	50
Nitrate	-	.05	.06	.06	.06	.05	.05	-	.12	-	.09
Silica	4	3.9	2.2	3.2	2.5	2.3	2.9	2.5	2.6	3.3	2.8
Sulfate	6	5	6	6	8	7	6	8	4	6	6
Phosphate	.08	.10	.10	.10	.10	.05	.10	.05	.10	.10	.10
Chromate	.05	.04	.05	-	-	.07	-	.06	-	.06	-
Fluoride	-	-	-	-	-	0	-	.09	-	0	-
Iron	.05	.04	0	-	-	0	-	.01	-	.01	-
Manganese	0	.01	.06	-	-	.30	-	.40	-	.60	-

CHEMISTRY, STATION 12.

	July 5/67	July 11/67	July 18/67	July 25/67	Aug 1/67	Aug 8/67	Aug 16/67	Aug 22/67	Nov 17/67	May 10/68	May 17/68	May 29/68
Temperature	7.5	7	9	11	9.5	DRY	DRY	DRY	4	3	4.5	5.5
Oxygen	10	10	10	9	8	"	"	"	8	8	8	7
pH	7.6	7.7	7.7	7.7	8.3	"	"	"	8.1	8.3	8.3	8.4
Alkalinity	50	55	60	65	65	"	"	"	60	60	65	55
Turbidity	3	2	3	5	5	"	"	"	5	5	5	0
Hardness-Total	45	50	50	60	60	"	"	"	60	65	65	65
Hardness-Calcium	35	40	40	45	45	"	"	"	50	50	45	50
Nitrate	.08	.03	.08	.07	.04	"	"	"	.04	.06	.07	.05
Silica	3.7	3.0	3.4	3.0	2.5	"	"	"	3.8	3.4	3.6	2.7
Sulfate	6	5	7	5	6	"	"	"	5	7	8	6
Phosphate	.1	.3	.15	.1	.2	"	"	"	.1	.2	.1	.1
Chromate	-	-	-	-	-	"	"	"	.05	.04	.06	.05
Fluoride	-	-	-	-	-	"	"	"	-	-	-	-
Iron	-	-	-	-	-	"	"	"	.05	.05	.05	.05
Manganese	-	-	-	-	-	"	"	"	.10	.40	.50	.50

CHEMISTRY, STATION 2. (continued)

	June 11/68	June 19/68	June 27/68	July 10/68	July 17/68	July 25/68	Aug 1968	Sept 1968	Oct 6/68	Nov 2/68	Dec 17/68
Temperature	7	7	6	11	10	9	DRY	DRY	6	3	2.5
Oxygen	9	9	7	6	8	9	"	"	11	11	11
pH	8.4	8.4	8.4	8.4	8.4	8.4	"	"	7.4	7.7	7.9
Alkalinity	60	50	40	50	60	75	"	"	70	65	70
Turbidity	0	0	0	0	0	0	"	"	0	0	0
Hardness-Total	65	55	45	55	65	70	"	"	90	75	70
Hardness-Calcium	50	45	35	40	45	50	"	"	55	55	55
Nitrate	.05	.06	.06	.06	.05	.05	"	"	.12	.07	.05
Silica	3.2	3	3	2.5	2.5	2.6	"	"	2.3	2.7	2.7
Sulfate	6	6	5	8	8	6	"	"	5	6	5
Phosphate	.1	.1	.15	.15	.15	.1	"	"	.1	.15	.1
Chromate	.05	.08	-	.04	-	-	"	"	-	-	-
Fluoride	-	-	-	.05	-	-	"	"	-	-	-
Iron	.05	0	-	0	-	-	"	"	-	-	-
Manganese	.50	.60	-	.40	-	-	"	"	-	-	-

CHEMISTRY, STATION 3.

	July 5/67	July 11/67	July 18/67	July 25/67	Aug 1/67	Aug 8/67	Aug 16/67	Aug 22/67	Sept 11/67	Sept 18/67	Sept 23/67	Oct 6/67	Oct 20/67	Nov 4/67
Temperature	9	9	10	11	9.5	9	9.5	8	8	7	8.5	8	4	1
Oxygen	10	10	9	9	7	7	7	7	8	8	8	8	8	7
pH	7.9	8.3	7.9	7.9	8.1	8.2	8.1	8.2	8	8.4	8.1	8.5	8	8.6
Alkalinity	55	60	60	65	60	60	60	70	80	80	70	70	80	75
Turbidity	7	6	3	5	5	5	0	5	3	5	8	5	5	5
Hardness-Total	50	60	60	65	65	-	70	65	70	75	75	80	75	60
Hardness-Calcium	40	40	45	55	50	-	50	55	60	60	65	65	65	50
Nitrate	.08	.03	.12	.06	.07	-	.07	-	.08	-	-	.06	.11	-
Silica	4	3.5	4.4	4	3.8	-	4.8	-	2.7	5	3.2	5	3.1	3.6
Sulfate	7	5	8	7	7	-	6	6	6	8	7	5	5	7
Phosphate	.1	.1	.15	.1	.2	-	.1	.08	.18	.2	-	.07	.15	.1
Chromate	-	-	-	-	-	-	-	.03	.06	.04	-	-	-	.05
Fluoride	-	-	-	-	-	.20	-	.20	.25	-	-	-	-	-
Iron	-	-	-	-	-	.07	-	.03	.03	.02	-	-	-	.03
Manganese	-	-	-	-	-	.5	-	.5	.4	.5	-	-	-	.1

CHEMISTRY, STATION 3. (continued)

	Nov 17/67	Dec 2/67	Dec 29/67	Jan 13/68	Jan 27/68	Feb 13/68	Feb 24/68	Mar 9/68	Mar 23/68	Apr 5/68	Apr 19/68	Apr 26/68	May 3/68	May 10/68
Temperature	3	0	2	0	0	0	2.5	2	3.5	5	4.5	5	6.5	4
Oxygen	9	11	10	11	13	13	12	13	10	8	8	9	8	8
pH	8.3	8.5	8.2	8.1	8.4	8.4	8.5	8.4	8.6	8.2	8.3	8.4	8.5	8.3
Alkalinity	75	80	70	75	75	75	65	65	60	60	65	70	60	65
Turbidity	5	2	5	3	5	5	6	0	0	0	5	0	0	5
Hardness-Total	70	75	85	80	90	80	70	65	65	55	75	65	65	65
Hardness-Calcium	60	60	60	60	70	70	45	40	45	45	50	50	45	50
Nitrate	.06	.08	.07	.06	.10	.09	.09	.11	.14	.09	.10	.06	.05	.04
Silica	4.6	2.5	4.8	4.8	2.8	3	2	2.3	4	4.5	3.5	3.4	4.2	3.4
Sulfate	6	5	7	6	7	7	8	12	6	9	9	7	6	7
Phosphate	.1	.15	.10	.1	.1	.1	.1	.1	.15	.1	.1	.05	.15	.2
Chromate	.04	.04	.04	.04	.04	.04	.07	.07	.06	.07	.06	.04	.05	.06
Fluoride	-	0	0	-	-	-	-	-	-	-	-	-	-	-
Iron	.05	0	.05	0	.08	.06	.05	.10	.05	.02	.07	.05	.05	.03
Manganese	.25	.25	.25	.30	.30	.30	.25	.25	.10	.05	.50	.02	.01	.25

CHEMISTRY, STATION 3. (continued)

	May 17/68	May 29/68	June 11/68	June 19/68	June 27/68	July 10/68	July 17/68	July 25/68	Aug 14/68	Sept 24/68	Oct 6/68	Oct 20/68	Nov 2/68	Dec 17/68
Temperature	6	6.5	8	8	7	12	11	9	10	6.5	5	5	4	2.5
Oxygen	7	7	8	9	8	8	7	8	8	10	11.8	11.3	11.8	13.6
pH	8.4	8.4	8.3	8.5	8.2	8.3	8.4	8.4	8.4	8.3	8.4	7.8	7.8	7.9
Alkalinity	60	55	60	50	50	60	65	70	70	70	70	70	65	70
Turbidity	5	0	0	0	0	0	0	0	0	0	0	0	0	0
Hardness-Total	70	65	70	55	45	65	70	75	75	73	80	75	80	70
Hardness-Calcium	55	50	50	45	35	50	50	55	50	51	50	55	60	55
Nitrate	.06	.05	.06	.05	.06	.06	.06	.05	-	-	.11	-	.06	.05
Silica	4.2	2.6	3.6	2.5	2.5	2.5	2.9	2.9	4	3.1	2.7	3.5	2.9	2.7
Sulfate	8	6	6	6	6	8	8	6	6	4.5	6	6	5	5
Phosphate	.10	.10	.10	.15	.10	.15	.10	.10	.10	.13	.10	.10	.20	.10
Chromate	.07	.05	.06	-	.06	-	.05	-	.08	.06	-	.07	-	.08
Fluoride	-	-	-	-	-	-	.30	-	.05	.10	-	0	-	0
Iron	.05	.05	.05	-	0	-	0	-	0	.01	-	.02	-	.05
Manganese	.50	.50	.50	-	.75	-	.40	-	.15	.50	-	.70	-	.70