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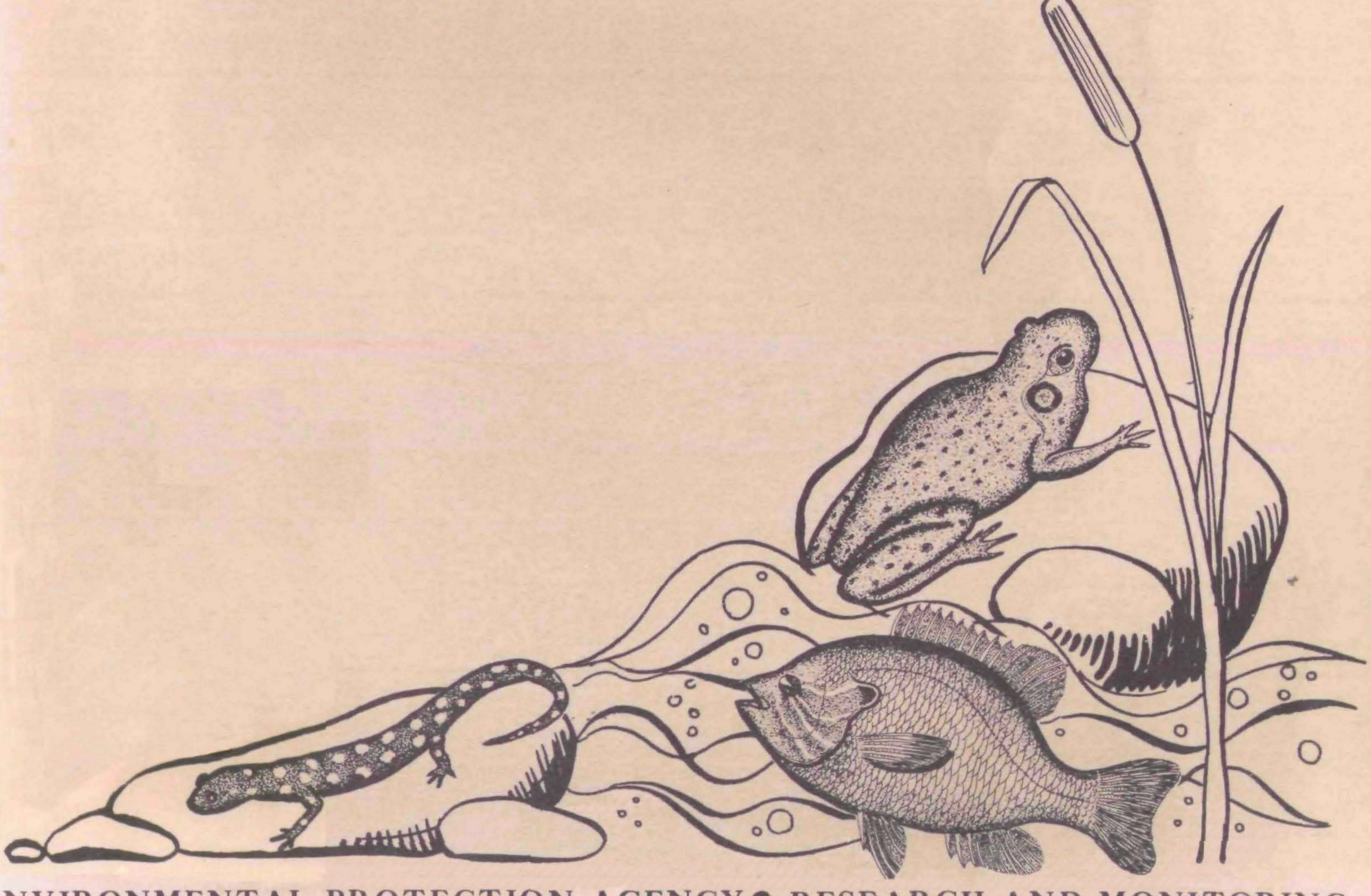
# Stream Faunal Recovery After Manganese Strip Mine Reclamation



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# STREAM FAUNAL RECOVERY AFTER MANGANESE STRIP MINE RECLAMATION

by

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for the

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ABSTRACT

Seasonal monitoring of certain chemical, physical, and biological parameters of streams draining manganese strip mine spoils in three stages of reclamation verifies that the community structure of fish and benthic macroinvertebrates in these streams remains severely depressed until complete reclamation of the spoils has been accomplished. Six years after reclamation, only the faunal community in the stream draining the fully reclaimed area has recovered.

Laboratory studies established the median tolerance limits of three native species of fishes to silt in suspension and to manganese ions. These studies suggest that the principal factor depressing the faunal communities in partially reclaimed and unreclaimed streams is the chronically high degree of turbidity and siltation. A comparison of the growth of rainbow trout fingerlings in clear vs. turbid water revealed a statistically significant slower growth in the turbid water, further substantiating the assumption that siltation and turbidity are limiting to those faunal communities.



This report was submitted in fulfillment of project number WP-01530 under the partial sponsorship of the Water Quality Office, Environmental Protection Agency.

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FIGURES

# SECTION I

## CONCLUSIONS

1. Monitoring activities established that faunal communities in streams draining partially reclaimed and unreclaimed manganese strip mine areas remain chronically suppressed. Streams draining reclaimed areas support more dense and diverse faunal communities, evidently as a result of lower levels of turbidity and siltation.

2. Ninety-six hour TLm studies rule out the possibility that incident levels of manganese in the study streams could be acutely toxic to the resident species of fishes. A comparison of the growth and survival of rainbow trout reared in clear and turbid waters indicated a statistically significant slower growth rate in turbid water, suggesting the possibility of other physiological effects of chronic exposure to high levels of silt in suspension.

3. Unreclaimed and partially reclaimed streams had a higher percentage of particles less than 0.841 mm in diameter than did the reclaimed stream (Slemp Creek) and the unaffected stream (Hurricane Branch).

4. Reclaimed areas produce levels of manganese ions as high as occur in unreclaimed areas, probably as a result of the leaching of ores brought nearer the surface by the mining process.

5. Although all taxa of bottom fauna seem to be affected equally by the high turbidities and siltation in unreclaimed and partially reclaimed streams, the overall diversity is reduced because of the scarcity of certain orders.

6. Faunal recovery in the reclaimed stream (Slemp Creek) was evidently complete six years after reclamation. Partial reclamation is ineffective in bringing about faunal recovery or changing the turbidity and silt load of affected waters.

# SECTION II

## RECOMMENDATIONS

Effective reclamation of most types of surface mining spoils is predicated on the control of a range of pollutants, the nature of which is determined by the geology of the area and associated environmental conditions, and any one of which may be limiting to the recovery of a stream's fauna. The results of this investigation suggest a number of conditions to be met for effective reclamation particularly of manganese strip mines, and in general any surface mining which tends to increase the degree of siltation and turbidity in receiving waters. The following recommendations relate to these findings and to areas of investigation which should be pursued in greater depth.

1. Reclamation should be such that manganese ion concentrations in the receiving streams are less than 7 mg/1, if acute toxicity to certain species of fishes is to be avoided. Concentrations of other forms of manganese such as is represented by $MnO_2$ can be tolerated at much higher levels.

2. Reclamation should reduce persistent turbidity levels to less than 75 Jackson turbidity units if a viable community of fish and macrobenthic organisms is to be maintained.

3. In establishing policies of reclamation procedures, it should be recognized that effective reclamation can be accomplished only through reclamation of all the disturbed portions of a watershed.

4. In the area of toxicology, more emphasis should be given to the study of the effects of chronic exposure to silt and heavy metals on the reproduction, growth, and physiology of fishes.

5. On the basis of laboratory and field observations, the use of clay silt to reduce the concentration of heavy metals in water appears promising and should be the object of further investigations.

## SECTION III

## INTRODUCTION

In recent years an upsurge of activity in the mining, road building, and other industries has greatly increased the quantities of silt and heavy metals entering aquatic environments. Boccardy and Spaulding (1968) state that in eight Appalachian states 832,605 acres of land have been disturbed by surface mining. This disturbance affects more than 5,000 miles of streams, and over 13,800 acres of impoundments. Current fossil fuel demands coupled with increases in the efficiency of strip mining operations serve to magnify the problem. Stricter legislation and increasing awareness of the problem is resulting in better mining practices and increased reclamation efforts, but little is known of the effectiveness of various reclamation efforts or the rates at which aquatic biological communities recover once effective reclamation has been accomplished.

Manganese strip mining operations in southeastern Smyth County, Virginia, during the mid 1950's have left several spoil areas that continue to contribute silt and manganese ions to the South Fork Holston River. In that area (Figure 1), 295 acres have been disturbed. The U. S. Forest Service has purchased portions of this and adjoining lands and in 1959 began reclamation efforts on Brushy Mountain, the watershed in which Slemp Creek originates. This work was completed in 1960 and in 1966 reclamation was completed on spoils areas of Bishop Branch owned by the Forest Service. Because of a policy of the Forest Service their reclamation efforts are limited to land which they own. Consequently, in 1966 when the Forest Service completed reclamation efforts on the Slemp Creek and Bishop Branch watersheds, 40 acres of spoil areas had been reclaimed. This included all of the spoil areas on Slemp Creek, and part of the disturbed area on the Bishop Branch watershed. Because of private ownership of the spoil areas on Georges Branch and Slabtown Branch at that time, no reclamation was attempted on those areas, resulting in a series of reclaimed, partially reclaimed, and unreclaimed tributaries of the South Fork Holston. Following a recent Forest Service purchase of spoil areas on Slabtown Branch, reclamation is planned for the Spring of 1971.

Prior to the reclamation efforts of the Forest Service, extensive damage to the property of local landowners as a result of flooding, deposition of silt and rock debris, and the fouling of water supplies along the tributaries was documented. Because of the extreme turbidity of the South Fork Holston, Buller Fish Hatchery was rendered "90% unusable." Previously clear waters of these tributaries and the South Fork Holston River were described by personnel of the Forest Service as "extremely turbid and heavily silted." These conditions persist in the partially reclaimed and unreclaimed tributaries of the South Fork. Turbidity values in the unreclaimed streams commonly are between 40 and 200 Jackson Turbidity Units and readings of 32,000 Jackson Turbidity Units (unpublished Forest Service stream survey report) have been recorded. Manganese ions have been measured in concentrations as high as 2.4 ppm.

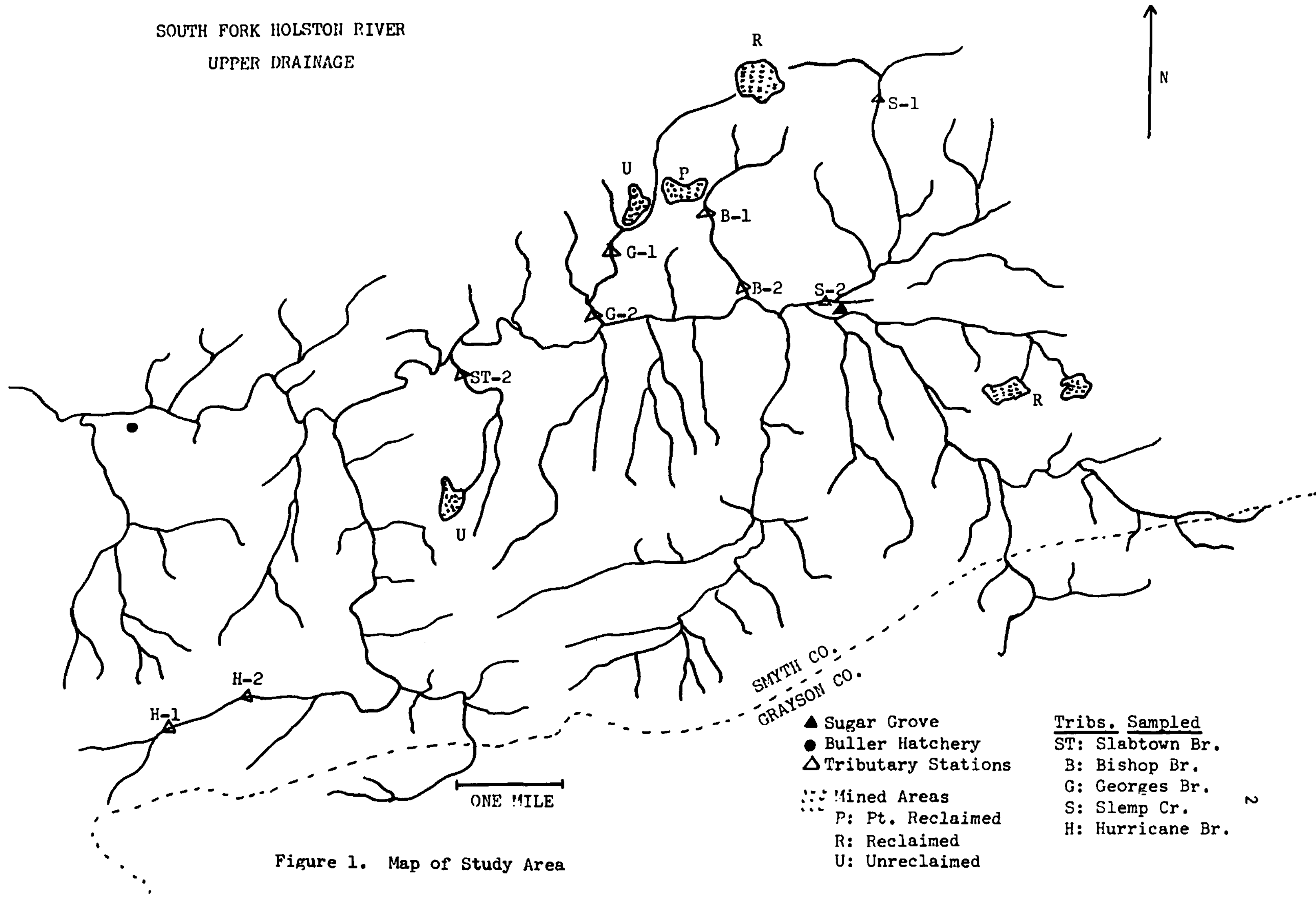


Figure 1. Map of Study Area

The purpose of this research was to evaluate the effect of manganese strip mine reclamation on stream faunal recovery. This evaluation proceeded along the lines of chemical, physical, and biological monitoring activities designed to assess stream faunal population differences through time and under varying environmental conditions. Acute and chronic toxicity studies designed to determine whether the silt and manganese levels in the affected streams were high enough to limit survival of two local fish species were corollary aspects of the research.

# SECTION IV

# METHODS AND MATERIALS

## THE STUDY STREAMS

### Slemp Creek

Slemp Creek originates on Brushy Mountain in the Jefferson National Forest. The upper reaches of Slemp Creek drain National Forest land, part of which is a reclaimed strip mine area, while the lower portion drains private farm land. Slemp Creek is seldom turbid, and although heavy deposits of sand and gravel occur in areas of low velocity, siltation is negligible. Slemp Creek and two others form the headwaters of the South Fork Holston River.

### Bishop Branch

Bishop Branch originates on Brushy Mountain and joins the South Fork about two miles downstream from the mouth of Slemp Creek. The upper portion of Bishop Branch flows through a partially reclaimed manganese strip mine area, while the lower portion flows through private farm land. Bishop Branch is a narrow (seldom exceeding four feet in width), fast flowing stream with few pools. In the slower portions, the bottom is largely sand and silt, while in the faster portions, small boulders and sand predominate. During low flow, about a 150-meter stretch of the stream flows underground 0.25 mile above its mouth. Above the underground section, the entire substratum is always covered with a fine layer of silt.

### Georges Branch

Georges Branch also originates on Brushy Mountain, with a ridge of land forming a divide between the spoils of Bishop Branch and Georges Branch. No reclamation has been undertaken on the spoils of Georges Branch. The stream is always turbid and the entire substratum is covered with a fine layer of silt.

### Slabtown Branch

Slabtown Branch flows into the South Fork about two miles downstream from Georges Branch and on the opposite side of the valley. One fork of the upper portion drains on unreclaimed strip mine area; and although that fork is intermittent during periods when it flows, it deposits enough silt in the other portions of the stream to maintain a constantly high turbidity.

### Hurricane Branch

Hurricane Branch which originates in the Iron Mountains about eight miles northeast of Sugar Grove serves as one of the control streams in the study. It is predominantly a long series of rapids with small pools. The water is not turbid even at high flow, and the substrate is composed largely of gravel and small boulders. Bedrock is encountered more frequently in this stream than in the others of this study.

## SELECTION OF A CONTROL STREAM

Control areas could not be established on the other streams described here because as tributary streams they originate on or near the strip mined areas, thus ruling out the possibility of using a portion of the stream above the pollution source as a control area. The two remaining alternatives were to compare the reclaimed stream with the unreclaimed and partially reclaimed ones, or to compare the reclaimed, unreclaimed, and partially reclaimed streams with a stream unaffected by strip mining activity. Hurricane Branch is unaffected by strip mining, but its waters are very soft (5-10 ppm) and have a low biological productivity. It was, therefore, not directly comparable to the other streams. With these facts in mind, it was decided that Slemp Creek should serve as the "control" stream and that Hurricane Branch should serve to represent the physical properties of a stream unaffected by strip mining.

## STATION SELECTIONS

With the exception of Slabtown Branch, two stations were selected on each of the study streams for sampling all parameters except substrate composition. Only one station was established on Slabtown Branch. The stations were established on the upper and lower sections of the streams and were chosen on the basis of how well they represented other sections of the streams. Each sampling area contained a riffle and a pool area. For the substrate analysis, an additional station was established in the mid-section of the stream.

## MONITORING ACTIVITIES

In order to document the continuing damage to the ecology of the study streams resulting from the influence of the unreclaimed strip mine areas and to evaluate the degree of recovery of streams draining reclaimed strip mine areas, the following parameters were sampled at approximately the intervals indicated: Water chemistry (dissolved oxygen, pH, alkalinity, total hardness, iron, and manganese) at two-month intervals; temperature and volume of flow at two-month intervals and coinciding with the measurements of water chemistry; fish and benthic macroinvertebrates quarterly; and substrate composition yearly.

Alkalinity, total hardness, pH, and dissolved oxygen were measured using the Hach Chemical Company's model AL-59 kit. The low-range tests of the kit were used for alkalinity and total hardness. Samples were taken at midstream and were analyzed on the site. The Hach Chemical Company's 1, 10 phenanthroline method for iron and the cold periodate method for manganese were employed, using that Company's AL-59 kit. After July, 1969, the same reagents for iron and manganese were used, but the determinations were made with a Bausch and Lomb Spectronic 20 colorimeter.

## Streambed Composition

With the aim of quantifying differences in the physical characteristics of the various stream classes being studied, an analysis of the particle sizes of the streambeds was undertaken. Of particular interest was the percentage of the total substrate composed of finer particles such as sand and silt which would be indicative of continuing erosional activities. All the techniques proposed elsewhere for extracting samples of the streambed were inappropriate for the streams in this study because of the preponderance of large rocks and boulders, so a different sampling device, consisting of a saw-toothed, metal cylinder with handles, was designed and constructed. Operation of the sampler required two men who rotated it clockwise and counterclockwise about $30^{\circ}$ in each direction, thus drilling the saw-toothed edge of the apparatus down into the streambed. After drilling the metal cylinder into the substrate, approximately four liters of the bottom material were scooped out and placed in a plastic bucket prior to separation into different particle size classes. Water containing silt particles in suspension was then dipped out and set aside in plastic buckets. Water was dipped from the scooped-out area until "dry," or in cases where penetration of the sampling device was inadequate to prevent seepage of water, until the water began to clear inside the sampling area.

After collection of the sample, the bottom materials and the scooped-out water were washed through a series of nine sieves (19, 12.7, 6.35, 3.36, 1.68, 0.841, 0.420, 0.210, and 0.105 mm openings) and their volume was measured by a method of displacement (McNeil and Ahnell, 1964). Water containing silt particles which passed through the finest sieve was placed in a large settling funnel and allowed to stand for 30 minutes, after which water containing most of the settleable solids was drawn off the bottom into a bucket, and was then stored in a plastic one gallon jug at least 24 hours prior to final measurement. At that time, the upper one half of the plastic jug was carefully removed, the water was poured off and the volume of the settled solids was measured. About 28 to 32 hours are required for the analysis of a series of 60 samples which is the number required for duplicate samples taken from pool and riffle areas on the upper, middle, and lower portions of the study streams.

## Volume of Flow

Volume of flow was determined using the formula $R = W D a V$ and the method of Robins and Crawford (1954) where R is equal to the volume of flow in cfs, W is average width, D is average depth in feet, V is the velocity in feet per second, and a is a coefficient of roughness (0.8 for rough bottoms and 0.9 for smooth bottoms). This float method was found to be most applicable to the study area because of the extreme shallowness of most areas of the streams. Average width was determined from measurements with a 50-foot steel tape at one-meter intervals. Depth measurements were taken in the center of the stream and halfway between the center and each bank, also at one-meter intervals. These readings were then averaged to determine mean depth.

Temperature

Air and water temperatures were taken after the method of Lagler (1956) with a centigrade thermometer at all stations whenever chemical data and fish and bottom fauna were collected.

Turbidity

For all samples after July, 1969, the procedure of the Hach Chemical Company was used to determine turbidity in standard Jackson Units. Using the Spectronic 20 colorimeter, percent transmittance was converted to turbidity in standard Jackson Units by referring to a table made from standard formazin solutions using a Jackson Candle Turbidimeter. Prior to July, 1969, turbidity measurements utilized the Hach Chemical Company's model AL-59 kit.

Fish Collections

Fish collections were made utilizing the model BP-IC backpack shocker obtained from Coffelt Electronics Company, Denver, Colorado. A six-foot whip electrode mounted on a single wooden pole was used. A switch on the pole controlled the current. About 1.5 amps were produced on AC current at an output of 325 volts.

At the time of each collection, a 150-foot section of stream at each station was shocked and the fish were collected with a long handled nylon dip net. The operation required a minimum of two men. In the case of soft water, such as in Hurricane Branch, it was necessary to throw crushed salt into the water upstream prior to shocking. The fish were released after identification to avoid overexploitation of existing stocks in the small streams.

Bottom Fauna Collections

Bottom fauna collections were made at approximately three-month intervals throughout the study. An unmodified Surber square foot sampler was the sampling device. Three samples were taken at every station each sampling period. The samples were transferred from the Surber sampler to a white enamel pan and separated from the accompanying debris at the sampling site. The sorted organisms were then preserved in vials of 70 percent ethanol. Identification was to order at the time of this report, but is being carried to genus.

ACUTE TOXICITY STUDIES

The Test Fish

The rainbow trout sac-fry were obtained from the new Wytheville National Fish Hatchery (Wytheville # 2) as eyed eggs and were hatched in aluminum hatching troughs at the old Wytheville National Fish Hatchery (Wytheville # 1) where the toxicity studies were run. Rainbow trout fingerlings also were obtained from Wytheville # 2.

The white sucker fry were obtained from Wisconsin's Department of Natural Resources fish hatchery at Woodruff, Wisconsin, via air freight. The fish were shipped in a sealed and oxygenated plastic bag containing about 20 liters of water. Transit time was about 13 hours. After transporting the fry to the fisheries laboratory on campus, the fry were transferred to plastic swimming pools filled with dechlorinated tap water. Total hardness and pH (total hardness 45 ppm, pH 7.2) was nearly identical to that of the Wisconsin hatchery.

The white sucker fingerlings were reared by transporting some of the Wisconsin fry to a cement pond at Virginia's Buller Fish Hatchery in late June, 1969. They were held there until the white sucker fingerling experiment in August, 1970, at which time they weighed an average of 1.6 grams.

When an attempt to hatch blacknose dace fry and a subsequent attempt to capture them in local streams failed, it was decided that juveniles and adults would be the life history stages of this species used in the toxicity experiments. The juveniles were captured in the headwaters of Big Stony Creek in Giles County and were held in a plastic swimming pool filled with dechlorinated tap water until they were used in the manganese toxicity study of July, 1970. The blacknose dace adults were seined from Meadowbrook Branch near Buller Hatchery in Smyth County.

The Bioassay Apparatus

The test containers for all the experiments were of a series of one gallon glass jars filled with either two or three liters of water, depending upon the weight of the fish and other experimental conditions. Fourteen-foot aluminum hatching troughs filled with running water served to maintain a relatively constant temperature. In all tests except the one with blacknose dace juveniles, each jar was supplied with one of a series of air stones connected to a small air compressor.

Water Quality

Three water qualities have been used in the toxicity experiments reported here. They are Slemp Creek (total hardness 35-45 ppm, pH 7.2), Wytheville # 2 spring water (total hardness 120 ppm, pH 7.5), and campus fisheries laboratory tap water (total hardness 45 ppm, pH 7.6). Slemp Creek water was used in the rainbow trout sac-fry experiments and the rainbow trout fingerling study in which suspended silt was the toxicant. Wytheville # 2 spring water was used to determine the tolerance of rainbow trout fingerlings to $Mn^{+2}$ ions. Fisheries laboratory tap water was used for all the white sucker and blacknose dace experiments.

Toxicants

The three toxicants which have been used in these experiments are $Mn(NO_3)_2$, $MnO_2$, and suspended silt. The $Mn(NO_3)_2$ was obtained as a 10,000 ppm atomic absorption standard solution from the Fisher Scientific Company, and as a 51.2 percent reagent grade solution from the same company. The atomic absorption standard solution was used for the rainbow trout sac-fry experiment and the 51.2 percent solution was used for the other experiments.

A 10,000 ppm solution of $Mn(NO_3)_2$ was always the strength of the solution pipetted into the diluent water. After pipetting, the solutions were stirred vigorously with a glass rod to insure thorough mixing before introducing the fish into the test containers.

The silt used in this series of experiments was obtained from the bed of a conical shaped depression located on the unreclaimed portion of the Bishop Branch strip mine. It was air dried and ground in a mortar and pestle prior to putting it into suspension. The silt was kept in suspension by moderately violent aeration.

The $MnO_2$ was in a powder form and was obtained from the Fisher Scientific Company.

Measurements to determine actual quantities of the various toxicants in solution or suspension were usually taken 48 hours after beginning the experiment. Materials in suspension were measured in terms of turbidity units, and manganese was measured colorimetrically using Hach Chemical Company's cold periodate oxidation method and a Spectronic 20 colorimeter.

CHRONIC EFFECTS OF SILT IN SUSPENSION

Facilities of the Buller Fish Hatchery near Marion, Virginia, were used to compare the growth of rainbow trout and white sucker fingerlings in clear versus turbid water. Two cement ponds 100 feet long, eight feet wide, and three feet deep were each divided into six compartments by 1/4-inch mesh screens. In the study conducted during the fall of 1969, water was delivered to the two ponds from an adjacent earthen pond in an attempt to avoid the occasional high turbidities of water coming directly from the South Fork Holston. Turbidity was induced in one pond by having the incoming water flow across a basket of semi-dried clay silt. Each of the ponds was stocked with three groups of fifty white sucker and rainbow trout fingerlings. Individual lengths and mean weights were taken at the beginning and end of the experiment.

Because of difficulties in maintaining a high turbidity in the turbid pond and in an attempt to attain a better statistical design, a second experiment was initiated in the fall of 1970. This time a circulating pump maintained a stirring action inside a 55-gallon drum to which clay silt was added daily. The amount of turbid water leaving the drum and entering the test pond was controlled by the amount of influent water. Since the suspected significant differences in length and weight changes could not be validated statistically in the first experiment, fish were tagged internally with a numbered, plastic tag in the second experiment in an attempt to improve the experimental analysis. In this experiment three groups of twenty-five rainbow trout and white suckers were stocked in each of the ponds and fed daily for thirty days. To allow for mortality and tag loss, twenty fish from each compartment were selected at random for the statistical analysis.

## SECTION V

## RESULTS AND DISCUSSION

### CHANGES IN STREAM SUBSTRATA ASSOCIATED WITH STRIP MINE RECLAMATION

Although no definitive values for degree of siltation prior to reclamation of the streams draining strip mined areas are available, from the statements of local residents it may be inferred that conditions in those streams were similar to those existing in the presently unreclaimed streams. Following this assumption, one can measure the effect of reclamation on stream substrata by comparing unreclaimed and partially reclaimed streams (Georges, Slabtown, and Bishop Branch) with reclaimed and unaffected streams (Slemp Creek and Hurricane Branch, respectively).

Substrate analysis to determine the percentage composition by particle size of the different stream substrates was undertaken in the summers of 1968, 1969, and 1970. In comparing the percentage of the stream substrates composed of particles less than 0.841 mm in diameter (Figure 2), several conclusions can be drawn. At first glance it would appear that the only significant difference in percentage of particles less than 0.841 mm in diameter exists between Hurricane Branch and all the other streams. It must be noted, however, that the upper portion of Slemp Creek is in an area of atypically low gradient. If this is taken into consideration, riffles of Slemp Creek, Hurricane Branch, and the lower portion of Bishop Branch have a substratum with a smaller percentage composed of particles less than 0.841 mm in diameter. The same relationship holds true only for Slemp Creek and Hurricane Branch where comparisons with respect to this particle size class are made among pools of the different streams. As was mentioned previously, a portion of Bishop Branch flows underground and during this course drops a tremendous sediment load so that the only deposition which takes place in the lower portion does so during periods of high flow and then is limited mainly to areas of lesser gradient; the pools. Riffles in Slabtown and Georges Branch had higher percentages of this size class of particles because the streams are constantly turbid, and deposition can take place even at low flow.

Since no substrate analyses were made prior to the summer of 1968, the only statements that can be made about rate of change of these streams' substratum following reclamation is that the percentage of finer sediments was comparably less after eight years. Novak's (1968) observations suggest a similar situation in 1966. The portions of Bishop Branch above the underground section demonstrate that partial reclamation is ineffective in reducing siltation.

### CHANGES IN TURBIDITY AND WATER CHEMISTRY ASSOCIATED WITH STRIP MINE RECLAMATION

The biological productivity of a stream is dependent upon a number of factors, primary among which are the type of streambed of substrate, degree

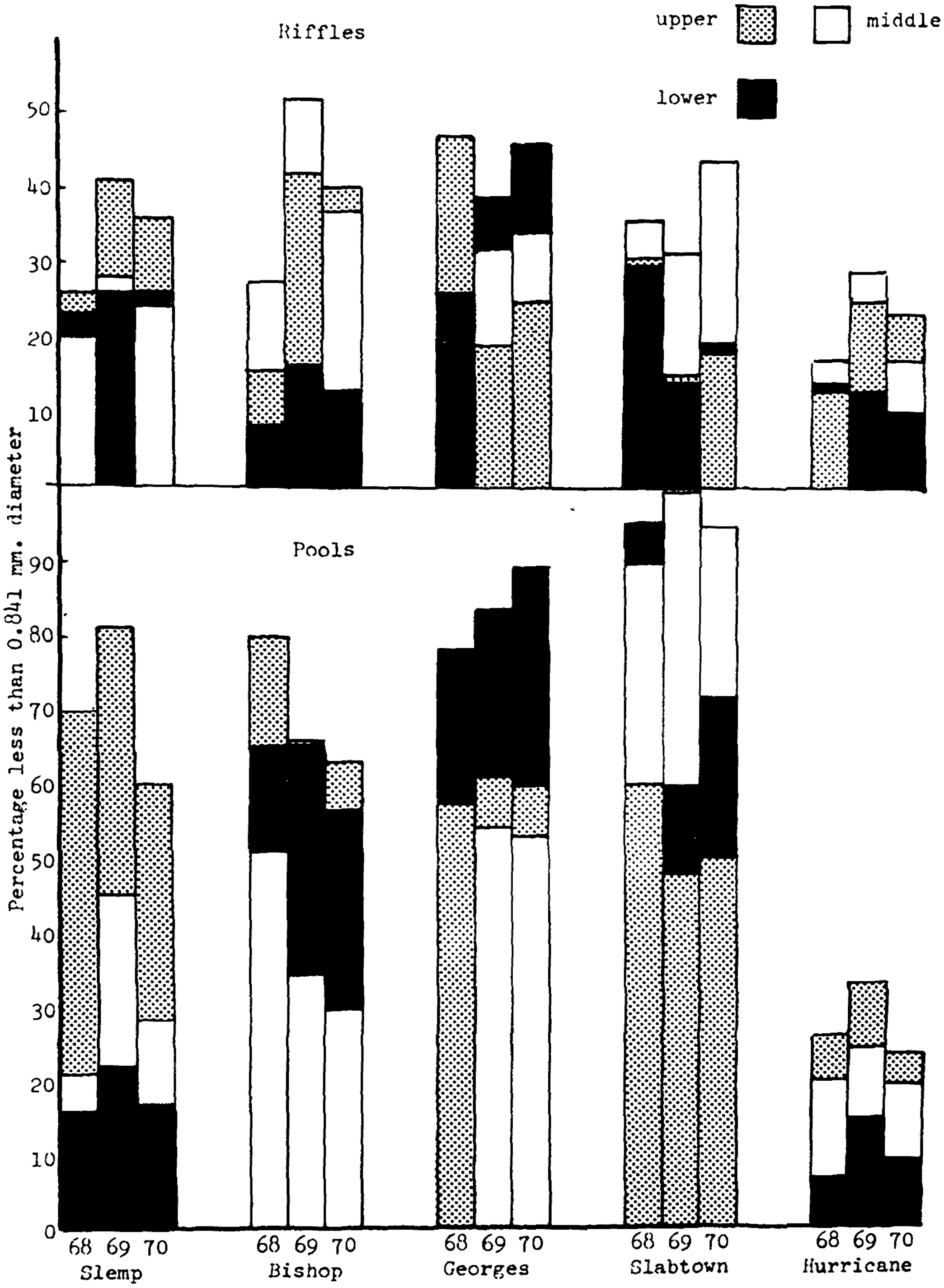


Figure 2. Percentage of the substrate of riffles and pools in the upper, middle, and lower sections of the study streams less than 0.841 mm. in diameter as measured in 1968, 1969, and 1970. No middle sample was taken in 1968. The particle size less than 0.841 mm. represents a natural break in the sieving series which is closely related to suspensoids which do not settle out easily in active water.

of turbidity, basic water chemistry (D.O., $CO_2$, pH, and total hardness), and the absence of toxic materials. Upon analysis of the data in Figure 3, it appears that the principal effect of reclamation of the watersheds of an affected stream (Slemp Creek) has been to dramatically reduce the stream's turbidity. Relatively high manganese concentrations persist, probably as a result of leaching of ores made more available to surface runoff as a result of the mining processes. As in the case of siltation, the high turbidity and manganese levels in the upper portion of Bishop Branch suggest the futility of partial reclamation.

ACUTE AND CHRONIC TOXICITY OF STRIP MINE EFFLUENTS

In order to determine whether the levels of silt and manganese ions in the study streams might be limiting to native species, a series of acute toxicity studies subjecting fry and fingerlings of rainbow trout, blacknose dace, and white suckers to $Mn(NO_3)_2$, silt, and $MnO_2$ was conducted. The data (Figure 4) negate the probability of acute toxicity resulting from the ambient levels of manganese in the study streams, but the occasional extreme turbidities experienced in Bishop, Georges and Slabtown Branch alone or coupled with siltation during the larval stage of development could be acutely lethal. Indeed, this acute lethality is strongly suggested when it is recognized that the upper portion of Georges Branch, the upper portion of Bishop Branch, and all of Slabtown Branch are practically or completely devoid of fish life, even though all conditions excepting turbidity and siltation would appear amenable to supporting a modest fish population.

Exposure of tagged rainbow trout and white sucker fingerlings to about 700 Jackson Turbidity Units of silt in suspension for a 30-day period produced no higher mortalities than occurred in the clear water control groups, but differences in mean length and weight increments were statistically highly significant between the two groups of trout fingerlings. The mean length increment was 25.7 mm in clear water and 19.0 mm in turbid water. The mean weight increment was 51.1 grams in clear water, and 30.6 grams in turbid water. No gross morphological differences were apparent, but this data tends to substantiate the hypothesis that high turbidity is the factor limiting fish populations in the unreclaimed streams.

Stream Faunal Recovery

One means of assessing the impact of various pollutants in aquatic environments is through a study of the fish and bottom faunal communities of a particular system. Figures 5-8 present good evidence of the continuing damage to communities of bottom fauna resulting from unreclaimed strip mine areas. They give equally good evidence that reclamation does in fact make possible recovery in these communities.

Although considerable variation exists between stations on a given stream and even between samples at a given station, certain trends can be detected in the seven bottom fauna collections made between July, 1968, and June, 1970. First, the number of organisms per square foot of sample

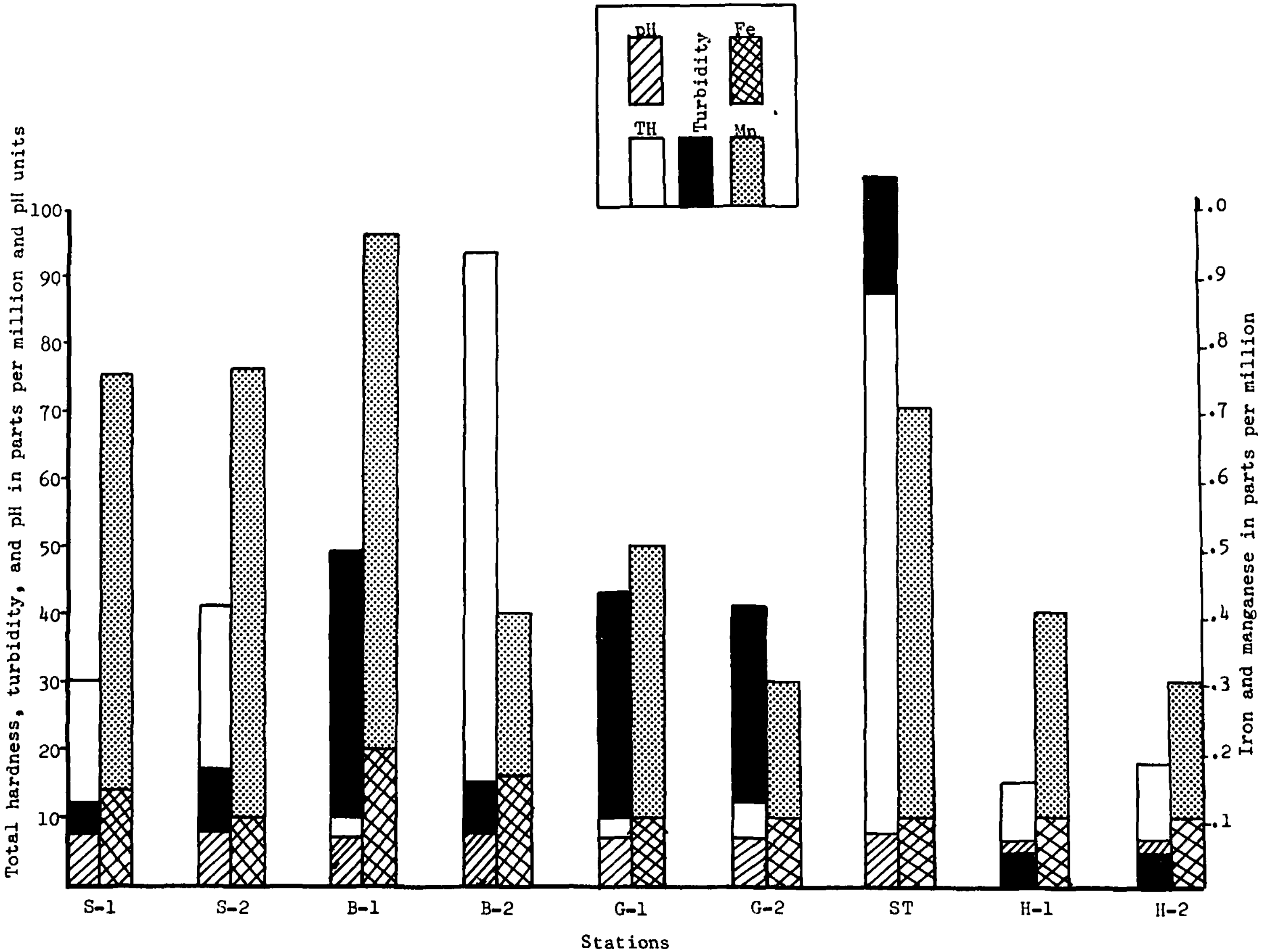


Figure 3. Some water quality parameters for ten sampling periods between July, 1968, and July, 1970. Data represents mean values for the ten periods.

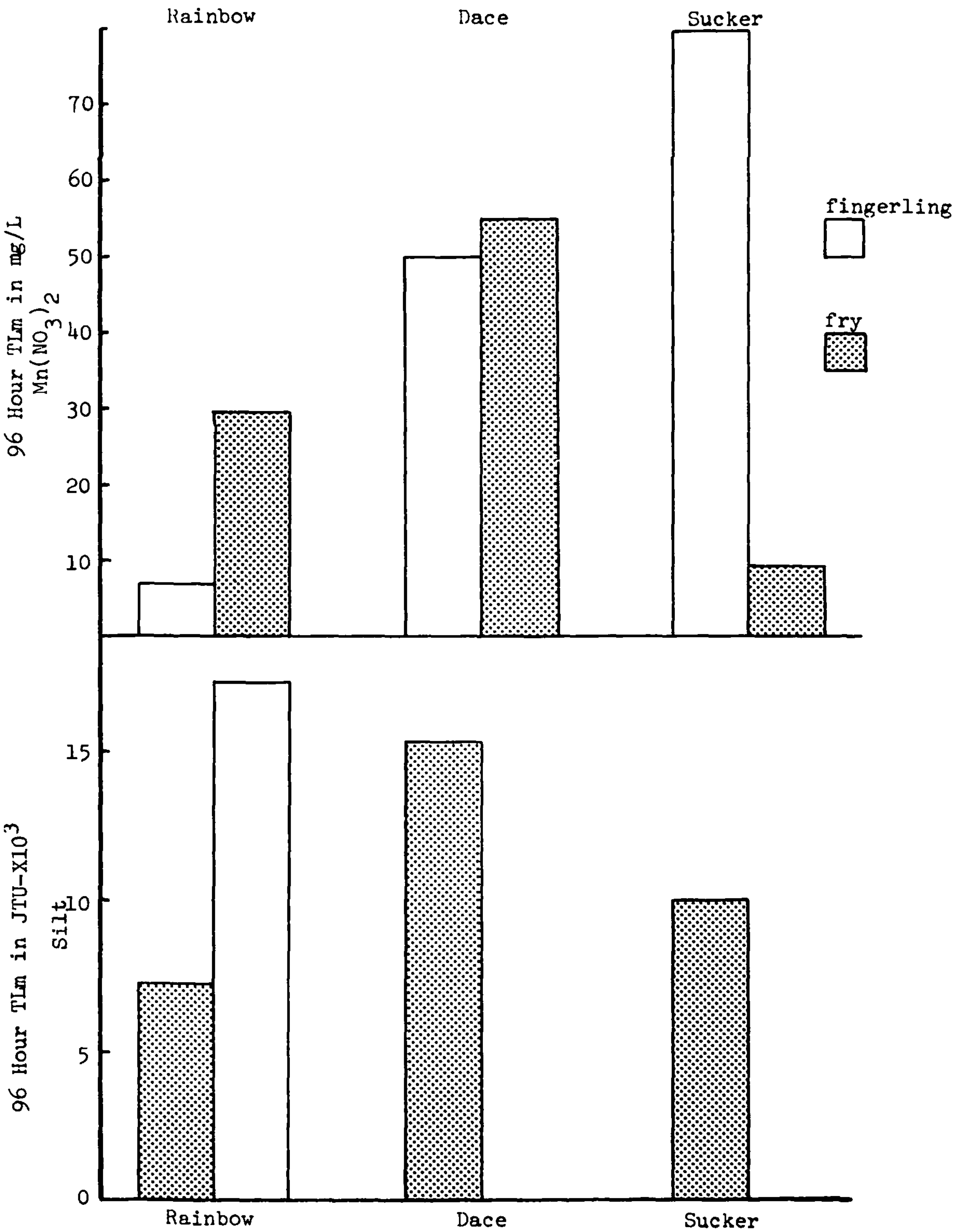


Figure 4. Median tolerance limits of two life history stages of three fish species to $Mn(NO_3)_2$ and silt.

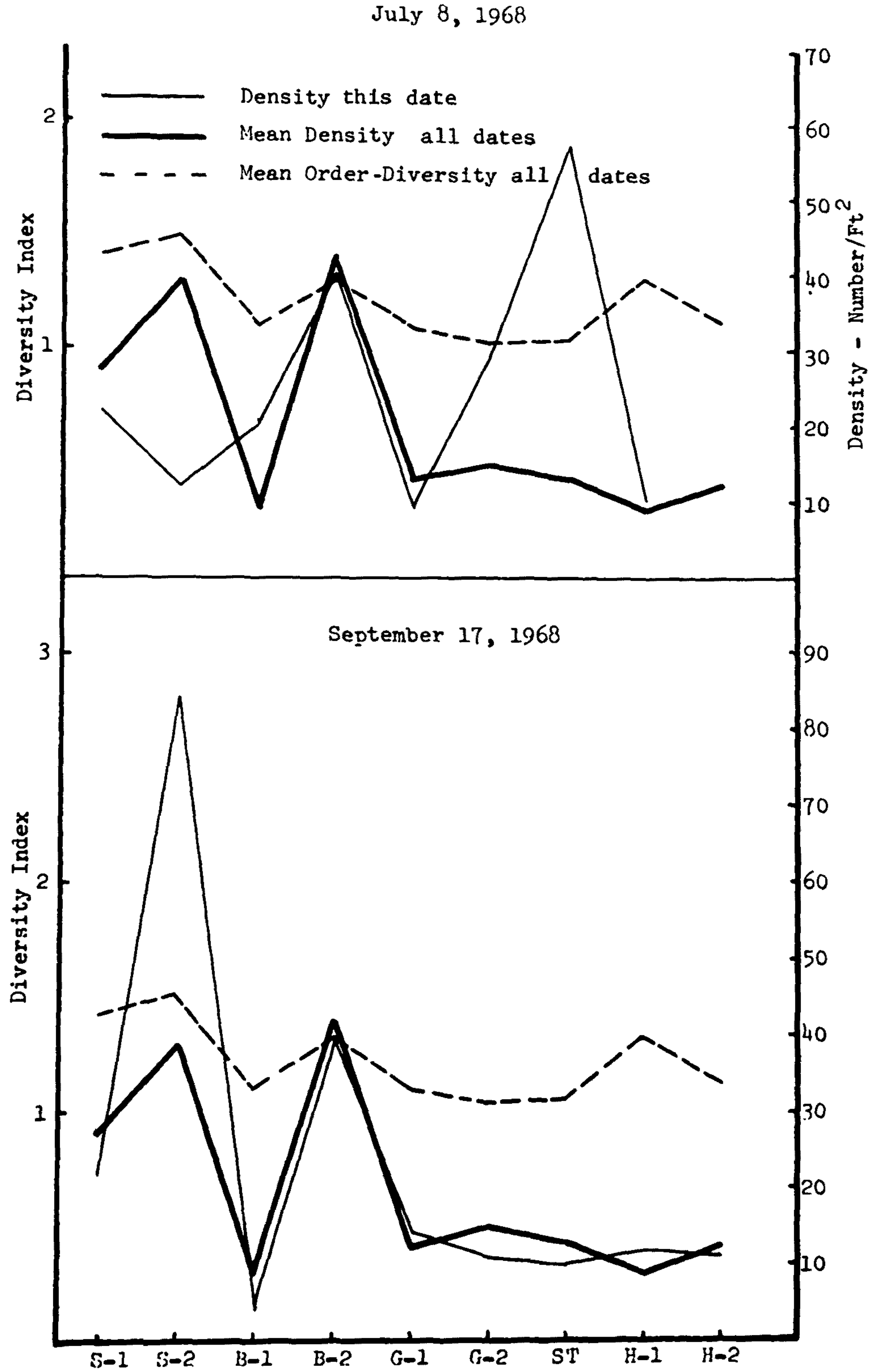


Figure 5. Density and diversity of bottom fauna. Diversity equals number of orders minus 1/the natural log of the number of organisms in that sample.

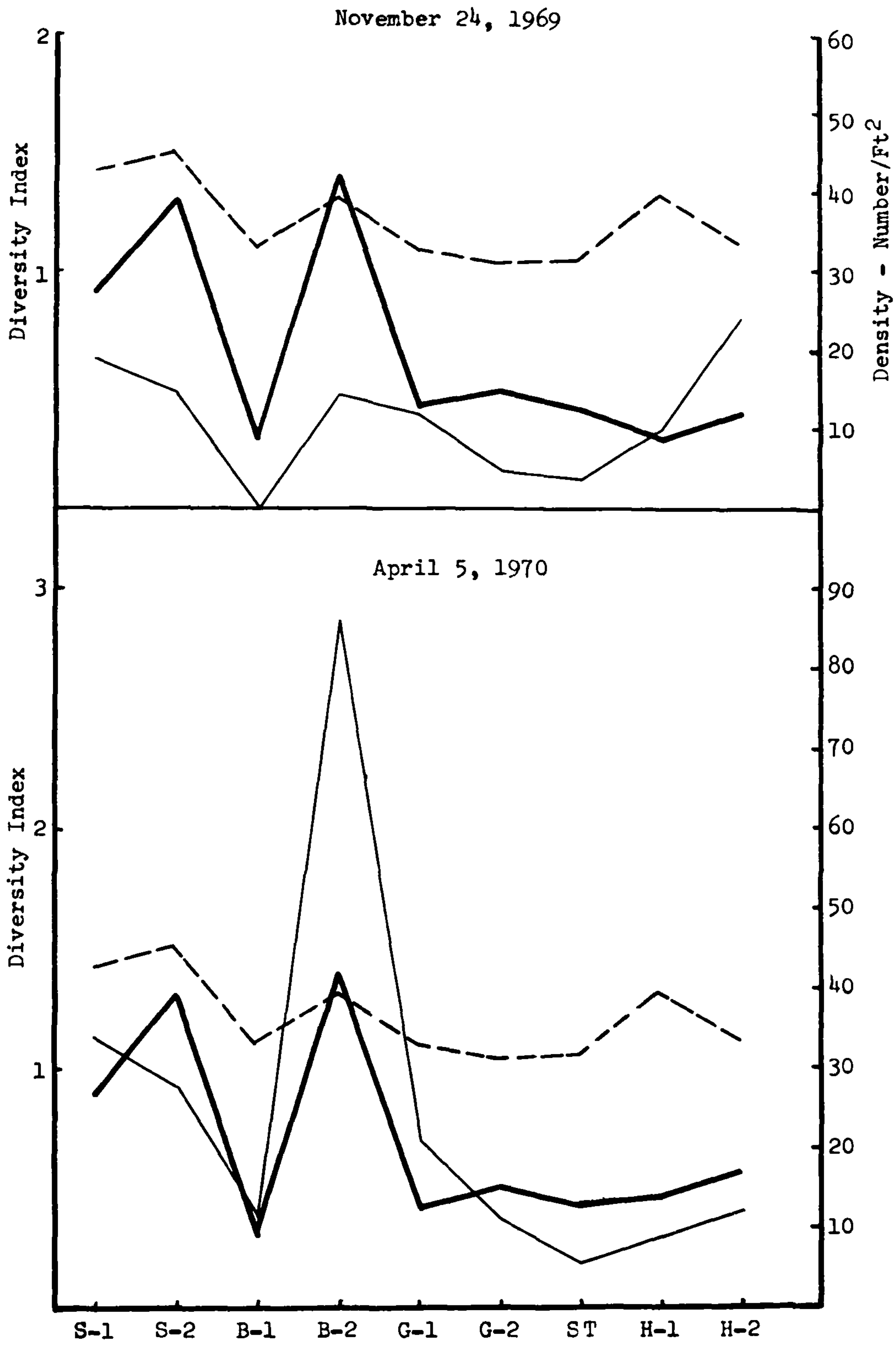


Figure 6. Density and diversity of bottom fauna.

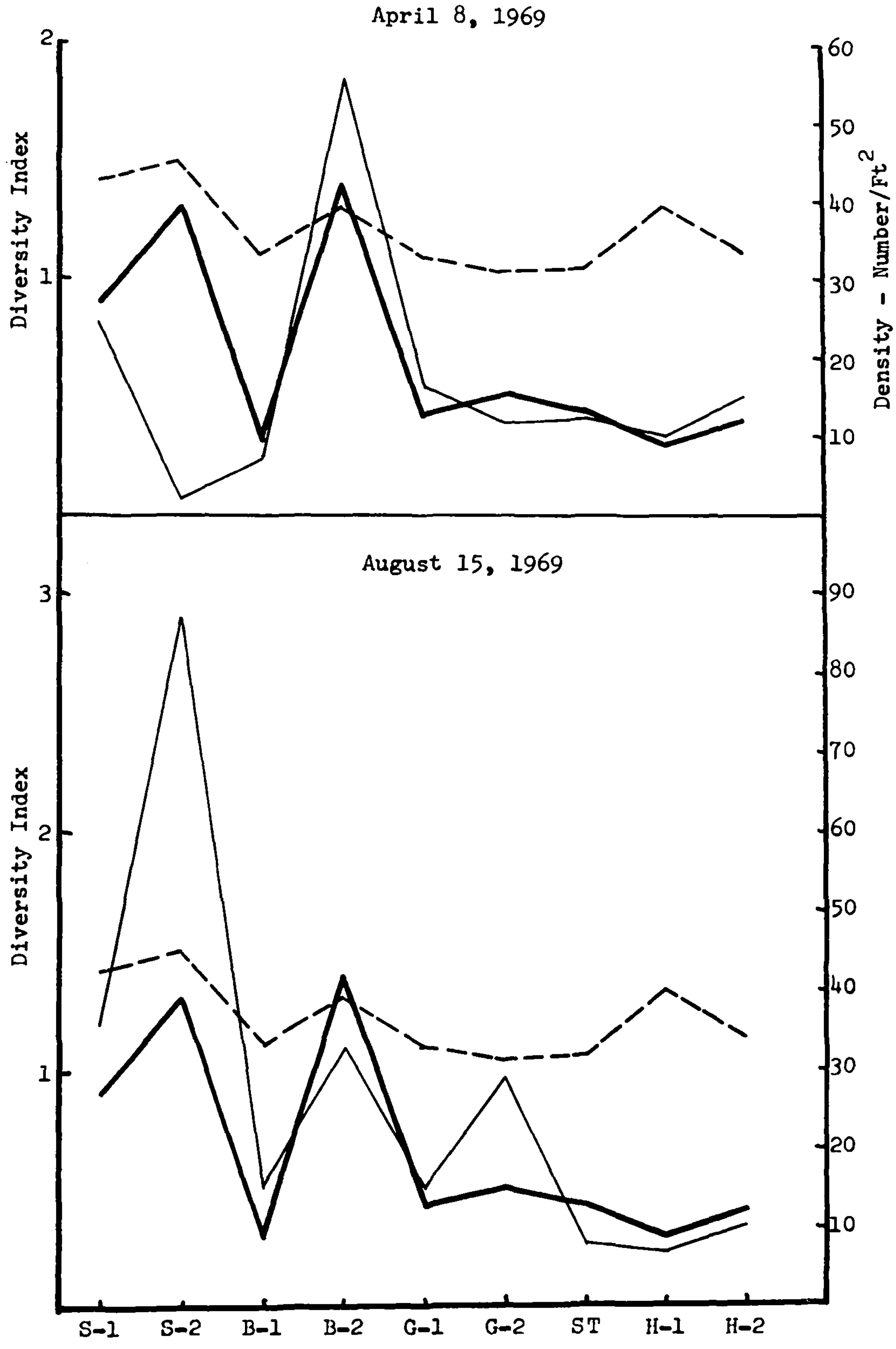


Figure 7. Density and diversity of bottom fauna.

June 25, 1970

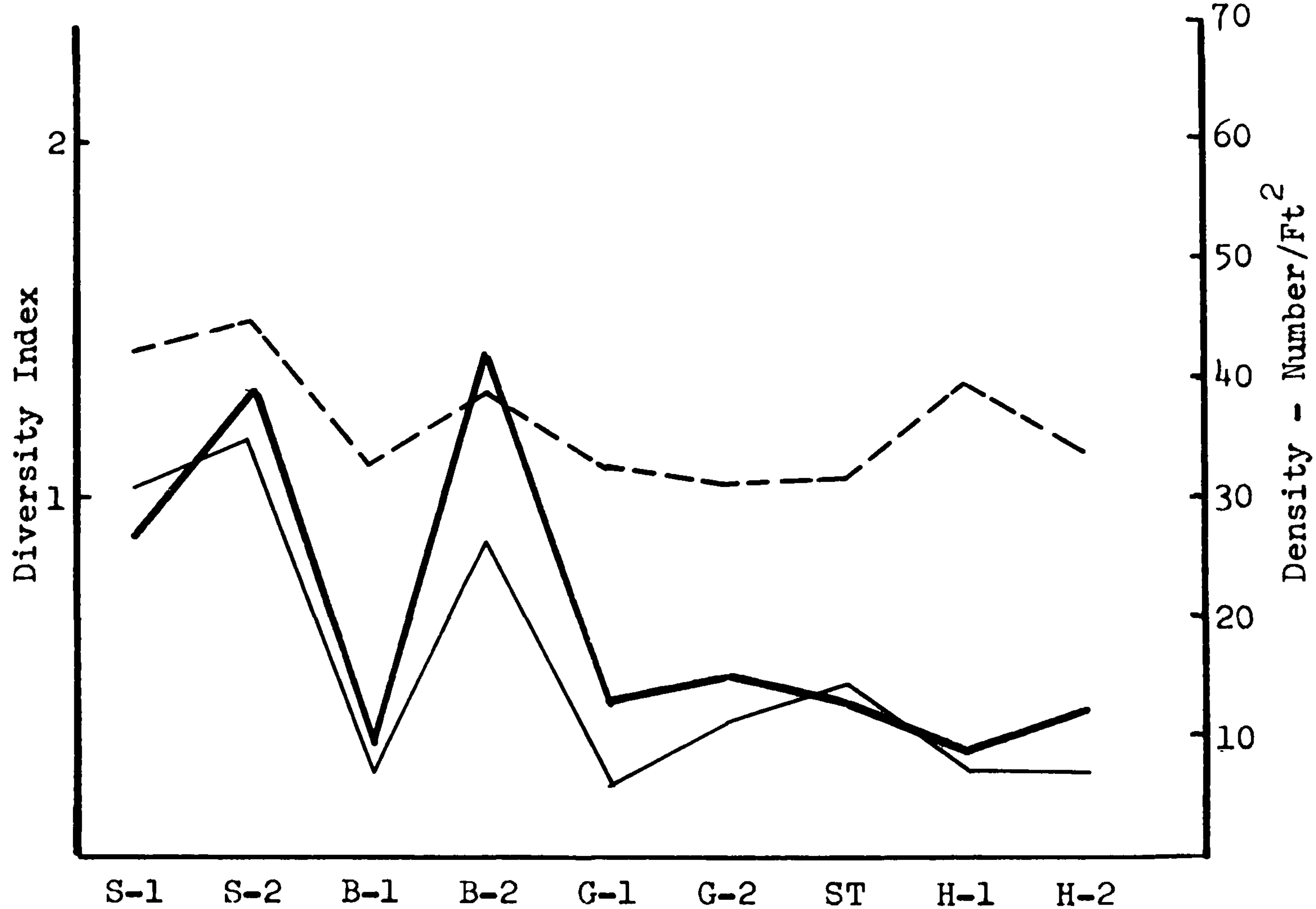


Figure 8. Density and diversity of bottom fauna.

area is higher on Slemp Creek and the lower portion of Bishop Branch than on any of the other streams with the exception of the July, 1968, samples on Slabtown Branch. That data was distorted by the presence of unusual numbers of small mayflies of the baetidae family. Although one might suspect that these data reflect the higher total hardnesses of Slemp Creek and Bishop Branch, that doesn't appear reasonable when it is considered that Slabtown Branch has a total hardness and alkalinity double that of Slemp Creek. Secondly, there would seem to be a significantly lower diversity of bottom faunal organisms in the streams draining unreclaimed areas than exists in Slemp Creek. This is not the usual case in instances of pollution by inorganic sediments, but apparently the standing crop of certain taxa in these streams is low enough that the pollution reduces their numbers to non-significance or even extinction. This supposition is given added weight when one traces the abundance of the relatively rare orders Coleoptera and Amphipoda through Figures 9-15.

Although Novak (1968) made similar findings on density and diversity in his study which began in 1966, the absence of bottom fauna samples prior to reclamation in 1960 and between reclamation and 1966 makes it impossible to speculate about the sequence of recovery in the bottom faunal communities of Slemp Creek. The only conclusions to be drawn are that recovery in Slemp Creek has occurred and appears to be complete. In all probability, the lower portion of Bishop Branch has not experienced recovery, because it was probably never seriously damaged.

The abundance and diversity of species of fish exhibit a pattern of recovery and depression very similar to that of the bottom fauna, with Slemp Creek and the lower station on Bishop Branch showing the greatest abundance. As the species diversity of tributary streams of this type is never great, recovery of the fish populations in Slemp Creek is probably complete (Figure 16). The slight recovery suggested by the collections on Georges Branch probably results from the vulnerability of the lower section of the stream to invasion from the South Fork.

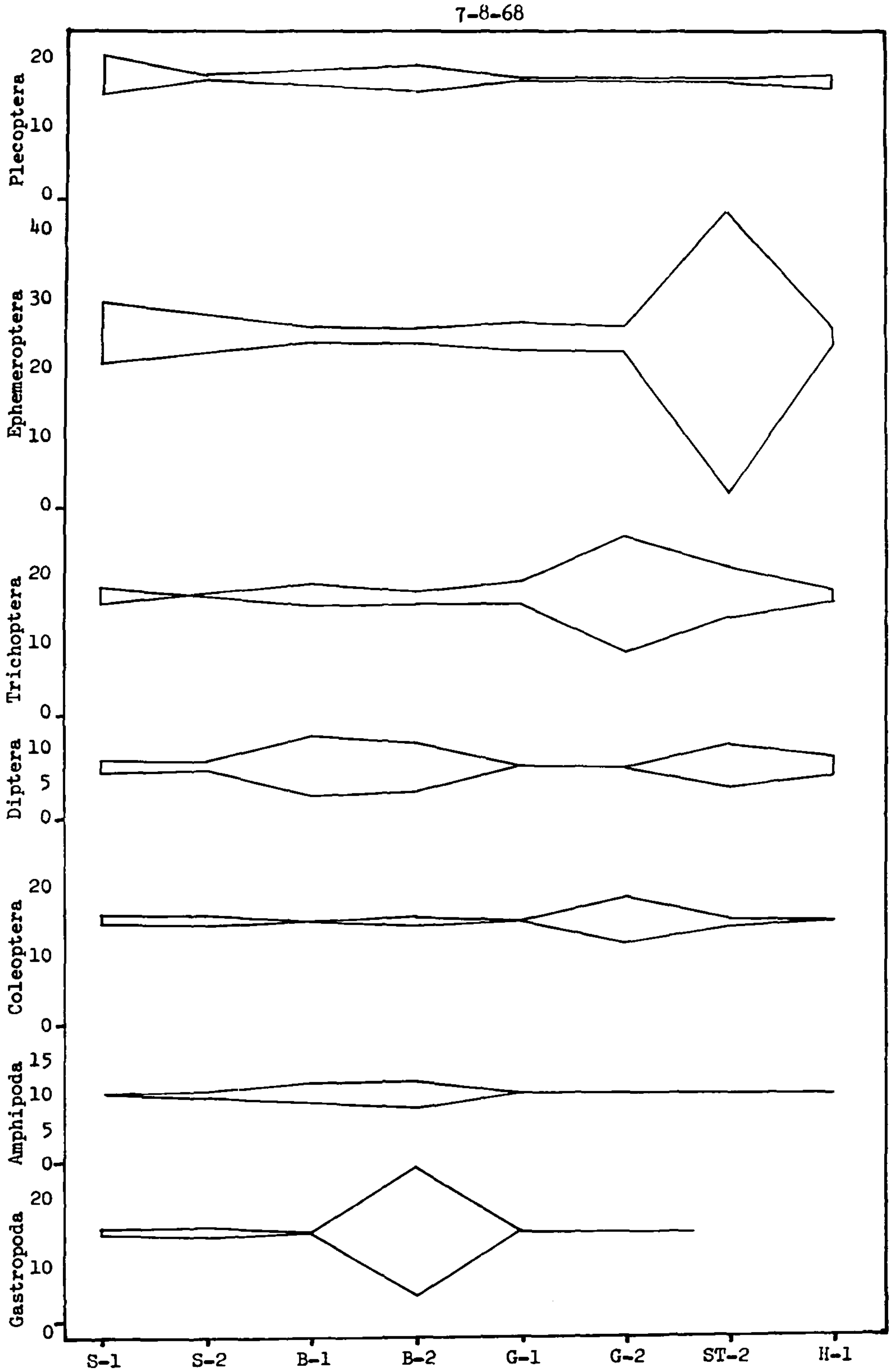


Figure 9. Density (number per ft$^2$) of selected orders of bottom fauna.

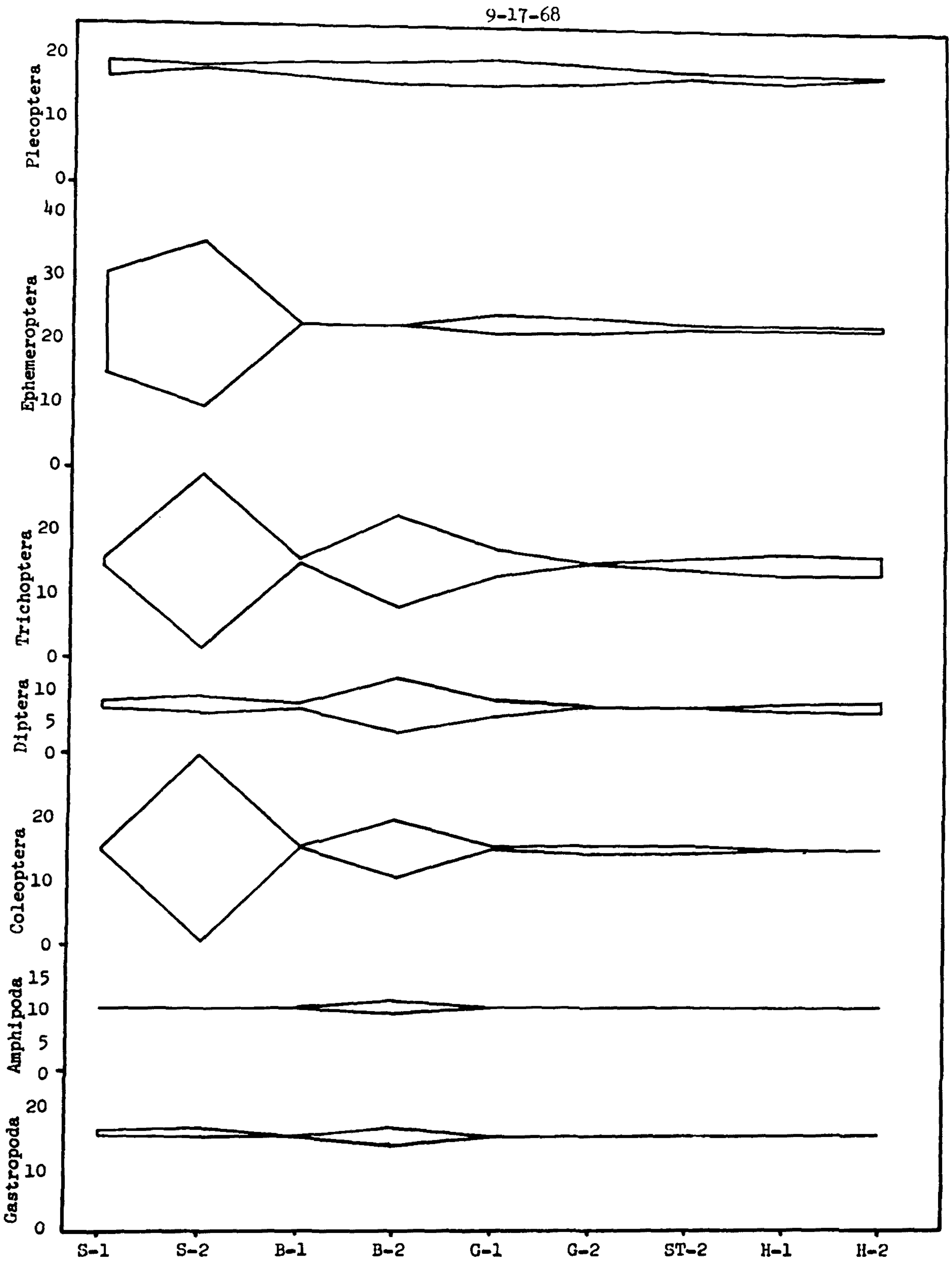


Figure 10. Density (number per $ft^2$) of selected orders of bottom fauna.

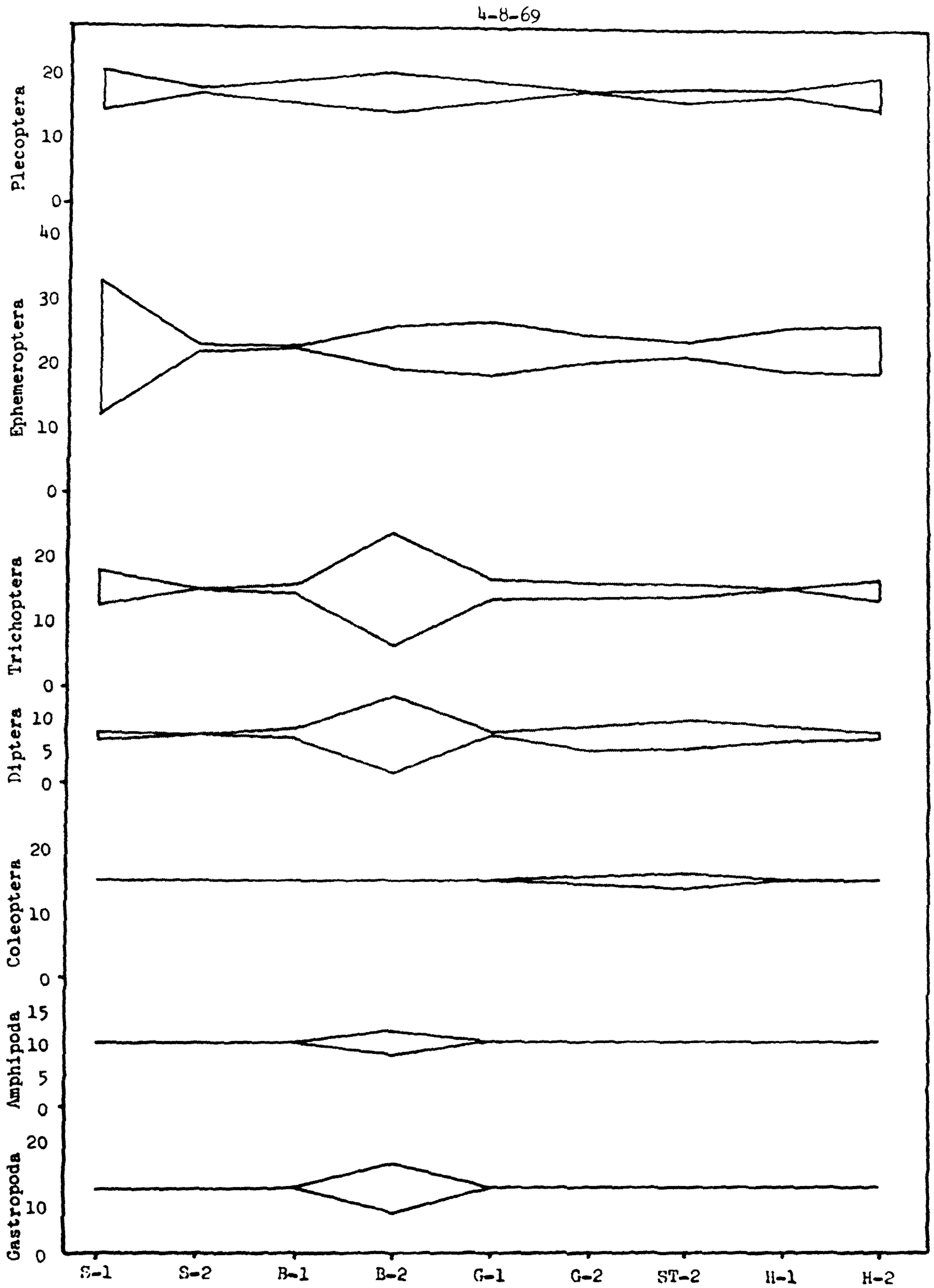


Figure 11. Density (number per $ft^2$) of selected orders of bottom fauna.

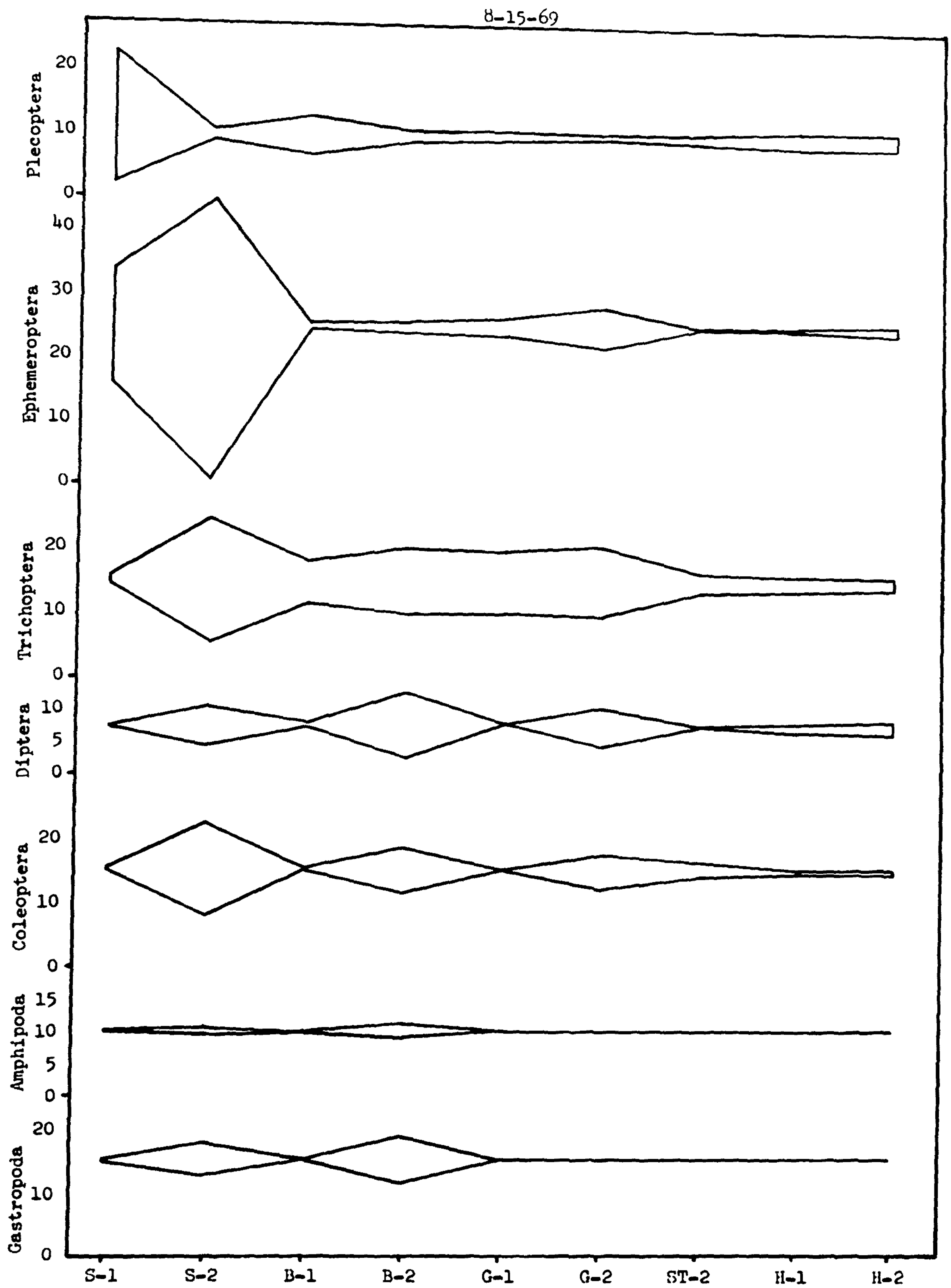


Figure 12. Density (number per ft$^2$) of selected orders of bottom fauna.

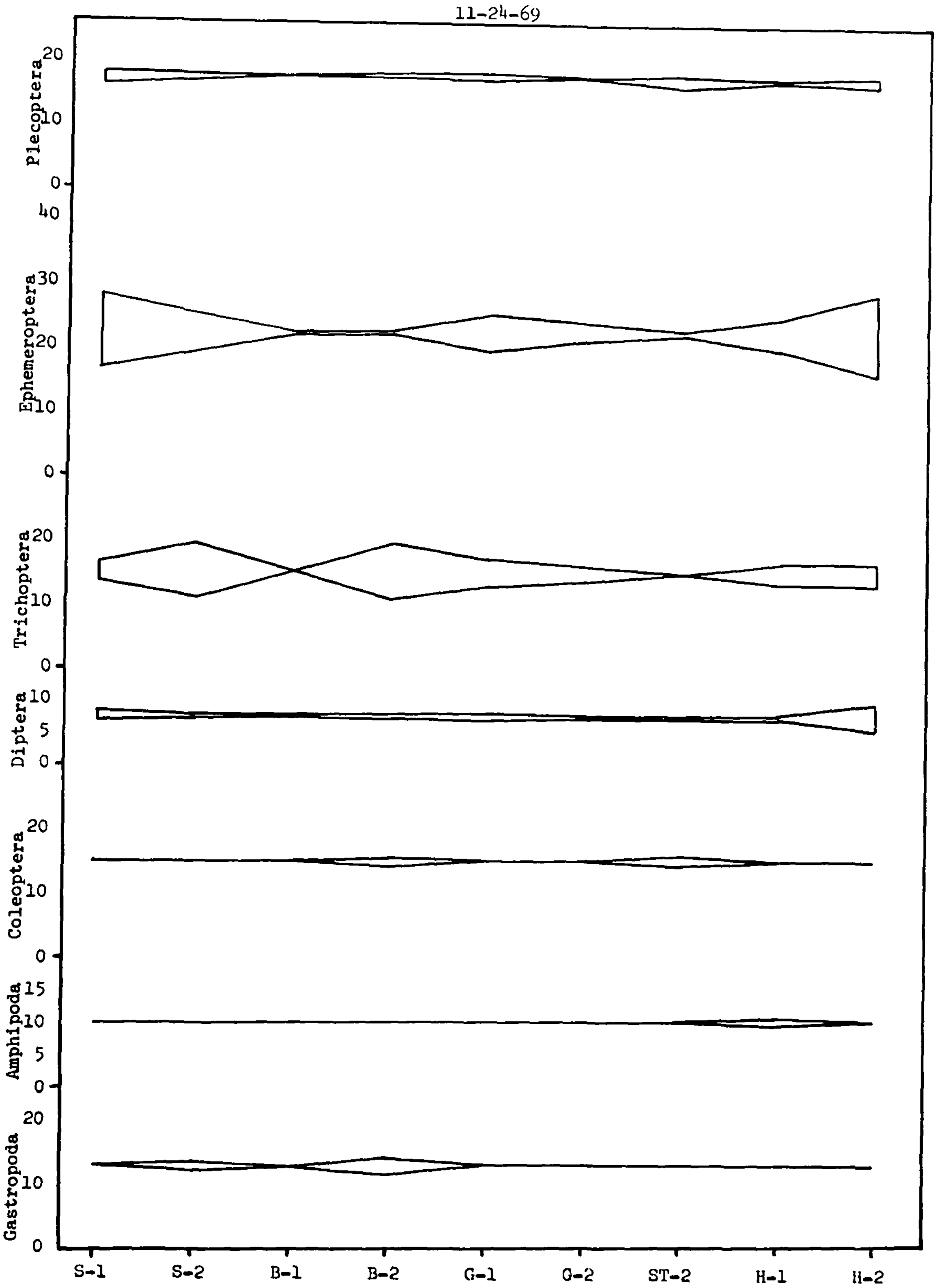


Figure 13. Density (number per $ft^2$) of selected orders of bottom fauna.

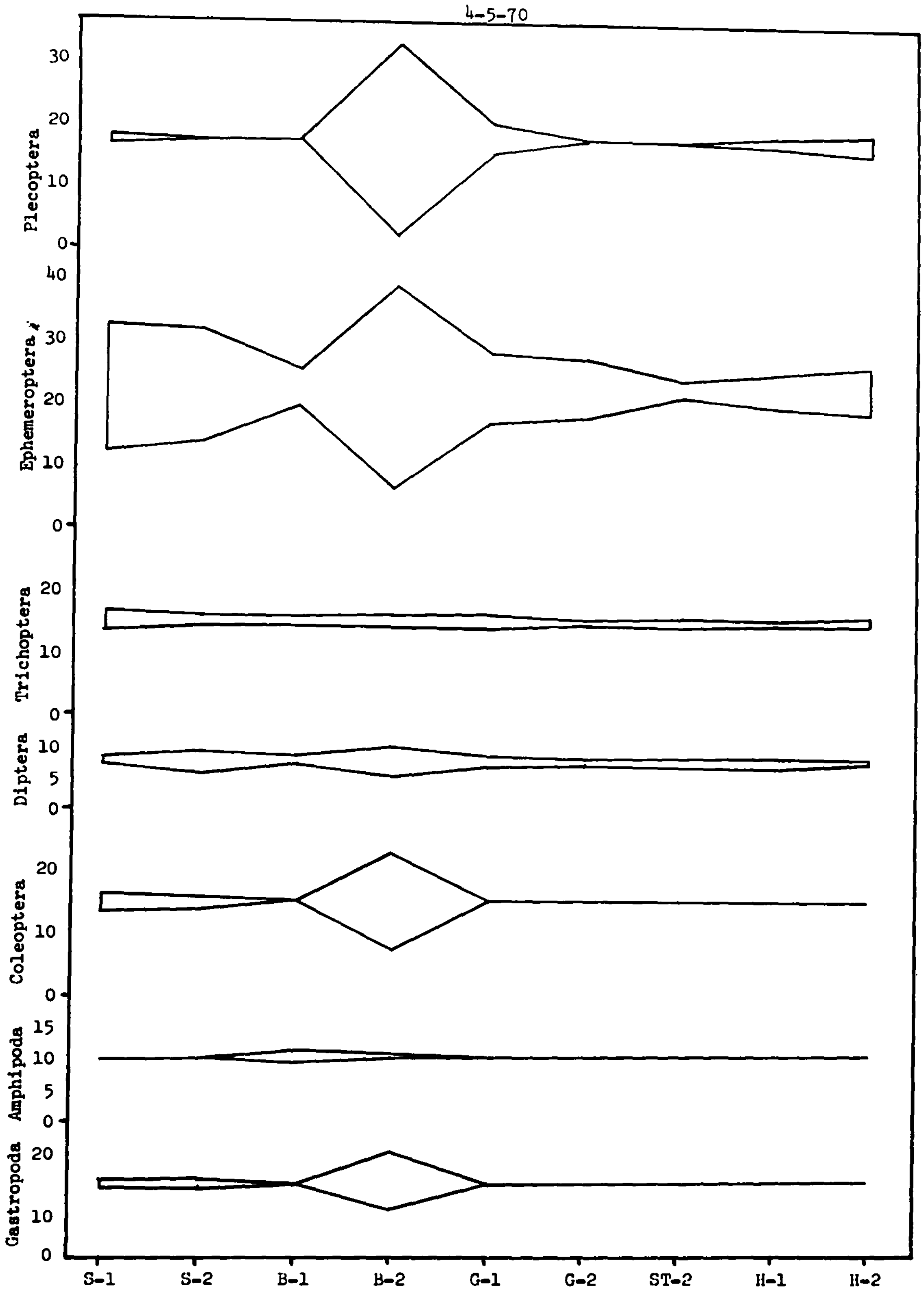


Figure 14. Density (number per $ft^2$) of selected orders of bottom fauna.

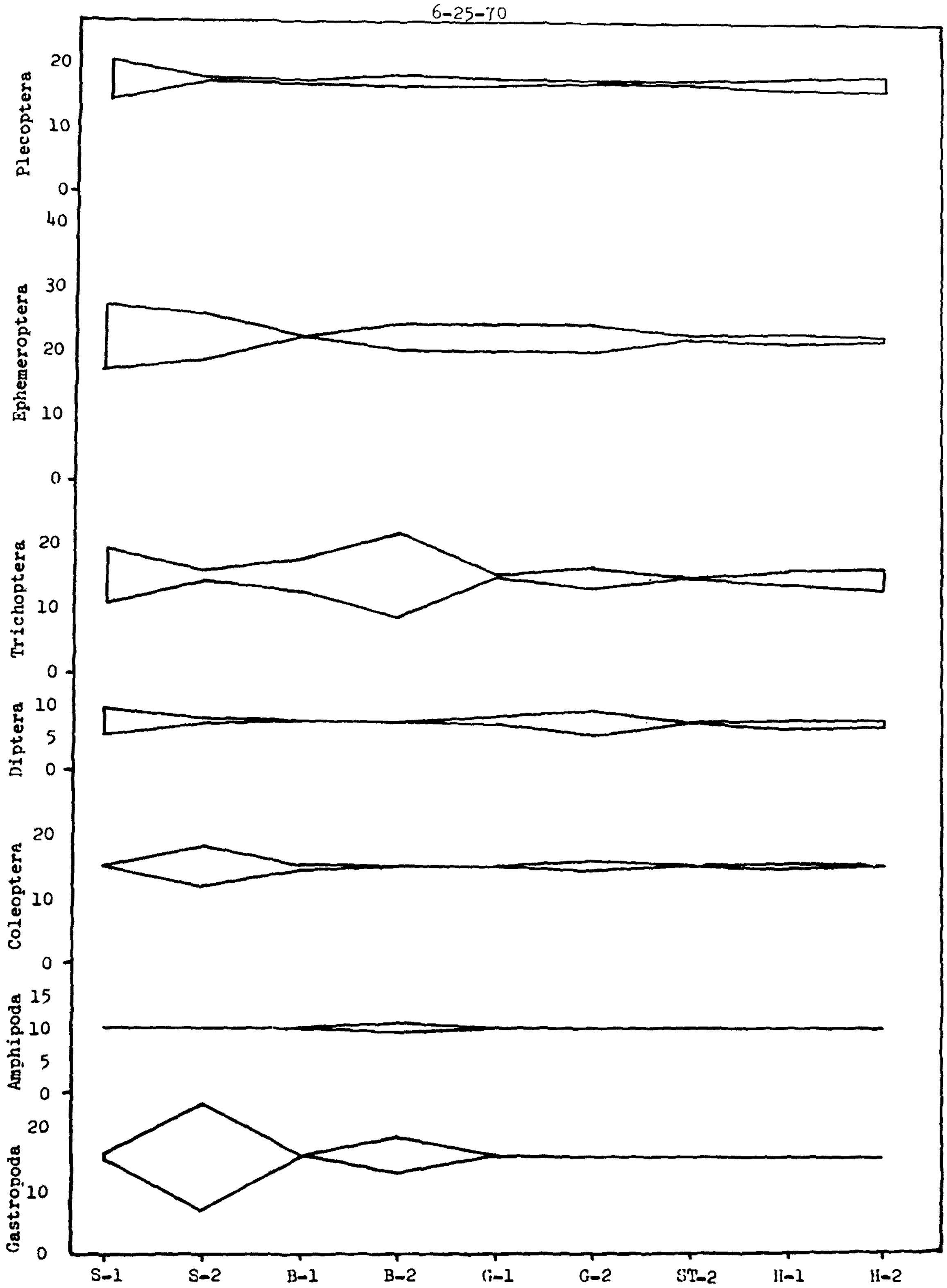


Figure 15. Density (number per $ft^2$) of selected orders of bottom fauna.

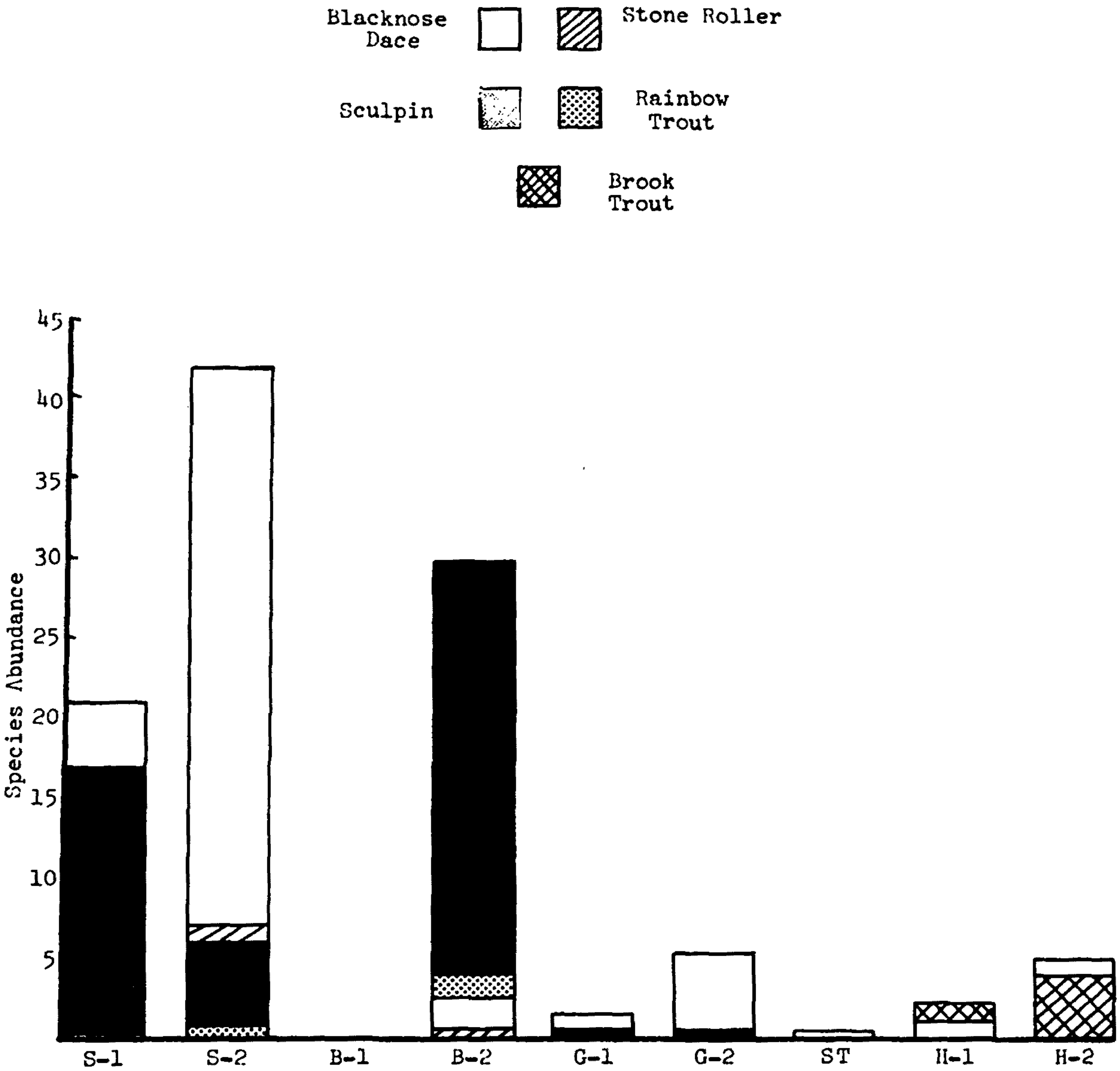


Figure 16. Species abundance of fishes collected between September, 1968, and July, 1970, as represented by mean values for five collections.

## SECTION VI

## ACKNOWLEDGMENTS

This report is coauthored by:

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SECTION VII

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Virginia Cooperative Fishery Unit


**6 Title**

STREAM FAUNAL RECOVERY AFTER MANGANESE STRIP MINE RECLAMATION

**10 Author(s)**


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Hill, Donley M.


**16 Project Designation**

EPA WQO Project No. WP-01530

**21 Note**

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**27 Abstract**


Seasonal monitoring of certain chemical, physical, and biological parameters of streams draining manganese strip mine spoils in three stages of reclamation verifies that the community structure of fish and benthic macroinvertebrates in these streams remains severely depressed until complete reclamation of the spoils has been accomplished. Six years after reclamation, only the faunal community in the stream draining the fully reclaimed area has recovered.

Laboratory studies established the median tolerance limits of three native species of fishes to silt in suspension and to manganese ions. These studies suggest that the principal factor depressing the faunal communities in partially reclaimed and unreclaimed streams is the chronically high degree of turbidity and siltation. A comparison of the growth of rainbow trout fingerlings in clear vs. turbid water revealed a statistically significant slower growth in the turbid water, further substantiating the assumption that siltation and turbidity are limiting to those faunal communities.

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