Transactions of the Illinois State Academy of Science
(1985), Volume 78, 1 and 2, pp. 67-80

MACROINVERTEBRATE POPULATIONS IN A THERMALLY IMPACTED RESERVOIR

Patricia Schultz-Benker
Daily Analytical Laboratory
Peoria, IL 61615
and
B. J. Mathis
Dept. of Biology
Bradley University
Peoria, IL 61625

ABSTRACT

The macroinvertebrate community of Duck Creek Reservoir, a thermally impacted impoundment, was examined over a twelve month period to determine the effect of heated effluents on distribution and abundance. The Shannon-Weaver function, $\bar{H}$, was used to express species diversity. The 34,139 organisms encountered were represented by 57 taxa including Nematomorpha, Annelida, Gastropoda, Ephemeroptera, Odonata, Hemiptera, Trichoptera, Coleoptera, and Diptera. Eighty-four percent of all individuals were tendipedid larvae with one species, *Glyptotendipes lobiferus*, contributing 57 percent of the total. Other dominant species present were *G. senilis, Dicrotendipes nervosus, Cyrnellus marginalis, Pentaneura monilis*, and *Caenis sp.* The number of individuals per square meter increased when water temperature was moderately elevated, but abundance and diversity both were significantly reduced by higher temperature at the immediate discharge area. Seasonal variation in the abundance of organisms appeared consistent with emergence patterns of the dominant species. Bathymetric distribution showed diversity and abundance greatest between two and four meters with a rapid decline between 6 and 10 meters. Below 10 meters, organisms were rarely encountered.

INTRODUCTION

In recent years, there has been considerable research into the effects of waste heat on aquatic habitats (Dahlberg and Conyers, 1974; Logan and Mauer, 1975;

Benda and Profitt, 1974). These studies and others have shown that macroinvertebrate diversity and abundance can be influenced by thermal effluents (Coutant, 1962; Parkin and Stahl, 1981; Warriner and Brehmer, 1966; Webb, 1981; and White, 1974). In this study, multi-plate samplers were used exclusively for collecting macroinvertebrates because depths were often greater than sixteen meters and anoxic conditions in the reservoir would have produced considerable sampling bias.

The primary objectives of this study were to characterize the macroinvertebrate community of Duck Creek Reservoir, and to determine the effect of heated effluent on macroinvertebrate community structure. This was accomplished by positioning Hester-Dendy samplers at various depths and thermal exposures, determining community structure with the use of a diversity index, establishing seasonal patterns of distribution and correlating macroinvertebrate distribution with temperature data.

DESCRIPTION OF THE STUDY AREA

Duck Creek Reservoir is located in Fulton County, approximately 3.2 km southwest of Canton, Illinois (Fig. 1). It was constructed to supply cooling water for a coal fired generating station by damming Duck Creek. In general, the reservoir has a north-south orientation and consists of one main channel with several small side arms. The sediment composition of the substrate is primarily a sand-clay mixture.

Work on the reservoir began in late 1975 and was completed in early 1976. The basin was filled by pumping water from the Illinois River. After the initial filling, additional river water has not been used. Located at an elevation of 161.5 meters above sea level, the surface area of the reservoir covers 256.4 hectares and has a total volume of 4.8×10^7 cubic meters. The maximum depth in the main channel is approximately 18.3 meters.

In addition to a rock dam which impounds Duck Creek, there is an inverted weir dam at the southern end of the reservoir where the generating station is located. Water that is to be used for cooling purposes is drawn into the plant below the inverted weir dam at a depth of 6.4 meters. Two pumps, each with a design capacity of 435 cubic meters per minute, move the water into the plant. During summer months, both pumps operate to circulate 795 cubic meters per minute.

The plant is a coal-fired facility containing a single 416.5 megawatt unit which has a design capacity of 3,970 BTU per kilowatt and produces 380 megawatts. The design condensor temperature rise (ΔT) is 7.4°C. After a single circulation, water leaves the plant through a 305 meter long discharge canal. Before re-entering the reservoir, heated water is passed over an energy dissipating spillway with a height of 12.2 meters.

Duck Creek Reservoir has a drainage basin of 4,015 hectares and also receives treated waste water from the City of Canton. The upper and lower parts of the reservoir are separated by a haulage road, but a conduit between the two serves to maintain an adequate water level in the lower reservoir. Water in the reservoir above the haulage road is unaffected by the elevated water temperature of the lower reservoir.

METHODS AND MATERIALS

Seventeen stations were selected for study. Thirteen were located in the lower reservoir and four were located in the upper reservoir above the haulage road.

Three artificial substrate samplers were placed at each station. The upper sampler was suspended at a depth of 0.61 meters, the middle sampler at a depth determined to be one-half of the total depth and the lower sampler at 0.61 meters from the bottom. In order to provide an identical substrate at each sampling location, a modified multi-plate sampler was employed in the study (Hester and Dendy, 1962). Plate orientation was kept constant each time the samplers were assembled to prevent any possible sampling bias (Harrold, 1978). The total exposed area of the sampler was 0.185 square meters.

With the exception of January, 1982, when weather conditions prevented access to the reservoir, samples were collected at approximately 30 day intervals from July, 1981 through June, 1982. Organisms were separated from debris and sediments by means of Wildco Model 190 No. 30 mesh sieve. They were then preserved in 90 percent alcohol and identified using taxanomic keys by Ross (1944), Burks (1953), Pennak (1978), Usinger (1956), Johannsen (1934, 1935, 1937, 1937a), Curry (1961) and Mason (1973).

Species diversity was determined by using an equation based on the information theory equation of Shannon and Weaver (1963). This function is:

$$\bar{H} = 3.3219 \left(\log_{10} N - \frac{1}{N} \Sigma n_i \log_{10} n_i\right)$$

where N = total number of individuals

n_i = number of individuals per i^{th} species

3.3219 = conversion factor from $\log_{10}$ to $\log_2$

Calculations were made on a Radio Shack TRS-80 Model III and a Cyber 170 Computer located at the Bradley University Computer Center.

In order to summarize the data, the seventeen stations were divided into zones on the basis of similar temperatures: Zone I (Stations 1 through 4); Zone II (Stations 5 through 8); Zone III (Stations 9, 12, 13 and 14); Zone IV (Stations 15 through 17) and Zone V (Stations 10 and 11). Bathymetric distributions were based on samples which were taken at the same depth or within the same range of depths.

RESULTS AND DISCUSSION

Temperature and Dissolved Oxygen

Average temperatures from both the upper and lower reservoir ranged from 20°C at Station 4, to 33°C at Station 10 in the discharge arm (Fig. 2). Elevated temperatures were consistently observed throughout Zone III, where the heated effluent enters the main body of the reservoir.

Temperature and dissolved oxygen profiles were used to determine the position of the thermocline and the occurrence of overturns. Throughout July and August, the thermocline occurred between six and nine meters. The fall overturn began during October and was completed by January. Temperature and dissolved oxygen was constant throughout the water column until March. The hypolimnion was re-established below nine meters during June.

Macroinvertebrates

A total of 34,139 macroinvertebrates representing 57 species were collected during the study. Twenty-five of the species were tendipedid larvae with the members of this family contributing 84.2 percent of all individuals. The remaining 16.8 percent were represented by Nematomorpha, Annelida, Amphipoda, Gastropoda, Ephemeroptera, Odonata, Hemiptera, Trichoptera, Coleoptera and two other Dipteran families, Culicidae and Heleidae. One species of Tendipedidae, *G. lobiferus*, constituted 56.6 percent of the total number of individuals (Table 1).

Tendipedids dominated the species composition at every station ranging from 55 percent at Station 5 to 99 percent at Station 11. At Station 10, which is adjacent to the warm water effluent, 98 percent of all organisms were tendipedids. Three species of Tendipedidae, *G. lobiferus*, *G. senilis* and *Dicrotendipes nervosus* were most numerous among this family and all three are known for their wide range of temperature tolerance (Beck, 1977). With few exceptions, *G. lobiferus* was the most abundant species at every station and was found in all samples where organisms were present. In the discharge area, however, *G. senilis* increased in abundance while *D. nervosus* numbers decreased.

As a percent of the total number of organisms collected, the Tendipedidae accounted for 49 percent in June and 100 percent in February. During every sampling period, either *G. lobiferus* or *G. senilis* was the dominant species present. Over 65 percent of all *G. lobiferus* occurred during July. The abundance of this single species is reflected in the increased number of individuals per m^2 during July and September, which corresponds to their expected pattern of emergence and repopulation (Iovino and Miner, 1970).

Two species of Tendipedidae appeared in the dominant species composition only during winter. *Dicrotendipes modestus* was present throughout the study, but only in winter was it encountered in significant numbers. *Cricotopus bicinctus* was not present at any time except winter. According to Iovino and Miner (1970), *C. bicinctus* has a high dissolved oxygen requirement. It was most abundant when high levels of dissolved oxygen were recorded.

In general, the species encountered in this study were typical of those indigenous to the Central Illinois River Basin and other Central Illinois reservoirs. Notably absent in this study were the large populations of clams and oligochaetes present in Peoria Lake (Richardson, 1921, 1921a, 1924, 1925 and 1928) and the chaoborids which are a dominant taxa in both Lake Carlyle and Lake Shelbyville (Dufford, Swadener and Waite, 1976 and 1977; Brigham, 1973, 1974, 1975 and 1976). However, these benthic species do not typically colonize multi-plate samplers and are more frequently encountered in dredge samples.

Macroinvertebrates collected from other thermally impacted waterways closely resembled populations encountered at Duck Creek Reservoir. At Baldwin Lake, communities sampled in the discharge area were dominated by *G. lobiferus* and *D. nervosus* (Parkin and Stahl, 1981). However, these authors also report that these species showed a preference for the Hester-Dendy sampler and were less common in dredge samples taken in the same area. Benda and Profitt (1974) found *G. lobiferus* the most abundant invertebrate collected near thermal discharges into the White River.

The number of organisms encountered varied substantially with the depth of the sampler and ranged from 0 to 8,033 individuals per m^2. Mean values for samples taken at a depth of 0.61 meters ranged from 147 individuals per m^2 at Station 13, to 1,412 individuals per m^2 at Station 1 (Fig. 3). Abundance was significantly reduced throughout the thermally influenced zones; however, Station 11 in the discharge arm had the highest mean number of individuals per m^2 within the lower reservoir.

The range in abundance of macroinvertebrates per m^2 is consistent with those found in similar studies in Illinois. In Peoria lake, Richardson (1925), found 844 to 1,684 individuals per m^2 and in 1928, 192 to 5,634 individuals per m^2 were present. In Lake Sangcris, the range was 57 to 5,028 individuals per m^2 (Webb, 1981), while at Baldwin Lake, the mean was 32 individuals per m^2 in the heated areas and 1,082 individuals per m^2 in unheated areas (Parkin and Stahl, 1981).

The Shannon-Weaver function has been used to illustrate the effect of environment stress by reflecting changes in community structure (Wilhm, 1967; Wilhm and Dorris, 1966; Mathis and Dorris, 1967; Mathis, 1968). $\overline{H}$ values ranged from 2.3 at Station 5 to 0.7 at Station 10 (Fig. 3). The highest values for $\overline{H}$ occurred at Stations 1 through 5, while in areas where the highest water temperatures occurred, reduced $\overline{H}$ values reflected the presence of a few temperature tolerant species.

Seasonal variation in $\overline{H}$ ranged from 0.6 in February (Day 50) to 2.1 in August (Day 250) (Fig. 4). In general, $\overline{H}$ decreased steadily with falling temperatures and increased as temperatures began to rise. In addition to changes in community structure induced by seasonal temperature variation, $\overline{H}$ was also influenced by seasonal reproductive patterns of dominant species.

When all samplers were considered and numbers of individuals were grouped according to similar sampling depths, the number of macroinvertebrates was highest between two and four meters, averaging 789 individuals per m^2. The lowest numbers were found between 16 and 18 meters where only one individual per m^2 was present. The most significant decline in abundance was between six and ten meters. This depth corresponds to the thermocline. Below ten meters, organisms were rarely encountered (Fig. 5).

As a percent of the total number of organisms collected, the Tendipedidae were dominant at all depths, ranging from 71 percent to 100 percent of all individuals. Below eight meters, *G. lobiferus* and *G. senilis* were most numerous. Both of these species have a low dissolved oxygen requirement and are considered by some to be facultative anaerobic (Beck, 1977).

Community structure, as assessed by $\overline{H}$, paralleled the bathymetric distribution of individuals (Fig. 5). Within the thermocline, $\overline{H}$ was dramatically reduced. An $\overline{H}$ value of 1.7 was determined for both the two to four meter and four to six meter ranges. $\overline{H}$ was zero between 16 and 18 meters, where either *G. lobiferus* or *G. senilis* was the only species found.

SUMMARY

Hester-Dendy samplers were used over a twelve month period to determine the effects of thermal enrichment on the community structure of macroinvertebrates in Duck Creek Reservoir. Fifty-seven species and 34,139 individuals were collected during the study. Twenty-five of the species and 84 percent of all individuals were tendipedid dipterans. The remaining 16 percent of the taxa were represented by Nematomorpha, Annelida, Amphipoda, Gastropoda, Ephemeroptera, Odonata, Hemiptera, Trichoptera, Coleoptera, and Diptera families Heleidae and Culicidae. With few exceptions, species composition and abundance of organisms were consistent with those reported in other thermally impacted reservoirs.

The Tendipedidae were the dominant organisms at each station, at all depths and during every season. *Glyptotendipes lobiferus* constituted 57 percent of all organisms collected, while *G. senilis* comprised 13 percent of the total number. Both species

are known to be tolerant of extreme temperatures and both were found abundantly in the discharge area. *Pentaneura monilis*, a temperature tolerant tanypod whose abundance increased with temperature, appeared to have replaced *Cyrnellus marginalis* near the outfall.

The average number of individuals per m^2 varied considerably between the upper and lower reservoir. In general, density was significantly greater at stations in the upper reservoir. The highest density in the lower reservoir was at Station 11, where water temperatures were moderately influenced by the effluent.

ACKNOWLEDGEMENTS

The authors wish to thank Mr. Robert Miller of the Central Illinois Light Company for his assistance with this research. This research was supported by a grant from the Central Illinois Light Company.

LITERATURE CITED

Beck, W.M., Jr. 1977. Environmental requirements and pollution tolerance of common fresh water Chironomidae. Environmental Monitoring Series, EPA-600/4-77-024. Environmental Monitoring and Support Laboratory, USEPA, Cincinnati. 261 p.

Benda, R.S. and M.A. Profitt. 1974. Effects of thermal effluents on fish and invertebrates. pp. 438-447 in Thermal Ecology, J.W. Gibbons and R.R. Sharitz (Eds.). Technical Information Center, U.S. Atomic Energy Commission (Conf.-730505). 670 p.

Brigham, A.R. 1973. Water quality investigations in the Lake Shelbyville, Illinois basin. Annual report submitted to the U.S. Army Corps of Engineers, St. Louis District. 44 p.

__________. 1974. Water quality investigations in the Lake Shelbyville, Illinois basin. Annual report submitted to the U.S. Army Corps of Engineers, St. Louis District. 42. p.

__________. 1975. Water quality investigations in the Lake Shelbyville, Illinois basin. Annual report submitted to the U.S. Army Corps of Engineers, St. Louis District. 23 p.

__________. 1976. Water quality investigations in the Lake Shelbyville, Illinois basin. Annual report submitted to the U.S. Army Corps of Engineers, St. Louis District. 41 p.

Burks, B.D. 1953. The mayflies, or Ephemeroptera, of Illinois. Ill. Nat. Hist. Surv. Bull. 26(1):1-216.

Coutant, C.C. 1962. The effect of a heated water effluent upon the macroinvertebrate riffle fauna of the Delaware River. Proc. PA. Acad. Sci. 36:58-71.

Curry, L.L. 1962. A key for the larval forms of aquatic midges (Tendipedidae: Diptera) found in Michigan. In. A.E.C. and N.I.H. Terminal Report No. 2. 162 p.

Dahlberg, M.D. and J.C. Conyers. 1974. Winter fauna in a thermal discharge with observations on a macrobenthos sampler. pp. 414-422 in Thermal Ecology, J.W. Gibbons and R.R. Sharitz (Eds.). Technical Information Center, U.S. Atomic Energy Commission (Conf.-730505). 670 p.

Dufford, D.W., S.D. Swadenser and S.W. Waite. 1976. Annual summary of biological investigations at Lake Carlyle 1974-1975. Annual report submitted to the U.S. Army Corps of Engineers, St. Louis District. 51 p.

__________, __________ and __________. 1977. Annual summary of biological investigations at Lake Carlyle 1975-1976. Annual report submitted to the U.S. Army Corps of Engineers, St. Louis District. 51 p.

Harrold, J.F., Jr. 1978. Relation of sample variations to plate orientation in the Hester-Dendy plate sampler. Prog. Fish-Cult. 40(1):24-25.

Hester, F.E. and J.S. Dendy. 1962. A multi-plate sampler for aquatic macroinvertebrates. Trans. Am. Fish. Soc. 91(4):420-421.

Iovino, A.F. and F.D. Miner. 1970. Seasonal abundance and emergence of Chironomidae of Beaver Reservoir, Arkansas (Insecta: Deptera). Kans. Entomol. Soc. Journal 43:197-216.

Johannsen, O.A. 1934. Aquatic Diptera. Part I. Nemocera, exclusive of Chironomidae and Ceratopogonidae. Cornell Univ. Agric. Exp. Sta. Mem. 164:1-70.

__________. 1935. Aquatic Diptera. Part II. Orthorrhapha-Brachycera and Cyclorrhapha. Cornell Univ. Agric. Exp. Sta. Mem. 177:1-62.

__________. 1937. Aquatic Diptera. Part III. Chironomidae: subfamilies Tanypodinae, Diamesinae and Orthocladiinae. Cornell Univ. Agric. Exp. Sta. Mem. 205:1-84.

__________. 1937a. Aquatic Diptera. Part IV. Chironomidae: subfamily Chironominae. Cornell Univ. Agric. Exp. Sta. Mem. 210:1-56.

Logan, D.T. and D. Maurer. 1975. Diversity of marine invertebrates in a thermal effluent. Water Pollut. Control Fed. 47(3):515-523.

Mason, W.T., Jr. 1973. An introduction to the identification of chironomid larvae. U.S. Environmental Protection Agency, National Environmental Research Center. Cincinnati, OH. 90 p.

Mathis, B.J. and T.C. Dorris. 1967. Community structure of benthic macroinvertebrates in an intermittant stream receiving oil field brines. Am. Midl. Nat. 80:428-439.

Mathis, B.J. 1968. Species diversity of benthic macroinvertebrates in three mountain streams. Trans. Ill. State Acad. Sci. 61(2):171-176.

Parkin, R.B. and J.B. Stahl. 1981. Chironomidae (Diptera) of Baldwin Lake, Illinois, a cooling reservoir. Hydrobiologia 76:119-128.

Pennak, R.W. 1978. Fresh-water invertebrates of the United States. John Wiley and Sons, New York. 803 p.

Richardson, R.E. 1921. The small bottom and shore fauna of the middle and lower Illinois and its connecting lakes, Chillicothe to Grafton: its valuation; its sources of food supply; and its relation to the fishery. Ill. Nat. Hist. Surv. Bull. 13:363-522.

__________. 1921a. Changes in the bottom and shore fauna of the middle Illinois River, and its connecting lakes since 1913-1915 as a result of the increase, southward, of sewage pollution. Ill. Nat. Hist. Surv. Bull. 14:33-75.

__________. 1924. Changes in the small bottom fauna of Peoria Lake, 1920 to 1922. Ill. Nat. Hist. Surv. Bull. 15:327-388.

__________. 1925. The Illinois River bottom fauna in 1923. Ill. Nat. Hist. Surv. Bull. 15:389-422.

__________. 1928. The bottom fauna of the middle Illinois River, 1913-1915. Ill. Nat. Hist. Surv. Bull. 17:387-476.

Shannon, C.E. and W. Weaver. 1963. The mathematical theory of communication. University of Illinois Press, Urbana. 117 p.

Ross, H.H. 1944. The caddis flies, or Trichoptera, of Illinois. Ill. Nat. Hist. Surv. Bull. 23(1):1-326.

Usinger, R.L., et al. 1956. Aquatic Insects of California. University of California Press, Berkley and Los Angeles.

Warriner, J.E. and M.L. Brehmer. 1966. The effects of thermal effluents on marine organisms. In Readings in Aquatic Ecology. R.F. Ford and W.E. Hazen (Eds.). W.B. Saunders, Philadelphia, pp. 381-393.

Webb, D.W. 1981. The benthic macroinvertebrates from the cooling lake of a coal-fired electric generating station. Ill. Nat. Hist. Surv. Bull. 32(4):358-377.

White, J.L. 1974. Diversity indices. In Ecological impact of thermal loading on a Piedmont River, an ecosystem approach (Vol. II). W.S. Woolcott (Ed.). pp. 555-588.

Wilhm, J.L. 1967. Comparison of some diversity indices applied to populations of benthic macroinvertebrates in a stream receiving organic wastes. Water Pollut. Control Fed. 39:1673-1681.

Wilhm, J.L. and T.C. Dorris. 1966. Species diversity of benthic macroinvertebrates in a stream receiving domestic and oil refinery effluentss. Am. Midl. Nat. 76(2):427-449.

Table 1. Relative abundance of macroinvertebrates collected from upper and lower Duck Creek Reservoir.

Species	Number Collected	Relative Abundance	Location by Zone
Glyptotendipes lobiferus	19,315	57%	I,II,III,IV,V
G. senilis	4,289	13%	I,II,III,IV,V
Dicrotendipes nervosus	3,955	12%	I,II,III,IV,V
Cyrnellus marginalis	2,543	8%	I,II,III,IV,V
Pentaneura monilis	1,179	4%	I,II,III,IV,V
Caenis sp.	1,082	3%	I,II,III,IV,V
Chironomus tentans	404	1%	I,II,III,IV,V
Endochironomus nigricans	213	1%	I,II,III,IV,V
Dicrotendipes modestus	181		I,II,III,IV,V
Harnishia abortiva	165		I,II,III
Argia sedula	132		I,II,III,IV,V
Limnodrilus sp.	106		I,IV
Hyalella azteca	68		I,II,III
Gordius sp.	66		I,II,IV,V
Cricotopus bicinctus	62		I,II,II,IV,V
Argia sp. a	45		I,II,III,IV,V
A. emma	31		I,II,III,IV,V
Potamyia flava	31		V
Polypedilium flavus	31		I,II,III,IV,V
Pentaneura flavifrons	28		I,II,III,V
Hydropsyche orris	25		II,V
Bezzia varicolor	21		I,II,III,V
Diamesa sp.	20		I,II,III,V
Argia vivida	17		I,II
Phaenospectra obediens	15		I,II,III
Enallagma praevarium	12		I,II,IV,V
Agraylea multipunctata	11		I,II
Tribelos sp.	10		II,III,V
Paralauterborniells sp.	9		I,II,V
Physa sp.	9		II,V
Palpomyia tibialis	8		I,II
Psectrocladius simulans	8		I,II,III,V
Dineutus sp.	8		I,II
Chaoborus punctipennis	7		I,II,V
Parachironomus monochromus	6		I,II
Cryptochironomus sp.	6		I,II
Enallagma sp.a	6		I,II

Table 1 (cont.)

Species	Number Collected	Relative Abundance	Location by Zone
Chironomus attenuatus	6		I
Cricotopus fugax	5		I,II
Ephemerella deficiens	4		I
Orthocladius sp.	4		I,IV
Enallagma carunculatum	4		II,IV,V
Procladius bellus	3		II
Probezzia sp. a	3		I,II,III
Tanypus stellatus	2		III
Gyretes sp.	2		I
Baetis sp.	2		I
Hexagenia limbata	1		II
Ishnura barberi	1		V
Chromagrion conditum	1		I
Lethocerus americanus	1		II
Coelotanypus concinnus	1		I
Einfeldia sp.	1		I
Chaoborus sp. a	1		II
Chaoborus rotundifolia	1		I
Probezzia copiosa	1		I
Ferrissia sp.	1		I
TOTAL NUMBER OF SPECIES	TOTAL NUMBER OF INDIVIDUALS		
57	34,139		

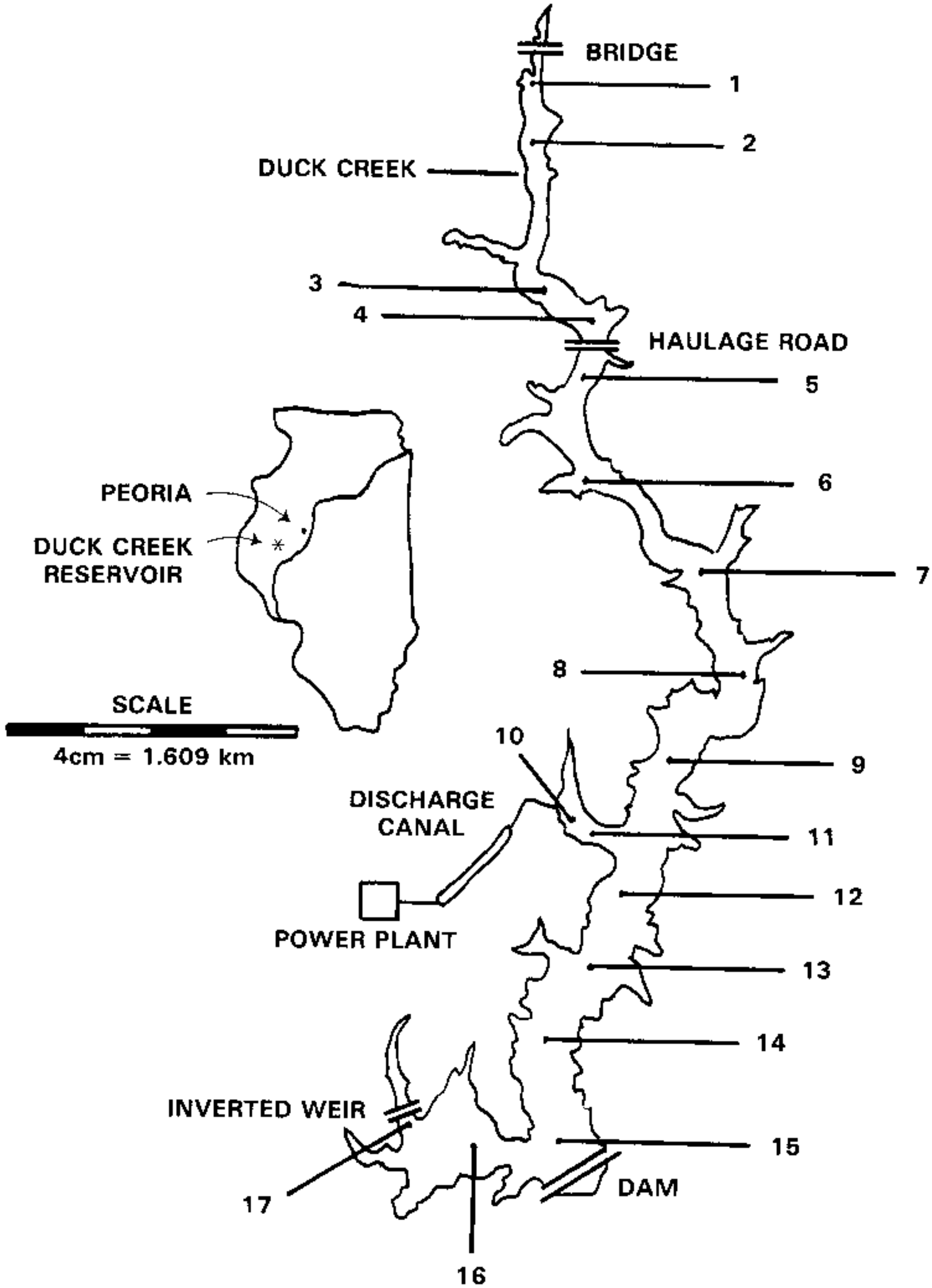

Fig. 1. MAP OF DUCK CREEK RESERVOIR SAMPLING STATIONS AND TEMPERATURE ZONES (Zone I-Stations 1-4; Zone II-Stations 5-8; Zone III-Stations 9, 12, 13 and 14; Zone IV-Stations 15-17; and Zone V-Stations 10 and 11).

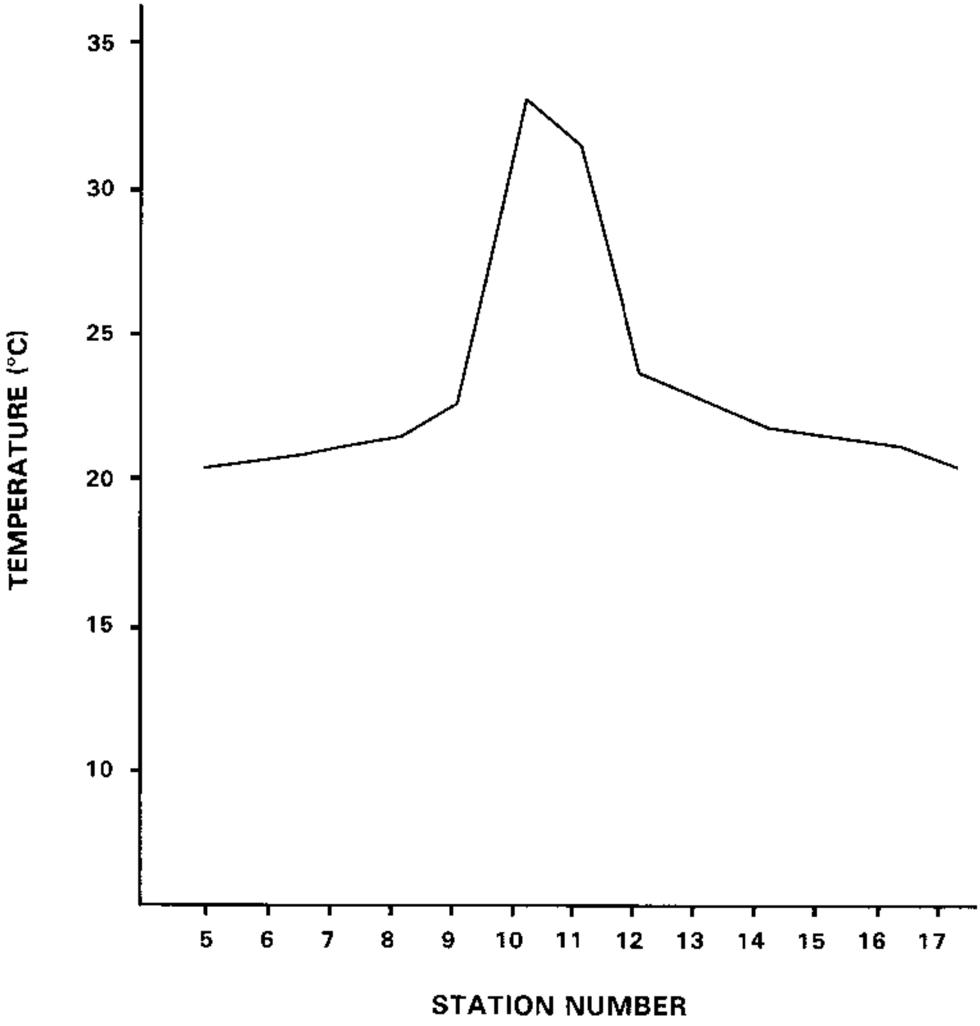

Fig. 2. MEAN TEMPERATURE FOR STATIONS IN LOWER DUCK CREEK RESERVOIR DURING 1981 AND 1982 AT A DEPTH OF 0.61 METERS.

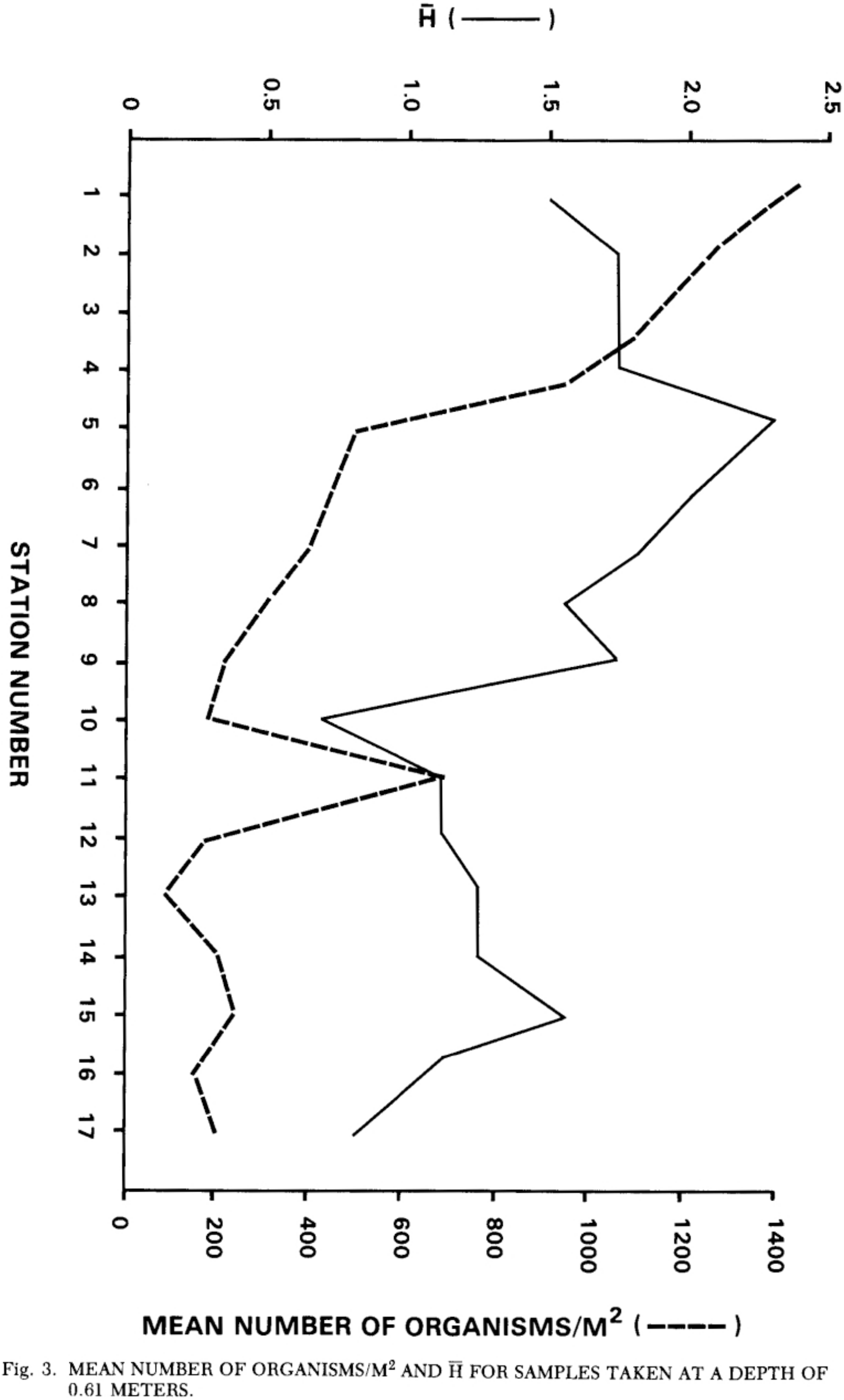

Fig. 3. MEAN NUMBER OF ORGANISMS/M² AND H̄ FOR SAMPLES TAKEN AT A DEPTH OF 0.61 METERS.

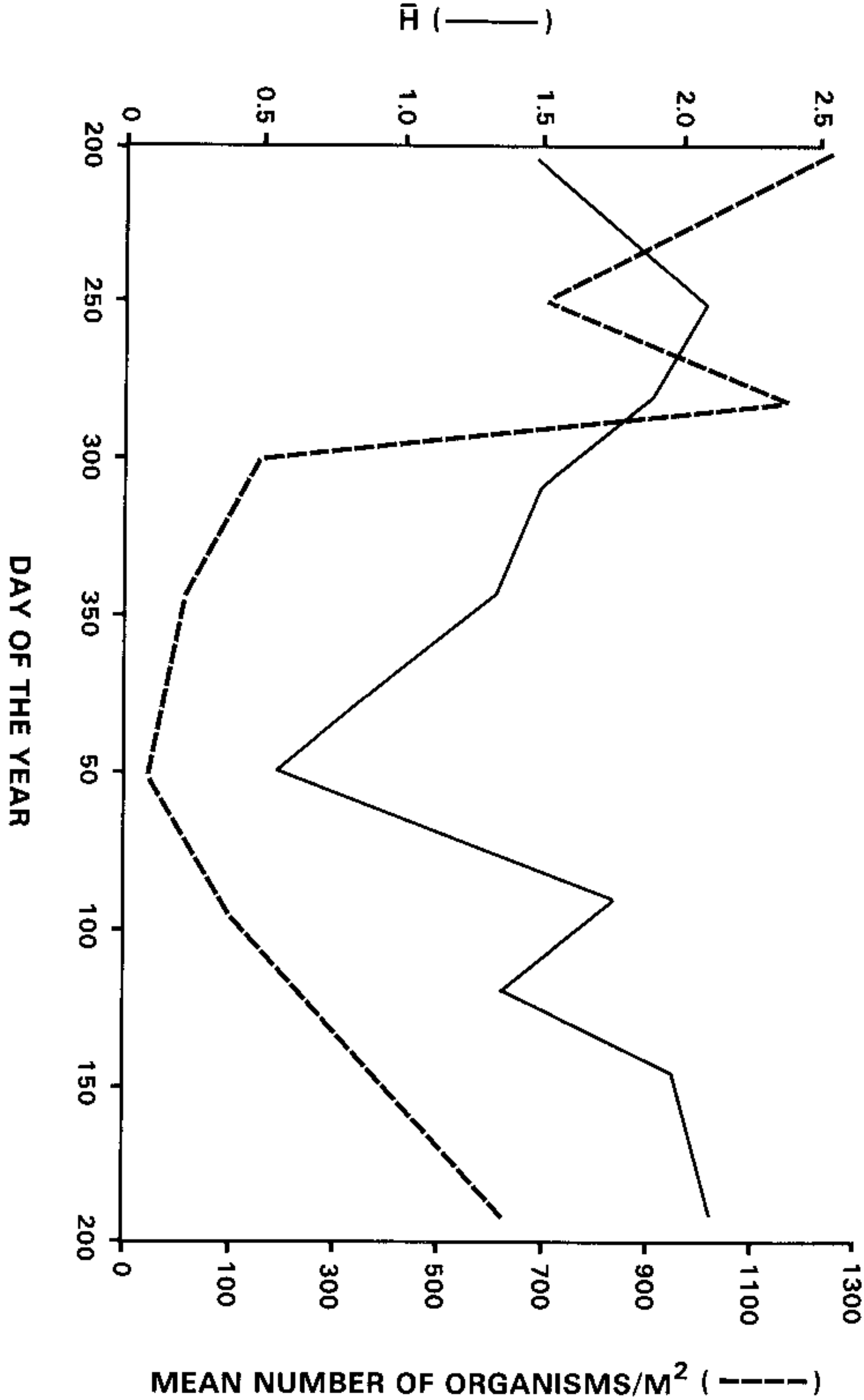

Fig. 4. SEASONAL VARIATION IN NUMBERS OF ORGANISMS/M^2 AND $\bar{H}$ FOR ALL SAMPLES TAKEN AT A DEPTH OF 0.61 METERS.

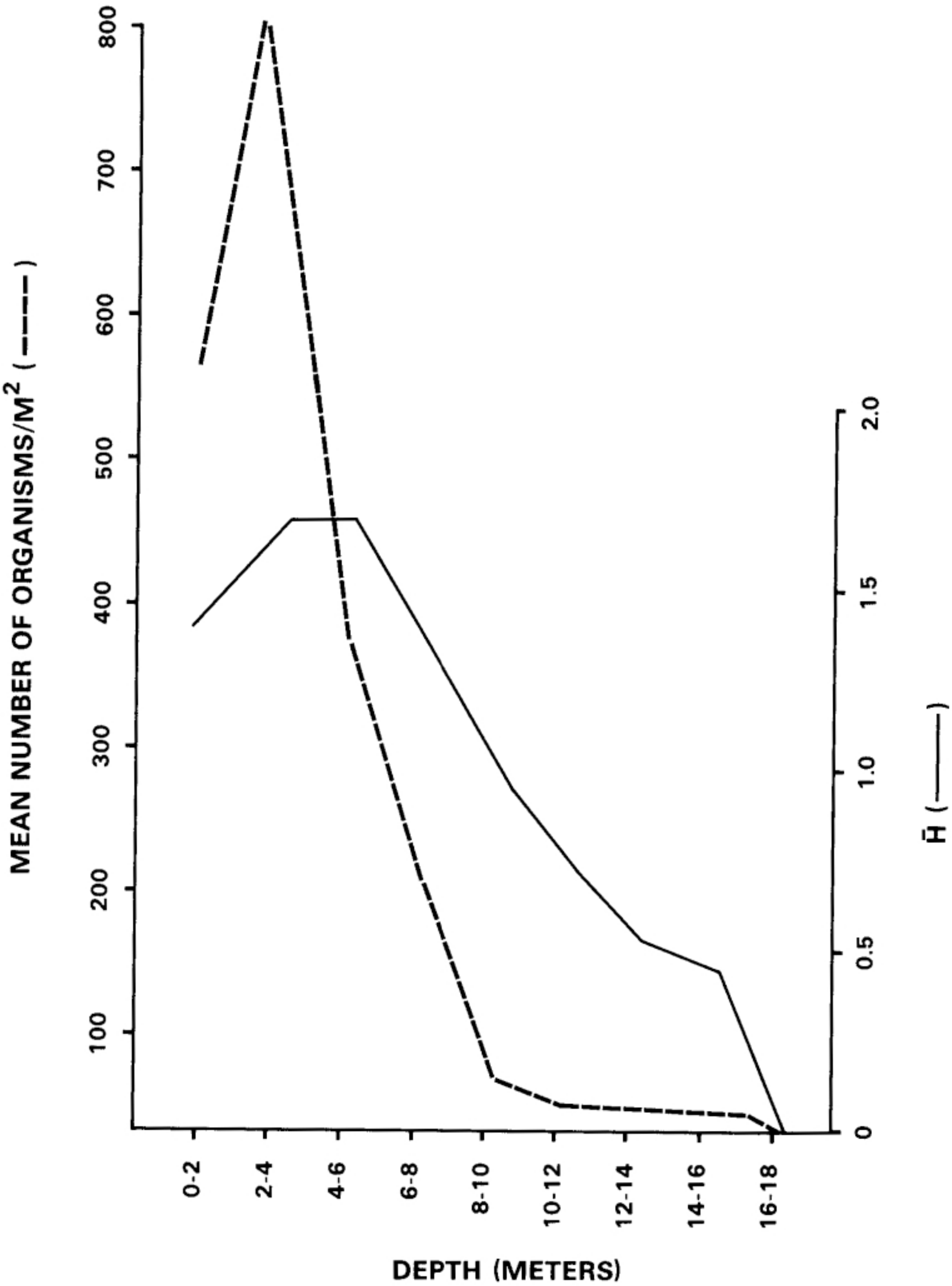

Fig. 5. BATHYMETRIC DISTRIBUTION OF ORGANISMS/M^2 AND $\overline{\text{H}}$.