BENTHIC MACROINVERTEBRATES AND PHYSICOCHEMICAL CONDITIONS OF BOOMER LAKE, PAYNE COUNTY, OKLAHOMA

By

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PREFACE

The objectives of the study were to: (1) describe certain limnological characteristics of Boomer Lake; (2) estimate seasonal variation in standing crop of benthic macroinvertebrates; (3) evaluate the relationship of bottom temperature and depth to abundance of Tendipedidae and _Hexagenia_ spp.; and (4) evaluate potential effects of condenser discharge water from a power plant on abundance of benthic macroinvertebrates.

Dr. P. A. Buscemi served as Committee Chairman before departing from the campus and Dr. R. W. Jones served as temporary chairman until Dr. R. C. Summerfelt was appointed as permanent chairman in spring, 1967. Dr. R. W. Jones continued to serve on the advisory committee with Dr. W. A. Drew. Mr. B. E. Brown directed the research and suggested the statistical analyses of macroinvertebrate distribution in relation to physicochemical estimates. Dr. D. E. Bee survised the statistical analyses and writing of the computer programs. Mr. G. Lance adapted computer programs for this study.

Mr. W. Frank Wade suggested the initial benthic study and assisted with field collections. Thanks are given to Dr. T. C. Dorris who was instrumental in procuring work space, transportation, and field equipment, and to Messrs. J. May, G. Keeler, and A. Faust who assisted with field and laboratory work.

Identifications of Naididae were verified by Dr. Walter J. Harman, Dytiscidae by Dr. Paul J. Spangler, Ceratopogonidae by Dr. Willis W. Wirth, and Unionidae by Dr. Harold D. Murray.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

The objectives of the study were to: (1) describe certain limnological characteristics of Boomer Lake; (2) estimate seasonal variation in standing crop of benthic macroinvertebrates; (3) evaluate the relationship of bottom temperature and depth to abundance of Hexagenia spp. and Tendipedidae; and (4) evaluate potential effects of condenser discharge water from a power plant on abundance of benthic macroinvertebrates.

Knowledge of population dynamics and ecology of macroinvertebrates of Boomer Lake is important to better understanding of factors influencing survival of fingerling flathead catfish, Pylodictis olivaris Rafinesque. The importance of benthos, especially insects, in the diet of fingerling flathead catfish is well-established (Minckley and Deacon, 1959).

Depth and bottom temperature were used in an attempt to account for variation in numbers of Hexagenia spp. and Tendipedidae. Depth of water was regarded as an important variable because indirectly it may influence oxygen concentrations, amount of vegetation, and type of substrate. Bottom temperature was used as a covariate because of potential influences of a warm-water outflow from a power plant located on the lake. Condenser discharge water from power plants at stream electric station outlets has been reported to reach temperatures of 44 and 46 C and to influence organisms considerably (Mihursky and Kennedy, 1966). Thus, at certain times, the water returning to the lake may reach temperatures high enough to alter the macroinvertebrate populations in the immediate vicinity of the flume.

CHAPTER II

DESCRIPTION OF LAKE

Boomer Lake, completed in 1925, is located three kilometers north of the intersection of state highways 51 and 77. The deepest portion of the lake is the old creek channel near the dam and the shallowest portion is on either side of the creek channel at the upper end where Boomer Creek widens into the lake (Fig. 1). The shallow areas at the north end were heavily vegetated during the summer of 1966 as was the shoreline (excluding the rip-rapped portion of the dam and wind-swept areas) to a depth of approximately one meter.

Surface area or mean depth (Table I) have been used as indices to standing crop or productivity. Rawson (1955) reported an inverse relationship between mean depth and standing crop of macroscopic bottom fauna, and mean depth and standing crop of net plankton. However, Hayes (1957) did not find a correlation between mean depth and productivity. Carlander (1955) found an inverse relationship between standing crop per acre and maximum depth of trout lakes and warm-water lakes. He also found no correlation between area of lakes or ponds and standing crops per acre. Boomer Lake is relatively shallow, and if this index is followed, should be productive. Factors affecting productivity of shallow impoundments would be bottom type, turbidity, amount and type of vegetation which is influenced by bottom type and turbidity, mineral content of basin, and length of growing season.

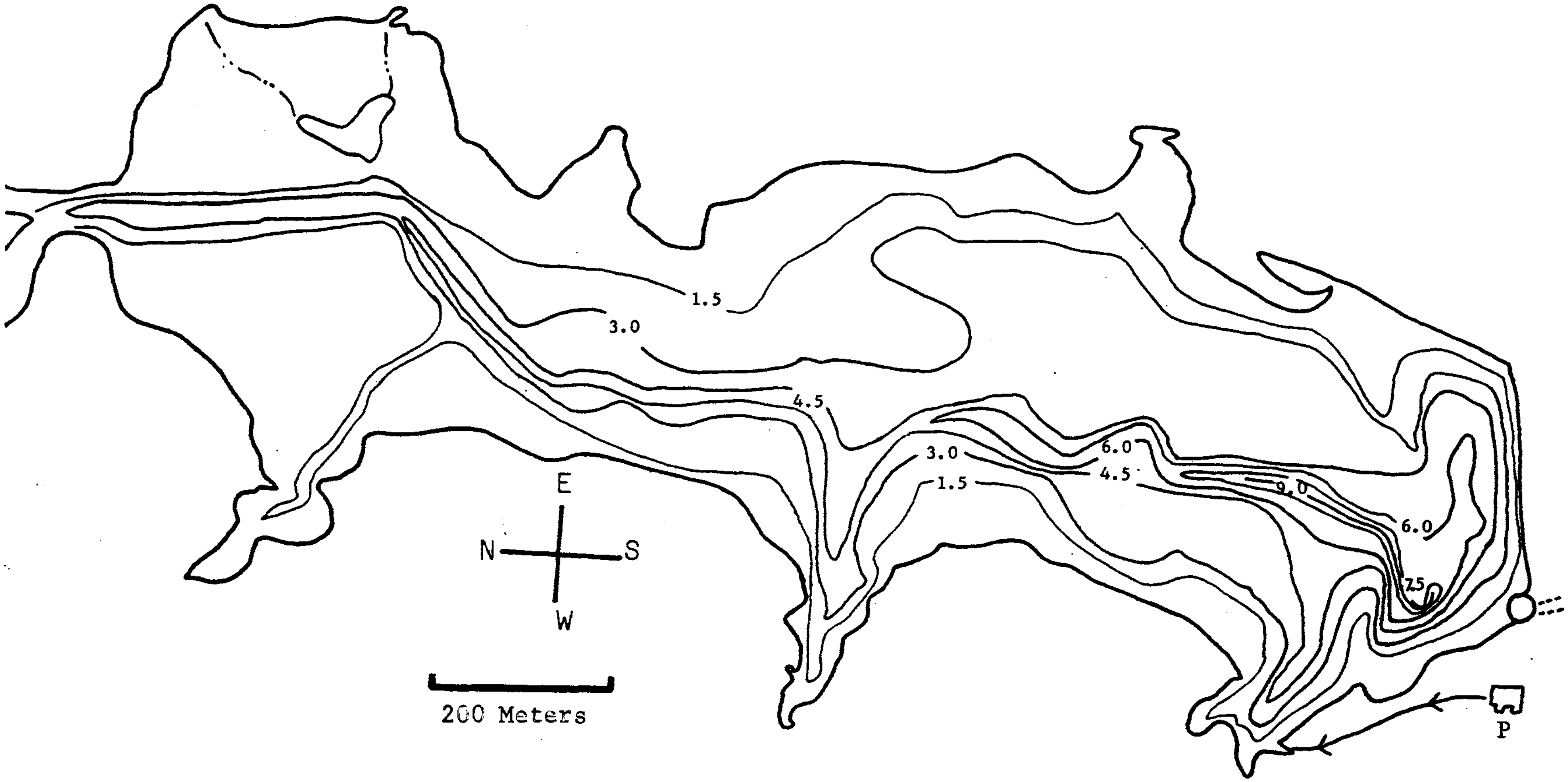

Figure 1. A Map of Boomer Lake Showing Bottom Topography. P = Power Plant and Flume.

TABLE I

MORPHOMETRIC DATA FOR BOOMER LAKE

Water-shed Hectares	Surface Area Hectares	Water Shed-Surface Area Ratio	Shoreline Length Kilometers	Shoreline Development	Mean Depth Meters
3,625	102	36 to 1	13.77	4.17	2.98

The storage capacity of the original reservoir was calculated to be 2.51 cubic megameters with a surface area of 92 hectares. In 1933, the spillway level was raised 0.61 meters which increased surface area to 102 hectares and storage capacity to 3.08 cubic megameters. Eakin (1936) reported that 210,953 cubic meters of sediment had accumulated between 1925 and 1935. However, Harper (1941) estimated that only 63,718 cubic meters of sediment had accumulated from 1925 to 1940.

The reservoir initially was used for a municipal water supply, but in 1951, due to a high bacterial count of the water and increased water needs, the city discontinued use of the lake for this purpose. Presently, the water is used for irrigation of the park around the lake and as a source of coolant water for the power plant turbines. Water is piped from near the bottom at the south-west corner of the lake to the power plant. After being used as a coolant water for the natural gas turbines, the water returns to the lake via a 305 meter concrete flume (Fig. 1). The water, as it enters the lake, is about 6 C warmer than the intake water.

CHAPTER III

METHODS

Physicochemical

Dissolved oxygen, pH, and temperature were measured near the bottom at the time of each benthos collection. Surface determinations, in addition to the above, included water transparency. Rainfall and lake level data were obtained from records maintained by personnel at the Boomer Lake power station.

Dissolved oxygen and temperature were measured with a Galvanic Cell Oxygen Analyzer with a thermister attached. Dissolved oxygen was measured close to the substrate-water interface by the following technique. A weight attached to a 0.30-meter chain was suspended from the base of the oxygen probe, and the probe, thermister, and weight lowered until the weight reached bottom. The probe and thermister were lowered a little farther and quickly raised and lowered to develop a 0.30-meter per second water current necessary for correct operation of the oxygen probe.

Hydrogen-ion concentration was measured with a Hellige Comparator and transparency of the water with a 20-centimeter Secchi's disk. A Kemmerer water sampler was used to collect water for pH.

A Bendix depth recorder, loaned by the Oklahoma Fishery Research Laboratory, Norman, was used to estimate depths as the lake was traversed in a boat. The depths which were recorded on paper, were transposed, in 1.5 meter intervals, to a map of the shoreline.

Shoreline development was calculated from a formula given by Welch (1948).

Benthic Fauna

Benthic samples were collected with a 15.24 by 15.24 cm Ekman dredge. After field washing the sample in a sieve with openings of 0.42-mm, the remaining benthos and debris were preserved in 10 per cent formalin. Additional washing and sorting were done in the laboratory and organisms were preserved in 70 per cent isopropyl alcohol.

Contents of Ekman dredge samples were identified and counts made of each taxa. Identifications were made with the aid of a binocular dissecting microscope and a compound microscope. Oligochaetes were whole-mounted in Piccolyte mounting medium for identifications.

Biomass estimations were made only for *Hexagenia* spp. The total Hexagenia spp. in each dredge sample was oven-dried at 100 C for twelve hours, cooled in dessicators to room temperature, and weighed in milligrams on an analytical balance.

CHAPTER IV

EXPERIMENTAL DESIGN

The portion of the lake included in the sampling design was 60.97 hectares, exclusive of the creek proper which was not considered. The 60.97 hectares was stratified into six areas which were chosen to study different habitats of the lake (Fig. 2). The locations of the areas were referred to by Range, Township, and Section. The Sections were divided into thirty-six quadrants numbered the same as in standard surveying procedure.

Area 1, 2.19 hectares, was a cove on the west side of the lake. A power plant coolant water entered this cove. R 2E, T 19N, S2 and part of quadrant 31.

Area 2, 2.65 hectares, also a cove, was located on the west side of the lake north of area 1. R 2E, T 19N, S2 and quadrant 19.

Area 3, 9.87 hectares, represented an open water area that was free from rooted aquatic vegetation. R 2E, T 19N, S2 and parts of quadrants 20 and 29.

Area 4, 1.46 hectares, which represented a shallow portion, started at the north end of the lake and extended into Boomer Creek. R 2E, T 19N, S2 and quadrants 4 and 5.

Area 5, 21.39 hectares, represented a deep part of the lake that was free of rooted aquatic vegetation. R 2E, T 19N, S2 quadrant 32 and portions of 20, 21, 28, 29, 30, and 31, and also S11 quadrants 1 and 2.

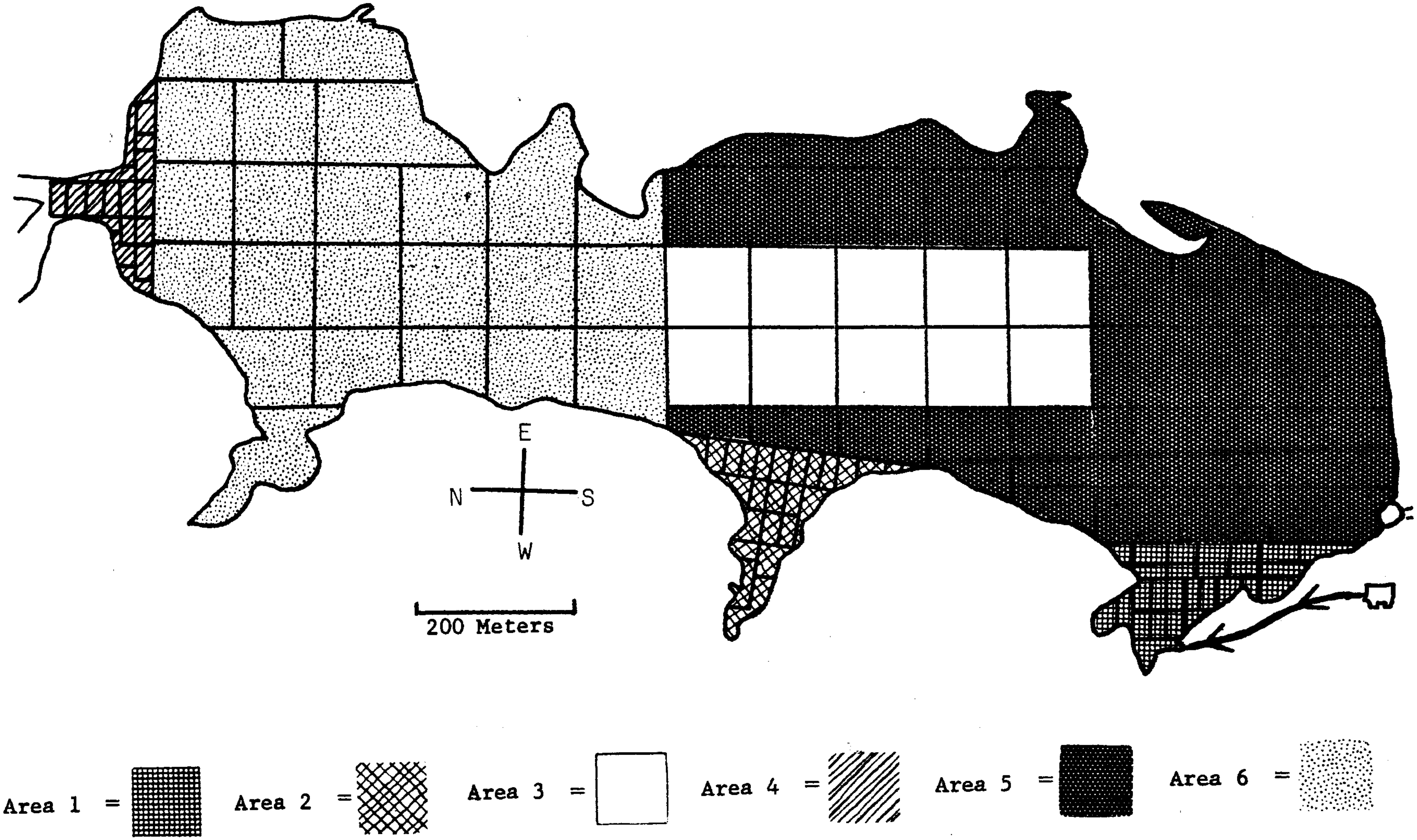

Figure 2. Sampling Areas and Subdivisions of Boomer Lake

Area 6 represented a shallow region and was 23.51 hectares. R 2E, T 19N, S2 and quadrants 8, 9, 17, and portions of 21 and 29.

The size of the small blocks in each area represents sampling stations that were randomly chosen, without replacement, using a table of random numbers. The blocks were designated as the smallest space which easily could be located and in which a boat could be stabilized during periods of high winds.

A sampling station refers to a randomly chosen block within an area where one Ekman dredge sample was taken and physicochemical characters measured.

Beginning 18 March, through 5 September, 1966, five Ekman dredge samples were taken randomly in areas 1, 2, 3, and 4, at approximately seven day intervals. Every fourth sampling period, an additional 10 random samples, five from area 5 and five from area 6, were collected to complete estimates of the entire lake. Samples were taken twice a month during September and October and once a month from November through February. During monthly sampling, all six areas were sampled. Total number of sampling periods was 32.

The values obtained from the five samples collected in each area were combined to compute a mean number per area per sampling period. The mean number per taxa per area per month ($\bar{S}_{ki}$) was determined by:

$$\bar{S}_{ki} = \frac{A_{ki}}{C_{ki}}$$

where A_{ki} = total number in a taxa for k^{th} stratum and i^{th} month, and C_{ki} = total number of Ekman dredge samples for k^{th} stratum and i^{th} month.

Since stratified, random sampling (Steel and Torrie, 1960) was conducted, the following formula, weighted on the basis of area size, was used to estimate the mean number per taxa for each month for the lake:

$$\bar{S}_i = \sum_k w_k \bar{S}_{ki}$$

where $w_k = \frac{N_k}{N}$ and N_k = size of k^{th} stratum and N = size of all strata combined.

Biomass estimations were made only for <u>Hexagenia</u> spp. Mean biomass for each area for each month ($\bar{X}_{ki}$) was estimated by:

$$\bar{X}_{ki} = \frac{j_{ki}}{C_{ki}}$$

where j_{ki} = total biomass in the k^{th} stratum and i^{th} month.

The $\bar{X}_{ki}$'s were combined to estimate the biomass of the lake for each month ($\bar{X}_i$) by:

$$\bar{X}_i = \sum_k w_k \bar{X}_{ki} .$$

Mean biomass per <u>Hexagenia</u> spp. for each stratum for each month ($\bar{Y}_{ki}$) was calculated by:

$$\bar{Y}_{ki} = \frac{j_{ki}}{A_{ki}}$$

where j_{ki} = total weight of samples in the k^{th} stratum and the i^{th} month.

The estimated mean biomass per Hexagenia spp. for all areas combined for each month ($\overline{Y}_i$) was:

$$\overline{Y}_i = \sum_k w_k \overline{Y}_{ki} \ .$$

The mean values for numbers and biomass per unit of area were on a 232.25 square centimeter basis. A conversion factor (43.05) was used to expand to per square meter.

Numbers of Hexagenia spp. and Tendipedidae were used separately in analyses of variance and covariance. Depth and bottom temperature were designated as independent variables and number collected as the dependent variable in covariance analyses. A transformation of $\sqrt{X + \frac{1}{2}}$ was applied to the number of organisms as suggested by Steel and Torrie (1960). All calculations were made on an IBM 7040 computer at the Oklahoma State University Computer Center.

CHAPTER V

PHYSICOCHEMICAL CONDITIONS

Rainfall and Lake Level

The rainfall for the Boomer Lake area averages some 81.28 cm per year. In 1966, total rainfall was only 60.98 cm, 20.30 cm below the mean. The greatest amount of precipitation (18.51 cm) was recorded in July, while the least amounts (0.48 cm) were recorded in March and November (Fig. 3).

In January of 1966, the lake was 0.92 meters below and by July had decreased to 1.34 meters below spillway level (Fig. 4). This was the lowest lake level encountered during the study. Copious rainfall in July resulted in a rise of 0.92 meters in the lake level. The July rainfall mentioned was 11.9 cm recorded for the 24-hour period ending 8:00 a.m. 23 July. Prior to this rainfall, the littoral vegetation was abundant. After the rainfall, the weekly benthic samples seemed to show progressively more decaying vegetation. This possibly could have been caused by the increased water level reducing the sunlight available to the plants and also to decreased transparency as a result of material being added to the lake during runoff.

Hydrogen-ion Concentration

The pH near the lake bottom ranged from 7.2 in July at 6.05 m to 9.0 in May at 0.18 m (Table II). Low pH was associated with anoxic

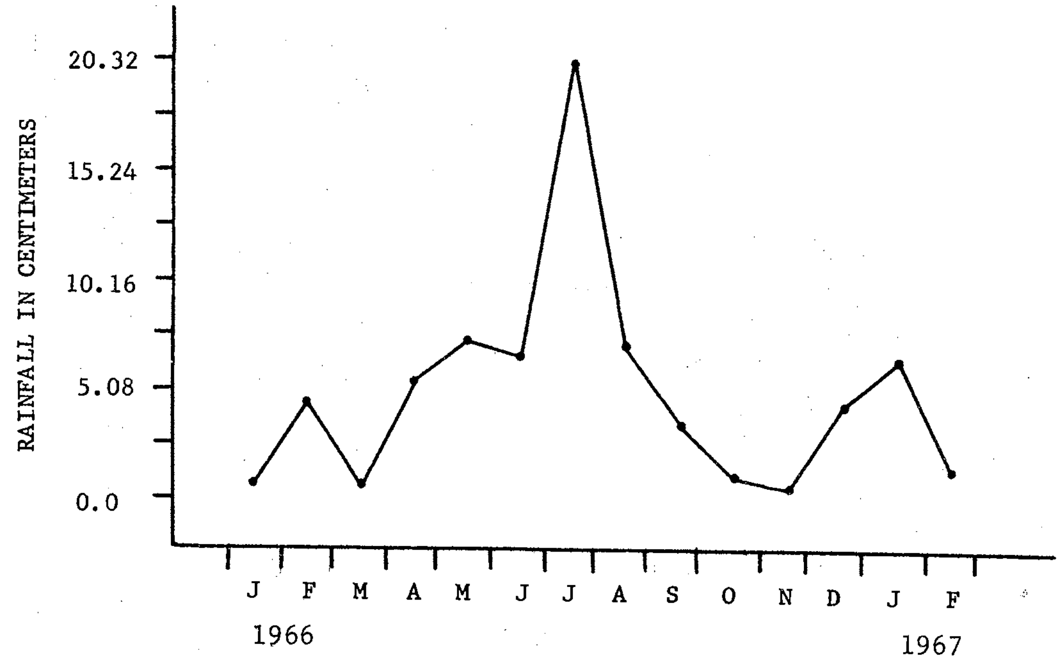

Figure 3. Monthly Rainfall

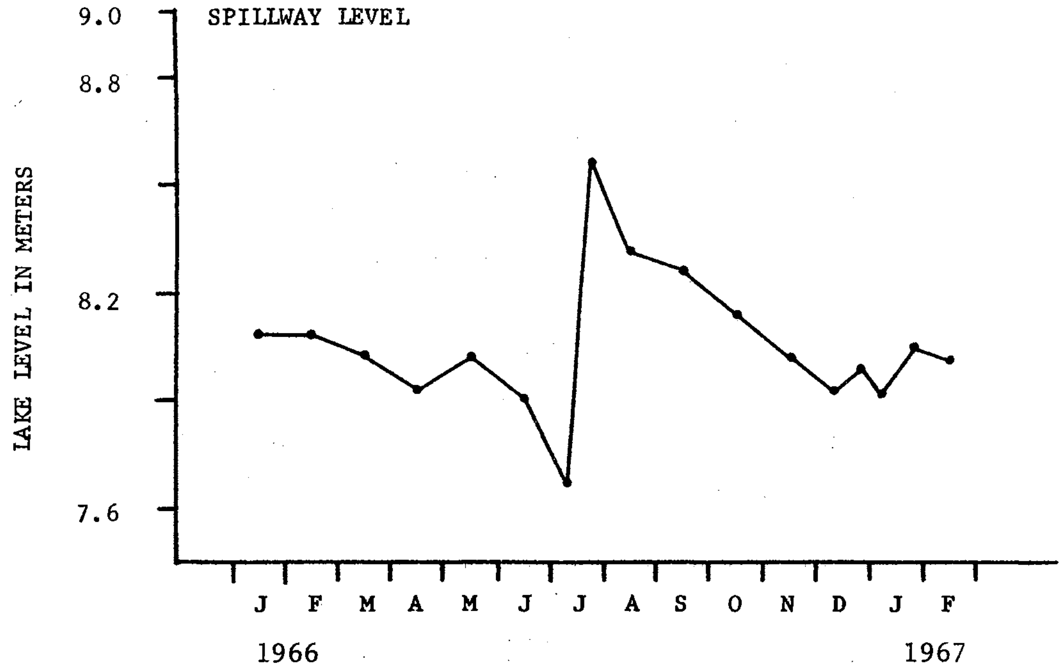

Figure 4. Lake Level Fluctuations for Each Month

conditions and a silt-clay substrate while high pH was associated with dissolved oxygen of 11 p.p.m. and dense littoral vegetation. Crowder (1940) measured pH of surface and bottom water from 6.6 to 8.0 during summer months. Littoral vegetation during Crowder's study was removed by the city of Stillwater. The higher pH measured during the present study possibly was associated with the occurrence of abundant macrophytes which remove free CO_2, break down the bicarbonate ion, and release hydroxyl ions (Ruttner, 1965).

TABLE II

MEAN QUARTERLY VALUES FOR DISSOLVED OXYGEN, PER CENT OF SATURATION, TEMPERATURE, AND RANGES FOR BOTTOM pH

Months	Bottom pH Range	Surface D. O.		Bottom D. O.		[1]Sur. Temp.	[1]Bot. Temp.
		p.p.m.	% Sat.	p.p.m.	% Sat.	C	C
Mar.-May	8.5-9.0	9.09	95	8.69	91	16.10	15.15
June-Aug.	7.2-8.4	6.85	92	6.32	81	28.11	26.94
Sept.-Nov.	8.2-8.6	9.93	112	9.40	105	19.72	18.79
Dec.-Feb.	8.2-8.5	11.71	100	11.79	100	7.11	6.81

[1] No data for March, 1966

Transparency of the Water

Fluctuations in transparency resulted from runoff and addition of suspended matter, wind action, and changes in plankton populations. Tebo (1955) indicated that in a eutrophic lake in Iowa, turbidity was almost entirely due to silt suspended in water after periods of high winds. Mean transparency of the Boomer Lake water on 6 May was 127 cm and was the highest measured (Fig. 5). This measurement was preceded

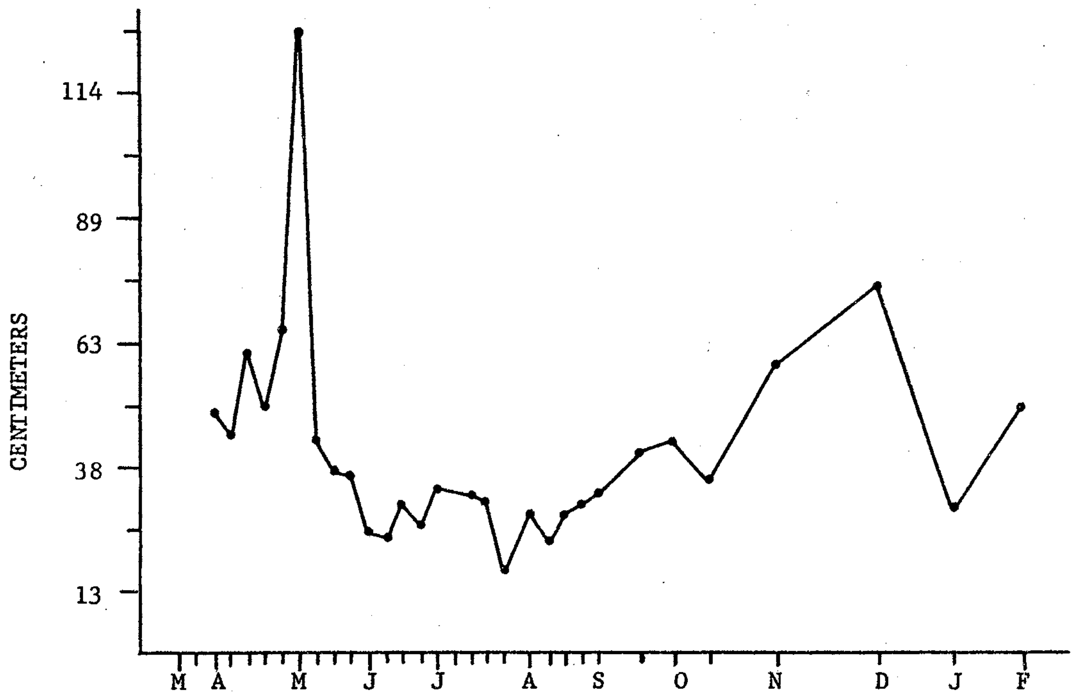

Figure 5. Mean Secchi Disc Transparency for Each Sampling Period

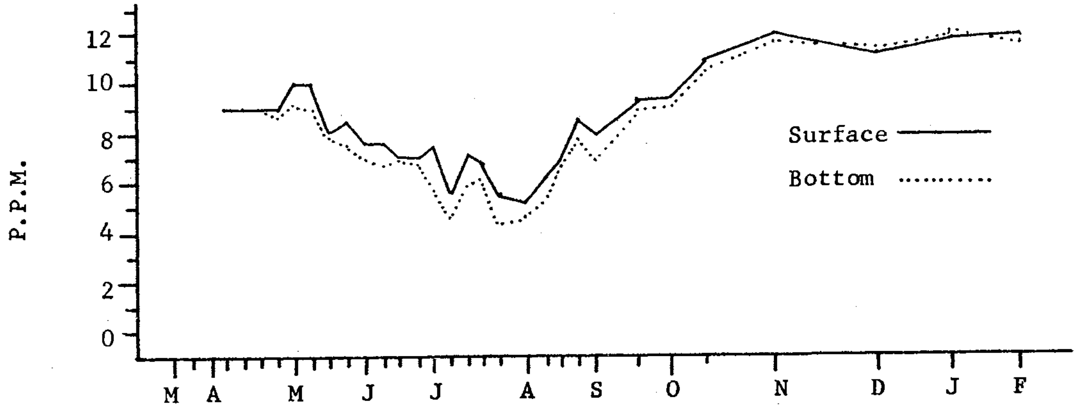

Figure 6. Mean Surface and Bottom Dissolved Oxygen for Each Sampling Period

by several days of calm, sunny weather which possibly resulted in a settling of particles. Buck and Cross (1952) attributed a clearing of Canton Reservoir to decomposition of newly flooded terrestrial vegetation which may have caused precipitation of soil particles. Transparency decreased to a mean of 16 cm on 28 July, and then increased to a mean of 76 cm on 28 December. The mean on 27 January was 30 cm, a decrease of 46 cm in one month. High turbidities followed rainfall but moderate turbidities were probably maintained due to wind action.

Dissolved Oxygen

The quarterly mean surface and bottom dissolved oxygen were lowest during summer and highest during winter (Table II). Per cent of saturation was lowest in summer and greatest in fall. Supersaturation of surface and bottom water during fall possibly was associated with calm days, relatively high temperatures, and high photosynthetic oxygen production. Dissolved oxygen in spring and fall was similar, indicating each as a transition season (Fig. 6). Only during June and July was dissolved oxygen 2.0 p.p.m. or lower measured. Anoxic conditions were indicated in the deeper areas on several sampling periods. Maximum surface and bottom dissolved oxygen measured was 12.64 p.p.m.

Temperature Profiles

Temperature data indicate that the lake water was almost in constant circulation. Stratification with development of a thermocline occurred for short periods only during the warmer months. A well-developed thermocline was present 6 May, but by 13 May, it was in the process of disappearing (Fig. 7). The profiles for March, April,

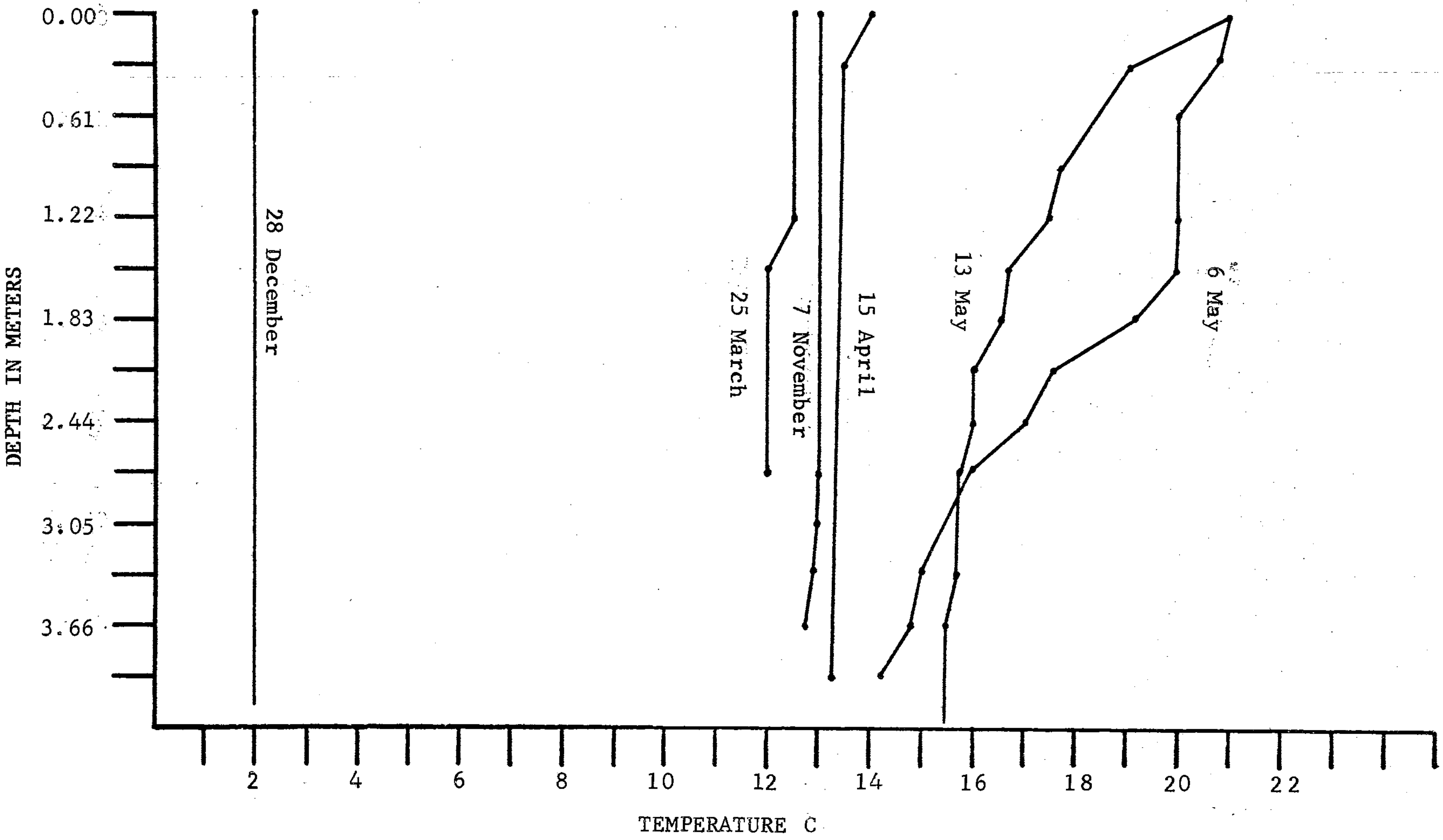

Figure 7. Temperature Profiles for March, April, May, November, and December

November, and December indicate a homothermous condition, which possibly resulted from wind action, was typical during the study.

The quarterly mean surface and bottom water temperatures were highest in summer and lowest in winter (Table II). Lowest mean surface and bottom temperatures were 1.7 C on 28 December. Highest mean surface and bottom temperatures were 32.96 and 30.85 C on 15 July.

Crowder (1940) classified Boomer Lake as a temperate lake of the third order according to Forel's definition in Welch (1952). To fit Forel's classification, the surface waters must vary above and below 4 C, surface and bottom temperatures must be similar, and circulation must be continuous except when frozen. Since the lake thermally stratified occasionally, it would not strictly fit Forel's definition of a third order lake. General absence of stratification is apparently due to the high average wind velocity and shallow water.

Interrelations of Environmental Variables

Transparency, pH, temperature, dissolved oxygen, and rainfall exhibited a trend characteristic of seasonal variation in climatic conditions. Amount of rainfall seemed to be the factor controlling transparency of the water and dissolved oxygen concentrations. The period in May when transparency was greatest was accompanied by a rise in dissolved oxygen and was preceded by relatively little rainfall. The rise in oxygen possibly was due to increased primary productivity during warm, sunny days when the lake was clear. Transparency and dissolved oxygen were lowest following the July rainfall. During the same period pH was also lowest. Low dissolved oxygen possibly was due to the high temperatures since dissolved oxygen is less soluble at high temperatures.

Dissolved oxygen possibly was affected by rainfall as a result of nutrients being added to the lake which may cause more chemical and biological oxidation to occur thus reducing the dissolved oxygen. A reduction in the volume of the euphotic zone due to decreased transparency also would decrease dissolved oxygen by decreasing photosynthesis. Also, the increased temperature probably resulted in increased metabolism which would require increased amounts of dissolved oxygen.

Transparency, pH, and dissolved oxygen increased during fall and winter when rainfall was a minimum. The decrease of 46 cm in transparency from December to January may have resulted from the rainfall in December. An increase in transparency during February was accompanied by low rainfall.

These phenomena indicate that dissolved oxygen, pH, transparency, and temperature were dependent for their values on climatic factors which were a result of a seasonal trend characteristic of the latitude and longitude.

CHAPTER VI

ECOLOGY OF *HEXAGENIA* SPP.

Standing Crop

Hexagenia spp. were found in all areas of the lake and because of their biomass and abundance, probably were important as dietary items for fishes. The population size of *Hexagenia* spp., for all areas combined, decreased to a minimum in August ($147.8/M^2$), increased to a maximum in December ($967.6/M^2$) and subsequently decreased (Fig. 8). Decrease of organisms was attributed to natural mortality, predation, and emergence, and increase of organisms to hatching of eggs laid by insects that emerged during the summer.

All areas exhibited a similar seasonal trend in numerical standing crop (Fig. 9). After emergence was virtually completed, there was an increase in number with the peak occurring in December in most areas. Sublette (1957) reported that *H. munda elegans* Traver reached peak number in February. There was, in area 4, a decrease in number, from December through February, which was greater than in other areas (Fig. 9). This decrease was attributed to movement to deeper water since area 4, on either side of the creek channel, was relatively shallow and sandy. Hunt (1953) attributed to growth and a demand for more extensive silt accumulations, the migration of young-of-year nymphs from shoal areas to deeper water and softer substrates.

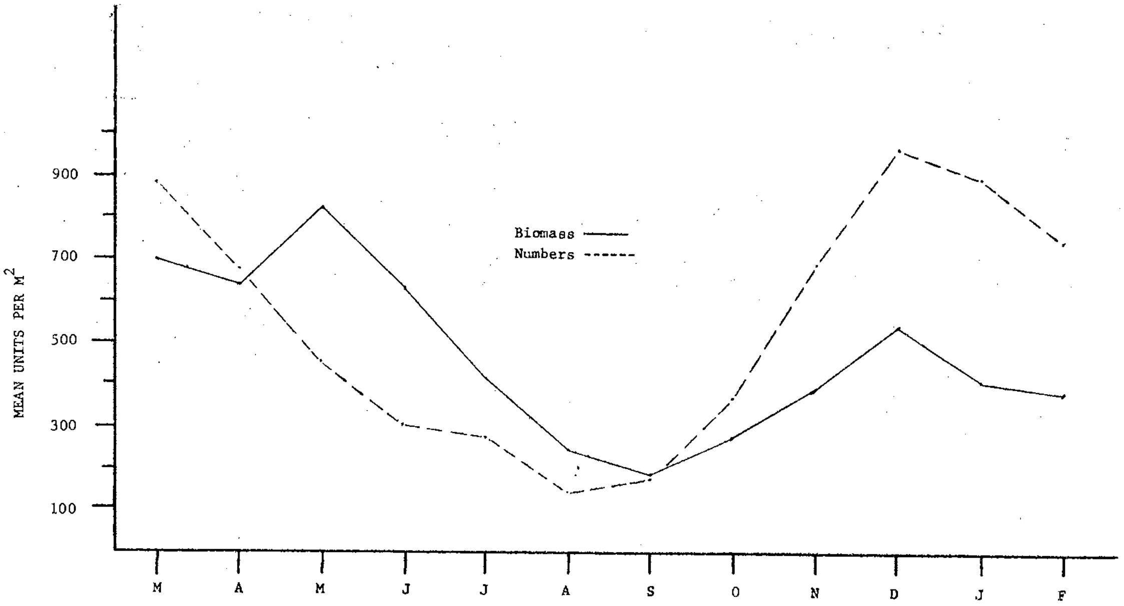

Figure 8. Mean Biomass (Milligrams) and Numbers of Hexagenia for Each Month

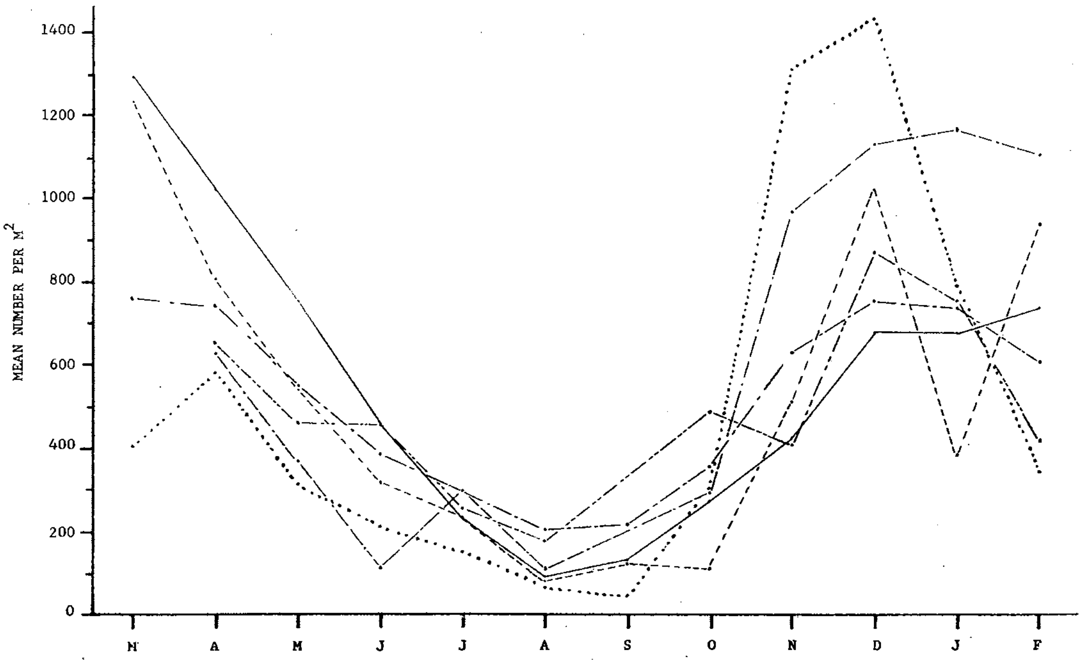

Figure 9. Mean Number of Hexagenia for Each Area for Each Month. Area 1 = (———), Area 2 = (-----), Area 3 = (—-—), Area 4 = (·········), Area 5 = (——--), Area 6 = (——·——).

Each area had a lower numerical standing crop in February, 1967, as compared with March, 1966. The heavy rainfall in late July possibly resulted in the addition of allocthonous material to the lake which smothered the demersal mayfly eggs.

Hexagenia populations of Boomer Lake were relatively large as compared with populations in other areas during similar times of the year (Table III). Maximal standing crop of all taxa found in Boomer Lake was $1800/M^2$ in February, 1967, as compared to $4500/M^2$ for Lake Texoma in February, 1951 (Sublette, 1953). In Lake Texoma, Chaoborus punctipennis contributed the major portion of the population but in Boomer Lake, C. punctipennis was less abundant than Hexagenia. Differences in standing crops of Hexagenia may result from variations in biological productivity of the environment, length of growing season, and length of life cycle. Inter- and intraspecies variation in time of emergence and length of life cycle may result in considerable variation in standing crops between closely associated lakes.

Mean biomass increased from 699.6 mg in March to 819.2 mg in May (Fig. 8). During April and May, biomass and numbers exhibited opposite trends which undoubtedly was a result of growth rate being greater than mortality rate. After May, biomass and numbers indicated similar trends until cessation of sampling in February. Total kilograms decreased from 427 in March to 113 in September (Table IV).

Maximum mean biomass per individual Hexagenia spp. (2.85 ± 0.73 mg) was attained in June (Fig. 10). Some individuals probably reached maximum biomass and began to emerge in May which would result in mayflies being present in late May or early June and thus throughout the summer. Decrease in biomass continued until November, the greatest

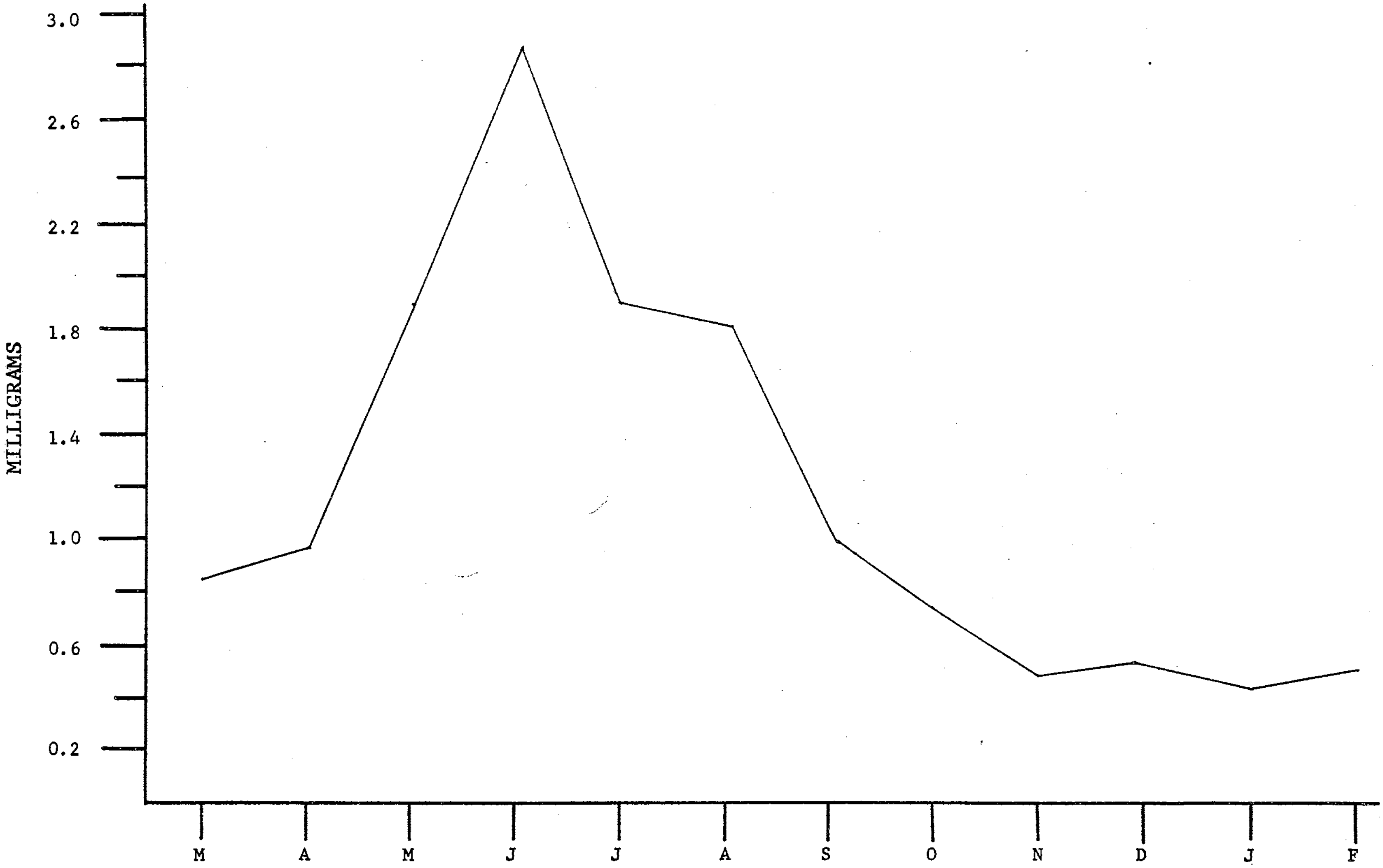

Figure 10. Mean Biomass per Individual *Hexagenia* for Each Month

decrease being in July and September. A decrease in the mean biomass per individual until November could have resulted from an influx of small mayflies, derived from the late summer hatch, into the population of large mayflies hatched in early summer. During December, January, and February, mean biomass per mayfly remained relatively constant (Fig. 10). Lowest mean biomass per mayfly was 0.49 ± 0.06 mg in December.

TABLE III

COMPARISON OF NUMERICAL STANDING CROPS OF *HEXAGENIA* FROM BOOMER LAKE WITH OTHER AREAS

Area	Source	Date	Approximate Mean No./M^2
Mississippi River, Keokuk, Iowa	Fremling 1960	9 July 1958	323
Lake Texoma, Oklahoma	Sublette 1953	19 July 1951	100
Western Lake Erie, south of Rattlesnake Island	Britt 1955	17 June 1952	388
		23 June 1953	300
Boomer Lake, Oklahoma	Present Study	May 1966	453
		June	302
		July	275

Hexagenia spp. reached maximum biomass per individual in June in all areas except area 6 where the maximum measurement was in July. Greatest and lowest biomass per individual were in June (4.97 ± 0.77 mg) and November (0.22 ± 0.03 mg) in areas 4 and 3, respectively.

TABLE IV

STANDING CROP OF HEXAGENIA SPP. FOR EACH MONTH AND APPROXIMATE 95 PER CENT CONFIDENCE INTERVALS

Month	No. of Samples	Number	Milligrams	Number (X 10^4)	Kilograms	Total Number (X 10^6)	Total Kilograms
		Per Square Meter		Per Hectare		in Lake	
March	40	881 ± 294	669.6 ± 364.4	144	6.9	538	427
April	110	677 ± 186	636.9 ± 220.9	111	6.4	414	389
May	90	453 ± 157	819.2 ± 372.8	74	8.2	276	501
June	90	302 ± 148	637.4 ± 495.3	49	6.4	184	390
July	120	275 ± 163	415.9 ± 218.8	45	4.2	168	254
August	90	148 ± 102	247.8 ± 251.3	24	2.5	90	152
September	40	172 ± 66	184.4 ± 88.3	28	1.8	105	113
October	50	365 ± 249	274.7 ± 208.9	60	2.8	223	168
November	30	690 ± 382	389.6 ± 366.7	113	3.9	422	238
December	30	968 ± 493	539.1 ± 262.5	159	5.4	591	330
January	30	897 ± 488	409.6 ± 260.7	146	4.2	547	250
February	30	750 ± 345	382.9 ± 252.8	123	3.8	458	234

[1] Confidence intervals only could be approximated because the data was not considered normally distributed.

Growth and Recruitment

Mayfly nymphs principally are scavengers and herbivores, feeding mostly on diatoms (Burks, 1953). *H. limbata* (Serville) seemed to feed on mud from which they derived nourishment (Hunt, 1953). In Lake Esrom (Denmark) primary production curves and *Chironomus anthracinus* (Zetterstedt) weight curves paralleled each other (Jónasson, 1965). If *Hexagenia* spp. attained its greatest biomass during or slightly lagging the period of maximum primary productivity, then the greatest biomass increase and hence emergence would be correlated with this period.

Morgan and Wilder (1936) showed that oxygen consumption of *H. recurvata* Morgan was directly proportional to temperature. Hunt (1953) related temperature with nymphal growth and found that growth continued until water temperatures began to decrease rapidly in November from an average of 10 C maintained in late October. In Boomer Lake, mean biomass per *Hexagenia* spp. remained relatively constant after October. If increased growth was initiated at about 10 C, then in 1966, the growth period before and after emergence could have lasted from March until sometime in December. The period of seven or eight months (after May emergence) allowed the nymphs to complete a major portion of their life cycle before becoming dormant in winter.

The nymphs hatched between May and October did not appear as a recruitment curve because the rate at which nymphs were leaving the population exceeded the rate at which nymphs were being added to the population. A recruitment curve appeared in September for numbers and in October for biomass. Recruitment refers to addition to the population as a result of growth. When all nymphs were large enough to be caught in the sieving progress, they were fully recruited. Recruitment continued until December for both biomass and numbers. After all nymphs were recruited, there was a decline in biomass and numbers which may be attributed to natural mortality and predation. In other words, the decrease in biomass in the lake after December and relatively constant biomass per individual during the same period, indicated that the decrease is due to natural mortality and predation and not to loss of weight per individual. Loss of weight due to emergence from December to February would be doubtful.

Depth Distribution

The depth distribution of Hexagenia spp. varied from 0.30 to 7.31 meters (Fig. 11). In summer and fall, Hexagenia spp. was distributed with maximum numbers at the 4.57 to 5.48 meter interval. In spring, 1966, and winter, 1967, maximum numbers were found at the 1.83 to 2.74 depths. The greater numbers at the 1.83 to 2.74 depths in spring is presumed to result from distribution of greater numbers of eggs in the shallow as compared with the deep water. Migration from deep to shallow water is not regarded as a factor causing the spring shift in abundance to shallow water because such a shift would result in a decrease in number of nymphs in the deep water and an increase in number in the shallow water. Changes in relative densities in shallow and deep water did not occur since, as the shallow water fauna increased in number, so did the deep water fauna (Fig. 11).

Adamstone and Harkness (1923) reported H. bilineata (Say) fairly uniformly distributed over all depths between 1.52 and 7.62 meters

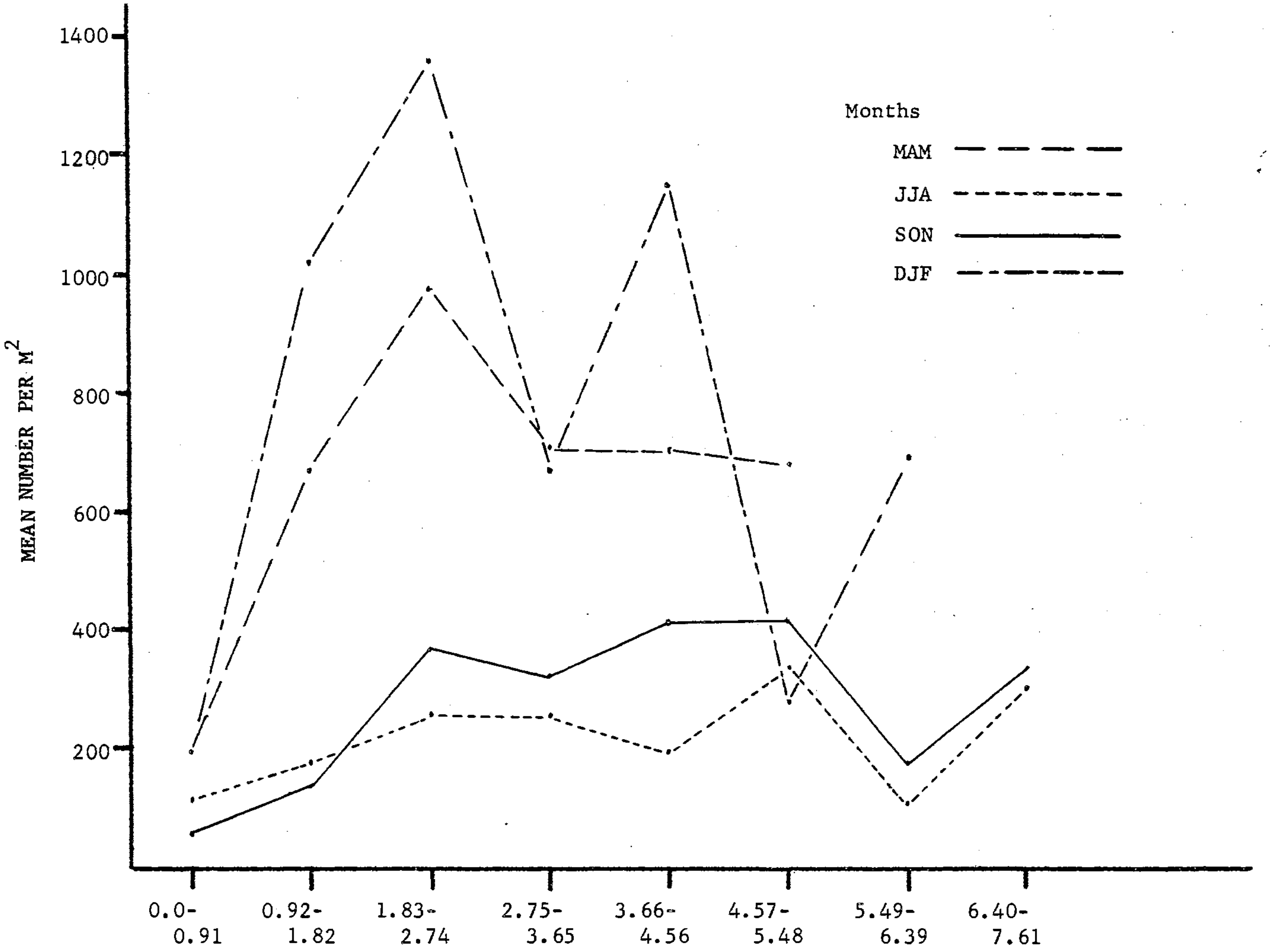

Figure 11. Depth Distribution of *Hexagenia* for Each Season

while Swanson (1967) found Hexagenia more numerous at the 5-7 meter interval.

Factors Effecting Distribution

Dissolved Oxygen

Various investigators have indicated that the reason for migrations of insects from deep to shallow water frequently resulted from development of anoxic or very low oxygen concentrations in the deep water. Hunt (1953) observed that a few nymphs of H. limbata succumbed under stagnation conditions in aquaria when dissolved oxygen was reduced to about 1.0 p.p.m. He also observed nymphs alive when analysis indicated no oxygen, but concluded that exposure to only 1.0 p.p.m. dissolved oxygen will result in death of most organisms within 38 to 40 hours. Britt (1955) found numerous dead Hexagenia spp. in bottom dredge samples from areas where the dissolved oxygen concentration was 0.7 p.p.m.

Dissolved oxygen concentrations as low as 0.0 p.p.m. occurred only in the warmer months in Boomer Lake since during winter and spring dissolved oxygen concentrations did not approach 1.0 p.p.m. Migrations away from anoxic conditions was not observed but would be anticipated in the summer.

Depth and Bottom Temperature

Depth and bottom temperature were the only parameters estimated that had a range great enough possibly to effect benthos distribution. Therefore, these were used as covariates, with number of organisms as the dependent variable, in a covariance analysis which was applied to each month from April through October. The covariates did not contribute significant information (0.05 level) to account for variation in number of organisms. Bottom temperature was not useful as a covariate in accounting for variation possibly because the range of temperatures measured was within the tolerance range of <u>Hexagenia</u> spp.

Depth as a covariate in the ranges observed in Boomer Lake, did not effect distribution. However, depth may influence factors such as oxygen, light penetration, availability of plants and type, depth, and organic content of sediments which in turn may effect <u>Hexagenia</u> spp. Apparently, these factors were of sufficient quantity and quality at depths sampled so that depth was not an effective covariate.

An analysis of variance for the months March through October was applied and no significant (0.05 level) sampling period by area interaction appeared. Mean number for areas 1 through 4 for each month was ranked (minimum to maximum) and Duncan's New Multiple Range Test (Steel and Torrie, 1960) applied at the 0.05 level of significance. Area 4 generally was significantly different from other areas during March through September but always was ranked last during this period (Table V). During October, November, and December, a change in rank occurred which culminated in mean number being greatest in area 4, although it generally was not significantly different from other areas. Rank again changed in January and February to result in area 4 being ranked last.

The most obvious difference in area 4 as compared with the rest of the areas is its shallowness (Fig. 1). The rank change during October, November, and December may indicate a greater distribution of eggs during summer in area 4. The change in January and February may be migration of nymphs to deeper water as previously discussed.

Adamstone and Harkness (1923) reported that for <u>H. bilineata</u> shallow waters of small protected bays or channels between islands were

TABLE V

DUNCAN'S NEW MULTIPLE RANGE TEST APPLIED TO MEAN NUMBER OF *HEXAGENIA* SPP. FOR EACH MONTH[1]

March	$4\ 3\ \underline{2\ 1}$
April	$4\ \underbrace{3\ \underline{2}}\underline{\ 1}$
May	$4\ \underline{2\ 3\ 1}$
June	$\underbrace{4\ \underline{2}}\underline{\ 3\ 1}$
July	$4\ \underline{1\ 2\ 3}$
August	$4\ \underline{2\ 1\ 3}$
September	$\underbrace{4\ 2\ \underline{1}}\underline{\ 3}$
October	$\underbrace{2\ \underline{1}}\underline{\ 4\ 3}$
November	$\underline{1\ 2\ 3\ 4}$
December	$\underline{1\ 3\ 2\ 4}$
January	$\underline{2\ 4\ 1\ 3}$
February	$\underbrace{4\ \underline{3}}\underline{\ 1\ 2}$

[1] Areas 1 through 4 are ranked (left to right) from mean minimum to mean maximum number per square meter. Underline designates no significant difference at 0.05 level.

generally most productive and that the open water was relatively unproductive. Apparently, in Boomer Lake, the coves and open water area were similar in terms of standing crop.

Length of Life Cycle

Length of life cycle (egg stage to adult emergence) is known to be related to various environmental factors, the most important being temperature. One and two year life cycles have been observed in the same mayfly species. A one year life cycle generally is associated with warmer, southern waters while a two year life cycle with cooler, northern waters. Mayflies with a one year life cycle have the following attributes: one size and age group of nymphs in the fall, winter, and spring; a transformation of the entire group during early summer; a scarcity of large individuals in late summer; and the appearance of large numbers of newly hatched young in mid- or late summer. The distinctness of these characteristics is influenced by weather conditions (Hunt, 1953). Emergence periods of mayflies became shorter downstream until they were confined to the early summer. This phenomenon was correlated with greater fluctuations in seasonal water temperatures downstream (Ide, 1935).

The following evidence indicates a one year life cycle for *Hexagenia* spp. in Boomer Lake:

1. Emergences occurred from May through September.
2. In late summer, relatively few individuals were collected.
3. The appearance of large numbers of small mayfly nymphs occurred in the fall.

4. Two size and age groups of <u>Hexagenia</u> spp. present in December possibly resulted from two summer emergences or was due to different species of mayflies in the population having different emergence periods.

5. A growth period of eight or nine months was evident from water temperature data and increases in weight per individual <u>Hexagenia</u> spp.

CHAPTER VII

SEASONAL VARIATION OF BENTHIC MACROINVERTEBRATES

Thirty taxa (taxonomic level in which organisms were classified in this study) were collected. However, seven taxa (*Chaoborus punctipennis*, *Caenis* sp., *Sialis* sp., *Hexagenia* spp., *Hyalella azteca*, *Branchiura sowerbyi*, and Tendipedidae) comprised 92.74 to 99.51 per cent of the total number collected. Insect taxa, other than those mentioned, contributed little to total numbers of macrobenthos (Table VI). Insects collected generally inhabit areas of aquatic emergent and submergent vegetation that are free from silt deposits. Thirty-four species of Tendipedidae were collected from tent traps set over vegetation in Cane River Lake, Louisiana (Buckley and Sublette, 1964). Berg (1949) found thirty-two species of insects having direct nutritive, protective, or respiratory relations to plants of the genus *Potamogeton*.

The high average turbidity of Boomer Lake may have limited the variation and abundance of insect fauna. Since most of the insects collected in the present study respire by means of gills, the turbidity of the water may adversely affect their respiration by clogging their gills or by reducing the rooted vegetation which would reduce their habitat. McGaha (1952) stated that silt may be detrimental to insects living on plants, discourage oviposition, or prevent insects from entering the plants. Harrel (1966) attributed reduced number of species collected at sixth order pools as compared to fifth order pools in

TABLE VI

[1]PER CENT CONTRIBUTION OF EACH TAXON TO TOTAL NUMBERS COLLECTED FOR EACH MONTH

Taxa	March	April	May	June	July	August	September	October	November	December	January	February
Nematoda	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Stylaria	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.08	0.47
Nais	0.06	0.00	0.00	0.07	0.06	0.09	0.16	0.04	0.10	0.00	2.49	0.00
Limnodrilus	0.32	0.03	0.05	0.22	0.06	0.37	0.00	0.53	0.10	0.00	0.88	0.62
Tubifex	0.13	0.13	0.00	0.00	0.78	1.55	1.13	0.62	0.38	0.57	2.65	0.15
Dero	0.00	0.03	0.00	0.00	0.00	0.00	0.16	0.00	0.86	0.00	0.08	0.00
Aeolosoma	0.00	0.00	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00
Branchiura	0.97	1.95	2.60	5.55	8.48	18.36	10.96	8.15	5.66	3.15	5.70	3.80
Hyalella	2.26	0.23	0.56	6.88	3.58	2.47	6.29	3.19	0.58	0.08	2.01	7.36
Procambarus	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hexagenia	55.66	49.79	56.32	52.59	39.04	22.01	18.55	30.56	48.71	55.41	42.25	37.60
Caenis	2.91	2.15	6.01	2.29	7.22	11.32	3.06	6.29	2.49	2.18	3.78	3.64
Ameletus	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.10	0.00	0.00	0.00
Sialis	0.84	0.78	1.53	1.63	5.55	5.39	3.87	1.95	0.86	1.05	0.40	0.54
Hydroporus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.08	0.00
Berosus	0.06	0.08	0.05	0.00	0.30	0.27	0.32	0.27	0.29	0.00	0.00	0.08
Gomphus	0.06	0.00	0.00	0.15	0.00	0.27	0.00	0.09	0.00	0.00	0.16	0.00
Ischnura	0.00	0.10	0.00	0.00	0.96	0.46	0.16	0.44	0.10	0.32	0.16	0.62
Epicordulia	0.00	0.03	0.00	0.00	0.12	0.27	0.00	0.00	0.00	0.00	0.00	0.00
Oecetis	0.06	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00
Cheumatopsyche	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chaoborus	10.99	11.18	6.88	3.85	4.90	9.50	26.29	27.19	18.22	15.59	7.79	8.76
Tendipedidae	25.08	33.48	25.54	26.18	28.06	26.85	28.71	20.37	21.57	21.41	30.84	36.12
Palpomyia	0.13	0.03	0.05	0.00	0.06	0.00	0.00	0.09	0.00	0.00	0.08	0.00
Physa	0.00	0.00	0.00	0.00	0.12	0.27	0.00	0.00	0.00	0.00	0.08	0.08
Gyraulus	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.08
Anodonta	0.00	0.00	0.00	0.22	0.00	0.09	0.00	0.09	0.00	0.00	0.08	0.00
Carunculina	0.00	0.00	0.00	0.15	0.12	0.09	0.00	0.09	0.00	0.00	0.08	0.08
Sphaerium	0.00	0.00	0.05	0.15	0.00	0.09	0.16	0.00	0.00	0.16	0.08	0.00
Pisidium	0.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

[1] Rounded to nearest 0.01

Otter Creek, to heavy siltation which reduced the number of available microhabitats.

The small number of gastropods and pelecypods possibly also may be a result of siltation smothering and reduction of habitat. Scarcity of snails in Lakes Chautauqua and Matanzas, Illinois, may have been caused by smothering as a result of siltation (Paloumpis and Starrett, 1960).

Oligochaete populations, except for Branchiura sowerbyi Beddard, were relatively small. The silt substrate present in much of the lake would seem to provide the oligochaetes with a suitable habitat but the sparse numbers collected indicate a small population.

The decrease in number of invertebrates occurred during spring and summer and the increase during fall and winter (Fig. 12). In the winter of 1966-67, a minimal increase occurred. The decrease during spring and summer largely was a result of emergence and predation while the increase during fall and winter was a result of recruitment of insects that were hatched from eggs laid during the summer and early fall.

Nematoda

Free living nematodes were collected on two occasions, two on 15 July and one on 21 July. Depth of capture varied from 0.69 to 1.99 meters. Tebo (1955) found nematodes most abundant on sand and gravel substrates at a water depth of 0.30 to 0.45 meters.

Annelida

Oligochaeta

Naididae-Stylaria lacustris (Linnaeus). The range of S. lacustris has been reported as Pennsylvania, New Jersey, Illinois, Michigan,

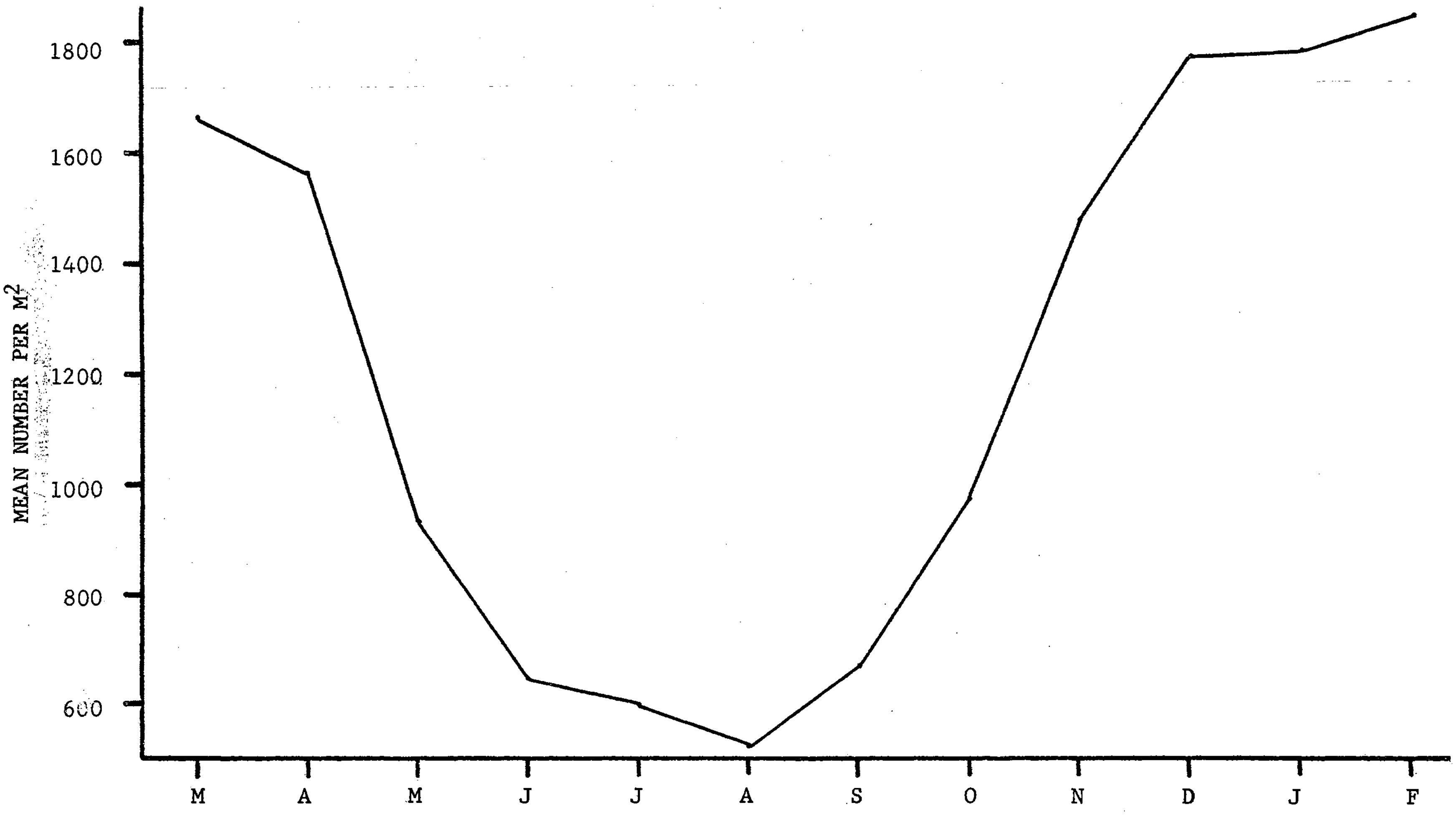

Figure 12. Mean Number of Invertebrates for Each Month

Tennessee, Florida, Ohio, Arkansas, and Connecticut (Brinkhurst, 1964). The collection from Boomer Lake represents the first known for the state and a western range-extension for the species. S. lacustris was associated with substrate of sandy-silt, and littoral vegetation composed of Najas, Potamogeton, and Chara. The small number collected during only three months of the study indicated that S. lacustris did not appear in previous examinations of Oklahoma waters possibly because the investigations were not conducted for a year or else an insufficient number of benthic studies have been initiated (Table VII). Extensive investigations possibly would reveal that S. lacustris is present in many Oklahoma impoundments.

TABLE VII

ENVIRONMENTAL CONDITIONS AT COLLECTION SITES
OF STYLARIA LACUSTRIS

Date	Area	Number Collected	Depth	Bottom Temp.	Bottom Dissolved Oxygen	pH
			Meters	C	p.p.m.	
22 Sept.	4	1	0.49	21.5	9.78	8.4
27 Jan.	2	1	0.74	7.0	12.66	8.3
24 Feb.	2	1	1.25	5.0	11.51	8.4
24 Feb.	4	2	0.60	6.5	12.50	8.4
24 Feb.	4	3	0.69	6.5	12.50	8.4

Nais communis (Pignet) was sporadically collected throughout the year and varied from 0 to 31 specimens per Ekman sample. The maximum number for all areas combined was 44.47 per M^2 on 27 January. Depth of capture varied from 0.29 to 3.99 meters.

Dero sp. was collected on five sampling dates at depths ranging from 1.21 to 6.29 meters.

Tubificidae-Branchiura sowerbyi Beddard was collected from all areas during the study and reached peak abundance (173.56/M^2) in January (Fig. 13). In August, B. sowerbyi comprised 18.35 per cent of the total number of invertebrates collected. In general, numbers in all areas increased from a minimum in May to a maximum in January. Depth distribution varied from 0.18 to 6.74 meters. Brinkhurst (1962) and Mann (1958) have reported B. sowerbyi in association with heated water from power stations but no such association was found in Boomer Lake.

Limnodrilus sp. was collected from all areas, but was mot numerous in areas 1 and 4 (Table VIII). Depth of capture varied from 0.15 to 5.79 meters.

TABLE VIII

TOTAL NUMBERS OF LIMNODRILUS AND TUBIFEX COLLECTED IN EACH AREA DURING THE STUDY FROM 750 EKMAN DREDGE SAMPLES

	Area					
	1	2	3	4	5	6
Limnodrilus	13	1	2	15	2	9
Tubifex	11	18	8	31	12	17

Tubifex sp. was collected from all areas and in general, was more numerous than Limnodrilus sp. (Table VIII). Depth of capture varied from 0.29 to 4.99 meters. Causey (1953) found T. tubifex practically restricted to the first 5 meters in three year old lakes while in lakes about 17 years old, they were found as deep as 13 meters.

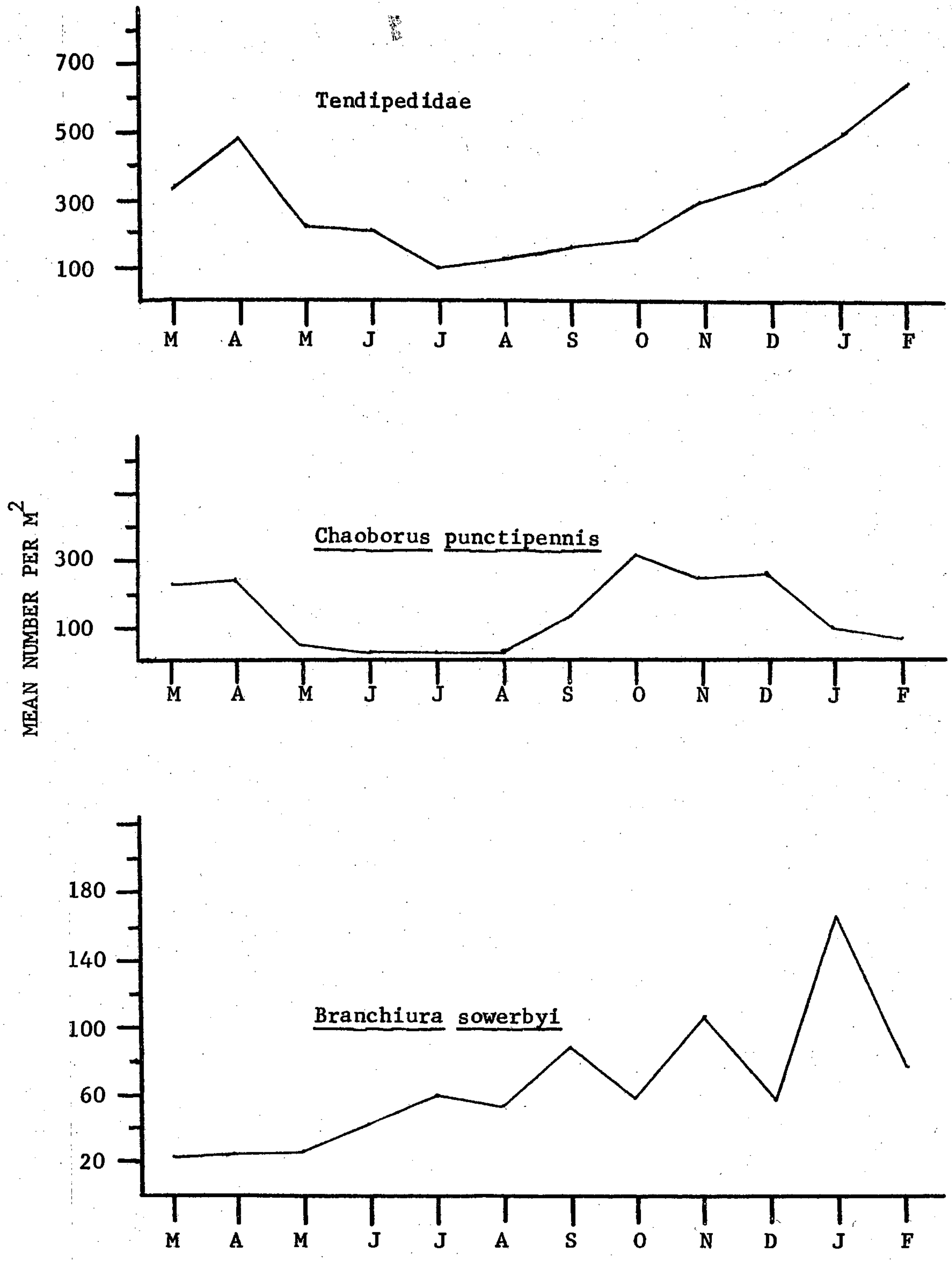

Figure 13. Mean Number of Tendipedidae, *Chaoborus punctipennis*, and *Branchiura sowerbyi* for Each Month

Aeolosomatidae-Aeolosoma sp. was collected three times at depths of 0.29 and 0.45 meters.

Arthropoda

Crustacea

Amphipoda

Talitridae-Hyalella azteca (Saussure) was most abundant in shallow areas of abundant aquatic vegetation but generally was collected from all depth sampled. In area three, at a depth of 3.73 meters, 41 were collected from one Ekman dredge sample. For all areas combined the greatest number collected ($136.32/M^2$) was in February. Buscemi (1961) collected, in Parvin Lake, Colorado, from 512 to $1,536/M^2$ at a depth of 0.5 meters in fall, winter, and spring, but in summer and fall few were found on the sediments while many were found in Elodea. Mackin (1941) stated that distribution covers the entire state of Oklahoma, in clear, permanent ponds. Tebo (1955) collected H. knickerbockeri in greatest numbers on heavy growths of filamentous algae (30 to 46 cm in depth) but also collected it in small numbers in deep water stations (121 to 152 cm in depth).

Decapoda

Astacidae-Procambarus sp. was captured on 6 and 13 May. Depth of capture varied from 0.60 to 2.74 meters. Orconectes sp. has been collected from the lake but was not collected during the present study.

Insecta

Ephemeroptera

Ephemeridae-Hexagenia spp. will be discussed in another chapter.

Baetidae-Caenis sp. was found in greatest numbers in January and February ($67.44/M^2$). Sublette (1957) recorded maximum numbers in mid-winter and a minimum in summer in Lake Texoma. Greatest numbers in any one area ($594.09/M^2$) occurred in area 4 on 28 July and was associated with aquatic vegetation. Depth distribution varied from 0.15 to 7.49 meters.

Ameletus sp. was collected on 8 and 15 July and 17 November. Depth of capture was 3.99, 3.65 and 3.99 meters respectively.

Neuroptera

Sialidae-Sialis sp. was collected in all areas. Greatest numbers ($94/M^2$) were recorded in area 1 on 21 July. The abundance of the nymph in area 1 may be associated with the water current. Sialis exhibited an opposite seasonal trend than Hexagenia since it was found in greatest numbers during summer. Depth distribution varied from 0.60 to 5.79 meters. Harrel (1966) also found greatest numbers in the summer.

Coleoptera

Dytiscidae-Hydroporus sp. was collected on 8 April (1.21 meters), 28 December 2.49 meters), and 27 January (1.49 meters). Only one specimen was collected each date.

Hydrophilidae-Berosus sp. was collected in all areas throughout the year. Greatest numbers were collected in area 4 and least numbers in area 5. Area 4 was heavily vegetated and greatest numerical abundance apparently varies with the amount of vegetation. Depth distribution varied from 0.24 to 4.99 meters.

Odonata

Three families of Odonata were collected, Gomphidae-*Gomphus* sp., Coenagrionidae-*Ischnura* sp., and Libellulidae-*Epicordulia* sp. *Ischnura* sp. was most frequently collected being captured on 17 out of 32 sampling dates. *Gomphus* sp. was collected on 7 dates while *Epicordulia* sp. was collected on five dates.

Gomphus sp. was collected at depths varying from 1.24 to 4.49 meters. *Ischnura* sp., was found from 0.49 to 4.49 meters and *Epicordulia* sp. was collected at depths ranging from 0.65 to 1.52 meters.

Trichoptera

Leptoceridae-*Oecetis* sp. was collected on three occasions. Depth of capture was 1.24, 1.37, and 3.65 meters.

Hydropsychidae-*Cheumatopsyche* sp. was collected from the lake twice during the study in areas one and five at depths of 1.75 to 3.35 meters. These hydropsychids are common in the flume in area 1. The specimen collected from area five was on the other side of the lake from the swift water of the flume. Hydropsychid larvae require a silt-free, solid substrate for net construction and a constant water current which will direct food into the nets (Fremling, 1960). Many of the larvae and emerging adults probably are carried from the flume into the lake proper and thus the flume contributes fish food to the arm of the lake receiving the effluent. Milne (1943) found that caddisflies provide food for fish close to shore.

Diptera

Culicidae-Chaoborus punctipennis (Say) monthly mean numbers for all areas decreased from 231.31 per M^2 in March to 21.04 per M^2 in June (Fig. 13). Greatest decrease was in May and probably was due to emergence. In September, mean numbers began increasing to an October high of 327.94 per M^2. After October, mean numbers decreased until cessation of sampling in February. The greatest decrease was during January. Dorris (1956) attributed late winter declines of C. punctipennis to mortality. Anderson and Hooper (1956) reported an annual minimum in July while in late summer and early fall a rapid increase occurred.

Stahl (1966) indicated that young larvae tend to be continuously planktonic while older larvae tend to be benthic during the daytime but at night, vertically migrate. This may account for the reduced numbers captured with the Edman dredge in Boomer Lake during summer months. Since larvae that hatched in May probably would be planktonic during the summer, they would escape the dredge. In Myers Lake, planktonic larvae were about two meters above the substrate (Stahl, 1966).

Depth distribution varied from 0.30 to 7.31 meters and, in general, was opposite to that found in Hexagenia spp. and Tendipedidae. Sublette (1957) found minimum numbers in the littoral and maximal numbers in the profundal region. Chaoborus exhibited maximum numbers in the deeper areas of Boomer Lake during all seasons (Fig. 14).

Chaoborus in Boomer Lake apparently has a 1-year life cycle. In 1966, emergence and egg laying was assumed to occur in late April or

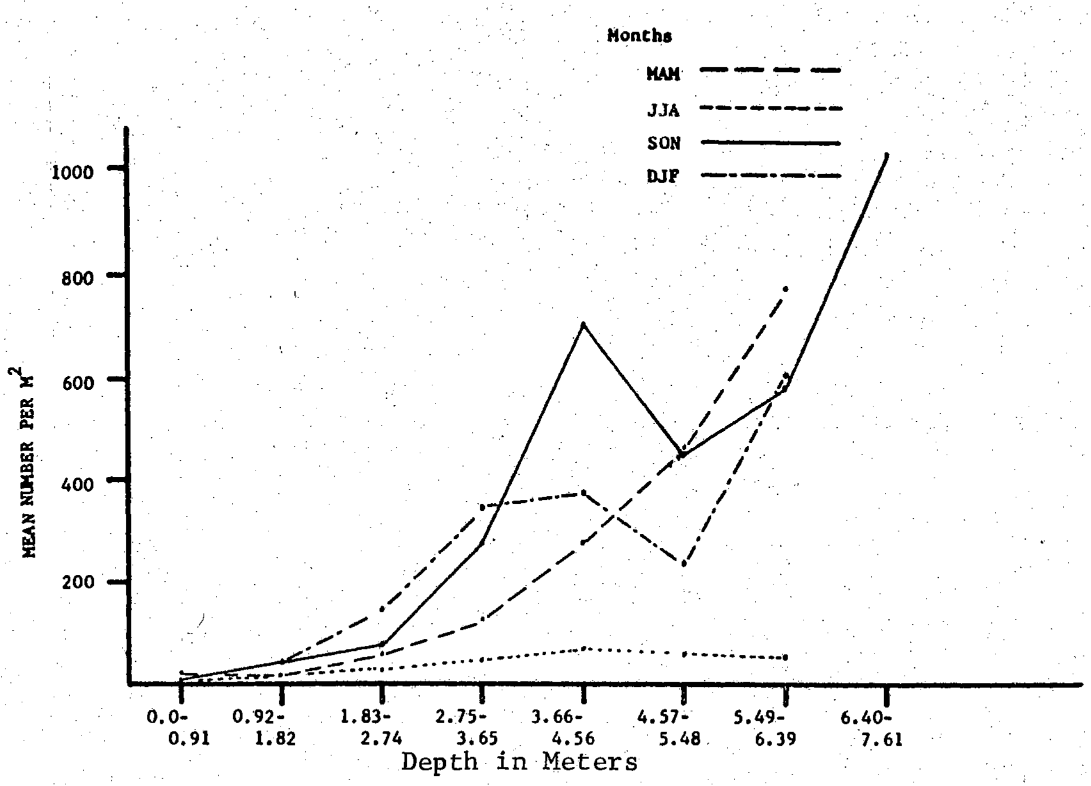

Figure 14. Depth Distribution of <u>Chaoborus</u> <u>punctipennis</u>

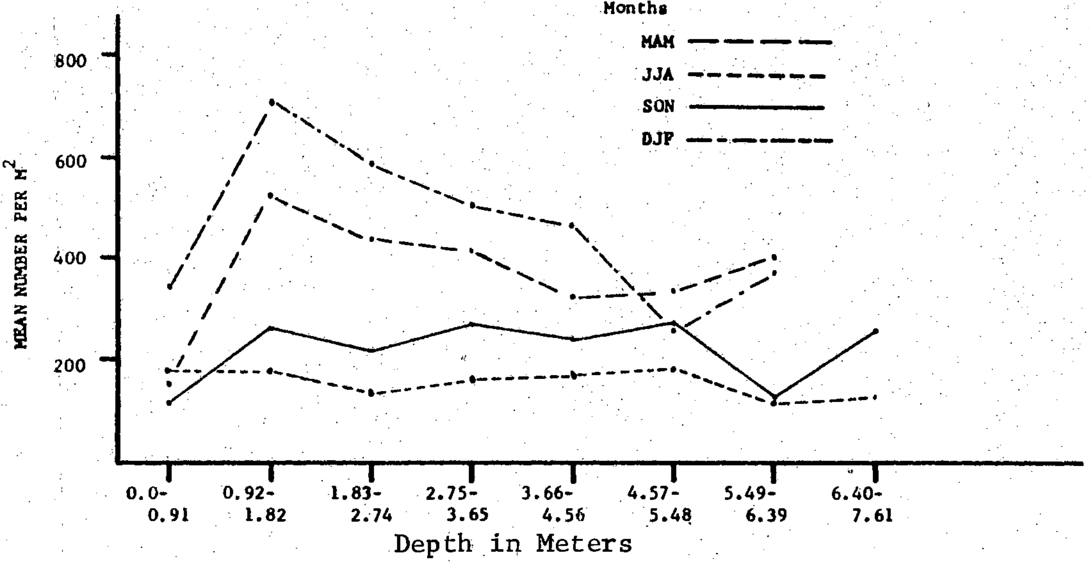

Figure 15. Depth Distribution of Tendipedidae

May. During the summer months, the larvae possibly were planktonic but in late August and September began appearing in the samples. This appearance was a result of growth which culminated in larvae large enough to be caught in the sieving process and also old enough to begin to be benthic inhabitants. The maximum number was obtained in October. A decrease in numbers continued until February, the greatest decrease being during January.

Tendipedidae-specimens were not identified to genus. In 1966, the maximum and minimum numerical standing crop, all areas combined, was 470.19/M^2 in April and 131.16/M^2 in July. Beginning in August, there was an increase in standing crop to a high of 665.32 per M^2 in February (Fig. 13). The May and July decline in numbers were attributed to emergences (Fig. 13). The pronounced decrease during January in _C. punctipennis_ and _Hexagenia_ spp. was not observed in Tendipedidae.

Tendipedidae was relatively uniformly distributed in depth during the summer and fall, but in winter and spring, showed a tendency for maximum numbers at the 0.91 to 1.82 meter interval (Fig. 15). The increase at these depths may be due to hatching.

Analysis of covariance was applied to each month from April through October. The covariates (depth and bottom temperature) did not account for variation in number of organisms at the 0.05 level of significance. Analysis of variance for months March through October was analyzed and no significant (0.05 level) sampling period by area interaction appeared.

The ineffectiveness of covariates for accounting for significant variation possibly resulted from treating the Tendipedidae as a group when in effect it is probably composed of several species which may not have the same response to the covariates. Mundie (1955) found a distinct zonation of species from shallow to deep water in Kempton Park East Reservoir, England.

Mean numbers in areas 1 through 4 were ranked and Duncan's New Multiple Range Test was applied using the 0.05 level of significance (Table IX). Area rank fluctuated somewhat but indicated that organisms were most abundant in area 4 and least abundant in area 3. Area 4 was relatively shallow, vegetated on either side of the creek channel, and had a sandy-silt substrate while area 3 had a silt substrate, no vegetation, and was relatively deep. Buckley and Sublette (1964) found that mean annual numerical standing crop of Tendipedidae in Cane River Lake was greatest at the 0.0 to 1.0 meter depth which was characterized by sandy silt with much detritus.

Seasonal trends in rank change were not observed in areas 1 and 2. These areas were similar to area 3 in terms of depth and substrate but different in terms of vegetation and location. However, the vegetated areas did not enter the sample sufficiently for comparisons.

Ceratopogonidae-Palpomyia sp. was collected six times and depth of capture varied from 1.1 to 3.5 meters.

Mollusca

Gastropoda

Physidae-Physa sp. and Planorbidae-Gyraulus sp. were collected on 6 and 3 sampling dates respectively. Depth of capture of both varied from 0.49 to 1.52 meters.

TABLE IX

DUNCAN'S NEW MULTIPLE RANGE TEST APPLIED TO MEAN NUMBER OF TENDIPEDIDAE FOR EACH MONTH[1]

March	$3\ \underline{2\ 4\ 1}$
April	$\underline{3\ 4\ 2\ 1}$
May	$\begin{array}{cccc} 4 & 2 & 1 & 3 \\ \cline{2-4} \\[-2ex] \cline{1-3} \end{array}$
June	$\underline{1\ 3\ 4\ 2}$
July	$\begin{array}{cccc} 3 & 2 & 1 & 4 \\ \cline{2-4} \\[-2ex] \cline{1-3} \end{array}$
August	$\underline{3\ 1\ 2\ 4}$
September	$\underline{2\ 3\ 1\ 4}$
October	$\begin{array}{cccc} 2 & 3 & 1 & 4 \\ \cline{3-4} \\[-2ex] \cline{1-3} \end{array}$
November	$\underline{3\ 2\ 1\ 4}$
December	$\begin{array}{cccc} 3 & 1 & 4 & 2 \\ \cline{3-4} \\[-2ex] \cline{2-3} \\[-2ex] \cline{1-2} \end{array}$
January	$\underline{3\ 2\ 1\ 4}$
February	$4\ \underline{3\ 2}\ 1$

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[1] Areas 1 through 4 are ranked (left to right) from mean minimum to mean maximum number per square meter. Underline designates no significant difference at 0.05 level.

Pelecypoda

Unionidae-*Anodonata grandis* Say was collected on six sampling dates at depths varying from 0.89 to 2.99 meters. The water level dropped to such a low level in July that part of the substrate in area 4 was exposed. Many molluscs (*A. grandis*) were observed in the vegetation.

Carunculina parva (Barnes) was collected on six sampling dates, and depth of capture varied from 0.49 to 3.35 meters.

Sphaeriidae-*Sphaerium* sp. was collected on eight sampling dates at depths ranging from 0.38 to 2.51 meters.

Pisidium sp. was collected only on 25 March at a depth of 2.13 meters. Seven specimens were collected.

CHAPTER VIII

EFFECT OF A COOLANT WATER ON BENTHIC MACROINVERTEBRATES

The coolant water from the power plant has created an artificial environment for stream invertebrate forms in the discharge flume that otherwise probably would be absent. The flume was not sampled thus the following description is based on casual observations made throughout the year. Two genera of trichopterans (Hydropsychidae: *Cheumatopsyche* sp. and *Hydropsyche* sp.) were abundant in the flume where sufficient habitat was present. Both genera usually were found living in close proximity. Only two specimens were collected from the lake. Black fly larvae (Simuliidae: *Simulium* sp.) also were found in abundance in the flume although they were second in population numbers to the trichopterous larvae. Debris (paper, boards, vegetation) lodged in the rocks of the flume served as excellent points of attachment for these larvae. Dipterous and trichopterous larvae possibly supplemented the diet of fishes since they probably were swept into the lake during periods of emergence. Invertebrates in the flume may be adversely affected by the warm water during summer months while during other periods of the year, the warm water may result in increased growth rate.

The months with the highest and lowest mean daily water flow leaving the power plant were July and April, respectively (Fig. 16). The amount of water leaving the power plant daily was dependent upon the amount of electricity used.

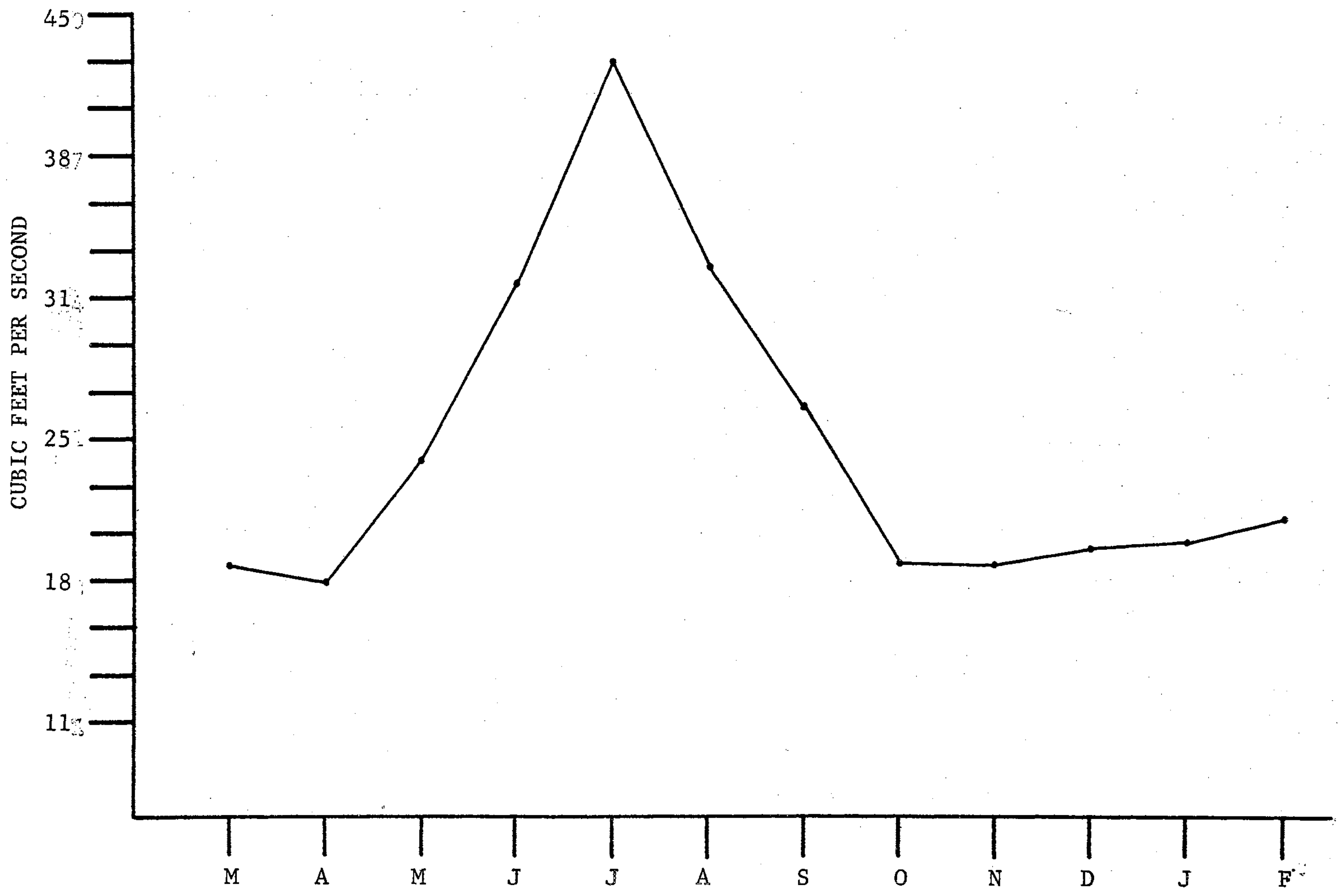

Figure 16. Daily Mean Flow of Coolant Water for Each Month

The difference between surface and bottom temperatures for most of the sampling periods was greater in area one than in area two (Fig. 17). The only apparent difference between the two coves which could account for the greater difference in area one, was the inflowing heated water from the power plant. The highest temperature attained in area one was 33.5 C, while in area two, the maximum temperature was 32.5 C. Due to a density difference, the inflowing water would flow over the cooler lake water resulting in a warming of surface water but having no observable effect on the temperature of the bottom water. Near the flume outlet, however, the force of the water entering the lake produced complete mixing. Effects of complete mixing may be a scouring of the area immediately in the path of the flume outlet and also maintenance of turbulance and suspension of bottom materials because of the current. These effects may limit the type of invertebrates able to inhabit this area.

Monthly mean number of Hexagenia spp. in areas 1 and 2 were similar for all months (Table VIII). Monthly mean number of Tendipedidae in areas 1 and 2 were different only during December and February (Table IX). Area 2 had a greater man number in December, while in February, area 1 had the greater mean number. These small differences in mean number of organism in areas 1 and 2 indicate that the heated water entering area 1 did not result in a greater abundance of Hexagenia spp. and Tendipedidae.

Sialis sp. was more abundant in area 1 than in other areas of the lake. This may have been in response to the current from the inflow water.

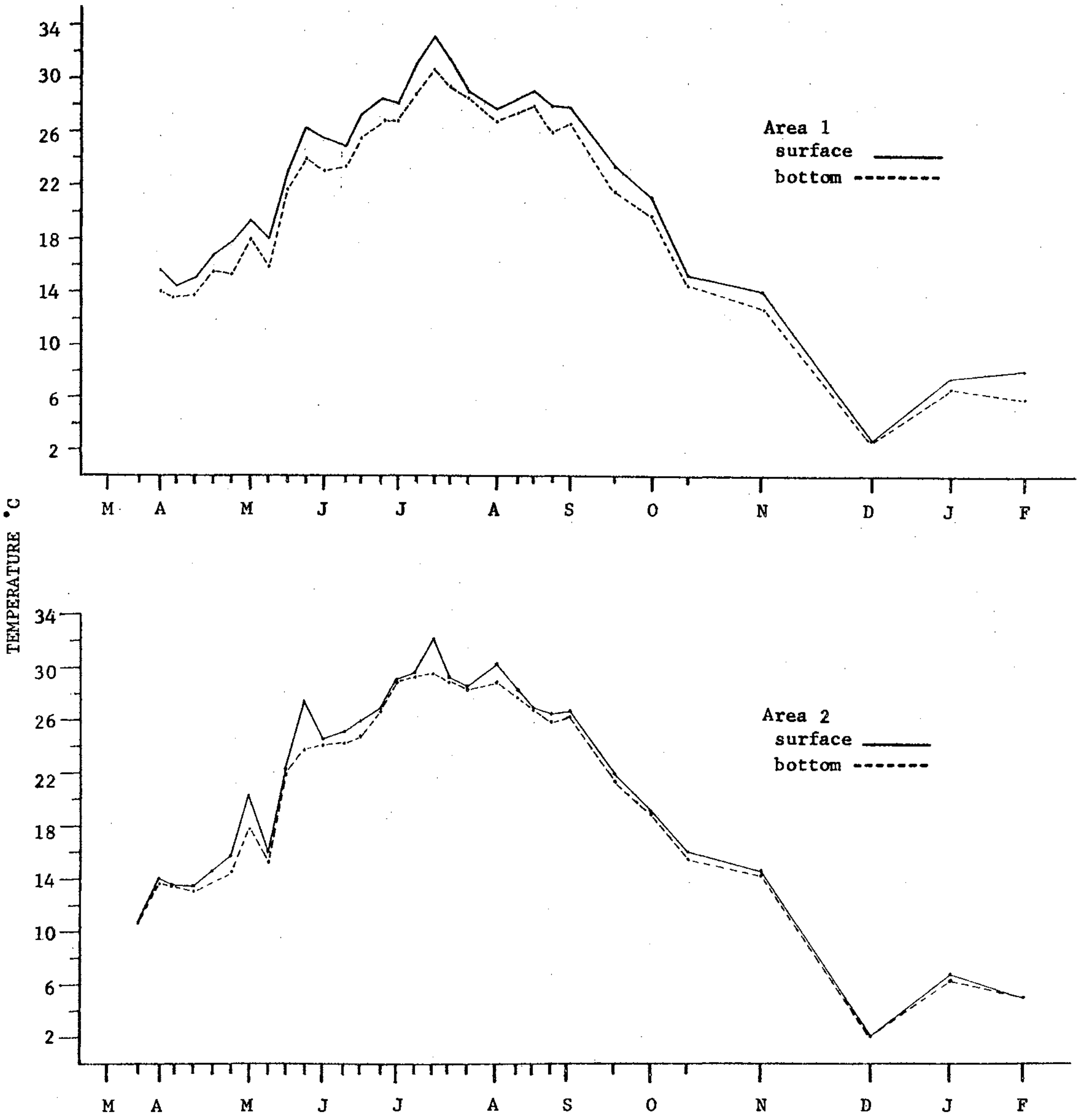

Figure 17. Mean Surface and Bottom Temperatures in Areas 1 and 2

B. sowerbyi has been reported in association with heated water from power stations, but in Boomer Lake no such association was evident.

CHAPTER IX

SUMMARY

The objectives of the study were to: (1) describe certain limnological characteristics of Boomer Lake; (2) estimate seasonal variation in standing crops of benthic macroinvertebrates; (3) evaluate the relationship of bottom temperature and depth to abundance of Hexagenia spp. and Tendipedidae; and (4) evaluate the potential effects of condenser discharge water from a power plant on abundance of benthic macroinvertebrates.

Boomer Lake did not strictly fit the definition of a temperate lake of the third order by Forel's classification but was closely related. The lake water was in circulation most of the year due to wind action. Reduced transparency was due to wind action and also was inversely related to rainfall.

Thirty taxa of invertebrates were collected, but only seven taxa comprised from 92.74 to 99.51 per cent of the numbers collected. From fourteen insect taxa collected, nine each contributed less than one per cent of the total number of invertebrates collected during each month. Gastropods and pelecypods were collected infrequently. The relatively low number of insects and molluscans was attributed to high turbidity which may have smothered the organisms or reduced the rooted vegetation, thus reducing their habitat. Total numerical standing crop was lowest in April, 1966 ($520/M^2$) and greatest in February, 1967 ($1850/M^2$). Decrease of organisms during spring and summer was attributed to predation and emergence, and an increase which occurred in the fall and winter was attributed to hatching of eggs in summer and early fall.

Abundance of Hexagenia spp. and Tendipedidae were found by analysis to vary independently of water depth and bottom temperature. Tendipedidae was treated as a distinct taxon which may have masked the results if more than one taxon was present.

Abundance of Caenis sp. and Hyalella azteca was greatest in areas of heavy vegetation and availability of vegetation appeared to be more important than other factors measured.

The coolant water from the power plant, being only about 6 C warmer than the lake proper, has created an environment for stream invertebrate forms in the flume. This was evident from the great numbers of trichopterous larvae (Cheumatopsyche sp. and Hydropsyche sp.) and dipterous larvae (Simulium sp.) present in the flume. The coolant water did not raise the benthic water temperature in area 1 above tolerance limits for the normal inhabitants. A scouring and suspension of sediment, which would destroy the habitat for lake dwellers, may have resulted from the water current. Greater numbers of Sialis sp. were found in area 1 and this may have been a result of the current. Mean standing crops of Hexagenia spp. in areas 1 and 2 were similar. Mean standing crops of Tendipedidae in areas 1 and 2 were different only during December, when area 2 had a greater standing crop, and in February, when area 1 had the greater standing crop. Thus a study of standing crops of Hexagenia spp. and Tendipedidae did not reveal a consistent difference which could be attributed to an effect of the heated effluent.

The biomass of Hexagenia spp. was greatest in May (8.19 kg/ha) and lowest in September (1.80 kg/ha). Numerical standing crop was lowest in August (148/M^2) and greatest in December (968/M^2). Growth period was approximately from March until December during 1966. Hexagenia spp. exhibited a one-year life cycle.

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