ANIMAL-SUBSTRATA RELATIONSHIPS
IN A GREAT PLAINS RESERVOIR

by 4589

JOSEPH MICHAEL SCHWARTZ

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Approved by:

G. Richard Marzolf
Major Professor

TABLE OF CONTENTS

INTRODUCTION

The abundance and distribution of benthic macroinvertebrates is controlled by various environmental sedimentary factors. Cole (1955) indicated the substrate nature had a distinct influence on the distribution and occurrence of microbenthic fauna in two Minnesota lakes. Humphries (1936) made analyses of the organic matter and particle size in the sediments of Lake Windermere. Although he was unable to establish a correlative relation between these sediment characters and species composition of the biota, he was successful in illustrating quantitative variations in the benthic animals with depth and particle size and organic matter. In Lake Michigan, Marzolf (1965) found no significant correlation with depth, particle size, or organic matter in the sediments but indicated that _Pontoporeia affinis_, the predominant macrobenthic invertebrate of that region, was correlated with the number of bacteria present in the sediments. Sanders (1958 and 1960) and Wieser (1960), both studying the benthic community of Buzzards Bay, Mass., discussed the influence of the sediments and sedimentary conditions on that benthic community structure.

Cummins (1962), Morgans (1956), and Beatty and Hooper (1958) proposed that the sediment characteristics of particle size and amount of organic matter may be useful measures in determining the limits of the animal's local distribution. Sanders (1958) indicated that clay content is probably the valid criterion for the distribution of benthic deposit feeders in Buzzards Bay. He also suggested that because clays have relatively larger surface areas, larger amounts of organic matter may bind to the clay's surface areas thereby providing an increased energy source for some benthic animals.

Great Plains reservoirs are comparatively new aquatic systems. As a result, literature dealing with benthic communities in these systems is scarce. Sublette (1957) discussed the horizontal and vertical distribution and seasonal succession of the macroscopic bottom animals in Lake Texoma, Oklahoma and Texas. Ransom (1968) subjected the benthic community structure in the Keystone Reservoir, Oklahoma to species diversity analyses. In Lewis and Clark Lake, South Dakota, Swanson (1967) attempted to define the environmental conditions limiting the distribution and abundance of *Hexagenia*, the dominant macroinvertebrate inhabiting the reservoir's substrate. There are continuing investigations being conducted by the U.S. Bureau of Sport Fisheries and Wildlife at the North Central Reservoir Investigations laboratory at Yankton, South Dakota, and at the South Central Reservoir Investigation laboratory at Fayetteville, Arkansas. Current studies at the North Central Reservoirs Investigations are attempting to define any correlative relation between the abundance of migrating benthos in the water column to the benthic biomass on the reservoir bottom and crustacean zooplankton, relationships between benthos in the limnetic zone and benthos loss through discharge, and the biology of the benthic organisms. South Central Reservoir benthic investigations are evaluation of fish predation effects on the littoral benthic community and stability in impoundments of varying ages.

Although not of the Great Plains region, Eggleton's study (1931) of three Michigan lakes in which he emphasises the ecological relations of the benthos rather than the qualitative (species composition) and quantitative aspects (numerical abundance) is still widely referred to.

The purposes of the present investigation were: 1) to describe the nature and distribution of the sediments in Tuttle Creek Reservoir on the basis of the variation in percent of clay, silt, and sand in the sediment of the reservoir basin and the percent of oxidizable organic matter and its relationship to particle size distribution; 2) to describe the numerical abundance, biomass, and horizontal distribution patterns of the benthic macroinvertebrate community; 3) to supply a tentative list of benthic organisms; 4) to describe or define any correlative relationships observed between the sediments and the benthic community in Tuttle Creek Reservoir, Kansas.

DESCRIPTION OF THE STUDY AREA

This study was conducted in the Tuttle Creek Reservoir, Kansas. The reservoir and dam is a project of the U.S. Army Corp of Engineers on the Big Blue River in Marshall, Pottawatomie, and Riley Counties, Kansas. Closure was on 21 July 1959, and conservation operation began on 20 April 1963. The dam is 19.8 km by river upstream from the confluence of the Kansas and Big Blue Rivers at approximately 39°15'30'' N latitude and 96° 35'30'' longitude. From this point the reservoir extends some

65 to 80 km in a general northerly direction up the Big Blue River valley.

The Big Blue River drainage basin comprises a total area of 25,080 sq. km. The major tributary, the Little Blue River, drains 9166 sq. km, or about 36 percent of the total area. Three-fourths of the basin lies in Nebraska, the balance in Kansas. An estimated 75 percent of the basin is cultivated land. The soils is the basin were developed from flinty or cherty limestone.

Tuttle Creek Reservoir, as is the case for many reservoirs of this Great Plains region, was constructed as a multiusage reservoir. The primary consideration was for flood control with public recreation, silt retention, and water conservation important secondary uses.

The Big Blue River carries a heavy sediment and organic detrital load that is deposited throughout the length of the reservoir. This factor in addition to shallowness of the lake, and the mixing effect of winds contribute to the turbid condition of the lake throughout the summer and fall. Elevation of the Tuttle Creek Reservoir surface has varied from 323.4 m above mean sea level (msl) on 11 February 1967 to 333.8 above mean sea level on 7 July 1965.

The reservoir does not normally stratify thermally due to the strong prevailing winds in Kansas, relatively low mean depth, and long fetch. The substrate is the original river channel and flood plain, which is covered with a deposit of sediment. The soils of the Blue River drainage basin are classified as to origin into four groups: residual, alluvial, loessial, and glacial. The lower portion of the basin consists mainly of residual and alluvial soils derived from shales and limestones. The upper portion has loessial soils underlain by glacial tills and alluvial sands (Kansas Water Resources Board, 1964). Hydrographic characteristics and morphometry of the reservoir are presented in Table 1.

Table 1. Hydrographic characteristics and morphometry of Tuttle Creek Reservoir based on 323.4 m mean sea level (msl).

Length (km)	23.20
Greatest width (km)	2.00
Max depth (m)	25.00
Avg depth (m)	8.00
Shoreline length (km)	209.00
Shoreline development	7.36
Surface area (ha)	6411.00
Storage capacity (km^3)	0.53
Gross storage elevation (m msl)	
Min. sed. reserve	305.00
Max. flood control	346.50
Normal cons. pool	327.90

MATERIALS AND METHODS

SEDIMENTS

Field sampling methods

The reservoir was divided into grid sections (0.25 km^2 each) and each grid section assigned a number (1-273) to facilitate the random selection of sampling sites. The lake was also divided into five sections (I-V) to aid in assessment of variation between different portions of the lake (Figure 1).

Sampling was carried on from 18 July 1968 to 14 August 1968. A single Ekman dredge grab was taken at each of 65 sampling

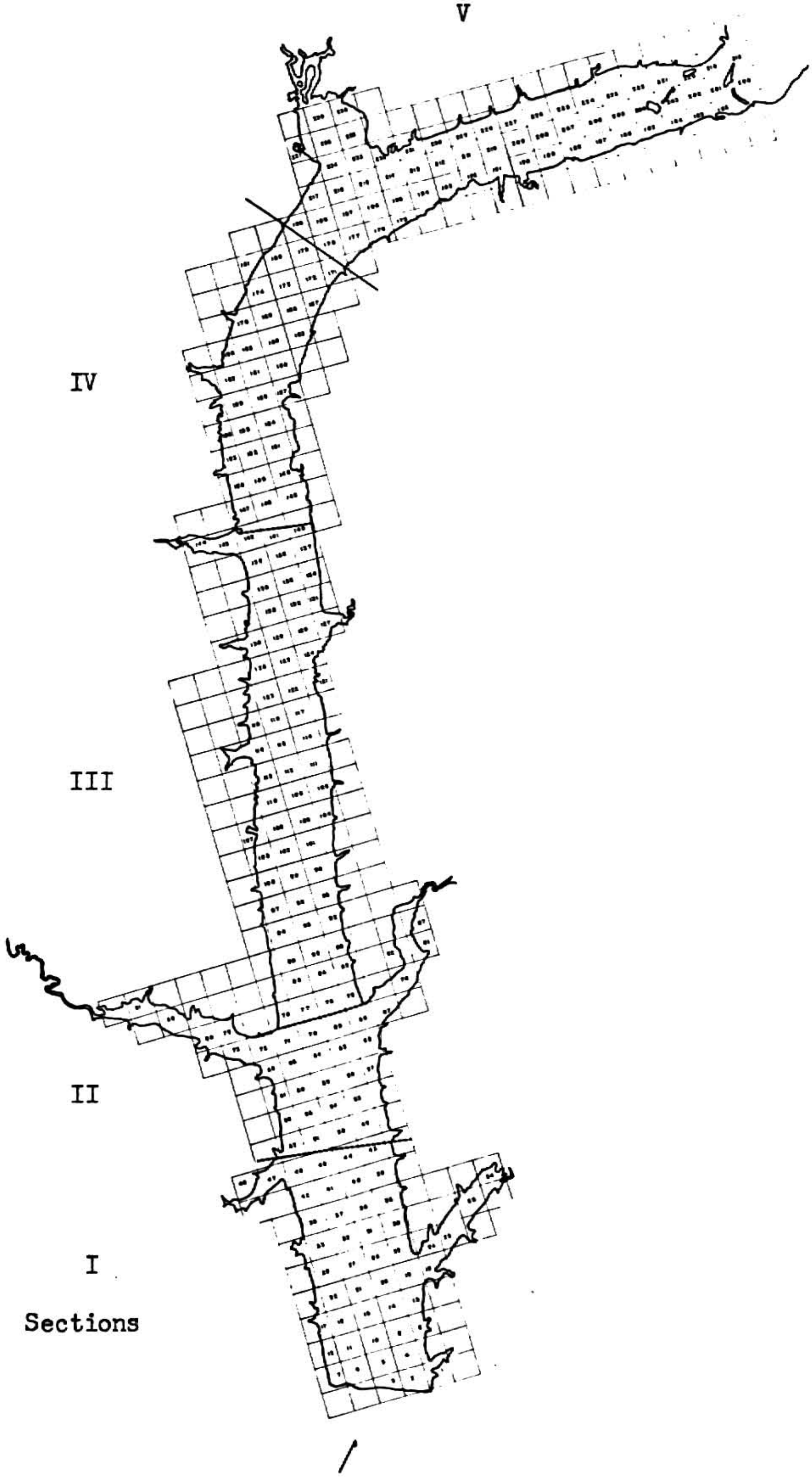
EXPLANATION OF FIGURE 1

Tuttle Creek Reservoir, Kansas and superimposed sampling grids with fish sampling stations

f_1 = 213 f_2 = 170

f_3 = 117 f_4 = 87

f_5 = 30 f_6 = 34


V
IV
III
II
I
Sections

sites. The samples were then cooled in an ice chest to delay bacterial action on the organic matter present in the sediment.

Laboratory analysis of sediments

The samples were taken immediately to a laboratory where they were divided into two subsamples for particle size analysis. The particle size distribution measurements and organic content measurements were made on the same sample.

Particle size distribution analysis

The particle size analysis was performed using the hydrometer analysis as described by Lambe (1951). Particle sizes are expressed in phi (ϕ) units, which substitutes a negative logarithm to the base two for the particle diameter in millimeters, and thereby transforms the arithmetically unequal class intervals of the Wentworth scale to equal intervals (Morgans, 1956). An increase of 1.0 in the phi value means the diameter value decreases by half. The median particle diameter (Md_{ϕ}) was the expression used in this study to describe each sample. Median phi is that measure where 50 percent of the sample, by weight, lies above and below the median diameter. Phi values facilitated statistical treatment as discussed by Krumbein (1936) and Morgans (1956).

Organic matter analysis

After reviewing various techniques of organic matter analysis, Morgans (1956) concluded that the Walkley-Black method (Walkley and Black, 1934; Walkley, 1947) was suitable for benthic studies. The procedure involves the partial oxidation of organic matter by chromic acid followed by a titration for the unused acid. Because of incomplete recovery of carbon by the wet oxidation techniques, a correction is made to allow for this incomplete recovery. The nature of substrate greatly influences the carbon recovery which may range from 60% to 90% (Walkley, 1947).

Recovery is assumed to be about 75%. Conversion factors as suggested by Morgans (1956) range from 1.34 to 2.0. The data presented here was converted by the factor 1.34 (Allison, 1965).

Loss of weight upon ignition was not feasible because the high water of hydration content of the clay fraction of the sediments would introduce an intolerable weighing error.

BENTHOS

Field sampling methods

Benthic samples were collected between 13 May 1969 to 28 July 1969 with a single Ekman dredge grab at each sampling site. In order to observe correlative relationships between benthic abundance and distribution and the characteristics of the sediments animals were collected from the same grids chosen for the particle size and organic analysis. On 28 July 1969 animals were collected according to a horizontal stratified random sampling design to establish the distribution of animals (Heltshe, 1969). Organisms were also collected at various fish sampling stations (See Figure 1) established in the reservoir to observe any correlative relationships between the distribution of benthic animals and the distribution of bottom fishes (Perry, 1970). A total of 92 sites were sampled and 110 dredge samples collected.

Benthic laboratory procedures

The samples were washed through a (420 micron) #40 Tyler sieve. The animals retained on the screen were then hand picked while alive and preserved in 70% alcohol.

Biomass was expressed as dry weight (mg per M^2). For dry weight determination, large numbers of each major group were selected at random, divided into three samples, and dried in an electric oven at 60°C. The conversion factor for converting the number of organisms in each sample to dry weight was the mean of the three samples.

STATISTICAL ANALYSIS

Whenever possible, non-parametric statistical techniques were applied. While not as powerful as parametric techniques that assume normal distribution, non-parametrics are essential where the distribution function of the random variable producing the data is either unspecified or specified except for an infinite number of unknown parameters (Conover, 1970). The Wilcoxon-Mann-Whitney test, which is covered adequately by many introductory statistics texts (Snedecor and Cochran, 1967; Fryer, 1966; Conover, 1970), was used in assessing the significance of differences between individual sections in regard to the environmental variables measured (depth, percent clay, percent organic matter, particle size).

If the benthic animals are randomly dispersed and not too abundant in any series of samples, the probability of finding "n" (any number) animals per unit area at one spot, is the same as the probability of finding "n" animals at another spot.

This type of distribution will obey the Poisson law and the frequency curve (frequency of obtaining of "n" animals, plotted against the number "n") will be a Poisson curve. A test of the null hypothesis which indicated a random distribution of organisms was performed according to Simpson, et. al. (1960). The coefficient of dispersion which assesses the degree of departure from a Poisson distribution was obtained as suggested by Hutchinson (1967).

Linear regressions were performed comparing numbers of the organisms (the dependent variable) with each environmental variable separately (the independent variable). The final analyses consisted of multiple regressions comparing 1) Chironomidae, the major group of animals found, against the combined environmental variables, 2) the total number of organisms against the combined environmental variables, and 3) a multiple regression with a transformed dependent variable ($\sqrt{\text{No. of organisms}}$) in order to eliminate heterogeneous variance (Bartlett, 1947).

The multiple regression analyses results are reported in terms of R^2 which is the multiple linear correlation coefficient. This defines the extent to which other variables account for the variation observed in the dependent variable. An R^2 of 1.0 indicates all the variation makes up the dependent variable has been accounted for (Fryer, 1966).

RESULTS

SEDIMENT:

The range of median <u>phi</u> (Md_{ϕ}) values for samples collected in this study is 8.26 ± 1.32 to 9.75 ± 0.84. In the Wentworth classification (Morgans, 1956) particles of this size are designated clays. The sediments in the reservoir have a uniform distribution of Md_ϕ values. The data was not sufficient to detect a difference ($\alpha = 0.05$) between Md_ϕ values between sections of the lake (Figure 2); existing differences are less than 0.82 phi units.

When the results of the analysis are plotted as percent sand, silt, and clay the similarity of the samples is apparent (Figure 3). Figures 4, 5, and 6 depict the percent sand, silt, and clay values respectively between sections of the lake.

Percentage of oxidizable organic matter was significantly less in Sections III and IV when compared with those percentages found in Section I (Figure 7). It must be noted that pooling the total percent measurements and testing the total lake with regard to sectional differences negated any observable sectional differences. Values of percentage of organic matter from Tuttle Creek range from 1.34 to 5.09 percent.

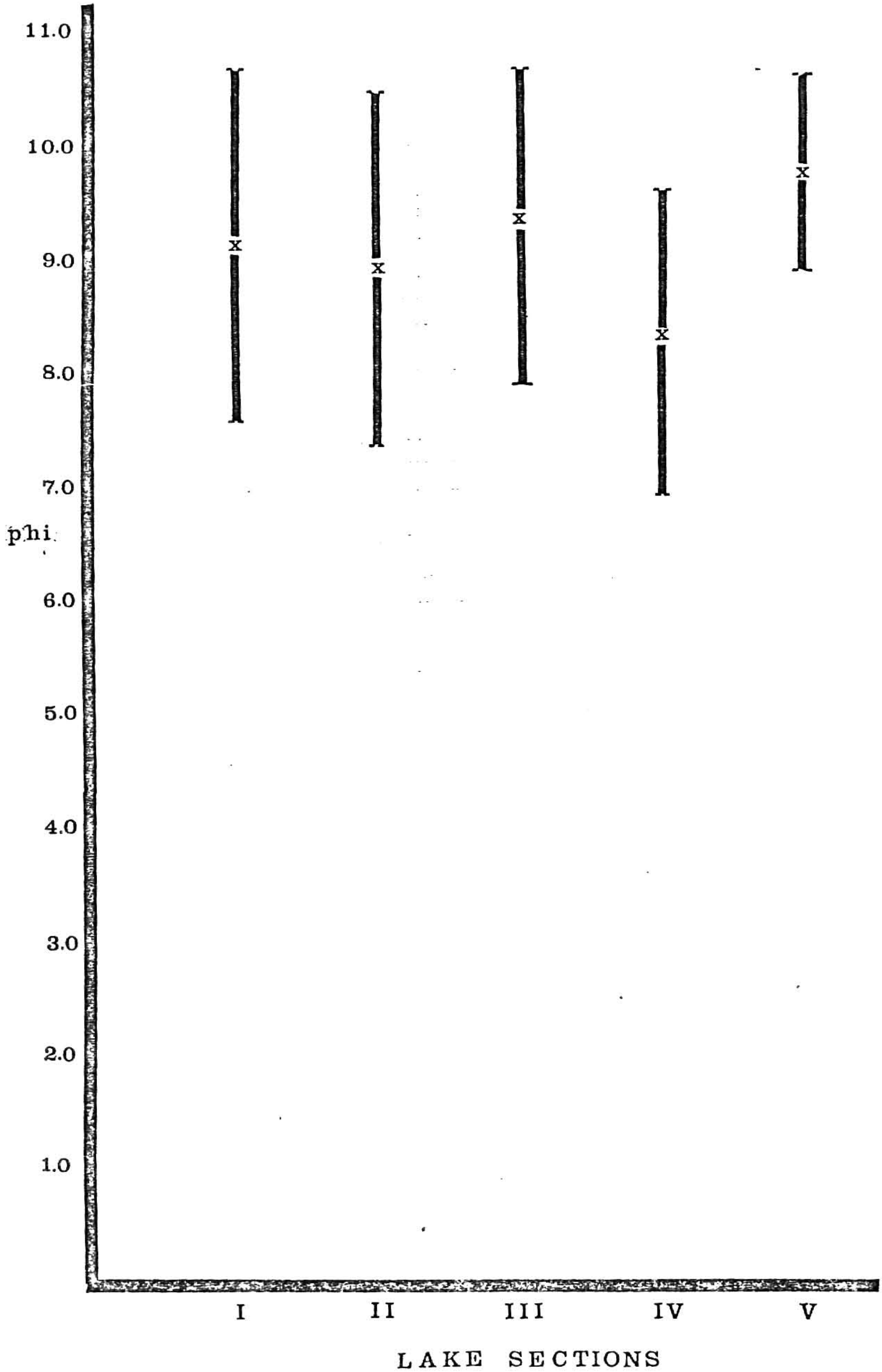
The characteristics of the sediments are summarized in Table 2.

Table 2. Characteristics of Sediments by Section

Sec.	Avg Md_ϕ	Avg (mm) diameter	Avg % sand	Avg % silt	Avg % clay	Avg % org. matter
I	9.16	0.0018	10.9	24.7	66.6	3.67
II	8.93	0.0022	12.5	26.6	62.6	3.26
III	9.31	0.0017	19.0	15.4	66.3	2.78
IV	8.26	0.0034	30.6	23.1	49.4	2.61
V	9.75	0.0013	17.6	13.3	69.1	3.14
Total lake	9.08	0.0020	18.0	20.6	62.8	3.09

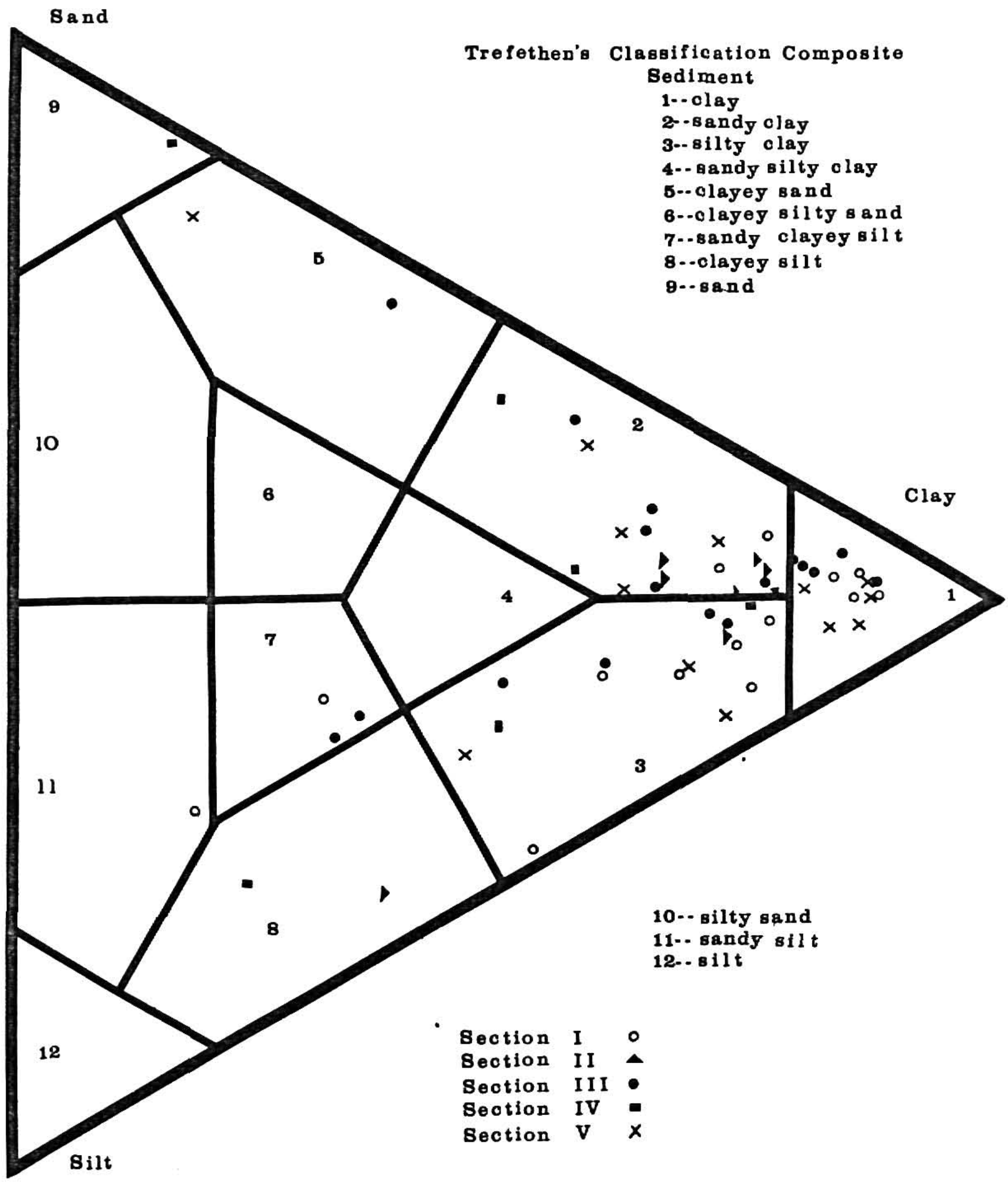
EXPLANATION OF FIGURE 2

Sectional average median *phi*
with one standard deviation


11.0
10.0
9.0
8.0
7.0
phi
6.0
5.0
4.0
3.0
2.0
1.0
I
II
III
IV
V
LAKE SECTIONS

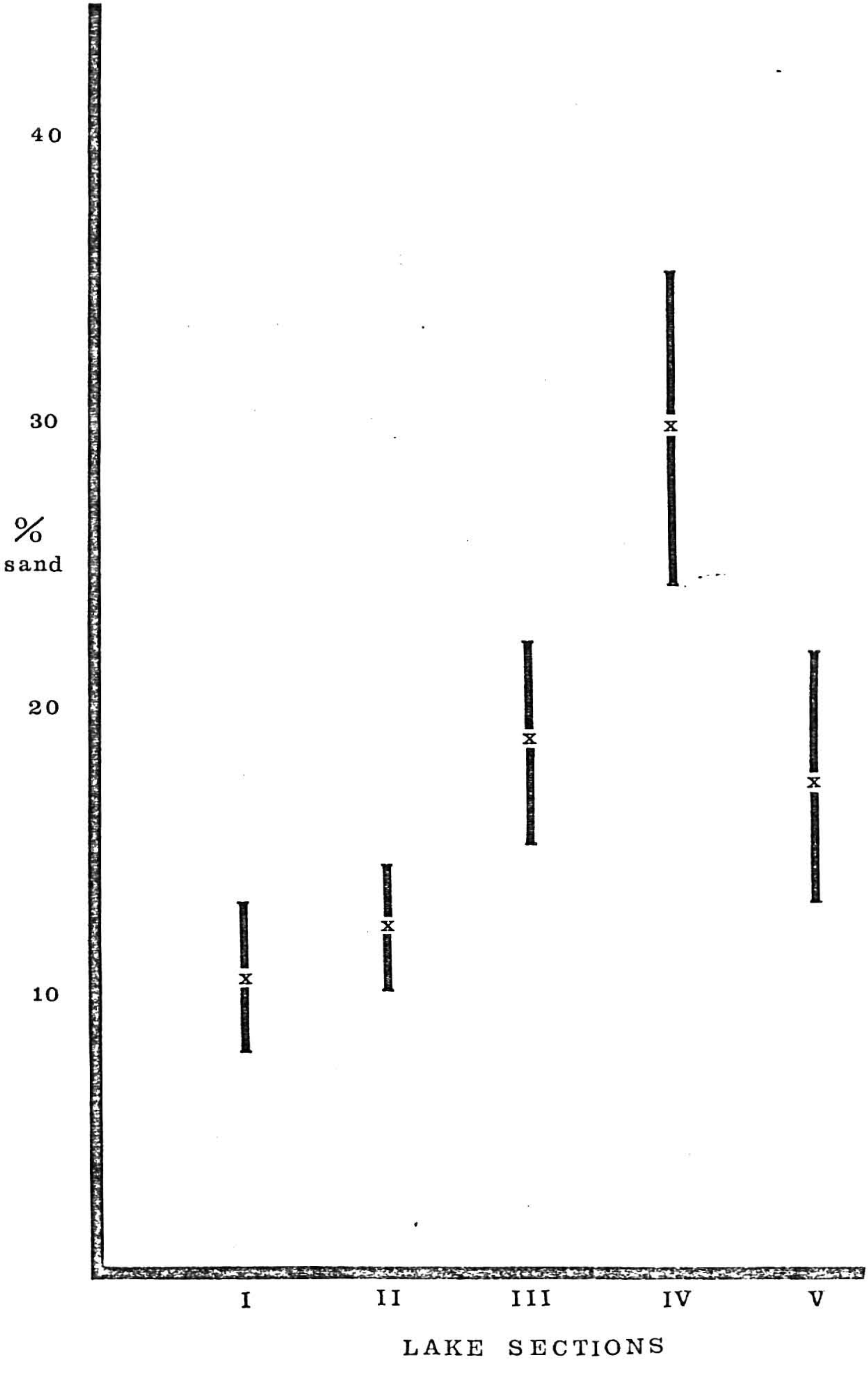
EXPLANATION OF FIGURE 3

The percentage distribution of sand, silt, and clay in the sediment samples from Tuttle Creek Reservoir


Sand
Trefethen's Classification Composite Sediment
1--clay
2--sandy clay
3--silty clay
4--sandy silty clay
5--clayey sand
6--clayey silty sand
7--sandy clayey silt
8--clayey silt
9--sand
10--silty sand
11--sandy silt
12--silt
Clay
Silt
Section I
Section II
Section III
Section IV
Section V
1
2
3
4
5
6
7
8
9
10
11
12

EXPLANATION OF FIGURE 4

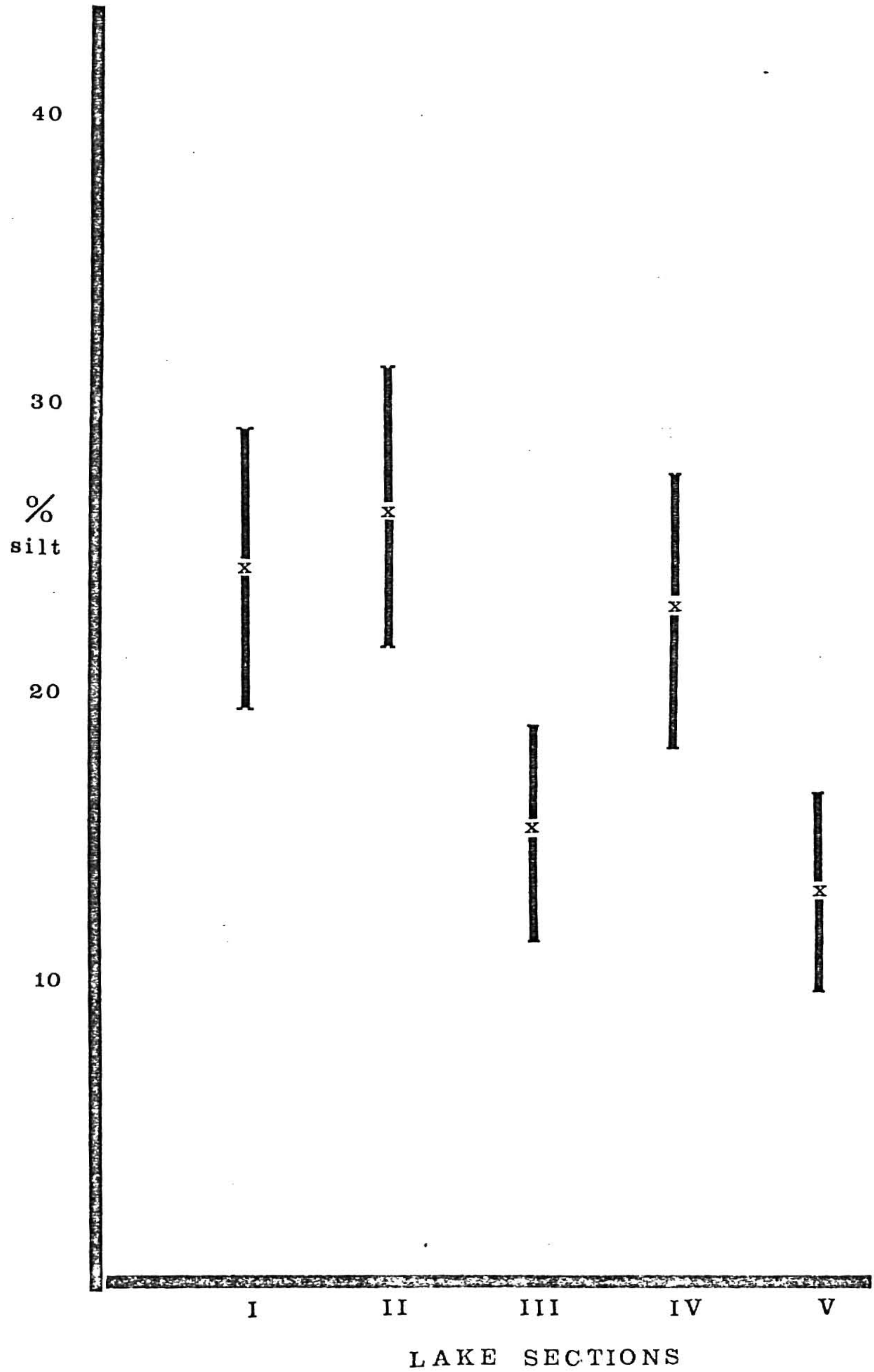
Sectional average percent sand
with one standard deviation


40
30
%
sand
20
10
x
x
x
x
x
I
II
III
IV
V
LAKE SECTIONS

EXPLANATION OF FIGURE 5

Sectional average percent silt

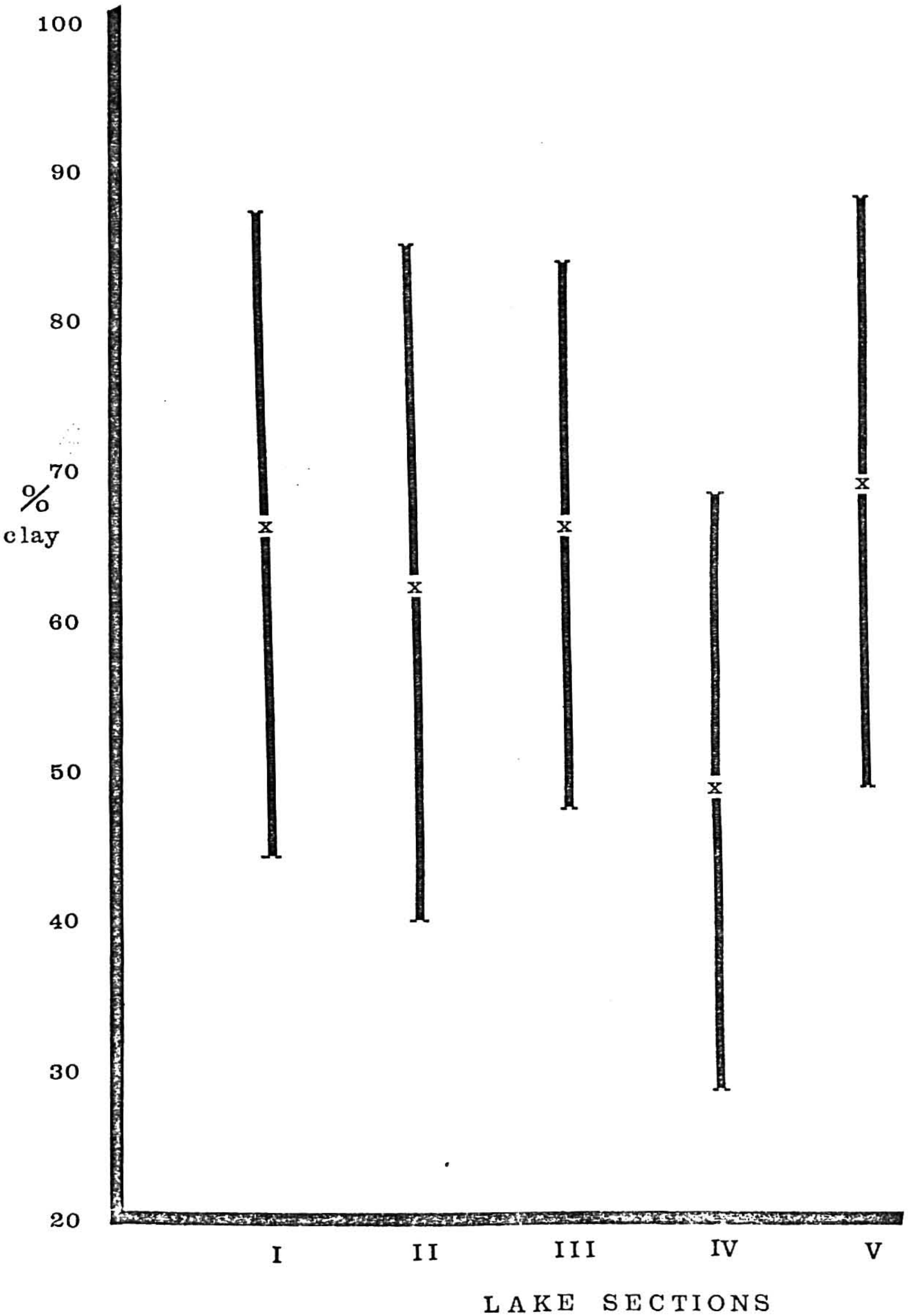
with one standard deviation



40
30
%
silt
20
10
I
II
III
IV
V
LAKE SECTIONS

EXPLANATION OF FIGURE 6

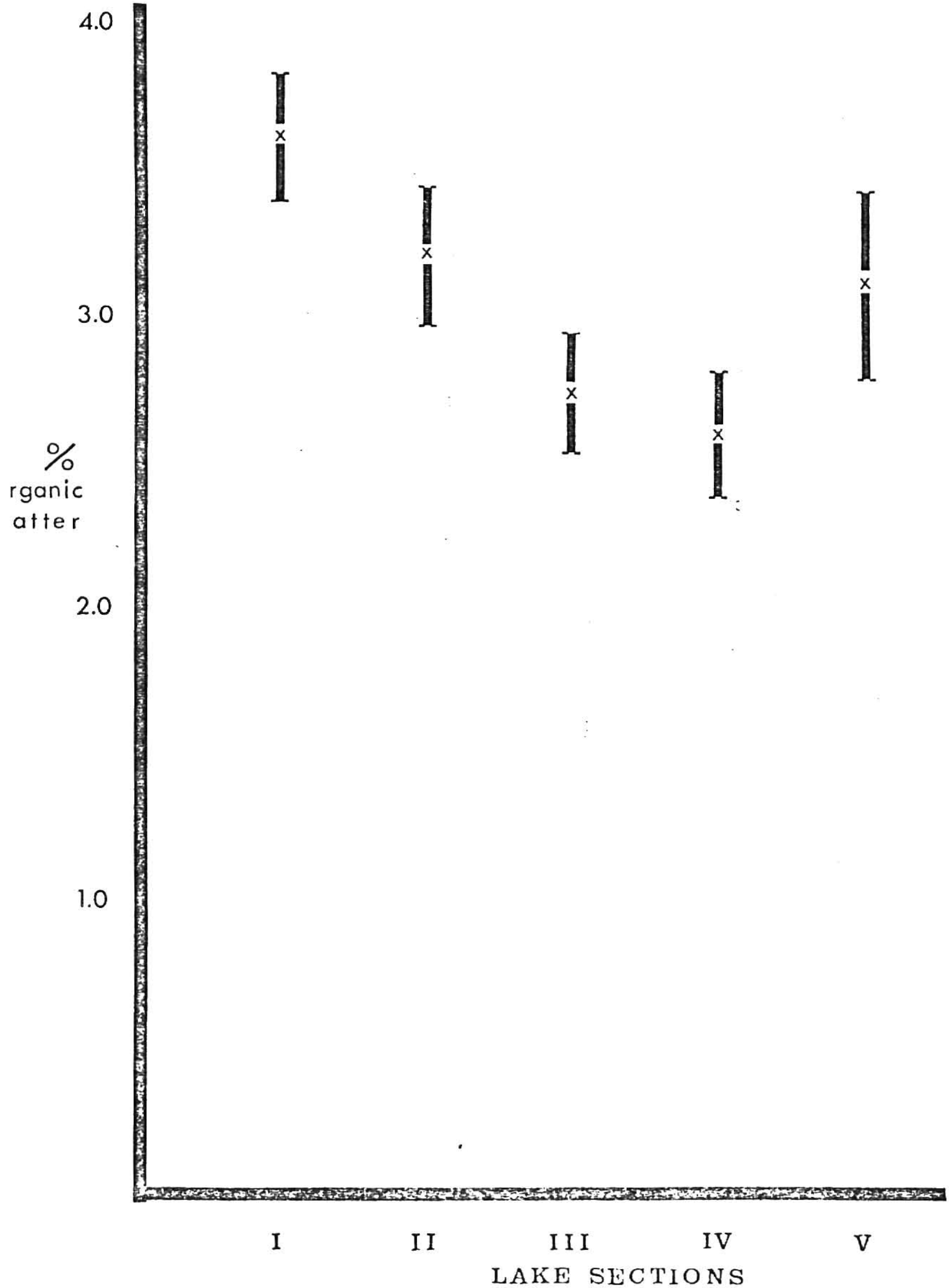
Sectional average percent clay
with one standard deviation



100
90
80
70
%
clay
60
50
40
30
20
I
II
III
IV
V
LAKE SECTIONS

EXPLANATION OF FIGURE 7

Sectional average percent organic matter
with one standard deviation


4.0
3.0
2.0
1.0
%
rganic
atter
I
II
III
IV
V
LAKE SECTIONS

BENTHOS:

Tuttle Creek benthic fauna may be characterized by comparatively low numerical abundance and sparseness of representative groups of animals. The description of fauna both qualitatively and quantitatively distinguishes Tuttle Creek Reservoir from various representative lakes found in the literature, Lake Texoma (Sublette, 1957), Douglas Lake (Eggleton, 1931), Lizard Lake (Tebo, 1955), and Upper and Lower Kananaskis Lakes (Fillion, 1967).

Qualitative Analysis of the Bottom Fauna

Oligochaeta

Oligochaetes were found in both the deep and shallow sample stations in the lake. They were dredged from practically all depths. Several specimens of _Branchiura sowerbyi_ were found, other oligochaetes were not identified.

Mollusca

Both classes Pelycepoda and Gastropoda were sparsely represented. Of all the phyla represented, Mollusca was the smallest group in abundance and number of genera present.

Insecta

Ephemeroptera

Hexagenia spp. were by far the most abundant of the mayflies represented. The specimens found were typically in water less than ten meters. No Ephemeroptera were found in Sections IV and V.

Diptera

Culicidae

The distribution of _Chaoborus spp._ in Tuttle Creek agrees with the observations of other investigators of freshwater lakes, that is, the number of organisms increased with depth (Eggleton, 1931; Sublette, 1957; Ransom, 1969). Chaoborus spp. was the most typical profundal benthic organism present in the soft clay sediments of the deeper waters.

Ceratopogonidae

Culicoides spp. was much less than Chaoborus spp. in numbers and extend of distribution. The actual numbers of Culicoides were also relatively small in comparsion to Chironomidae; however, their predaceous larvae may possibly impart a greater ecological impact on the benthic community than their numbers might suggest.

Chironomidae

Subfamily Pelopiinae (Tanypodinae)

Three genera of Pelopiinae were found: Pentaneura spp., Tanypus spp., Coelotanypus spp. Of the three identified, Pentaneura was by far the most abundant genus. Coelotanypus was found rarely in a few isolated samples.

Subfamily Tendipedinae

Polypedilum spp., Tanytarsus spp., and Tendipes spp. were the genera found evident. Polypedilum spp., also with a predaceous larval form, was quite abundant. These forms were distributed throughout the lake.

Quantitative Analysis of the Bottom Fauna

Because of the large amount of variation between samples taken and the limited number of samples taken in comparision to the large possible sample area, the estimates are only approximate, subject to sampling error, and deviate somewhat from the true conditions in the lake at sampling time.

The Chironomidae were by far the dominant group in terms of percent of total number (75%) and percent of dry weight (47%) (See Table 3).

Table 3. Average dry weight and numbers of organisms per square meter for the total lake.

	Weight (mg)	Percent	Numbers	Percent
Chironomidae	72.27	46.50	344.08	75.39
Oligochaeta	22.19	14.40	58.40	12.80
Culicidae	6.41	4.20	37.72	8.26
Ceratopogonidae	1.32	0.80	6.63	1.45
Ephemeroptera	50.12	32.20	7.73	1.61
Mollusca	2.97	1.90	2.22	0.49
Total	155.28	100.00	456.42	100.00

Three samples were taken from each fish station, the mean number of animals recorded, and compared with the mean from a later date (Figure 1). These observations, in addition to the final stratified random benthic sampling, indicated that the benthic population increased during the summer. For three fish sampling stations, at f_1 there was an increase of 248 to 622 organisms per square meter, at f_2 a decrease of 444 to 178 organisms per square meter, and at f_3 a decrease of 547 to 488 organisms per square meter for the two days sampled, 13 June 1969 and 31 July 1969 respectively. At the remaining three fish sampling stations (f_4, f_5, and f_6) increases of 355 to 496, 207 to 516, and 258 to 557 organisms per square meter were observed respectively for the two sampling dates, 13 June 1969 and 8 July 1969.

In the horizontal stratified random sampling (28 July 1969) not only was there an increase in total numerical abundance as compared with the earlier random sampling ($915.0/m^2$ vs $456.4/m^2$) but also the animal distribution altered, that is, Culicidae numerical abundance and biomass greatly increased over that of Chironomidae (Table 4).

Table 4. Average dry weight and numbers of organisms per square meter for the total lake using the horizontal stratified random sampling technique.

	Weight (mg)	Percent	Numbers	Percent
Chironomidae	39.98	15.60	190.4	20.82
Oligochaeta	25.27	9.90	66.5	7.27
Culicidae	104.91	40.90	617.1	67.46
Ceratopogonidae	5.30	2.10	26.5	2.90
Ephemeroptera	74.80	29.20	11.0	1.21
Mollusca	5.89	2.30	4.4	0.49
Total	256.45	100.00	915.9	100.00

The distribution of the Tuttle Creek benthic macroinvertebrates is not randomly dispersed instead, the individuals of the benthic population are aggregated in some areas and rarified in others (Table 5). The coefficient of dispersion as discussed in Hutchinson (1957) was 4.2.

Linear regression analyses with number of organisms correlated with each environmental variable measured showed no significant relationships ($\alpha = 0.05$). The same was also true for Chironomidae correlated with particle size, percent organic matter, percent clay, and depth.

Combining the variables in a multiple regression did explain some of the variation. The first analysis yielded a R^2 of 0.18 which compared Chironomidae with the parameters (median

EXPLANATION OF TABLE 5

The test of the null hypothesis testing for random distribution of all kinds of animals.

H_0: benthic organisms have random dispersion

H_1: benthic organisms do not have random dispersion

No. anim. per dred.	obs. freq. (f)		Poission Probability	theor. freq. (f_c)		$f - f_c$	$\frac{(f - f_c)^2}{f_c}$
0	0		0.00050	0.003			
1	1	6	0.00049	0.029	0.654	5.346	43.69
2	1		0.00242	0.145			
3	4		0.00796	0.477			
4	6		0.01966	1.180		4.820	19.68
5	4		0.03873	2.323		1.677	1.21
6	2		0.06351	3.810		1.810	0.86
7	4		0.08954	5.372		1.372	0.35
8	8		0.11013	6.607		1.393	0.29
9	2		0.12004	7.202		5.202	3.75
10	4		0.11883	7.129		3.129	1.37
11	3		0.10694	6.416		3.416	1.82
12	2		0.08769	5.261		3.261	2.02
13	3		0.06664	3.998		0.998	0.25
14	4		0.04731	2.838		1.162	0.48
15	1		0.03075	1.845		0.845	0.39
16	3		0.01906	1.143		1.857	3.02
17	1		0.01105	0.663			
18	1		0.00596	0.357			
19	1	8	0.00309	0.185	1.338	6.662	33.17
20	0		0.00151	0.091			
21	5		0.00070	0.042			
	60						T = 112.35

$\bar{x} = 9.88$
n = 15 classes
degrees of freedom = 13
critical region: $T > \chi^2_{.95,13}$

$T > 22.36$

$112.35 > 22.36$
therefore Reject H_0

benthic organisms do not have random dispersion *phi*, percent organic matter, percent clay, depth). This left 0.82 of the variation unexplained. From graphic plots made from the second analysis, a heterogenous variance was observed. In order to "weight" the variance to a more normal and equal condition the dependent variable was transformed by the use of a square root transformation (Bartlett, 1947). The squares of percent organic matter and depth were added to the regression model because the earlier plots showed a quadratic shape. Percent clay and median *phi* did not add significantly to the multiple linear correlation coefficient, R^2. The final R^2, after these changes to better linearize the model, was 22%. The unexplained variability (0.78) constitutes those unknown and unmeasured variables present in the lake's ecosystem or in the failure of the organisms to be stimulated, and thus respond to these environmental cues.

DISCUSSION

SEDIMENTS:

The results of my examination of the sediments showed uniformity of the sedimentary environment of Tuttle Creek Reservoir. Particle size distribution in sediments has been described as a function of three factors: roughness velocity, settling velocity, and threshold velocity (Sanders, 1958; Cummins, 1962). Roughness velocity is the current velocity required to transform laminar flow to turbulent flow over a given particle size. The critical velocity required to create turbulent flow is dependent on particle size and is inversely related to current velocity. This means the larger the particle size diameter, the slower the current velocity need be to produce the turbulence. The settling velocity of a particle is defined by Stokes' Law for particles less than 0.18 mm diameter. Stokes' Law, which defines the terminal velocity of a falling sphere, states:

$$V = 2/9 \times gr(D-d)/n$$

where (all in c.g.s. units)

- V = velocity of sedimentation
- g = acceleration due to gravity
- r = radius of the spherical particles
- n = coefficient of viscosity of the fluid
- D = density of the spherical particle
- d = density of the fluid

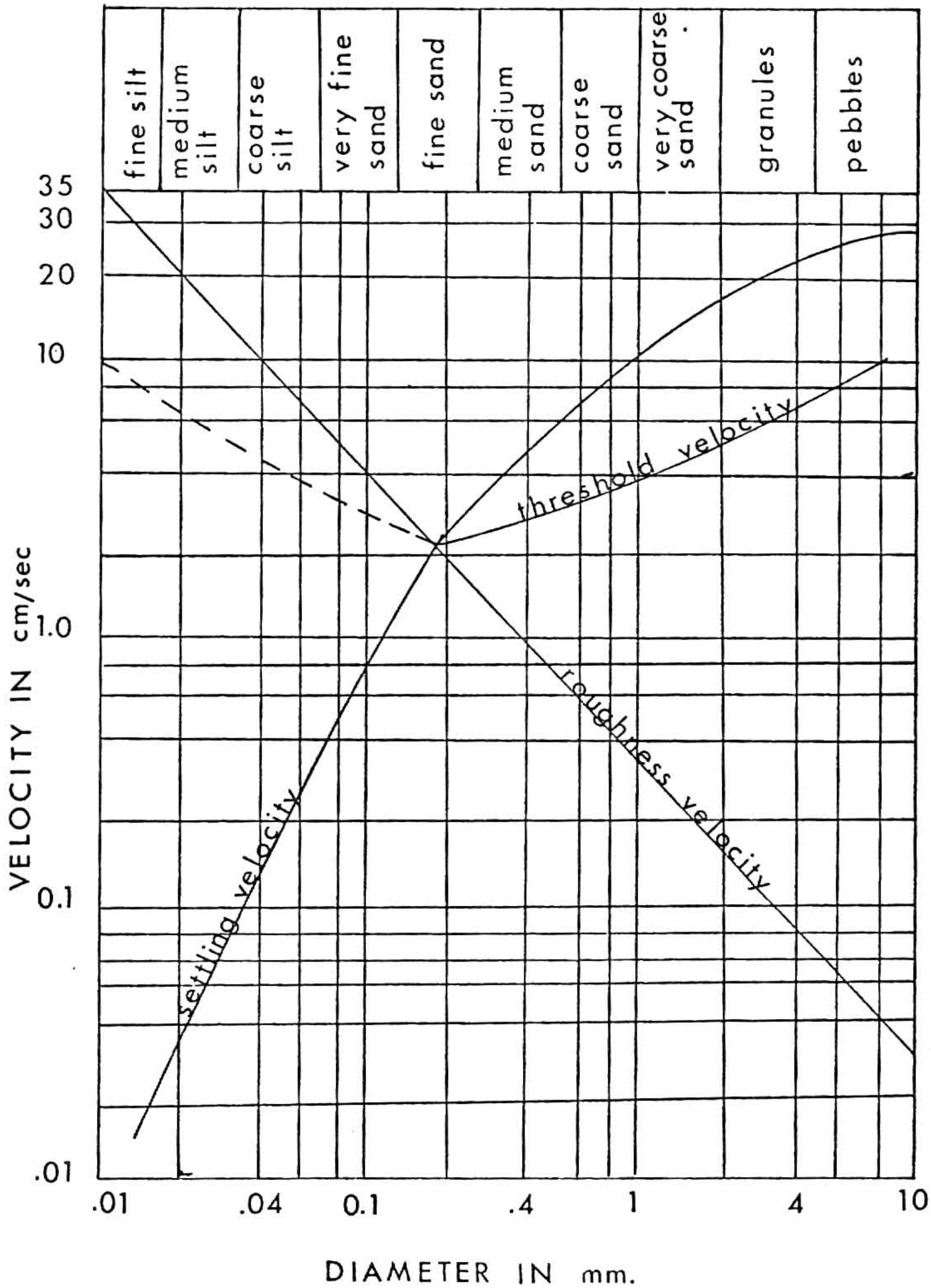
Particles with diameters larger than 0.18 mm fall slower than predicted by Stokes' Law because their larger diameters produce greater turbulence slowing their settling rates (Figure 8). Threshold velocity is that velocity required to move a particle along the bottom. Threshold velocity is at a minimum for particles of less than 0.18 mm diameter (Figure 8).

Figure 8 shows the roughness velocity, settling velocity, and threshold velocity are the same for grains of 0.18 mm diameter; therefore, sand grains (0.18 mm diameter) are most easily transported. The corollary to this proposition is that clays and coarser sediments are more difficult to move, and better sorting of particle sizes in the act of transport increases as the particle size diameters approach 0.18 mm.

Interpreting the Tuttle Creek sediment data with these relationships in mind implies that the settling velocity is low in large portions of the lake because a large quantity of

EXPLANATION OF FIGURE 8

Relation of grain diameter to settling velocity, threshold velocity, and roughness velocity. From Sanders (1958).


fine silt
medium silt
coarse silt
very fine sand
fine sand
medium sand
coarse sand
very coarse sand
granules
pebbles
35
30
20
10
1.0
0.1
.01
VELOCITY IN cm/sec
threshold velocity
roughness velocity
settling velocity
.01
.04
0.1
.4
1
4
10
DIAMETER IN mm.

of clay particles were deposited; however, this is not to say threshold velocity did not erode sediments in Tuttle Creek.

Four sediment samples contained pre-impoundment soils. This would indicate sufficient current velocity occurred to prevent deposition and promote erosion. This observation allows me to infer there were currents present equal to or exceeding threshold velocity in Tuttle Creek Reservoir.

Measurements of organic matter reported in the literature show wide variation. Beatty and Hooper (1958) observed organic matter to vary from 16 to 50 percent but they made no attempt to correlate organic matter to particle size in Sugarloaf Lake. Krumbein and Caldwell (1939) reported values for Barataria Bay, Louisiana, to vary from 0.0 to 7.6 and they did define a correlative relationship between organic matter and particle size.

The mechanism of organic matter distribution is intuitively felt to be the same as for particle size distribution. Krumbein and Caldwell (1939) suggested that in their Barataria Bay sediment study particle size and organic matter distributions are functions of the "quietness" of the water since they are deposited under similar conditions. They found significant correlation between organic carbon content and the logarithim of particle size means. They also reported an exponential relationship between size in millimeters and organic carbon content. No such relationships were found from the observations from Tuttle Creek Reservoir.

The range of particle sizes from Barataria Bay were from 2.80 median <u>phi</u> to 7.05 median <u>phi</u>. No clay sized particles were reported. Tuttle Creek has a particle size range of 5.40 median _phi_ to 10.60 median _phi_, with the majority of the particles in the clay classification. Tuttle Creek Reservoir sediments typically contained a greater amount of organic material than Barataria Bay. The observed difference of sedimentary factors (particle size and organic matter content) for both areas might be expected since each area is a separate aquatic system, one fresh water and the other marine, and the range of particle sizes is quite different.

Wherein Krumbein and Caldwell (1939) observed a correlative relation between organic matter and particle size for the particle size range found in Barataria Bay, Tuttle Creek sedimentary data does not show such a relationship. First, as mentioned above, the two systems have different particle size ranges. Second, the current velocities that may be responsible for laying down a layer of organic matter would vary considerably between the two systems. Barataria Bay opens into the Gulf of Mexico and no streams enter into the bay; therefore, the bay is subjected to tidal currents and the currents that flow along the gulf shore and sweep in and out of the bay. Tuttle Creek Reservoir, in contrast, is open at the north end where water flows in and at the south end where the outflow is located (Figure 1). The current effect is analogous to water flowing through a narrow trough. Thus, the tidal currents moving in and out of Barataria erode organic deposits, whereas, heavy detrital loads are washed into Tuttle Creek Reservoir and settle out.

BENTHOS:

Tuttle Creek Reservoir, when compared with Lake Texoma (Sublette, 1957), Keystone Reservoir (Ransom, 1968), and Lizard Lake (Tebo, 1955), had low densities of benthic macroinvertebrates and a relatively simple benthic community structure, that is, few kinds of organisms.

Tuttle Creek appears, on the basis of indices of secondary production, i.e., fish and zooplankton condition and abundance (Klaassen and Marzolf, personal communication), to be a productive lake. Why was there the apparently low number of macrobenthic organisms observed?

Ruttner (1961) suggests the oxygen content of the stratum of water adjacent to the sediments (mud-water interface) may be a powerful limiting factor in the abundance of certain populations of benthos. He went on to state the oxygen concentration influences the midge larve distribution on the basis of numbers and biomass. In view of the ephemeral nature of stratification in Tuttle Creek Reservoir, oxygen concentration has not been considered as limiting. Wind generated currents promote mixing of the waters and allow little if any stratification to occur (Dufford, 1970).

Rodina (1961) stated a correlative relationship exists between quantity of bacterial biomass in the sediments and the development of bottom fauna. She suggested that benthic animals feed on vitamin rich bacteria rather than detritus that loses its nutritional value in the degradative processes. If this observation is valid, a low benthic bacterial biomass may limit a benthic animal population. No observations have been made concerning the quantity of bacteria in the sediments of Tuttle Creek Reservoir. The quantity of benthic bacteria may be limiting the benthic animal population in Tuttle Creek Reservoir. A study to define any correlative relationships between benthic bacteria and macroinvertebrates is necessary to test the hypothesis of a limiting function of energy-biomass of benthis bacteria.

Distribution data of bottom organisms in relation to depth showed no uniformity from deep to shallow water. Eggleton (1931) reported similar observations from his investigation of two Michigan and one New York lakes. Eggleton's data indicated that at certain times of the year numerical abundance of benthic fauna increased with depth, wherein, other times of the year, the numerical abundance decreased with depth. Sublette (1957) reported <u>Pelopia</u> <u>stellata</u> abundance increased with depth in June and July, 1949. <u>Polypedilum</u> <u>digitifer</u> for those same months increased numerically down to 2.0 meters then rapidly decreased numerically with increasing depth. Miller (1938) showed that the numbers of oligochaeta increased at greater depths in five Algonquin Park lakes. In Tuttle Creek, <u>Chaoborus</u> <u>spp</u>. abundance increased with depth.

If data describing depth relationships from this and other studies mentioned above can be used to formulate generalities one might be: the relationship of animals to depth is species specific.

As a result of his barnacle study, Connell (1961) suggested interspecific competition may be enhanced by various abiotic environmental factors to which organisms are subjected, and by their physiological abilities to adjust to such abiotic factors. In view of this hypothesis, the distribution of benthic organisms in Tuttle Creek Reservoir may be a manifestation of interspecific competition for certain substrate areas.

Fish predation on the biomass of the benthic community has been shown to decrease benthic populations (Ball and Hayne, 1952, 1956; Hruska, 1961). The 1952 study of Ball and Hayne reported that following the removal of the fish populations from Third Sister Lake, Michigan, the standing crop of benthic organisms doubled until a dynamic equilibrium was reached whose limits were determined by factors other than fish predation. Ball and Hayne (1956) indicated the presence of fish reduced the benthic standing crop and the rate of benthic production increased. The converse of this observation was that the absence of fish promoted a higher standing crop and a decreased benthic production rate. Hruska (1961) studied the effect of carp (<u>Cyprinus carpio</u>) predation on the bottom fauna of two ponds, by placing wire cages over portions of the ponds' bottoms to protect a portion of the benthic population from predation. He found the concentration of Chironomid larvae much greater in the protected areas.

The relation of bottom fauna to fish may be considered twofold. First, the benthic animals may directly serve as a food source to those fish that actively seek the animals and consume them. Second is the indirect relation, that is, the fish prey on other animals which in turn obtain nourishment from the bottom fauna.

Of the fish which directly feed on the bottom, carp (*Cyprinus carpio*), carp sucker (*Carpiodes carpio*), and smallmouth buffalo (*Ictiobus bubalus*) were taken in Tuttle Creek Reservoir. Stomach contents show extensive feeding on bottom fauna during June and September, 1969 (Perry, 1970).

BENTHOS-SEDIMENT RELATIONSHIPS:

The nature of the substrate serves two important functions for benthic macroinvertebrates particularity aquatic insects (Moon, 1940). First, the substrate offers foundation and shelter from turbulent waters and a stable base for many aquatic insects. No evidence is available from Tuttle Creek Reservoir to support or refute the observation that Tuttle Creek's flocculent clay sediments have the stability and firmness necessary for tube building and other related activities.

Secondly, the particle sizes that make up the sediments provide the surfaces for: 1) aquatic flora growth necessary for hervivorous benthic animals; 2) accumulation of bacterial biomass that may be utilized by benthic animals; 3) accumulation of detrital materials utilized by deposit feeders. Tuttle Creek Reservoir is a turbid lake throughout much of the year (Dufford, 1970). This results in low light penetration of the water. Little or no light in the deeper waters where benthic samples were taken, negates aquatic floral growth as a factor in benthic distribution.

The importance of the second function of particle surface areas (bacterial biomass ulitization by benthic organisms) has not been measured in Tuttle Creek Reservoir; therefore, its effect can not be fully appreciated.

Detrial accumulation, (organic matter content), and the utilization of this detrital accumulation by benthic deposit feeders is the third role of particle surface areas. Detrital accumulation would increasingly bind on the clays' relatively larger surface areas. This detrital accumulation on particle surface areas has been examined by several investigators. Sanders (1958) suggested this increasing detrital accumulation on increasing surface areas was a major factor in defining deposit feeders' distribution and abundance in Buzzards' Bay. Moon (1939) also indicated that fauna living in muddy substrates are dependent on a detrital based food chain. Organic matter was uniformily distributed and did not appear significant in limiting or enhancing benthic abundance in Tuttle Creek Reservoir. Lellak (1965) reported no direct correlation between benthic numerical abundance and the amount of organic nitrogen, hydrolysable carbohydrates, and organic carbon in fresh and/or dry sediments. He concluded the content of these sedimentary substances is not a limiting factor in benthic macroinvertebrate nutrition and therefore quantitative development and production.

Taken separately, the sedimentary variables show no correlation with the total benthic numerical abundance and distribution. It may be concluded that the variances observed in organic matter values, percentages sand, silt, and clay values, and depth values are not large enough to be major factors in explaining variation in animal abundance or distribution. Although the relation between organic matter and benthic abundance did not show significance, this measurement, combined with depth did explain 22% of the variance in numerical abundance which was significant ($\alpha = 0.05$).

These observations raise the next important question. Given those sedimentary variables measured account for little of the variation in total benthic abundance and distribution, what are those variables that account for so much of the unexplained variation? I suggest measurements of bottom current velocities and estimates of sedimentary bacterial populations should be added to future studies of Tuttle Creek Reservoir that hope to better describe the biotic and abiotic environmental factors that act upon the benthic macroinvertebrate community.

SUMMARY

1. The sedimentary environment of Tuttle Creek Reservoir is homogeneous for particle size and percent of oxidizable organic matter.

2. Little variation was found in the percent of clay, silt, and sand of the sediment in the reservoir substratum.

3. No correlative relationship was established between particle size distribution and percent of oxidizable organic matter.

4. Numerical abundance, biomass, and horizontal distribution patterns of the benthic macroinvertebrate community showed homogeneity in the sedimentary environment of Tuttle Creek Reservoir.

5. Tuttle Creek Reservoir bottom fauna may be characterized by low numbers and simple community structure.

6. Bacterial biomass was suggested to be an energy source for certain benthic animals and a possible limiting factor in benthic abundance and distribution.

7. Statistical analysis indicated the benthic distribution of Tuttle Creek Reservoir is superdispersed.

APPENDIX

Tuttle Creek Reservoir data utilized

in the statistical analyses

SECTION I

GRID	DEPTH (M)	Mdø	CLAY %	O.M. %	ANIMALS PER SQUARE METER Chironomidae	Ceratopognidae	Culicidae	Oligochaeta	Ephemeridae	Mollusca	Total
1	14.0	8.5	54.8	3.61	266						266
3	16.5	10.4	87.3	3.61		44					44
6	7.5	5.7	19.0	4.02	178				44		222
8	17.0	10.6	89.0	3.21	89			222			311
10	16.0	10.0	77.5	4.28	89			44			133
11	10.5	6.0	32.8	3.77	133			89			222
23	15.5	10.0	75.7	5.09	133			44			177
24	15.5	9.9	74.0	4.28	89			89			222
25	14.5	9.0	60.7	4.28	133				44		178
32	15.5	10.5	87.0	3.75	133			44			178
35	17.3	9.5	68.8	2.55	355						355
43	11.2	10.4	84.7	3.08	222	44		44			311
48	11.8	10.1	78.6	3.75	89		89	266			444
60	10.2	9.6	20.7	3.21	311	44					355

SECTION II

GRID	DEPTH (M)	Mdø	CLAY %	O.M. %	ANIMALS PER SQUARE METER Chironomidae	Ceratopognidae	Culicidae	Oligochaeta	Ephemeridae	Mollusca	Total
62	10.9	10.1	77.7	2.68	488			44			533
66	15.2	9.9	73.5	2.95	178		44	311			488
71	9.9	9.8	74.5	3.35	355			44			400
76	6.2	6.8	38.2	2.41	355						355
83	12.4	10.2	79.8	3.75	89			89			178
87	5.3	6.2	21.8	4.69	178			44	89		311
88	6.5	7.8	53.0	3.27	577						577
92	6.0	9.4	66.2	3.20	488						488
100	9.0	10.2	78.5	3.08	266			44			311

SECTION III

GRID	DEPTH (M)	Mdϕ	CLAY %	O.M. %	Chironomidae	Ceratopognidae	Culicidae	Oligochaeta	Ephemeridae	Mollusca	Total
					ANIMALS PER SQUARE METER						
105	11.2	9.0	60.5	2.83	222		89		89		400
108	9.9	10.3	80.0	2.81	755	89	44		44		932
109	10.2	10.5	85.3	2.68	400			311			711
115	9.6	10.7	89.2	2.95	311		44	89			444
118	9.9	10.2	78.6	2.55	178		133	44			355
123	7.6	6.1	32.7	2.54	444						444
125	9.6	10.3	81.3	3.08	710						710
126	7.4	8.0	50.5	2.80	266		44	44			355
131	8.7	10.0	38.4	1.47	1288						1288
134	9.0	9.8	71.9	2.90	89				44		133
144	12.4	9.4	65.6	3.35					44	44	89
148	7.6	9.9	74.0	2.95	799		44				844
154	9.0	10.3	85.3	2.68	977				44		1021
157	8.1	8.8	57.3	2.68	133						133
160	2.8	6.2	35.2	4.02	533		89				622
161	7.6	9.5	66.2	3.08	89		266				355
163	7.0	9.4	74.5	2.01	577						577

SECTION IV

GRID	DEPTH (M)	Mdϕ	CLAY %	O.M. %	Chironomidae	Ceratopognidae	Culicidae	Oligochaeta	Ephemeridae	Mollusca	Total
					ANIMALS PER SQUARE METER						
166	7.6	8.0	50.6	3.22	577		178				755
168	5.3	5.4	24.4	1.34	488		133				622
174	11.5	8.8	58.1	2.01	311	44	133				488
203	4.6	10.0	76.5	2.68	266			89			355
205	11.7	8.0	16.0	3.22	178						178
208	4.6	8.0	50.0	2.81	222						222

SECTION V

GRID	DEPTH (M)	Mdϕ	CLAY %	O.M. %	ANIMALS PER SQUARE METER Chironomidae	Ceratopognidae	Culicidae	Oligochaeta	Ephemeridae	Mollusca	Total
220	4.6	10.3	81.5	3.88	178		222	311			710
222	3.1	10.1	76.8	3.88	622						622
225	2.2	9.2	62.3	3.62	400			222			622
226	9.3	9.8	72.6	4.95	178	89	178	355			799
231	0.9	7.6	46.0	4.28	1199			44		89	1332
243	0.9	9.2	62.5	1.74	932			222			1154
250	7.1	10.5	87.0	2.55	266	44	44				355
251	1.6	9.9	73.0	1.60	133						133
252	4.8	10.6	88.5	2.55	355			89			444
259	5.3	8.9	58.2	2.68	355		178	133			666
261	0.5	9.6	69.0	2.95	266		266				533
262	1.1	10.6	87.8	3.48	44		89	44			178
264	0.6	9.8	17.6	2.68	133			133			266
269	1.7	10.4	84.0	3.20	577						577

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ANIMAL-SUBSTRATA RELATIONSHIPS
IN A GREAT PLAINS RESERVOIR

by

Joseph Michael Schwartz

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The numerical abundance and distribution of the benthic macroinvertebrae community of Tuttle Creek Reservoir, Kansas, was studied during the summer months of 1968 and 1969 with regard to their association with the bottom sediments.

The reservoir sediments are relatively homogeneous in terms of particle size distribution, percent of sand, silt, and clay and percent of organic matter found in the sediments.

Sand, silt, and clay constitude 18.0%, 20.6%, and 62.8% of the sediment respectively. Organic matter was found to average 3.09% in the sediment.

Benthos were identified, counted, and correlated with the depth, percent organic matter, particle size, and percent clay. The number of animals per square meter ranged 44 to 1332.

The numerical distribution of organisms showed no significant correlation with the above mentioned variables when tested with each variable separately. Depth and organic matter correlated with number of animals explained 22% of the variabilty in numerical distribution.