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A close examination of the benthos of the 0-5 m zone of a lake cove was undertaken at Lake Jeanette, 10 km north of Greensboro, North Carolina. Monthly samples were made from September, 1973 through April, 1974. The sampling technique devised for this project was successful; it insured minimal maintenance and uniform treatment of samples during collection. The incorporation of SCUBA allowed the investigator to come in contact with the study area and make direct observations. Time involved in sample processing was minimized by the use of Anderson's floatation method for the extraction of organisms from sediments.

The cove was well-oxygenated. Organic nutrients were available from both allochthanous and autochthanous sources. Bottom waters proved to be circumneutral with respect to pH. The available evidence indicated that the lake is a second class, warm, monomictic lake.

Insect larvae, pelecypods, platyhelminthes, amphipods, ostracods, bryozoans, and annelids made up the macroinvertebrate community of the cove benthos. Total numbers of the macroinvertebrates indicated increasing populations during the winter. These populations exhibited clumped distribution in the 0-5 m cove depths. Depth was limiting in the case of tabanids, trichopterans, planarians, amphipods, megalopterans, odonates, and possibly pelecypods, ephemeropterans, and coleopterans. Oviposition habits of adult insects and mobility of larval forms

were also believed to have influenced distribution. A chironomid-oligochaete coexistence evaluation indicated that perhaps their predator-prey relationship was influencing their populations in the cove.

In a problem of this exploratory nature, statistical analyses were found to be too critical, but were employed in the organization of data and the detection of trends of distribution.

Some Aspects of the Ecology of Benthic Macroinvertebrates in a Cove of Lake Jeanette

by

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Approved by

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APPROVAL PAGE

This thesis has been approved by the following committee of the Faculty of the Graduate School at The University of North Carolina at Greensboro.

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INTRODUCTION

The lake benthos can offer meaningful information concerning fish and wildlife management, insect control, pollution indication, and trophic functions of aquatic systems. Inadequate study has caused recent scientific attention to be focused on lake benthic communities in hopes that reliable data will be available to concerned agencies and corporations.

Nutrients, degree of light penetration, predators, and chemical balances in lake water determine the limits for benthic inhabitants. Conclusive studies of lake bottom communities are difficult since any sampling technique interrupts the relationships established among the many parameters inherent to the water-substrate interface. The field problem of benthic study has caused investigators to group data collection into chemical, physical, and biological factors, measure them separately, define the environment and biota, and then attempt to determine their interactions.

Usually an entire lake bottom is studied and divided into three sections, the littoral, sublittoral, and the profundal. These zones vary with individual lakes, and depth serves as the defining characteristic for the zones. In recent studies, Peterka (1972) chose sections measuring 0-3 m, 3-8 m, and 8-12 m at Lake Ashtabula, a 20-yr old eutrophic resevoir in North Dakota whose maximum depth was 15 m. He sampled the summer months of April, June, and August. Bottom sediment types were not mentioned, but his 0-3 m zone had the most diversity including molluscs, dipterans, ephemeropterans, trichopterans, amphipods, haliplids, and odonates. His figures were reported in adjusted terms of number/m^2 and are quite large causing him to conclude that the lake was eutrophic. At Acton Lake, the depth sample stations used by Daniel (1972) measured 1 m, less than 3 m, 6 m, and greater than 9 m. Acton Lake is almost 20 years old and has a maximum depth of 10.4 m. Daniel noted that the wet-weight biomass of the benthic fauna was greatest in late winter. He found chironomids the most predominant organism in collections, that chaoborids were found in deeper water sediments, and that annelid numbers were increasing with time.

Lenat, an active benthic investigator in North Carolina, sampled the littoral, sublittoral, and profundal zones at Lake Wylie on the border of North Carolina and South Carolina (Lenat and Weiss 1973). He took samples from various depths between 7 and 40 feet (2.22 - 13 m). He mentioned the substrates of his sample stations and felt that they were the limiting factor in most of the littoral zones of Lake Wylie. His conclusion was based on productivity. Coarse sands appeared least productive because of low organic content and because they made unstable conditions for organisms. Firm sand was very productive. Mud was felt to be the most productive and clay second to mud. His information was obtained on two dates (one in spring and the other in fall) at 13 stations located throughout the lake at distances greater than 2 mi apart.

The internal structure of the shallow zones of lakes has either been considered uniform or of too high variability between lakes to merit close examination, and, therefore, has been disregarded in benthic investigation. The purposes of this study were to gather some general limnological data for Lake Jeanette, to closely examine and define the benthos of a shallow zone well-protected by watershed woodlands, and to use a uniform sampling technique so that different sampling techniques would not have to be equated.

MATERIALS AND METHODS

Lake Jeanette is a dendritic, impounded lake situated 10 km north of Greensboro, North Carolina. It is approximately 30 years old, has an area of 112 ha, has a maximum depth of 10 km, and is surrounded by oak-hickory woodlands. The lake is stocked with game and forage fishes and supports diverse populations of wildlife.

Observations from an aerial survey in June, 1973 facilitated the selection of a sampling cove not affected by clearing and urban development. With this choice, heavy sedimentation and pollution effects were minimized.

Figure 1 illustrates the lake and the sampling area. The cove measured 270 m from the source of the cove to the lake, and was 90 m wide where it joined the lake. To determine the depth contours, nine temporary transects were established across the width of the cove, and water depths were measured every meter along the transects. Wooden incremental staff gauges were installed in the cove to indicate fluctuation in the water level during the sampling period.

There were 25 sampling stations in the cove, and they were distributed among four permanent transects referred to as T1, T2, T3, and T4 (Fig. 1). The number of stations per transect varied according to water depths along the transects. Five depth zones were sampled: the 0-1 m zone, the 1-2 m zone, the 2-3 m zone, the 3-4 m zone, and the 4-5 m zone.

Active sampling began in September, 1973 and continued monthly through April, 1974. Each monthly sampling consisted of two main

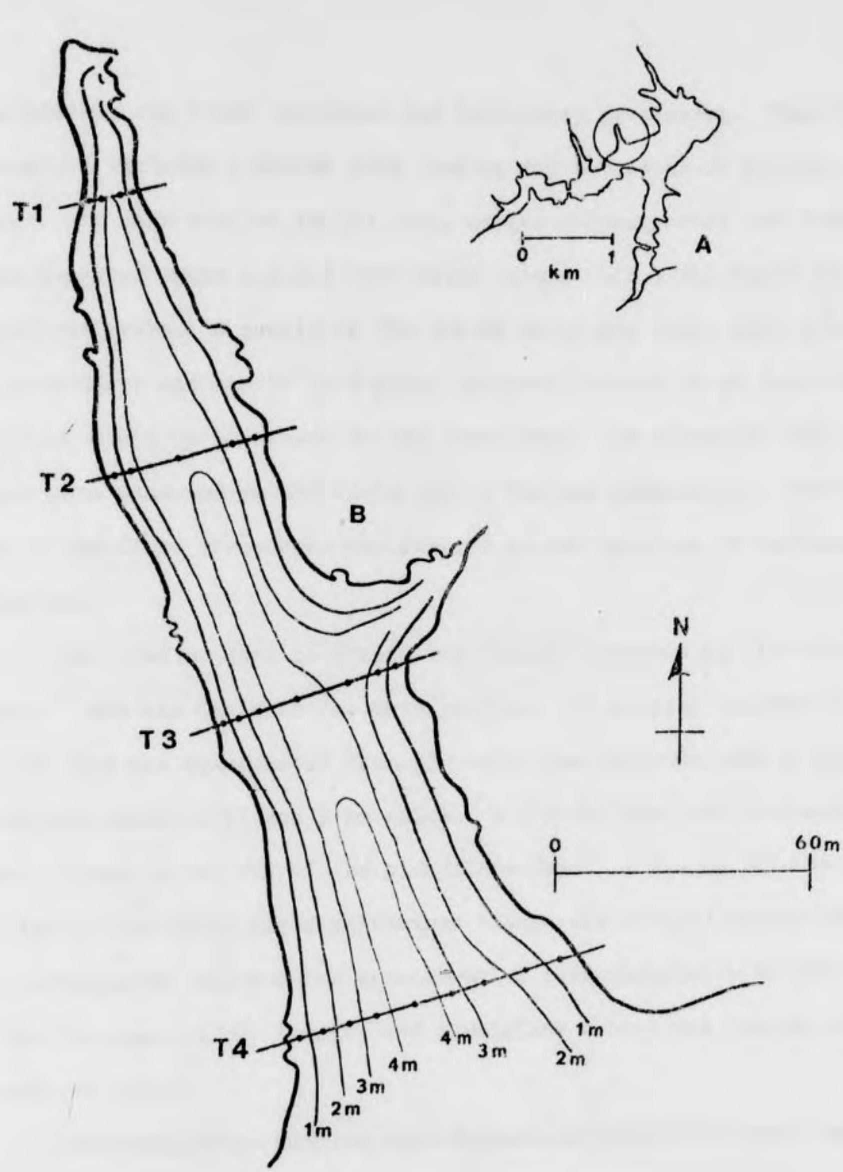

Figure 1. Sampling Cove. A. Sampling cove in relation to the rest of Lake Jeanette. (After official County map). B. A contour map of the sampling cove. The four sampling transects are labeled T1, T2, T3, and T4. Sampling stations are indicated by dots. Depths of the contour lines are indicated.

procedures, the field procedure and laboratory processing. The field procedure included a Secchi disk reading and notations of weather conditions. At each station in the cove, oxygen concentration and temperature were measured every 0.5 m in the water column with a YSI Model 54 Oxygen Meter and probe. A sample of the bottom water was taken with a Kemmerer water sampler and stored in a glass stoppered bottle in an ice bath until it could be processed in the laboratory. pH values of the bottom water were measured in the field with a Hellige comparator. The majority of the field procedures was devoted to the sampling of sediments and organisms.

The sampler used to obtain the sediment samples is illustrated in Figure 2 and was designed for this project. It sampled an area of 165 cm^2 and was constructed from plywood, pipe fittings, and a plexiglass tube whose wall was 3 mm thick. A plywood disk was fastened by eight screws to one end of the plexiglass tube. A 2.5 cm hole was drilled in the wood, and a galvanized flange was mounted around the hole; this arrangement allowed for attachment of interchangeable handles. The entire fitting-- disk, flange, and plexiglass tube-- was sealed with a fiberglass resin.

Interchangeable handles were devised for different depth sampling. For samples taken in less than 1 m of water, a T-bar handle was used. The sampler was placed on the bottom and pushed into the sediments. A cork was inserted in the flange, and the T-bar was screwed into the flange. The sampler was then pulled from the bottom by the handle.

For samples taken in water greater than a meter in depth, an extension handle was used. This handle consisted of joining 120 cm

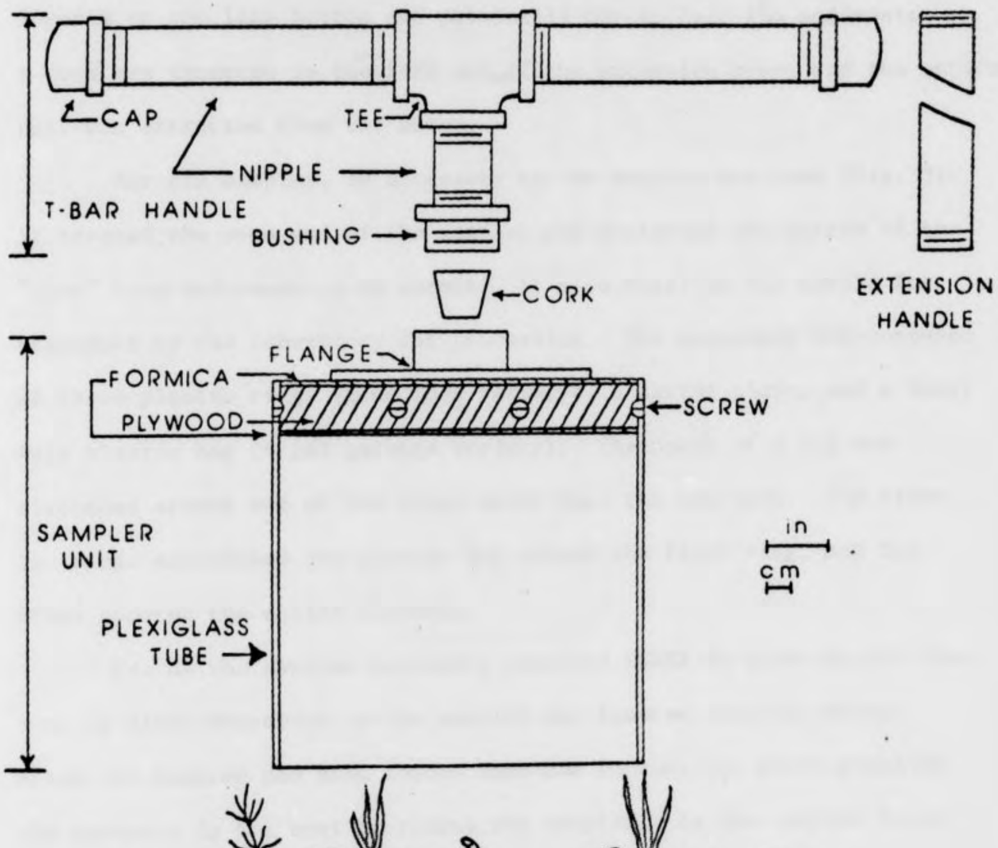

Figure 2. Scale Drawing of Sampler with T-bar Handle or Extension Handle.

lengths of 1.27 cm pipe until a desired length was attained. The handle was attached to the sampler unit by screwing the extension handle to a bushing and then to the sampler. From the boat, the sampler was hand-lowered to the lake bottom and physically thrust into the sediments. A cork was inserted in the free end of the extension pipe, and the entire unit was extracted from the water.

For all samples, an accessory to the sampler was used (Fig. 3). It covered the open end of the sampler and protected the bottom of the "core" from underwashing on ascent. It also retained the sample for transport to the laboratory for processing. The accessory was composed of three plastic rings (game toss variety), a spring clamp, and a heavy duty plastic bag (4 gal garbage variety). The mouth of a bag was stretched around one of the rings which kept the bag open. The other two rings sandwiched the plastic bag around the first ring, and the clamp secured the entire assembly.

Use of the sampler accessory required SCUBA in water deeper than 1 m. A diver descended as the sampler was lowered into the water. After the sampler had been forced into the bottom, the diver signaled the operator in the boat to remove the sampler. As the sampler broke contact with the bottom sediments, the accessory was slid under the bottom of the sampler. The accessory was raised to the top of the plexiglass tube, and was held there for the duration of the ascent to the surface.

At the surface, the pipe was uncorked and the sample fell into the plastic bag of the accessory. Each sample was labeled, sealed, and placed in another plastic bag for reinforcement. The sample was stored

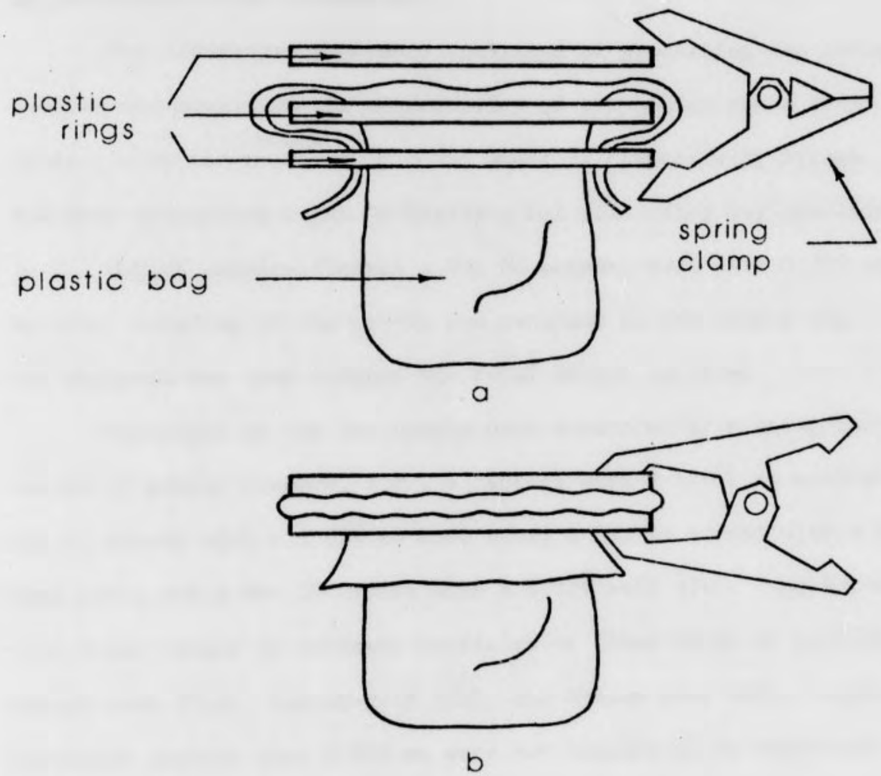

Figure 3. Sampler Accessory. a. Exploded drawing of plastic bag being stretched around a plastic ring. b. Plastic bag is secured by two other rings and clamped by spring clamp.

in a styrofoam cooler until it could be transported later that day to be processed in the laboratory.

The laboratory procedure consisted of processing the sediment samples and measuring the conductivity of the bottom water samples. Conductivity was measured by a YSI Model 31 Conductivity Bridge. Sediment processing began by draining and discarding any overlying water in the bagged samples through a No. 50 screen, mesh size 0.279 mm. Any material retained in the screen was returned to the sample bag. The wet sediment was then weighed and total weight recorded.

Materials in the wet sample were separated by rinsing through a series of graded screens, a No. 4 screen with a 5.156 mm mesh size, a No. 12 screen with a 1.524 mm mesh size, a No. 24 screen with a 0.279 mm mesh size, and a No. 50 screen with a 0.279 mesh size. The Wentworth Soil Scale refers to sediment particles of these sizes as pebbles, very coarse sand (VCS), coarse sand (CS), and medium sand (MS), respectively. Particles smaller than 0.279 mm were not considered in this study and were discarded.

A modification of the conventional stack method of separating sediments with screens was developed and is illustrated in Figure 4. This apparatus was constructed from a set of screens, pipe, and pipe fittings. The graded screens were mounted on a stand in such a manner as to permit swiveling. Rinsing of sediments was expedited since water could be injected into each screen without disrupting drainage. Rinsed sediments could be swung to the side until finer sediments were rinsed.

After rinsing, the contents of each screen were rinsed into a jar and placed in a refrigerator at 5° C until all samples for each month

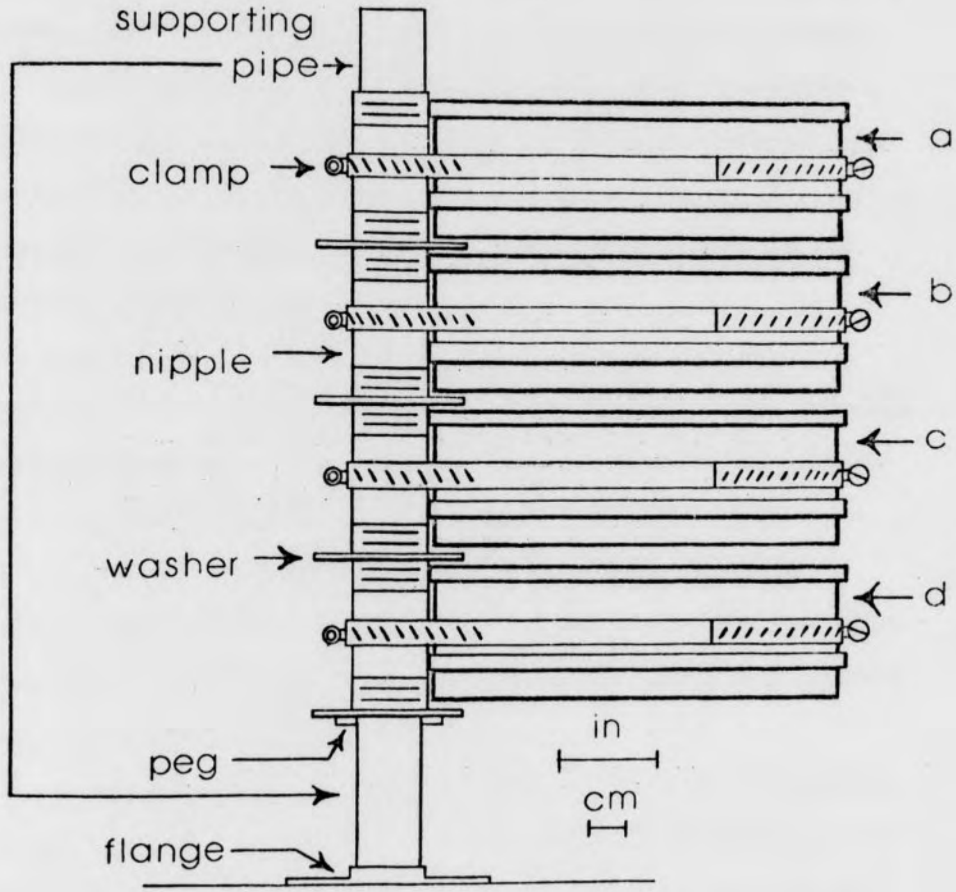

Figure 4. Sieve Stand for Separating and Rinsing Benthic Sediments. a. No. 4 screen. b. No. 12 screen. c. No. 24 screen. d. No. 50 screen.

were rinsed. Each of the 25 monthly samples were separated into four component parts according to particle size when sifting was complete.

The sediments were removed from the refrigerator, drained in a vacuum flask, and weighed. Partial sample weights were recorded. For each sample the percentage compositions of pebbles, VCS, CS, MS, and portion lost were calculated. Subjective notations as to color and composition of the sediments were made.

Each sediment sample was placed in a sugar solution with a specific gravity of 1.12 as suggested by Anderson (1959). The organisms were extracted by this floatation method and preserved in 10% formalin until identified. The sediments were then discarded.

Statistical analyses were performed through the Triangle University Computation Center, Research Triangle, North Carolina. Tele-storage and Retreival (TSAR 1974) programs and the Statistical Analysis System (Service 1972) programs were used.

Of the TSAR programs, CROSS SORT was used to obtain preliminary frequency distributions. The PRINT function was used to organize data. The MEAN program was used to compute the mean number or organisms per monthly samples at the various depths. Standard deviations were also produced by the MEAN procedure. ANOVA 2WAY was used for analysis of the chemical, sediment, and organism data to examine the relationships between depths, transects, positions in the cove, and different dates. Calculation of oxygen saturations and percent composition of sediment samples were also made possible by the TSAR package.

SAS programs, MEANS, SORT, and PRINT, were used to organize sediment samples by the subjective notations on composition and in the evaluation of chironomid-oligochaete relationships.

RESULTS

Morphometry. Illustrations of the bottom contours of the cove are seen in Figure 5. The water level dropped 1 m between the beginning of September and the end of October. The lake attained its full capacity again by December and remained there for the duration of the study.

Chemistry. The warmest temperature in the layer of water on the bottom of the cove was 27.5^{o} C recorded in September, and the coldest temperature was 6.0^{o} C recorded in January. pH values ranged between 6.8 and 7.4 during the sample period. Conductivity measurements averaged 61.1 umhos in September, 58.5 umhos in October, 56.7 umhos in November, 51.9 umhos in December, 52.4 umhos in January, 48.4 umhos in February, 47.3 umhos in March, and 50.2 umhos in April.

Dissolved oxygen was measured in ppm. Values between 4 and 10 ppm were recorded in September, between 7 and 9 ppm in October and November, between 9 and 11 ppm from December through February, between 10 and 12 ppm in March, and between 8 and 12 ppm in April.

Oxygen saturation values were calculated from the observed oxygen concentrations and the oxygen solubilities reported by Truesdale, Downing, and Lowden (1955, cited by Hutchinson 1957). The lake water was between 60 and 120% saturated with oxygen in September. In October, the saturation of oxygen in the lake water ranged from 79 - 96%, in November from 71 - 90%, in December from 79 - 86%, in January from 48 - 94%, in February from 85 - 97%, in March from 92 - 110%, and in April from 21 - 120%. Incidences of supersaturation occurred in

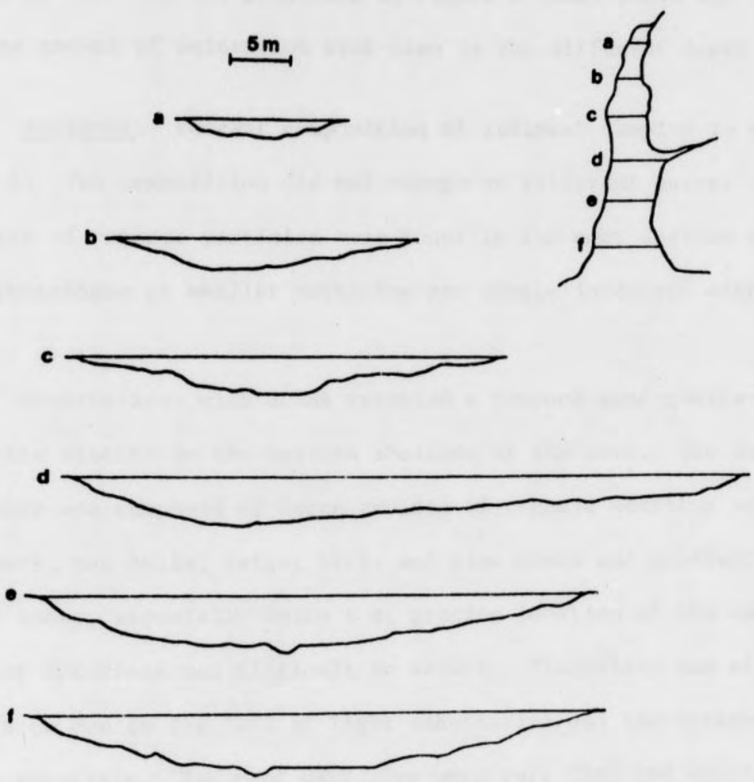

Figure 5. Bottom Contours of Temporary Transects Established Across the Width of the Cove.

September, March, and April. Percentages of dissolved oxygen on the bottom of the cove are presented in Figure 6 which shows the change in average amount of saturation over time in the different depth zones.

Sediment. Percent composition of sediment samples is shown in Table I. The composition did not change on different dates. High percentages of coarser particles were found in the most shallow zones, and the percentages of smaller particles per sample increased with increasing depth.

Observations with SCUBA revealed a compact sand-quartz-clay substrate mixture in the eastern shallows of the cove. The western substrate was composed of large amounts of organic detritus such as leaf fragments, nut hulls, twigs, bark, and pine cones and needles. In deeper zones, especially below 4 m, precise location of the water-sediment interface was difficult to detect. Visibility was often less than 20 cm due to the lack of light penetration and the darkness of the bottom materials. Sediment particles were very fine and smoothly distributed. At some stations the layer of ooze was easily penetrated to a depth of about 15 cm. Small shallow depressions appeared at random intervals on the bottom. There was no visible variation in the sediment of the deeper zones over time.

Vegetation. In late summer, a large mass of emergent vegetation was observed in the eastern portion of the cove between T2 and T3. The mass was not observed after October, but was present in April. Alder bushes, *Alnus serrulata* and button bushes, *Cephalanthus occidentalis* were emergent throughout the eastern portion shallows. *Chara sp*. was

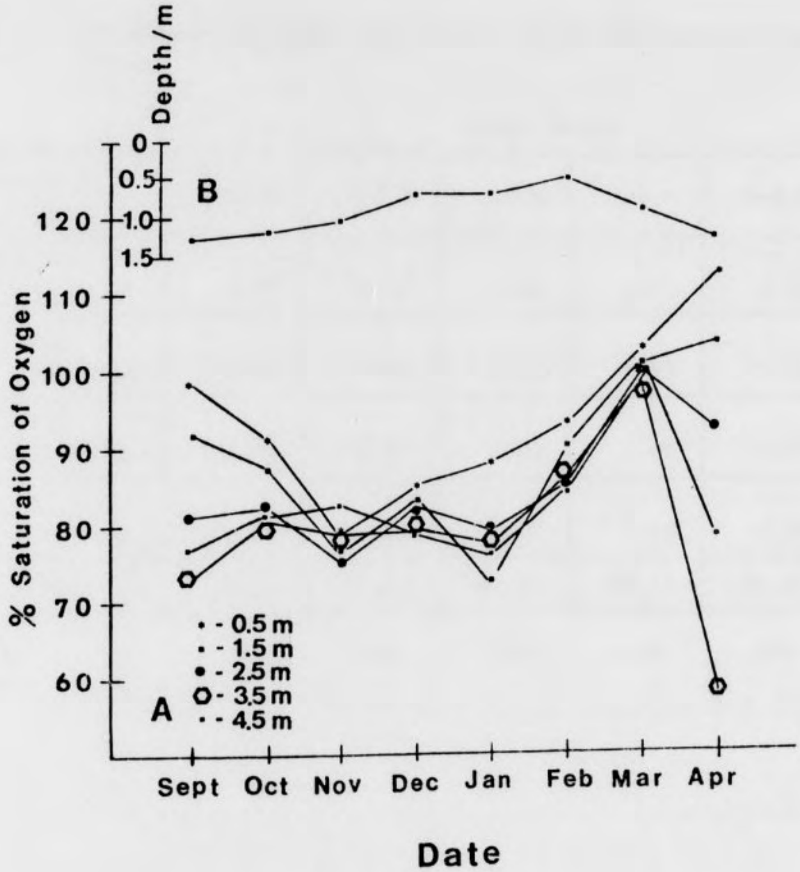

Figure 6. A. Oxygen Saturations on the Cove Bottom.
B. Secchi Disk Transparencies.

Table I. Percentage of Sample Composition Based on Weight of Particle Sizes.

	Water Depths				
Particle Size	0-1 m	1-2 m	2-3 m	3-4 m	4-5 m
Pebble > 5.156 mm	3.10	3.10	3.10	3.10	3.10
VCS < PEB > 1.524 mm	5.56	4.35	2.58	1.96	1.96
CS < VCS > 0.703 mm	10.96	5.97	2.71	2.31	1.84
MS < CS > 0.279 mm	15.81	9.29	4.19	3.46	2.19
Fine < MS	64.57	77.29	87.42	89.17	90.91
Total	100	100	100	100	100

found to cover the cove bottom between 0-2 m depths in the late summer and early spring.

Miscellaneous. Precipitation and Secchi disk transparencies are found in Table II. Only days with at least 0.5 inches of precipitation are included in this table. If a 24-hr period had more than 0.5 inches precipitation, each multiple of 0.5 was considered a day of 0.5 inch precipitation. Weighting the days in this manner was employed to distinguish the months with the heaviest precipitation at one time.

Macroinvertebrates. Figures 7 through 13 illustrate the contents of each benthic sample taken. The total number of organisms captured is presented in tabular form along with the number of samples taken and the total number of organisms collected in each depth zone per monthly sample.

The total number of organisms collected increased from 336 in September to 647 in November. A drop in total number was seen in January's collection and was followed by a return to larger collections of 728 and 793 in February and March, respectively. A decline in numbers was experienced in April when 673 organisms were trapped.

The bottom fauna of the cove was composed of annelids, bryzoans, platyhelminthes, molluscs, and arthropods. Large colonies of the bryozoan, *Pectinatella magnifica*, present in September on submerged objects, disappeared during the winter, but statoblasts were collected each month. The stationary colonies were observed again by the collection data in April.

Table II. Monthly precipitation and Secchi Disk Transparencies. Climatological data (U.S. Department of Commerce 1973-74) are taken from monthly reports from the National Atmospheric and Oceanic Administration, Greensboro-High Point-Winston-Salem Airport

Month	Secchi	Precipitation cm	(inches)	Days with 0.5" Precipitation
Sept	1.22	2.92	(1.15)	1
Oct	1.14	5.87	(2.31)	1
Nov	1.03	3.15	(1.24)	0
Dec	0.66	16.36	(6.44)	7
Jan	0.66	11.63	(4.58)	6
Feb	0.46	7.95	(3.13)	3
Mar	0.84	8.43	(3.32)	2
Apr	1.22	5.46	(2.15)	1

# of samples	Depth/m	ANNELIDA	DIPTERA	EPHEMEROPTERA	ODONATA	MEGALOPTERA	COLEOPTERA	TRICHOPTERA	AMPHIPODA	MOLLUSCA	OSTRACODA	ARACHNIDA	PLATYHELMINTHES	BRYOZOA	TOTAL
8	0-1	16	86	3		6	2		1			2			116
8	1-2	13	22	1							1	1		1	39
5	2-3	4	18	1	1	1									25
4	3-4	3	71									1			75
2	4-5	2	78									1			81
TOTAL		38	75	5	1	7	2		1		1	5		1	336

SEPTEMBER

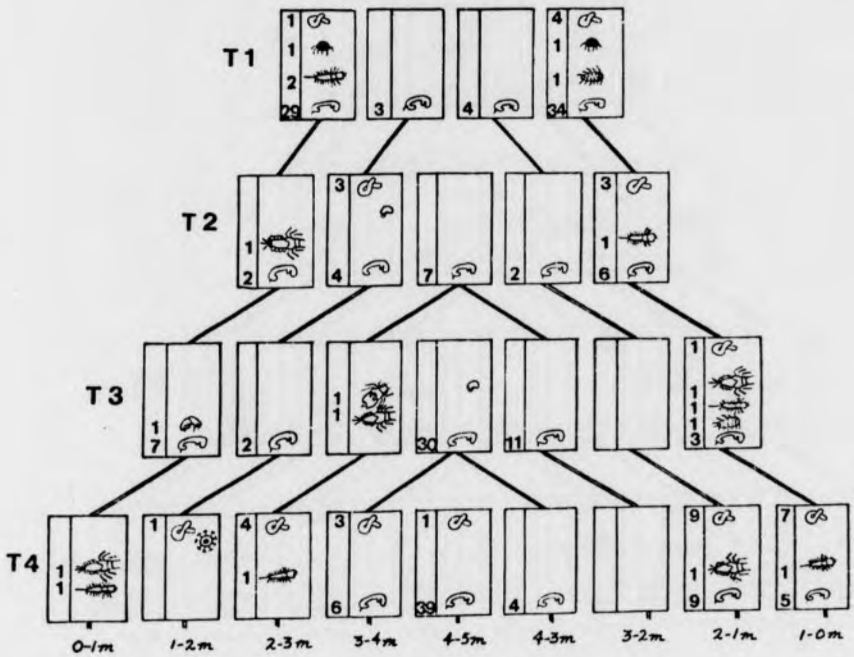

Figure 7. September Samples and Tabulation of Population Sizes According to Depth.

# of samples	DEPTH (m)	ANNELIDA	DIPTERA	EPHEMEROPTERA	ODONATA	MEGALOPTERA	COLEOPTERA	TRICHOPTERA	AMPHIPODA	MOLLUSCA	OSTRACODA	HYDRACARINA	PLATYHELMINTHES	BRYOZOAN	TOTAL
8	0-1	2	44	3	5	4	2		2						62
8	1-2	17	132	2	4	5	1				1				162
5	2-3	6	83	1		1						2		1	94
3	3-4	3	36	1	1										41
1	4-5		50												50
TOTAL		28	345	7	10	10	3		2		1	2		1	409

OCTOBER

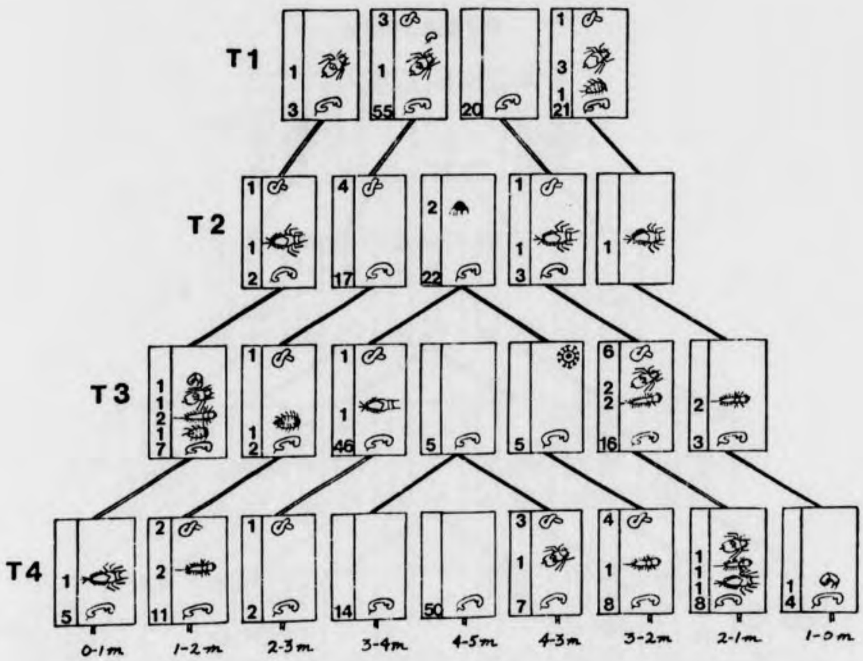

Figure 8. October Samples and Tabulation of Population Sizes According to Depth.

# OF SAMPLES	DEPTH	ANNELIDA	DIPTERA	EPHEMEROPTERA	ODONATA	MEGALOPTERA	COLEOPTERA	TRICHOPTERA	AMPHIPODA	MOLLUSKA	OSTRACODA	HYDRACARINA	PLATYHELMINTHES	BRYOZOAN	TOTAL
8	0-1	24	196	21	6	7	15		1			3		1	274
8	1-2	44	184	8	2		1				2	2		1	244
5	2-3	28	38	16						1	2	3			88
3	3-4	1	24							1	3				29
1	4-5		11								1				12
TOTAL		97	453	45	8	7	16		1	2	8	8		2	647

NOVEMBER

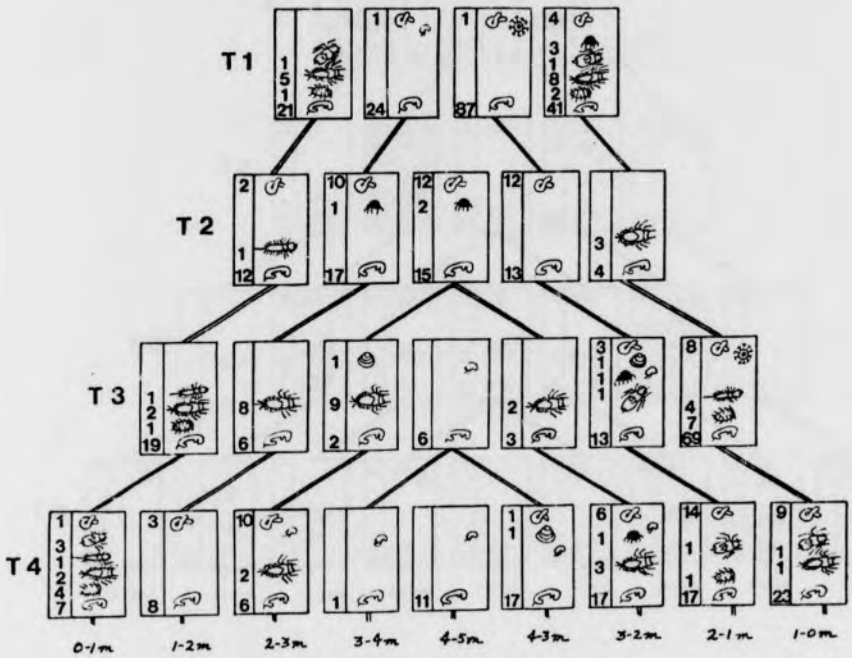

Figure 9. November Samples and Tabulation of Population Sizes According to Depth.

# of samples	DEPTH m	ANNELIDA	DIPTERA	[illegible]	ODONATA	MEGALOPTERA	COLEOPTERA	[illegible]	AMPHIPODA	[illegible]	OSTRACODA	[illegible]	[illegible]	[illegible]	TOTAL
8	0-1	22	6	1		1			1			2		4	37
8	1-2	17	243	27	6	1	2		12	17	2	5	1	2	355
5	2-3	28	53	9					1						91
3	3-4	5	14	2							1			1	23
1	4-5		7												7
TOTAL		72	323	39	6	2	2		14	17	3	7	1	7	415

JANUARY

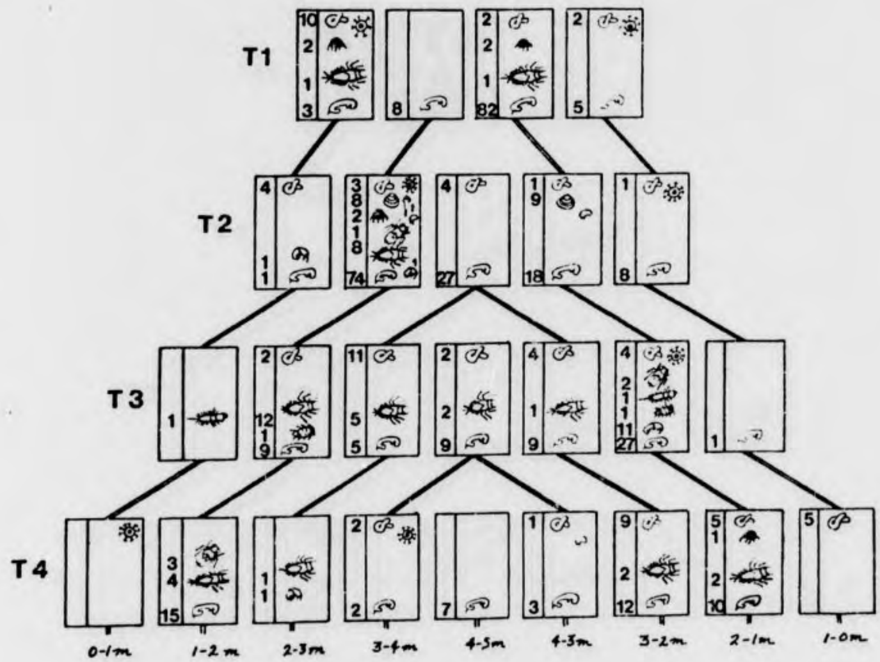

Figure 10. January Samples and Tabulation of Population Sizes According to Depth.

# of samples	DEPTH m	ANNELIDA	DIPTERA	EPHEMEROPTERA	ODONATA	HEMIPTERA	COLLEMBOLA	TRICOPTERA	AMPHIPODA	MOLLUSCA	OSTRACODA	HYDRACARINA	PLATYHELMINTHES	BRYOZOAN	TOTAL
8	0-1	50	82	4	1		3		3			2	1	4	150
8	1-2	34	206	14	1	1	1			1	3	12		2	275
5	2-3	72	79	8	1	1				1	1	2		1	166
3	3-4	10	47	2							2			1	62
1	4-5	1	71								1	1		1	75
TOTAL		167	485	28	3	2	4		3	2	7	17	1	9	728

FEBRUARY

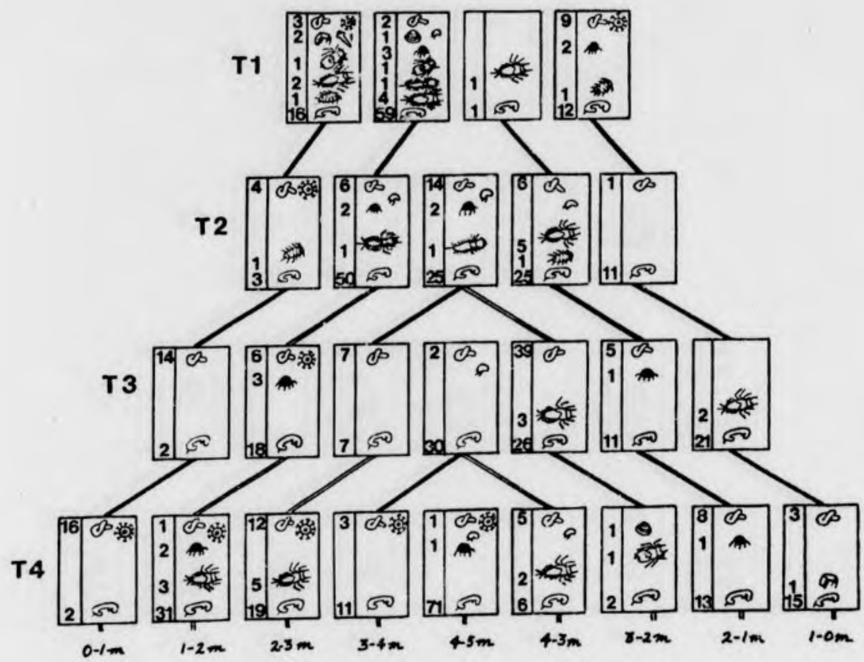

Figure 11. February Samples and Tabulation of Population Sizes According to Depth.

# of Samples	Depth/m.	ANNELIDA	DIPTERA	EPHEMEROPTERA	ODONATA	MEGALOPTERA	COLEOPTERA	TRICHOPTERA	AMPHIPODA	MOLLUSCA	OSTRACODA	ARACHNIDA	PLATYHELMINTHES	PROTOZOAN	TOTAL
8	0-1	37	121	2	4		2	1	1		1	6			175
8	1-2	52	150	5	3	2	2		1	7	1	8	1		232
5	2-3	110	113	7		1				1	1	5		2	240
3	3-4	62	29	4			1			1				1	98
1	4-5	1	47												48
TOTAL		262	460	18	7	3	5	1	2	9	3	19	1	3	793

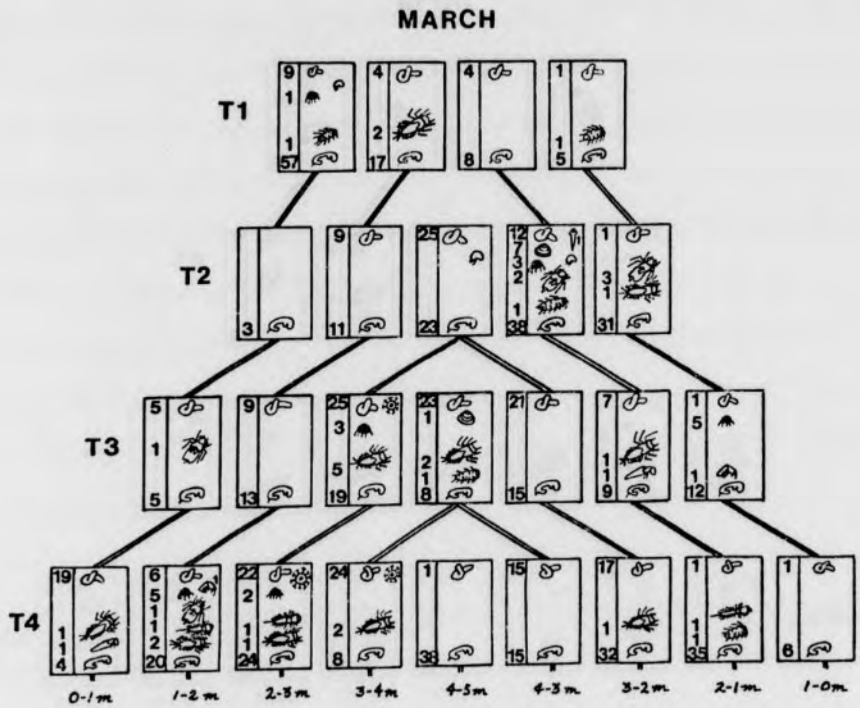

Figure 12. March Samples and Tabulation of Population Sizes According to Depth.

# of samples	Depth/m	ANNELIDA	DIPTERA	[illegible]	ODONATA	MEGALOPTERA	COLEOPTERA	TRICHOPTERA	AMPHIPODA	MOLLUSCA	OSTRACODA	HYDRACARINA	PLATYHELMINTHES	BRYOZOAN	TOTAL
8	0-1	25	191	6	3		2	1	5	1		8		3	245
8	1-2	48	178	6	6			10	1	4		7		2	262
5	2-3	43	51	18	2					3	1				118
3	3-4	20	11	5			2				1	1			39
1	4-5	2	9												11
TOTAL		138	440	35	11		4	11	6	8	2	16		5	675

APRIL

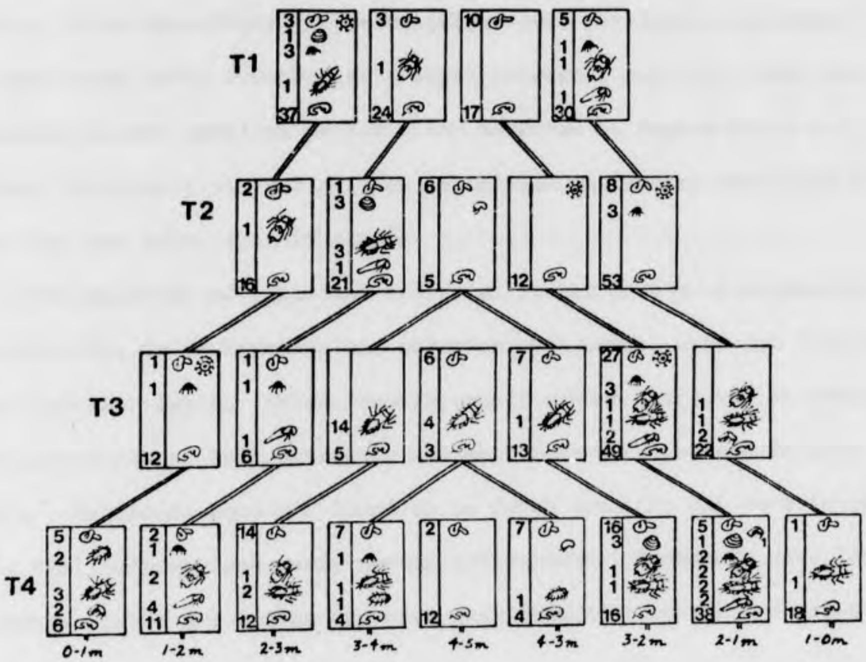

Figure 13. April Samples and Tabulation of Population Sizes According to Depth.

The platyhelminth triclad, Dugesia, was a rare specimen collected only three times during the entire study, once each in January, February, and March. They were not collected below 2 m.

Large pelecypods, specifically Anodonta, were known to be present in the lake for empty shells were observed at the lake's edge after apparent muskrat harvests. They were not, however, collected in benthic samples. Only Sphaeriidae representatives were retrieved, and these were not found until November at a depth between 2 and 3 m. They were collected in each sampling period after November at depths above 4 m, but most frequently above 3 m. The collection in January exhibited more clams than any other monthly sample.

The majority of organisms collected in the cove were arthropods. The arachnids, Order Hydracarina, observed each month, were not limited to any specific depth. After January, their number increased in samples. Of the crustaceans, both ostracods and amphipods were present in some samples. Ostracods were not found to be depth specific and were found in the fall, winter, and early spring collections. Amphipods were found each month in the 0-1 m zone and with less frequency in the 1-3 m region. They were not observed below 3 m.

The Insecta by far had the most representatives in the cove benthos. The megalopterans, specifically Sialis, were not found in great abundance, but the largest numbers found were in the 0-2 m region. They were found more often in the fall than in January and after. April's collection revealed megalopterans absent from the benthos.

Odonata larvae, both anisopteran and zygopteran, were not found with as much frequency as anticipated. After the September sample with its low production of one dragonfly larva from the 2-3 m zone, they did appear more often in the later samples. As with the megalopterans, the odonates seemed to be concentrated in the 0-2 m region, and were not collected below 3 m.

Ephemeroptera larvae, Hexagenia primarily, were rare in September and October samples, but were well represented in the other monthly samples. They were found in depths from 0-4 m, were not as numerous in the 3-4 m zone as in the 1-4 m region, and they were not found in the 4-5 m samples.

Coleopteran larvae seemed to be most commonly found at depths between 0-2 m. Their occurrence was rare on all occasions except in November when a total of 15 individuals was found in the eight samples taken from the 0-1 m zone.

Trichopteran larvae were noted only in the later samples. One was reported in March, followed by 11 in April. All were found in samples from the 0-2 m region.

Dipterans were the most abundant of the benthic fauna in the cove during the sampling period. They were found at all depths and only rarely were they completely absent from a sample. Absence was noted in six samples in September, in one in October, and in four in January. Because of the abundance of dipterans, a more detailed analysis was pursued (Table III). Note that the table values are total numbers, or a summation of all samples taken in each depth zone, not average numbers per sample.

Members of the families Chironomidae, Ceratopogonidae, Tabanidae, and Culicidae were identified and counted. Of those families, the

Table III. Tabulation of Dipteran Populations According to Depth and Months.

	# of Samples	Depth/m	S	O	N	J	F	M	A	Total
			Months							
Chaoborus	8	0-1	1	0	-	-	-	-	-	1
	8	1-2	4	51	66	20	-	2	5	148
	5	2-3	15	60	13	22	12	15	1	138
	4	3-4	37	10	13	5	16	5	-	86
	2	4-5	55	8	5	5	43	20	2	138
Total			112	129	97	52	71	42	8	511
Chironomids	8	0-1	53	28	167	14	65	106	161	594
	8	1-2	11	59	102	203	187	133	163	858
	5	2-3	2	13	20	23	52	88	46	244
	4	3-4	25	15	3	5	23	22	9	102
	1	4-5	21	29	2	1	14	13	5	85
Total			112	144	294	246	341	362	384	1883
Ceratopogonids	8	0-1	26	14	27	4	17	15	26	129
	8	1-2	7	22	16	20	19	15	10	109
	5	2-3	1	10	5	8	15	10	4	53
	4	3-4	9	1	8	4	8	2	2	34
	1	4-5	2	13	4	1	14	4	2	40
Total			45	60	60	37	73	16	44	365
Tabanids	8	0-1	6	2	2	-	-	-	4	14
	8	1-2	-	-	-	-	-	-	-	
	5	2-3	-	-	-	-	-	-	-	
	4	3-4	-	-	-	-	-	-	-	
	1	4-5	-	-	-	-	-	-	-	
Total			6	2	2				4	14

tabanids, specifically Chrysops, were the rarest. They were recovered in samples taken in September, October, and November, and then not again until those of April. When collected, they were restricted to the 0-1 m zone.

The only culicid sampled was Chaoborus. Members of that genus were present on all sampling dates and they were found at the various depths. However, the 0-1 m zone was devoid of any Chaoborus from October until April.

Ceratopogonids were common constituents of the dipteran population in the study cove, being found at all depths during any of the sampling months. This observation is also true of the chironomids except that the chironomids were the most predominant population in the cove.

The only other invertebrate group found in collections were oligochaete members of the Phylum Annelida. Next to the dipterans they were the most abundant population. They were found at all depths, but most frequently in the more shallow zones. From October until January, they were not trapped in 4-5 m collections.

Chironomid-oligochaete associations were examined. Chironomids and annelids were found together in 69% of all samples. Annelids were rarely found, only 3% of the time, when chironomids were absent. When annelids were absent, the chironomids were found in lesser numbers, in only 21% of the samples, than when found in the coexistence situation. When annelids were not present in a sample and chironomids were, the chironomids sampled averaged six to seven individuals. In samples where coexistence occurred, the chironomid average doubled to 14 individuals per sample. This represents a 100% increase and a much more stable situation noting that coexistence was the most common occurrence in the samples.

Statistical analyses. Computer print-outs for TSAR programs processing data concerning sediment weights, conductivity, and oxygen gave the necessary information for preparation of figures and tables. SAS results on the basis of the subjective sediment data attempted to characterize different samples as either organic or non-organic. A range between the two extremes was also attempted as well as organism association with the various sample types.

Samples did not fit into defined categories and no relationships between organisms and sediment types could be determined.

DISCUSSION AND SUMMARY

This study has provided supportive evidence that Lake Jeanette, according to Hutchinson's (1957) criteria, is a second class, warm, monomictic lake. It is a relatively young lake under wildlife management and, therefore, receives no major contribution of either chemical or thermal pollutants.

Sampling technique. Benthic sampling and processing is a very difficult, laborious, and time consuming procedure. For this reason it has repelled and frustrated many investigators. The problems of benthic sampling have been well enumerated by Holme (1964), and many attempts have been made to circumvent the difficulties. Methods such as the Ekman dredge, Peterson grab, sweep net, and multiple plate collectors are the only samplers readily available to the investigator and have, therefore, become accepted as the standard benthic sampling procedures.

Attempts to improve benthic studies have caused deviations from the conventional methods. Designs for oceanographic and limnological purposes have been interchanged and modified. The result is numerous custom-made sampling devices. To name a few: Kajak and his associates (1965, 1971) used a plexiglass tubular sampler; Duke et al. (1968) produced a plastic core and stopper arrangement for shallow marine sampling; Menzies and Rowe (1968) built a LUBS, large undisturbed bottom sampler; Mackey (1972) devised an airlift method for obtaining benthos; Frey, Bason, and Scott (1973) used "can cores"; and then Rowe and Clifford (1973) modified a Birge-Ekman grab for hand operation for use with SCUBA. Each sampler has its own advantages and disadvantages. No one technique has yet satisfied the requirements for the "perfect" sampler. None of these samplers is produced on a large scale market so as to increase availability to investigators. Therefore, the investigator is required to either accept out-dated methods or construct his own sampler, be it a copy of a more recent design or an original device to meet his needs.

The sampling method designed to study the cove benthos of Lake Jeanette was successful. It eliminated tedious and perhaps erroneous equating of various sampling techniques. The procedure used allowed uniform treatment of samples during collection. The absence of movable sampler parts reduced the chance of malfunction as was experienced with an Ekman grab when sediment particles lodged in spring mechanisms prevented closure of the bite and caused unnecessary interruption of the mud-water interface. The added feature of a collection bag accessory insured orderly and easy transport and storage of samples. Incorporation of SCUBA in the collection technique was an asset to benthic sampling. The investigator could observe the study area which was impossible or not feasible when conventional sampling methods were originated. Modification of the sifting process greatly reduced time spent in sample preparation.

Morphometry. The depth measurements indicated a very gradual slope in the cove from north to south. At T1 on the eastern shore, a very sharp drop from 1-2 m was found. The basin was very smooth, though, with no acute obstructions detectable other than fallen trees at the shoreline and an inflow trench where a drainage stream entered the eastern side of the cove between T2 and T3.

The shape of the bottom or input of streams apparently did not obviously influence the distribution of organisms. Clumped distribution with varying densities could not be related to basin shape. The drop in water level had no apparent affect on the total number of organisms collected either. No interruption of the observed increase of organisms in the cove was seen during October and November samples, the months most likely to reveal alteration resulting from these causes. The drop might have caused a reduction in the rate of increase of population size, but no data presented here can support that hypothesis. The example of *Chaoborus* might illustrate an effect of the drop in water level on individual populations. The population disappeared totally from the 0-1 m zone from October through March. Since this organism has a daily cycle between the sediments and their overlying water, removal of water above the substrate inhabited by *Chaoborus* would drastically change the environment either killing the population or causing a migration. Whichever occurred in the 0-1 m zone, the population was not able to reestablish itself again until April.

Chemistry. The bottom waters of Lake Jeanette proved to be circumneutral with respect to pH. Ionic concentration was within the range of values Weiss, Anderson, and Lenat (1972) reported for Belews Lake, a much younger, North Carolina lake. If 1600 umhos/cm approximates 1,000 mg dissolved solids per liter water (Barnstead Company 1971) the values recorded for the cove water indicated a low level of dissolved solids. The values could also be interpreted as indicating that eutrophication was of a low degree.

The conductivity of the cove water dropped steadily from September until March, but in April an increasing trend was detected. There appears to have been perhaps a cyclic nature to the conductivity in the cove. The drop in ionic concentration from September to March indicated a binding or perhaps an uptake of inorganic nutrients by populations or the mud substrate. Considering that mud liberates ions as oxygen disappears (Hutchinson 1957), it was difficult to determine what was happening to ion availability to the benthos. Oxygen in ppm was increasing in the winter. Colder water physically can absorb more oxygen than warmer summer waters. Oxygen in these terms is increasing, not disappearing, and ions were decreasing according to the conductivity data. Oxygen saturation, however, was decreasing, but not to extreme depletion. It is suggested that populations in the cove were depleting oxygen and ions from the water in the process of body maintenance. In the spring, with the advent of increased photosynthetic activity, oxygen levels increased and so did the ionic concentration.

Oxygen in the cove did not approach dangerously low levels, but could be considered relatively abundant during the sampling period. In September, the cove appeared stratified with oxygen deficits below 1-2 m. High percentages of saturation for oxygen were both expected and observed in the 0-1 m and 1-2 m zones. The percents of saturation in the entire cove declined during the winter months and then increased in the spring. By April, however, the bottom of the shallow zones had begun to be supersaturated with oxygen, whereas the percent of saturation declined markedly below 3 m.

The decrease in oxygen on the bottom below 3 m is evidence of lack of photosynthetic activity in that zone probably resulting from shallow light penetration, a Secchi disk transparency of 1.22 m. The supersaturation of oxygen in the shallow zone could be attributed to increased or optimal conditions for photosynthesis. The beginning of thermal stratification in April would deter mixing of the oxygen produced and absorbed in the upper, shallow zones to the lower, deeper zones, and would increase distinction between oxygen saturations.

Sediment. The observed percentage composition of the sediment samples was anticipated. The coarser, larger particles were expected to fall out of the water near their origin or not be carried in the water flow far from shore. Less dense, smaller particles were expected to settle at a slower rate and could, therefore, be transported in greater quantities than coarser particles to the deeper zones.

The small shallow depressions observed in the fine benthic sediments are believed to be caused by chironomid tubes as illustrated in Jonasson (1969).

During December, January, and February, the highly erodable soils surrounding the lake were exposed to rinsing by heavy precipitation falling in those months (Table II). The observed decrease in transparency values from September to February, 1.22 m to 0.46 m, respectively, could have been influenced by rain washes through construction clearing occurring in the Lake Jeanette watershed. Photographic evidence supporting this conclusion shows distinct inflow patterns of sediment-laden water in the lake body. The introduction of sediment to the water could also bind or absorb ions from the water and cause the observed decrease in conductivity during the months.

In March and April, transparency increased in the lake water. While March was a wet month, the individual rains were not heavy enough to maintain the high sedimentation washes of the previous months. The effects of sediment in the water were eased. Accumulation of sediment was not investigated, and since percentage composition did not change during the sample period, it is assumed that sediment entering the lake body was very fine and slow to settle. The water transparency was never greatly cleared, exhibiting a maximum transparency of 1.22 m.

Vegetation. Vegetation deteriorated in the 0-1 m zone when it was exposed to the drop in water level experienced in the late fall. Annual dying of some of the plants, dessication, and burial by discarded autumnal foliage from the surrounding woodlands were responsible for the deterioration of the vegetation. Dying aquatic plants and defoliation increased the amount of organic detritus in the cove during the winter. The presence and absence of vegetation causes a continual change in physical barriers, refuges and brood chambers for insect larvae, supply materials for tube building organisms, and food and food traps.

Macroinvertebrates. The devised sampling technique collected small sample populations with high deviations between the sample populations of benthic organisms, and indicated that macroinvertebrates were distributed in clumps throughout the study cove.

Depth appeared to have some limiting effect on the distribution of populations of tabanids, trichopterans, planarians, amphipods, megalopterans, and odonates (Fig. 14). These populations were found from 0 m to some deeper range limit. Pelecypods, ephemeropterans, and coleopterans possibly had lower limits to their ranges, but this is debatable when the number of samples collected below 4 m is considered. No population sampled demonstrated an upper and a lower limit. Depth did not appear to regulate distribution of annelids, hydracarinids, ostracods, culicids, ceratopogonids, or chironomids.

Differences in chemical concentrations, physical stresses, sediment sizes, and food availability are the limitation factors associated with change in depth. In addition, mobility of a population and in the case of larval populations, oviposition habits of the adults could limit a population's location to the shallows.

Of these organisms found in the 0-3 m region, all but the planarians and amphipods were larval populations. The eggs of tabanids, megalopterans, and odonates were deposited at the water's edge, and as development proceeded, access to the shore insured favorable conditions for emergency. This was true of trichopterans also, but Pennak (1953) states that oviposition habits of this order are varied. Deposit of eggs or hatched larvae in the water might have occurred over deeper water. Most Insecta larvae appear to originate near the shore; since they are found great distances from the shore, they must migrate to deeper water. The tabanids, however, are not structurally adapted for mobility, and hence were not collected at deeper water stations.

Planarians and amphipods represented populations passing their entire life cycle in the water. Neither of these were numerous enough to be significant inhabitants in the cove; yet since amphipods are

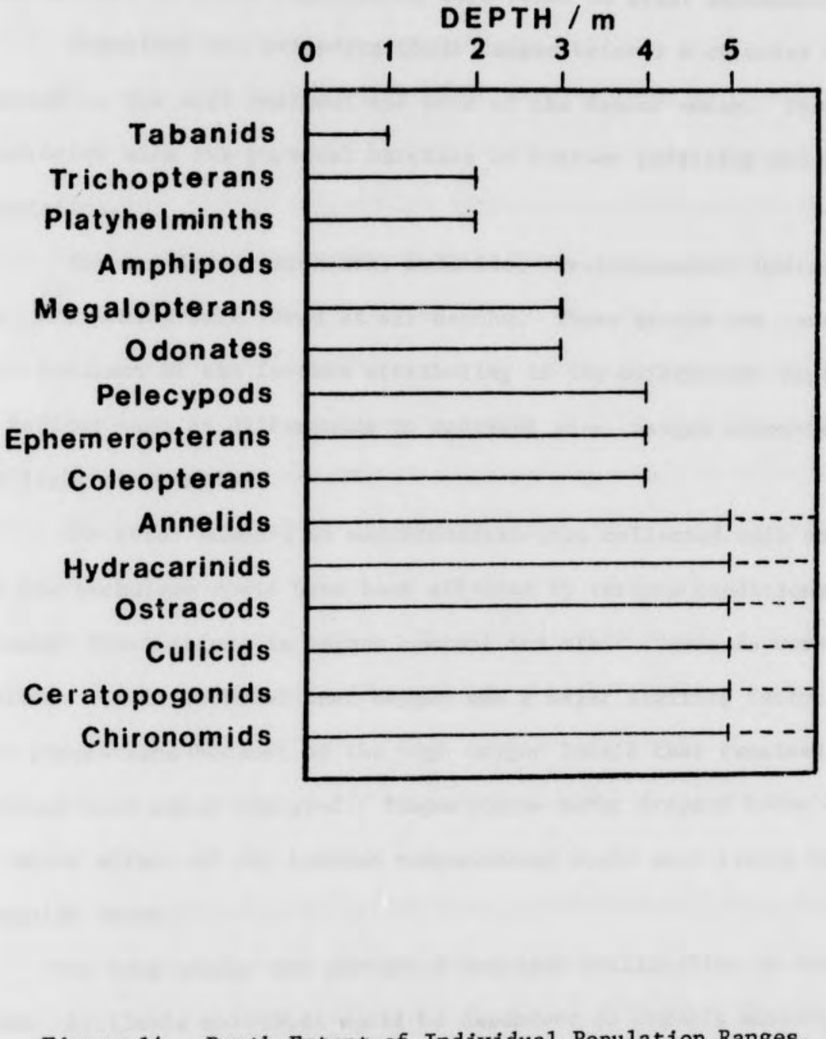

Figure 14. Depth Extent of Individual Population Ranges. The lower limit or deepest depth of sample that each organism was found in, at anytime during the study period is marked in meters.

indicators of unpolluted waters, their presence was significant. Odonates also are indicators of unpolluted conditions. It is curious that neither of these populations were found in great abundances.

Organisms not extending their ranges below 3 m of water were not exposed to the soft sediment and ooze of the deeper zones. They were confronted with the physical barriers of coarser particles and dense vegetation.

The annelids, ostracods, culicids, ceratopogonids, hydracarinids, and chironomids were found at all depths. These groups are considered more tolerant of the factors attributing to the differences depth makes in habitat such as differences in sediment size, oxygen concentration, and light penetration.

The total numbers of macroinvertebrates collected each month by the new technique could have been affected by various conditions. Seasonal fluctuations in oxygen content and other chemicals were recognized. It is doubtful that oxygen was a major limiting factor for cove populations because of the high oxygen levels that remained in the cove and were never depleted. Temperatures never dropped below 4° C. The major effect of the lowered temperatures would most likely be reduced metabolic rates.

The long winter mix permitted nutrient availability to the benthic fauna. Available nutrients would be dependent on organic materials present and their conditions. As already mentioned, the heavy washes through the surrounding watershed, defoliation, and dying aquatic vegetation maintained a supply of plant detritus to the cove. Lush and Hynes (1973) presented evidence that water reaching lakes through watersheds contained soluble organic materials in a form accessible to organisms as food. Hence, organic nutrients probably were not limiting factors either.

The numbers collected indicated that populations were not limited, but rather were increasing in numbers. Oxygen deficits and a decrease in ionic concentration would be associated with macroinvertebrate populations increase. The observed high oxygen saturations in the shallows would be required for organisms needing high levels of oxygen for survival such as amphipods and developing insect eggs and larvae.

Nutrient deficiency and decreased oxygen concentration in the hypolimnion, along with cropping of populations by predators might be considered unfavorable conditions and probably result in decreased population numbers. Baker and Schmitz (1972) observed that gizzard shad are effective predators on benthic organisms. Gizzard shad are present in Lake Jeanette, but the predatory effects of them were not investigated in this study. It is known that insect emergence reduces number of aquatic insect larvae in late spring, summer and early fall. Low total numbers of organisms collected in September most likely were a result of these conditions.

As the restraints of stratification were relaxed after September, total numbers of organisms in the cove increased. 1) Decreased predator pressures resulting from temperature drops and reduced metabolic rates, and 2) the development of eggs laid in the summer and early fall accounted for the noted population increase.

The decrease in total numbers recorded in January might be the result of increased predation, but most likely can be attributed to sampling error. The cold temperatures of the water and the inclimate weather made sampling a very unpleasant experience and prevented sediment sampling in December, and perhaps influenced the precision of the sampling technique in January.

The upward trend in population numbers resumed after January and continued to increase through the next two months. A stratification began to occur in April, insect emergency commenced, and the total numbers decreased. Predation pressures are also assumed to have increased in intensity at this time.

Loden (1974) presented evidence of chironomid predation on aquatic oligochaetes. It was this information that instigated the examination of chironomid-oligochaete associations in this study. Even though gut analyses were not performed, a numerical correlation and possibly a relationship was discovered. The organisms were found most often coexisting. Coexistence seemed much more favorable to the chironomids since the frequency of finding chironomids alone in ratio to the frequency of finding them with oligochaetes was 24% : 76%. When found with annelids, the number of chironomids was seen to increase 100% from the numbers found in samples without oligochaetes.

Brinkhurst (1969, cited by Peterka 1972) found the number of oligochaetes in relation to the number of chironomids as an indication of the organic enrichment or state of eutrophy of the water system observed. The more organic material, the greater microbial activity and growth, the more food available to the oligochaetes, and the more ability to support a predatory chironomid population. Since the mean number of both populations was so low, it should be safe to say that the cove did not show an advanced state of eutrophy.

Statistical analyses. The attempts to categorize samples by sediment types were futile and the results produced were not conclusive. The defining terms for the categories were too subjective. If more strigent physical tests could have been employed in determining substrate nature, the computer would have produced completely different and revealing results. Since this study is a problem of field biology, the rigors of statistical analysis were too severe or critical and the methodology too crude to detect the intricate patterns of distribution existing in the benthic macroinvertebrate community of the cove. However, the investigator feels that the trends suggested in this text have a sound foundation and could lead to more detailed analysis of benthic habitats.

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