POPULATION DYNAMICS OF HYDRA IN PINE LAKE

by

Patricia S. Reeder

Submitted in Partial Fulfillment of the Requirements

for the Degree of

Master of Science

in the

Biological Sciences

Program

Lauren Schroeder June 13, 1979

Advisor Date

6-13-79

Dean of the Graduate School Date

YOUNGSTOWN STATE UNIVERSITY

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June 11, 1979
Dean of the Graduate School — Date

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ABSTRACT

POPULATION DYNAMICS OF HYDRA IN PINE LAKE

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Conflicting reports on the density patterns of hydra populations in temperate lakes have been published. Some authors have found an annual unimodal pattern while others have reported a bimodal pattern. I studied hydra in Pine Lake, a shallow medium hard water Ohio Water Service Lake in southeastern Mahoning County, Ohio, in order to examine the population characteristics of hydra collected on slides and the relationship of these characteristics to environmental factors. The environmental factors examined were wind velocity and direction, temperature, transparency, zooplankton density, chloride ion concentration and conductivity.

Two species of hydra, *Hydra oligactis* and *Hydra pseudoligactis*, were found to coexist in Pine Lake in the fall. The population density pattern observed was bimodal with spring and fall maxima. Bud ratios and dry weights of hydra collected on slides in open water showed they were healthy and reproducing asexually.

Temperature and zooplankton density were not significantly related to growth axis density, hydra density or bud ratio. Water transparency had a positive relationship to growth axis density, hydra density and bud ratio in the upper half of the water column and a

strong correlation with zooplankton density throughout the water column. An upward migration of the spring population from lower to higher depths was observed and may be related to water turbulence generated by wind or to an increased rate of detachment of hydra from plants in the littoral zone and subsequent movement of detached hydra into open waters.

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation to Dr. Lauren Schroeder for his valuable advice and support during this research. I also wish to thank Drs. David MacLean and Dale Fishbeck for input in the preparation of this manuscript.

This research would not have been possible without the assistance of many students in the collection and maintenance of hydra. I wish to express my appreciation to Marie Semko, Marie Mussolino, Tony McIlduff, Don Scott, Wes Hilbert, Bill Callaghan, Karl Heaver and George Mateja.

Finally I wish to thank Mr. Steve Mihalko of Pine Lake and the Ohio Water Service for the use of Pine Lake and its facilities.

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LIST OF SYMBOLS

SYMBOL	DEFINITION
GA	Growth Axis
H	Hydra
sd	Per Slide per Day
SD	Standard Deviation
SE	Standard Error
ID	Identification Number
M	Meter
Ho	*Hydra oligactis*
Hp	*Hydra pseudoligactis*
ug	Micrograms
W	Wind
T^{o}	Temperature in Degrees Celsius
No/L	Number per Liter
Vel	Velocity in Miles per Hour

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INTRODUCTION

Biologists usually consider hydra to be sessile organisms with limited modes of locomotion and members of the aufwuchs community. If hydra are part of the aufwuchs they would be limited to the littoral zone due to the lack of supports in deeper water. Although rarely confirmed by direct observation, abundant evidence for the occurrence of hydra in open waters far from plant supports has been recorded. A limited number of hydra have been reported collected by plankton tows (Miller, 1936; Moen, 1951; Carrick, 1956; Kofoid, 1904 and Eddy, 1927) although some of these tows may have been through plant beds (Miller, 1936, Moen, 1951). Welch and Loomis (1924) observed large numbers of floating and subsurface hydra in Douglas Lake, Michigan following strong wave action. The presence of hydra in open waters has been demonstrated indirectly by colonization of artificial substrates (Miller, 1936, Bryden, 1952, Carrick, 1956, Batha, 1974, and Schroeder et al, unpub), fish nets (Clemens, 1922, Moen, 1951), fish troughs (Beardsley, 1902, Clady and Ulrickson, 1968), waterworks intake screens (Hudgins, 1931) and the lateral movement of marked hydra (Bryden, 1952).

Seasonal population pulses of hydra have been observed on plant supports by Welch and Loomis (1924) and Griffing (1965), on artificial supports in open waters by Carrick (1956), Batha (1974) and Schroeder et al (unpub) and on both natural and artificial supports by Miller (1936) and Bryden (1952). Bryden and Batha found one annual peak in population density, varying from late spring to fall, while Carrick (1956), Moen (1951), Yu (1976) and Schroeder et al (unpub) found two annual peaks, one in late spring and another in the fall. Miller (1936) observed two annual population peaks for hydra on submerged vegetation but only one on slides.

The appearance of planktonic hydra has been attributed to wave action (Welch and Lommis, 1924), floating caused by food shortage (Griffing, 1965, Lomnicki and Slobodkin, 1966), changes in specific gravity (Kofoid, 1904) and temperature (Batha, 1974). Lomnicki and Slobodkin (1966) observed the floating behavior of H. littoralis in the laboratory and concluded that the number of hydra that are floating depends on the degree of crowding and starvation. Schroeder and Reeder (1980) found the rate of sinking of hydra was inversely related to duration of fasting, inversely related to rearing temperature and directly related to water temperature. These data indicate that starved hydra in cold water would remain in the water column for the longest period of time.

The decline in hydra population density has been attributed to high temperature (Welch and Loomis, 1924), low temperature (Bryden, 1952, Batha, 1974), lack of food (Bryden, 1952), predators and parasites (Griffing, 1965), competition for supports (Miller, 1936, Batha, 1974), floating to unfavorable environments (Griffing, 1965) and rapid sinking in convergences (Batha, 1974). Most of these authors agree that hydra tolerate the range of pH, dissolved oxygen and water pressure reported by Welch and Loomis (1924), conditions found in most temperate lakes. Bryden (1952) suggested the downward migration on bulrushes prior to the decline noted by Welch and Loomis (1924) was due to the high transparency of Douglas Lake while the tendency for hydra to remain on the slides at 10 - 20 cm in Kirkpatrick's Lake could be ascribed to the lake's very low transparency (0.3 - 0.9 meters).

The purpose of this study was to determine the population dynamics of hydra found in the open waters of Pine Lake, a shallow Ohio Water Service lake in southeastern Mahoning County, Ohio. Annual population density patterns, percentage colonization of artificial substrates, and the condition of the hydra as indicated by their bud ratios and weight were determined. Factors which might influence the appearance or disappearance of hydra in the planktonic phase were included in the study. These factors were availability of food, temperature, transparency, conductivity of the water, concentration of chloride ions and the direction and velocity of the wind.

METHODS

Hydra collection and counting

The observational period extended over fifteen months from April, 1977 to June, 1978. When hydra were present collections were made weekly. After the hydra disappeared collections were biweekly with the exception of the period of ice cover, December, 1977 to March, 1978. Collections were made through the ice over a three week period from the last of February to the middle of March.

Hydra were collected on 25 by 75 mm glass microscope slides. Four slides were inserted horizontally into #7 one-holed rubber stoppers. Seven rubber stoppers strung at 0.5 M intervals on plastic clothesline constituted one hydra trap. Each trap, consisting of 7 stoppers and 28 slides, was anchored at the bottom with a concrete filled can and buoyed at the top with two styrofoam floats. One float was attached closely to the 0.5 M stopper, the other extended 1 - 2 M along the surface of the water. Four clean traps were set in the lake on each collection date. Collected slides from three of the traps were placed in separate vials filled with lake water and returned to the laboratory for counting. The number of slides recovered from each trap was recorded. The hydra were gently removed from the slide and vial and counted in 11 cm culture dishes. The number of hydra for each bud class (0 buds, 1 bud, - - - n buds) were recorded separately for each slide from each trap. Hydra counts were always made the day of collection. The slides from the fourth trap were collected in separate vials of 4% formaldehyde, stoppered and returned to the laboratory for counting. The preserved hydra were kept for gut analysis. Hydra counts were recorded as growth axes density per slide per day and hydra per slide per day. Any visible polyps, whether attached or unattached to a parent hydranth, is a growth axis. A hydra is a polyp with a basal disc and may or may not have additional growth axes.

On the day of collection, if enough hydra were available, a sample of 15 - 20 hydra was taken by removing all hydra in a given space in the culture dish and transferred to a tared aluminum boat. Samples were from as many depth levels as possible. The hydra were dried overnight in a vacuum oven at 60°C., removed to a $CaCl_2$ dessicator and reweighed to a precision of 0.1 µg, using a Model G-2 Cahn Electrobalance.

Identification of hydra

Hydra were identified by the nematocyst morphology based on keys by Ewer (1948) and Hyman (1930, 1931).

Wind

Wave conditions were noted on the day of collection. Wind direction and velocity were obtained from the National Weather Service located at Youngstown Municipal Airport, Youngstown, Ohio.

Temperature

Temperatures were measured with a Model FT3 Hydrographic Thermometer (Applied Research Austin). The probe cable was marked at 0.5 M lengths and temperatures in $0^{o}C$ were recorded for air, surface water and intervals of 0.5 M to the lake bottom (approximately 3.5 M).

Transparency

An 8 inch Secchi disc with cord marked at 10 cm lengths was used to measure transparency, recorded in meters.

Water Analysis

Water was collected at 1 M and 3 M using a Kemmerer sampler. During late summer and the fall of 1977 the lower water level at the lake occasionally required collection at 2.8 M rather than 3.0 M. The water was used to measure chloride ion content and conductivity.

Chloride ion analysis

The Mercuric Nitrate method as described in Water and Wastewater Analysis Procedures Catalog #10, Hach Chemical Company, p. 16, was used for chloride ion analysis. The procedure was modified by the use of 1/3 of a Diphenylcarbazone Indicator - Buffer powder pillow for each sample. This procedure made the endpoint easier to see. Triplicate samples were done for each depth. Results were calculated as the mean of three samples.

Conductivity

Measurements were made with a Lab-line Lectro MHO-Meter, Model MC-1, Mark 1v, using a K = 1.0 cell at 10^3 multiplication level. Triplicate readings were taken for each depth and the mean calculated.

Zooplankton density

Water was collected by a 2.97 L Kemmerer sampler, except for the weeks of 24/3/77 and 1/4/77 when a single sample was collected using a 9 liter Wilson bottle. Comparison of zooplankton collections by bottle and by vertical net tows (Hodgkiss, 1977) suggests that the use of of a Kemmerer sampler may result in a decreased number of zooplankton due to escape of some of the faster moving organisms but rarer species are collected by this method compared to net collections. The water was poured through the sieve portion of a plankton net and the collected plankton washed into a 250 ml plastic wide-mouth bottle using a stream of filtered lake water from a wash bottle. Approximately 80 - 100 ml of sample resulted from this method. Triplicate samples were taken at depths of 1 M and 3 M. From 3/24/77 to 7/26/77, 10 ml of 40% formalin was added to each bottle to preserve the organisms. From 8/8/77 to the end of the observational period the zooplankton were preserved by adding 10 ml of club soda, allowing to stand about 4 minutes, then adding 10 ml 40% sucrose solution followed by addition of 10 ml of absolute formalin. This is the method developed by Haney and Hall (1973) and results in retention of eggs and less ballooning of carapaces for cladocerans. The preservation described above was done at the collection site. In the laboratory, each zooplankton sample was concentrated by pouring through a #20 silk bolting cloth and washing into a vial with about 3 ml of a mixture of 4% sucrose - 4% formaldehyde in water. Zooplankton were counted in a Sedgwick-Rafter counting chamber, and identified by use of taxonomic keys in Ward and Whipple (1959) and Pennak (1953). The Sedgwick-Rafter was placed on a lined Petri dish to facilitate counting. Counts were made using a dissecting microscope with overhead lighting and a black background. Total counts were taken for each triplicate sample at both depths. Means, standard deviations and standard errors were calculated for each taxon and for total zooplankton at 1 M and 3 M. The means and standard errors from the two depths were then totalled and divided by two to give a mean value, expressed as No./liter, with standard error for the water column.

RESULTS

Population dynamics of hydra

Planktonic hydra collected at Pine Lake throughout an observational period of fifteen months showed an annual bimodal density pattern similar to the pattern observed by Carrick (1956), Yu (1976), Schroeder et al (unpub). A sharp increase in numbers of hydra colonizing slides occurred in the springs of 1977 and 1978 on May 13 and May 25, respectively. Decline in population density was rapid with no hydra found two weeks after the peak population density. Population densities expressed as mean number of growth axes per slide per day are given in Table 1. Hydra densities are in Figure 2. The large standard error is a reflection of the irregular colonization patterns. The change in total mean growth axes per slide per day with time is shown by Figure 1, using standard errors as a measure of central tendency. Hydra reappeared on the slides August 23, 1977, the only summer occurrence. Due to the fifteen day period between collections, the high water temperature and the location of all hydra at the 0.5 M level on one trap, reproduction was undoubtedly an important factor in the number of hydra collected on August 23, 1977. Some of the hydra from August 23 were identified by Bill Callaghan of this laboratory as H. pseudoligactis, Pallas. Ninety-three per cent of hydra found on September 20, 1977 were clustered on the outer quarter inch of one slide. The long interval (11 days) between collections and the warm water probably resulted in reproduction making a significant

Table 1. Changes in Hydra density with time.

DATE	GA/sd	SE
16/4/77	0.268	0.067
23/4/77	0.634	0.154
30/4/77	0.125	0.042
7/5/77	0.188	0.062
13/5/77	5.673	0.972
21/5/77	0.144	0.031
28/5/77	0.004	0.004
23/8/77	0.376	0.293
20/9/77	0.265	0.254
27/9/77	0.004	0.004
4/10/77	0.052	0.016
14/10/77	0.210	0.043
20/10/77	0.057	0.020
27/10/77	0.015	0.008
3/11/77	0.055	0.022
10/11/77	0.308	0.099
17/11/77	0.194	0.037
23/11/77	0.006	0.005
20/4/78	0.721	0.179
27/4/78	0.661	0.109
4/5/78	1.238	0.288
11/5/78	0.613	0.106
18/5/78	0.194	0.038
25/5/78	2.323	0.202
1/6/78	2.034	0.294
8/6/78	0.017	0.010

Fig. 1.--Changes in growth axes per slide per day with time. Vertical lines indicate standard errors.

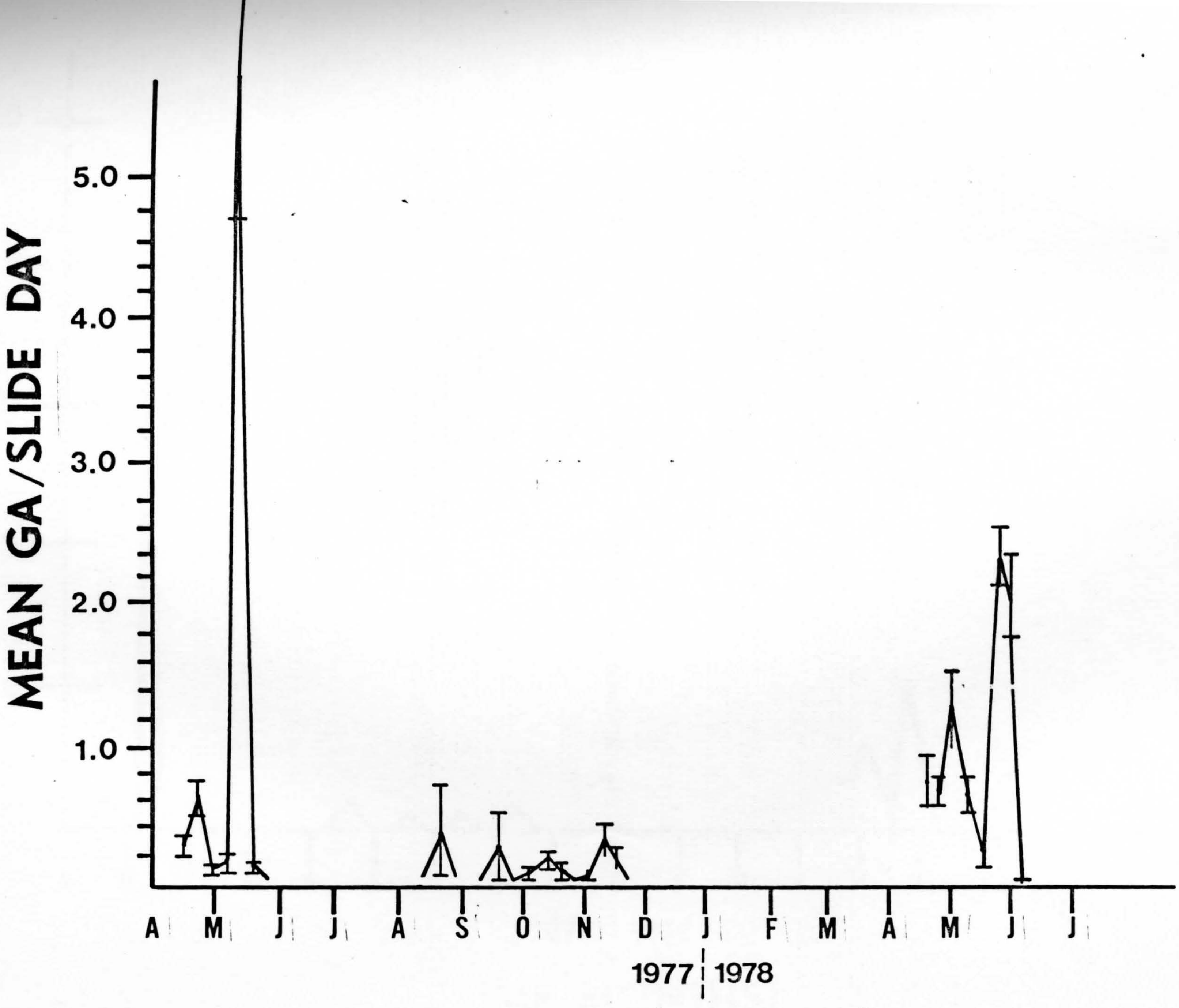
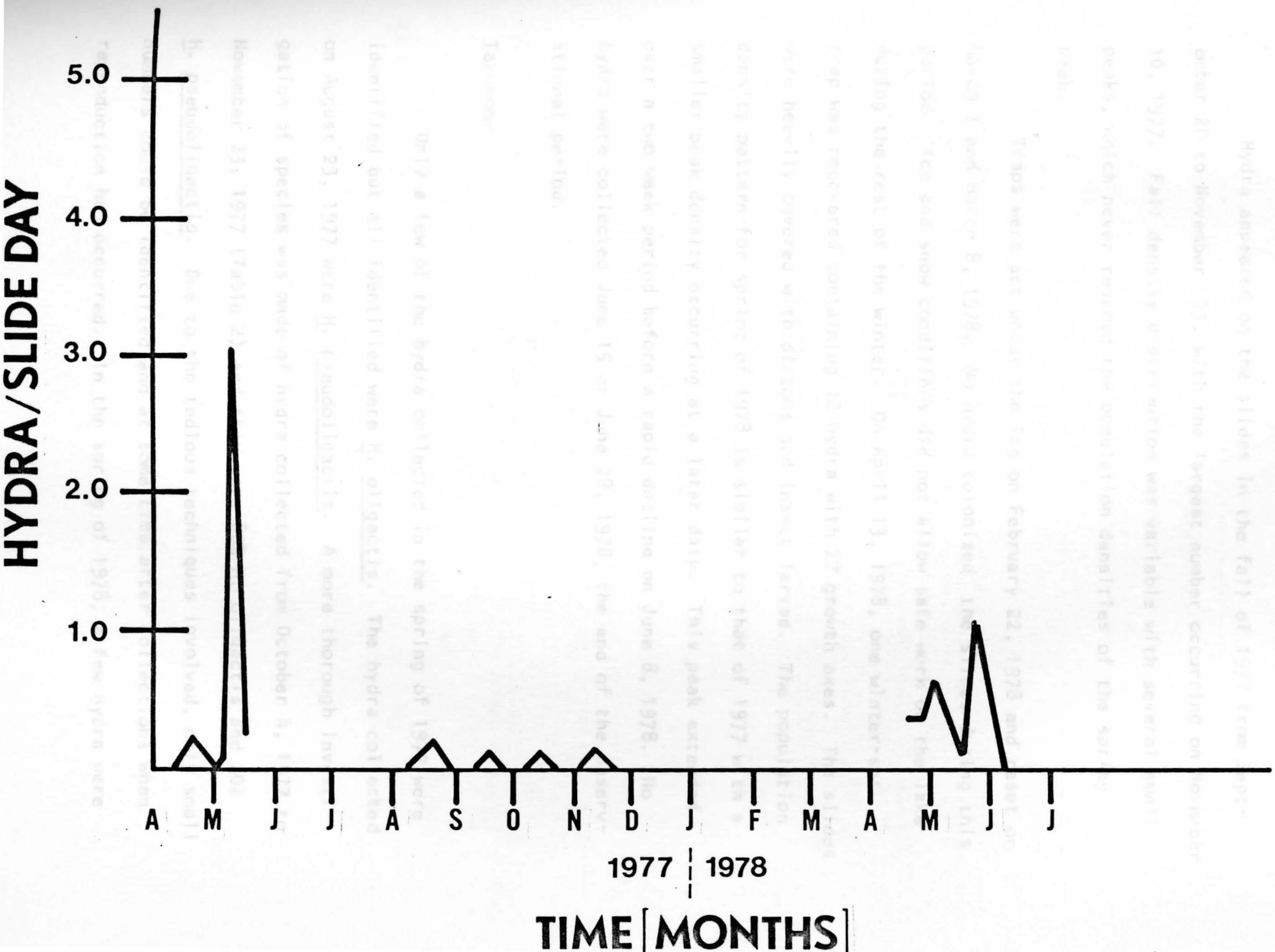

MEAN GA/SLIDE DAY
5.0
4.0
3.0
2.0
1.0
A M J J A S O N D J F M A M J J
1977 1978

Fig. 2.--Change in hydra per slide per day with time.


HYDRA/SLIDE DAY
5.0
4.0
3.0
2.0
1.0
A
M
J
J
A
S
O
N
D
J
F
M
A
M
J
J
1977
1978
TIME [MONTHS]

contribution to the high numbers and clustering.

Hydra appeared on the slides in the fall of 1977 from September 20 to November 23, with the largest number occurring on November 10, 1977. Fall density distribution was variable with several small peaks, which never reached the population densities of the spring peak.

Traps were set under the ice on February 22, 1978 and reset on March 1 and March 8, 1978. No hydra colonized the slides during this period. Ice and snow conditions did not allow safe work on the lake during the rest of the winter. On April 13, 1978, one winter-set trap was recovered containing 12 hydra with 27 growth axes. The slides were heavily covered with diatoms and insect larvae. The population density pattern for spring of 1978 is similar to that of 1977 with a smaller peak density occurring at a later date. This peak extended over a two week period before a rapid decline on June 8, 1978. No hydra were collected June 15 or June 28, 1978, the end of the observational period.

Taxonomy

Only a few of the hydra collected in the spring of 1977 were identified but all identified were *H. oligactis*. The hydra collected on August 23, 1977 were *H. pseudoligactis*. A more thorough investigation of species was made of hydra collected from October 4, 1977 to November 23, 1977 (Table 2) and they were 80% *H. oligactis* and 20% *H. pseudoligactis*. Due to the tedious techniques involved, only small numbers could be identified and at some time after collections when reproduction had occurred. In the spring of 1978, a few hydra were

Table 2. Identification of fall species of Hydra in Pine Lake

DATE	ID	DEPTH (M)						
		0.5	1.0	1.5	2.0	2.5	3.0	3.5
20/9/77	I-86			Hp				
4/10/77	I-114	mixed depths			Ho			
	II-14	"	"		Ho			
	II-15	"	"		Hp			
					Ho			
	II-18	"	"		Hp			
					2Ho			
	II-22	"	"		Hp			
20/10/77	I-104		Hp			Ho		Ho
	II-9							Ho
	II-18							Hp
	II-19							3Ho
27/10/77	II-20						Hp	4Ho
3/11/77	II-25							4Ho
								Hp
	I-114					Ho		Ho
	II-14			Ho				
	II-22							3Ho
								Hp
10/11/77	I-117			Ho	Ho			
	II-14				2Ho			Ho
	II-23							Ho
	II-26					Ho	Ho	
	II-27							5Ho
								Hp
17/11/77	II-28		3Ho	2Ho	3Ho		Ho	
				Hp			2Hp	3Ho
	II-4					Ho		
	II-5					Ho		
	II-23	Ho						
23/11/77	II-23						Ho	

were identified from each day's collection, a total of 56, all *H. oligactis*.

No sexual hydra were collected but some became sexual during laboratory cultivation. All males had testes without nipples and all theca were smooth indicating the sexual hydra were *H. oligactis*.

Condition of hydra

Growth is expressed quantitatively as mean bud ratio, the number of growth axes per hydra (Table 3, Figure 3). The bud ratios used in Figure 3 are mean values for all hydra collected on the specified date. Results at each level and total means are given in Table 3. Over the observational period the total mean bud ratio varied from 1.58 to 2.54 (collections of less than 10 hydra were not used due to unreliability of small samples). Bud ratios show that the attached hydra were reproducing. Some hydra were found with six buds. The budding may have occurred after attachment to slides. Newly detached buds were counted as single hydranths as were adult hydranths without buds. This was the most practical method of counting but if newly detached buds could have been counted separately and only adults used in the bud ratio calculation the figures would have been higher in some cases. It was noticed during the May 13, 1977 peak that large numbers of single hydranths were very small. However, at the 1978 maximum populations (May 25) the bud ratio was much greater (2.22).

Table 3. Bud ratios of Hydra at Pine Lake (GA/H)

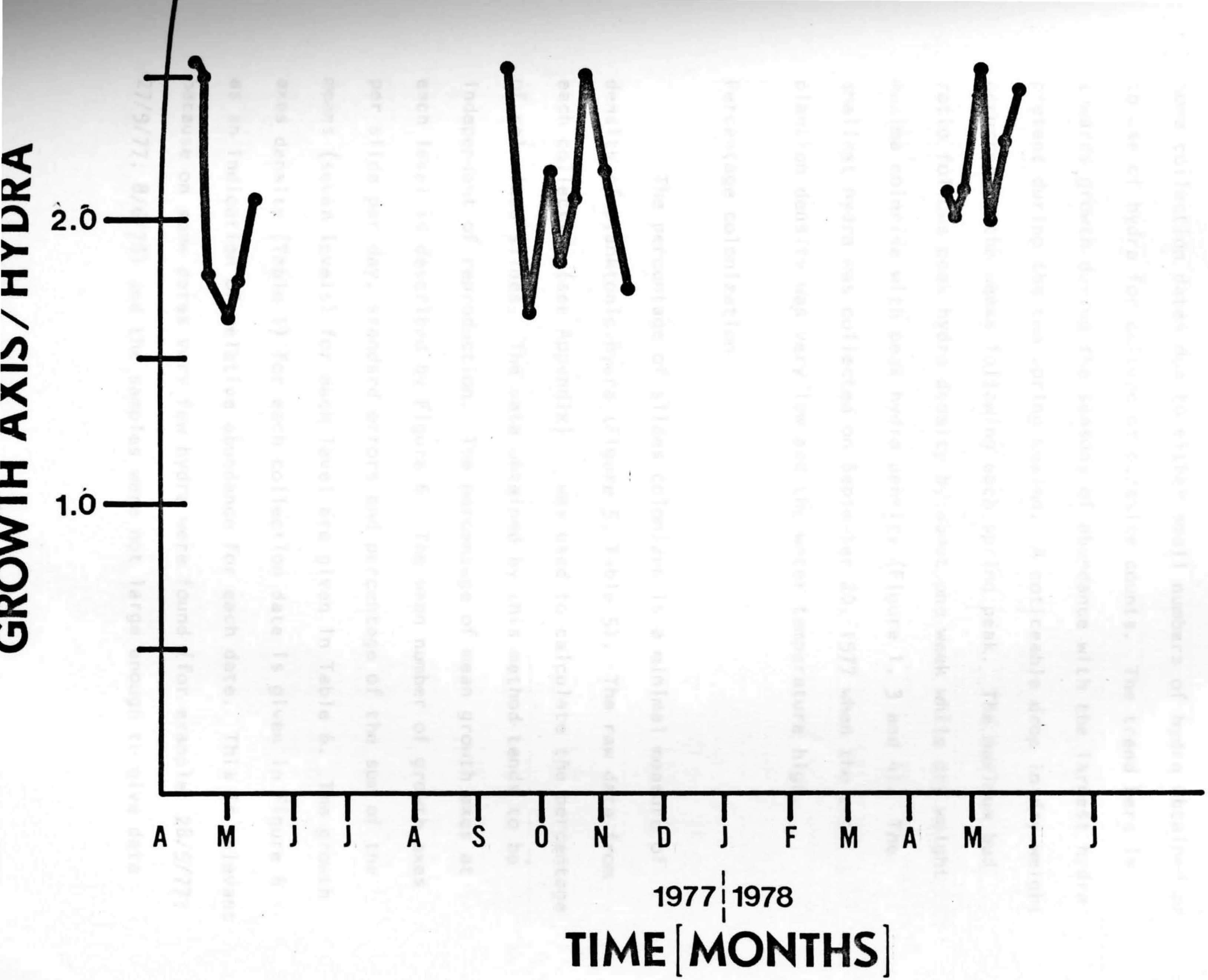
DATE	DEPTH (M)							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	MEAN
16/4/77	----	2.33	----	3.33	----	3.28	2.16	2.54
23/4/77	----	----	1.00	----	2.65	2.77	2.40	2.50
30/4/77	1.00	1.00	----	2.50	1.67	1.50	2.04	1.76
7/5/77	1.50	1.33	1.86	1.00	1.00	1.67	1.65	1.61
13/5/77	3.00	1.75	1.66	1.80	1.84	1.67	1.67	1.73
21/5/77	----	1.80	2.50	3.00	1.67	2.30	2.00	2.08
28/5/77	----	----	----	----	----	3.00	----	3.00[a]
23/8/77	1.58	----	----	----	----	----	----	1.58[b]
20/9/77	----	----	2.51	----	2.00	----	1.00	2.47[c]
27/9/77	----	----	----	----	----	----	3.00	3.00[a]
4/10/77	----	----	2.00	1.00	2.00	1.60	1.75	1.64
14/10/77	2.75	2.00	2.00	2.10	2.44	2.20	2.09	2.15
20/10/77	----	1.00	1.33	2.00	1.00	2.33	1.67	1.79
27/10/77	----	----	----	----	----	3.00	1.75	2.00[a]
3/11/77	----	----	1.00	----	3.00	----	2.50	2.43
10/11/77	----	----	2.00	2.00	1.00	1.63	2.21	2.14
17/11/77	2.00	1.65	2.13	1.78	1.63	1.63	1.53	1.68
23/11/77	----	----	3.00	----	----	1.00	----	2.00[a]
20/4/78	----	2.00	2.19	2.88	2.08	1.91	1.93	1.99
27/4/78	1.56	1.86	1.58	1.63	1.75	1.83	1.99	1.81
4/5/78	2.67	2.00	2.29	2.00	2.82	2.10	1.95	2.00
11/5/78	----	2.29	2.82	2.68	2.27	2.00	2.42	2.42
18/5/78	3.20	----	3.00	1.88	1.88	1.50	1.77	1.82
25/5/78	2.09	2.55	2.41	2.36	1.93	2.03	1.85	2.22
1/6/78	2.50	2.53	2.13	2.37	2.14	1.84	1.67	2.36
8/6/78	----	----	2.00	----	----	1.00	1.50	1.83[a]

[a] 6 or less hydra collected

[b] all hydra on one trap

[c] over 93% of hydra on one slide

Fig. 3.--Change in bud ratios with time. Growth axis per hydra = bud ratio.


GROWTH AXIS/HYDRA
2.0
1.0
A M J J A S O N D J F M A M J J
1977 | 1978
TIME [MONTHS]

Dry Weights

Dry weights of hydra as a measure of size is a good indicator of condition (Figure 4, Table 4). There are no dry weight data for some collection dates due to either small numbers of hydra obtained or to use of hydra for culture or parasite counts. The trend here is towards growth during the seasons of abundance with the largest hydra present during the two spring maxima. A noticeable drop in dry weight occurred in the weeks following each spring peak. The maximum bud ratio follows peak hydra density by about one week while dry weight maxima coincide with peak hydra density (Figure 1, 3 and 4). The smallest hydra was collected on September 20, 1977 when the zooplankton density was very low and the water temperature high.

Percentage colonization

The percentage of slides colonized is a minimal measure of density of planktonic hydra (Figure 5, Table 5). The raw data from each collection (see Appendix) was used to calculate the percentage of colonized slides. The data obtained by this method tends to be independent of reproduction. The percentage of mean growth axes at each level is described by Figure 6. The mean number of growth axes per slide per day, standard errors and percentage of the sum of the means (seven levels) for each level are given in Table 6. The growth axes density (Table 1) for each collection date is given in Figure 6 as an indication of relative abundance for each date. This is relevant because on some dates very few hydra were found (for example: 28/5/77; 27/9/77; 8/6/78) and the samples were not large enough to give data

Table 4. Dry weights of Pine Lake Hydra (μg/GA)

DATE	DEPTH (M)							
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	MEAN
16/4/77	----	----	----	20.0	----	25.0	20.0	21.7
23/4/77	----	----	----	----	23.0	21.0	21.0	21.7
30/4/77	----	----	----	----	----	40.0	26.0	33.0
7/5/77	----	----	----	----	----	----	----	----[a]
13/5/77	----	----	38.0	38.0	33.0	28.0	35.0	34.4
21/5/77	----	----	----	----	----	----	24.0	24.0
28/5/77	----	----	----	----	----	----	----	----[b]
10/6/77	----	----	----	----	----	----	----	----
22/6/77	----	----	----	----	----	----	----	----
7/7/77	----	----	----	----	----	----	----	----
26/7/77	----	----	----	----	----	----	----	----
8/8/77	----	----	----	----	----	----	----	----
23/8/77	----	----	----	----	----	----	----	----[a]
1/9/77	----	----	----	----	----	----	----	----
9/9/77	----	----	----	----	----	----	----	----
20/9/77	----	----	12.4	----	----	----	----	12.4
27/9/77	----	----	----	----	----	----	----	----[a]
4/10/77	----	----	----	----	----	----	----	----[a]
14/10/77	----	29.3	----	----	28.3	----	27.9	28.5
20/10/77	------ 41.5 (combined depths) ---------------							41.5
27/10/77	----	----	----	----	----	----	----	----[a]
3/11/77	----	----	----	----	----	----	----	----[a]
10/11/77	----	----	----	----	----	----	25.3	25.3
17/11/77	----	----	----	----	----	----	35.9	35.9
23/11/77	----	----	----	----	----	----	----	----[a]
1/12/77	----	----	----	----	----	----	----	----
22/2/78	----	----	----	----	----	----	----	----
1/3/78	----	----	----	----	----	----	----	----
8/3/78	----	----	----	----	----	----	----	----
13/4/78	----	----	----	----	----	----	----	----
20/4/78	----	----	24.0	----	32.1	23.1	22.3	25.4
27/4/78	----	----	30.0	29.0	29.0	25.0	27.0	28.0
4/5/78	24.9	37.0	26.7	30.2	23.0	31.2	29.0	28.9
11/5/78	----	----	----	----	----	----	----	----[a]
18/5/78	----	----	----	29.0	24.0	28.0	32.0	28.3
25/5/78	37.3	44.0	40.9	45.4	44.1	29.6	29.6	38.7
1/6/78	27.0	21.5	25.5	26.1	28.7	31.2	33.0	27.6
8/6/78	----	----	----	----	----	----	----	----[a]
15/6/78	----	----	----	----	----	----	----	----
28/6/78	----	----	----	----	----	----	----	----

[a] some hydra present but dry weight not taken

Fig. 4.--Changes in dry weights of hydra with time. μg = micrograms; GA = growth axis.

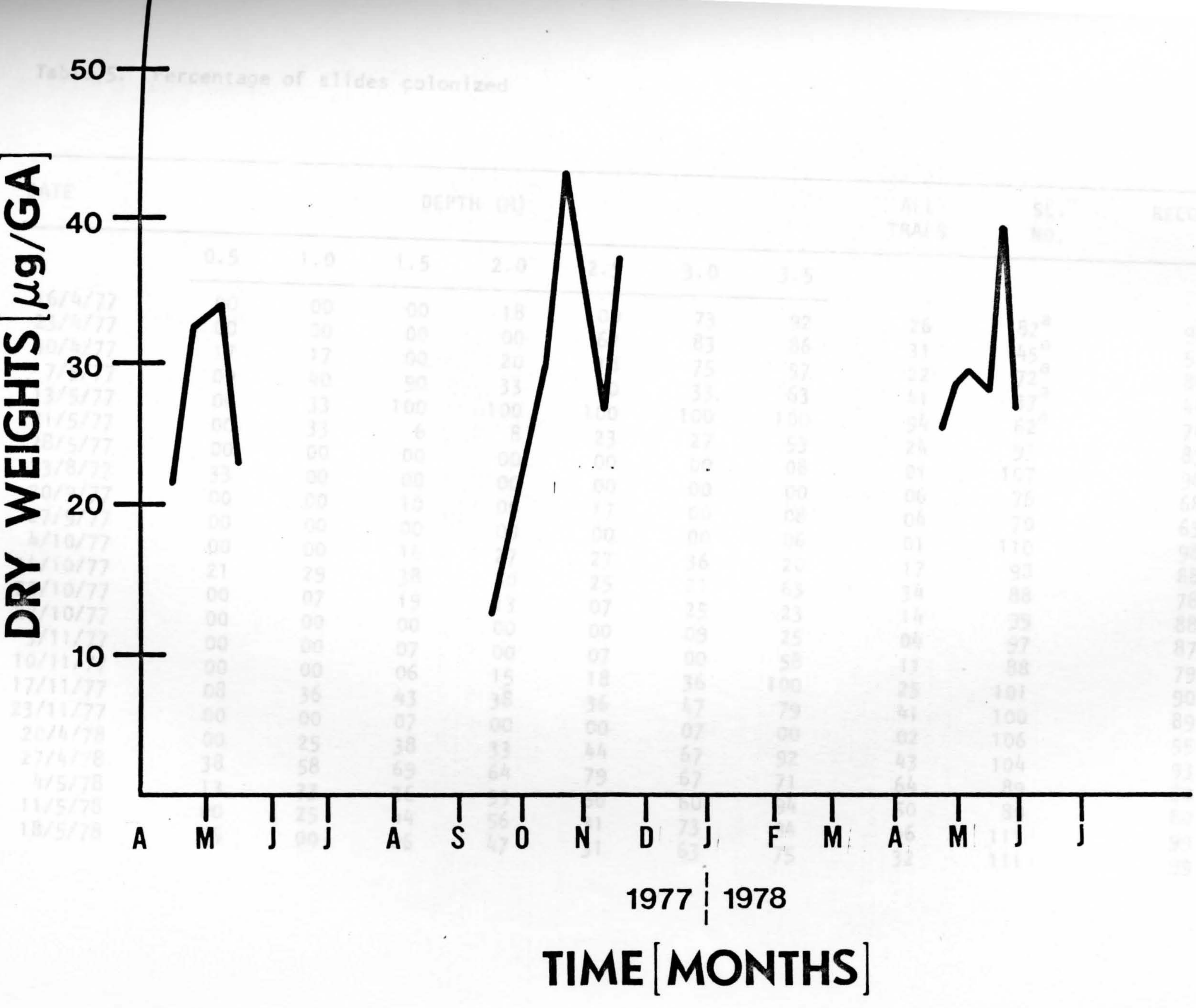

DRY WEIGHTS [µg/GA]
50
40
30
20
10
A
M
J
J
A
S
O
N
D
J
F
M
A
M
J
J
1977
1978
TIME [MONTHS]

Table 5. Percentage of slides colonized

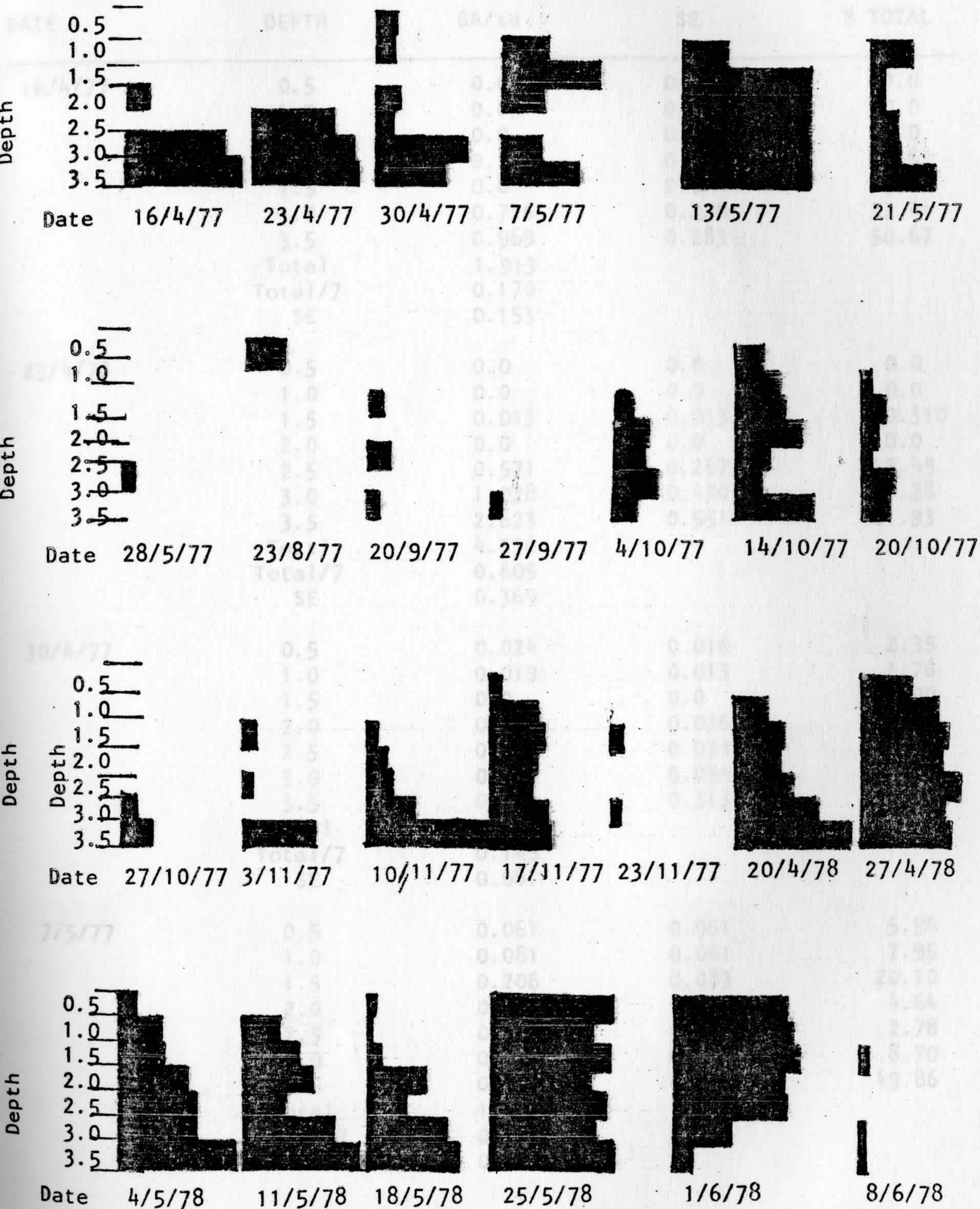
DATE	DEPTH (M)							ALL TRAPS	SL. NO.	RECOVERY %
	0.5	1.0	1.5	2.0	2.5	3.0	3.5			
16/4/77	00	00	00	18	00	73	92	26	82[a]	98
23/4/77	00	00	00	00	67	83	86	31	45[a]	54
30/4/77	17	17	00	20	18	75	57	22	72[a]	86
7/5/77	00	40	90	33	00	33	63	41	37[a]	44
13/5/77	00	33	100	100	100	100	100	94	62[a]	74
21/5/77	00	33	6	8	23	27	53	24	93	83
28/5/77	00	00	00	00	00	00	08	01	107	96
23/8/77	33	00	00	00	00	00	00	06	76	68
20/9/77	00	00	10	00	17	00	08	04	70	63
27/9/77	00	00	00	00	00	00	06	01	110	98
4/10/77	00	00	14	27	23	36	20	17	98	88
14/10/77	21	29	38	50	25	21	63	34	88	78
20/10/77	00	07	19	13	07	25	23	14	99	88
27/10/77	00	00	00	00	00	09	25	04	97	87
3/11/77	00	00	07	00	07	00	58	11	88	79
10/11/77	00	00	06	15	18	36	100	25	101	90
17/11/77	08	36	43	38	36	47	79	41	100	89
23/11/77	00	00	07	00	00	07	00	02	106	95
20/4/78	00	25	38	33	44	67	92	43	104	93
27/4/78	38	58	69	64	79	67	71	64	89	80
4/5/78	13	33	36	53	60	60	94	50	89	80
11/5/78	00	25	44	56	31	73	94	46	111	99
18/5/78	06	00	06	47	31	63	75	32	111	99

Table 5 (Continued).

25/5/78	100	81	94	81	94	87	100	92	111	99
1/6/78	88	94	100	87	88	47	13	75	110	98
8/6/78	00	00	06	00	00	00	00	03	95	85

[a] Hydra from three traps

Fig. 5.--Percentage colonization of slides. M = depth in meters from lake surface.



Depth
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Date
16/4/77
23/4/77
30/4/77
7/5/77
13/5/77
21/5/77
28/5/77
23/8/77
20/9/77
27/9/77
4/10/77
14/10/77
20/10/77
27/10/77
3/11/77
10/11/77
17/11/77
23/11/77
20/4/78
27/4/78
4/5/78
11/5/78
18/5/78
25/5/78
1/6/78
8/6/78

Table 6. Mean growth axes per slide per day at seven levels.

DATE	DEPTH	GA/sd	SE	% TOTAL
16/4/77	0.5	0.0	0.0	0.0
	1.0	0.0	0.0	0.0
	1.5	0.0	0.0	0.0
	2.0	0.228	0.156	11.89
	2.5	0.0	0.0	0.0
	3.0	0.716	0.220	37.44
	3.5	0.969	0.283	50.67
	Total	1.913		
	Total/7	0.170		
	SE	0.153		
23/4/77	0.5	0.0	0.0	0.0
	1.0	0.0	0.0	0.0
	1.5	0.013	0.013	0.310
	2.0	0.0	0.0	0.0
	2.5	0.571	0.267	13.49
	3.0	1.028	0.430	24.28
	3.5	2.623	0.551	61.93
	Total	4.236		
	Total/7	0.605		
	SE	0.369		
30/4/77	0.5	0.024	0.016	2.35
	1.0	0.019	0.013	1.76
	1.5	0.0	0.0	0.00
	2.0	0.051	0.036	5.03
	2.5	0.051	0.033	5.03
	3.0	0.286	0.094	28.18
	3.5	0.584	0.313	57.64
	Total	1.014		
	Total/7	0.145		
	SE	0.081		
7/5/77	0.5	0.061	0.061	5.96
	1.0	0.081	0.061	7.95
	1.5	0.206	0.083	20.10
	2.0	0.047	0.030	4.64
	2.5	0.029	0.029	2.78
	3.0	0.090	0.060	8.70
	3.5	0.509	0.247	49.86
	Total	1.027		
	Total/7	0.147		
	SE	0.063		

Table 6 (Continued)

DATE	DEPTH	GA/sd	SE	% TOTAL
13/5/77	0.5	0.0	0.0	0.00
	1.0	0.555	0.555	1.00
	1.5	1.148	0.208	3.92
	2.0	1.433	0.370	4.89
	2.5	2.833	0.605	9.67
	3.0	6.797	1.700	23.19
	3.5	16.545	1.888	56.45
	Total	29.311		
	Total/7	4.187		
	SE	2.230		
21/5/77	0.5	0.0	0.0	0.00
	1.0	0.150	0.068	16.41
	1.5	0.039	0.039	4.27
	2.0	0.094	0.094	10.25
	2.5	0.048	0.026	5.26
	3.0	0.250	0.104	27.35
	3.5	0.334	0.104	36.46
	Total	0.914		
	Total/7	0.131		
	SE	0.146		
28/5/77	0.5	0.0	0.0	0.00
	1.0	0.0	0.0	0.00
	1.5	0.0	0.0	0.00
	2.0	0.0	0.0	0.00
	2.5	0.0	0.0	0.00
	3.0	0.027	0.027	100.00
	3.5	0.0	0.0	0.00
	Total	0.027		
	Total/7	0.004		
	SE	0.004		
23/8/77	0.5	2.200	1.673	100.00
	1.0	0.0	0.0	0.00
	1.5	0.0	0.0	0.00
	2.0	0.0	0.0	0.00
	2.5	0.0	0.0	0.00
	3.0	0.0	0.0	0.00
	3.5	0.0	0.0	0.00
	Total	2.220		
	Total/7	0.314		
	SE	0.314		

Table 6 (Continued)

DATE	DEPTH	GA/sd	SE	% TOTAL
20/9/77	0.5	0.0	0.0	0.00
	1.0	0.0	0.0	0.00
	1.5	1.827	1.827	93.42
	2.0	0.0	0.0	0.00
	2.5	0.121	0.121	6.20
	3.0	0.0	0.0	0.00
	3.5	0.007	0.007	0.39
	Total	1.956		
	Total/7	0.279		
	SE	0.258		
27/9/77	0.5	0.0	0.0	0.00
	1.0	0.0	0.0	0.00
	1.5	0.0	0.0	0.00
	2.0	0.0	0.0	0.00
	2.5	0.0	0.0	0.00
	3.0	0.0	0.0	0.00
	3.5	0.027	0.027	100.00
	Total	0.027		
	Total/7	0.004		
	SE	0.004		
4/10/77	0.5	0.0	0.0	0.00
	1.0	0.0	0.0	0.00
	1.5	0.041	0.031	11.34
	2.0	0.039	0.017	10.59
	2.5	0.066	0.044	18.32
	3.0	0.081	0.036	22.69
	3.5	0.133	0.097	37.06
	Total	0.360		
	Total/7	0.051		
	SE	0.019		
14/10/77	0.5	0.073	0.049	5.70
	1.0	0.114	0.074	8.30
	1.5	0.125	0.098	9.08
	2.0	0.210	0.100	15.25
	2.5	0.183	0.109	13.31
	3.0	0.790	0.042	5.70
	3.5	0.588	0.167	42.66
	Total	13.773		
	Total/7	1,377		
	SE	0.680		

Table 6 (Continued).

DATE	DEPTH	GA/sd	SE	% TOTAL
20/10/77	0.5	0.0	0.0	0.00
	1.0	0.012	0.012	2.70
	1.5	0.042	0.023	10.87
	2.0	0.045	0.035	11.60
	2.5	0.012	0.012	3.11
	3.0	0.147	0.097	38.06
	3.5	0.128	0.083	33.46
	Total	0.383		
	Total/7	0.055		
	SE	0.022		
27/10/77	0.5	0.0	0.0	0.00
	1.0	0.0	0.0	0.00
	1.5	0.0	0.0	0.00
	2.0	0.0	0.0	0.00
	2.5	0.0	0.0	0.00
	3.0	0.039	0.039	31.86
	3.5	0.083	0.049	68.14
	Total	0.123		
	Total/7	0.018		
	SE	0.013		
3/11/77	0.5	0.0	0.0	0.00
	1.0	0.0	0.0	0.00
	1.5	0.010	0.010	2.56
	2.0	0.0	0.0	0.00
	2.5	0.030	0.030	7.69
	3.0	0.0	0.0	0.00
	3.5	0.357	0.131	89.74
	Total	0.399		
	Total/7	0.057		
	SE	0.050		
10/11/77	0.5	0.0	0.0	0.00
	1.0	0.0	0.0	0.00
	1.5	0.019	0.180	0.85
	2.0	0.044	0.034	2.10
	2.5	0.026	0.017	1.24
	3.0	0.133	0.066	6.33
	3.5	1.896	0.513	89.49
	Total	2.097		
	Total/7	0.300		
	SE	0.263		

Table 6 (Continued).

DATE	DEPTH	GA/sd	SE	% TOTAL
17/11/77	0.5	0.021	0.021	1.63
	1.0	0.286	0.139	21.20
	1.5	0.173	0.059	12.87
	2.0	0.143	0.064	10.60
	2.5	0.133	0.081	9.84
	3.0	0.296	0.159	21.90
	3.5	0.296	0.066	21.96
	Total	1.347		
	Total/7	0.192		
	SE	0.040		
23/11/77	0.5	0.0	0.0	0.00
	1.0	0.0	0.0	0.00
	1.5	0.033	0.033	73.68
	2.0	0.0	0.0	0.00
	2.5	0.0	0.0	0.00
	3.0	0.012	0.012	26.32
	3.5	0.0	0.0	0.00
	Total	0.045		
	Total/7	0.006		
	SE	0.005		
20/4/78	0.5	0.0	0.0	0.00
	1.0	0.107	0.054	1.98
	1.5	0.313	0.170	5.77
	2.0	0.219	0.091	4.05
	2.5	0.464	0.209	8.58
	3.0	0.781	0.236	14.43
	3.5	3.527	1.100	65.19
	Total	5.411		
	Total/7	0.773		
	SE	0.469		
27/4/78	0.5	0.154	0.073	3.42
	1.0	0.154	0.049	3.44
	1.5	0.450	0.121	10.02
	2.0	0.636	0.224	14.15
	2.5	0.643	0.173	14.30
	3.0	0.631	0.230	14.03
	3.5	1.827	0.504	40.63
	Total	4.496		
	Total/7	0.642		
	SE	0.213		

Table 6 (Continued)

DATE	DEPTH	GA/sd	SE	% TOTAL
4/5/78	0.5	0.076	0.051	0.92
	1.0	0.153	0.061	1.85
	1.5	0.163	0.069	1.98
	2.0	0.457	0.151	5.55
	2.5	0.457	0.129	5.55
	3.0	0.400	0.154	4.85
	3.5	6.536	1.226	79.30
	Total	8.241		
	Total/7	1.177		
	SE	0.896		
11/5/78	0.5	0.0	0.0	0.00
	1.0	0.143	0.070	3.34
	1.5	0.286	0.114	6.67
	2.0	0.599	0.220	13.97
	2.5	0.304	0.133	7.09
	3.0	0.496	0.100	11.57
	3.5	2.456	0.449	57.36
	Total	4.281		
	Total/7	0.612		
	SE	0.317		
18/5/78	0.5	0.143	0.143	10.53
	1.0	0.0	0.0	0.00
	1.5	0.027	0.027	1.97
	2.0	0.143	0.044	10.53
	2.5	0.134	0.070	9.87
	3.0	0.294	0.099	21.71
	3.5	0.616	0.143	45.39
	Total	1.357		
	Total/7	0.194		
	SE	0.079		
25/5/78	0.5	2.706	0.499	16.69
	1.0	2.411	0.610	14.87
	1.5	3.099	0.716	19.12
	2.0	2.901	0.624	17.90
	2.5	1.187	0.281	7.33
	3.0	1.467	0.384	9.05
	3.5	2.437	0.381	15.04
	Total	16.207		
	Total/7	2.315		
	SE	0.273		

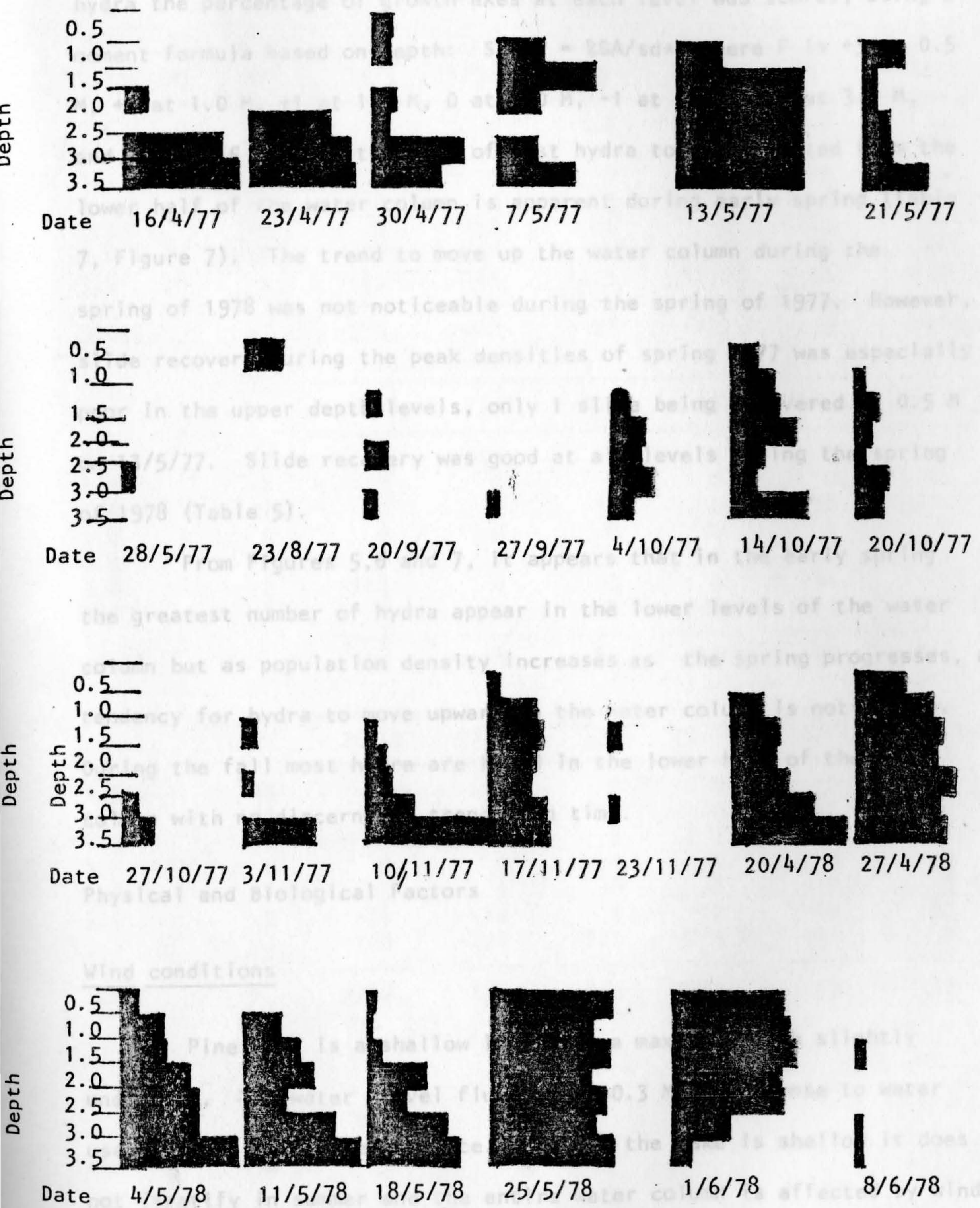
Table 6 (Continued).

DATE	DEPTH	GA/sd	SE	% TOTAL
1/6/78	0.5	2.706	0.729	19.15
	1.0	5.349	1.357	37.87
	1.5	2.794	0.454	19.79
	2.0	1.943	0.644	13.76
	2.5	0.956	0.199	6.76
	3.0	0.333	0.123	2.36
	3.5	0.044	0.036	0.32
	Total	14.124		
	Total/7	2.018		
	SE	0.690		
8/6/78	0.5	0.0	0.0	0.00
	1.0	0.066	0.066	57.00
	1.5	0.0	0.0	0.00
	2.0	0.0	0.0	0.00
	2.5	0.0	0.0	0.00
	3.0	0.020	0.020	17.00
	3.5	0.030	0.030	26.00
	Total	0.116		
	Total/7	0.017		
	SE	0.009		

GA/sd Growth axes per slide per day

SE Standard error

Fig. 6.--Plot of percentage growth axes versus depth for each collection date. M = depth in meters from lake surface. GA/sd = growth axes per slide per day.


Depth
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Date
16/4/77
23/4/77
30/4/77
7/5/77
13/5/77
21/5/77
28/5/77
23/8/77
20/9/77
27/9/77
4/10/77
14/10/77
20/10/77
27/10/77
3/11/77
10/11/77
17/11/77
23/11/77
20/4/78
27/4/78
4/5/78
11/5/78
18/5/78
25/5/78
1/6/78
8/6/78

as meaningful as dates with larger sample size.

In an attempt to locate the depth of greatest concentration of hydra the percentage of growth axes at each level was scored, using a moment formula based on depth: Score = %GA/sd*f where F is +3 at 0.5 M, +2 at 1.0 M, +1 at 1.5 M, 0 at 2.0 M, -1 at 2.5 M, -2 at 3.0 M, and -3 at 3.5 M. The tendency of most hydra to be collected from the lower half of the water column is apparent during early spring (Table 7, Figure 7). The trend to move up the water column during the spring of 1978 was not noticeable during the spring of 1977. However, slide recovery during the peak densities of spring 1977 was especially poor in the upper depth levels, only 1 slide being recovered at 0.5 M on 13/5/77. Slide recovery was good at all levels during the spring of 1978 (Table 5).

From Figures 5,6 and 7, it appears that in the early spring the greatest number of hydra appear in the lower levels of the water column but as population density increases as the spring progresses, a tendency for hydra to move upward in the water column is noticeable. During the fall most hydra are found in the lower half of the water column with no discernible trend with time.

Physical and Biological Factors

Wind conditions

Pine Lake is a shallow lake with a maximum depth slightly under 4 M. The water level fluctuated ±0.3 M in response to water usage by the Ohio Water Service. Because the lake is shallow it does not stratify in summer and the entire water column is affected by wind

Table 7. Distribution of Hydra in the water column in 1977 and 1978.

1977

DEPTH (M)	Mf[a]	16/4	23/4	30/4	5/5	13/5	21/5
0.5	+3	0	0	6	18	0	0
1.0	+2	0	0	4	16	2	32
1.5	+1	0	0	0	20	4	4
2.0	0	0	0	0	0	0	0
2.5	-1	0	-14	-5	-3	-10	-5
3.0	-2	-75	-48	-56	-18	-46	-54
3.5	-3	-159	-186	-116	-150	-168	-108
SCORE		-234	-248	-167	-127	-218	-131

		28/5	23/8	20/9	27/9	4/10	14/10
0.5	+3	0	300	0	0	0	18
1.0	+2	0	0	0	0	0	16
1.5	+1	0	0	93	0	11	9
2.0	0	0	0	0	0	0	0
2.5	-1	0	0	-6	0	-18	-13
3.0	-2	-200	0	0	0	-46	-12
3.5	-3	0	0	-3	-300	-111	-129
SCORE		-200	+300	+84	-300	-164	-111

		20/10	27/10	3/11	10/11	17/11	23/11
0.5	+3	0	0	0	0	6	0
1.0	+2	6	0	0	0	42	0
1.5	+1	11	0	3	1	13	74
2.0	0	0	0	0	0	0	0
2.5	-1	-3	0	-8	-1	-10	0
3.0	-2	-76	-64	0	-12	-44	-52
3.5	-3	-100	-204	-270	-269	-66	0
SCORE		-162	-268	-275	-281	-59	+22

Table 7 (Continued).

1978

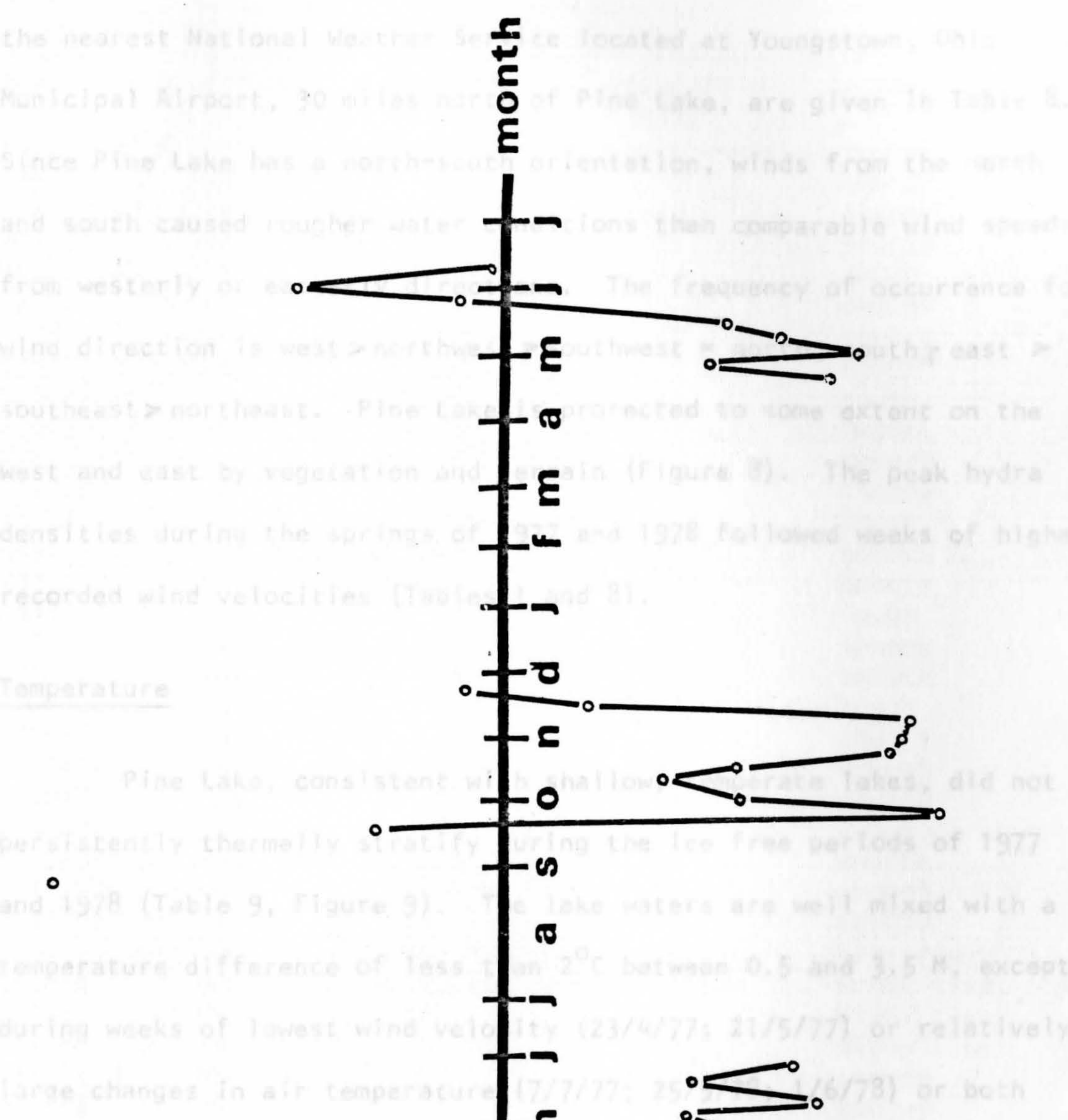
DEPTH (M)	Mf[a]	20/4	24/4	4/5	11/5	18/5	25/5
0.5	+3	0	+9	+3	0	+33	+51
1.0	+2	4	6	4	6	0	+30
1.5	+1	6	10	2	7	2	19
2.0	0	0	0	0	0	0	0
2.5	-1	-9	-14	-6	-7	-10	-7
3.0	-2	-28	-28	-10	-24	-44	-18
3.5	-3	-195	-123	-237	-171	-135	-45
SCORE		-222	-140	-242	-189	-154	+30

		1/6	8/6
0.5	+3	57	0
1.0	+2	76	114
1.5	+1	20	0
2.0	0	0	0
2.5	-1	-7	0
3.0	-2	-4	-34
3.5	-3	-3	-78
SCORE		+139	+2

[a] Mf is the factor used to multiply the percentage of total GA/sd (Table 5) at designated depth.

Fig. 7.--Distribution of hydra in water column. Score is based on % growth axes per slide per day.

Mf = +3 at 0.5 M
+2 at 1.0 M
+1 at 1.5 M
0 at 2.0 M
-1 at 2.5 M
-2 at 3.0 M
-3 at 3.5 M


month
m j j a s o n d j f m a m j j
score
+300
+200
+100
−100
−200
−300

generated turbulence. The subjective observations of the water turbulence conditions and the wind data on collection dates as reported at the nearest National Weather Service located at Youngstown, Ohio Municipal Airport, 30 miles north of Pine Lake, are given in Table 8. Since Pine Lake has a north-south orientation, winds from the north and south caused rougher water conditions than comparable wind speeds from westerly or easterly directions. The frequency of occurrence for wind direction is west > northwest > southwest = north > south > east > southeast > northeast. Pine Lake is protected to some extent on the west and east by vegetation and terrain (Figure 8). The peak hydra densities during the springs of 1977 and 1978 followed weeks of highest recorded wind velocities (Tables 1 and 8).

Temperature

Pine Lake, consistent with shallow, temperate lakes, did not persistently thermally stratify during the ice free periods of 1977 and 1978 (Table 9, Figure 9). The lake waters are well mixed with a temperature difference of less than 2^{o}C between 0.5 and 3.5 M, except during weeks of lowest wind velocity (23/4/77; 21/5/77) or relatively large changes in air temperature (7/7/77; 25/5/78; 1/6/78) or both (1/9/77) (Table 9). The rate of temperature increase during the spring of 1977 was less than the rate during the spring of 1978. The 1977 spring water temperatures were a few degrees warmer (mean = 15.5^{o}C) than during the spring of 1978 (mean = 13^{o}C).

Table 8. Wind conditions[a].

DATE	DIRECTION	VELOCITY (MPH)	VELOCITY (MAX)[b]	OBSERVATIONS
16/4/77	WNW	8	19	smooth
23/4/77	S	9	13	choppy
30/4/77	SW	7	21	smooth
7/5/77	N	16	17	rough
13/5/77	NW	10	28(NNW)	choppy
21/5/77	SW	11	13	choppy
28/5/77	WNW	10	17	smooth
10/6/77	N	10	21	rough
22/6/77	W	9	18	smooth
7/7/77	W	8	18	smooth
26/7/77	N	15	17	choppy
8/8/77	SW	13	17	rough
8/23/77	SW	8	17	smooth
1/9/77	SW	10	14	smooth
9/9/77	SSE	13	15	rough
20/9/77	W	14	17	choppy
27/9/77	WNW	10	20	smooth
4/10/77	NW	13	17	rough
14/10/77	NNE	12	21	choppy
20/10/77	NNW	12	21	smooth
27/10/77	E W	4	14	smooth
3/11/77	SSE	15	17	rough
10/11/77	WNW	13	17	smooth
17/11/77	WSW	8 16	21	smooth
23/11/77	SE	14 10	21	choppy
1/12	SW	16 26	18	very rough
22/2/78	NW	9 13	37(1/26)	windy (ice)
1/3/78	NW	12 16	17	Windy (ice)
8/3/78	ENE	15 10	17	windy (ice)
13/4/78	NW	14 17	29(4/1)	choppy
20/4/78	NW	13	18	choppy
27/4/78	N	14 17	18	choppy
4/5/78	ESE	14 17	15	choppy
11/5/78	SSE	15 13	23(9/5)	smooth
18/5/78	NW	7	17	smooth
25/5/78	WNW	8	23(20/5)	smooth
1/6/78	SE SW	9	17	smooth
8/6/78	W N	12 5	17	smooth
15/6/78	SE NE	8 3	16	smooth
28/6/78	NW	14	18	smooth

[a] Wind direction and velocities from National Weather Service, Municipal Airport, Youngstown, Ohio

[b] VEL(MAX) is the highest wind velocity reported between collections

Fig. 8.--Map of Pine Lake. Source is U.S. Geological Survey Map, Columbiana, Ohio, 1962.

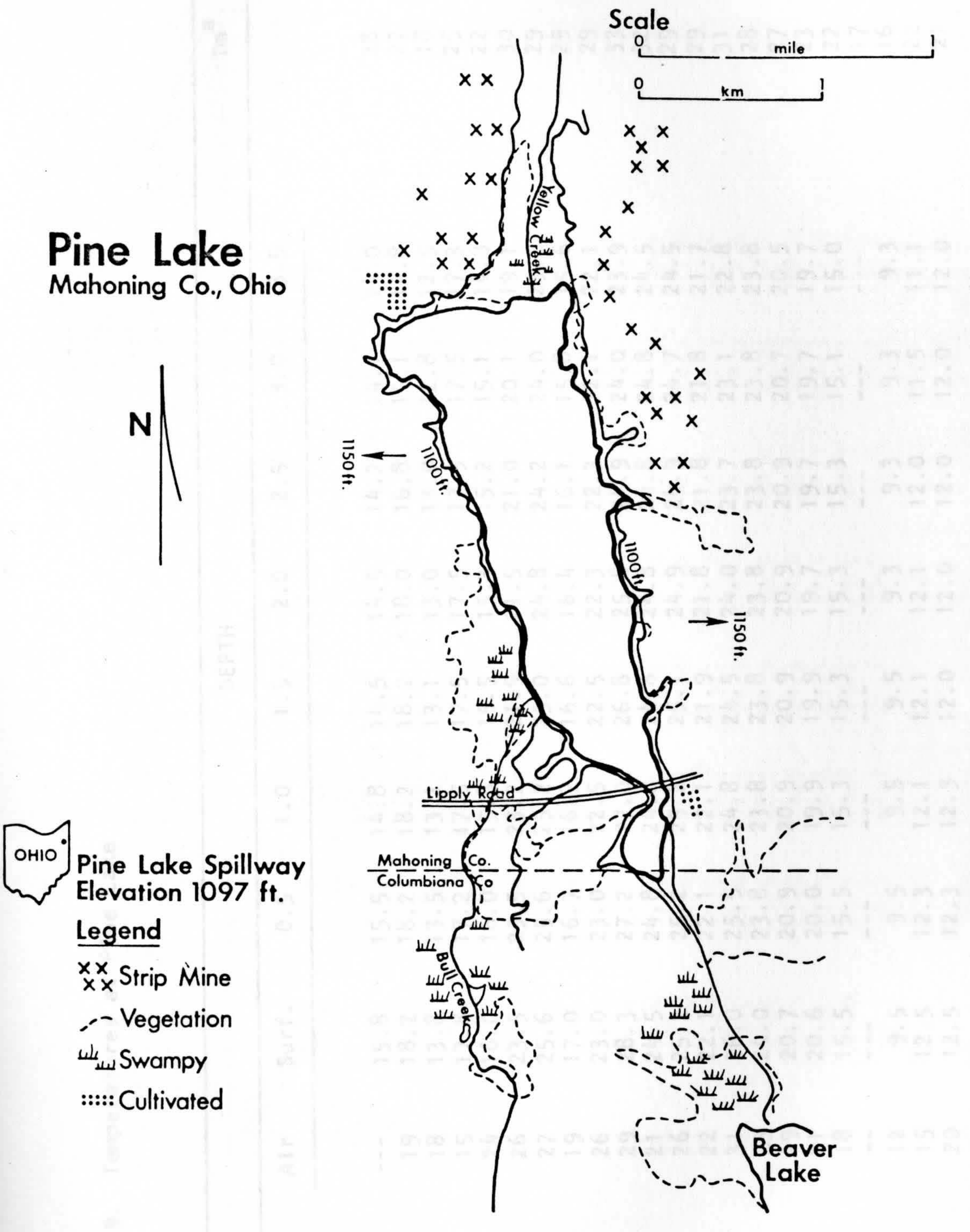

Pine Lake
Mahoning Co., Ohio
Scale
0
mile
1
0
km
1
N
Yellow Creek
1150 ft.
1100 ft.
1100 ft.
1150 ft.
Lipply Road
Mahoning Co.
Columbiana Co
Bull Creek
Beaver Lake
OHIO
Pine Lake Spillway
Elevation 1097 ft.
Legend
Strip Mine
Vegetation
Swampy
Cultivated

Table 9. Temperatures at Pine Lake

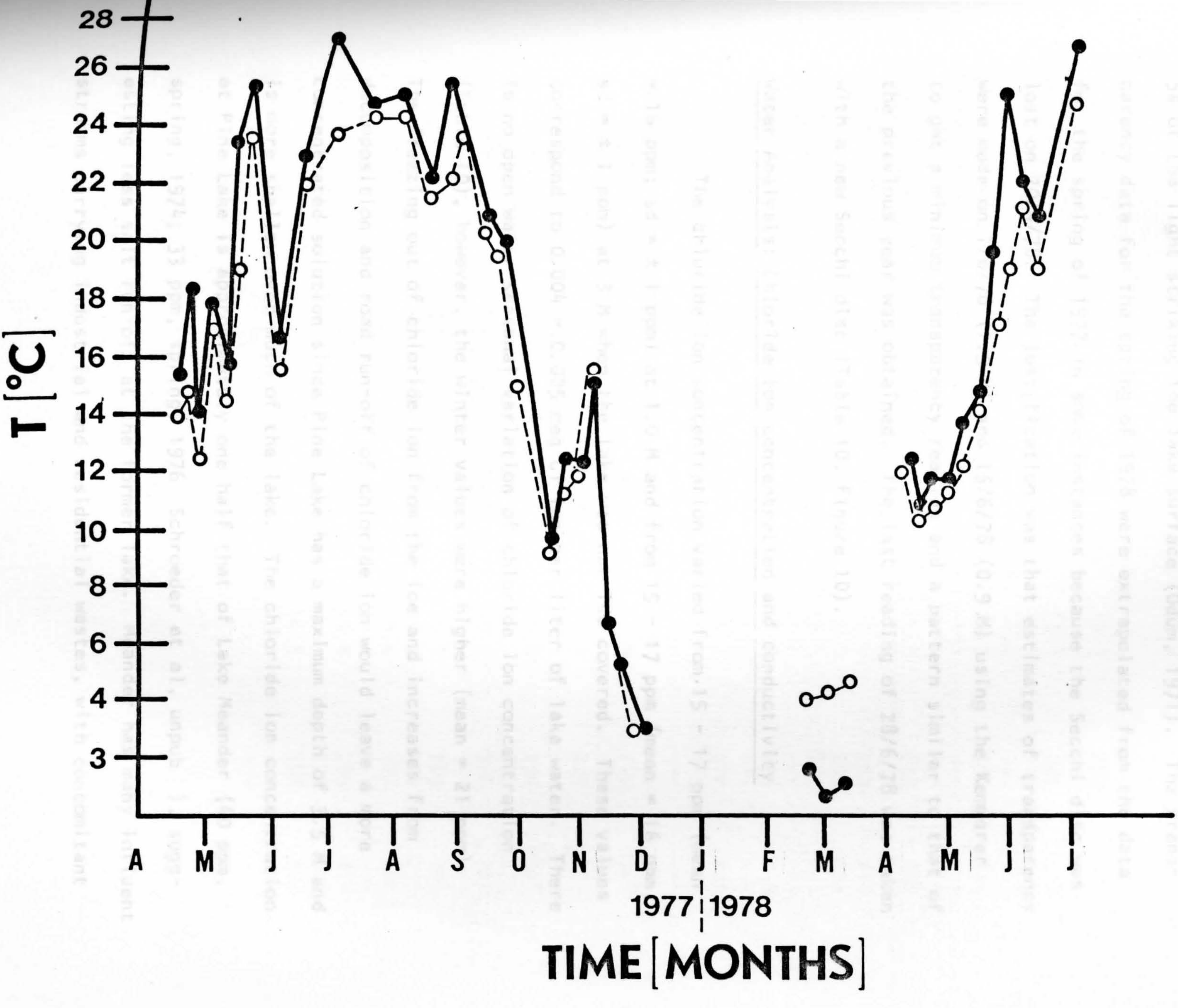
DATE	DEPTH									Tm[a]	Wm[a]
	Air	Surf.	0.5	1.0	1.5	2.0	2.5	3.0	3.5		
1977											
16/4	---	15.8	15.5	14.8	14.5	14.5	14.2	14.1	14.0	28	19
23/4	19	18.2	18.2	18.2	18.2	18.0	16.8	15.1	14.8	27	13
30/4	18	13.8	13.5	13.1	13.1	13.0	13.0	12.8	12.5	18	21
7/5	15	17.8	17.2	17.5	17.5	17.5	17.5	17.5	17.3	25	17
13/5	24	16.0	16.0	15.8	15.5	15.3	15.2	15.1	14.8	22	28
21/5	26	23.5	23.5	23.2	21.9	21.5	21.0	20.1	19.1	30	13
28/5	27	25.6	25.6	25.2	25.0	24.8	24.2	24.0	23.8	29	17
10/6	19	17.0	16.7	16.7	16.6	16.4	16.1	15.8	15.6	29	21
22/6	26	23.0	23.0	22.5	22.5	22.3	22.3	22.1	22.1	29	18
7/7	29	28.3	27.2	27.0	26.8	25.8	24.9	24.0	23.9	33	18
26/7	21	24.5	24.8	24.8	24.8	24.8	24.8	24.8	24.5	32	17
8/8	26	25.2	25.2	25.2	25.1	24.9	24.9	24.7	24.5	29	17
23/8	22	22.1	22.1	22.1	21.9	21.8	21.8	21.8	21.7	29	17
1/9	31	26.0	25.5	24.8	24.5	24.0	23.7	23.1	22.8	31	14
9/9	23	24.0	23.8	23.8	23.8	23.8	23.8	23.8	23.8	28	15
20/9	19	20.7	20.9	20.9	20.9	20.9	20.9	20.7	20.5	27	17
27/9	21	20.6	20.0	19.9	19.9	19.7	19.7	19.7	19.7	23	20
4/10	18	15.5	15.5	15.3	15.3	15.3	15.3	15.1	15.0	22	17
14/10	--	---	---	---	---	---	---	---	---	17	21
20/10	12	9.5	9.5	9.5	9.5	9.3	9.3	9.3	9.3	16	21
27/10	15	12.5	12.3	12.1	12.1	12.1	12.0	11.5	11.1	22	14
3/11	20	12.5	12.3	12.3	12.0	12.0	12.0	12.0	12.0	21	17

Table 9 (Continued).

DATE	DEPTH									Tm[a]	Wm[a]
1977	Air	Surf.	0.5	1.0	1.5	2.0	2.5	3.0	3.5		
10/11	10	15.0	15.1	15.1	15.1	15.3	15.3	15.3	15.3	23	17
17/11	9	6.4	6.5	6.5	6.5	6.5	6.5	6.5	6.5	12	21
23/11	6	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	13	21
1/12	11	3.0	3.0	3.0	3.0	2.8	2.8	2.8	2.8	7	18
1978											
22/2	-7	0.2	1.8	3.8	3.8	3.8	3.8	4.0	4.0	-18	37
1/3	-5	0.2	0.8	3.8	3.8	3.8	4.1	4.3	4.3	-15	17
8/3	---	1.0	1.0	3.8	4.5	4.5	4.5	4.5	4.5	-18	17
13/4	14	12.5	12.2	12.1	12.1	12.1	12.1	12.0	12.0	25	29
20/4	7	10.3	10.3	10.7	10.7	10.7	10.7	10.7	10.7	16	18
27/4	18	11.7	11.7	11.3	11.3	11.3	11.2	11.1	11.1	16	18
4/5	11	11.8	11.8	11.8	11.8	11.8	11.8	11.7	11.6	20	15
11/5	23	13.5	13.5	13.3	13.3	13.2	13.0	12.5	12.5	19	23
18/5	18	15.0	14.8	14.5	14.3	14.	14.0	14.0	14.0	19	17
25/5	25	20.0	19.5	18.0	18.0	18.0	18.0	17.8	17.0	27	23
1/6	27	26.0	25.0	24.5	24.3	24.0	23.0	20.0	19.0	29	17
8/6	22	22.0	22.0	21.8	21.5	21.5	21.3	21.3	21.0	27	17
15/6	24	21.0	20.3	19.8	19.5	19.5	19.3	19.3	19.0	28	16
28/6	30	27.0	26.5	26.3	25.5	25.0	25.0	24.9	24.8	31	18

[a] Tm and Wm are maximum air temperature and wind velocities reported for the period between collections by National Weather Service, Youngstown, Ohio.

Fig. 9.--Changes in water temperature with time. Solid line = temperature at 0.5 M. Broken line = temperature at 3.5 M.



T [°C]
28
26
24
22
20
18
16
14
12
10
8
6
4
3
A M J J A S O N D J F M A M J J
1977 | 1978
TIME [MONTHS]

Transparency

Secchi disc transparency gives the zone of penetration of 5% of the light striking the lake surface (Odum, 1971). The transparency data for the spring of 1978 were extrapolated from the data for the spring of 1977 in some instances because the Secchi disc was lost on 20/4/78. The justification was that estimates of transparency were made on 1/6/78 (1.9 M) and 15/6/78 (0.9 M) using the Kemmerer to get a minimum transparency reading and a pattern similar to that of the previous year was obtained. The last reading of 28/6/78 was taken with a new Secchi disc (Table 10, Figure 10).

Water Analysis: Chloride ion concentration and conductivity

The chloride ion concentration varied from 15 - 17 ppm (mean = 16 ppm; sd = ± 1 ppm) at 1.0 M and from 15 - 17 ppm (mean = 16 ppm, sd = ± 1 ppm) at 3 M when the lake was not ice covered. These values correspond to 0.004 - 0.005 meq Cl ion per liter of lake water. There is no open water seasonal variation of chloride ion concentration (Table 10), however, the winter values were higher (mean = 21 ppm). The freezing out of chloride ion from the ice and increases from decomposition and road run-off of chloride ion would leave a more concentrated solution since Pine Lake has a maximum depth of 3.5 M and is more shallow over much of the lake. The chloride ion concentration at Pine Lake is approximately one half that of Lake Meander (40 ppm, spring, 1974; 33 ppm, spring, 1976 Schroeder et al, unpub), suggesting less salt run-off at the former lake. Meander has many influent streams carrying industrial and residential wastes, with concomitant

Table 10. Physical factors at Pine Lake.

DATE	SECCHI (M)	CHLORIDE[c] (ppm) 1 M	3 M	CONDUCTIVITY[c] (umhos) 1 M	3 M
16/4/77	1.05	15.1	15.3	292	303
23/4/77	1.30	----	----	---	---
30/4/77	2.15	16.6	15.4	301	310
7/5/77	2.20	15.3	15.1	294	289
13/5/77	1.67	----	----	---	---
21/5/77	2.71	16.8	16.3	300	288
28/5/77	1.35	----	----	---	---
10/6/77	0.70	----	----	---	---
22/6/77	0.45	15.6	15.9	259	261
7/7/77	0.30	16.5	15.8	260	277
26/7/77	0.25	16.4	15.6	237	212
8/8/77	0.22	15.7	15.9	252	251
23/8/77	0.50	16.1	15.6	259	253
1/9/77	0.70	----	----	---	---
9/9/77	0.40	16.0	16.5	256	260
20/9/77	0.45	----	----	---	---
27/9/77	0.45	15.8	15.7	262	258
4/10/77	0.50	----	----	---	---
14/10/77	----	----	----	---	---
20/10/77	0.65	----	----	---	---
27/10/77	0.80	16.3	15.9	270	268
3/11/77	0.75	----	----	---	---
10/11/77	0.55	16.3	15.9	223	247
17/11/77	0.87	----	----	---	---
23/11/77	0.85	16.6	16.9	290	278
1/12/77	0.95	16.5	16.7	279	272
22/2/78	1.35	20.0	19.6	396	371
1/3/78	1.55	----	----	---	---
8/3/78	1.25	19.0	20.7	369	364
13/4/78	0.85	16.3	16.8	274	275
20/4/78	0.85	15.9	16.4	283	281
27/4/78	1.05[a]	----	----	---	---
4/5/78	1.30[a]	16.0	16.4	286	282
11/5/78	2.15[a]	----	----	281	283
18/5/78	2.20[a]	15.9	16.5	258	262
25/5/78	2.35[a]	----	----	---	---
1/6/78	2.60[a,b]	----	----	---	---

Table 10 (Continued).

DATE	SECCHI (M)	CHLORIDE[c] (ppm) 1 M	3 M	CONDUCTIVITY[c] (umhos) 1 M	3 M
8/6/78	1.35[a]	----	----	---	---
15/6/78	0.95[a,b]	16.6	16.4	293	298
28/6/78	0.50	16.2	19.3	318	333

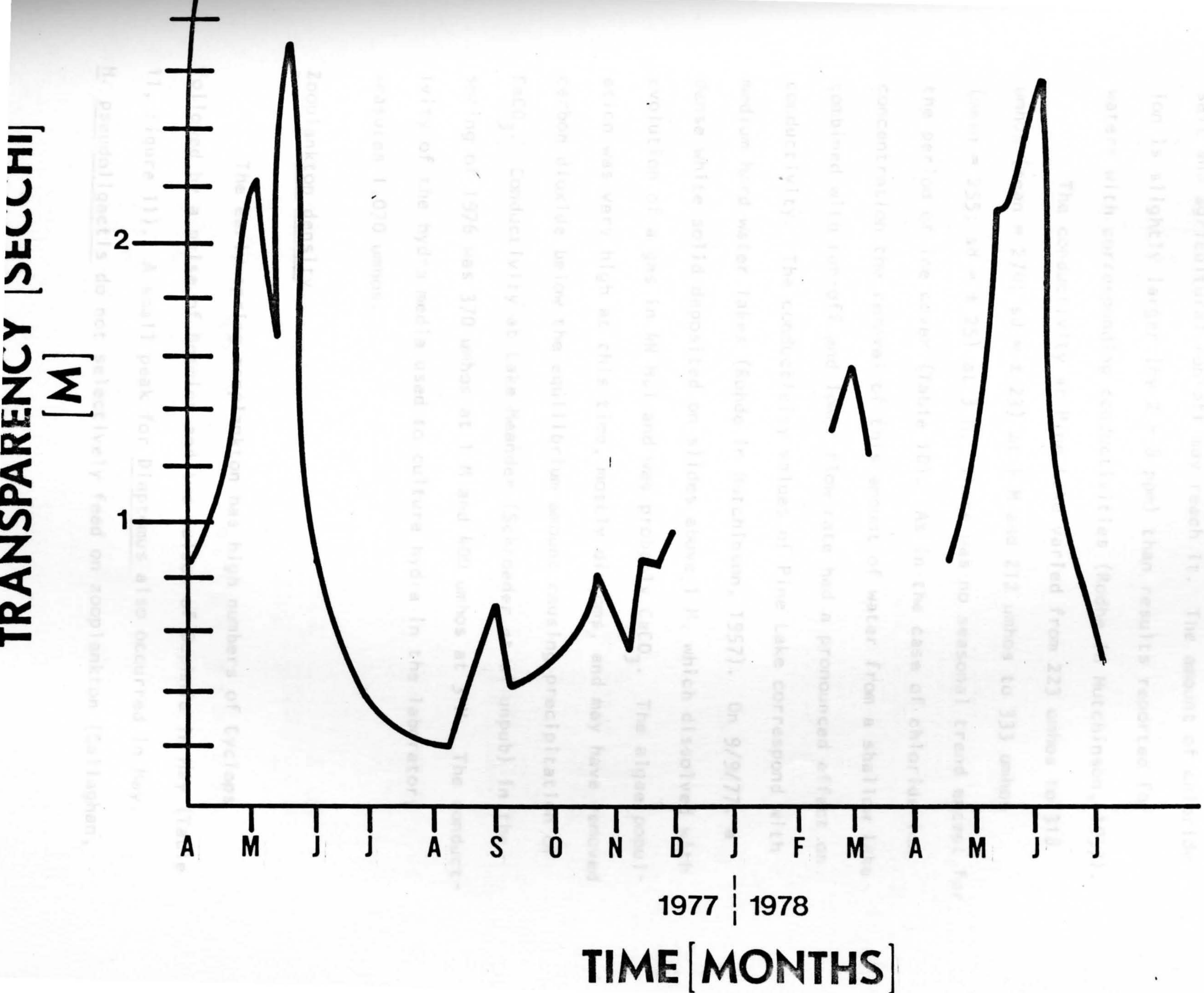
[a] interpolated from 1977 data

[b] estimated values: 1/6/78 = 1.9; 15/6/78 = 1.0

[c] mean chloride for observational period = 16.1 ± 1.0 (1M)
16.2 ± 0.9 (3M)

mean conductivity for observational period = 274 ± 23 (1M)
275 ± 25 (3M)

Fig. 10.--Changes in water transparency (Secchi) with time. M = meter. 1978 data from April 27 to June 8 extrapolated from 1977.


TRANSPARENCY [SECCHI] [M]
2
1
A M J J A S O N D J F M A M J J
1977 1978
TIME [MONTHS]

ions. Pine Lake is in a rural area with two influent streams and receives little or no industrial run-off or sewage although some road salt and agricultural run-off may reach it. The amount of chloride ion is slightly larger (by 2 - 8 ppm) than results reported for waters with corresponding conductivities (Rodhe in Hutchinson, 1957).

The conductivity at Pine Lake varied from 223 umhos to 318 umhos (mean = 274; sd = ± 23) at 1 M and 212 umhos to 333 umhos (mean = 255; sd = ± 25) at 3 M. There was no seasonal trend except for the period of ice cover (Table 10). As in the case of chloride ion concentration the removal of this amount of water from a shallow lake combined with run-off and lower flow rate had a pronounced effect on conductivity. The conductivity values of Pine Lake correspond with medium hard water lakes (Rohde in Hutchinson, 1957). On 9/9/77, a dense white solid deposited on slides above 1 M, which dissolved with evolution of a gas in 4N HCl and was probably $CaCO_3$. The algae population was very high at this time, mostly diatoms, and may have removed carbon dioxide below the equilibrium amount causing precipitation of $CaCO_3$. Conductivity at Lake Meander (Schroeder et al unpub) in the spring of 1976 was 370 umhos at 1 M and 400 umhos at 3 M. The conductivity of the hydra media used to culture hydra in the laboratory measures 1,070 umhos.

Zooplankton density

The early spring zooplankton has high numbers of Cyclops followed by a pulse of Bosmina and two pulses of Daphnia in May (Table 11, Figure 11). A small peak for Diaptomus also occurred in May. H. pseudoligactis do not selectively feed on zooplankton (Callaghan,

Table 11. Zooplankton density at Pine Lake (No./Liter).

DATE	DEPTH	CYC	DIAP	BOSM	DAPH	CHYD	CERIO	LEPTO	DIAPH	NAUP	LEYD	TOTAL
1977												
24/3[a]	1M	112	6	38	13							189
	3M	25	2	19	6							52
	W	69	4	29	10							121
1/4[a]	1M	30	11	9	6							56
	3M	9	1	34	1							20
	W	20	6	22	4							38
8/4	1M	23(5)	3(1)	34(15)	17(10)							77(32)
	3M	26(2)	2(.4)	15(.8)	7(.5)							50(2)
	W	24(4)	2(.7)	25(8)	21(5)							64(17)
16/4	1M	8(1)	3(.7)	24(5)	24(3)							59(7)
	3M	8(.3)	.2(.1)	10(.9)	6(2)							24(3)
	W	8(.9)	2(.4)	17(4)	15(2)							42(5)
23/4	1M	19(1)	6(1)	86(11)	121(30)							232(41)
	3M	33	2	87	48							172
	W	17	4	86	84							202
30/4	1M	5(.2)	12(6)	4(2)	66(10)							93(14)
	3M	17(1)	3(.7)	44(10)	70(11)							134(19)
	W	11(.8)	8(4)	24(6)	68(11)							114(16)

Table 11 (Continued).

DATE	DEPTH	CYC	DIAP	BOSM	DAPH	CHYD	CERIO	LEPTO	DIAPH	NAUP	LEYD	TOTAL
7/5	1M	7(1)	7(.1)	13(3)	88(14)							117(15)
	3M	8(1)	4(.6)	14(3)	97(9)							123(12)
	W	8(1)	6(.4)	13(3)	92(11)							120(13)
13/5	1M	5(1)	18(5)	18(6)	44(14)							193(30)
	3M	6(.5)	7(.6)	13(3)	54(8)							81(22)
	W	5(.8)	13(3)	15(4)	35(20)							137(26)
21/5	1M	1(.4)	4(1)	1(.5)	85(20)							91(22)
	3M	4(2)	9(.9)	2(.3)	96(5)							112(6)
	W	3(1)	6(1)	2(.4)	90(12)							101(14)
28/5	1M	.8(.1)	10(2)	.3(.3)	225(12)							2 (12)
	3M	1(.3)	2(1)	.5(.2)	120(11)							125(13)
	W	.9(.2)	6(1)	.4(.3)	173(11)							180(12)
10/6	1M	4(2)	10(1)	1(.3)	27(5)							45(4)
	3M	2(.2)	4(.9)	1(.5)	29(.7)							35(2)
	W	3(1)	7(2)	1(.4)	28(3)							40(3)
22/6	1M	2(.2)	3(.8)	13(6)	22(4)							41(7)
	3M	2(.4)	1(.2)	.9(.1)	29(4)							33(4)
	W	2(.3)	2(.5)	7(3)	26(4)							37(5)
7/7	1M	5(2)	3(.6)	1(.2)	5(2)	38(9)						54(9)
	3M	21(3)	.2(.2)	0	3(.6)	2(1)						27(.9)
	W	13(3)	1(.4)	.6(.1)	4(1)	20(5)						40(5)
26/7	1M	.9(.1)	.8(.5)	.4(.3)	8(2)	1(.3)						11(2)
	3M	.3(0)	.6(.1)	2(.4)	9(1)	1(.3)						13(1)
	W	.6(.1)	.7(.3)	1(.4)	8(2)	1(.3)						12(2)

Table 11 (Continued)

DATE	DEPTH	CYC	DIAP	BOSM	DAPH	CHYD	CERIO	LEPTO	DIAPH	NAUP	LEYD	TOTAL
8/8	1M	2(.6)	.1(.1)	2(1)	30(.8)	.1(.1)	1(.3)					37(2)
	3M	.5(.2)	.2(.1)	.2(.1)	79(17)	.2(.1)	11(2)					93(18)
	W	1(.4)	.2(.1)	1(.6)	55(9)	.2(.1)	6(1)					65(10)
23/8	1M	0	.9(.4)	.1(.1)	25(2)	2(.7)	2(.6)					3 (1)
	3M	0	0	1(.7)	16(3)	.9(.4)	2(.3)					20(4)
	W	0	.5(.2)	.7(.4)	21(3)	1(.6)	2(.5)					26(3)
1/9	--	----	----	----	----	----	----					----
9/9	1M	.5(.2)	.2(.1)	0	10(2)	0	.6(.3)	.2(.1)	.1(.1)			12(3)
	3M	.9(.5)	.6(.3)	0	9(2)	0	1(.5)	0	.7(.4)			12(2)
	W	.7(.4)	.4(.2)	0	10(2)	0	.9(.3)	.1(.1)	.4(.2)			12(2)
20/9	1M	.7(.2)	.2(.2)	0	2(.4)	0	.2(.2)	.3(.2)	0			4(.4)
	3M	2(.5)	1(.8)	.1(.1)	3(1)	0	.3(.2)	.4(.3)	.1(.1)			7(1)
	W	1(.4)	.6(.5)	.1(.1)	3(.7)	0	.3(.2)	.4(.2)	.1(.1)			5(.8)
27/9	1M	2(.6)	1(.2)	.1(.1)	8(1)	.1(.1)	0	0	.5(.2)			12(2)
	3M	8(.9)	12(3)	.7(.2)	32(6)	0	.4(.3)	0	2(.9)			56(9)
	W	5(.7)	7(2)	.4(.2)	20(4)	.1(.1)	.2(.2)	0	1(.5)			34(5)
4/10	1M	3(.4)	1(.1)	0	3(.5)	0	.1(.1)	2(.1)	1(.3)			9(.8)
	3M	5(.2)	2(.6)	0	3(1)	.3(0)	0	.8(.6)	2(.4)			11(2)
	W		2(.4)	0	3(1)	.2(0)	.1(.1)	.5(.4)	2(.4)			10(2)

Table 11 (Continued).

DATE	DEPTH	CYC	DIAP	BOSM	DAPH	CHYD	CERIO	LEPTO	DIAPH	NAUP	LEYD	TOTAL
14/10	--	---	----	----	----	----	-----	-----	-----	----	----	-----
20/10	1M	7(.2)	4(.6)	.2(.1)	4(.5)	0	0	.1(.1)	.1(.1)	2(1)		16(2)
	3M	8(2)	1(.6)	0	3(.2)	0	0	.1(.1)	.5(.2)	.1(.1)	.1(.1)	14(2)
	W	8(1)	3(.6)	.1(.1)	3(.7)	0	0	.1(.1)	.3(.2)	.8(.8)	.1(.1)	15(2)
27/10	1M	12(4)	2(.4)	0	2(.6)	.1(.1)	0	.1(.1)	0	.1(.1)		17(4)
	3M	23(8)	1(.4)	0	5(2)	0	0	0	0	0		30(9)
	W	18(6)	2(.4)	0	4(1)	.1(.1)	0	.1(.1)	0	.1(.1)		23(7)
3/11	1M	3(.7)	1(.5)	0	4(2)	.3(0)	0	0	0	0		9(2)
	3M	11(1)	2(.5)	.1(.1)	5(1)	0	0	0	.1(.1)	0		17(.6)
	W	7(.8)	1(.5)	.1(.1)	4(1)	.2(0)	0	0	.1(.1)	0		13(1)
10/11	1M	10(4)	1(.3)	.4(.3)	9(4)	.9(.1)	0	0	0	0		23(4)
	3M	13(1)	2(.5)	.2(.1)	11(2)	1(.4)	0	0	0	0		27(3)
	W	11(3)	1(.4)	.3(.2)	10(3)	1(.3)	0	0	0			25(3)
17/11	1M	9(1)	3(.4)	0	19(4)	.8(.5)	0	0	.2(.1)	.3(.2)		33(4)
	3M	10(3)	2(.1)	0	10(1)	.3(.2)	0	0	.1(.1)	0		22(4)
	W	9(2)	3(.3)	0	14(3)	.6(.3)	0	0	.2(.1)	.2(.1)		28(4)
23/11	1M	2(.5)	5(3)	1(.3)	6(2)				.1(.1)			14(6)
	3M	5(.9)	2(.3)	.2(.1)	9(.9)							16(2)
	W	3(.7)	3(2)	.6(.2)	8(1)					.1(.1)		15(4)

Table 11 (Continued).

DATE	DEPTH	CYC	DIAP	BOSM	DAPH	CHYD	CERIO	LEPTO	DIAPH	NAUP	LEYD	TOTAL
1/12	1M	14(.2)	8(2)	0	21(1)	.1(.1)						43(2)
	3M	14(1)	4(.6)	0	24(4)	0				.1(.1)		42(13)
	W	14(.7)	6(1)	0	23(3)	.1(.1)				.1(.1)		43(7)
<u>1978</u>												
22/2	1M	1(.3)	.3(.2)	.8(.2)	0	0						2(.4)
	3M	12(2)	8(4)	.1(.1)	.8(.2)	0					.3(.3)	29(6)
	W	7(1)	4(2)	.5(.2)	.4(.1)						.2(.2)	15(3)
1/3	1M	3(.8)	.5(.5)	.3(0)	1(.2)							5(2)
	3M	----	----	----	----							----
	W	----	----	----	----							----
8/3	1M	5(1)	0	.1(.1)	.1(.1)		.2(.2)					6(.9)
	3M	1(.5)	0	0	0		0					1(.5)
	W	3(.8)	0	.1(.1)	.1(.1)		.1(.1)					4(.7)
13/4	1M	16(1)	.2(.1)	3(1)	.1(.1)	.2(.2)				.2(.1)		20(.7)
	3M	19(2)	.2(.1)	3(.6)	1(.3)	.1(.1)						22(1)
	W	18(2)	.2(.1)	3(.8)	.8(.2)	.2(.2)				.1(.1)		21(1)
20/4	1M	17(2)	.9(.1)	5(1)	2(.1)	.2(.1)						34(3)
	3M	19(3)	.6(.1)	8(.3)	1(.3)	.3(.2)						29(2)
	W	18(2)	.8(.1)	6(.8)	2(.2)	.3(.2)						24(3)

Table 11 (Continued).

DATE	DEPTH	CYC	DIAPH	BOSM	DAPH	CHYD	CERIO	LEPTO	DUAPH	NAUP	LEYD	TOTAL
27/4	1M	7(3)	.9(.4)	6(1)	4(2)	.6(.1)				.2(.1)		18(3)
	3M	7(.6)	1(.7)	8(4)	3(.2)	.8(.2)				.1(.1)		23(6)
	W	7(2)	1(.6)	7(2)	3(.9)	.7(.2)				.2(.1)		21(5)
4/5	1M	8(1)	4(1)	50(7)	13(4)	.8(.3)				.3(.2)		74(11)
	3M	7(.5)	1(.7)	60(9)	13(2)	.1(.1)				0		84(18)
	W	9(.7)	3(.9)	55(8)	13(3)	.5(.2)				.2(.1)		79(15)
11/5	1M	11(.4)	1(.5)	124(32)	32(5)	2(.4)				.2(.1)		172(38)
	3M	13(.7)	2(.7)	94(21)	48(8)	4(.7)				.3(.3)		165(26)
	W	12(.5)	2(.6)	109(26)	40(7)	3(.6)				.3(.2)		169(32)
18/5	1M	10(.8)	3(.1)	34(13)	72(20)	.1(.1)						119(32)
	3M	6(.9)	.9(.2)	66(11)	49(3)	.3(.3)						121(10)
	W	8(.9)	2(.2)	55(12)	61(12)	.2(.2)						121(21)
												135(3)
25/5	1M	2(.4)	12(2)	53(2)	66(.7)	1(.2)						
	3M	4(1)	3(1)	73(4)	63(1)	1(.1)						144(4)
	W	3(.8)	7(1)	63(3)	64(1)	1(.1)						139(4)
1/6	1M	2(.4)	2(.3)	10(3)	40(14)	.5(.2)						57(14)
	3M	7(2)	4(.4)	33(10)	85(6)	0						129(15)
	W	4(1)	3(.4)	22(7)	62(10)	.3(.1)						93(15)

Table 11 (Continued).

DATE	DEPTH	CYC	DIAP	BOSM	DAPH	CHYD	CERIO	LEPTO	DIAPH	NAUP	LEYD	TOTAL
8/6	1M	2(.7)	19(4)	.2(.2)	73(26)	.1(.1)						95(30)
	3M	4(.9)	9(1)	.4(.3)	39(7)	.2(.1)		.3(.2)				53(8)
	W	3(.8)	14(3)	.3(.3)	56(17)	.2(.1)		.2(.1)				74(19)
15/6	1M	2(.4)	12(5)	.2(.1)	16(5)			.9(.2)				41(10)
	3M	2(.8)	8(1)	.2(.1)	15(3)			.6(.1)				26(3)
	W	2(.6)	10(3)	.2(.1)	15(4)			.8(.2)				34(6)
28/6	1M	2(.4)	14(2)	0	6(1)	.9(.4)		.4(.2)	.1(.1)			25(3)
	3M	1(.4)	5(.4)	.1(.1)	8(1)	.3(.2)						15(.5)
	W	2(.4)	10(1)	.1(.1)	7(1)	.6(.3)		.2(.1)	.1(.1)			20(2)

[a] Collected single sample with Wilson bottle.

[W] Water column density = $\frac{1M + 3M}{2}$

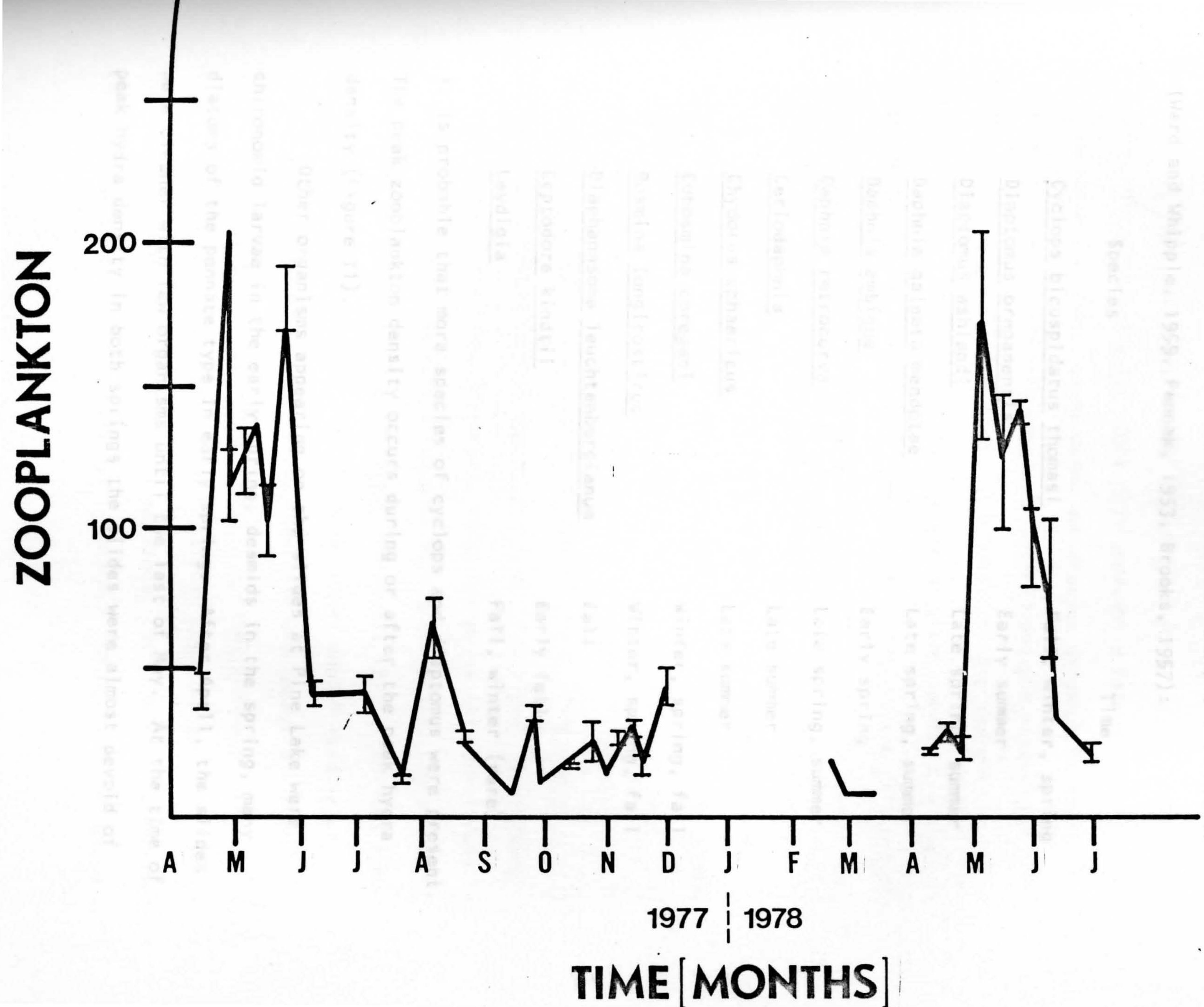
CYC = *Cyclops* spp.
DIAP = *Diaptomus* spp.
BOSM = *Bosmina* spp.
DAPH - *Daphnia* spp.
CHY = *Chydorus sphaerixus*
CERIO = *Ceriodaphnia spp.*
LEPTO = *Leptodora kindtii*

Table 11 (Continued).

DIAPH = *Diaphanasoma leuchtenbergianum*
LEYD = *Leydigia*
TOTAL = Total number per liter

( ) = Standard Error

Fig. 11.--Changes in zooplankton density with time. No./L zooplankton represents total number zooplankton per liter lake water.


ZOOPLANKTON
200
100
A M J J A S O N D J F M A M J J
1977
1978
TIME [MONTHS]

1978, unpub). Consequently the zooplankton found at Pine Lake were not analyzed quantitatively to species. The presence of the following species was established by dissection and microscopic examination (Ward and Whipple, 1959, Pennak, 1953, Brooks, 1957):

Species	Time
Cyclops bicuspidatus thomasi	Fall, winter, spring
Diaptomus oreganensis	Early summer
Diaptomus ashlandi	Late spring, summer
Daphnia galeata mendotae	Late spring, summer
Daphnia ambigua	Early spring
Daphnia retrocurva	Late spring, summer
Ceriodaphnia	Late summer
Chydorus sphaericus	Late summer
Eubosmina coregani	Winter, spring, fall
Bosmina longirostirus	Winter, spring, fall
Diaphanasoma leuchtenbergianum	Fall
Leptodora kindtii	Early fall
Leydigia	Fall, winter (rare)

It is probable that more species of cyclops and diaptomus were present. The peak zooplankton density occurs during or after the peak hydra density (Figure 11).

Other organisms appearing on the slides at Pine Lake were chironomid larvae in the early spring, desmids in the spring, many diatoms of the pennate type in early spring. After April, the slides were cleaner with few organisms until the last of May. At the time of peak hydra density in both springs the slides were almost devoid of other organisms. The steep decline in hydra density was accompanied by the deposition of mite egg cases. These were present as a dense accumulation of flat white masses. The eggs were hatched in the laboratory in lake water and identified as water mite larvae. Contact between mites and hydra for eight days apparently harmed neither. During early June many larval cases appeared on slides. In early August, the larval and mite cases disappeared and the slides were colonized by Epistylis flavicans, a colonial ciliate (Ward and Whipple, 1959). In September a large diatom bloom occurred in the water and $CaCO_3$ was deposited on the slides. Later in the fall, slides were very clean through the last collection of 1/12/77. Slides collected for two weeks beneath the ice in March of 1978 were clean.

During the observational period the obvious forms of algae and protozoa present in the water were noted although a thorough investigation of algae in Pine Lake was not a primary objective of this study. On 27/5/77 many regularly spiraled blue-green filamentous algae were noticed, accompanied by a lowered Secchi disc reading although zooplankton density was at its peak. The algae, identified as Lyngbya contorta Lemm. (Prescott, 1970) increased throughout June to a very dense bloom. In July a colonial blue-green algae, tentatively identified as a species of Microcystis (Prescott, 1970), replaced the Lyngbya and Secchi readings fell to their lowest annual reading of 0.25 M. The bloom appeared to be monospecific and imparted a dirty green color and a foul odor to the water. A total phytoplankton count made in water collected 8/8/77 was 1118 colonies per ml. The colonies were large and three dimensional and it was not possible to accurately count algal cells per colony but 100 cells would not be too high a number. At this time the poor condition of fish was noted by Steve Mihalko at Pine Lake. Microcystis is reportedly toxic to fish (Prescott, 1970). By September the bloom of Microcystis had declined and a large diatom pulse, consisting of several species of centric diatoms (Stephanodiscus spp. dominant) and a filamentous green algae. $CaCO_3$ precipitated from the water at this time. The diatom pulse continued through the fall. Water collected during the winter under the ice was clear with no large amounts of algae. Early spring of 1978 brought a new diatom pulse, mostly of the pennate type. Bright green desmids, unidentified as to species, occurred during the late spring. Some Microcystis was noted on 18/5/78 but no bloom occurred before suspension of collections on 28/6/78. No Lyngbya were found during the spring of 1978.

In addition to the algae described above, two other interesting organisms occurred. In September of 1977, an unidentified animal appeared in small numbers in the zooplankton samples. The organism consisted of an oval case with two long many-segmented appendages at the narrow end of the oval. These were found throughout the fall. The second organism occurred as a pulse of ciliates, Codonella cratera (Eddy and Hodson, 1961) and appeared in the latter part of October and throughout November of 1977.

Correlation Analysis

Correlation analysis (Dixon, 1974) was used to determine the relationships of time, temperature, transparency and zooplankton density to hydra population density, growth axes density and bud ratios. Data from single depths and combined depths (above 2.5 M, below 2.5 M and total water column, 0.5 - 3.5 M) were used for correlation analysis. Two and one-half meters was used as the dividing level when combining depths because of the tendency for hydra to be attached to slides below 2.0 M throughout most of the observational period (figure 9) and because the maximum Secchi disc reading was 2.7 M with much lower readings during most of the observational period (Table 10).

A summary of the correlation values is given in Table 12. There is a significant correlation between time and bud ratio only at 1.5 M and between temperature and hydra or growth axes density only at 0.5 M. Zooplankton density did not have a significant correlation with hydra related factors at any level. A highly significant correlation occurs between transparency and zooplankton density at all levels (P 0.01) while transparency has a significant correlation with hydra density and growth axes density at 1.0 M, 2.0 M and 0.5 - 2.0 M combined depths and with bud ratio at 0.5 M, 1.0 M and 2.0 M. Transparency is the only factor which shows consistent correlation in the upper half of the water column with hydra density, growth axes density or bud ratio and with zooplankton density throughout the water column.

Table 12. Correlation values for factors at Pine Lake

DEPTH (M)	FACTOR	T_i	H	GA	T^o	S	Z	GA/H
0.5	Ti	1.000	0.254	0.310	-0.167	0.106	-0.264	0.284
	H		1.000	0.981**	0.409*	0.237	0.016	0.432*
	GA			1.000	0.421*	0.325	0.041	0.467*
	T^o				1.000	0.334	0.342	0.003
	S					1.000	0.565**	0.446*
	Z						1.000	0.228
	GA/H							1.000
1.0	Ti	1.000	0.328	0.364	-0.164	0.106	-0.264	0.303
	H		1.000	0.995**	0.327	0.500*	0.107	0.439*
	GA			1.000	0.337	0.492*	0.077	0.436*
	T^o				1.000	0.316	0.331	-0.120
	S					1.000	0.656**	0.477*
	Z						1.000	0.140
	GA/H							1.000
1.5	Ti	1.000	0.316	0.335	-0.163	0.106	-0.264	0.522**
	H		1.000	0.991**	0.312	0.392	0.124	0.301
	GA			1.000	0.323	0.384	0.102	0.319
	T^o				1.000	0.291	0.328	-0.213
	S					1.000	0.565**	0.341
	Z						1.000	-0.011
	GA/H							1.000
2.0	Ti	1.000	0.305	0.350	-0.161	0.106	-0.264	0.179
	H		1.000	0.989**	0.135	0.476*	0.310	0.367

Table 12 (Continued).

DEPTH (M)	FACTOR	T_i	H	GA	T^o	S	Z	GA/H
2.0	GA			1.000	0.164	0.506**	0.297	0.390
	T^o				1.000	0.282	0.323	-0.196
	S					1.000	0.565**	0.500*
	Z						1.000	0.097
	GA/H							1.000
2.5	Ti	1.000	0.022	0.037	-0.152	0.106	-0.041	0.257
	H		1.000	0.996**	0.036	0.291	0.232	0.315
	GA			1.000	0.043	0.302	0.268	0.353
	T^o				1.000	0.267	0.321	-0.179
	S					1.000	0.813**	0.276
	Z						1.000	0.320
	GA/H							1.000
3.0	Ti	1.000	-0.142	-0.164	-0.170	0.106	-0.041	-0.138
	H		1.000	0.996**	-0.043	0.208	0.166	0.141
	GA			1.000	0.040	0.209	0.185	0.184
	T^o				1.000	0.216	0.270	-0.151
	S					1.000	0.813**	0.340
	Z						1.000	0.372
	GA/H							1.000
3.5	Ti	1.000	-0.083	-0.054	-0.174	0.106	-0.091	0.132
	H		1.000	0.996**	-0.100	0.134	0.131	0.111
	GA			1.000	-0.122	0.134	0.152	0.151
	T^o				1.000	0.179	0.248	-0.187

Table 12 (Continued).

DEPTH (M)	FACTOR	T_i	H	GA	T^o	S	Z	GA/H
3.5	S					1.000	0.813**	0.128
	Z						1.000	0.170
	GA/H							1.000
0.5 - 2.0	Ti	1.000	0.340	0.370	-0.167	0.106	-0.264	0.326
	H		1.000	0.998**	0.346	0.452*	0.147	0.207
	GA			1.000	0.363	0.466*	0.112	0.233
	T^o				1.000	0.304	0.332	-0.185
	S					1.000	0.565**	0.297
	Z						1.000	-0.107
	GA/H							1.000
2.5 - 3.5	Ti	1.000	-0.085	-0.069	-0.173	0.106	-0.041	-0.108
	H		1.000	0.997**	-0.081	0.171	0.152	-0.015
	GA			1.000	-0.092	-0.176	0.178	0.012
	T^o				1.000	0.221	0.270	0.094
	S					1.000	0.813**	0.062
	Z						1.000	0.286
	GA/H							1.000
0.5 - 3.5	Ti	1.000	-0.002	0.022	-0.166	0.106	-0.173	-0.245
	H		1.000	0.994**	0.060	0.278	0.323	-0.220
	GA			1.000	0.053	0.289	0.353	-0.191
	T^o				1.000	0.272	0.333	0.338
	S					1.000	0.706**	-0.154
	Z						1.000	0.301
	GA/H							1.000

Table 12 (Continued).

T_i = Time (days)
H = Hydra per slide per day
GA = Growth axes per slide per day
T^o = Temperature, ^oC.
S = Secchi disc reading (M)
Z = Zooplankton density (No./liter)
GA/H = Bud ratio

DISCUSSION

Planktonic hydra in Pine Lake have two population density peaks annually. A large late spring pulse with rapid decline and disappearance of hydra in early summer is followed by a much smaller fluctuating fall pulse which declines with the onset of winter. Due to short collection intervals and temperatures below 20°C during both population pulses most of the hydra found on slides are likely colonizers although reproduction may be an important contributor to the hydra density on slides. H. oligactis growth rate increases with increasing temperature to a maximum at 25°C (Schroeder unpub). The temperatures at Pine Lake during hydra population increase varies from 12°C to 20°C. This is a narrower range at lower temperatures than reported for Kirkpatrick's Lake by Bryden (1952) (21° to 31°C). Miller (1936) reported population doubling every two or three days at Douglas Lake with summer temperatures up to 25°C.

Since the collection site was in open waters approximately 100 M from shore and during the season when plant growth is not plentiful the early spring population may come from hydra which have overwintered on the bottom or on plant debris. The distance from shore where incipient vegetation might provide substrates is too far for hydra to travel by the conventional modes of locomotion described by Rushforth (1973). Yu (1976) claims that Chlorhydra viridissima travelled only 1.5 M per month while Carrick (1956) reports hydra movement is limited to several times body length. The overwintering hydra under the combined influences of wave action, wind-generated currents or floating induced by starvation (Lomnicki and Slobodkin, 1966) would disperse through the water column, becoming plankters.

The existence of a planktonic phase for hydra is now generally accepted (Reisa, 1973, Schroeder and Reeder, 1970). Its importance in numbers compared to the sessile population is undoubtedly small but its potential as a means of colonization may be great and therefore of importance in population dynamics. This study is concerned only with the population dynamics of planktonic hydra in Pine Lake. It cannot be extrapolated to the sessile population on vegetation in the littoral zone. Colonization of slides by hydra has been reported by Bryden (1952), Miller (1936), Carrick (1956), Batha (1974) and Yu (1976). Bryden reports one peak in the fall at Kirkpatrick's Lake in Tennessee. Carrick found H. littoralis, H. oligactis and H. pseudoligactis have a greater population density on slides in the late spring and the fall in Lake Erie. Carrick's limited work with H. oligactis and H. pseudoligactis shows the coexistence of the two species in the fall but not the spring, in agreement with my findings at Pine Lake. Miller (1936) reported a single population peak for H. oligactis in water 0.5 to 15 M deep at Douglas Lake during the May through August period. The numbers of hydra found by Miller on clean slides were small, suggesting planktonic hydra are rare in Douglas Lake. Miller found H. oligactis on vegetation in the May to July period, H. oligactis and H. pseudoligactis on vegetation with only H. oligactis on slides in October and November, but some H. pseudoligactis on slides in the late fall. Batha (1974) reported the appearance of hydra on slides in Lake Michigan up to one and one-half miles offshore. The hydra in Lake Michigan colonized slides in May or June and population density peaked in September or October. Yu observed two population peaks for H. americana in California lakes, one in August and another in October, but only one peak in the fall for Chlorhydra viridissima. Two population peaks, one in the late spring and another in the fall have been found for H. oligactis in Meander Lake (Schroeder et al, unpub).

Bimodal patterns of hydra population dynamics have also been observed on vegetation at Douglas Lake (Miller, 1936) and Pickerel Lake (Griffing, 1965). Moen (1951) observed the appearance of summer and fall peaks of planktonic hydra in a shallow (2 feet) Iowa nursery lake but his study was not focused on population dynamics but rather on the associated fish kill.

The existence of two population peaks at Pine Lake agrees with the work of Carrick at Lake Erie and Schroeder at Lake Meander. Kirkpatrick's Lake, where Bryden did his study is a warm water lake, much smaller than Pine Lake, is not ice covered during winter and his collections were biweekly during the summer, making reproduction a probable important factor. The main interest of his work to this study is in the reported recapture of stained hydra at some distance from their release point, indicating migration through the water as plankters. Welch and Loomis (1924) reported seeing dense floating populations of hydra after heavy storms, suggesting wave action detached hydra from the bulrushes and dispersed them into the surface waters. However, both Miller (1936) and Young (1945) discounted wave action as a cause of release of planktonic hydra. Young found hydra attached to Scirpa through heavy storms while other periphytic organisms were swept away. On calm days, Bryden found hydra attached to submerged glass slides within 3 cm of the water surface but on rough days, hydra were attached only at depths greater than 10 cm. The observations of Young and Bryden suggest that hydra are firmly attached to substrates and can withstand movement due to heavy waves but when exposed repeatedly to air by surface waves they are more easily detached from their supports.

The state of hydra taxonomy makes comparison of the data from Pine lake with that from other studies difficult. Batha (1974) did not completely identify his species, referring to "brown hydra" and pointing out that there is no reliable means of identification to species of thousands of hydra on the day of collection. Identification at a later time introduces errors due to reproduction, mortality, parasitism and laboratory culture conditions. Welch and Loomis (1924), Miller (1936) and Bryden (1952) worked with _H. oligactis_, the predominant hydra species at Pine Lake. Carrick (1956) studied _H. littoralis_ for most of his thesis but the limited data on _H. oligactis_ and _H. pseudoligactis_ indicates a 10:1 ratio for the two species.

The hydra identified from Pine Lake (Table 2) showed an approximate 5:1 ratio of _H. oligactis_ to _H. pseudoligactis_ in the fall. Identification was made some time after collection and differential reproduction could have occurred. All spring hydra which were identified were _H. oligactis_. A total of 56 hydra were identified throughout the spring of 1978. The summer hydra collected on one date, August 23, 1977, were identified as _H. pseudoligactis_, as were the hydra collected on September 20, 1977. Griffing reported a mixture of _H. oligactis_ and _H. pseudoligactis_ at Pickerel Lake in Michigan in the spring. He found a species specific movement of _H. oligactis_ from the epilimnion to the metalimnion and _H. pseudoligactis_ from the metalimnion to the epilimnion with the increase of water temperature in summer. With the data now available from Pine Lake, the two species in this lake appear to coexist in the fall and the number of H. pseudoligactis diminishes as the winter approaches.

The degree of colonization of slides gives a measure of frequency. At peak hydra density in the spring nearly 100% colonization of slides occurred (Figure 5) in agreement with Schroeder's results from Meander Lake (unpub). Fall colonization was closer to 50%. When colonization by density of hydra at the seven depths measured is considered (Figure 6) it appears that the hydra are most dense in the lower-middle part of the water column for the first part of the vernal pulse but gradually migrate upwards until they are well distributed in the column at peak density, shifting to the upper middle portion by the end of the pulse in the spring of 1978. I consider the data from the spring of 1978 to be more reliable when comparing colonization of depth levels because slide recovery was over 95% for the period while in the spring of 1977 many of the 0.5 M and 1.0 M slides were lost, especially during the peak density period. Only one slide was recovered at 0.5 M on May 13, 1977. This may have been due to faulty construction of stoppers so that slides popped off easily or to dragging of traps when slides were collected. Batha (1974) reported large losses of hydra when the slide racks were dragged by the boat. The wind conditions are similar for the two periods but the vernal pulse occurred twelve days earlier in 1977.

The reason for upward migration of planktonic hydra in the spring of 1978 remains unknown. The data is unexpected in the light of a laboratory study by Schroeder and Reeder (1980) which indicated that small starved hydra at low temperatures would remain suspended in the water column for the longest periods of time while large well-fed hydra in warm water would sink more rapidly. The hydra at Pine Lake increase in size throughout the spring as the temperature increases. At the time of maximum density in the plankton they had maximum dry weight, were well-budded and were distributed throughout the water column almost equally. Zooplankton density was high and the hydra on the slides were well fed. The week following the maximum density, the population had decreased somewhat but was still high (Table 1, Figures 1 and 2) and the dispersion into the upper water column was even more pronounced (Figures 6 and 7). The simplest explanation for this may lie in the topography of Pine Lake. It is a shallow narrow lake (Figure 8), 3.5 Km long by 1.5 Km wide (maximum width) with a maximum depth of less than 4 M. It is oriented with its long axis north and south. Winds from the north, south and north-west cause more turbulence than winds of comparable velocity from other directions (Tables 8 and 9). Maximum wind velocity during the weeks preceding the spring hydra peaks were the highest of the season and were from the north-northwest. It is conceivable that high winds from the appropriate direction could cause the mixing of the entire water column and keep the hydra suspended despite high hydra weights and warm temperature. This hypothesis does not explain why the largest hydra were found on the slides at the top of the water column on the week of May 25, 1978, but the possibility exists that they attained their growth after attaching to slides. The following week, the maximum wind throughout the week was less (17 mph) and the heaviest hydra were in the bottom of the water column.

Another objection to simple wind generated turbulence as an explanation for hydra dispersal is that the upward migration was gradual through the spring and thus cannot be explained on the basis of one day of high wind velocity.

Another explanation for the upward trend might be that the release of planktonic hydra by the sessile population increases during the spring due to some deteriorating environmental factor such as starvation and/or overcrowding. Lomnicki and Slobodkin (1966) and Griffing (1965) suggested attached hydra populations exposed to stress might release floaters which would act as colonizers if an appropriate habitat were found. Batha (1974) suggested that large numbers of zooplankton in the water may not be available to hydra attached to vegetation on bottom substrates. He used this explanation for the low zooplankton density found when he collected planktonic hydra and high zooplankton density when no hydra were to be found. The objection in applying this hypothesis to Pine Lake is that the most starved hydra would be detached to float and the hydra found on our slides were healthy and well-fed. It does not seem probable that they would remain suspended in the upper warm water long enough to assimilate food and reproduce but as described in the previous section they may have grown after attachment to slides.

The fall hydra population at Pine Lake is not dispersed through the water column with any discernible trend but most hydra remain in the lower middle part of the water. Batha (1974) reported a similar dispersal for hydra on his slides in Lake Michigan.

The lack of a significant relationship between hydra density and bud ratio and temperature in the correlation analysis (Table 12) agrees with the conclusion of Miller (1936) but not Welch and Loomis

(1924) who postulated the high summer temperatures of Douglas Lake as responsible for the decline in population density. Miller claimed water temperatures at Douglas Lake were within the optimum for hydra and pointed out that hydra were plentiful in Bryden's Kirkpatrick Lake when the water temperature was as high as 31°C.

In addition to the effect on maximum density, the possible effect of temperature on appearance and disappearance of spring and fall hydra and on the period of maximum growth must be considered. Hydra were already in the plankton when our spring sampling was begun (temperatures of 15°C, 10°C in 1977 and 1978 respectively). Batha (1974) considered a water temperature of 9°C and of 5°C as possible cues for the appearance and disappearance of planktonic hydra. Bryden (1952) considered low temperature to be one of the factors responsible for fall disappearance. Our fall populations appeared when the water temperature was 20°C and disappeared when it was 5°C. All collections of hydra, fall and spring, fell within Miller's postulated range of 10 to 20°C (1936) with the exception of that on June 1, 1978, when the lake temperature was up to 25°C at 0.5 M but the population decline had begun.

There may be a relationship between the equitability of lake temperature and the maximum density of hydra attained. In the spring of 1977 when even temperatures occurred over the growth period the hydra reached a peak density two and one-half times that of the spring of 1978 when a steeper temperature gradient occurred in May.

There is no significant correlation between hydra density and zooplankton density. The hydra appeared well-fed in both spring and fall pulses (bud ratios and dry weights, Tables 3 and 4). During both spring pulses the zooplankton density was above the 100/liter found necessary for growth of hydra in laboratory cultures at 20°C (Schroeder and Callaghan, unpub). In the fall, zooplankton density was well below 100/liter, reaching a maximum of 34/liter and a minimum of 5/liter during the season. Since the hydra were healthy it is obvious they were feeding on other food, possible chironomid larvae. Carrick (1956) found chironomid larvae to be a principal food source of hydra. It should be noted, however, that the slides were clean for most of the fall, the zooplankton low and the water turbid due to a large centric diatom bloom. Gut analysis of fall collected hydra may help clarify this problem.

The chloride and conductivity data (Table 10) indicate that Pine Lake is a medium hard water lake with some small source of chloride ions from inflow or run-off. The lack of variation throughout the year makes it doubtful that these factors affect hydra population dynamics.

The only environmental factor with which hydra density and bud ratio showed a consistently significant correlation was transparency. Obviously light alone would not cause hydra to grow and reproduce but the interactions of light, phytoplankton density and zooplankton density may be operating here. In studies at Lake Windmere in 1934 by Ullyot reported in Hutchinson (1957) an inverse variation of transmission with phytoplankton density was observed when seasonal variations in turbidity of non-biological origin are not important. I believe Pine Lake falls into this category. Silt or mud was noticed in the water samples only once or twice. When the water was turbid the causative agent was most likely a bloom of algae. There is a high correlation between transparency and zooplankton density at all depth levels. In early spring a pennate diatom pulse occurs, keeping the transparency low. As the algae increase the zooplankton have more food and increase in numbers, diminishing the numbers of phytoplankton with a resulting increase in transparency. The plankton population continues increasing, with a succession of species of crustaceans, until early summer when inorganic nutrients become scarce and the population crashes. A blue green algae bloom often occurs in the summer (Hutchinson 1957). In Pine Lake there were 2 blue green algae blooms in the summer of 1977, Lyngbya contorta in June and a species of Microcystis in July. Hutchinson (1957) reports that even in fairly hard water with a reasonable sodium content at summer temperatures the blue green algae grow rapidly, outcompeting other forms. Some species of Microcystis have been reported to be monospecific with a maximum in July and a minimum in August when a high constant temperature, a sediment nutrient supply and water depth of 1 to 3 M are available. Pine Lake appears to fit this category and by June of 1977 the water transparency was declining rapidly and reached a low of 0.25 M in early August. The late summer blue green algae bloom was accompanied by the appearance of Chydorus sphaericus in the open waters. As the blue green algae died a fall pulse of centric diatoms occurred and continued until winter. There was also a fall pulse of a ciliate Codonella cratera (Eddy and Hodson 1961) in the open water. In the winter of 1977 the lake was covered with ice and several inches of snow and plankton density was very low (5/liter). In the summer of 1978 there was no Lyngbya bloom but Microcystis was detected in the water by the middle of May and the transparency fell rapidly with rising temperature during June. The above summary describes the phytoplankton in Pine Lake. Hutchinson (1957) reports a reversed occurrence of the fall and spring diatom pulses for most lakes but points out that Chandler (1942) found fall blooms of centric diatoms and spring blooms of pennate diatoms in Lake Erie.

The succession of phytoplankton species is related to zooplankton density and therefore the increase in numbers of hydra. Pulses of diatoms and green algae in the spring in temperate lakes are removed by increasing numbers of zooplankton which feed on phytoplankton, with a corresponding increase in water transparency. The zooplankton in turn provide food for hydra.

With depletion of mineral nutrients and increasing temperature the diatoms and green algae are replaced by blue-green algae blooms (Hutchinson 1957) and the zooplankton density decreases. While the abundant zooplankton at Pine Lake is undoubtedly related to the increase in size and numbers of hydra, there is no supportive data to relate it to hydra decline. Hydra have been known to survive for weeks without food (Griffing 1965) and one would expect a diminishing number of progressively unhealthy hydra over a period of time if starvation were a factor.

The distribution of zooplankton between 1 M and 3 M is similar for most collection dates. This is probably due to the turbulent mixing which occurs constantly at Pine Lake.

The role of parasites in hydra population dynamics is an unknown factor. Griffing (1965) suggested parasites and predators as possible causes for hydra decline at Pickerel Lake. At Pine Lake only two hydra were found with the lethal <u>Hydramoeba hydroxena</u> attached.

Deterioration of amoeba infested hydra observed in the laboratory can take place rapidly and an adverse effect if these parasites are present in lake water during a period of rising temperature cannot be ruled out. Many of the ciliate parasites, Trichodina pedicularis and Kerona pedicularis, were found on hydra but are not considered to be lethal. Hydra has few predators, Microstomum and fish being the principal ones (Carrick 1956). One unidentified planarian was found on slides during the entire observational period. Anchistropus minor, a cladoceran, is a predator on hydra (Hyman 1926, Carrick 1956) but was not found at Pine Lake.

The possibility that competition for supports plays a role in disappearance of hydra has been proposed by Miller (1936), Batha (1974) and Carrick (1956). Carrick reported competition for supports between large quantities of Plumatella repens and hydra. At Pine Lake the slides were free of large quantities of other organisms during most of the spring and fall when hydra were present. The most striking example of colonization by other organisms was exactly at the time of spring decline when large portions of the slides were covered with water mite egg cases. There was space left for hydra on some slides and it is impossible to know if the egg cases could have had an adverse effect on hydra colonization with our present data. I did find that hydra and water mite larvae could coexist for a period of a week and could see no evidence that hydra consumed the water mites as reported by Carrick (1956).

This study of population dynamics of hydra in the plankton of Pine Lake establishes a bimodal annual population density pattern which is not significantly correlated to temperature or food shortage.

The quantity of chloride ions and total ions in the lake water does not appear to affect hydra populations. A positive relationship exists between hydra density and transparency of lake water, the latter being affected by phytoplankton density which is in turn determined by the high zooplankton density. Zooplankton density increases rapidly by removal of the phytoplankton from the lake, during the spring but not during the fall. Distribution of hydra throughout the water column may be strongly related to wind-caused turbulence in a shallow lake. An upward migration of hydra during the vernal pulse could be due to wind-generated turbulence or colonization from hydra attached to littoral vegetation.

Further investigations at Pine Lake should include observations of the hydra population attached to vegetation. This might help elucidate the conflicting data from laboratory studies of sinking rates of hydra and the apparent migration upwards in the water column during the spring pulse. Gut analysis of fall and spring hydra should be done considering the differences in densities and pattern for the two population pulses. The precipitous decline of hydra populations in late spring remains unexplained although the occurrence of water mite cases on supports is an interesting but inconclusive piece of datum to be added to that of other workers who have postulated competition for supports as a factor in the disappearance of hydra. A method for fast identification of hydra species would be of distinct advantage to the field of hydra ecology.

CONCLUSIONS

Hydra occur in the planktonic phase in Pine Lake. The population density pattern is bimodal with a large spring pulse which declines rapidly and a smaller fall pulse which fluctuates throughout the fall and declines at the onset of winter.

Two species of hydra, Hydra oligactis and Hydra pseudoligactis, coexist in the fall in Pine Lake in an approximate five to one ratio of H. oligactis to H. pseudoligactis. No. H. pseudoligactis were found in spring populations.

During the vernal pulse hydra appeared to migrate upwards in the water column. The reason for this upward migration is not known but may be related to wind-generated water turbulence or colonization from rapidly increasing populations on plants.

There is a positive relationship between hydra density and transparency of lake water. There is no significant correlation between hydra population patterns and zooplankton density or temperature. A strong correlation exists between transparency and zooplankton density. Chloride ion concentration and conductivity do not vary over the year and place Pine Lake in the category of a medium hard-water lake.

APPENDIX

Experimental Data For Growth Axis and Hydra Counts for Each Collection Date at Pine Lake

The table in the appendix gives the $\frac{\text{number of growth axes}}{\text{number of hydra}}$ for each slide on four traps for each collection date. When no hydra were found on a slide a 0 is entered. When a slide was missing an x is entered. The depth from the Lake's surface is given in meters. The $\frac{\text{total number of growth axes}}{\text{total number of hydra}}$ collected on a given date is represented as total for date.

APPENDIX

Data from hydra collections at Pine Lake[a,b]

Trap #	Slide #	Depth 0.5	1.0	1.5	2.0	2.5	3.0	3.5
				16/4/77				
1	1	0	0	0	0	0	x	4/2
	2	0	0	0	0	0	0	3/1
	3	0	0	0	0	0	0	1/1
	4	0	0	0	0	0	0	3/1
2	1	0	0	0	x	0	9/3	12/5
	2	0	0	0	0	0	10/6	5/3
	3	0	0	0	0	0	2/2	7/3
	4	0	0	0	0	0	0	16/8
3	1	0	0	0	0	0	9/3	18/12
	2	0	0	0	0	0	1/1	0
	3	0	0	0	8/3	0	16/6	8/3
	4	0	0	0	12/4	0	13/4	6/3
4	No individual slide counts							
	# Slides	4	4	4	4	4	4	4
	Total For Date			224/98				
				23/4/77				
1	1	0	x	x	x	x	x	x
	2	x	x	x	x	x	x	x
	3	x	x	x	x	x	x	x
	4	x	x	x	x	x	x	x
2	1	0	0	0	0	0	8/3	6/2
	2	0	0	0	0	0	3/1	30/11
	3	0	x	0	0	x	x	0
	4	x	x	x	x	x	x	x
3	1	0	0	0	0	5/3	25/9	15/6
	2	0	0	0	0	0	23/8	35/16
	3	0	x	0	0	7/2	23/8	36/13
	4	0	x	0	0	16/6	10/4	33/13
4	1	0	0	1/1	0	12/6	3/1	14/7
	2	0	0	0	0	0	0	14/6
	3	x	0	0	0	0	0	8/5
	4	x	0	0	0	0	0	11/5

APPENDIX (Continued)

Trap #	Slide #	Depth 0.5	1.0	1.5	2.0	2.5	3.0	3.5
	Total for date			315/128				
				30/4/88				
1	1	1/1	0	0	2/1	1/1	0	0
	2	1/1	0	0	3/1	0	3/1	x
	3	0	0	0	0	0	1/1	0
	4	0	0	0	0	3/1	6/4	x
2	1	0	0	0	0	0	2/2	7/4
	2	0	0	0	0	0	0	22/12
	3	0	1/1	0	x	0	2/2	13/5
	4	0	0	0	0	0	x	x
3	1	0	0	0	0	0	x	0
	2	0	0	0	0	0	x	3/1
	3	0	0	0	0	0	x	x
	4	0	1/1	0	x	x	6/4	x
4	1	x	0	0	0	1/1	0	0
	2	x	0	0	0	0	0	0
	3	x	0	0	0	0	0	0
	4	x	0	0	0	x	4/2	0
	Total for Date				83/47			
				7/5/77				
1	1	x	0	4/1	0	0	3/2	2/1
	2	x	0	3/3	1/1	0	2/1	1/1
	3	x	x	0	1/1	0	0	3/2
	4	x	x	x	x	x	0	0
2	1	0	1/1	4/1	0	x	0	16/9
	2	0	3/2	1/1	0	x	0	0
	3	0	0	x	0	x	x	16/9
	4	x	x	x	x	x	x	0
3	1	x	x	x	x	x	x	x
	2	x	x	x	x	x	x	x
	3	x	x	x	x	x	x	x
	4	0	x	x	x	x	x	x
4	1	3/2	0	1/1	x	1/1	0	0
	2	0	0	0	x	0	0	5/4
	3	0	x	0	x	x	x	0
	4	0	x	0	x	x	x	0

APPENDIX (Continued)

Trap #	Slide #	DEPTH 0.5	1.0	1.5	2.0	2.5	3.0	3.5
	Total for Date			83/47				
				7/5/77				
1	1	x	0	4/1	0	0	3/2	2/1
	2	x	0	3/3	1/1	0	2/1	1/1
	3	x	x	0	1/1	0	0	3/2
	4	x	x	x	x	x	0	0
2	1	0	1/1	4/1		x	0	16/9
	2	0	3/2	1/1	0	x	0	0
	3	0	0	x	0	x	x	16/9
	4	x	x	x	x	x	x	0
3	1	x	x	x	x	x	x	x
	2	x	x	x	x	x	x	x
	3	x	x	x	x	x	x	x
	4	0	z	x	x	x	x	x
4	1	3/2	0	1/1	x	1/1	0	0
	2	0	0	0	x	0	0	5/4
	3	0	x	0	x	x	x	0
	4	0	x	0	x	x	x	0
	Total for Date			71/44				
				13/5/77				
1	1	x	x	8/5	15/9	13/7	x	71/46
	2	x	x	11/8	1/1	28/13	54/29	89/49
	3	x	x	x	x	x	x	64/39
	4	x	x	x	x	x	x	x
2	1	0	0	12/5	4/4	1/1	21/17	45/18
	2	x	10/4	2/2	23/12	14/7	40/23	138/83
	3	x	0	3/1	2/1	16/8	7/5	179/96
	4	x	x	6/4	3/2	20/9	43/20	114/66
3	1	x	x	4/3	13/6	30/20	27/15	120/61
	2	x	x	11/5	6/3	2/1	99/54	80/51
	3	x	x	5/2	12/6	29/12	71/37	88/59
	4	x	x	x	7/5	x	5/4	104/61
4	No individual slide counts							
	Total	3/1	25/16	36/24	71/38	81/47	82/40	327/221

APPENDIX (Continued)

Trap #	Slide #	Depth 0.5	1.0	1.5	2.0	2.5	3.0	3.5
	# Slides	1	3	4	4	4	4	4
	Total for date		2395/1387					
			21/5/77					
1	1	x	4/2	0	0	1/1	0	0
	2	x	1/1	5/2	0	2/1	0	5/2
	3	x	0	0	0	0	0	6/4
	4	x	x	0	0	x	0	x
2	1	0	0	0	0	0	0	2/2
	2	0	0	0	x	0	0	0
	3	0	0	0	x	0	0	0
	4	x	6/3	0	x	x	x	0
3	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	4/1	11/4
	3	0	0	0	0	0	0	0
	4	0	5/3	0	0	2/1	3/1	3/2
4	1	x	2/1	0	9/3	0	7/3	4/2
	2	x	0	0	0	0	0	5/2
	3	x	0	0	0	0	9/5	4/2
	4	x	0	0	x	x	0	0
	Total for date		100/48					
			28/5/77					
1	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	x
2	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	x
3	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	x
4	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0

APPENDIX (Continued)

Trap #	Slide #	Depth 0.5	1.0	1.5	2.0	2.5	3.0	3.5
	4	x	x	0	0	0	3/1	0
	Total for date		3/1					
			23/8/77					
1	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0
	4	0	0	0	0	0	x	x
2	1	0	0	0	0	x	0	0
	2	0	0	0	0	x	0	0
	3	0	0	0	x	x	0	0
	4	x	0	0	x	x	0	0
3	1	75/42	0	0	0	0	0	x
	2	20/11	0	0	0	0	0	x
	3	326/214	0	0	0	0	0	x
	4	8/4	0	0	0	0	0	x
4	1	0	x	0	x	0	x	0
	2	0	x	x	x	x	x	x
	3	x	x	x	x	x	x	x
	4	x	x	x	x	x	x	x
	Total for date		429/271					
			20/9/77					
1	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0	0	x	x	x	x	0
	4	0	0	x	x	x	x	0
2	1	x	x	x	x	x	x	x
	2	x	x	x	x	x	x	x
	3	x	x	x	x	x	x	x
	4	x	x	x	x	x	x	x
3	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0	0	0	0	x	0	0
	4	0	0	0	0	x	x	1/1

APPENDIX (Continued)

Trap #	Slide #	Depth 0.5	1.0	1.5	2.0	2.5	3.0	3.5
4	1	0	0	201/80	0	8/4	0	0
	2	0	0	0	0	0	0	0
	3	0	0	0	0	x	0	0
	4	x	0	0	0	x	0	0
	Total for date			210/85				
				27/9/77				
1	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	3/1
2	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0
	4	x	0	0	x	0	0	0
3	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0
4	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0
	Total for date			3/1				
				4/10/77				
1	1	0	0	0	1/1	0	3/1	10/6
	2	0	0	1/1	0	0	0	0
	3	0	0	0	0	0	0	0
	4	0	0	0	x	x	0	x
2	1	0	0	3/1	0	1/1	1/1	0
	2	0	0	0	0	4/1	2/1	0
	3	0	0	0	0	0	0	0
	4	x	x	0	0	0	x	0
3	1	0	0	0	1/1	0	0	1/1
	2	0	0	0	0	0	0	0
	3	x	0	0	0	x	0	0
	4	x	x	x	0	x	x	0

APPENDIX (Continued)

Trap #	Slide #	Depth 0.5	1.0	1.5	2.0	2.5	3.0	3.5
4	1	0	0	0	1/1	1/1	1/1	3/1
	2	0	0	0	1/1	0	1/1	0
	3	0	0	0	0	0	0	0
	4	0	0	0	2/2	1/1	2/2	3/1
	Total for date		36/22					
			14/10/77					
1	1	0	4/2	1/1	6/3	4/2	3/1	16/6
	2	0	1/1	0	1/1	0	0	15/7
	3	0	0	0	1/1	0	0	8/4
	4	0	0	x	0	0	0	0
2	1	0	1/1	0	0	12/4	0	20/9
	2	0	0	0	0	x	0	7/4
	3	x	0	0	x	x	0	0
	4	x	x	x	x	x	0	0
3	1	4/1	0	x	x	6/3	4/2	5/2
	2	6/2	0	x	x	0	0	12/5
	3	1/1	0	x	x	0	0	7/6
	4	0	x	x	x	x	x	0
4	1	0	10/4	1/1	9/4	0	4/2	3/1
	2	0	0	8/3	4/1	0	0	1/1
	3	0	0	0	0	0	0	0
	4	0	0		0	0	0	0
	Total for date		185/86					
			20/10/77					
1	1	0	0	0	1/1	0	0	0
	2	0	0	1/1	0	0	0	0
	3	0	0	0	0	0	0	0
	4	x	0	0	0	0	0	6/4
2	1	0	0	0	0	1/1	3/1	0
	2	0	0	2/1	0	0	0	0
	3	0	0	0	0	0	0	0
	4	x	0	0	x	0	0	x
3	1	0	1/1	0	3/1	0	1/1	3/1
	2	x	0	0	0	1/1	1/1	0
	3	x	0	0	0	0	0	0
	4	x	0	0	0	0	0	x

APPENDIX (Continued)

Trap #	Slide #	0.5	1.0	1.5	2.0	2.5	3.0	3.5
		Depth						
4	1	0	0	1/1	0	0	0	0
	2	0	0	0	0	0	9/3	1/1
	3	0	0	0	0	0	0	0
	4	x	x	0	0	x	0	x
	Total for date		34/19					
			27/10/77					
1	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	x	0	0	0	0	0	0
	4	0	0	0	0	0	0	0
2	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	x	0
	3	0	0	0	0	x	x	x
	4	x	0	0	0	x	x	x
3	1	0	0	0	0	0	0	3/2
	2	0	0	0	0	0	0	0
	3	0	0	0	0	0	x	0
	4	0	0	0	0	0	0	3/2
4	1	0	0	0	0	0	3/1	3/1
	2	0	0	0	0	0	0	1/1
	3	0	0	0	0	0	0	0
	4	x	0	0	0	0	0	0
Total for date				10/5				
			3/11/77					
1	1	x	0	0	0	0	0	10/3
	2	x	0	0	0	0	0	4/1
	3	x	0	0	0	0	0	0
	4	x	x	x	0	x	0	0
2	1	0	0	0	0	3/1	0	x
	2	0	0	0	0	0	0	x
	3	0	0	0	0	0	x	x
	4	0	0	0	x	x	x	x
3	1	x	0	1/1	0	0	0	4/2
	2	x	0	0	0	0	x	1/1
	3	x	0	0	0	0	x	0
	4	x	x	0	0	0	x	0

APPENDIX (Continued)

Trap #	Slide #	Depth 0.5	1.0	1.5	2.0	2.5	3.0	3.5
4	1	0	0	0	0	0	0	6/3
	2	0	0	0	0	0	0	4/1
	3	0	0	0	0	0	0	1/1
	4	0	0	0	0	0	0	0
	Total for date		34/14					
			10/11/77					
1	1	0	0	0	3/1	0	1/1	8/4
	2	0	0	0	0	0	3/1	38/17
	3	0	0	0	x	0	0	8/4
	4	0	0	0	x	x	0	1/1
2	1	0	0	0	0	1/1	1/1	51/21
	2	0	0	0	0	0	0	12/6
	3	0	0	0	0	0	0	6/2
	4	0	0	0	x	0	0	8/4
3	1	0	0	3/1	0	1/1	0	9/3
	2	0	0	0	0	0	0	23/10
	3	0	0	0	0	0	0	7/3
	4	0	0	0	0	0	0	9/5
4	1	0	0	0	1/1	x	2/1	6/4
	2	0	0	0	0	x	6/4	10/4
	3	0	0	0	0	x	x	1/1
	4	0	0	0	0	x	x	x
	Total for date		218/102					
			17/11/77					
1	1	2/1	0	2/1	0	1/1	3/1	2/1
	2	0	0	0	0	0	2/2	2/1
	3	0	0	0	0	0	0	1/1
	4	0	0	0	0	0	x	6/3
2	1	0	7/5	3/1	1/1	0	1/1	0
	2	0	0	0	6/2	0	0	0
	3	0	0	0	1/1	0	0	2/2
	4	0	0	x	0	0	0	x
3	1	0	4/2	3/1	1/1	1/1	3/2	4/4
	2	x	1/1	4/2	4/2	1/1	3/2	2/1
	3	x	0	0	0	8/4	0	1/1
	4	x	0	x	0	0	0	4/2

APPENDIX (Continued)

Trap #	Slide #	Depth 0.5	1.0	1.5	2.0	2.5	3.0	3.5
4	1	0	0	4/2	4/2	3/1	10/7	75/37
	2	x	0	4/2	8/2	4/2	6/2	x
	3	x	0	0	0	0	10/5	x
	4	x	0	0	x	0	x	x
	Total for date		525/264					
			27/4/78					
1	1	5/3	x	7/4	x	2/1	18/8	26/10
	2	0	x	5/2	x	1/1	x	13/7
	3	x	x	x	x	x	x	8/4
	4	x	x	x	x	x	x	x
2	1	0	0	1/1	2/1	8/5	5/3	33/19
	2	0	3/1	2/1	16/10	9/4	11/6	8/4
	3	0	0	0	0	4/2	0	14/7
	4	1/1	1/1	8/7	2/2	16/8	0	42/20
3	1	1/1	2/1	3/2	6/4	0	0	0
	2	2/2	2/1	0	5/2	5/2	5/3	0
	3	0	3/1	4/3	8/5	2/1	0	0
	4	5/2	0	3/1	0	8/5	4/2	0
4	1	0	1/1	8/5	0	5/4	8/5	13/6
	2	0	0	0	10/6	3/3	1/1	3/2
	3	0	1/1	0	0	0	1/1	19/11
	4	x	0	x	x	0	x	x
	Total for date		412/227					
			4/5/78					
1	1	0	0	1/1	0	5/3	16/7	69/37
	2	0	0	3/2	0	0	3/1	106/53
	3	0	0	0	0	3/1	3/1	31/21
	4	0	0	x	0	0	0	115/57
2	1	0	0	0	0	0	0	0
	2	0	5/2	3/1	0	3/1	2/1	14/8
	3	0	0	0	0	0	0	62/33
	4	0	0	0	3/1	0	3/2	41/24
3	1	4/2	0	5/2	8/4	4/3	7/4	50/25
	2	4/1	0	0	2/1	0	4/2	40/24
	3	0	3/1	4/1	12/5	3/1	0	53/26
	4	0	0	0	3/1	10/4	1/1	7/3

APPENDIX (Continued)

Trap #	Slide #	Depth 0.5	1.0	1.5	2.0	2.5	3.0	3.5
4	1	0	0	3/1	x	0	1/1	0
	2	0	0	0	0	0	1/1	8/4
	3	0	0	0	2/1	1/1	0	14/8
	4	16/5	0	0	0	7/4	1/1	0
	Total for date		151/83					
			25/5/78					
1	1	13/8	11/6	56/19	23/11	4/2	35/20	6/3
	2	5/3	61/25	24/11	36/15	17/6	9/6	16/9
	3	31/16	9/4	3/1	38/13	9/5	6/3	45/21
	4	25/11	6/3	4/2	16/5	3/2	33/14	19/11
2	1	8/3	42/18	0	5/1	11/6	6/5	5/3
	2	37/13	35/10	38/14	0	0	0	21/14
	3	23/12	0	8/8	9/3	7/6	1/1	9/5
	4	3/1	17/8	12/5	36/18	5/4	7/4	8/5
3	1	5/1	23/10	10/6	62/27	4/2	10/6	22/10
	2	8/4	0	60/22	23/10	7/3	9/5	29/17
	3	16/6	0	18/7	32/14	1/1	7/4	20/12
	4	41/17	7/2	26/11	26/15	2/1	8/3	12/10
4	1	42/16	9/2	6/3	0	4/2	x	24/11
	2	1/1	10/3	60/23	10/3	9/4	8/4	6/2
	3	15/7	28/12	20/10	0	30/13	15/4	7/4
	4	30/15	12/3	8/2	9/3	20/12	0	23/10
	Total for date		1810/817					
			1/6/78					
1	1	18/5	30/12	13/8	10/5	8/4	0	0
	2	3/1	44/17	15/5	11/7	10/5	5/2	0
	3	50/18	12/4	17/4	22/8	4/3	0	4/2
	4	0	56/23	33/17	8/3	5/2	0	0
2	1	43/21	34/13	15/8	8/3	1/1	1/1	0
	2	6/1	46/19	8/5	28/14	0	0	0
	3	16/7	5/2	15/9	67/24	7/4	7/3	0
	4	19/7	23/8	28/16	29/10	15/6	11/6	0
3	1	10/4	0	15/4	x	15/5	x	0
	2	20/5	72/27	6/3	3/2	2/2	0	0
	3	9/5	10/6	1/1	4/4	8/5	0	0
	4	73/24	78/34	35/16	5/2	8/3	0	0

APPENDIX (Continued)

Trap #	Slide #	Depth 0.5	1.0	1.5	2.0	2.5	3.0	3.5
4	1	0	149/55	27/16	0	3/2	0	0
	2	26/10	20.8	5/2	6/2	3/1	4/2	1/1
	3	2/1	12/4	36/17	3/2	0	4/2	0
	4	8/6	8/5	44/16	0	18/7	3/3	0
	Total for date		1566/663					
			8/6/78					
1	1	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0
	3	x	0	0	0	0	x	0
	4	0	0	x	0	x	0	x
2	1	0	0		0	0	0	x
	2	0	x	0	0	0	0	0
	3	0	0	0	x	0	0	0
	4	x	0	0	0	0	0	0
3	1	0	0	0	0	0	2/1	0
	2	x	0	0	0	0	0	3/2
	3	0	x	0	0	0	0	0
	4	0	0	x	0	x	0	0
4	1	0	x	0	0	0	0	0
	2	0	0	6/3	0	0	x	0
	3	x	0	0	0	0	0	0
	4	0	x	0	0	x	0	0
	Total for date		11/6					

[a] Figures in table represent $\frac{\text{No. Growth Axes}}{\text{No. Hydra}}$

[b] Total for date represents sum of growth axes and hydra for all slides on a given date.

REFERENCES CITED

Batha, J. 1974. The Distribution and Ecology of the Genus Hydra in the Milwaukee Area of Lake Michigan. Ph.D. Dissertation. The University of Wisconsin. 172 pp.

Beardsley, A.E. 1902. The destruction of trout fry by hydra. U.S. Fish and Wildlife Service Fishery Bulletin. 22: 157-60.

Brooks, John Langdon 1957. The systematics of North American daphnia. Memoirs of the Conn. Acad. of Arts and Sciences. XII: 1-180.

Bryden, Robert R. 1952. Ecology of Pelmatohydra oligactis in Kirkpatricks Lake, Tennessee. Ecol. Mono. 22:45-68.

Carrick, Louis Burrell 1956. A Study of Hydras in Lake Erie. Ph.D. Dissertation. Ohio State Univ. 318 pp.

Clady, Michael and Ulrikson, Gerald U. 1968. Mortality of recently hatched bluegill fry as a result of Hydra. The Progressive Fish Culturist 30:39-40.

Clemens, W.A. 1922. Hydra in Lake Erie. Science 55:445-446.

Dixon, W.J. (ed.). 1974. BMD Biomedical Programs. Univ. Calif. Press. Berkeley, 773 pp.

Eddy, S. 1927. The plankton of Lake Michigan. Bull. Ill State Nat. Hist. Surv. 17:203-232.

Eddy, Samuel and Hodson, A.C. 1961. Taxonomic Keys to the Common Animals of the North Central States. Burgess Publishing Co. Minneapolis, Minn. 162 pp.

Ewer, R.F. 1948. A review of the Hydridae and two new species of Hydra from Natal. J. of Zool. Proc. 118:226-244.

Griffing, Thomas Charles 1965. Dynamics and Energetics of Populations of Brown Hydra. Ph.D. Dissertation. Univ. of Mich. Ann Arbor. 67 pp.

Haney, James F. and Hall, Donald J. 1973. Sugar-coated Daphnia: A preservation technique for Cladocera. Limn. and Ocean. 18:331-333.

Hodgkiss, I.J. 1977. The use of simultaneous sampling bottle and vertical net collections to describe the dynamics of zooplankton populations. Hydrobiologia 52:197-205.

Hudgins, B. 1931. Turbidity, plankton and mineral content of the Detroit water supply. J. Am. Water Works Assoc. 23:435-444.

Hutchinson, G.E. 1957. A Treatise on Limnology. Vol. I. Geography, Physics and Chemistry. John Wiley and Sons, Inc. N.Y. 1015 pp.

Hyman, L.H. 1926. Note on the destruction of hydra by a chydorid cladoceran, Anchistropus minor Birge. Trans. Amer. Micro. Soc. 45:298-301.

Hyman, Libbie H. 1930. Taxonomic studies on the hydras of North America. II. The characters of Pelmatohydra oligactis (Pallas). Am. Mic. Soc. Trans. 49:322-333.

________ 1931. Taxonomic studies on the hydras of North America. Am. Mic. Soc. Trans. 50:302-315.

Kofoid, C.A. 1904. The Plankton of the Illinois River, 1984 - 1899, with Introductory Notes Upon the Hydrography of the Illinois River and its Basin. Part II. Constituent Organisms and their Seasonal Distribution. Bull. Ill. State Lab. Nat. 8:1-360.

Lomnicki, A. and Slobodkin, L.B. 1966. Floating in Hydra littoralis Ecol. 47:881-889.

Miller, D.E. 1936. A limnological study of Hydra oligactis in Douglas Lake, Michigan. Trans. Amer. Micros. Soc. 43:203-235.

Moen, J. 1951. Hydra in an Iowa nursery lake. Proc. Iowa Acad. Sci. 58:501-505.

Odum, Eugene P. 1971. Fundamentals of Ecology. 3rd ed. W.B. Saunders Co. Philadelphia. 574 pp.

Pennak, Robert W. 1953. Fresh-water Invertebrates of the United States. Ronald Press. N.Y. 769 pp.

Prescott, G.W. 1970. How to know the fresh-water algae. Wm. C. Brown Co. Dubuque, Iowa. 348 pp.

Reisa, J.J. 1973. Ecology p. 60-105. In: Burnett, A.L. (ed). Biology of Hydra. Academic Press, Inc. New York. 466 pp.

Rushforth, Norman B. 1973. Behavior of Hydra. p. 3-41. In Burnett, A.L. (ed). Biology of Hydra. Academic Press, Inc. New York. 466 pp.

Schreoder, L.A. and Reeder, P.S. 1980. Effects of temperature and fasting on the rate of sinking of Hydra oligactis. Limn. and Ocean. 25: in press.

Ward, H.G. and Whipple, G.C. 1959. Fresh-water Biology (J.W. Edmonson, ed.). John Wiley and Sons. New York. 1248 pp.

Welch, Paul S. and Loomis, Helen A. 1924. A limnological study of Hydra oligactis in Douglas Lake, Michigan. Amer. Micros. Soc. 43:203-235.

Young, O.W. 1945. A limnological investigation of periphyton in Douglas Lake, Michigan. Trans. Amer. Micros. Soc. LXIV:1-20.

Yu, H. 1976. Bioecological studies of freshwater hydra and planaria. Ph.D. Dissertation. Univ of Calif. Riverside. 152 pp.