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Winter limnology of the shallow pond, Levi Carter Lagoon, Omaha, Nebraska.

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WINTER LIMNOLOGY OF THE SHALLOW POND, LEVI CARTER LAGOON, OMAHA, NEBRASKA

A Thesis

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ACKNOWLEDGEMENTS

I am deeply grateful to Dr. Merle E. Brooks of the Biology Department, University of Nebraska at Omaha, under whose guidance and assistance this study was made. For aid and suggestions, I wish to thank Dr. Richard Stasiak and Dr. Karl H.D. Busch. For help in the collection of specimens, I thank Percy R. Zeigler and Ron Bruno. For help in the identification of specimens, I thank Charles Ray. To all of the above, grateful acknowledgement is given.

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View from north bank

INTRODUCTION

This study deals with the environmental condition of winter and the effect it has on pond life. Special emphasis is given to pond fish.

Levi Carter Lagoon is located at 13th and Carter Lake Boulevard in Omaha, Nebraska. It is fed by a storm sewer and collects most of its water from street drainage so it is not a typical pond. It empties into Carter Lake via a culvert. Fifty years ago the pond was the northwest bank of Carter Lake and prior to 1877 held waters from the Missouri River. The pond is approximately 200 meters long and 40 meters wide. There are many trees in adjacent areas that provide nutrients to the pond by shedded leaves. The bottom is covered with one to three feet of loosely packed organic material consisting primarily of decaying vegitation.

The study was conducted from January 23 to March 16, 1973. Most of the time, ice covered the lagoon. Over the period of study, weather was warmer and wetter than normal.

Statistics from the Omaha Weather Bureau (taken 1 mile from the pond) show the average January temperature up 0.3°F. from normal and precipitation up 0.62 water inches above normal. The February temperature was 2.1°F. above normal and precipitation was 0.08 water inches below normal. March was the wettest in recorded history and the second warmest in

27 years. The high precipitation added to the instability of pond communities as it increased turbidity and washed nutrients and chemicals from the streets into the pond.

A review of the literature indicates that little has been written on winter ecology of ponds. From available literature it can be concluded that ponds in general contain many desmids and few diatoms (Welch, 1952 and Stern, 1968). Welch (1952) stated that ponds in general contain large numbers and varieties of insect larvae and protozoans.

Shallow ponds often are subject to winterkills for fish and invertebrates. Dineen (1953) reported that snow and ice exclude light and free carbon dioxide increases. Lindeman (1942) stated that snow and ice exclude light and limit photosynthesis with the result that bacteria and aquatic organisms deplete the existing dissolved oxygen supplies. However, Mason (1965) concluded that turbidity rather than snow and ice determines the extent to which photosynthesis is limited.

Hutchinson (1944) stated rapid chemical changes take place in a small body of water. Petersen (1926) stated that succession of pond animals is tied to conditions of temperature and depth of water.

Welch (1952) stated that diversification of pond plankton disappears in winter. Petersen (1926) found an absence of pond plankton in winter and Stern (1968) agreed that

Euglena will disappear with the onset of winter.

The predominent fish found in this study was the bluegill, *Lepomis macrochirus*. Cooper, Wagner, and Krantz (1971) stated that the bluegill showed superiority in competing with all fish except the carp. This is in spite of Ricker's (1945) findings showing that bluegill suffer a natural mortality rate of 50 to 65% per year.

Bluegill feed on what is available though they tend to be selective. Selective feeding is confirmed by Gerking (1962) and Werner (1969). Gerking (1962) stated that bluegill fed mainly on plankton until they reached a length of 200 mm. Werner (1969) worked out a formula to test for selective feeding, $E=\frac{r-p}{r+p}$. *E* is the selective factor, *r* is the proportion of organisms in the fish stomach, and *p* is the proportion of organisms in the plankton samples. Werner also stated that bluegills feed by sight. Gerking (1962) confirmed this with his findings that bluegill do not feed much at night. Wohlschlag (1959) stated that young bluegill utilize protein more efficiently than older fish. MacPhee (1961) illustrated that the amount of food a fish ate, when competing with other fish, was proportional to its size and its agressiveness. He also indicated that a bass would eat more than a sunfish of comparable size and a larger fish would eat more food than a smaller fish.

Some work has been done on the effect of lower temperature on fish. Agersborg (1930) stated that a sudden drop of 2°C. results in fish exhibiting unstable swimming movements; a sudden drop of 4°C. results in fish exhibiting symptoms of oxygen starvation and a sudden drop of 6°C. results in death. Hathaway (1927) stated that food consumption drops rapidly with a drop in temperature. Gerking (1954), Breder (1935), and Moffett and Hunt (1943) agree there is a reduction of feeding in winter. This is in spite of Wohlschlag's (1959) research that shows winter swimming movements need higher respiratory rate than summer swimming movements. He attributed the higher rates to increased plant and carbohydrate intake in winter but Gerking (1962) stated there have been no cellulase enzymes found in fish and that plants are eaten by fish as roughage. Frymire (1956) in a winter bluegill feeding study stated that small fish eat more in proportion to body weight than large fish. Lindeman (1942) found that small fish are less tolerant to low oxygen levels than large ones. This is probably due to metabolic rates of smaller fish being less affected by temperature changes than larger fish as found by O'Hara (1967).

MATERIAL AND METHODS

Most of the pond was frozen solid or had water too shallow to sample. The north portion of the pond, the inlet, and surrounding area retained a water depth of one foot under the ice. This area was divided into three collection stations (see Fig. 2).

Chemical tests that included temperature, free carbon dioxide, dissolved oxygen, and hydrogen-ion concentration were conducted with a Hach water testing kit, model AL 36B, Hach Chemical Co., Ames, Iowa, at each station. The samples were taken and tests conducted at the pond between eight and ten o'clock in the morning which is the time of day Wang (1928) and Bamforth (1958) believe is best to approximate daily temperature and chemical averages. All samples, chemical and biological, were collected three times a week from January 23 to March 16.

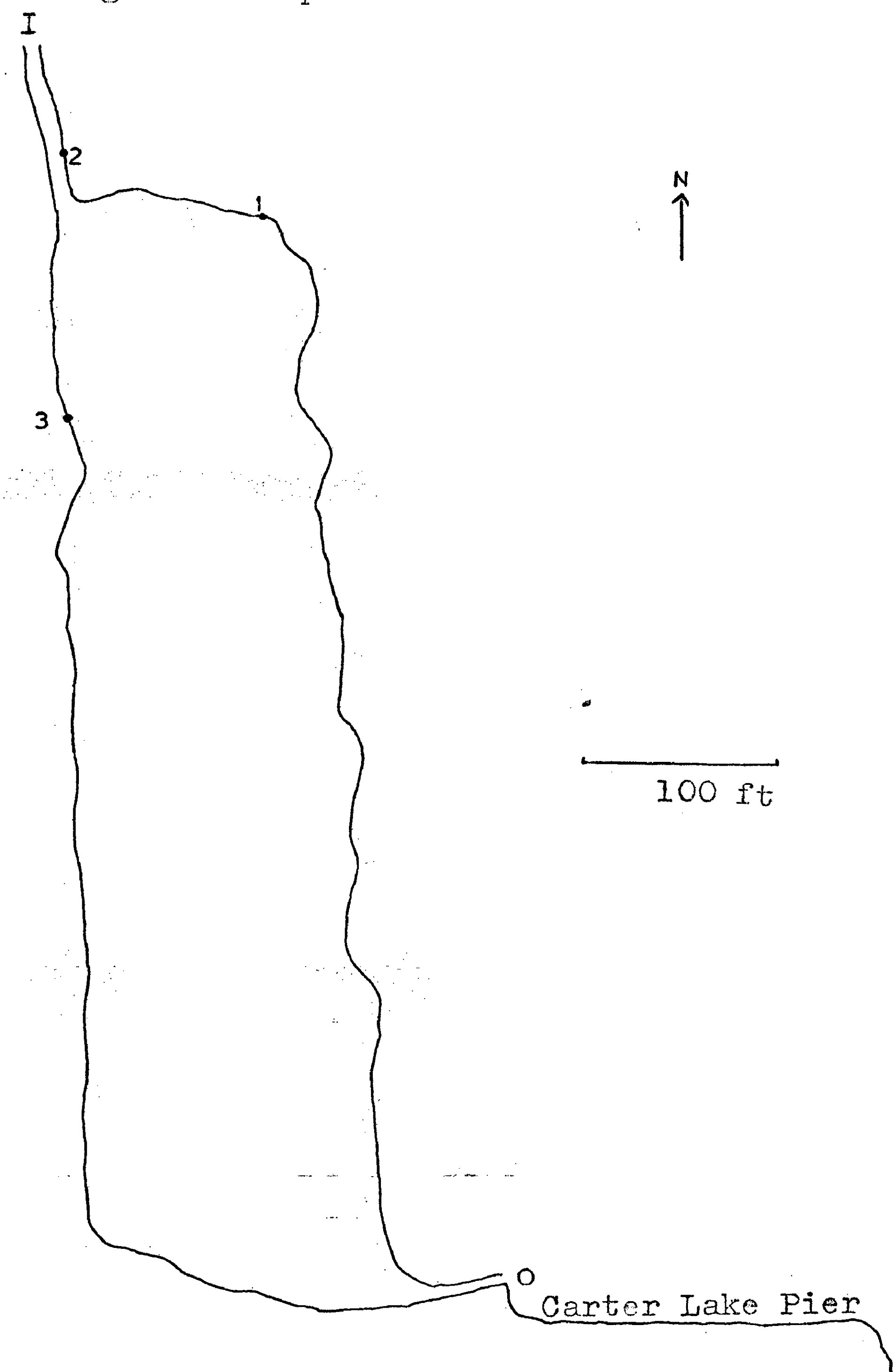
In the biological survey, ten sweeps with a plankton dip net were made at each station. One half of each collection was preserved in 70% isopropyl alcohol and examined under a dissecting microscope. The other half was placed in a plastic vial containing pond water and was examined for live biota with a compound microscope. Pond inhabitants were identified with keys and descriptions found in: Borror and White (1970), Brooks (unpublished), Eddy (1969), Eddy and Hodson (1970), Jahn (1970), Kudo (1966), Pennak (1953), Ward and Whipple (1959), and Whitford and Schumacher (1969).

Since ice fishing produced no results, minnow traps were set at each station to catch fish for stomach content analysis, selective feeding, and population studies. In the population study, 114 fish (most of which were bluegill) were caught in minnow traps, tagged by cutting off half of one pelvic fin, and released. Fish were again captured by traps and seining with ¼ inch bar mesh seine. The Petersen method or Lincoln index of capture and recapture discussed in Ricker (1958) was utilized to determine the size of a part of the bluegill population.

In testing for selective feeding, 73 fish were utilized for stomach content analysis. The stomach contents were examined with a dissecting microscope and compared with plankton samples. Werner's (1969) formula was utilized to determine selective feeding of the fish. Adequate samples of bluegill were caught at each station to compare stomach contents with the plankton taken at that station. No other fish was caught in sufficient numbers to warrant a stomach content comparison for each station. For this reason the stomach contents of all other fish were compared with plankton found in the whole pond.

A map of the area was drawn with the aid of a transit and meteorological data were obtained from the Omaha Weather Bureau at Eppley Airfield (approximately one mile from the collection sites).

Figure 2. Map of Pond



I: Inlet
O: Outlet to Carter Lake
1,2,3: Sampling Stations

RESULTS

The weather over the period of study was warmer and wetter than normal. Air temperature varied from -15°C. on February 16 to 14°C. on 13 March (Fig. 3). Significant precipitation fell on January 27; the 1st, 12th and 13th of February; and the 3rd, 5th, 9th, 10th, and 13th of March (Fig. 4). Hours of daily sunshine are shown in Fig. 5.

Water temperatures were recorded at each station. At collection site No. 1, water temperatures ranged from 1 to 9.5°C. Collection site No. 2, located at the inlet, had a water temperature range from 4 to 8°C. Collection site No. 3 had temperature variations from 2 to 9.5°C. For more details on water temperatures see Fig. 6.

Free carbon dioxide varied from 70 to 10 mg. per liter at site 1, 85 to 10 mg. per liter at site 2, and 45 to 10 mg. per liter at site 3. See Fig. 7.

Total oxygen, dissolved and undissolved, fluctuations were in part due to phytoplankton increases and decreases. Site 1 showed total oxygen variation from 1 to 18 mg. per liter. Site 2 had rather constant total oxygen that varied from 7 to 14 mg. per liter. Site 3 varied in total oxygen from 7 to 17 mg. per liter. See Fig. 8.

Hydrogen-ion concentration was stated by Rao (1955) to rise with an increase in photosynthesis and temperature and decrease with an increase of free carbon dioxide. Like the other chemical tests, the pH varied from station to station although it did stay in the basic range (See Fig. 9). Site 1 had a pH variation from 7 to 8.6. Site 2 had pH variations from 7.9 to 9. Site 3 had variations from 7.8 to 8.6.

The pond's biological communities were unstable and populations fluctuated rapidly. Vertebrates other than fish found in the pond included the muskrat (*Ondatra zibethica*) and the bullfrog (*Rana catesbiana*). Fish found in the pond in order of abundance were:

1. Bluegill, *Lepomis macrochirus*
2. Black bullhead, *Ictalurus melas*
3. Orangespotted sunfish, *Lepomis humilis*
4. Largemouth bass, *Micropterus salmoides*
5. Tadpole madtom, *Noturus gyrinus*
6. Golden shiner, *Notemigonas crysoleucas*
7. Carp, *Cyprinus carpio*
8. White crappie, *Pomoxis annularis*.

Macroplankton found in plankton samples is listed as found (in order of abundance):

1. Copepods, *Cyclops* and *Canthocamptus*
2. Rotifers, *Epiphanes* and *Philodina*
3. Nematodes (free living)
4. Bryozoan statoblasts, *Plumatella*
5. Filamentous green algae, *Cladophora*, *Spirogyra*, and *Oedogonium*

6. Tardigrada, _Hypsibius_
7. Ostracod shells
8. Cladoceran, _Ilyocryptus spinifer_
9. Free floating plant, _Lemna minor_
10. Diptera larvae, _Ceratopogonidae_, _Chaoborus_, _Helius_, and _Tendipes_
11. Protozoan, _Difflugia_
12. Oligochaetes
13. Damselfly larvae of the family _Coenagrionidae_
14. Cladoceran ephippial eggs
15. Water boatman, _Corixidae_
16. Invertebrates found in small amounts include the crayfish (_Orconectes_), the beetle, _Dytiscus_, _Planeria_ worm, _Hydra_, _Physa_, and _Amnicola_ snails, _Collembola_ (_Podura aquatica_), and the water mite, _Hydrachnidae_.

Micro-organisms observed under the compound microscope are also listed in order of abundance:

1. Diatoms, 9 varieties of pennales diatoms with the majority being _Navicula_
2. The protozoan, _Euglena_
3. The blue-green algae, _Oscillatoria_
4. Other protozoan flagellates, _Chlamydomonas_, _Monas_, _Bodo_, _Cryptomonas_, and _Peranema_
5. Protozoan ciliates, _Paramecium_, _Vorticella_,

Colpoda, Gymnostomes, Hypostomes, Epistylis, and Spirostomum

6. Desmids, Scenedesmus and Closterium.

Plankton samples varied from station to station but usually nematodes, statoblasts, copepods, rotifers, and tardigrads were the most prominent. A breakdown of plankton samples according to the three collection sites is shown in Figs. 10-20 and Table I. Microplankton samples consisted primarily of diatoms, Euglena, Oscillatoria, and other flagellates. Note that in the tables and lists plankton has been categorized according to abundance in the plankton sample irregardless of it being a plant or animal.

Table I. Station Breakdown of Organism Abundance

Organism	Station 1		Station 2		Station 3	
	No.	Rank	No.	Rank	No	Rank
Nematodes	1452	1	127	6	485	3
Statoblasts	1096	2	141	5	218	4
Copepods	799	3	599	2	1510	1
Rotifer, *Epiphanes*	765	4	1058	1	832	2
Tardigrada	108	5	168	3	192	5
Rotifer, *Philodina*	49	6	—	—	53	9
Spirogyra	28	7	150	4	180	6
Lemna minor	26	8	11	10	7	13
Cladophora	25	9	30	8	100	7
Ostracod shells	23	10	2	13	57	8
Ilyocryptus	13	11	11	10	27	10
Ephippial egg	13	11	—	—	6	14
Difflugia	13	11	—	—	17	11
Diptera larvae	11	12	—	—	9	12
Annelids	7	13	14	9	4	15
Hormidium	1	14	6	11	4	15
Water boatman	1	14	—	—	—	—
Collembola	1	14	1	14	1	17
Oedogonium	—	—	60	7	—	—
Damselfly larvae	—	—	4	12	2	16

Table I. Continued: Microplankton

Organism	Station 1		Station 2		Station 3	
	No.	Rank	No.	Rank	No.	Rank
Diatoms	78,140	1	186,500	1	32,400	2
Euglena	12,100	3	79,500	2	43,800	1
Oscillatoria	46,400	2	9,900	3	6,300	4
Flagellates	9,100	4	7,300	4	7,200	3
Ciliates	200	5	800	5	200	6
Closterium	200	5	200	6	—	—
Scenedesmus	—	—	—	—	500	5

For stomach content analyses, 73 fish were caught in minnow traps. They varied from 20 to 100 mm. in standard length. Of the 73 fish 57 were bluegill, 3 were largemouth bass, 6 were orangespotted sunfish, 5 were black bullheads, 1 was a madtom and one was a golden shiner. For the bluegill, the station by station breakdown was 19 from station 1, 15 from station 2, and 23 from station 3. Results of the stomach content analyses are shown in Tables II and III.

It is interesting that of the 73 fish examined, 15 had stomachs that contained no distinguishable material. Nine of these were bluegill: three were captured at station 1, two at station 2 and four at station 3. Two largemouth bass, three black bullheads, and one golden shiner were captured with no distinguishable stomach contents.

Werner's formula was used to determine selectivity in feeding by comparing stomach contents with plankton samples. Table IV shows selectivity results for bluegill.

Table II. Bluegill Stomach Content Analyses

Organism	Station 1		Station 2		Station 3	
	No.	Rank	No.	Rank	No.	Rank
Copepod	153	1	326	1	345	1
Filamentous algae	26	2	11	2	9	2
Damselfly larvae	13	3	3	5	2	5
Diptera larvae	9	4	3	5	—	—
Collembola	8	5	—	—	—	—
Physa	5	6	4	4	—	—
Water boatman	4	7	—	—	2	5
Nematode	3	8	3	5	6	3
Ilyocryptus	2	9	9	3	3	4
Higher plant	1	10	—	—	—	—
Statoblast	—	—	1	6	—	—
Coleopteran	—	—	1	6	—	—
Rotifer	—	—	1	6	—	—
Clam	—	—	—	—	1	6

Table III. Stomach Content Analyses

Organism	Fish			
	Bass	Bullheads	Madtoms	Orangespotted Sunfish
Nematodes	8	—	—	—
Copepods	2	2	6	263
Diptera larvae	1	—	—	2
Filamentous algae	—	4	—	—
Ilyocryptus	—	1	1	—
Lemna minor	—	—	—	—

Table IV. Bluegill Feeding Selectivity

Organism	Index of Selectivity		
	Station 1	Station 2	Station 3
Water boatman	.97	—	.48
Damselfly larvae	.97	.57	.82
Diptera larvae	.88	.28	.74
Collembola	.85	—	—
Filamentous algae	.58	-.54	-.52
Copepods	.58	.57	.28
Ilyocryptus	.50	.69	.04
Nematode	-.92	-.73	-.78
Rotifer	—	-.98	-.79
Statoblast	—	-.99	—

The orangespotted sunfish had selective feeding indices of .56 for copepods, .45 for Lemna minor, and .43 for diptera larvae. The black bullhead had selective feeding indices of .93 for Ilyocryptus, .82 for filamentous algae, and .02 for copepods. The largemouth bass had selective feeding indices of .94 for diptera larvae, .58 for nematodes, and -.21 for copepods. The madtom had indices of .93 for Ilyocryptus and .54 for copepods.

No tardigrada were found in any of the stomach contents. This may have been due to fish selecting against them (they were fairly common in plankton samples) or may have been due to the soft bodied tardigrada being rapidly digested. Nematodes, statoblasts and rotifers may have been swallowed incidentally.

In a population study, 107 bluegill, 2 largemouth bass, and 5 black bullheads were marked and released. Only bluegills were recaptured. Of the bluegill caught on the second catch, 3 were marked, so using the Petersen method or Lincoln index (estimate population size by multiplying the number of fish originally marked by the size of the second catch and dividing that product by the number of recaptured marked fish) it was estimated the population of bluegills from 20 to 100 mm. in standard length was 1,319.

Figure 3. Air Temperature °C

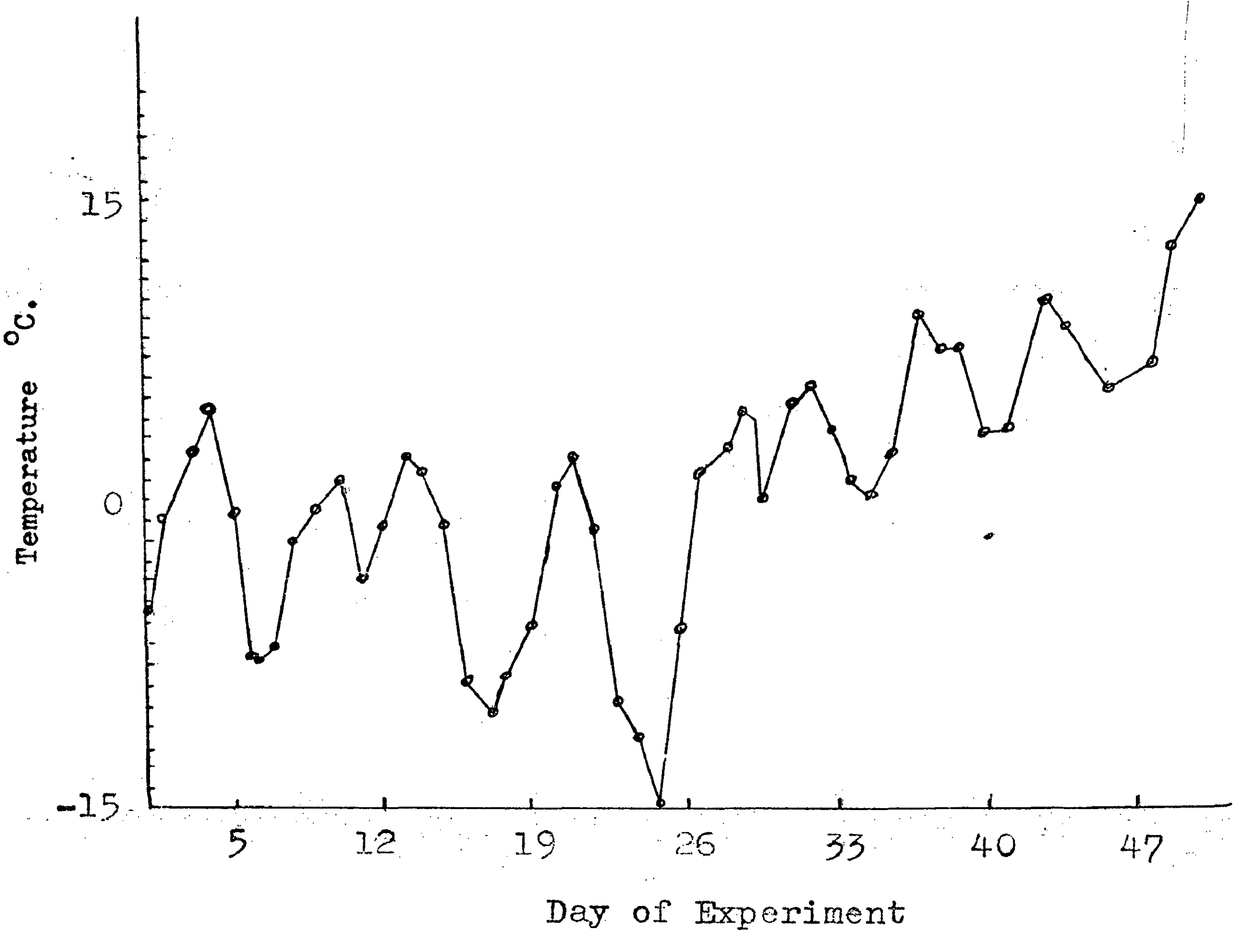


Figure 4. Precipitation (In.)

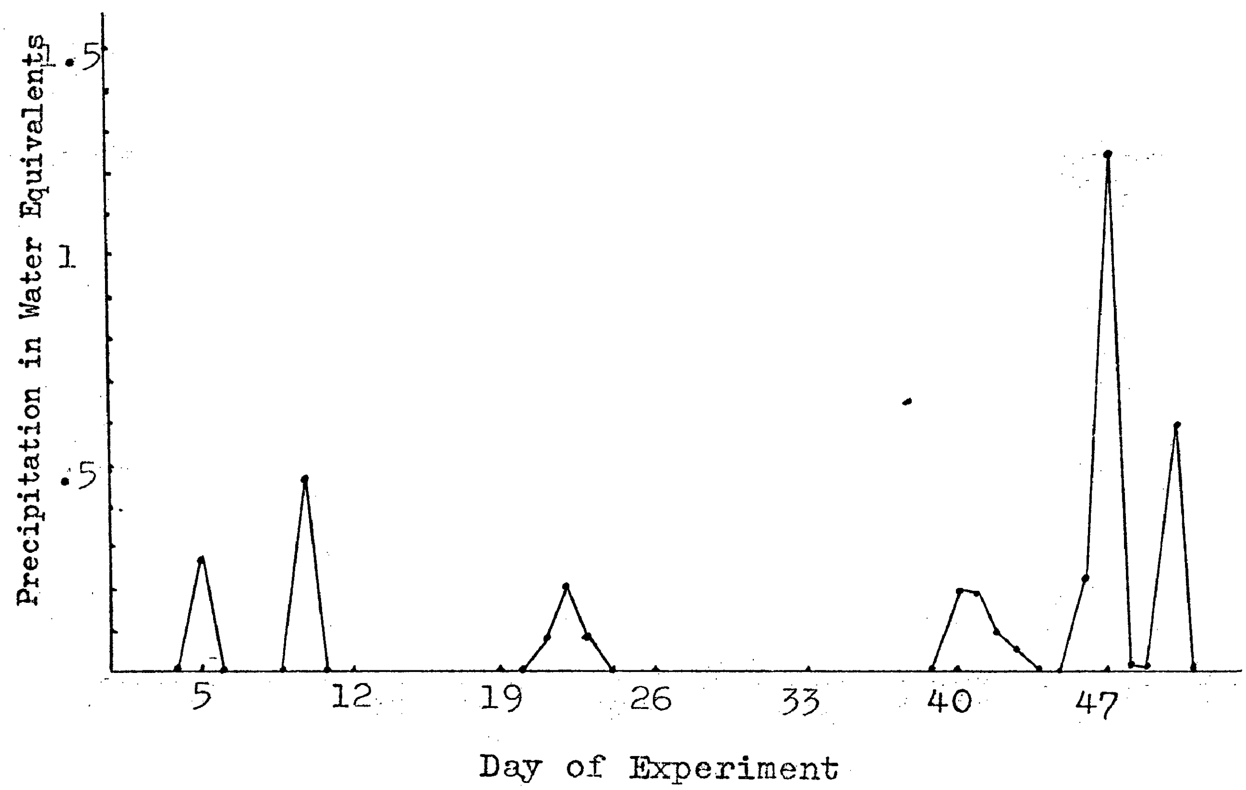


Figure 5. Hours of Sunlight

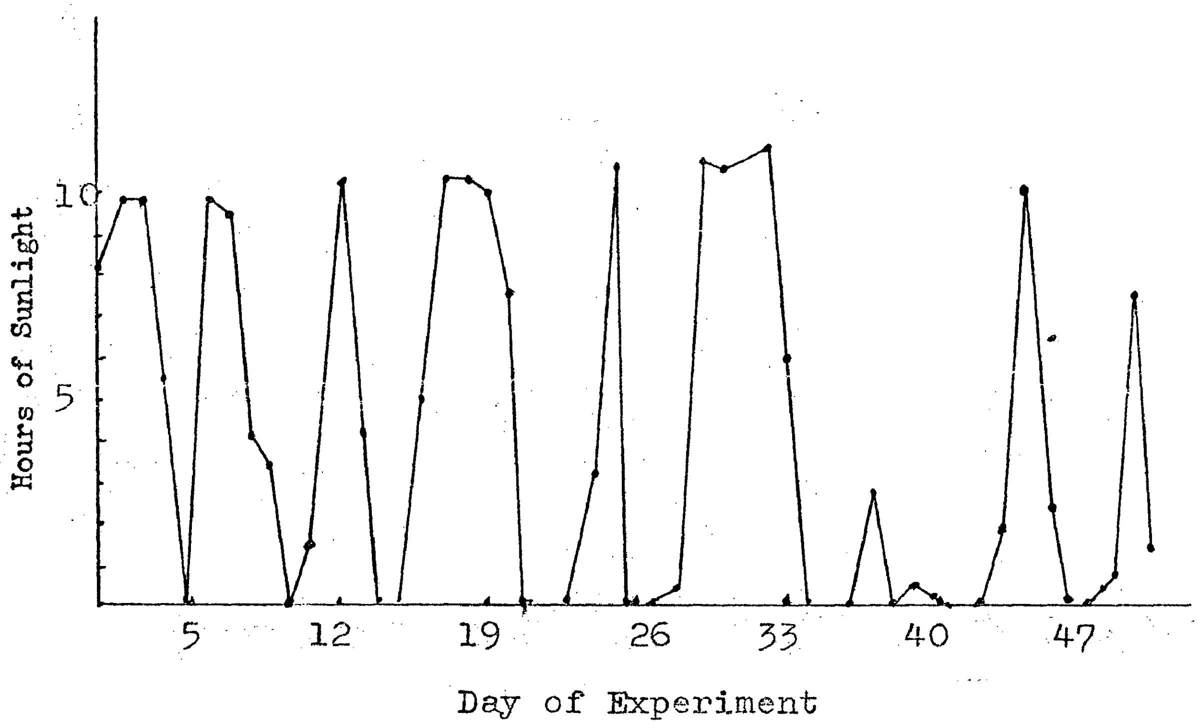


Figure 6. Water Temperature °C.

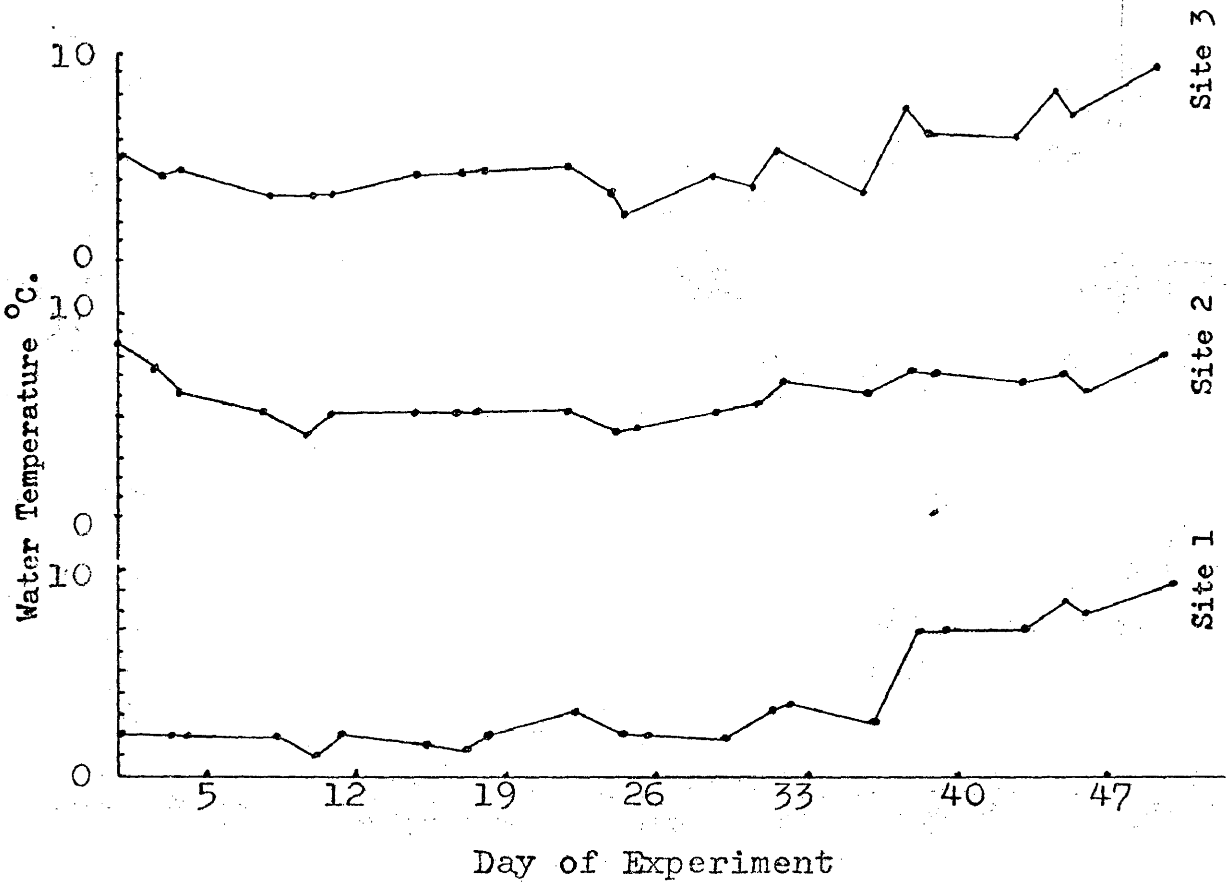


Figure 7. Free Carbon Dioxide

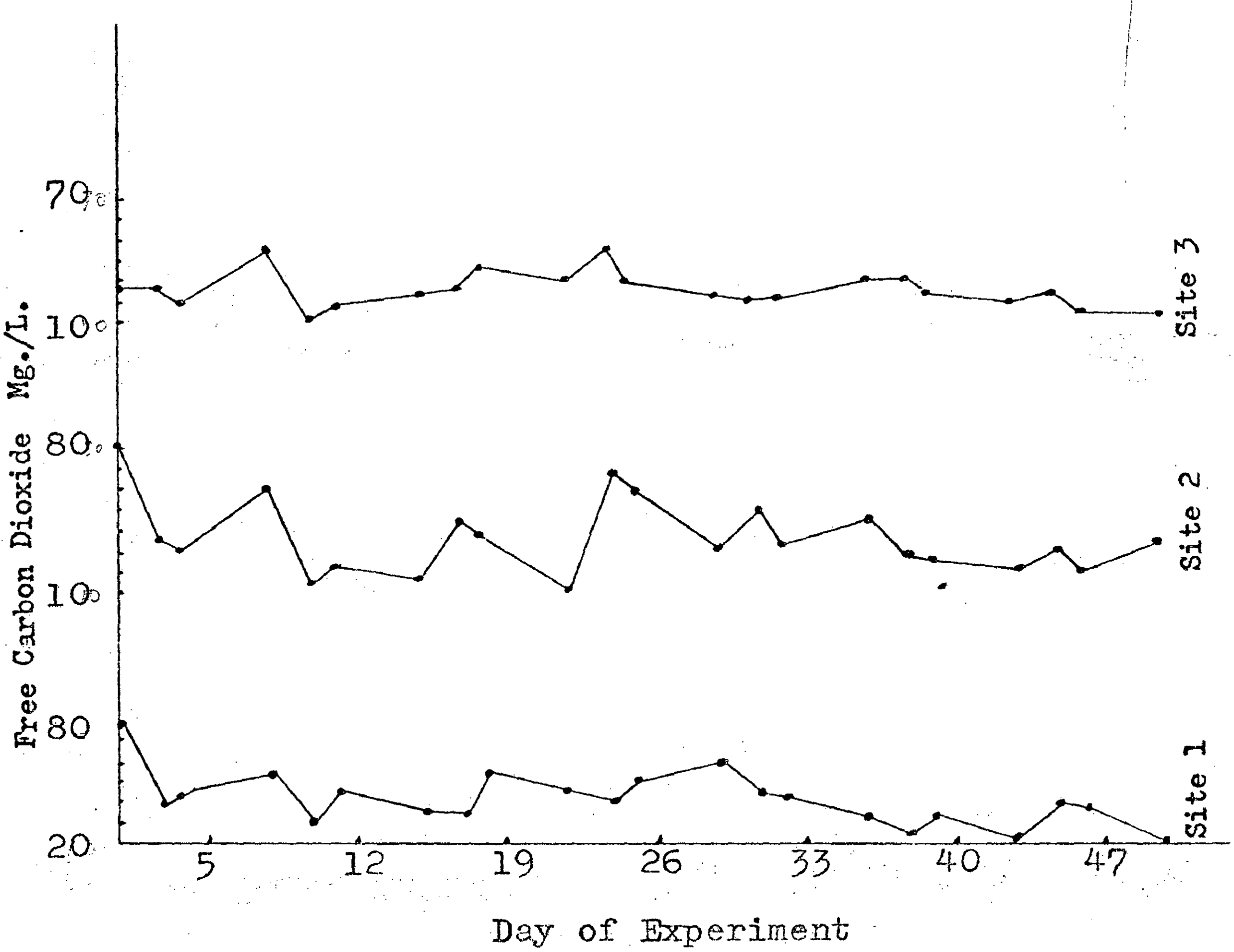


Figure 8. Total Oxygen

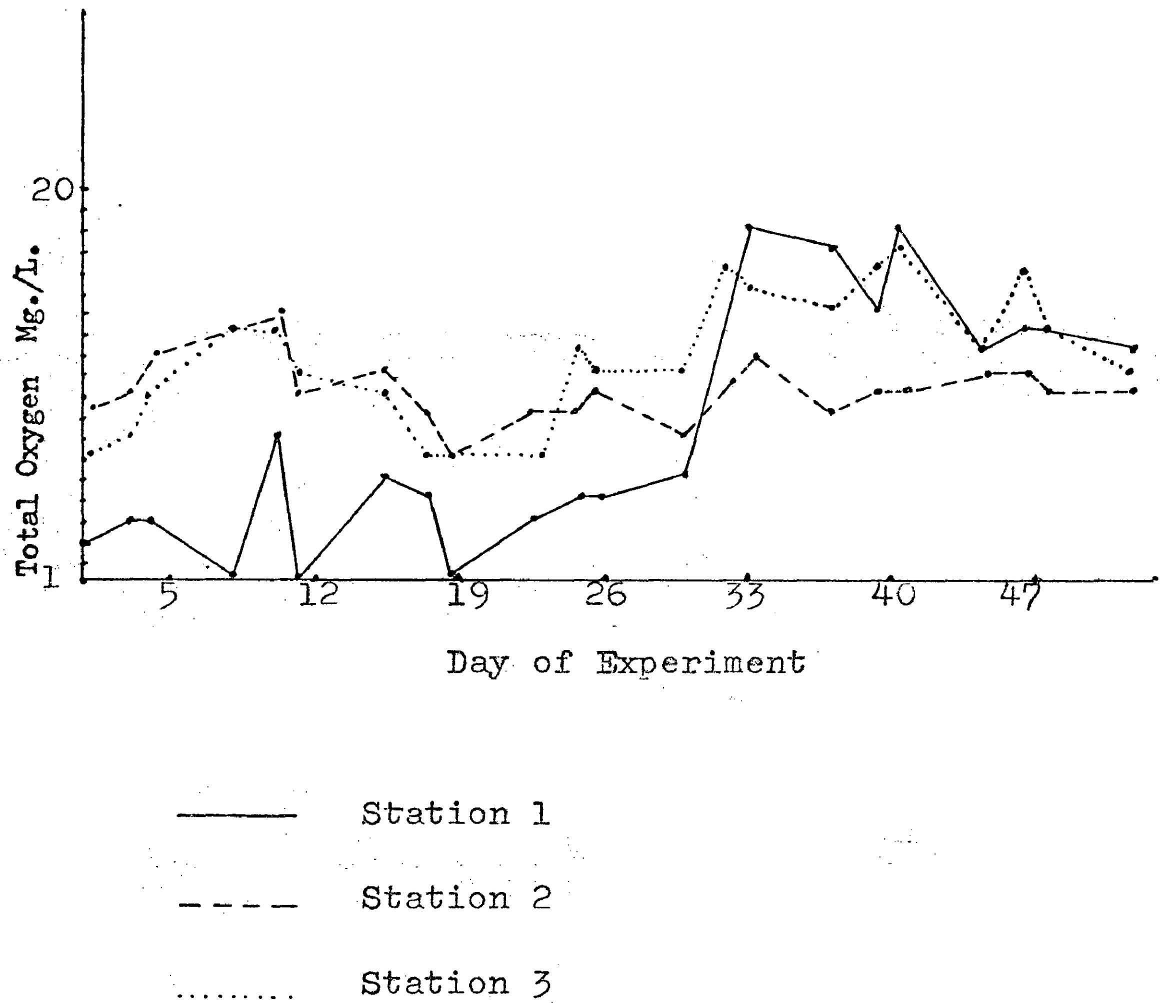


Figure 9. Hydrogen-ion Concentration

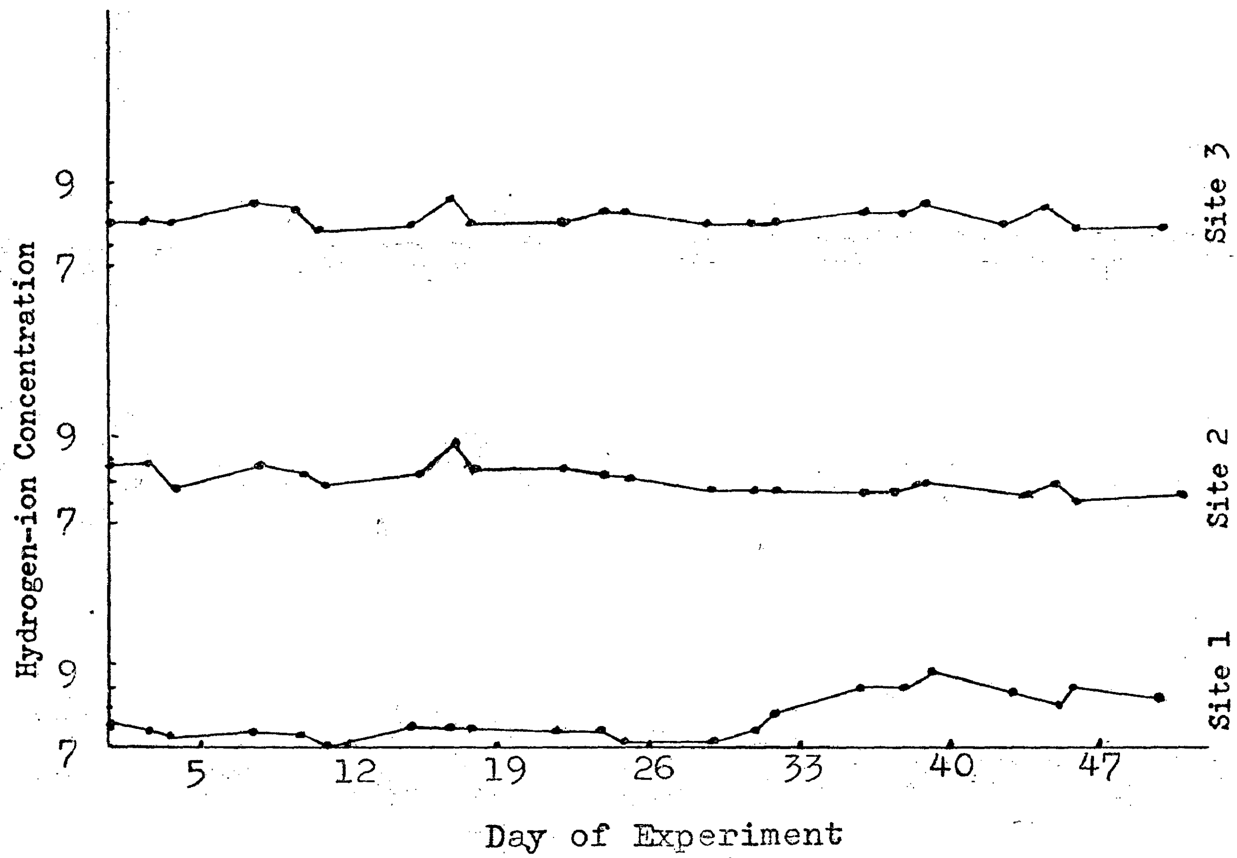


Figure 10. Copepod Populations

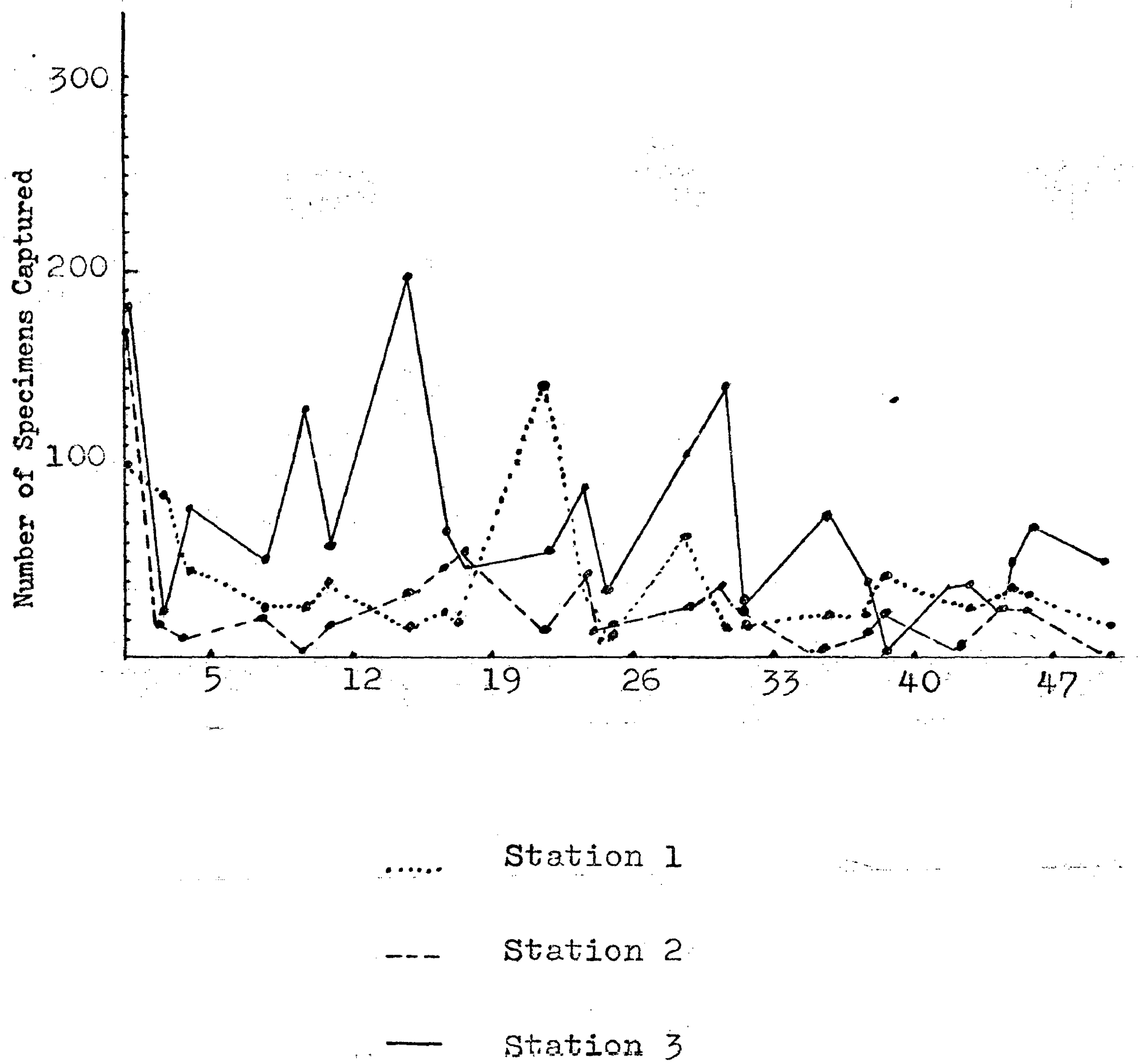


Figure 11. Epiphanes Rotifer Populations

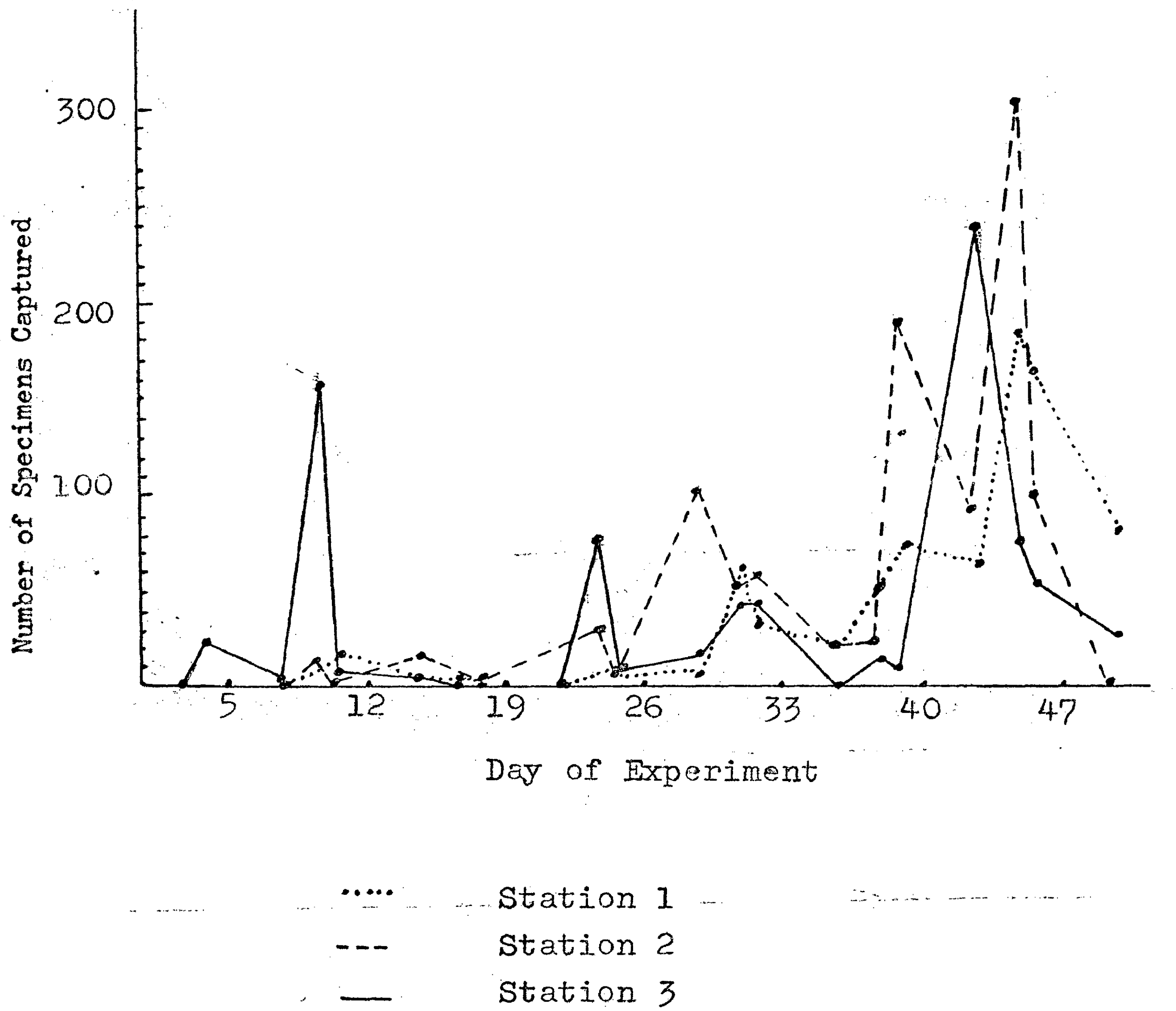


Figure 12. Nematode Populations

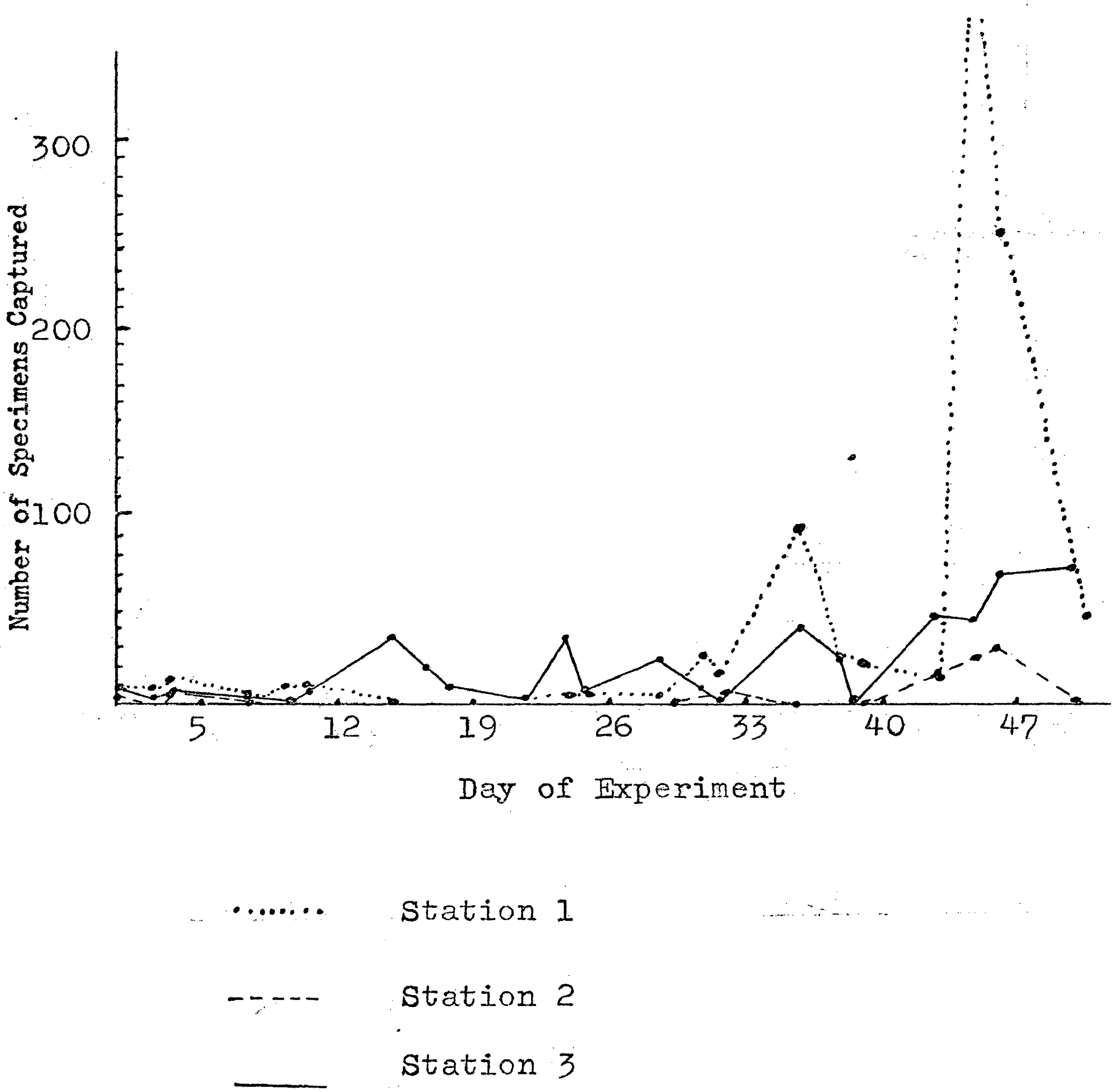


Figure 13. Tardigrada Populations

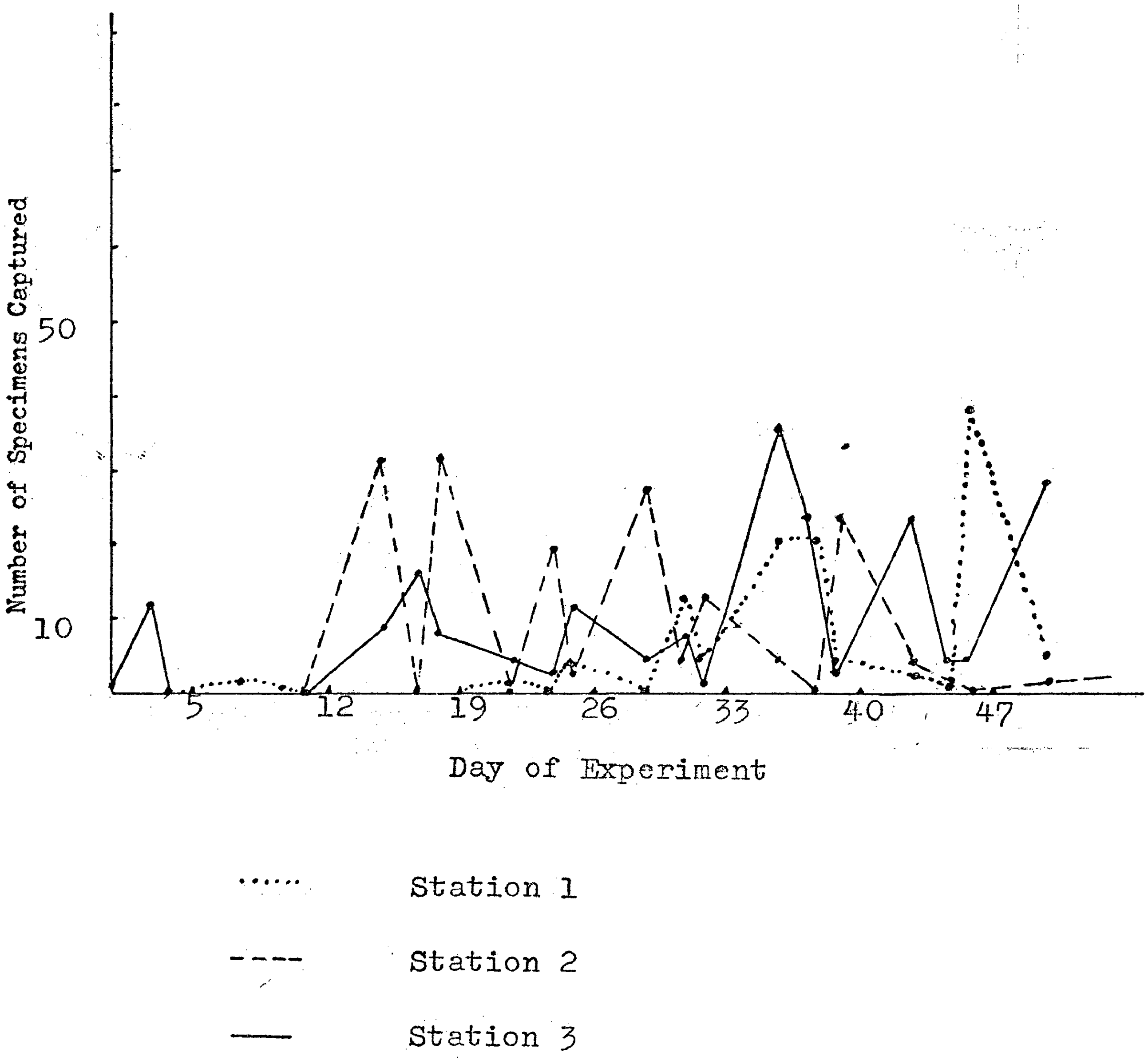


Figure 14. <u>Ilyocryptus</u> Populations

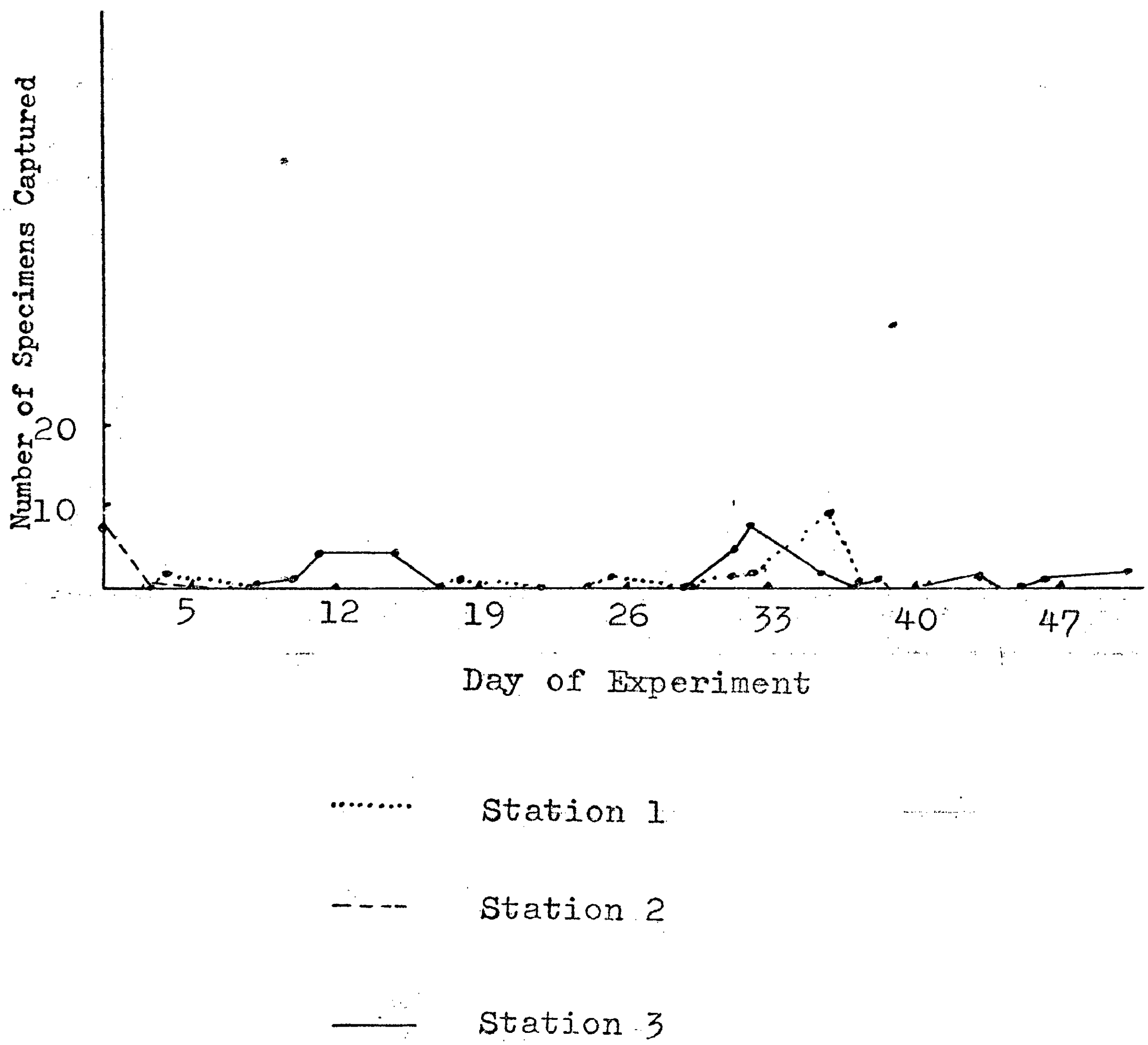


Figure 15. <u>Cladophora</u> Populations

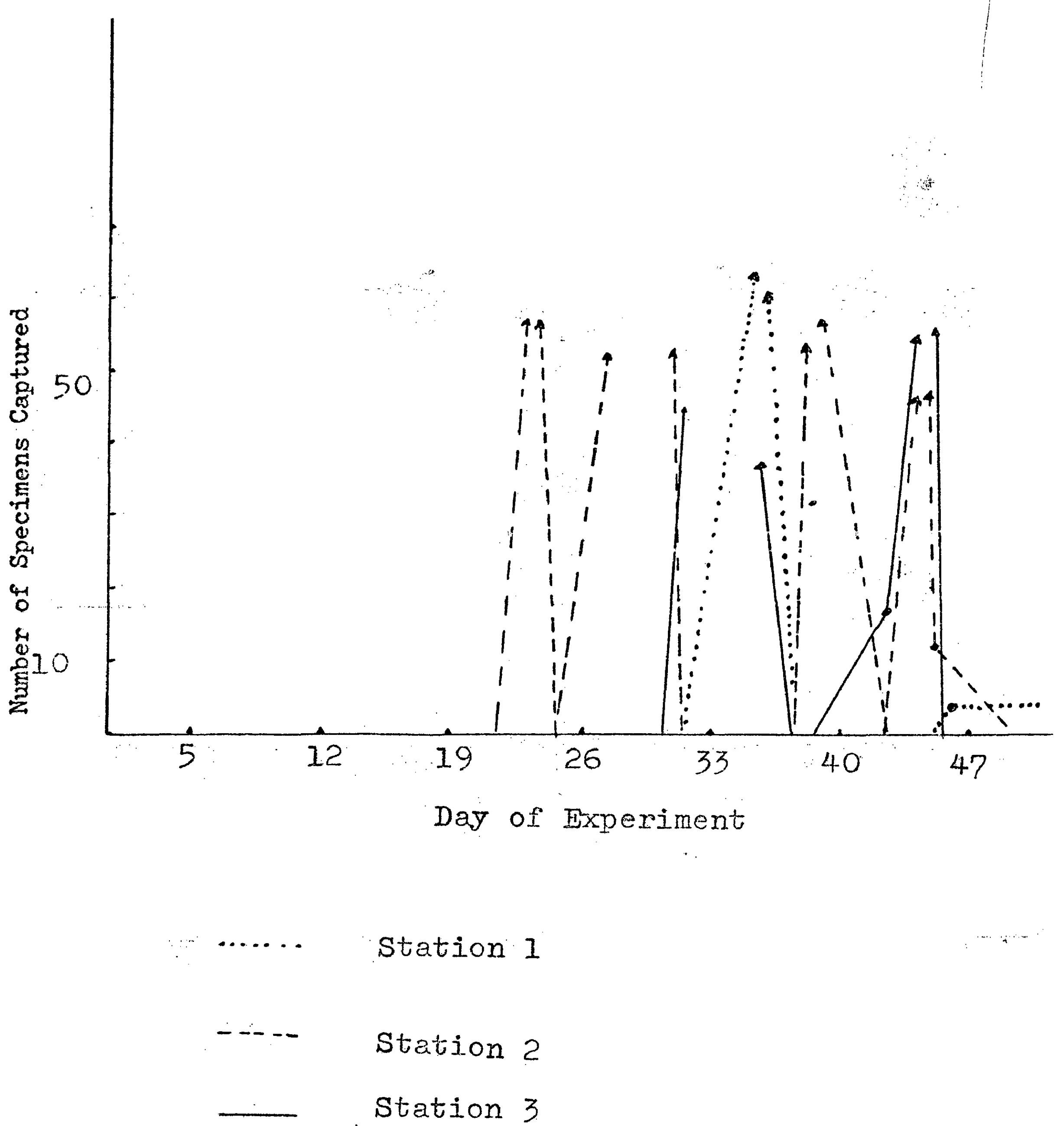


Figure 16. Spirogyra Populations

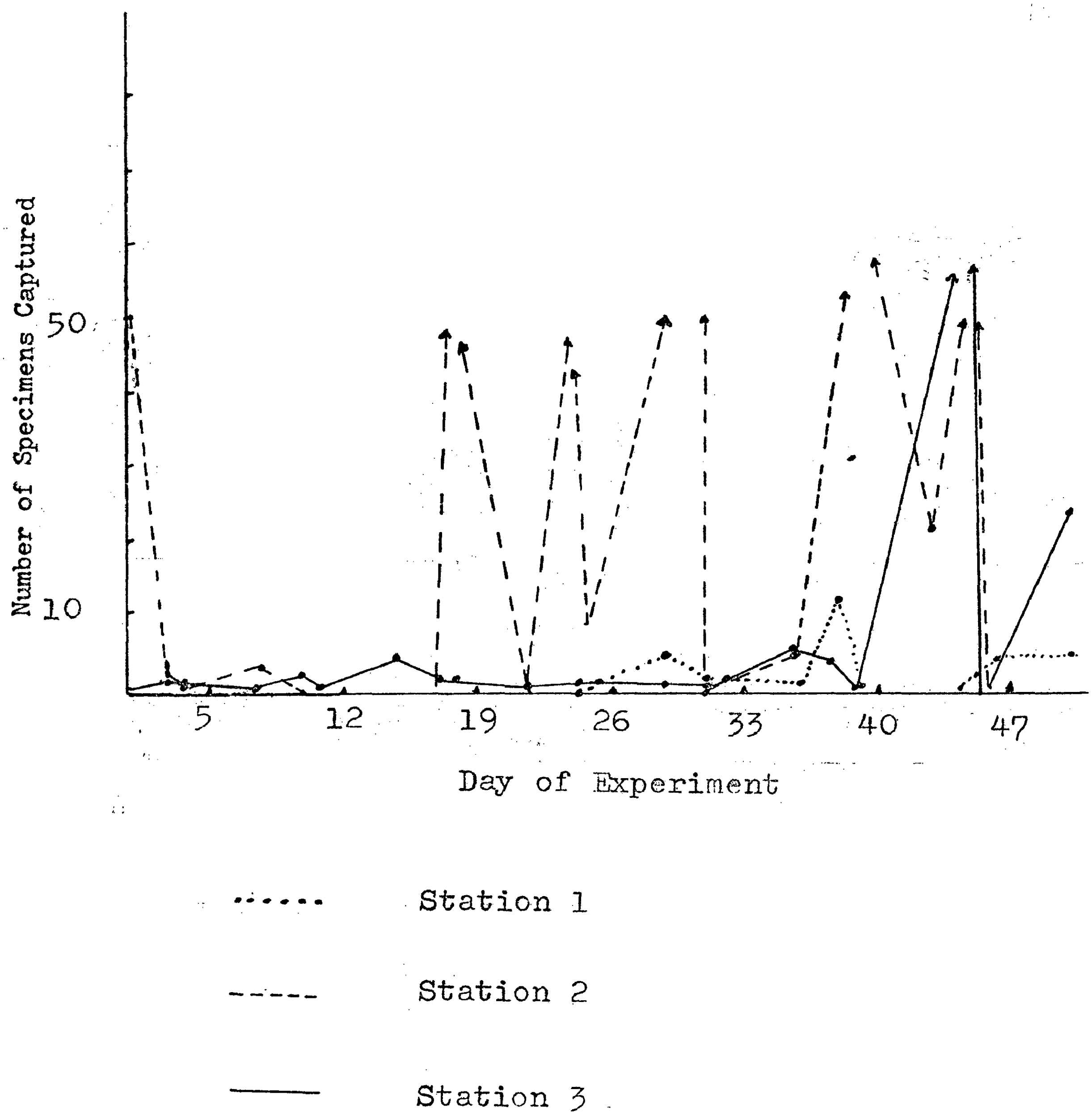


Figure 17. Diatom Populations

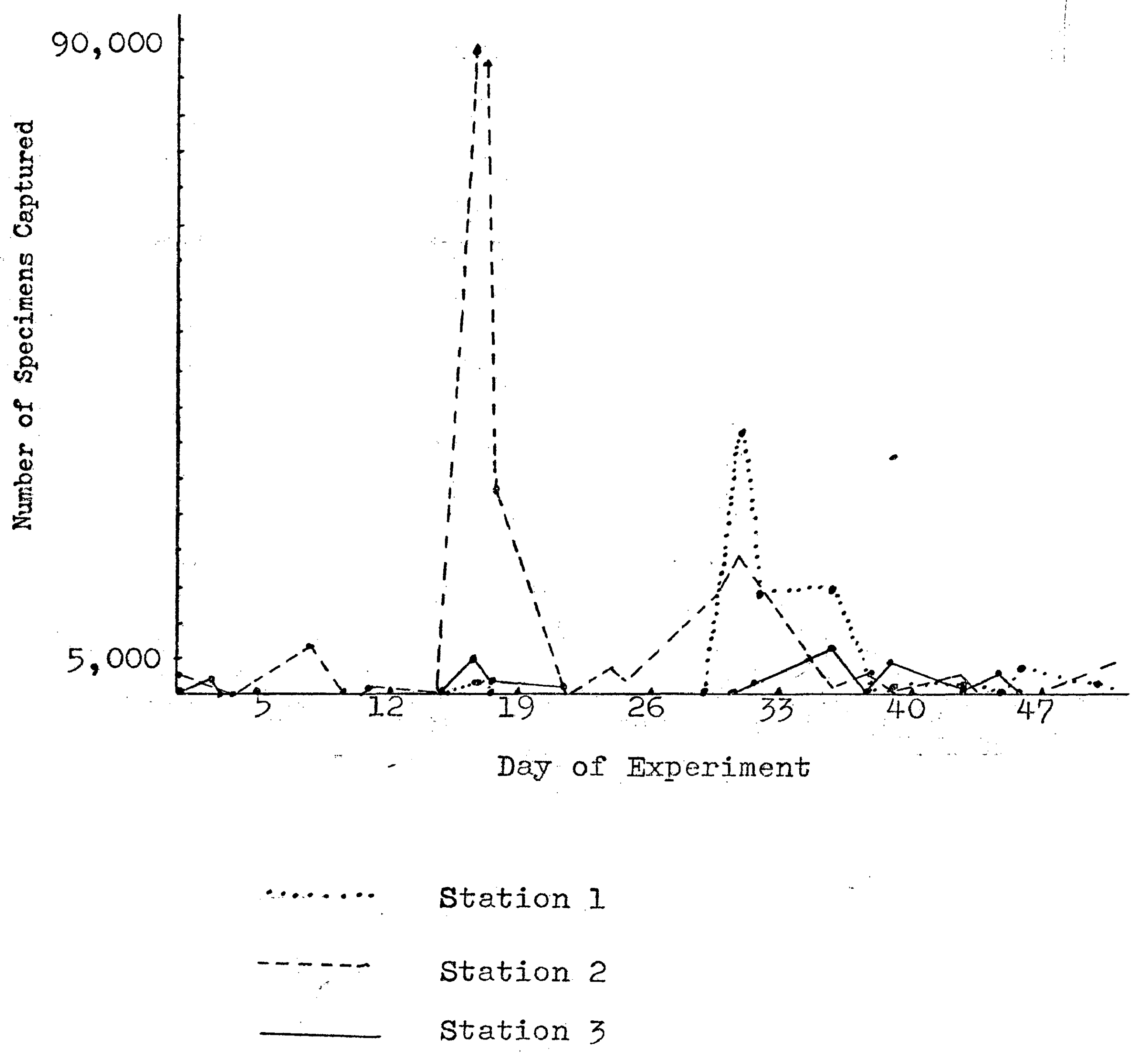


Figure 18. Euglena Populations

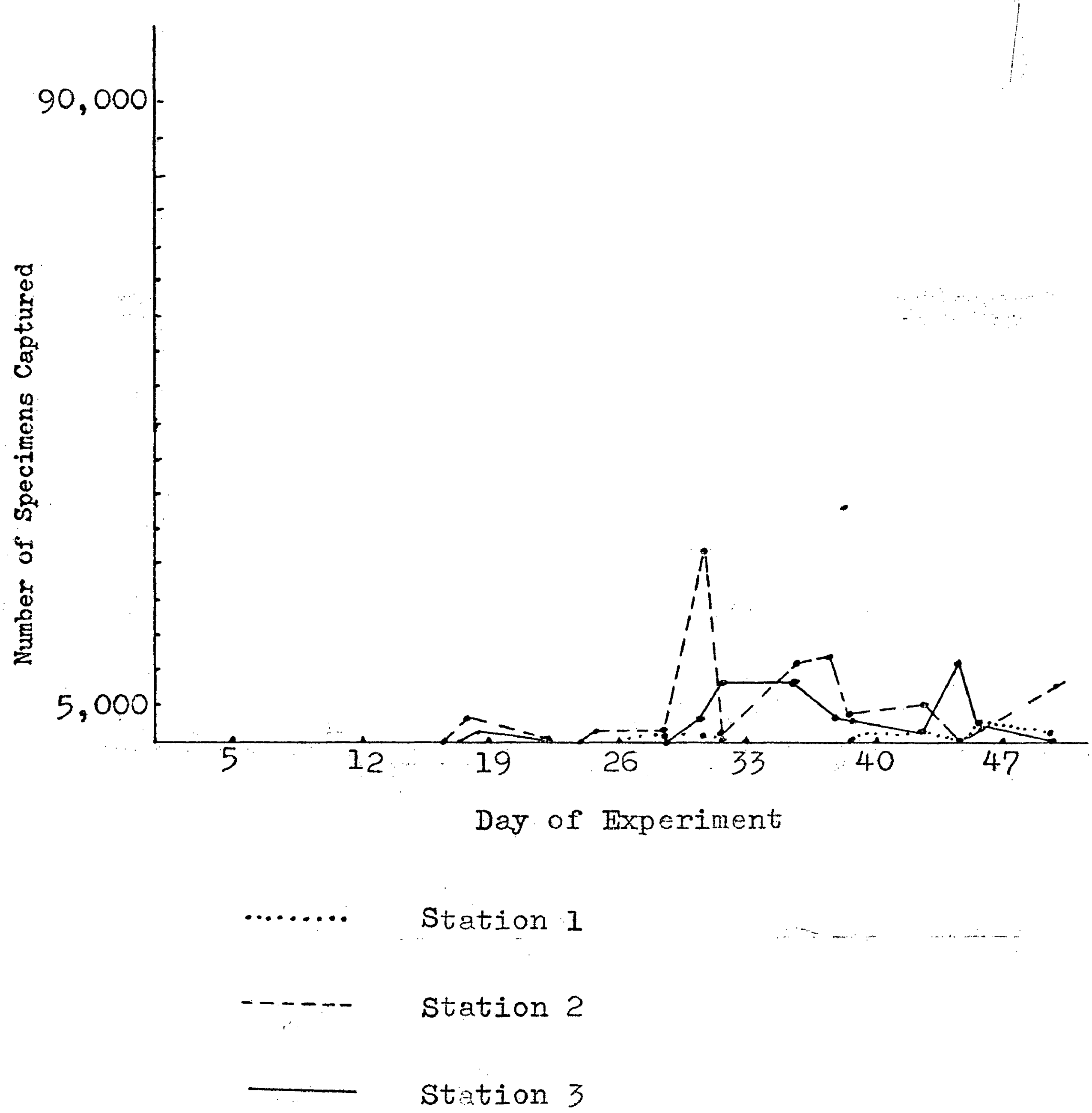


Figure 19. Oscillatoria Populations

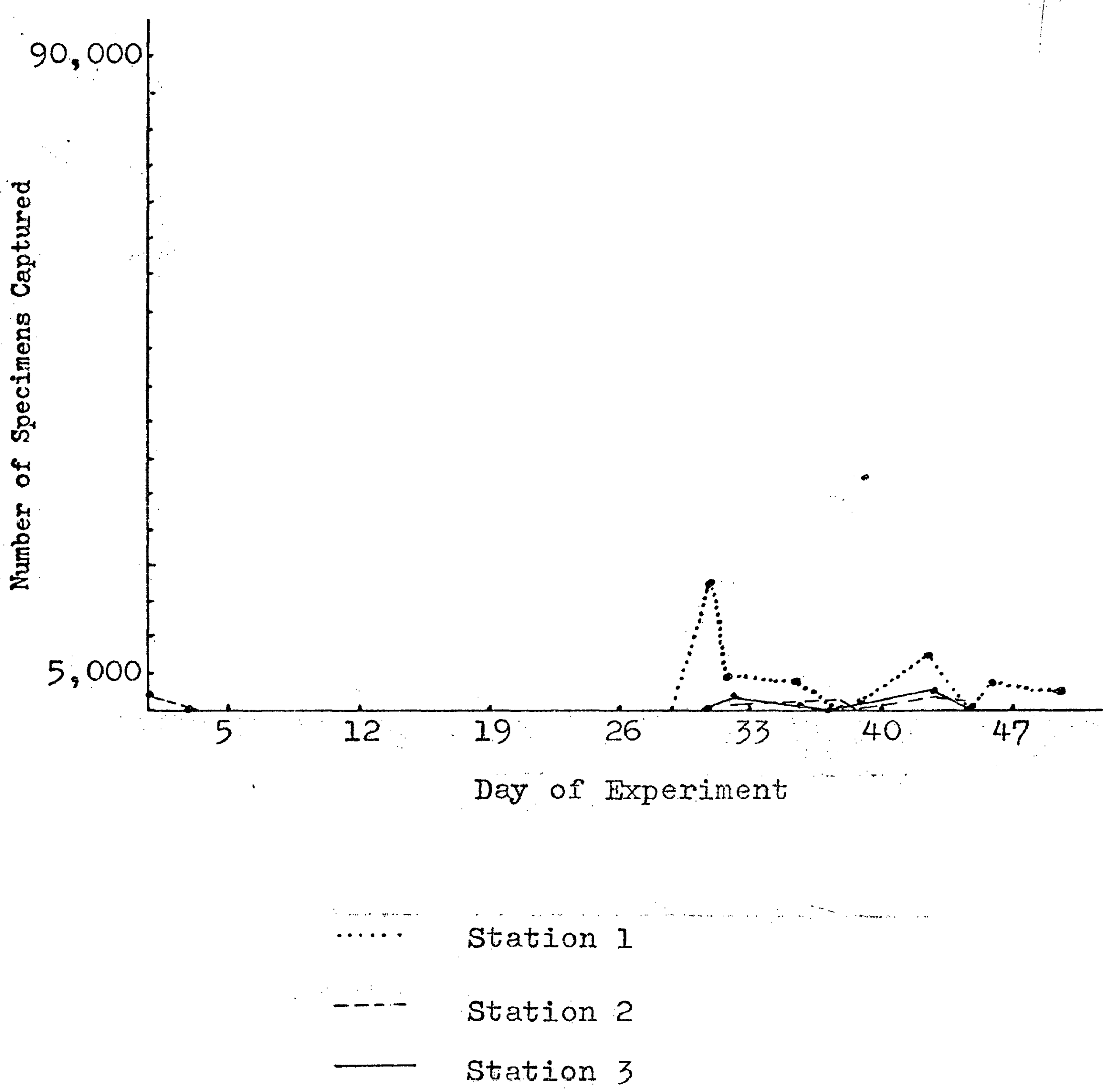
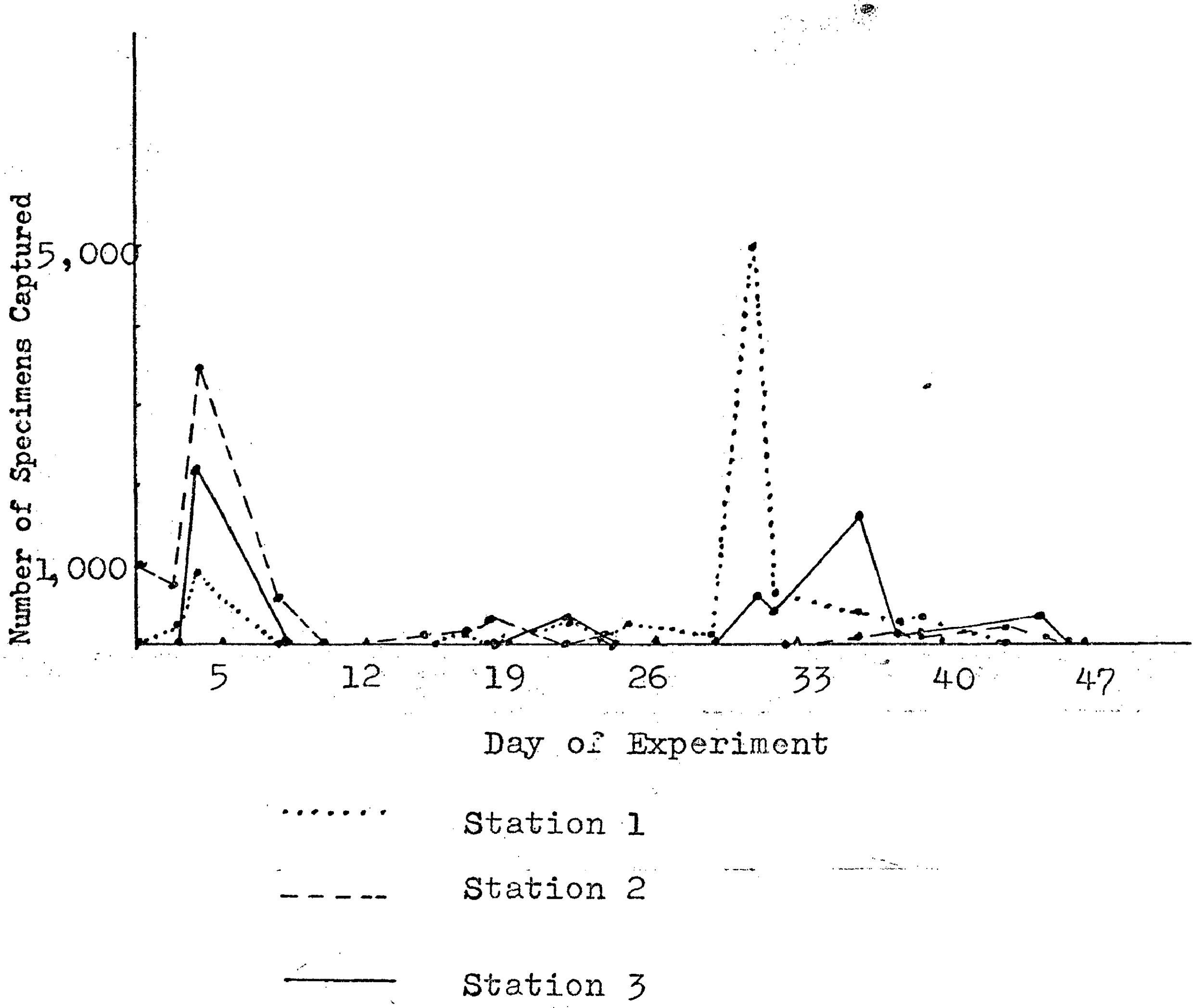


Figure 20. Flagellate Populations



DISCUSSION

In the fall of 1972, a preliminary study on Levi Carter Lagoon showed that in the fall fish ate considerably more than in winter.

Selective feeding tests showed that winter bluegills caught at each station varied in feeding habits from those of the other stations with a tendency though to favor water boatman, damselfly larvae, and dipteran larvae.

Due to few fish captured, the remaining winter fish had their stomachs compared to plankton samples taken from the pond at large. Most of the selected food organisms appeared to be copepods, dipteran larvae, and filamentous algae.

The population study of bluegill showed 3 of 107 marked were recaptured, so estimates reveal 1,319 bluegills from 20 to 100 mm. in standard length inhabit the pond.

Chemical and plankton samples varied from day to day and from station to station. In this lack of continuity, the pond should be considered as a summation of microcosms.

The plankton communities fluctuated wildly. Possible factors have been examined.

The rotifers according to Pennak (1953) are omniverous. Station 1 rotifer populations increased following increases in *Euglena*. In all three areas, rotifers increased with temperature increases. The rotifers are extremely hardy organisms. Dunn (1970) reported that they were the first organisms to return after a pond community was destroyed by an algal bloom. Pennak (1968) reported finding dense rotifer populations in winter.

Copepods were another abundant pond plankter. Dineen (1953) reported finding Canthocamptus as a winter copepod. It is interesting to note that in Levi Carter Lagoon, in Carter Lake (sample taken July 21, 1972), and in the Missouri River (as reported by Cowell, 1970) the copepods were the most abundant of the plankton. Pennak (1953) reported that temperature affects copepod populations though low dissolved oxygen does not. Station 1 copepod increases followed increases in temperature.

Nematodes were reported by Pennak (1953) as being extremely adaptable, able to withstand low dissolved oxygen, and sustain on dead plants and animals. At stations 1 and 3, nematodes increased with increases in temperature. At station 1 and station 2, the nematodes increased with rapid decreases of Spirogyra and Cladophora. The dead filamentous algae may have been a food source for nematodes.

Pennak (1953) reported that tardigrada feed on filamentous algae and are affected by low dissolved oxygen. The dissolved oxygen did not appear to affect the tardigrads as they were found in oxygen concentration as low as 2 mg. per liter. In all three areas, tardigrada appeared to increase with increases in filamentous algae. At station 3, the tardigrads increased with increasing temperatures.

Pennak (1953) reported that cladocera feed on bacteria, algae, and protozoa. Stern (1968) stated that cladocera increased with increases in photoperiod. No relationship between hours of sunlight and Ilyocryptus increase was shown for the pond. However, increases noted in all three areas were accompanied with increases in the flagellate population which the cladocera may have used as a food source.

Hutchinson (1944) reported that diatoms increase in winter and spring when waters are richest in phosphate, nitrate, and silicate. Howland (1931) stated that diatoms increase when temperature is low and salt concentration and pH are high. Rao (1955) stated that diatom increases followed increases in rainfall and dissolved oxygen concentration. It is interesting that the most dominent of the phytoplankton of the Missouri River was found by Cowell (1970) to be diatoms. Diatoms were also the most abundant of the phytoplankton in Levi Carter Lagoon. No diatom increase was noted following precipitation or dissolved oxygen increases. However, at stations 1 and 2, diatom increases accompanied rises in pH. At the third station, diatoms increased with a rise in temperature and at the second station diatom increase reflected increases in hours of sunlight.

Euglena were the second most prominent micro-organism found in Levi Carter Lagoon. They were reported as a summer form by Rao (1955) and Stern (1968). Pennak (1953) reported that they exist in wide pH ranges. At stations 2, 3, Euglena increased following temperature increases. Also at station 3, Euglena increases corresponded with rises in dissolved oxygen.

Oscillatoria was reported to depend on photoperiod and be limited by high dissolved oxygen Rao (1955) and was found by Hutchinson (1944) to experience winter highs. In the lagoon, dissolved oxygen did not prove itself a limiting factor for Oscillatoria. At the first station, Oscillatoria did increase with temperature increases.

Besides Euglena, other small flagellates were abundant in the pond. Wang (1928) reported that flagellates are affected mainly by temperature. They were found to be unaffected by low dissolved oxygen and able to grow in anaerobic conditions by Lindeman (1942). Bamforth (1958) reported organic debris to increase flagellate populations. At station 1, small flagellates increased as the pH increased. This may be a reflection of what Bamforth pointed out as increased organic debris increasing flagellate populations.

Bamforth (1958) reported that as organic debris increased flagellate populations it also limits populations of ciliates. Ciliates were only found in trace amounts in the winter sampling of Levi Carter Lagoon.

Other micro-organisms found in trace amounts were the desmids, Scenedesmus and Closterium. This is in contrast to the findings of Welch (1952) and Stern (1968) that stated that typical ponds have high desmid and low diatom populations.

In Levi Carter Lagoon, the diatoms were high and the desmids were low. The Missouri River may have had some influence on the biota found in the pond. Cowell (1970) reported finding large amounts of copepods, diatoms, and *Difflugia*. Likewise large amounts of copepods and diatoms were found in the pond and *Difflugia* was the only member of the Subphylum Sarcodina found in the pond.

SUMMARY

A limnological study was conducted from January 23 to March 16, 1973 on Levi Carter Lagoon. The pond was attached to a larger lake (Carter Lake) and has become a street drainage catch basin. The higher than normal 1973 winter precipitation amplified the atypical nature of the pond as increased amounts of nutrients and chemicals would wash in from the streets with each precipitation.

Temperature, dissolved oxygen, free carbon dioxide, and hydrogen-ion concentration were measured three times a week with a Hach water testing kit. Precipitation, air temperature, and daily hours of sunlight were also recorded. Plankton samples were taken with a dip net and examined three times a week. Pond fish were captured and examined for stomach contents and selectivity in feeding. Bluegill, *Lepomis machrochirus*, were tagged, released, and recaptured for a population study.

Results showed that each sample site produced different chemical and biological results so possibly the pond should be considered as a summation of microcosms rather than an integral pond. The plankton reflected the Missouri River origin of the pond as copepods and diatoms were the predominent plankton. Bluegill were the most abundant fish in the pond. They appeared to be best able to survive the winter in the pond.

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