LIMNOLOGY FILES

(1)

Lintep: interrelationships in a woodland temporary pond

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A temporary pond is a fleeting habitat which has been overlooked by most biologists. Consequently the possibilities of testing ecological principles there have not been fully explored. These hollows hold water anywhere from a few weeks in the Sudan deserts (Rzóska 1961) to over eleven months in New York (Broch 1965). In that time-span full aquatic development of the animals must occur. So processes which take much longer elsewhere are telescoped here. There are few organisms in a temporary pond. However those that there are tend to be super-abundant. This, as well as the small size of temporary ponds make sampling and physical-chemical measurements easy and accurate. The temporary pond is a condensed microcosm that offers a natural test situation.

Temporary ponds occur wherever there are shallow basins with no outlet. Their surface is usually above that of the watertable at least part of the year, so they are dependent on rains and snowmelt waters. They have been described from areas as divergent as Michigan (Kenk 1949), Western Canada (Mozley 1932, Hartland-Rowe 1966, 1971), Louisiana (Moore 1963, 1968, 1970), New Zealand (Barklay 1966), and the Sudan (Rzóska 1961). Though many different ecotones are represented, there are some things that all temporary ponds have in common. They are all shallow and ephemeral. The shallowness makes them suseptible to widely varying temperatures. This is not true of most aquatic habitats. All temporary ponds reported on were inhabited by fairy shrimp for part of their wet season. With the exception of the Sudan desert ponds, all have a layer of detritus on the bottom, the decomposition of which keeps pond oxygen levels low.

Succession occurs very rapidly in all temporary ponds. They are usually inhabited very soon after they fill, and animal numbers arehigh until the end of the wet phase.

The differences in ponds may be attributed to their differing surroundings, and to the differences in length of the wet phase. In northern USA and Canada there are woodland ponds,and grassland ones. Perhaps the biggest difference between the two is the higher oxygen content of the grassland ponds. Since they are more windswept mixing of the water is usually more complete. There are two general types of ponds in this area that may be distinguished by the length of time that they hold water. Vernal ponds fill in the spring, and dry up in the summer, whereas autumnal ponds fill in the fall and stay wet until the following summer (Wiggins 1973). The ponds described from Louisiana (Moore 1970) and Oklahoma and Kansas (Prophet 1963) are similiar to North American ponds, with the main differences being in the lack of winter ice cover, and higher summer temperatures. A pond studied in England (Hall 1961) was incompletely described, but appears to be similiar to the grassland ponds of north America.

Little work has been done on tropical temporary ponds. There are probably very many in areas that get all of their rainfall in a few spurts. Rzóska (1961) describes extensive pools that form in the scrub desert of the Sudan after rains. These differ substantially from temperate ponds insofar as they are usually much more short-lived, and have a sandy clay bottom lacking detritus. Another type of temporary pond occurs on top of peat bogs in New Zealand (Barclay 1966).

Only a few of the studies of temporary ponds have been purely descriptive. Most investigators have picked a specific organism and explored its adaptations to specific rigors encountered in temporary ponds. Since the fairy shrimp are unique to temporary waters they have been most studied. The distribution of different species of Anostracans, and the physical-chemical characteristics of different ponds have been described (Hartland-Rowe 1971, Prophet 1963, Moore 1963). Experimental work on the hatching requirements of fairy shrimp eggs has led to the isolation of characters unique to temporary ponds which the eggs must have (Broch 1965, Hall 1961) The elegant experiments of Broch clearly established that exposure to air was a requirement of the eggs before they would hatch upon inundation.

Though copepods occur in many places other than temporary ponds, work has been done comparing the copepods of temporary and permanent ponds (Cole 1966), and analyzing the adaptations of some copepods to the temporary pond environment (Brewer 1964).

Since oxygen levels tend to be low in temporary ponds the animals must be adapted to survive at low oxygen concentrations. Some animals such as the adult beetles avoid the problem completely by breathing air. Laboratory studies have been made to determine what sorts of oxygen levels can be tolerated by common temporary pond animals Moore and Burn 1968).

One of the most interesting of temporary pond inhabitants is the caddisfly. Only members of three families inhabit temporary ponds; it appears that the Limnephilidae and the Phryganeidae evolved independent adaptations to temporary pond conditions.(Wiggins 1973). It was the evolution of a dessication-resistant gelatinous egg matrix that allowed the caddisflies to inhabit temporary ponds.

Work on the temporary pond as a whole has not gone far beyond the descriptive level. There are some primary productivity investigations (Donald 1971), and a few inferences as to the fertilizing effect of drying out. But there have been no predator prey behavior studies for which the superconcentrated environment is ideal. Nor has there been any investigation of the food chain of this detritus-based system.

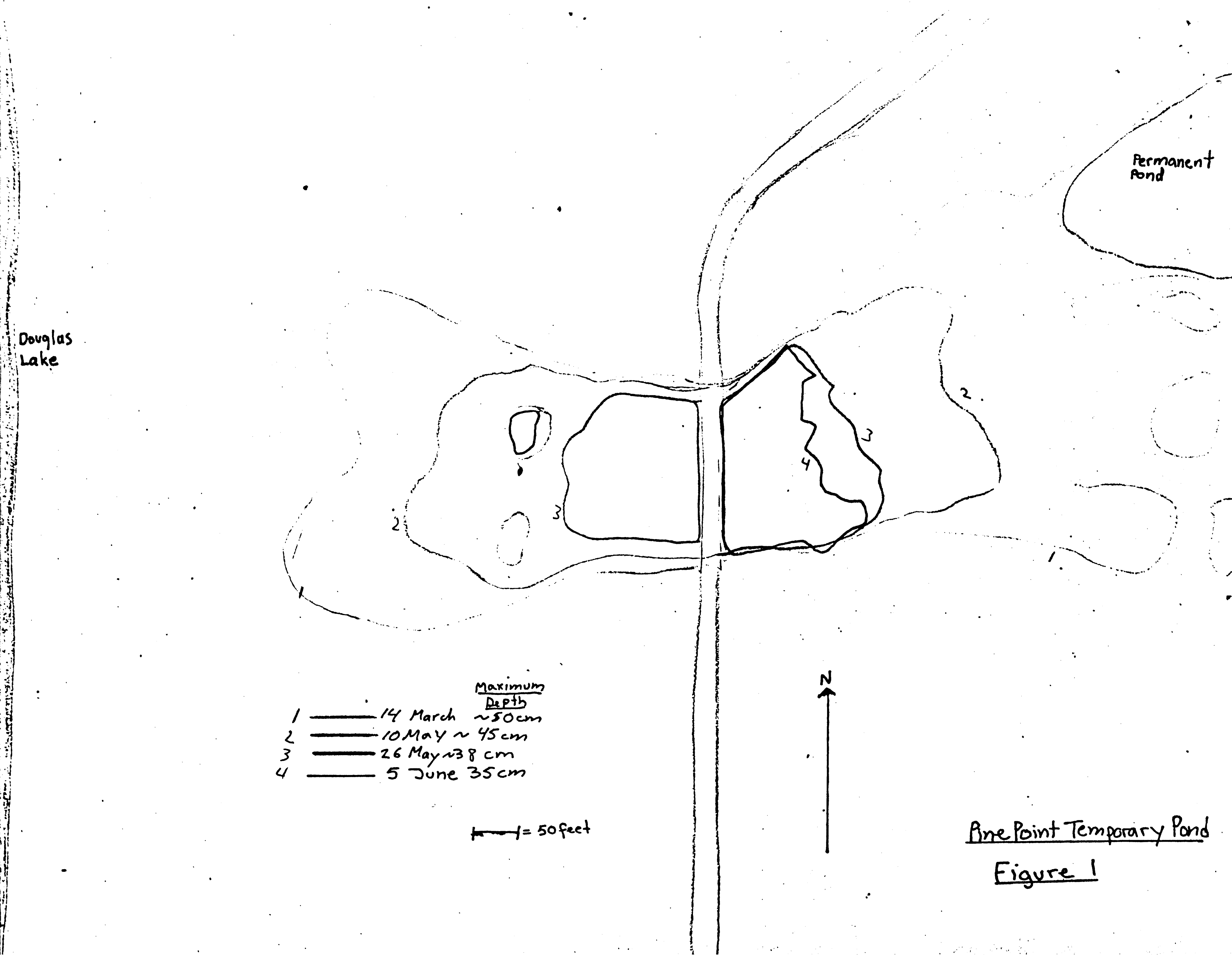
Introduction

The present paper attempts to describe a classical woodland temporary pond focusing on the aspects of the limnology and biology that will be useful for further studies. Field work was begun by checking the pond for water in January. Open water was present in the middle of March at which time qualitative collections of animals were begun. These collections were continued through the middle of August. The pond was visited several times a week from the middle of May to the middle of August. During this time-span any observations which seemed to hint towards a general explanation of what is going on in a temporary pond were followed up by lab and field studies. But in most cases the further studies served only to determine if there was an interesting problem in hand; though answers were hinted at, the work was not complete enough to prove anything. It is around a few interesting phenomena that were observed in the pond that this paper will be arranged.

Pine Point Temporary Pond is located about three-hundred feet from the shore of Douglas Lake on a tract of land owned by the University of Michigan Biological Station. It is a woodland pond that is totally unconnected with the lake. Though there was ice on the bottom of the pond in January, the first filling of the year is with the spring meltwaters. This year and last the pond held water until July when it dried out for three weeks this year. Late summer rains refilled it to the level of the 25 June 1973.

The surrounding forest consists mainly of maples (Acer saccharum) which also grow right in the basin of the pond. Dead maple leaves formed most of the pond bottom detritus. Also growing in the forest are Populus tremuloides, Populus grandidentata, Betula papyrifera, Pinus strobus, and Pinus resinosa. The ground-cover consisted of Aralia nudicaulis, Maianthemum canadense, Clintonia borealis, Polygala paucifolia, Vaccinium britonii, V. lamarkii, Rubus sp. and Gaultheria procumbens In the pond basin itself grew dense clumps of Ilex verticillata as well as Chamaedaphne calyculata, and Rosa sp. As the pond grew shallow Iris sp., and Carex sp. grew in the muck.

From the end of May through the fall the pond was eighty percent shaded. The water was consistently a very deeply stained brown; this made animal observations in the deep water very difficult. Another impedence to observation was the perfect mirror quality of the pond surface. When the pond first formed, it covered "vast" areas for a short time. These shallow expanses quickly dried up, so for the rest of the summer the pond was confined to a basin that was a little



Pine Point Temporary Pond

Figure 1

steeper-edged. Even then, however, it was shallow enough so that every centimeter of depth lost substantially decreased the area of the pond (figure 1).

Perhaps the most limiting condition in Piptep (Pine Point Temporary Pond) is the paucity of oxygen. This was traced through the season, through the day, and in different depths of the pond. It is one of the important factors to be considered in understanding temporary ponds. Another important condition is the dense population, and the rapidity with which one species will fade to be replaced by another. Through the season the main predators were continually replaced by others whose prey strategies were significantly different. To some extent succession was determined by the water conditions (see discussion of mosquitoes). But many animals faded when there was no indication that the pond would soon be dried up. To some extent there was uneven distribution of animals in the pond. Many of the crustacea clumped in sunny areas; other animals retreated to the bottom when it was colder, and many were more abundant in shallower waters. Before the interrelationships of the various phenomena can be worked out, they must be described, and the exact life histories of organisms in this specific pond (Piptep) established. That is the goal

Methods

Piptep was visited at least once a week from the 15 May through 15 August. At that time qualitative collections of animals were made using a plankton net for smaller things and a kitchen saive attached to a pole for large, fast organisms such as gyrinids and dytiscids.

The collections were preserved in the field in 10% formalin. Two stakes were positioned in the pond, one at the deepest place, and the other in water about half as deep. (Figure 2) These stakes were labelled one, and nine, respectively. Water temperature was measured at one; near the surface it was the same as the temperature at nine. Oxygen samples were fixed in the field from one and nine in 300ml BOD bottles. In all cases the water was surface water obtained by submerging the bottle in the pond and letting the water flow, but not bubble, in. Dissolved oxygen was determined in the lab by the Alsterberg modification of the Winkler method.

Water was brought back to the lab for pH and conductivity tests in a BOD bottle. The pH was determined by a Beckman model N pH meter not more than half an hour after the sample was taken. Conductivity was measured with an Industrial Instruments Inc. Conductivity Bridge, model RC 1602.

On one occasion light penetration was measured.

The pond was mapped on the 11 June with a 150 foot steel tape and a Brunton pocket transit. The pond borders were broken down into straight-sided segments. Then the the lengths of the segments and the angles between segments were measured.

All organisms collected were identified as far as could be accurately done using available keys, and experts in residence. Dr. John Gannon identified the cladocerans and the copepods. Dr. Arlan Edgar identified the snails, leeches, ostracods, mites, conchostracans, and oligochaetes.

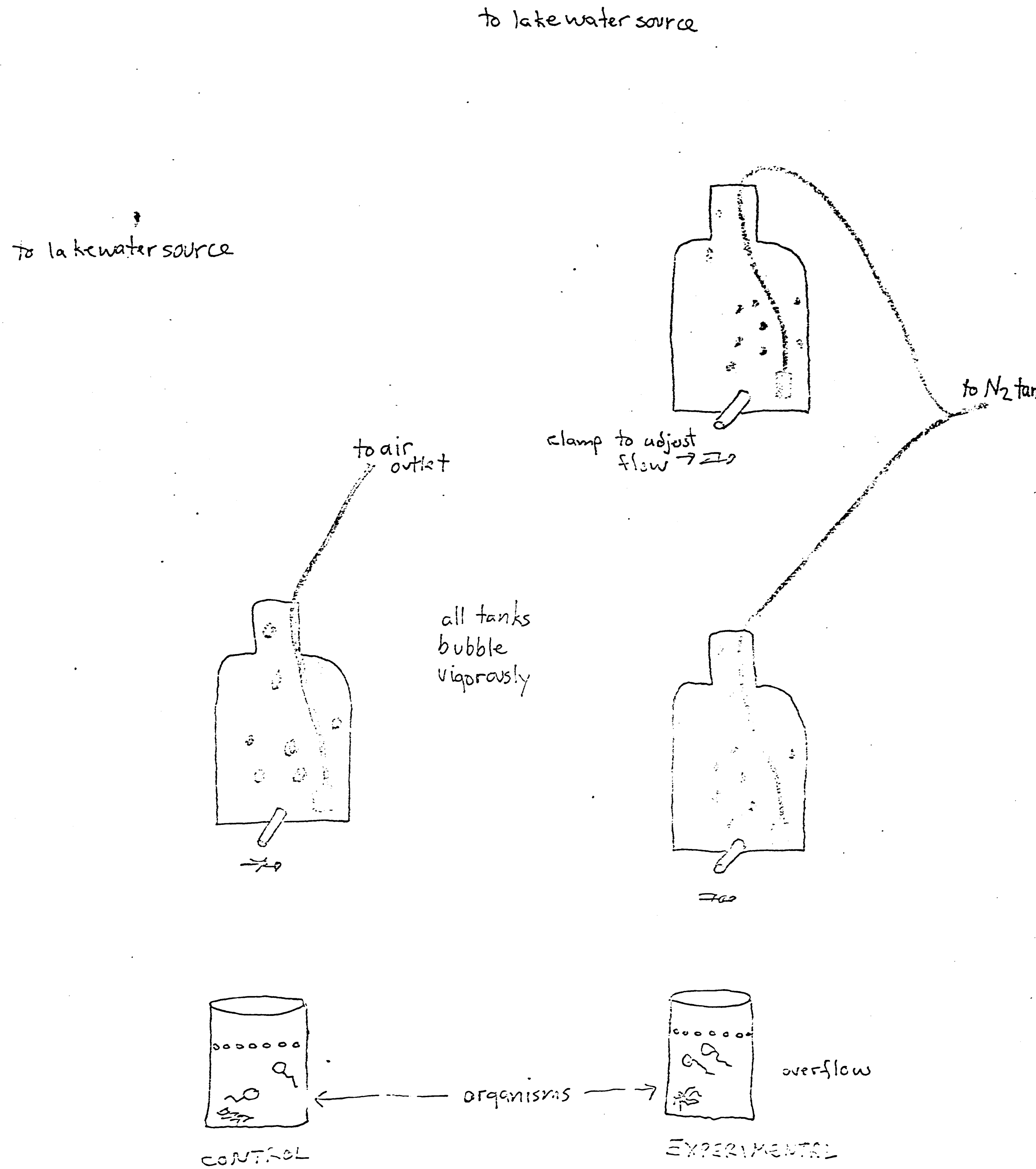
Dr. Fred Test identified the amphibians. The remainder of the organisms were identified using keys by Pennak, Ward and Whipple, Usinger, Arnett, Roth, Hilsenhoff, and Mason (see bibliography).

Feeding behavior of beetle larvae was observed in the lab in small aquaria filled with gently aereated pond water.

Special equipment was set up for the experiments at low oxygen tensions. A cylinder of nitrogen gas was used with the apparatus shown in figure 3 to partially de-oxygenate the water. The control was identical with the only difference being that air instead of oxygen was bubbled in. The number of tadpoles and Libelullas introduced into the test setup and the control were the same. Water that was deoxygenated with nitrogen was covered with a two inch layer of mineral oil to form a totally anaerobic environment. The animals were introduced to it by means of a tube so they would not get any oil on their bodies.

<u>Results and Discussion</u>

The percent saturation of oxygen varied greatly in Piptep. It varied according to date, time of day, and depth of the place the sample was taken. All samples were taken from the surface as any lower level was likely to introduce too much detritus into the sample bottle. From the 28 May to the 11 June afternoon oxygen level in the shallow location dropped from 40% saturation to 6% saturation. Similiar drops occurred in the deep water at station one over the summer (figure 4). Increases in oxygen usually followed rainstorms. In general there was most oxygen in the d[illegible] water in the afternoon, and least in the shallow



to lake water source
to lakewater source
to N2 tan
to air outlet
clamp to adjust flow
all tanks bubble vigorously
organisms
overflow
CONTROL
EXPERIMENTAL

Figure 3

EFFICIENCY® LINE NO. 6636

These tables, if needed at all, should be in an appendix since all information is in the figures.

13:35–16:30 o'clock
8:30–10:30 o'clock

Physical-chemical Data Table 1

Date	#	1 time	2 collection	3 air temp. °C	4 water temp °C	5 depth cm	6 pH	7 O_2 deep mg/l	8 O_2 shallow mg/l	9 conductivity	10 comment	11 O_2 % sat deep	12 O_2 % sat shallow	13
[illegible]	1													
24 March	2		*		6°C									
28 March	3		*		7.5°									
31 March	4		*											
5 April	5		*		4.0						skim ice			
12 April	6		*	30.0	2.0						½" ice			
19 April	7		*		6.0									
21 April	8		*											
24 April	9		*											
14 May	10		*				6.53	5.4						
15 May	11				17.0									
18 May	12	9:00		14.0		42.5		4.04		5790				
18 May	13	15:45		14.0	13.5					corrected: 494				
17 May	14	10:30			7.9		6.19	7.00		4350/23.0°c		27		
19 May	15	18:30		8.5	8	41.8	[illegible]							
19 May	16	16:00		20	16	41.5	6.36							
20 May	17	8:45		12	10	41	6.26			529/24.5°c				
20 May	18	16:10	*	22	19	40	6.2	3.84		532/24.5c		43		
21 May	19	14:30		25	21	39.9	6.22			5800		[illegible]		
22 May	20	16:30		23	18	39.3	6.28	3.8	1.9 at 12.5cm					
22 May	21	20:23		18.5	17	38.3			4.91					
23 May	22	0:20		13.0	15.0		6.19	2.54	.88					
23 May	23	4:55		6	13.0		6.23	2.4	0.4					
23 May	24	8:45		12	12		6.12	2.0	0.46			19	4	
23 May	25	12:45		22	17		6.02	2.24	1.36					
26 May	26	15:00	*	14		36.5								
28 May	27	16:30		13.0	12	39.3	6.39	4.2	4.26	428		40	40	
29 May	28	14:50	*	15.0										
30 May	29	16:30		20.5										
31 May	30	13:17		18.1	14									
2 June	31	15:30		21.5										

EFFICIENCY, LINE NO. 6636

Physical-chemical Data p2

Date	1 time	2 collection	3 air temp	4 water temp	5 depth	6 pH	7 O_2 deep (mg/l)	8 O_2 shallow (mg/l)	9 conductivity	10 comment	11 O_2 %sat	12 O_2 %sat	13
4 June	10:15												
4 June	15:05	* actually 3 June	28	18.5	35.4	6.07	2.6	1.22			28	13	
5 June	8:45												
11 June	9:15		24	[illegible]	27	6.18			556				
11 June	14:25	*	27.5	24			1.68	0.6			20	6	
15 June	15:40		28.5	21.5			0.30				3		
17 June	12:50	* actually 18 June	20.0										
20 June	14:15		24.5	19	24					Light Penetration			
21 June	9:20		20	17	25	6.1	0.6	0.1	578		6	1	
21 June	15:00												
23 June	9:45		17.5	15	19								
24 June	13:40		20	17									
25 June	10:10		19.5	15	16	6.1	0.28	0.00			7	0	
25 June	14:25	*	25	18.5									
1 July	11:10	*	24	17	21	6.11	1.4	1.24	63.80				
4 July	9:40		19.5	18	21								
5 July	13:35		21	21	19.5	6.1	1.0	0.4	66.2		11	4	
7 July	14:00	*	32		16.5								
14 July	16:30				1					1 sq ft 1 green [illegible]			
18 July	13:35		29		0								
28 July	AM	*								refilled 8 sq ft			
30 July	15:00	*			~~10~~ 16					refilled most of rt. half.			
1 Aug	15:00	*			9	5.7	1.2						
3 Aug	15:00	*	27	19	13		2.4		53.6		21		
15 Aug	13:00	*		21	8	5.8	1.4		44@23°C		32		

TELEDYNE POST

20MA-600 10X10 TO CM.
LITHO IN U.S.A.

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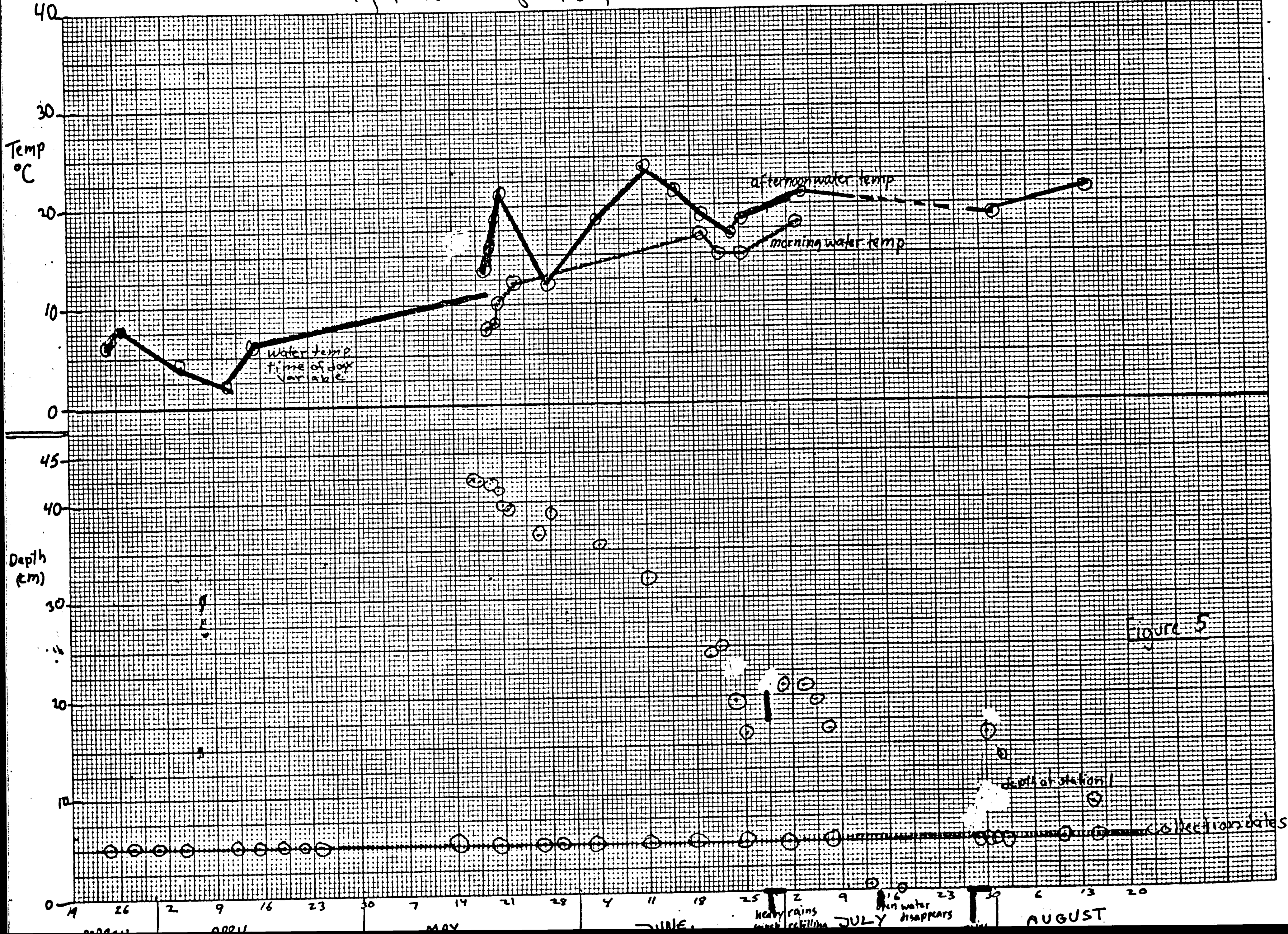

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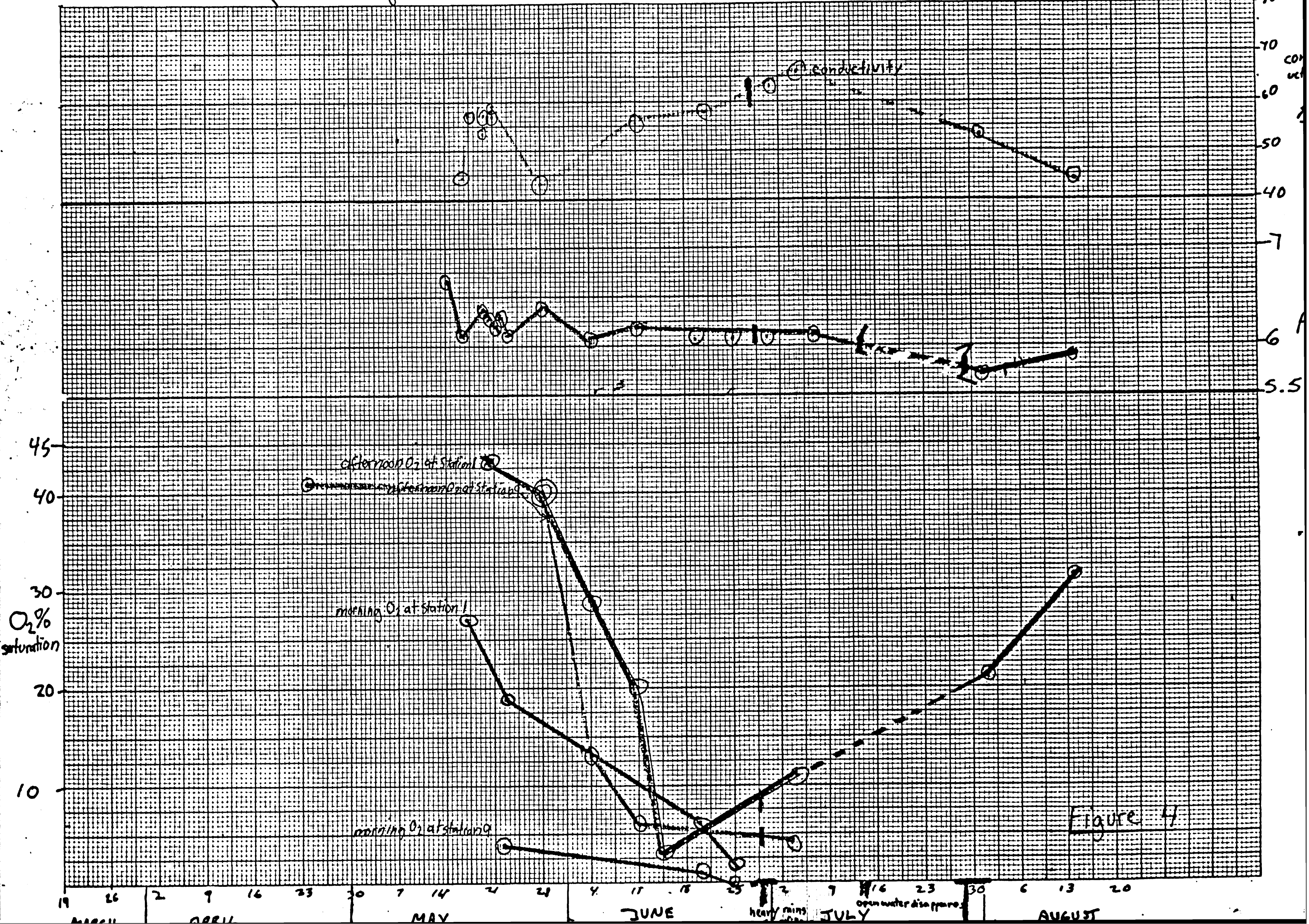


Figure 4

morning water. Morning readings were all those taken between 8:30 and 10:30 while afternoon readings were taken between 13:35 and 16:30. Readings falling outside of these times were not graphed (table 1).

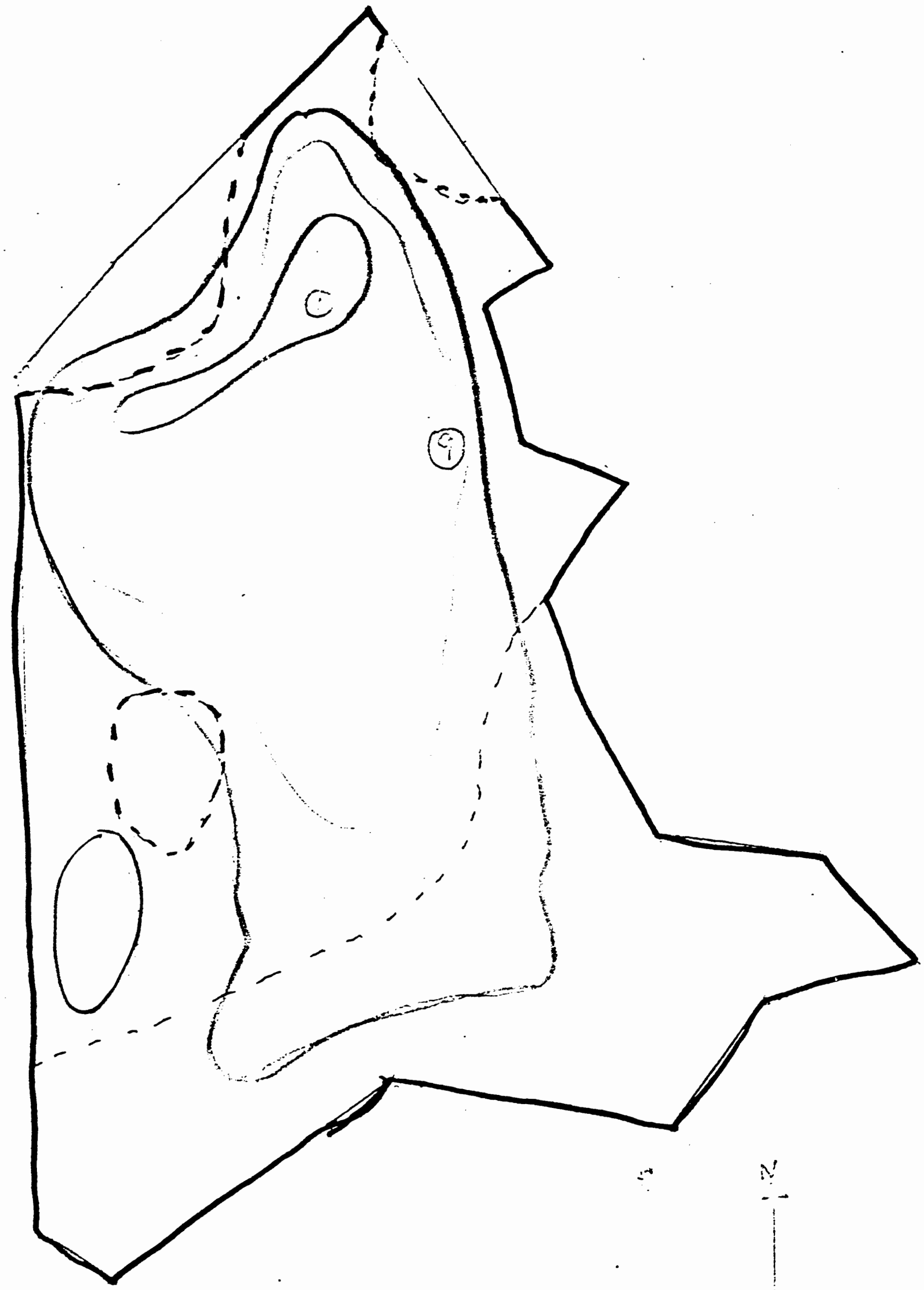
Temperature was also found to vary with time of day, and was graphed accordingly. There were larger morning-afternoon temperature differences early in the season (May) than there were later (June-July). In May the differences were over 5 ^{o}C while in June they were seldom over 3 ^{o}C. Over the spring and summer the pond warmed from a minimum of 4^{o}C on 12 April to a maximum of 28^{o}C on the 11 June. (Figure 5). Since most water bodies tend to be more constant in temperature, this fluctuation could have been important in the types of animals found in Piptep, and in the duration of their stay.

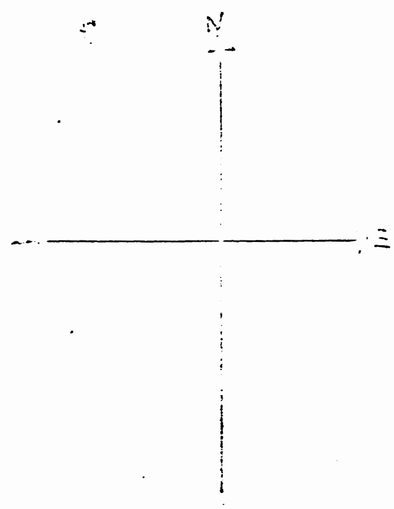
Conductivity and pH were also measured, but they were found to vary only slightly. PH tended to decrease over the summer, while conductivity increased (figure 4). The variation is so slight that it is unlikely to have had a great effect on the animals. Conductivity was consistently very low in comparison with nearby water bodies only a tenth of the normal conductivity which is not a hundred yards

Depth decreased fairly regularly until open water dissappeared 14 July. However each rainstorm was reflected in a little upward notch. A series of heavy rains refilled the pond around the 25 July. It remained filled for the duration of the study. Obviously the presence or absence of water is one of the most important charatceristics of the pond.

Pine Point Temporary Pool

Figure 6





	Maximum
5 June	55 cm
20 June	2[illegible] cm
25 June	16 cm
11 July	10cm

—— = 10 feet

The decrease in area was directly correlated with the decreases in depth. As area decreased, numbers of animals decreased, and did not increase upon a reflooding. So by the time the pond finally dried up it had become rather dilute. The irregular depths of the pond meant that the decrease in area per cm decrease in depth was not constant (figure 6).

Many different kinds of invertebrates are found in temporary ponds. Some were always present, some left when a stage of their life cycle was over, and others were only very sporadically present. Always present were Sphaerium occidentale, Lumbriculidae, Naidium breviseta, Cyclops vernalis, collembolans, Gyrinus sp. and Gerris sp. The insects flew away when the water was gone, but the others were always present. Some animals visited the pond only very sporadically, but were truly aquatic while there. All animals in this category were adult beetles who apparently flew in, and left very shortly. All of them were collected only once.

The most interesting sort of animals were those that were in the pond for only a while, and then either died, or left the pond. It is these animals that arouse questions concerning the reasons for their dissappearance. Is it related to something about the water chemistry, is there a set pattern to their life cycle, or are they greatly preyed upon? Fairy shrimp were among the first animals to appear in the pond; they were also the first to leave, not being found after the end of April. The last week or so the females were gravid, so the adult fairy shrimp were probably completing their life cycle that early.

Table 3

Organisms collected from Piptep

Phylum
  Class
    Order
      Family
        Genus species

Arthropoda
  Crustacea
    Copepoda
      Cyclops vernalis
      Cyclops bicuspidatus
      Harpacticoida

    Cladocera
      Daphnia pulex
      Ceriodaphnia lacustris
      Simocephalus expinosus
      Scapholeberis kingi

    Ostracoda

    Concostraca
      Lynceus brachyurus

    Anostraca
      Chirocephalopsis bundyi

  Arachnida
    Hydracarina
      Hydrachna sp.
      Hydrophantes sp.

  Insecta
    Hemiptera
      Gerridae
        Gerris sp
      Corixidae
      Notonectidae

    Coleoptera
      Dytiscidae
        Dytiscus sp
        [illegible]abus sp.
        [illegible]cilius sp.
        Hydropor[illegible]nae
        [illegible]
        [illegible] sp

      Hydrophilidae
        Sphaeridium sp.
        Hyd[illegible]era sp.
        Hyd[illegible] sp

Gyrinidae
Gyrinus sp

Odonata
Lestidae
Lestes sp

Libellulidae
Libellula sp

Diptera
Culicidae
Aedes sp

Chaoboridae
Chaoborus americanus

Ceratopogonidae
Alluaudomyia sp

Trichoptera
Limnephilidae
Limnephilus sp

Phryganeidae
Ptilostomis sp

Annelida
Oligochaeta
Lumbriculidae
Naididae
Naidium breviseta

Hirudinea
Oculobdella lucida

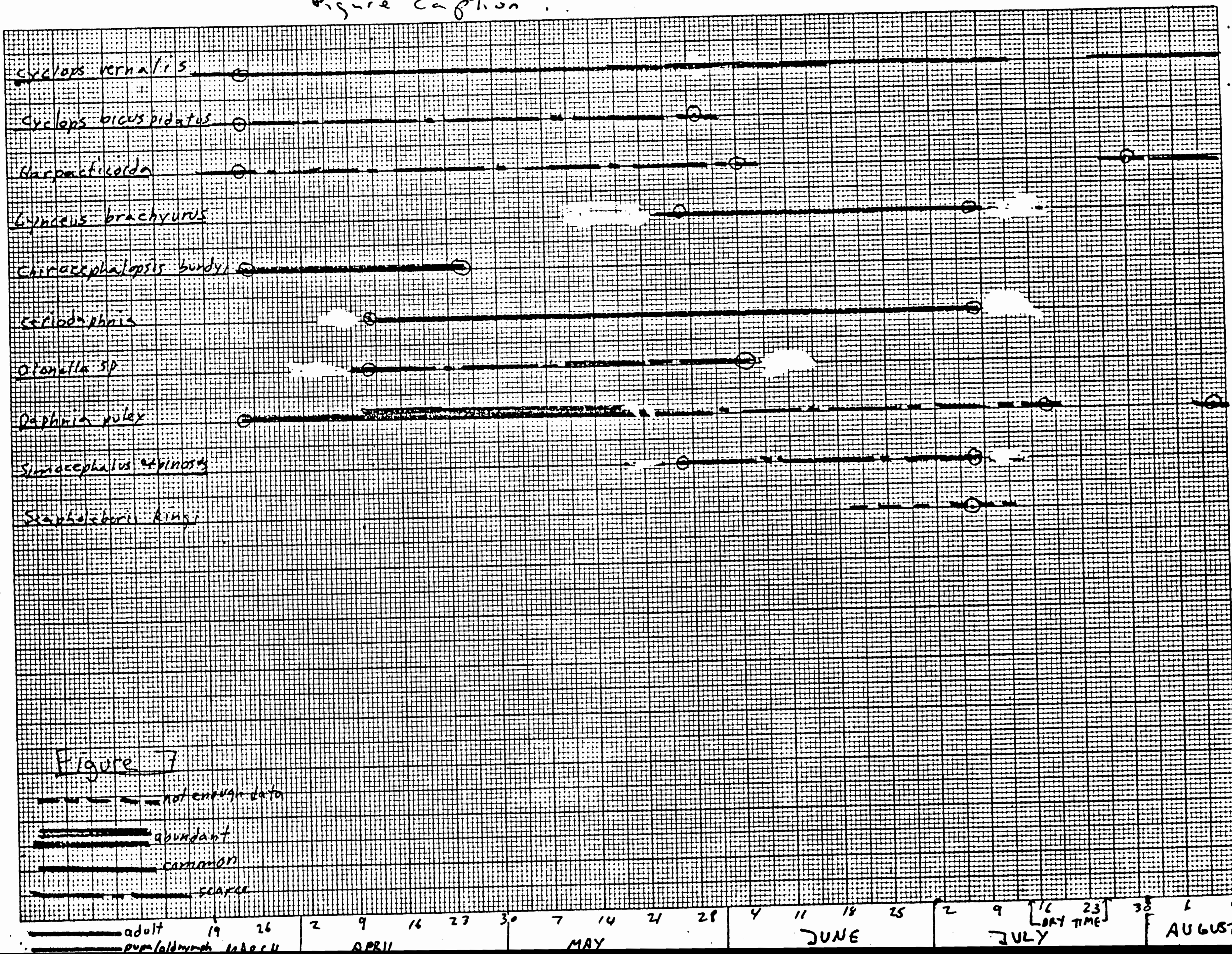
Mollusca
Pelecypoda
Sphaerium occidentale

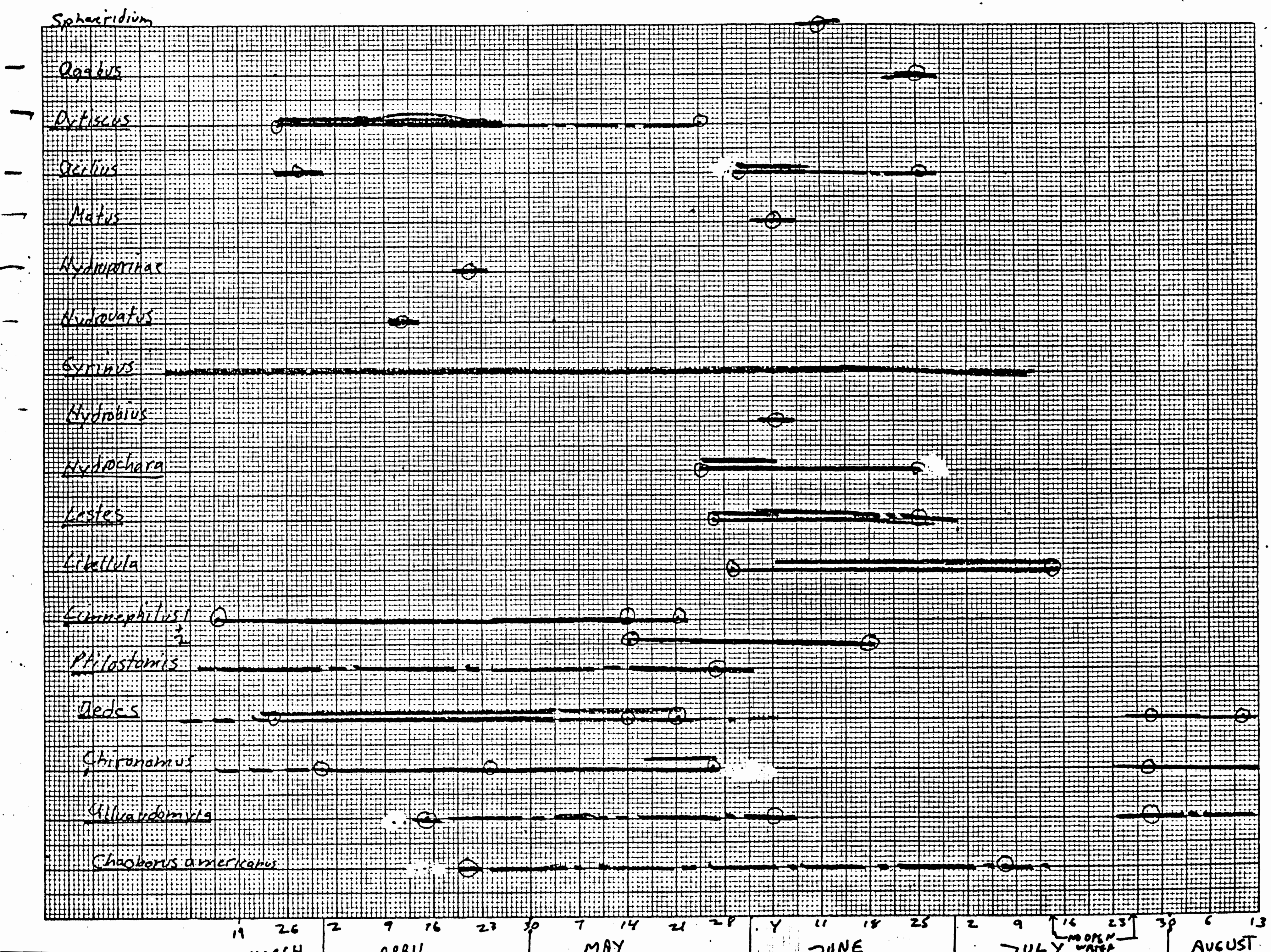
Gastropoda
Stagnicola palustris elodes
Planorbula armigera
Aplexa hypnorum

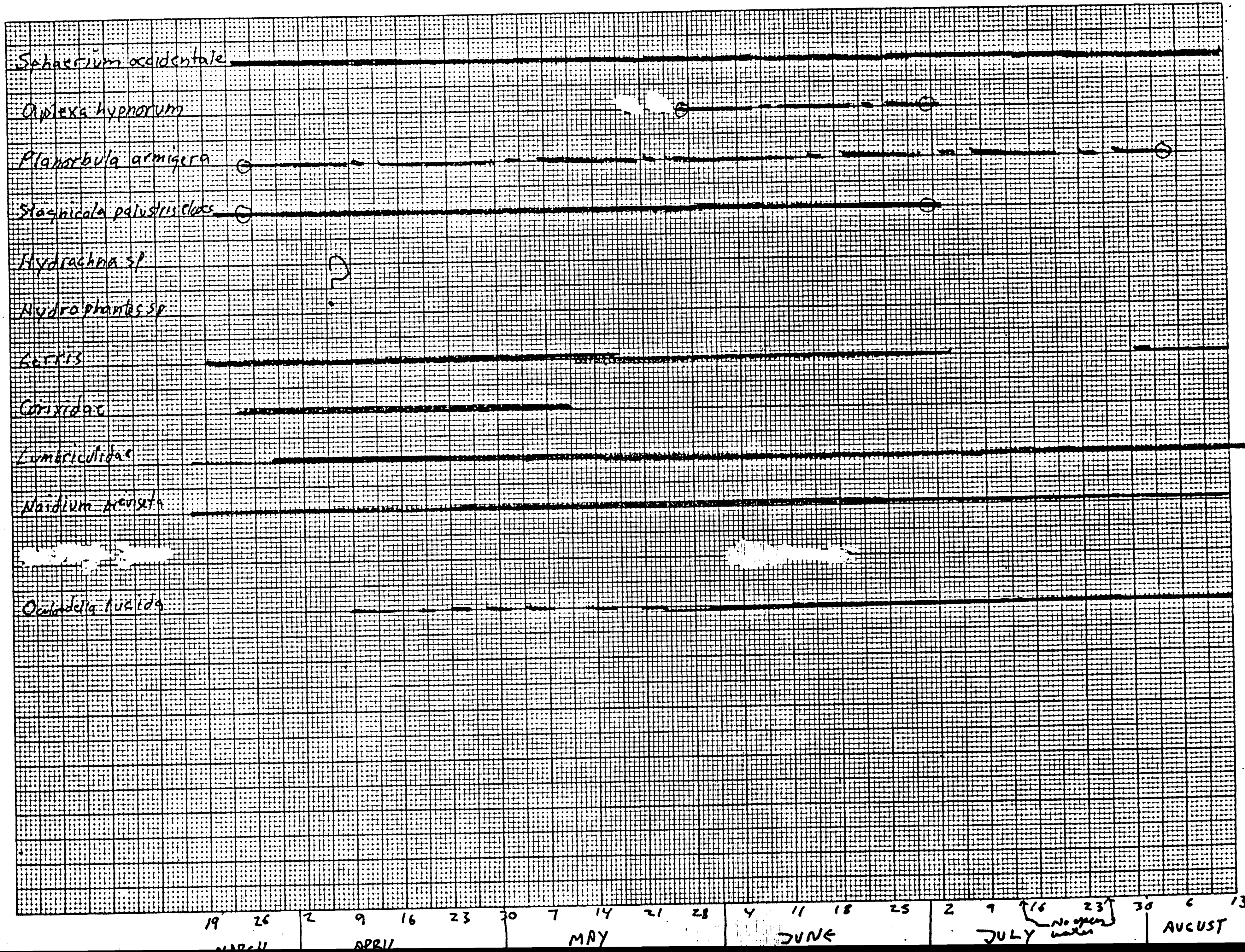
Chordata
Amphibia
Ranidae
Bufo americanus
Hyla crucifer

Ambystoma laterale

Figure caption?




Sphaeridium
Agabus
Dytiscus
Acilius
Hydroporinae
Hydrovatus
Gyrinus
Hydrobius
Hydrochara
Lestes
Libellula
Limnephilus
Ptilostomis
Aedes
Chironomus
Ulvaredomyia
Chaoborus americanus
19 26
2 9 16 23 30
7 14 21 28
4 11 18 25
2 9 16 23 30
6 13
MARCH
APRIL
MAY
JUNE
JULY
NO OPEN WATER
AUGUST


Sphaerium occidentale
Aplexa hypnorum
Planorbula armigera
Stagnicola palustris elodes
Hydrachna sp
Hydrophantes sp
?
Gerris
Corixidae
Lumbriculidae
Naidium
Ocaladella lucida
19
26
MARCH
2
9
16
23
APRIL
30
7
14
21
28
MAY
4
11
18
25
JUNE
2
9
16
23
No open water
JULY
30
6
13
AUGUST

Aside from a few strays the only predator that the fairy shrimp had was the Dytiscus larvae. They were numerous early in the season, and probably preyed significantly on the fairy shrimp population. But it cannot be suggested that these Dytiscus larvae were directly responsible for the dissappearance of the fairy shrimp. Unfortunately chemical measurements were not made until after the fairy shrimp were gone. Early formation of eggs to last until the next spring is probably an evolved adaptation of fairy shrimp to the generalized temporary pond environment. It means that they can live in ponds that dry up early in the season; there are fewer predators early in the year, so that too could have put the selective advantage with those fairy shrimp that formed eggs early.

A number of animals dissappeared from the pond around the end of May. Though this coincided with the appearance of a number of predators no relationship between the two was confirmed. The laboratory experiments that would be necessary to establish that are beyond the scope of this paper. A number of insects emerged, and were not seen again in the pond. These were Limnephilus sp 1, Ptilostomis sp., Aedes sp. Chironomus sp, and Allaudomyia sp. Of these the mosquito, midge, and biting midge were all observed in the jaws of one or more of the new predators. The two caddisflies were probably too big to be eaten. Other prey organisms that dissappeared at this time were two copepods, Cyclops bicuspidatus, and a harpacticoid copepod, Alonella sp, and Daphnia pulex became much rarer. Both a copepod and a Daphnia pulex were observed being eaten by

Hydrochara larvae which hatched around the 26 June.

Though six animals which were prey to new predators disappeared when the predators came, there are other animals that were also prey that did not disappear at that time. Both Cyclops vernalis and Ceriodaphnia lacustris remained present. Simocephalus expinosus and Scapholeberis kingi did not appear until the predators were big enough so they would probably not feed on anything that small. Again, it must be repeated, any correlation is still entirely hypothetical.

The predators that appeared in close succession to one another at the end of May were two beetle larvae, Acilius sp and Hydrochara sp , and two odonate larvae, Lestes sp, and Libellula sp. These predators appeared in the order listed, a few days separating one from the other. Collectively they covered most of the pond niches. Acilius would hang near the surface of the water anywhere in the pond. At night it would stay in the leaf litter. Hydrochara and Lestes would perch on a twig, or a grass stem and await prey. Occasionally Hydrochara was observed in underwater mosses. Libellula stayed on the bottom among the leaves. Occasionally it was observed scuttling around, as if it was stirring up things that it then scooped into its spoon-like labium.

Feeding behavior of three of the predators was observed in the field and in the lab. Libellula's motions were watched, but it seemed [illegible] things and so was hard to observe. In [illegible] always at the bottom of the pond where visibility was very poor. The feeding behavior of the beetles was especially interesting a = adult l = larva, n = nymph p = pupa

Table 4

	24 March	28 March	31 March	5 April	12 April	15 April	19 April	21 April	24 April	14 May	20 May	26 May	29 May	4 June	11 June	18 June	25 June	1 July	7 July	28 July	30 July	1 Aug	3 Aug	10 Aug	15 Aug
Harpacticoida	a						a	a		a	a	a	a	a							a				
...lops bicuspidatus	a	a	a		a	a		a	a	a	a	a	a												
...nalis	a	a	a	a	a	a		a		a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
...cus brachyurus												a		a			a		a						
...riodaphnia					a	a			a	a		a	w/eggs a	w ephippia a ephippia a	a	a	a		a						
...mella sp					a																				
...apholeberis kingi																			a						
Daphnia pulex	a		a	a	a	a	a	a	a	a	a	a ephippia a	a eggs a	a ephippia a	ephippia a	ephippia a								a	a
Simocephalus ...																			a						
...irocephalopsis ...	a	a	a	a	a	a	a	ovigerous a	a																
...umbriculus		a		a			a	a	a	a	a	a	a		a	a			a	a	a	a	a		a
...laidium ...	... (beetle)			a	a	a	a						a										a		a
...phaeridae...	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a	a
...latella ...	found hibernating in leaches at end of summer and earlier ...													a		a									a
Stagnicola ...	a		a					a	-		a			a	a		a	a							
...lexa hypn...													a				a	a							
...planorbula ...	a					a							a	a								a	a		

a = adult n = nymph l = larva p = pupa

	24 March	28 March	31 March	5 April	12 April	15 April	19 April	21 April	24 April	14 May	20 May	26 May	29 May	4 June	11 June	18 June	25 June	1 July	7 July	28 July	30 July	1 Aug	3 Aug	10 Aug	15 Aug
1 Aedes	l	l	l	l	l	l	l	l	l hatch	P	P		l few	l few						l	l	l	l	P	P
2 Chironomus			l								l	l	l		a					l	l	l	l		
3 [illegible]						l					l			l						l	l	l	l	l	l
4 [illegible]							l								l	l			l						
5 [illegible]	l					l	l	l	l	l / l-p	l				l	l									
6 [illegible]																									
7 Gerris	[illegible] there was open water						a																		
8 Corixidae							a	a																	
9 [illegible]												l	n	n	n	n	n								
10 Libellula													n	n		n	n								
11 Agabus																	a								
12 Dytiscus	l	l	l			l	l	l	l		l	l	l	l	l	l	l								
13 Acilius		C												a											
14 [illegible]								a																	
15 [illegible]																									
16 [illegible]																									
	[illegible]					there was open water																			
														a											
												l	la	l	l / a	l	al	l							

insofar as they were frequently cannibalistic. Since they are probably all from the same female, and therefore siblings, there must be an adaptive advantage to lowering their numbers early. Perhaps food gets scarce enough late in the season so that they would all die if some were not eliminated. The only predator on a beetle larva is another beetle larva in this pond. It could be another larva of a different family, or it could be a sibling. Predation of both sorts was observed. Acilius was observed eating Acilius, Aedes pupae, Hydrochara larvae, red Chironomus worms from silt cases on leaves, tadpoles, Lestes, & Chaoborus americanus. Hydrochara was observed feeding on chironomids, Daphnia pulex and Ceriodaphnia lacustris, ostracods, mosquito larvae and other Hydrochara when it first hatched. Later it fed on Hydrochara, Acilius, tadpoles, chironomids, and mosquito larvae and pupae.

In the laboratory certain preferences were noted in choice of food. The beetle larvae, both Hydrochara and Acilius would usually attack the largest organism around. A just-hatched Hydrochara grabbed and ate a chironomid that was several times longer than the larva. Tadpoles were often eaten, but if there was something else in the tank that was edible such as a damselfly nymph or another dytiscid, that was more likely to be eaten first. This selection process could be due to the fact that tadpoles are mainly water, and therefore are most likely to be less nourishing. One Acilius larva was even observed eating an adult Corixid bug.

Dytiscus has not been included in the above discussion, though it was abundantly present in April, when it was the main predator. Its numbers occurred before the lab work of this project was begun so its feeding behavior is not known. However it occurred at a time when there were mosquito larvae, tadpoles, and fairy shrimp, so it is likely that it fed on these animals. Unless animals such as birds and porcupines (which were observed around Piptep) ate dytiscids, or they died naturally, they were extensively cannibalistic. For the numbers were great in April, and then dropped to the point that only one Dytiscus was observed in the pond the whole last half of May. Perhaps others had already pupated. Similiar patterns of great abundance, then great paucity were followed by the other beetle larvae.

In a sense the odonates were easier to watch because the hatched to adults directly from the pond. Their numbers increased at first and stayed high until emergence. All of the Lestes emerged at once; the Libellulas were still around in the muck after the pond lost its open water. Though emergence was not observed, they probably emerged from there as their wing pads were already huge. Perched vertically on sedge stalks, Lestes snapped its elongate labium on moscuito larvae, chironomids, Chaoborus, and probably many more littler things which were not observed. Unlike the beetles, Lestes ate only things that were substantially smaller than itself. They also tended to clump together where there were grass stalks, whereas the beetles tended to be spaced evenly through the pond.

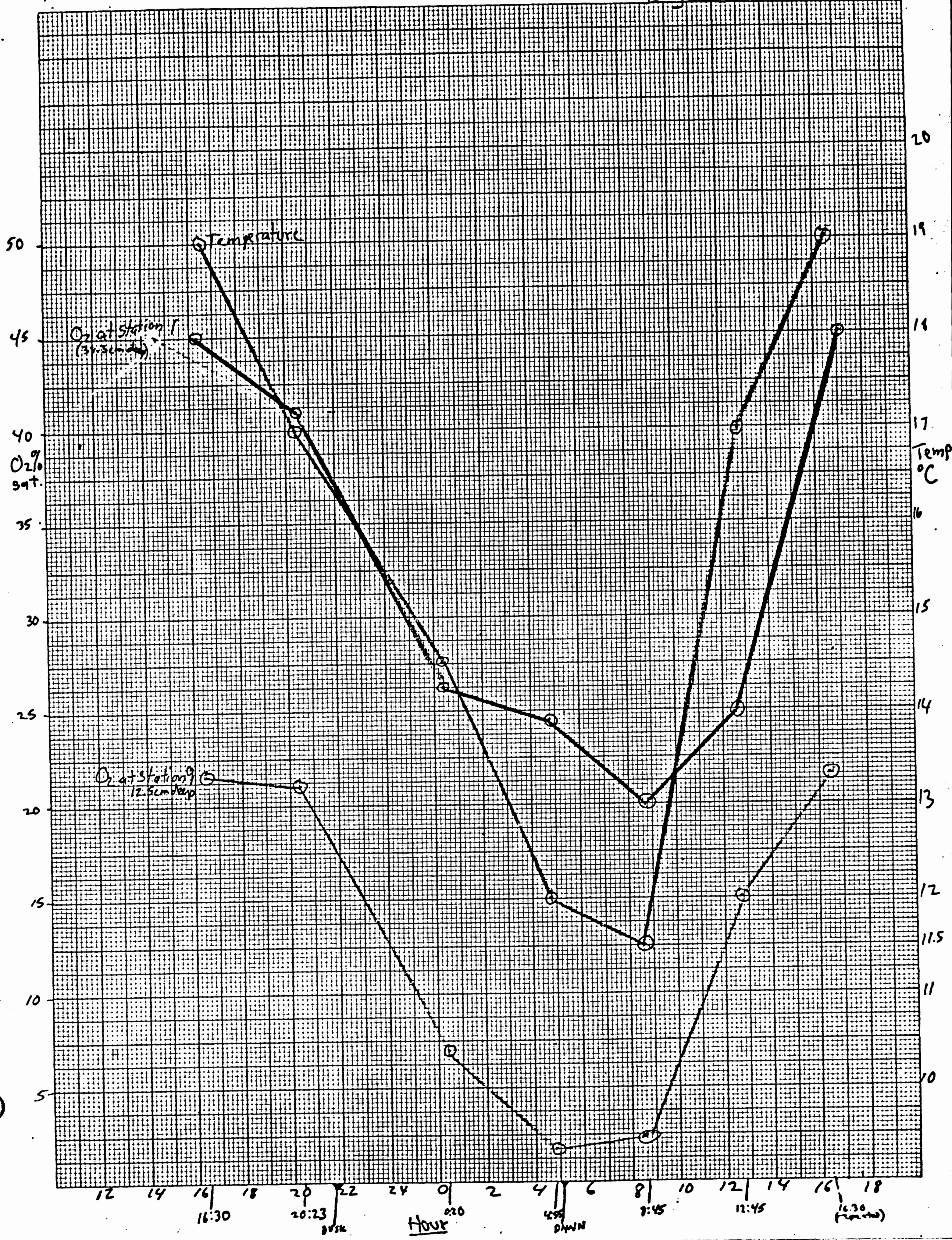
Some organisms seemed to have nothing to do with the network of interaction just described. Neither the mites (Hydrachna and Hydrophantes) nor the clam shrimp (Lynceus brachyurus) were ever observed preyed upon, yet they were big enough to make observing easy. The red coloration of the mites immediately suggests that they are distasteful (poisonous) to some extent. Perhaps the hard shell of the clam shrimp protects it.

The leach Oculobdella lucida was collected several times, though it was never conspicuous enough to be observed in the pond. Dr. Edgar reported finding this leach curled up inside the shells of fingernail clams when temporary ponds approached drying out. So clamshells were investigated in August. As predicted, leaches were found in 10% of all Sphaerium occidentalis examined. This is a unique way of surviving the dry season.

In general, little was discovered about the way that Piptep animals survive the dry season. The cladocerans formed drought-resistent ephippia, the fairy shrimp laid eggs, the fingernail clams stayed right where they were. The lumbriculids probably burrowed down into the muck. The insects could either hatch and fly away, or lay eggs in the dry pond bottom. Other organisms could either burrow down to dampness, or estivate as larvae, or adults, or lay eggs that would not hatch until the following spring. All of these strategies are probably utilized by different animals, but nothing was observed here.

The advent of the predators, and the demise of the prey at the end of May were marked by another big change: it was then that the oxygen fell to very low levels of

Figure 8


Temperature
O_2 at station 1 (37.5cm deep)
O_2 at station 9 12.5cm deep
O_2% sat.
Temp °C
Hour
16:30
20:23
Dusk
0:20
4:55
Dawn
8:45
12:45
16:30

saturation. It was apparent that laboratory experiments on animals at low oxygen levels, and more exact measuring of field oxygen would be interesting. The 23 May, a diurnal study of oxygen in Piptep was made. The pond was visited every four hours for twenty-four hours. Oxygen was found to decrease from 45% at 16:30 to 20% at 8:30. In the shallow water it underwent a similiar decrease but there was much less oxygen all around, so in the early morning oxygen was down to 2% (figure8). The difference in oxygen saturation is about twenty percent between the surface of the shallow station and the surface of the deep, even though the two are at identical temperatures. Oxygen is lowest in the early morning which probably represents depletion of the oxygen accumulated by the photosynthesizers during the day. There was not very much rooted vegetation or phytoplankton in Piptep, so most of the photosynthesis must be carried on by the periphyton. There would be an equal amount, more or less, in deep and shallow water. But the light penetration is probably much less in deep water, so it would be expected that there would be less oxygen in deep water (table 5). Probably the best explanation of the lack of oxygen in the shallow water is related to the respiration of the decomposers of the leaf litter. The bottom layers of the deep water never get as warm as those in the shallow water do (table4). Therefore respiration will be taking place at a slower rate in the deep water. This must be important enough to make up for the decrease in photosynthesis in poorer light conditions.

Decrease in overall oxygen in the pond was a predicter of the pond drying up. It dried up soon after oxygen

Table 3

Light Penetration in Piptep

20 June

Depth (m)	No Filter	Red Filter	Green Filter	Blue Filter	UV Filter
Surface	100%	100%	100%	100%	100%
24cm	10.53%	20%	3.7%	0.00%	0.00%

Table 4

20 May 16:10

Temperature as a function of depth at nine Piptep locations

1. depth	1. temp	2. cm	2. °C	3. d	3. t	4. d	4. t	5. d	5. t
0	21	0	20	0	20	0	21	0	18
10	19	10	19	8.4	18	10	18	10	18
40	14	16	16			29	15	23	16

6. d	6. t	7. d	7. t	8. d	8. t	9. d	9. t
0	18	0	18	0	19	0	10
10	19	10	18	10	18	10	11
26	18	24	17	25	15	16	17

saturation hit zero in the shallow water. Perhaps some pond organisms have evolved a means whereby they speed up their development when subjected to low oxygen concentrations. the adaptive advantage of such a mechanism is obvious. This could be investigated with laboratory experiments which kept animals at low oxygen concentrations for long periods of time.

By the time experimental conditions were set up to test animal behavior at low oxygen concentration, the only large animals left in the pond were tadpoles and Libellulas. Four Libellulas and seven tadpoles were put in the container shown in figure 3. At the start of the experiment the water was 97% saturated with oxygen. The water entering one container was scrubbed with nitrogen so three hours later it had only 9% saturation. The other container remained at 97% saturation. The experiment was run for eighteen hours after which time the nitrogen tank ran out. As long as the oxygen was low all of the organisms were in the top quarter inch of the container, where there would be minimal oxygen diffusing through the surface, just as in the pond. Nine hours after the start of the experiment (six hours after low oxygen conditions had been reached) two of the Libellulas died. One of the remaining two had crawled out of the water entirely, while the other had its hind end sticking out, and pumping, as it would do to breathe when in water. Earlier the two had had their heads sticking out of the water. In the control all of the organisms were at the bottom of the container for the entire time. None of the tadpoles died, though one was floating belly up for quite awhile.

It was assumed that the organisms that survived in the low oxygen tank were able to do so by utilizing surface oxygen that was diffusing through. The floating near the top behavior had also been observed in the pond at times of low oxygen. To complete the experiment it was thought desirable to see if the animals would quickly die in conditions of no oxygen. So mineral oil was poured on top of nitrogen scrubbed water, then three tadpoles and three Libellulas were introduced. A little water contaminated the scrubbed water in the transfer, but that oxygen was quickly used up in respiration. All of the animals died within the day, while none died in the control with no mineral oil on the water surface. These animals were able to withstand low oxygen concentrations when they could be in close contact with the surface film, but zero oxygen naturally killed them.

Many factors influence the workings of the temporary pond. There are important variations is temperature, depth, oxygen concentration, and species. All of these are interrelatied in a system that is based on the detritus decomposing at the bottom of the pond, for primary productivity is probably rather low in these dark waters. The combonation of conditions that characterize a tempory pond make it a harsh environment, and one that is not too common. So few animals have evolved to survive in it. Those that do are usually plentiful while they last. This simplified condition makes it easier to spot exactly what the animals are doing. So it is quickly observed that as the Chironomus larvae grow large they cluster in the shallow waters soon to dry up and build little silk cases. Early in May there was much clumping of animals like Daphnia and Aedes pupae. They tended to congregate in sunny shallow areas. Other animals were most frequently found among the sedge stems; there congregated the mites, Lestes, and probably a whole slew of things too small to see.

To study any segment of the pond it is necessary to know what happens through the season, for it is not static. One problem might be isolated as important at one time, such as the role of Dytiscus as only large predator. But that changes, and the many generations of animals that have evolved adaptations for temporary pond life go through the changes. In a sense the present contains the past life and future of the pond, and these two make now the ideal time for certain things to happen. The continuity of change must be understood before specific problems can be looked at, for the problems are adaptations to changes in the pond over the year. A single leach crawling into a finger-nail clam represents thousands of years of winters and dry seasons. And only these give meaning to the act of the leach.

Conclusion

This is only a beginning. Piptep has been described as it varied over time with the purpose of highlighting significant questions. The most significant things appeared around the end of May and the beginning of June. This time span might well be examined more closely. The role of oxygen level in the development of larvae could be interesting. Primary productivity and respiration are important factors in determining the low oxygen nature of the pond. The evolutionary advantages of cannibalism among siblings in beetle larvae, and the exact extent of cannibalism in beetle diet could be studied. Nothing was done with microscopic animals, but they must be most important in Piptep. The pond was white with some protozoan at the end of the summer, and the pond often had a bacterial scum. Piptep is a system whose workings could be understood insofar as it is small and has a beginning and an end every year.

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