A Zooplankton Profile of Morris, Ward, Mullahy, and Reddington Lakes

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ABSTRACT

The purpose of this study was two-fold: to determine a zooplankton profile of four under-studied lakes located in the University of Notre Dame Environmental Research Center (UNDERC), and to test the predation avoidance hypothesis of diel vertical migration in these lakes. Three of the 4 lakes have very different fish assemblages, making them appropriate for this study. Two 24-hour sampling periods allowed the construction of zooplankton density distributions based on depth and time of day. The results were not directly consistent with the predation avoidance hypothesis. However, when accounting for other factors, such as the physical and chemical characteristics of the lakes and other predation pressures, some support can be given to this hypothesis.

INTRODUCTION

Zooplankton are important organisms in aquatic ecosystems, as they play a significant role in food web structures. Many studies have focused on zooplankton behavior, especially that of diel vertical migration. The adaptive significance of vertical migration has eluded researchers for years. Various studies have been performed, attempting to pinpoint main causes of this behavior. One hypothesis states that migratory zooplankton gain a metabolic advantage after feeding in the upper part of the water column by sinking passively into deeper waters. However, recent studies dismissed this reasoning by suggesting that migratory zooplankton do not receive a metabolic advantage over non-migratory ones (Stich and Lampert 1984; Guisande et al. 1991). Other studies have proposed that food or oxygen availability are important factors in migration.

Currently, however, the predation avoidance hypothesis has the greatest support (Enright 1977, Wright et al. 1980, Stich and Lampert 1981, Ohman et al. 1983, Orcutt and Porter 1983, as cited in Dini 1989; Bollens et al. 1992). Studies show that high planktivory by fish has been associated with orderly, consistent migration of zooplankton, while low planktivory has been associated with disorderly, inconsistent migration (Dini and Carpenter 1988). In July 1988 a study was conducted to determine the significance of fish predation, food availability, and water depth on the migratory patterns of *Daphnia*. Peter Lake, in Gogebic County, Michigan, was divided into sections, with each section having different water depths and containing varying amounts of fish and food. Their results supported a hierarchical view of vertical migration, with the presence of fish being the primary factor, and food availability the second factor (Dini and Carpenter 1992).

This study firstly provides zooplankton profiles of four lakes which have not been extensively studied. Secondly, it tests the predation avoidance hypothesis by monitoring zooplankton behavior in lakes with different predation pressures. Because it is likely that migratory behavior is not due to one single factor (Dini 1989), many variables were monitored. Since the lunar cycle has been shown to affect migration pattern (Gliwicz 1986), the two sampling periods were performed at similar times in the cycle, and cloud cover was monitored. Oxygen availability associated with productivity has been shown to be a factor in diel migration, not only directly, but also indirectly through its influence on predators (Hanazato 1992). Temperature, as well can be an important element in zooplankton distributions (Marcogliese and Esch 1992). Therefore, during each sampling period oxygen and temperature data were collected at each depth.

Materials and Methods

The four lakes studied were Morris, Ward, Mullahy, and Reddington Lakes, located in the University of Notre Dame Environmental Research Center (UNDERC) in Gogebic County, Michigan. These small lakes are close in proximity, yet were believed to have different characteristics, including fish assemblages. From past studies, Morris Lake was shown to have mainly piscivorous fish, including Northern pike (*Esox lucius*) and yellow perch (*Perca flavescens*), while Ward and Mullahy were thought to have piscivorous fish populations. Reddington Lake had never before been studied.

Every sample was taken from the deepest spot in each lake, determined by firstly mapping all four lakes with a sonar. Two-24 hour sampling periods were performed in each lake on two dates, roughly a month apart. In each lake one sample was taken every three hours at 1-meter intervals with a 12-l Schindler-Patalas trap equipped with a 63-µm mesh net. June samples were preserved in a 10% formalin solution and July samples in a Lugol's solution. In an effort to reduce the process of counting, only the top and bottom meter sample at four of the eight times were processed. Each sample was diluted to a constant level and then 1 ml of each was drawn from the sample after swirling it to mix uniformly. Samples were counted under a light microscope in a Sedgewick-Rafter chamber. If excessive plant matter in the sample inhibited counting, the sample was diluted again and the number of organisms modified accordingly. Chaoborids caught in the Schindler-Patalas trap were enumerated to determine a vertical profile.

To determine the types and amounts of fish in each lake, three baited minnow traps were set at random around the shoreline of each lake. In Reddington Lake one trap was placed in the lag around it, while two were in the main lake, being suspended at 2m depths from the bog mat which surrounds the lake. The traps were collected 26 hours later and the fish were counted and classified. Also, electro-fishing for yellow perch in Morris Lake took place during this study.

Approximately every two weeks for10 weeks (6 times total) oxygen and temperature data were collected at each meter in each lake. These data, as well as weather conditions, were also taken at every sampling time during both 24-hour sampling periods.

To determine the chemical composition of each of the four lakes, surface and bottom samples were collected and subjected to many tests. The following tests were performed using a HACH spectrophotometer: Alkalinity (Buret Titration Method), nitrate (Cadmium Reduction Method), phosphate (Phos Ver 3 Method), and color. Also, hydrogen sulfide concentrations, conductivity, and pH levels were determined.

Results

Since only one sample was taken at each depth in each sampling period, this prohibited the use of statistics in analyzing the data. Therefore, in order to determine migration patterns, the raw data was scaled. In using only the top meter samples, the counts from 3 p.m., 9 p.m., and 6 p.m. were averaged and the mean number of zooplankton during daylight hours was determined. The numbers of zooplankton from the 12 a.m. samples were used for the darkness value. The percent change from the light to dark values was calculated and scaled with the greatest change equal to 100. These scaled values are shown in Table 1.

The table indicates that in Morris in both June and July no species was migrating significantly. In Ward Lake, slight vertical migration was seen in June, but in July strong reverse migration occurred in all species but *Bosmina* sp. and the copepods, which were not present in numbers necessary to make judgements. Mullahy Lake showed reverse migration of practically all species during both sampling periods. And, in Reddington Lake *Bosmina* sp. exhibited reverse migration in both June and July, while the other taxa generally showed no migration patterns.

The small-fish assemblages determined from minnow traps in each lake are shown in Table 2. No fish were present in the Morris traps. Both Ward and Mullahy Lakes had dense assemblages of planktivorous fish. In Reddington Lake, trap R1, located in the lag surrounding the main lake, contained many (75) planktivorous fish, but the traps in the main lake contained only 2 and 3 fish each.

Total zooplankton densities from the sum of the top and bottom meter of each lake are compared in Figure 1. Morris, Ward, and Reddington exhibited decreases in zooplankton densities from June to July, while Mullahy's densities remained constant.

Trends in certain species densities in the top and bottom meters of the lakes are mostly specific to each lake. For instance, from June to July, *K. Cochlearis* densities in Mullahy increased 20-fold, while in Ward they decreased 3-fold. *Bosmina* sp., however, in both Morris and Ward lakes, had a population surge from June to July, with densities increasing 8- and 3-fold, respectively.

Table 1. Scaled values of diel vertical migration. Numbers indicate percent change of zooplankton in the upper meter from daylight hours to darkness hours.
100 = highest value
* = reverse migration
( ) = based on low values.

	Mor-June	Mor-July	War-June	War-July
B.rubens	29	33	36	
K.cochlearis	31	52	61	*82
P.vulgaris	50	*(75)	65	*100
Asplanchna sp.	48	*(100)	71	
Nauplii	43	25	13	*100
Bosmina sp.		5	0	*71
Copepods		*67		*(100)
K.longispina		17	45	*(100)

	Mul-June	Mul-July	Red-June	Red-July
B.rubens	16		30	(33)
K.cochlearis	*80	*82	33	*16
P.vulgaris		*83	20	45
Asplanchna sp.		*100	*71	
Nauplii	*70	*77	36	50
Bosmina sp.	*(50)	*86	*84	*52
Copepods		*(100)	*75	(25)
K.longispina			70	33

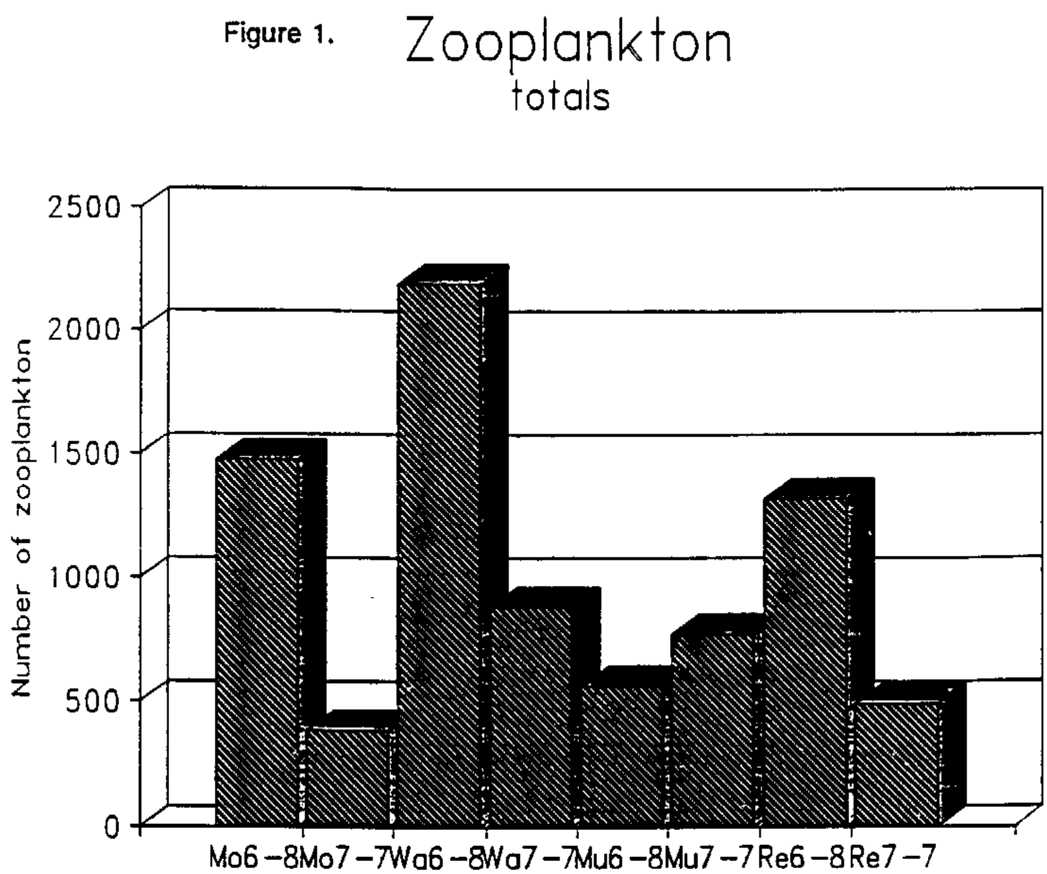
Table 2: Minnow traps
set 7-5-93 6 p.m.
collected 7-6-93 8:30 p.m.

W= Ward
R= Reddington
M= Mullahy
T= Total

	W1	W2	W3	T	R1	R2	R3	T	M1	M2	M3	T
N. Redbelly Dace (Phoxinus eos)	99	0	2	101	33	0	0	33	147	110	12	269
Fathead Minnow (Pimephales promelas	4	0	0	4	13	0	0	13	0	0	1	1
Brook Stickleback (Culaea inconstans)	2	5	3	10	17	0	0	17	3	7	1	11
Common Shiner (Notropis cornutus)	1	0	0	1	0	0	0	0	0	1	0	1
Central Mudminnow (Umbra limi)	0	1	1	2	0	0	0	0	0	0	0	0
Yellow Perch (Perca flavescens)	1	0	0	1	0	0	3	3	0	0	1	1
Finescale Dace (Chrosomus neogaeus)	0	0	0	0	12	2	0	14	0	0	0	0
Pumpkinseed (Lepomis gibbosus)	0	0	0	0	0	0	0	0	1	0	0	1
Totals	107	6	6	119	75	2	3	80	151	118	15	284

Notes:
* 3 traps were also set in Morris but had no minnows.
* Traps were set at 3 random places around the shorelines, sitting on the bottom.
* Trap R1 was placed in the lag, while R2 and R3 were placed in the main lake.
Due to great depth, these traps had to be suspended about 2.5 m from the bog mats.
The 5 fish in the 2 traps were found dead.

Figure 1.


Zooplankton
totals
Number of zooplankton
2500
2000
1500
1000
500
0
Mo6-8
Mo7-7
Wa6-8
Wa7-7
Mu6-8
Mu7-7
Re6-8
Re7-7

B. rubens populations decreased over the one month period in all four lakes, showing an 18-fold decrease in Morris, 90-fold in Ward, 206-fold in Mullahy, and a 9-fold drop in Reddington.

The oxygen and temperature curves for each lake are shown in Figures 2, 3, 4, and 5. Each lake from June to July showed an overall increase in temperature and decrease in percent oxygen saturation.

The two lakes which had never before been mapped, Mullahy and Reddington, are shown in Figures 6 and 7. Table 3 shows the physical make-up of both lakes.

Discussion

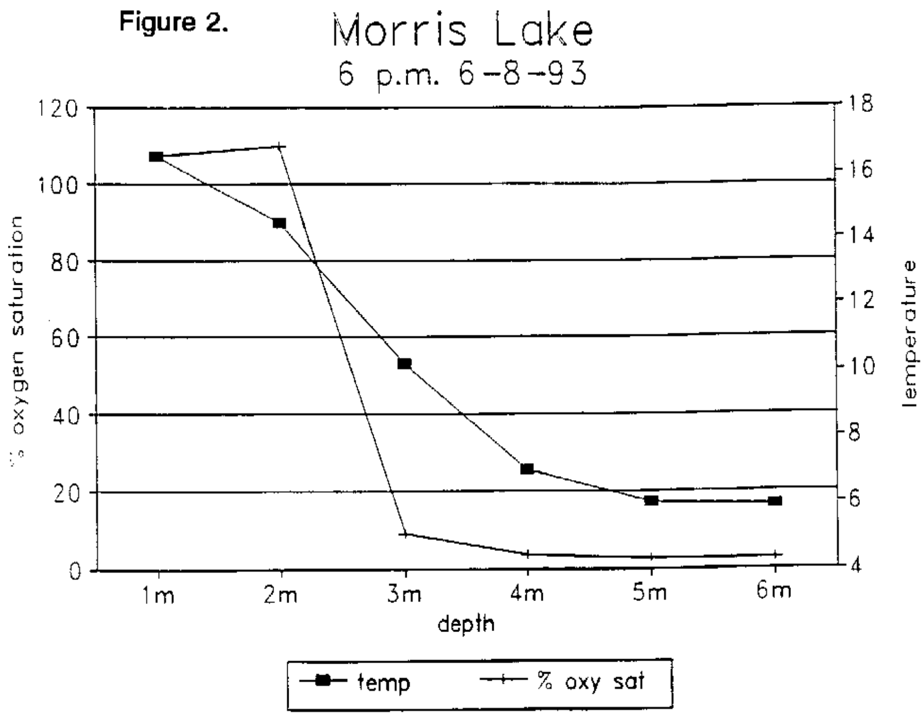
Zooplankton migration patterns in the four lakes were extremely varied. The trends found do not explicitly follow anticipated trends based on lake characteristics, including fish assemblages. Ward and Mullahy Lakes, as determined by the minnow trap haulings, are definitely characterized by high planktivory, while Morris Lake contains almost exclusively piscivores. In Reddington the lag around the lake has a high planktivore population, but the main lake does not support a planktivorous fish assemblage. Therefore, expected trends, according to the predation avoidance hypothesis, would be those of strong migration in Ward and Mullahy Lakes and no migration in Morris and Reddington.

The results in Morris show that no significant migration occurred when comparing scaled values to other lakes except the reverse migration of copepods shown in July. Since Morris did not support a significant copepod population in June, comparisons of vertical migration patterns cannot be made.

Ward Lake showed the biggest change in migration patterns from June to July, with most of the taxa vertically migrating in June and reverse-vertically migrating in July. This could be attributed to the increasing numbers of *Bosmina* sp. and copepods in the top and bottom meter in July, as these animals are visual predators of smaller zooplankton. If planktivorous fish, which are selectively predaceous, are presented ample numbers of large zooplankton such as *Bosmina* sp. and copepods, possibly these zooplankters could afford to reverse-vertically migrate and be able to forage.

Mullahy Lake showed reverse-vertical migration in practically all its species. This lake is only 5 feet deep, supporting a huge littoral zone. Light penetrates to virtually every point in the lake, so this lake is not appropriate for studying the predation avoidance hypothesis, since zooplankton have no place to hide from predators. Therefore, this reverse migration could result from the

Figure 2.


Morris Lake
6 p.m. 6-8-93
120
100
80
60
40
20
0
% oxygen saturation
18
16
14
12
10
8
6
4
temperature
1m
2m
3m
4m
5m
6m
depth
temp
% oxy sat

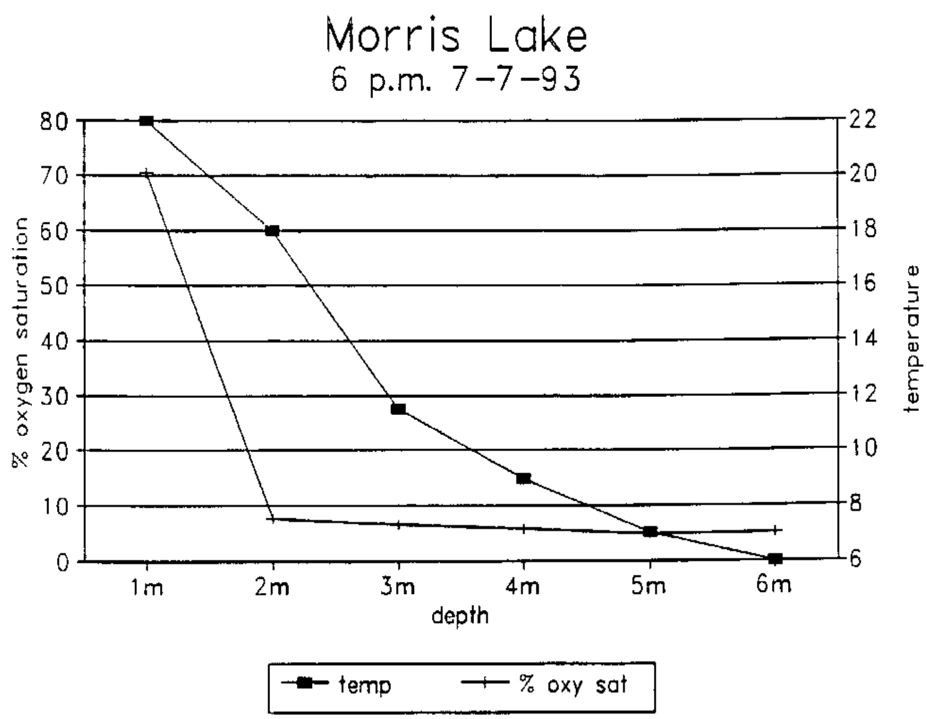
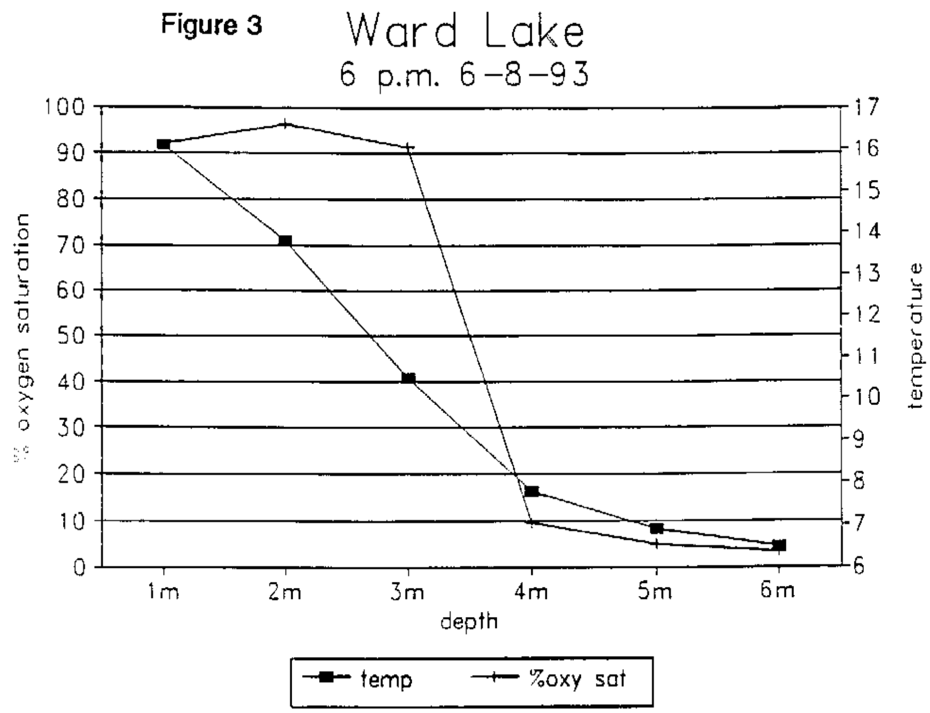

Morris Lake
6 p.m. 7-7-93
80
70
60
50
40
30
20
10
0
% oxygen saturation
22
20
18
16
14
12
10
8
6
temperature
1m
2m
3m
4m
5m
6m
depth
temp
% oxy sat

Figure 3


Ward Lake
6 p.m. 6-8-93
% oxygen saturation
temperature
depth
1m
2m
3m
4m
5m
6m
temp
%oxy sat

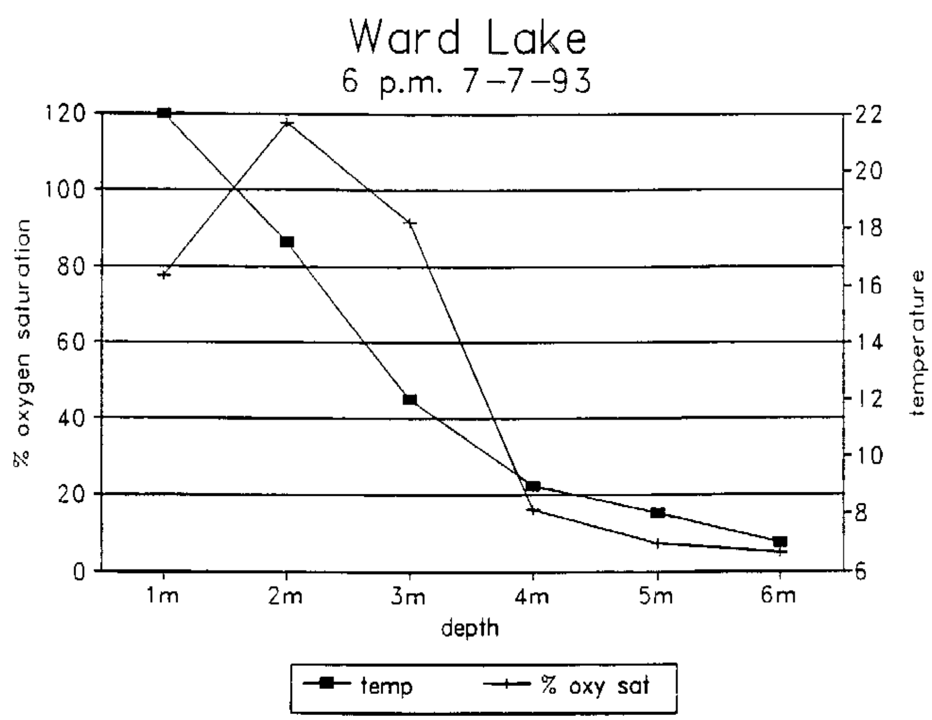
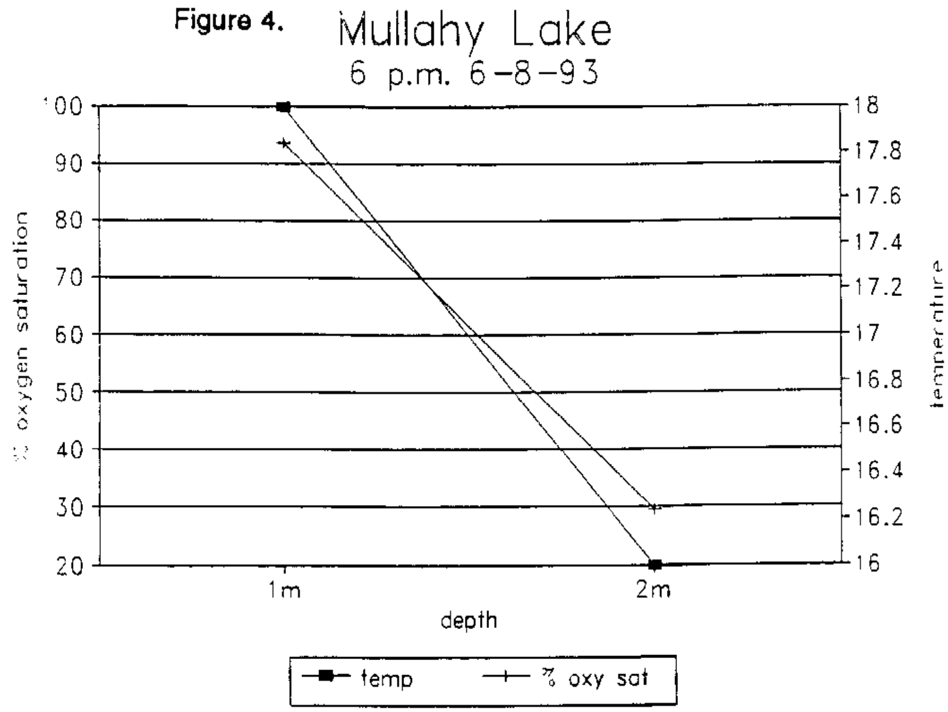

Ward Lake
6 p.m. 7-7-93
% oxygen saturation
temperature
depth
1m
2m
3m
4m
5m
6m
temp
% oxy sat

Figure 4.


Mullahy Lake
6 p.m. 6-8-93
100
90
80
70
60
50
40
30
20
% oxygen saturation
18
17.8
17.6
17.4
17.2
17
16.8
16.6
16.4
16.2
16
temperature
1m
2m
depth
temp
% oxy sat

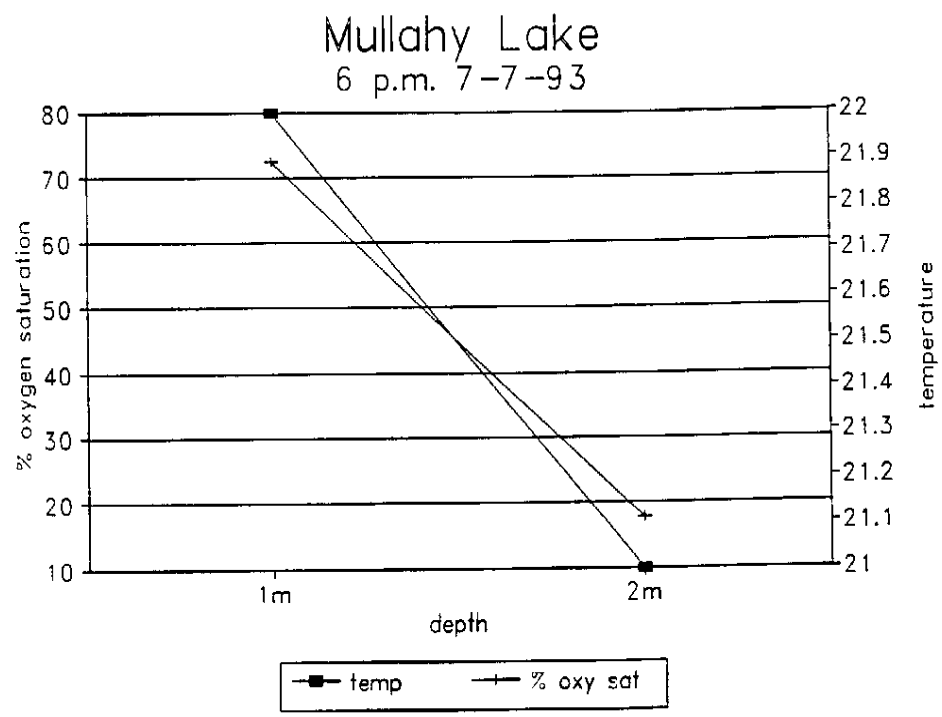
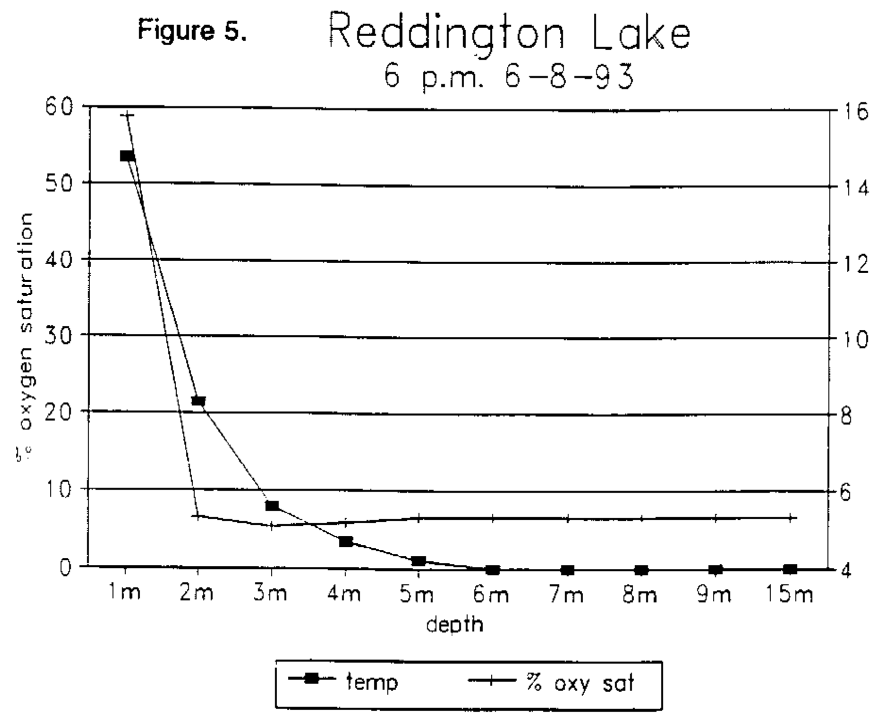

Mullahy Lake
6 p.m. 7-7-93
80
70
60
50
40
30
20
10
% oxygen saturation
22
21.9
21.8
21.7
21.6
21.5
21.4
21.3
21.2
21.1
21
temperature
1m
2m
depth
temp
% oxy sat

Figure 5.


Reddington Lake
6 p.m. 6-8-93
60
50
40
30
20
10
0
% oxygen saturation
16
14
12
10
8
6
4
temperature
1m
2m
3m
4m
5m
6m
7m
8m
9m
15m
depth
temp
% oxy sat

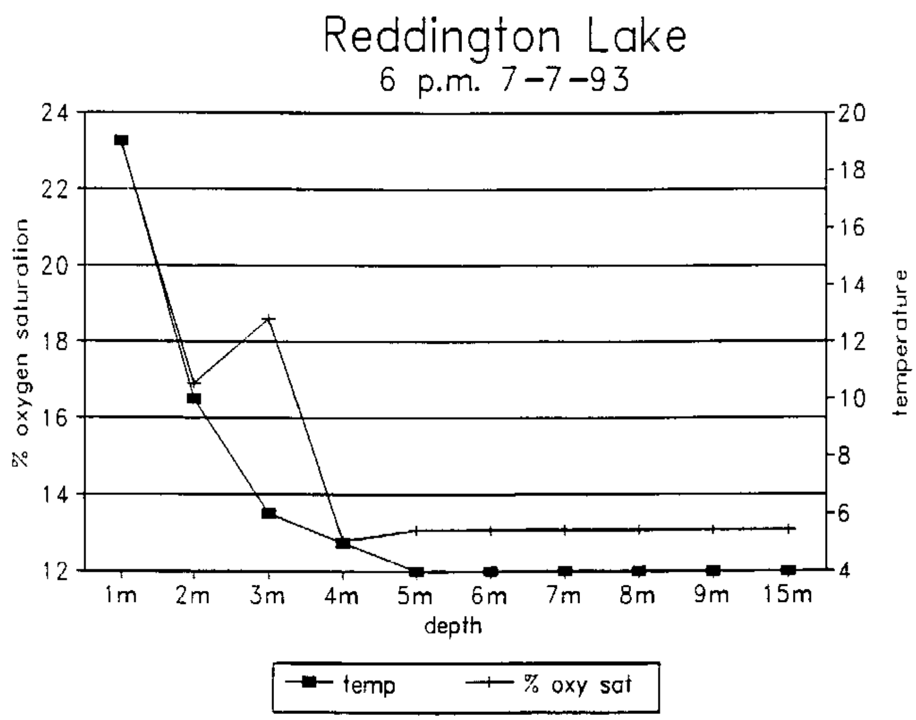

Reddington Lake
6 p.m. 7-7-93
24
22
20
18
16
14
12
% oxygen saturation
20
18
16
14
12
10
8
6
4
temperature
1m
2m
3m
4m
5m
6m
7m
8m
9m
15m
depth
temp
% oxy sat

Figure 6

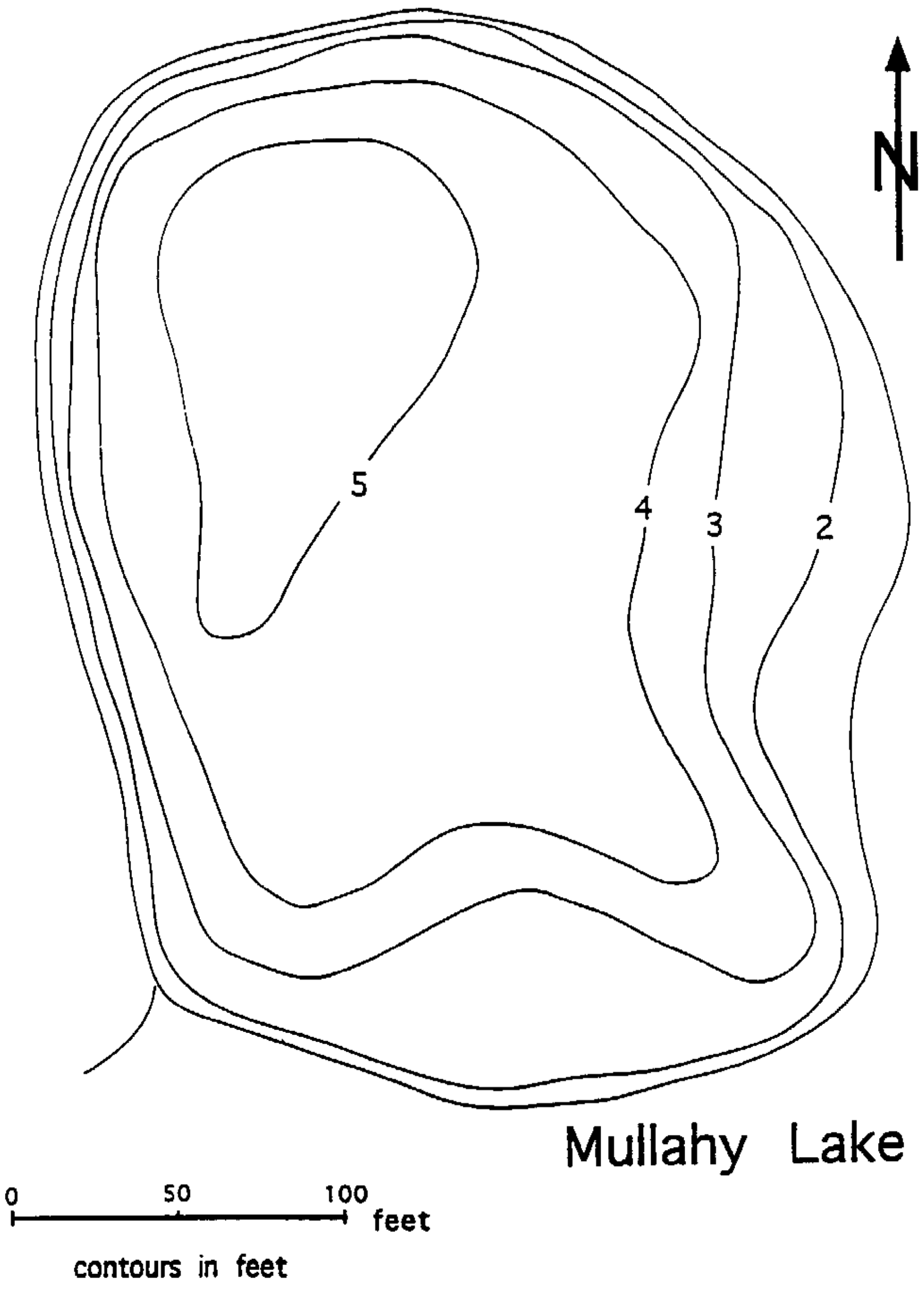
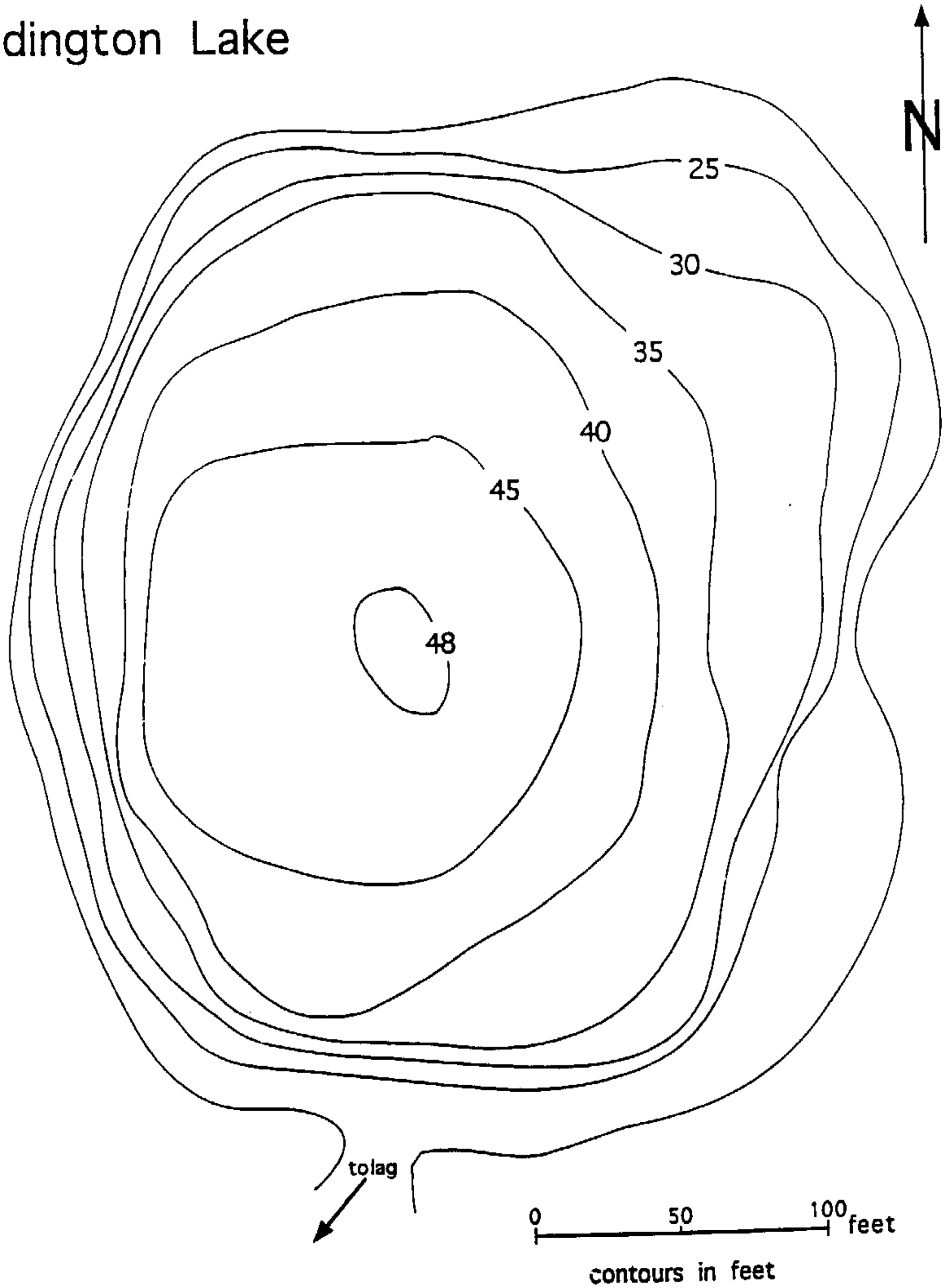


Figure 7.

Reddington Lake



Zooplankton Profile

Table 3. Physical characteristics of Mullahy and Reddington Lakes.

	Mullahy	Reddington
surface area (acres)	1.2	1.7
($ft.^2$)	52,272	72,536
length of shoreline (ft.)	975	1160
shore development	1.2	1.2
mean breadth (ft.)	149	181
maximum length (ft.)	350	400
maximum depth (ft)	5	48
volume ($ft.^3$)	185,773	2,432,092
mean depth (ft.)	3.6	33.5

zooplankton's lack of a better place to go.

In Reddington Lake in June there was significant reverse vertical migration by ail three of the largest zooplankton, *Asplanchna* sp., *Bosmina* sp. and the copepods. Other species showed no significant patterns. Since the main lake of Reddington supports no notable planktivorous fish population, possibly the large zooplankters can afford to forage in the upper waters during the day due to low predation pressures.

The changes in the summed upper and lower meter zooplankton densities exhibited over the one month test period cannot be solid indicators of predation, for densities may or may not depend on fluctuations in food availability or predation pressures (Pennak 1989). However, it is interesting that *Bosmina* sp. and the copepods showed significant increases in Morris and Ward Lakes from June to July, while the total zooplankton populations decreased sharply. Predation effects can probably account for these density distributions.

The oxygen and temperature profiles of each lake are normal for these kinds of lakes. A closer look at Reddington, though, suggests that there is very little oxygen at the levels of 2m and below. (At the 2m depth in June, there was only 7% saturation.) This supports the presently-made assumption that Reddington cannot sustain a fish population, because fish cannot survive in low levels of oxygen, as evidence by the 5 dead fish found in the 2m minnow traps in Reddington. Reddington's unique oxygen-temperature curve also suggests that the lake is merimictic because of the low oxygen concentrations in the 2-4m depths in early summer, only a short time after overturn of most lakes.

The presence of *Chaoborus* sp. in the lakes did not seem to effect migration patterns. There were no significant trends in *Chaoborus* densities. It should be noted, however, that Morris Lake contained many *Chaoborus*, some of which were in the pupae stage.

Water chemistry effects on zooplankton have not been well documented. In this study there were no significant links between chemistry data and zooplankton populations.

Conclusion

This study did not give direct support to the predation avoidance hypothesis in the expected manner. However, by analyzing the migration patterns and taking into account lake physical conditions, chemical characteristics, and predation pressures other than fish, this study can lend the hypothesis some indirect support. Further studies should be done using more replicates for each sample and tracking zooplankton densities in each meter of the lakes rather than only in the top and bottom meter. Also, ascertaining lake productivity would be helpful in determining reasons for the observed migration patterns. Although much work still needs to be done to test the predation avoidance hypothesis, this investigation provides a foundation for more research on vertical migration and a speculative approach to the migration patterns observed in this study.

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