

The Effects of Light on Vertical Migration of
Chaoborus in Three Lakes in Northern Wisconsin

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Abstract

The vertical migratory patterns in larval *Chaoborid* (Diptera: Chaoboridae) species have been defined as a means to avoid predation. The rationale is that *Chaoborus* avoid predation by staying in the dark hypolimnetic waters during the day and migrating to the surface under the cover of night. If light is the major factor affecting *Chaoborid* migration, there should be a difference in migration between nights with a full moon and nights with a new moon. This study addresses that problem using sampling nights from 28 June, 1995 and 12 July, 1995 in three lakes in Northern Wisconsin. Results suggest that moonlight did effect *Chaoborid* migration in two of the three lakes, Crampton Lake and Brown Lake. However, no discernible difference was found in the third lake, Forest Service Bog. The lack of effect in Forest Service Bog could be due to its dark stained bog waters which squelch any differences in light intensity at the surface or possibly due to the low pH (<5.0) in Forest Service Bog, which makes it unlikely to contain fish. Data from a concurrent study on zooplankton in the lakes showed a highly variable correlation between migratory patterns of zooplankton and *Chaoborus*.

Introduction

Larvae of the genus *Chaoborus* (Diptera: Chaoboridae) are members of many lake zooplankton communities throughout North America (Von Ende 1973, Tsalkitzis 1994). When present in sufficient numbers, *Chaoborus* larvae have been shown to affect the abundance, spatial distribution and even presence of their prey (Moore 1994).

The genus is marked by its characteristic transparent appearance and the presence of a large prehensile antennae. When living, larval members of this genus are characteristically clear with their internal organs and fat bodies visible. For this reason, *Chaoborus* have been known as the glass larva or the phantom midge.

The vertical migratory pattern of *Chaoborus* has been the subject of a number of studies (Von Ende 1973, Malueg 1966, Tsalkitzis 1994). The pattern of diel migration is that the larva remain in or near the lake sediments during the daylight hours and migrate toward the surface as light decreases, presumably to escape predation by fish (Maleug 1966). The diel migratory pattern of the phantom midge also allows cohabitation of competing species by spatial distribution (Tsalkitzis 1994).

Light has been hypothesized to be the impetus behind larval migration of *Chaoborus* in lakes.(Maleug 1966, Von Ende 1973). Assuming that this is so, there should be a difference in the extent of migration of larvae into the epilimnion with differences in light intensities. Specifically, more light penetrating the water column at night should decrease the numbers and distance migrated by the larvae. To address this hypothesis, we took advantage of the natural cycles of the moon to affect the amount of light present at night by monitoring the migration

of *Chaoborus* on a night with a full moon and a night with a new moon. The experiment was performed on private land in the upper reaches of Wisconsin nearly 16km from the nearest town, so background light was at a minimum on nights without a moon.

It has been suggested that certain species of *Chaoborus* react more vigorously to changes in light penetration (Tsalkitzis 1994). So, we also monitored the species of *Chaoborus* present for a qualitative assessment of differences in migratory patterns according to species.

Procedure

The effect of light on the vertical migration of *Chaoborus* was tested by sampling three separate lakes for the presence of the larvae at various depths. The sampling involved using a Schindler trap which filtered through an 80-mesh Wisconsin trap. Samples were taken at one meter intervals once every two hours in a 24-hour period. We performed one sampling period with a new moon on 28, June, 1995 and one with a full moon on 12 July, 1995. Samples were preserved with formalin in the field and %70 EtOH after processing. Processing the samples involved inspection under a dissecting microscope and counting numbers of *Chaoborus*.

Sampling periods began with a chemical analysis of the lakes to be sampled several days prior to sampling. We tested for nitrate, phosphate and sulfate concentrations as well as testing for the presence of hydrogen sulfide. Material most relevant to this experiment, however, was an oxygen-temperature profile and Secchi depth taken before each sampling period.

Sampling the three lakes was performed in a circuit beginning with Forest

Service Bog, moving to Crampton Lake, and finishing with Brown Lake. A box containing empty, labeled bottles was kept at each lake in an effort to save time. The circuit generally consumed the 2 hours between samples, which made sampling a continuous process. We divided sampling duties between three people, each taking an eight-hour shift.

The sampling station at each lake was marked by an anchored float. The station at Forest Service Bog and Brown Lake was at approximately the deepest point, 3 meters and 4 meters respectively. But the station at Crampton was at 10m while the deepest part of the lake was 16m.

After a sampling period, the samples were first inspected by another researcher counting zooplankton. Since the zooplankton research required only several ml from each sample for microscopic work, we felt that the samples were unaffected with respect to numbers of *Chaoborus*. The samples were then processed by inspecting successive aliquots of the sample under a dissecting scope until all the water was inspected. The *Chaoborus* were counted, removed, placed into a petri dish and their numbers recorded. The counted *Chaoborus* were then identified to species according to The Nearctic Chaoborinae (Cook, 1953). Specimens not identified right after the sampling period were preserved in labeled vials with %70 EtOH.

Results

The results of the migration study are displayed in two forms. First, the number of *Chaoborus* found in each sample at each depth is displayed for each lake in a 3-D bar graph (Fig. 1-6). Secondly, the total number of *Chaoborus* found in each sample are displayed for each lake in a simple 2-D column graph.

The results from Crampton show a marked decrease in the total number of *Chaoborus* larvae present found in the 2nd (full moon) sample when compared to

the first (fig. 4). In the first sample, a maximum of 72 *Chaoborus* were found in the water column at 12am. The maximum number of *Chaoborus* found in sample two came at 2am with 38 (fig. 7). The number of specimens found in the daytime never fell below 13 for the first sample, while the second sample saw a low of only 1 phantom midge captured at 2pm at a depth of 9m (fig 7,2,1). The presence or absence of a moon should not affect the amount of *Chaoborus* larvae present in the water column during the day. However, a marked difference in the numbers of larvae can be seen between the first and second samples. This is probably due to an emergence of the larvae in that lake sometime between 28 June and 12 July, the sampling dates. In an attempt to compensate for this, I also plotted the ratio of the number of specimens found in each sample to the number found in the most abundant sample. The ratio is expressed as a percent (fig. 10). The graph produced shows a closer correlation between the first and second samples, but the first sample still shows a greater number of *Chaoborus* in the water column as compared to the first sample.

Brown lake also displayed a marked difference in the migration pattern of its phantom midge population. In both samples, virtually no *Chaoborus* were collected between 8am and 4pm (fig. 3,4,8). In the first sample, a marked increase in *Chaoborus* collected begins with the 6pm sample and continues until the 2am sample (fig 8). The second sample, on the other hand, shows only a slight increase at 8pm, a sharp spike at 10pm, and dwindling numbers throughout the night (fig 3, 4, 8).

The *Chaoborus* in Forest Service Bog showed little change in diel migratory patterns between the first and second samples. In both samples, very few *Chaoborus* were found in the daytime, and, in both samples, a marked increase in the number of *Chaoborus* occurred at 10pm (fig.5,6,9). One point of interest with regards to species dynamics was the discovery of a large number of larvae in the

water column at 6am in the second sample. The larvae discovered were all of the species *Chaoborus punctipennis* and were conspicuously lacking from the first sample set in Forest Service Bog.

The species *Chaoborus punctipennis* dominated the populations studied in Brown Lake and Crampton Lake. However, the population in Forest Service Bog was dominated by *Chaoborus americanus* and *Chaoborus trivittatus* in the first sample set and *Chaoborus americanus* and *Chaoborus punctipennis* in the second sample set with a diminished population of *Chaoborus trivittatus*.

Discussion

The results of this experiment were mixed in hypothesis that *Chaoborus* can alter their migratory patterns according to differences in nocturnal light intensity and raised some interesting questions regarding the vertical migration of zooplankton and that of *Chaoborus*. A familiar pattern of decreased numbers of larvae in the water column was detected in Brown and Crampton on nights with a full moon, but almost no difference was found in Forest Service Bog.

Although no precise pH readings were taken from Forest Service Bog during this study, the bog lake has historically been shown to hold waters with a pH below 5.0 (Von Ende 1973), which would make the lake, for all practical purposes, fishless. If, indeed, Forest Service Bog is fishless in 1995, this may help to explain the lack of response by *Chaoborus* populations to changes in light intensity. However, the question then becomes: Why are the *Chaoborus* migrating in the first place? There are several ways to solve this dilemma.

First, the second sample set contained a number of *punctipennis* larvae. *Punctipennis*, especially the earlier instars, have been shown to be exempt from pressures to migrate owing to their small size and relative invisibility (Tsalkitzis 1994). One explanation could be that the *punctipennis* population in Forest

Service Bog clouded the results of the second sample set. That is, their migratory pattern conflicted with the migratory patterns of the *americanus* and *trivittatus* populations present such that while the *americanus* and *trivittatus* populations were responding to differences in light intensity, the *punctipennis* population did not respond and gave artificially high numbers in the water column. Since the monitoring of species in each lake was strictly qualitative, there is no way to account for this. This explanation does fold somewhat under the evidence presented in Brown Lake.

Brown Lake's strictly *punctipennis* population did exhibit a difference in migratory patterns between the sample set. This evidence suggests that *punctipennis* do respond to changes in light, which makes it unlikely that they are clouding the migrations of *americanus* and *trivittatus* species in Forest Service Bog.

Another explanation for the results in Forest Service Bog is its relative non-transparency against Brown and Crampton Lakes. For differences in light to have an effect, the differences must be detectable into the hypolimnetic waters of the lake. Forest Service Bog has characteristic dark-stained waters and it is very possible that the difference in light intensity between full-moon and new-moon nights is not detectable in the hypolimnion. Since no functioning light meter was available, this factor was not measured and cannot, therefore be excluded.

The populations of Brown and Crampton lake responded in an interesting manner. In both lakes, the full moon corresponded with a decreased total number of larvae in the water column and also a sharp spike in which an unusually high number of larvae were found in the upper reaches of the water. In Crampton the spike came at 2am when nearly 20 larvae were found in the first meter of water alone (fig. 1). In Brown, the 2am spike produced a total of 79 *Chaoborus* in the water column only to drop to 39 in the water column at 4am

with 31 of those being in the lowest meter of water (fig. 3,4,8). This data seems to suggest a safety-in-numbers approach by the larvae in times of higher light intensity. That is, by migrating as a group, the larvae stand a better chance of not being eaten by a fish while in the epilimnion. Such coordination by a planktonic organism is, as of now, a pretty far-fetched idea and much more testing would need to be done to prove this hypothesis.

The changing composition of the population of *Chaoborus* in Forest Service Bog was a remarkable and somewhat unexpected event. Von Ende characterizes Forest Service Bog as containing a mixture of *americanus* and *trivittatus* but no *punctipennis* (Von Ende 1973). Considering that *punctipennis* is the most abundant *Chaoborus* species in North America (Maleug 1966, Von Ende 1973, Tsalkitzis 1994), it isn't too surprising to find invasion of the species from a nearby lake. What was surprising, however, is that numbers of *punctipennis* in Crampton suggested an emergence between 28 June and 12 July, while the numbers in Brown suggested no change, and the numbers in Forest Service Bog suggest a heavy recruitment period between 28 June and 12 July. Von Ende suggests the life cycle of species of *Chaoborus* differ from lake to lake (Von Ende 1973). Apparently, there is a recruitment period in Forest Service Bog which roughly corresponds to an emergence in Crampton Lake on the UNDERC property.

Chaoborus have been implicated in affecting the spatial distribution and presence of their prey (Moore, 1994). However, in a study conducted simultaneous to my experiment testing the migratory patterns of zooplankton, no strong correlation could be drawn between the migratory patterns of *Keratella*, *Polyarthra* and the *Chaoborus* present in the lake. Three possible scenarios for the relationship between *Chaoborus* and their prey are: 1) zooplankton can migrate opposite *Chaoborus* in order to escape predation, 2) *Chaoborus* may migrate with their prey for continual feeding, 3) there may be no relationship

between the two. In Forest Service Bog, *Keratella* and *Polyarthra* seemed to migrate against *Chaoborus* during the new moon sample and with the *Chaoborus* during the full moon sample (Honkamp, unpublished data). In Brown lake, zooplankton migration seemed to weakly oppose *Chaoborus* during the new moon sample, and no correlation could be gleaned from the full moon sample (Honkamp, unpublished data). In Crampton lake, *Chaoborus* and zooplankton migration were opposed strongly in the full moon sample and no strong correlation could be drawn from the new moon sample (Honkamp, unpublished data).

A study on the diet of *C. punctipennis* (Moore, 1994), showed wide variation in *Chaoborid* diet through time. At times "soft rotifers" such as *Keratella* and *Polyarthra* constituted almost a third of the *Chaoborid* diet and at other times constituted less than 5% of the diet (Moore, 1994). Changes in *Chaoborid* feeding patterns occurred over periods of weeks. It is possible that the lack of coordination between migratory patterns of *Chaoborus* and zooplankton in Brown, Crampton, and Forest Service Bog is due to such changes in *Chaoborid* diet. During the 28 June (new moon) sample, no correlation could be found between *Chaoborid* migratory patterns and the migratory patterns of the "soft rotifers" of Crampton Lake. This could represent a time in which soft rotifers constituted little of the *Chaoborid* diet. On the 12 July (full moon) sample, however, soft rotifer migratory patterns very strongly opposed *Chaoborid* migratory patterns in Crampton. This could represent a time in which the soft rotifers were a major part of the *Chaoborid* diet. To definitively test this hypothesis would require a continual monitoring of zooplankton and *Chaoborid* migration in a lake along with *Chaoborid* gut analyses.

This experiment, while successful in its attempt to monitor the migration of *Chaoborus* larvae in several lakes on the UNDERC property, suffered from a

number limitations. First, there is no duplication of data. The samples are from only one new moon and one full moon night. Differences in migratory patterns may only be due to differences in sampling techniques of the individuals.

Multiplication of data is the largest single drawback to this experiment.

Secondly, no light meter was available. It would be extremely helpful to know exactly how much the light intensity changed between the two sample sets in each of the lakes. Crampton, for instance, is a relatively clear oligotrophic lake which exhibited a Secchi depth of over 3m most of the summer. Brown lake is a eutrophic lake and its waters rival the dark staining in Forest Service Bog, a true quaking Sphagnum Bog. To know the difference in moonlight penetration in each of these lakes would benefit the experiment greatly. Lastly, exact times were not recorded for samples gathered from each lake. For example, the 4am sample begins at Forest Service Bog at approximately 4am. It then proceeds to Crampton at about 4:45am, as the sun begins to rise, and ends at Brown lake around 5:30am- well after the sun has risen. This factor could be accounted for by recording the time each sample is taken. Effects of the rising sun could be accounted for again by a light meter.

Acknowledgments

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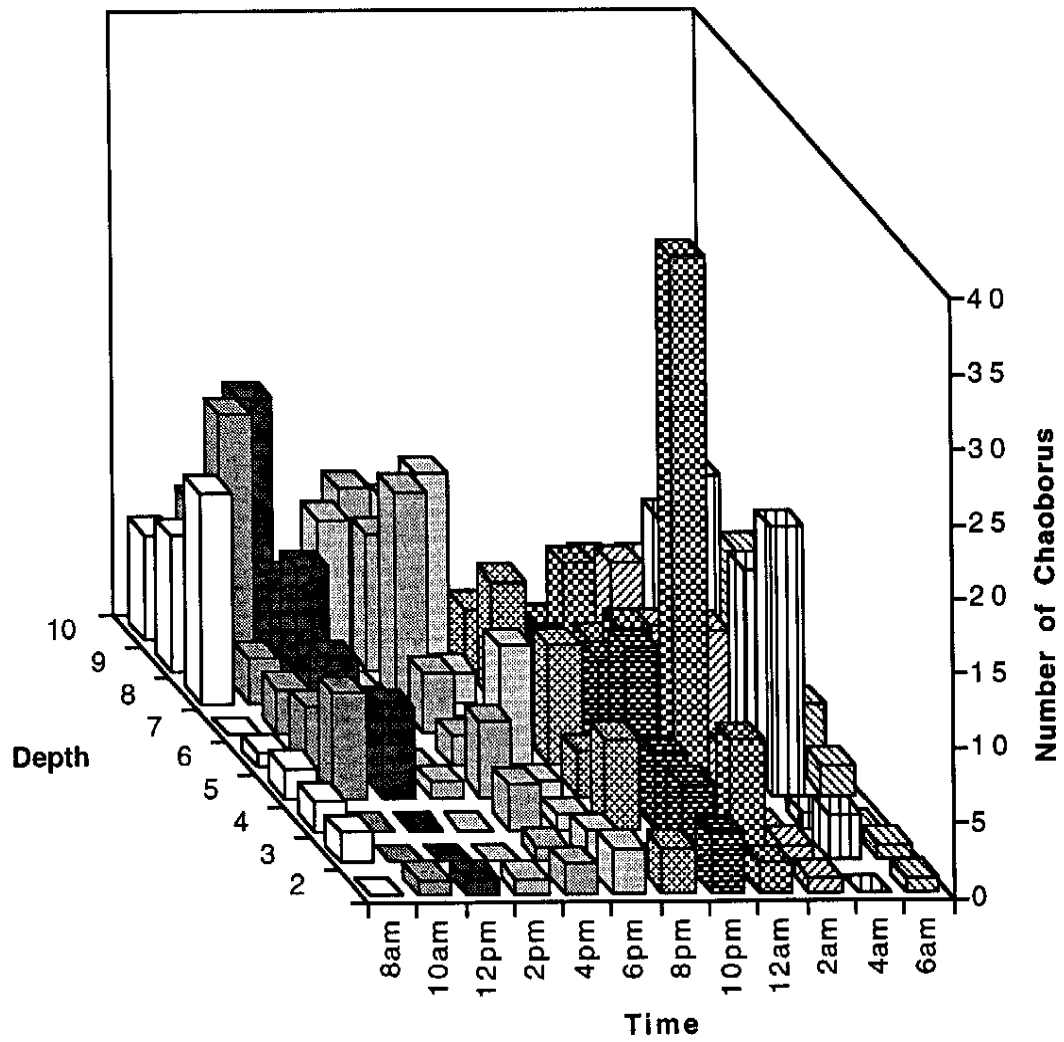


Figure 1. Crampton- New Moon

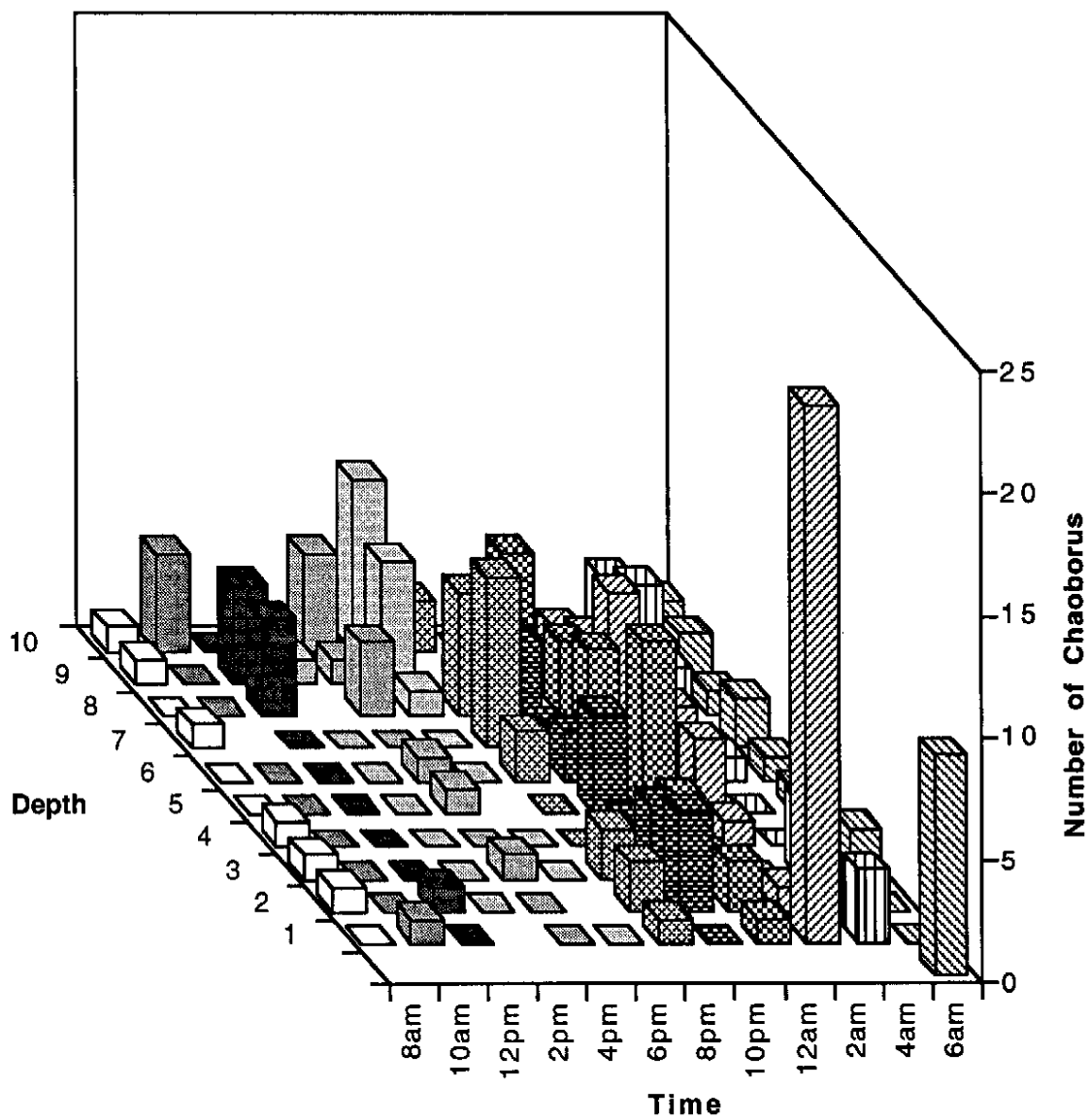


Figure 2. Crampton- Full Moon

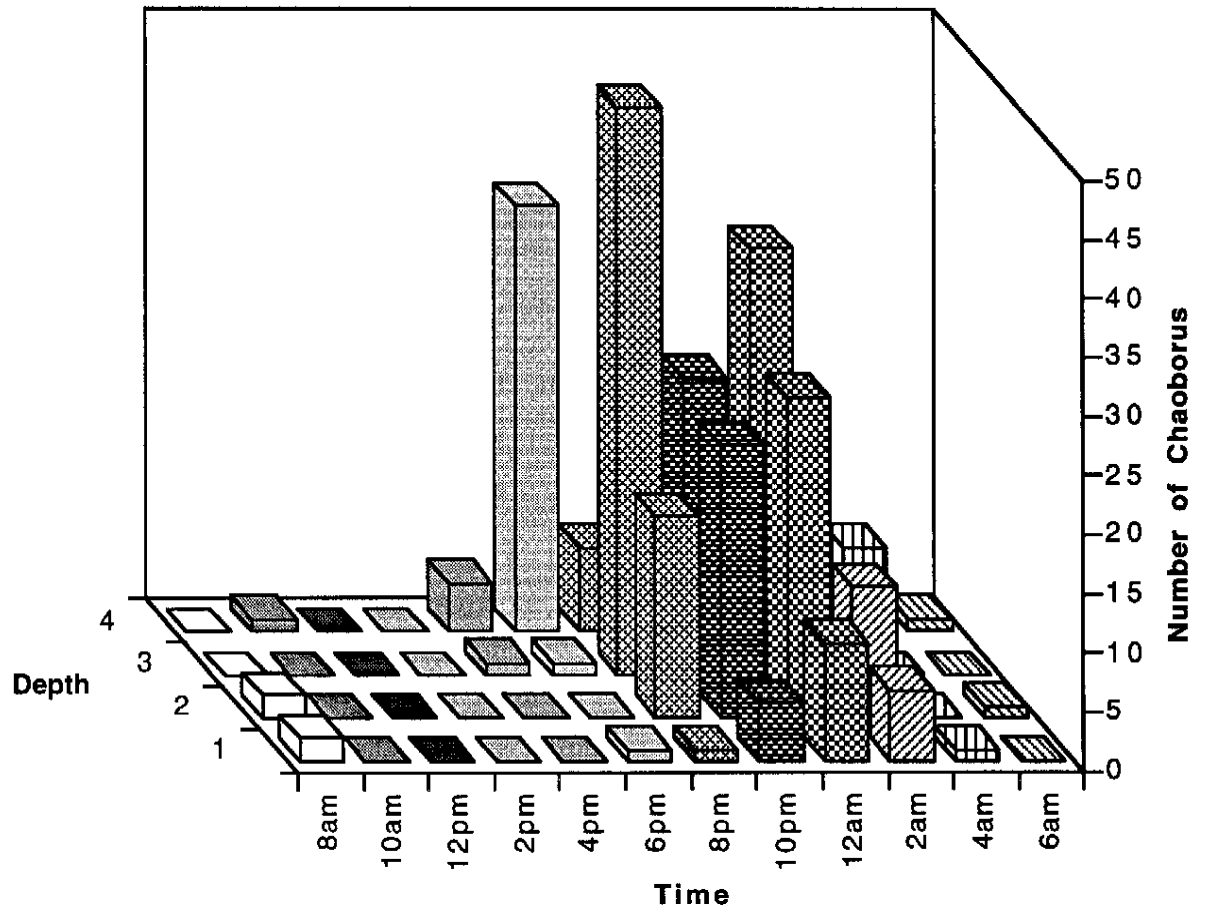


Figure 3. Brown- New Moon

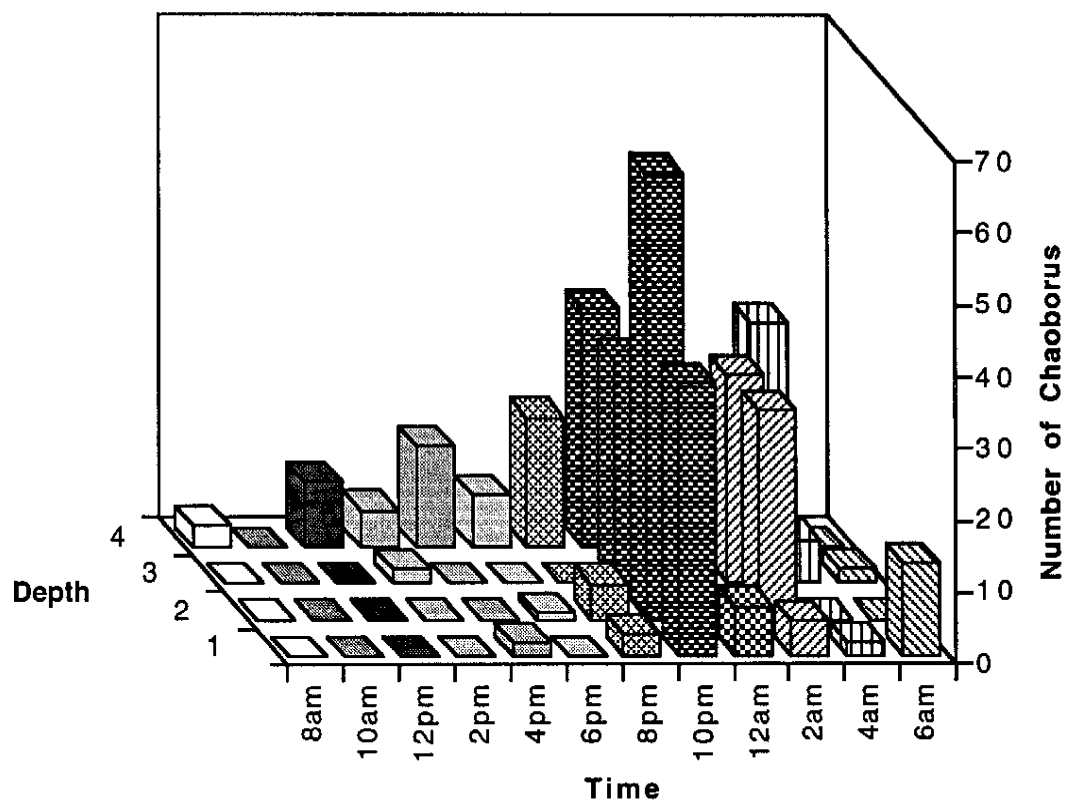


Figure 4. Brown- Full Moon

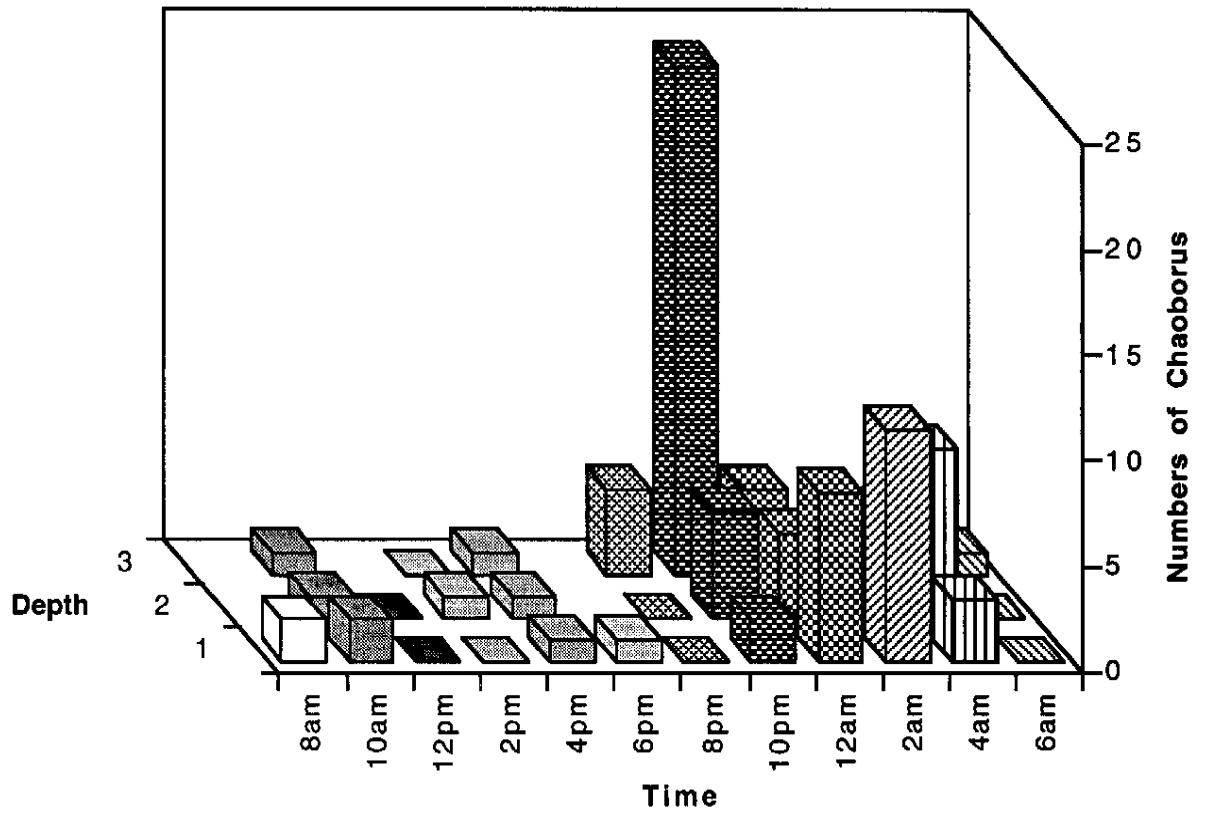


Figure 5. Forest Service Bog- New Moon

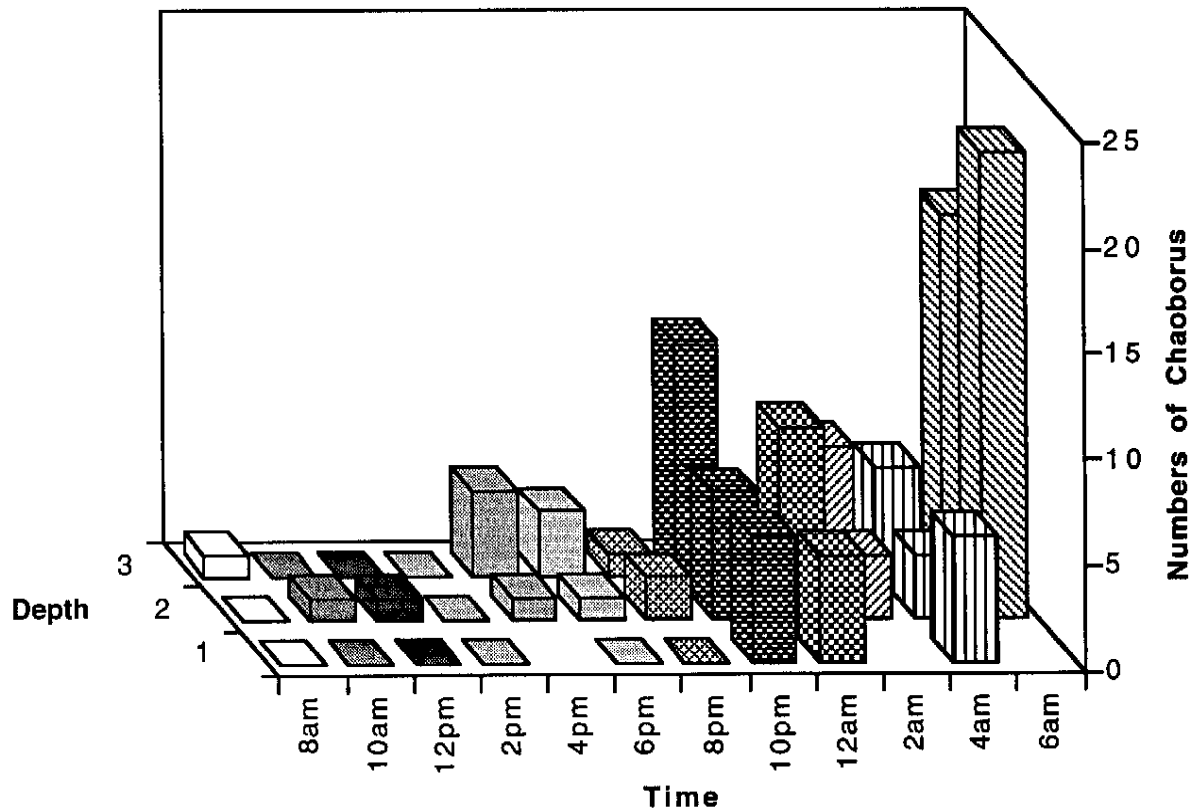


Figure 6. Forest Service Bog- Full Moon

Brown- Full Moon (see Figure 4).

	8am	10am	12pm	2pm	4pm	6pm	8pm	10pm	12am	2am	4am	6am
1m	0	0	0	0	2	0	3	38	7	5	2	0
2m	0	0	0	0	0	1	5	62	0	29	0	2
3m	0	0	0	2	0	0	0	31	23	29	6	0
4m	3	0	9	5	14	7	18	33	1	0	31	9

Forest Service Bog- New Moon (see Figure 5).

	8am	10am	12pm	2pm	4pm	6pm	8pm	10pm	12am	2am	4am	6am
1m	-	2	0	0	1	1	0	2	8	11	3	0
2m	2	1	0	1	1	-	0	5	4	5	8	0
3m	-	1	-	0	1	-	4	24	4	0	3	1

Forest Service Bog- Full Moon (see Figure 6).

	8am	10am	12pm	2pm	4pm	6pm	8pm	10pm	12am	2am	4am	6am
1m	0	0	0	0	-	0	0	6	5	-	6	22
2m	0	1	1	0	1	1	2	6	9	3	3	17
3m	1	0	0	0	4	3	1	11	2	6	5	13

Migration Data in Tabular Form

Crampton- New Moon (see Figure 1).

	8am	10am	12pm	2pm	4pm	6pm	8pm	10pm	12am	2am	4am	6am
1m	0	-	-	0	2	0	0	5	1	1	0	1
2m	0	1	1	1	2	3	3	4	2	1	0	1
3m	2	0	0	0	1	2	0	5	8	1	3	1
4m	2	0	0	0	3	1	6	5	0	0	1	0
5m	2	7	6	1	5	1	3	10	36	3	18	2
6m	1	4	0	0	2	8	8	7	6	9	13	4
7m	0	3	5	0	4	0	5	4	7	4	5	2
8m	14	3	9	1	14	2	8	4	4	5	15	10
9m	9	17	6	10	9	13	4	2	7	7	10	-
10m	7	9	16	-	10	9	2	0	1	5	5	9

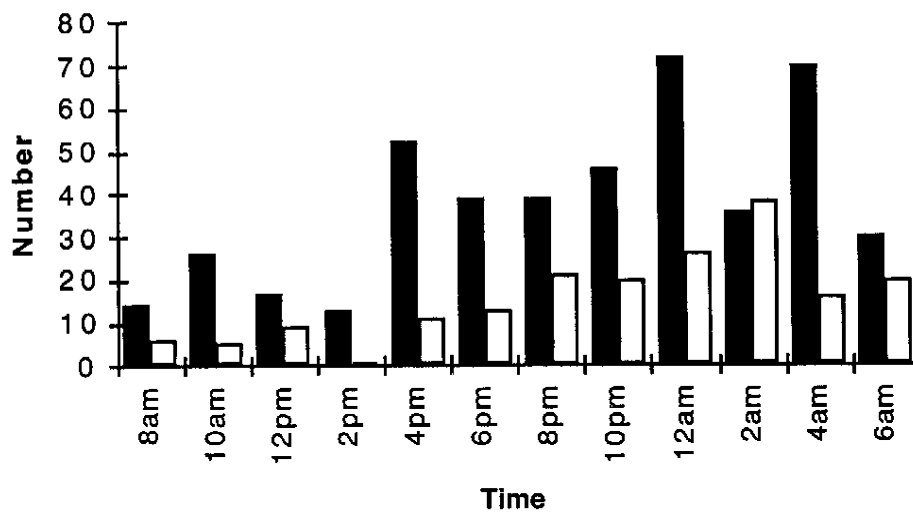
Crampton- Full Moon (see Figure 2).

	8am	10am	12pm	2pm	4pm	6pm	8pm	10pm	12am	2am	4am	6am
1m	0	1	0	-	0	0	1	0	1	22	3	0
2m	1	0	1	0	0	-	2	4	2	1	-	2
3m	1	0	0	0	1	0	2	3	1	0	3	0
4m	1	0	0	0	0	0	0	1	2	1	0	1
5m	0	0	0	0	1	-	0	4	7	3	0	1
6m	0	0	0	0	1	0	2	2	1	3	1	2
7m	1	-	0	0	0	0	7	1	4	-	0	1
8m	0	0	4	-	3	1	5	3	3	5	2	2
9m	1	0	4	1	1	5	-	2	1	2	4	2
10m	1	4	0	0	4	7	2	0	4	1	3	4

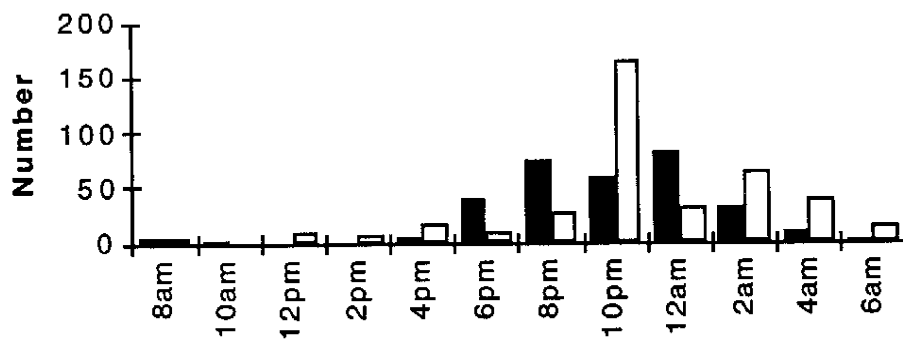
Brown- New Moon (see Figure 3).

	8am	10am	12pm	2pm	4pm	6pm	8pm	10pm	12am	2am	4am	6am
1m	2	0	0	0	0	1	1	5	10	6	1	0
2m	2	0	0	0	0	0	17	23	27	11	0	1
3m	0	0	0	0	1	1	48	25	36	7	0	0
4m	0	1	0	0	4	36	7	6	7	8	7	1

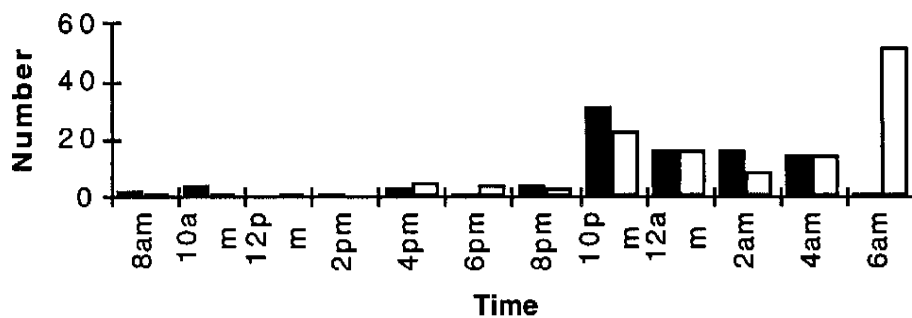
Crampton: Chaoborus in Water Column



Brown: Total Chaoborus in Water Column



Forest Service Bog: Chaoborus in Water Column



Figs.7,8,9. Comparing total numbers of *Chaoborus* found in the water column between first and second sampling periods. Dark bars represent new moon (28 June) sampling period, light bars represent full moon (12 July) sample.

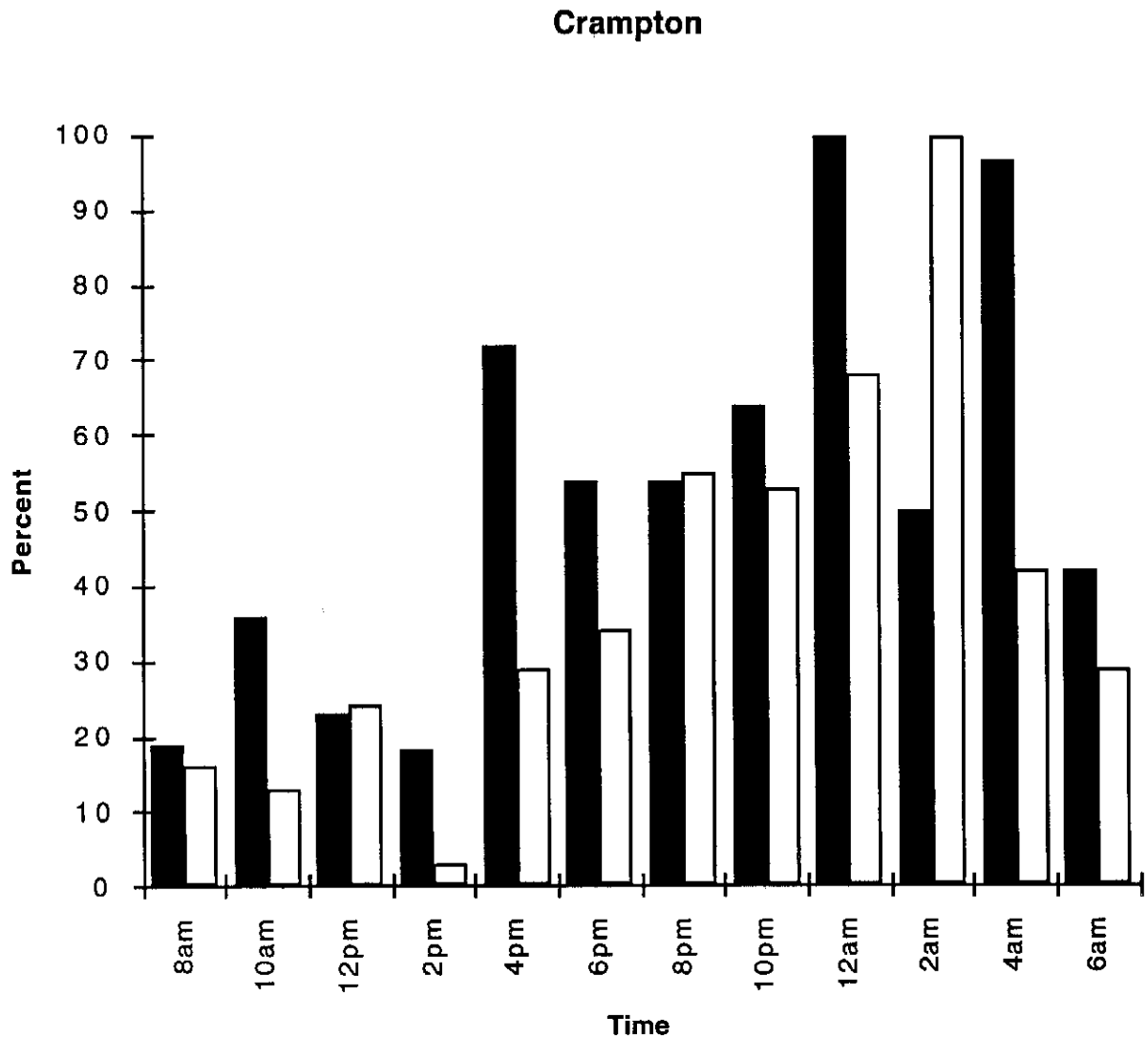


Fig. 10. Comparison of number of *Chaoborus* in water column as a percentage of highest value discovered for each sample (refer to fig. 1 and 2 and tables). Dark and light bars denote new moon and full moon samples respectively.

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Note: title of unpublished report by Nick Honkamp may have changed since the time this paper was cited.