Zooplankton-Algal Interaction in Brown and Crampton Lakes and Forest Service Bog

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Abstract

This study set out to find the zooplankton population and diversity changes that occur in Brown and Crampton Lakes and Forest Service Bog located at the University of Notre Dame Environmental Research Center in Gogebic County, Michigan. Additionally, it attempted to draw correlations between phytoplankton and zooplankton populations and behavior by comparing data between two similar studies involving zooplankton and phytoplankton occurring simultaneously. Results were compared to each lake individually and across the different environments. Additional conditions that were also similarly monitored included dissolved nutrients, weather and lunar cycles, and dissolved oxygen and temperature readings. Findings from this study partially supported the predation avoidance and diel migratory theories that plankton behavior is influenced by food and predatory factors. In addition, the dependence of phytoplankton and zooplankton on each other for recycling of essential dissolved nutrients, oxygen, and food were also partially supported. Finally, new information regarding two relatively unstudied lakes, Gilbert and Gillen, provided mapping and dissolved nutrient data for these two environments.

Introduction

Zooplankton, along with phytoplankton, form the basis of the aquatic food chain. They consist principally of the Crustacea and Rotifera species as well as the Clasocera species. They feed primarily on phytoplankton and, in the case of carnivorous species, other zooplankton. Because of this food web structure, the behavior of zooplankton in relation to phytoplankton and other zooplankton has been extensively studied. Previous studies by Bergquest (1985) found that changes in the zooplankton community can have significant affects on the phytoplankton and primary producer communities. Moss has stated that it is only through recycling of nutrients such as ammonia and phosphates from zooplankton excretion to phytoplankton incorporation that steady populations can maintain themselves. In addition, Moss has proven that some species of plankton "may be rejected since they are of unmanageable shape, or chemically unacceptable" (Moss, 1980). Thus, chemical, size, species, and shape all play a role in zooplankton viability.

Many such studies have also focused on the diel vertical migration of zooplankton. The adaptive significance of this behavior has been the focus of various studies. One hypothesis states that zooplankton gain a metabolic advantage by feeding in the upper waters and sinking in the deeper, darker waters passively. Other studies have dismissed this reasoning and concluded that zooplankton gain no such advantage over non-migratory species (Stich and Lampert 1984). Still other studies have focused on the importance of oxygen and temperature factors are important in migratory behaviors.

The currently popular theory, however, is the predation avoidance hypothesis that has gained considerable support (Stich and Lampert 1981, Orcutt and Porter 1983, and Dini 1989). This theory postulates that high planktivory by fish and larger zooplankton species such as Chaoborus is correlated with consistent migration of zooplankton (Dini and Carpenter, 1988). During the daylight the zooplankton descend in the water column to safer, darker waters in response to visual predation. At night, they ascend under the cover of darkness to feed on the smaller phytoplankton which are abundant at the surface due to their photosynthetic capabilities. This is an example of nocturnal migration. Another pattern, called reverse migration, shows a peak zooplankton concentration at the surface during the daylight hours. In doing so, plankton avoid feeding invertebrate predators (Ohman and Frost, 1983). To test these various theories, 24 hour sampling of the aquatic habitats was employed.

Since migratory behaviors are likely due to multiple causes, several variables were monitored. The lunar cycle, oxygen availability, temperature, and dissolved nutrient levels were monitored during each sampling period at each depth. In addition, data from the phytoplankton and Chaoborus studies conducted concurrently were also analyzed.

Materials and Methods

Brown and Crampton lakes and Forest Service Bog, located in the University of Notre Dame Environmental Research Center (UNDERC) in Gogebic County, Michigan, were studied in this sample. These lakes, although close in proximity, have shown to be very different physically and chemically. Crampton is known to support a large fish assemblage, Brown was known to support a heavy algal structure, while Forest Service Bog was devoid of fish and exhibited a low pH characteristic of a large bog.

During the three 24 hour sampling periods, samples were taken at every meter from the deepest spot in each lake, determined by sonar mapping. Samples were taken every two hours over a 4 meter depth in Brown, a 10 meter depth in Crampton, and a 3 meter depth in Forest Service Bog. To keep sampling site consistency, a milk jug with an attached anchor was placed at the initial sampling site in each lake/bog. The samples were collected using a Schindler Trap with a 63 um mesh net attachment. Samples were contained in glass vials with 10% formalin solution.

During each sampling, weather condition and the lunar cycle were documented. In addition, water temperature and dissolved oxygen was measured at every meter in each lake using a Hach oxygen/temperature probe. Light levels were determined using a light probe and a secchi dish reading was performed at each lake. A Hach portable pH meter was used to determine pH readings in each lake/bog.

To concentrate the samples, each sample vial was again filtered and centrifuged. These samples were then placed in 1 mL Segdewich-Rafter cells and identified using a compound microscope. The numbers obtained were then multiplied by the amount of sample in the post-centrifuge sample vial. To improve statistical accuracy, two separate samples were counted from each specimen in the first and second 24 hour sampling periods, while three samples were counted from the third 24 hour sampling period. These numbers were then averaged to obtain more consistent zooplankton numbers.

Prior to each 24 hour sampling period, water chemistry was taken from the top and bottom waters of each lake/bog. Chemistry tests for phosphorous, ammonia, nitrates, sulfates, and hydrogen sulfide concentrations were determined using a Hach Water Chemistry Analysis Kit.

Depth maps, as mentioned above, were compiled using a compass, sonar device, a boat with a trolling motor, and a stopwatch. Maps were constructed for Crampton Lake and Forest Service Bog. In addition, two newly discovered lakes, Gilbert and Gillen, were mapped and also tested for water chemistry and temperature/dissolved oxygen profiles.

Results

In an attempt to reduce counting while keeping statistical confidence, three different depths were identified and counted in each lake/bog. Samples were analyzed from the 1,4 and 10 meter depths in Crampton, the 1,2 and 4 meter depths in Brown, and the 1,2 and 3 meter depths in Forest Service Bog.

The primary zooplankton in Brown Lake during the first sampling period was the rotifers Kertatella and Polyarthra. The second sampling period saw the continued dominance of Keratella and Polyarthra with the emergence of the rotifer Filinia. The third sampling period mirrored the first with Keratella and Polyarthra again dominating. Many species were intermediate in density among the three periods: the crustacea Nauplii and rotifer Synchaeta during the first two periods, Ploesoma and Filinia during the third period. In total, 14 genera of zooplankton were present in the first period, with 10 and 11 genera represented in the second and third sampling periods, respectively.

Crampton Lake had the rotifers Keratella and Kellicottia dominating during the first sampling period. The crustacea Nauplii joined these two rotifers to constitute the dominate zooplankton in the second sampling period while the third period saw the rotifers Polyarthra and Keratella predominate. In addition, Nauplii showed intermediate levels in the first and third periods while dominating during the second period while the rotifer Polyarthra steadily increased in number from the first through the third. The crustacea Cyclops also showed a strong emergence during the second and third sampling periods. Genera diversity held constant over the three periods with

13 represented in the first sampling period and 12 in the second and third sampling periods.

The predominant zooplankton in Forest Service Bog during the first, second, and third sampling periods were the rotifers Polyarthra and Keratella. Forest Service Bog's intermediate species also included the crustacea Nauplii and Cyclops which increased in number throughout the summer and peaked during the third period. Overall, the number of genera peaked in the second period with 14 while the first and third periods totaled 10 genera each.

Overall, comparisons across the different lakes and bog showed that rotifers dominated over crustaceans in all environments with crustaceans showing a late emergence during late July. Migrational comparisons were also noted between the different environments. Diel migration patterns were noted in Brown's first sample while reverse migration and a sustained surface concentration dominating during the second and third sampling periods. Crampton's dominant rotifer populations exhibited diel migration during the first and second periods while the crustacea Nauplii and Cyclops exhibited a pattern that put them near the surface most of the day. Forest Service Bog's patterns were extremely varied. No clear cut migratory patterns could be determined from the data.

Actual zooplankton population numbers were no evaluated in this study, it was possible to make some general observations. Brown Lake supported the highest number of zooplankton in every sample with a peak during the second sampling period. Crampton supported about one-third the total number of zooplankton as Brown with Forest Service Bog supporting only a minimal number overall and in comparison with Brown and Crampton.

Weather conditions were fairly constant throughout the experiment. Air and water temperatures during the experiment varied only slightly (1-2°) from lake to lake. Dissolved oxygen readings were also comparable. Crampton's dissolved oxygen stayed very stable with a slight increase in surface oxygen during the third sampling period. Forest Service Bog showed the lowest dissolved oxygen readings with less than 50% saturation below 1.5 meters. Brown showed decreased saturation readings during the first sampling period with a rebound occurring during the second and third periods.

Chemistry analysis showed Brown to have the highest concentrations of the limiting nutrients phosphate and nitrate. Crampton was the most limited nutrient lake with phosphate concentrations hovering around 0.00 to 0.05 mg/L. Forest Service Bog was the most acidic with consistent pH readings around 5.0.

The mapping of Crampton Lake produced two deep depressions showing the deepest parts of this lake to be 45-50 feet deep. Gilbert Lake was found to be approximately 20-25 feet at its deepest, while the newly mapped Gillen Lake proved to be fairly deep at 40 feet. Also, a new map of Forest Service Bog was also generated.

Discussion

Predation accounted for the large numbers of rotifers in comparison to crustacea in all the aquatic environments. Rotifers are the main food source for larger zooplankton and insect larvae. Thus, through prolific reproduction, high numbers are maintained which insure high adult concentrations. Crustacea, however, are immune to predation by these organisms. Their growth is slower, as evidenced by their late emergences in July, and they are readily preyed upon by fish. Thus, they depend more on migratory movements to maintain adequate adult populations. Crampton's deep waters and high fish populations prove this point as evidenced especially during Crampton's second sample.

As was mentioned previously, parallel studies of phytoplankton and Chaoborus concentrations and movement were also monitored during this study. They provided many algal-zooplankton and zooplankton-Chaoborus interactions. The Chaoborus were thought to exhibit strong diel migration patterns. Because of their high predatory rate on smaller zooplankton such as the rotifers, rotifers migration patterns could be affected. During the second sampling period, this was the most evident. Nauplii, which are generally not preyed upon by Chaoborus but are by fish, stayed in the upper waters most of the day to feed unaffected by Chaoborus predation at night. Rotifers such as Keratella and Kellicottia, however, generally displayed a migratory pattern which saw them stay in the deeper waters during the day to avoid predation by fish and insect larvae, and one or two quick diel migrations at night to feed in the darkness while sinking quickly again to avoid predation by similarly migrating Chaoborus. A similar pattern,to presumably avoid insect and fish predation, was observed in the absence of Chaoborus during the first sampling period in Crampton. Following Dini's work, zooplankton exhibiting such behavior are possibly able to "exploit a greater body of water in which to feed," thus giving them a metabolic food advantage (Dini, 1989). Furthermore, it has been proposed that by staying in cooler, deeper water during much of their lifespan and rising only to feed in the warmer, phytoplankton rich upper waters, zooplankton gain an "energy advantage" by being able to slow down their metabolic rate by living predominately in cooler water (Dini, 1989).

Studies by Bergquest have also indicated that the size of the zooplankton with respect to its predator has important consequences. Since larger zooplankton like Chaoborus feed by filtering water through their mouth appendages, some zooplankton are unacceptable food because of size and shape restrictions. This represents a plausible explanation in Moss' research for zooplankton such as Nauplii in Crampton who did not consistently migrate to avoid predation (Bergquest, 1985). In addition, research by Ohman and Frost has documented cases in which zooplankton reverse migrate: rising to the surface during the daylight to feed and dropping to lower waters at night as some zooplankton exhibited in Brown Lake (Ohman and Frost, 1983).

A well documented zooplankton-algal interaction occurred in Brown Lake during its algal bloom in the first sampling period. As observed from the graphs, zooplankton mean densities bottomed out during the first Brown sampling period but rebounded during the second and third periods. Toxic organic compounds secreted by the large numbers of phytoplankton an algae in Brown during the late June algal bloom have been suspected of negatively impacting zooplankton populations (Moss). As fewer zooplankton survived, predatory pressures on phytoplankton decreased and allowed their continued build-up. Furthermore, phytoplankton are able to out-produce zooplankton even during heavy grazing by zooplankton. Zooplankton, even with abundant phytoplankton food supplies, will not be able to match phytoplankton reproduction and could succumb to toxic excretion by the overabundant phytoplankton (Bergquest, 1985).

Chaoborus migratory behavior and predatory pressure on smaller rotifers was decreased in Forest Service Bog due to decreased Chaoborus numbers. This decreased population could be caused directly by the low pH associated with typical bogs. This, in conjunction with its relatively low secchi depth readings of around 2.0 meters, could account for the fact that the dominant rotifers Polyarthra and Keratella present in Forest Service were able to stay within the upper 2.5 meters of the bog and presumably feed.

Finally, Moss and Bergquest 's theories that the recycling of essential nutrients such as phosphate and nitrate between zooplankton and phytoplankton is essential for high population levels of each proved true in this experiment. As evidenced by the low concentrations of these nutrients in chemical analysis, Crampton's plankton samples were moderately low in comparison to Brown Lake which had much higher dissolved nutrient levels. In addition, Moss' claim that high levels of phytoplankton inhibit zooplankton populations through toxic byproducts seems to be observed in Crampton. The moderate zooplankton populations observed in Crampton's second sample strike a balance between enough phytoplankton to facilitate adequate recycling of chemical nutrients but few enough phytoplankton to avoid toxic side-effects.

Finally, the fairly constant dissolved oxygen/temperature readings did not seem to affect changes in plankton populations. All the reading followed a consistent pattern of increasing temperature throughout the summer and decreasing dissolved oxygen readings. Migratory movements and algal interactions that were noted in this study were only preliminary observations procured from the findings of previous studies. To find direct linkages, more specific studies are needed. However, findings of Bergquest and Moss concerning algal/zooplankton interactions were somewhat supported as was the predation avoidance theory of Dini.

Conclusion

Them multiple variables involved in this experiment make widespread generalizations difficult. Even so, Dini's nocturnal migration theory was validated to a greater extent than other migratory behavior such as reverse migration. These results were especially true in the Crampton Lake which was best suited to this kind of study. Also, the rapid reproduction and population numbers of rotifers in comparison to crustacea was also shown. However, Bergquest's data that showed phytoplankton to out-produce all kinds of zooplankton was also evident. Along with this, Moss' assertion that toxic chemicals from a large algal community can inhibit zooplankton number was also seen in Brown Lake during its late June algal bloom. Forest Service Bog was also shown to be very low in plankton levels in general which is assumed to be due to its low pH of around 5.0. Finally, some of the first information concerning depth and composition of two newly studied lakes, Gilbert and Gillen, was detailed.

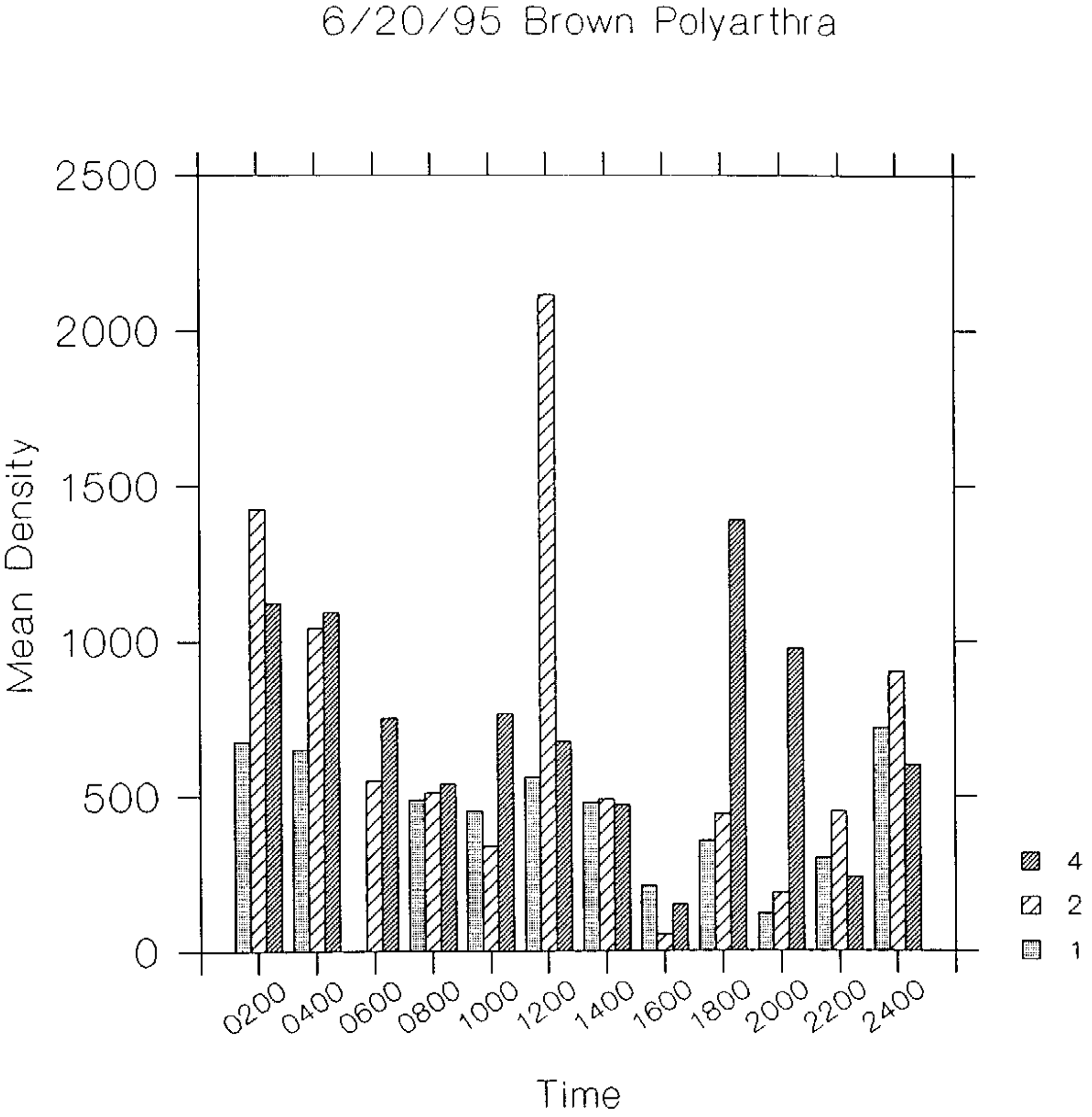
However, because many factors have been studied and documented to affect changes in plankton communities, this study's main concentration was to document the cyclical changes that occur in plankton populations and diversity across the summer. The plankton movements and interactions occurring in this study were only observations procured from earlier experiments. To find direct and new linkages, new studies are needed which seek to monitor a single variable, unlike the multiple ones monitored in this study. Plankton's essential role as primary producers and their foundational role in the food web place them in an extremely important position. Further research must be done to elucidate the factors which directly and indirectly affect their survival and, ultimately, all the organisms which they support.

ZOOPLANKTON MEAN DENSITIES (per 12 L Schindler Trap)

SPECIES	FSB 6/16	FSB 6/28	FSB 7/17	BRWN 6/16	BRWN 6/28	BRWN 7/17	CRPT 6/16	CRPT 6/28	CRPT 7/17
ASPLANCHNA	8.8	7.5	0	72.2	135.8	6.1	6.4	10	10
BOSMINA	5.3	5.8	4.4	16.8	2.5	0.6	21.9	63.3	26.1
BRANCHIONUS	0	0	0	0.6	1.7	0	2.3	0	0
CYCLOPS	29.2	19.2	66.7	173.3	80.8	146.7	118.9	404.4	149.4
DAPHNIA	16.8	3.3	0	24.9	22.5	0	2.7	5	0.6
DIAPTOMUS	26.3	27.5	10	241.6	41.7	157.2	95.5	93.9	22.8
FILINIA	12.2	44.2	2.2	55.4	1375.8	263.3	0.9	37.2	22.2
HOLOPEDIUM	0.8	21.7	10.6	0	0.83	0	18.3	8.9	0
KELLICOTTIA	47.7	23.3	0	187.5	50.8	78.3	1251.7	633.3	75
KERATELLA	4989.3	2309.2	1439.4	3259.2	1024.2	1862.8	1017.9	1118.3	1611.1
LECANE	0	10.8	0	0	1.7	0	0	0	0.6
NAUPLII	179	167.5	164.4	282.6	325	380.6	444	536.7	249.4
PLOESOMA	0	23.2	31.1	0	77.5	404.4	0	7.8	15.6
POLYARTHRA	590.8	377.5	247.2	618.7	1609.2	1321.1	239.3	158.3	277.8
SYNCHAETA	35	5.8	1.1	586.2	236.7	0.6	45.4	11.1	3.3
TRICHOCERA	296.8	160.8	0	150.2	643.3	202.8	387.9	279.2	71.1

UNDERC Table 2

				DISSOLVED NUTRIETS AND SECCHI DEPTHS					
NUTRIENT ION	FSB 6/16	FSB 6/28	FSB 7/17	BRWN 6/16	BRWN 6/28	BRWN 7/17	CRPT 6/16	CRPT 6/28	CRPT 7/17
SECCHI	2.5	2.2	2	0	1.7	1.4	0	3.3	3.5
FUC	0	16	16	0	17	15	0	9	8
N03	0.33	0.28	0.52	2.3	0.15	0.09	0.17	0.43	0.38
NH4	0	0	0	0	0	0	0	0	0.04
PO4	0.07	0.05	0.24	0.13	0.1	0.1	0	0.27	0.04
SO4	0	0.25	0	0	0.12	0	0	0.75	0.5


6/20/95 Brown Polyarthra
Mean Density
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2000
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1000
500
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0400
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Time
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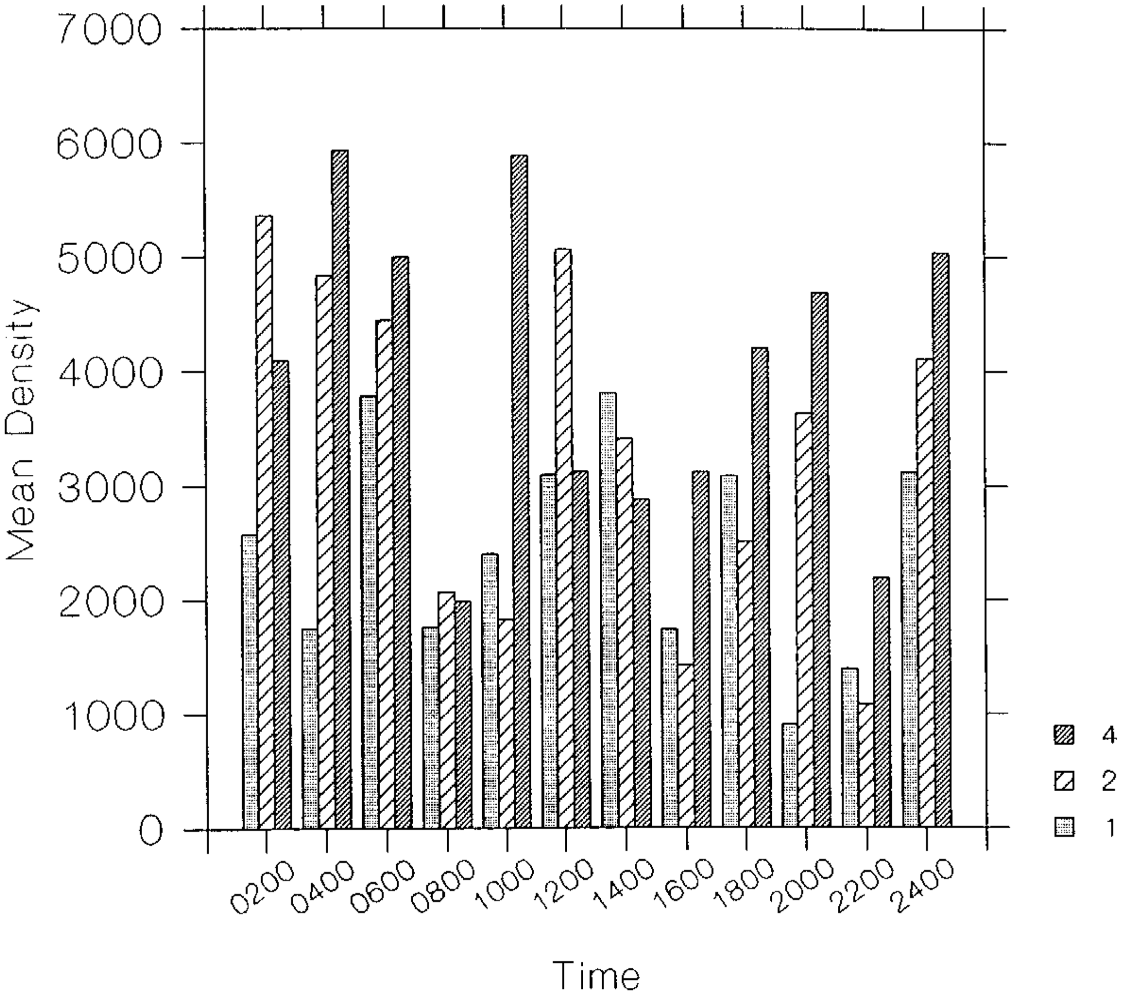
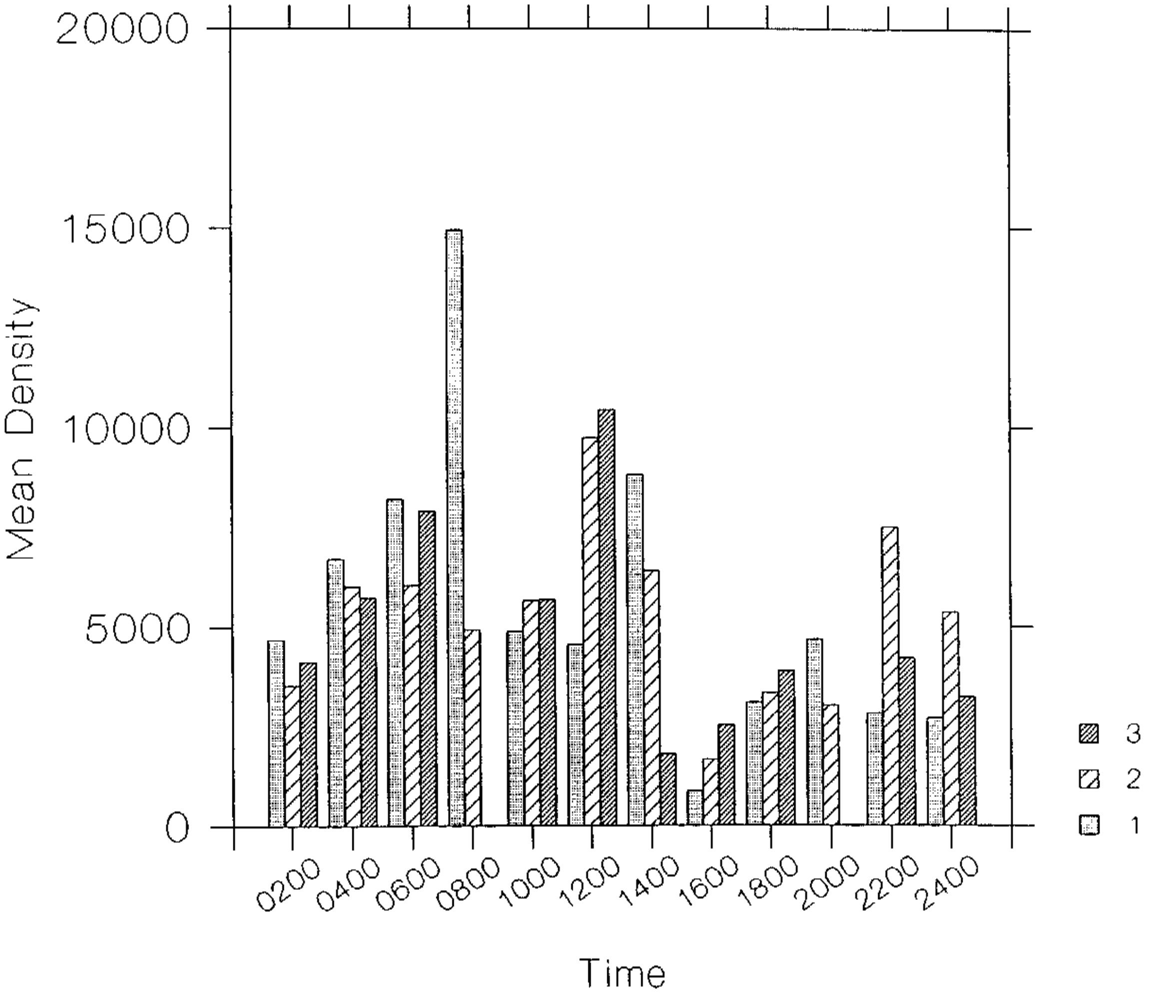
1

6/20/95 Brown Keratella

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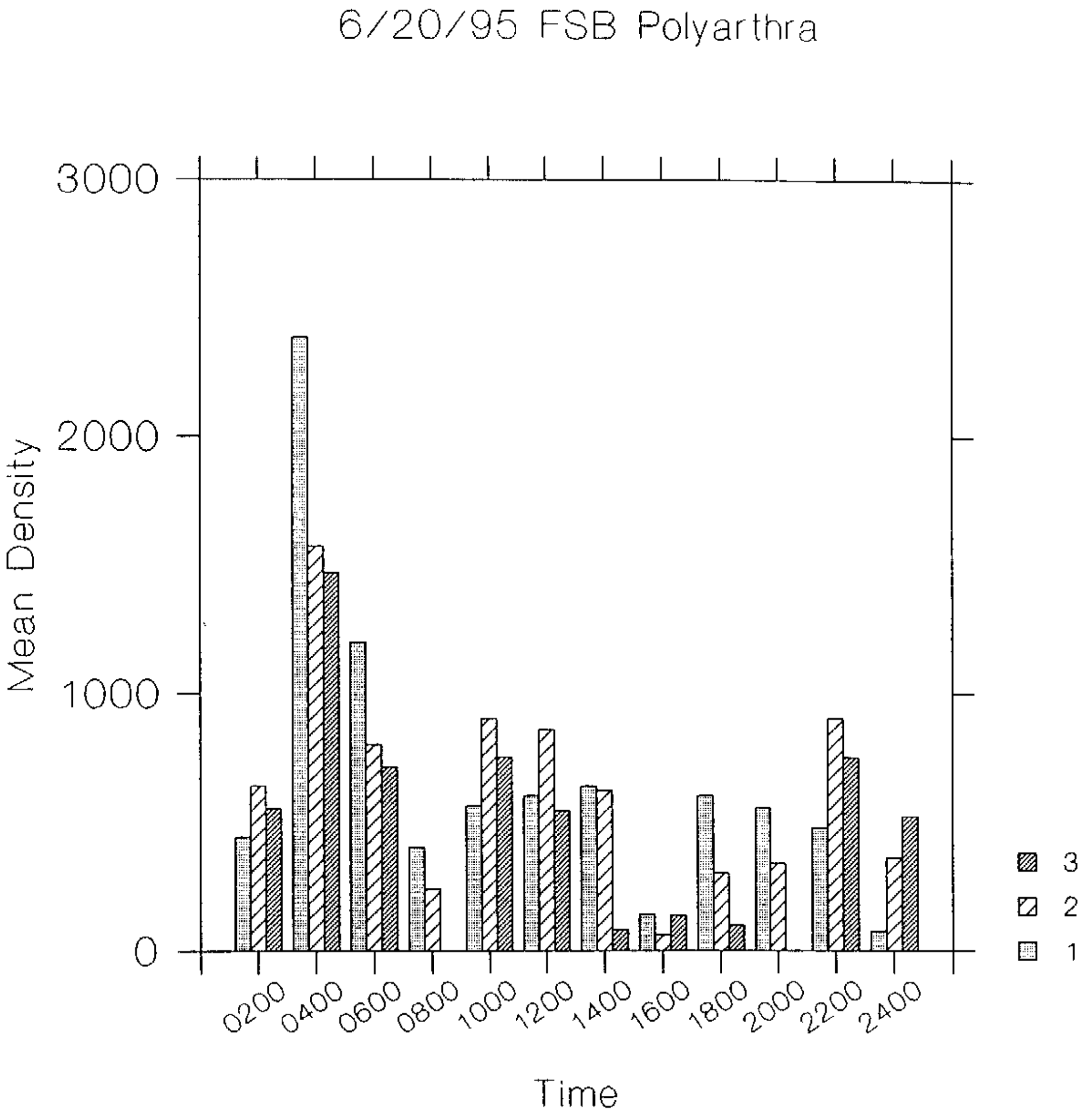
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Mean Density
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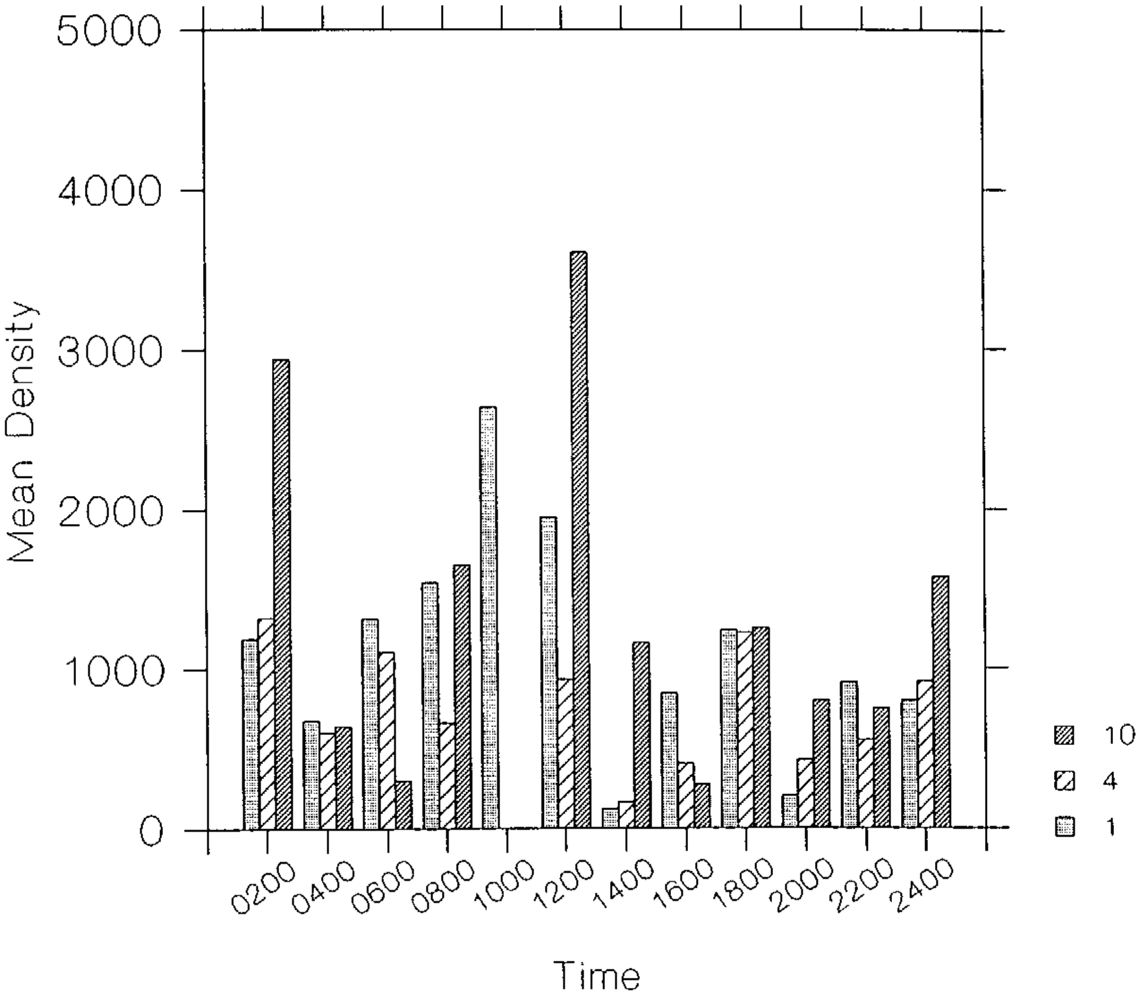

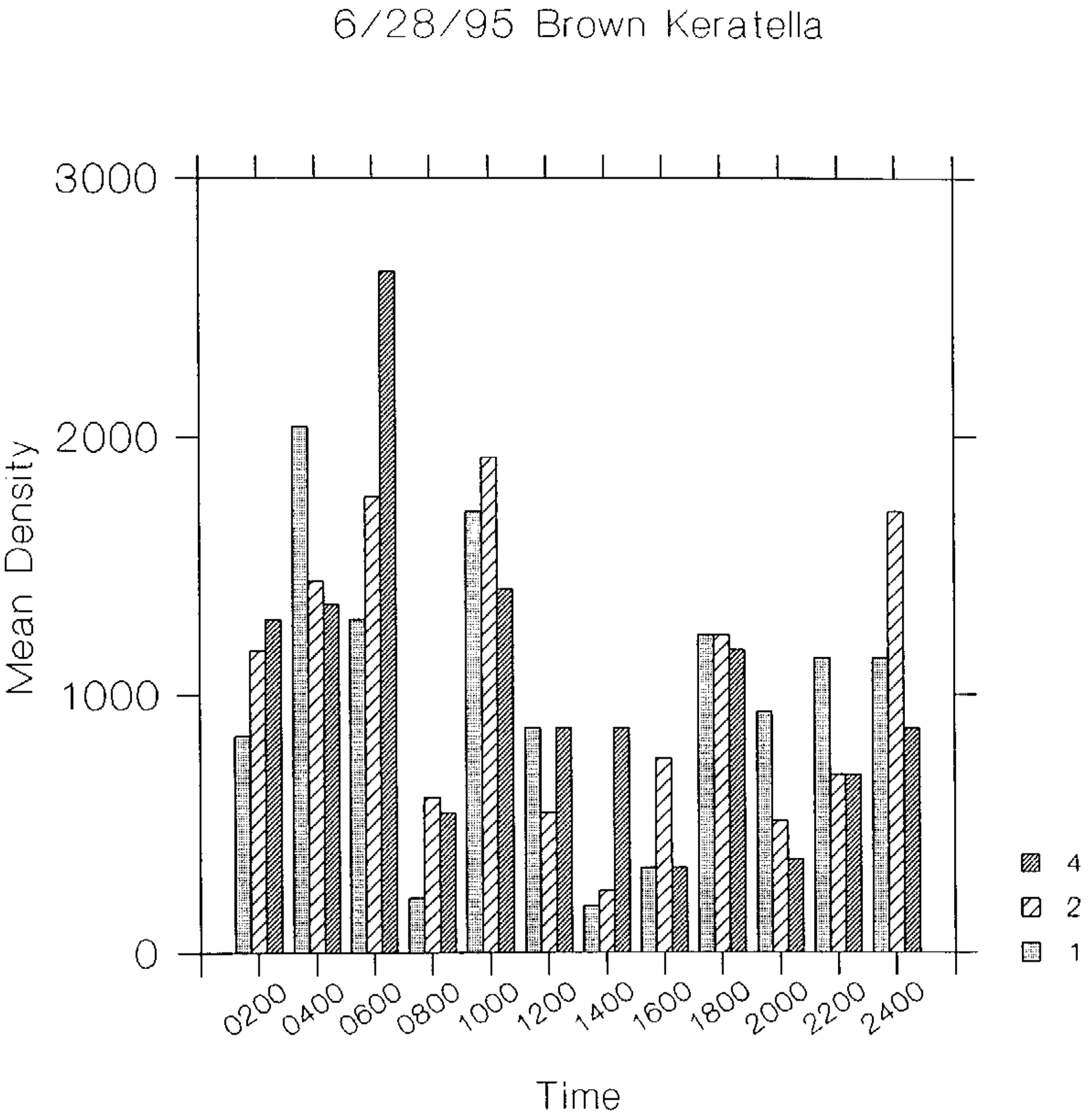
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Mean Density
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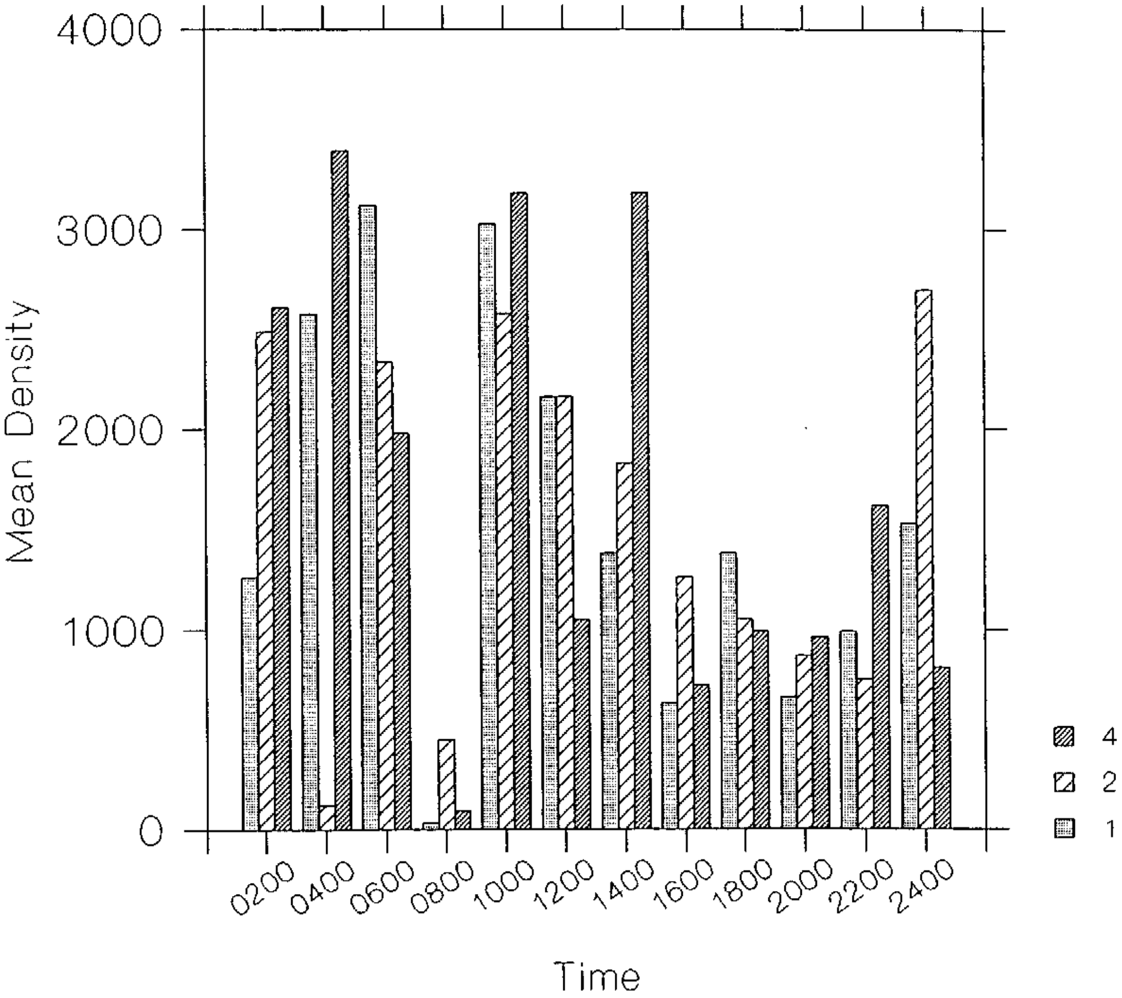
6/28/95 Brown Polyarthra



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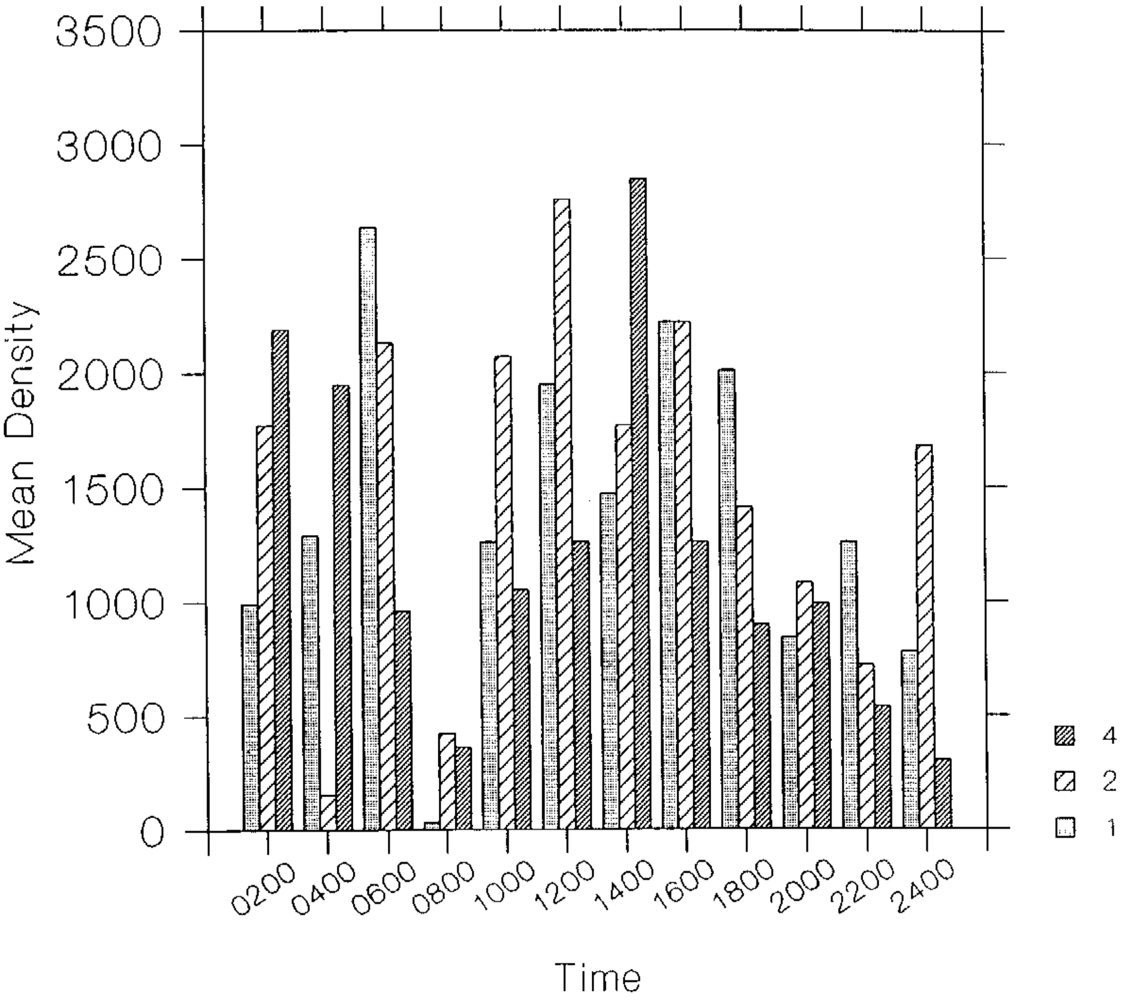

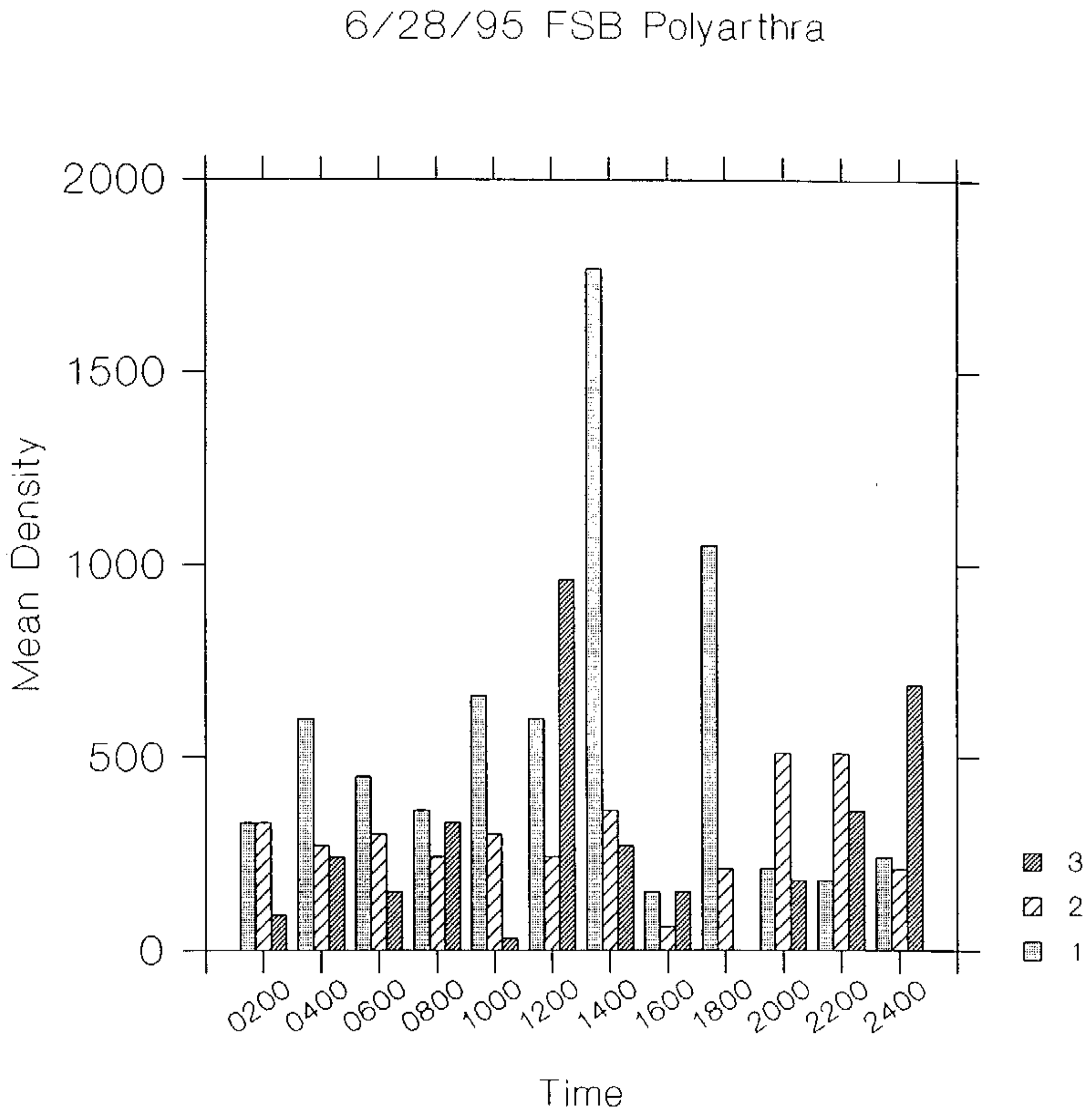
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Mean Density
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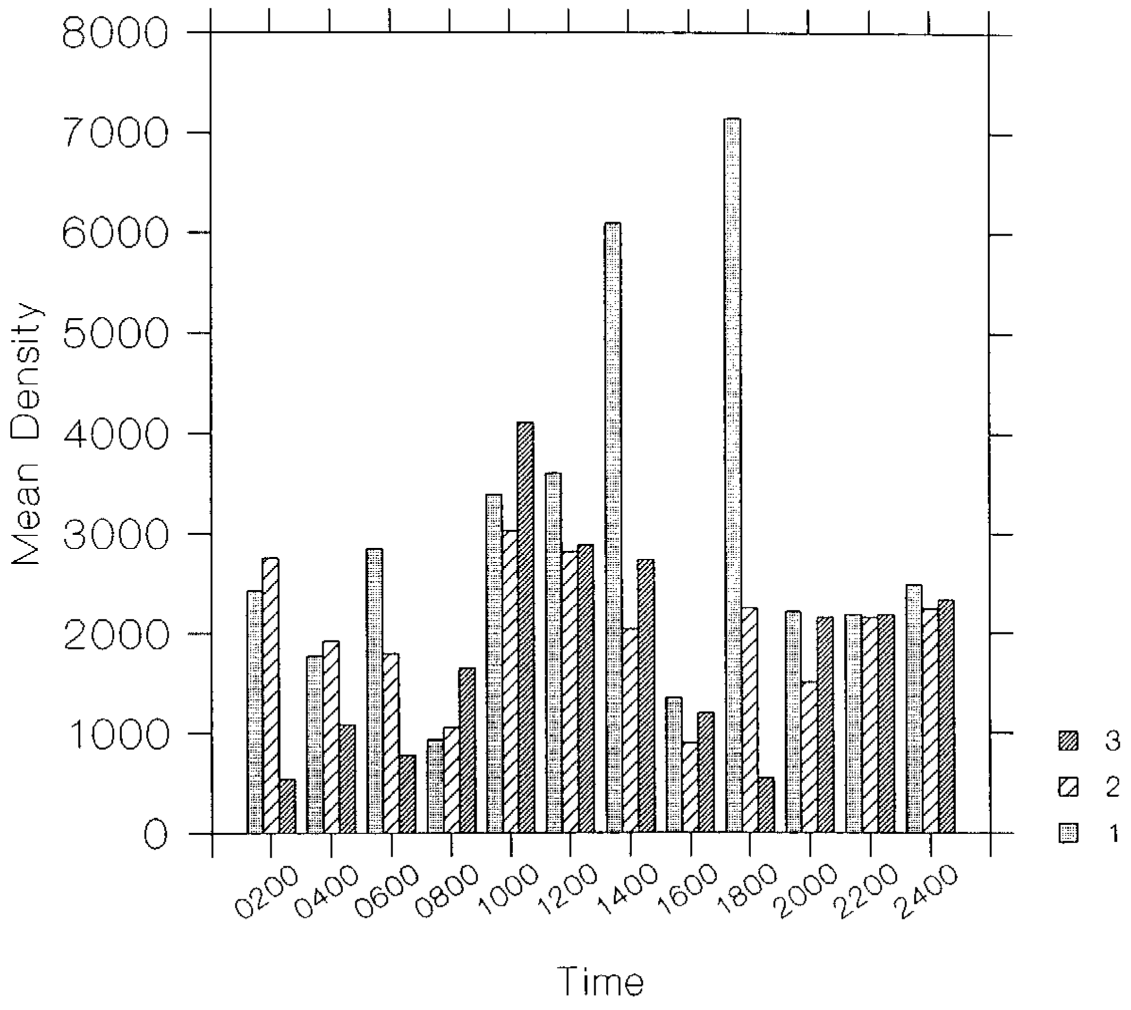

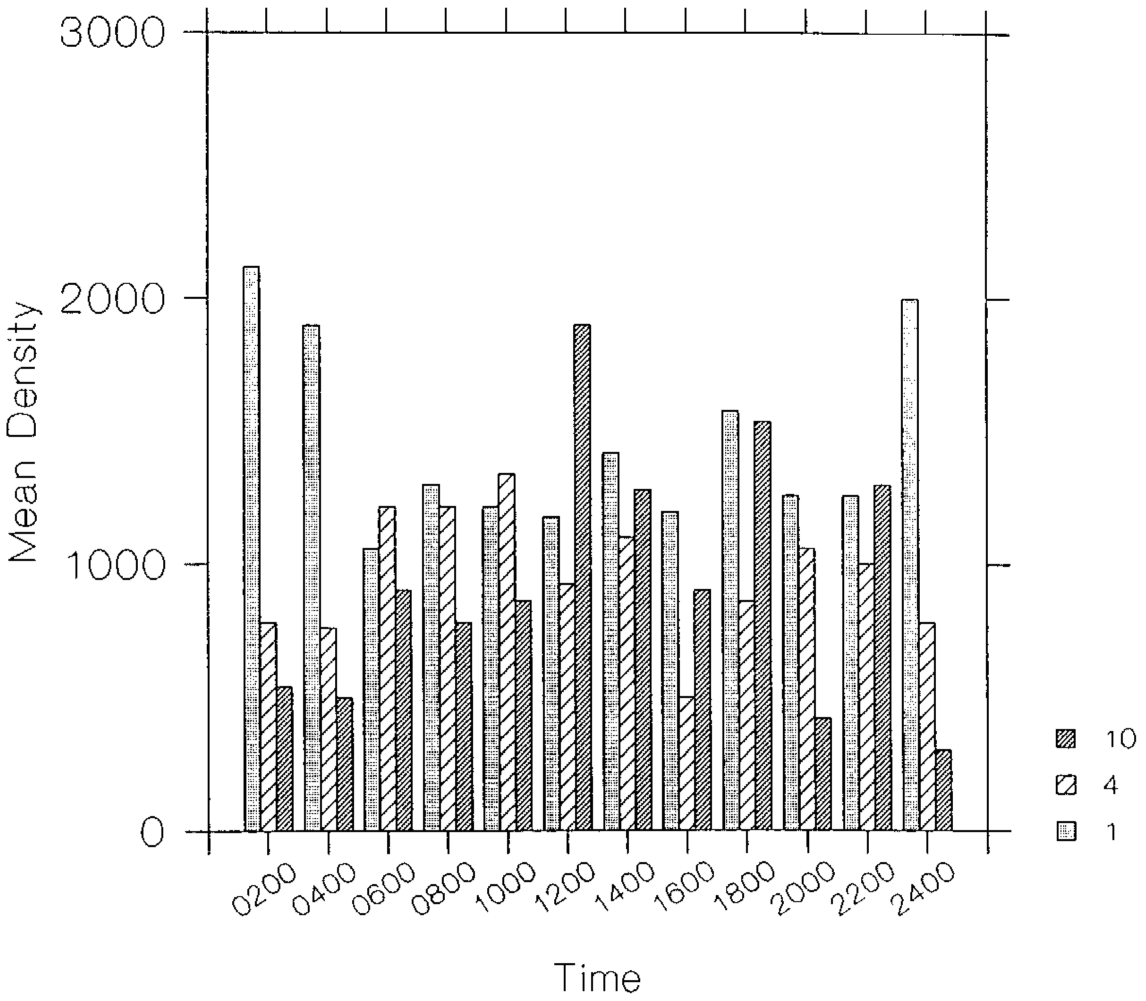

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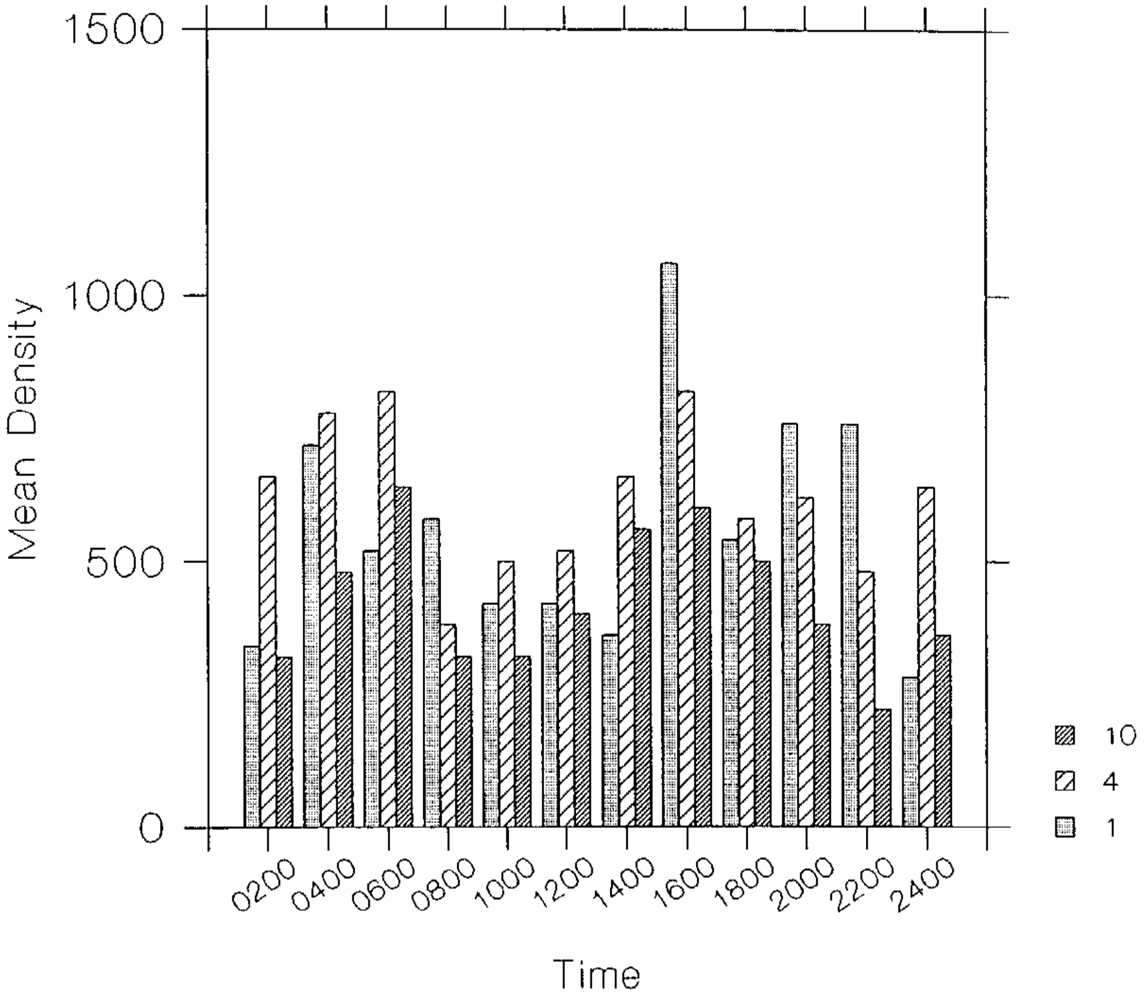

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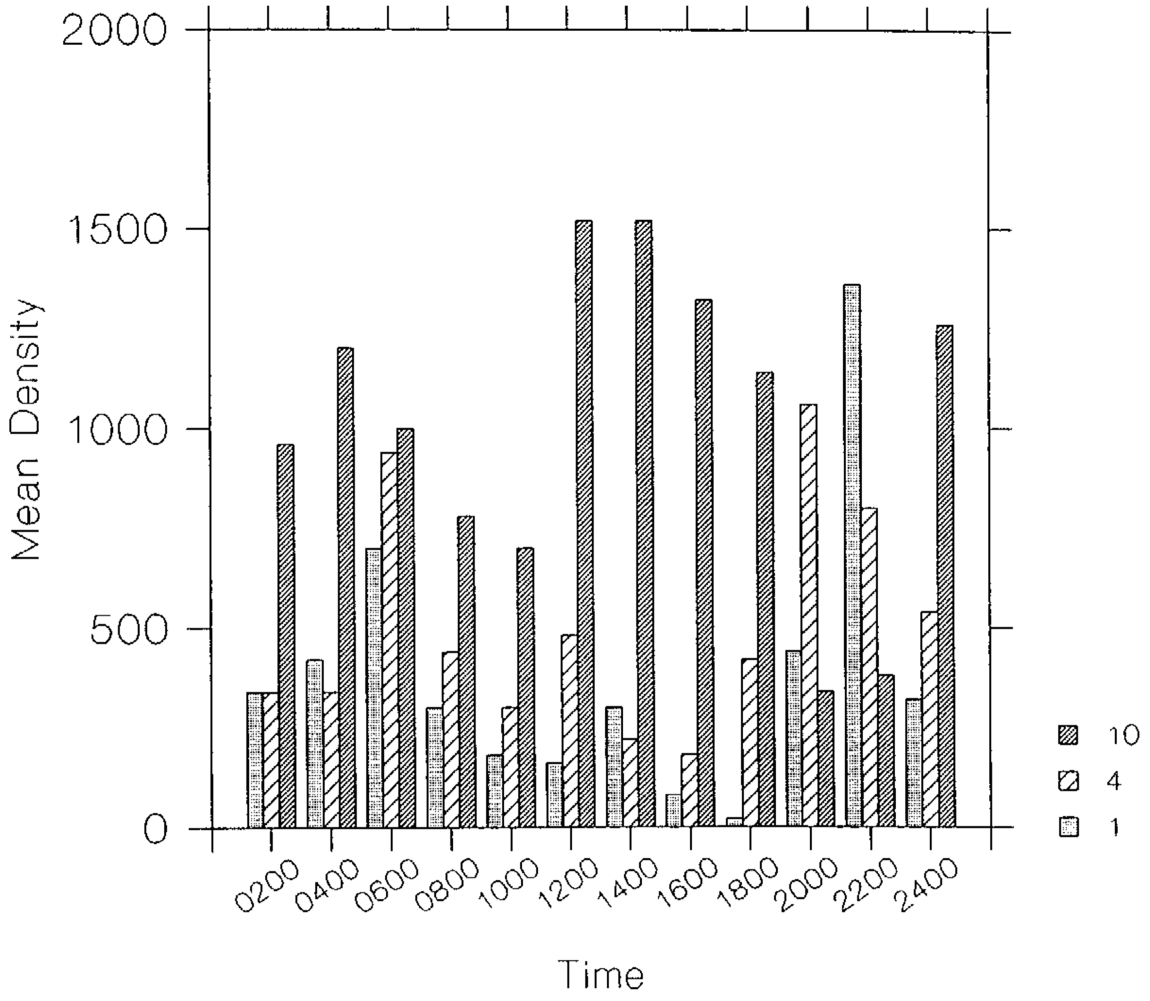
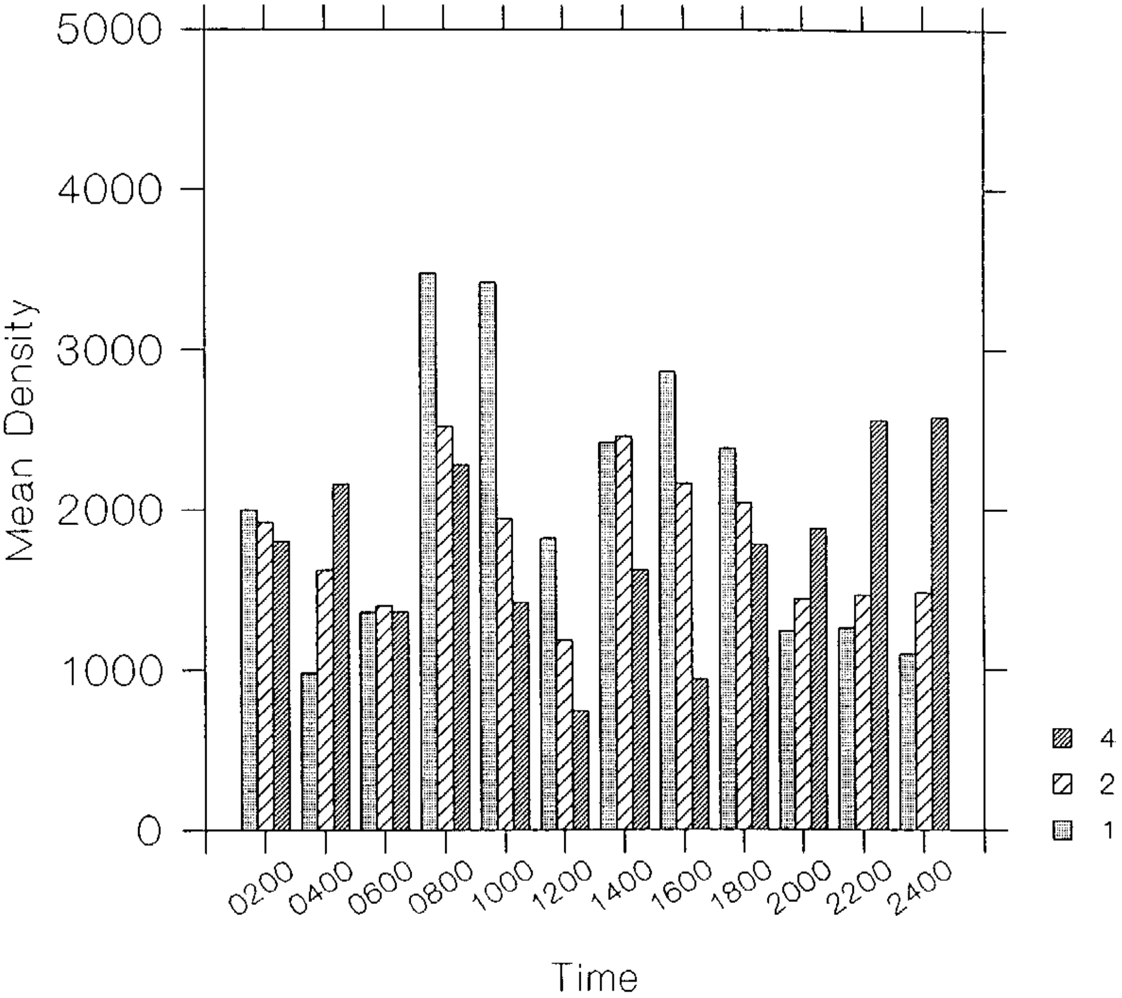
6/28/95 Crapmton Kellicottia



7/17/95 Brown Keratella



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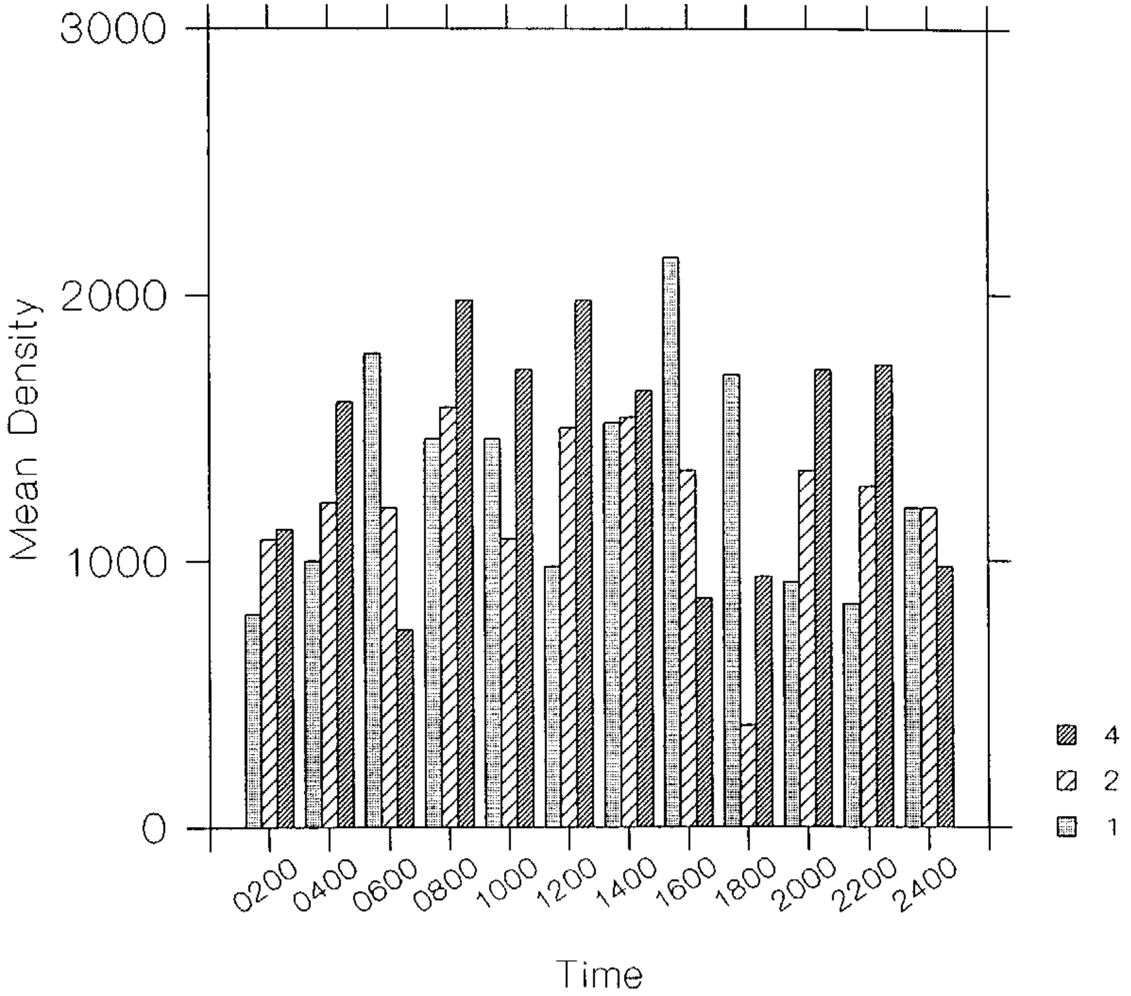

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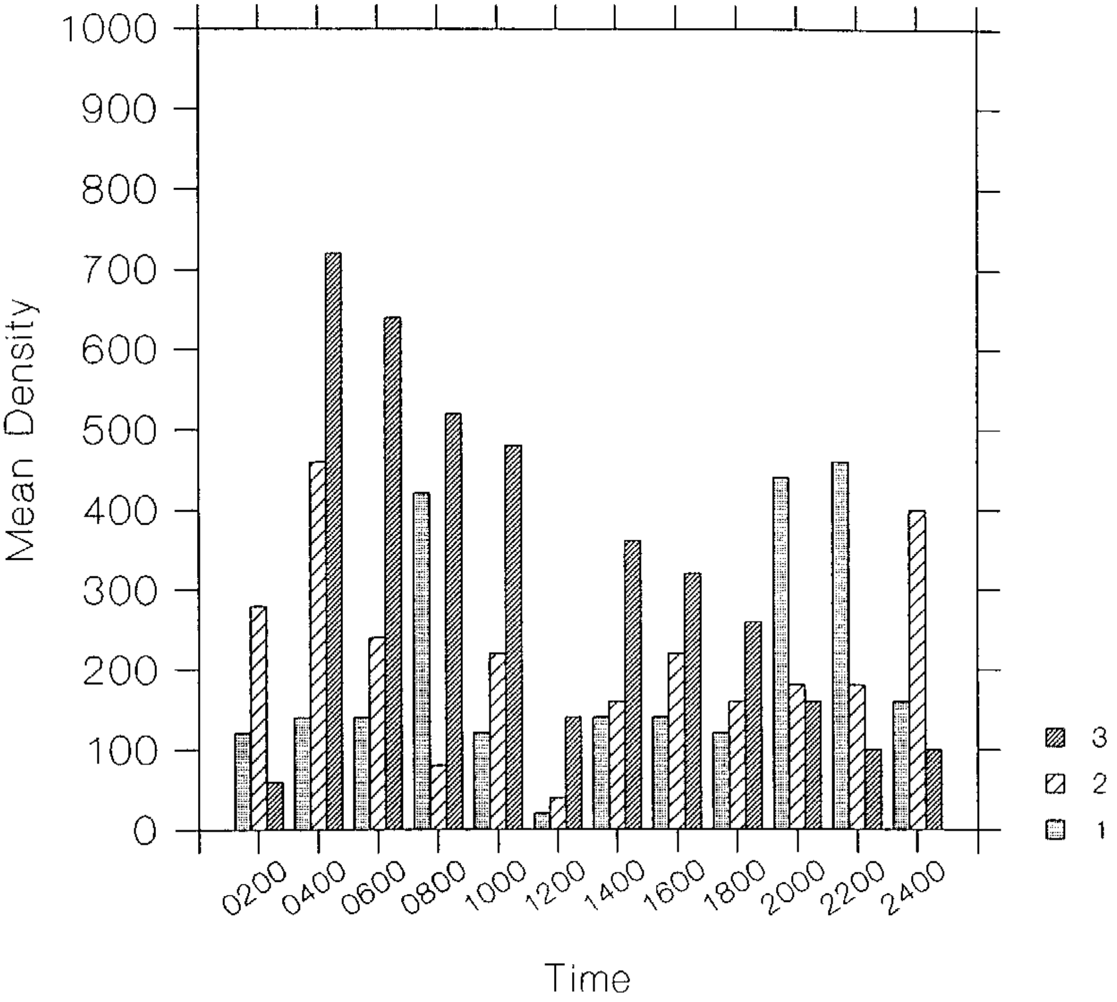

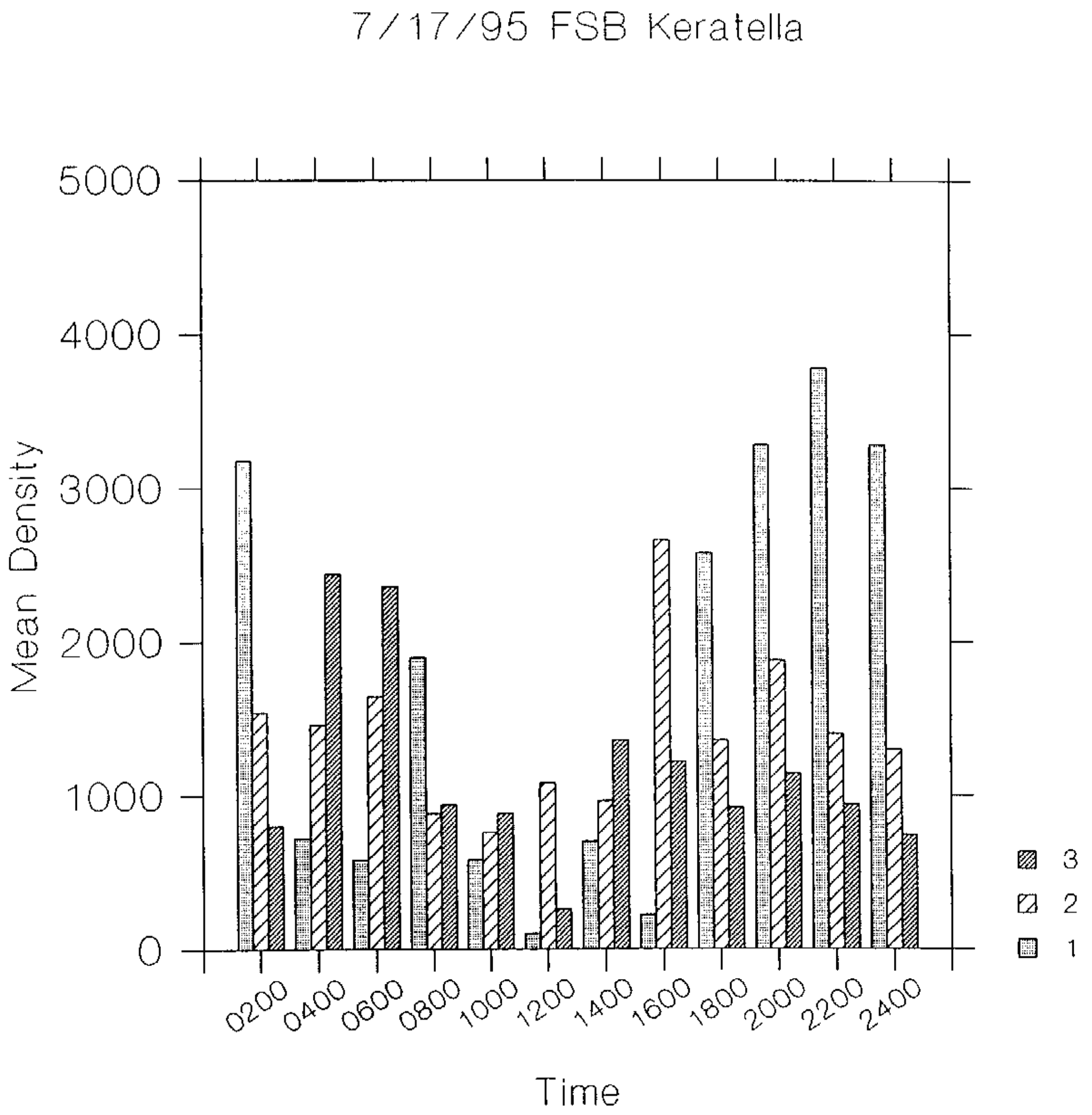

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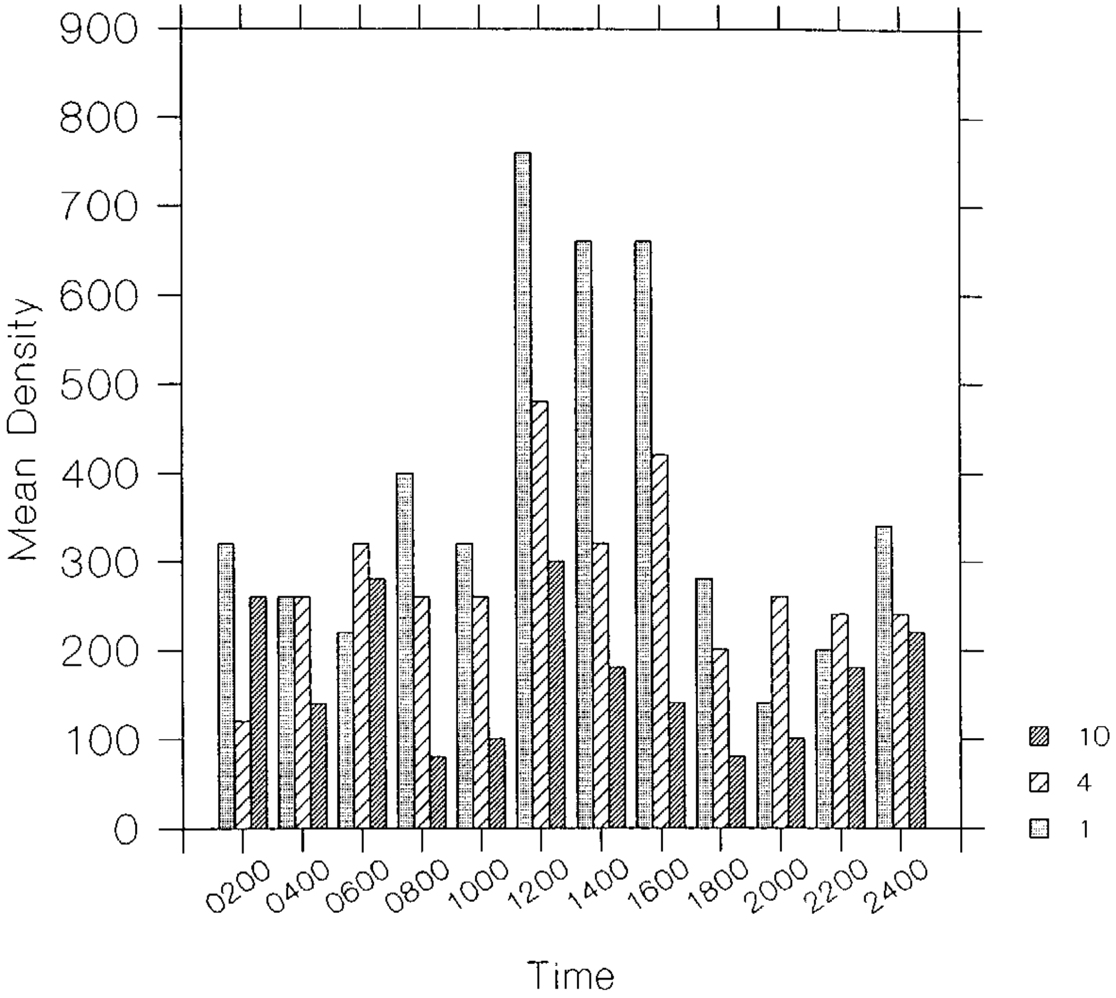
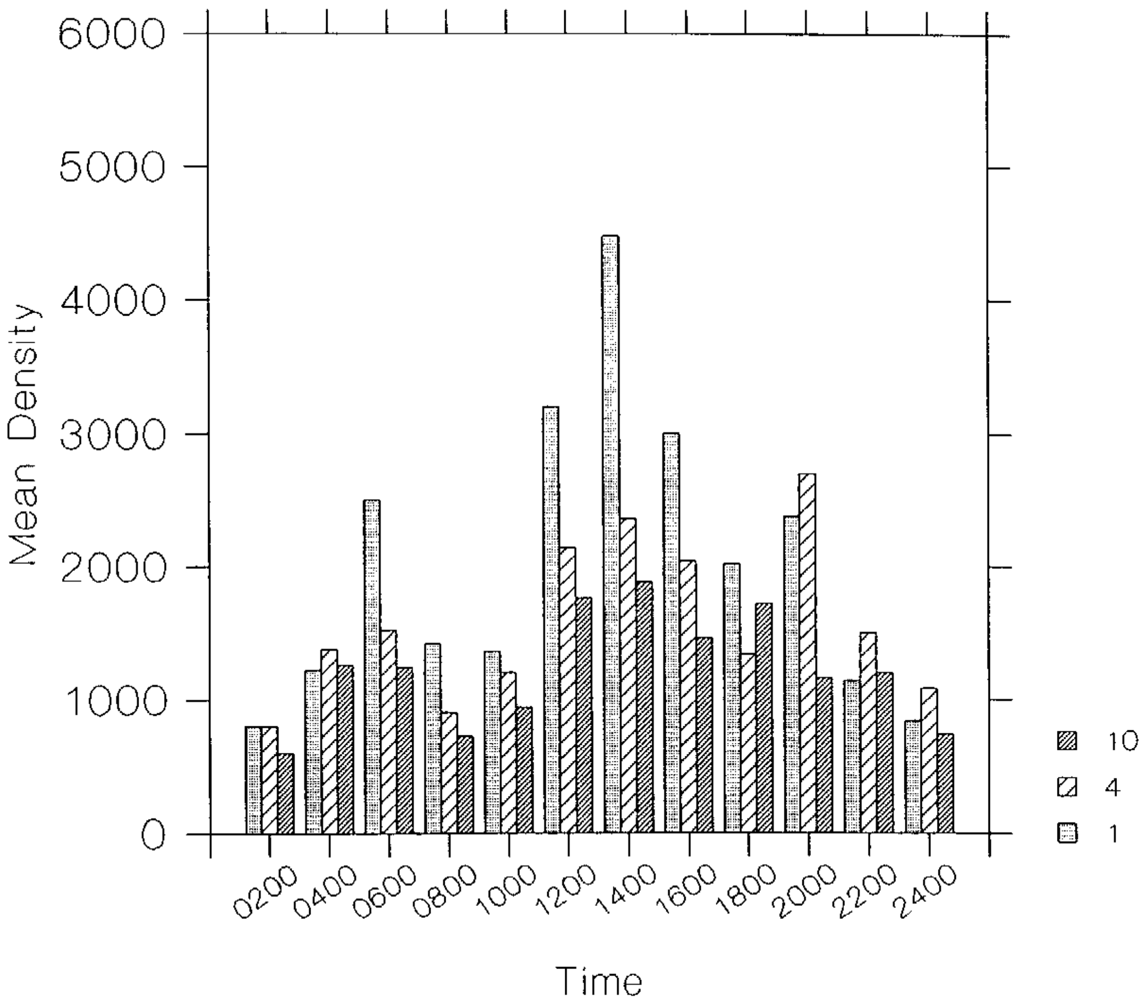
7/17/95 Crampton Polyarthra





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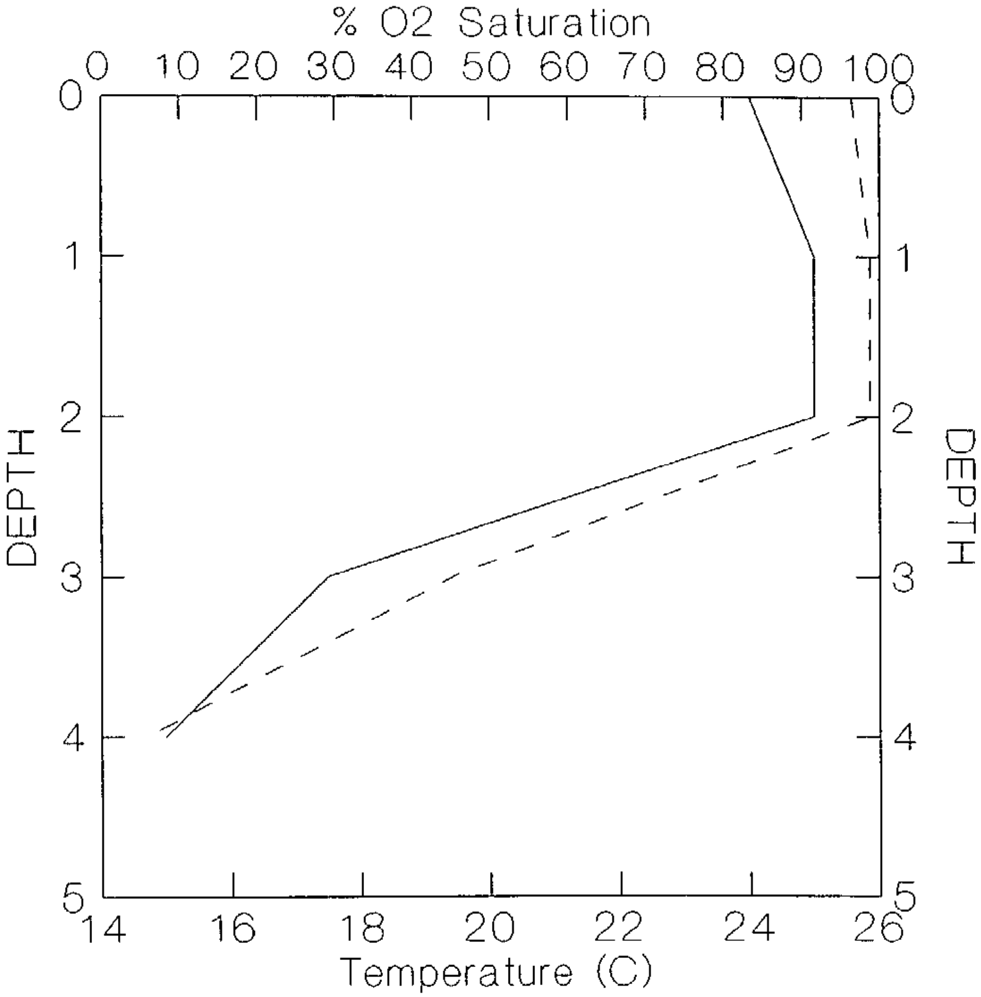
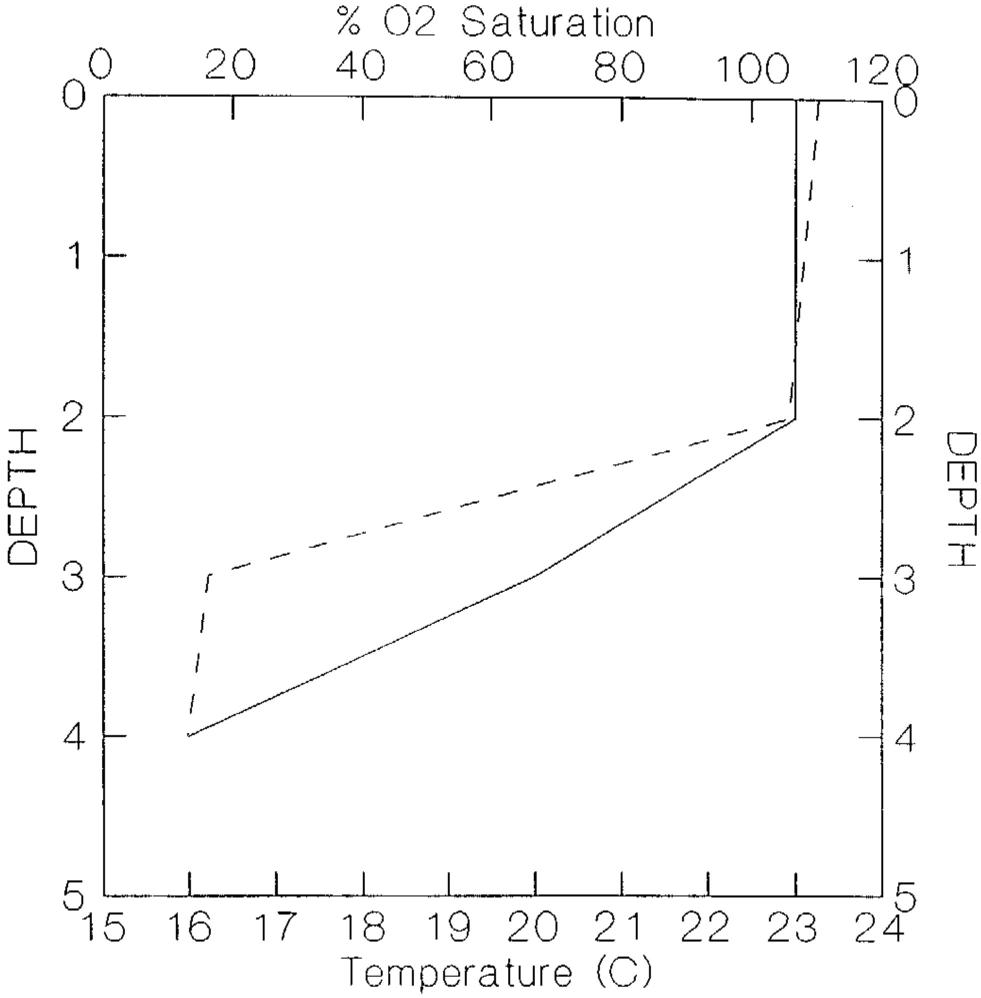
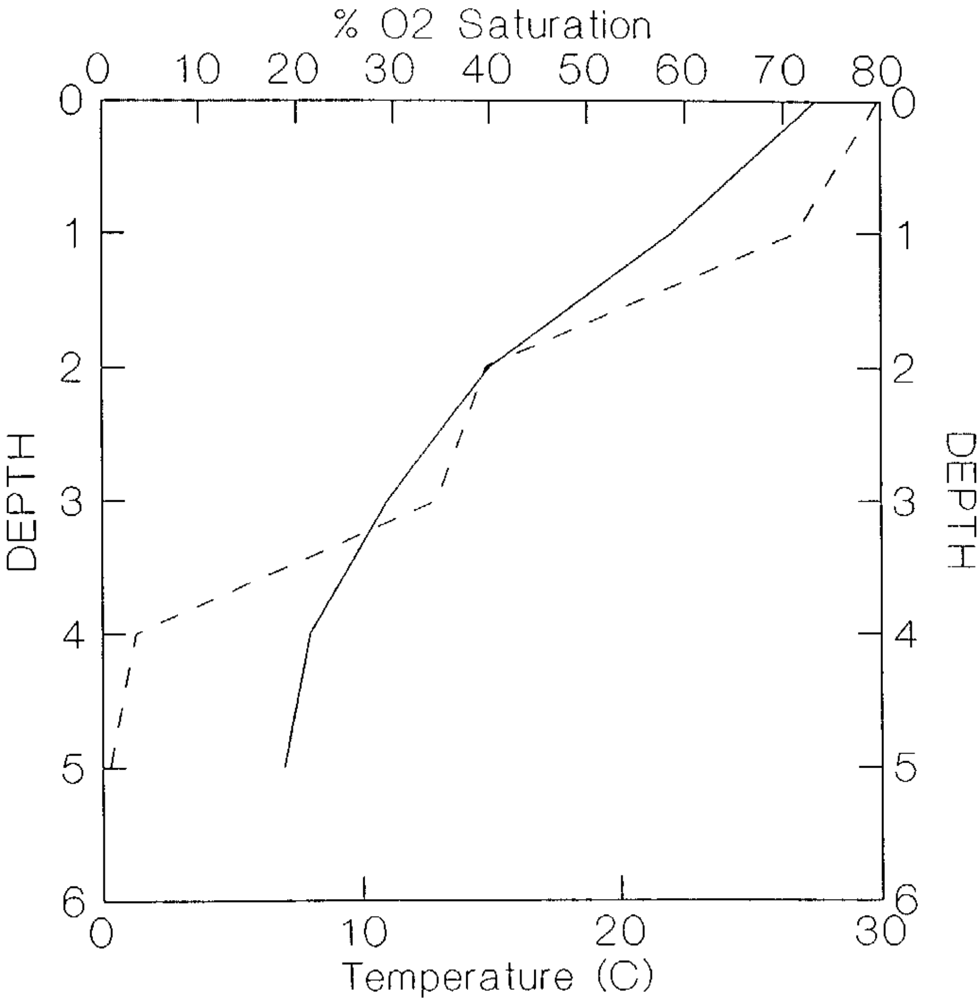
Brown Lake 6/28/95

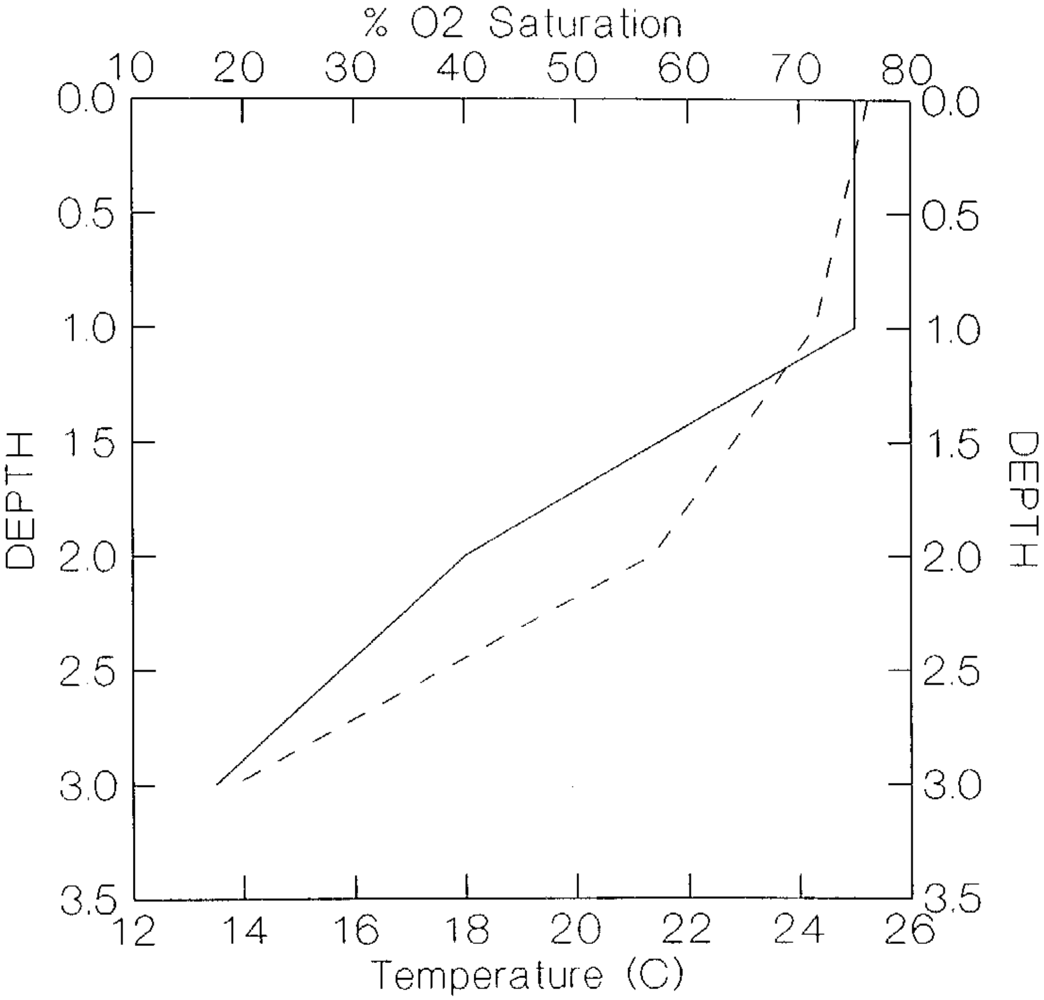


Brown Lake 7/17/95





Forest Service Bog 6/16/95



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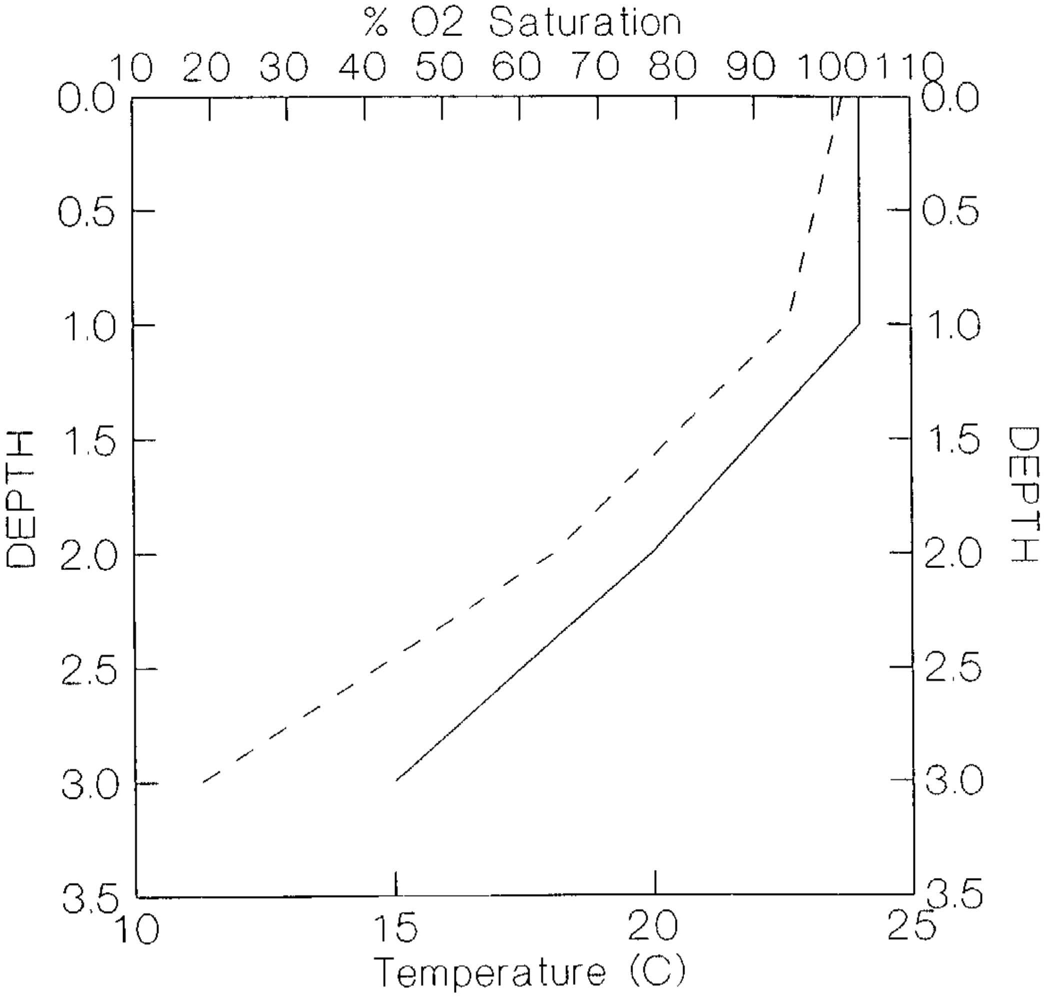
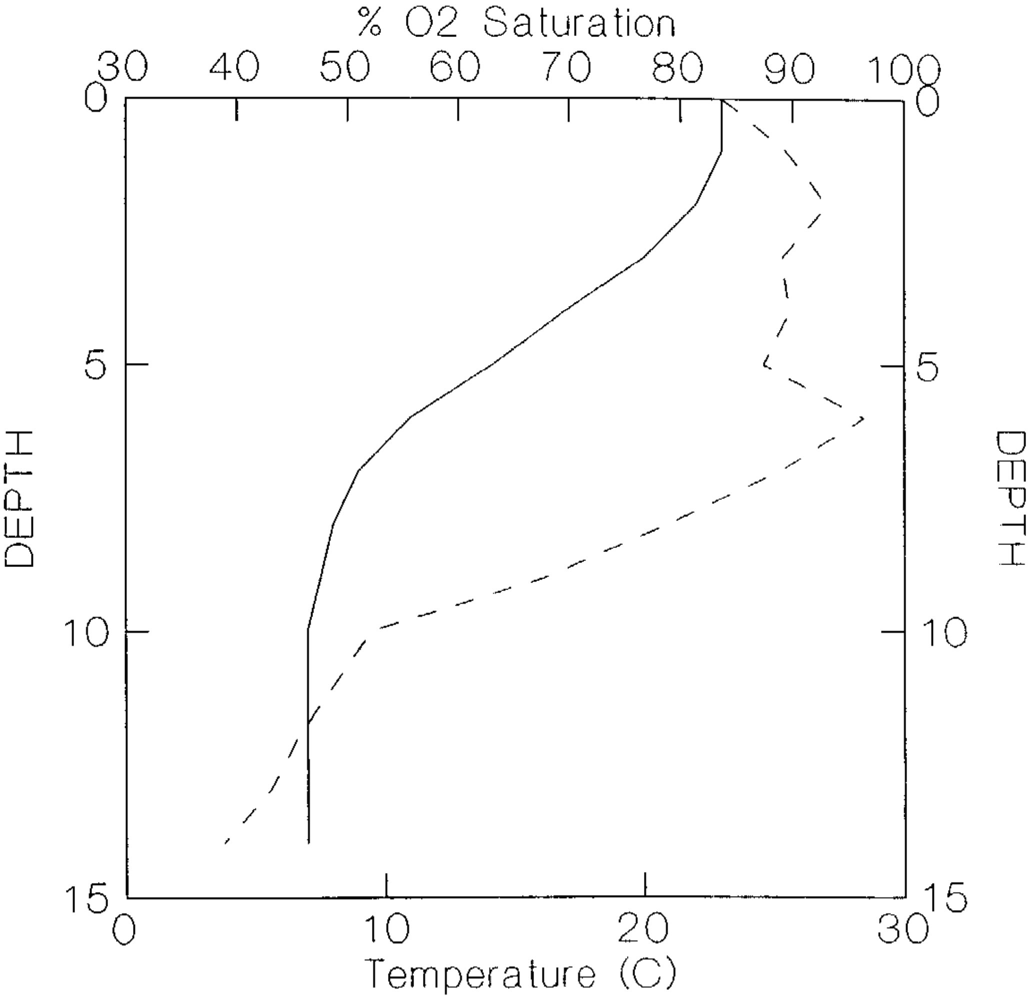
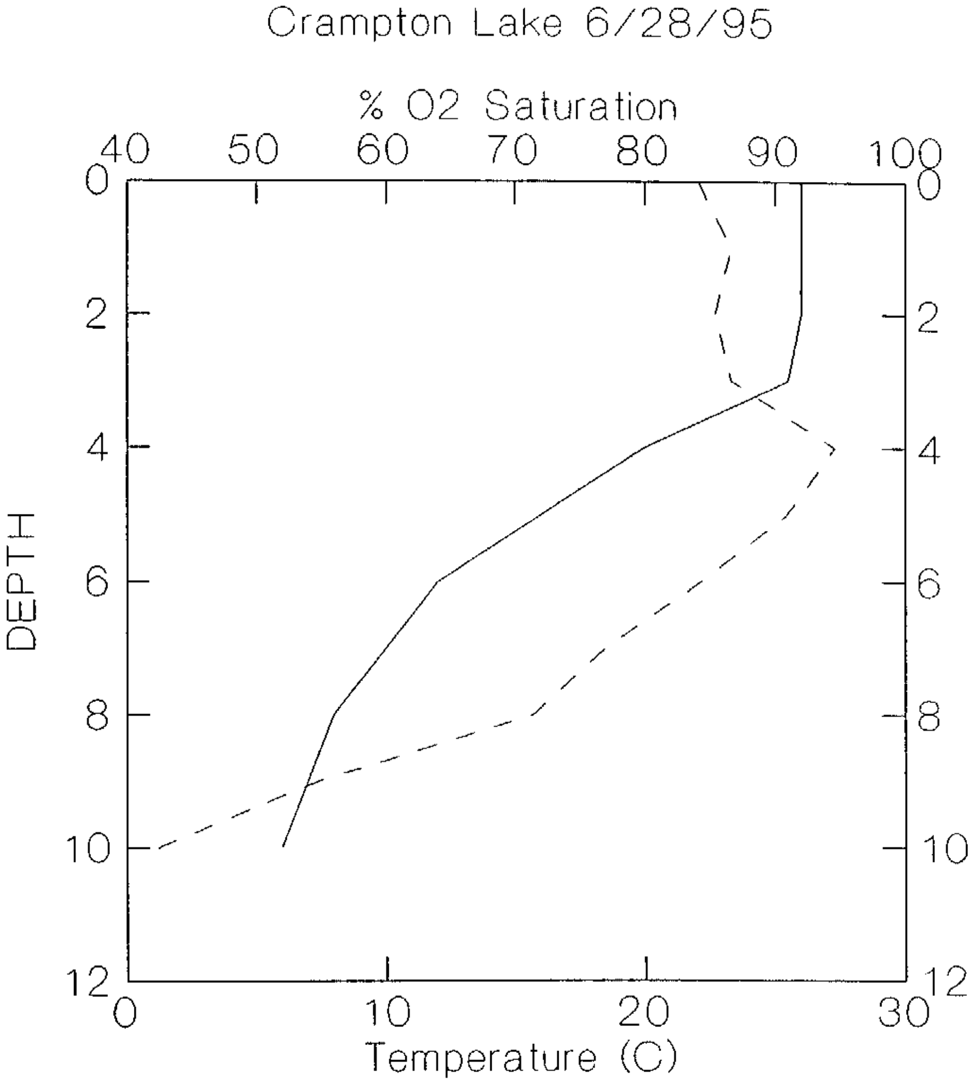
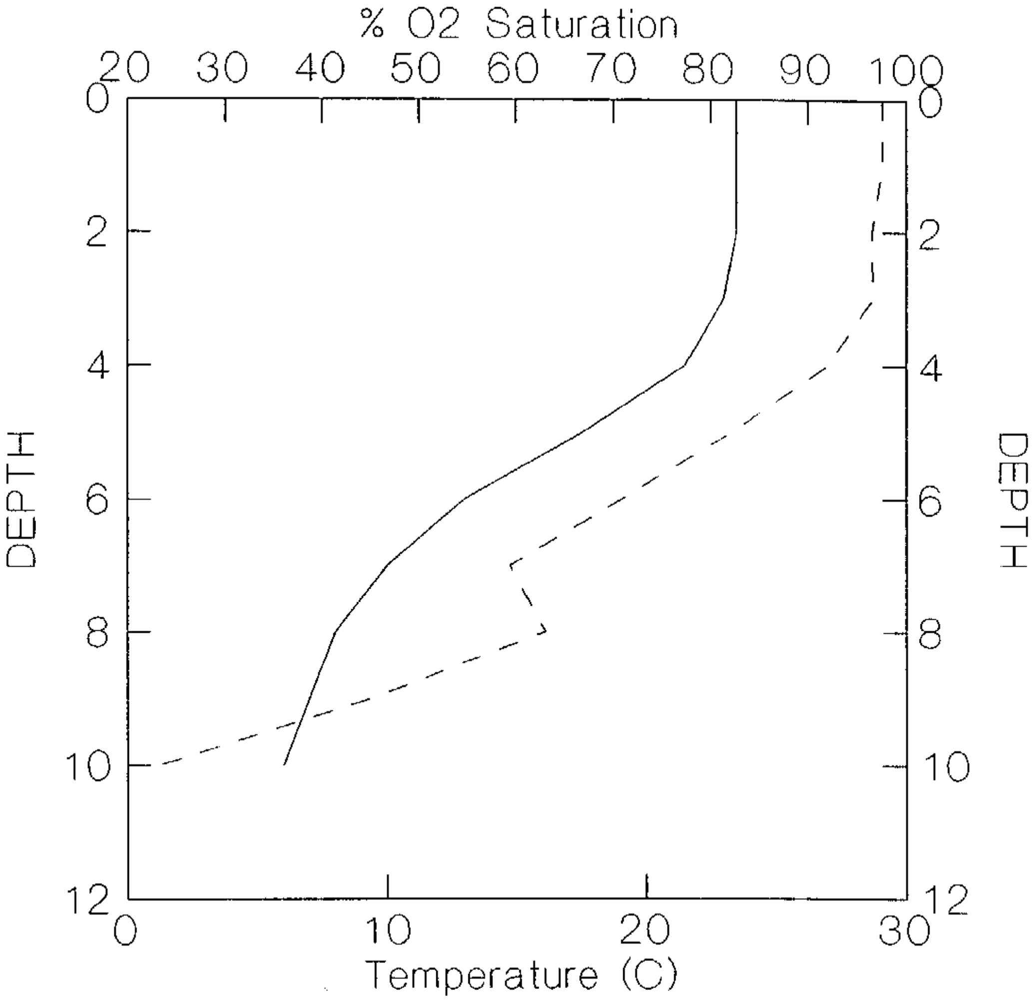
Forest Service Bog 7/17/95



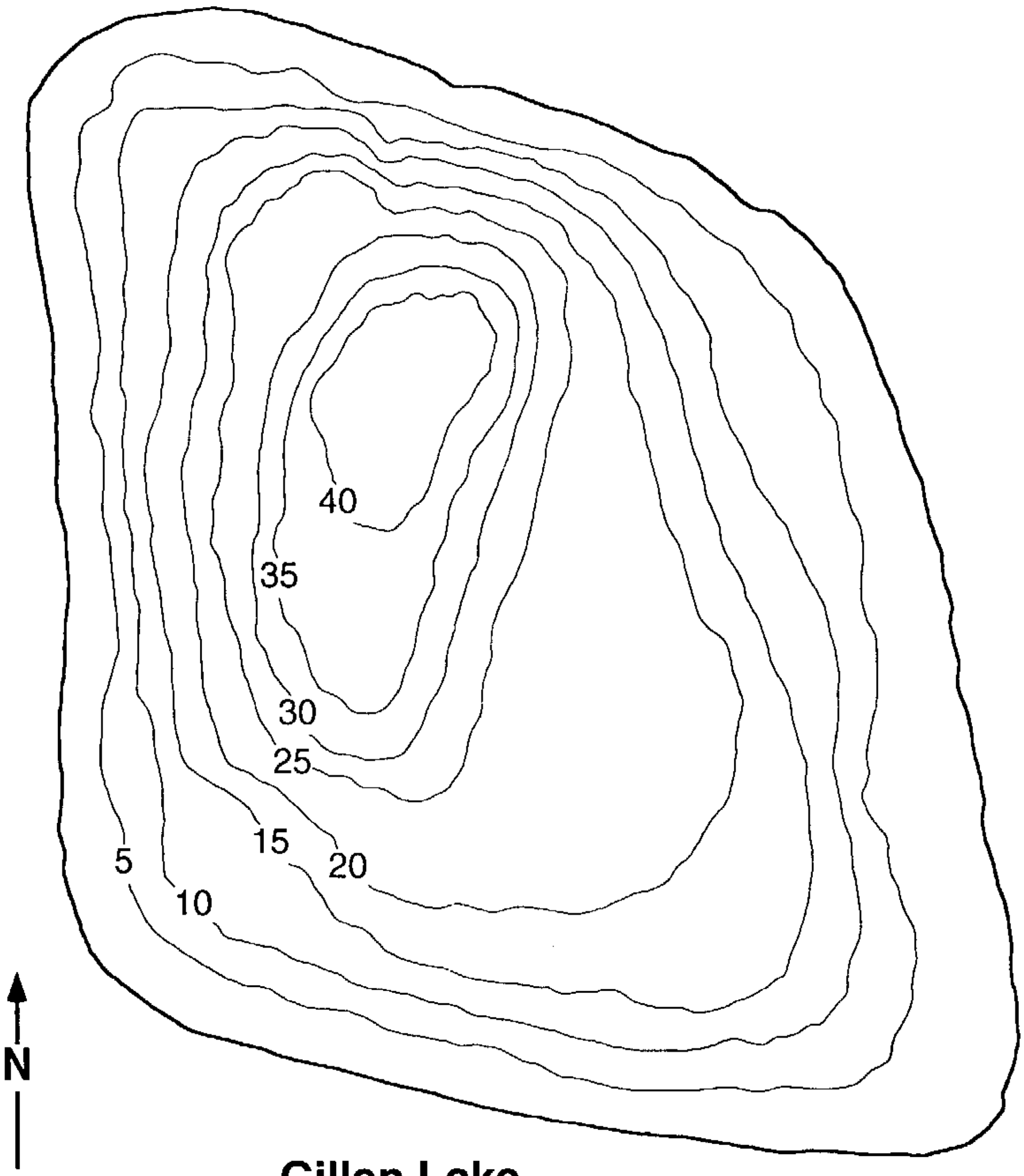


Crampton Lake 6/16/95


Crampton Lake 6/28/95
% O2 Saturation
40
50
60
70
80
90
100
0
2
4
6
8
10
12
DEPTH
DEPTH
0
10
20
30
Temperature (C)



Crampton Lake 7/17/95



Gillen Lake

University of Notre Dame
Environmental Research Center

Source: Honkamp, Stets & Tarkowski 1995

100 meters

contour depths in feet
1 m = 3.28 ft.; 1 ft. = .305 m

Brown Lake

University of Notre Dame
Environmental Research Center
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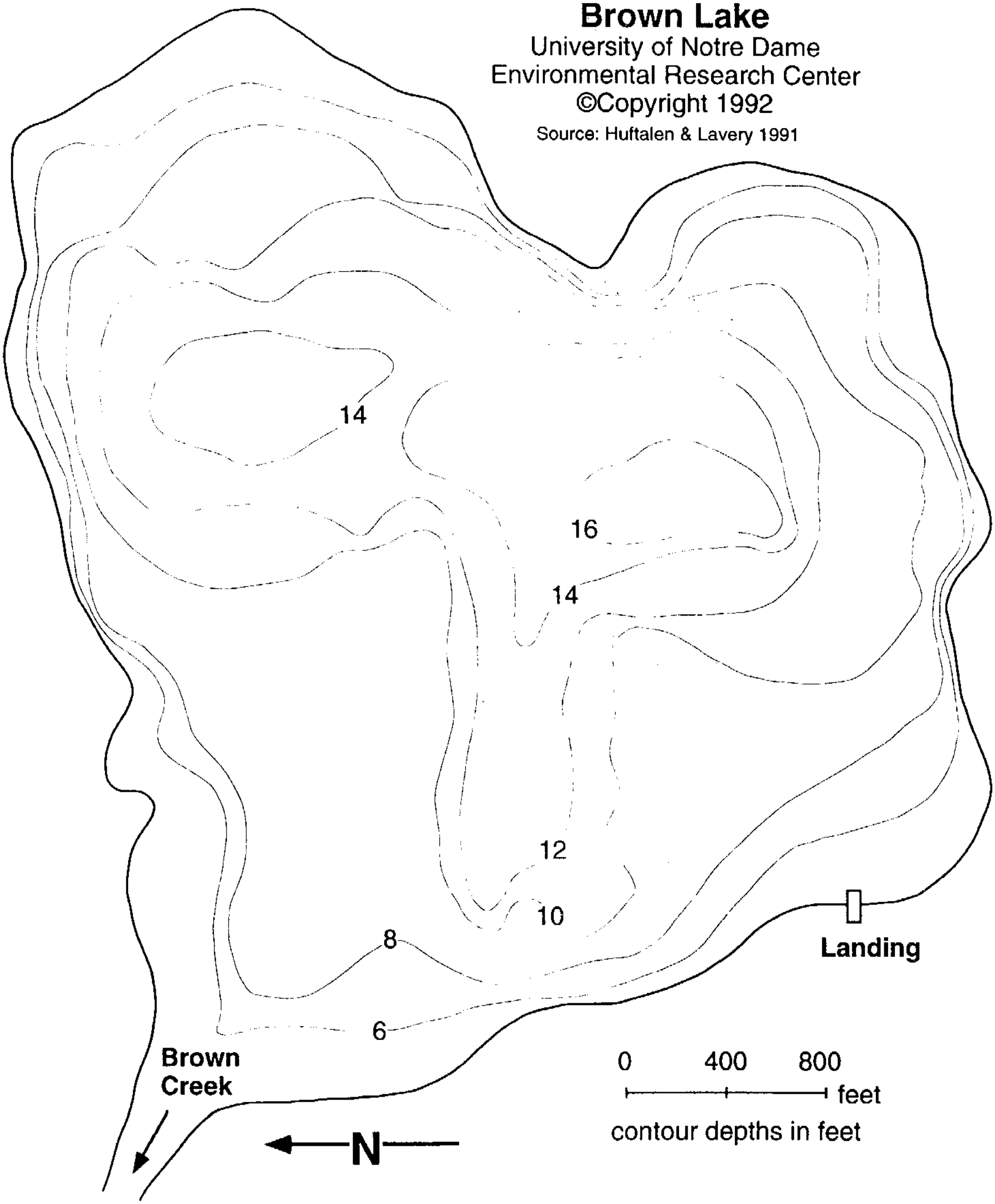
Source: Huftalen & Lavery 1991



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