Water Chemical Confines of the Aquatic Hemiptera

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Abstract

Aquatic Hemiptera occupy a wide range of habitats. Different species reside in specific water chemistry ranges. Thirteen sites were sampled for aquatic Hemiptera in order to demonstrate water chemistry qualities such as pH, alkalinity, conductivity, color, and light ranges with regard to the presence of specific species. Hemiptera from the Families Gerridae, Corixidae, Notonectidae, Belostomatidae, Pleidae, Nepidae, Hydrometridae, Microvelidae, and Veliidae were collected. Several possible correlations between water chemistry and species were found. The species (Notonectidae) *N. undulata* was found within small ranges for acidity, conductivity, and alkalinity. The Family Corixidae also displayed several connections between water chemistry and species. *S. mackinacensis*, *S. alternata*, and *S. compressoidea* all seemed to exhibit similar water chemistry ranges for pH, conductivity, and alkalinity. *S. decorata* and *S. transfigurata* were found only in highly acidic sites. *H. atopodonta* occupied sites with a narrow range of water color. *C. audeni* was the only Corixidae found at sites with light levels above 2.3 meters. *S. decorata* and *S. transfigurata* were never found within the same ranges for alkalinity and conductivity. *S. alternata* and *S. decorata* also never overlapped with regards to alkalinity and conductivity. *S. penniensis* and *S. conocephala* were never found within the same ranges for pH, conductivity, and color. All of the species within the Family Gerridae were found within wide ranges of habitats. Two pairs of Gerridae species were often found together: *G. marginatus* and *G. comatus*, and *G. argenticollis* and *G. buenoi*. The species (Veliidae) *M. pulchella* was only found in sites with low alkalinity.

<u>Introduction</u>

The aquatic Hemiptera are unique insects due to their unparalleled use of habitat. Not only is this Order of insect able to live in the littoral zone of lakes and bogs, but they also thrive upon the water surfaces. Since the aquatic Hemiptera are the only insect group to populate this particular habitat, less competition between insects occurs. (Dolling, 1991) As a result, much speciation occurs within the aquatic Hemiptera Order, making the aquatic Hemiptera an extremely populous and diverse group of insects.

The study of the aquatic Hemiptera's habitat is important from an economical standpoint. Most aquatic Hemiptera are predacious, with some of the species being voracious feeders of mosquito larvae. Through studying the environmental perimeters of aquatic Hemiptera, the use of these insects as a biological control agent against mosquitoes could be implemented. (Jayakumar, 1991) Despite this potential benefit, a limited amount of research has been accumulated on the specific habitats of the aquatic Hemiptera in a natural environment. Most of the research reported has taken place within a laboratory environment. Perhaps the reason for this void in information is the extreme diversity of the aquatic Hemiptera and their interaction with their habitat. In 1985, Bennett and Streams commented that it was possible for one aquatic Hemiptera species to occupy one specific habitat while a second, very similar species will occupy a completely different habitat perimeter. Some research has been done on specific species to determine certain confines of their habitat. Of the studies of species of aquatic Hemiptera found in Wisconsin, several perimeters have been found. Bennett and Streams (1986) discovered that (Notonectidae) *N. lunata* was found in the vegetation of fish ponds, while *N. undulata* was found predominately in fishless ponds and only associated with vegetation during the first instars. They also discovered the *N. insulata* was found in deeper water without fish or vegetation, while *N. irrorata* was randomly distributed with respect to vegetation and water depth. Another study by Bendell (1988) found that (Gerridae)

Meterobates Hesperius was never located in a lake with water acidity below the pH of 5.1.

These studies clearly indicate that specific perimeters do exist for certain species of aquatic Heteroptera. In order to determine the particular limitations of each species, a sampling of a great many lakes with different qualities must be taken. This experiment sampled thirteen sites with different qualities for aquatic Hemiptera. The project intended to utilize the data collected from this sampling in order to document the specific range of perimeters, if any, in which each aquatic Hemiptera species of Michigan is found in its natural environment.

Materials and Methods

Thirteen different lakes and bogs were sampled for Hemiptera. These sites included Brown Lake, Bolger Bog, Crampton Lake, Cranberry Lake, Bog Pot, Hummingbird Lake, Ed's Bog, Morris Lake, Reddington Lake, Tender Bog, Forest Service Bog, North Gate Bog, and Tuesday Lake. All of the sites were located on the property of the University of Notre Dame's Environmental Research Center located on the boarder of Wisconsin and the Upper Peninsula of Michigan. Each site varied in size, depth, surrounding vegetation, acidity, alkalinity, color, light, and conductivity. Bogs and acidic lakes were the main focus in the choice of sampling sites. Non-acidic lakes were included in the selection to allow for comparison. A major factor presiding over the selections was the accessibility of each lake or bog.

Water Chemistry Tests

In the first step of the project, water chemistry tests were performed. These tests included Temperature and Oxygen Profile, color, pH, conductivity, alkalinity, light, and sulfide. At each site, tests were performed from a boat in the deepest part of the lake or bog. Temperature, oxygen, pH, and conductivity were measured using the meter for each perspective test. Light was measured using a Secchi Disk. The Forel-Uhl method was used to test color. The presence of sulfide was determined by using the Kemmerer

Sampler. At half the Secchi Disk depth, a sample of water was taken using the Kemmerer Sampler and placed in a clean, plastic container. Conductivity and pH readings were also taken from the shore of each site. Each water sample which was taken was immediately placed in a refrigerator and processed for color and alkalinity within twenty-four hours. Tests for alkalinity and color were performed using the HACH protocol found in the HACH Water Analysis Handbook. All of the sites were sampled twice, with each sampling taking place a month apart.

Insect Sampling

The second part of the experiment consisted of sampling each site for Hemiptera. Using dip nets, the littoral zone of each site was sampled. Depending on the state of the edges of each site, the littoral zone was sampled either by foot or from a boat. If the perimeter was solid enough, the sampling was accomplished by using waders. When the perimeter was either not solid or overgrown with vegetation, a metal boat or rubber raft was utilized for sampling. All of the Hemiptera which were found were placed in glass jars filled with ninety percent ethanol. Each of the sites was sampled twice, with each sampling time spaced a month apart. Each round of sampling of the thirteen sites was performed within five days of each other in order to ensure that similar species would be found in the same stage of their life cycle. During the first set of samplings, two hours was spent collecting at each site. Due to increased efficiency at collecting, and hour and a half was spent at each site during the second sampling period. The total amount of littoral zone that was sampled was dependent upon the size of the site. Larger lakes had a smaller portion of littoral zone sampled, whereas the smaller lakes had a greater proportion of littoral zone sampled. Despite the size of the sampling site, different types of substrates and areas with varying vegetation were observed and sampled.

Identification of Insects

The final step in the experiment consisted of identifying the insects which had been collected. Using a dissecting microscope, insects were identified according to species. If immatures were found, these samples were identified according to Family or even Genus, if possible. Different keys were used in order to ensure the correct identification. After identification, each insect was place in a separate, small vile filled with ninety percent ethanol along with a label indicating the name of the species, site where it was found, and the date of the sampling.

Results

The water chemistry tests revealed the perimeters for the thirteen sites as shown in Table 1. Most of the sites were acidic, with twelve of them averaging under the pH of 6.9. North Gate Bog was the most acidic at an average of 4.2 and Brown Lake the least with an 8.15 average. A majority of the sites also displayed low conductivity. Ten of the sites averaged under 24.2. Forest Service Bog was the least conductive at 8.5, while Brown had a high conductivity at 104. Most of the sites were also of low alkalinity. Tender Bog, North Gate Bog, and Cranberry Lake were the least alkaline at 0, while Brown was the most alkaline at 50. A wide range of water color was demonstrated by the thirteen sites. The colors ranged from an average of 41 in Crampton to 320.5 in North Gate Bog. Light was also varied between the thirteen sites. Reddington Lake was the darkest with an average .65 meter Secchi Depth reading. Crampton provided the most light with an average 3.3 meter Secchi Depth reading. The calculated average of each perimeter sampled for each site is shown on Table 2. Oxygen/ Temperature readings for each site are as shown in Appendixes I-XXVI.

Hemiptera were found and collected at all of the thirteen sites. Hemiptera from the Families Gerridae, Corixidae, Notonectidae, Belostomatidae, Pleidae, Nepidae, Hydrometridae, Microvelidae, and Valiidae were found. Species and abundance within the collection are shown in Table 3. The most abundant site was Morris Lake with seventy-eight insects from twelve different species. Forest Service Bog was the most diverse site with thirteen different species and sixty-one insects collected. Ed's Bog was also very abundant, with twelve species collected from fifty-nine insects. North Gate Bog, Cranberry Lake, and Bog Pot also displayed diversity with ten species each from sixty-one, twenty-nine, and sixty-six insects respectively. In Bolger Bog, nine species of Hemiptera were found from thirty-nine insects. Eight species of insects were identified among Tuesday's forty-five insects that were collected. Both Brown and Reddington Lakes produced six species from twenty-three insects. Hummingbird Lake also maintained six different species, although only seventeen insects were collected from this site. In Tender Bog, five species of Hemiptera were identified from forty-eight insects. Crampton Lake was the least diverse site with only one species of Hemiptera identified out of thirty-eight insects that were collected.

The Gerridae, Corixidae, Notonectidae, Belostomatidae, Pleidae, Nepidae, and Hydrometridae Families were all found during both sampling periods. The Mesovelidae and the Veliidae were only found in the second, later sampling period. All of the instars, except for the Notonectidae Family, were found only during the second sampling period. The difference in distribution of insects between the first and second samplings can be seen in Tables 4 and 5.

Discussion

Two trends were noted from the results of the water chemistry tests. All of the sites except Morris decreased in their pH readings during the month between samplings. All of the Secchi Disk depths increased in length between the two readings except for Bog Pot, Morris, and North Gate. The readings for alkalinity, color, and conductivity fluctuated from the first sampling to the second, although no general trend was evident. Perhaps these fluctuations in water characteristics could explain the variation of species present at the same site during different sampling periods.

From the data collected on the Family Notonectidae, only a correlation between pH, conductivity, alkalinity, and the species *undulata* was detected. *N. undulata* was found within a small range for acidity, conductivity, and alkalinity. (Figures 1-3) Water color and light did not seem to effect the presence or absence of *undulata* since the sites where this insect was found possessed wide ranges for color and Secchi depth readings. (Figures 30-31) On the other hand, *N. lunata* generalized within several ranges of habitats, occurring in wide ranges for pH, conductivity, alkalinity, color, and Secchi depth. (Figures 1-5) The Notonectidae instars also were generalists with regard to water qualities, yet none were collected from lakes with fish. No correlation could be determined for *N. insulata* and *N. borealis*, since these species were only collected from one site.

Several possible correlations were apparent within the Family Corixidae. *S. mackinacensis*, *S. alternata*, and *S. compressoidea* all seemed to exhibit similar water chemistry ranges for pH, conductivity, and alkalinity. With regards to pH, *S. mackinacensis* was found between 4.7 and 6, *S. alternata* between 4.7 and 5.5, and *S. compressoidea* between 4.1 and 6. (Figure 6) All three species were found in an extremely low alkalinity range of 0 to 6 g/mL. (Figure 7) Both *S. mackinacensis* and *S. alternata* occupied the low conductivity range of 8 to 15 us/cm, while *S. compressoidea* was found in a larger range from 8 to 36. (Figure 8) Color only seemed to effect S. *mackinacensis* and *S. alternata*, with *S. mackinacensis* occupying the slightly smaller range of 51-98, compared to *S. alternata*'s 36-127. *S. compressoidea* was found in a wide range of colored water. (Figure 9) Light did not determine habitat for any of these three species, as they were found in all light ranges from .7m to 2.3 m (Figure 10).

Other species exhibited different ranges of habitats. Both *S. decorata* and *S.transfigurata* occupied high pH ranges. (Figure 6) *S. transfigurata* also occupied higher ranges of alkalinity and conductivity compared to most of the other species that were collected. (Figure 7 and 8) *C. audeni* was the only Corixidae found at light levels above 2.3 meters. *H. atopodonta* occupied the widest ranges for pH, alkalinity, and conductivity, thus generalizing over all habitats. Yet, *H. atopodonta* only occupied a narrow range of water color ranges from 98 to 104. *H. knighti* was also found over a wide pH range. No correlation could be determined between water chemistry and species for *S. conocephala, S. johnstoni, S. doloebra, S. variablis, H. scabricula, H. michganensis, H. variablis, H.vulgaris, H. kennicotti*, and *C. alaskensis*.

Certain species were not found within overlapping ranges for specific water qualities. For alkalinity and conductivity, *S. decorata* and *S. transfigurata* both had wide ranges but were never found within the same range for these qualities. This also occured for *S. alternata* and *S. decorata* with regards to pH, conductivity, and color. *S. penniensis* and *S. conocephala* never overlapped in their ranges for pH, conductivity, and color. These findings could suggest that these qualities are confines for the habitats of these particular species.

Compared to the other Families of Hemiptera that were studied, the species of Gerridae occupied the widest range of water qualities. Their ability to adapt to a great many habitats is possibly due to their capability to live on the water surface rather than in the water. All Gerridae species were found in wide pH ranges, although *G. dissortis* was found in an extremely small range of 4.6- 4.7 for only two sites. (Figure 11) *G. marginatus* and *G. comatus* were found in almost all ranges of alkalinity. *G. argenticollis* and *G. buenoi* also occupied wide ranges, yet they were considerably lower from 0 to 28 mg/L. *G. alacris* was found in the lowest range from 0 to 15 mg/L. (Figure 12) With regards to conductivity, *G. marginatus* and *G. comatus* were again generalists. *G. buenoi* occupied a broad, but lower range. A habitat restriction as a result of conductivity may exist for *G. argenticollis* because it was only found within the small range of 8 to 30 from eight different sites. (Figure 13) *G.argenticollis, G. buenoi, G. comatus*, and *G. marginatus* all occupied wide ranges for color, with *G. comatus* and *G. marginatus* smaller than *G. argenticollis* and *G. buenoi*. *G. dissortis* appeared in a wide range of water colors for only two collection sites, ranging from 114 to 274. (Figure 14) *G. marginatus* has the widest range of light of all of the Gerridae species found. *G. argenticollis* and *G. buenoi* both fell into the same ranges of light from .7 to 2.3 m. *G.*

comatus had the smallest range of light by only being found in sites that had .7 to 1.6 meter Secchi depth readings. *G. dissortis* again had a wide range of water chemistry qualities, appearing from sites with .8 m to 1.6 m of light. (Figure 15) Nothing could be confirmed about the habitat of *G. inseperatus* since this species was only found at one site. Overall, the species *G. marginatus* and *G. comatus* followed the same trends together, while *G. argenticollis* and *G. buenoi* were found at sites with the same water qualities.

The other families of Hemiptera that were found displayed different ranges for different species. The Pleidae (*P. striola*), Nepidae (*R. fusca*), and Mesovelidae (*M. musanti)* all appeared in wide ranges of water qualities. These ranges were specific to each species and are fairly certain due to the great number of sites from which they were collected. The Belostomatidae (*L. americanus*) appeared in a wide range of water qualities for pH, color, and light, yet only appeared in sites with low alkalinity and conductivity. (Although the instars appeared at sites with slightly higher alkalinity and conductivity.) The Veliidae (*M. pulchella*) was found at a wide ranges for pH and light, yet only appeared in areas of low alkalinity (0-12 mg/L), conductivity (20.2- 36 us/cm), and high ranges of color (177- 274). (Figures 16-20)

Table 1. Water Chemical Perimeters of Sampling Sites

Sample 1- 5/25/96					
Site	Ph	Conductivity	Alkalinity	Color	Secchi
Br	8	1.01	50	104	1.1
Bol	6	20	10	144	0.9
BP	5.5	13.4	2	127	0.9
Cran	4.7	15.1	0	98	1.2
Cram	6.1	14.4	4	62	3.1
Ed's	4.6	16	4	114	1.2
F.S.	4.7	8	6	51	1.2
Hum	4.7	20.3	2	217	0.7
Mor	7.1	56.2	26	208	1
N.G.	4.1	30	0	402	0.8
Red	5.7	22.5	8	298	0.6
T.B.	4.3	26.4	0	151	1.2
T	6	11.5	2	63	1.5
Sample 2- 6/27/96					
Site	Ph	Conductivity	Alkalinity	Color	Secchi
Br	8.3	107.5	50	54	1.6
Bol	7.3	28.4	14	145	0.95
BP	5.7	15	2	182	0.8
Cran	4.7	11.2	0	95	1.3
Cram	6.2	14.2	6	20	3.5
Ed's	4.7	14.1	2	140	1.6
F.S.	5.2	9	0	36	2.3
Hum	4.9	20.2	0	274	0.75
Mor	6.7	61.3	28	183	0.7
N.G.	4.3	36	0	239	0.7
Red	7.1	23	12	246	0.7
T.B.	4.5	20.5	0	177	1.6
T	6.4	12.4	1	58	1.75

key

Br = Brown Lake
Bol = Bolger Bog
BP = Bog Pot
Cran = Cranberry Lake
Cram = Crampton Lake
Ed's = Ed's Bog
FS = Forest Service Bog
Hum = Hummingbird Lake
Mor = Morris Lake
NG = North Gate Bog
Red = Reddington Lake
TB = Tender Bog
T = Tuesday Lake

Table 2. Average Measurements

Site	pH	Conductivity (um/cm)	Alkalinity (mg/L)	Color (pts.	Secchi (m)
Brown	8.15	104	50	79	1.35
Bolger	6.65	24.2	12	144.5	0.925
BP	5.6	14.2	2	154.5	0.85
Cran	4.7	13.15	0	96.5	1.25
Cram	6.15	14.3	5	41	3.3
Ed's	4.65	15.05	3	127	1.4
FS	4.95	8.5	3	43.5	1.75
Hum	4.8	20.25	1	245.5	0.725
Mor	6.9	58.75	27	195.5	0.85
NG	4.2	33	0	320.5	0.75
Red	6.4	22.75	10	272	0.65
TB	4.4	23.5	0	164	1.4
Tues	6.2	11.95	1.5	60.5	1.625

Table 3. Total Hemiptera Collected

Species	Br	Bol	BP	Cran	Cram	Ed	FS	Hum	Mor	NG	Red	TB	T
G. marginatus	3	1	4		1		1	1	4				
G. argenticollis		2	2			9	4		1	7	4	6	
G. comatus	2	1	2	1				3	3		1		
G. buenoi			1			1	1	2	1	2	3		2
G. dissortis						3		1					
G. alacris		3										2	
G. inseperatus		1											
G. instar		4	6	1	37	4	2	6	3	2	1	8	5
C. Sig. penniensis				1			1						
C. Sig. conocephala						2							
C. Sig. johnstoni			3										
C. Sig. mackinacensis				2			1						7
C.Sig. compressoidea				2			10			4		2	4
C. Sig. alternata			1			1	5						
C. Sig. decorata			2						4				
C. Sig. doloebra						1							
C. Sig. transfigurata	1								23				
C. Sig. knighti				2							3		
C. Sig. variablis													1
C. Hesp. scabricula							2						
C. Hesp. atopodonta	1			1									
C. Hesp. michganensis				1									
C. Hesp. vulgaris						1							
C. Hesp. kennicotti									1				
C. Call. audeni						1							1
C. Call. alaskensis							1						
C. instar		2	3			5	3		17	2	3		19
N. lunata	2	1					1		4		1		1
N. insulata				1									
N. borealis						2							
N. undulata						1	4			1			
N. instar		3	36	8		12	15	1		30	2	26	
B. Leth. amer.										1			2
B. instar		2	1	5		11			10	1	1	1	1
P. Plea striola	14	16						1	1	4			
Nep. Ranatra fusca		1	3	3		4	7		2	3	1	2	2
Hydro. Hydro martini			1						1				
M. M. musanti		2	1			1	3		3	1			
M. M. crytophila										1			
V. M. pulchella								2		2	3	1	
V. M. buenoi				1									
Total Gerris	**5**	**12**	**15**	**2**	**38**	**17**	**8**	**13**	**12**	**11**	**9**	**16**	**7**
Total Sigara	**1**	**0**	**6**	**7**	**0**	**4**	**17**	**0**	**27**	**4**	**3**	**2**	**12**
Total Hespercorixa	**1**	**0**	**0**	**2**	**0**	**1**	**2**	**0**	**1**	**0**	**0**	**0**	**0**
Total Callicorixa	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**1**
Total Corixidae	**2**	**2**	**9**	**9**	**0**	**11**	**23**	**0**	**44**	**6**	**6**	**2**	**32**
Total Notonectidae	**2**	**4**	**36**	**9**	**0**	**15**	**20**	**1**	**5**	**31**	**3**	**26**	**1**
Total	**9**	**16**	**60**	**20**	**38**	**43**	**51**	**14**	**61**	**48**	**18**	**44**	**40**

Total Hemiptera **23 39 66 29 38 59 61 17 78 61 23 48 45**

Table 4. First Sampling Collection

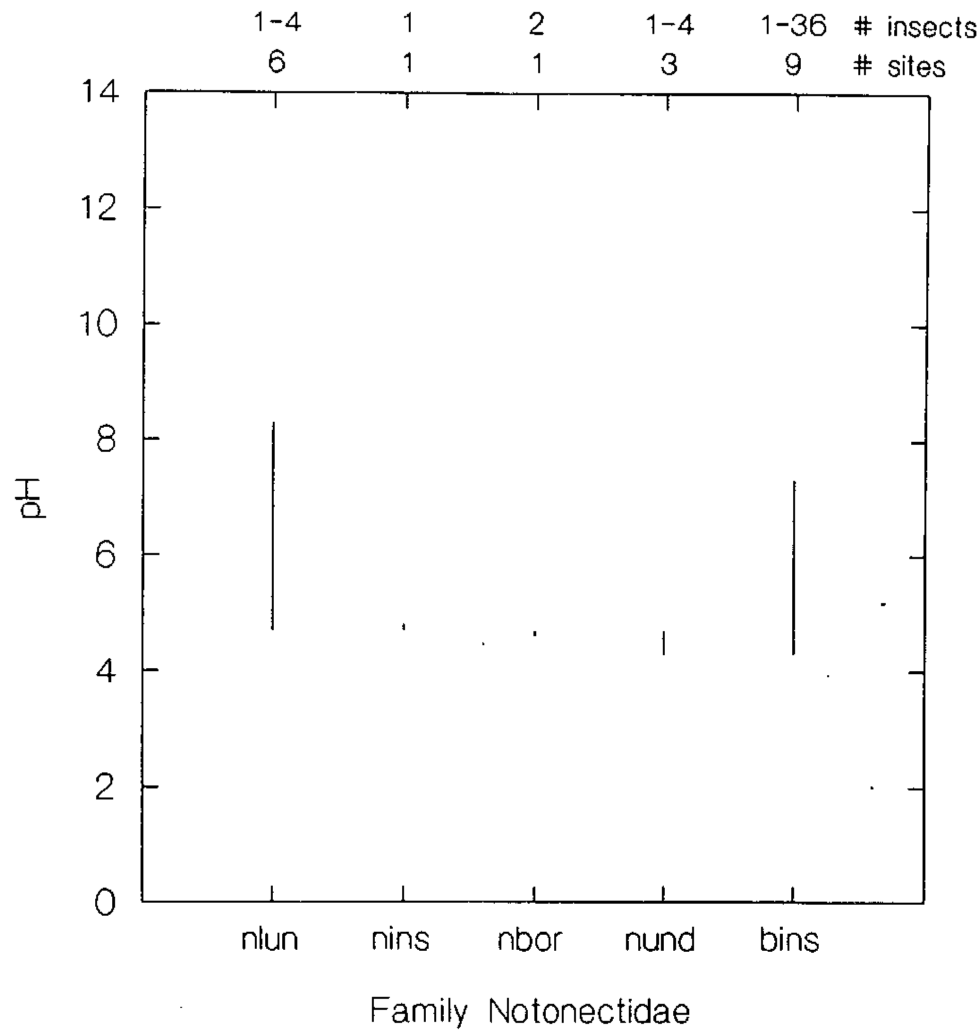
Species	Br	Bol	BP	Cran	Cram	Ed	FS	Hum	Mor	NG	Red	TF	T
G. marginatus	2	1	2		1		1	1	1				
G. argenticollis		1	1			1	2			5	1	2	
G.comatus		1									1		
G. buenoi			1			1				1	1		
G. dissortis								1					
G. instar		1		1					2			1	1
G. alacris												2	
G. inseperatus		1											
C. Sig. penniensis							1						
C. Sig. conocephala						1							
C. Sig. johnstoni			3										
C. Sig. mackinacensis				1			1						5
C. Sig. compressiodea				2			10			3			3
C. Sig. alternata			1				3						
C. Sig. decorata			2						4				
C. Sig. doloebra						1							
C. Sig. transfugurata	1								13				
C. Hesp. scarbicula							2						
C. Hesp. atopodonta	1			1									
C. Hesp. michganensis				1									
C. Hesp. vulgaris						1							
C. Calli audeni						1							
N. lunata	1	1					1		3		1		1
N. insulata				1									
N. borealis						1							
N. undulata							4						
B. Leth. amer.										1			2
P. Plea striola	11	11						1	1	3			
Nep. Ranatra fusca						1	2		2			1	2
Hydro. Hydro martini									1				
N. instar												12	
Total Gerridae	**2**	**5**	**4**	**1**	**1**	**2**	**3**	**2**	**3**	**6**	**3**	**5**	**1**
Total Sigara	**1**	**0**	**6**	**3**	**0**	**2**	**15**	**0**	**17**	**3**	**0**	**0**	**8**
Total Hespercorixa	**1**	**0**	**0**	**2**	**0**	**1**	**2**	**0**	**0**	**0**	**0**	**0**	**0**
Total Callicorixa	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total Corixidae	**2**	**0**	**6**	**5**	**0**	**4**	**17**	**0**	**17**	**3**	**0**	**0**	**8**
Total Notonectidae	**1**	**1**	**0**	**1**	**0**	**1**	**5**	**0**	**3**	**0**	**1**	**12**	**1**
Total	**5**	**6**	**10**	**7**	**1**	**7**	**25**	**2**	**23**	**9**	**4**	**17**	**10**
Total Hemiptera	16	17	10	7	1	8	27	3	27	13	4	18	14

Table 5. Second Sampling Collection

Species	Br	Bol	BP	Cran	Cram	Ed	FS	Hum	Mor	NG	Red	TB	T
G. marginatus	1		2						3				
G. argenticollis		1	1			8	2		1	2	3	4	
G. comatus	2		2	1				3	3				
G. buenoi							1	2	1	1	2		2
G. dissortis						3							
G. alacris		3											
G. inseperatus													
G. instar		3	6		37	4	2	6	1	2	1	7	4
C. Sig. penniensis				1									
C. Sig. conocephala						1							
C. Sig. johnstoni													
C. Sig. mackinacensis				1									2
C.Sig. compressoidea										1		2	1
C. Sig. alternata						1	2						
C. Sig. decorata													
C. Sig. doloebra													
C. Sig. transfigurata									10				
C. Sig. knighti				2							3		
C. Sig. variablis													1
C. Hesp. scabricula													
C. Hesp. atopodonta													
C. Hesp. michganensis													
C. Hesp. vulgaris													
C. Hesp. kennicotti									1				
C. Call. audeni													1
C. Call. alaskensis							1						
C. instar		2	3			5	3		17	2	3		19
N. lunata	1								1				
N. insulata													
N. borealis						1							
N. undulata						1				1			
N. instar		3	36	8		12	15	1		30	2	14	
B. Leth. amer.													
B. instar		2	1	5		11			10	1	1	1	1
P. Plea striola	3	5								1			
Nep. Ranatra fusca		1	3	3		3	5			3	1	1	
Hydro. Hydro martini			1										
M. M. musanti		2	1			1	3		3	1			
M. M. crytophila										1			
V. M. pulchella								2		2	3	1	
V. M. buenoi				1									
Total Gerris	**3**	**7**	**11**	**1**	**37**	**15**	**5**	**11**	**9**	**5**	**6**	**11**	**6**
Total Sigara	**0**	**0**	**0**	**4**	**0**	**2**	**2**	**0**	**10**	**1**	**3**	**2**	**4**
Total Hespercorixa	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**
Total Callicorixa	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**1**
Total Corixidae	**0**	**2**	**3**	**4**	**0**	**7**	**6**	**0**	**27**	**3**	**6**	**2**	**24**
Total Notonectidae	**1**	**3**	**36**	**8**	**0**	**14**	**15**	**1**	**2**	**31**	**2**	**14**	**0**
Total	**4**	**12**	**50**	**13**	**37**	**36**	**26**	**12**	**38**	**39**	**14**	**27**	**30**

Total Hemiptera	**7**	**22**	**56**	**22**	**37**	**51**	**34**	**14**	**51**	**48**	**19**	**30**	**31**

Fig. 1. pH Ranges of Family Notonectidae



Family Notonectidae
nlun = Notonecta lunata
nins = Notonecta insulata
nbor = Notonecta borealis
nund = Notonecta undulata
ninst = Notonecta instars

Fig. 2. Conductivity Ranges of Family Notonectidae

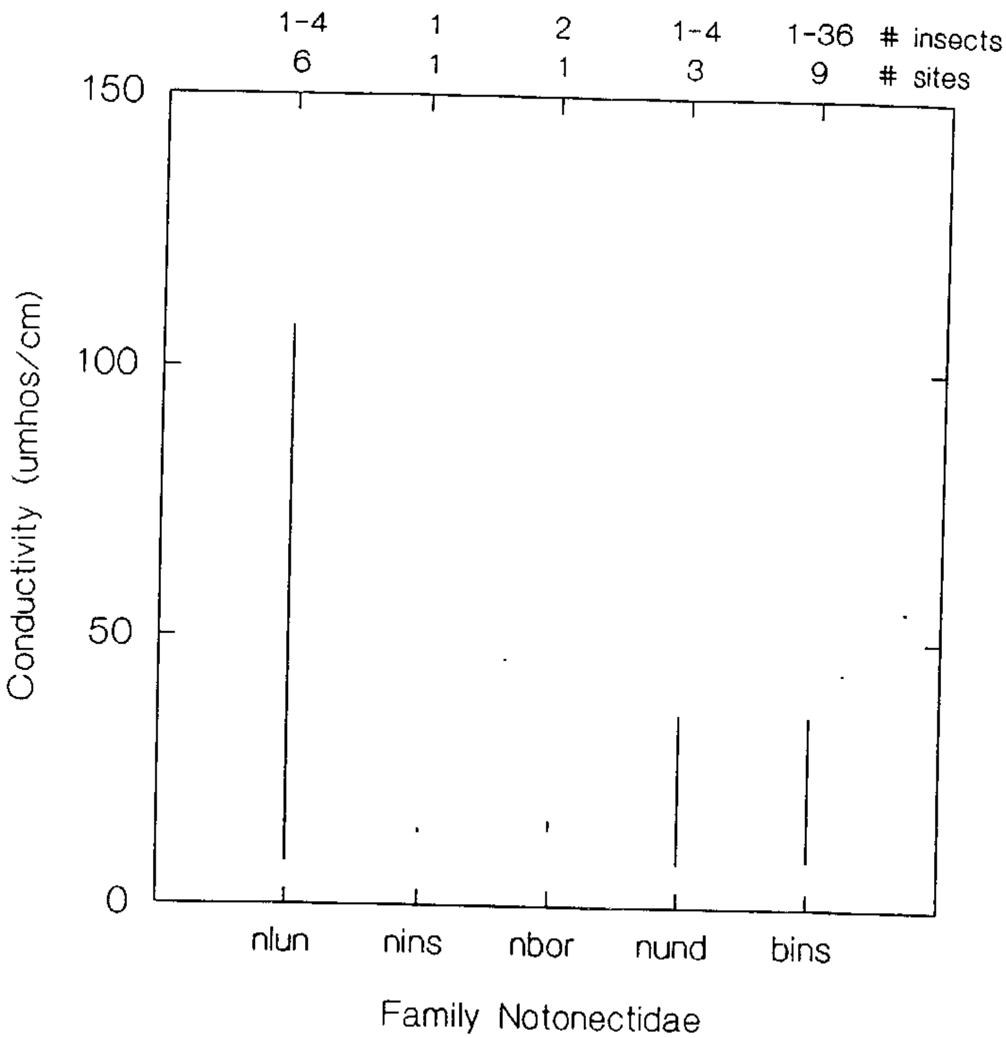


Fig. 3. Alkalinity Ranges of Family Notonectidae

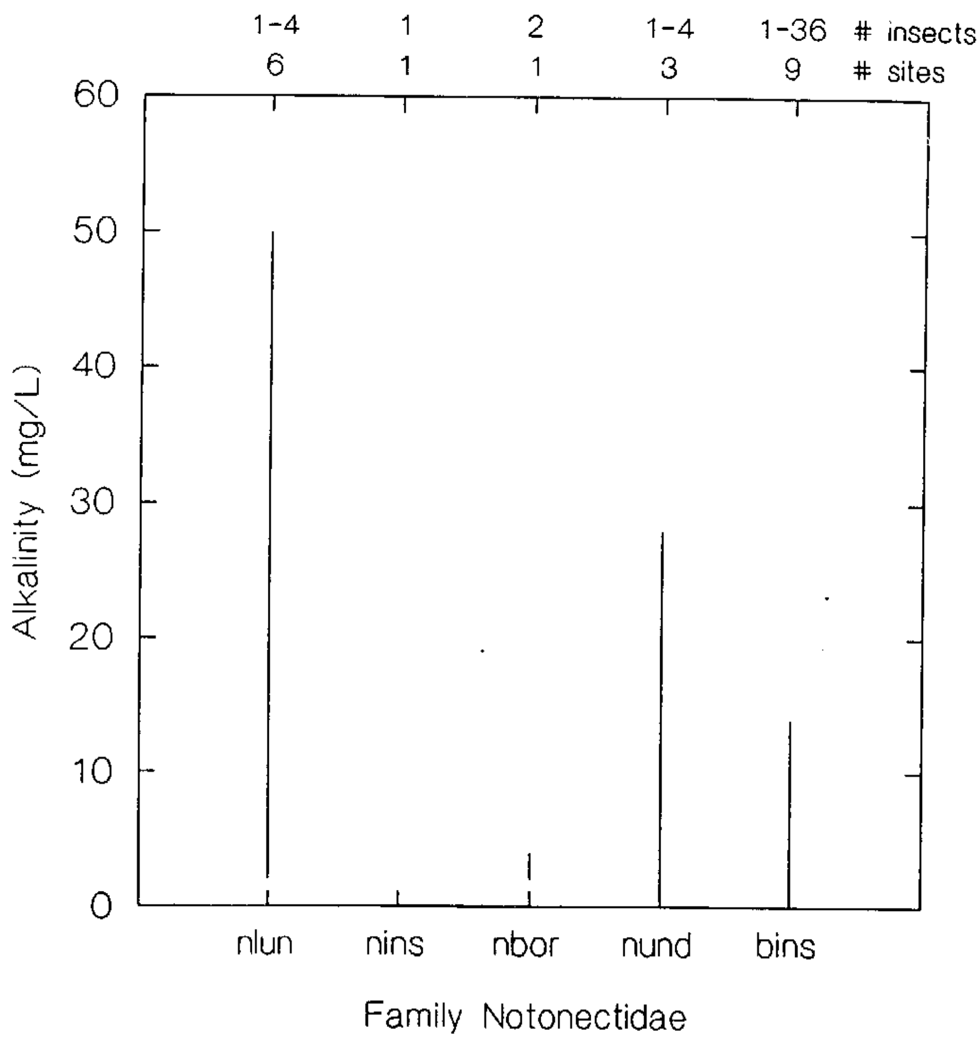


Fig. 4. Water Color Ranges of Family Notonectidae

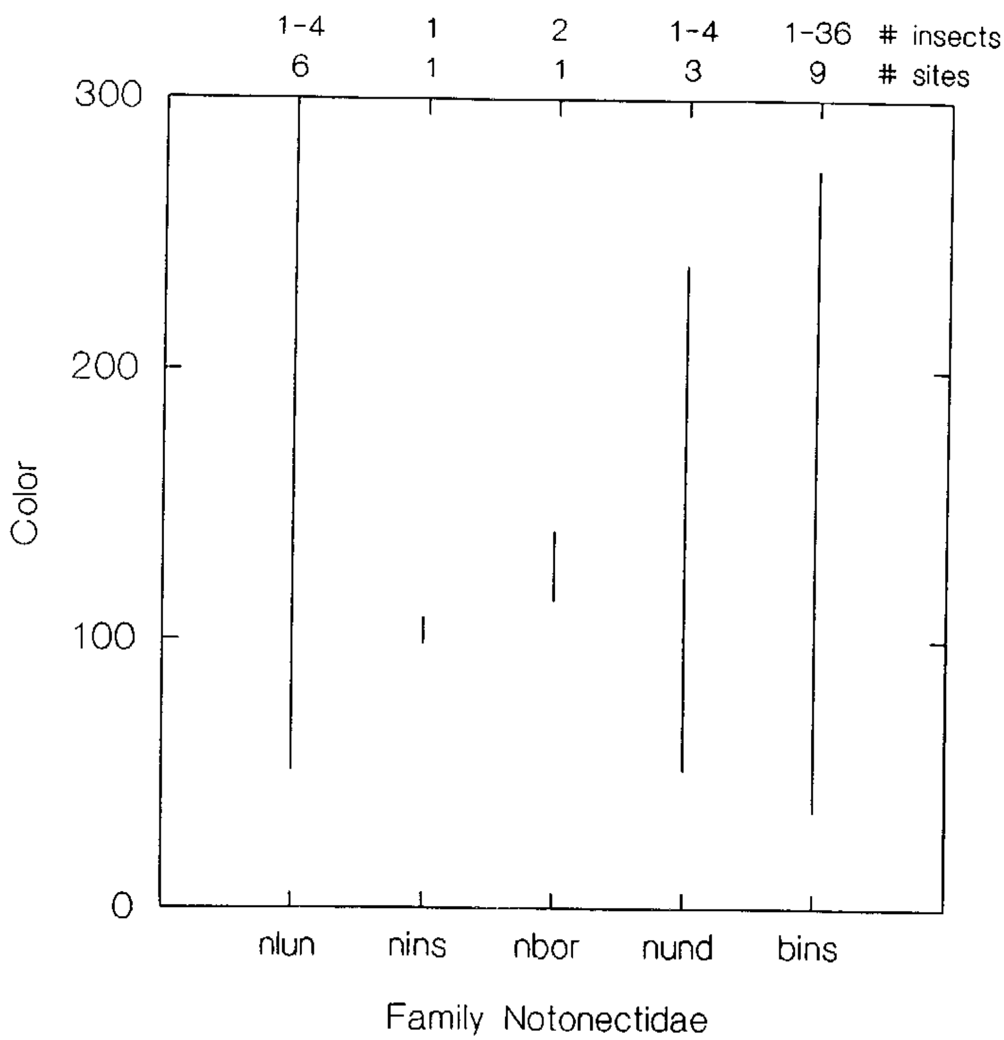


Fig. 5. Secchi Depth Ranges of Family Notonectidae

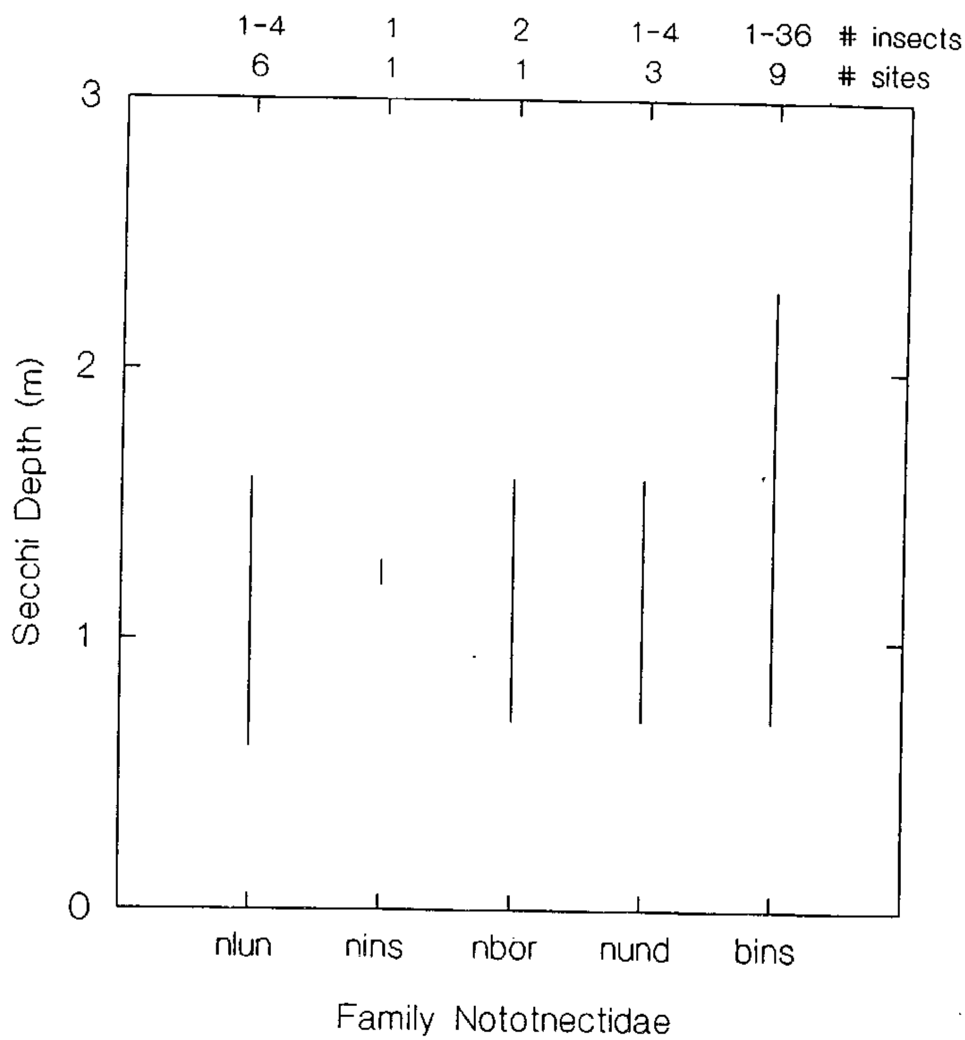
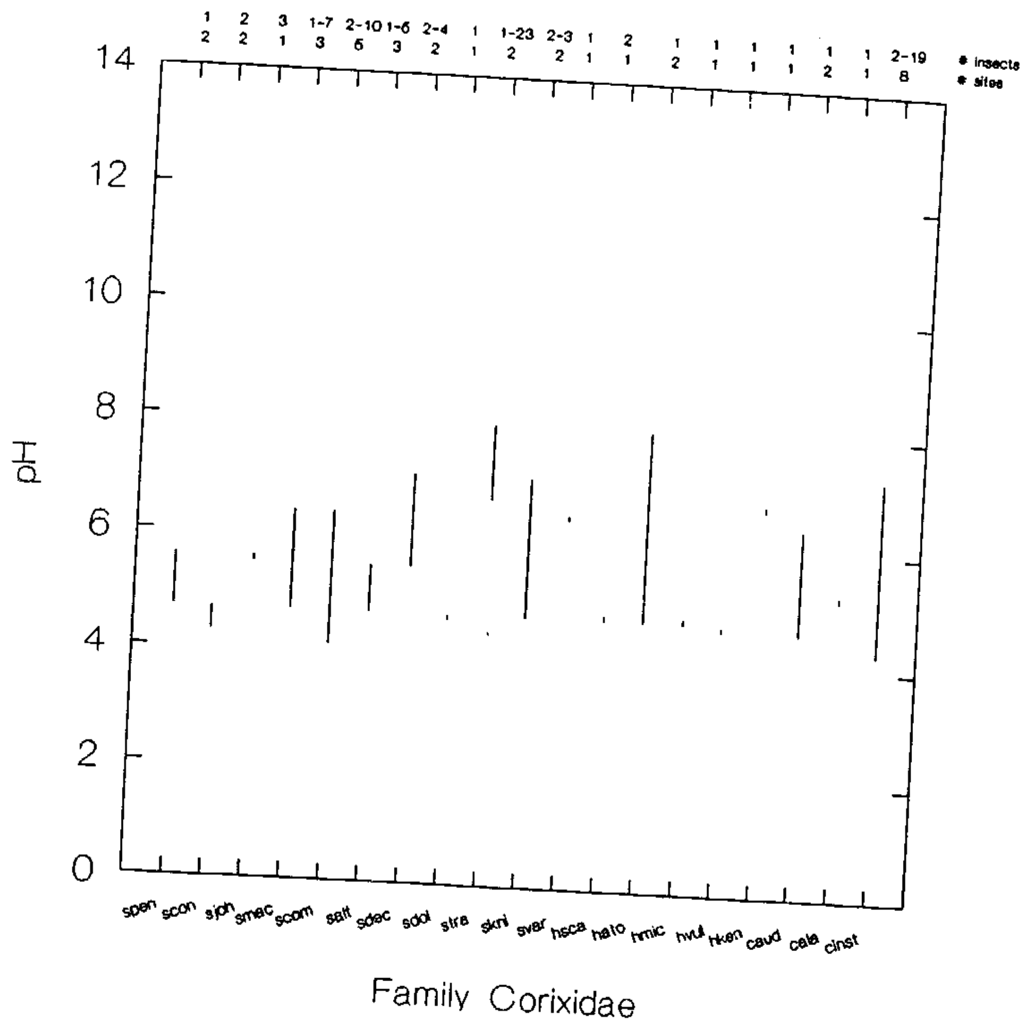


Fig. 6. pH Ranges of Family Corixidae



Family Corixidae

spen = Sigara penniensis
scon = Sigara conocephala
sjoh = Sigara johnstoni
smac = Sigara mackinacensis
scom = Sigara compressoidea
salt = Sigara alternata
sdec = Sigara decorata
sdol = Sigara doloebra
stra = Sigara transfigurata
skni = Sigara knighti
svar = Sigara variablis
hsca = Hespercorixa scabricula
hato = Hespercorixa atopodonta
hmic = Hespercorixa michganensis
hvul = Hespercorixa vulgaris
hken = Hespercorixa kennicotti
caud = Callicorixa audeni
cala = Callicorixa alaskensis
cinst = Corixidae instars

Fig. 7. Alkalinity Ranges of Family Corixidae

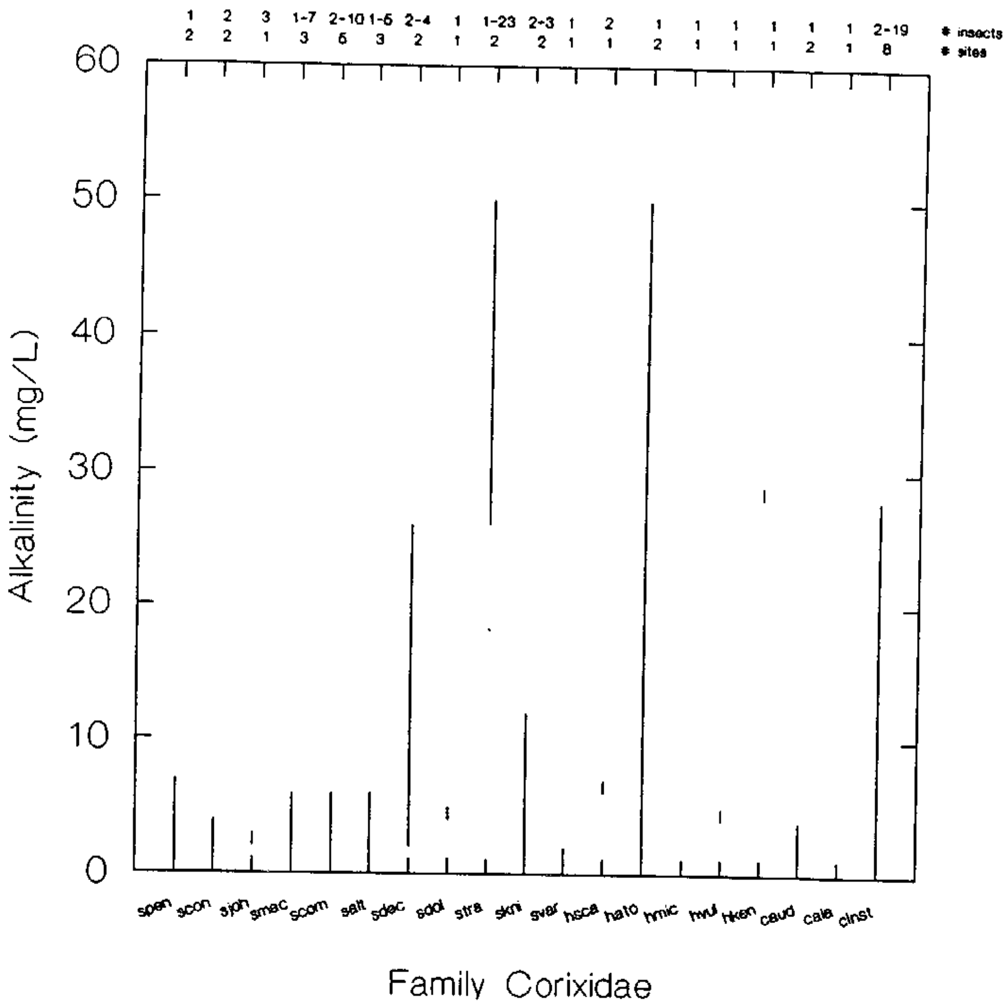
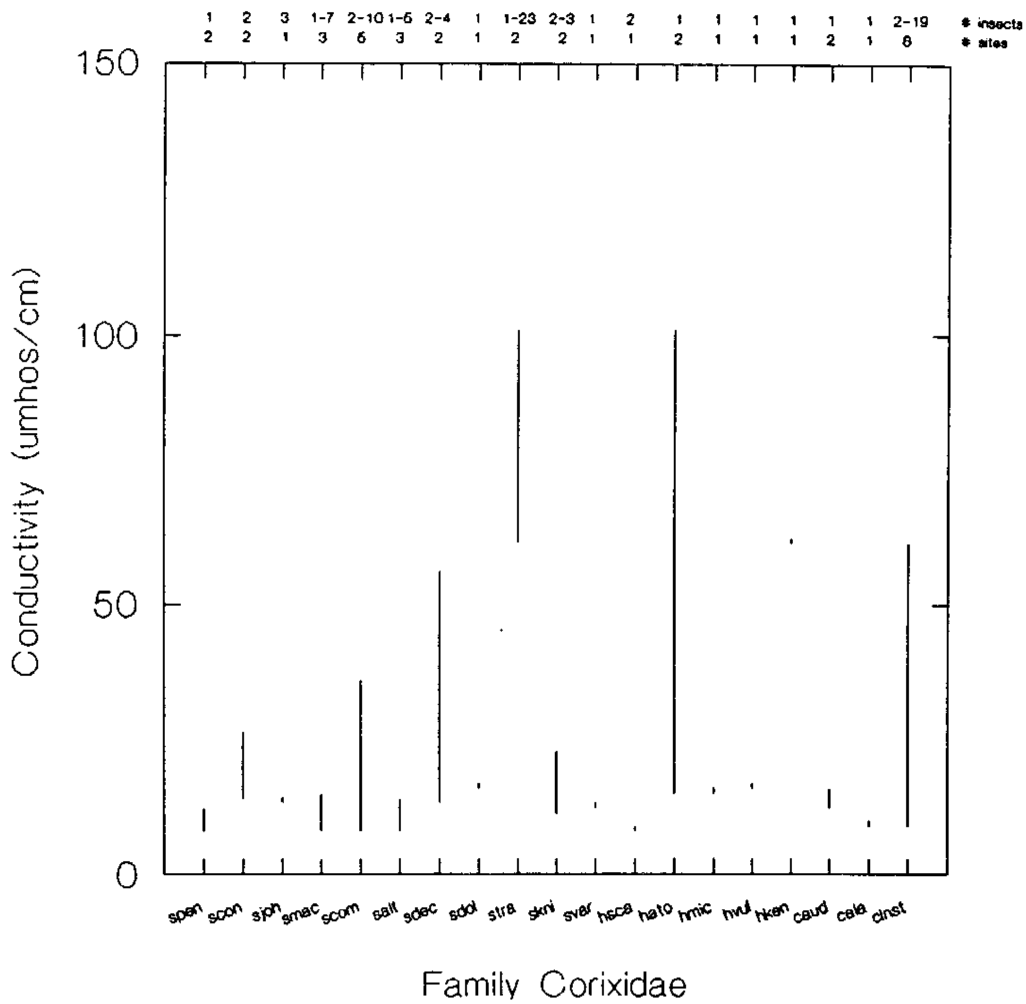


Fig. 8. Conductivity Ranges of Family Corixidae



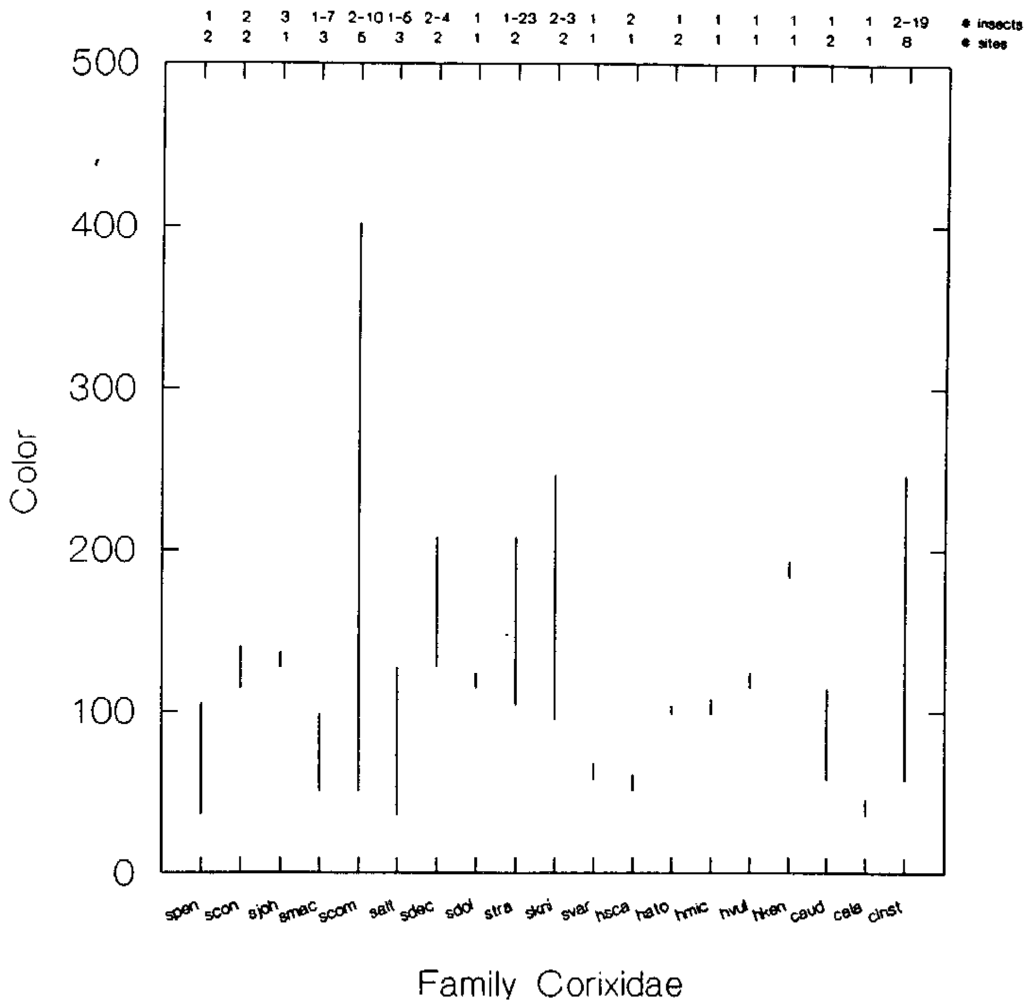


Fig. 9. Water Color Ranges of Family Corixidae

Fig. 10. Secchi Depth Ranges of Family Corixidae

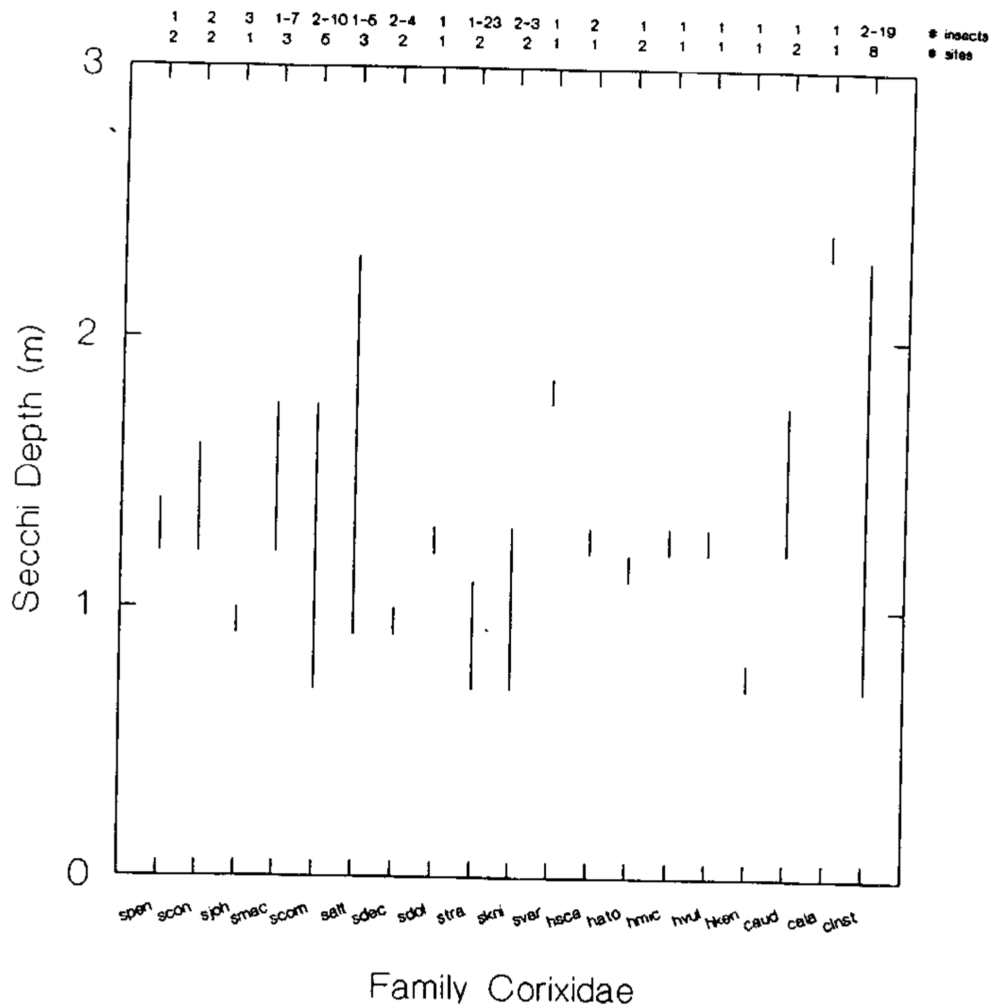


Fig. 11. pH Ranges of Family Gerridae

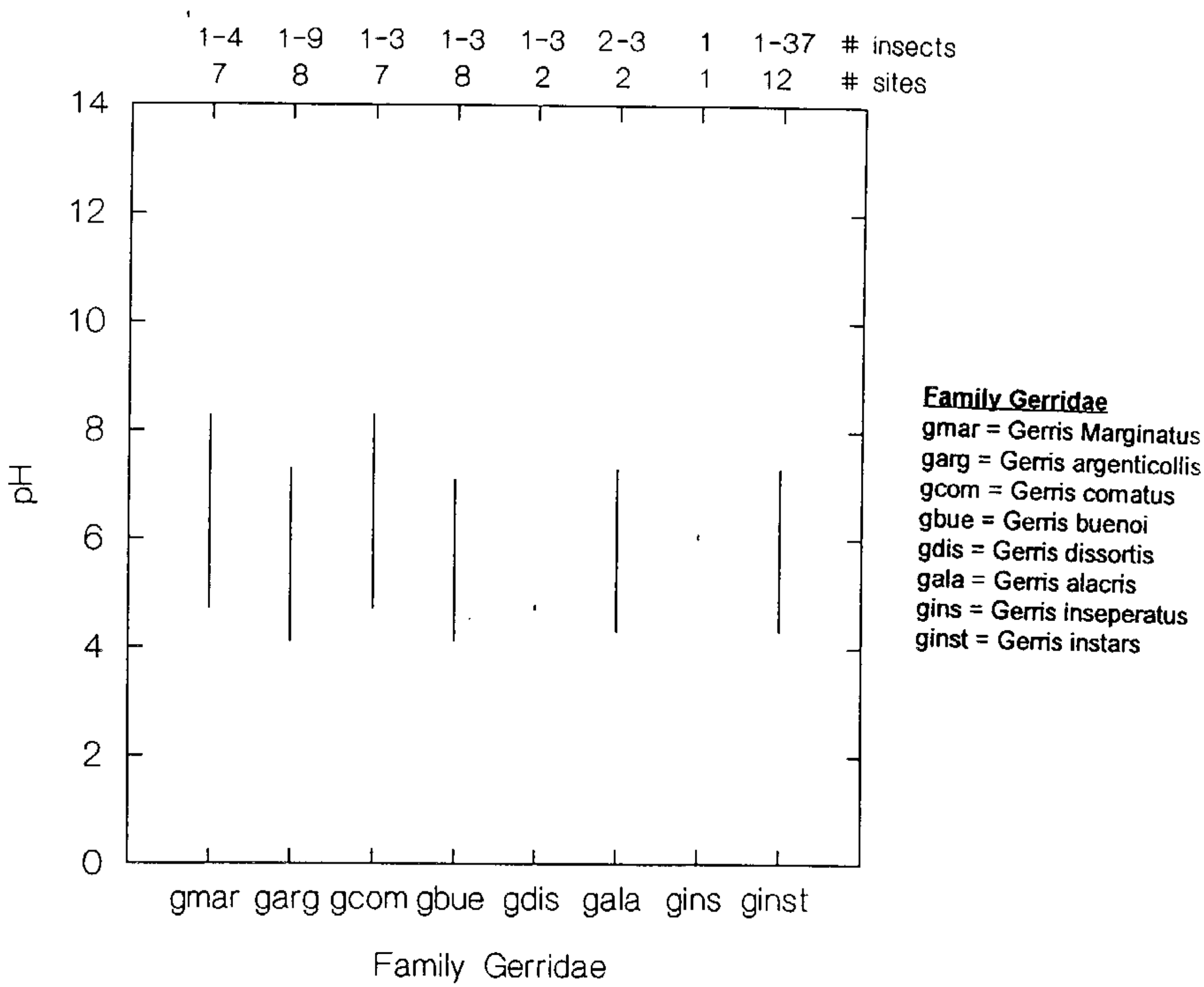


Fig. 12. Alkalinity Ranges of Family Gerridae

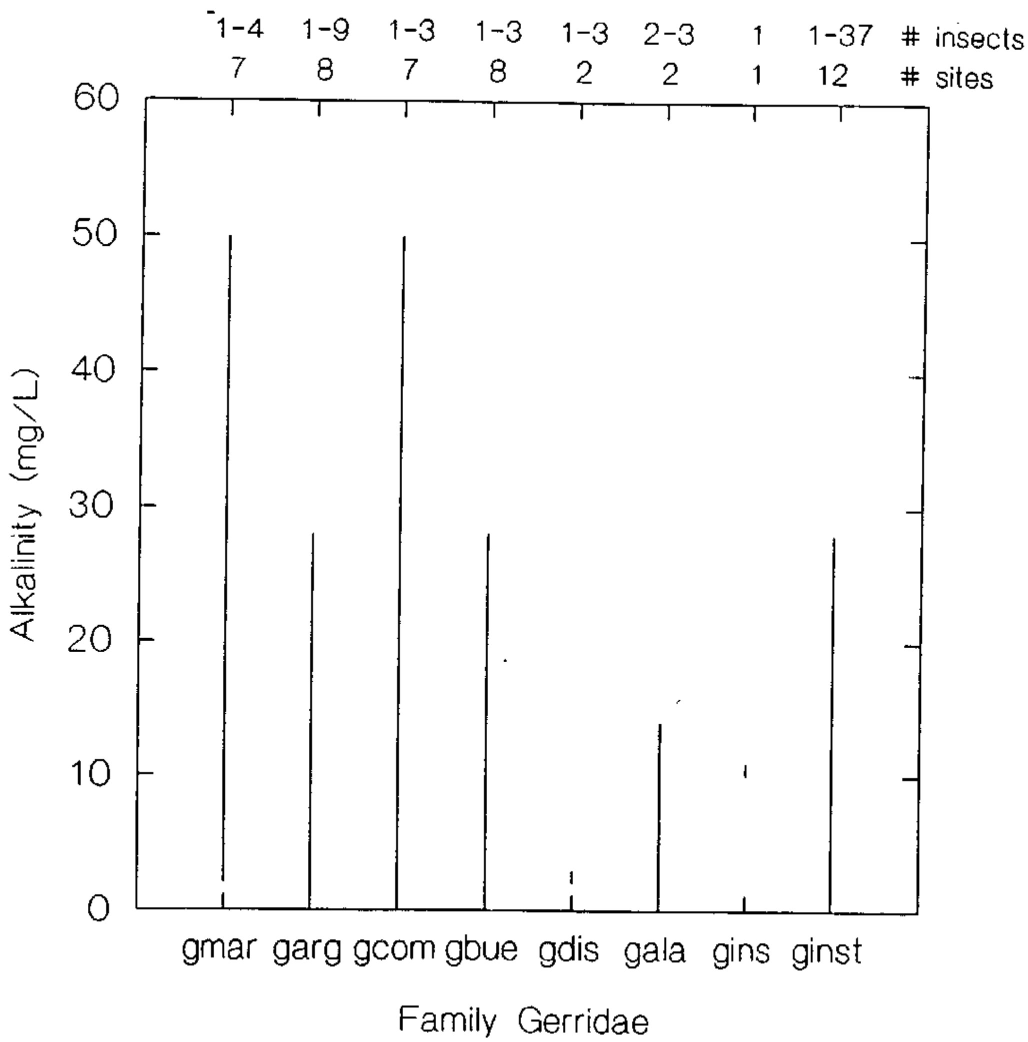


Fig. 13. Conductivity Ranges of Family Gerridae

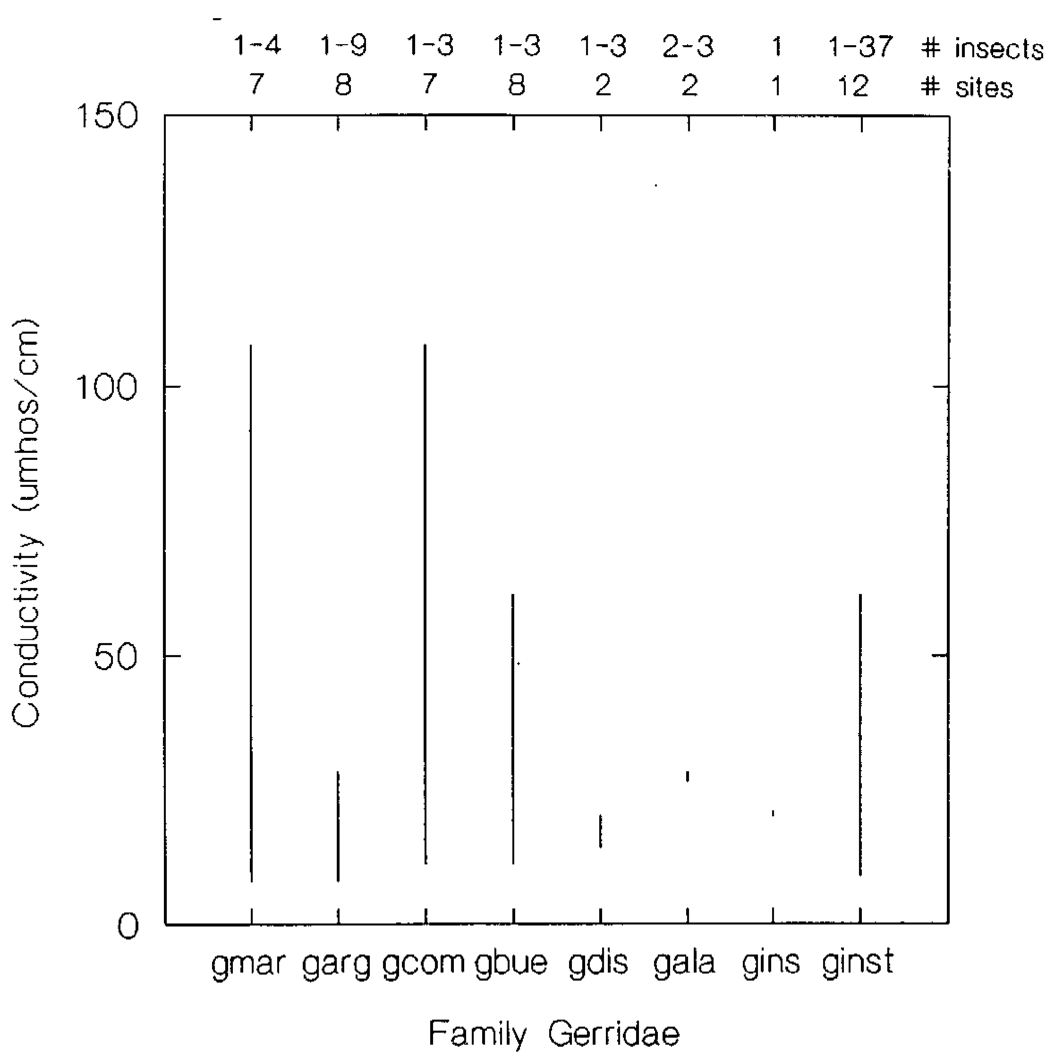


Fig. 14. Water Color Ranges of Family Gerridae

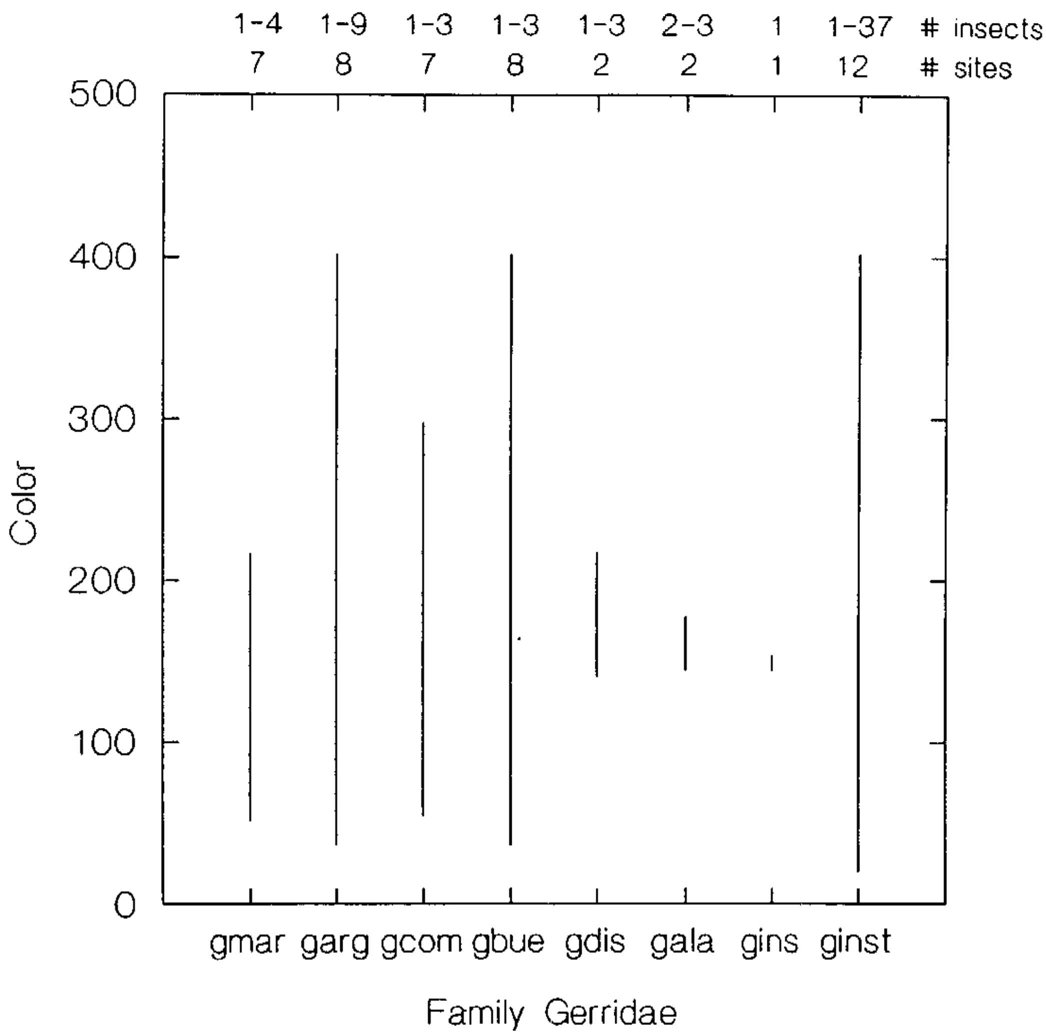


Fig. 15. Secchi Depth Ranges of Family Gerridae

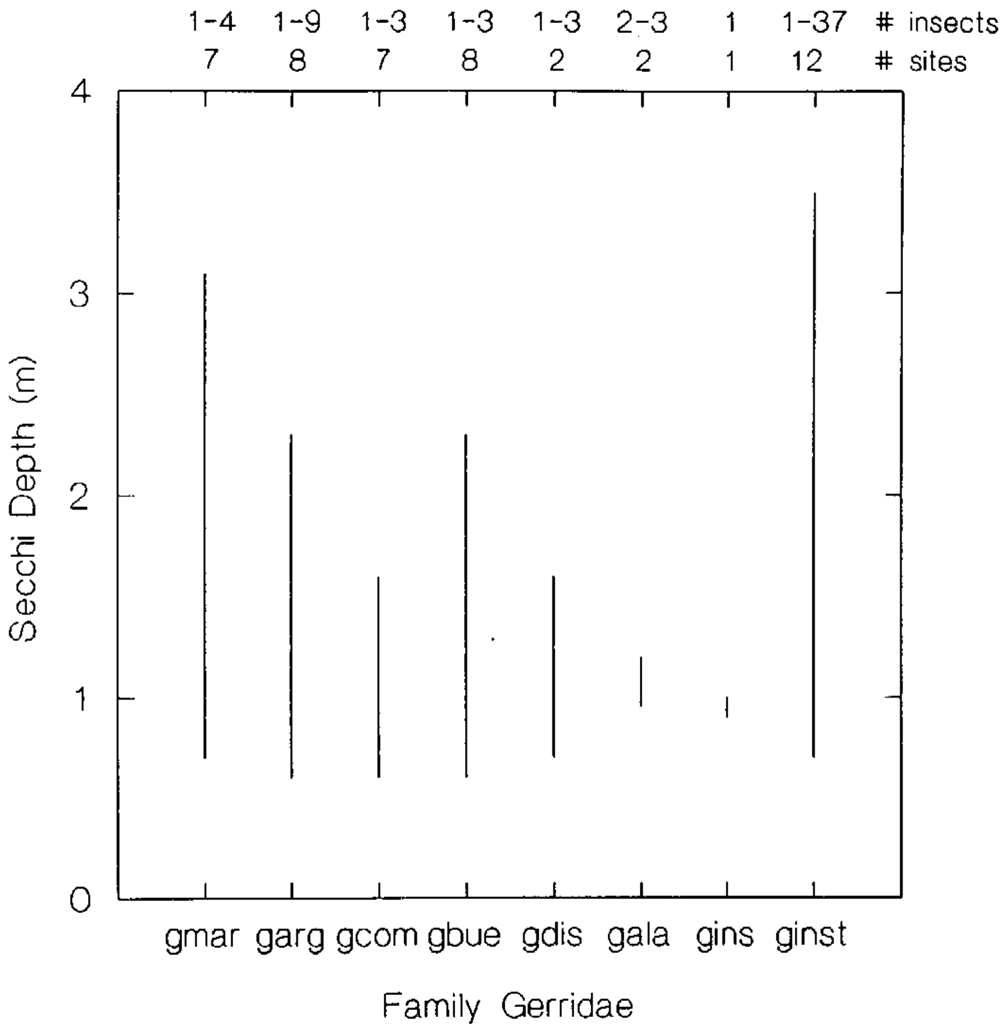
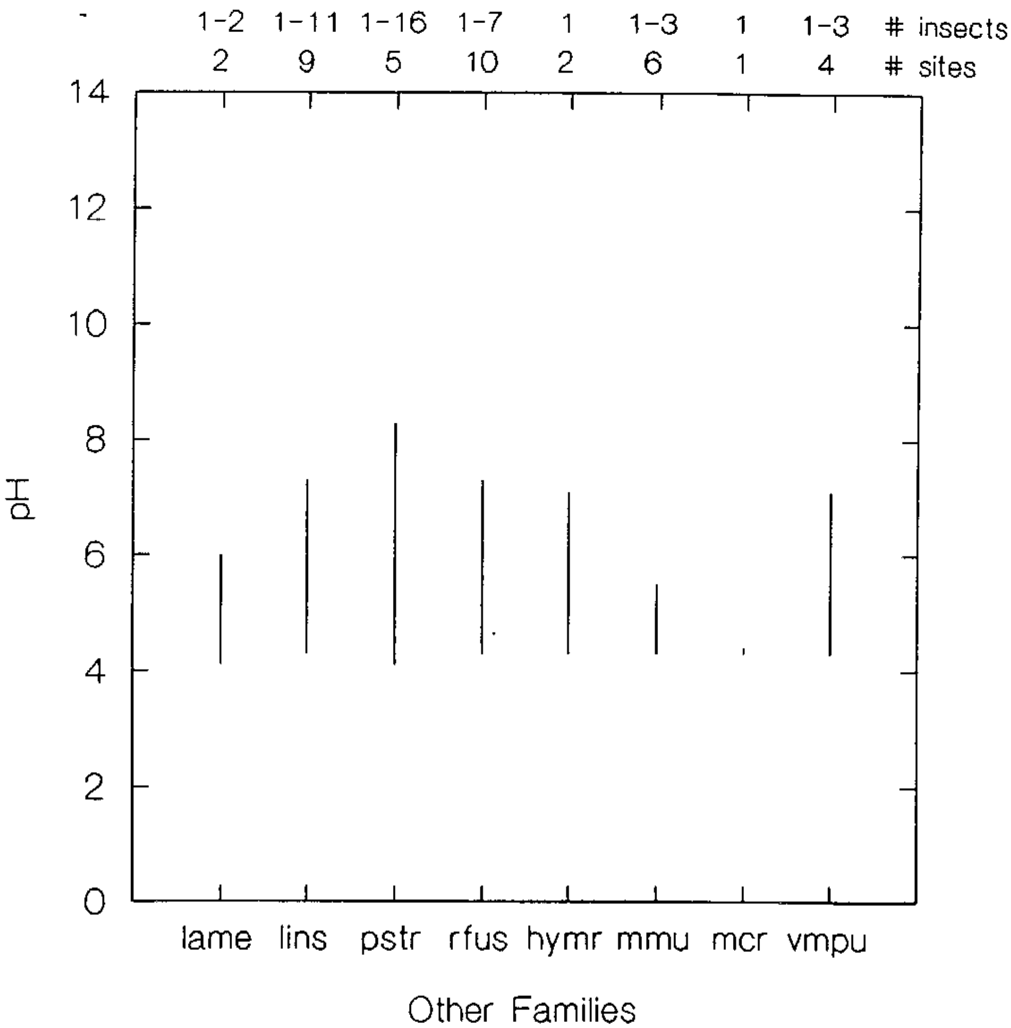


Fig. 16. pH Ranges of Pleidae, Neipdae, Mesovelidae,Belostomatidae, and Veliidae Families



Other Families
lame = Belostomatidae Lethocerus americanus
Bins = Belostomatidae instars
pstr = Pleidae Plea striola
rfus = Nepidae Ranatra fusca
hyma = Hydrometridae Hydrometra martini
mmu = Mesoveliidae Mesovelia musanti
mcr = Mesoveliidae Mesoveila crytophila
vmpu = Veliidae Microvelia pulchella

Fig. 17. Alkalinity Ranges of Pleidae, Neipdae, Mesovelidae,Belostomatidae, and Veliidae Families

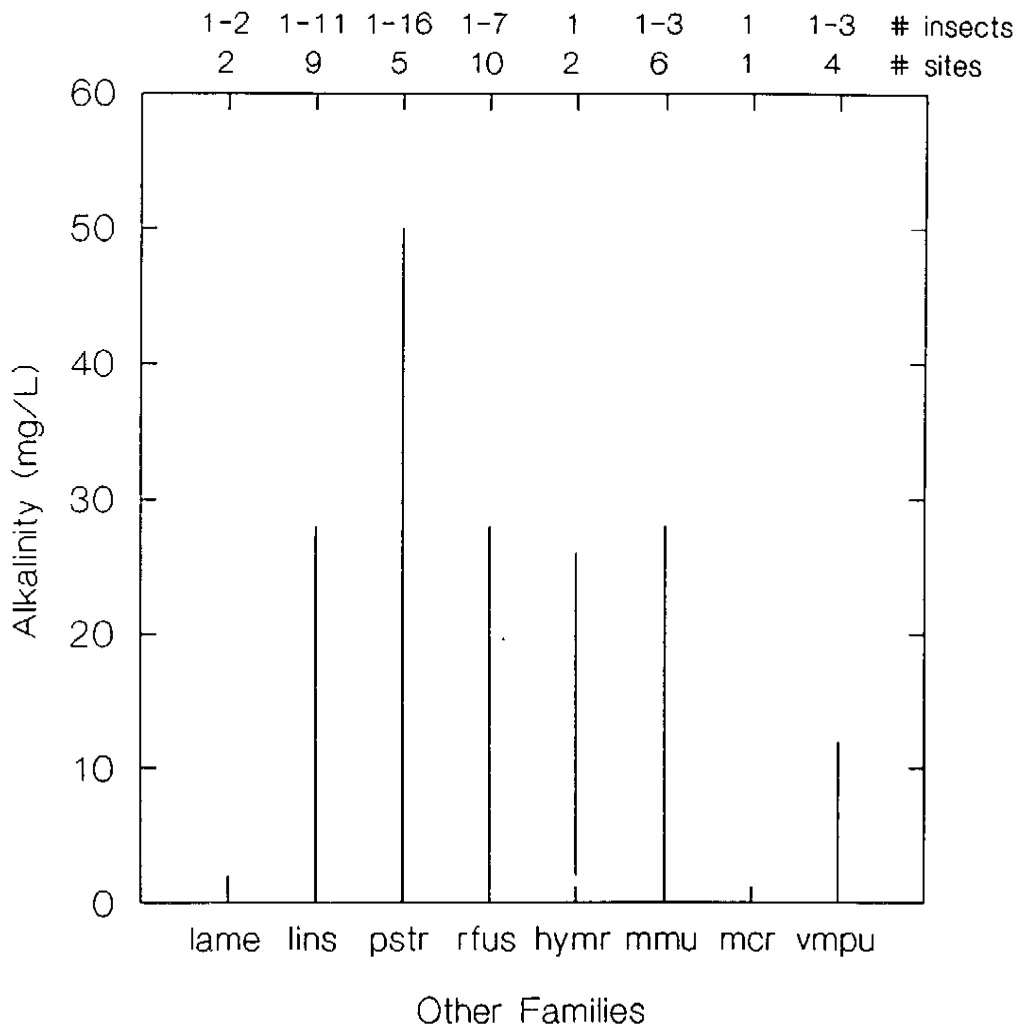


Fig. 18. Conductivity Ranges of Pleidae, Neipdae, Mesovelidae,Belostomatidae, and Veliidae Families

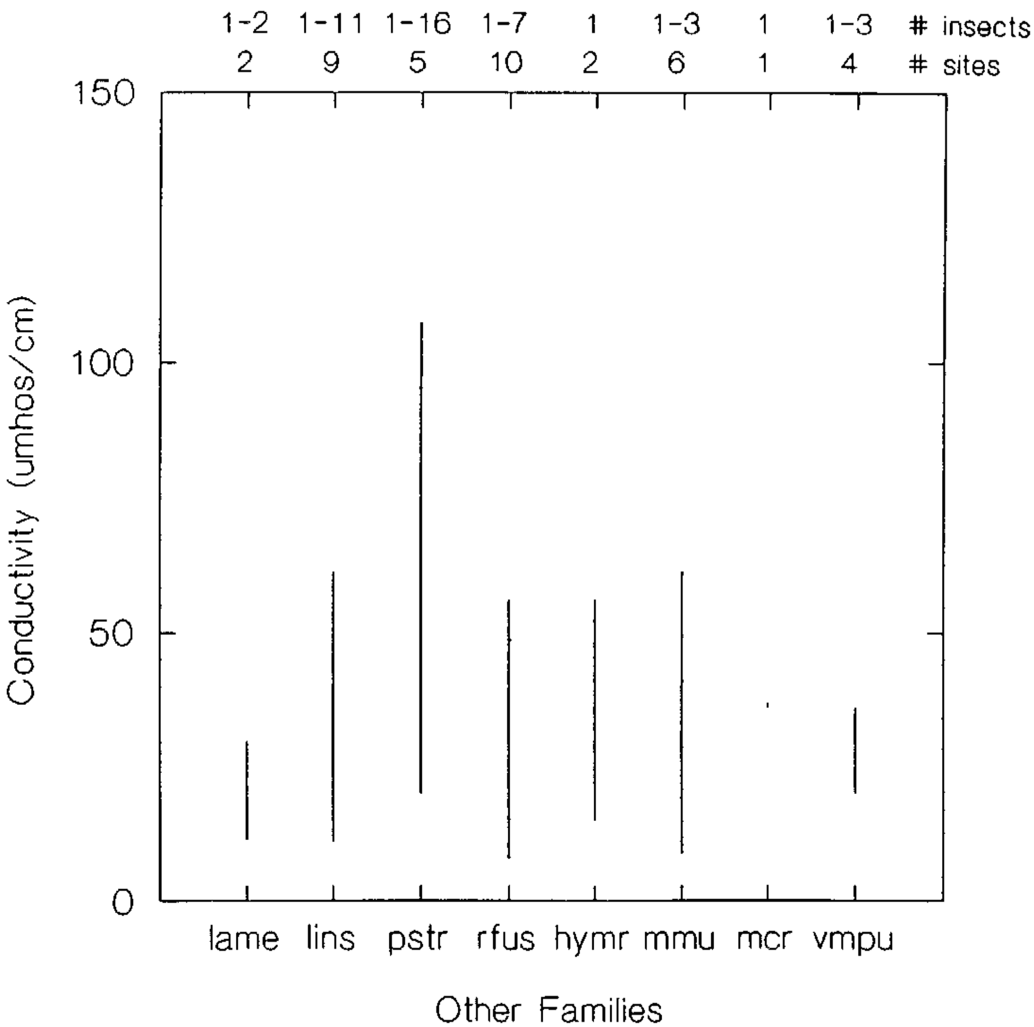


Fig. 19. Water Color Ranges of Pleidae, Neipdae, Mesovelidae,Belostomatidae, and Veliidae Families

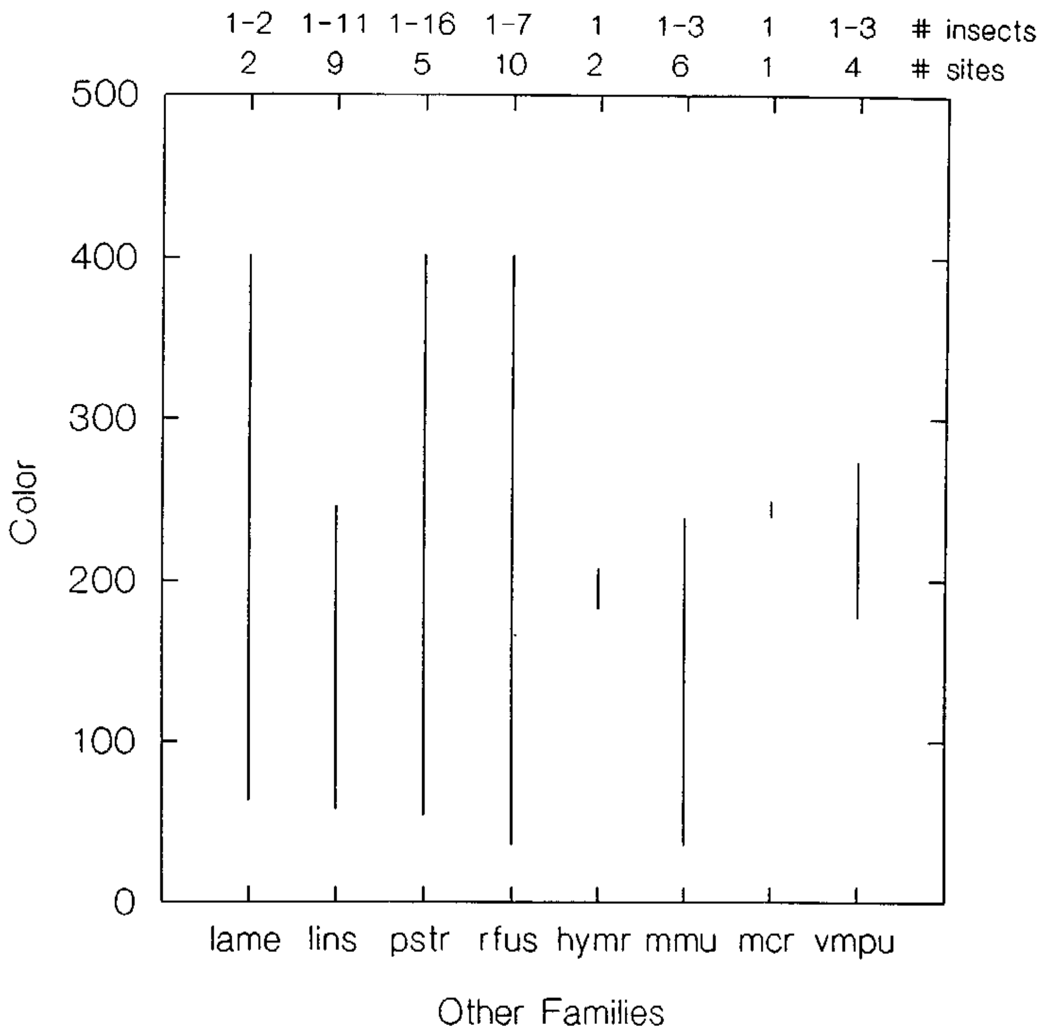
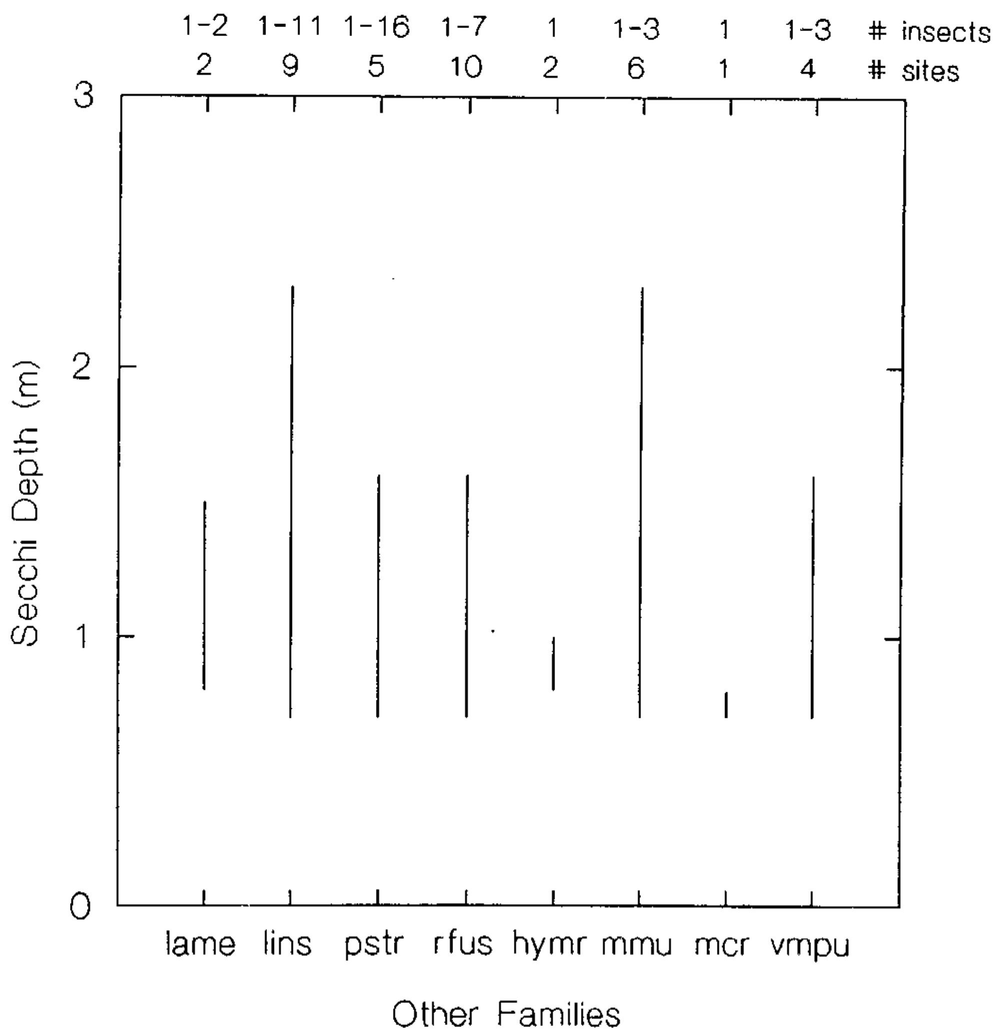
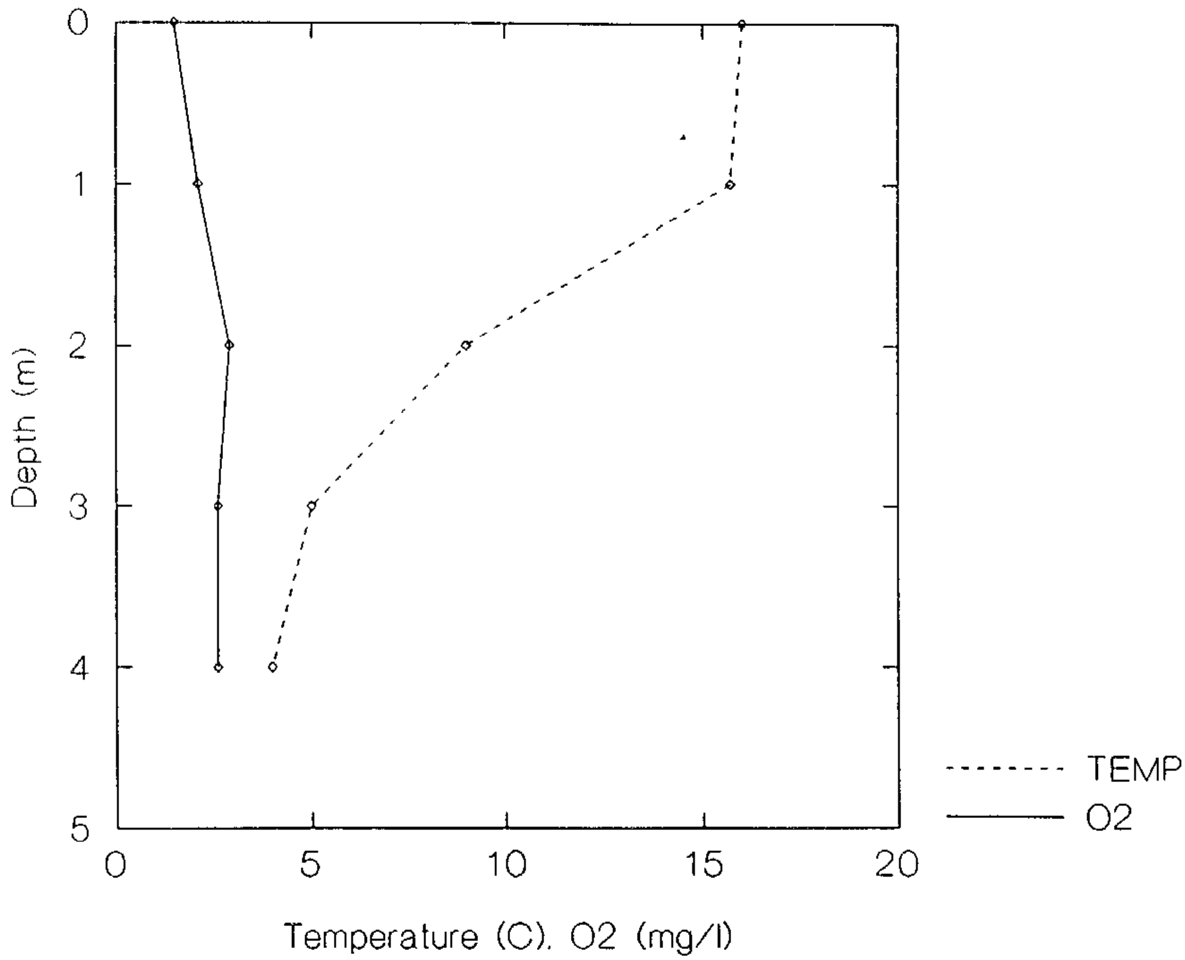


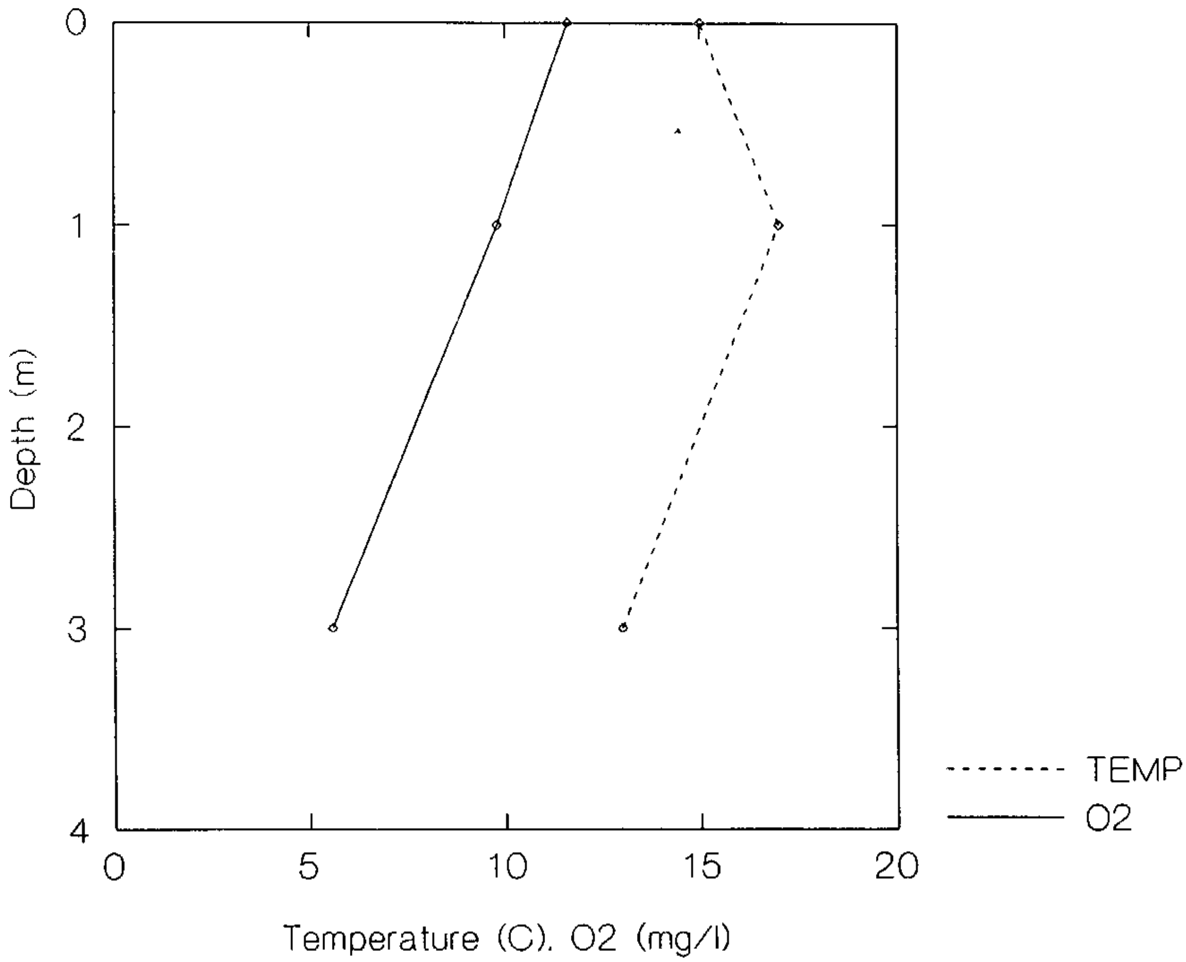
Fig. 20. Sècchi Depth Ranges of Pleidae, Neipdae, Mesovelidae,Belostomatidae, and Veliidae Families



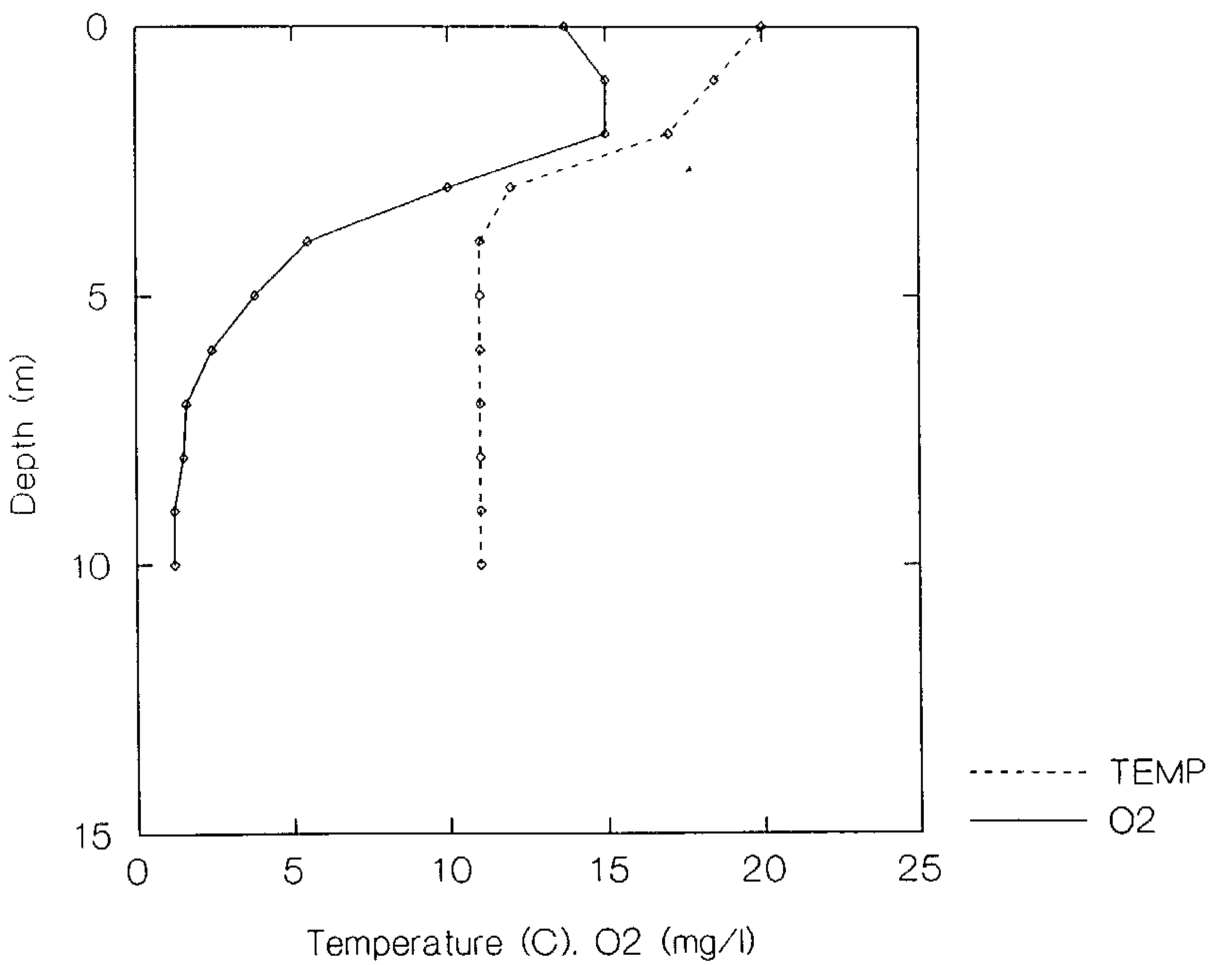
Appendix I. Oxygen /Temperature Profile of Bolger Bog- Sample 1



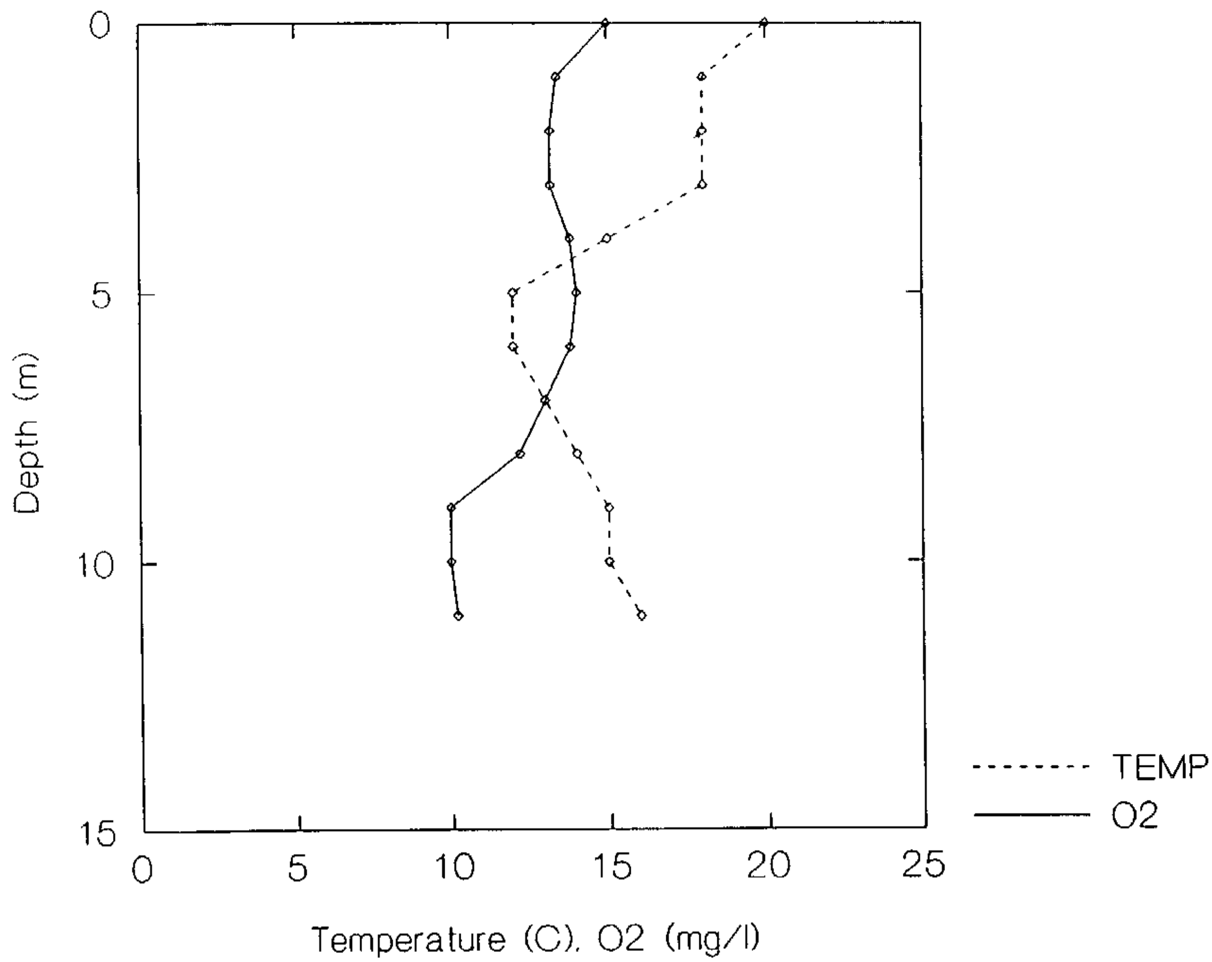
Appendix II. Oxygen /Temperature Profile of Bog Pot- Sample 1

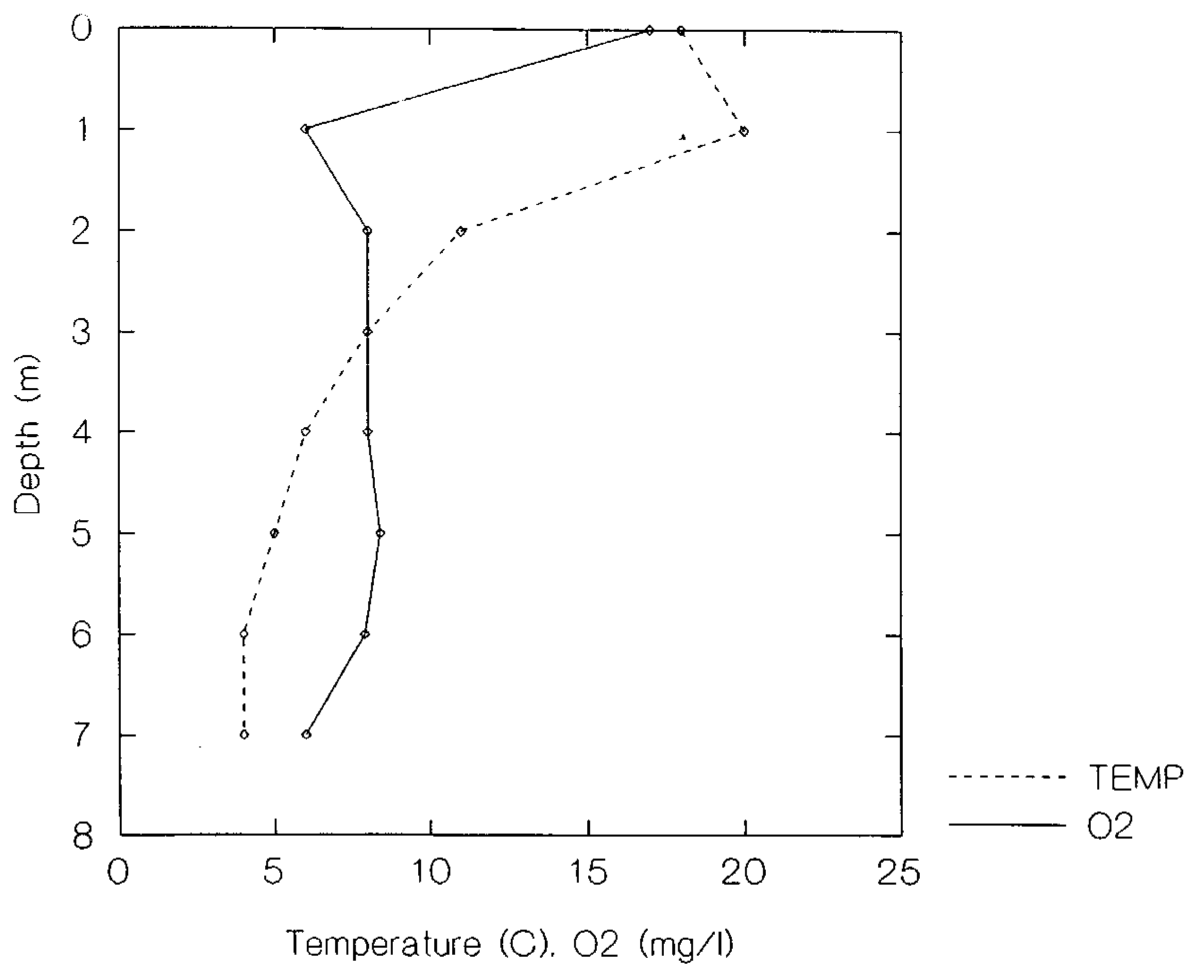


Appendix III. Oxygen /Temperature Profile of Brown Lake- Sample 1



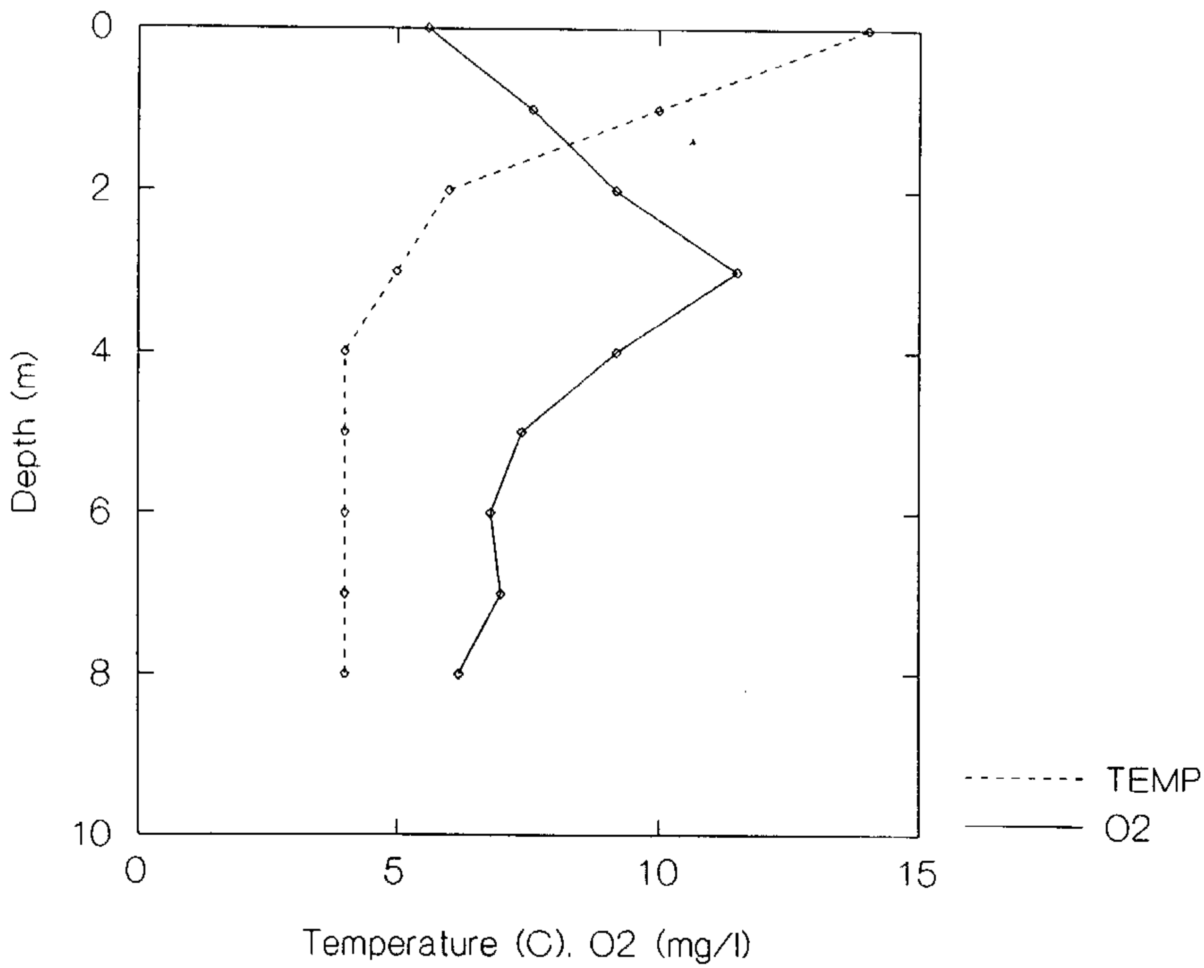
Appendix IV. Oxygen /Temperature Profile of Crampton Lake- Sample 1



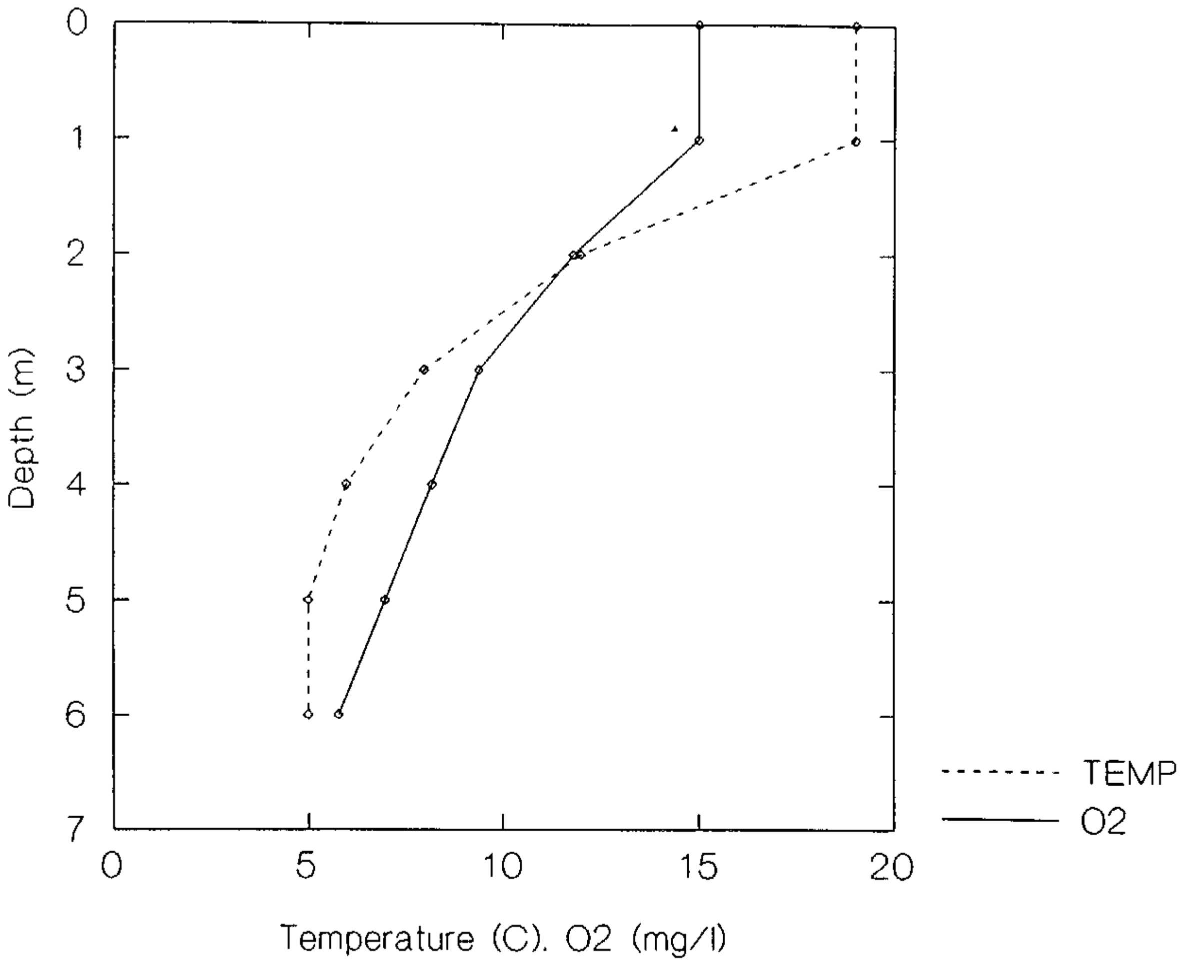


Depth (m)
0
1
2
3
4
5
6
7
8
0
5
10
15
20
25
Temperature (C), O2 (mg/l)
TEMP
O2

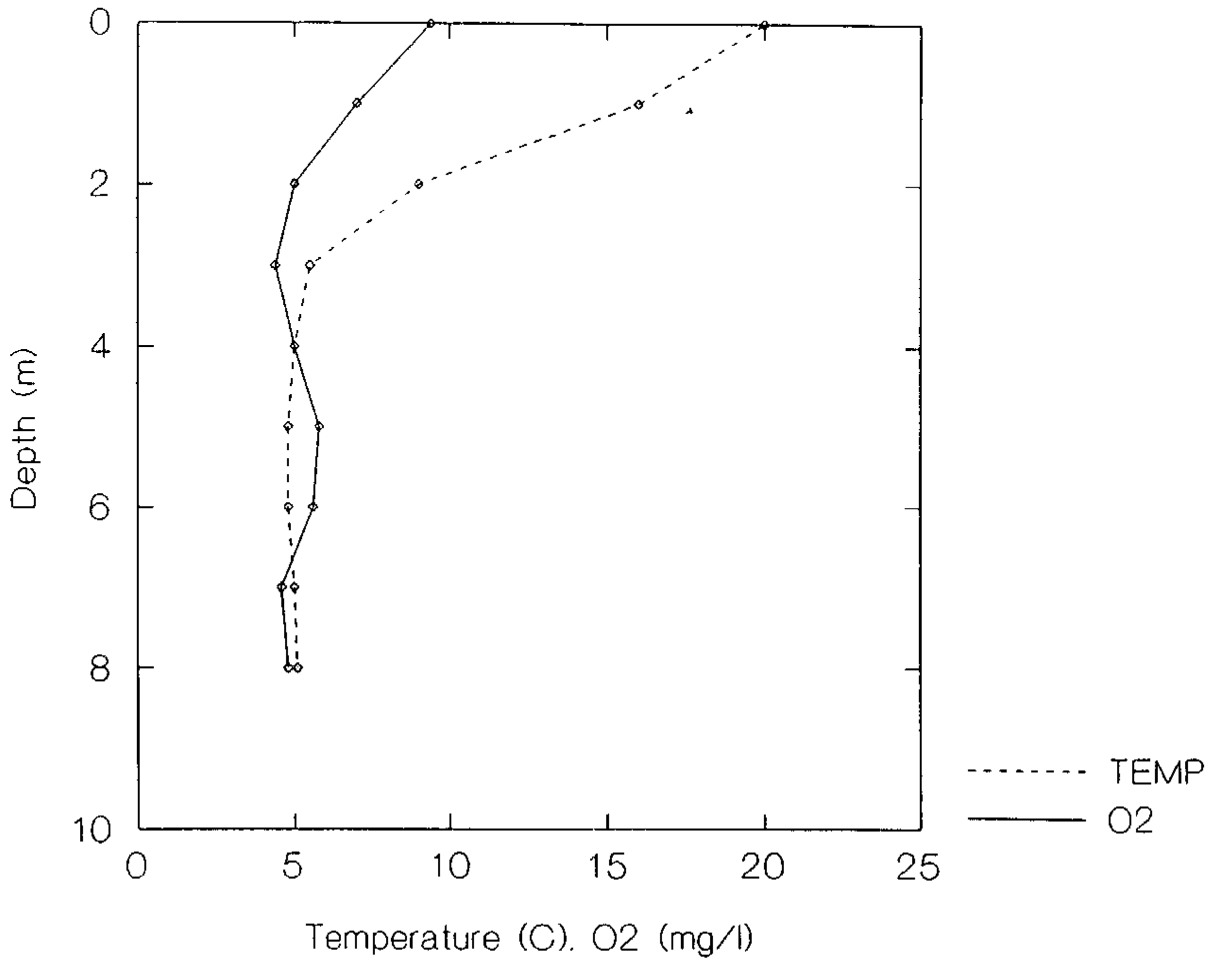
Appendix VI. Oxygen/ Temperature Profile of Ed's Bog- Sample 1



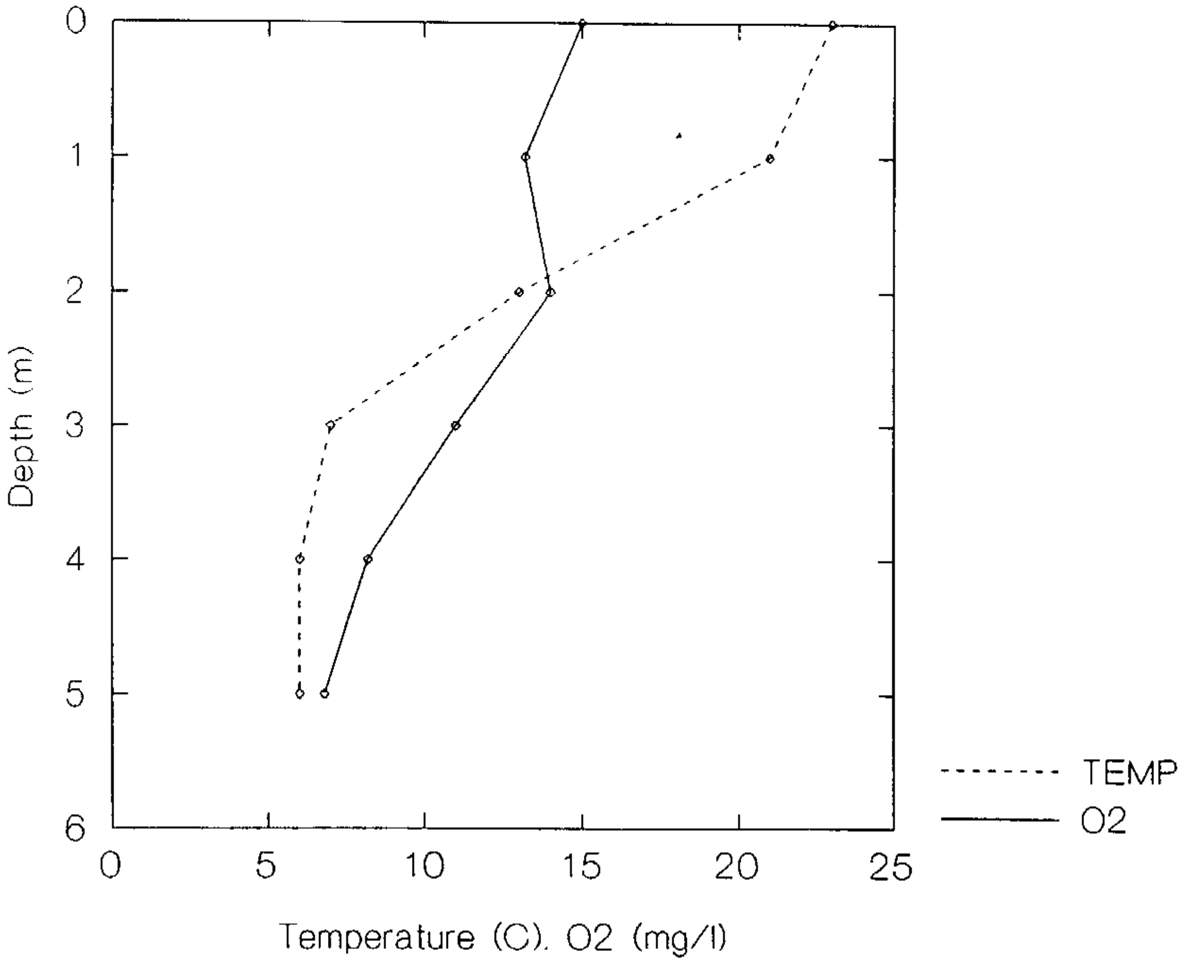
Appendix VII. Oxygen Temperature Profile of Forest Service Bog- Sample 1



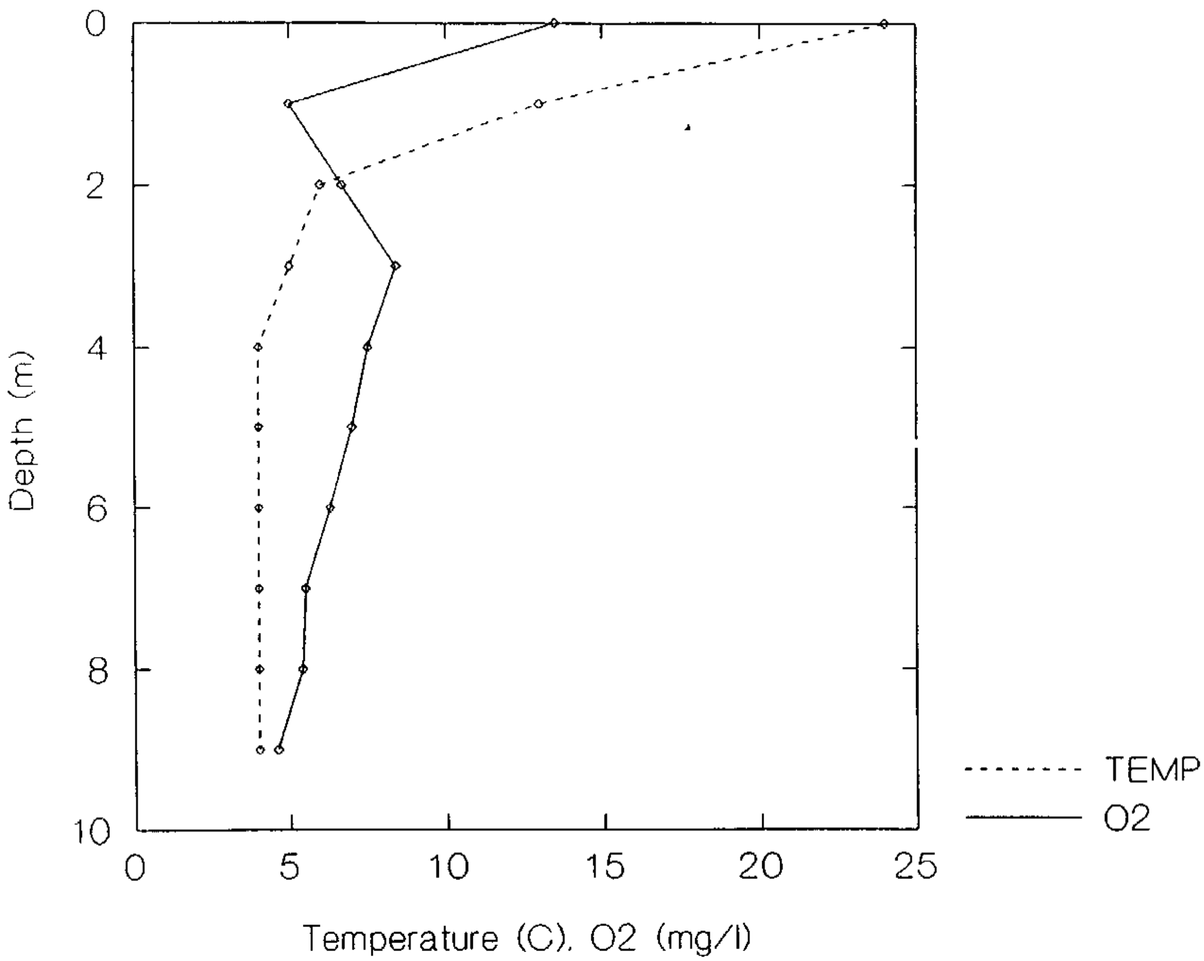
Appendix VIII. Oxygen/ Temperature Profile of Hummingbird Lake-Sample 1



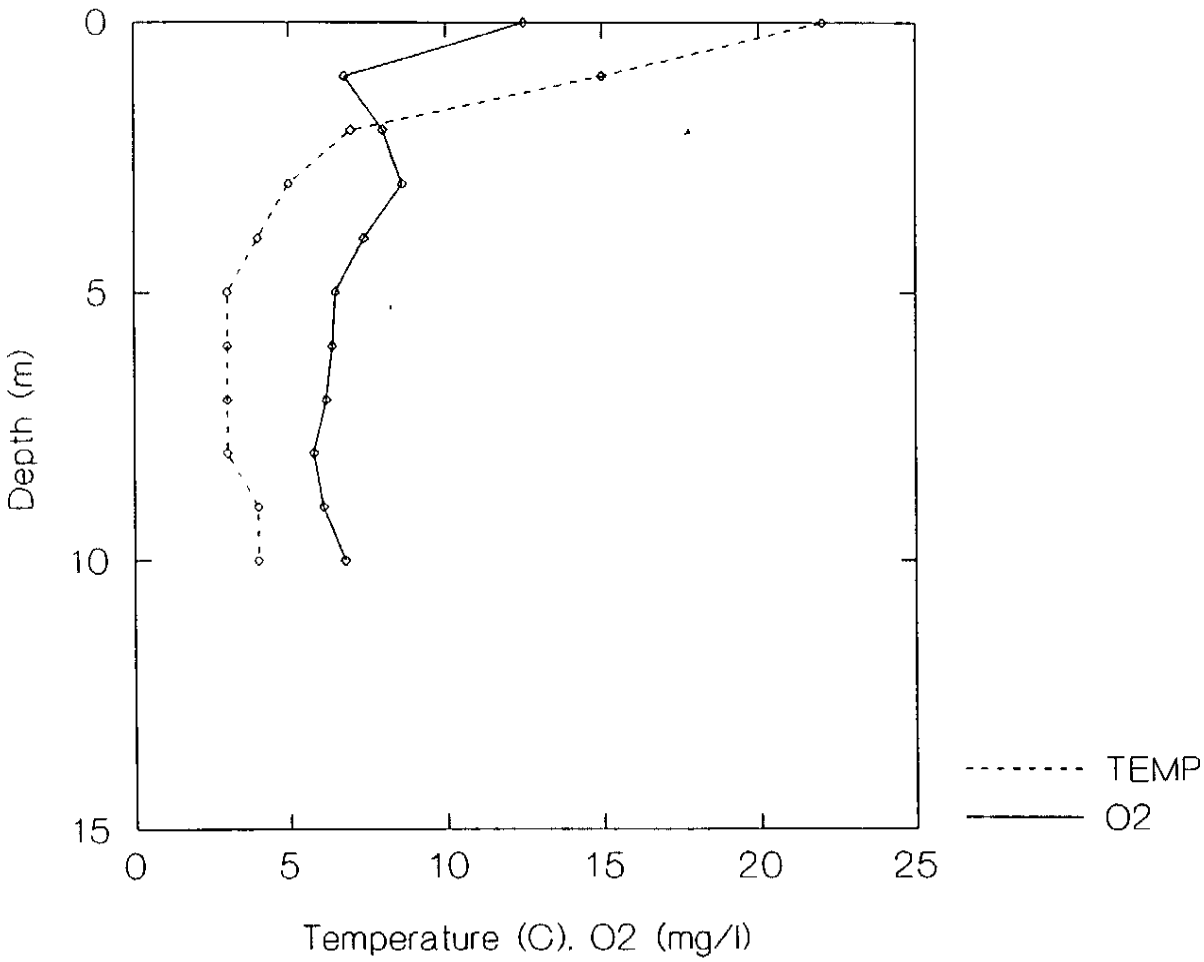
Appendix IX. Oxygen/ Temperature Profile of Morris Lake- Sample 1



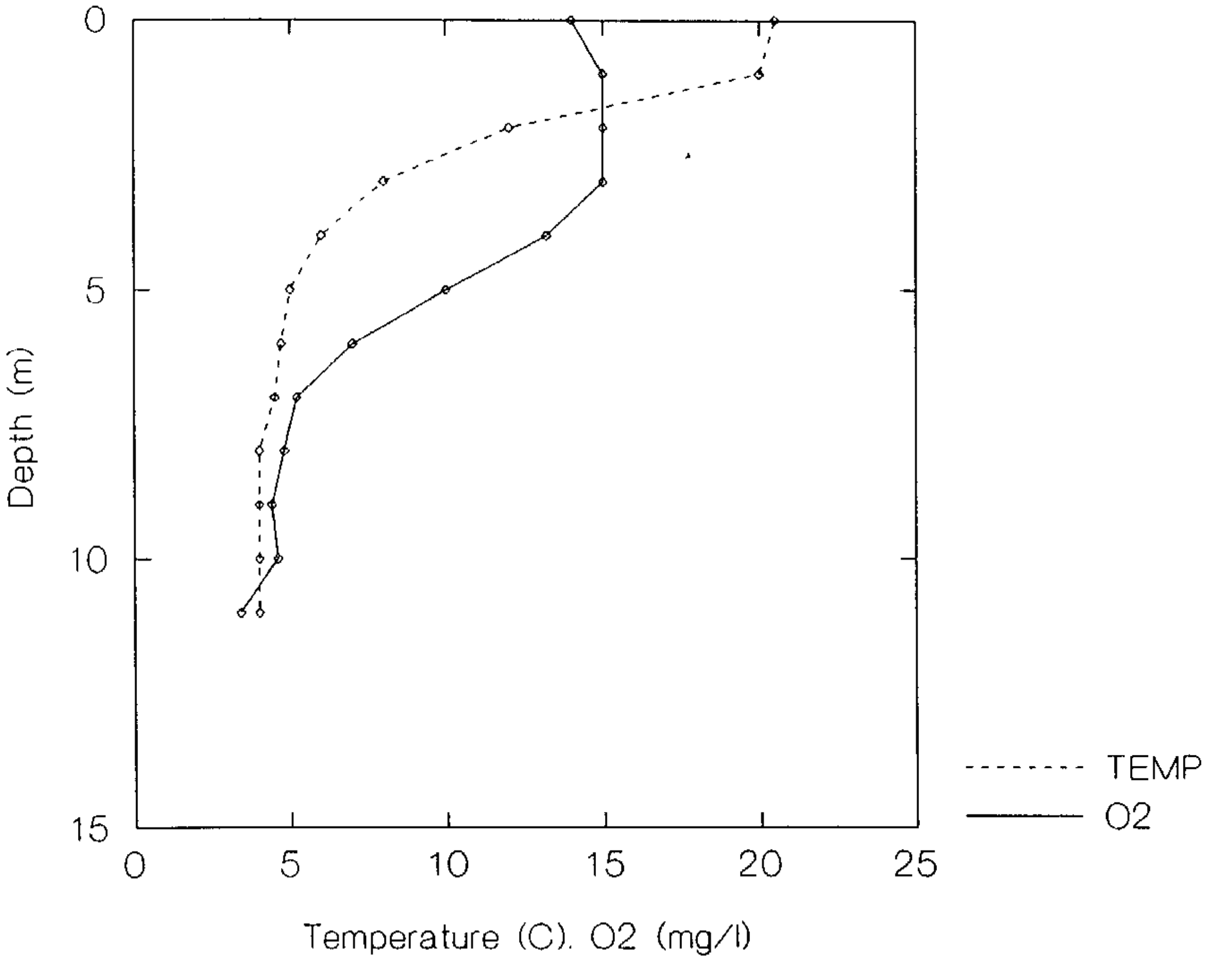
Appendix X. Oxygen/ Temperature Profile of North Gate Bog- Sample 1



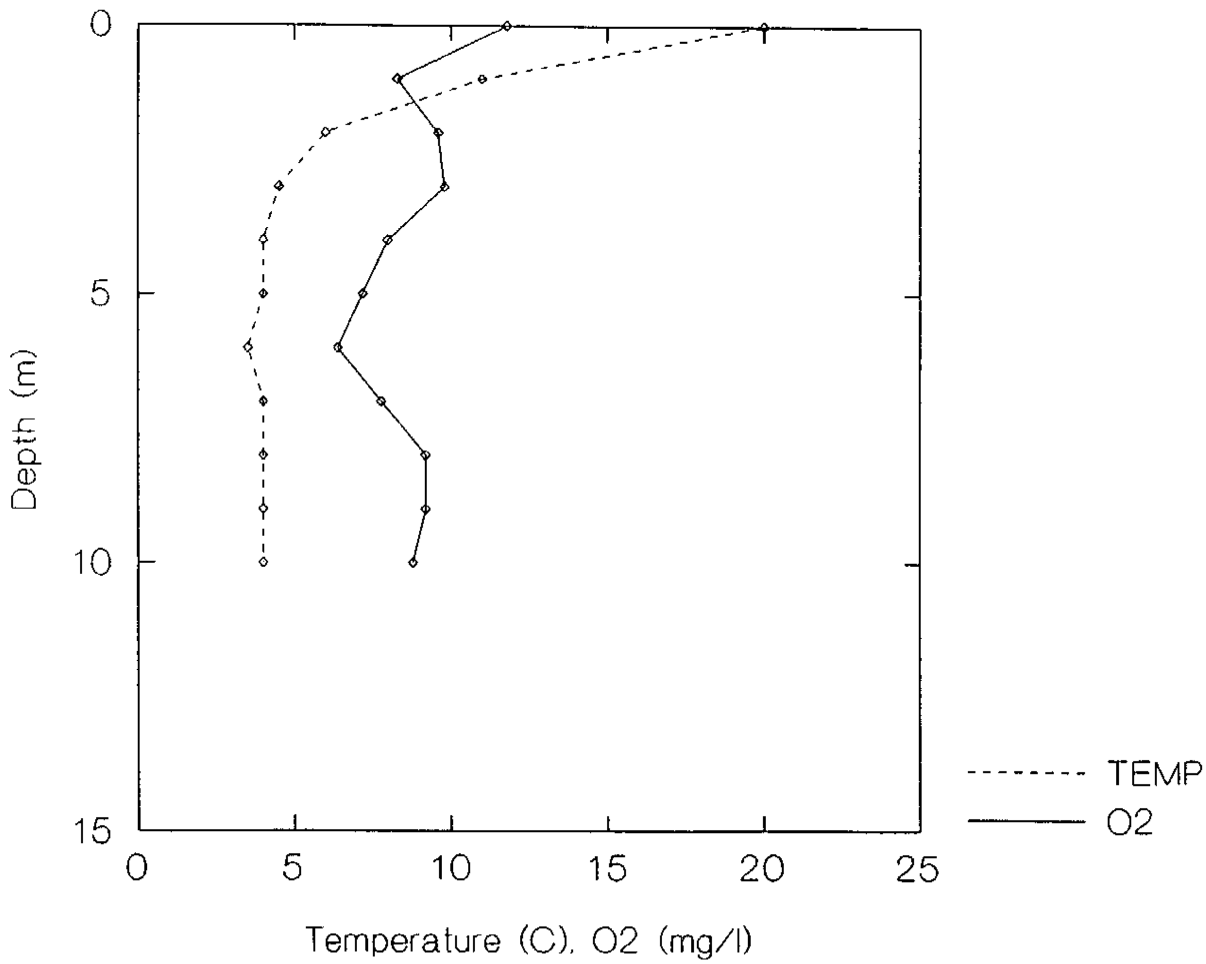
Appendix XI. Oxygen/ Temperature Profile of Reddington Lake- Sample 1



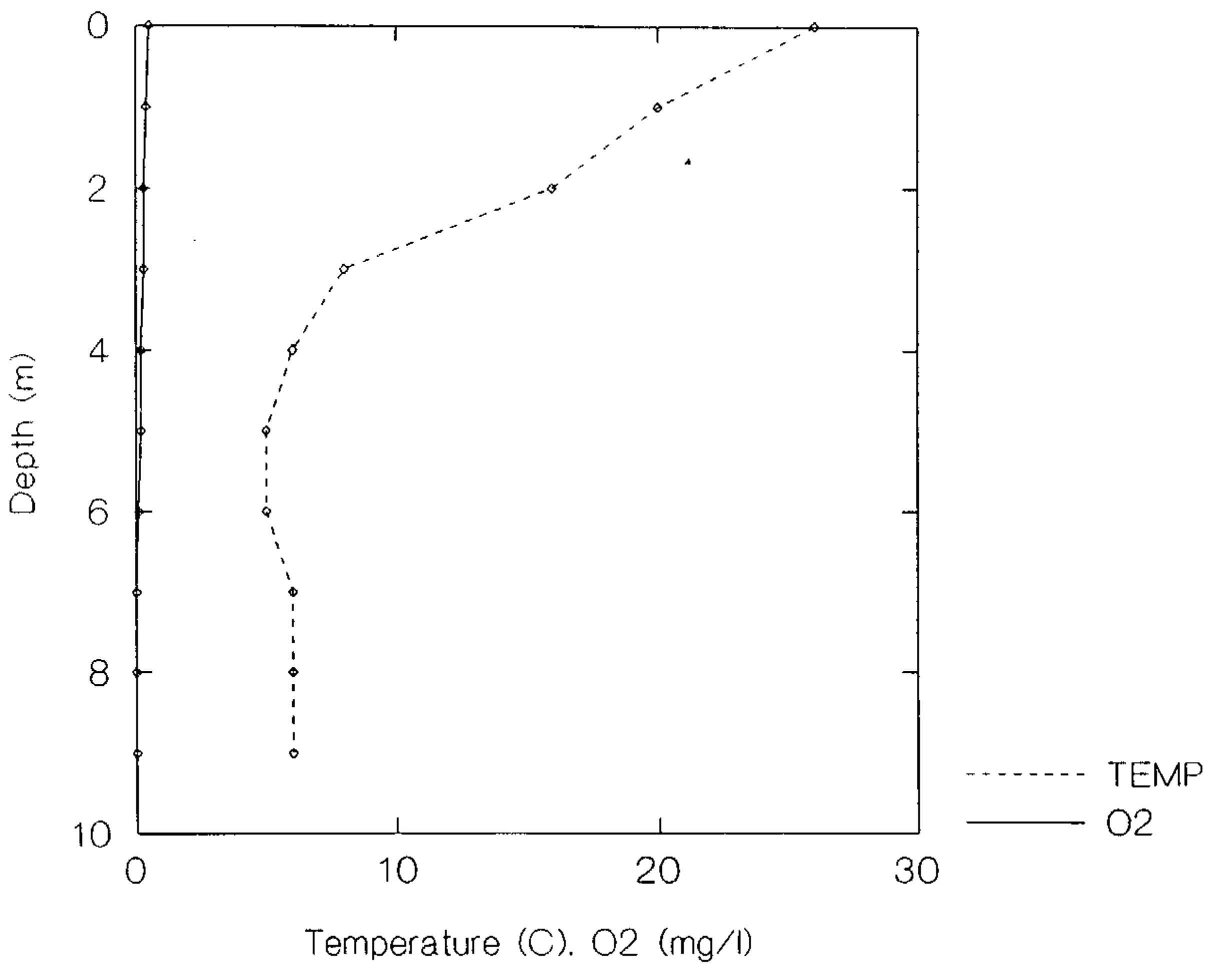
Appendix XII. Oxygen/ Temperature Profile of Tuesday Lake -Sample 1



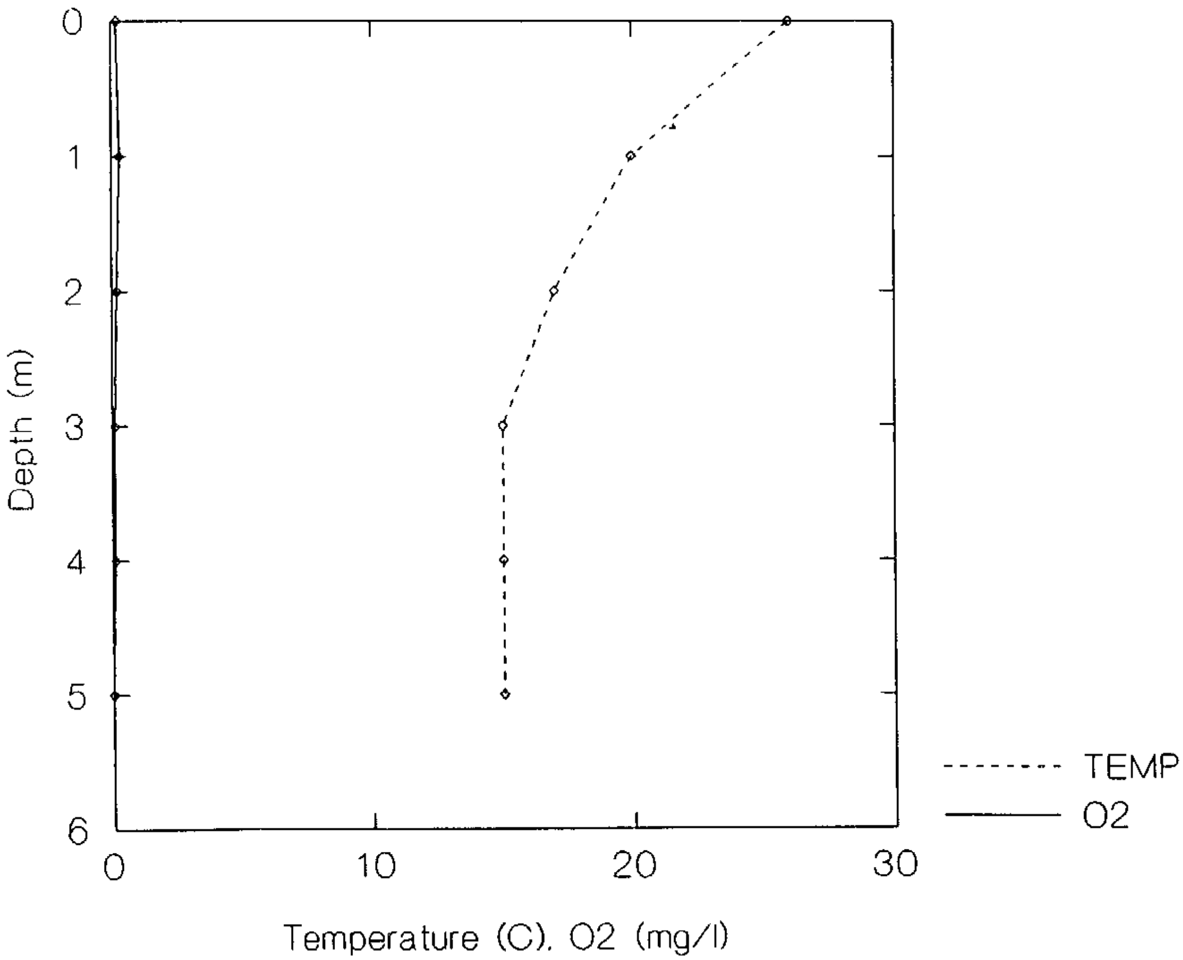
Appendix XIII. Oxygen/ Temperature Profile of Tender Bog- Sample 1



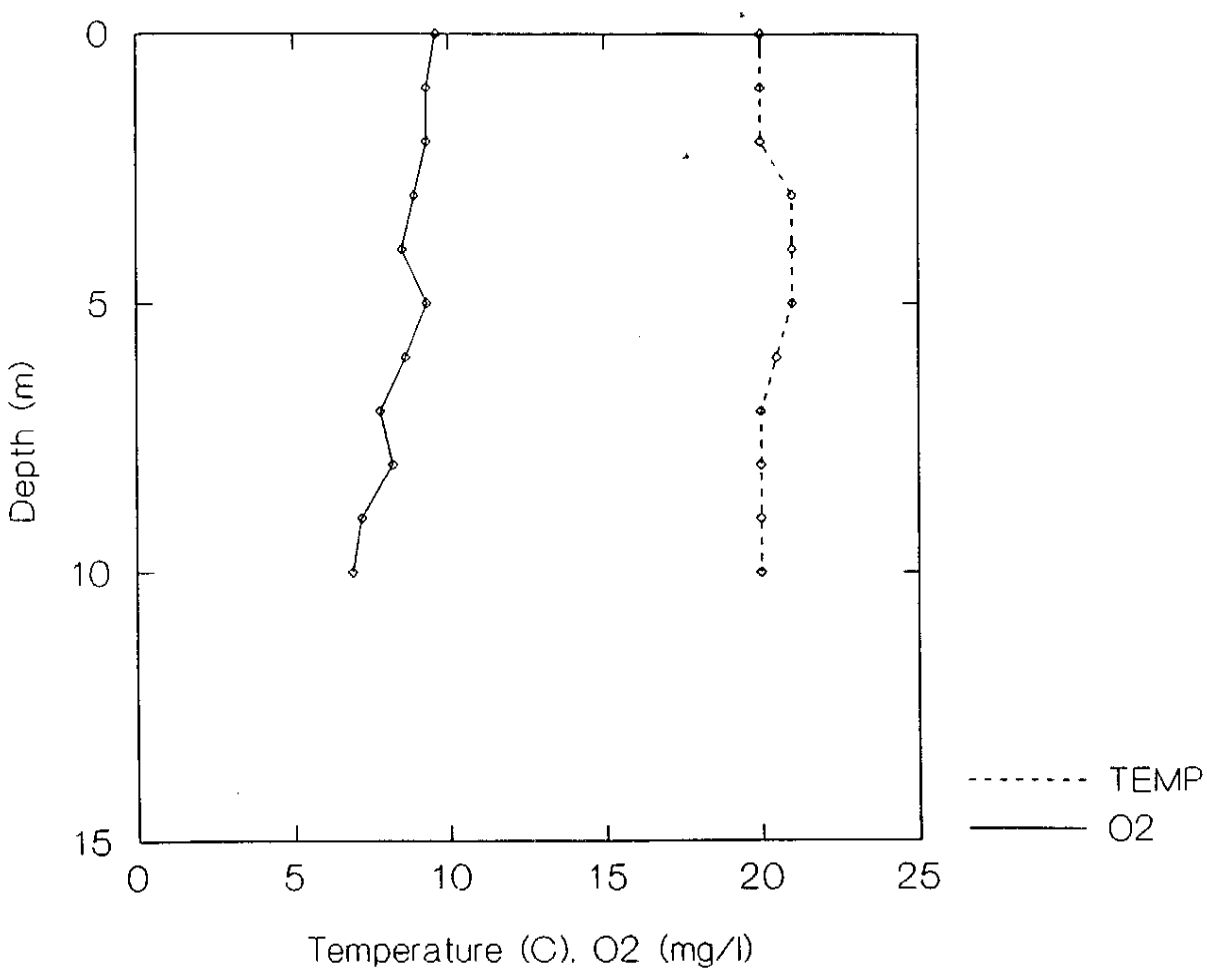
Appendix XIV. Oxygen/ Temperature Profile of Bolger Bog- Sample2



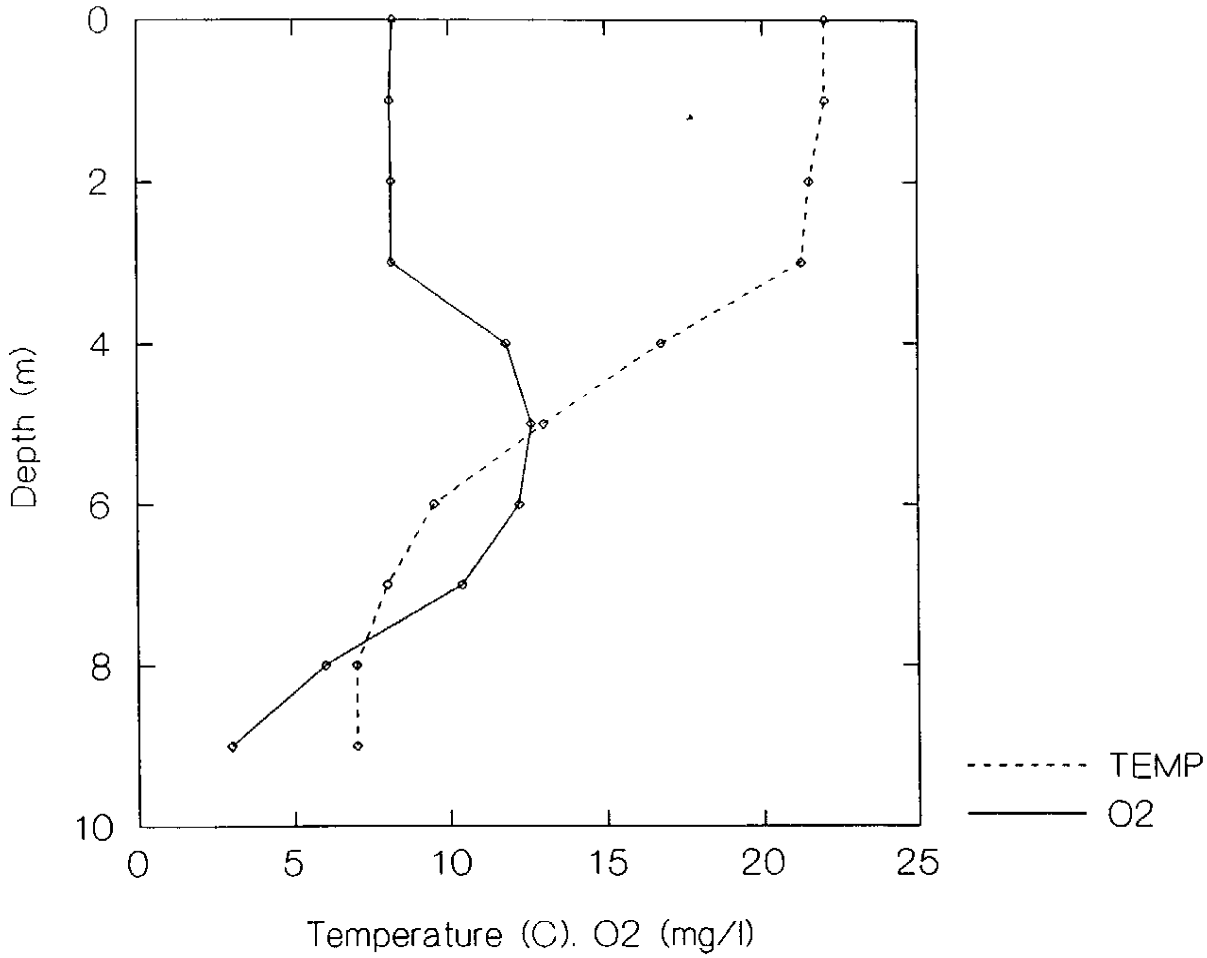
Appendix XV. Oxygen/ Temperature Profile of Bog Bot- Sample 2



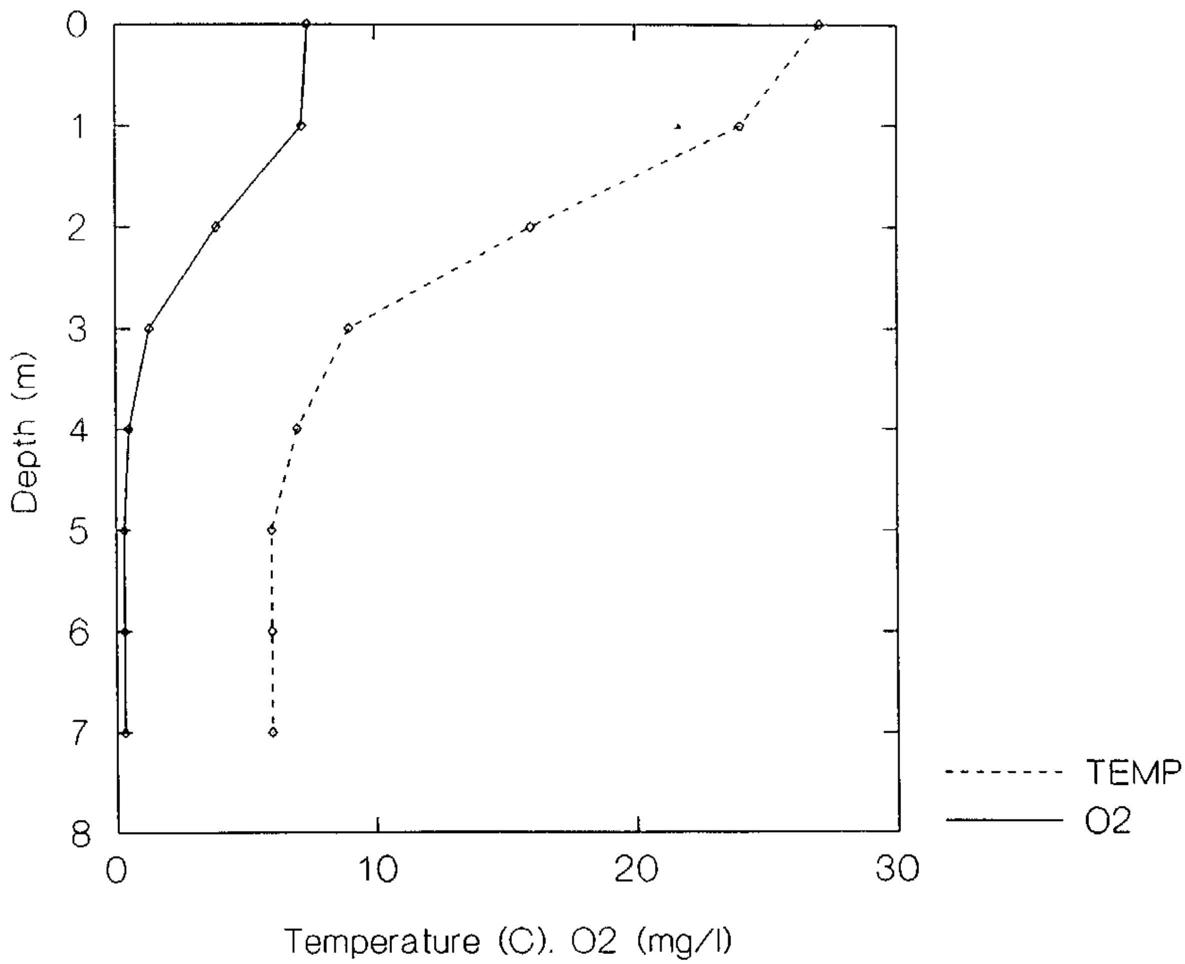
Appendix XVI. Oxygen/ Temperature Profile of Brown Lake- Sample 2



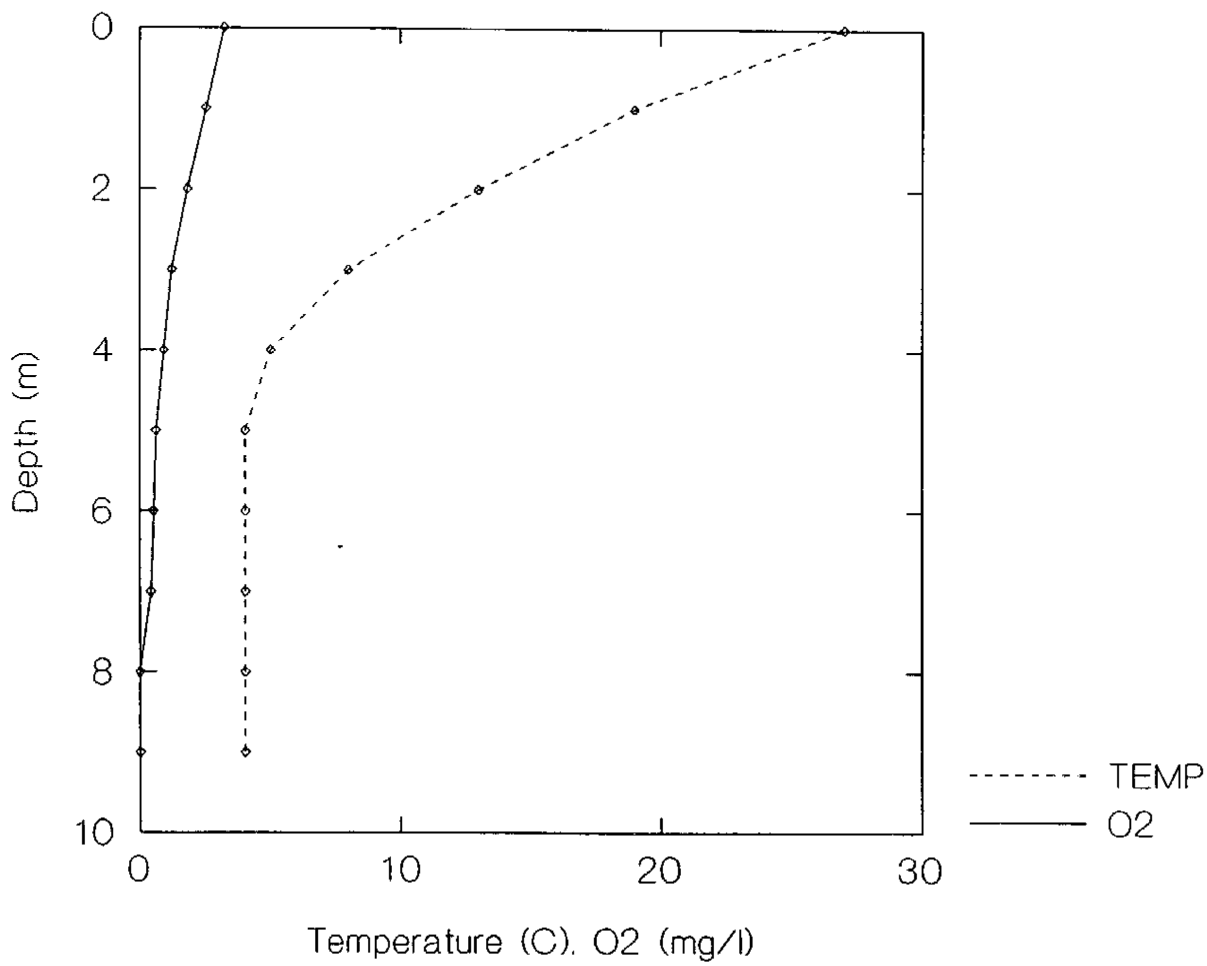
Appendix XVII. Oxygen/ Temperature Profile of Crampton Lake- Sample 2



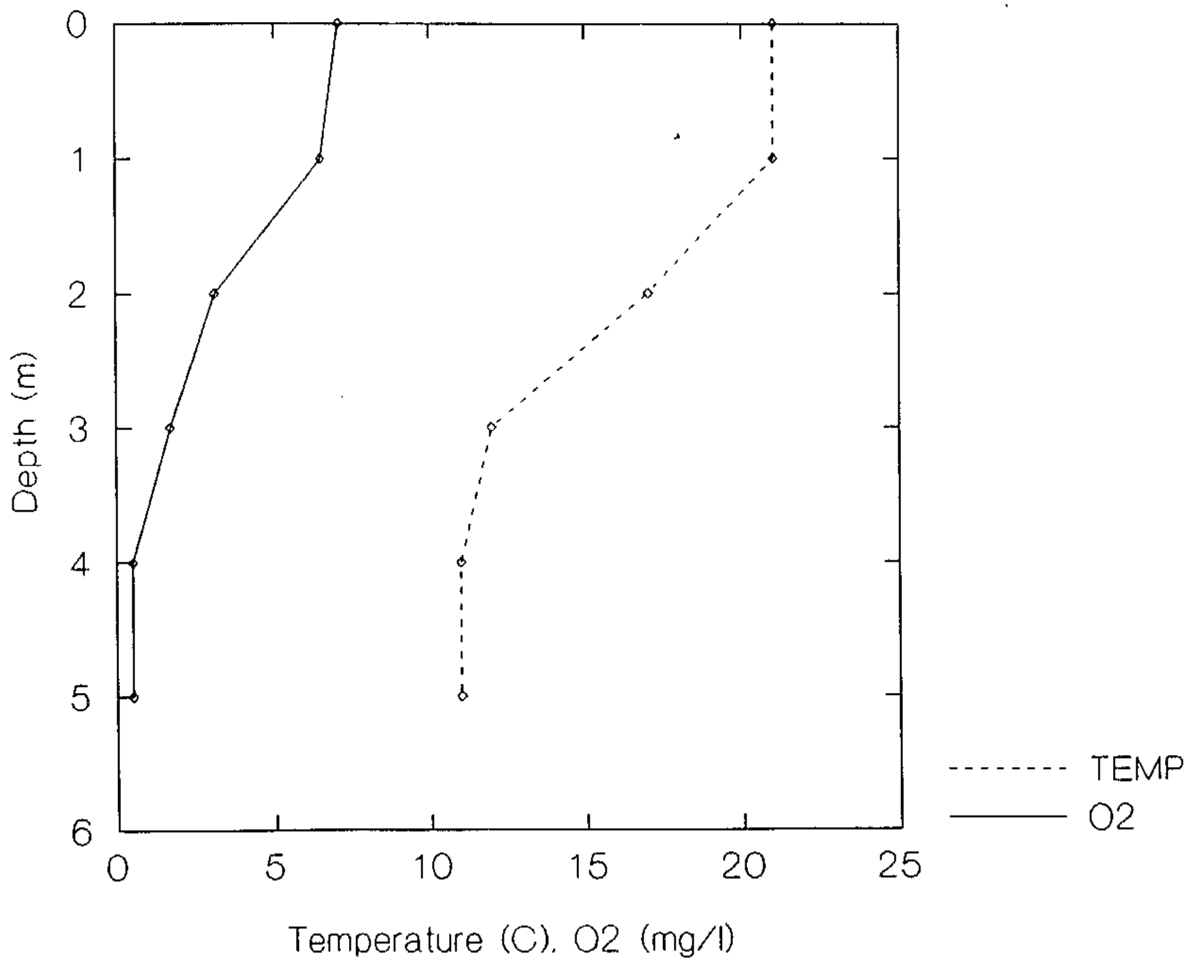
Appendix XVIII. Oxygen/ Temperature Profile of Cranberry Lake- Sample 2



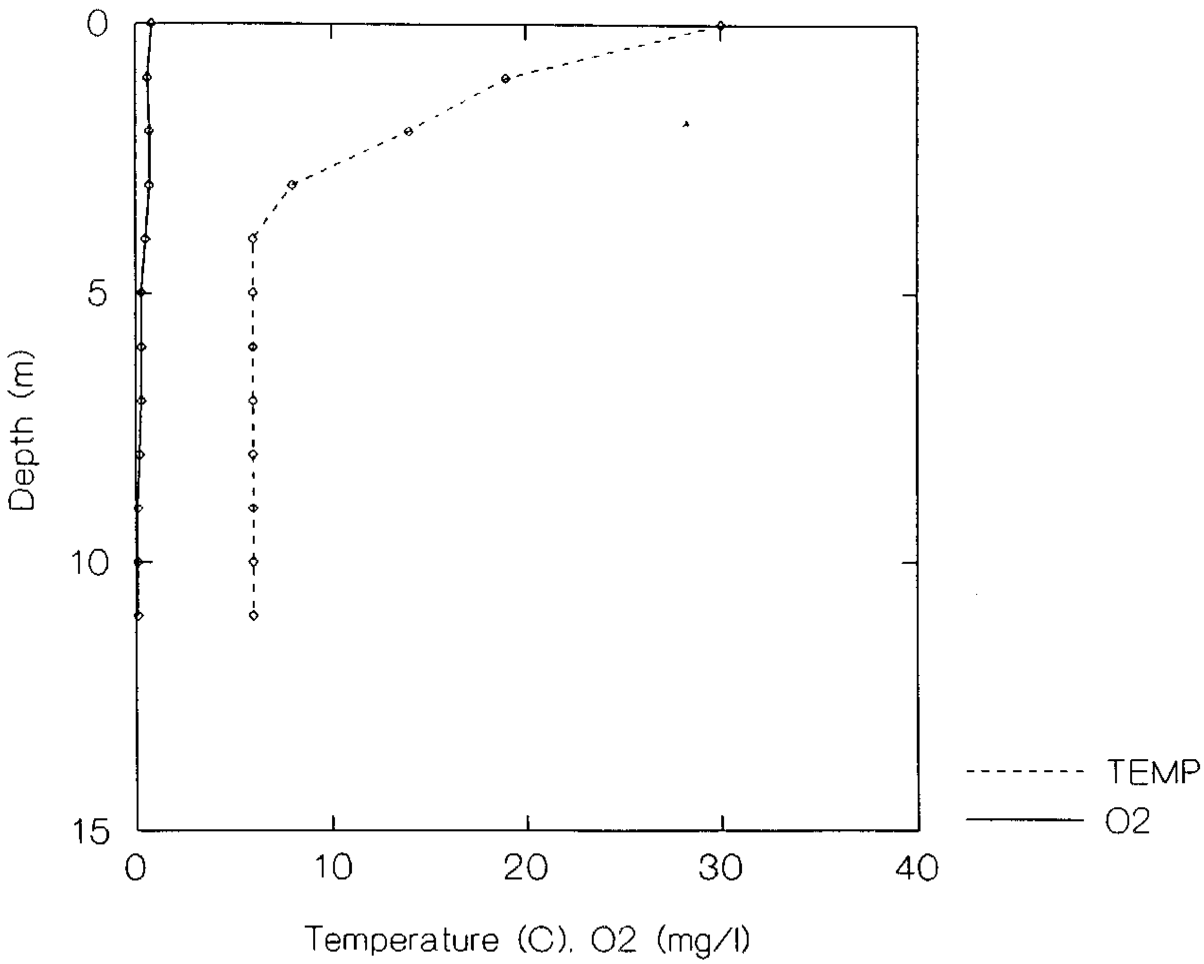
Appendix XIX. Oxygen/ Temperature Profile of Ed's Bog- Sample 2



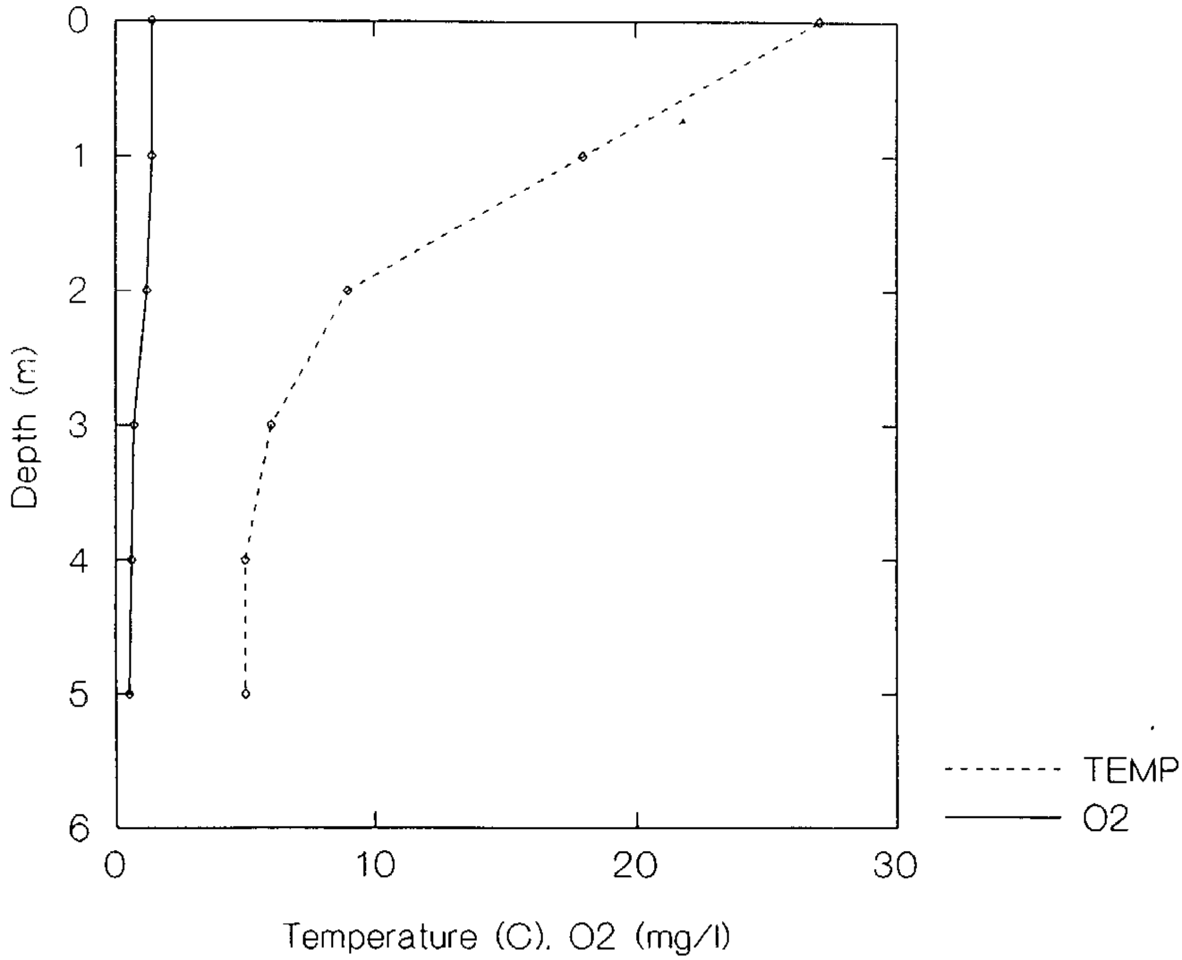
Appendix XX. Oxygen/ Temperature Profile of Forest Service Bog- Sample 2



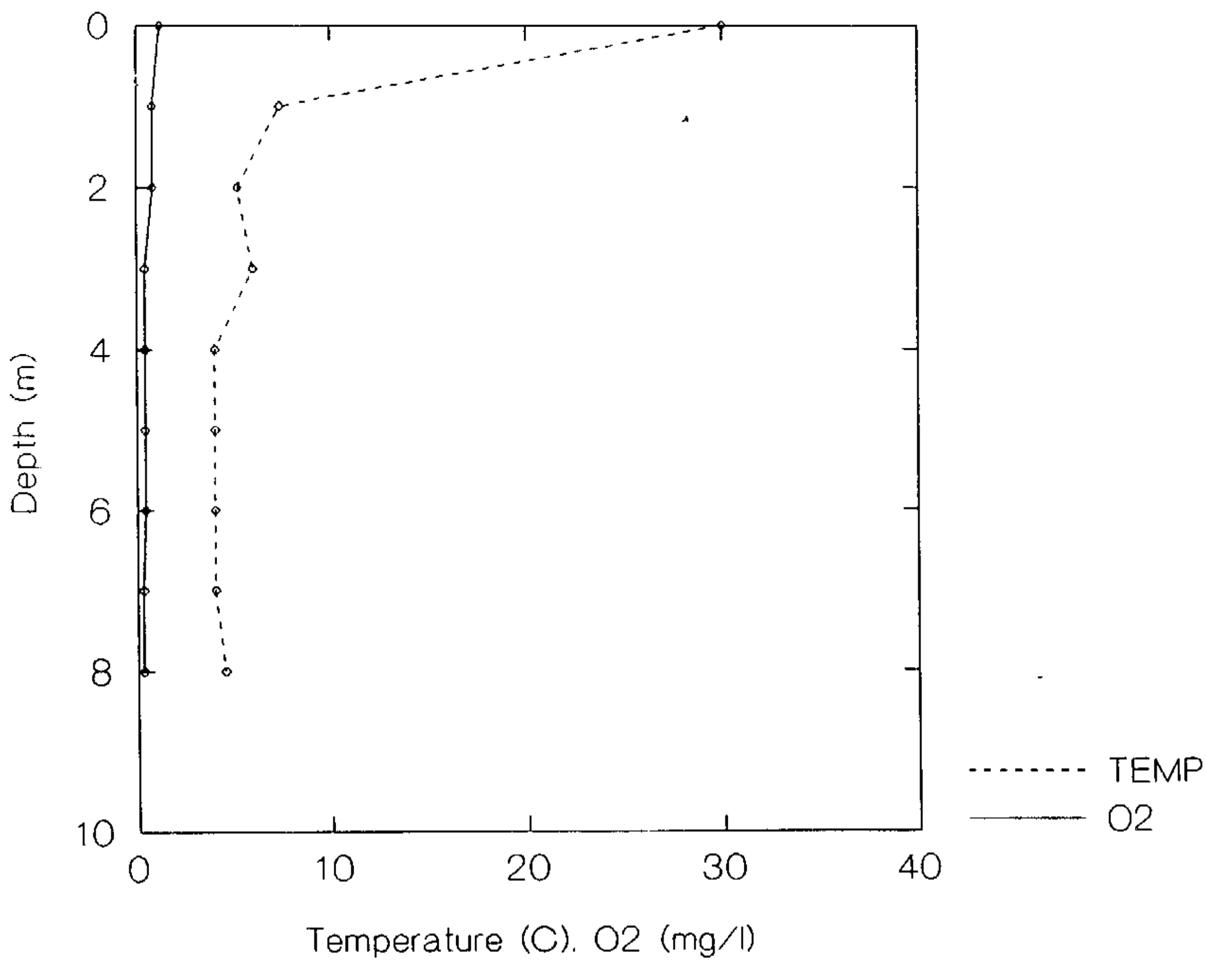
Appendix XXI. Oxygen/ Temperature Profile of Hummingbird Lake- Sample 2



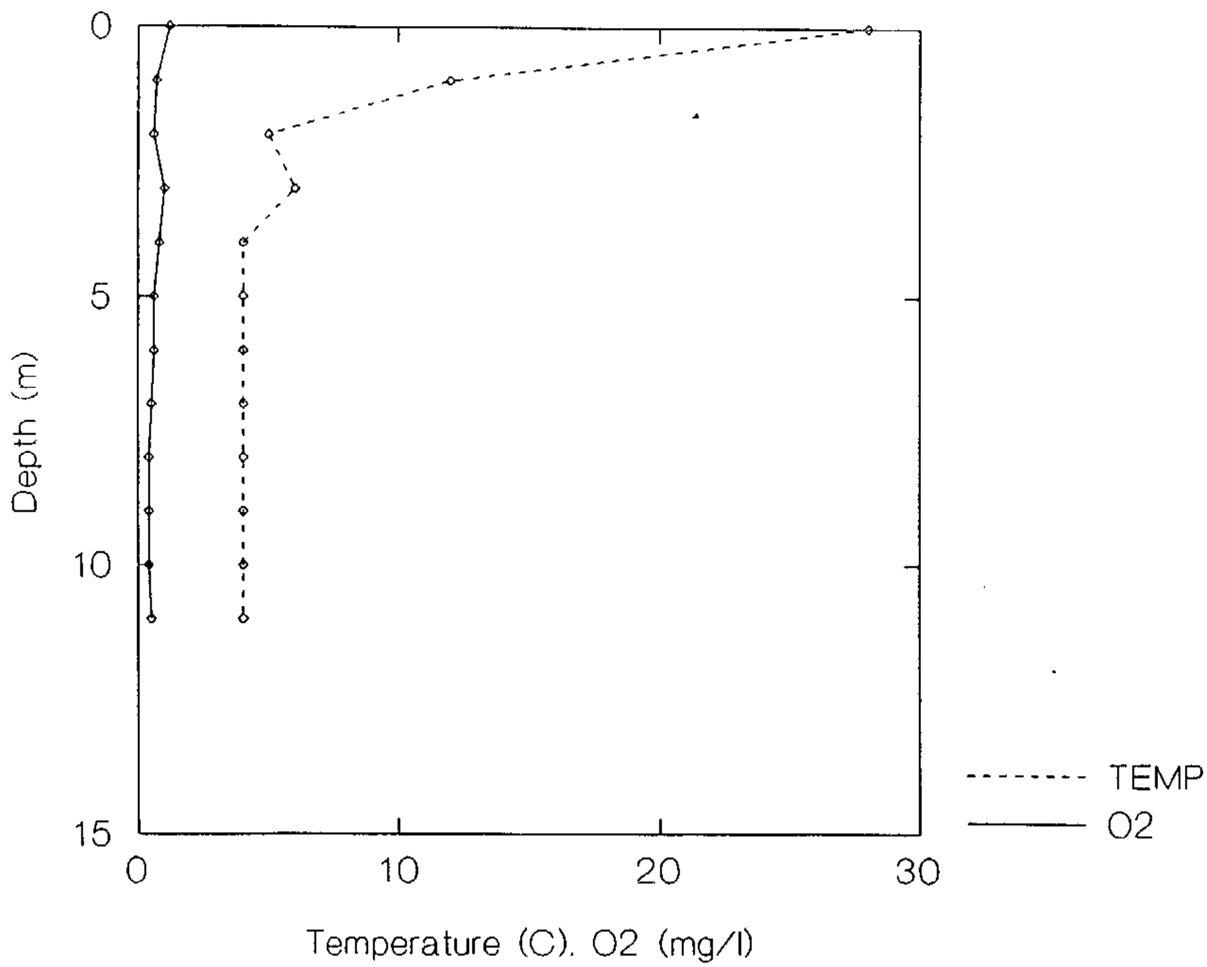
Appendix XXII. Oxygen/ Temperature Profile of Morris Lake- Sample 2



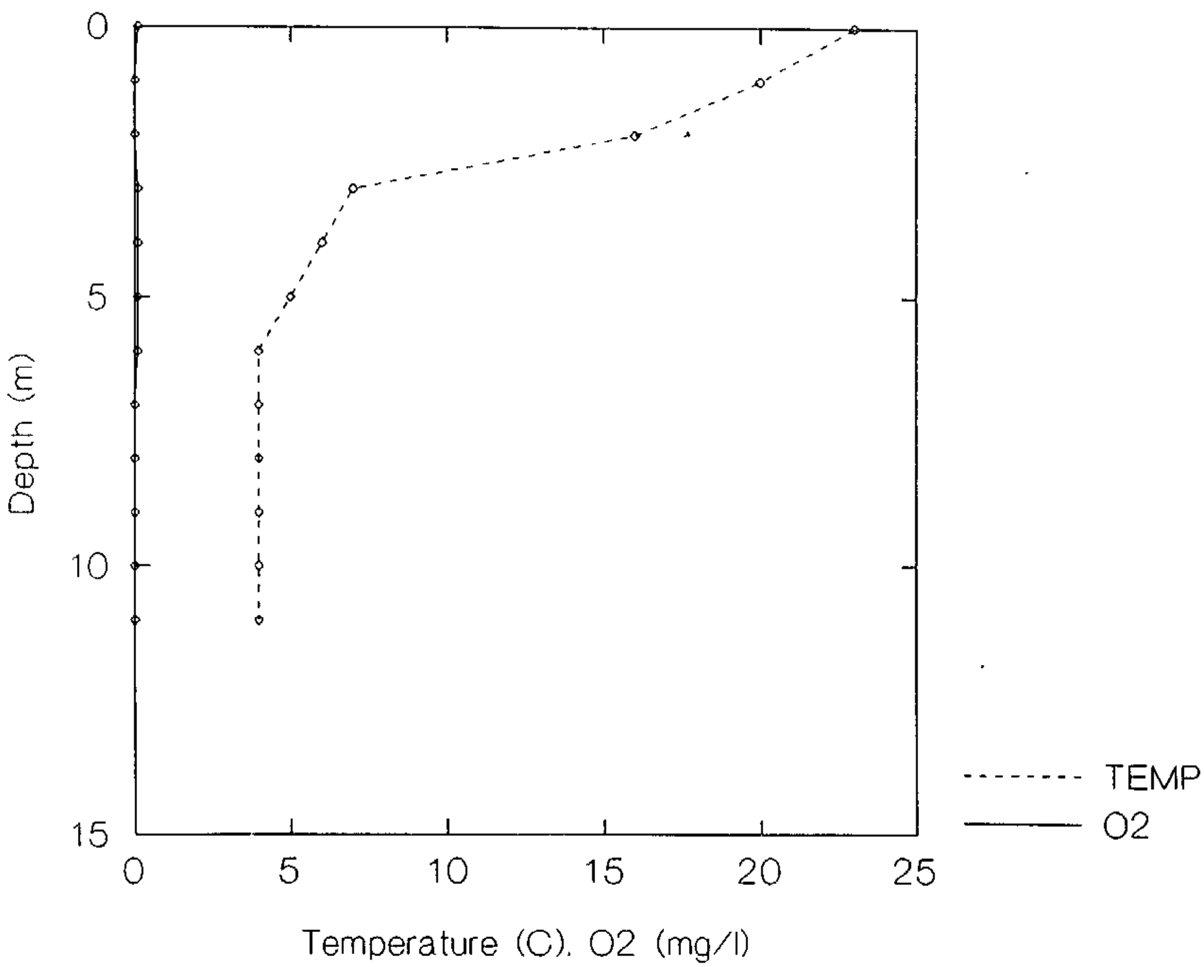
Appendix XXIII. Oxygen/ Temperature Profile of North Gate Bog- Sample 2



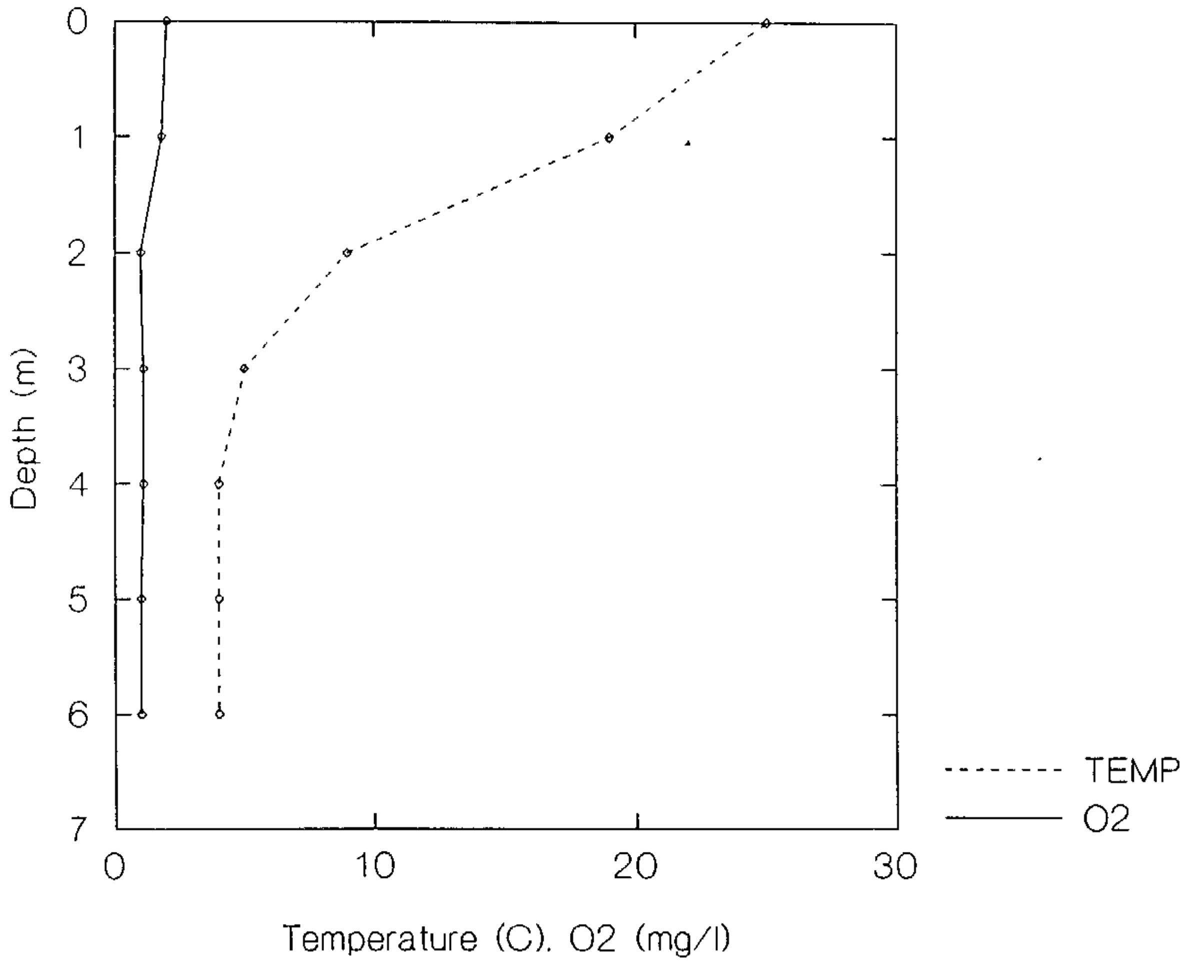
Appendix XXIV. Oxygen/ Temperature Profile of Reddingtion Lake- Sample 2



Appendix XXV. Oxygen/ Temperature Profile of Tuesday Lake- Sample 2



Appendix XXVI. Oxygen/ Temperature Profile of Tender Bog- Sample 2



Appendix XXVII. First Sampling

Species	Br	Bol	BP	Cran	Cram	Ed	FS	Hum	Mor	NG	Red	TF	T
G. marginatus	X	X	X		X		X	X	X				
G. argenticollis		X	X			X	X			X	X	X	
G.comatus		X									X		
G. buenoi			X			X				X	X		
G. dissortis								X					
G. inseperatus		X											
G. instar		X		X					X			X	X
G. alacris												X	
C. Sig. penniensis							X						
C. Sig. conocephala						X						X	
C. Sig. johnstoni			X										
C. Sig. mackinacensis				X			X						X
C. Sig. compressiodea				X			X			X			X
C. Sig. alternata			X				X						
C. Sig. decorata			X						X				
C. Sig. doloebra						X							
C. Sig. transfugurata	X								X				
C. Hesp. scarbicula							X						
C. Hesp. atopodonta	X			X									
C. Hesp. michganensis				X									
C. Hesp. vulgaris						X							
C. Calli audeni						X							
N. lunata	X	X					X		X		X		X
N. insulata				X									
N. borealis						X							
N. undulata							X						
B. Leth. amer.										X			X
P. Plea striola	X	X						X	X	X			
Nep. Ranatra fusca						X	X		X			X	X
Hydro. Hydro martini									X				
N. instar												X	

Appendix XXVIII. Second Sampling

Species	Br	Bol	BP	Cran	Cram	Ed	FS	Hum	Mor	NG	Red	TB	T
G. marginatus	X		X						X				
G. argenticollis		X	X			X	X		X	X	X	X	
G. comatus	X		X	X				X	X				
G. buenoi							X	X	X	X	X		X
G. dissortis						X							
G. alacris		X											
G. inseperatus													
G. instar		X	X		X	X	X	X	X	X	X	X	X
C. Sig. renniensis				X									
C. Sig. penniensis													
C. Sig. conocephala						X							
C. Sig. johnstoni													
C. Sig. mackinacensis				X									X
C.Sig. compressoidea										X		X	X
C. Sig. alternata						X	X						
C. Sig. decorata													
C. Sig. doloebra													
C. Sig. transfigurata									X				
C. Sig. knighti				X							X		
C. Sig. variablis													X
C. Hesp. scabricula													
C. Hesp. atopodonta													
C. Hesp. michganensis													
C. Hesp. vulgaris													
C. Hesp. kennicotti									X				
C. Call. audeni													X
C. Call. alaskensis							X						
C. instar		X	X			X	X		X	X	X		X
N. lunata	X								X				
N. insulata													
N. borealis						X							
N. undulata						X				X			
N. instar		X	X	X		X	X	X		X	X	X	
B. Leth. amer.													
B. instar		X	X	X		X			X	X	X	X	X
P. Plea striola	X	X								X			
Nep. Ranatra fusca		X	X	X		X	X			X	X	X	
Hydro. Hydro martini			X										
M. M. musanti		X	X			X	X		X	X			
M. M. cryptohila										X			
V. M. pulchella								X		X	X	X	
V. M. buenoi				X									

Appendix XXIX. Rankings of Sites

(from averages)

Abundance (highest to lowest)

1) Morris
2) Bog Pot
3) Forest Service and North Gate
4) Ed's
5) Tender Bog
6) Tuesday
7) Bolger Bog
8) Crampton
9) Cranberry
10) Brown and Tender Bog
11) Hummingbird

Species Diversity (highest to lowest)

1) Forest Service
2) Ed's and Morris
3) North Gate, Cranberry, and Bog Pot
4) Bolger Bog
5) Tuesday
6) Brown, Reddington, and Hummingbird
7) Tender Bog
8) Crampton

pH (lowest to highest)

1) North Gate
2) Tender Bog
3) Ed's
4) Cranberry
5) Hummingbird
6) Forest Service
7) Bog Pot
8) Crampton
9) Tuesday
10) Reddington
11) Bolger
12) Morris
13) Brown

Conductivity (lowest to highest)

1) Forest Service
2) Tuesday
3) Cranberry
4) Bog Pot
5) Crampton
6) Ed's
7) Hummingbird
8) Reddington
9) Tender Bog
10) Bolger Bog
11) North Gate
12) Morris
13) Brown

Alkalinity (lowest to highest)

1) Tender Bog
2) Hummingbird
3) Tuesday
4) Bog Pot
5) Ed's and Forest Service
6) Crampton
7) Reddington
8) Bolger
9) Morris
10) Brown

Color (lowest to highest)

1) Crampton
2) Forest Service
3) Tuesday
4) Brown
5) Cranberry
6) Ed's
7) Bolger
8) Bog Pot
9) Tender Bog
10) Morris
11) Hummingbird
12) Reddington
13) North Gate

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