Water Chemical and Habitat Confines of Aquatic Hemiptera

BIOS 569 - Practicum in Aquatic Biology

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Abstract

Hemiptera are found in a broad range of aquatic habitats and have shown promise for species-level habitat perimeters. Ten sites were sampled for aquatic Hemiptera and tested for pH, alkalinity, color, conductivity, light penetration, temperature, and dissolved oxygen. Hemiptera specimens were collected from the families Gerridae, Corixidae, Notonectidae, Belostomatidae, Pleidae, Nepidae, Hyrometridae, Microveliidae, and Veliidae. Data were combined with known morphometric and fish population data. Morphometric parameters included maximum depth, surface area, and shoreline development. Also included were the results of a similar study by Renee Ireton from the summer of 1996. Possible correlations to specific habitat characteristic ranges were found for species in the families Corixidae, Notonectidae, Gerridae, Belostomatidae, Veliidae, and Pleidae.

Introduction

The Hemiptera are one of the most diverse and abundant orders of insects. Aquatic species of Hemiptera may be found in virtually every existing freshwater aquatic habitat. This diversity and abundance within the Hemiptera make this order a very promising candidate for use as a biological indicator of many aquatic ecosystem characteristics.

The health of an aquatic ecosystem can be assessed by noting alterations in the organization of biota at the community level. Studies that appraise the health of natural environments by observing biota are based on the premise that the most accurate information regarding the integrity of an ecosystem can be obtained by monitoring the organisms that actually live within the area of interest (Doust *et al.* 1994).

The use of indicator species to evaluate aquatic ecosystems has many advantages over traditional analytical chemical tests, as has already been shown for pollution monitoring. Many hazardous organic compounds produce adverse biological effects at concentrations below existing analytical detection capabilities. Chemical techniques are also incapable of predicting the detrimental effects certain pollutants can have on ecosystems. This is because several environmental-quality parameters (temperature, water hardness, and pH) mediate their toxic response. Finally, many toxicants may act differently in combination than they do individually (Doust *et al.*, 1994). Chemical testing alone cannot predict the cumulative impact of mixed contaminants upon the biotic components of the environment, but the effects upon on organism in that environment may show evidence of all these factors (Mizell *et al.*, 1996). It is noted that species differ inherently in their susceptibilities towards toxicants, and as a result the presence or absence of a given species may indicate much about the health of an aquatic ecosystem (Doust *et al.*, 1994).

The aquatic Hemiptera make use of a broad range of habitats within a water body. This order of insect may live in the littoral zone of lakes and bogs as well as upon the water surface. The water surface is not well populated by any other insect group. As a result, Hemiptera encounter little competition in this habitat. (Dolling, 1991) This diversity of habitat allows much speciation within the Hemiptera order, making it an excellent candidate for use as an environmental indicator organism. Its abundance would facilitate the use of species within this order for water quality monitoring in a variety of aquatic habitats.

Past studies of the aquatic Hemiptera species found in Wisconsin have discovered several habitat perimeters. A 1986 study by Bennet and Streams found that (Notonectidae) *N. lunata* inhabits the vegetation of fish ponds, while *N. undulata* primarily inhabits fishless ponds and is not associated with vegetation during the adult stage. *N. insulata* was found in deeper water without fish or vegetation, while *N. irrorata* showed random distribution with respect to vegetation and water depth. With respect to chemical perimeters, a study by Bendell (1988) discovered that (Gerridae) *Meterobates hesperitus* never inhabits a lake with water acidity below the pH of 5.1.

Finally, a study by 1996 UNDERC student Reneé Ireton found that (Notonectidae) *N. undulata* inhabits small ranges for acidity, conductivity, and alkalinity. Within the family Corixidae, *S. mackinacensis*, *S. alternata*, and *S. compressoidea* all showed similar water chemistry ranges for pH, conductivity, and alkalinity. In addition, *S. mackinacensis* and *S. alternata* both occupied a low conductivity range and relatively low color ranges. *H. atopodonta* also occupied only a narrow range of water color. (Gerridae) *G. comatus* occupied a small light range of 0.7 to 1.6 meter Secchi depth readings. Ireton's work focused primarily on bogs and small, fishless lakes.

These studies indicate that specific perimeters do exist for certain species of aquatic Hemiptera. Once clear habitat associations are established for a specific Hemiptera species, the presence of that species may be used to evaluate certain characteristics of an aquatic environment. This study expands upon Ireton's work at UNDERC to include eight larger, fish-containing lakes in addition to two stream habitats. In addition possible correlations between certain morphometric parameters and fish populations were also examined for each of the ten sites and Ireton's original thirteen sites. The project utilizes sampling data to establish ecosystem perimeters and trends for species of aquatic Hemiptera in their natural environment.

Materials and Methods

Ten different aquatic sites were sampled for Hemiptera. Eight lakes were sampled including Bay Lake, Bergner Lake, Kickapoo Lake, Mullahy Lake, Nansen Lake, Raspberry Lake, and Tenderfoot Lake. Two streams were sampled: Brown Creek (near the South Gate) and Tenderfoot Creek (at the riffle near the gravel pit as well as at the northern road crossing). All of these sites were located on the property of the University of Notre Dame Environmental Research Center (UNDERC). On Tenderfoot Lake only the littoral zone bordering UNDERC property was sampled. The property is situated on the border between Wisconsin and the Upper Peninsula of Michigan. Sites provided variety in size, depth, shoreline development vegetation, acidity, alkalinity, color, light, and conductivity. Choice of sampling sites focused on fish-inhabited lakes.

Water Chemistry Tests

Each aquatic site was first evaluated for the presence and degree of certain water chemical characteristics. The tests included measurements of temperature and oxygen, color, pH, conductivity, alkalinity, light, and sulfide. Tests were performed at each lake from a boat or raft over the deepest point in the lake. At the stream sites the tests were performed using waders to test at the center of the stream. Temperature, oxygen, pH, and conductivity were each tested on the site using the appropriate meter. A secchi disk was used to evaluate light penetration. Four water samples were taken at each site: two at one-half secchi depth using a VanDorn sampler and two at the surface. Each water sample was put into a clean glass jar and placed in a cooler for protection from heat and light. The remaining tests were performed within twenty-four hours at the lab using protocols found in the 1989 HACH Water Chemistry Analysis Handbook. These included tests for apparent color, sulfide, and alkalinity. All sites were sampled immediately before insect collection. Sampling took place twice, with a month between each sampling period.

Insect Sampling

After water chemistry work was completed on site the Hemiptera sampling was conducted. The littoral zone of each lake was sampled using a dip net. Most lakes were sampled on foot from the shore or the water using waders, though the instability of some shorelines required the use of a boat or raft for sampling. All the Hemiptera found at a site were placed in a labeled glass jar filled with 80% ethanol. There were two collection periods which took place one month apart. During each collection period sites were sampled within as few days as possible to ensure that all insects of a particular species would be at a similar stage in their life cycle. The first collection period lasted four days with approximately two hours devoted to insect sampling on each site. Only three days were required for the second collection period, and increased efficiency and familiarity with both the sites and the collection methods allowed sampling time to be cut to one and one-half hours per site. The large size of some sites allowed sampling of only a small percentage of the littoral zone, but sampling was conducted on as many different substrates and geographic areas within a site as possible.

Identification of Insects

Each collected specimen was identified as accurately as possible with the keys available. All of the adult male Hemiptera were identified to species. Females were also identified to species whenever possible. Immatures were identified to Family or Genus. Identification was accomplished using forceps and a dissecting microscope. Six different keys were used to help ensure accurate identification. Each identified insect was placed into a four dram vial and preserved in ninety percent ethanol. The vial also contained a label bearing the name of each species, location of the sample site, and the sample date.

Results

Water chemistry testing yielded perimeters for each of the ten sites tested as shown in Table 1. The lakes tested were relatively neutral, ranging from 6.0 for Bergner Lake to 7.9 for Tenderfoot Lake. Readings for pH from the first sampling period were discarded due to problems with equipment accuracy. Conductivity readings covered a broad range. Bergner Lake had the lowest conductivity with an average reading of 11.2 µmhos/cm while Ward Lake had the highest with an average of 140.0 µmhos/cm. Five sites had readings over 80.0 µmhos/cm. Alkalinity readings ranged from 0.0 mg/l for Bay, Bergner, and Raspberry Lakes to 58.0 mg/l for Ward Lake. Six of the ten sites displayed alkalinities over 30.0 mg/l. Alkalinity data from the first sampling period were discarded due to testing inaccuracies. Color (in platinum/cobalt points) was lowest in Bay Lake at an average of 14.5. The highest color reading was for Nansen Lake at 134.88. In five of the ten sites color readings fell between 50.0 and 80.0. All the lakes showed Secchi disk readings over 1 meter. Secchi depths ranged from 1.40 m. in Nansen Lake to an average of 3.55 m. in Bay Lake. Only one Secchi depth reading is available for Nansen Lake because not all needed equipment could be transported to the site for the first sampling period. Average measurements for each chemical property are in Table 1. An oxygen/temperature profile sites from the first sampling period is shown in Appendices I-IX. All lakes displayed surface oxygen saturation at or near 100%. Oxygen saturation at the lowest reading depth varied among lakes, but it was consistently less than the surface level. Most lakes showed a rise in oxygen readings (above those at surface level) at some point below the surface.

Hemiptera were collected at all ten sites, but not always during both collection periods. The combined species and abundance data for both collection periods are displayed in Table 3. In the first collection period Hemiptera from the families Gerridae, Nepidae, and Notonectidae were found. The vast majority of species collected during the first collection period were in the family Gerridae. No species were found at this time in Bergner Lake, Tenderfoot Creek, or Ward Lake. Collection data are shown in Table 4. During the second collection period Gerridae, Nepidae, and

Notonectidae were found again. In addition species were found in the families Belostomatidae, Corixidae, Mesoveliidae, Pleidae, and Veliidae. All instars were found in the second collection period. Table 5. displays insect data from the second collection period.

Abundance was lowest in Tenderfoot Creek with 2 insects from one species. Highest abundance and diversity were seen in Ward Lake with 58 insects from 11 species. Tenderfoot Lake also displayed high abundance and diversity with 57 insects from 9 species. Bergner Lake showed relatively high abundance with 38 insects, but low diversity at 3 species. Similar abundance and diversity were observed in Kickapoo Lake and Mullahy Lake. Kickapoo yielded 26 insects from 6 species while Mullahy yielded 25 insects from 7 species. Bay Lake also yielded 25 insects, but these came from only 4 species. In Nansen Lake 19 insects from 5 species were collected. Raspberry showed the lowest abundance and diversity for any lake with 5 insects collected from 3 species. Brown Creek yielded 8 insects from 3 species.

Discussion

For those water chemistry tests which were conducted during both sampling periods only one clear trend was evident. Every site except for Raspberry Lake increased in conductivity from the first sampling period to the second. Secchi depths and color readings fluctuated between the two sampling periods with no apparent trend. It may be possible that particular fluctuations in certain chemical characteristics may influence the variations in presence and maturity of insects at different times of the summer. All lake oxygen/temperature profiles indicated stratification typical of a dimictic lake in early summer. Subsurface areas of supersaturation observed in Bay, Kickapoo, Mullahy, and Raspberry Lakes were likely the result of algal photosynthetic activity.

Data from this study in the summer of 1997 were combined with data collected by UNDERC student Renee Ireton in the summer of 1996 for different sites on the UNDERC property. The combined insect collection data from 1996 and 1997 are presented in Appendix IX. Morphometric parameters and fish population information were also examined for all the sites from 1996 and 1997. These data are presented in Table 2. and Appendices XV-XVIII.

Each family studied tended to show general trends towards specificity or broad tolerance for many of the water quality characteristics studied. Species within the family Corixidae tended to show the narrowest perimeters for the greatest number of characteristics. Some convincing perimeters were also suggested within the family Notonectidae. The same is true of the Pleidae, Veliidae, and Mesoveliidae. Overall the Gerridae tended to occupy the broadest range of water quality values.

The data suggest a number of prospective correlations for species within the family Corixidae. In general the greatest species diversity for Corixidae was seen in lakes below pH 7 (Appendix X). Overall the Corixidae were less prevalent in lakes with Secchi disk readings over 2m and surface areas over 2 ha (Appendices XIV and XVI). Corixidae were also generally less abundant in lakes with higher feeding fish (Appendix XVIII).

Comparable water quality ranges were seen within the species *S. mackinacensis*, *S. alternata*, and *S. compressoidea*. All three species exhibited tolerance in a low alkalinity range of 0 to 6 mg/l (Fig. 7). *S. compressoidea* occupied a conductivity range from 8 to 36 um/cm, while both *S. mackinacensis* and *S. alternata* showed a more narrow range of 8 to 15 um/cm (Fig. 8). In relation to pH *S. compressoidea* was found between 4.1 and 6, *S. mackinacensis* between 4.7 and 6, and *S. alternata* between 4.7 and 5.5 (Fig. 6). Color correlations seem possible for *S. alternata* between 36 and 127 and for *S. mackinacensis* between 51 and 98, while *S. compressoidea* was found within a much broader color range (Fig. 9). Secchi depth readings from 0.7m to 2.3m for all three species indicate a broad tolerance for light penetration (Fig. 10).

Within the sites sampled *S. transfigurata* showed tolerance for high and narrow values of pH, alkalinity, and conductivity. *S. transfigurata* was found in a pH range of 6.7 to 8.0, an alkalinity range of 26-50 mg/l, and a conductivity range of 61.3-101 um/cm (Figs 6-8). It also was found in a narrow range of 5.5 to 7m for maximum lake depth and 1.19 to 1.27 for shoreline development. *P. nana* was found in a lake with high light penetration and Secchi depth readings of 2.7-3.5m. All other Corixidae were found in lakes with more shallow light penetrations. *H. atopondonta* showed the widest tolerances for pH, alkalinity, and conductivity, but only was found in water color from 98 to 104 and light penetrations with Secchi readings from 1.1 to 1.2m (Figs 6-10).

Water quality ranges between certain species of Corixidae were never seen to overlap. While both *S. decorata* and *S. transfigurata* occupied wide ranges for alkalinity and conductivity, both were never found in lakes with the same value for either characteristic. The same phenomenon is seen between *S. alternata* and *S. decorata* for pH, conductivity, and color. *S.penniensis* and *S. conocephala* diverged on those same characteristics. It appears that either chemical tolerance alone or chemical tolerance combined with competition and specialization may prevent these pairs of species from inhabiting the same water body.

The family Notonectidae showed more tendency towards species generalization for the water qualities studied. *N. undulata* was found only in sites with alkalinity readings below 30 mg/l (Fig 3), but it showed a wide tolerance for color and light penetration (Figs 4 and 5). A wide tolerance was shown by *N. lunata* for pH, conductivity, alkalinity, color, and light penetration (Figs 1-5).

Species within the family Gerridae showed a wide tolerance range for most site characteristics. This is likely due to the ability of this family to inhabit the water surface and thereby be less subjected to the affects of certain water chemical properties. There was, however, a general trend towards greater species diversity in lakes with high color (Appendix XIII) and shallow Secchi disk readings (Appendix XIV). *G. dissortis* did show a narrow range of 7-13.7m for maximum lake depth (Appendix XV), but a very wide range from 13.5 to 247 for water color (Fig 14). *G. buenoi, G. marginatus,* and *G. comatus* were found in very broad ranges for alkalinity, while *G. argenticollis* occupied a lower range from 0 to 28 mg/l. The smallest alkalinity range was exhibited by *G. alacris* from 0 to 15 mg/l (Fig. 12). *G. comatus* was found within the largest range for light penetration, followed closely by *G, dissortis* (Fig.15). In general *G. marginatus* and *G. comatus* appeared to favor similar water qualities, as did *G. argenticollis* and *G. buenoi.*

Some promising correlations are suggested by data for the remaining Hemiptera families. Within the family Pleidae the species *Plea striola* was found only in waters with conductivity readings above 20 um/cm (Fig. 18). *P. striola* was also found in a small range of 3.5-7m for maximum lake depth and 1.05 to 1.27 for shoreline development (Appendices XV and XVII). While the Belostomatidae (*L, americanus)* showed wide ranges for ph, color, light penetration, alkalinity, and conductivity, it did show a very narrow range of 1.04 to 1.07 for shoreline development and was never found in lakes with a fish population index over 2 (Appendices XVII and XVIII). *L. americanus* was also found only in lakes with areas below 6 ha (Appendix XVI). Wide pH and light penetration ranges were exhibited by the Veliidae (*M. pulchella*), but it was only found in sites with low alkalinity (0-12 mg/l) and conductivity (10.7-36 um/cm) (Figs 17 and 18).

This study indicates that Hemiptera would be a highly promising choice for further study as an aquatic habitat indicator organism for a variety of water characteristics. The development of a reliable quantitative sampling method for Hemiptera would likely provide further helpful correlations. Future study should also include a greater number of sampling sites and more frequent water-chemical sampling to give more complete water quality ranges. The development and analysis of solid correlations for Hemiptera in relatively pristine habitats such as those in this study might also provide a useful baseline for comparison with future research in more polluted areas.

Table 1. Water Chemical Perimeters of Sampling Sites

Sample 1: 6/1/97-6/4/97					
Site	pH	Cond. (um/cm)	Alk. (mg/l)	Color (Pt-Co)	Secchi (m)
Bay Lake		14.7		13.50	3.70
Bergner Lake		10.7		70.00	2.20
Brown Creek		78.8		104.00	
Kickapoo Lake		42.4		90.00	1.40
Mullahy Lake		86.0		80.25	1.60
Nansen Lake		27.1		137.50	
Raspberry Lake		11.4		37.25	2.60
Tenderfoot Creek		77.5		69.50	
Tenderfoot Lake		76.7		36.50	2.70
Ward Lake		135.4		58.00	2.70
Sample 2: 6/29/97-7/1/97					
Site	pH	Cond. (um/cm)	Alk. (mg/l)	Color (Pt-Co)	Secchi (m)
Bay Lake	7.6	14.8	0.0	16.00	3.40
Bergner Lake	6.0	11.6	0.0	54.75	2.20
Brown Creek	7.1	105.4	47.0	76.50	
Kickapoo Lake	7.6	73.6	39.5	66.00	1.63
Mullahy Lake	7.6	110.3	36.0	79.40	1.30
Nansen Lake	7.0	31.6	10.5	132.25	1.40
Raspberry Lake	7.3	11.3	0.0	35.00	2.70
Tenderfoot Creek	7.6	95.5	38.0	71.00	
Tenderfoot Lake	7.9	84.3	33.5	43.50	3.50
Ward Lake	7.6	144.5	58.0	56.50	2.25
Average Measurements					
Site	pH	Cond. (um/cm)	Alk. (mg/l)	Color (Pt-Co)	Secchi (m)
Bay Lake	7.6	14.8	0.0	14.75	3.55
Bergner Lake	6.0	11.2	0.0	62.38	2.20
Brown Creek	7.1	92.1	47.0	90.25	
Kiackapoo Lake	7.6	58.0	39.5	78.00	1.52
Mullahy Lake	7.6	98.2	36.0	79.83	1.45
Nansen Lake	7.0	29.4	10.5	134.88	1.40
Raspberry Lake	7.3	11.4	0.0	36.13	2.65
Tenderfoot Creek	7.6	86.5	38.0	70.25	
Tenderfoot Lake	7.9	80.5	33.5	40.00	3.10
Ward Lake	7.6	140.0	58.0	57.25	2.48

Table 2. Other Perimeters

Site	Max. Depth (m)	Area (ha)	Shore. Develop.	Fish Pop. Index
Bay Lake	14.0	67.0	2.6	3
Bergner Lake	12.0	18.0	1.4	3
Brown Creek				2
Kiackapoo Lake	3.3	7.9	1.3	3
Mullahy Lake	1.3	1.1	1.4	1
Nansen Lake	3.3	4.0	1.3	n
Raspberry Lake	6.0	4.6	1.2	3
Tenderfoot Creek				2
Tenderfoot Lake	9.1	194.0	1.9	3
Ward Lake	7.0	2.7	1.1	2

Fish Population Index : 3: > or = 2 species piscivorous fish; 2: 1 species piscivorous fish; 1: no known piscivorous fish; 0: no known fish; n : no information

Table 3. Total Hemiptera Collected

Family	Species	Bay	BCr	Ber	Kic	Mul	Nan	Ras	TCr	TLk	War
Belostomatidae	Leth. amer.										1
	instar					3					1
Corixidae	Palm. nana									2	
	Tri. nais										15
	instar					2				7	2
Gerridae	G. buenoi		5		2	5	8	1		3	5
	G. comatus	2	2		11	6	5		2	14	2
	G. dissortis	2									
	G. instar	18		20	2		4	3		7	4
Mesoveliidae	M. mulsanti	3		4		6	1			14	7
Nepidae	Ranatra fusca		1		2					1	
Notonectidae	N. irrorata				2						
	N. lunata				7					1	
	N. undulata							1			
	N. instar					2	1				3
Pleidae	Plea striola										2
Veliidae	M. pulchella			14		1				8	16

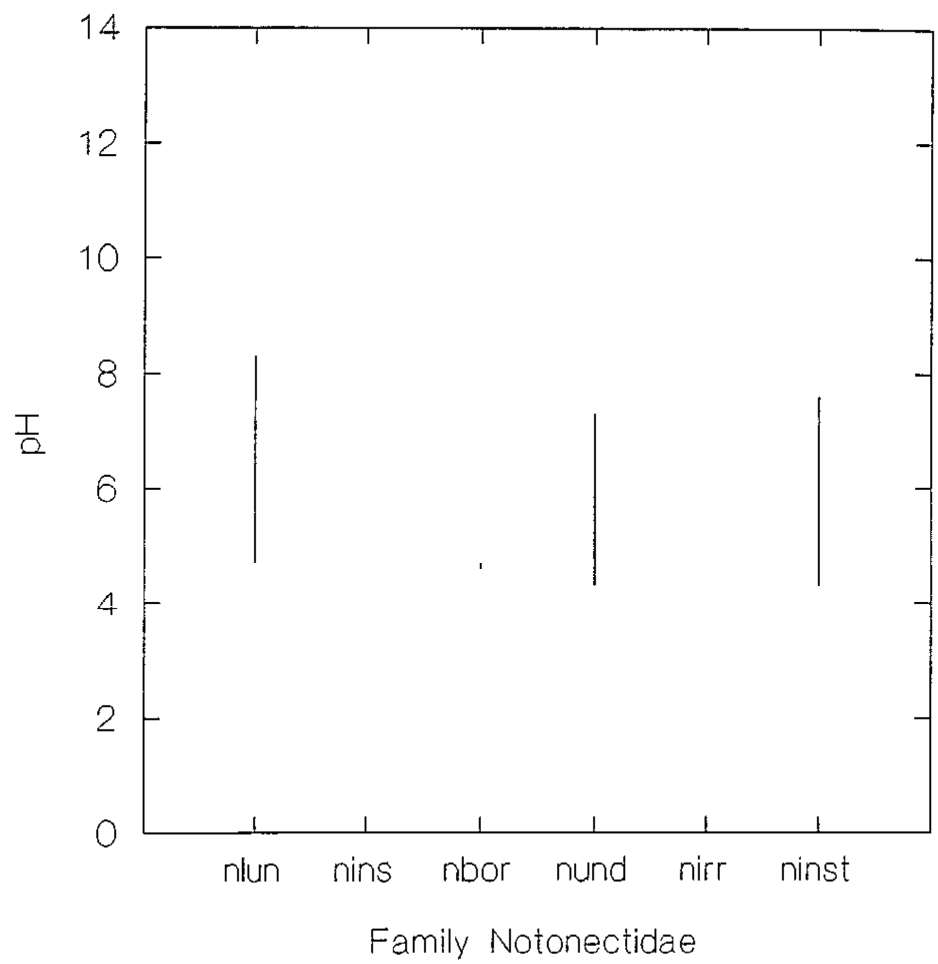
Table 4. First Sampling Collection

Family	Species	Bay	BCr	Ber	Kic	Mul	Nan	Ras	TCr	TLk	War
Belostomatidae	Leth. amer.										
	instar										
Corixidae	Palm. nana										
	Tri. nais										
	instar										
Gerridae	G. buenoi				1	3	6			2	
	G. comatus	2	2		11	5	5			10	
	G. dissortis	2									
	G. instar										
Mesoveliidae	M. mulsanti										
Nepidae	Ranatra fusca									1	
Notonectidae	N. irrorata				2						
	N. lunata				7					1	
	N. undulata							1			
	N. instar										
Pleidae	Plea striola										
Veliidae	M. pulchella										

Table 5. Second Sampling Collection

Family	Species	Bay	BCr	Ber	Kic	Mul	Nan	Ras	TCr	TLk	War
Belostomatidae	Leth. amer.										1
	instar					3					1
Corixidae	Palm. nana									2	
	Tri. nais										15
	instar					2				7	2
Gerridae	G. buenoi		5		1	2	2	1		1	5
	G. comatus					1			2	4	2
	G. dissortis										
	G. instar	18		20	2		4	3		7	4
Mesoveliidae	M. mulsanti	3		4		6	1			14	7
Nepidae	Ranatra fusca		1		2						
Notonectidae	N. irrorata										
	N. lunata										
	N. undulata										
	N. instar					2	1				3
Pleidae	Plea striola										2
Veliidae	M. pulchella			14		1				8	16

Fig. 1. pH Ranges of Family Notonectidae



Family Notonectidae	#insects	#sites
nlun = *Notonecta lunata*	1-7	8
nins = *Notonecta insulata*	1	1
nbor = *Notonecta borealis*	2	1
nund = *Notonecta undulata*	1-2	1
nirr = *Notonecta irrorata*	2	1
ninst = *Notonecta* instars	1-36	12

Fig. 2. Conductivity Ranges of Family Notonectidae

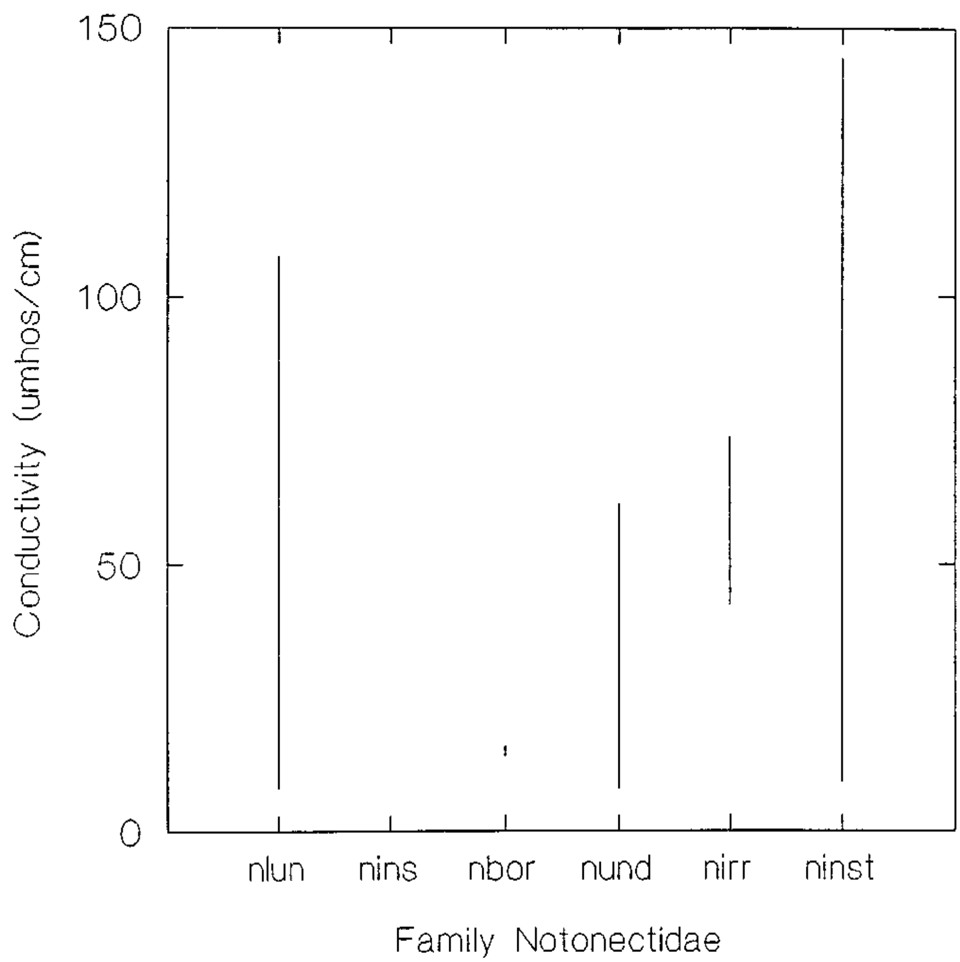


Fig. 3. Alkalinity Ranges of the Family Notonectidae

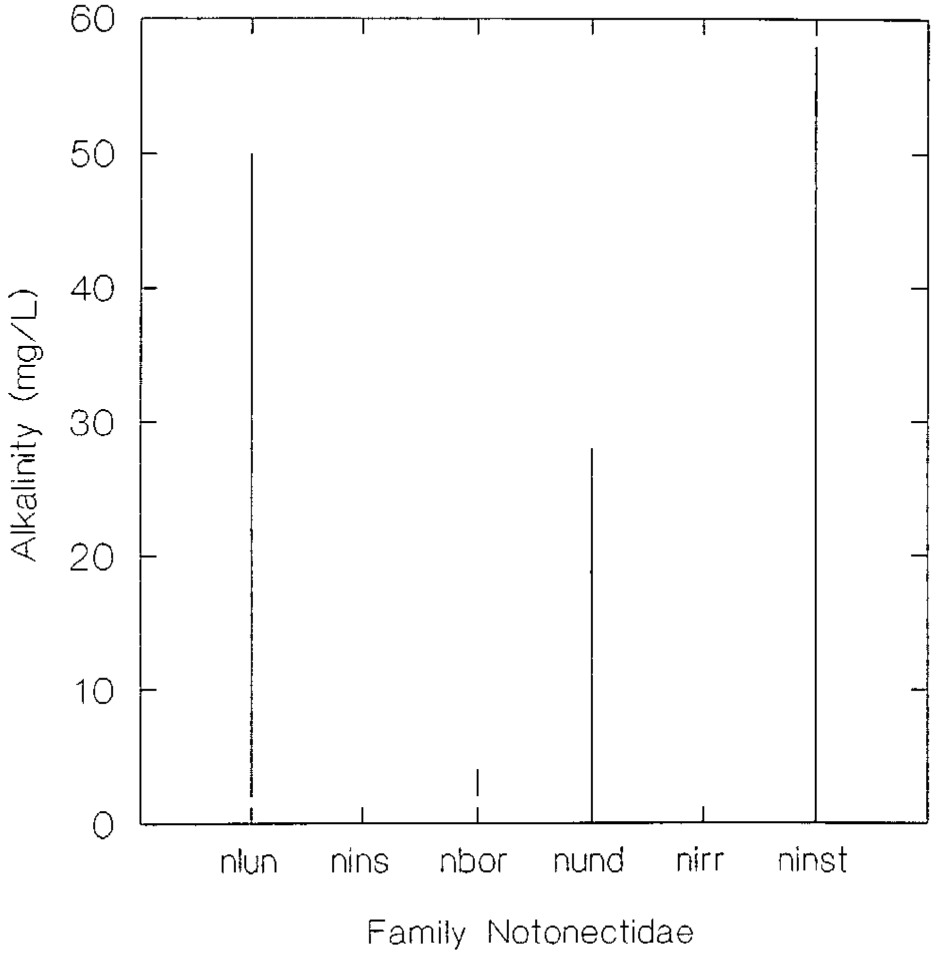


Fig. 4. Water Color Ranges of Family Notonectidae

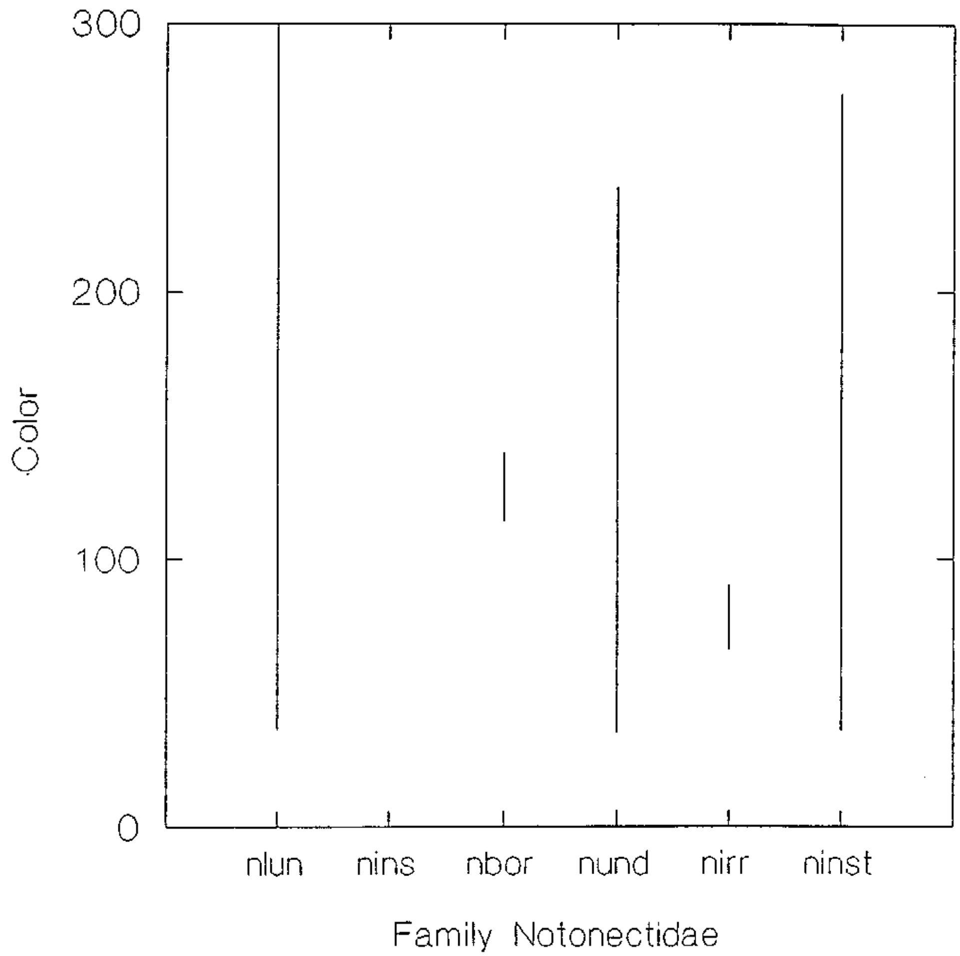


Fig. 5. Secchi Depth Ranges of Family Notonectidae

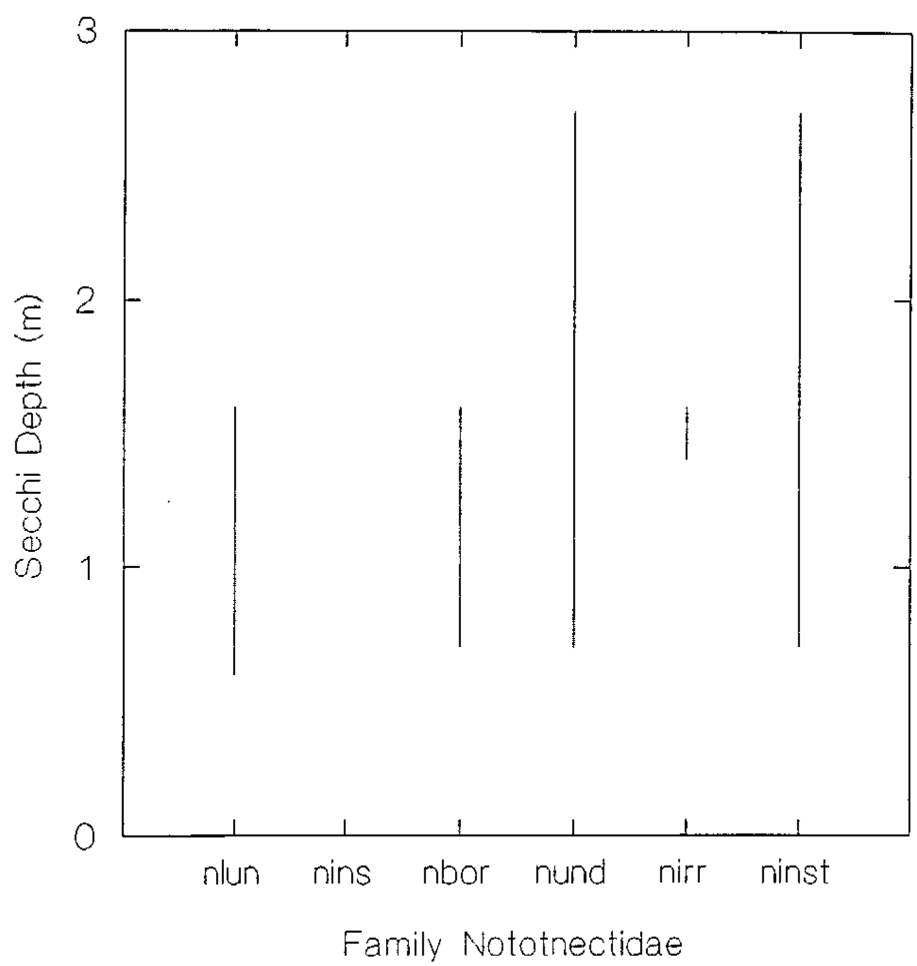
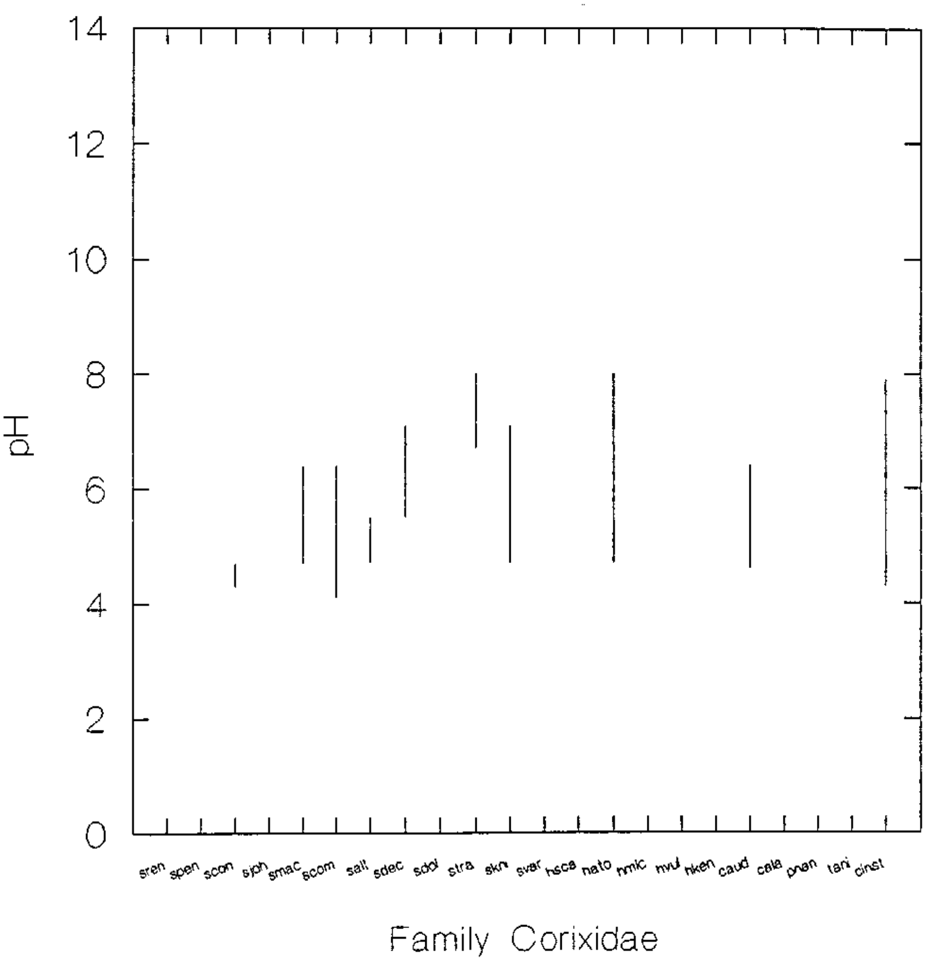


Fig. 6. pH Ranges of Family Corixidae



Family Corixidae	#insects	#sites		#insects	#sites
spen = *Sigara penniensis*	1	2	svar = *Sigara variablis*	1	1
scon = *Sigara conocephala*	2	2	hsca = *Hespercorixa scabricula*	2	1
sjoh = *Sigara johnstoni*	3	1	hato = *Hesperocorixa atopodonta*	1	2
smac = *Sigara mackinacensis*	1-7	3	hmic = *Hesperocorixa michiganensis*	1	1
scom = *Sigara compressiodea*	2-10	6	hvul = *Hesperocorixa vulgaris*	1	1
salt = *Sigara alternata*	1-6	3	hken = *Hesperocorixa kennicotti*	1	1
sdec = *Sigara decorata*	2-4	2	caud = *Callicorixa audeni*	1	2
sdol = *Sigara doloebra*	1	1	cala = *Callicorixa alaskensis*	1	1
stra = *Sigara transfigurata*	1-23	2	pnan = *Palmacorixa nana*	2	1
skni = *Sigara knighti*	2-3	2	tnai = *Trichocorixa nais*	15	1
			cinst = Corixidae instars	2-19	11

Fig. 7. Alkalinity Ranges of Family Corixidae

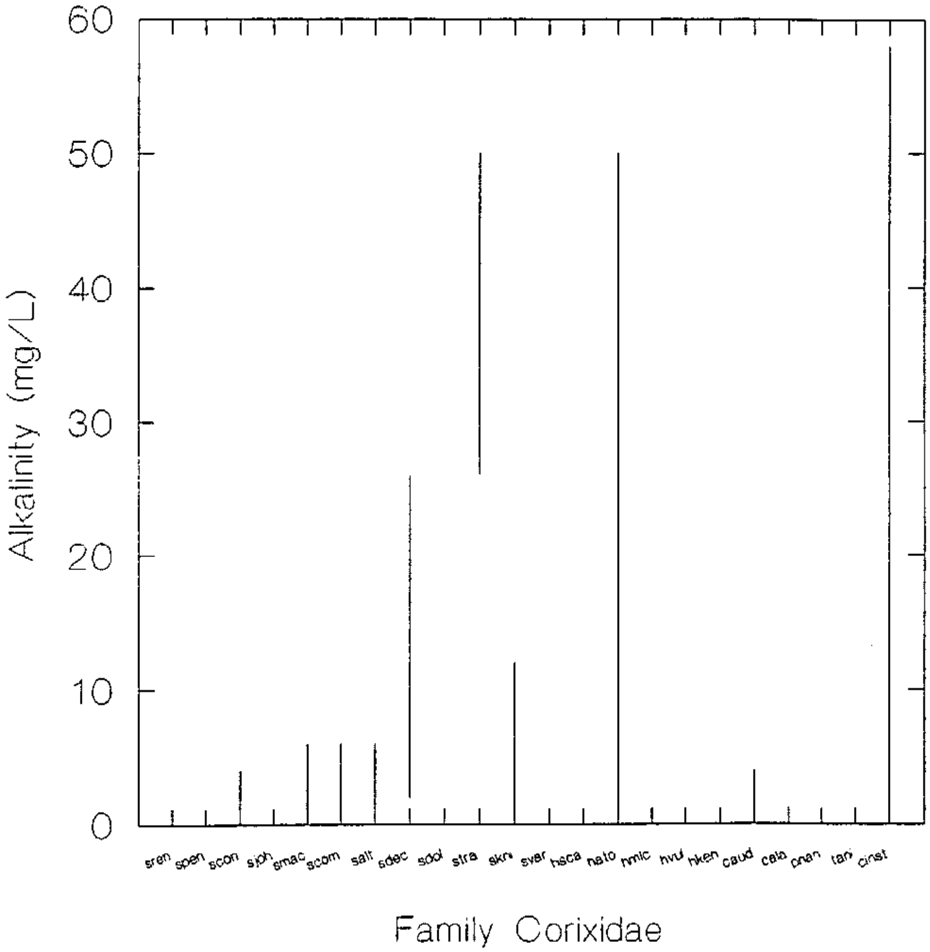
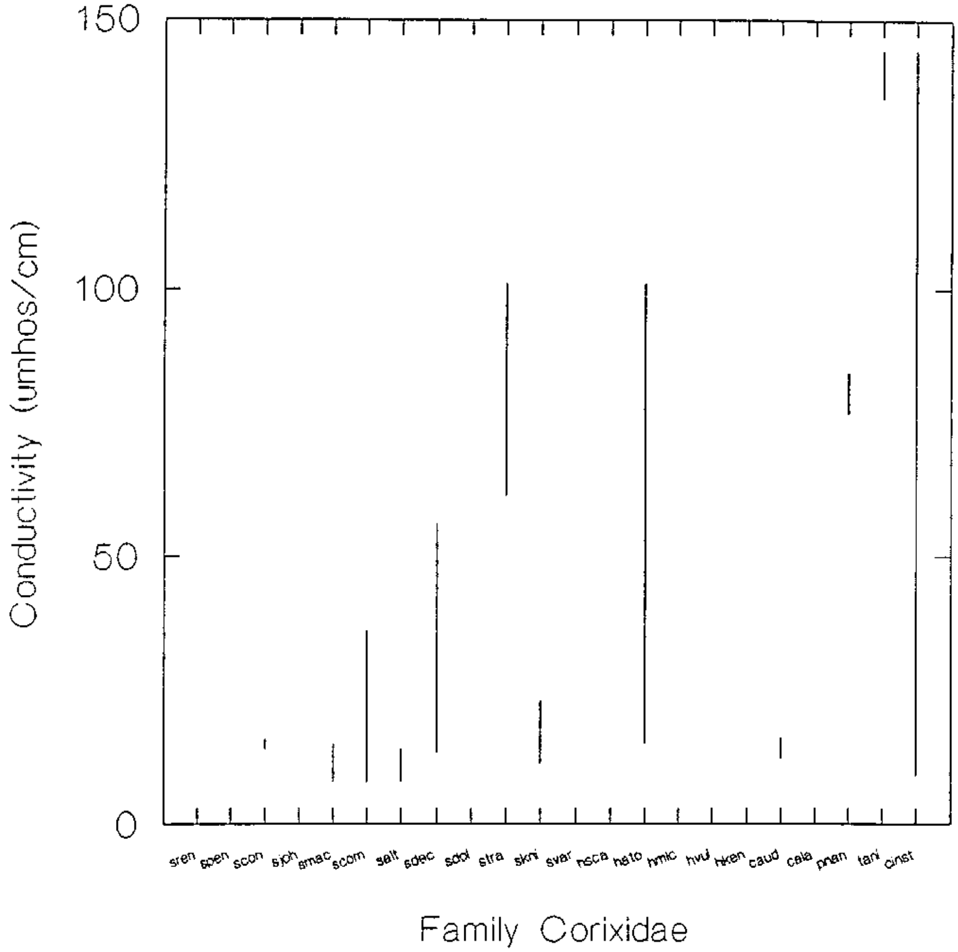


Fig. 8. Conductivity Ranges of Family Corixidae



<u>**Fig. 9. Water Color Ranges of Family Corixidae**</u>

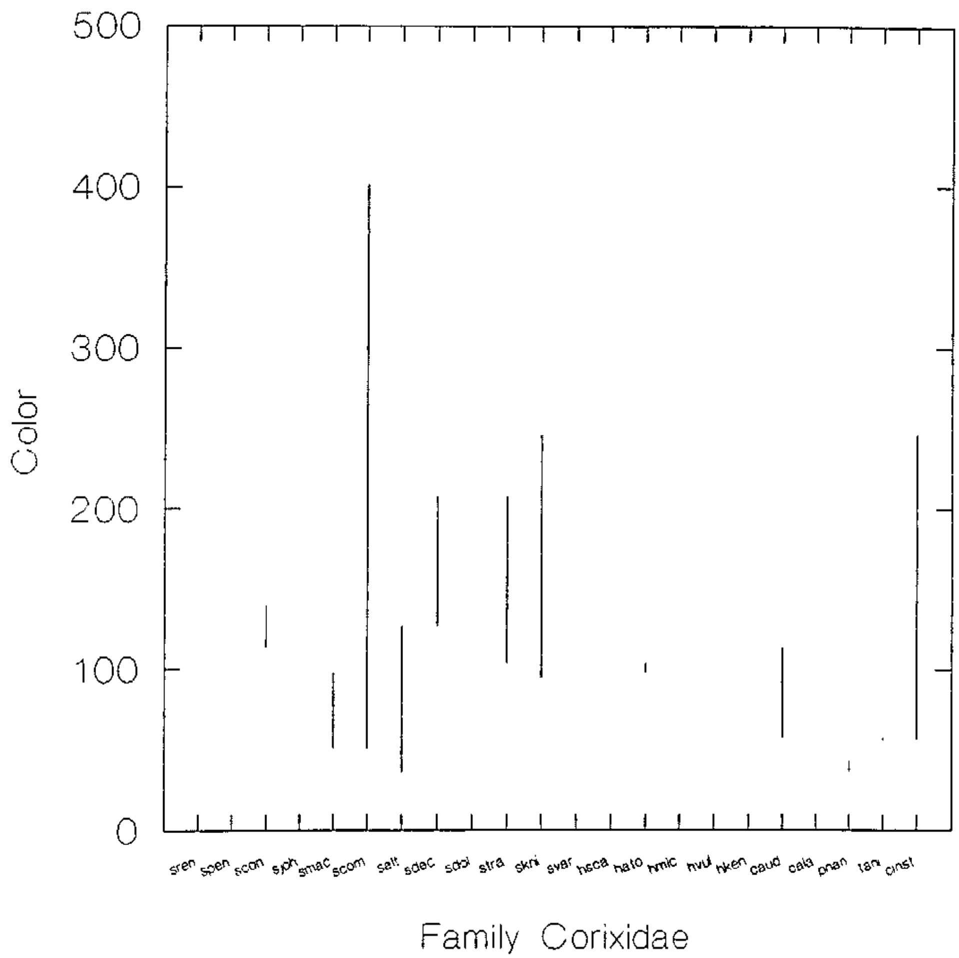


Fig. 10. Secchi Depth Ranges of Family Corixidae

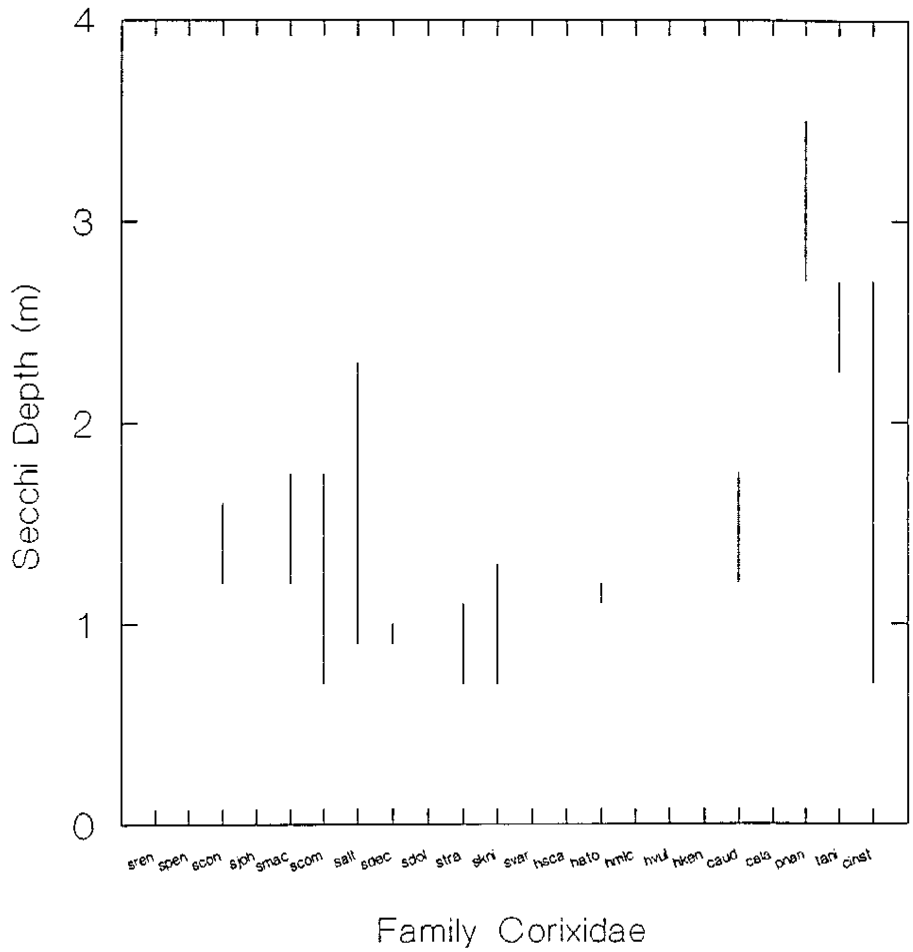
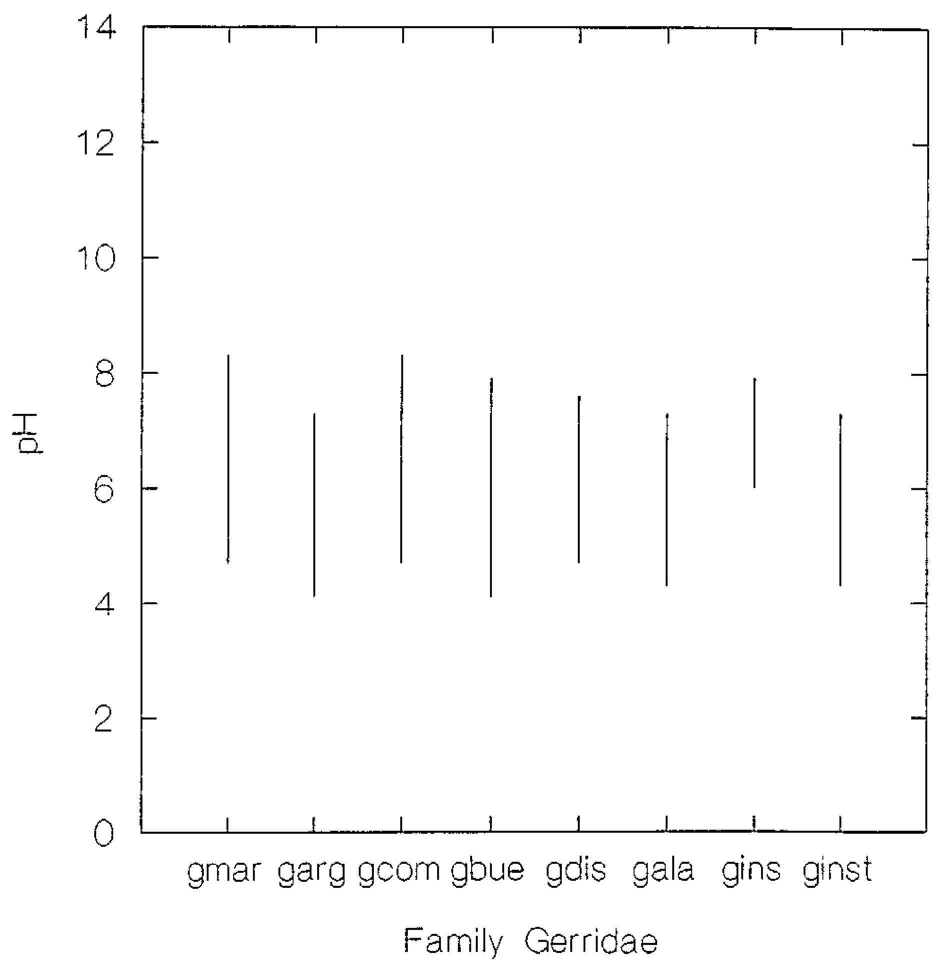


Fig. 11. pH Ranges of Family Gerridae



Family Gerridae	#insects	#sites
gmar = *Gerris marginatus*	1-4	7
garg = *Gerris argenticollis*	1-9	8
gcom = *Gerris comatus*	1-14	15
gbue = *Gerris buenoi*	1-8	15
gdis = *Gerris dissortis*	1-3	3
gala = *Gerris alacris*	2-3	2
gins = *Gerris inseperatus*	1	1
ginst = *Gerris* instars	1-37	19

Fig. 12. Alkalinity Ranges of Family Gerridae

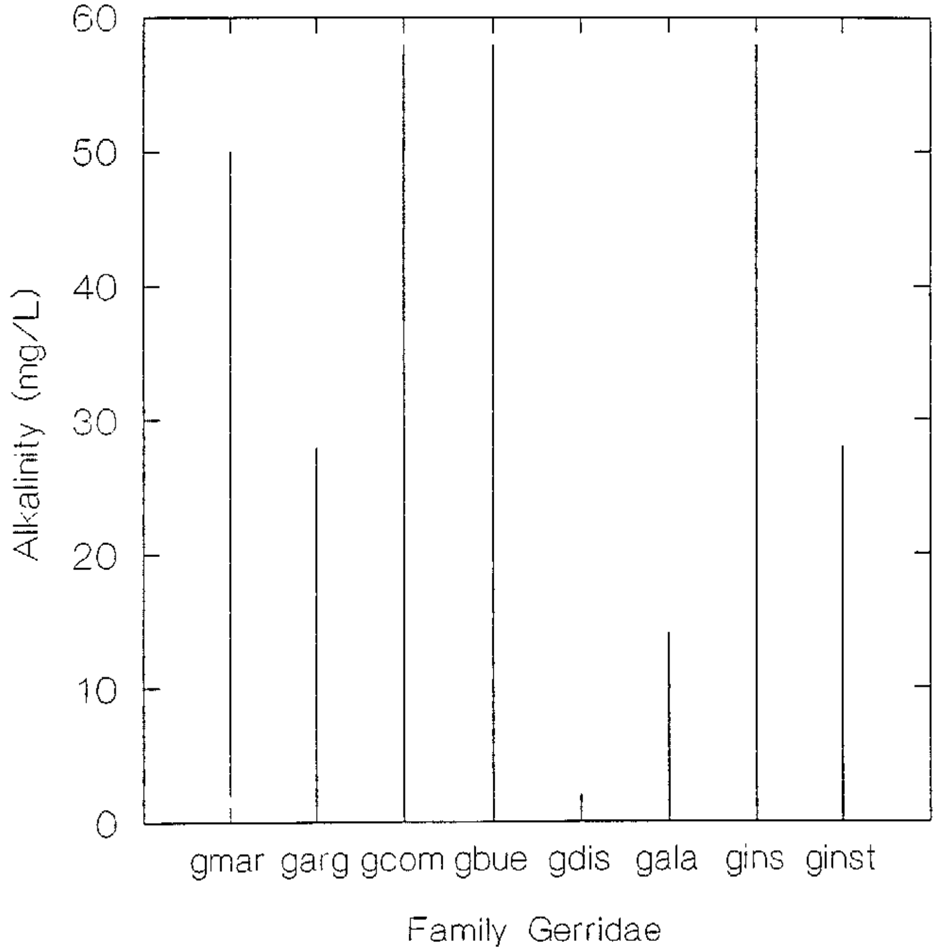


Fig. 13. Conductivity Ranges of Family Gerridae

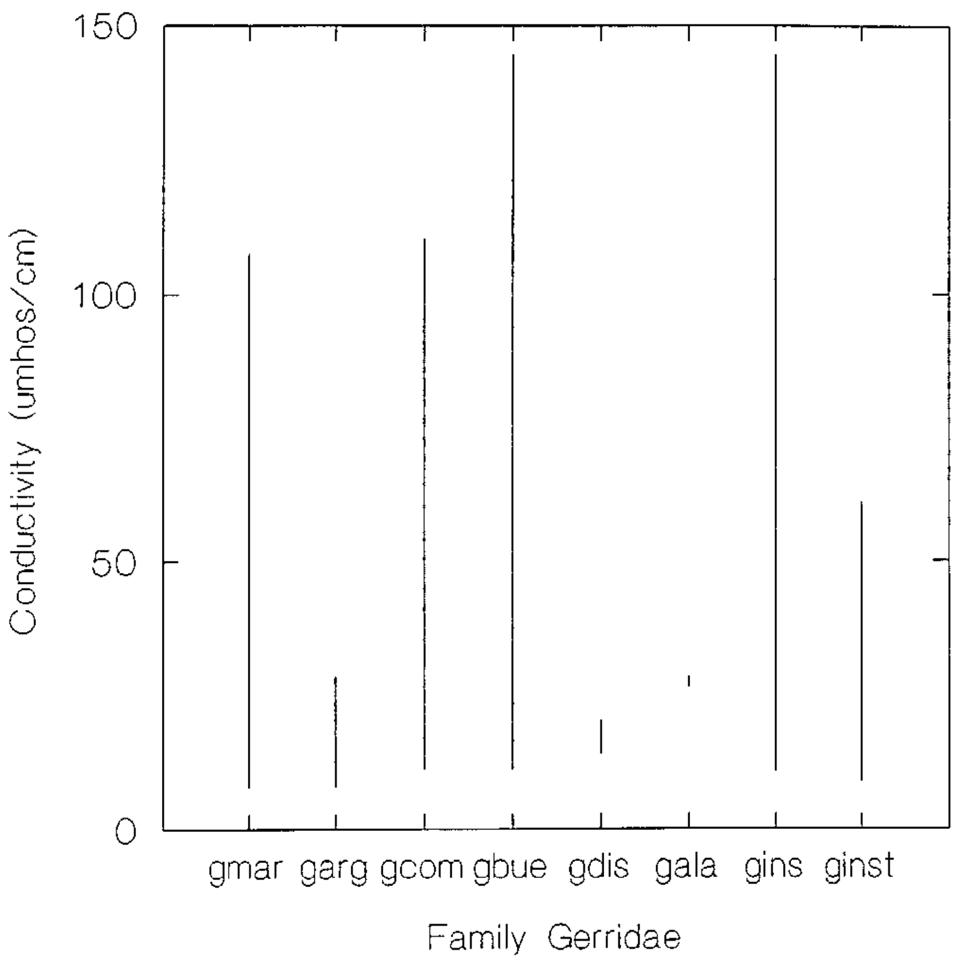


Fig. 14. Water Color Ranges of Family Gerridae

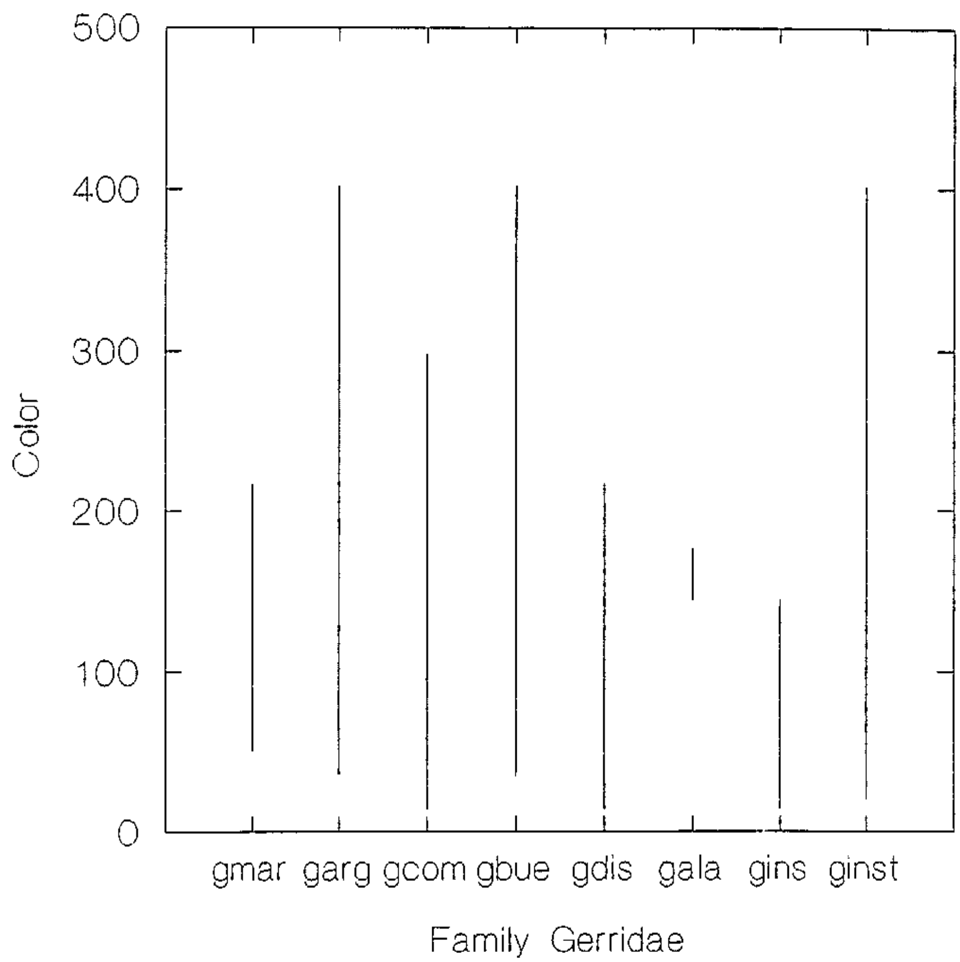


Fig. 15. Secchi Depth Ranges of Family Gerridae

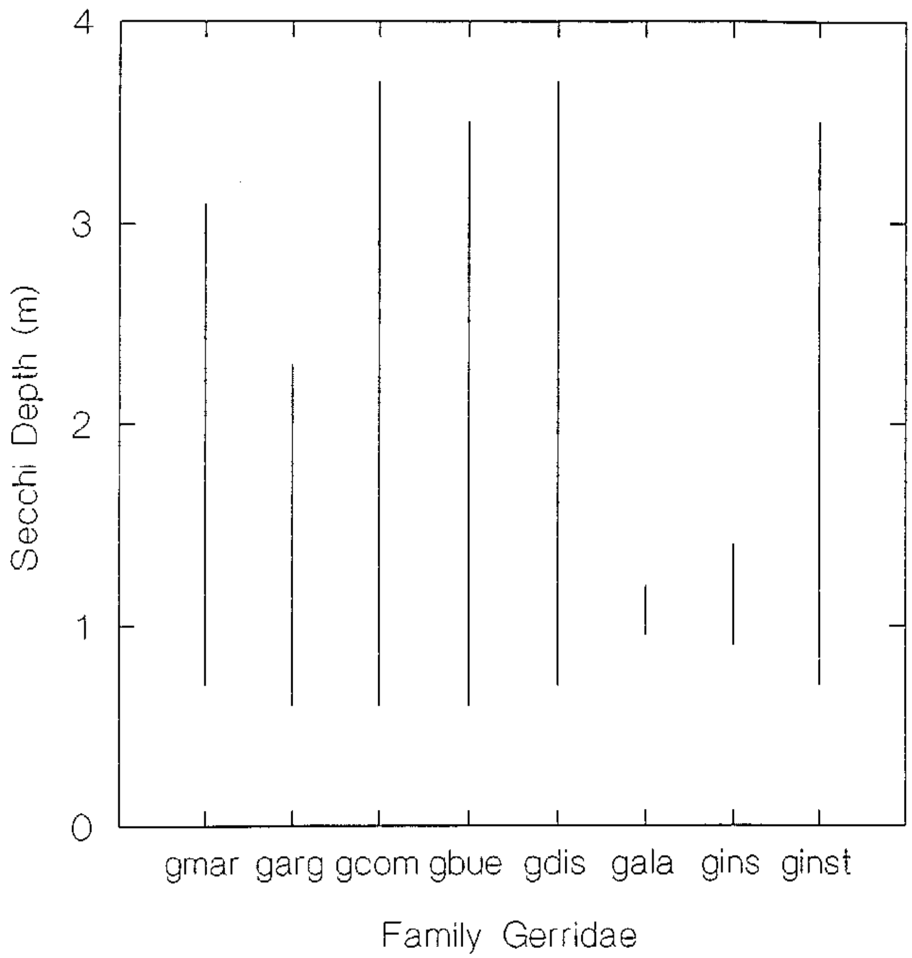
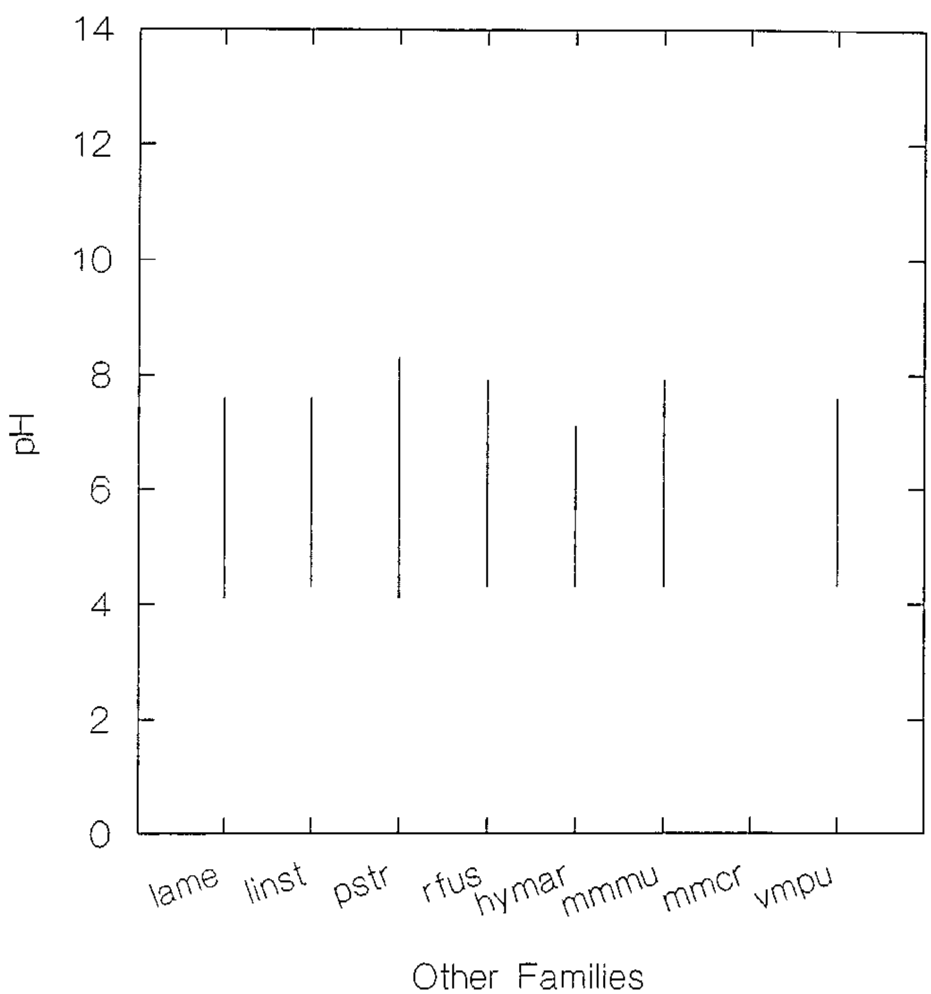


Fig. 16. pH Ranges of Pleidae, Nepidae, Mesoveliidae, Belostomatidae, and Veliidae Families



Other Families	#insects	#sites
lame = Belostomatidae *Lethocerus americanus*	1-2	3
linst = Belostomatidae instars	1-11	11
pstr = Pelidae *Plea striola*	1-16	6
rfus = Nepidae *Ranatra fusca*	1-7	13
hymar = Hydrometridae *Hydrometra martini*	1	2
mmmu = Mesoveliidae *Mesovelia mulsanti*	1-14	12
mmcr = Mesoveliidae *Mesovelia cryptophilia*	1	1
vmpu = Veliidae *Microvelia pulchella*	1-16	8

Fig. 17. Alkalinity Ranges of Pleidae, Nepidae, Mesoveliidae, Belostomatidae, and Veliidae Families

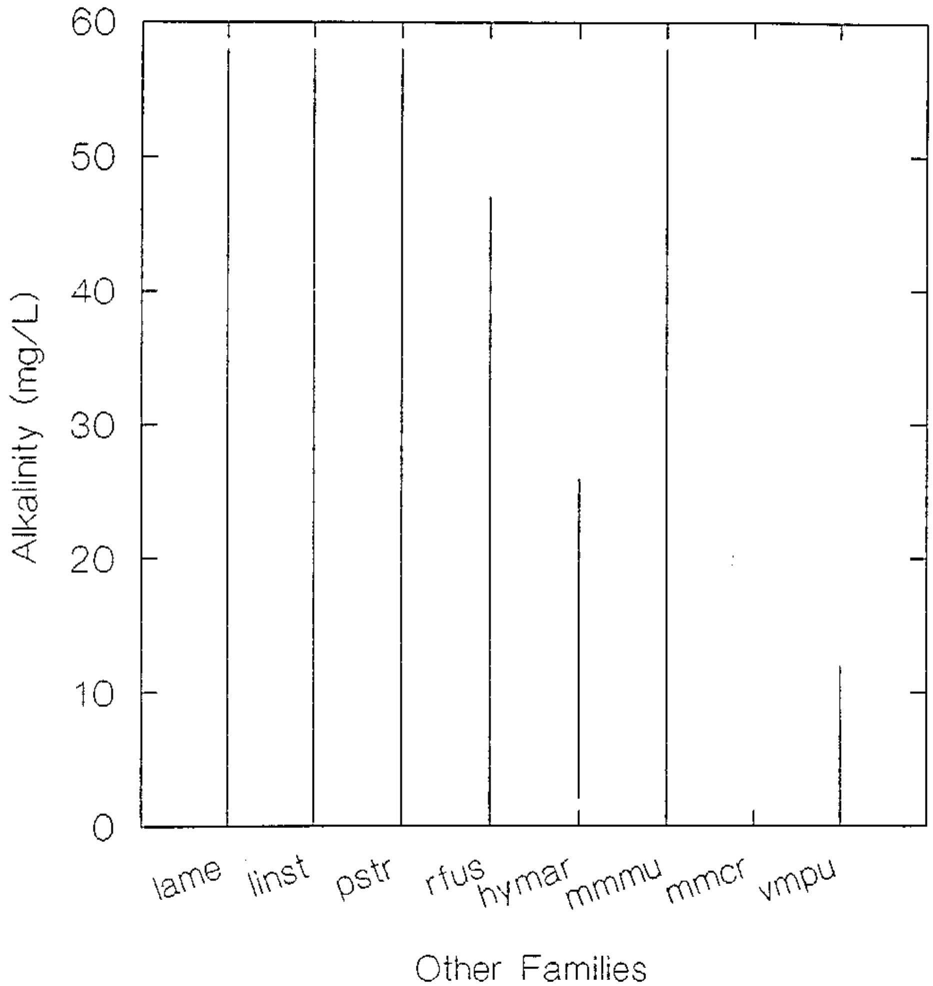


Fig. 18. Conductivity Ranges of Pleidae, Nepidae, Mesoveliidae, Belostomatidae, and Veliidae Families

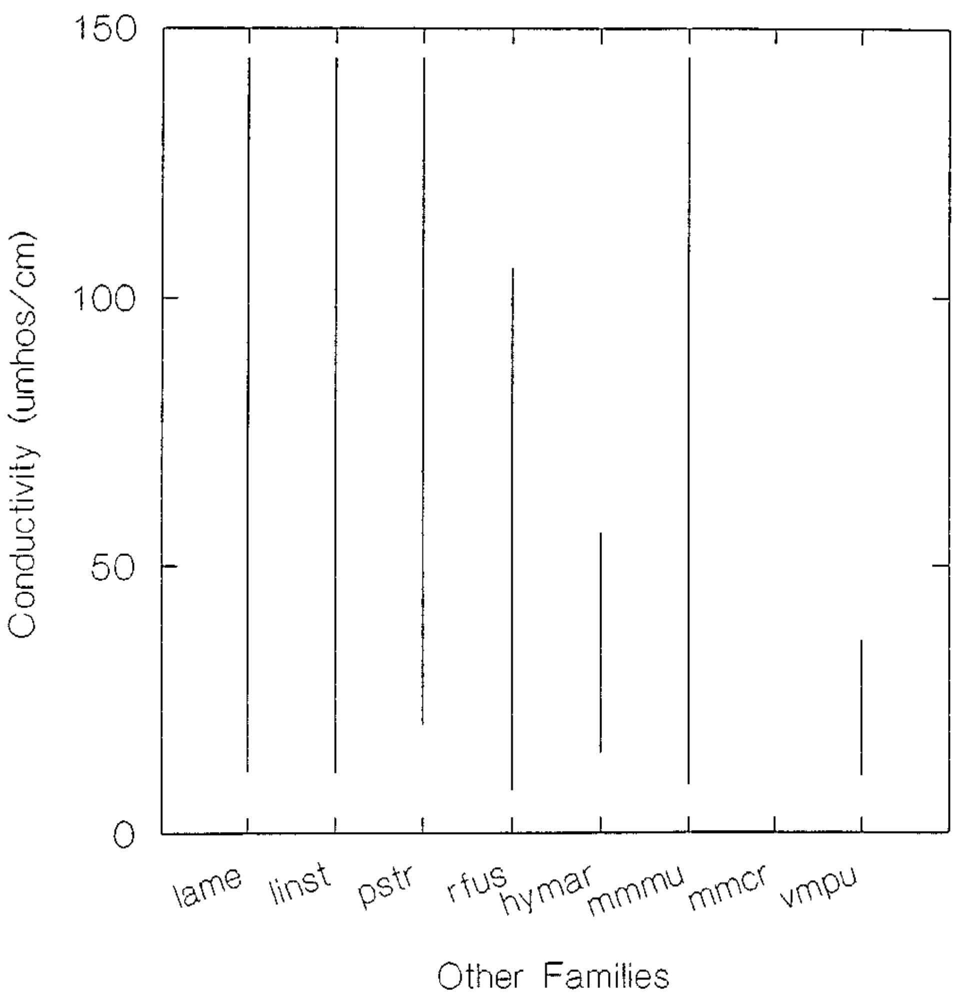


Fig. 19. Water Color Ranges of Pleidae, Nepidae, Mesoveliidae, Belostomatidae, and Veliidae Families

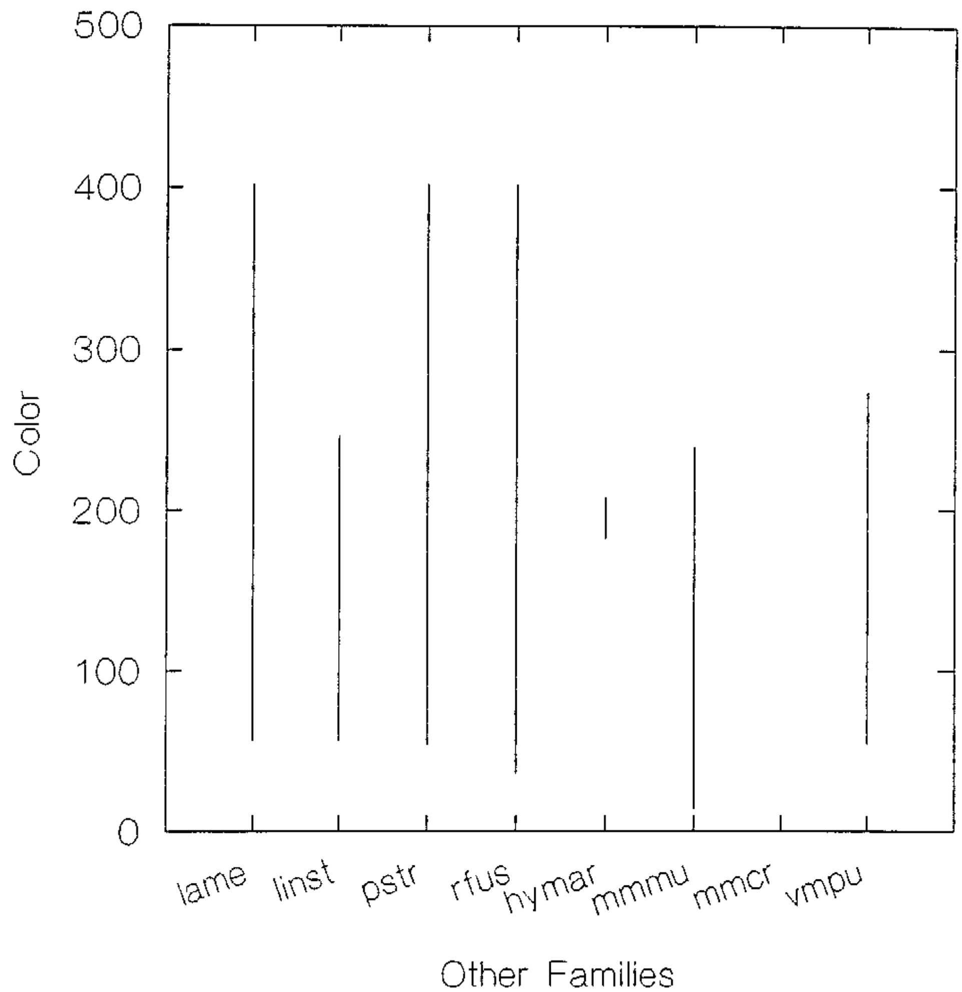
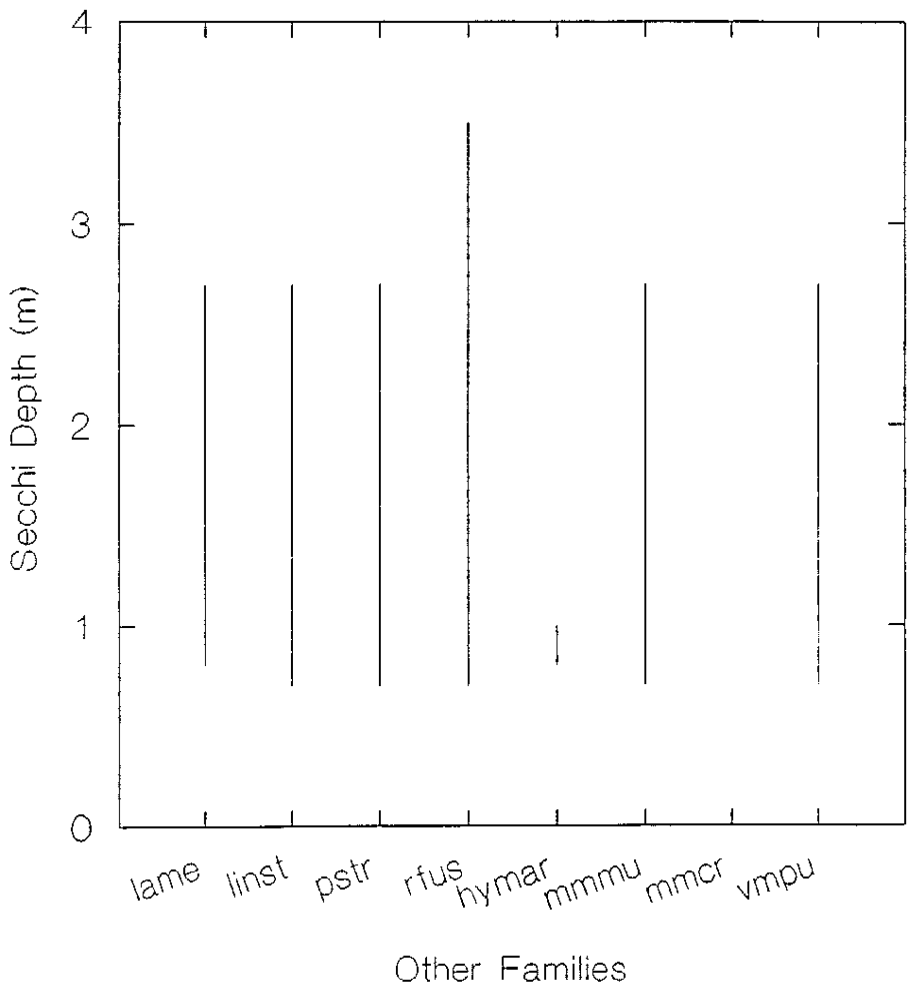
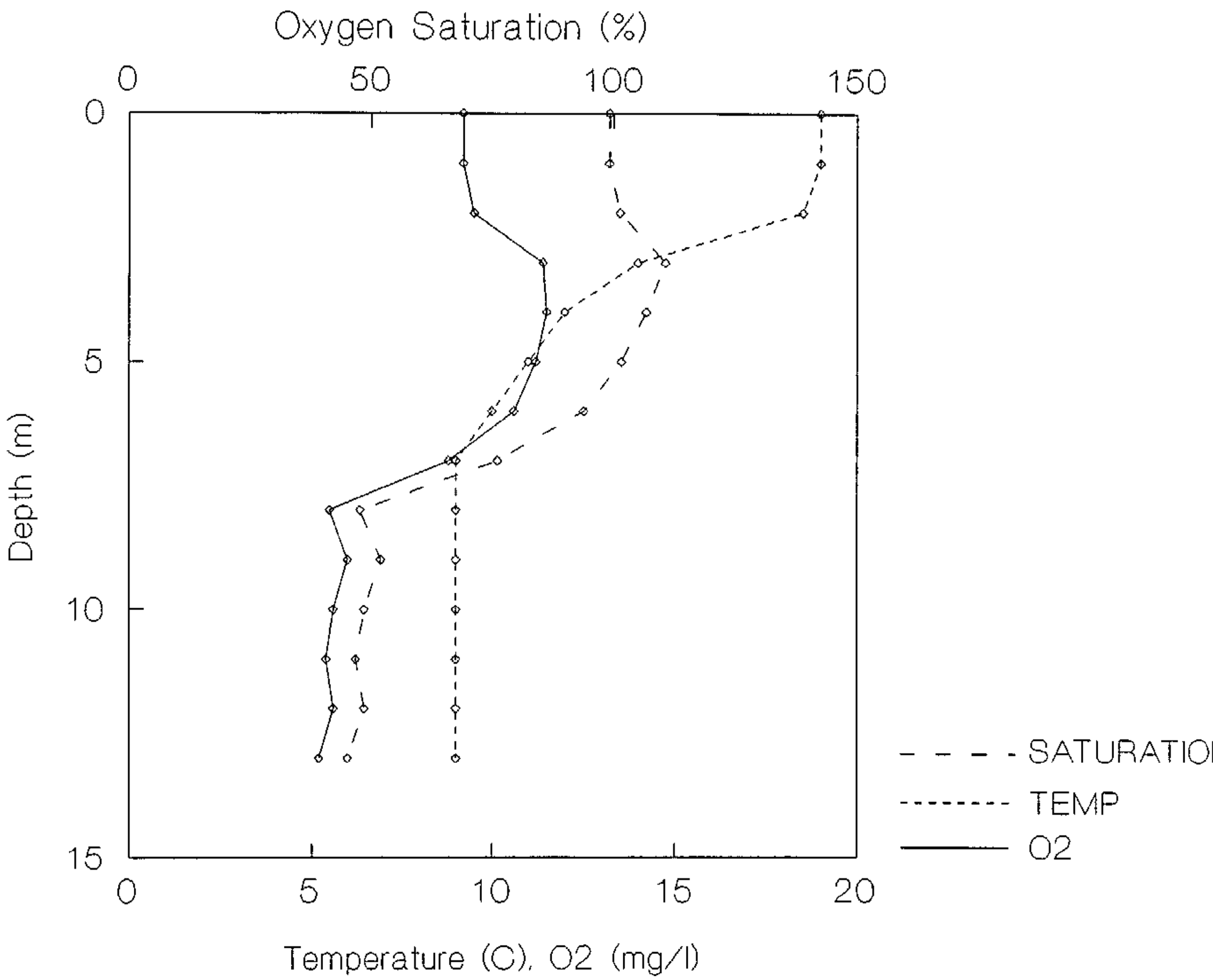


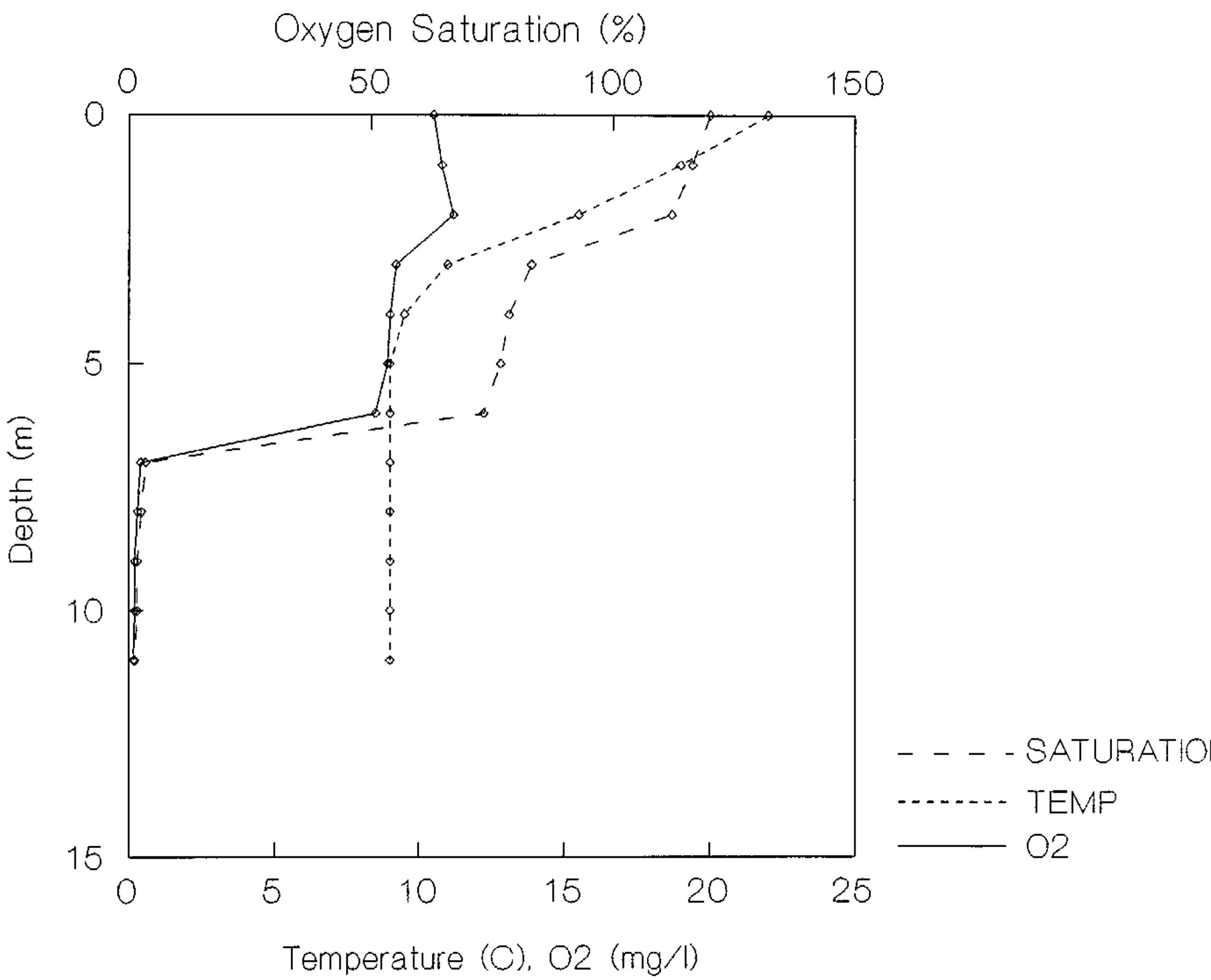
Fig. 20. Secchi Depth Ranges of Pleidae, Nepidae, Mesoveliidae, Belostomatidae, and Veliidae Families



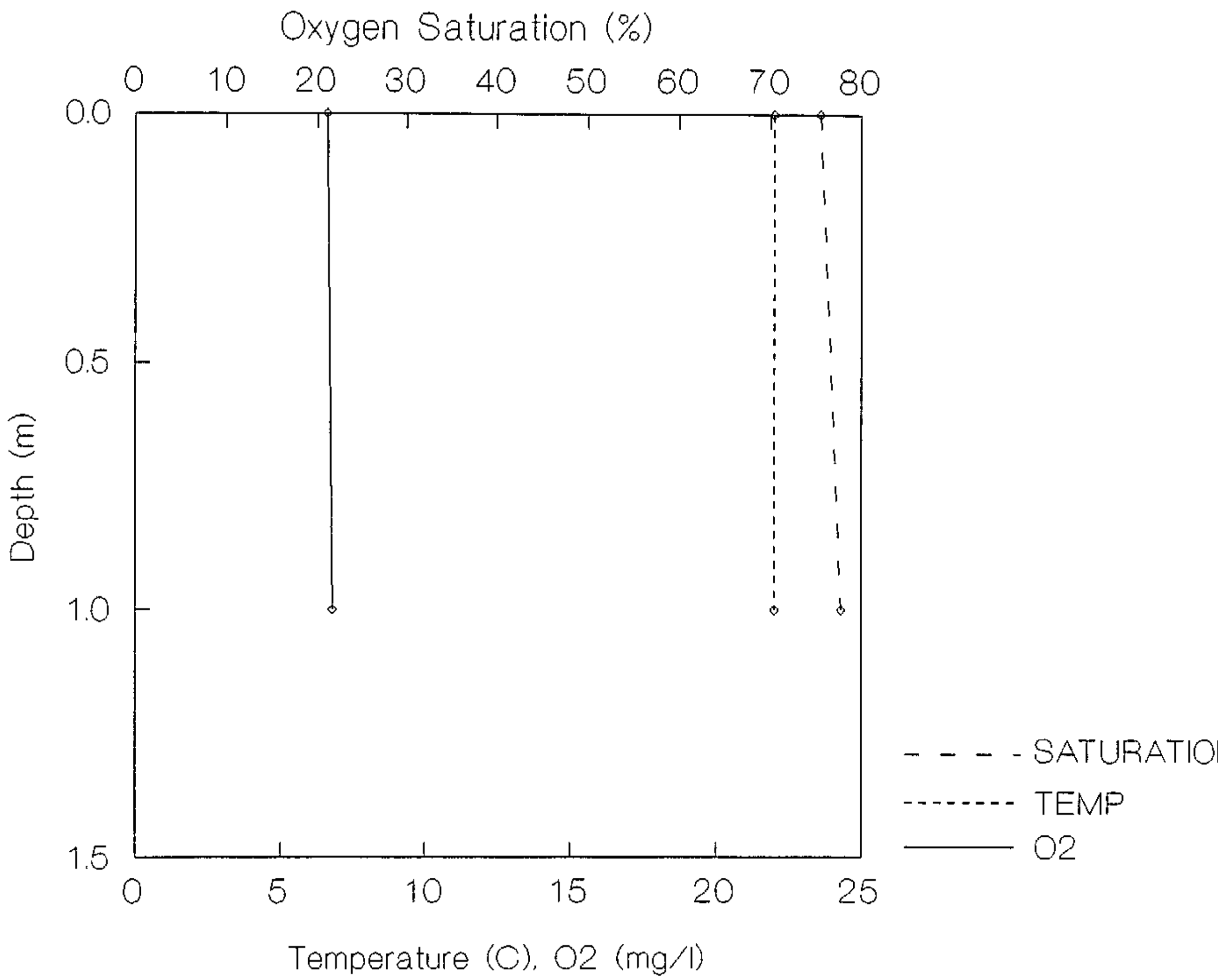
Appendix I. Oxygen/Temperature Profile of Bay Lake



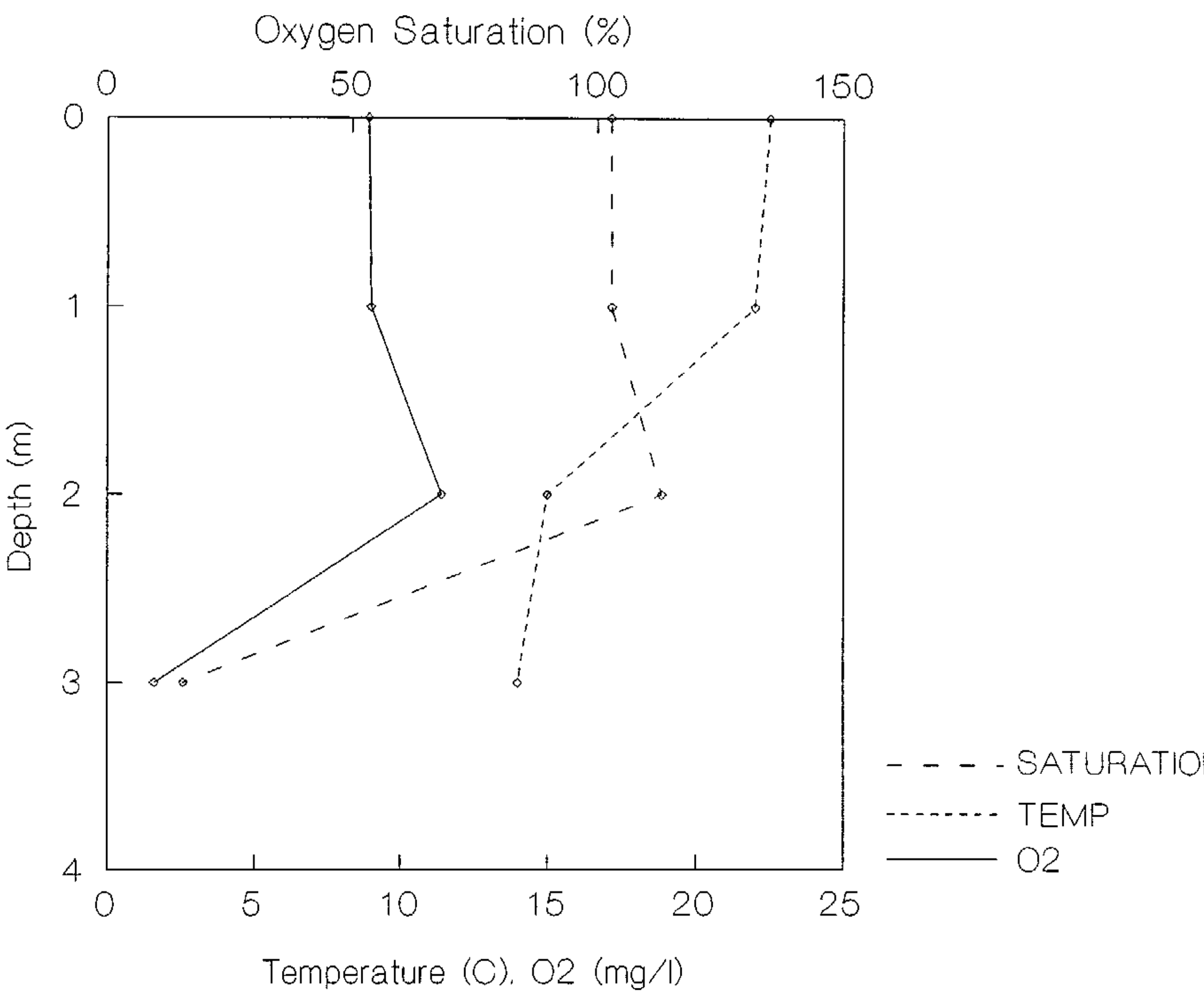
Appendix II. Oxygen/Temperature Profile of Bergner Lake



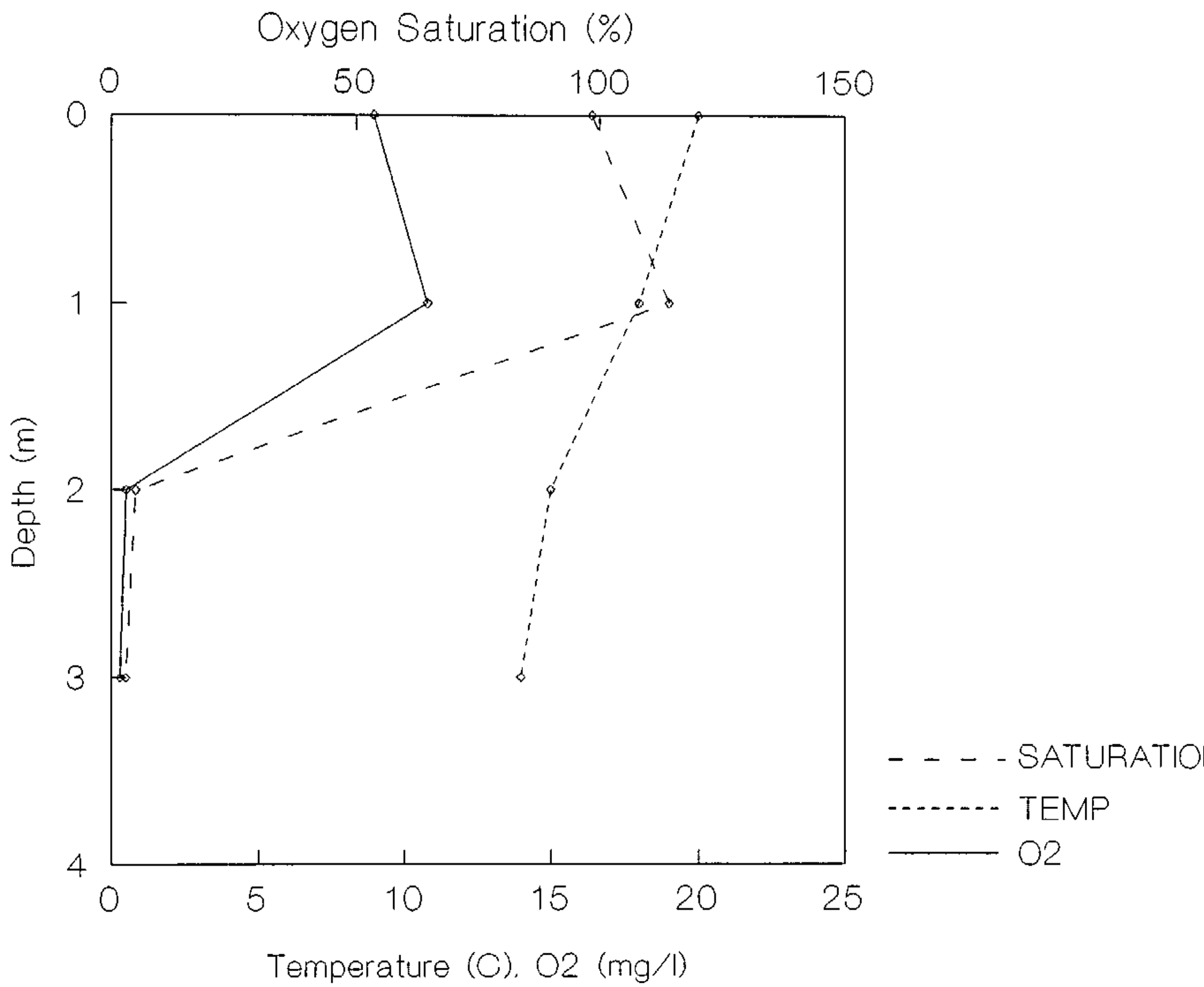
Appendix III. Oxygen/Temperature Profile of Brown Creek



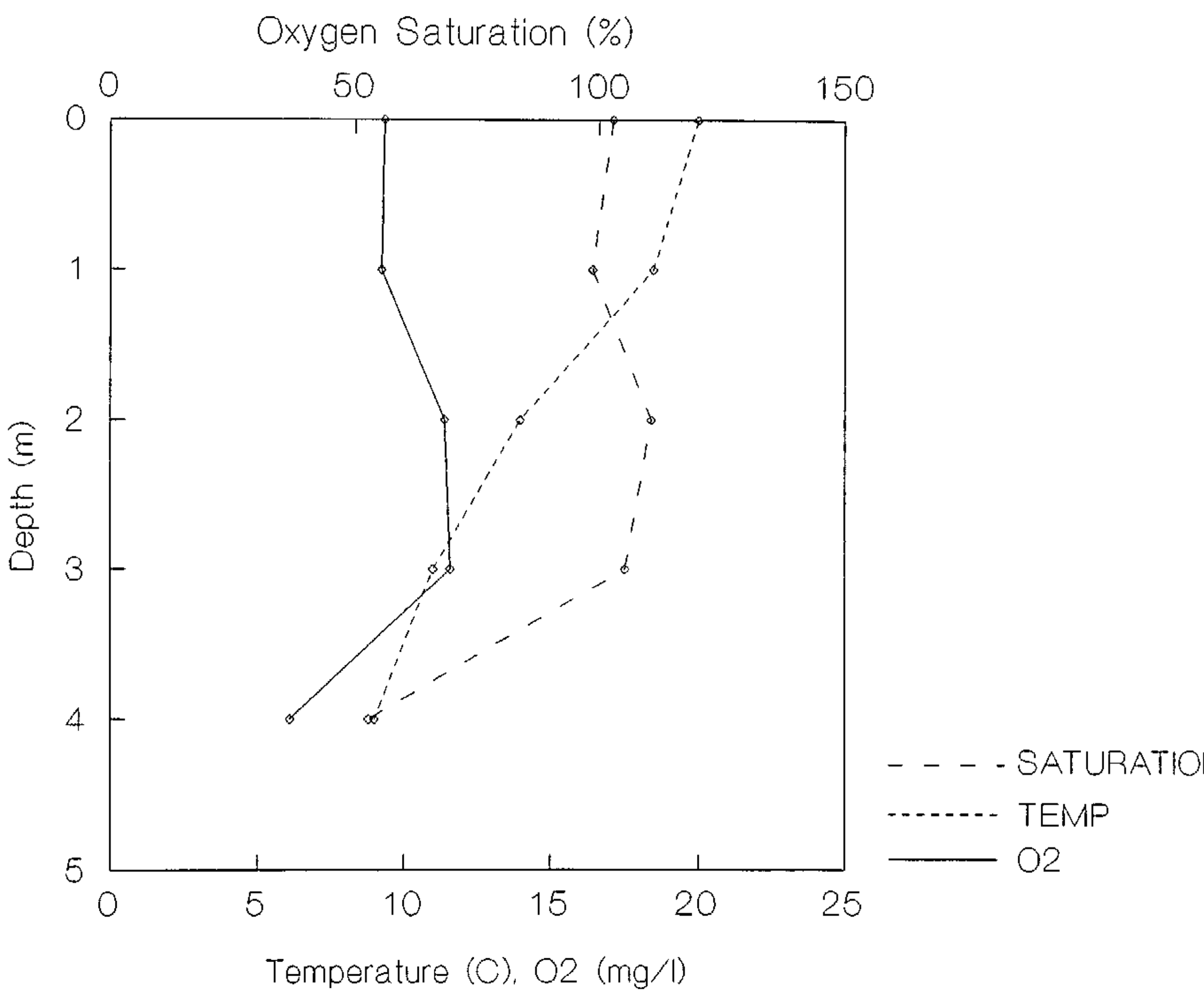
Appendix IV. Oxygen/Temperature Profile of Kickapoo Lake



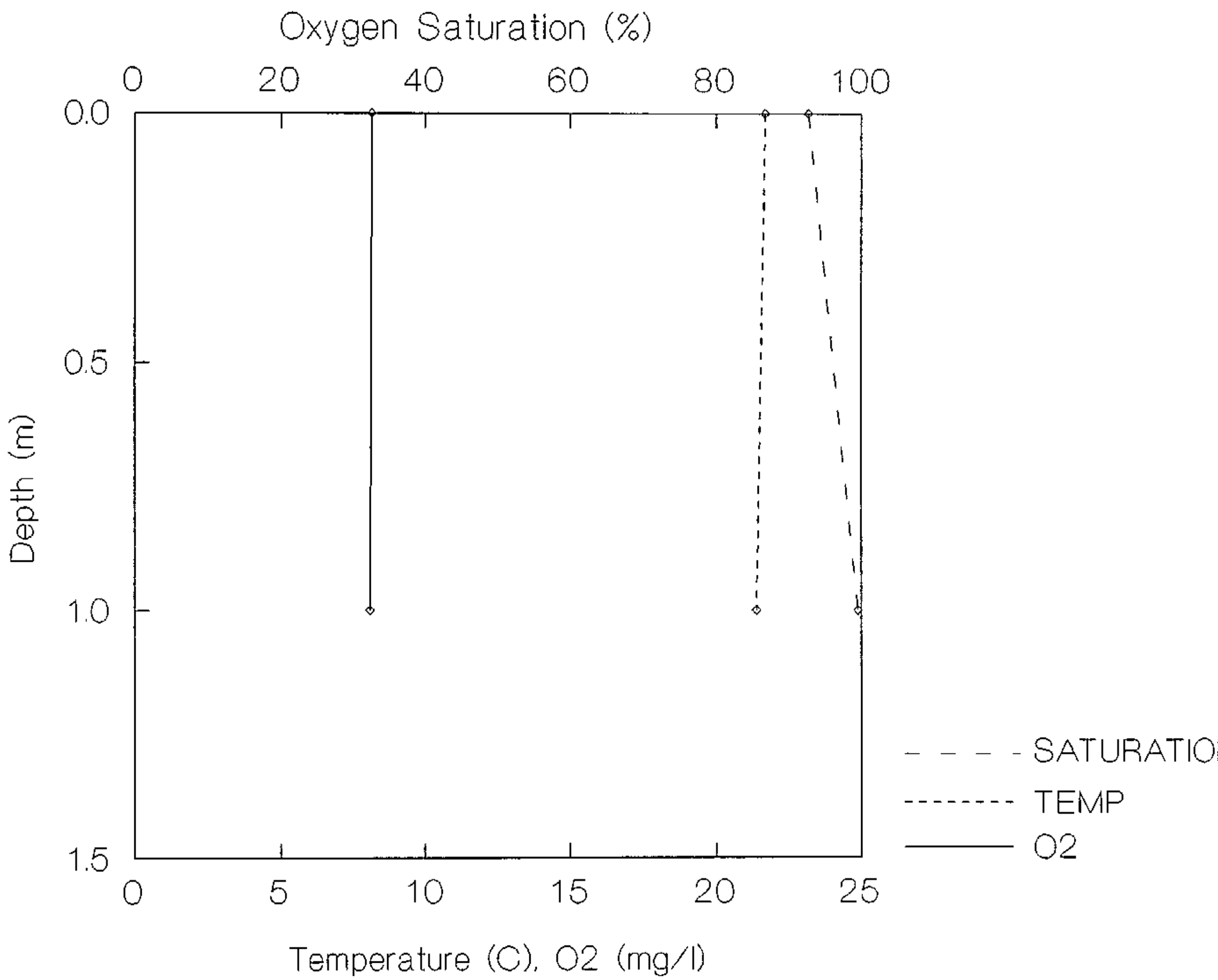
Appendix V. Oxygen/Temperature Profile of Mullahy Lake



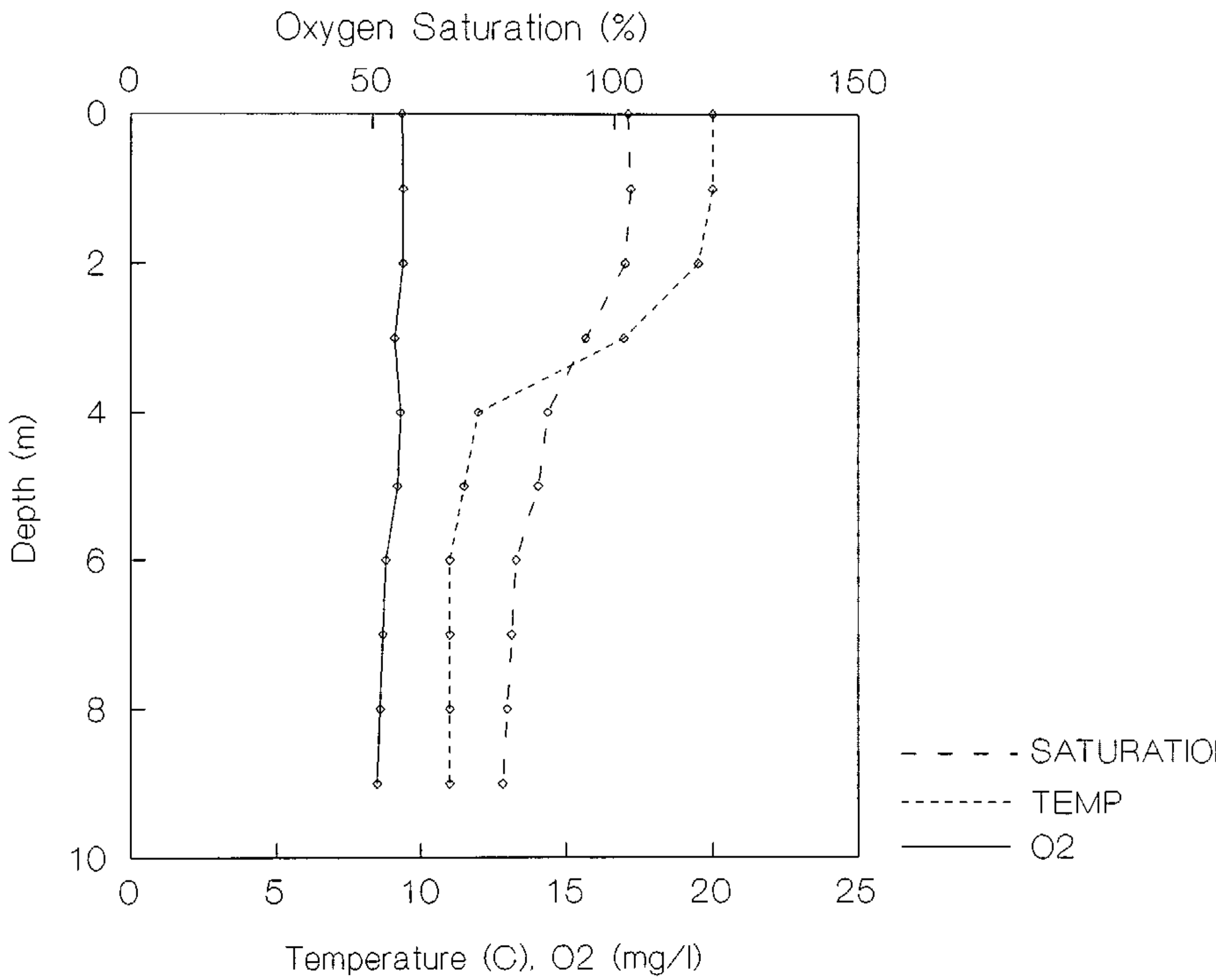
Appendix VI. Oxygen/Temperature Profile of Raspberry Lake



Appendix VII. Oxygen/Temperature Profile of Tenderfoot Creek



Appendix VIII. Oxygen/Temperature Profile of Tenderfoot Lake



Appendix IX. Combined 1996-1997 Species Totals

Fa	Species	Bay	Ber	Bog	Bol	BrC	BrL	Crm	Crn	Ed	FS	Hum	Kic	Mor	Mul	Nan	NG	Ras	Red	TB	TCr	TLk	Tue	War
Bel	.instar			1	2				5	11				10	3		1		1	1			1	1
Bel	Leth. amer.																1						2	1
Cor	.instar			3	2					5	3			17	2		2		3			7	19	2
Cor	Call. alaskensis									1														
Cor	Call. audeni									1													1	
Cor	Hesp. atopodonta						1		1															
Cor	Hesp. kennicotti													1										
Cor	Hesp. michiganensis								1															
Cor	Hesp. scabricula										2													
Cor	Hesp. vulgaris									1														
Cor	Palm. nana																					2		
Cor	Sig. alternata			1						1	5													
Cor	Sig. compressoidea								2		10						4			2			4	
Cor	Sig. concocephala									2														
Cor	Sig. decorata			2								4												
Cor	Sig. doloebra									1														
Cor	Sig. johnstoni			3																				
Cor	Sig. knighti								2										3					
Cor	Sig. mackinacensis								2		1												7	
Cor	Sig. penniensis								1		1													
Cor	Sig. transfigurata						1					13		10										
Cor	Sig. variablis																						1	
Cor	Tri. nais																							15
Ger	G. .instar	18	20	6	4			37	1	4	2	6	2	3		4	2	3	1	8		7	5	4
Ger	G. alacris				3															2				
Ger	G. argenticollis			2	2					9	4			1			7		4	6				
Ger	G. buenoi			1		5				1	1	2	2	1	5	8	2	1	3			3	2	5
Ger	G. comatus	2		2	1	2	2		1			3	11	3	6	5			1		2	14		2
Ger	G. dissortis	2								3		1												
Ger	G. inseparatus				1																			
Ger	G. marginatus			4	1		3	1			1	1		1										
Hyd	Hydro. martini			1										1										
Mes	M. cryptophila																1							
Mes	M. mulsanti	3	4	1	2					1	3			3	6	1	1					14		7
Nep	Ranatra fusca			3	1	1			3	4	7		2	2			3		1	2		1	2	
Not	N. .instar			36	3				8	12	15	1			2	1	30		2	26				3
Not	N. borealis									1	1													
Not	N. insulata								1															
Not	N. irrorata												2											
Not	N. lunata				1		2				1		7	4					1			1	1	
Not	N. undulata									1	4						1	1						
Plei	Plea striola				16		14					1		1			4							2
Veli	M. buenoi								1															
Veli	M. pulchella		14									2			1		2		3	1		8		16
	total Hemiptera	25	38	66	39	8	23	38	24	59	61	34	26	58	25	19	61	5	23	48	2	57	45	58
	total species	4	3	14	13	3	6	2	13	17	16	10	6	14	7	5	14	3	11	8	1	9	11	11

Sites: Bay Lake (Bay), Bergner Lake (Ber), Bog Pot (Bog), Bolger Bog (Bol), Brown Creek (BrC), Brown Lake (BrL), Crampton Lake (Crm), Cranberry Lake (Crn), Ed's Bog (Ed), Forest Service Bog (FS), Hummingbird Lake (Hum), Kickapoo Lake (Kic), Morris Lake (Mor), Mullahy Lake (Mul), Nansen Lake (Nan), North Gate Bog (NG), Raspberry Lake (Ras), Reddington Lake (Red), Tender Bog (TB), Tenderfoot Creek (TCr), Tenderfoot Lake (TLk), Tuesday Lake (Tue), Ward Lake (War)

Appendix X. 1996-1997 Species Totals: Lakes Ranked by Average pH

	pH	4.2	4.4	4.65	4.7	4.8	4.95	5.6	6	6.15	6.2	6.4	6.65	6.9	7	7.1	7.3	7.6	7.6	7.6	7.6	7.6	7.9	8.15
Fa	Species	NG	TB	Ed	Crn	Hum	FS	Bog	Ber	Crm	Tue	Red	Bol	Mor	Nan	BrC	Ras	Bay	Kic	TCr	Mul	War	TLk	BrL
Bel	.instar	1	1	11	5			1			1	1	2	10							3	1		
Bel	Leth. amer.	1									2											1		
Cor	.instar	2		5			3	3			19	3	2	17							2	2	7	
Cor	Call. alaskensis			1																				
Cor	Call. audeni			1							1													
Cor	Hesp. atopodonta				1																			1
Cor	Hesp. kennicotti													1										
Cor	Hesp. michiganensis				1																			
Cor	Hesp. scabricula						2																	
Cor	Hesp. vulgaris			1																				
Cor	Palm. nana																						2	
Cor	Sig. alternata			1			5	1																
Cor	Sig. compressoidea	4	2		2		10				4													
Cor	Sig. concocephala			2																				
Cor	Sig. decorata					4		2																
Cor	Sig. doloebra			1																				
Cor	Sig. johnstoni							3																
Cor	Sig. knighti				2							3												
Cor	Sig. mackinacensis				2		1				7													
Cor	Sig. penniensis				1		1																	
Cor	Sig. transfigurata					13								10										1
Cor	Sig. variablis										1													
Cor	Tri. nais																					15		
Ger	G. .instar	2	8	4	1	6	2	6	20	37	5	1	4	3	4		3	18	2			4	7	
Ger	G. alacris		2										3											
Ger	G. argenticollis	7	6	9			4	2				4	2	1										
Ger	G. buenoi	2		1		2	1	1			2	3		1	8	5	1		2		5	5	3	
Ger	G. comatus				1	3		2				1	1	3	5	2		2	11	2	6	2	14	2
Ger	G. dissortis			3		1												2						
Ger	G. inseparatus												1											
Ger	G. marginatus					1	1	4		1			1	1										3
Hyd	Hydro. martini							1						1										
Mes	M. cryptophila	1																						
Mes	M. mulsanti	1		1			3	1	4				2	3	1			3			6	7	14	
Nep	Ranatra fusca	3	2	4	3		7	3			2	1	1	2		1			2				1	
Not	N. .instar	30	26	12	8	1	15	36				2	3		1						2	3		
Not	N. borealis			1			1																	
Not	N. insulata				1																			
Not	N. irrorata																		2					
Not	N. lunata						1				1	1	1	4					7				1	2
Not	N. undulata	1		1			4										1							
Ple	Plea striola	4				1							16	1								2		14
Vel	M. buenoi				1																			
Vel	M. pulchella	2	1			2			14			3									1	16	8	
	total Hemiptera	61	48	59	24	34	61	66	38	38	45	23	39	58	19	8	5	25	26	2	25	58	57	23
	total species	14	8	17	13	10	16	14	3	2	11	11	13	14	5	3	3	4	6	1	7	11	9	6

Appendix XI. 1996-1997 Species Totals: Lakes Ranked by Average Conductivity

	cond. (umhos/cm)	8.5	11.2	11.4	12	13.2	14.2	14.3	14.8	15.1	20.3	22.8	23.5	24.2	29.4	33	58	58.8	80.5	86.5	92.1	98.2	104	140
Fa	**Species**	*FS*	**Ber**	**Ras**	*Tue*	*Crn*	*Bog*	*Crm*	**Bay**	*Ed*	*Hum*	*Red*	*TB*	*Bol*	**Nan**	*NG*	**Kic**	*Mor*	**TLk**	**TCr**	**BrC**	**Mul**	*BrL*	**War**
Bel	.instar				1	5	1			11		1	1	2		1		10				3		1
Bel	Leth. amer.				2											1								1
Cor	.instar	3			19		3			5		3		2		2		17	7			2		2
Cor	Call. alaskensis									1														
Cor	Call. audeni				1					1														
Cor	Hesp. atopodonta					1																	1	
Cor	Hesp. kennicotti																	1						
Cor	Hesp. michiganensis					1																		
Cor	Hesp. scabricula	2																						
Cor	Hesp. vulgaris									1														
Cor	Palm. nana																		2					
Cor	Sig. alternata	5					1			1														
Cor	Sig. compressoidea	10			4	2							2			4								
Cor	Sig. concocephala									2														
Cor	Sig. decorata						2				4													
Cor	Sig. doloebra									1														
Cor	Sig. johnstoni						3																	
Cor	Sig. knighti					2						3												
Cor	Sig. mackinacensis	1			7	2																		
Cor	Sig. penniensis	1				1																		
Cor	Sig. transfigurata										13							10					1	
Cor	Sig. variablis				1																			
Cor	Tri. nais																							15
Ger	G. .instar	2	20	3	5	1	6	37	18	4	6	1	8	4	4	2	2	3	7					4
Ger	G. alacris												2	3										
Ger	G. argenticollis	4					2			9		4	6	2		7		1						
Ger	G. buenoi	1		1	2		1			1	2	3			8	2	2	1	3		5	5		5
Ger	G. comatus					1	2		2		3	1		1	5		11	3	14	2	2	6	2	2
Ger	G. dissortis								2	3	1													
Ger	G. inseparatus													1										
Ger	G. marginatus	1					4	1			1			1				1					3	
Hyd	Hydro. martini						1											1						
Mes	M. cryptophila															1								
Mes	M. mulsanti	3	4				1		3	1				2	1	1		3	14			6		7
Nep	Ranatra fusca	7			2	3	3			4		1	2	1		3	2	2	1		1			
Not	N. .instar	15				8	36			12	1	2	26	3	1	30						2		3
Not	N. borealis	1								1														
Not	N. insulata					1																		
Not	N. irrorata																2							
Not	N. lunata	1			1							1		1			7	4	1				2	
Not	N. undulata	4		1						1						1								
Plei	Plea striola										1			16		4		1					14	2
Vel	M. buenoi					1																		
Vel	M. pulchella		14								2	3	1			2			8			1		16
	total Hemiptera	61	38	5	45	24	66	38	25	59	34	23	48	39	19	61	26	58	57	2	8	25	23	58
	total species	16	3	3	11	13	14	2	4	17	10	11	8	13	5	14	6	14	9	1	3	7	6	11

Appendix XII. 1996-1997 Species Totals: Lakes Ranked by Average Alkalinity

	alkalinity (mg/l)	0	0	0	0	0	0	1	1.5	2	3	3	5	10	10.5	12	27	33.5	36	38	39.5	47	50	58
Fa	Species	Bay	Ber	Crn	NG	Ras	TB	Hum	Tue	Bog	Ed	FS	Crm	Red	Nan	Bol	Mor	TLk	Mul	TCr	Kic	BrC	BrL	War
Bel	.instar			5	1		1		1	1	11			1		2	10		3					1
Bel	Leth. amer.				1				2															1
Cor	.instar				2				19	3	5	3		3		2	17	7	2					2
Cor	Call. alaskensis										1													
Cor	Call. audeni								1		1													
Cor	Hesp. atopodonta			1																			1	
Cor	Hesp. kennicotti																1							
Cor	Hesp. michiganensis			1																				
Cor	Hesp. scabricula											2												
Cor	Hesp. vulgaris										1													
Cor	Palm. nana																	2						
Cor	Sig. alternata									1	1	5												
Cor	Sig. compressoidea			2	4		2		4			10												
Cor	Sig. concocephala										2													
Cor	Sig. decorata							4		2														
Cor	Sig. doloebra										1													
Cor	Sig. johnstoni									3														
Cor	Sig. knighti			2										3										
Cor	Sig. mackinacensis			2					7			1												
Cor	Sig. penniensis			1								1												
Cor	Sig. transfigurata							13									10						1	
Cor	Sig. variablis								1															
Cor	Tri. nais																							15
Ger	G. .instar	18	20	1	2	3	8	6	5	6	4	2	37	1	4	4	3	7			2			4
Ger	G. alacris						2									3								
Ger	G. argenticollis				7		6			2	9	4		4		2	1							
Ger	G. buenoi				2	1		2	2	1	1	1		3	8		1	3	5		2	5		5
Ger	G. comatus	2		1				3		2				1	5	1	3	14	6	2	11	2	2	2
Ger	G. dissortis	2						1			3													
Ger	G. inseparatus															1								
Ger	G. marginatus							1		4		1	1			1	1						3	
Hyd	Hydro. martini									1							1							
Mes	M. cryptophila				1																			
Mes	M. mulsanti	3	4		1					1	1	3			1	2	3	14	6					7
Nep	Ranatra fusca			3	3		2		2	3	4	7		1		1	2	1			2	1		
Not	N. .instar			8	30		26	1		36	12	15		2	1	3			2					3
Not	N. borealis										1	1												
Not	N. insulata			1																				
Not	N. irrorata																				2			
Not	N. lunata								1			1		1		1	4	1			7		2	
Not	N. undulata				1	1					1	4												
Plei	Plea striola				4			1								16	1						14	2
Veli	M. buenoi			1																				
Veli	M. pulchella		14		2		1	2						3				8	1					16
	total Hemiptera	25	38	24	61	5	48	34	45	66	59	61	38	23	19	39	58	57	25	2	26	8	23	58
	total species	4	3	13	14	3	8	10	11	14	17	16	2	11	5	13	14	9	7	1	6	3	6	11

Appendix XIII. 1996-1997 Species Totals: Lakes Ranked by Average Color

	color (pt/co)	14.8	36.1	40	41	43.5	57.3	60.5	62.4	70.3	78	79	79.8	90.3	96.5	127	135	145	155	164	196	246	272	321
Fa	**Species**	**Bay**	**Ras**	**TLk**	*Crn*	*FS*	**War**	*Tue*	**Ber**	**TCr**	**Kic**	*BrL*	**Mul**	**BrC**	*Crn*	*Ed*	**Nan**	*Bol*	*Bog*	*TB*	*Mor*	*Hum*	*Red*	*NG*
Bel	.instar						1	1					3		5	11		2	1	1	10		1	1
Bel	Leth. amer.						1	2																1
Cor	.instar			7		3	2	19					2			5		2	3		17		3	2
Cor	Call. alaskensis															1								
Cor	Call. audeni							1								1								
Cor	Hesp. atopodonta											1			1									
Cor	Hesp. kennicotti																				1			
Cor	Hesp. michiganensis														1									
Cor	Hesp. scabricula					2																		
Cor	Hesp. vulgaris															1								
Cor	Palm. nana			2																				
Cor	Sig. alternata					5										1			1					
Cor	Sig. compressoidea					10		4							2					2				4
Cor	Sig. concocephala															2								
Cor	Sig. decorata																		2			4		
Cor	Sig. doloebra															1								
Cor	Sig. johnstoni																		3					
Cor	Sig. knighti														2								3	
Cor	Sig. mackinacensis					1		7							2									
Cor	Sig. penniensis					1									1									
Cor	Sig. transfigurata											1									10	13		
Cor	Sig. variablis							1																
Cor	Tri. nais						15																	
Ger	G. .instar	18	3	7	37	2	4	5	20		2				1	4	4	4	6	8	3	6	1	2
Ger	G. alacris																	3		2				
Ger	G. argenticollis					4										9		2	2	6	1		4	7
Ger	G. buenoi		1	3		1	5	2			2		5	5		1	8		1		1	2	3	2
Ger	G. comatus	2		14			2			2	11	2	6	2	1		5	1	2		3	3	1	
Ger	G. dissortis	2														3						1		
Ger	G. inseparatus																	1						
Ger	G. marginatus				1	1						3						1	4		1	1		
Hyd	Hydro. martini																		1		1			
Me	M. cryptophila																							1
Me	M. mulsanti	3		14		3	7		4				6			1	1	2	1		3			1
Ne	Ranatra fusca			1		7		2			2			1	3	4		1	3	2	2		1	3
Not	N. .instar					15	3						2		8	12	1	3	36	26		1	2	30
Not	N. borealis					1										1								
Not	N. insulata														1									
Not	N. irrorata										2													
Not	N. lunata			1		1		1			7	2						1			4		1	
Not	N. undulata		1			4										1								1
Ple	Plea striola						2					14						16			1	1		4
Vel	M. buenoi														1									
Vel	M. pulchella			8			16		14				1							1		2	3	2
	total Hemiptera	25	5	57	38	61	58	45	38	2	26	23	25	8	24	59	19	39	66	48	58	34	23	61
	total species	4	3	9	2	16	11	11	3	1	6	6	7	3	13	17	5	13	14	8	14	10	11	14

Appendix XIV. 1996-1997 Species Totals: Lakes Ranked by Average Secchi Depth

	secchi (m)	0.65	0.73	0.75	0.85	0.85	0.93	1.25	1.35	1.4	1.4	1.4	1.45	1.52	1.63	1.75	2.2	2.48	2.65	3.1	3.3	3.55		
Fa	Species	*Red*	*Hum*	*NG*	*Bog*	*Mor*	*Bol*	*Crn*	*BrL*	*Ed*	**Nan**	*TB*	**Mul**	**Kic**	*Tue*	*FS*	**Ber**	**War**	**Ras**	**TLk**	*Crm*	**Bay**	**BrC**	**TCr**
Bel	.instar	1		1	1	10	2	5		11		1	3		1			1						
Bel	Leth. amer.			1											2			1						
Cor	.instar	3		2	3	17	2			5			2		19	3		2		7				
Cor	Call. alaskensis									1														
Cor	Call. audeni									1					1									
Cor	Hesp. atopodonta							1	1															
Cor	Hesp. kennicotti					1																		
Cor	Hesp. michiganensis							1																
Cor	Hesp. scabricula															2								
Cor	Hesp. vulgaris									1														
Cor	Palm. nana																			2				
Cor	Sig. alternata				1					1						5								
Cor	Sig. compressoidea			4				2				2			4	10								
Cor	Sig. concocephala									2														
Cor	Sig. decorata		4		2																			
Cor	Sig. doloebra									1														
Cor	Sig. johnstoni				3																			
Cor	Sig. knighti	3						2																
Cor	Sig. mackinacensis							2							7	1								
Cor	Sig. penniensis							1								1								
Cor	Sig. transfigurata		13			10			1															
Cor	Sig. variablis														1									
Cor	Tri. nais																	15						
Ger	G. .instar	1	6	2	6	3	4	1		4	4	8		2	5	2	20	4	3	7	37	18		
Ger	G. alacris						3					2												
Ger	G. argenticollis	4		7	2	1	2			9		6				4								
Ger	G. buenoi	3	2	2	1	1				1	8		5	2	2	1		5	1	3			5	
Ger	G. comatus	1	3		2	3	1	1	2		5		6	11				2		14		2	2	2
Ger	G. dissortis		1							3												2		
Ger	G. inseparatus						1																	
Ger	G. marginatus		1		4	1	1		3							1					1			
Hyd	Hydro. martini				1	1																		
Mes	M. cryptophila			1																				
Mes	M. mulsanti			1	1	3	2			1	1		6			3	4	7		14		3		
Nep	Ranatra fusca	1		3	3	2	1	3		4		2		2	2	7				1			1	
Not	N. .instar	2	1	30	36		3	8		12	1	26	2			15		3						
Not	N. borealis									1						1								
Not	N. insulata							1																
Not	N. irrorata													2										
Not	N. lunata	1				4	1		2					7	1	1				1				
Not	N. undulata			1						1						4			1					
Ple	Plea striola		1	4		1	16		14									2						
Vel	M. buenoi							1																
Vel	M. pulchella	3	2	2								1	1				14	16		8				
	total Hemiptera	23	34	61	66	58	39	24	23	59	19	48	25	26	45	61	38	58	5	57	38	25	8	2
	total species	11	10	14	14	14	13	13	6	17	5	8	7	6	11	16	3	11	3	9	2	4	3	1

Appendix XV. 1996-1997 Species Totals: Lakes Ranked by Maximum Depth

	max. depth (m)	1.25	2	3.25	3.25	3.5	4.5	5.5	6	6	6.71	7	7	7	7.5	9.14	12	13.7	15	15.3	16	19		
Fa	**Species**	**Mul**	*Bog*	**Kic**	**Nan**	*Bol*	*FS*	*BrL*	*NG*	**Ras**	*Mor*	*Ed*	*Hum*	**War**	*Crn*	**TLk**	**Ber**	**Bay**	*TB*	*Crm*	*Red*	*Tue*	**BrC**	**TCr**
Bel	.instar	3	1			2			1		10	11		1	5				1		1	1		
Bel	Leth. amer.								1					1								2		
Cor	.instar	2	3			2	3		2		17	5		2		7					3	19		
Cor	Call. alaskensis											1												
Cor	Call. audeni											1										1		
Cor	Hesp. atopodonta							1							1									
Cor	Hesp. kennicotti										1													
Cor	Hesp. michiganensis														1									
Cor	Hesp. scabricula						2																	
Cor	Hesp. vulgaris											1												
Cor	Palm. nana															2								
Cor	Sig. alternata		1				5					1												
Cor	Sig. compressoidea						10		4						2				2			4		
Cor	Sig. concocephala											2												
Cor	Sig. decorata		2										4											
Cor	Sig. doloebra											1												
Cor	Sig. johnstoni		3																					
Cor	Sig. knighti														2						3			
Cor	Sig. mackinacensis						1								2							7		
Cor	Sig. penniensis						1								1									
Cor	Sig. transfigurata							1			10		13											
Cor	Sig. variablis																					1		
Cor	Tri. nais													15										
Ger	G. .instar		6	2	4	4	2		2	3	3	4	6	4	1	7	20	18	8	37	1	5		
Ger	G. alacris					3													2					
Ger	G. argenticollis		2			2	4		7		1	9							6		4			
Ger	G. buenoi	5	1	2	8		1		2	1	1	1	2	5		3					3	2	5	
Ger	G. comatus	6	2	11	5	1		2			3		3	2	1	14		2			1		2	2
Ger	G. dissortis											3	1					2						
Ger	G. inseparatus					1																		
Ger	G. marginatus		4			1	1	3			1		1							1				
Hyd	Hydro. martini		1								1													
Me	M. cryptophila								1															
Me	M. mulsanti	6	1		1	2	3		1		3	1		7		14	4	3						
Nep	Ranatra fusca		3	2		1	7		3		2	4			3	1			2		1	2	1	
Not	N. .instar	2	36		1	3	15		30			12	1	3	8				26		2			
Not	N. borealis						1					1												
Not	N. insulata														1									
Not	N. irrorata			2																				
Not	N. lunata			7		1	1	2			4					1					1	1		
Not	N. undulata						4		1	1		1												
Ple	Plea striola					16		14	4		1		1	2										
Vel	M. buenoi														1									
Vel	M. pulchella	1							2				2	16		8	14		1		3			
	total Hemiptera	25	66	26	19	39	61	23	61	5	58	59	34	58	24	57	38	25	48	38	23	45	8	2

Appendix XVI. 1996-1997 Species Totals: Lakes Ranked by Area

	area (ha)	0.06	0.08	0.21	0.28	0.76	0.91	1.07	1.11	1.24	1.25	1.83	2.74	4.04	4.63	5.93	7.87	17.8	25.8	32.9	67.3	194		
Fa	Species	TB	Ed	FS	NG	Hum	Tue	Bol	Mul	Red	Crn	Bog	War	Nan	Ras	Mor	Kic	Ber	Crm	BrL	Bay	TLk	BrC	TCr
Bel	.instar	1	11		1		1	2	3	1	5	1	1			10								
Bel	Leth. amer.				1		2						1											
Cor	.instar		5	3	2		19	2	2	3		3	2			17						7		
Cor	Call. alaskensis		1																					
Cor	Call. audeni		1				1																	
Cor	Hesp. atopodonta										1									1				
Cor	Hesp. kennicotti															1								
Cor	Hesp. michiganensis										1													
Cor	Hesp. scabricula			2																				
Cor	Hesp. vulgaris		1																					
Cor	Palm. nana																					2		
Cor	Sig. alternata		1	5								1												
Cor	Sig. compressoidea	2		10	4		4				2													
Cor	Sig. concocephala		2																					
Cor	Sig. decorata					4						2												
Cor	Sig. doloebra		1																					
Cor	Sig. johnstoni											3												
Cor	Sig. knighti									3	2													
Cor	Sig. mackinacensis			1			7				2													
Cor	Sig. penniensis			1							1													
Cor	Sig. transfigurata					13										10				1				
Cor	Sig. variablis						1																	
Cor	Tri. nais												15											
Ger	G. .instar	8	4	2	2	6	5	4		1	1	6	4	4	3	3	2	20	37		18	7		
Ger	G. alacris	2						3																
Ger	G. argenticollis	6	9	4	7			2		4		2				1								
Ger	G. buenoi		1	1	2	2	2		5	3		1	5	8	1	1	2					3	5	
Ger	G. comatus					3		1	6	1	1	2	2	5		3	11			2	2	14	2	2
Ger	G. dissortis		3			1															2			
Ger	G. inseparatus							1																
Ger	G. marginatus			1		1		1				4				1			1	3				
Hyd	Hydro. martini											1				1								
Me	M. cryptophila				1																			
Me	M. mulsanti		1	3	1			2	6			1	7	1		3		4			3	14		
Nep	Ranatra fusca	2	4	7	3		2	1		1	3	3				2	2					1	1	
Not	N. .instar	26	12	15	30	1		3	2	2	8	36	3	1										
Not	N. borealis		1	1																				
Not	N. insulata										1													
Not	N. irrorata																2							
Not	N. lunata			1			1	1		1						4	7			2		1		
Not	N. undulata		1	4	1										1									
Ple	Plea striola				4	1		16					2			1				14				
Vel	M. buenoi										1													
Vel	M. pulchella	1			2	2			1	3			16					14				8		
	total Hemiptera	48	59	61	61	34	45	39	25	23	24	66	58	19	5	58	26	38	38	23	25	57	8	2
	total species	8	17	16	14	10	11	13	7	11	13	14	11	5	3	14	6	3	2	6	4	9	3	1

Appendix XVII. 1996-1997 Species Totals: Lakes Ranked by Shoreline Development

	shoreline dev.	1.04	1.05	1.07	1.08	1.19	1.19	1.2	1.23	1.23	1.27	1.27	1.31	1.31	1.35	1.39	1.42	1.42	1.7	1.91	2.01	2.64		
Fa	**Species**	*Tue*	**War**	*NG*	*Red*	*Mor*	**Ras**	*Ed*	*BrL*	*Hum*	*Bol*	**Nan**	*Crn*	**Kic**	*TB*	**Ber**	*Crm*	**Mul**	*Bog*	**TLk**	*FS*	**Bay**	**BrC**	**TCr**
Bel	.instar	1	1	1	1	10		11			2		5		1			3	1					
Bel	Leth. amer.	2	1	1																				
Cor	.instar	19	2	2	3	17		5			2							2	3	7	3			
Cor	Call. alaskensis							1																
Cor	Call. audeni	1						1																
Cor	Hesp. atopodonta								1				1											
Cor	Hesp. kennicotti					1																		
Cor	Hesp. michiganensis												1											
Cor	Hesp. scabricula																				2			
Cor	Hesp. vulgaris							1																
Cor	Palm. nana																			2				
Cor	Sig. alternata							1											1		5			
Cor	Sig. compressoidea	4		4									2		2						10			
Cor	Sig. concocephala							2																
Cor	Sig. decorata									4									2					
Cor	Sig. doloebra							1																
Cor	Sig. johnstoni																		3					
Cor	Sig. knighti				3								2											
Cor	Sig. mackinacensis	7											2								1			
Cor	Sig. penniensis												1								1			
Cor	Sig. transfigurata					10			1	13														
Cor	Sig. variablis	1																						
Cor	Tri. nais		15																					
Ger	G. .instar	5	4	2	1	3	3	4		6	4	4	1	2	8	20	37		6	7	2	18		
Ger	G. alacris										3				2									
Ger	G. argenticollis			7	4	1		9			2				6				2		4			
Ger	G. buenoi	2	5	2	3	1	1	1		2		8		2				5	1	3	1		5	
Ger	G. comatus		2		1	3			2	3	1	5	1	11				6	2	14		2	2	2
Ger	G. dissortis							3		1												2		
Ger	G. inseparatus										1													
Ger	G. marginatus					1			3	1	1						1		4		1			
Hyd	Hydro. martini					1													1					
Me	M. cryptophila			1																				
Me	M. mulsanti		7	1		3		1			2	1				4		6	1	14	3	3		
Nep	Ranatra fusca	2		3	1	2		4			1		3	2	2				3	1	7		1	
Not	N. .instar		3	30	2			12		1	3	1	8		26			2	36		15			
Not	N. borealis							1													1			
Not	N. insulata												1											
Not	N. irrorata													2										
Not	N. lunata	1			1	4			2		1			7						1	1			
Not	N. undulata			1			1	1													4			
Ple	Plea striola		2	4		1			14	1	16													
Vel	M. buenoi												1											
Vel	M. pulchella		16	2	3					2					1	14		1		8				
	total Hemiptera	45	58	61	23	58	5	59	23	34	39	19	24	26	48	38	38	25	66	57	61	25	8	2
	total species	11	11	14	11	14	3	17	6	10	13	5	13	6	8	3	2	7	14	9	16	4	3	1

Appendix XVIII. 1996-1997 Species Totals: Lakes Ranked by Fish Population Index

	fish population	0	0	0	0	1	1	1	1	1	2	2	2	2	2	2	3	3	3	3	3	3	3	n
	3: 2 or more species piscivorous fish; 2: 1 species piscivorous fish; 1: no known piscivorous fish; 0: no known fish; n: no information																							
Fa	**Species**	*Ed*	*FS*	*NG*	*TB*	*Bog*	*Crn*	*Hum*	**Mul**	*Tue*	*Bol*	*Mor*	*Red*	**War**	**BrC**	**TCr**	**Bay**	**Ber**	*BrL*	*Crm*	**Kic**	**Ras**	**TLk**	**Nan**
Bel	.instar	11		1	1	1	5		3	1	2	10	1	1										
Bel	Leth. amer.			1						2				1										
Cor	.instar	5	3	2		3			2	19	2	17	3	2									7	
Cor	Call. alaskensis	1																						
Cor	Call. audeni	1								1														
Cor	Hesp. atopodonta						1												1					
Cor	Hesp. kennicotti											1												
Cor	Hesp. michiganensis						1																	
Cor	Hesp. scabricula		2																					
Cor	Hesp. vulgaris	1																						
Cor	Palm. nana																						2	
Cor	Sig. alternata	1	5			1																		
Cor	Sig. compressoidea		10	4	2		2			4														
Cor	Sig. concocephala	2																						
Cor	Sig. decorata					2		4																
Cor	Sig. doloebra	1																						
Cor	Sig. johnstoni					3																		
Cor	Sig. knighti						2						3											
Cor	Sig. mackinacensis		1				2			7														
Cor	Sig. penniensis		1				1																	
Cor	Sig. transfigurata							13				10							1					
Cor	Sig. variablis									1														
Cor	Tri. nais													15										
Ger	G. .instar	4	2	2	8	6	1	6		5	4	3	1	4			18	20		37	2	3	7	4
Ger	G. alacris				2						3													
Ger	G. argenticollis	9	4	7	6	2					2	1	4											
Ger	G. buenoi	1	1	2		1		2	5	2		1	3	5	5						2	1	3	8
Ger	G. comatus					2	1	3	6		1	3	1	2	2	2	2		2		11		14	5
Ger	G. dissortis	3						1									2							
Ger	G. inseparatus										1													
Ger	G. marginatus		1			4		1			1	1							3	1				
Hyd	Hydro. martini					1						1												
Mes	M. cryptophila			1																				
Mes	M. mulsanti	1	3	1		1			6		2	3		7			3	4					14	1
Nep	Ranatra fusca	4	7	3	2	3	3			2	1	2	1		1						2		1	
Not	N. .instar	12	15	30	26	36	8	1	2		3		2	3										1
Not	N. borealis	1	1																					
Not	N. insulata						1																	
Not	N. irrorata																				2			
Not	N. lunata		1							1	1	4	1						2		7		1	
Not	N. undulata	1	4	1																		1		
Ple	Plea striola			4				1			16	1		2					14					
Vel	M. buenoi						1																	
Vel	M. pulchella			2	1			2	1				3	16				14					8	
	total Hemiptera	59	61	61	48	66	24	34	25	45	39	58	23	58	8	2	25	38	23	38	26	5	57	19
	total species	17	16	14	8	14	13	10	7	11	13	14	11	11	3	1	4	3	6	2	6	3	9	5

Appendix XIX. 1996-1997 Species Totals: Lakes Ranked by Abundance

Fa	Species	TCr	Ras	BrC	Nan	BrL	Red	Crn	Bay	Mul	Kic	Hum	Ber	Crm	Bol	Tue	TB	TLk	Mor	War	Ed	FS	NG	Bog
Bel	.instar						1	5		3					2	1	1		10	1	11		1	1
Bel	Leth. amer.															2				1			1	
Cor	.instar						3			2					2	19		7	17	2	5	3	2	3
Cor	Call. alaskensis																				1			
Cor	Call. audeni															1					1			
Cor	Hesp. atopodonta					1		1																
Cor	Hesp. kennicotti																		1					
Cor	Hesp. michiganensis							1																
Cor	Hesp. scabricula																					2		
Cor	Hesp. vulgaris																				1			
Cor	Palm. nana																	2						
Cor	Sig. alternata																				1	5		1
Cor	Sig. compressoidea							2								4	2					10	4	
Cor	Sig. concocephala																				2			
Cor	Sig. decorata											4												2
Cor	Sig. doloebra																				1			
Cor	Sig. johnstoni																							3
Cor	Sig. knighti						3	2																
Cor	Sig. mackinacensis							2								7						1		
Cor	Sig. penniensis							1														1		
Cor	Sig. transfigurata					1						13							10					
Cor	Sig. variablis															1								
Cor	Tri. nais																			15				
Ger	G. .instar		3		4		1	1	18		2	6	20	37	4	5	8	7	3	4	4	2	2	6
Ger	G. alacris														3		2							
Ger	G. argenticollis						4								2		6		1		9	4	7	2
Ger	G. buenoi		1	5	8		3			5	2	2				2		3	1	5	1	1	2	1
Ger	G. comatus	2		2	5	2	1	1	2	6	11	3			1			14	3	2				2
Ger	G. dissortis								2			1									3			
Ger	G. inseparatus														1									
Ger	G. marginatus					3						1		1	1				1			1		4
Hyd	Hydro. martini																		1					1
Mes	M. cryptophila																						1	
Mes	M. mulsanti				1				3	6			4		2			14	3	7	1	3	1	1
Nep	Ranatra fusca			1			1	3			2				1	2	2	1	2		4	7	3	3
Not	N. .instar				1		2	8		2		1			3		26			3	12	15	30	36
Not	N. borealis																				1	1		
Not	N. insulata							1																
Not	N. irrorata										2													
Not	N. lunata					2	1				7				1	1		1	4			1		
Not	N. undulata		1																		1	4	1	
Plei	Plea striola					14						1			16				1	2			4	
Veli	M. buenoi							1																
Veli	M. pulchella						3			1		2	14				1	8		16			2	
	total Hemiptera	2	5	8	19	23	23	24	25	25	26	34	38	38	39	45	48	57	58	58	59	61	61	66
	total species	1	3	3	5	6	11	13	4	7	6	10	3	2	13	11	8	9	14	11	17	16	14	14

Appendix XX. 1996-1997 Species Totals: Lakes Ranked by Species Diversity

Fa	Species	TCr	Crm	Ras	BrC	Ber	Bay	Nan	BrL	Kic	Mul	TB	TLk	Hum	Red	Tue	War	Crn	Bol	Mor	NG	Bog	FS	Ed
Bel	.instar										3	1			1	1	1	5	2	10	1	1		11
Bel	Leth. amer.															2	1				1			
Cor	.instar										2		7		3	19	2		2	17	2	3	3	5
Cor	Call. alaskensis																							1
Cor	Call. audeni															1								1
Cor	Hesp. atopodonta								1									1						
Cor	Hesp. kennicotti																			1				
Cor	Hesp. michiganensis																	1						
Cor	Hesp. scabricula																						2	
Cor	Hesp. vulgaris																							1
Cor	Palm. nana												2											
Cor	Sig. alternata																					1	5	1
Cor	Sig. compressoidea											2				4		2			4		10	
Cor	Sig. concocephala																							2
Cor	Sig. decorata													4								2		
Cor	Sig. doloebra																							1
Cor	Sig. johnstoni																					3		
Cor	Sig. knighti														3			2						
Cor	Sig. mackinacensis															7		2					1	
Cor	Sig. penniensis																	1					1	
Cor	Sig. transfigurata								1					13						10				
Cor	Sig. variablis															1								
Cor	Tri. nais																15							
Ger	G. .instar		37	3		20	18	4		2		8	7	6	1	5	4	1	4	3	2	6	2	4
Ger	G. alacris											2							3					
Ger	G. argenticollis											6			4				2	1	7	2	4	9
Ger	G. buenoi			1	5			8		2	5		3	2	3	2	5			1	2	1	1	1
Ger	G. comatus	2			2		2	5	2	11	6		14	3	1		2	1	1	3		2		
Ger	G. dissortis						2							1										3
Ger	G. inseparatus																		1					
Ger	G. marginatus		1						3					1					1	1		4	1	
Hyd	Hydro. martini																			1		1		
Mes	M. cryptophila																				1			
Mes	M. mulsanti					4	3	1			6		14				7		2	3	1	1	3	1
Nep	Ranatra fusca				1					2		2	1		1	2		3	1	2	3	3	7	4
Not	N. .instar							1			2	26		1	2		3	8	3		30	36	15	12
Not	N. borealis																						1	1
Not	N. insulata																	1						
Not	N. irrorata									2														
Not	N. lunata								2	7			1		1	1			1	4			1	
Not	N. undulata			1																	1		4	1
Plei	Plea striola								14					1			2		16	1	4			
Veli	M. buenoi																	1						
Veli	M. pulchella					14					1	1	8	2	3		16				2			
	total Hemiptera	2	38	5	8	38	25	19	23	26	25	48	57	34	23	45	58	24	39	58	61	66	61	59
	total species	1	2	3	3	3	4	5	6	6	7	8	9	10	11	11	11	13	13	14	14	14	16	17

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References

Bendell, Barry. 1988. Lake acidity and the distribution and abundance of water striders (Hemiptera: Gerridae) near Sudbury, Ontario. Can.Jour.Zoo. 66:2209-2211

Bennet, Donald V. and Fredrick A. Streams. 1986. Effects of vegetation on Notonecta (Hemiptera) distribution in ponds with and without fish. OIKOS. 46: 62-69.

Blatchley, W.S. 1926. Heteroptera or True Bugs or Eastern North America. The Nature Publishing Company. Indianapolis.

Bobb, Marvin L. 1994. Insects of Virginia: No:7, The Aquatic and Semi-Aquatic Hemiptera of Virginia. Virginia Polytechnic Institute and State University. Blackburg, Virginia.

Bringham, Allison R., Warren U. Bringham, Arnold Grilka. 1982. Aquatic Insects and Oligochaetes of North and South Carolina. Midwest Aquatic Enterprises. Mahomet, Illinois.

Brooks, Arthur R. and Leonard A. Kelton. 1967. Aquatic and Semiaquatic Heteroptera of Alberta, Saskatchewan, and Manitoba. The Entomological Society of Canada. Ottowa.

Dolling, W.R. 1991. The Hemiptera. Oxford University Press. Oxford.

Doust, Jon Lovett, Monica Schmidt, and Lesley Lovett Doust. 1994. Biological assessment of aquatic pollution: a review, with emphasis on biomonitors. Biol. Rev. 69: 147-86

HACH Water Analysis Handbook. 1989. HACH Company. Loveland, Colorado.

Hilsenhoff, William L. Aquatic Insects of Wisconsin. Natural History Council. University of Wisconsin-Madison

Ireton, Reneé C. 1996. Water Chemical Confines of the Aquatic Hemiptera (unpublished)

Mizell, Merle, Eric Romig, John Stegman, Roxanna Smolowitz, Rajesh Katayani. 1996. Zebrafish embryo monitoring of the aquatic environment: dose-response synergism revealed in combinations of pollutant chemical mixtures. The Biological Bulletin. 191:292-4

Slater, J.A. and R.M. Baranowski. 1978. How to Know the True Bugs. Wm. C. Brown Company Publishers. Dubuque, Iowa.