

Water Chemical and Habitat Confines of Aquatic Hemiptera

BIOS 569 - Practicum in Aquatic Biology

**Maria L. Goodrich
247 Breen-Phillips Hall
Dr. Ronald A. Hellenthal
1997**

Abstract

Hemiptera are found in a broad range of aquatic habitats and have shown promise for species-level habitat parameters. 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 an 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 Renéé 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 $\mu\text{mhos/cm}$ while Ward Lake had the highest with an average of 140.0 $\mu\text{mhos/cm}$. Five sites had readings over 80.0 $\mu\text{mhos/cm}$. 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 XVII).

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 $\mu\text{m}/\text{cm}$, while both *S. mackinacensis* and *S. alternata* showed a more narrow range of 8 to 15 $\mu\text{m}/\text{cm}$ (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 $\mu\text{m}/\text{cm}$ (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
<i>Fish Population Index</i> : 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

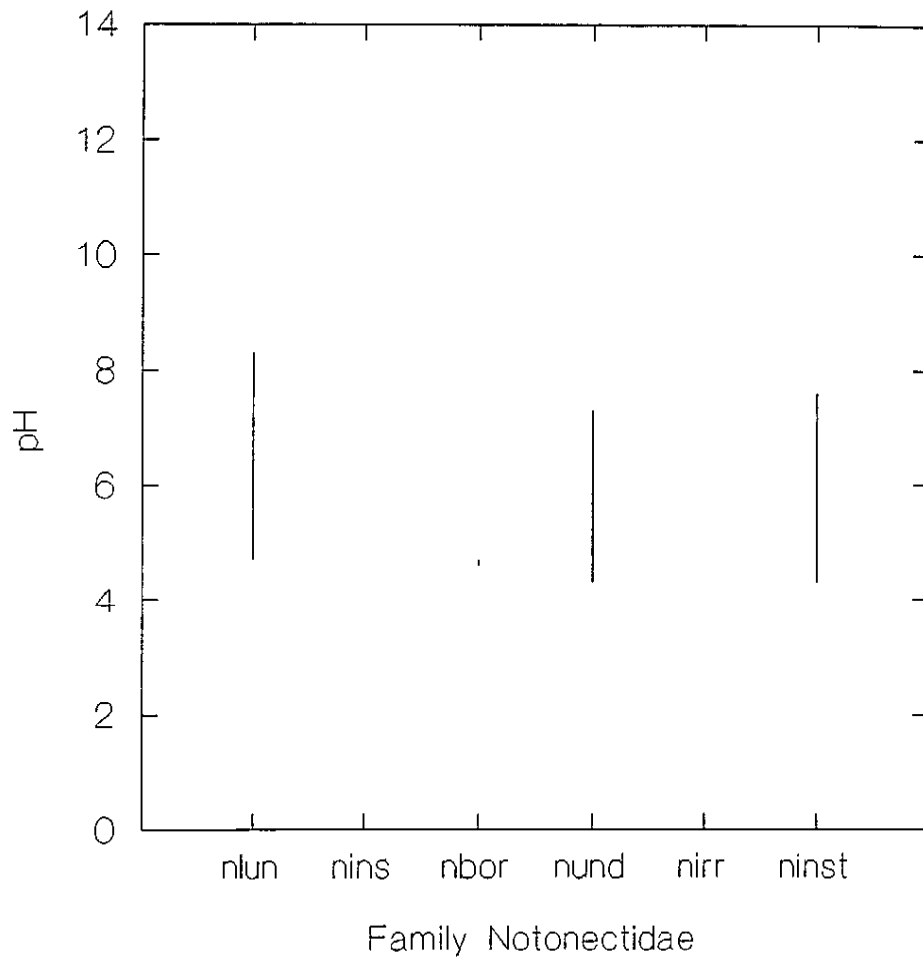
Table 4. First Sampling Collection

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 = <i>Notonecta lunata</i>	1-7	8
nins = <i>Notonecta insulata</i>	1	1
nbor = <i>Notonecta borealis</i>	2	1
nund = <i>Notonecta undulata</i>	1-2	1
nirr = <i>Notonecta irrorata</i>	2	1
ninst = <i>Notonecta instars</i>	1-36	12

Fig. 2. Conductivity Ranges of Family Notonectidae

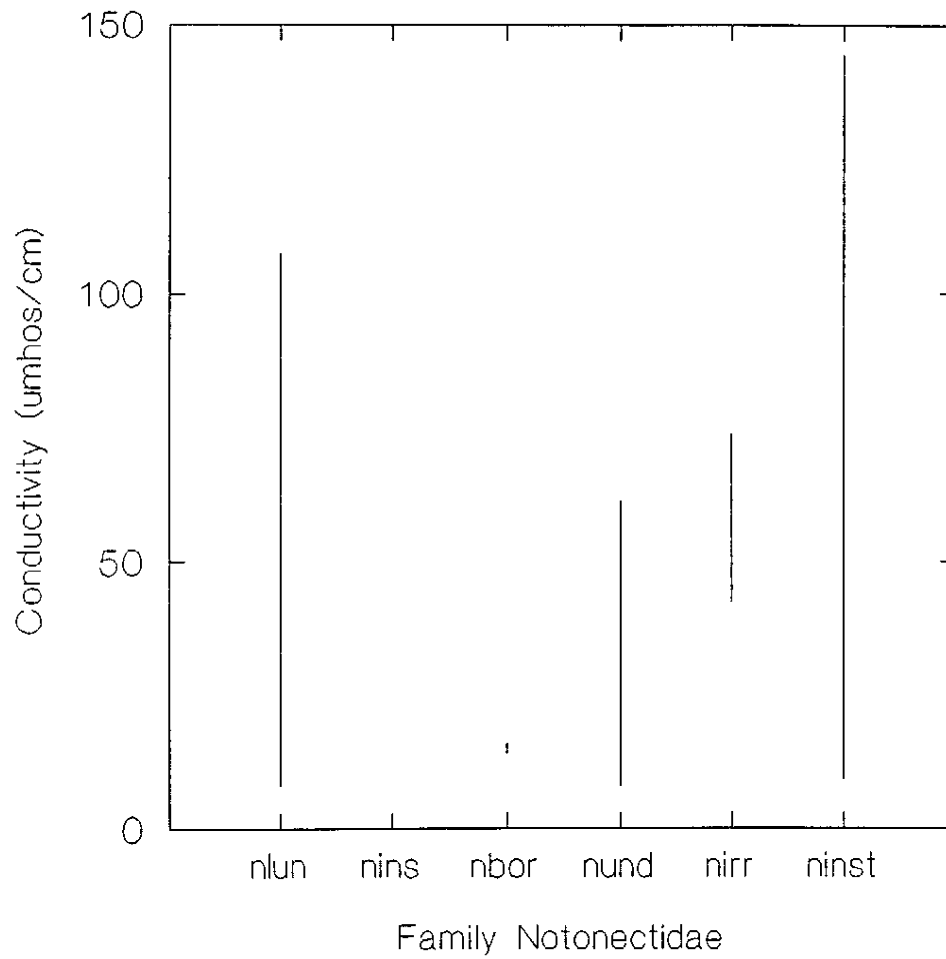


Fig. 3. Alkalinity Ranges of the Family Notonectidae

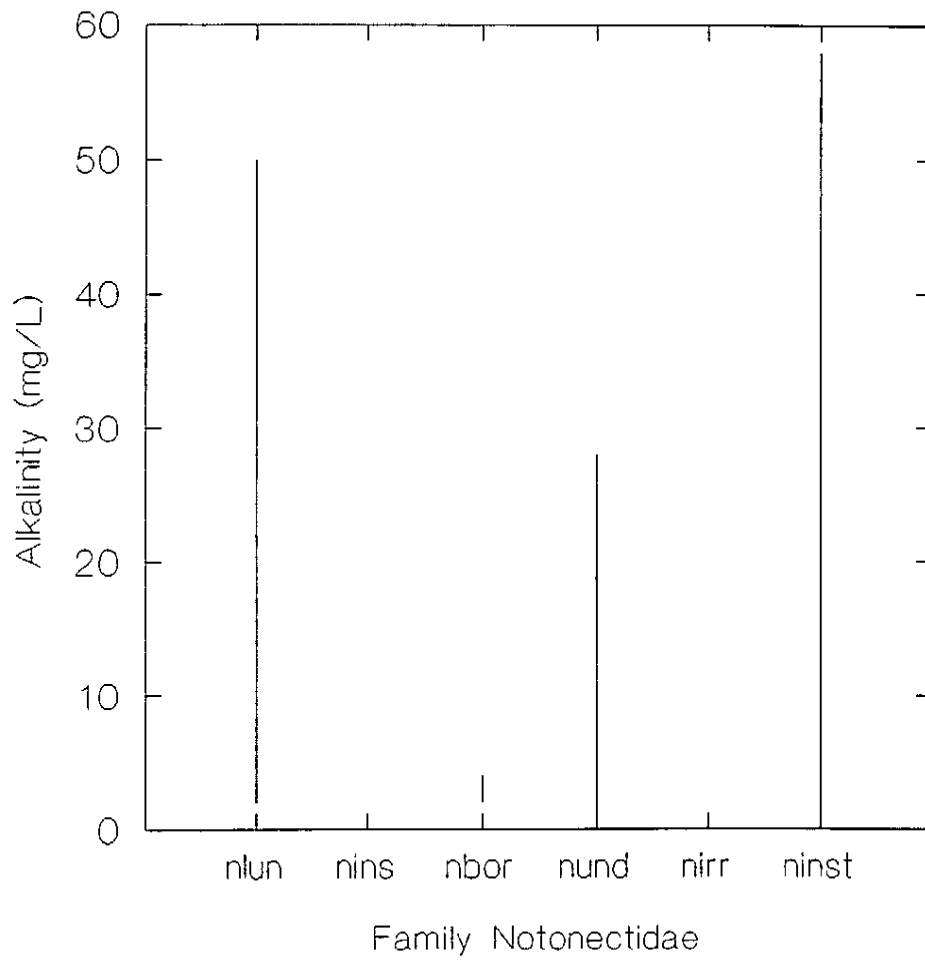


Fig. 4. Water Color Ranges of Family Notonectidae

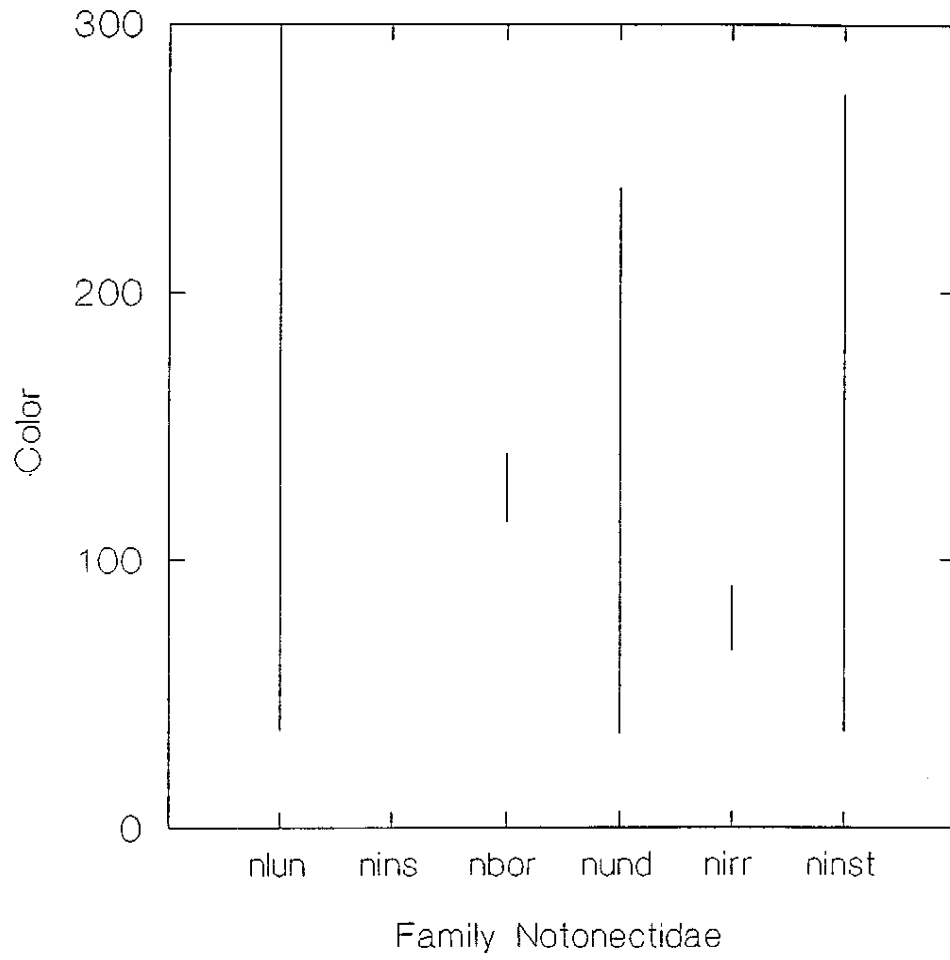


Fig. 5. Secchi Depth Ranges of Family Notonectidae

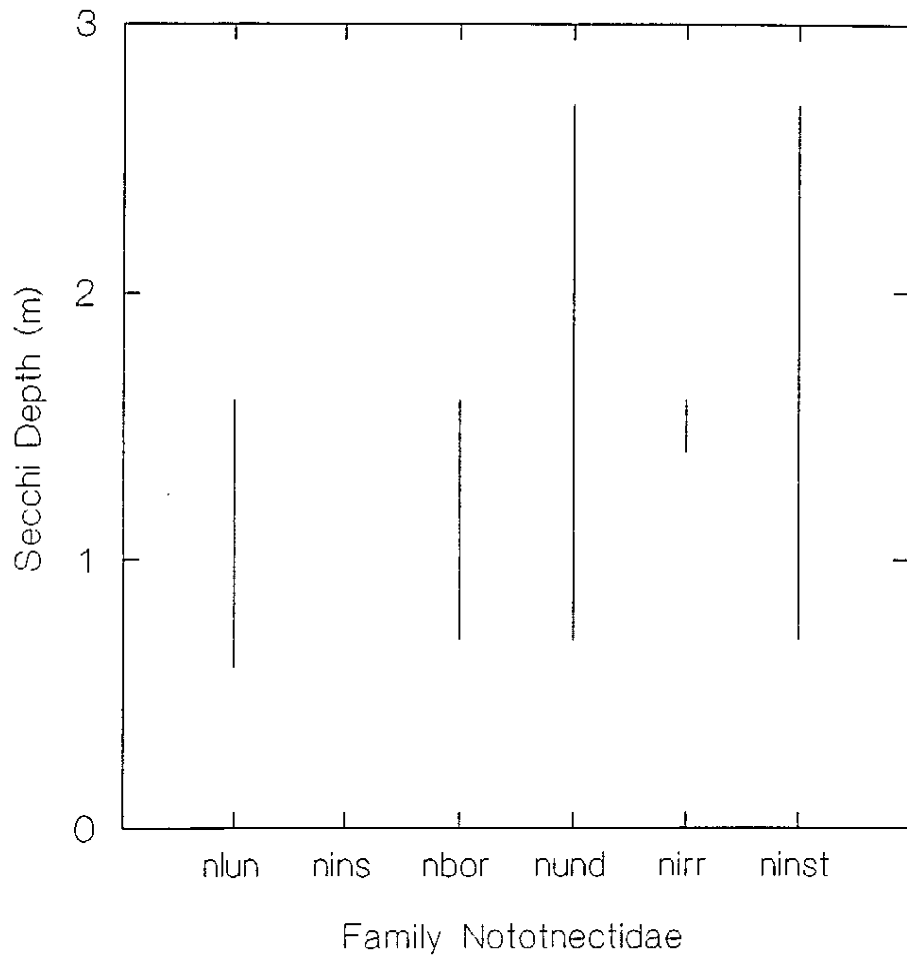
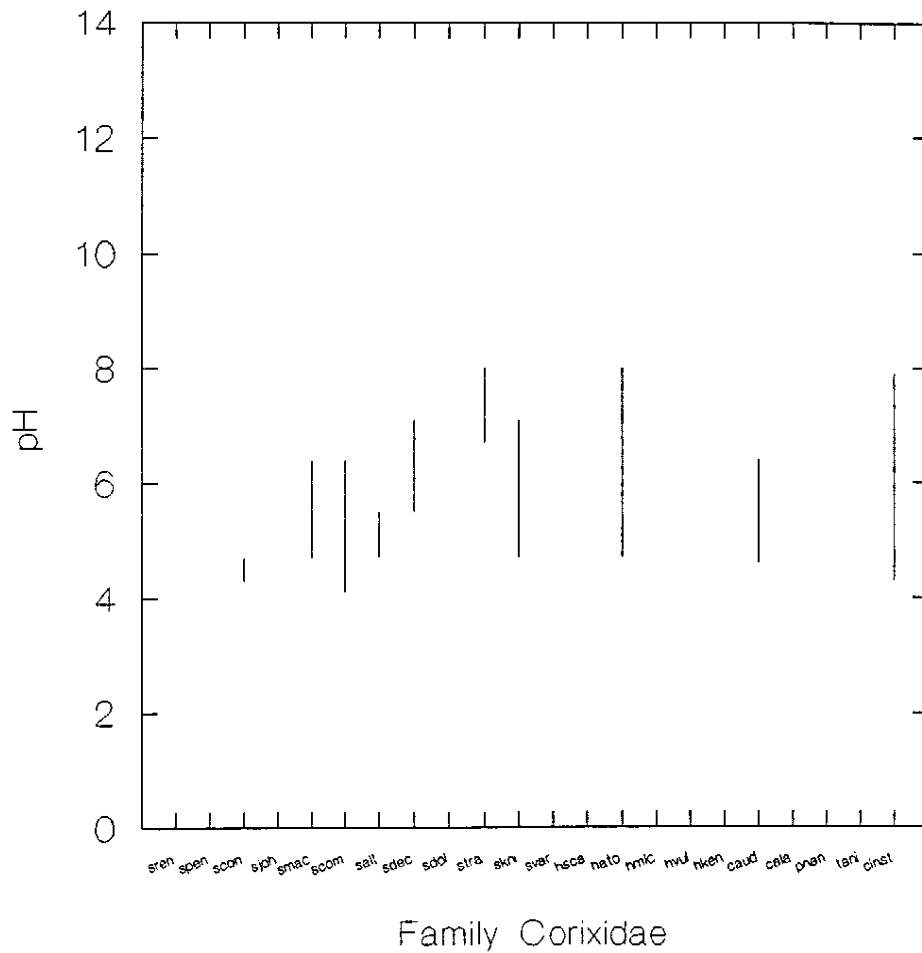


Fig. 6. pH Ranges of Family Corixidae



Family Corixidae

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

Fig. 7. Alkalinity Ranges of Family Corixidae

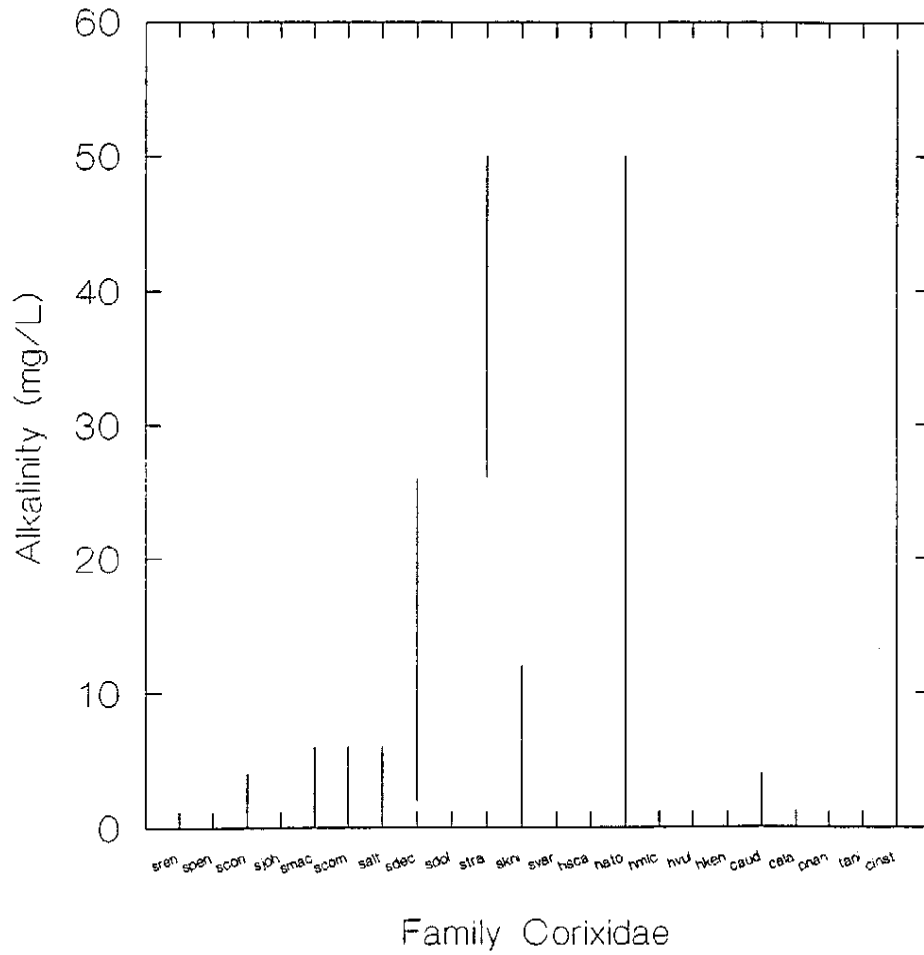


Fig. 8. Conductivity Ranges of Family Corixidae

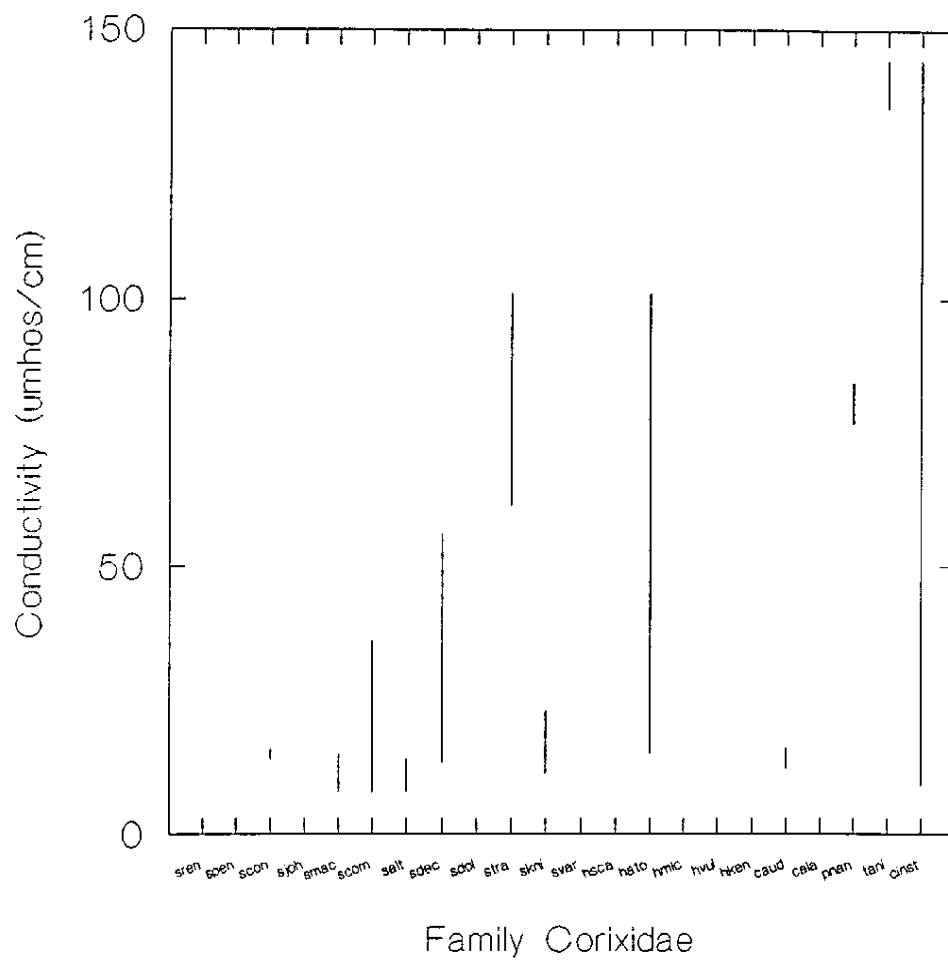


Fig. 9. Water Color Ranges of Family Corixidae

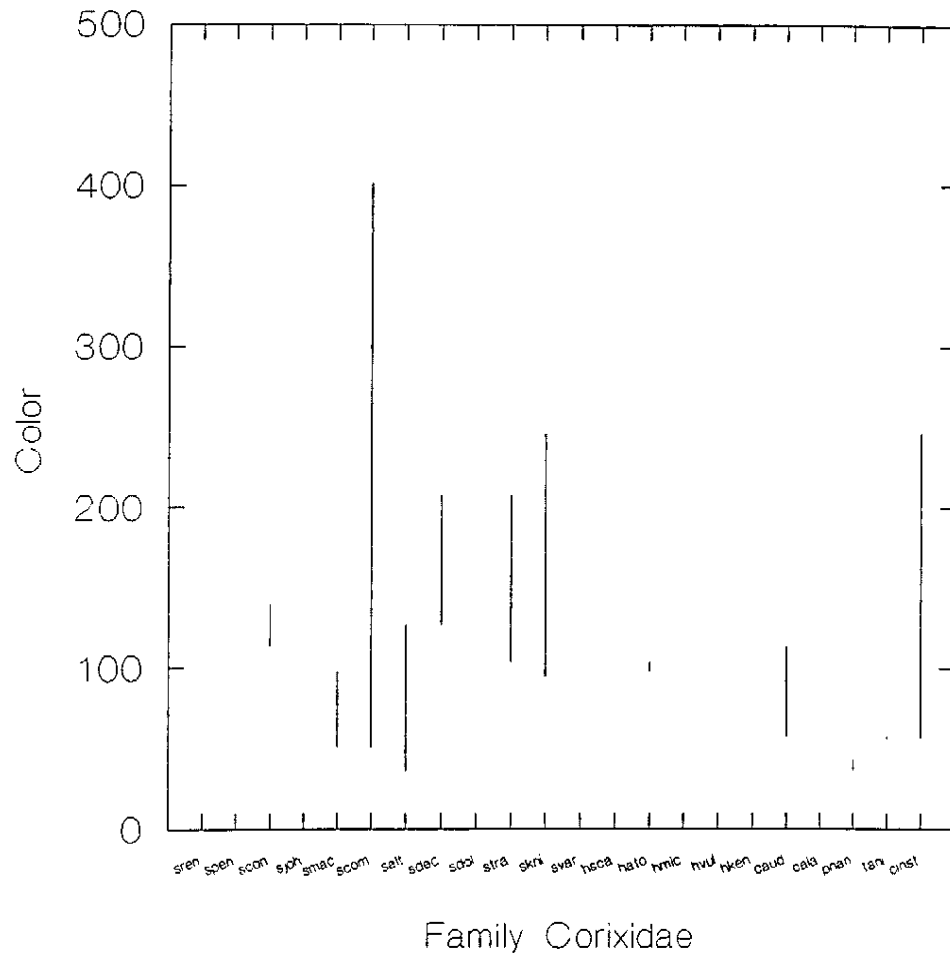


Fig. 10. Secchi Depth Ranges of Family Corixidae

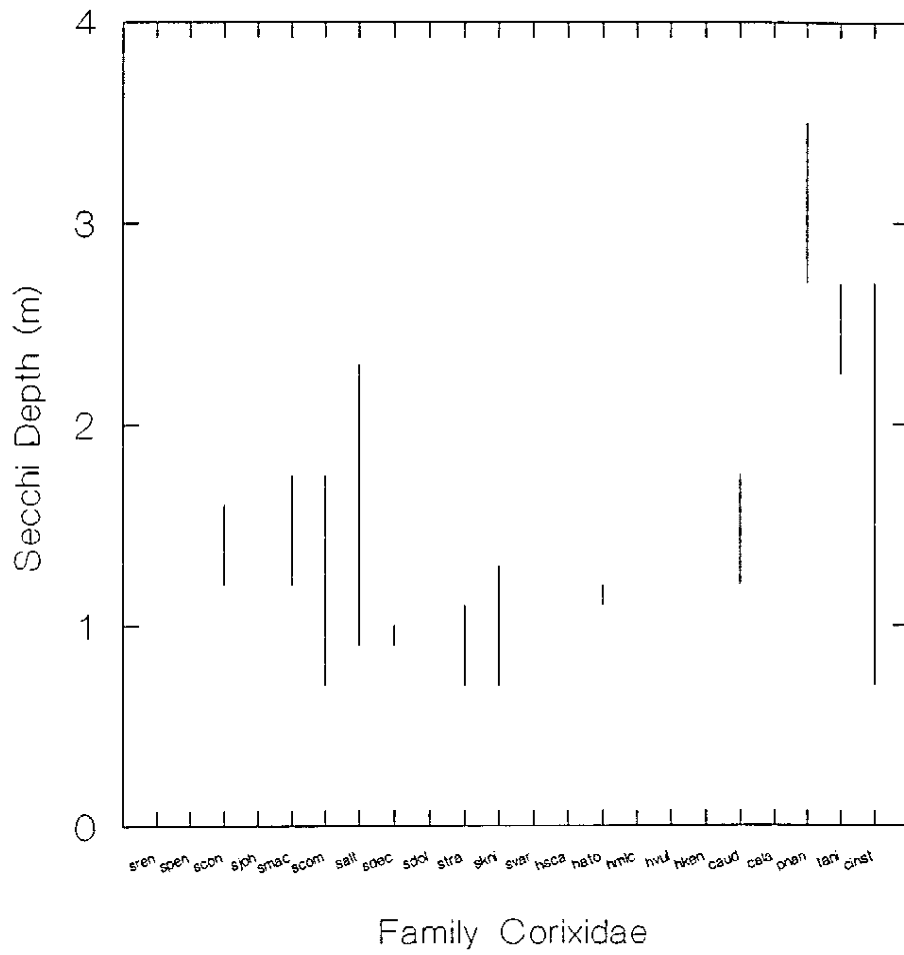
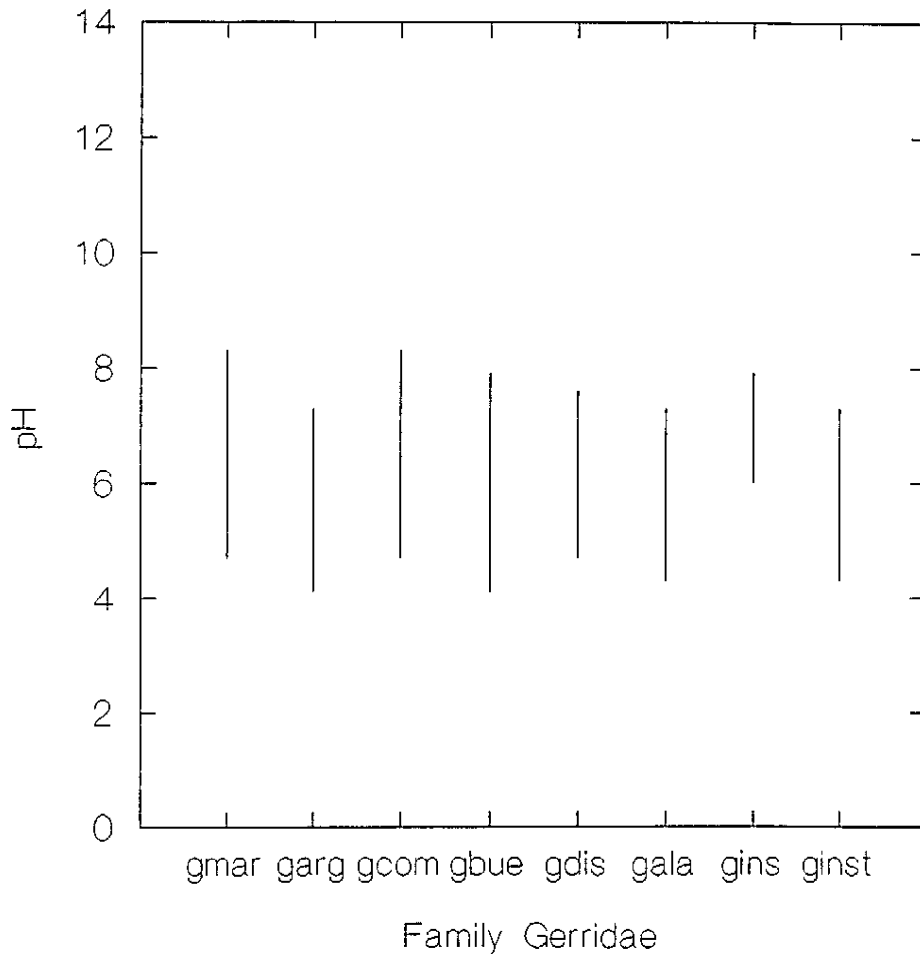


Fig. 11. pH Ranges of Family Gerridae



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

Fig. 12. Alkalinity Ranges of Family Gerridae

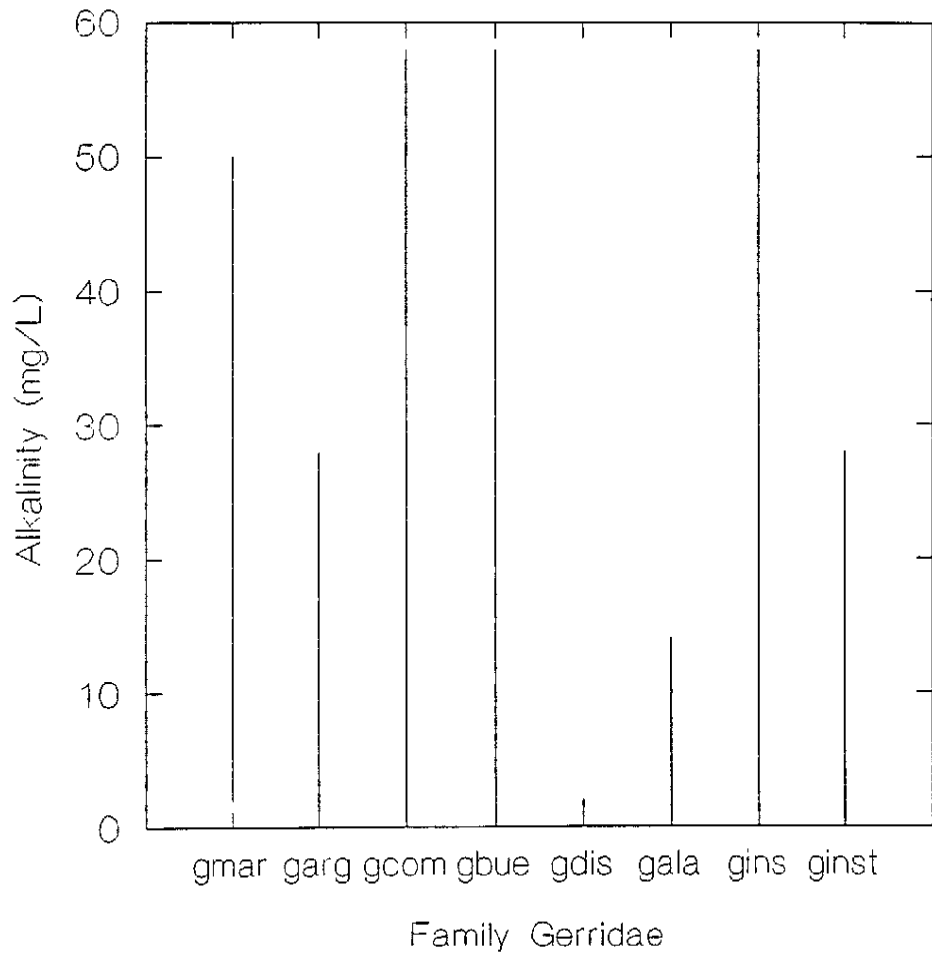


Fig. 13. Conductivity Ranges of Family Gerridae

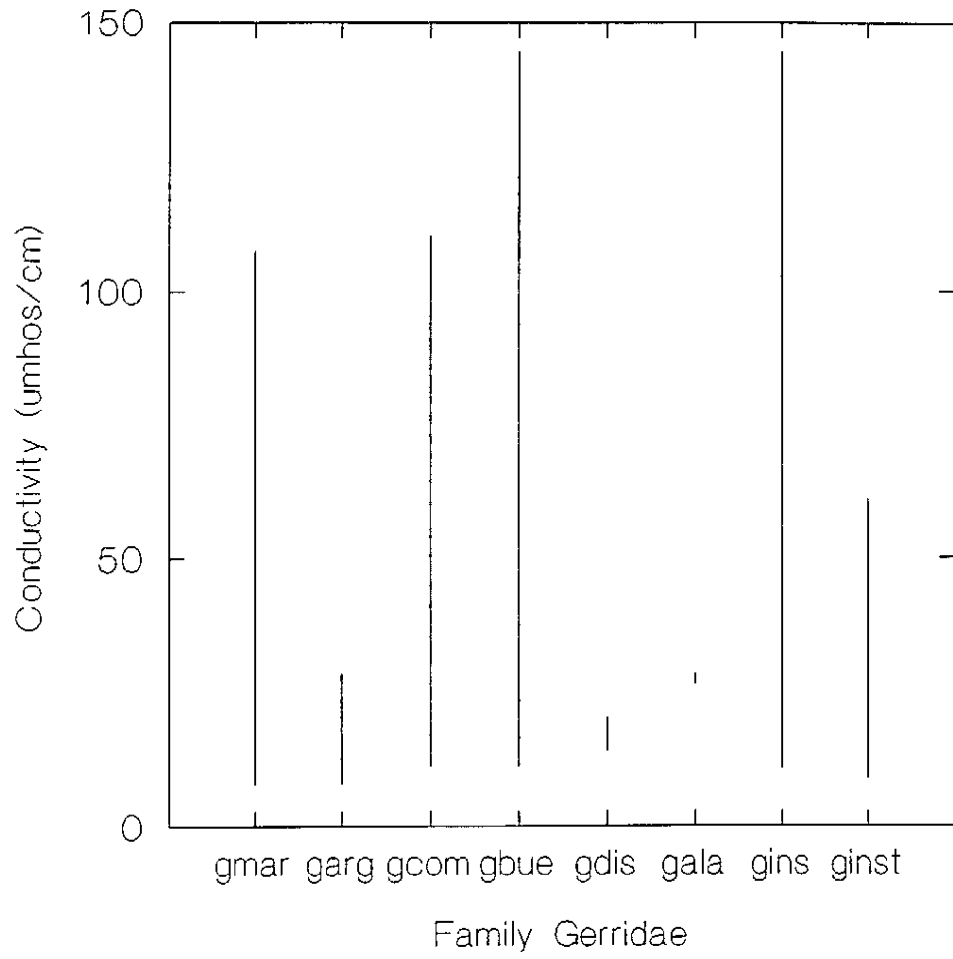


Fig. 14. Water Color Ranges of Family Gerridae

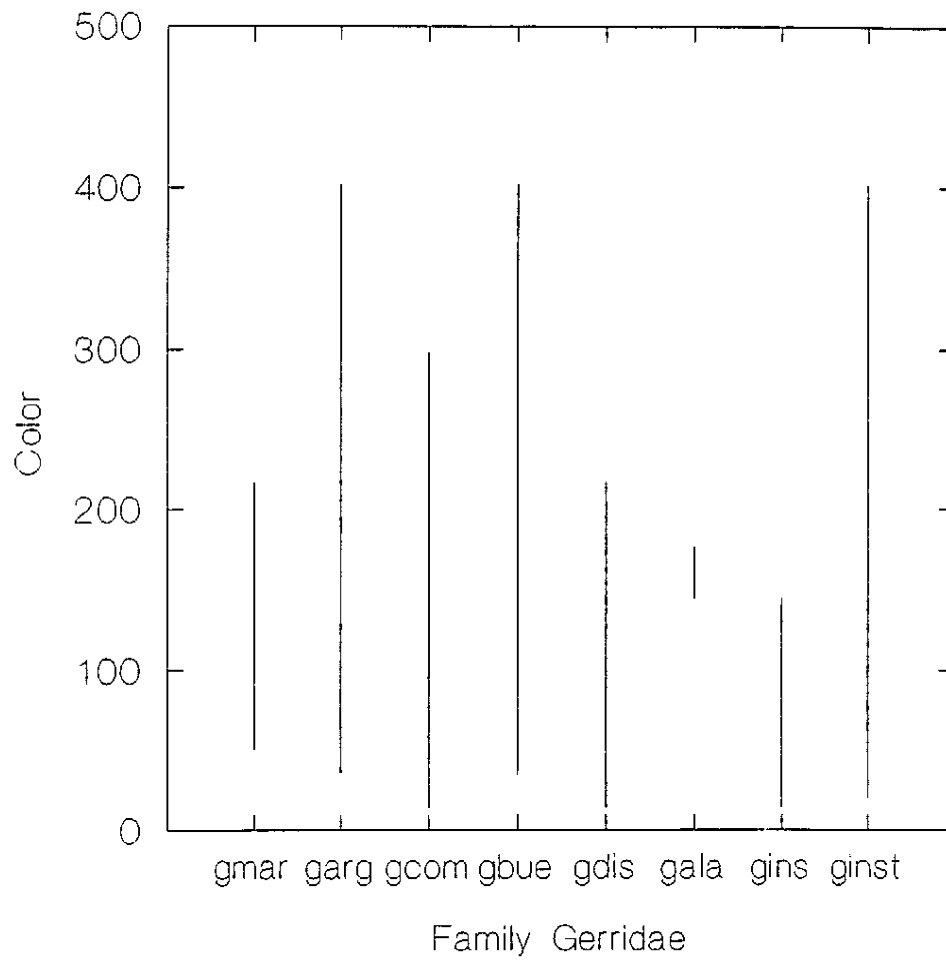


Fig. 15. Secchi Depth Ranges of Family Gerridae

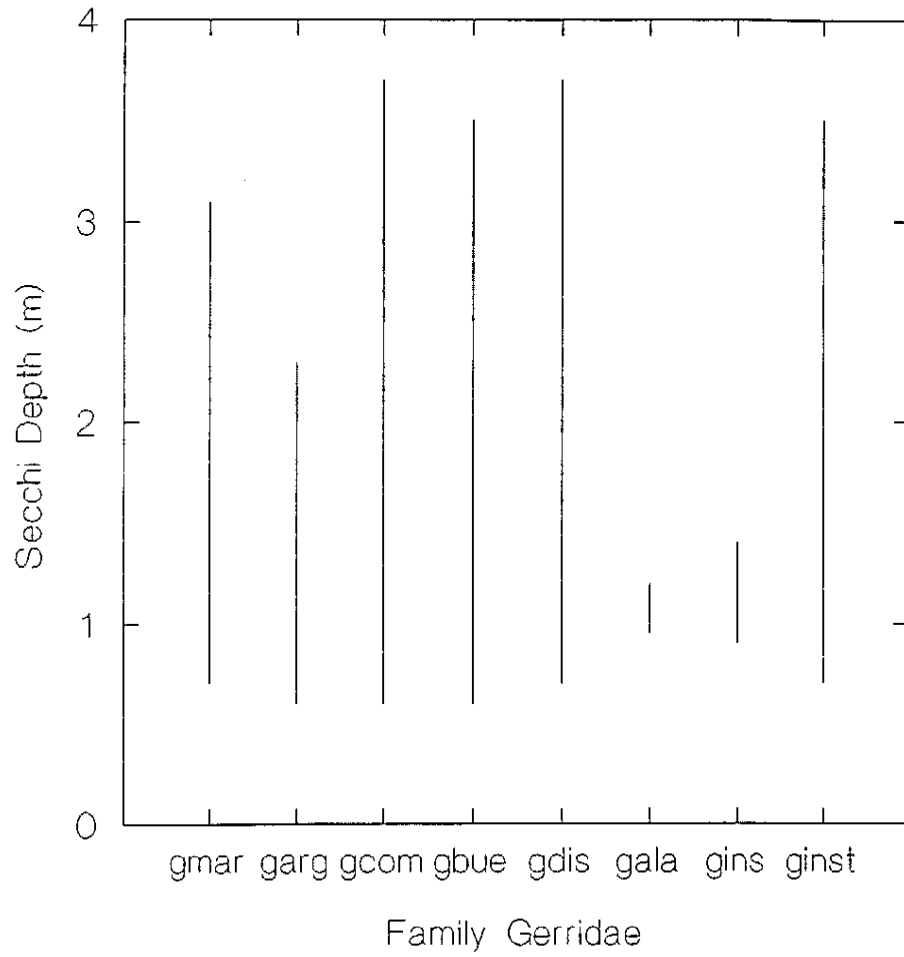
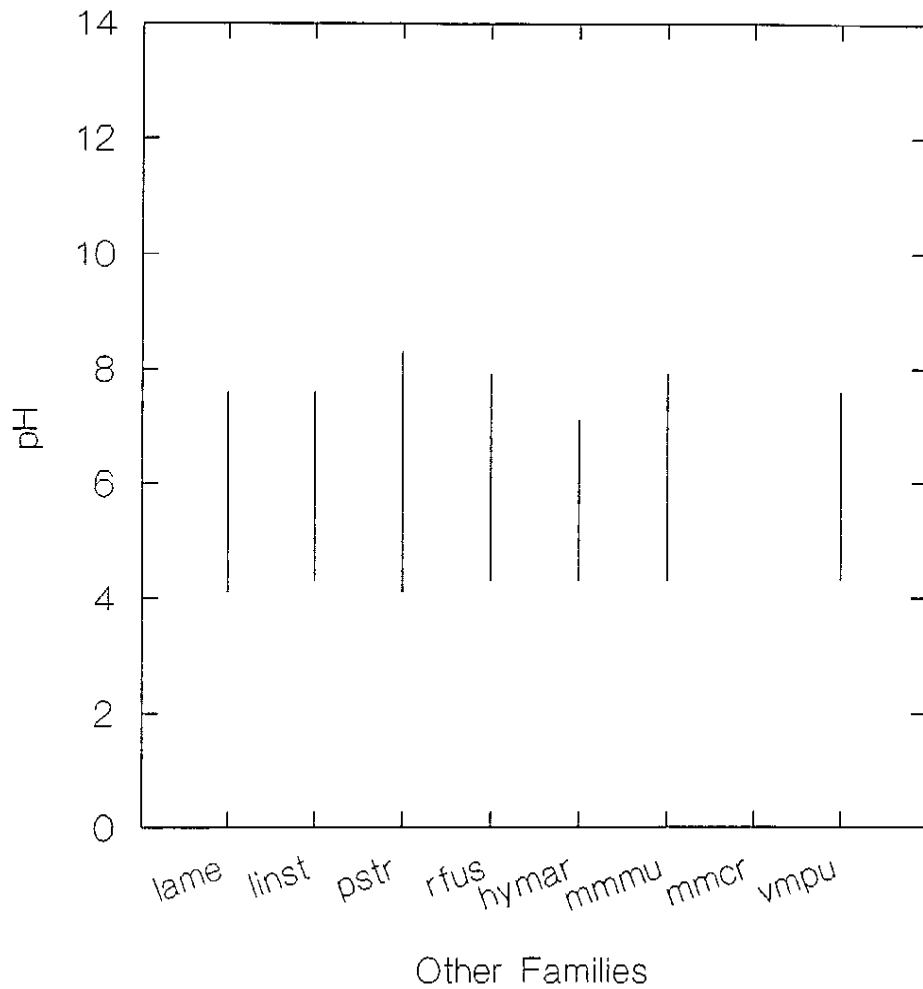


Fig. 16. pH Ranges of Pleidae, Nepidae, Mesoveliidae, Belostomatidae, and Veliidae Families



Other Families

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

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

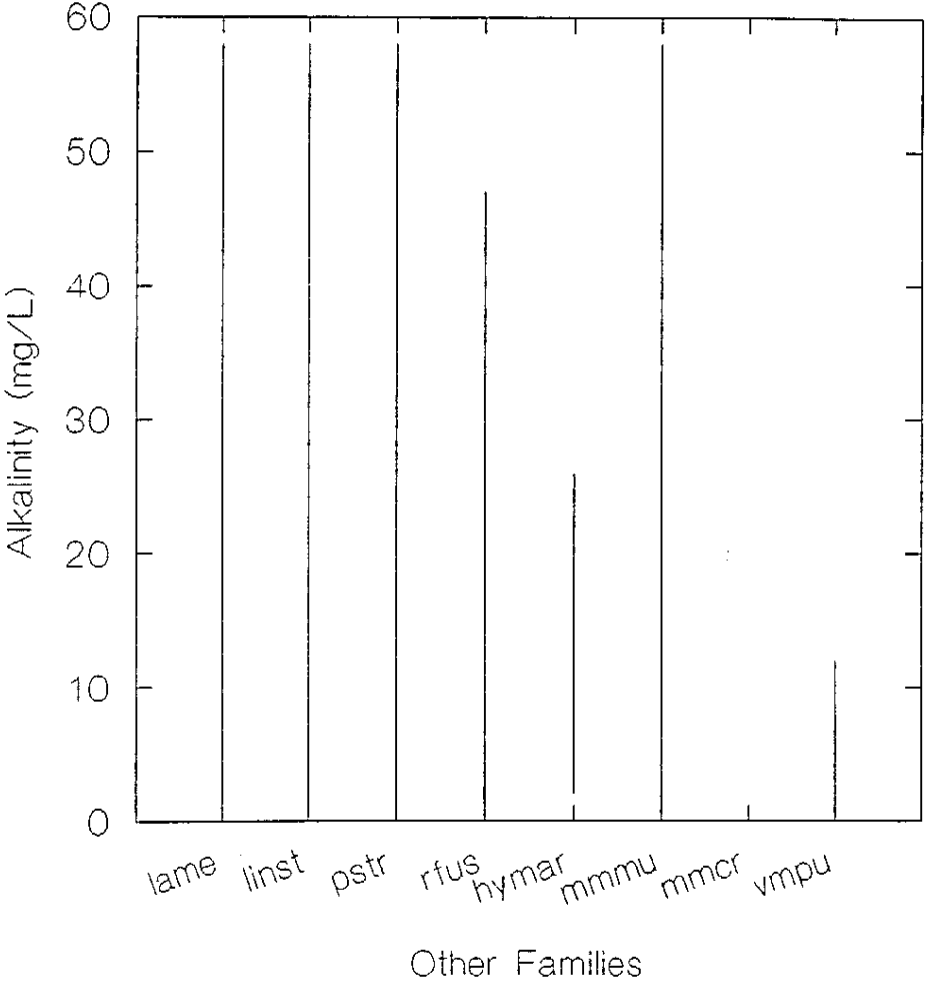


Fig. 18. Conductivity Ranges of Pleidae, Nepidae, Mesoveliidae, Belostomatidae, and Veliidae Families

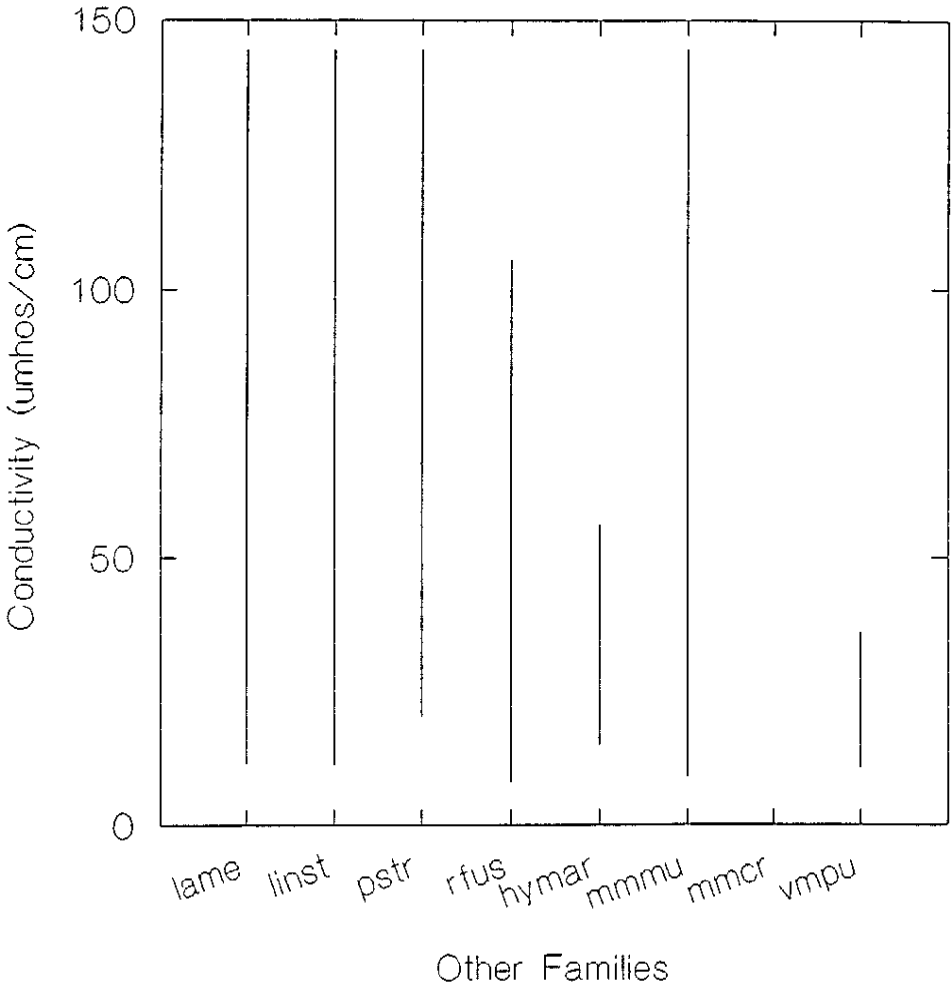


Fig. 19. Water Color Ranges of Pleidae, Nepidae, Mesoveliidae, Belostomatidae, and Veliidae Families

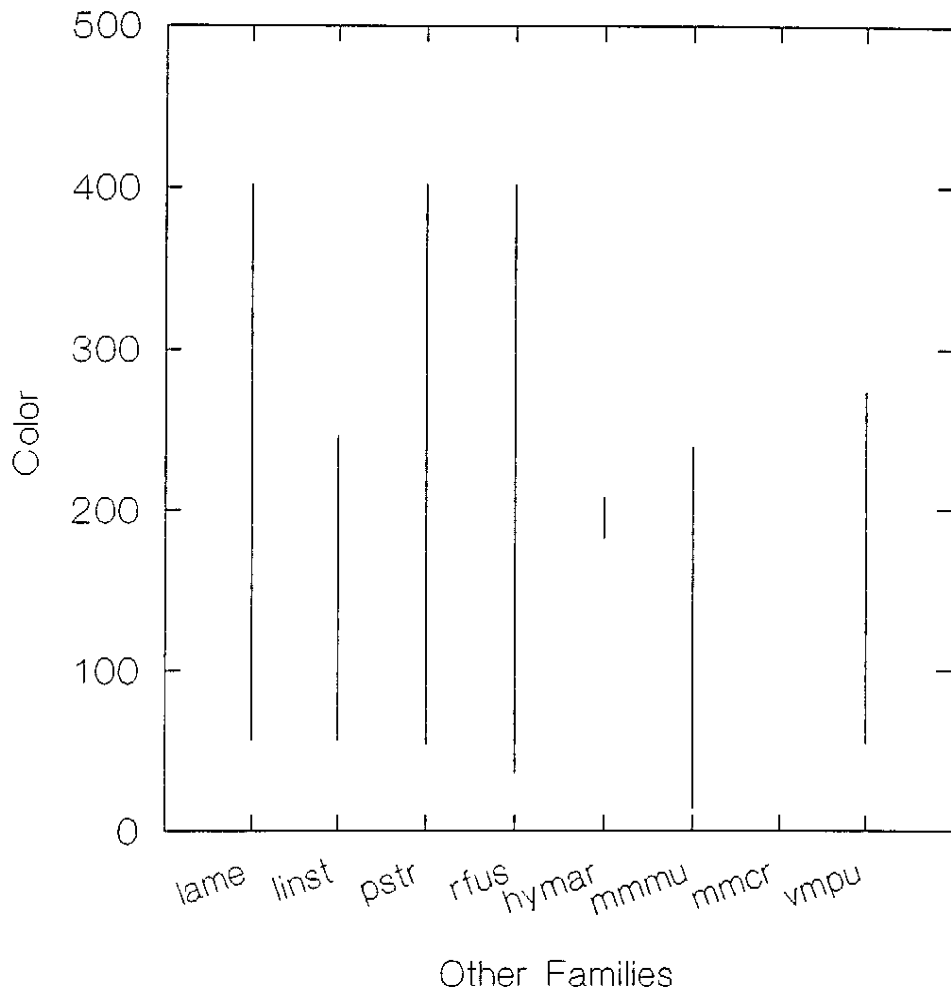
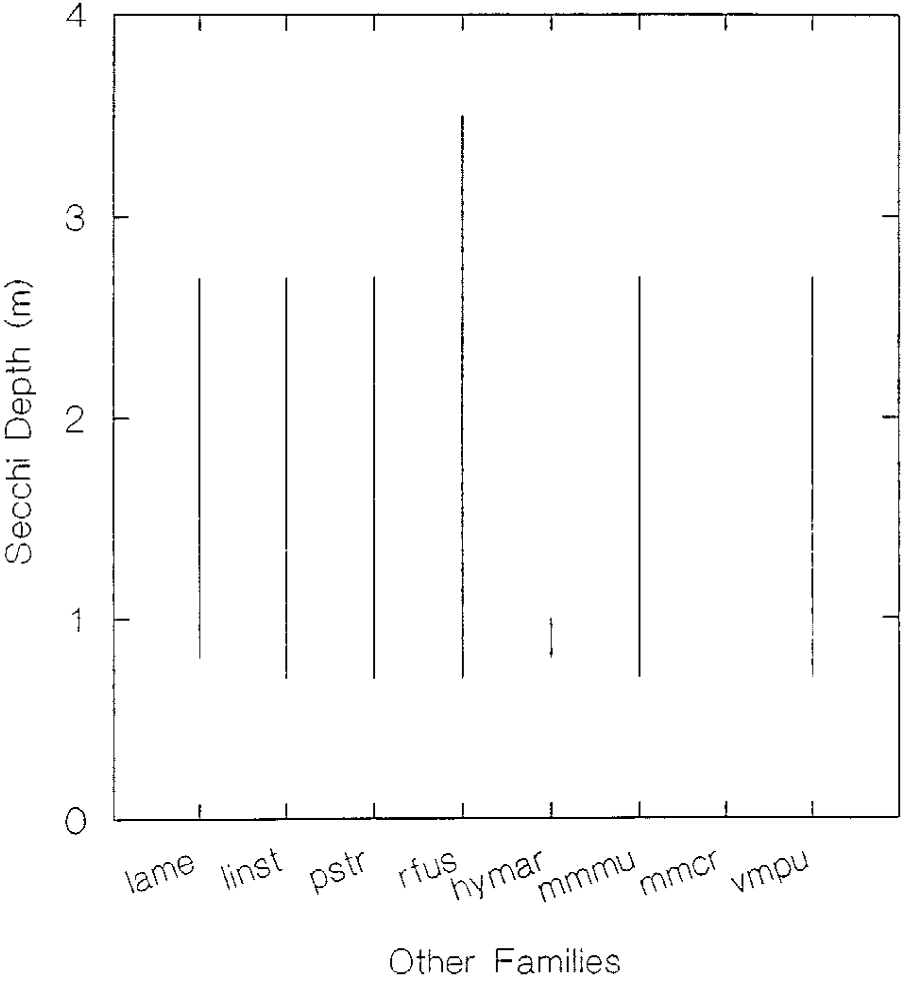
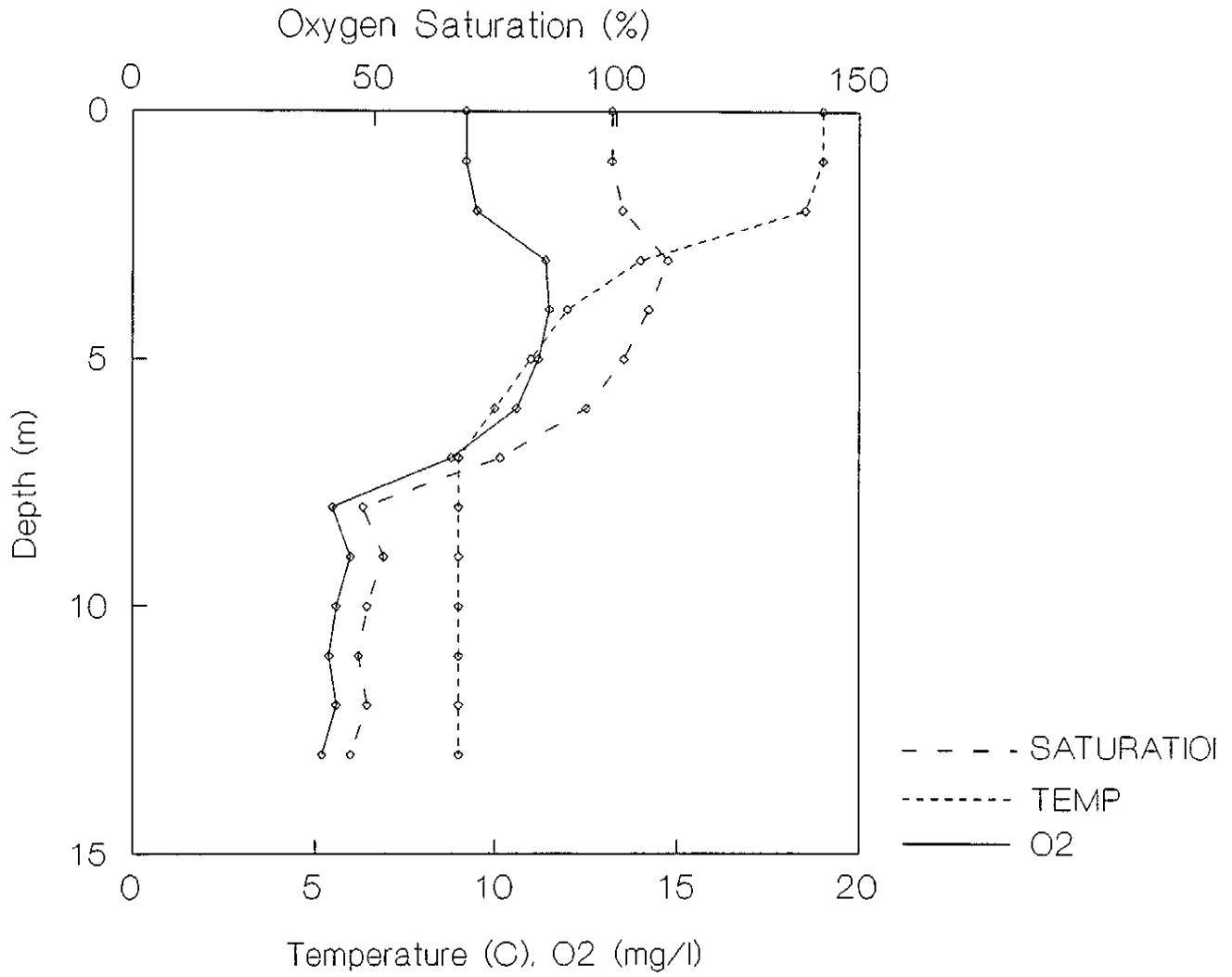


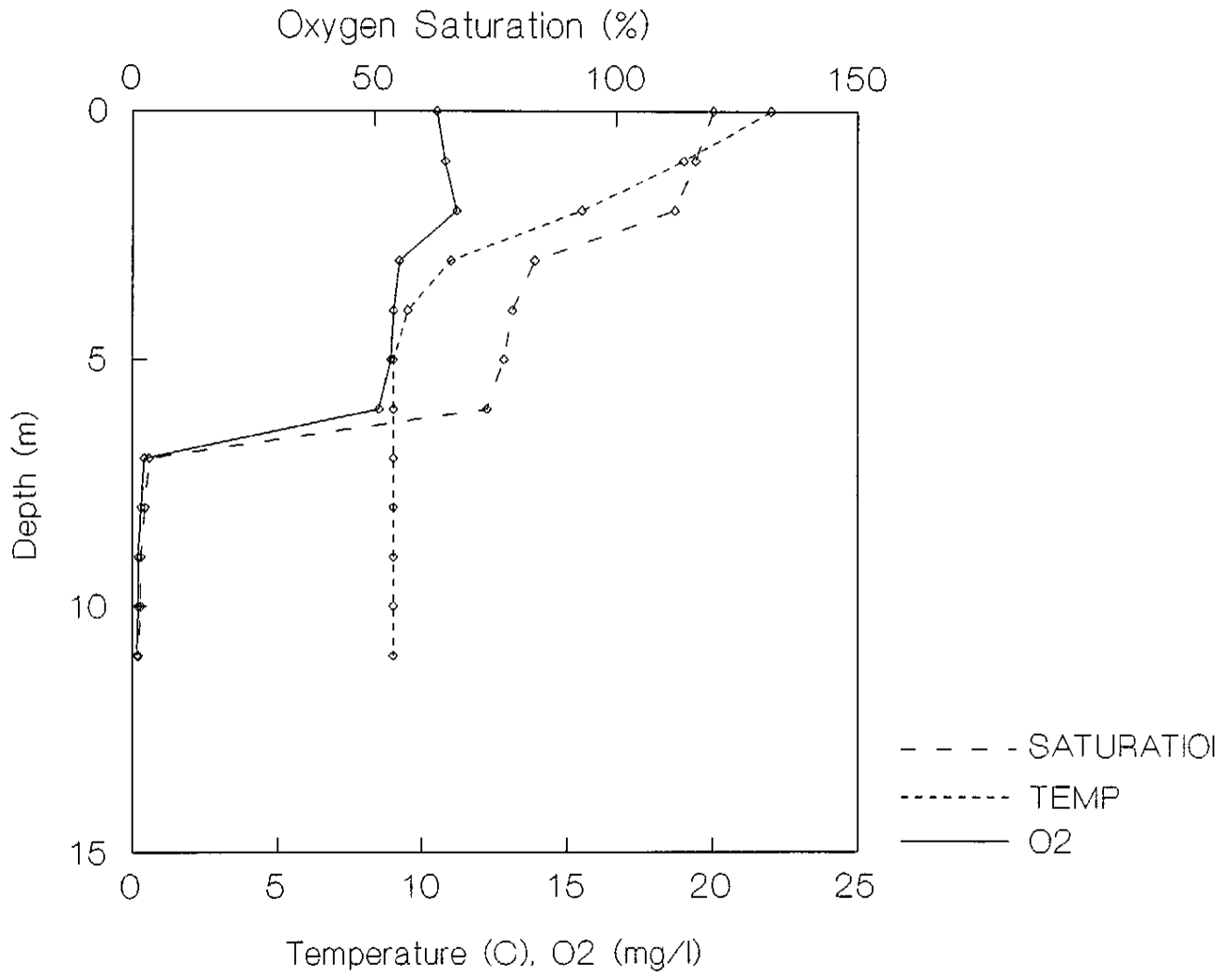
Fig. 20. Secchi Depth Ranges of Pleidae, Nepidae, Mesoveliidae, Belostomatidae, and Veliidae Families



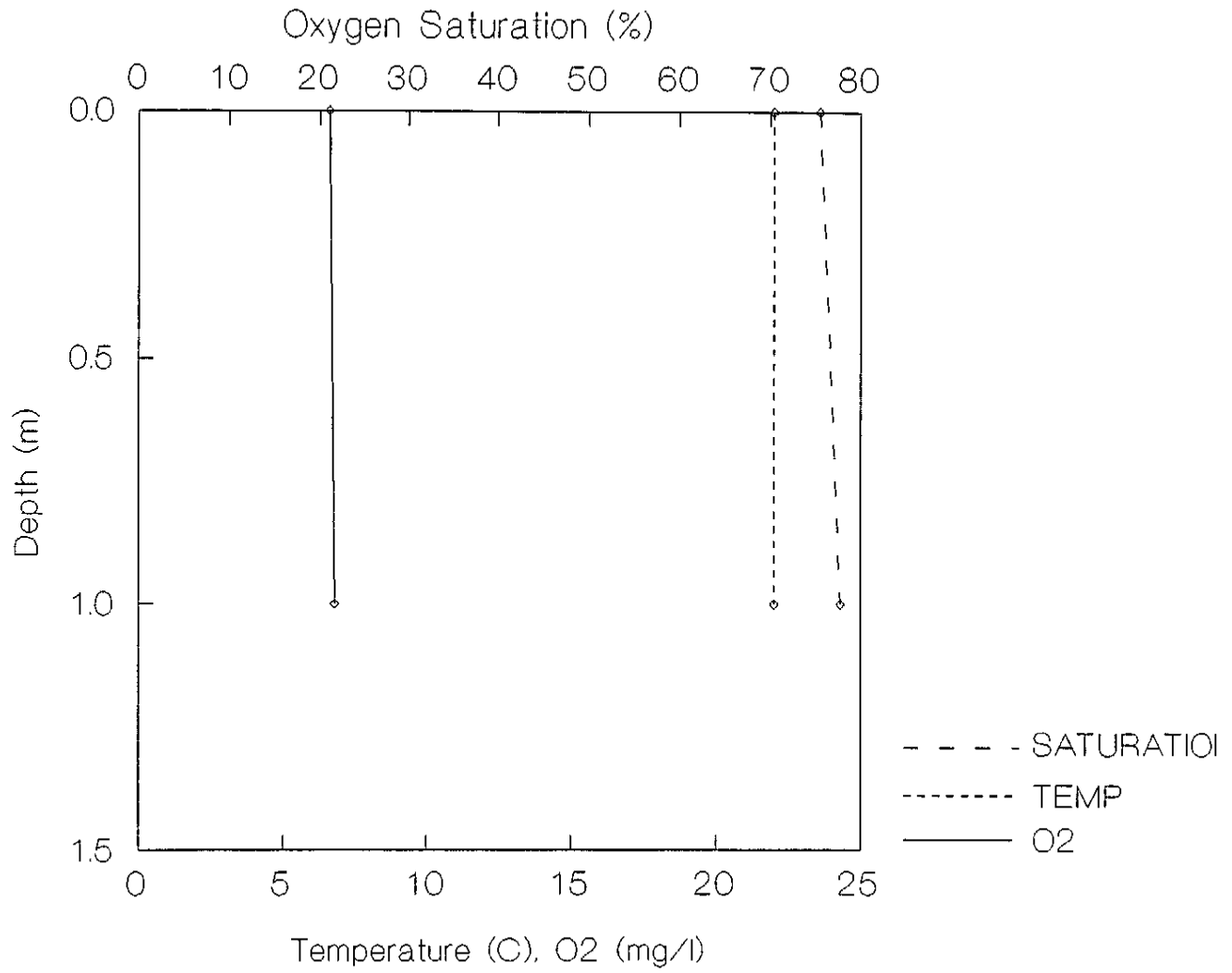
Appendix I. Oxygen/Temperature Profile of Bay Lake



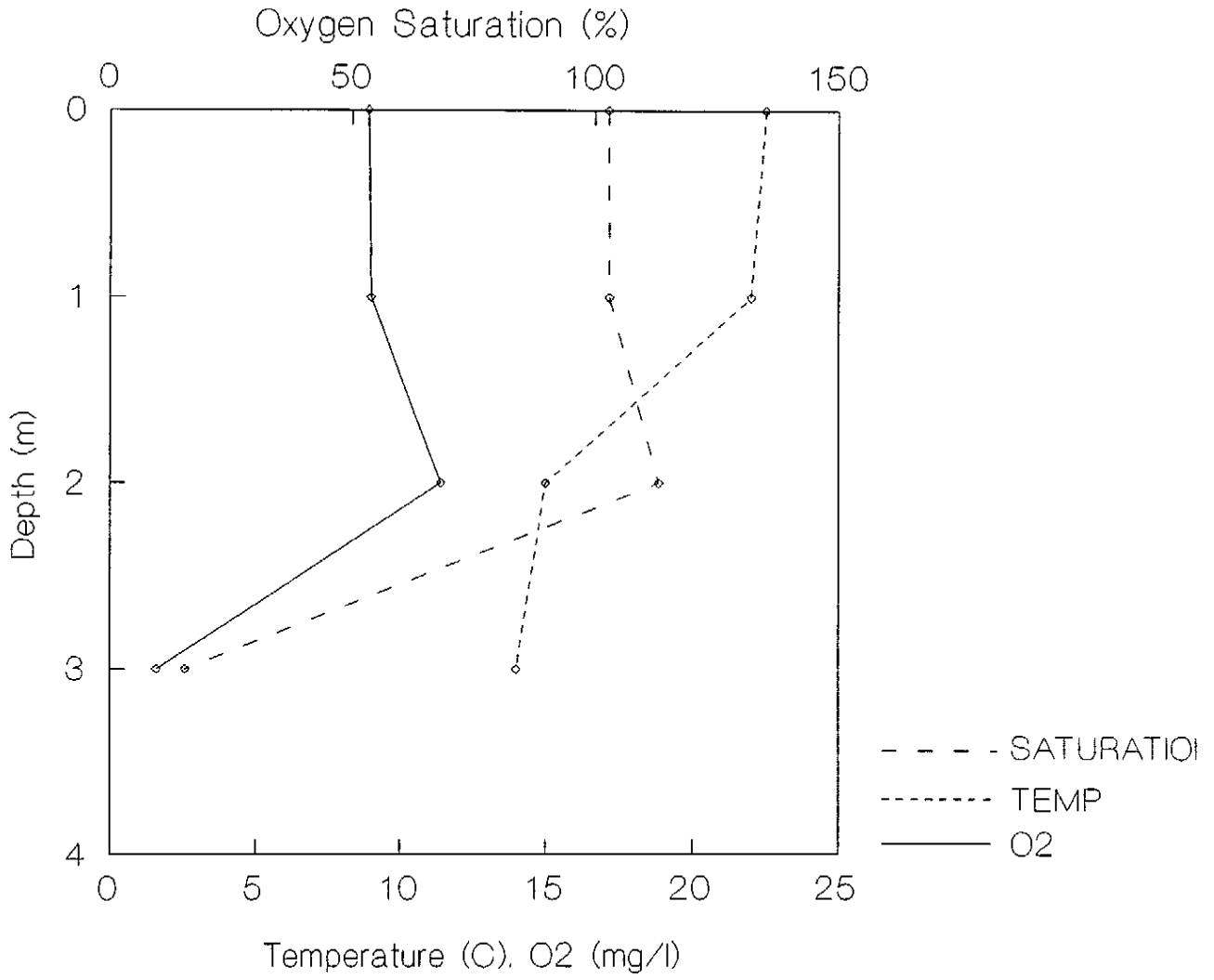
Appendix II. Oxygen/Temperature Profile of Bergner Lake



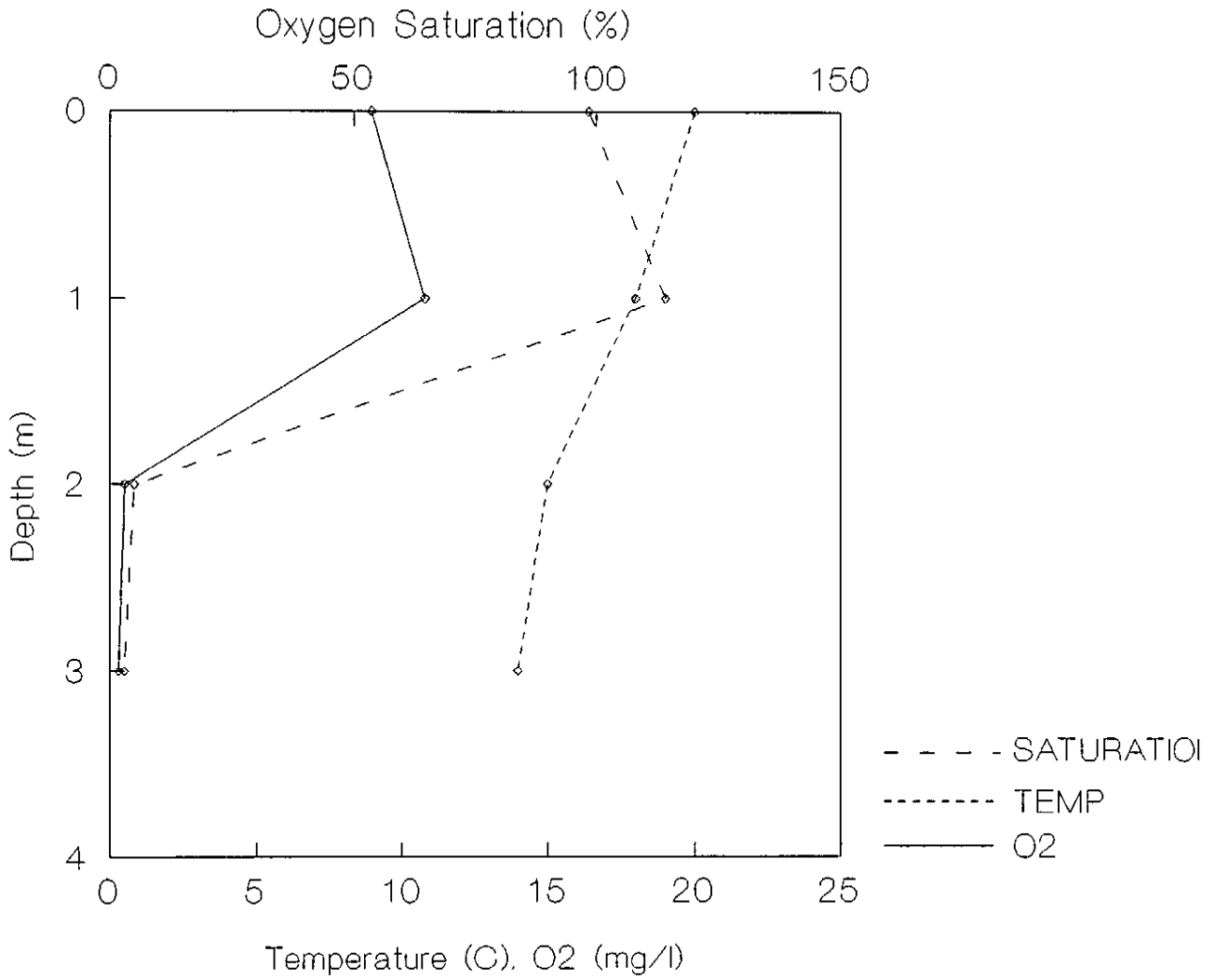
Appendix III. Oxygen/Temperature Profile of Brown Creek



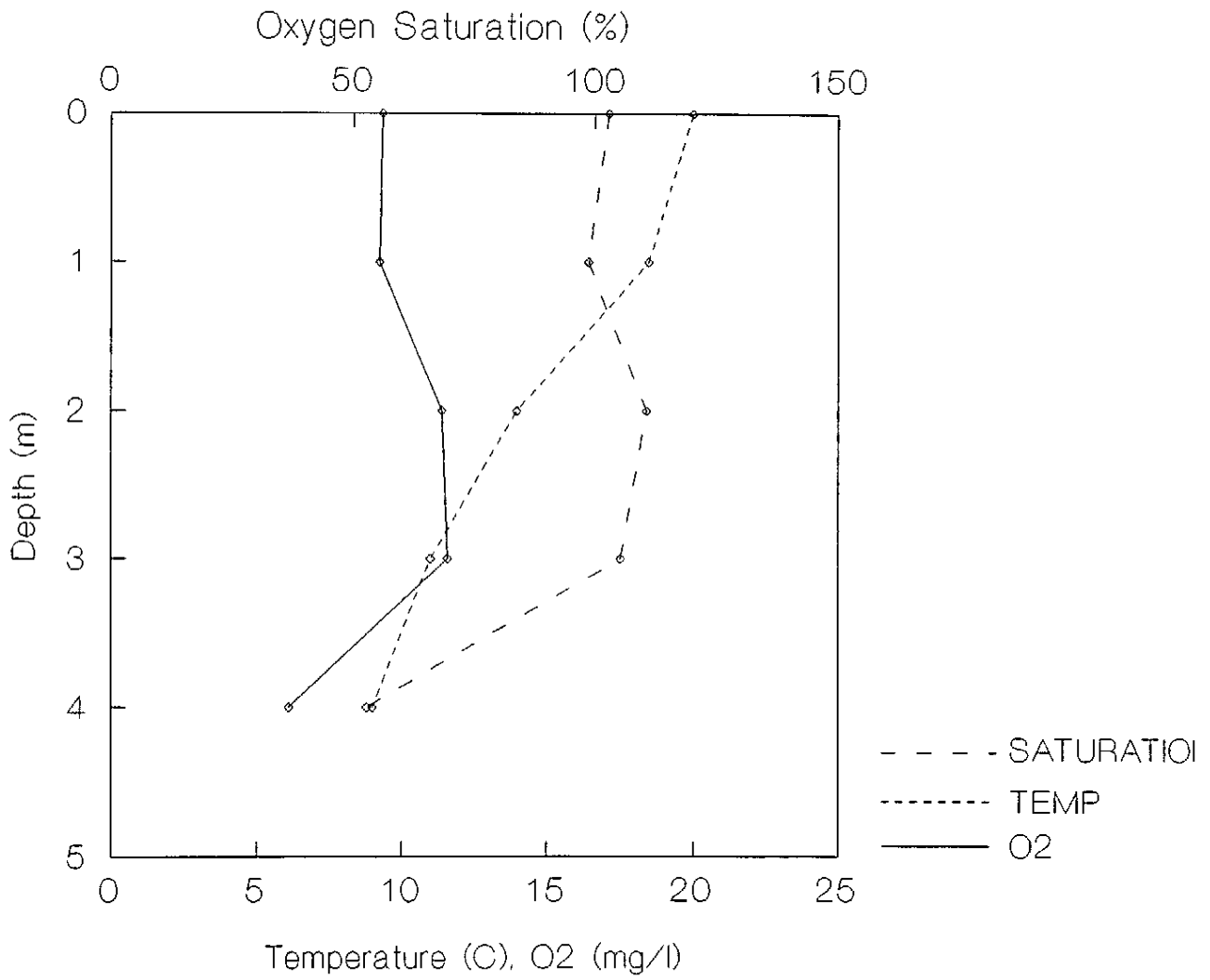
Appendix IV. Oxygen/Temperature Profile of Kickapoo Lake



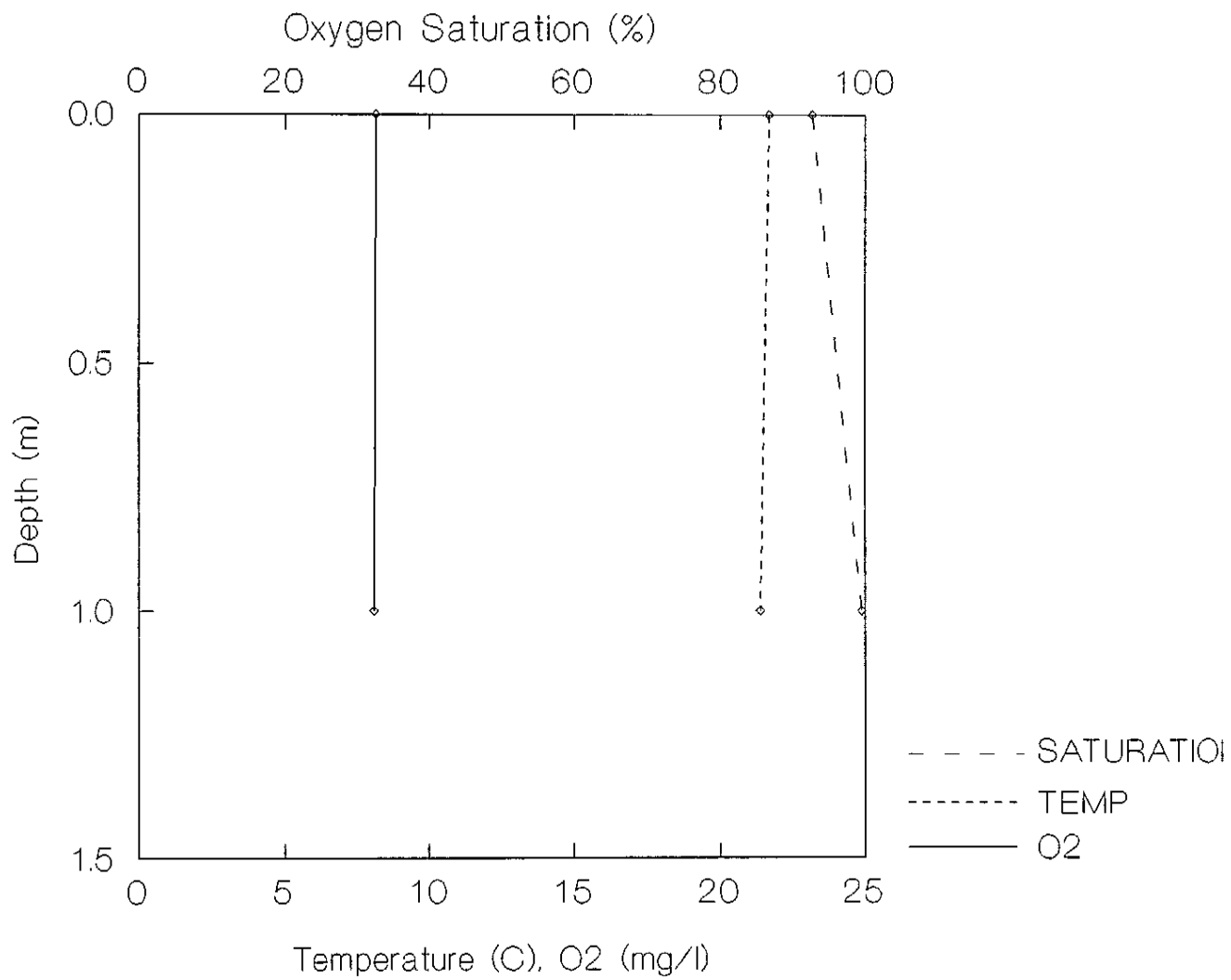
Appendix V. Oxygen/Temperature Profile of Mullahy Lake



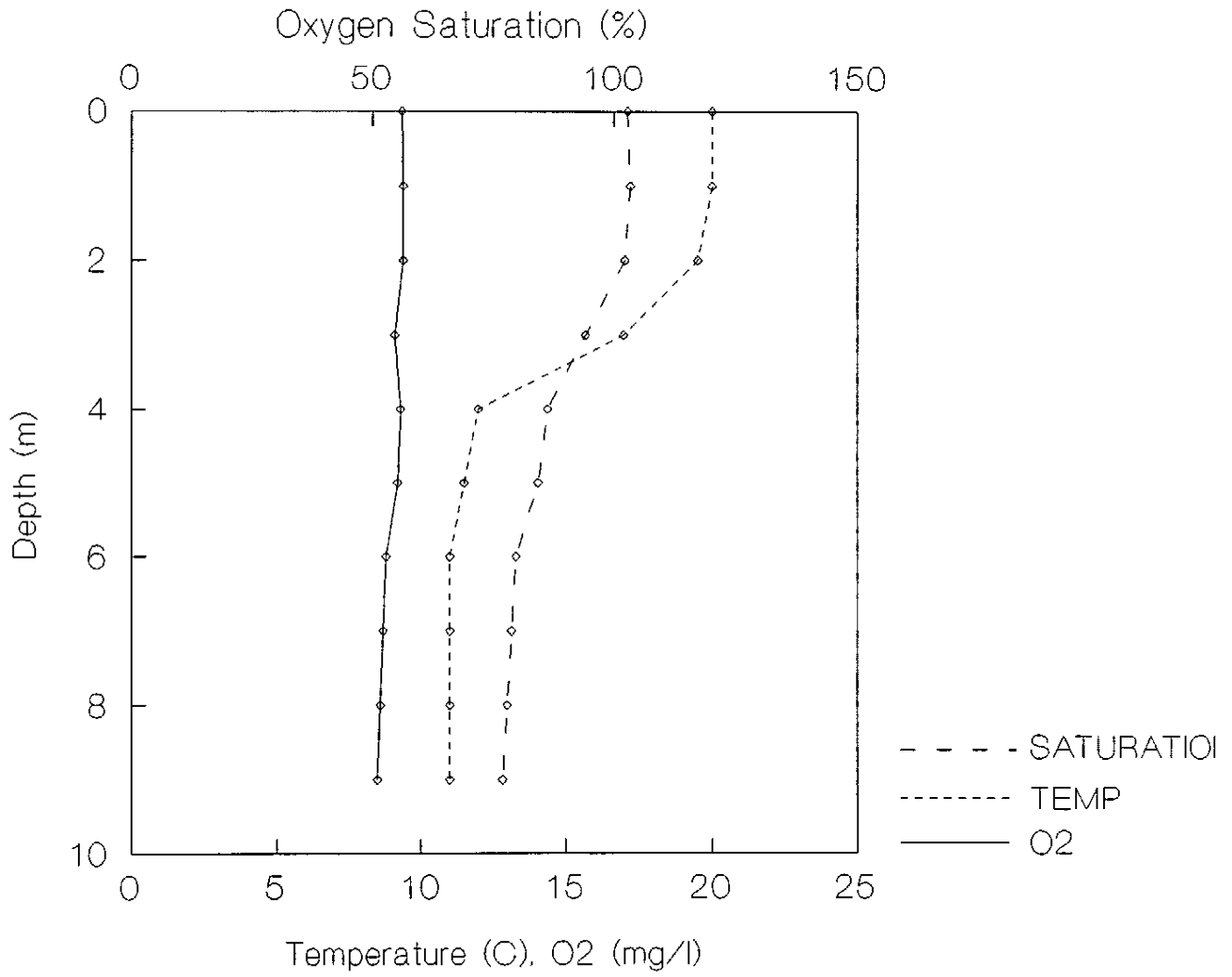
Appendix VI. Oxygen/Temperature Profile of Raspberry Lake



Appendix VII. Oxygen/Temperature Profile of Tenderfoot Creek



Appendix VIII. Oxygen/Temperature Profile of Tenderfoot Lake



Appendix IX. Combined 1996-1997 Species Totals

Fal Species	Bay	Ber	Bog	Bol	Brc	Brl	Crm	Crm	Ed	FS	Hum	Kie	Mar	Mul	Nan	NG	Ras	Red	TB	TCr	TLk	Tue	War	
Bell .instar			1	2					5	11														
Bell Leth. amer.																								
Cor .instar			3	2						5	3											7	19	2
Cor Call. alaskensis										1														
Cor Call. audeni										1														
Cor Hesp. atopodonta									1															
Cor Hesp. kennicotti									1															
Cor Hesp. michiganensis										1														
Cor Hesp. scabrucula																								
Cor Hesp. vulgaris										1														
Cor Palm. nana																								
Cor Sig. alternata										1	5													
Cor Sig. compressoides									2		10													
Cor Sig. conocephala										2														
Cor Sig. decorata																								
Cor Sig. dolcebra																								
Cor Sig. johnstoni																								
Cor Sig. knighti										2														
Cor Sig. mackinacensis										2														
Cor Sig. pennsylvanicus										1														
Cor Sig. transfigurata																								
Cor Sig. variabilis																								
Cor Tri. nalis																								
Ger G. .instar	18	20	6	4				37	1	4	2	6	2	3										15
Ger G. alacris				3																				
Ger G. argenticollis				2						9	4		1											
Ger G. buenoi				1		5				1	1	2	2	1	5	8	2	1	3					
Ger G. comatus	2		2	1	2				1			3	11	3	6	5								
Ger G. dissortis										3														
Ger G. inseparatus				1								1												
Ger G. marginatus			4	1				3	1			1												
Hyc Hydro. maritimi																								
Hyc Hydro. cryptophila																								
Met M. multisani	3	4	1	2						1	3		3		6	1								7
Nef Ranatra fusca			3	1	1				3	4	7		2											
Not N. .instar				3					8	12	15	1												
Not N. borealis										1														
Not N. insulata										1														
Not N. irrorationa																								
Not N. lunata				1							1		7	4										
Not N. undulata											1	4												
Plei Plea striola				16								1												
Vell M. buenoi																								
Vell M. pulchella												2												
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 (Crm), Ed's Bog (Ed), Forest Service Bog (FS), Hummingbird Lake (Hum), Kickapoo Lake (Kic), Morris Lake (Mor), Mullaly Lake (Mul), Nansen Lake (Nan), North Gale 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
Fai Species	NG	JB	Ed	Cm	Hum	FS	Bog	Ber	Cm	Tue	Red	Bel	Mor	Nan	Brc	Ras	Bay	Kic	TCr	Mul	War	TLk	Btl	
Bel. inslar	1	1	11	5			1			1	1	2	10								3	1		
Bel. leth amer.	1																							
Cor. inslar	2		5				3	3			19	3	2	17								2	2	7
Cor. Call. alaskensis			1								1													
Cor. Call. audeni			1																					
Cor. Hesp. atopodonta					1									1										1
Cor. Hesp. kennicotti																								
Cor. Hesp. michiganensis					1																			
Cor. Hesp. scabricula							2																	
Cor. Hesp. vulgaris			1																					
Cor. Palm. nana																								2
Cor. Sig. alternata			1				5	1																
Cor. Sig. compressoides	4	2			2		10			4														
Cor. Sig. conocephala			2																					
Cor. Sig. decorata						4		2																
Cor. Sig. dolobra			1																					
Cor. Sig. johnstoni								3																
Cor. Sig. knighti					2							3												
Cor. Sig. mackinacensis					2		1			7														
Cor. Sig. penthenis					1		1																	
Cor. Sig. transfigurata						13					1													1
Cor. Sig. variabilis																								
Cor. Tr. mais																							15	
Ger. G. .inslar	2	8	4	1	6	2	6	20	37	5	1	4	3	4	4	3	18	2					4	7
Ger. G. alacis		2										3												
Ger. G. argenticollis	7	6	9			4	2				4	2	1	8	5	1		2				5	5	3
Ger. G. buenoi	2		1		2	1	1			2	3	1	3	5	2		2	2				2	2	14
Ger. G. comatus					3		2				1	1	3	5	2		2	11	2		6	2	6	2
Ger. G. dissortis																								
Ger. G. inseparatus																								
Ger. G. marginatus						1	4	1				1	1											3
Hyd. Hydro. martini							1						1											
Met. M. cryptophila	1											2	3	1										
Met. M. mulsanti	1		1			3	1	4					3	1			3					6	7	14
Net. Fanatra fusca	3	2	4	3	8	1	7	3		2	1	1	2	1	1									1
Not. N. .inslar	30	26	12	8	1	15	36				2	3		1							2	3		
Not. N. borealis			1			1																		
Not. N. insulata				1																				
Not. N. irrorata																								
Not. N. lunata	1					1				1	1	1	4											2
Not. N. undulata			1			4																		
Plel. Plea sirioia	4				1							16	1											14
Vel. M. buenoi					1																			
Vel. M. pulchella	2	1						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	14.31	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	Be	Ras	Tue	Co	Bo	Co	Bay	Ed	Hum	Red	TB	Bo	Nan	NS	Kie	Mo	TLK	TCr	BFC	MUI	Ed	War	
Bel. instar				1	5	1			1		1	1	2		1		10					3		1
Bel. Leht. amer.				2																				1
Cor. instar				19		3			5		3		2		2		17		7					2
Cor. Call. alaskensis									1															
Cor. Call. audeni				1					1															
Cor. Hesp. atopodontia																								1
Cor. Hesp. kennicottii																								
Cor. Hesp. michiganensis																								
Cor. Hesp. scabricula																								
Cor. Hesp. vulgaris									1															
Cor. Palm. nana																								2
Cor. Sig. alternata						1			1															
Cor. Sig. compressoides				4	2							2			4									
Cor. Sig. conocephala																								
Cor. Sig. decorata						2					4													
Cor. Sig. dolobra									1															
Cor. Sig. johnstoni																								
Cor. Sig. knighti																								
Cor. Sig. mackinacensis				7	2						3													
Cor. Sig. pennsylvanicus																								
Cor. Sig. transfigurata											13													1
Cor. Sig. variabilis				1																				1
Cor. Tr. nais																								15
Ger. G. instar		2	20	3	5	1	6	37	18	4	6	1	8	4	4	2	3		7					4
Ger. G. alacris																								
Ger. G. argenticollis		4				2			9		4	2	3		7	1								
Ger. G. buenoi		1		1	2	1			1	2	3	6	2	8	2	2	1	3		5	5			5
Ger. G. cornutus					1	2			2	3	1	1	1	5	2	11	3	14	2	2	6			2
Ger. G. dissortis									2	3	1													
Ger. G. inseparatus													1											
Ger. G. marginatus		1				4	1				1		1				1							3
Hyd. Hydro. martini																								
Mei. M. cryptophila						1																		
Mei. M. musantoni		3	4			1			3	1			2	1	1		3	14			6			7
Net. Ranatra fusca		7				3							1		3	2	2							
Not. N. instar		15		2	3	3			4	12	1	2	3	1	30						1			3
Not. N. borealis		1							1															
Not. N. insulata						1																		
Not. N. irrorata																	2							
Not. N. lunata		1		1							1		1		1		7	4	1					2
Not. N. undulata		4							1						1									
Plei. Plea. striola											1		16		4									14
Vell. M. buenoi																								2
Vell. M. pulchella			14							2	3	1			2									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	0	0	0	1	1.5	2	3	3	5	10	10.5	12	27	33.5	36	38	38	39.5	47	50	58	
Fal Species	Bay	Ber	Com	NG	Ras	TP	Hum	Tue	Boj	Ed	FS	Com	Red	Nan	Boj	Mor	TLK	Mul	TCr	Kic	Brc	Brl	War					
Bel. instar			5	1		1		2		1	1	1	1															
Bel. Leht. amer.																												
Cor. instar											19	3	5	3														
Cor. Call. alaskensis																												
Cor. Call. audeni											1		1															
Cor. Hesp. atopodonta																												
Cor. Hesp. kennicottii																												
Cor. Hesp. michiganensis																												
Cor. Hesp. scabrícula																												
Cor. Hesp. vulgatis																												
Cor. Palm. nana																												
Cor. Sig. alternata																												
Cor. Sig. compressoides																												
Cor. Sig. conocephala																												
Cor. Sig. decorata																												
Cor. Sig. dolobra																												
Cor. Sig. johnstoni																												
Cor. Sig. knighti																												
Cor. Sig. mackinacensis																												
Cor. Sig. pennsylvanica																												
Cor. Sig. transfigurata																												
Cor. Sig. variabilis																												
Cor. Tr. nalis																												
Get. G. instar	18	20	1	2	3	8	6	5	6	4	2	37	1	4	4	3	7											
Get. G. alacris						2																						
Get. G. argenticollis						7			2	9	4		4		2	1												
Get. G. buenoi						2	1	2	1	1	1		3	8	1	3	5											
Get. G. conatus	2			1			3	2	2				1	5	1	3	14	6	2	11	2							
Get. G. dissortis																												
Get. G. inseparatus																												
Get. G. marginatus									4																			
Hyd. Hydro. martini																												
Met. M. cryptophylla																												
Met. M. multisani	3	4							1	1	3			1	2	3	14	6										
Nep. Fanatria fusca																												
Not. N. instar																												
Not. N. borealis																												
Not. N. insulata																												
Not. N. irrorata																												
Not. N. lunata																												
Not. N. undulata																												
Ple. Plea striata																												
Vell. M. buenoi																												
Vell. M. pulchella																												
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 (p/v/c)	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
Fal Species	Bay	Ras	TLk	Cm	RS	War	Tue	Ber	TCr	Kic	Brl	MUl	BRC	Cm	Ed	Nan	Bol	Bog	JB	Mor	Hum	Red	NS
Bell Instar						1	1					3		5	11		2	1	1	10		1	1
Bell Leth. amer.							2																
Cor Instar			7		3	2	19					2			5		2	3		17		3	2
Cor Call. alaskensis															1								
Cor Call. aldeni							1								1								
Cor Hesp. atopodonta											1			1									
Cor Hesp. kennicotti																					1		
Cor Hesp. michiganensis														1									
Cor Hesp. scabrifolia					2																		
Cor Hesp. vulgaris															1								
Cor Palm. nana			2																1				
Cor Sig. alternata					5										1								
Cor Sig. compressoides					10				4					2								2	4
Cor Sig. conocephala															2								
Cor Sig. decorata																		2					
Cor Sig. dolobrata															1								
Cor Sig. johnstoni																		3					
Cor Sig. knighti														2									3
Cor Sig. mackinacensis						1	7							2									
Cor Sig. penninensis						1								1									
Cor Sig. transfigurata											1										10	13	
Cor Sig. variabilis									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																							
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		1	2	3	2
Ger G. comatus	2		14			2				2	2	6	2	1		5	1	2		3	3	1	
Ger G. dissortis		2													3								
Ger G. inseparatus																	1						
Ger G. marginatus					1						3						1	4		1	1		
Hyd Hydro. martini																							
Met M. cryptophila																							
Met M. mulsanti	3		14		3	7		4				6			1	1	2	1		3			1
Neg Ranatra fusca			1		7		2			2				3	4		1	3	2		2		3
Noil N. instar					15	3						2		8	12	1	3	36	26		1	2	30
Noil N. borealis					1										1								
Noil N. insulata														1									
Noil N. irrorata										2													
Noil N. lunata			1		1		1			7	2						1			4		1	
Noil N. undulata					4										1								1
Plei Plea. strifolia						2					14						16				1		4
Vel M. buenoi														1									
Vel M. pulchella			8			16		14				1							1				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	Feb	Hum	MG	Bog	Mor	Bof	Cm	Brl	Ed	Nan	TB	Mul	Kic	Tue	FS	Ber	War	Ras	TLK	Crm	Bay	B/C	T/Cr
Bel. instar	1		1	1	10	2	5		11		1	3		1									
Bel. Leht. amer.			1											2									
Cor. instar	3		2	3	17	2			5			2		19	3					7			
Cor. Call. alaskensis									1														
Cor. Call. audeni									1					1									
Cor. Hesp. atopodonta									1														
Cor. Hesp. kennicotti					1																		
Cor. Hesp. michiganensis										1													
Cor. Hesp. scabrifolia															2								
Cor. Hesp. vulgaris										1													
Cor. Palm. nana																							
Cor. Sig. alternata				1					1						5					2			
Cor. Sig. compressoidea			4											4	10								
Cor. Sig. conocephala									2														
Cor. Sig. decorata			4	2																			
Cor. Sig. dolobra									1														
Cor. Sig. johnstoni					3																		
Cor. Sig. knighti	3								2														
Cor. Sig. mackrhaensis									2														
Cor. Sig. pennsylvanicus										1													
Cor. Sig. transfigurata		13									1												
Cor. Sig. variabilis																							
Cor. Tri. natis																							
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	2	1	2			9	6					4								
Ger. G. buenoi	3	2	2	1	1				1	8		5	2	2	1					3			
Ger. G. comatus	1	3		2	3	1	1	2		5	6	11								14		2	2
Ger. G. dissortis									3														
Ger. G. inseparatus						1																	
Ger. G. marginatus			1	4	1	1		3							1								
Hyd. Hydro. martini				1	1																		
Met. M. cryptophila			1																				
Met. M. mulsanti			1	1	3	2			1	1	6												
Nep. Ranatra fusca	1	3	3	3	2	1	3		4	2					3	4	7						
Not. N. instar	2	1	30	36		3	8		12	1	26	2		2	15								
Not. N. borealis									1						1								
Not. N. insulata							1																
Not. N. irrorationa													2										
Not. N. lunata	1				4	1		2					7	1	1								
Not. N. undulata			1						1						4								
Plel. Plea stiroia			4			1	16	14															
Vell. M. buenoi							1																
Vell. M. pulchella	3	2	2								1					14	16						
total Hemiptera	23	34	61	66	58	39	24	23	59	19	48	25	26	45	61	38	58	5	57	38	25		
total species	11	10	14	14	14	13	13	6	17	5	8	7	6	11	16	3	11	3	9	2	4		

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	7.5	9.14	12	13.7	15	15.3	16	19	
Fa Species		Mul	Bog	Kic	Nan	Bof	FS	BL	MG	Ras	Mor	Ed	Hum	War	Cm	TLK	Ber	Bay	TB	Cm	Red	Tue	Brc	TCR
Bel Leith. amer.		3	1			2			1		10	11		1	5					1		1	1	
Cor Instar		2	3			2	3		2		17	5		2		7						3	19	
Cor Call. alaskensis												1											1	
Cor Call. audeni												1												
Cor Hesp. atopodontia								1							1									
Cor Hesp. kennicotti											1													
Cor Hesp. michiganensis																								
Cor Hesp. scabrifolia							2					1												
Cor Hesp. vulgaris												1												
Cor Palm. nana																								
Cor Sig. alternata			1				5					1												
Cor Sig. compressoides							10		4														2	
Cor Sig. conocephala												2				4								
Cor Sig. decorata			2												1									
Cor Sig. dolobrea																								
Cor Sig. johnstoni			3																					
Cor Sig. knighti																								
Cor Sig. mackinacensis																								
Cor Sig. pennsylvanicus								1																7
Cor Sig. transfigurata									1		10		13											
Cor Sig. variabilis																								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			7		1	9		5					2			4		
Ger G. argenticollis			2			2	4		2		1	1	2	5		3			6			3	2	5
Ger G. buenoi		5	1	2	8		1		2	1	1	1	3	2	1	14			2			1		2
Ger G. comatus		6	2	11	5	1		2			3		3	2	1	14			2					2
Ger G. dissortis												3	1											
Ger G. inseparatus						1																		
Ger G. marginatus			4			1	1	3			1		1											1
Hyd Hydro. martini			1								1													
Met M. cryptophylla									1															
Met M. mulsanti		6	1		1	2	3		1	3	3	1		7		14	4	3						
Nep Ranatra fusca			3	2		1	7		3		2	4			3	1			2			1		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						1	1	2		4	4	1				1						1		1
Not N. undulata						16		14	4	1	1	1												
Plef Plea strobila													1	2										
Vel M. buenoi															2	16								1
Vel M. pulchella		1														8	14							
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											1		3		

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		
Species	TP	ET	FS	NG	Hum	Tue	Bof	Mul	Red	Cm	Bog	War	Nan	Ras	Mor	Kic	Bar	Cm	Bt	Bay	TLK	BRC	TCR
Bel. inslar	1	11																					
Bel. Leth. amer.				1		2	2	3	1	5	1	1			10								
Cor. inslar		5	3	2		19	2	2	3		3	2			17								7
Cor. Call. alaskensis		1																					
Cor. Call. audeni		1								1													1
Cor. Hesp. atopodonta																							
Cor. Hesp. kennicotti																							
Cor. Hesp. michiganensis										1													
Cor. Hesp. scabricula			2																				
Cor. Hesp. vulgata		1																					
Cor. Palm. nana																							2
Cor. Sig. alternata		1	5								1												
Cor. Sig. compressoidea	2		10	4						2													
Cor. Sig. conocephala		2																					
Cor. Sig. decorata					4						2												
Cor. Sig. dolioebra		1									3												
Cor. Sig. johnstoni									3	2													
Cor. Sig. knighti																							
Cor. Sig. mackinacensis			1			7				2													
Cor. Sig. penninensis			1							1													
Cor. Sig. transfigurata								13							10								1
Cor. Sig. variabilis							1																
Cor. Tri. nais												15											
Ger. G. inslar	8	4	2	2	6	5	4	4	1	1	6	4	4	3	3	2	20	37			18		7
Ger. G. alacis	2						3				2												
Ger. G. argenteoollis	6	9	4	7			2		4		2				1								
Ger. G. buenoi		1	1	2	2	2	5	3	1	1	1	5	8	1	1	2							3
Ger. G. comatus					3		1	6	1	1	2	2	5		3	11							2
Ger. G. dissortis		3																					2
Ger. G. inseparatus							1				4												3
Ger. G. marginatus			1																				1
Hyd Hydro. marini											1												
Met M. cryptophila				1																			
Met M. muisenii		1	3	1			2	6			1	7	1		3		4						3
Nep Ranatra fusca	2	4	7	3		2	1	1	1	3	3	3			2	2							1
Nol N. inslar	26	12	15	30			3	2	2	8	36	3	1										
Nol N. borealis		1	1																				
Nol N. insulata										1													
Nol N. irrorata																2							
Nol N. lunata		1	1			1	1		1						4	7							1
Nol N. undulata		1	4	1										1									
Plel Plea striola				4		1	16					2											14
Vei M. buenoi										1													
Vei M. pulchella	1			2	2			1	3			16											8
Total Hemiptera	48	59	61	61	34	45	39	25	23	24	66	58	19	5	58	26	38	38	23	25	25	57	8
total species	8	17	16	14	10	11	13	7	11	13	14	11	5	3	14	6	3	2	6	4	4	9	3

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	1.21	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		
Fal Species	Tie	War	MG	Ref	Mor	Ras	Ed	B/L	Hum	Bol	Nan	Cm	Kic	TB	Ber	Cm	Mul	Bog	TLK	FS	Bay	Brc	TCr	
Bell. instar amer.	1	1	1	1	1	10	11				2													
Cor. instar	19	2	2	3	17		5				2													
Cor. Call. alaskensis							1																	
Cor. Call. audeni	1						1																	
Cor. Hesp. atopodontia								1																
Cor. Hesp. kennicottii					1																			
Cor. Hesp. michiganensis																								
Cor. Hesp. scabricula								1																
Cor. Hesp. vulgaris																								
Cor. Palm. nana																								
Cor. Sig. alternata							1																	
Cor. Sig. compressoides	4		4																					
Cor. Sig. conocephala							2																	
Cor. Sig. decorata									4															
Cor. Sig. dolobëbra							1																	
Cor. Sig. johnstoni																								
Cor. Sig. knighti					3																			
Cor. Sig. mackinacensis	7																							
Cor. Sig. pennsylvanicus																								
Cor. Sig. transfigurata						10			1	13														
Cor. Sig. variabilis	1																							
Cor. Tri. nais		15																						
Ger. G. instar	5	4	2	1	3	3	4		6	4	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		3		3	1	5	1	11						6	2	14	2	2	
Ger. G. dissortis							3		1															
Ger. G. inseparatus										1														
Ger. G. marginatus					1				3	1	1								4			1		
Hyd. Hydro. martini						1																		
Met. M. crypophila				1																				
Met. M. multiselli		7	1	1	3		1			2	1				4					14	3	3		
Neq. Ranatra tusca	2		3	1	2		4			1	1	3	2	2										
Not. N. instar		3	30	2			12		1	3	1	8	26											
Not. N. borealis							1																	
Not. N. insulata												1	2											
Not. N. irrorata													7											
Not. N. lunata	1			1	4			2		1											1	1		
Not. N. undulata			1				1															4		
Plel. Plea striola		2	4			1		14	1	16														
Vel. M. buenoi													1											
Vel. M. pulchella		16	2	3					2						1	14								
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 XIX. 1996-1997 Species Totals: Lakes Ranked by Abundance

Fa Species	TCr	Ras	B/C	Nan	Brl	Ped	Cm	Bay	Mul	Kic	Hum	Ber	Cm	Bol	Tue	Th	TLK	Mor	War	Ed	FS	MG	Bog	
Bel Instar						1	5		3					2	1	1		10	1	1	11		1	1
Bel Leth. amer.															2	2				1				
Col. instar						3			2					2	19		7	17	2	5	3	2	3	3
Col Call. alaskensis																								
Col Call. audeni															1						1			
Col Hesp. atopodonta					1															1				
Col Hesp. kennicottii																								
Col Hesp. michiganensis											1													
Col Hesp. scabridula																								
Col Hesp. vulgatus																								
Col Palm. nana																								
Col Sig. alternata																								
Col Sig. compressoides													2								1	5	1	1
Col Sig. conocephala																					2			
Col Sig. decorata											4													
Col Sig. dolobea																								
Col Sig. johnstoni																								
Col Sig. knighti													3											
Col Sig. mackinacensis													2											
Col Sig. pennsylvanicus																								
Col Sig. transfigurata																								
Col Sig. variabilis																								
Col Trl. natis																								
Getl G. instar		3		4		1	1	18		2	6	20	37	4	5	8	7	3	4	4	4	2	2	6
Getl G. alacris																								
Getl G. argenticollis																								
Getl G. buenoi		1		5	8	3			5	2	2			2	2	6	3	1	5	1	9	4	7	2
Getl G. cornutus		2		2	5	1	1	2	6	11	3			1	2		14	3	2	3	1	1	2	1
Getl G. dissortis											1													
Getl G. inseparatus														1										
Getl G. marginatus											1			1										
Hyd Hydro. martini																								
Metl M. cryptophila																								
Metl M. mulsanti					1			3	6			4		2			14	3	7	1	3	1	1	1
Notl Ranatra fusca					1					2				1	2									
Notl N. instar									2		1			3										
Notl N. borealis																								
Notl N. insulata											1													
Notl N. irrorata																								
Notl N. lunata										2				1	1									
Notl N. lunata										7				1	1									
Notl N. undulata																								
Plel Plea striola											1			16										
Veil M. buenoi																								
Veil M. pulchella																								
total Hemiptera	2	5	8	19	23	23	24	25	25	26	34	38	38	39	45	48	57	58	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	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	B/L	Kic	Mul	TB	TLK	Hum	Red	Tue	War	Cm	Bol	Mor	NG	Bog	FS	Ed
Bell. instar																							
Bell. Leih. amer.										3	1			1	2	1							
Cor. instar										2		7		3	19	2							
Cor. Call. alaskensis																							
Cor. Call. audeni															1								
Cor. Hesp. atopodonta										1													
Cor. Hesp. kennicotti																							
Cor. Hesp. michiganensis																							
Cor. Hesp. scabricula																							
Cor. Hesp. vulgaris																							
Cor. Palm. nana												2											
Cor. Sig. alternata																							
Cor. Sig. compressoides											2												
Cor. Sig. conocephala																							
Cor. Sig. decorata													4										
Cor. Sig. dolcebra																							
Cor. Sig. johnstoni																							
Cor. Sig. knighti														3									
Cor. Sig. meckinacensis															7								
Cor. Sig. pennsylvanicus																							
Cor. Sig. transfigurata										1			13										
Cor. Sig. variabilis															1								
Col. Tri. nans																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. alaberis											2			4				3	1	7	2	4	9
Ger. G. argenticollis											6							2	1	7	2	4	9
Ger. G. buenoi			1		5		8		2	5		3	2	3	2	5		1	1	2	1	1	1
Ger. G. comatus		2			2	2	5	2	11	6		14	3	1		2	1	1	3	1	3	2	3
Ger. G. dissortis						2							1										3
Ger. G. inseparatus																		1	1				
Ger. G. marginatus			1					3					1					1	1			4	1
Hye Hydro. marini																							
Mei. M. cryptophylla																						1	
Mei. M. mulisanti					4	3	1			6		14				7		2	3	1	1	3	1
Nep. Ranatra fusca				1					2		2	1		1	2	3	3	1	2	3	3	7	4
Not. N. instar																							
Not. N. borealis										2	26		1	2		3	8	3		30	36	15	12
Not. N. insularis																	1						1
Not. N. irrorata										2													
Not. N. lunata								2	7					1	1					4		1	1
Not. N. undulata				1																			4
Plel. Plea striola								14					1			2		16	1	4			1
Veil. M. buenoi										1			2	3		16							
Veil. M. pulchella																	1						
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

Acknowledgements

I would like to thank the Bernard J. Hank Family for the funding which made this project possible. For the assistance of his knowledge, guidance, and patience I would like to thank Dr. Ronald Hellenthal. Thanks to Jeff Runde for his help with last-minute repairs and backwoods rescues. For water chemistry instruction and pack-mule services I would like to thank Noah Gray. Finally I would like to thank my partners Christie Brown, Hollis Janowak, and Amy Zulich for their ceaseless energy, patience, and assistance.

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 of 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. Ottawa.
- 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.