REGIONAL COPPER-NICKEL STUDY

BENTHIC INVERTEBRATES OF LAKES

MEQB Regional Copper-Nickel Study

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ABSTRACT

A study of the benthic invertebrates in lakes of the Regional Copper-Nickel Study Area (Study Area) was conducted in 1976 and 1977. Quantitative and qualitative samples were collected in order to describe the benthic invertebrate communities in the littoral and profundal zones of Study Area lakes. Profundal zone densities ranged from 129 organisms/m^2 to 3869 organisms/m^2. The dominant taxa collected in the profundal zone were Chaoborus spp., Hexagenia limbata, Procadius spp., and Chironomus spp. Four types of lakes were found based on invertebrate associations: Chaoborus/Hexagenia limbata/Procladius; Chaoborus/Procladius; Chaoborus; Chironomus. Little difference was noted in transect sampling across the profundal zone; many more taxa were collected in the littoral zone than in the profundal zone. Bivalve populations were found throughout the Study Area.

Lakes within the Study Area were found to be similar to other lakes in the upper midwest and Canada.

INTRODUCTION TO THE REGIONAL COPPER-NICKEL STUDY

The Regional Copper-Nickel Environmental Impact Study is a comprehensive examination of the potential cumulative environmental, social, and economic impacts of copper-nickel mineral development in northeastern Minnesota. This study is being conducted for the Minnesota Legislature and state Executive Branch agencies, under the direction of the Minnesota Environmental Quality Board (MEQB) and with the funding, review, and concurrence of the Legislative Commission on Minnesota Resources.

A region along the surface contact of the Duluth Complex in St. Louis and Lake counties in northeastern Minnesota contains a major domestic resource of copper-nickel sulfide mineralization. This region has been explored by several mineral resource development companies for more than twenty years, and recently two firms, AMAX and International Nickel Company, have considered commercial operations. These exploration and mine planning activities indicate the potential establishment of a new mining and processing industry in Minnesota. In addition, these activities indicate the need for a comprehensive environmental, social, and economic analysis by the state in order to consider the cumulative regional implications of this new industry and to provide adequate information for future state policy review and development. In January, 1976, the MEQB organized and initiated the Regional Copper-Nickel Study.

The major objectives of the Regional Copper-Nickel Study are: 1) to characterize the region in its pre-copper-nickel development state; 2) to identify and describe the probable technologies which may be used to exploit the mineral resource and to convert it into salable commodities; 3) to identify and assess the impacts of primary copper-nickel development and secondary regional growth; 4) to conceptualize alternative degrees of regional copper-nickel development; and 5) to assess the cumulative environmental, social, and economic impacts of such hypothetical developments. The Regional Study is a scientific information gathering and analysis effort and will not present subjective social judgements on whether, where, when, or how copper-nickel development should or should not proceed. In addition, the Study will not make or propose state policy pertaining to copper-nickel development.

The Minnesota Environmental Quality Board is a state agency responsible for the implementation of the Minnesota Environmental Policy Act and promotes cooperation between state agencies on environmental matters. The Regional Copper-Nickel Study is an ad hoc effort of the MEQB and future regulatory and site specific environmental impact studies will most likely be the responsibility of the Minnesota Department of Natural Resources and the Minnesota Pollution Control Agency.

PURPOSE

This regional characterization is intended to describe the dominant taxa of the region and their relationships, as well as the similarities and differences between the sites sampled. It provides a basis for assessing the potential impacts of copper-nickel development. It does not, in general, provide the baseline data necessary to detect impacts of development at particular sites. Techniques for developing such a baseline and ways in which these data might be used in planning a baseline monitoring program are discussed in a separate report, Biological Monitoring of Aquatic Ecosystems (Regional Copper-Nickel Study 1978).

INTRODUCTION

Two distinct zones are present along the bottom profiles of lakes. These zones are the littoral (the zone which supports benthic vegetation), and the profundal, (area with no benthic primary producers). Distinct groups of benthic invertebrates inhabit the littoral and profundal zones (Brinkhurst 1974), colonizing the substrate and aquatic vegetation. Other invertebrates such as Chaoborus spp. can be found migrating between the profundal substrates and the hypolimnion (Hilsenhoff and Narf 1968).

The benthic invertebrate fauna is generally more diverse in the littoral zone than in the profundal zone. The differences in density of organisms are not consistent between the two zones. Within the profundal zone there is a general decrease in abundance with increasing depth (Brinkhurst 1974).

Benthic invertebrate species have specific physical-chemical requirements and because of this have been used to indicate lake types (Brinkhurst 1974). These lake classification systems generally deal with indicator species of organic pollution and/or lake productivity. The size of the benthic invertebrate population also provides information on the relative productivity of lakes. Benthic invertebrate larvae and adults serve as a major food source for forage and young-of-the-year game fish (Scott and Crossman 1973, Pope et al. 1973) therefore, benthic invertebrate populations can provide information on the potential for fish production.

Because of the importance of benthic invertebrates in the lake ecosystem and the information they can provide on lakes, a survey of the benthic invertebrates of the Regional Copper-Nickel Study Area (Study Area) was initiated in May, 1976. This survey was designed to provide basic information on the dominant species of benthic invertebrate, their relative abundance and distribution within the Study Area. By relating these biological parameters to physical-chemical conditions, it is possible to generally describe lakes in which no sampling was done. This characterization then provides a basis for the prediction of impacts on lake ecosystems in the Study Area.

METHODS

Study Area

The Study Area encompasses 2130 sq mi of Lake and St. Louis counties in northeastern Minnesota (Figure 1). This area is divided into two major watersheds by the Laurentian Divide. Water north of this divide flows to Hudson Bay while water south of this divide flows to Lake Superior. Lakes within the Study Area range from shallow and bog-stained to deep and clear. The deep-clear lakes are generally located along the northern boundaries of the Study Area.

Study Lakes

In 1976 five lakes were selected for quantitative and qualitative sampling (Figure 1 and Table 1). These lakes were selected on the basis of potential for impacts. One lake with high potential for impact and one lake with low potential for impact was chosen from both north and south of the Laurentian Divide. In addition, Birch Lake was chosen as a primary lake because of its high potential for impact and its importance in the Study Area. A further criteria for these lakes was that their ecological classification by the Minnesota Department of Natural Resources (MDNR) was to be similar.

Two quantitative and two qualitative stations were located in each lake except for Birch Lake where four stations were sampled. Quanlitative stations were located along the shoreline in the littoral zone.

In 1977 seven lakes were sampled quantitatively (Table 1). These lakes were chosen because they represented a wider range of lake types. A further criteria in selection was their accessibility by boat. Single stations were located in the profundal zone of each lake except Birch Lake where two stations (LB-1 and LB-3) were sampled. In addition, to examine the relationship of depth to the distribution of profundal organisms, two transects of five stations each were sampled across White Iron Lake using the 1976 station locations as center points. No qualitative stations were sampled in 1977.

Field Procedures

Lake benthic invertebrates were sampled quantitatively with a Petite Ponar dredge (15.6 X 15.6 cm). Three replicates per site were collected in 1976 and two per site in 1977. Samples were sieved through a No. 40 U.S. Standard Sieve and preserved in ten percent formalin in the field. Qualitative samples were collected from all substrates at each site with aquatic insect nets and by hand for two man-hours and preserved in ten percent formalin. Collections of mussels (Pelecypoda) were made by SCUBA in deeper areas in and adjacent to qualitative sampling sites. Detailed field procedures can be found in another report (Regional Copper-Nickel Study 1977).

Laboratory Methods

Samples were sieved to remove the formalin, and organisms were sorted from the debris and represerved in 70 percent alcohol before identification. When possible, insects were identified to genus and species; other invertebrates were identified to the class or family level. The groups of invertebrates considered in this study are listed in Table 2. Detailed laboratory procedures can be found in another report (Regional Copper-Nickel Study 1977).

Sampling Frequency

Quantitative and qualitative samples were collected in May and October, 1976, while in 1977 quantitative samples were collected in May. Sampling months were selected based on data presented by Shults et al. (1976) for Shagawa Lake, which is located in the Study Area. They reported maximum benthic invertebrate densities in May and October.

RESULTS AND DISCUSSION

Density of Benthic Invertebrates

The density of benthic organisms in the lakes of the Study Area was generally low, ranging from $129/m^2$ in Tofte Lake (May, 1977) to $3869/m^2$ in Colby Lake (May, 1976)(Table 3).

Dominant Profundal Taxa

Table 4 and Figures 2 and 3 present data on the relative abundance of the four most abundant taxa collected from Study Area lakes. The most abundant organisms found in quantitative samples were *Chaoborus* spp., *Hexagenia limbata*, Procladius spp., and Chironomus spp. These taxa comprised 89 and 87 percent of all individuals collected in 1976 and 1977, respectively. Chaoborus spp. was the most abundant and widespread invertebrate found in the area and constituted 23 to 91 percent of the fauna in lakes where it was collected. Tofte Lake was the only lake where Chaoborus spp. was absent. Procladius spp., the second most abundant organism collected, was found in all lakes except Tofte and Wynne, and, when present, accounted for 1 to 38 percent of all individuals. Hexagenia limbata was collected in 6 of the 10 lakes, comprising up to 54 percent of the individuals at a station; however, it was not found at all stations in those lakes where it was collected. Chironomus spp. also appeared in six lakes and ranged from 1 percent of the organisms in Colby and Birch lakes to 100 percent in Tofte Lake. The mean numbers of organisms per m^2 for all taxa collected in 1976 and 1977 quantitative samples are presented in Appendix A, Tables 1 and 2, respectively.

Comparison of Lakes on the Basis of Dominant Profundal Taxa

Figure 4 demonstrates the differences between lakes based on the average percent abundance for the four dominant taxa. Six of the lakes (Colby, White Iron, Birch, White Iron, and Greenwood) are characterized by large numbers of Chaoborus spp. and the presence of Procladius spp. and Hexagenia limbata These lakes all have fine silt substrates. Two lakes (Seven Beaver and Bear Island) are characterized by abundant Chaoborus spp. and the presence of Procladius spp., but lack Hexagenia limbata. These two lakes have substrates containing coarse detritus, a habitat which does not support Hexagenia limbata (Fremling 1970). Wynne Lake has a hard clay substrate and supports only Chaoborus spp. Tofte Lake, the deepest lake sampled, has very soft and flocculent sediment and low dissolved oxygen in the bottom waters in the summer (less than 2 ppm at a depth of 12 m in July, 1976, and 1977)(Regional Copper-Nickel Study 1978b). Both of these factors probably restrict the fauna in Tofte Lake to almost nothing but Chironomus spp. Thus, the bottom substrate and chemical characteristics of Study Area lakes appear to determine the occurrence of the dominant taxa.

Distributions Within Lakes

Samples taken along transects in White Iron Lake were all in the profundal zone as the littoral zone was too rocky for dredge sampling. The dominant organisms found along the transects were the four dominant profundal organisms discussed above (Table 5). Depth at transect stations ranged from 2.5 to 6 m and appeared to have little effect on the benthic fauna of White Iron Lake. The average percent composition for the transect sites in White Iron was similar to the average percent composition of the other Study Area lakes with the Hexagenia limbata/Chaoborus/Procladius association (Figure 4).

Because the littoral zone of Study Area lakes is generally rocky and narrow, no quantitative sampling was done in this zone; hence, comparisons between littoral and profundal zones can only be made on the basis of qualitative samples in the littoral zone and quantitative samples in the profundal zone. These samples indicated a greater invertebrate diversity in the littoral zone with 73 genera in 10 orders (Table 6) as compared to 18 genera in 9 orders in the profundal zone (Appendex 1, Tables 1 and 2).

The most abundant taxa in the littoral zone within each order were: Acroneuria lycorias (Plecoptera); Stenonema tripunctatum, Leptophlebia, and Ephemerella temporalis (Ephemeroptera); Basiaeshna janata (Odonata); Corixidae (Hemiptera); Hydroptila, Grammotaulis, and Molanna tryphena (Trichoptera); Sialis (Megaloptera); Dytiscidae (Coleoptera); Endochironomus, Glyptotendipes, and Procladius (Diptera); Physa (Gastropoda); Hyalella azteca (Crusteacea). All taxa from littoral qualitative samples (Table 6) except Didymops transversa, Somatochlora williamsoni, and Arypnia improba were also collected in stream riffle or pool areas in the Study Area (Regional Copper-Nickel Study 1978a). These taxa are not restricted to the littoral zone in lakes (Walker and Corbex 1975, Wiggins 1977).

Pelecypoda

Bivalve faunas often react quickly to any disruption of the aquatic ecosystem (Fuller 1974). The presence of bivalves in the Study Area is an important indication of the extent of present impacts in the Area. Imlay (1969) has recommended "documentation of existing populations" in areas of potential environmental change. Mussel species collected by SCUBA are included in Table 7. Mussels were found at all stations sampled in 1976, with Actinonaias carinata carinata and Anodonta grandis grandis the most widespread species.

Comparisons With Other Studies

The dominance of four taxa (Chaoborus spp., Hexagenia limbata, Procladius spp., and Chironomus spp.) in the profundal zone is similar to the findings of several other studies in the Upper Midwest and Canada. Hilselhoff and Narf (1968) sampled statewide in Wisconsin lakes and found that the profundal zone was dominated by Chaoborus spp., Chironomus spp., Procladius spp., and ceratopogonids. The other invertebrates found were thought to originate in the littoral zone. Schults et al. (1976) studied Burntside and Shagawa lakes, located near Ely, in the Study Area. Shagawa Lake which has been enriched by sewage input from Ely is dominated by Chaoborus [redacted]. and Chironomus [redacted]. The dominance of Chaoborus [redacted]. is similar to many Study Area lakes. Burntside, a deep and clear lake, is dominated by amphipods, Chaoborus [redacted]. and pelecypods, which is different from the Study Area lakes investigated. The Burntside Lake fauna is probably typical of deep, clear lakes in the Study Area. The Burntside fauna is similar to the benthic fauna reported from Experimental Lakes Area (ELA) lakes with a mean depth greater than ten meters (Hamilton 1971). In (ELA) lakes with a mean depth less than ten meters, Hamilton (1971) found that Chaoborus, and chironomids including Procladius and Chironomus were the dominant benthic invertebrate taxa. This pattern is similar to Study Area lakes of similar depth.

Although Hexagenia limbata was found in six of ten lakes sampled in the Study Area and observed emerging in Shagawa Lake by Regional Copper-Nickel Study staff, it was not reported by Hilsenhoff and Narf (1969), Hamilton (1971), or Shults et al. (1976). It was, however, found to be an important profundal organism in the Churchill and Reindeer river lakes system in northern Saskatchewan (Willard 1975, Sawchyn 1975). Its absence in the silty-bottomed ELA lakes, Wisconsin lakes, and Shagawa Lake is surprising since it is widespread in silty-bottomed, well-oxygenated lakes and rivers (Fremling 1970). Data from the present study seem to confirm its preference for silty substrates, a condition found in many Study Area lakes.

The range of densities of benthic invertebrates in Study Area lakes (129-3869 organisms/m^2) is approximately equal to that reported for ELA lakes less than ten meters in depth (230-3600 organisms/m^2)(Hamilton 1971).

Densities in Study Area lakes are also comparable to those in oligotrophic Burntside Lake where 1100 to 2400 organisms/m^2 were reported by Shults et al. (1976). This is in contrast to the higher density reported in Shagawa Lake (29,000/m^2, June 1973) by Shults et al. (1976) which can be attributed to the effects of nutrient inputs from the sewage treatment plant.

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Table 1. Physical and chemical characteristics of Study Area lakes that were sampled for benthic invertebrates in 1976 and 1977.

LAKE	STATION NUMBER	DEPTH AT SITE(m)	SUBSTRATE	pH[a]	COLOR[a] (Pt-Co units)	ALKALINITY[a] (mg/l as $CaCo_3$)	SURFACE AREA (km^2)	YEAR SAMPLED	IMPACT POTENTIAL
Bear Island	1	6	Coarse sand	7.40	39.50	15.50	8.64	1977	
Birch	1	5.2	Fine silt	7.10	54.90	23.40	25.62	1976-77	High
	2	5.2	"					1976	
	3	7.2	"					1976-77	
	4	7.0	"					1976	
Colby	1	6.0	Fine silt	7.10	133.75	33.0	2.24	1976	High
	2	6.8	"					1976	
Gabbro	1	4.9	Fine silt	7.25	100.25	17.75	3.63	1976	Low
	2	3.9	"					1976	
Greenwood	2	1.6	Coarse organic material-fine silt	6.65	170.00	8.00	5.06	1977	
Sand	1	2.5	Coarse organic material-fine silt	7.25	80.00	21.50	2.05	1977	
Seven Beaver	1	1.4	Coarse Detritus	6.5	172.5	13.67	5.63	1977	Med.
	2	1.5	" "					1977	
Tofte	1	15	Fine silt	8.55	3.0	70.5	.47	1977	
White Iron	1-1	2.5	Fine silt	6.95	73.75	17.15	13.85	1977	High
	-2	3.5	"					1977	
	-3	10.0	"					1976-77	
	-4	5.5	"					1977	
	-5	2.5	"					1977	

Table 1 (contd.)

LAKE	STATION NUMBER	DEPTH AT SITE(m)	SUBSTRATE	pH[a]	COLOR[a] (Pt-Co units)	ALKALINITY[a] (mg/l as $CaCo_3$)	SURFACE AREA (km^2)	YEAR SAMPLED	IMPACT POTENTIAL
White Iron	2-1	2.3	Fine silt					1977	
(contd.)	2	3.4	"					1977	
	3	4.2	"					1976-77	
	4	3.0	"					1977	
	5	2.0	"					1977	
Wynne	1	6	Hard clay	7.2	73.75	42.5		1977	

[a]Summertime averages (June, July, and August) from Regional Copper-Nickel Study (1978b).

Table 2. Invertebrate groups classified as benthic invertebrates in the Regional Copper-Nickel Study.

Nematoda
Annelida
Isopoda
Amphipoda
Decapoda
Acari
Insecta
Gastropoda
Pelecypoda

Table 3. Mean total number of benthic invertebrates m-2 collected per lake in 1976 and 1977 with a Ponar dredge.

LAKE	1976 May	1976 Oct.	May, 1977
White Iron	517	610	473
Colby	538	3860	---
Seven Beaver	761	---	---
Gabbro	784	474	---
Birch	850	1351	1033
Tofte	---	---	129
Wynne	---	---	237
Greenwood	---	---	323
Bear Island	---	---	581
Sand	---	---	1399

Table 4. Overall percent relative abundance of the four dominant benthic invertebrate taxa collected in quantitative lake samples in 1976 and 1977. Percentages calculated from mean number of organisms per site.

TAXA \ DATE	1976	1977
Hexagenia limbata	3	6
Chaoborus	77	68
Chironomus	3	5
Procladius	6	8
Total Percentage of these taxa	89	87

Table 5. Abundance percentages of most abundant taxa in two transects in White Iron Lake, 1977. (Percentages are calculated from the mean number of organisms per site.)

	WHITE IRON LAKE										
	TRANSECT 1					TRANSECT 2					Percentage of Total Organisms Collected in Two Transects 1977
	Site					Site					
TAXA	1	2	3	4	5	1	2	3	4	5	
Hexagenia limbata	71	43	23	0	43	30	15	19	43	8	28
Chaoborus	0	43	23	78	0	35	55	55	36	46	40
Chironomus	0	0	8	0	0	13	5	0	7	0	5
Procladius	14	0	39	0	43	0	0	6	0	0	8

Table 6. Relative abundance of lake benthic invertebrate taxa qualitatively collected in two hours per site in May and October, 1976.

SITE	BIRCH LAKE								WHITE IRON LAKE				GABBRO LAKE				SEVEN BEAVER LAKE				COLBY LAKE			
	1		2		3		4		1		2		1		2		1		2		1		2	
TAXA	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct
PLECOPTERA																								
Capniidae									1															
Acroneuria lycorias				2						1														
Perlinella drymo			1																					
EPHEMEROPTERA				1																				1
Isonychia sp.													1											
Siphlonuridae																							1	
Siphlonurus sp.																					4			
Siphlonurus marshalli																	2							
Heptageniidae																2								2
Arthroplea bipunctata															1		13		1		1		3	
Stenacron sp.		13		16			1	8		31		11		16		4			1			19		11
Stenacron candidum								1																
Stenacron interpunctatum								1		1		9		2					5					2
Stenacron minnetonka																			1					1
Stenonema sp.															2	8								
Stenonema tripunctatum		29	1					8	2	15		8		19					1		2	46	10	37
Siphloplecton interlineatum			4												2		2							
Baetidae																								1
Callibaetis sp.			1				1					5										24		
Cloeon sp.																						1		
Leptophlebiidae		1		6				1		3		1				4								7
Leptophlebia sp.			9	3			15	5				2		40	3	16	5		7		13	4	19	
Ephemerella sp.		1	1				8															4	1	2
Ephemerella versimilis																							1	
Ephemerella temporalis		2					4			2			2		7	1	77		22		10		16	
Caenis sp.								2				1												
Ephemera simulans		20					1	13											2			1		
Hexagenia sp.										1														2
Hexagenia limbata			1	2			1															2		

Table 6 (contd.).

SITE	BIRCH LAKE								WHITE IRON LAKE				GABBRO LAKE				SEVEN BEAVER LAKE				COLBY LAKE			
	1		2		3		4		1		2		1		2		1		2		1		2	
TAXA	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct
ODONOTA																								
Coenagrionidae				8				3				1									19		1	3
Enallagma sp.												8										3	1	
Gomphidae				1				2		1														
Dromogomphus spinosus			2							1														1
Hagenius brevistylus			1						1												1			
Aeshnidae															1									
Aeshna sp.				3								3												
Basiaeschna janata		1	2	1				1														2		3
Boyeria sp.										1				1									1	
Boyeria vinosa									6	1														
Didymops transversa																							1	
Macromia sp.	1			1			1																	
Macromia illinoiensis							1																	
Somatochlora williamsoni																					1			
Tetragoneuria sp.		1		9																				
HEMIPTERA																								
Gerridae													1											
Gerris sp.							1										2				1		1	
Notonecta sp.				3			1								2		1				6		1	
Ranatra sp.				5				1				8									1	9		8
Belostoma sp.							1	1	1	1												5		4
Lethocerus sp.																								1
Corixidae		2	10	18			20	3		4		13	1				7		1		8	20		33
TRICHOPTERA																								
														1										
Nyctiophylax moestus								1														1		1
Polycentropus cinereus				2								1										8		
Polycentropus interrupta												2												
Hydroptillidae				1						1		1		5										
Agraylea sp.																						3		
Hydroptila sp.																56								
Ochrotrichia sp.		3										1		2								5		19

Table 6 (contd.).

SITE	BIRCH LAKE								WHITE IRON LAKE				GABBRO LAKE				SEVEN BEAVER LAKE				COLBY LAKE			
	1		2		3		4		1		2		1		2		1		2		1		2	
TAXA	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct
TRICHOPTERA (cont.)																								
Agrypnia improba																	1							
Banksiola crotchi												1					2							
Phryganea cinerea								1				1												
Ptilostomis sp.		1		1			1	2				3					1							
Limnephilidae										1				1		1								
Grammotaulis sp.							2										28		5		27		1	
Nemotaulius hostilis												1												
Pycnopsyche guttifer							1		1										1					
Agarodes distinctum		8																						
Molanna sp.																1								
Molanna blenda								2																
Molanna tryphena		1						2				1					17		3			2		2
Helicopsyche borealis		17						1		3				4					1					3
Ceraclea sp.								1						1										1
Ceraclea neffi														2					3			5		5
Ceraclea resurgens										1														
Triaenodes injusta																								1
Triaenodes tarda																						1		
MEGALOPTERA																								
Chauloides rastricornis				1				3																
Sialis sp.				7				2				1										2		1
COELOPTERA																								
Haliplus sp.			1A				2A-1L										3A				1A		2A	1A
Dytiscidae		2A	5A	2			7	2						4			6A				4A	1A		
Gyrinidae								1							1									
Dineutus sp.							2																	
Gyrinus sp.		1		3A			8	6									3A				1A			1A
Hydrophilidae		1A		1			1A														1A			
Ectopria nervosa														2		3								
Dubiraphia sp.								2		1				1										1
Macronychus glabratus														2										
Donacia sp.								1																

Table 6 (contd.).

SITE	BIRCH LAKE								WHITE IRON LAKE				GABBRO LAKE				SEVEN BEAVER LAKE				COLBY LAKE			
	1		2		3		4		1		2		1		2		1		2		1		2	
TAXA	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct
DIPTERA			1																		1A		2A	
			1																					
Tabanidae								1																
Aedes sp.			25														2		1					
Chironomidae																								
Clinotanypus sp.				1						2												1		
Conchapelopia sp.		5		2				14				5							3		1	100	6	5
Dicrotendipes sp.				8																				
Endochironomus sp.			1					1		6						1					1		1	7
Eukiefferriella sp.				4																				
Glyptotendipes sp.			4	8			3	1		1		2									9			7
Larsia sp.																1								
Palpomyia group				2						25											1			12
Polypedilum sp.										1														2
Procladius sp.			3	17						7		2												
Stenochironomus sp.										1														
Xenochironomus sp.												1				2			1					
Chironomidae pupae																					2			
GASTROPODA													2		2	1	2				4	6		
cf. Amnicola limosa																							16	
Campeloma decisum																								
Ferrissia sp.			1						1	7		1		1		1								
Gyraulus sp.															2	9								
Helisoma anceps	2		1						1												1			
H. campanulata																								
H. corpulentum																							1	
H. trivolvis			6				7		1				3								1			
Helisoma sp.																2								
Physa gyrina	6	4	2	2			43	3	81	3	61	4	13	2		1	12		27		81	1	61	
Sphaerium striatinum							1																	
Stagnicola sp.											30		1				1						30	

Table 6 (contd.).

SITE	BIRCH LAKE								WHITE IRON LAKE				GABBRO LAKE				SEVEN BEAVER LAKE				COLBY LAKE			
	1		2		3		4		1		2		1		2		1		2		1		2	
TAXA	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct
DECAPODA										1			1	1	2						1			
CRUSTACEA																								
Crangonyx sp.				1																		1	1	
Hyalella azteca	1	17	7	14			29	54				41	1		4		24		2		37	29	33	10
NEMATODA																								
TURBELLARIA																						1		1
HIRUDINEA		6	2	4				11		2	1	2		1	1	3	2		3			2		
OLIGOCHAETA		2		1		2		1																
PELECYPODS																								
Sphaeriidae		2		7				2				1							6		1		42	9
OTHER																								
Lepidoptera																1							1	

Table 7. Clams collected by SCUBA in July, 1976.

TAXA \ STATION	LWI-1	LWI-2	LG-1	LG-2	LC-1	LC-2	LB-1	LB-2	LB-3	LB-4	LSB-1	LSB-2
Unionidae			X	X	X		X		X	X		
Actinonaias carinata carinata	X	X	X	X	X		X		X		X	X
Anodonata sp.								X	X			
Anodonata grandis grandis	X	X	X	X	X	X	X	X	X	X	X	X
Anodonata inbecilis					X	X						
Lampsilis sp.						X						
Strophitus-*Anodontoides*-*Anodonata* sp.												X

APPENDIX

Table 1. Mean number of lake benthic invertebrates m^{-2} collected with three Ponar dredge in May and October, 1976.

Table 2. Mean number of lake benthic invertebrates m^{-2} collected in May, 1977, with two Ponar dredge.

Table 1. Mean number of lake benthic invertebrates m^{-2} collected with three Ponar dredge in May and October, 1976.

SITE	SEVEN BEAVER				WHITE IRON				COLBY				GABBRO				BIRCH							
	1		2		1		2		1		2		1		2		1		2		3		4	
TAXA	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct	May	Oct
Ephemeroptera																								
Hexagenia sp.																								
Hexagenia limbata					14.4	14.4	100.4	172	14.4				71.8	14.4	28.7	129.2	14.4	28.7	71.8	28.7	28.7			71.8
Trichoptera																								
Leptoceridae								28.7																
Hydropsychidae										14.4						14.4				43.0				
Diptera																								
Chaoborus sp.	516.6		588.21		43.0	100.4	57.4	631.4	114.8	904.0	617.0	6615.4	420.6	200.9	559.6	315.7	559.6	645.8	401.8	1707.6	861.0	1191.0	559.6	760.6
Palponyia group	14.4		28.7												14.4		14.4	14.4		14.4	43.0			
Chironomidae																								
Ablabesmyia sp.															14.4									
Cardiocladius sp.						14.4												14.4						14.4
Clinotanypus sp.			43.4			14.4									14.4		28.7				14.4	14.4	43.0	28.7
Chironomus sp.					516.6	43.0				71.8		28.7									14.4		14.4	14.4
Chonchapelopia sp.																	14.4		14.4					
Coelotanypus sp.								18.7								43.0			14.4	28.7				
Cryptochironomus sp.					28.7								14.4				43.0							
Eukiefferiella sp.						14.4																		
Polypedilum sp.															14.4					14.4	28.7			
Potthastia sp.																14.4								
Procladius sp.	86.1		129.2			14.4		14.4			100.5		43.0	43.0	100.5	28.7	57.4	43.0		114.8	186.6	287.0	143.5	129.1
Psectrotanypus sp.						14.4		71.8		28.7			14.4			14.4	14.4	28.7		14.4				
Tanytarsus sp.			14.4																					
Zavrelimyia sp.								28.7								43.0								
Unidentified Chironomidae													14.4			28.7		14.4						
Megaloptera																								
Sialidae																								
Sialis sp.																14.4				14.4		43.0		
Hemiptera																								
Corixidae	14.4				43.0		14.4		114.8	14.4														
Hirudinea																								
Pelecypoda																								
Sphaeriidae	14.4				43.0		14.4		114.8	14.4			71.8	14.4	114.8	28.7		28.7	14.4	28.7				
Nematoda																								
Oligochaeta	28.7		43.0		200.9	14.4	14.4		14.4		100.5		57.4				71.8		28.7		71.8	14.4	28.7	
*Mean Total Number/Site	674.6		847.1		846.6	244.2	186.6	975.7	258.4	1033.3	818.0	6687.1	707.8	272.7	861.2	674.6	818.1	818.1	545.5	2009.1	1248.6	1549.8	789.2	1027.0

*Number m^{-2}

Table 2. Mean number of lake benthic invertebrates m^{-2} collected in May, 1977, with two Ponar dredge.

TAXA \ SITE	GREENWOOD LAKE	TOFTE LAKE	WYNNE LAKE	BEAR ISLAND LAKE	SAND LAKE	BIRCH LAKE		WHITE IRON LAKE									
								TRANSECT 1					TRANSECT 2				
						1	2	1	2	3	4	5	1	2	3	4	5
Ephemeroptera																	
Ephemeriidae								21.5	21.5					21.5			
Hexagenia limbata	21.5				86.1	64.5		215.2	64.5	64.5		64.5	150.6	64.5	129.1	129.1	21.4
Diptera																	
Chaoboridae																	
Chaoborus sp.	129.1		215.2	344.4	1140.8	86.1	731.8		64.5	64.5	150.6		172.2	236.7	365.9	107.6	129.1
Ceratopogonidae																	
Palpomyia group						21.5											
Chironomidae																	
Ablabesmyia sp.					21.5												21.5
Chironomus sp.		129.1		107.6						21.5			64.5	21.5		21.5	
Clinotanypus sp.																	21.5
Coelotanypus sp.						21.5	21.5				21.5		21.5			21.5	21.5
Conchapelopia sp.	21.5														21.5	21.5	
Epoicocladius sp.						21.5											
Larsia sp.														43.0	21.5		
Polypedilum sp.						64.5	21.5						21.5		86.1		
Procladius sp.	86.1			21.5	129.1		86.1	43.0		107.6		64.5			43.0		
Psectrotanypus sp.					21.5												
Unidentified chironomidae	21.5		21.7	107.0			64.5				21.5		21.5	43.0			
Megaloptera																	
Sialidae																	
Sialis sp.	21.5											21.5					43.0
Hemiptera																	
Corixidae	21.5						86.1										
Nematoda																	21.5
Oligocheata										21.5							
Sphaeriidae								21.5					43.0				
*Mean Total Number/Site	322.7	129.1	236.9	581.1	1399.0	1054.5	1011.5	301.2	150.5	279.6	193.6	150.5	494.8	430.2	667.1	301.2	279.5

*Number m^{-2}.

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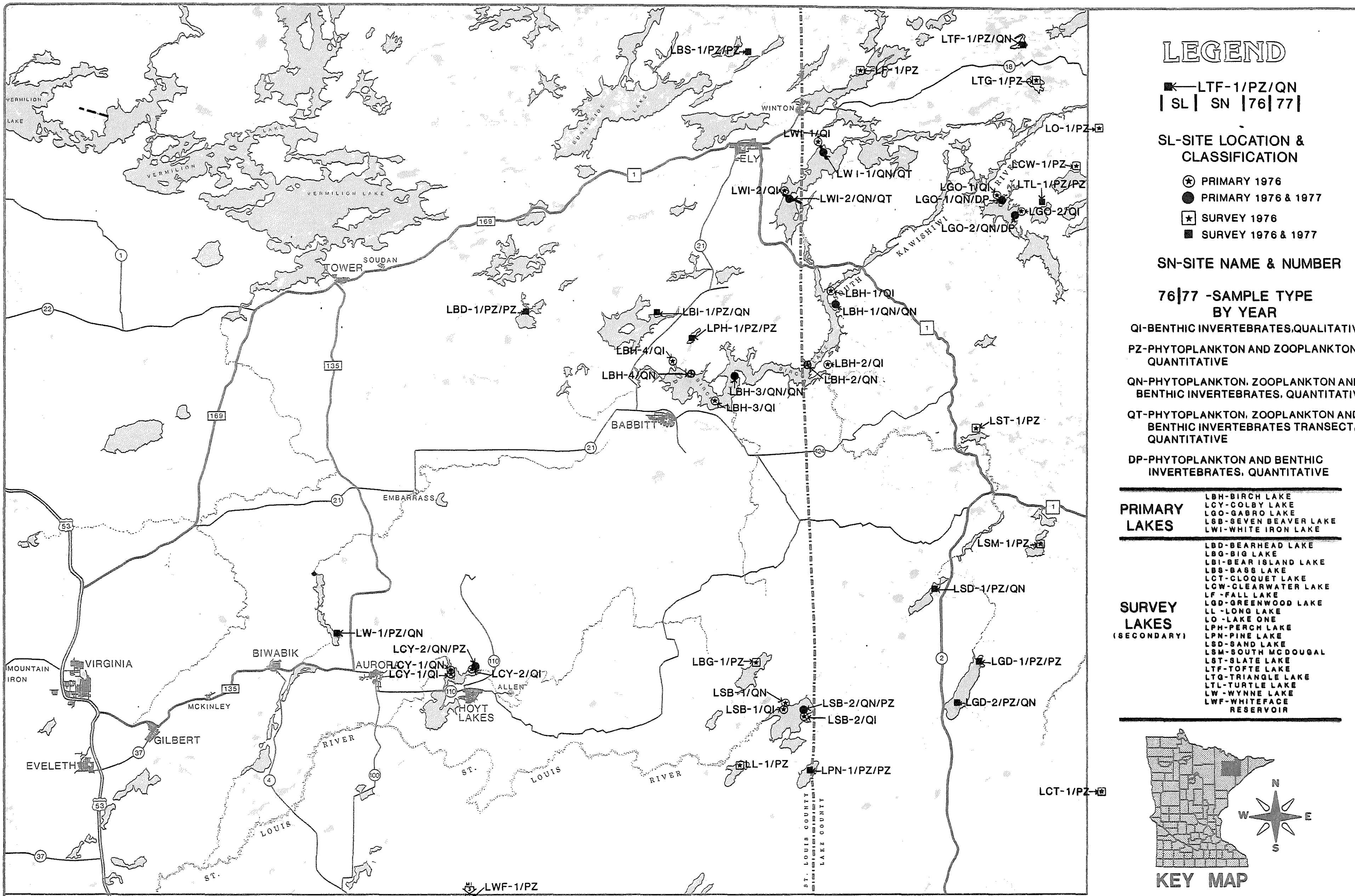

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0 1 2 3 4 5 10 15 KILOMETERS

MEQB REGIONAL COPPER-NICKEL STUDY

FIGURE 1. AQUATIC BIOLOGY LAKE STUDY SITES

FIGURE 2.

RELATIVE ABUNDANCE OF THE FOUR DOMINANT TAXA COLLECTED IN 1976 QUANTITATIVE LAKE SAMPLES. PERCENTAGES CALCULATED FROM MEAN NUMBER OF ORGANISMS PER SITE

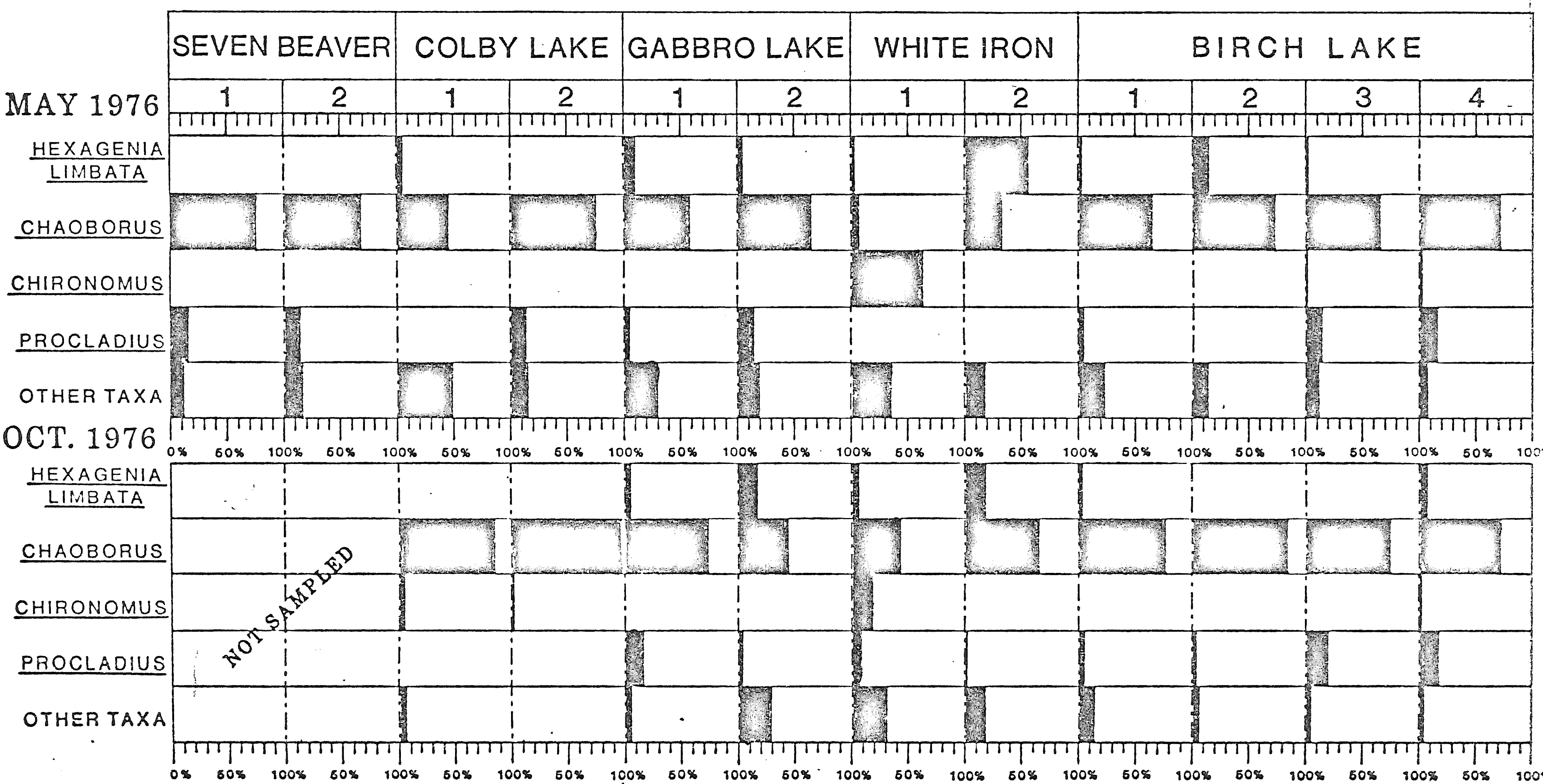
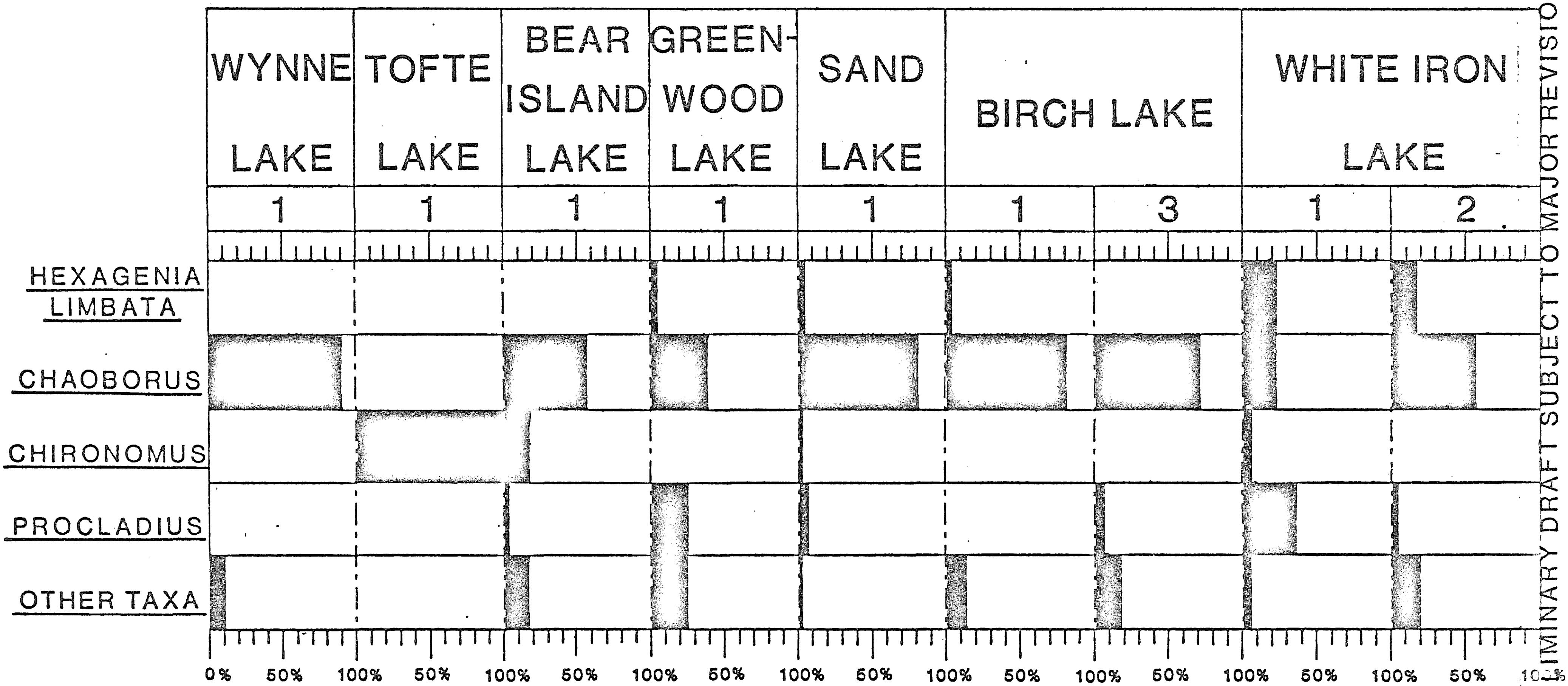


FIGURE 3.

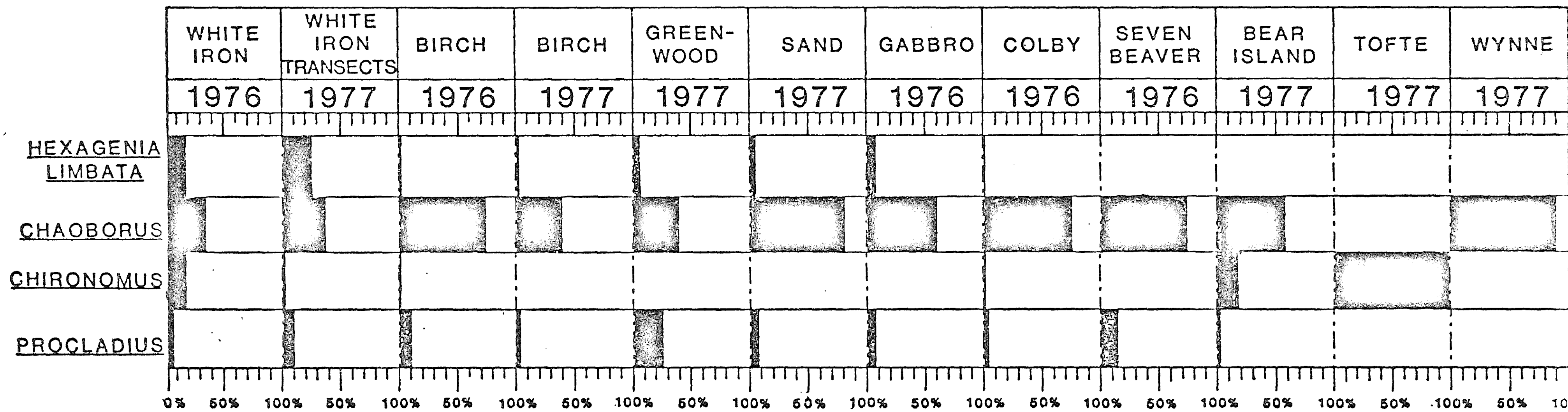
RELATIVE ABUNDANCE OF THE FOUR DOMINANT BENTHIC INVERTEBRATES COLLECTED IN 1977 QUANTITATIVE LAKE SAMPLES. PERCENTAGES CALCULATED FROM THE MEAN NUMBER OF ORGANISMS PER SITE



PRELIMINARY DRAFT SUBJECT TO MAJOR REVISION DO NOT QUOTE

FIGURE 4.

AVERAGE PERCENT COMPOSITION OF DOMINANT TAXA IN STUDY AREA LAKES



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