1976

Leeches (Hirudinea) of Isle Royale National Park, Michigan

Martin W. Grosnick
Northern Michigan University

THE LEECHES (HIRUDINEA)

OF

ISLE ROYALE NATIONAL PARK,

MICHIGAN

by

Martin W. Grosnick

B.S., Northern Michigan University

A Thesis

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Arts in Biology

School of Graduate Studies

Northern Michigan University

Marquette

May, 1976

THE LEECHES (HIRUDINEA)

OF

ISLE ROYALE NATIONAL PARK,

MICHIGAN

by

MARTIN W. GROSNICK

THIS THESIS IS RECOMMENDED FOR APPROVAL BY THE STUDENT'S THESIS COMMITTEE.

Martin Kopenski
Chairman

Philip A. Doepke

Wm. L. Robinson

APPROVED BY Roy E. Heath, DEAN OF GRADUATE STUDIES ON 4/8/76.
Date

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS.

NORTHERN MICHIGAN UNIVERSITY

MARQUETTE, MICHIGAN

MAY, 1976

ABSTRACT

Fourteen species of leeches (Hirudinea) representing four families were collected in Isle Royale National Park, Michigan, of which nine species are new records. A total of 1308 specimens were collected from 15 lentic sites and eight lotic sites.

The leeches encountered were indicative of the Lake Superior region, with the exception of *Dina dubia*, a near-Arctic species. The more cosmopolitan species such as *Helobdella stagnalis* and *Erpobdella punctata* were low in abundance.

The lentic leech fauna is characterized by *Nephelopsis obscura*, *Placobdella ornata*, *Glossiphonia complanata* and *Haemopis marmorata*. *N. obscura* was found in every lentic site and totalled over half the leeches collected. The lotic waters are characterized by *Mooreobdella fervida* and to a lesser extent, *N. obscura*.

Lentic waters were found to contain nearly six times the leech fauna as compared to lotic waters. Similarly, lentic sites produced an average of 4.3 species as compared to 1.4 species of lotic sites.

Although most species were collected throughout the measured pH range, *Theromyzon meyeri*, *Haemopis grandis* and

Mooreobdella fervida preferred slightly acidic waters, while *Dina dubia* was found only in slightly alkaline waters.

Dina dubia and *Nephelopsis obscura* demonstrated their northern character by preferring cool, clear waters, while *Placobdella ornata* was most likely found in warmer, brownish waters.

The single factor common to most collection sites was the presence of underwater debris for the attachment and protection of the leeches.

ACKNOWLEDGMENTS

I would like to thank the National Park Service staff for their help during the field work portion of this study, as well as Dr. William Robinson and Dr. Philip Doepke for serving on my graduate committee and for reviewing this thesis.

Most of all, special thanks goes to Dr. Martin Kopenski for serving as my major advisor, and for his continued guidance, encouragement and patience.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION

Although leeches have been mentioned in several ecological studies of the fauna of Isle Royale National Park, no study entirely devoted to these annelids has been attempted. This study intends to fill this gap, as well as gaining an ecological insight into the habits and preferences of this poorly understood class of animals.

LITERATURE REVIEW

The first comprehensive biological survey of Isle Royale was undertaken by the Michigan Board of Geological Survey in 1905, and results were published by Ruthven (1906) and Adams (1908). Five species of leeches were collected and identified. In a survey of inland lakes in 1929, Koelz mentioned leeches found in the stomachs of collected fish, but failed to identify the species. No other published information on the island's leech fauna has been located by the author.

Investigations geographically near Isle Royale, and thus useful for comparison, are: Kopenski (1969), Marquette County, Michigan; Miller (1937), Sawyer (1968) and Klemm (1972), Lower Michigan; Bere (1931) and Sapkarev (1967), Wisconsin; Nachtrieb, Hemingway and Moore (1912), Keith (1954, 1960), Minnesota; Moore (1922, 1924) and Thomas (1966), Northern Ontario.

Similar studies of importance in other areas include: Herrmann (1970), distribution and ecology of Colorado leeches; Sawyer (1972), a systematic account of individual North American species; Pawlowski (1936), studies of leeches in regard to their food, substrate and water preferences; Bennike (1943), Sandner (1951) and Mann (1955), studies of leech distribution according to physical and chemical characteristics of the water they inhabit.

Only recently have leech studies in the Great Lakes Region become more ecology oriented rather than a simple listing of species. The works of Sapkarev (1967), Kopenski (1969), Sawyer (1972) and others are more complete ecologically than those of Bere (1931) or Miller (1937). No doubt the credit for increased quantitative study is due to the European studies of Pawlowski, Bennike, Sandner and Mann.

CHAPTER II

METHODS AND MATERIALS

CHEMICAL METHODS

The water of each collection site was tested for approximate pH with pHydrion Vivid 3-9 indicator tape. No other chemical analyses were performed.

PHYSICAL METHODS

The measured and observed physical features for each collection site were recorded. These included:

1. LENTIC vs. LOTIC WATERS. The water of each collection site was first determined to be either lentic or lotic.
2. WATER TEMPERATURE. The water temperature at the depth of leech collection was measured with a centigrade thermometer.
3. WATER DEPTH. The depth at which the leeches were collected was measured with a meter stick.
4. WATER COLOR. Only gross visual observations of water color were made.
5. BOTTOM COMPOSITION. The type of substrate found at each site and the amount of debris present were noted.

BIOLOGICAL DATA

The dominant floral and faunal inhabitants observed as well as those known by the author to inhabit each collection site were recorded.

LEECH COLLECTION

Specimens were collected by the following methods:

1. Examining the undersides of submerged logs, sticks, boards, rocks and other large objects.
2. Examining the leaves and roots of aquatic vegetation.
3. Examining mud and heavy silt.
4. Capturing free-swimming specimens with a hand net.
5. Examining vertebrate hosts (either alive or dead).

Leeches found adhering to objects were removed with forceps or knife blade and placed in a small jar containing water.

TIME COLLECTION

The total time spent collecting leeches at each site was recorded for determining relative abundance in different water types.

PRESERVATION

The leech specimens were first narcotized by adding a small amount of menthol crystals into leech-containing jars. The jars then stood for 4-12 hours. The length of time depended on the size of the leeches and the amount of menthol used.

The narcotized leeches were then cleaned of their secreted mucus, usually with paper towelling, and then carefully placed between 12 cm square glass plates so as to preserve them flattened and straight. The glass plates, after being loosely bound with elastic bands, were immersed in a 10% formalin solution for fixation. Some larger specimens were injected internally with the fixative. After at least 6 hours in the formalin, the leeches were removed and preserved in 70% ethanol. Each jar contained a field label with information as to the collection site, collector and date. Additional habitat notes were recorded separately.

IDENTIFICATION

The keys of Pennak (1953) and Sawyer (1972) were helpful for basic taxonomy and separating similar species. Other works used were Soos (1965, 1969), Edmondson (1959), and Mann (1962).

Important characteristics used to identify the individual species were the presence and arrangement of eyespots, position of the gonopores and the number of annuli separating them, overall size and shape, pigmentation patterns, and numerous characteristics unique to a particular genus or species. For certain species, external features were not sufficient for accurate identification. Hence, dissection of internal reproductive organs (as in some erpobdellids) or mouth parts (*Haemopis* spp.) were necessary.

FINAL DISPOSITION OF SPECIMENS

One condition for the issuance of a collection permit by the National Park Service was that all collected specimens must ultimately be deposited in a permanent collection available to the public. Hence, all leeches collected for this study will become part of the Northern Michigan University's Museum of Zoology.

CHAPTER III

THE STUDY AREA

HISTORY

Isle Royale, an archipelago of 544 km^2 in Lake Superior, is composed of a main island 72 km long and up to 14.5 km wide, and over 200 small islands. Historically, the island has been under French and British rule, and was included as part of the United States in the Peace of Paris Treaty (1783) because of poor mapping. Although only 24 km from Canada and 32 km from Minnesota, Isle Royale is politically a part of Keweenaw County, Michigan. The state of Michigan ceded the land to the Federal Government in 1940, thus formally creating Isle Royale National Park. The park is administered by the National Park Service (Department of Interior) to insure preservation of its wilderness character. Approximately 16,000 people visit each year, with most activity at concessioner operated facilities at either end of the island and at 30 campgrounds connected by 160 miles of foot trails. Legislation was introduced in 1971 to include portions of the park in the National Wilderness Preservation System to prevent further development, but passage has been unsuccessful to date.

GEOLOGY

Isle Royale is the northern edge of the upending of horizontal pre-Cambrian basaltic lava flows and sedimentary layers under Lake Superior. Subsequent erosion, stream deposition and glaciation helped create the distinct topography of alternate parallel ridges and valleys found today. Lesser ridges produced the many chains of islands. Numerous glaciers covered the island within the last three million years (the last approximately 11,000 years ago), and the bedrock is still rebounding from the weight.

FLORA

The last retreating ice sheet (the Wisconsin) left the ridges smooth and barren; the postglacial disintegration of rock combined with the scant glacial till of the valleys to help form the sandy and rocky loam that thinly covers the bedrock. Many ridges are still covered with only lichens and low shrubs, due in part to the lack of soil. The cool, damp areas near Lake Superior are characterized by conifers, while the warmer, drier areas inland and the southwestern section of the park are typically birch-maple forests.

FAUNA

Isolation has restricted the number of mammals inhabiting Isle Royale. Moose (*Alces alces*) number about 1000, regulated mainly by the availability of preferred foods and secondarily by the predation of wolves (*Canis lupus lycaon*, approximately 30). Red fox, snowshoe hares, beaver and red squirrels are common.

COLLECTION SITES

For this study a total of 54 subsites at 23 collection sites were examined for leeches. This included nine inland lakes, eight creeks and rivers, and six bays and harbors of Lake Superior. Figure 1 lists these sites and their location.

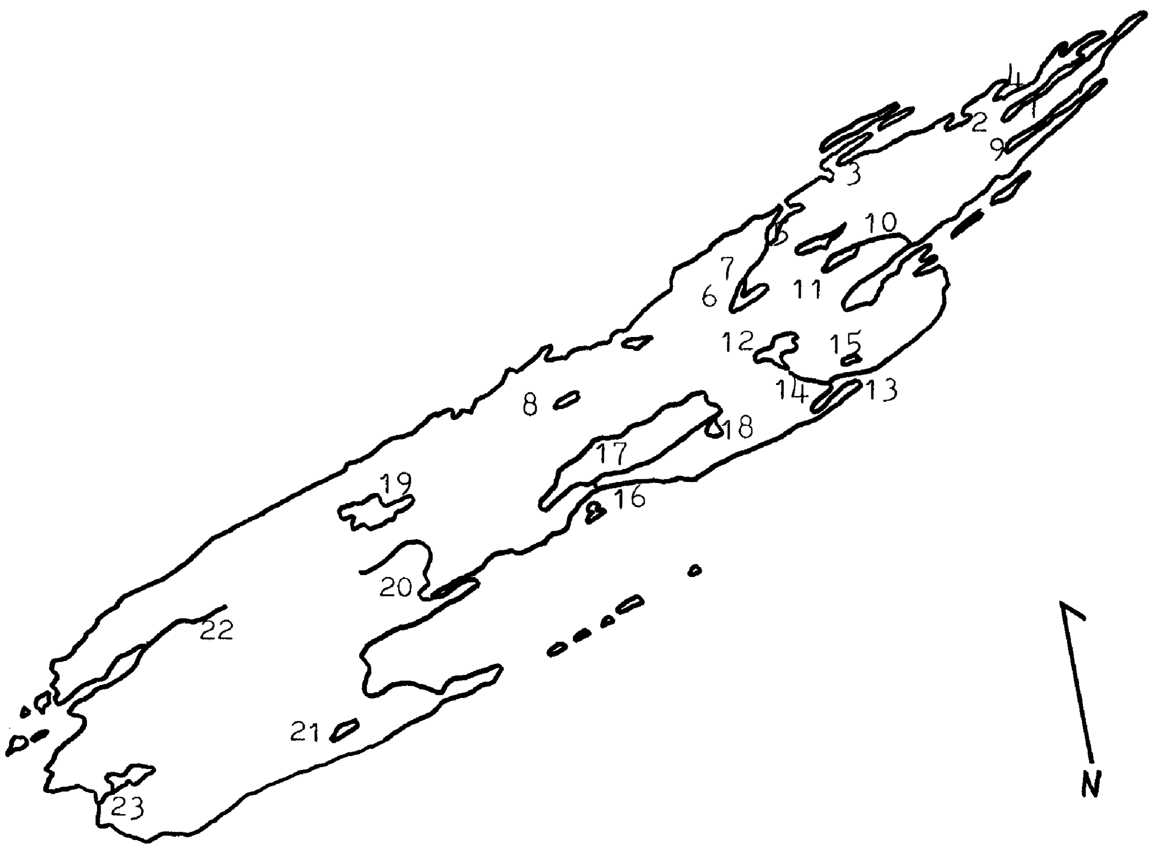
In the Appendix, Table A2 summarizes the chemical and physical data for each collection site. Also, Tables A3 and A4 summarize the flora and fauna (respectively) observed by this author and others at each site.

The following is a brief description of each collection site, as well as a listing of the dominant floral and faunal inhabitants:

INLAND LAKES

SITE 6. CHICKENBONE LAKE. This aptly named 96 hectare lake receives its water from nearby Lake Livermore and three smaller streams. Outflow is via Chickenbone Creek to McCargoe Cove. Maximum water depth is 6.5 m. The bottom ranges from soft mud in deeper water to sandy-mud in the littoral zone. Animals present were snails and clams, red mites, freshwater sponges, painted turtles (*Chrysemys picta belli*), yellow walleye (*Stizostedion vitreum vitreum*) and yellow perch (*Perca flavescens*). Vegetation consists mainly of

FIGURE 1. COLLECTION SITES, ISLE ROYALE NATIONAL PARK.



1. Duncan Bay
2. Duncan Bay Creek
3. Pickerel Cove
4. Stockly Bay
5. McCargoe Cove
6. Chickenbone Lake
7. Chickenbone Creek
8. Hatchet Lake
9. Tobin Harbor
10. Benson Creek
11. Angleworm Lake
12. Lake Richie
13. Chippewa Harbor
14. Richie Creek
15. Lake Mason
16. Siskiwit River
17. Siskiwit Lake
18. Wood Lake
19. Lake Desor
20. Little Siskiwit River
21. Lake Halloran
22. Washington Creek
23. Feldtmann Creek

yellow water lily (<u>Nuphar variegatum</u>) and various pondweeds (<u>Potamogeton</u> spp.).

SITE 8. HATCHET LAKE is a 53 hectare lake between the Greenstone and Minong Ridges. The southwest end (inlet) is soft, near bottomless peat; edges are gravel with large rocks; and the northeast end (outlet) is hard sand. Maximum water depth is 5.5 m. Aquatic insect larvae appeared scarce, but there were numerous schools of cyprinid minnows, and many green frogs (<u>Rana clamitans</u>) near the shoreline. The yellow water lily was the only higher plant evident.

SITE 11. ANGLEWORM LAKE. This appropiately named lake of 48.5 hectares is sandwiched between two parallel ridges. Maximum water depth is 9 m. The bottom is muddy with abundant submerged sticks and logs. Aquatic animals include clams (<u>Utterbachia</u> sp.), caddisfly and dragonfly larvae, scuds, planaria, sponges and western painted turtles. Reported fish are yellow perch and northern pike (<u>Esox lucius</u>). The flora consists mainly of <u>Potamogeton</u> spp., <u>Myriophyllum</u> sp., horsetails (<u>Equisetum</u> sp.) and yellow water lily.

SITE 12. LAKE RICHIE is an irregular shaped 210 hectare lake with a maximum depth of 11 m. The shoreline is typically steep bedrock with sandy bottomed coves, and numerous submerged sticks and logs. Fauna consists mainly of snails (including <u>Lymnea stagnalis</u>), clams, caddisfly larvae, scuds and minnows (<u>Notropis</u> spp.) in the littoral zone, with northern pike, yellow perch, and the common white sucker (_Catostomus commersoni_) reported as dominant fish species. Vegetation is usually restricted to the shallow coves--mainly _Equisetum_ sp. and emergent bulrushes (_Scirpus_ sp.).

SITE 15. LAKE MASON. This shallow, 20 hectare lake has no apparent inlet, but an outlet (via several beaver ponds) into Chippewa Harbor. The bottom near shore is normally hard sand with some gravelled sections. In deeper areas, the bottom is soft mud. Small aquatic insects are not abundant; however, some clam and snail shells are evident. Sponges, bryozoans and planaria were common. Northern pike is the dominant fish. Flora consists mainly of the yellow water lily and sedges (_Carex_ spp.).

SITE 17. SISKIWIT LAKE. This lake, with an area of 1800 hectares and maximum depth of 46 m, is Isle Royale's largest and deepest lake. Water is received from seven small streams, but exits only via the Siskiwit River into Lake Superior. The lake bottom is typically gravel and rocky, except for small sandy coves at each end of the lake. Submerged sticks and logs are common in the sandy areas. A scarcity of organisms reflects the oligotrophic nature of the lake. Some caddisfly and mayfly larvae, snails (_Lymnea_ sp.) and horsehair worms were found. Dominant fish species include lake trout (_Salvelinus namaycush_) and Siskiwit Lake whitefish

(*Coregonus clupeaformis neohantoniensis*), with scattered areas of northern pike. Localized areas of yellow water lily and emergent sedges were observed.

SITE 18. WOOD LAKE. This small, sandy-bottomed lake of about 40 hectares is actually an extension of Lake Siskiwit. Faunal life, consisting of snails (including *Lymnea stagnalis*) and scattered clam beds, is somewhat sparse except for numerous horsehair worms. Fish include northern pike and yellow perch. The dominant aquatic vegetation is emergent bulrushes.

SITE 19. LAKE DESOR. Somewhat isolated by altitude, this second largest lake (425 hectares) has no apparent inlet or outlet except swampy areas at each end. This deep lake (17 m) is definitely oligotrophic, with a sandy bottom and occasional boulders. Very few submerged logs and little silt were observed. Reported fish are mainly Lake Desor whitefish (*Coregonus clupeaformis dustini*), cisco (*Coregonus artedii*) and white sucker (*Catostomus commersoni*). Aquatic fauna was scarce; however, some horsehair worms, scuds and snails (*Physa* sp.) were observed. No aquatic plants were observed, although Koelz (1929) reported *Potamogeton* sp. and *Chara* sp..

SITE 21. LAKE HALLORAN is a shallow, almost rectangular lake of 76 hectares with a maximum depth of 3 m. The shoreline is mainly sandy-mud with large rocks, and either end is soft mud with peat. Fauna consists of snails (*Physa* sp.), clams (*Utterbachia* sp.), horsehair worms, frogs (*Rana* spp.), northern pike and yellow perch. Observed flora were yellow water lily and pondweed (*Potamogeton richardsonii*).

BAYS AND HARBORS

SITE 1. DUNCAN BAY is a 5 km long harbor connected to Lake Superior by a narrow channel. The bottom is mainly sandy-mud with a few areas of gravel. Submerged debris is abundant. Amphipods, small snails, caddisfly and dragonfly larvae were plentiful, as were yellow perch and northern pike. Emergent bulrushes were restricted to scattered sandy coves.

SITE 3. PICKEREL COVE is a long, narrow cove adjacent to and connected with Robinson Bay. Nestled between two parallel ridges, its shoreline is typically boulders on bedrock except for shallow, sandy coves. The fauna consists mainly of snails (*Physa* sp. and *Lymnea stagnalis*) and large insect larvae (caddisfly, dragonfly and stonefly). No aquatic plants were observed.

SITE 4. STOCKLY BAY is almost an identical but slightly smaller version of Pickerel Cove, with the same bottom composition and faunal inhabitants. No aquatic plants were observed.

SITE 5. McCARGOE COVE. Occupying a 4 km narrow fault in the island, this sheltered cove changes from a clean gravel-boulder shoreline with cold, clear water at the mouth to a muddy, heavily silted shallow end with dark, warmer water. The latter condition can be attributed to Chickenbone Creek, which empties into the head of the cove. Fauna consists mainly of amphipods, insect larvae and snails (including *Lymnea stagnalis*). Aquatic vegetation is sparse, except for yellow water lily and *Potamogeton* spp. at the head of the cove.

SITE 9. TOBIN HARBOR. The shoreline of this 7.5 km extension of Lake Superior ranges from large boulders on gravel to fine gravel, with numerous sandy coves littered with submerged debris. The head of the bay has a dark water color and muddy bottom, resulting from the outflowing of Tobin Creek. Fauna observed were scuds, snails, caddisfly larvae, and less abundant dragonfly larvae. Aquatic plants were found at the shallow end only, namely bulrushes and pondweeds.

SITE 13. CHIPPEWA HARBOR is a well protected 3.7 km long harbor on Isle Royale's southshore. The shoreline is basically solid rock, with small soft-bottomed sandy coves littered with logs and sticks. Small snails (including *Stagnicola* sp.) plus the larger *Lymnea stagnalis*, mayfly and dragonfly larvae were abundant. Amphipods and insect larvae were scarce. Many of the coves have emergent bulrushes and overhanging sedge hummocks.

CREEKS AND RIVERS

SITE 2. DUNCAN BAY CREEK. This creek is essentially a series of old beaver ponds slowly emptying into Duncan Bay. The bottom is mud, and the lower section has many sedge hummocks, water lilies and horsetails. Western painted turtles, frogs and northern pike inhabit the lower section.

SITE 7. CHICKENBONE CREEK. The lotic portion between Chickenbone Lake and McCargoe Cove flows over large rocks (gravel bottom) with a surface velocity measured at 0.5 meters/second in late June. Aquatic insects (mainly caddisfly larvae) were numerous in the eddies. No fish are known to inhabit the lotic sections.

SITE 10. BENSON CREEK. Flowing from the lake of the same name, this creek empties into Rock Harbor at Daisy Farm Campground. Water content is very dependent on season and rainfall, and was found to be very low at the time of my visit. Several small *Physa* sp. snails and limited numbers of insect larvae were observed. Rainbow trout (*Salmo gairdneri*) have been caught in lower sections of this creek.

SITE 14. RICHIE CREEK. The only outlet from Lake Richie, this creek flows alternately through small beaver ponds and fast flowing sections. The lotic section examined was 3 m wide and 25 cm (average) deep, and had a late June surface velocity of 0.8 m/s at its center and reverse eddies near the edges. The bottom has hard sand-gravel with large rocks. Numerous sponges, bryozoans, planaria, beetle and caddisfly larvae were observed. No fish were observed in lotic sections.

SITE 16. SISKIWIT RIVER. Emptying Siskiwit Lake, this river maintains a near steady flow after the spring runoff. Portions flow over bedrock, other sections have a gravel bottom. During early July, the measured current velocity ranged from 0.5 m/s to 0.8 m/s, with edges slower or reversed. In the eddies, snails (mainly *Physa* sp.) and caddisfly larvae were abundant, with smaller insect larvae and dragonfly larvae less so. The only observed vegetation were horsetails in a small widening of the river. Early spring runs of rainbow trout are common, but the few specimens caught in Lake Siskiwit indicate most are stopped by a series of waterfalls.

SITE 20. LITTLE SISKIWIT RIVER. Located 8 km to the southwest of the Siskiwit River, this creek empties a series of beaver ponds and swamps. Normally small, the water worn banks of this stream reflect the quite heavy spring runoff. Water striders (Gerridae), caddisfly and dragonfly larvae were observed.

SITE 22. WASHINGTON CREEK is a narrow (typically 1 m) stream flowing between small pools over a gravel bottom lined with large rocks. The surface current in late July was measured at 0.5 m/s in the narrower sections, but was slower elsewhere. A slow moving, wide and shallow section occurs as it empties into Washington Harbor. The lotic sections examined were somewhat barren--only occasional insect larvae were encountered. Spawning steelheads (*Salmo gairdneri*) are frequently caught in early spring, and occasionally brook trout (*Salvelinus fontinalis*) are caught during the summer.

SITE 23. FELDTMANN CREEK drains the lake of the same name into Lake Superior. Over its 1.5 km length it is typically narrow (0.5 m), with large rocks on gravel. Portions of the stream are contained in beaver ponds. The only faunal inhabitants found in the lotic sections were blackfly (Simuliidae) larvae, sponges and bryozoans. No fish are known to inhabit the creek, probably due to low water during the summer months.

CHAPTER IV

RESULTS AND DISCUSSION

NUMBER COLLECTED

The detailed examination of the 23 collecting sites in this study produced a total of 582 adult leeches. In addition, 726 *Placobdella ornata* juveniles were accumulated incidental to the collection of their parents. Except in the discussion of reproduction of this species, they were not included in this study.

Fourteen species of adult leeches were identified. This includes nine new records for Isle Royale, along with the five species listed in the published works of Ruthven (1906) and Adams (1908).

RELATIVE ABUNDANCE

Table 1 lists the species identified, the number of specimens collected, the relative abundance and frequency of occurrence of each species.

The most common leech encountered on Isle Royale was *Nephelopsis obscura*, both in numbers of individuals collected (305) and frequency of occurrence (78% of the study sites). Next in decreasing abundance were *Placobdella ornata*, *Glossiphonia complanata*, *Haemopis marmorata* and

TABLE 1. LEECHES COLLECTED; RELATIVE ABUNDANCE AND FREQUENCY OF OCCURRENCE OF EACH SPECIES.

	ABUNDANCE		FREQUENCY	
	NO. OF SPECIMENS	PER CENT	NO. OF SITES	PER CENT
Nephelopsis obscura	305	52.7%	18	78%
Placobdella ornata *	92+	15.7	12	52
Glossiphonia complanata	53	9.1	11	48
Haemopis marmorata *	34	5.8	10	44
Mooreobdella fervida *	30	5.2	6	26
Dina parva *	20	3.4	2	9
Dina dubia *	19	3.3	2	9
Haemopis grandis	10	1.7	4	17
Placobdella parasitica *	6	1.2	2	9
Theromyzon meyeri *	5	0.9	3	13
Erpobdella punctata	2	0.3	2	9
Macrobdella decora	2	0.3	2	9
Helobdella stagnalis *	1	0.2	1	4
Piscicola milneri *	1	0.2	1	4

* denotes a new record

+ does not include 726 juveniles

Mooreobdella fervida. These five species comprised 88.5% of the specimens collected.

FREQUENCY OF OCCURRENCE

Table 1 (previous page) lists the percentage of occurrence at collection sites for each species of leech collected. The species most frequently encountered were *Nephelopsis obscura*, followed by *Placobdella ornata*, *Glossiphonia complanata*, *Haemopis marmorata* and *Mooreobdella fervida*. Each of the remaining nine species was found in less than 20% of the collection sites. *Helobdella stagnalis* and *Piscicola milneri* were lowest in frequency of occurrence; each was found at only one collection site.

TIME COLLECTION

The time spent collecting in each habitat type was as follows (from Table A5, Appendix):

Inland Lakes	693 min.	(41.3%)
Bays and Harbors	616 min.	(36.9%)
Creeks	362 min.	(21.8%)

Thus, 78.2% of the collecting time was in lentic waters, and 21.8% in lotic. This may seem disproportionally in favor of lentic waters, but reflects the scarcity of flowing water on Isle Royale. Most streams are essentially a series of beaver ponds, and thus are not truely lotic.

Considering only the adult leeches collected, an average of 2.9 minutes were spent finding each leech. The average for lotic waters was 13.9 minutes per leech, and 2.4 minutes per leech in lentic waters. Thus we can infer that lakes and harbors have approximately 5.8 times the leech fauna as creeks. This is understandable, considering that many species are poorly adapted for survival in moving water.

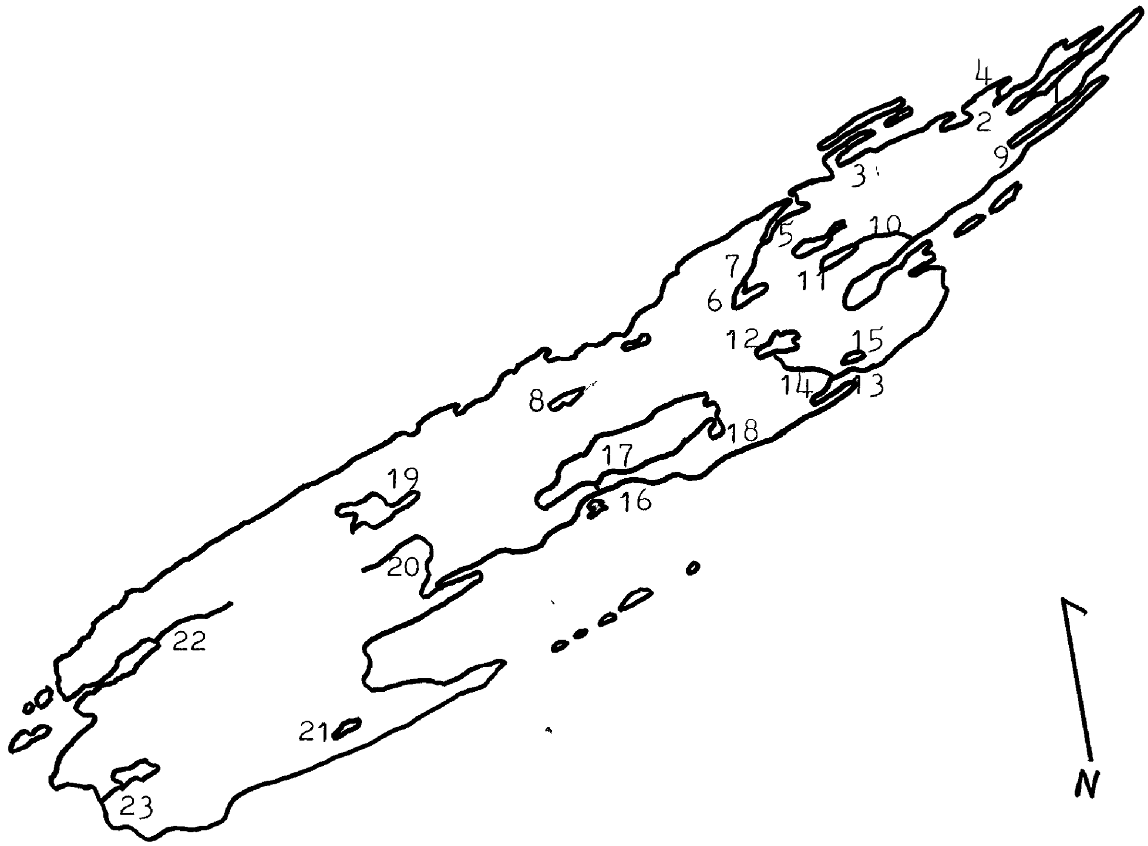
GEOGRAPHICAL DISTRIBUTION

ISLE ROYALE. Figure 2 lists the collection sites of this study and indicates their approximate location. The exact geographical location for each site is included in Table A1 of the Appendix. Figures 3, 4, 5 and 6 on pages 24 and 25 show the geographic distribution for members of each of the four families of leeches.

Members of the family Glossiphonidae appear to be widely distributed on Isle Royale (Figure 3). *Glossiphonia complanata* was found primarily in lentic waters, with a near equal affinity for sheltered harbors and inland lakes. Likewise, *Placobdella ornata* preferred lentic waters, but with few exceptions favored inland lakes over bays and harbors. The remaining species of this family (*Theromyzon meyeri*, *Placobdella parasitica* and *Helobdella stagnalis*) were also collected in lentic waters, but with limited distributions.

Only one specimen (*Piscicola milneri*) of the family Piscicolidae was collected, thus making it near impossible

FIGURE 2. COLLECTION SITES, ISLE ROYALE NATIONAL PARK.



1. Duncan Bay
2. Duncan Bay Creek
3. Pickerel Cove
4. Stockly Bay
5. McCargoe Cove
6. Chickenbone Lake
7. Chickenbone Creek
8. Hatchet Lake
9. Tobin Harbor
10. Benson Creek
11. Angleworm Lake
12. Lake Richie
13. Chippewa Harbor
14. Richie Creek
15. Lake Mason
16. Siskiwit River
17. Siskiwit Lake
18. Wood Lake
19. Lake Desor
20. Little Siskiwit River
21. Lake Halloran
22. Washington Creek
23. Feldtmann Creek

FIGURE 3. GEOGRAPHICAL DISTRIBUTION OF FAMILY GLOSSIPHONIDAE

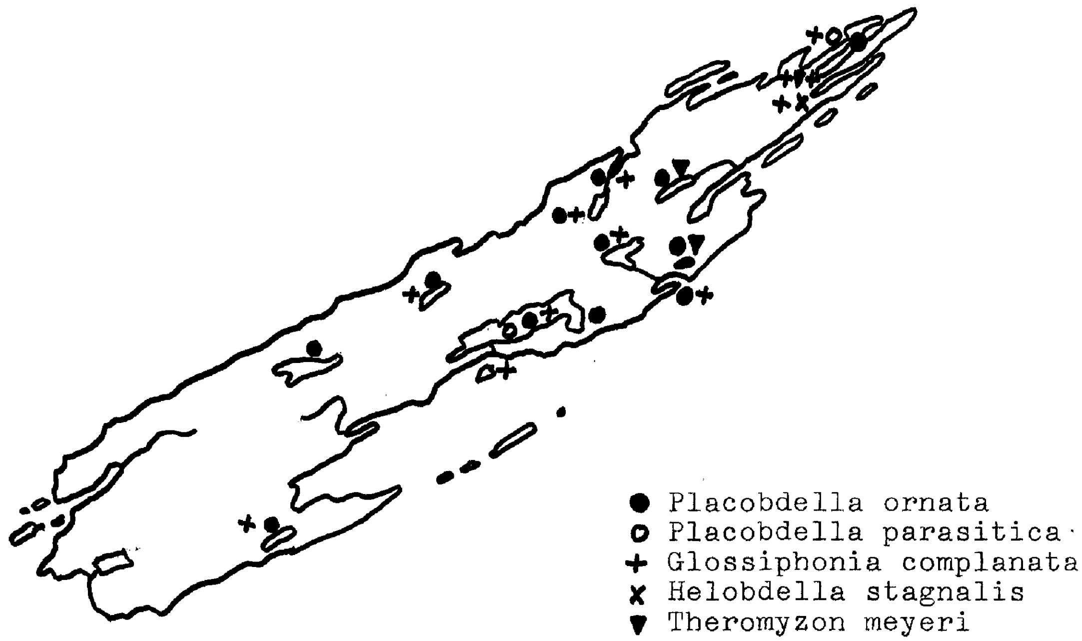


FIGURE 4. GEOGRAPHICAL DISTRIBUTION OF FAMILY PISCICOLIDAE

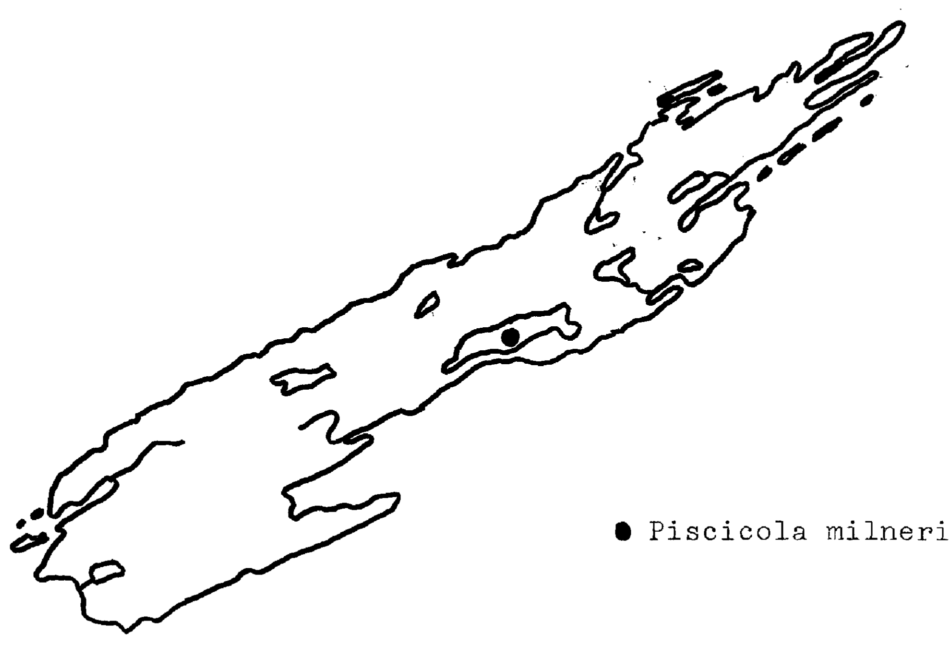


FIGURE 5. GEOGRAPHICAL DISTRIBUTION OF FAMILY HIRUDIDAE

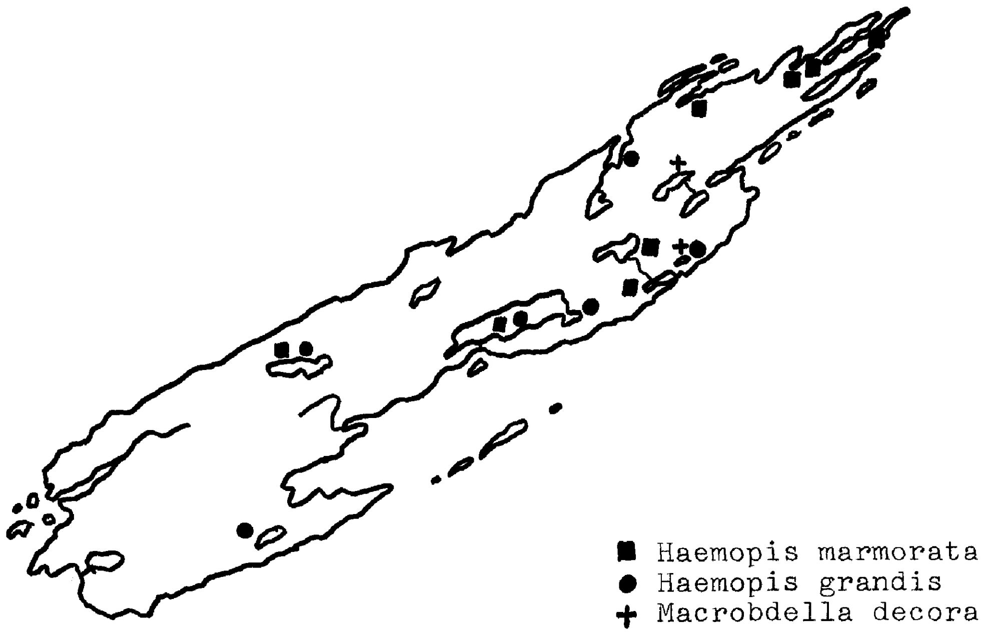
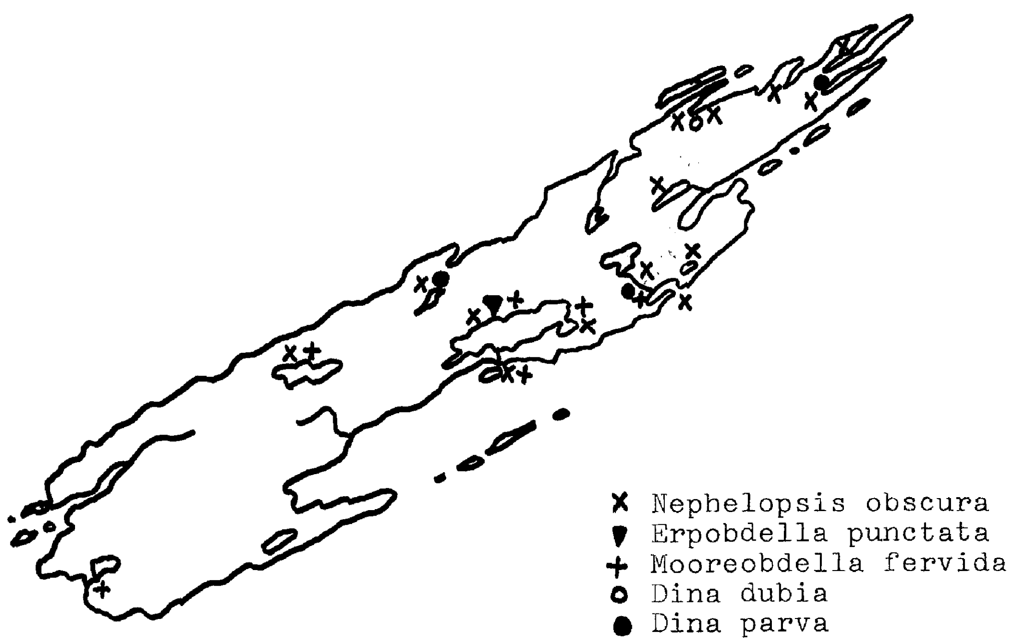


FIGURE 6. GEOGRAPHICAL DISTRIBUTION OF FAMILY ERPOBDELLIDAE



to estimate its distribution (Figure 4). Field work by Koelz (1929) and casual observations by the author in years prior to this study indicate that these fish leeches are not common.

The hirudids are less evenly distributed than the glossiphonids (Figure 5) and appear to be restricted more to the sandy areas of inland lakes or sheltered harbors. This holds true especially for *Haemopis marmorata*, and *H. grandis* to a lesser extent. The distribution of *Macrobdella decora* appears to be very limited.

One member of the family Erpobdellidae, *Nephelopsis obscura*, rivals the glossiphonids in its wide distribution (Figure 6). With only one exception, this leech was found in every collection site in which leeches were found. *Mooreobdella fervida* was found to be the most common leech in lotic waters, while *Erpobdella punctata*, *Dina parva* and *D. dubia* populations were too scattered to form any conclusions on distribution.

LAKE SUPERIOR REGION. All leech species collected on Isle Royale have been found by other researchers in Lake Superior or its connecting waters, or in states or provinces adjacent to it. Table 2, page 27, summarizes their findings.

For most species, distribution appears to be throughout the Lake Superior region. One notable exception is *Dina dubia*, a common cold water species of near-Arctic and Rocky Mountain regions and other similar but disjunct localities.

TABLE 2. DISTRIBUTION OF LEECH SPECIES REPORTED FROM LAKE SUPERIOR AND CONNECTING WATERS.

	ONTARIO		MINNESOTA			WISCONSIN	MICHIGAN	
	Moore 1925	Thomas 1966	Keith 1954	Moore 1912	Sawyer 1972	Bere 1931	Kopenski 1969	Sawyer 1972
Glossiphonia complanata	X	X	X	X	X	X	X	X
Helobdella stagnalis	X	X		X	X	X	X	X
Theromyzon meyeri			*	*				
Placobdella parasitica		X	X	X	X	X	X	X
Placobdella ornata		X	X	X	X	X	X	
Piscicola milneri	X	X					X	
Macrobdella decora	X		X	X		X	X	X
Haemopis grandis	X	X	X	X			X	X
Haemopis marmorata	X		X	X		X	X	X
Erpobdella punctata	X	X	X	X		X	X	X
Dina dubia								X
Dina parva	X	X	X	X	X	X	X	
Mooreobdella fervida			X	X	X		X	X
Nephelopsis obscura	X	X	X	X	X	X	X	X

* Reported as *Theromyzon occidentalis*, thought by many to be identical to *T. meyeri* (Sawyer, 1972).

Sawyer (1972) found this species in Luce and Schoolcraft counties of Upper Michigan. It is now apparent that Isle Royale has its own isolated population.

Other species not found on Isle Royale, but collected by others in the Lake Superior region include:

Helobdella fusca. Collected by J. P. Moore in Minnesota (1912) and Lake Nipigon, Ontario (1924).

Helobdella nepheloidea. Collected from Lake Nipigon by Moore (1924). Presently known as *H. elongata*.

Placobdella montifera. Collected in Minnesota (Moore, 1912; Keith, 1954) and Ontario (Moore, 1924; Thomas, 1966).

Actinobdella triannulata. Found in Lake Nipigon by Moore (1924).

Piscicola geometrica. Reported by Keith (1954) in Duluth, Minnesota. Sawyer (1972) doubts its existence in the United States, and suggests that collected specimens are probably *P. milneri*.

Illinobdella alba. Found in Marquette Co., Michigan by Kopenski (1969).

Haemopis lateralis. Collected in Minnesota by Moore (1912) and Keith (1954), and in Marquette Co., Michigan by Kopenski (personal communication).

Haemopis plumbeus. Minnesota collections by Moore (1912).

The absence of these species (and others) can probably be attributed to two main factors: (1) The absence of preferred hosts on Isle Royale, and/or (2) The isolation of

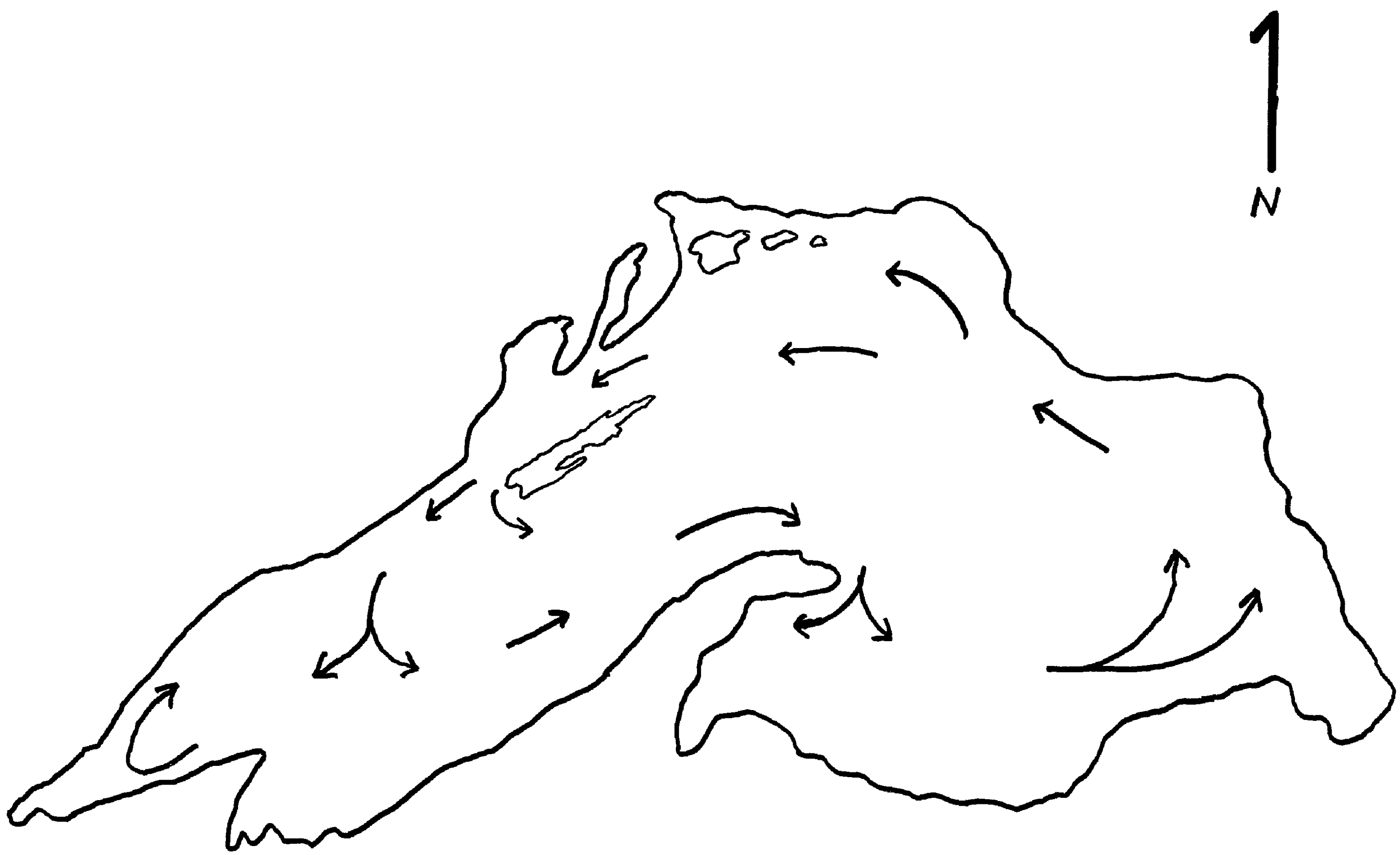
Isle Royale preventing easy colonization of new species.

For example, Placobdella montifera, has been known to parasitize certain warm water fish (large mouth bass, Micropterus salmoides; carp, Cyprinus carpio and others) that are unknown on Isle Royale. Although they do feed on other organisms (insect larvae, mussels, frogs), only fish could provide the mobility to immigrate (Hoffman, 1967).

The absence of Haemopis lateralis is probably the result of the water barrier between Isle Royale and the mainland--this free-living species exhibits terrestrial habits (Sawyer, 1972) and thus it is unlikely that it would emigrate across open water.

COLONIZATION OF SPECIES. After the retreat of the last glaciation about 11,000 years ago, Isle Royale was nearly devoid of life. Repopulation by species then began. Johnson (1965), in his herpetofauna study of Northern Michigan and Isle Royale, believed that Isle Royale reptiles originated from Canada. Considering that it is the nearest land mass (24 km to the north) and that water currents flow from the northeast (see Figure 7), it is safe to assume that most leeches are also of Canadian origin. Smaller species may have been carried by colonizing or migrant birds, either in a parasitic condition (e.g., Theromyzon meyeri) or possibly attached to an aquatic host (e.g., Placobdella spp. attached to a turtle, or Piscicola milneri on a lake trout). Drifting debris may have carried live leeches to the shores

FIGURE 7. SURFACE CURRENTS OF LAKE SUPERIOR. From Adams, 1908.



of Isle Royale (e.g., Glossiphonia complanata attached to aquatic plants) or the egg capsules of erpobdellids like Nephelopsis obscura attached to drifting logs. Dead animals, such as moose carcasses, drifting from Canada could have brought scavenger species like Haemopis spp. and Erpobdella punctata. Man, in recent times, may have imported some species as fish bait.

Individual species undoubtedly colonized Isle Royale by more than one means and over a great length of time, which in turn tended to distribute each species into varied habitats. Further intra-island migration of host species caused further dispersal. Thus, colonization of many species was probably universal, and final distribution was most likely the result of a combination of other factors such as food, predation and reproduction.

ANTICIPATED NEW RECORDS

A study of the present leeches found on Isle Royale can only suggest the species that may have attempted colonization and failed, and may eventually succeed, or species that may be introduced (naturally or not) in the future and survive. Also, in view of the several species in which only one or two specimens were found in this study, there exists the possibility that other species may exist in limited numbers and distribution. Consequently, the author offers the following suggestions as to the species that may be found in the future.

Future studies of the fish populations might produce one or possibly two piscicolids, *Illinobdella alba* and *I. punctata*. Kopenski (1969) found these leeches parasitizing yellow perch (*Perca flavescens*) in Upper Michigan. Also, a glossiphonid leech, *Actinobdella triannulata*, is known to parasitize suckers (*Catostomus* spp.) in Ontario (Meyer and Moore, 1954). Transient waterfowl may harbor and subsequently leave behind the western *Theromyzon rude*. Less likely finds might be closely related species of the genera *Placobdella*, *Glossiphonia*, and possibly *Helobdella*.

Fortunately, Isle Royale is immune to most unnatural developments such as dam building, irrigation and animal transplants that might upset the established leech fauna and ultimately change the aquatic ecosystems. One exception, however, is the importation of live leeches (cultured or live trapped on the mainland) for fish bait by some park visitors. In addition to the possible introduction of new species, these imported leeches could harbor a foreign (to Isle Royale) fungal growth or metacercariae of undesirable digenetic trematodes. As a matter of precaution, the importation of (and possibly, use of) leeches should be terminated for reasons similar to the banning of cut-bait on the inland lakes of Isle Royale.

ECOLOGICAL FACTORS REGULATING LEECH DISTRIBUTION

CHEMICAL FACTORS. Because of logistical limitations during the field portion of this study, chemical analysis of the habitat waters was restricted to approximate pH. But since chemical properties of water probably have a bearing on habitat preference of leeches, the following is a discussion of the findings of other researchers on this subject.

TOTAL ALKALINITY. Kopenski (1969), in his study of Marquette Co., Michigan, found that while most leeches have a wide range of tolerance for total alkalinity (expressed as ppm dissolved $CaCO_3$), certain species exhibited preferences. Considering only the more abundant species of this study, he found that *Nephelopsis obscura*, *Glossiphonia complanata* and *Haemopis marmorata* preferred the 60-99 ppm range, while *Placobdella ornata* and *P. parasitica* were more likely to be found in waters over 100 ppm. He concluded that total alkalinity had only an indirect effect on leech distribution--in that it affected the abundance of preferred food rather than the leech itself.

Herrmann (1970), in the plains and mountains of Colorado, encountered these same species in habitats with lower levels of alkalinity. In addition, he found *Dina dubia*, *Glossiphonia complanata* and *Helobdella stagnalis* regularly in soft waters (less than 10 ppm).

The only available data on the total alkalinity of Isle Royale waters comes from Sharp and Nord (1960). They described the inland lakes as typical of the Laurentian

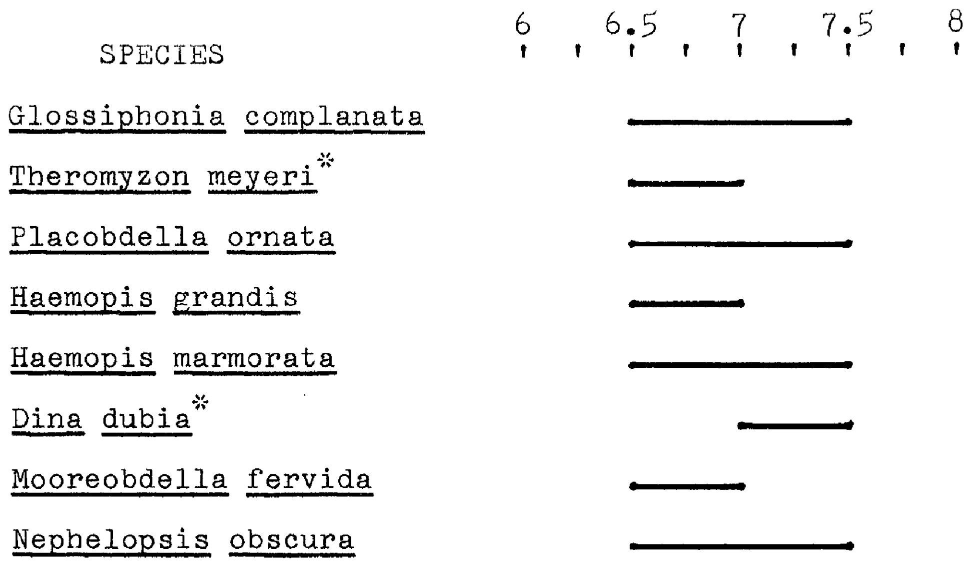
Shield area--soft. Total alkalinity ranged from 17.6 ppm (Lakes Siskiwit and Richie) to 32.5 ppm in Chickenbone Lake.

HYDROGEN ION CONCENTRATION (pH). Figure 8 gives the pH ranges measured in the habitats of selected species. pH readings were in the 6.5 to 7.5 range, reflecting the soft water conditions. Unfortunately, no other pH data from Isle Royale could be found to verify this somewhat narrow range of values.

The four most abundant species (*Nephelopsis obscura*, *Placobdella ornata*, *Glossiphonia complanata* and *Haemopis marmorata*) were collected throughout the range of measured pH values, suggesting that pH was not a limiting factor. Other species, however, appeared to have some preferences: *Theromyzon meyeri*, *Haemopis grandis* and *Mooreobdella fervida* were found in waters of pH 6.5 to 7.0, while *Dina dubia* appeared to favor more alkaline conditions (pH 7.0 to 7.5).

Other researchers found the more abundant species of this study in a wide range of pH values. Herrmann (1970) found these lentic species to be somewhat tolerant: *Glossiphonia complanata*, pH 6.3-10.2; *Dina dubia*, pH 6.4-9.9; *Nephelopsis obscura*, pH 6.3-9.8; and three others preferring near neutral to basic values: *Dina parva*, pH 7-9.8; *Placobdella ornata*, pH 7.2-9.7; and *Haemopis marmorata*, pH 7.7-9.4. Kopenski (1969) found these species in a slightly narrower range of pH values, with the majority of

FIGURE 8. pH RANGE OF SELECTED SPECIES.



* indicates limited sample

leeches between pH 7.0 and 8.5.

Although leech species may tolerate a wide range of chemical conditions, most show a preference (as demonstrated by abundance and frequency) for a particular set of conditions. Both Sandner (1951) and Kopenski (1969) concluded that perhaps a combination of chemical factors had more influence than any one factor; and that this indirect control was exercised through the absence or presence of preferred food and/or hosts.

PHYSICAL FACTORS

LOTIC vs. LENTIC. Table 3 compares the relative abundance and frequency of occurrence of each leech species in both lotic and lentic waters. A total of 95.5% of the 582 adult leeches collected were found in lentic waters.

Lentic waters also produced the greater diversity of leeches, 14 species as compared to four in lotic waters. The most frequent, as well as abundant, species were *Nephelopsis obscura*, *Placobdella ornata*, *Glossiphonia complanata* and *Haemopis marmorata*. The least common were *Helobdella stagnalis* and *Piscicola milneri*.

The species collected from lotic waters were: *Mooreobdella fervida*, *Nephelopsis obscura*, *Dina parva* and *Glossiphonia complanata*. Each species was also found in lentic waters.

The most frequent leech of lotic waters, *Mooreobdella fervida* (57% of sites), had a frequency of occurrence of

TABLE 3. RELATIVE ABUNDANCE AND FREQUENCY OF OCCURRENCE OF INDIVIDUAL SPECIES ACCORDING TO HABITAT TYPE.

	RELATIVE ABUNDANCE		FREQUENCY OF OCCURRENCE	
SPECIES	LENTIC	LOTIC	LENTIC	LOTIC
Nephelopsis obscura	53.0%	38%	100%	28%
Placobdella ornata	14.5	-	75	-
Glossiphonia complanata	9.3	4	62	14
Haemopis marmorata	6.1	-	62	-
Dina dubia	3.8	-	12	-
Mooreobdella fervida	3.2	50	12	57
Dina parva	3.2	8	6	14
Placobdella parasitica	3.0	-	12	-
Haemopis grandis	1.8	-	25	-
Theromyzon meyeri	0.9	-	19	-
Erpobdella punctata	0.4	-	12	-
Macrobdella decora	0.4	-	12	-
Helobdella stagnalis	0.2	-	6	-
Piscicola milneri	0.2	-	6	-

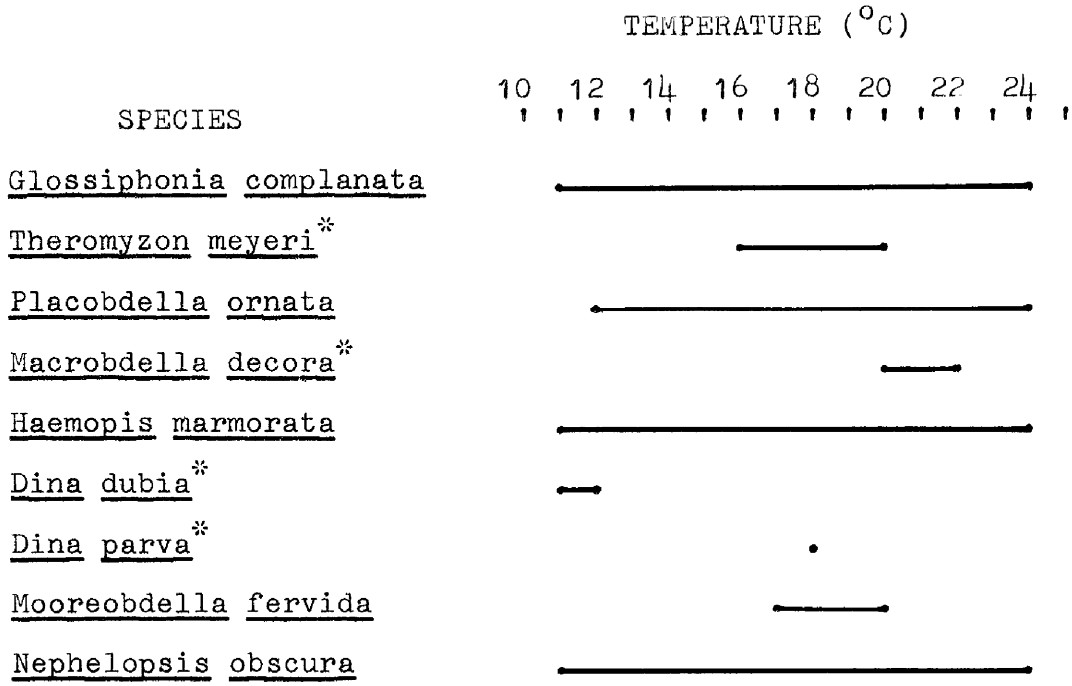
only 12% in lentic, and therefore, showed a distinct preference for lotic conditions. Kopenski (1969) found the reverse situation true, while Herrmann (1970) collected this species in lentic sites only. Nephelopsis obscura, ranking second in frequency (29%) among species found in lotic sites, was the most frequent in lentic sites (100%). Apparently the favorable conditions needed by this leech are found in both habitat types. Kopenski (1969) and Herrmann (1970) found this species only in lentic waters. The remaining two species, Dina parva and Glossiphonia complanata, were each found at only one lotic site.

Three of the four lotic species are erpobdellids, while Glossiphonia complanata is a glossiphonid. Thus, hirudids and piscicolids were found only in lentic conditions.

WATER TEMPERATURE. The water temperature for collection sites tended to be similar for each particular habitat. Temperatures of inland lakes ranged from 19°C to 24°C; harbors from 11°C to 14°C; and creeks, more dependent on their source, ranged from 14°C to 21°C.

Figure 9 gives the water temperature range measured in habitats of selected leech species on Isle Royale. Note that the four most abundant species (Nephelopsis obscura, Placobdella ornata, Glossiphonia complanata and Haemopis marmorata) all possess a similar wide range of temperature preferences, suggesting that they are not restricted by

FIGURE 9. TEMPERATURE RANGE OF SELECTED SPECIES.



* information based on a limited number of observations and are included only as a reference.

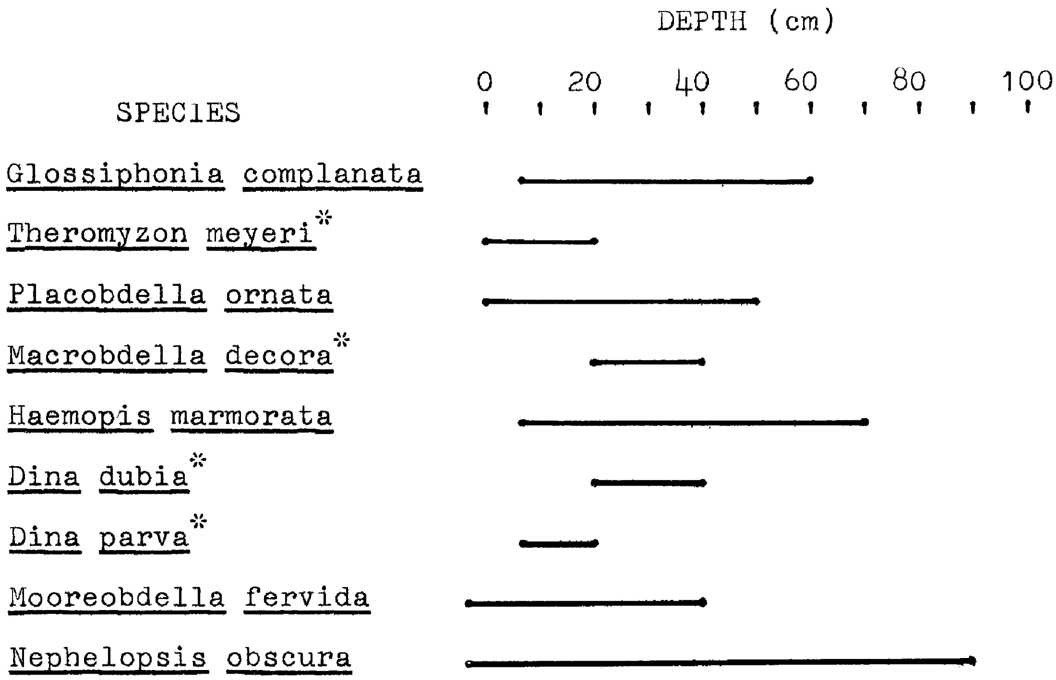
water temperature in their choice of habitat. This is understandable, since all habitats experience similar cool temperatures during spring and fall. A possible exception, _Nephelopsis obscura_, appears to prefer cooler temperatures since the number of specimens collected decreased with rising water temperatures. Kopenski (1969) never found this species above 16°C in Upper Michigan. This preference for cooler water is indicated by its range which is restricted to the northern United States, the Rocky Mountain region and Canada.

Leeches in warm water were decidedly more active than leeches of the same species in cold water. Specimens collected at 11°C were typically sluggish, while those in 20°C-24°C water were more likely to attempt an escape. This in turn could indirectly affect the leeches ability ot feed and escape predation.

Most authors do not consider water temperature as a single limiting factor in leech distribution and abundance, but rather as a co-factor along with other variables. Bennike (1943) generalized that leeches fail to reproduce in waters not reaching a temperature of 11°C, but Becker and Katz (1965) and Herrman (1970) found _Piscicola salmositica_ and _Helobdella stagnalis_ (respectively) propagating at 5°C. Since all waters on Isle Royale reach at least 11°C, water temperature probably does not hinder reproduction.

WATER DEPTH. Figure 10 summarizes the water depths at

FIGURE 10. COLLECTION DEPTHS FOR SELECTED SPECIES.



* indicates limited sample

which certain species were collected. Most leeches were found in the 0-0.5 m range (due in part to the methods of collection), with a maximum recorded depth of 0.9 m. An exception was *Piscicola milneri*, found attached to a lake trout caught on an artificial lure at an approximate depth of 5 m. One characteristic of both inland lakes and harbors of Lake Superior limiting the leeches to shallow depths is the presence usually of a drop-off near the shore.

Again the most abundant species showed the greatest range, suggesting their abundance is the result of an ability to tolerate a wide range of depths.

Kopenski (1969) found leeches most abundant in the 0-1.2 m range, and concluded that although they are probably present in deeper water, they are limited by the lack of available vegetation and substratum for attachment, and low oxygen concentrations. Sapkarev (1967), in Lake Mendota, Wisconsin, found the maximum density of glossiphonids at 0-3 m, and erpobdellids at 0-0.5 m. Depth ranges can be misleading however, since most collecting is done in shallow water. Use of mechanical means such as an Ekman dredge is at best haphazard when one considers the mobility of most free living leeches.

WATER COLOR. No quantitative measurements of water color were taken during this study. Instead, each site was classified in approximate terms such as clear, tan, brown, etc. Table 4 compares the number of individuals to the water color in which they were collected.

Dina dubia and *Nephelopsis obscura* demonstrated their preference for the clear, cool waters, while *Mooreobdella fervida* and *Placobdella ornata* were more likely found in browner waters. *Dina parva*, although based on a small sample, was the only species preferring dark brown waters. *Glossiphonia complanata* and *Nephelopsis obscura* appeared to tolerate the full range of conditions.

Water color in itself is probably not a limiting factor in distribution and abundance, but may serve as an indicator of other controlling factors. For example, darker waters usually denote warmer temperatures and higher organic content, which in turn can influence the abundance of food or the presence of preferred hosts.

Kopenski (1969) found instances of great numbers and variety of species in both clear and brown waters, and thus concluded that water color was a poor indicator of leech species present.

BOTTOM COMPOSITION. Figure 11 lists the type of bottom where selected species were found. The number refers to the frequency of occurrence of similar conditions. Specific conclusions from the data should be avoided, since the classifications are general and do not take into consideration slight differences or transition zones.

The two glossiphonids included in the comparison,

TABLE 4. NUMBER OF LEECHES COLLECTED IN EACH WATER COLOR TYPE.

SPECIES	VERY CLEAR	CLEAR	TAN	BROWN	DARK BROWN
Glossiphonia complanata	3	23	3	12	12
Helobdella stagnalis	-	1	-	-	-
Theromyzon meyeri	-	-	1	3	1
Placobdella parasitica	-	1	5	-	-
Placobdella ornata	-	3	40	35	14
Piscicola milneri	-	-	1	-	-
Macrobdella decora	-	-	1	-	1
Haemopis grandis	-	-	8	-	3
Haemopis marmorata	-	12	2	19	-
Erpobdella punctata	-	-	1	1	-
Dina dubia	19	2	-	-	-
Mooreobdella fervida	-	5	25	1	-
Dina parva	-	-	-	2	18
Nephelopsis obscura	4	195	38	27	43

FIGURE 11. BOTTOM COMPOSITION OF COLLECTION SITES FOR SELECTED SPECIES.

BOTTOM COMPOSITION	*Glossiphonia complanata*	*Placobdella ornata*	*Macrobdella decora*	*Haemopis grandis*	*Haemopis marmorata*	*Dina parva*	*Mooreobdella fervida*	*Nephelopsis obscura*	TOTAL
SAND									
Sand, detritus	5	10	2	5	7		2	15	46
Sand, boulders		1			1			1	3
Sand, detritus, boulders	2	1			1		1	3	8
SAND/GRAVEL									
Sand/gravel, detritus	2	1			1			2	6
Sand/gravel, boulders						1	1	2	4
GRAVEL	1							1	2
Gravel, detritus		1						1	2
Gravel, boulders	2	1			1	1	2	4	11
Gravel, bedrock		1						1	2
Gravel, detritus, boulders	1							1	2
Gravel, boulders, bedrock	2	1			3		1	6	13
MUCK					1				
Muck, detritus	3	3						3	9
Muck, detritus, boulders	1	1			1			1	4

Glossiphonia complanata and *Placobdella ornata*, typically preferred areas of sand and/or fine gravel with submerged sticks and logs. Of the hirudids, *Haemopis marmorata* and *H. grandis* were most commonly found hiding under submerged logs and sticks on a sandy bottom. This was also the most frequent preference of *Nephelopsis obscura*, with a nearly equal affinity for large rocks on a gravel bottom. Some species, such as *Theromyzon meyeri* and *Placobdella ornata* were found attached to the undersides of yellow water lily pads.

Although most species exhibited substrate preferences, the most important factor was the presence of submerged objects to attach to or hide under. Kopenski (1969) listed protection from predation and water currents, and the presence of food organisms seeking the same protection as possible reasons for the need of submerged objects.

BIOLOGICAL FACTORS

FEEDING HABITS. Table 5 lists the foods preferred by the leeches on Isle Royale, based on my own observations and published reports from other geographical areas.

Glossiphonidae. Members of this family use their muscular proboscis to withdraw body fluids or soft viscera of their host through a small pore-like mouth, and either feed on whole organisms or are ectoparasites on both invertebrates and vertebrates.

Glossiphonia complanata, commonly known as the snail leech, depends heavily on snails for food. All sites from which this species was collected on Isle Royale contained snails, notably *Lymnea stagnalis*, *Physa* spp. and *Planorbis* spp. Sapkarev (1967) and Kopenski (1969) reported the latter two genera being preyed upon by this leech. Sawyer (1972) observed a brooding *G. complanata* adult feeding on *Physa* spp. Other reported foods are aquatic annelids and insect larvae.

Helobdella stagnalis appears to have very similar food preferences to *G. complanata*, but it also scavenges dead animal carcasses in the water and sucking blood from vertebrate wounds (Moore, 1912).

Like others of its genus, *Theromyzon meyeri* is thought to feed exclusively on the blood of waterfowl by infesting the nasal cavities or other highly vascularized areas. Meyer (1954) and Moore (1966) found examples of this in Canada, and Moore suggested this genus could be responsible

TABLE 5. FOOD OF ISLE ROYALE LEECHES.

SPECIES	Other leeches	Earthworms	Aq. annelids	Snails	Crustaceans	Aq. insects	Fish	Salamanders	Frogs	Turtles	Birds	Mammals	Scavenging
Glossiphonia complanata	X		X	X		X							
Helobdella stagnalis	X		X	X		X	X		X			X	X
Theromyzon meyeri											X		
Placobdella parasitica	X		X			X	X	X	X	X			
Placobdella ornata			X	X		X			X	X	X	X	
Piscicola milneri							X						
Macrobdella decora			X				X	X	X	X		X	
Haemopis grandis		X	X	X	X	X	X						X
Haemopis marmorata	X	X	X	X	X	X	X						X
Erpobdella punctata	X	X	X	X		X			X			X	X
Dina dubia						X							
Mooreobdella fervida			X		X	X							X
Dina parva			X		X	X							X
Nephelopsis obscura	X		X	X		X							X

for significant young waterfowl mortality. Because of this specialized feeding, its distribution is directly related to that of migratory waterfowl. Considering the abundance of such species as loons (Gavia immer), black ducks (Anas rubripes) and mergansers (Mergus spp.) on Isle Royale, this leech is probably more plentiful than indicated by this study.

Placobdella ornata and P. parasitica are commonly known as the turtle leeches. Only one species of turtle (western painted, Chrysemys picta belli) is found on Isle Royale, and with few exceptions, all populations are limited. Of the 12 collecting sites producing Placobdella spp., 10 are known by this author to contain this turtle. Sawyer (1972) found that although both feed chiefly on turtles, P. ornata is less dependent on turtles than P. parasitica. Considering the low turtle population on Isle Royale, this may explain the greater relative abundance of P. ornata (15.7%) as compared to P. parasitica (1.2%). Other recorded hosts include: P. parasitica attached to a yellow perch, and another to a larger leech, Macrobdella decora (Ryerson, 1915); Kopenski (1969) found this same species parasitizing a red-spotted newt (Notopthalmus viridescens); Miller (1937) listed snails and Moore (1966) recorded birds as a source of food for P. ornata. In early August, 1974, the author was shown and identified a P. ornata that had attached to the pectoral area and had drawn a considerable amount of blood from a person swimming in Lake Desor. The author has not encountered any mention of human parasitism in published works.

Piscicolidae. This family represents the true fish leeches, on which they feed almost exclusively by withdrawing body fluids through a muscular proboscis.

Only one specimen of this family, *Piscicola milneri*, was collected from a lake trout (*Salvelinus namaycush*) during this study. This was the same host described by Ryerson (1915), while Moore (1964) found this species attached to the fins of a white sucker (*Catostomus commersoni*) in Alberta.

Hirudidae. Members of this family possess a large mouth with lips, but lack an eversible proboscis. Some species have jaws with teeth to penetrate their host's body wall and withdraw body fluids, while others have vestigial jaws with no teeth and must consume their prey whole or attach to existing wounds.

Both *Macrobdella decora* and *Haemopis marmorata* possess jaws, but prefer somewhat different foods. *M. decora* is a true blood sucker, and thus feeds mainly on fish, amphibians, turtles and large mammals. The specimens collected during this study were found swimming free, but Adams (1908) found one parasitizing a frog (*Rana* sp.) on Isle Royale. Rupp and Meyer (1954) observed this leech (along with *H. grandis*) attacking brook trout (*Salvelinus fontinalis*) in Maine. Others report it feeds voraciously on insect larvae and amphibian eggs. This leech was not observed feeding during this study.

Haemopis marmorata is an active predator, predominantly of smaller aquatic organisms (leeches, insects, crustaceans, etc.) and sometimes fish. The author observed one specimen consuming the soft insides of a closed clam (*Utterbachia* sp.). It appeared to have entered through a small hole near the hinge, but it is not known if the leech made the hole. Other observations of the author included regurgitated horsehair worms (probably *Gordius* sp.), snail shells and blood.

Haemopis grandis, lacking jaws and teeth, is dependent on small aquatic animals for food. One specimen was found scavenging on a northern pike (*Esox lucius*) head. Rupp and Meyer (1954) noted its secondary involvement with *Macrobdella decora* attacking brook trout--the *H. grandis* would attach to the open wounds caused by the *M. decora*, and then suck blood.

During late June, 1972, the author observed what appeared to be several leeches attached to the flank area of a nursing cow moose. Denuded areas and open sores probably caused by scraping against trees to rid itself of the winter tick (*Dermacentor albipictus*) were numerous, and it is hypothesized here that *Haemopis marmorata* were drawing blood from these wounds. The leeches were probably attracted to the exposed wounds while the moose was feeding on aquatic vegetation in the water. Unfortunately, I could approach the moose no closer than 8 m and could only surmise the identity of the leech species by its size and dark color. Correspondence from L. David Mech and an interview of Rolf Peterson, both involved in recent years with Purdue University's wolf-moose research on Isle Royale, indicated they had not observed this during their studies.

Erpobdellidae. This family lacks both jaws and a muscular proboscis and so must swallow their food whole. Thus, their food is restricted to small aquatic insects, snails and the like.

Erpobdella punctata feeds mainly on aquatic insects, plus other annelids and snails. The great abundance of this type of food is not reflected in the limited numbers of this leech. Therefore, we must conclude that food is not a limiting factor. *Nephelopsis obscura*, *Mooreobdella fervida* and *Dina parva* have similar preferences for small aquatic organisms. All four species are known to act as scavengers on larger dead animals in water (Moore, 1912, 1920, 1924). In addition, *N. obscura* feeds on small snails, and Sawyer (1972) observed an unfed adult eating an immature *Erpobdella punctata*. During this study, the author had reports of a small blue-black leech attaching to and drawing blood from the feet of humans wading in Hatchet Lake. However, I was unable to witness any such incident to verify if the leech in question was *Dina parva*. No other leech collected at that site fits the description. Little is known of the feeding habits of *D. dubia*, other than that Sawyer (1972) found insect larvae in dissected individuals. Neither species of *Dina* were observed feeding during this study.

The majority of the leech species on Isle Royale can utilize several alternative food sources. This does not preclude preferences for particular species, which in turn can affect distribution and abundance of the leeches. As an example, although *Placobdella ornata* and *P. parasitica* may use turtles as a primary host and ultimately be influenced by their abundance and distribution, they can still feed on aquatic insect larvae, frogs, etc., in the absence of turtle blood.

REPRODUCTION. The following is a summary of the important reproductive habits of the leeches found on Isle Royale, as well as an attempt to correlate this information with relative abundance and distribution.

Glossiphonidae. Members of this family, lacking an eversible penis, use hypodermic implanation for sperm transfer. Sperm is deposited in spermatophores which directly penetrate the body wall of another leech or are attached to the substratum for later implantation. Eggs in cocoons are later attached to the substrate (except *Helobdella stagnalis*, on its venter), whereupon the parent broods them until hatching. Newly-hatched young then attach themselves to their parent's ventral surface while developing.

Brooding *Glossiphonia complanata* were found by Sawyer (1972) from April to early June in lower Michigan, suggesting breeding occurs only in early spring. Since collections for this study began in mid-June, this may explain why only non-breeding adults were found. Mann (1962) suggested this species breeds twice per year in England, but Moore (1966) found no evidence of this in North America. Fecundity of G. complanata appears to be greater in North America than in England: Mann (1957) found a mean of 33 young in England, while Sawyer (1972) recorded a mean of 129, and Moore (1966) found one adult with 121 eggs in Alberta.

Helobdella stagnalis differs from other glossiphonids by attaching the eggs to their own venter rather than the substratum. Breeding appears to occur more than once per year, with an average of 20 young produced (Kopenski, 1969). Only one non-breeding adult was found on Isle Royale.

Sawyer (1972) observed a captive Theromyzon meyeri lay 209 eggs in seven cocoons, and then position itself over the eggs and periodically circulate fresh water over them by body movements. He also has observed T. meyeri young attached to their parent's venter. Only adults were encountered in this study.

Placobdella ornata and P. parasitica have very similar reproductive habits. Breeding occurs from spring through autumn (through late fall for P. parasitica), but predominantly during the warm summer months (Sawyer, 1972). During this study, 726 P. ornata young were collected along with 12 adults for an average brood size of 60.5 individuals. One large adult was brooding approximately 125 yellowish eggs. Kopenski (1969) concluded that from 90-100 young are produced per brood, with more than one brood per year possible.

Piscicolidae. Members of this family use spermatophores in reproduction like the glossiphonids, and some deposit the cocoons (with only one egg each) on their host. Only one of these true fish leeches, Piscicola milneri, was collected. Specific details on its reproductive habits are not known.

Hirudidae. These gnathobdellids posses a penis for sperm transfer between individuals, and thus do not form spermatophores. Eggs are deposited in capsules which are abandoned in mud or damp earth. Unfortunately, little is known about the reproductive habits of most species.

Haemopis marmorata appears to breed from late spring to early summer, as newly hatched young have been found from June 30 to mid-October (J. P. Moore, 1922; J. E. Moore, 1966). Since H. grandis shares some habits with this species, its reproduction may be similar. Moore (1923) found that engorgement of food in the spring by Macrobdella decora was a prerequisite to breeding and found newly-hatched young in New York during July and August.

Erpobdellidae. Members of this family lack a penis and so use spermatophores (like glossiphonids) for sperm transfer. Eggs are deposited in flattened cocoons which are firmly attached to the undersides of large rocks and logs, and then abandoned.

Nephelopsis obscura appears to reproduce during the spring and summer months, with the possibility of more than one brood per year (Kopenski, 1969). Kopenski found an average of seven young in 20 dissected cocoons, but believed the number should be greater. Sawyer (1972) reports Verrill (1875) found 5-10 eggs or young per cocoon. The unique *N. obscura* cocoons were omnipresent on Isle Royale, particularly in cooler waters, reflecting the great abundance of this leech. Inspection of numerous cocoons failed to reveal any young, nor were any adults observed depositing eggs in cocoons. A large number of cocoons were found empty or decomposing, suggesting that their strong adherence to the substrate and their chitin-like composition allowed them to weather the winter intact.

Sawyer (1970) found *Erpobdella punctata* to lay an average of 10 cocoons with an average of five eggs during April and May, which then hatched in 3-4 weeks. He also found a 93% mortality rate during the first year, due mainly to cannibalism and snail predation of cocoons. No cocoons, and only two adults, were found on Isle Royale.

Sawyer (1972) found a breeding population (May, 1967) of *Dina dubia* in 12°C water of Southern Michigan. Isolated individuals then deposited an average of 7.9 cocoons with an average of 4.15 eggs per cocoon. Little is known of the reproductive habits of *Dina parva* and *Mooreobdella fervida*, but it is reasonable to expect them to parallel other erpobdellids.

Glossiphonids are more fecund and protective than the hirudids and erpobdellids, and thus should give their young an advantage over others. But reproduction cannot be the single most important factor, since the most abundant leech *Nephelopsis obscura* is not a glossiphonid. Thus, we must conclude that reproduction is intertwined with other factors such as feeding and predation in determining abundance and distribution.

PREDATION OF LEECHES. Although incomplete, the list of animals known to prey upon leeches encompasses most of the larger fish, turtles, waterfowl, wading birds and other non-aquatic birds. Additionally, leeches are preferred bait for some fisherman and are thus live-trapped. And for many leeches, large or small, other leeches pose a sizeable threat. For example, the larger *Haemopis marmorata* has been known to eat *Helobdella stagnalis*, *Erpobdella punctata*, *Nephelopsis obscura*, *Dina dubia* and other *H. marmorata* (J. P. Moore, 1912, 1924; J. E. Moore, 1966; Kopenski, 1969). But smaller leeches can parasitize the larger: Sawyer (1972) observed *Glossiphonia complanata* feeding upon *Erpobdella punctata*, *Haemopis grandis* and *H. marmorata*. Kopenski (1969) concluded that the hirudids, with their greater size and large mouths, probably take the most leeches, while the erpobdellids with their medium size and increased activity are probably the most preyed upon.

On Isle Royale, we can reasonably assume that larger fish (northern pike, yellow walleye, yellow perch, lake trout, brook trout), western painted turtles, common loons, ducks (common and red-breasted mergansers), wading birds (great blue heron, american bittern) and others take an indeterminate toll of the leech population. However, it is doubtful if this predation has any great effect.

PARASITES OF LEECHES. Leeches, as an integral part of their ecosystem, also serve as hosts in the life cycle of other parasitic organisms. The most common, as reported by Moore (1964) and Sawyer (1972), are encysted metacercariae of digenetic trematodes (Platyhelminthes: Trematoda). These endoparasitic flatworms (flukes) of vertebrates use invertebrates as intermediate hosts. Cysts were observed in the body wall of some leech specimens, notably *Nephelopsis obscura*, during this study. Sawyer (1971) found *Erpobdella punctata* serving as a host for juvenile nematomorphs (horsehair worms), and lists hemoflagellates and trypanosomes as other parasites.

Although important as an intermediate host in the life cycle of other organisms, this parasitism probably has little effect on the abundance and distribution of leeches.

CHAPTER V

CONCLUSIONS

1. Fourteen species of leeches, representing four families, were found in the waters of Isle Royale National Park. *Placobdella ornata*, *Haemopis marmorata*, *Mooreobdella fervida*, *Dina parva*, *Dina dubia*, *Placobdella parasitica*, *Theromyzon meyeri*, *Helobdella stagnalis* and *Piscicola milneri* are new records, while *Nephelopsis obscura*, *Glossiphonia complanata*, *Haemopis grandis*, *Erpobdella punctata* and *Macrobdella decora* have been previously recorded.

2. The leeches found on Isle Royale are indicative of the 23 species found in the Lake Superior region. An exception is *Dina dubia*, a near-Arctic species. The leech fauna is further characterized by the low abundance of many cosmopolitan species (e.g., *Helobdella stagnalis* and *Erpobdella punctata*).

3. The lentic leech fauna of Isle Royale is characterized by four species: *Nephelopsis obscura*, *Placobdella ornata*, *Glossiphonia complanata* and *Haemopis marmorata*. All were found in 62% or more of the sites examined, and all share a preference for insect larvae as food. *Nephelopsis obscura*

was found in every lentic site and totalled over half of all leeches collected.

4. The lotic waters are characterized by *Mooreobdella fervida*, and to a lesser extent, *Nephelopsis obscura*. The former is well adapted to moving water, while the presence of *N. obscura* in lotic waters is probably an offshoot of its great abundance in lentic waters.

5. Using the average time spent collecting each leech as an indicator, the abundance of leeches appears to be nearly six times greater in lentic waters than in lotic waters. Also, the lentic sites had an average of 4.3 species of leeches as compared to only 1.4 species in lotic waters.

6. Species preferring slightly acidic waters were *Theromyzon meyeri*, *Haemopis grandis* and *Mooreobdella fervida*, while *Dina dubia* was collected only in slightly alkaline waters.

7. Leeches were found in waters with a variety of bottom compositions, but the single feature common to most sites was underwater debris (logs, sticks, rocks) for attachment and protection.

8. Greater distribution and abundance of leeches appears to be a direct result of the species ability to tolerate a diversity of physical and chemical conditions.

SELECTED BIBLIOGRAPHY

Adams, Charles C. 1908. An ecological survey of Isle Royale, Lake Superior. A report from the University of Michigan Museum, published by the State Biological Survey, as a part of the report of the Board of the Geological Survey for 1908. Leeches, pp. 250-252.

Bennike, S.A.B. 1943. Contributions to the ecology and biology of the Danish freshwater leeches. Folia Limnologica Scandinavica 2:1-109.

Bere, Ruby. 1931. Leeches from the lakes of northeastern Wisconsin. Wisconsin Academy of Science Transactions 26:437-440.

Cheng, Thomas C. 1964. The Biology of Animal Parasites. W.B. Saunders Co., Philadelphia. 727 pp.

Davis, Ronald W. 1971. A key to the freshwater Hirudinoidea of Canada. Journal of the Fisheries Research Board of Canada. 28(4):543-552.

Eddy, Samuel and A.C. Hodson. 1961. Taxonomic Keys to the Common Animals of the North Central States. Burgess Publishing Co., Minneapolis. 162 pp.

Edmondson, W.T., ed. 1959. Freshwater Biology, 2nd edition. John Wiley and Sons, Inc., New York.

Herrmann, Scott J. 1970. Systematics, distribution and ecology of Colorado Hirudinea. American Midland Naturalist 83(1):1-37

Hoffman, G.L. 1967. Parasites of North American Freshwater Fishes. University of California Press, Berkeley and Los Angeles. Hirudinea, pp. 288-298.

Hubbs, Carl L. and Karl F. Lagler. 1958. Fishes of the Great Lakes Region. The University of Michigan Press, Ann Arbor. 213 pp.

Huber, N. King. 1975. The Geologic Story of Isle Royale National Park. Government Printing Office, Washington D.C. In press.

Johnson, Wendel J. 1965. A zoogeographical analysis of the Herpetofauna in Northern Michigan and adjacent Isle Royale. M.S. Thesis, Michigan State University.

Johnsson, R.G., and P.C. Shelton. 1960. The Vertebrates of Isle Royale National Park. Wolf's Eye 4(3):24 pp. Isle Royale Natural History Association, Houghton, Michigan.

Keith, M.M. 1954. A survey of the leeches (Hirudinea) of the Duluth area. Proceedings, Minnesota Academy of Science 22:91-92.

__________. 1955. Notes on some leeches (Hirudinea) from the Yukon Territory, Canada, and Alaska. Proceedings, Minnesota Academy of Science 23:103-104.

__________. 1960. A simplified key to the leeches of Minnesota. Proceedings, Minnesota Academy of Science 27:190-199.

Klemm, Donald J. 1972. Freshwater leeches (Annelida: Hirudinea) of North America. Biota of Freshwater Ecosystems Identification Manual No. 8. Government Printing Office, Washington, D.C. 53 pp.

Koelz, Walter. 1929. A survey of the lakes of Isle Royale, with an account of the fishes occurring in them. Unpublished manuscript. University of Michigan.

Kopenski, Martin L. 1969. Selected studies of Michigan leeches. Ph.D. Thesis, Michigan State University.

Krefting, L.W. 1951. What is the future of the Isle Royale moose herd? Transactions of North American Wildlife Conference 16:461-470.

Lagler, K.F., and C.R. Goldman. 1959. Fishes and Sport Fishing in Isle Royale National Park. Isle Royale Natural History Association, Houghton, Michigan.

Linn, Robert M. 1957. The spruce-fir, maple-birch transition in Isle Royale National Park, Lake Superior. Ph.D. Thesis, Duke University.

Mann, K.H. 1955. The ecology of the British freshwater leeches. Journal of Animal Ecology 24:98-119.

__________. 1957. A study of a population of the leech Glossiphonia complanata (L.). Journal of Animal Ecology 26:99-111.

Mann, K.H. 1962. Leeches (Hirudinea): their structure, physiology, ecology and embryology. Permamon Press, New York.

__________. 1964. A Key to the British Freshwater Leeches with Notes on Their Ecology. Freshwater Biological Association Scientific Publication No. 14.

Mathers, Carol K. 1948. The leeches of the Okobji region. Iowa Academy of Science Proceedings 55:397-425.

Mech, L. David. 1966. The Wolves of Isle Royale. Government Printing Office, Washington, D.C. 210 pp.

Meyer, Marvin C. 1937. Notes on some leeches from Ontario and Quebec. Canadian Field-Naturalist 51:117-119.

__________. 1954. The larger animal parasites of freshwater fishes of Maine. Maine Department of Inland Fish and Game Bulletin No. 1.

Miller, John A. 1937. A study of the leeches of Michigan with keys to orders, suborders and species. Ohio Journal of Science 37:85-90.

Moore, J.E. 1964. Notes on the leeches (Hirudinea) of Alberta. National Museum of Canada Natural History Papers No. 27.

__________. 1966a. Further notes on Alberta leeches (Hirudinea). National Museum of Canada Natural History Papers No. 32.

__________. 1966b. New records of leeches (Hirudinea) for Saskatchewan. Canadian Field-Naturalist 80(1):59-60.

Moore, J.P. 1912. Leeches of Minnesota. In Geological and Natural History Survey of Minnesota, Zoology 5 (pt. III, Classification):64-150.

__________. 1922. The freshwater leeches (Hirudinea) of southern Canada. Canadian Field-Naturalist 36:6-11, 37-39.

__________. 1923. The control of blood-sucking leeches, with an account of the leeches of Palisades Interstate Park. New York State College of Forestry, Roosevelt Wild Life Bulletin 2(1):1-53.

__________. 1924. The leeches (Hirudinea) of Lake Nipigon. University of Toronto Studies in Biology 23:17-30.

Moore, J.P. 1936. The leeches of Lake Nipissing. Canadian Field Naturalist 50:112-114.

Moore, J.P., and Marvin C. Meyer. 1951. Leeches (Hirudinea) from Alaska and adjacent waters. Wasmann Journal of Biology 9:11-77

Nachtreib, Henry F., Ernest E. Hemingway, and J.P. Moore. 1912. The leeches of Minnesota. Geological and Natural History Survey of Minnesota, Zoology, vol. 5.

Pawlowski, L.K. 1936. Zur okologie der Hirudineen--Fauna der Wigryseen. Arch. Hydro-Biol. Rybact. 10:1-47.

Pennak, Robert W. 1953. Freshwater invertebrates of the United States. Ronald Press, New York. Hirudinea, pp. 302-320.

Richardson, L.R. 1942. Observations on the migratory behavior of leeches. Canadian Field-Naturalist 56:67-70.

__________. 1943. The freshwater leeches of Prince Edward Island and the problem of the distribution of leeches. Canadian Field-Naturalist 57:89-91.

Rupp, R.S., and Marvin C. Meyer. 1954. Mortality among brook trout, Salvelinus fontinalis, resulting from attacks of freshwater leeches. Copeia 1954(4):294-295.

Ruthven, A.G. 1906. An ecological survey in the Porcupine Mountains and Isle Royale, Michigan. In Michigan Geological Survey, Annual Report 1905. pp. 17-55.

Ryerson, C.G.S. 1915. Notes on the Hirudinea of Georgian Bay. In Canadian Biological Board, Contributions to Canadian Biology, 1911-1914. Fasc. 2, pp. 165-176.

Sandner, H. 1951. Badania nad fauna Pijawek. Acta Zool. Oecol. Lodz. 4:1-50

Sapkarev, J.A. 1968. The taxonomy and ecology of leeches (Hirudinea) of Lake Mendota, Wisconsin. Wisconsin Academy of Sciences, Arts and Letters Transactions. 56:225-253.

Sawyer, Roy T. 1968. Notes on the natural history of the leeches (Hirudinea) on the George Reserve, Michigan. Ohio Journal of Science 68(4):226-228.

__________. 1970. Observations on the natural history and behavior of Erpobdella punctata (Annelida:Hirudinea). American Midland Naturalist 83(1):65-80.

Sawyer, Roy T. 1971. Erpobdellid leeches as new hosts for the nematomorph, _Gordius_ sp. _Journal of Parasitology_ 57(2):285

__________. 1972. North American freshwater leeches, exclusive of the Piscicolidae with a key to all species. _Illinois Biological Monographs_ 46:1-154.

Sharp and Nord. 1960. A fishery survey of some of the lakes of Isle Royale National Park. Isle Royale National Park files, Houghton, Michigan.

Sooter, C.A. 1937. Leech infesting young waterfowl in northwest Iowa. _Journal of Parasitology_ 23(1):108-109.

Thomas, M.L.H. 1966. Benthos of four Lake Superior bays. _Canadian Field-Naturalist_ 80(4):200-212.

APPENDIX

TABLE A1. SUMMARY OF LEECHES COLLECTED.

SITE/LOCATION/DATE	Glossiphonia complanata	Helobdella stagnalis	Theromyzon meyeri	Placobdella parasitica	Placobdella ornata	Piscicola milneri	Macrobdella decora	Haemopis grandis	Haemopis marmorata	Erpobdella punctata	Dina dubia	Dina parva	Mooreobdella fervida	Nephelopsis obscura	TOTAL
1 Duncan Bay T67N, R33W, S33 6/18/72	10			1	1				1					28	41
2 Duncan Bay Creek T66N, R33W, S6 6/19/72			3						5					1	9
3 Pickerel Cove T66N, R34W, S9 6/20/72									5					45	50
4 Stockly Bay T66N, R34W, S1 6/21/72	3										19			4	26
5 McCargoe Cove T66N, R35W, S24 6/24/72	5				2				4					48	59
6 Chickenbone Lake T66N, R35W, S35 6/25/72	5				9									4	18
7 Chickenbone Creek T66N, R35W, S26 6/25/72													6		6

TABLE A1 (cont'd)

SITE/LOCATION/DATE	Glossiphonia complanata	Helobdella stagnalis	Theromyzon meyeri	Placobdella parasitica	Placobdella ornata	Piscicola milneri	Macrobdella decora	Haemopis grandis	Haemopis marmorata	Erpobdella punctata	Dina dubia	Dina parva	Mooreobdella fervida	Nephelopsis obscura	TOTAL
8 Hatchet Lake T65N, R36W, S22 6/26/72	11				2							18		40	71
9 Tobin Harbor T66N, R33W, S34 7/13/72	7	1							2		2			70	82
10 Benson Creek T66N, R34W, S22 7/18/72															0
11 Angleworm Lake T66N, R34W, S28 7/18/72			1		11		1							1	14
12 Lake Richie T66N, R35W, S1 7/19/72	1				23				9	1				1	35
13 Chippewa Harbor T65N, R34W, S18 7/23/72	6				3				5					16	30
14 Richie Creek T65N, R34W, S18 7/23/72												2	1	5	8
15 Lake Mason T65N, R34W, S17 7/23/72			1		3		1	2						1	8

TABLE A1 (cont'd)

SITE/LOCATION/DATE	Glossiphonia cimplanata	Helobdella stagnalis	Theromyzon meyeri	Placobdella parasitica	Placobdella ornata	Piscicola milneri	Macrobdella decora	Haemopis grandis	Haemopis marmorata	Erpobdella punctata	Dina dubia	Dina parva	Mooreobdella fervida	Nephelopsis obscura	TOTAL
16 Siskiwit River T65N, R36W, S36 7/24/72	1												5	4	10
17 Siskiwit Lake T65N, R36W, S24 7/26/72	3			5	17	1		5	1	1			1	10	
18 Wood Lake T65N, R35W, S27 7/26/72					11			1					1	10	
19 Lake Desor T64N, R37W, S1 7/28/72					1			2	1				16	17	37
20 Little Siskiwit River T64N, R37W, S24 7/31/72															0
21 Lake Halloran T64N, R37W, S9 8/1/72	1				9			1						2	13
22 Washington Creek T64N, R38W, S21 8/4/72															0
23 Feldtmann Creek T63N, R38W, S19 8/3/72														1	1

TABLE A2. SUMMARY OF CHEMICAL AND PHYSICAL DATA.

SITE/ SUBSITE	WATER TYPE	WATER pH	WATER TEMPERATURE	WATER DEPTH (cm)	WATER COLOR	BOTTOM COMPOSITION
1A	Lentic	7.0	$13^{\circ}C$	20-40	Clear	Sand/gravel, detritus
B	Le	7.5	13°	30-50	Clear	Sand/gravel, detritus
C	Le	7.0	14°	30	Clear	Sand/gravel, boulders
2A	Le	7.0	17°	20-30	Brown	Muck
B	Lotic	7.0	18°	0-20	Dk. Brn.	Muck
3A	Lentic	7.5	11°	20-40	Clear	Sand, detritus
B	Le	7.5	13°	15-30	Clear	Gravel, boulders
C	Le	7.5	14°	20-40	Clear	Gravel, boulders, bedrock
D	Le	7.5	14°	20-50	Clear	Gravel, boulders, bedrock
4A	Le	7.5	12°	20-40	V. Clear	Gravel
5A	Le	7.5	12°	20-80	V. Clear	Sand, detritus
B	Le	7.5	12°	20-50	V. Clear	Gravel, boulders, bedrock
C	Le	7.0	12°	20-30	Clear	Gravel, boulders
D	Le	7.0	15°	20-30	Brown	Muck, detritus
E	Le	7.0	17°	20-40	Clear	Gravel, boulders, bedrock
6A	Le	7.0	19°	30-40	Brown	Muck, detritus
B	Le	7.0	19°	20-40	Brown	Muck, detritus
C	Le	7.0	20°	20-30	Brown	Gravel, bedrock
7A	Lotic	7.0	20°	0-10	Tan	Gravel, boulders
B	Lo	7.0	20°	0-10	Tan	Gravel, boulders
8A	Lentic	7.0	22°	20-50	Dk. Brn.	Gravel, boulders
B	Le	7.0	22°	20-80	Dk. Brn.	Gravel, boulders

TABLE A2 (cont'd)

SITE/ SUBSITE	WATER TYPE	WATER pH	WATER TEMPERATURE	WATER DEPTH	WATER COLOR	BOTTOM COMPOSITION
9A	Lentic	7.0	11°C	15-80 cm	V. Clear	Sand, detritus
B	Le	7.0	11°	20-50	Clear	Sand, detritus, boulders
C	Le	7.0	14°	10-60	Clear	Sand, detritus, boulders
D	Le	7.0	11°	30-50	Clear	Sand, detritus
10A	Lotic	6.75	14°	0-20	Clear	Gravel, boulders
11A	Lentic	6.75	21°	15-40	Tan	Sand, detritus
12A	Le	6.75	24°	0-25	Tan	Sand, detritus
B	Le	6.5	21°	5-30	Tan	Sand, detritus
13A	Le	7.25	14°	25-60	Tan	Sand, detritus, boulders
B	Le	7.25	15°	15-50	Brown	Sand, detritus
C	Le	7.0	15°	15-50	Brown	Sand, detritus
14A	Lotic	7.0	18°	5-20	Brown	Sand/gravel, boulders
15A	Lentic	6.5	20°	20-50	Dk. Brn.	Sand, detritus
B	Le	6.5	20°	10-30	Dk. Brn.	Sand, detritus
16A	Lotic	6.5	18°	5-20	Clear	Gravel, boulders, bedrock
B	Lo	6.5	18°	10-60	Clear	Gravel, detritus, boulders
17A	Lentic	6.5	20°	10-40	Clear	Gravel, boulders, bedrock
B	Le	6.5	20°	15-90	Tan	Sand, detritus
C	Le	6.5	20°	10-40	Tan	Sand, detritus
D	Le	6.5	21°	20-40	Tan	Sand, detritus
E	Le	6.5	22°	5-40	Tan	Sand, detritus

TABLE A2 (cont'd)

SITE/ SUBSITE	WATER TYPE	WATER pH	WATER TEMPERATURE	WATER DEPTH	WATER COLOR	BOTTOM COMPOSITION
18A	Lentic	6.75	19°	20-50	Tan	Sand, detritus
B	Le	6.75	19°	10-40	Tan	Sand, detritus
19A	Le	7.0	23°	5-10	Tan	Sand, boulders
B	Le	7.0	22°	20-60	Tan	Sand, detritus
C	Le	7.0	22°	20-50	Tan	Sand, detritus, boulders
20A	Lotic	6.75	21°	0-15	Dk. Brn.	Gravel, boulders
B	Lo	6.75	21°	0-20	Dk. Brn.	Gravel, boulders, bedrock
21A	Lentic	6.75	21°	10-30	Dk. Brn.	Muck, detritus, boulders
B	Le	6.75	21°	15-30	Dk. Brn.	Gravel, detritus
22A	Lotic	6.75	18°	5-15	Tan	Gravel, boulders
23A	Lo	6.75	21°	5-10	Tan	Gravel, boulders

TABLE A3. SUMMARY OF FLORAL INHABITANTS.

SITE	*Myriophyllum*	*Nuphar*	*Scirpus*	*Potamogeton*	*Sparganium*	*Utricularia*	*Equisetum*	*Chara*	*Carex*	NONE OBSERVED
1			X							
2		X					X		X	
3										X
4										X
5		X		X						
6		X		X						
7										X
8		X								
9			X	X						
10										X
11	X	X		X			X	X		
12			X		X		X			
13			X						X	
14		X								
15		X	X			X				
16							X			
17		X	X							
18		X	X							
19							X			
20										X
21		X		X		X				
22										X
23										X

TABLE A4. SUMMARY OF FAUNAL INHABITANTS.

SITE	Sponges	Planaria	Horsehair worms	Bryozoans	Clams	Snails	Amphipods	Insect larvae	Mites	Percidae	Catostomidae	Cottidae	Cyprinidae	Salmonidae	Esocidae	Frogs	Turtles
1						X	X	X			X				X		X
2															X	X	X
3						X		X			X	X		X			
4						X		X			X	X		X			
5						X	X	X		X	X	X	X	X	X		X
6	X			X	X	X			X	X			X		X	X	X
7								X									
8								X					X	X	X	X	
9						X	X	X			X	X		X	X		
10						X		X									
11	X	X		X	X	X		X		X					X		X
12	X				X	X	X	X		X			X		X	X	X
13						X	X	X			X	X	X	X	X	X	X
14	X	X		X				X									
15	X	X		X	X	X		X	X	X					X	X	X
16						X	X							X			
17	X		X			X		X		X	X		X	X	X		
18			X		X	X							X		X	X	X
19			X			X	X	X						X			
20								X									
21			X		X	X				X			X		X	X	X
22								X						X			
23	X			X				X									

TABLE A5. COLLECTION TIME FOR EACH SITE.

	SITE	TIME
1	Duncan Bay	139 minutes
2	Duncan Bay Creek	85
3	Pickerel Cove	106
4	Stockly Bay	43
5	McCargoe Cove	132
6	Chickenbone Lake	82
7	Chickenbone Creek	55
8	Hatchet Lake	68
9	Tobin Harbor	126
10	Benson Creek	22
11	Angleworm Lake	38
12	Lake Richie	93
13	Chippewa Harbor	70
14	Lake Richie Creek	40
15	Lake Mason	60
16	Siskiwit River	70
17	Siskiwit Lake	157
18	Wood Lake	62
19	Lake Desor	116
20	Little Siskiwit River	50
21	Lake Halloran	65
22	Washington Creek	25
23	Feldtmann Creek	15

TOTAL = 1671 minutes