THE CANADIAN WILDLIFE SERVICE LRTAP BIOMONITORING PROGRAM

PART 2

FOOD CHAIN MONITORING IN ONTARIO LAKES: TAXONOMIC CODES AND COLLECTIONS

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Canadian Wildlife Service Technical Report Series No. 246

This series may be cited as:

McNicol, D.K.; Mallory, M.L.; Bendell, B.E.; 1996. The Canadian Wildlife Service LRTAP Biomonitoring Program, Part 2. Food Chain Monitoring in Ontario Lakes: Taxonomic Codes and Collections. Technical Report Series No. 246, Canadian Wildlife Service, Ontario Region.

Issued under the Authority of the
Minister of Environment
Canadian Wildlife Service

Catalogue No. CW69-5/246E
ISBN 0-662-24072-3

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FORWARD

The loss and degradation of habitat is a major waterfowl management problem in North America today. Formerly secure habitats in the vast boreal forest of eastern Canada are now affected by large-scale land-use practices, including hydropower and recreational developments, certain forestry practices, industrial effluent pollution and atmospheric contamination. The emission and deposition of acidic substances (primarily sulphur dioxide SO_2 and nitrous oxides NO_x, and commonly referred to as "acid rain") and subsequent environmental effects have received considerable attention over the past two decades. Much of eastern Canada is highly sensitive to acid rain since its thin, coarsely-textured soil and granitic bedrock (characteristic of Canadian Shield) has little inherent ability to neutralize acidic pollutants. As a result, acid rain may contribute to declining growth rates and increased mortality in trees. High levels of acidic deposition can result in the acidification of lakes, rivers and streams. Along with elevated levels of metals leached from surrounding soils, high acidity can seriously impair the ability of water bodies to support aquatic life, resulting in a decline in species diversity and undesirable impacts on water-dependent wildlife, such as waterfowl.

Research and monitoring into various aspects of the acid rain problem has been carried out under the auspices of the Long Range Transport of Air Pollutants (LRTAP) Program, an interdepartmental initiative of the federal government involving Agriculture Canada, Fisheries and Oceans Canada, Natural Resources Canada, Health and Welfare Canada and Environment Canada. As a result of combined federal and provincial efforts, Canada has made significant progress towards reducing the environmental threat of acid rain. A Canadian Acid Rain Control Program was formalized in 1985 by establishing federal-provincial agreements to reduce aggregate SO_2 emissions of the seven easternmost provinces to 2.3 million tonnes per year by 1994 (a target which has been achieved). Because more than 50% of the acid rain that falls in eastern Canada comes from the United States, Canada also signed an agreement with the U. S. in 1991 to reduce SO_2 and NO_x emissions, and to establish a permanent national limit on SO_2 of 3.2 million tonnes by the year 2000. In 1995, Canada began to develop a national strategy on acidifying emissions that aims to protect acid-sensitive ecosystems, human health and air visibility beyond the year 2000.

As part of Environment Canada's efforts to study the acid rain problem, the Canadian Wildlife Service (CWS) initiated a research program in 1980 to assess the impacts of acidic deposition on wildlife and wildlife habitats in eastern Canada. Objectives of the first phase of the CWS LRTAP program were to determine which species and habitats were most at risk from acidification, and to establish cause-and-effect relationships between acidification and biological changes, chiefly in bird communities. The results of this phase of the program are contained in two volumes of the CWS Occasional Paper Series (Numbers 62 and 67); McNicol *et al.* (1987a) describe work on waterfowl and their food chains in small lakes in northern Ontario, while DesGranges (1989) summarizes results of surveys of freshwater bird communities in Québec, as well as phyto-ecological studies of their associated habitats, in relation to acidification. Research in Québec also focused on relationships between acid rain, forest dieback (especially sugar maple stands) and the associated effects on forest bird communities (Darveau *et al.* 1992). CWS studies were also conducted in the Lepreau area in southwestern New Brunswick, where the relationships between wetland acidity, fish presence, invertebrate biomass and habitat use by young waterfowl broods were examined (Parker *et al.* 1989, 1992). CWS and the Long Point Bird Observatory implemented the Canadian Lakes Loon Survey in the 1980s. This volunteer-based survey gathers data on the breeding success of Common Loons (*Gavia immer*) nesting across Canada, including many lakes in acid-stressed regions of eastern Canada. CWS has also played a major role in interdisciplinary studies of calibrated basins, especially in Atlantic Canada, where Kerekes *et al.* (1994) have studied nutrient release in and limnological characteristics of acidified waters in Kejimkujik National Park, particularly as it pertains to the ecology of fish-eating birds. Scheuhammer (1991) described the results of research at the National Wildlife Research Centre on the fate of heavy metals in waterfowl food chains, as well as laboratory studies of the effects of dietary heavy metals on the reproductive output of birds under controlled conditions.

Together, these efforts provided the basis for the development and implementation of the CWS LRTAP Biomonitoring Program in 1987. This national program is comprised of research and monitoring activities conducted by the National Wildlife Research Centre and by Regional Offices in Ontario and Atlantic Canada. Instrumental to program delivery are partnerships with various federal and provincial resource agencies, non-government organizations, universities and consultants. Objectives of the program are: to track biotic changes expected to occur in sensitive aquatic ecosystems as acidifying emissions are reduced, and to evaluate the adequacy of emission control programs to meet environmental objectives to protect aquatic biota important to wildlife.

In Ontario, the threat of acidification of aquatic ecosystems east and north of the Great Lakes prompted the CWS to implement a long term Biomonitoring Program to assess the effects of acid rain on waterfowl and their habitats and to evaluate biotic responses to emission control programs. Based on the premise that ecosystem health and recovery must be assessed using biotic as well as abiotic indicators, data on waterfowl (and common loon) distribution and production, water chemistry, landscape features and relationships of birds to their food (primarily fish and aquatic macroinvertebrates) have been gathered at three study sites in Ontario (Algoma, Muskoka, Sudbury) since 1987. This unique dataset spans several years and currently contains information on over 600 water bodies, including large oligotrophic lakes, small headwater lakes, wetlands and chico swamps.

This report contains information pertaining to the CWS LRTAP Biomonitoring Program and is Part 2 of a series of Canadian Wildlife Service Technical Reports which describe various aspects of the program as follows:

Part 1: A Strategy to Monitor the Biological Recovery of Aquatic Ecosystems in Eastern Canada from the Effects of Acid Rain
Part 2: Food Chain Monitoring in Ontario Lakes: Taxonomic Codes and Collections
Part 3: Site Locations, Physical, Chemical and Biological Characteristics
Part 4: Procedures Manual

For more information on the Canadian Wildlife Service LRTAP Biomonitoring Program or to obtain copies of this or any of the reports in this series, please contact:

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ABSTRACT

As part of the Canadian Wildlife Service (CWS) Long Range Transport of Air Pollutants (LRTAP) Biomonitoring Program, littoral zones of 62 small lakes and wetlands in the Algoma, Muskoka and Sudbury regions of Ontario are sampled on a regular basis for various prey of resident waterfowl. These prey include macroinvertebrates, fish and amphibians, many of which are acid-sensitive and absent from lakes degraded by acid precipitation. This Food Chain Monitoring Program (FCMP) will detect changes in the composition and abundance of major prey as damaged aquatic ecosystems recover from the effects of acid precipitation as a result of emission abatement programs. This report contains information on the locations, methods and timing of these collections. More importantly, this report summarizes the invertebrate, fish and amphibian taxa collected between 1987 and 1994, along with the locations of the collections, the taxonomic keys used for identifications and the minimum pHs at which the specimens have been caught. This information is intended as a reference for other researchers working on these same taxa or types of lakes, but we caution that the effectiveness of our sampling procedures varies among taxa, and thus minimum pHs of collection may not represent the true thresholds for some species.

RÉSUMÉ

Dans le cadre du Programme de biosurveillance du transport á distance des polluants atmosphériques (TADPA), le Service canadien de la faune (région de l'Ontario (RO)) échantillonne régulièrement les zones littorales de 62 petits lacs et marais dans les régions ontariennes d'Algoma, de Muskoka et de Sudbury, afin de répertorier les diverses proies de la sauvagine résidente. Ces espèces-proies sont notamment les macroinvertébrés aquatiques, les poissons et les amphibiens, dont bon nombre sont sensibles aux acides et donc absents des lacs touchés par les précipitations acides. Les responsables du Programme de surveillance de la chaîne alimentaire (PSCA) relèveront les changements dans la composition et l'abondance des principales proies au fur et à mesure que les programmes de réduction des émissions acides permettront aux écosystèmes aquatiques de se restaurer. Le rapport informe sur les endroits, les méthodes et les moments de l'échantillonnage. De plus, il résume les taxons d'invertébrés, de poissons et d'amphibiens recueillis entre 1988 et 1994, les endroits de ces collectes, les clés taxinomiques utilisées pour l'identification et le pH minimal de l'eau où les spécimens ont été récoltés. Il s'adresse aux chercheurs qui étudient les mêmes taxons ou types de lacs, mais nous tenons à les prévenir que l'efficacité des procédures d'échantillonnage varie selon les taxons et que le pH minimal peut donc s'avérer inexact pour certaines espèces.

ACKNOWLEDGEMENTS

The findings presented in this report were gained through years of work by many individuals involved with CWS (Ontario Region) LRTAP research and monitoring activities. Financial support for this work has been provided by the Long Range Transport of Air Pollutants (LRTAP) Program of Environment Canada, as well as CWS (Ontario Region). Cooperation for this work was provided by several federal and provincial agencies (Algonquin Provincial Park, Canadian Museum of Nature, Fisheries and Oceans Canada (GLLFAS), Lesley Frost Centre, National Water Research Institute, National Wildlife Research Centre, Natural Resources Canada (CFS), Ontario Ministry of Energy and Environment, Ontario Ministry of Natural Resources, Royal Ontario Museum), non-government organizations (Haliburton Forest and Wild Life Reserve Ltd.) and universities (McGill, Wales). Valuable advice through various stages of the project has been provided by Pete Blancher, Lise Brisebois, Tony Diamond, Dean Jeffries, Joe Kerekes, Keith Marshall, Ken Ross, Tony Scheuhammer, Mark Wayland and Dan Welsh.

Skilled identifications were provided by Dr. Francis Cook (Canadian Museum of Nature), Janette Cormack, Erling Holm (Royal Ontario Museum), Nancy House, Luc Leblanc, Enid Stiles (McGill University) and Mark Wayland (CWS-PN). Field collection of data was conducted by the authors, as well as Janette Cormack, John Haselmayer, Jocelyn Heneberry, Nancy House, Luc Leblanc, Don Morgan, Mark Porter, Jason Reaume, Ken Ross, Valerie Schell, Suzanne Sinden, Russ Walton, Mark Wayland and Bob Webster. Archiving of all fish and invertebrate material was completed by Jessica Scarlett. We thank Don Kurylo and the staff at the Great Lakes Forestry Centre for all chemical analyses. We also thank Lise Brisebois for her work on developing and managing the database which handles this information, and Russ Walton for his help in preparing this document.

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1.0 INTRODUCTION

Acid precipitation has been associated with changes to aquatic ecosystems in acid-sensitive areas of eastern North America and Europe (Haines 1981, Dillon *et al.* 1984, Schindler 1988). As a result, the reproductive success of water dependent birds has been affected mainly through habitat loss and altered density and quality of prey (Ormerod and Tyler 1987, Blancher and McNicol 1988, McAuley and Longcore 1988). In eastern Canada, much of the breeding habitat for several species of waterfowl and the Common Loon (*Gavia immer*) is threatened by acid precipitation (McNicol *et al.* 1987a).

Ecological and ecotoxicological processes at work in lower trophic levels affect aquatic birds (reviewed in Longcore *et al.* 1993). Some trace metals (notably aluminum and mercury) are mobilized in highly acidic waters and may accumulate in certain fish and invertebrate prey, causing impaired reproduction in waterfowl and loons (Scheuhammer 1991). Other toxicological effects include a reduction in the concentration of usable forms of calcium (Ca) which become less abundant in acidic lakes. This results in invertebrate prey with low Ca concentrations which could lead to Ca stress in avian predators (Blancher and McNicol 1991), as reported in terrestrial systems (Graveland *et al.* 1994).

Ecologically, species that are not acid-tolerant (e.g. some water striders like *Metrobates hesperius*, mayflies, leeches and gastropods; Bendell 1988, Bendell and McNicol 1991) are lost and acid-tolerant species become dominant (e.g. the dragonfly *Leucorrhinia glacialis*, the hemipterans *Notonecta* and *Sigara*; McNicol and Wayland 1992, Bendell and McNicol 1995a). In lakes with and without fish, there is a decrease in overall invertebrate species diversity and prey quality as lakes become more acidified (Bendell and McNicol 1987a, Mallory *et al.* 1994, McNicol *et al.* 1995b). In fishless lakes, invertebrate abundance may remain constant or even increase as pH declines. However, in lakes containing fish, acid-tolerant fish species (e.g. yellow perch *Perca flavescens*) persist and become effective, dominant predators on invertebrates. Such conditions lead to reduced invertebrate abundance and poor brood-rearing habitat for some insectivorous waterfowl species (McNicol and Wayland 1992). The ultimate effect of decreasing pH on avian predators varies with the severity of acidification and with the foraging habits of the species, but has clearly led to reproductive effects for some waterbirds, arising from shifts in habitat selection and diet (Longcore *et al.* 1993).

The Canadian Wildlife Service (CWS) Long Range Transport of Air Pollutants (LRTAP) Biomonitoring Program aims to document the rate, nature and scope of biological recovery in aquatic ecosystems of eastern Canada from acidification following implementation of acid rain controls in Canada and the United States (described in McNicol *et al.* 1995d). To meet this objective, broad scale surveys are conducted by the CWS to monitor waterfowl, loons and their habitats in selected regions sensitive to or affected by acid rain. In Ontario, waterfowl and their prey are monitored in three acid-sensitive areas (Algoma, Muskoka, Sudbury) affected by acid precipitation. Monitoring involves the use of acid-sensitive invertebrates and birds as biological indicators that respond to changes in the aquatic food web (especially within the critical pH range of 5 - 6) across all surface waters at risk in these study areas, which include wetlands, small and large lakes. The CWS (Ontario Region) LRTAP Biomonitoring Program is comprised of several components which involve an extensive series of surveys, sampling procedures and data collections described in Part 4 of this series (McNicol *et al.* 1996b).

1.1 Food Chain Monitoring Program (FCMP)

The Food Chain Monitoring Program (FCMP), a component of the CWS (Ontario Region) LRTAP Biomonitoring Program, is designed to detect changes in the composition and abundance of major waterfowl and loon prey, based on the outcome of dietary studies (McNicol *et al.* 1987b, Bendell and McNicol 1995b). Examining biological recovery at lower trophic levels (fish, amphibians, invertebrates) provides the basis for interpreting patterns of waterfowl and loon distribution and productivity, and whether certain organisms lag behind other species in recovery (i.e. taxa-specific rates of recovery). Baseline characterization (physical, chemical and fish status) was undertaken for all study lakes (roughly 640) in the three areas. Fish community composition was an important variable both because fish are preferred prey for piscivorous waterbirds, such as loons, Common Mergansers *Mergus merganser* and Hooded Mergansers *Lophodytes cucullatus*, and because fish compete with other species, including American Black Ducks *Anas rubripes*, Mallards *A. platyrhynchos*, Wood Ducks *Aix sponsa*, Common Goldeneye *Bucephala clangula* and Ring-necked Ducks *Aythya collaris*, for common aquatic invertebrate prey. Complete characterization of invertebrate communities is impractical for the number of lakes surveyed, but invertebrate composition and abundance can to some extent be predicted from the structure of fish communities (McNicol and Wayland 1992, Mallory *et al.* 1994, McNicol *et al.* 1995b), since fewer invertebrates are found where fish predators are prevalent. However, detailed monitoring of macroinvertebrates, amphibians and fish is conducted on a rotating basis for 62 lakes (20 each in Algoma and Muskoka, 22 in Sudbury) chosen to represent the range of pH and fish status in small lakes (<10 ha) that are typical breeding habitat for waterfowl species of these regions. Collections are targeted for specific components of the aquatic invertebrate community that comprise principal waterfowl foods or are acid-sensitive indicator species (e.g. leeches, water striders).

Here we emphasize aspects of invertebrate taxonomy and minimum pH associations not reported elsewhere. Major invertebrate taxonomic groups encountered were: Hirudinea, Arachnoidea, Crustacea, Decapoda, Ephemeroptera, Odonata, Hemiptera, Coleoptera, Trichoptera, Diptera and Mollusca. Over 230 taxa have been identified in the biomonitoring program to date (1988-1994), most of which are listed in this report. However, some incidental species, such as terrestrial insects, or groups that are caught but not kept (e.g. chironomid larvae), are not listed. A list of all taxonomic keys used for invertebrate identification is provided. A complete description of study areas and food chain lakes is found in McNicol *et al.* (1996a), sampling procedures are discussed in McNicol *et al.* (1996b), while details on data handling and management are provided in McNicol and Brisebois (1995).

2.0 STUDY AREAS

The CWS (Ontario Region) LRTAP Biomonitoring Program focuses on three areas in Ontario east and north of the Great Lakes that are characterized by highly acid-sensitive lakes and wetlands (Fig. 1). A wide range of historical and current acidification is exhibited in these areas. These sites also vary substantially in their expected responses to emission reductions, and are ideal for monitoring recovery in response to a reduction in acidic deposition (McNicol *et al.* 1995a,c).

2.1 Algoma

The Algoma study area is located near the eastern shore of Lake Superior within the Canadian Shield (area centre at 47° 01' N latitude, 83° 55' W longitude). The region is underlain with granitic bedrock covered with glacial till. Forest cover is predominantly mixed hardwoods of the Great Lakes - St. Lawrence Zone. Most sites receive a wet sulphate (SO_4) deposition load of > 20 kg/ha/yr with some local deposition being much higher due to high annual precipitation (Shaw *et al.* 1992). Nine 5 x 5 km study plots containing roughly 240 lakes have been established (Fig. 1). Historical chemical data are available for 26 lakes (Neary *et al.* 1990),

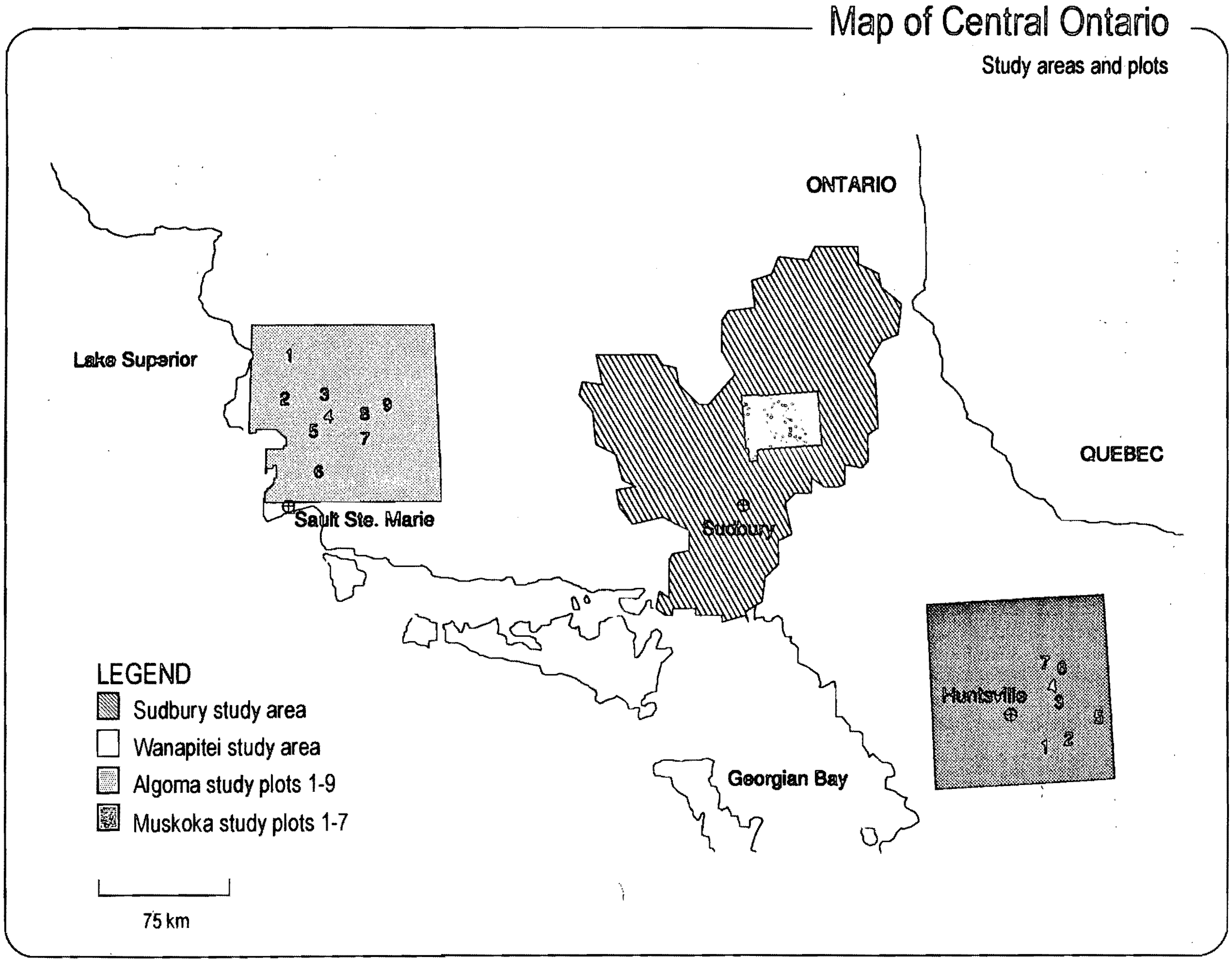

Figure 1. Locations of CWS (Ontario Region) LRTAP Biomonitoring areas.

of which 13 also have biological data (Kelso and Jeffries 1988). Twenty of these lakes, with a minimum of 2 per plot, are used in the FCMP. The Turkey Lakes Watershed calibrated basin is contained within Plot 2 and includes four DFO Biomonitoring Program lakes (Shaw *et al.* 1995). A total of 36 lakes studied by CWS since 1980 in the Ranger Lake area are contained within Plots 7 and 9. Results of work examining food chain relationships in small lakes and wetlands in the Ranger Lake area are summarized in several publications, including Bendell and McNicol (1987a, b, 1995b), Blancher and McNicol (1986, 1991), Mallory *et al.* (1994), and McNicol *et al.* (1987a,b).

2.2 Muskoka

The Muskoka study area is situated in central Ontario (area centre at 45° 30' N, 79° 06' W) and includes portions of Algonquin Park (Plots 4, 6 and 7), the Lesley Frost Centre (Plot 2), and the Haliburton Forest and Wild Life Reserve (Plot 5). It also lies within the Canadian Shield and has a granitic bedrock underlay with shallow glacial till and a mixed hardwood forest cover of the Great Lakes - St. Lawrence Zone. The area is considered highly sensitive to acid deposition and receives the highest SO_4 loading of all three areas, currently averaging >30 kg/ha/yr. Seven 5 x 5 km plots containing roughly 240 lakes are enclosed in the study area. The FCMP uses 20 lakes, with a minimum of 2 per plot. Three Ontario Ministry of Environment and Energy lakes (part of the DFO Biomonitoring Program) are included in these plots (Shaw *et al.* 1992), while roughly 60 lakes have historical chemical data (Neary *et al.* 1990).

2.3 Sudbury

The Sudbury study area (area centre 46° 54' N, 80° 41' W) has a heterogenous mixture of surface deposits that have produced lakes with a broad range of pHs surrounding Sudbury (principally northeast and southwest of the city; see McNicol *et al.* 1995a). Sulphate deposition from long range sources is less than received in Muskoka, but deposition from local smelters is considered to be the highest in the province (Neary *et al.* 1990), and has affected lake chemistries over a broad area (illustrated in Fig. 1). However, emission controls have been put in place which have effectively reduced SO_2 emissions.

Research and monitoring of recovery from the effects of acidification continues in the Sudbury area today (Keller *et al.* 1992, Gunn 1995). CWS has been active in the Sudbury area since 1983, results from which are summarized in McNicol *et al.* 1987a, 1995a. The Wanapitei study area (part of the Sudbury study area) lies 50 km northeast of Sudbury, covers approximately 460 km^2, and contains roughly 378 small lakes and wetlands (Fig. 1). Given the historical database and the heterogenous nature of lake chemistries in a small area, the study site is treated as one plot containing roughly 160 lakes. Most of these lakes have recent annual water chemistry, fish and waterfowl data, and nearly half have been equipped with duck boxes (McNicol *et al.* 1996c). Of these, 22 lakes are part of the FCMP.

2.4 Characteristics of FCMP Lakes

A complete description of the location and physical, chemical and biological characteristics of all biomonitoring study lakes is contained in McNicol *et al.* (1996a). Information on the Wanapitei study site can also be found in McNicol *et al.* (1987a, 1995a) and McNicol and Mallory (1994). Characteristics of FCMP lakes in the three study areas (mean chemistry, fish community and locations) are summarized in Tables 1a-c. Chemical values presented here are 4-year means (fall sampling) based on the most recent four years of data collected for each site between 1988-1995. Because certain fish species are more effective competitors for invertebrate prey or are more preferred prey themselves (McNicol and Wayland 1992), the dominant fish species and/or assemblage (Fish Type) in each lake is presented.

Table 1a. Location (given as Universal Transverse Mercator (UTM) coordinates) and characteristics of 20 Algoma FCMP lakes. Chemical values are four year means (1988, 1992, 1994, 1995). Fish are scored as present (P) or absent (A); for Fish Type, dominant fish groups are scored as Cyp (cyprinid), Bst (brook stickleback), or WS (white sucker).

Plot	Wetld	UTM Zone	UTM East	UTM North	Area (ha)	Depth (m)	pH	Alk (μeq/L)	DOC (mg/L)	Fish	Fish Type
1	17	16	6998	52364	2.4	6.0	4.90	-11.0	5.6	A	
1	23	16	7002	52397	3.2	3.0	5.20	-0.3	6.5	A	
2	7	16	6943	52137	8.2	2.3	6.98	212.6	4.8	A	
2	16	16	6980	52155	7.5	8.5	6.30	32.7	3.7	A	
3	12	16	7188	52155	3.2	1.3	5.21	0.4	6.1	A	
3	33	16	7216	52163	6.5	2.5	6.05	26.3	5.2	P	Cyp
4	12	16	7211	52046	2.2	5.3	5.22	-4.6	5.5	A	
4	29	16	7239	52028	6.1	1.7	5.15	-3.6	4.1	A	
5	19	16	7151	51942	4.7	3.8	6.16	26.2	6.2	P	Cyp
5	24	16	7168	51971	5.4	2.4	5.26	3.7	10.2	A	
6	5	16	7175	51721	2.9	5.7	6.03	15.3	5.1	A	
6	23	16	7209	51734	4.2	1.4	5.68	15.9	8.5	P	BSt
7	2	17	2838	51895	4.1	7.0	5.90	25.7	12.5	A	
7	9	17	2859	51898	7.7	2.4	5.48	17.0	15.9	P	Cyp
7	20	17	2899	51897	3.4	3.0	7.02	213.7	6.8	P	Cyp
8	4	17	2858	52050	5.8	5.2	6.02	30.0	11.7	P	Cyp
8	18	17	2883	52043	9.9	3.6	6.14	24.4	8.7	P	WS
9	3	17	2984	52114	7.6	1.3	6.05	30.7	10.0	P	WS
9	11	17	3003	52096	5.0	1.4	5.75	15.6	8.6	P	WS
9	16	17	3013	52109	4.8	3.3	6.56	70.5	7.7	P	WS

Table 1b. Location (given as Universal Transverse Mercator (UTM) coordinates) and characteristics of Muskoka 20 FCMP lakes. Chemical values are four year means (1990, 1991, 1993, 1995). Fish are scored as present (P) or absent (A); for Fish Type, dominant fish groups are scored as Cyp (cyprinid), Bst (brook stickleback), YP (yellow perch), and Pum (pumpkinseed).

Plot	Wetld	UTM Zone	UTM East	UTM North	Area (ha)	Depth (m)	pH	Alk (μeq/L)	DOC (mg/L)	Fish	Fish Type
1	23	17	6596	50068	5.8	4.6	6.46	52.7	3.2	P	YP
1	32	17	6628	50068	3.7	3.0	5.67	16.5	4.4	P	Cyp
2	2	17	6732	50035	5.0	9.1	5.22	-1.0	6.0	P	Cyp
2	18	17	6716	50067	5.7	5.5	5.81	9.8	3.1	P	Cyp
2	27	17	6760	50076	7.2	7.6	5.80	9.0	4.0	P	Pum
3	2	17	6660	50250	3.0	7.3	5.79	18.6	7.2	P	Cyp
3	12	17	6680	50264	3.7	4.3	5.33	8.1	11.0	A	
3	35	17	6692	50298	4.4	1.7	5.40	15.9	5.9	A	
4	15	17	6633	50363	8.0	4.0	5.33	1.8	3.1	P	BSt
4	22	17	6666	50371	4.6	5.8	5.42	1.1	2.8	A	
4	35	17	6670	50393	5.3	6.4	6.16	31.9	3.4	A	
5	8	17	6888	50178	5.0	1.5	5.02	-9.7	4.3	A	
5	16	17	6905	50184	7.2	9.1	5.38	-1.3	5.0	A	
6	8	17	6751	50435	7.6	10.7	5.92	15.1	3.6	P	YP
6	13	17	6703	50438	10.9	18.6	5.70	8.4	3.1	P	Cyp
6	33	17	6682	50480	2.4	4.3	5.66	9.0	4.5	A	
7	3	17	6627	50473	3.3	6.7	6.06	21.0	3.4	A	
7	5	17	6602	50472	9.8	5.8	5.44	10.1	4.6	A	
7	11	17	6602	50484	9.4	10.7	5.69	7.4	5.1	A	
7	16	17	6576	50508	4.9	7.9	6.60	101.6	4.7	P	YP

Table 1c. Location (given as Universal Transverse Mercator (UTM) coordinates) and characteristics of 22 Sudbury FCMP lakes. Chemical values are four year means (1991, 1993, 1994, 1995). Fish are scored as present (P) or absent (A); for Fish Type, dominant fish groups are scored as Cyp (cyprinid), WS (white sucker), or YP (yellow perch).

Lake	UTM Zone	UTM East	UTM North	Area (ha)	Depth (m)	pH	Alk (μeq/L)	DOC (mg/L)	Fish	Fish Type
16	17	5133	51922	4.4	7.3	6.43	66.4	6.7	P	Cyp
197	17	5166	51880	5.0	11.6	5.76	11.4	8.2	P	WS
199	17	5165	51896	2.0	5.8	6.47	76.4	7.2	A	
316	17	5176	51945	1.6	1.0	5.57	15.5	9.4	A	
240	17	5111	51948	7.8	15.5	5.04	-9.1	2.1	P	YP
242	17	5111	51942	1.1	5.2	6.05	53.7	7.9	A	
248	17	5105	51952	4.8	2.7	4.56	-26.2	3.0	A	
256	17	5078	51963	7.1	2.4	6.20	33.3	3.6	P	YP
259	17	5098	51970	2.8	4.3	4.84	-12.5	2.5	A	
402	17	5285	51975	6.5	8.2	4.43	-37.5	0.9	A	
404	17	5274	51979	6.0	5.8	5.21	-1.4	1.9	P	YP
408	17	5292	51986	6.0	2.1	4.28	-53.2	3.5	A	
410	17	5296	52007	8.6	5.5	5.56	4.7	2.6	P	YP
479	17	5376	51967	8.6	1.2	5.50	13.3	9.7	P	Cyp
530	17	5277	52032	2.0	11.6	5.41	4.4	4.8	A	
589	17	5226	52048	3.9	2.1	5.25	1.1	6.2	A	
593	17	5215	52059	3.5	9.8	5.24	-0.9	3.4	A	
902	17	5089	51855	1.8	9.1	5.72	14.2	4.8	P	Cyp
905	17	5104	51892	2.1	3.7	6.62	123.8	4.4	P	YP
920	17	5138	51897	3.4	3.4	6.80	175.4	6.4	A	
922	17	5102	51990	5.5	8.2	5.36	-0.5	2.0	A	
958	17	5313	51950	10.8	5.5	6.04	24.5	4.6	P	YP

3.0 FISH AND AMPHIBIAN SAMPLING PROCEDURES

Fish and amphibians are sampled regularly in all food chain lakes, with other study lakes sampled at longer intervals. The primary focus of fish collections is on the small, minnow-type species that are prey for piscivorous waterfowl and loons, as well as the medium-sized fish (e.g. yellow perch) that compete with insectivorous waterfowl for invertebrate prey. Because many fish feed on invertebrates, fishless lakes tend to have high abundance of certain invertebrates. For lakes with fish, invertebrate abundance is also high where fish with small mouth gapes (e.g. northern redbelly dace, *Phoxinus eos*) are predominant, because these species do not eat larger invertebrates. In contrast, few invertebrates are typically found where fish have larger mouth gapes (e.g. yellow perch). To date, more than 10,000 fish have been captured from 638 lakes, representing 25 species (16 in Muskoka, 15 in Algoma, 22 in Sudbury). Small, non-game species predominate, including Cyprinidae (13 spp.), yellow perch and white sucker (*Catostomus commersoni*).

Baseline fish sampling was conducted during the summer months (June to August) in 1988, 1989 and 1990 for most lakes (some Sudbury lakes were not completed until 1994). Subsequent fish sampling is undertaken during the month of June as part of the FCMP. Sampling is conducted by helicopter for Algoma and Muskoka, but by ground at Sudbury. Standard, commercial minnow traps (Gee type with wire mesh) are used. Six traps are placed in the nearshore area of each lake to sample major habitat types associated with inlets, outlets, marshy bays and peninsulas. Each trap is baited with a standard amount (1/4 cup) of Purina Puppy Chow (9% fat content), and 2 small slices of wieners. Traps are retrieved after a minimum 24 hr period (or before 48 hrs when weather prevents traps being picked-up). All specimens are immediately euthanized in MS-222 in accordance with CCAC guidelines.

Once samples are returned to the base camp, fish specimens are separated from non-fish material (leeches, crayfish, tadpoles, newts and assorted macroinvertebrates) and each is preserved. Fish and amphibian tadpoles are preserved by first fixing for three days in buffered 10% formalin, followed by one day in clean water and finally are stored in 70% EtOH. Invertebrates are immediately stored in 70% EtOH. All fish, amphibian and invertebrate specimens are identified to species (where possible), sorted and counted by qualified taxonomists.

4.0 INVERTEBRATE SAMPLING PROCEDURES

The invertebrate component of the FCMP is designed to detect changes in the occurrence, composition and abundance of major waterfowl foods. The FCMP program described below differs considerably from the biomonitoring program undertaken by DFO (Shaw *et al.* 1992, 1995). The DFO National Biomonitoring Program (among other things) characterizes the relative abundance and community structure of benthic invertebrates (notably Dipterans, including Chironomids) in the littoral and mid-profundal zones of selected study sites (usually larger lakes (> 10 ha) and rivers). In the FCMP, aquatic invertebrates are sampled at randomly selected sites within the near-shore area of each study lake (Fig. 2; see also McNicol *et al.* 1996a for more information on sampling locations). Specific components of the aquatic invertebrate community that comprise principal waterfowl foods (Bendell and McNicol 1995b) or are acid-sensitive indicator species (e.g. leeches and water striders) are sampled. To date, more than 25,000 macroinvertebrates representing 159 taxa (genera or species) have been collected from the 62 core lakes (113 spp. in Muskoka 1991, 114 in Algoma 1992, 102 in Sudbury 1994). Major taxonomic groups recorded were: Coleoptera (34 spp.), Odonata (27), Hemiptera (25), Trichoptera (23), Hirudinea (12), Gastropoda (12) and Ephemeroptera (9). The combined results of macroinvertebrate and fish sampling conducted in Ontario food chain lakes have been used to predict macroinvertebrate responses at critical points along the pH gradient (McNicol *et al.* 1995b). In all regions, the number of acid-sensitive taxa per lake is related to pH, and should increase as lakes recover from

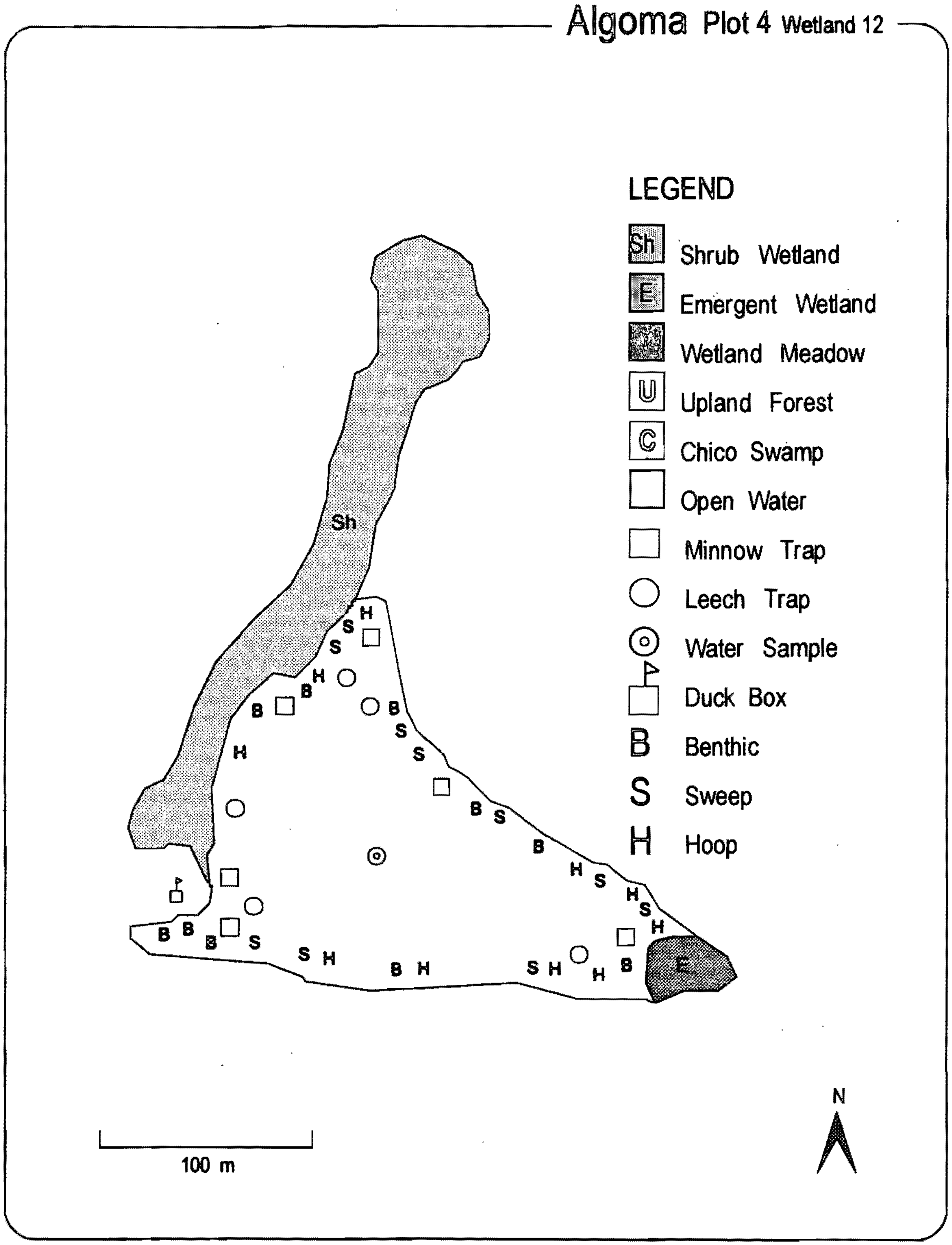

Figure 2. Map depicting a FCMP lake in Algoma and showing locations of invertebrate, fish and water sampling sites from 1992.

acidification. However, to predict macroinvertebrate responses to recovery, one must consider the concurrent effects of fish, as they are a dominant factor structuring these communities.

Five collection techniques are used in the FCMP (funnel traps (F), minnow traps (M), hoops (H), sweep nets (S) and benthic net drags (B)) and are designed to sample most macroinvertebrates found in littoral zones of northern forested lakes. These sampling techniques were developed from cause-and-effect research conducted through the 1980s (see Bendell 1986, 1988, Bendell and McNicol 1987a,b, 1991, 1993, 1995a, McNicol and Wayland 1992). Target organisms and protocols for each method are summarized in Table 2. Invertebrates collected by all but the benthic net drags are immediately stored in 70% EtOH in numbered whirlpac bags for later identification. Benthic samples are kept cool in water and all macroinvertebrates in the samples are sorted within 24 hrs. These invertebrates are also preserved in 70% EtOH and placed in numbered whirlpac bags. The sampling protocol is described in Part 4 (McNicol *et al.* 1996b), and summarized below.

4.1 Funnel Trap

The funnel trap is designed to collect leeches (Bendell and McNicol 1991), a key indicator species. Certain species are acid-sensitive and appear to disperse well, and thus should invade lakes that are experiencing chemical recovery (McNicol *et al.* 1995b). While a major component of the core program in all three study areas, much of the work on leeches has focused on Sudbury lakes where chemical change is expected to be most dramatic and biological recovery should occur most rapidly (McNicol and Mallory 1994). Funnel traps were used to sample leeches on 40 lakes in the Wanapitei area in 1987, 1992 and 1994. Five 1.5 L glass mason jars baited with 50 g of beef liver are set horizontally on the surface of the sediments in water < 0.5 m deep. After 24 hrs, the contents of each trap are removed, preserved and stored as outlined above.

4.2 Minnow Trap

Standard wire minnow traps are used to collect a variety of fish, amphibians and macroinvertebrates (section 3.0). Six traps baited with Puppy Chow and weiners are set in near-shore areas of each lake for 24 hrs. All materials collected in these traps are collapsed into one sample per lake and stored in bottles.

Table 2. Sampling methods, intensity and target organisms of the FCMP conducted in Ontario lakes.

	Collection Method				
	Sweep	Hoop	Benthic	Funnel	Minnow
Target group	Hemiptera	Trichoptera	Anisoptera, Ephemeroptera, Gastropoda	Hirudinea	Nekton / Fish / Amphibians
Location	Open Water < 5m to shore	Shoreline < 0.5m deep	On Bottom < 1m deep	On Bottom < 1m deep	Near Shore < 1m deep
Samples / lake	10	10	10	5	6
Collection approach	10 Dipnet Passes	Visual Search $0.31 m^2$	Sediment Drag $0.14 m^2$	Bottle Trap 24 hr	Wire Trap 24 hr

4.3 Hoop

The hoop, a circular piece of coated wire, is used primarily for sampling larval trichopterans; however, other invertebrates are also collected. It has a defined area measuring 0.32 m^2 and is tossed either from shore or from a boat in water < 0.5 m deep. All invertebrates are handpicked from the substrate and vegetation within the hoop with the aid of an Underwater Viewing Device (UVD). The UVD is a plastic pail which has had its original bottom removed and replaced by a piece of clear plastic secured with screws and sealed water-tight. By pushing the bottom of the pail into the water and viewing through it, glare from waves and sunlight is minimized so the bottom substrate can be scanned effectively. Ten randomly selected sites are sampled per lake. Ten minutes are allotted per hoop site; inevitably all trichopterans are collected in a shorter time period (normally five minutes or less).

4.4 Sweep Net

The sweep net collects nektonic invertebrates found in the water column at depths ranging from 0.33 to 1.0 m. A D-frame dip net with a 0.85 mm mesh and a capture area of 625 cm^2 is swept in 10 consecutive arcs over the bow of a forward moving boat. Each sweep describes an arc from the water surface to as near the substrate as possible and back to the surface. Ten samples are collected per lake.

4.5 Benthic Net Drag

The benthic net drag samples benthic macroinvertebrates using a 0.85 mm mesh D-frame dip net (as in 4.4). From the side of a boat or canoe, the net is dragged 0.5 m over the substrate, collecting the top 1-2 cm of substrate, in water < 1.0 m deep for a total sample area of 0.14 m^2. A collapsible, wooden, L-shaped frame is used as a guide to aid sampling. Care is taken to avoid sections where woody debris or underwater hazards would hamper sampling. The collected material is then sieved through a 1 mm^2 mesh for later sorting. Ten samples are collected per lake.

5.0 SAMPLING SCHEDULE

The schedule of biomonitoring activities conducted in the three study areas between 1987-95 (including baseline characterization, water sampling and food chain monitoring) is summarized in Table 3. The FCMP is undertaken on core lakes during the middle two weeks of June (roughly June 6 - 26), as this is an appropriate time for sampling most groups, and also matches the period of peak hatch for most local waterfowl (Sinden 1995). Sampling sites within lakes are selected using a random number table and identified on individual scale maps of each lake (see Fig. 2 for an example). Locations of all sampling sites used to date are presented in Part 3 of this series (McNicol *et al.* 1996a).

6.0 TAXONOMIC IDENTIFICATIONS

Specimens are routinely identified to the lowest possible taxonomic level, typically genus and usually species. The FCMP uses a standard set of taxonomic keys (section 8.0) for identifications, and has maintained a reference collection to compare specimens with original identifications. The FCMP has also made use of a talented set of taxonomists. In particular, Dr. Francis Cook of the Canadian Museum of Nature and Erling Holm of the Royal Ontario Museum have been very helpful in handling identifications of amphibians and fish, respectively. Barry Bendell has been the chief invertebrate taxonomist and coordinator of invertebrate identifications to date. Individuals that have performed identifications and the year that they contributed are noted in Table 4.

Table 3. Schedule of biomonitoring activities in the three study areas in Ontario (A=Algoma, M=Muskoka, S=Sudbury), including baseline characterization and water sampling (all lakes), FCMP (core lakes) and indicator species (Sudbury only).

	Biomonitoring Activity			
Year	Baseline Characterization	FCMP	Water Sampling	Indicator Species
1987		S	S	S
1988	A	A[1],S	A	
1989	A,S	A[1],S		
1990	A,M	A	S,M	
1991	M	M	S, M	
1992		A	S,A	S
1993	S		S,M	
1994	S	S	S,A	S
1995			S,A,M	

[1] Sampling conducted in the Ranger Lake area only

Table 4. Persons that identified aquatic invertebrates, fish and amphibians in each collection year according to method. Dashes indicate where the collection method was not undertaken.

	Collection Method				
Year	Sweep	Hoop	Benthic	Funnel	Minnow
1987	JC	-	JC	BB	-
1988	JC	-	JC	-	BB
1989	JC	-	JC	-	BB
1990	VS	VS	VS	BB	BB
1991	MW	MW	BB	BB	BB, EH, ES
1992	BB	BB	BB	BB	BB, EH, ES
1993	-	-	-	-	EH
1994	BB	BB	NH	BB	BB, EH, FC

BB - Barry Bendell; FC - Francis Cook; JC - Janette Cormack; EH - Erling Holm; NH - Nancy House; VS - Valerie Schell; MW - Mark Wayland; ES- Enid Stiles

Verified sample identifications are added to the CWS LRTAP Biomonitoring Database and Reporting System (a relational database developed using ORACLE) using a species-specific taxonomic code system (see McNicol and Brisebois 1995). This procedure facilitates pooling of data at higher taxonomic levels when required. Each sample/individual is assigned an archive number and stored in specimen cabinets at the CWS (Ontario Region) office in Nepean, ON for reference and retrieval. Access to archived specimens by interested individuals is encouraged and can be arranged by contacting the senior author.

7.0 INVERTEBRATE, FISH AND AMPHIBIAN COLLECTIONS

Between 1990 and 1994, over 150 invertebrate, nine amphibian and 24 fish species (excluding hybrids) were collected in FCMP studies. If data from preliminary testing of FCMP protocols in the Ranger Lake and Wanapitei areas in 1987-1989 are included (Table 3), the number of invertebrate taxa increases to over 200. Many other invertebrate taxa were collected in baseline characterization of other study lakes (e.g. large nektonic hemipterans). A taxonomically-ordered list of invertebrates is presented in Table 5, while Table 6 (invertebrates), Table 7 (fish) and Table 8 (amphibians) include study regions, methods and minimum pHs (based on 3-year averages (1995 excluded) from fall sampling) where each taxon was collected. In Table 6, pHs in italics refer to taxa collected in 1988 or 1989 only, which include some lakes that were not continued as part of the long term FCMP study design. We also reiterate that our sampling program was designed to be effective for target organisms, but it is not necessarily effective for other organisms which are collected occasionally. Thus, some of the minimum pHs in the accompanying tables may be biased high if the species is not a member of the target group (e.g. water striders).

8.0 TAXONOMIC KEYS

The following sections list the set of keys used to identify aquatic invertebrates in the FCMP. Keys to various aquatic insect taxa are listed first, followed by keys to other aquatic invertebrates. Note that amphibian tadpoles are identified using an unpublished key developed by Dr. Francis Cook, while fish are identified according to the descriptions in Scott and Crossman (1985).

8.1 Aquatic Insects

- **Ephemeroptera**

Edmunds, G. F., S. L. Jensen and L. Berner. 1976. The Mayflies of North and Central America. University of Minnesota Press, Minneapolis.

- **Odonata**

Walker, E. M. 1953. The Odonata of Canada and Alaska. Zygoptera. Vol. 1. University of Toronto Press, Toronto.

Walker, E. M. 1958. The Odonata of Canada and Alaska. Anisoptera. Vol. 2. University of Toronto Press, Toronto.

Walker, E. M. and P. S. Corbet. 1975. The Odonata of Canada and Alaska. Anisoptera: Macromiidae, Corduliidae, Libellulidae. Vol. 3. University of Toronto Press, Toronto.

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Table 5. Taxonomic list of invertebrates identified from the FCMP (1990-1994).

- Platyhelminthes
  - Turbellaria
    - Tricladia
- Nematoda
- Nematomorpha
  - Gordiida
- Annelida
  - Oligochaeta
  - Hirudinea
    - Gnathobdellida
      - Hirudinidae
        - *Macrobdella decora*
        - *Mollibdella grandis*
        - *Percymoorensis marmoratis*
    - Pharyngobdellida
      - Erpobdellidae
        - *Erpobdella punctata*
        - *Mooreobdella fervida*
        - *Nephelopsis obscura*
      - Glossiphoniidae
        - *Batracobdella picta*
        - *Glossiphonia complanata*
        - *Helobdella elongata*
        - *Helobdella stagnalis*
        - *Placobdella ornata*
        - *Placobdella parasitica*
        - *Theromyzon*

- Arthropoda
  - Arachnoidea
    - Acariformes
      - Arrenuridae
        - *Arrenurus*
      - Eylaidae
        - *Eylais*
      - Limnocharidae
        - *Rhyncholimnochares*
      - Hydrachnidae
        - *Hydrachna*
      - Hydrodromidae
        - *Hydrodroma*
      - Limnesiidae
        - *Limnesia*
      - Pionidae
        - *Piona*
      - Lebertiidae
        - *Lebertia*
      - Unionicolidae
        - *Neumania*
      - Family ?
        - Genus X
  - Crustacea
    - Isopoda
      - Asellidae
        - *Asellus*
    - Amphipoda
      - Crangonyctidae
        - *Crangonyx richmondensis*
      - Talitridae
        - *Hyalella azteca*
    - Decapoda
      - Cambaridae
        - *Cambarus bartonii*
        - *Cambarus robustus*
        - *Orconectes propinquus*
        - *Orconectes virilis*
  - Insecta
    - Ephemeroptera
      - Siphlonuridae
        - *Siphlonurus*
      - Metretopodidae
        - *Siphloplecton*
      - Baetidae
        - *Callibaetis*
        - *Cloeon*
      - Heptageniidae
        - *Arthroplea bipunctata*
        - *Stenacron*
        - *Stenonema*
      - Leptophlebiidae
        - *Chloroterpes*
        - *Leptophlebia*
      - Ephemeridae
        - *Hexagenia*
      - Ephemerellidae
        - *Eurylophella*

Table 5 continued on next page

- Caenidae
    - *Caenis*
- Baetiscidae
    - *Baetisca*
- Odonata
    - Gomphidae
        - *Gomphus exilis*
        - *Gomphus spicatus*
        - *Hagenius brevistylus*
    - Aeshnidae
        - *Aeshna canadensis*
        - *Aeshna eremita*
        - *Aeshna interrupta*
        - *Aeshna tuberculifera*
        - *Aeshna umbrosa*
        - *Basiaeschna janata*
        - *Nasiaeshna pentacantha*
    - Cordulegastridae
        - *Cordulegaster diastatops*
    - Macromiidae
        - *Didymops transversa*
    - Corduliidae
        - *Cordulia shurtleffi*
        - *Epitheca*
        - *Somatochlora cingulata*
        - *Somatochlora minor*
        - *Somatochlora walshii*
        - *Somatochlora williamsoni*
    - Libellulidae
        - *Celithemis eponina*
        - *Leucorrhinia frigida*
        - *Leucorrhinia glacialis*
        - *Leucorrhinia hudsonica*
        - *Leucorrhinia intacta*
        - *Libellula incesta*
        - *Libellula julia*
        - *Libellula quadrimaculata*
        - *Sympetrum ambiguum*
        - *Sympetrum costiferum*
        - *Sympetrum danae*
        - *Sympetrum internum*
        - *Sympetrum obtrusum*
        - *Sympetrum vicinum*
    - Lestidae
        - *Lestes disjunctus*
        - *Lestes dryas*
        - *Lestes eurinus*
    - Coenagrionidae
        - *Chromagrion conditum*
        - *Enallagma*
- Plecoptera
    - Leuctridae
        - *Leuctra*
- Hemiptera
    - Gerridae
        - *Gerris buenoi*
        - *Gerris comatus*
        - *Metrobates hesperius*
        - *Rheumatobates rileyi*
        - *Trepobates inermis*
    - Mesoveliidae
        - *Mesovelia mulsanti*
    - Corixidae
        - *Dasycorixa hybrida*
        - *Hesperocorixa scabricula*
        - *Palmacorixa buenoi*
        - *Sigara compressoidea*
        - *Sigara decoratella*
        - *Sigara defecta*
        - *Sigara dolabra*
        - *Sigara douglasensis*
        - *Sigara johnstoni*
        - *Sigara mackinacensis*
        - *Sigara macropala*
        - *Sigara mulletensis*
        - *Sigara penniensis*
        - *Sigara signata*
        - *Sigara solensis*
    - Notonectidae
        - *Buenoa*
        - *Notonecta borealis*
        - *Notonecta insulata*
        - *Notonecta undulata*

    - Pleidae
        - *Neoplea striola*
    - Belostomatidae
        - *Lethocerus americanus*
    - Nepidae
        - *Ranatra fusca*
- Coleoptera
    - Haliplidae

Table 5 continued on next page

- *Haliplus canadensis*
- *Haliplus convexus*
- *Haliplus cribrarius*
- *Haliplus immaculicollis*
- *Haliplus pantherinus*
- *Peltodytes*

- Dytiscidae
    - *Acilius c.f. athabascae*
    - *Acilius semisulcatus*
    - *Acilius sylvanus*
    - *Agabus*
    - *Colymbetes*
    - *Coptotomus*
    - *Dytiscus alaskanus*
    - *Dytiscus cordieri*
    - *Dytiscus dauricus*
    - *Dytiscus fasciventris*
    - *Dytiscus harrisii*
    - *Dytiscus verticalis*
    - *Graphoderus fasciatocollis*
    - *Graphoderus liberus*
    - *Graphoderus perplexus*
    - *Hydaticus*
    - *Hydroporus*
    - *Hygrotus*
    - *Ilybius*
    - *Laccophilus*
    - *Neoscutopterus*
    - *Rhantus*
- Gyrinidae
    - *Dineutus*
    - *Gyrinus*
- Hydrophilidae
    - *Helocombus*
    - *Tropisternus*
- Ptiliidae
- Helodidae (Scirtidae)
    - *Scirtes*
- Elmidae
    - *Dubiraphia*
    - *Macronychus*
- Chrysomelidae
    - *Donacia*
    - *Neohaemonia*
    - *Pyrrhalta*

- Megaloptera
    - Sialidae
        - *Sialis*
    - Corydalidae
        - *Chauliodes*
- Neuroptera
    - Sisyridae
        - *Sisyra*

- Trichoptera
    - Polycentropodidae
        - *Phylocentropus*
        - *Polycentropus*
        - *Nyctiophylax*
    - Hydroptilidae
        - *Agraylea*
        - *Hydroptila*
        - *Oxyethira*
    - Phryganeidae
        - *Agrypnia improba*
        - *Agrypnia c.f. pagetana*
        - *Agrypnia straminea*
        - *Agrypnia vestita*
        - *Banksiola crotchi*
        - *Banksiola smithi*
        - *Phryganea*
    - Limnephilidae
        - *Anabolia*
        - *Glyphopsyche irrorata*
        - *Hydatophylax-Pycnopsyche*
        - *Limnephilus*
        - *Platycentropus amicus*
    - Lepidostomatidae
        - *Lepidostoma*
    - Sericostomatidae
        - *Agarodes*
    - Molannidae
        - *Molanna*
    - Leptoceridae
        - *Ceraclea*
        - *Mystacides*
        - *Oecetis*
        - *Triaenodes*
- Lepidoptera
    - Pyralidae
        - *Acentria*

Table 5 continued on next page

- *Langessa*
- *Parapoynx*

- Diptera
  - Chaoboridae
    - *Chaoborus albatus*
    - *Chaoborus americanus*
    - *Chaoborus trivittatus*
  - Ceratopogonidae
    - *Bezzia-Palpomyia*
    - *Probezzia*
  - Tabanidae
    - *Chrysops*

- Mollusca
  - Gastropoda
    - Prosobranchia
      - Valavatidae
        - *Valvata lewisi*
      - Hydrobiidae
        - *Amnicola limosa*
      - Viviparidae
        - *Campeloma decisum*
    - Pulmonata
      - Ancylidae
        - *Ferrissia*
      - Planorbidae
        - *Gyraulus deflectus*
        - *Helisoma anceps*
        - *Planorbella campanulata*
        - *Planorbella trivolvis*
        - *Promenetus exacuous*
      - Physidae
        - *Physella gyrina*
  - Bivalvia
    - Veneroida
      - Sphaeriidae
        - *Pisidium*
        - *Sphaerium*

Table 6. A list of aquatic invertebrate taxa collected from three Ontario study areas (Sudbury (S), Algoma (A) and Muskoka (M)), showing the taxonomic code, collection method (funnel trap (F), minnow trap (M), hoop (H), sweep net (S) and benthic net drag (B)) and corresponding minimum pH (based on three year average pH per wetland, excludes 1995).

Taxon	Taxonomic Code	Collection Location	Collection Method	Minimum pH
TURBELLARIA				
Tricladia	TRICLADI	S,A,M	F,B	6.36
NEMATOMORPHA				
Gordiida	GORDIIDA	A	B	5.24
OLIGOCHAETA	OLIGOCHA	S,A,M	S,B	4.23
HIRUDINEA				
Hirudinidae	HIRUDINE	A,M	S,B	5.64
Macrobdella decora	M_DECORA	S,A,M	F,M,B	4.76
Mollibdella grandis	M_GRANDI	S,A,M	F,M	5.12
Percymoorensis marmoratis	P_MARMOR	S,A,M	F,M,B	4.74
Erpobdellidae	ERPOBDEL	A,M	F,S,B	5.53
Erpobdella punctata	E_PUNCTA	S,A,M	F,M,S,H,B	5.08
Mooreobdella fervida	M_FERVID	S,A,M	F,S,B	5.10
Nephelopsis obscura	N_OBSCUR	S,A,M	F,M,B	5.08
Glossiphoniidae	GLOSSIPH	S,A	F,B	5.70
Batracobdella picta	B_PICTA	S,A,M	F,M,B	5.24
Glossiphonia complanata	G_COMPLA	S,A,M	F,H,B	5.83
Helobdella	HELOBDE_	A,M	B	5.24
Helobdella elongata	H_ELONGA	A	B	5.24
Helobdella stagnalis	H_STAGNA	S,A,M	F,B	5.10
Placobdella ornata	P_ORNATA	S,A	F,M,H	5.64
Placobdella parasitica	P_PARASI	A	F	4.76
Theromyzon	THEROMY_	A,M	F,S	5.53
ACARIFORMES	ACARI	S	S,B	5.25
Arrenuridae				
Arrenurus	ARRENUR	A,M	S,B	5.05
Eylaidae				
Eylais	EYLAIS_	A,M	S,B	4.87
Limnocharidae				
Rhyncholimnochares	RHYNCHO_	A,M	S,B	4.95
Hydrachnidae				

Table 6 continued on next page

Taxon	Taxonomic Code	Collection Location	Collection Method	Minimum pH
Hydrachna	HYDRACH_	S,A,M	S,B	4.76
Hydrodromidae				
Hydrodroma	HYDRODR_	S,A,M	S,B	4.95
Limnesiidae				
Limnesia	LIMNESI_	S,A,M	S,B	4.87
Pionidae				
Piona	PIONA_	S,A,M	S,B	5.10
Lebertiidae				
Lebertia	LEBERTI_	M	B	6.37
Unionicolidae				
Neumania	NEUMANI_	A	B	5.08
Family?				
Genus X	ACARINX_	S,A	S,B	4.74
ISOPODA				
Asellidae				
Asellus	ASELLUS_	A	B	5.82
AMPHIPODA				
Crangonyctidae				
Crangonyx richmondensis	C_RICHMO	S,A,M	F,M,H,S,B	4.76
Talitridae				
Hyalella azteca	H_AZTECA	S,A,M	F,H,S,B	5.24
DECAPODA				
Cambaridae				
Cambarus bartonii	C_BARTON	S,A,M	F,M	5.20
Cambarus robustus	C_ROBUST	S	F,M	6.40
Orconectes	ORCONEC_	S	B	6.43
Orconectes propinquus	O_PROPIN	S,A,M	F,M,B	6.12
Orconectes virilis	O_VIRILI	S,M	M	6.37
EPHEMEROPTERA	EPHEMERO	S,A,M	S,B	5.20
Siplonuridae	SIPHLONU	A	B	6.24
Siphlonurus	SIPHLON_	A,M	S,B	5.71
Metretopodidae				
Siphloplecton	SIPHLOP_	M	B	5.58
Baetidae	BAETIDAE	S	S,B	7.36
Callibaetis	CALLIBA_	A,M	B	6.24
Cloeon	CLOEON_	A,M	S,B	4.37

Table 6 continued on next page

Taxon	Taxonomic Code	Collection Location	Collection Method	Minimum pH
Heptageniidae				
Arthroplea bipunctata	A_BIPUNC	A	S	5.20
Stenacron	STENACR_	A	B	6.54
Stenonema	STENONE_	S	B	6.61
Leptophlebiidae	LEPTOPHL	A,M	B	5.20
Chloroterpes	CHLOROT_	S	B	6.66
Leptophlebia	LEPTOPH_	S,A	B	4.87
Ephemeridae				
Hexagenia	HEXAGEN_	M	B	5.24
Ephemerellidae				
Eurylophella	EURYLOP_	A,M	H,S,B	5.12
Caenidae				
Caenis	CAENIS_	S,A,M	H,S,B	5.10
Baetiscidae				
Baetisca	BAETISC_	S	M	6.62
ODONATA				
Gomphidae				
Gomphus	GOMPHUS_	S,A,M	S,B	5.24
Gomphus exilis	G_EXILIS	S	B	6.12
Gomphus spicatus	G_SPICAT	S	B	5.86
Hagenius brevistylus	H_BREVIS	S,A,M	B	5.82
Aeshnidae				
Aeshna	AESHNA_	S,M	S,B	5.15
Aeshna canadensis	A_CANADE	S,M	F,M,B	5.63
Aeshna eremita	A_EREMIT	S,A,M	F,M,H,S,B	4.37
Aeshna interrupta	A_INTERR	S,A,M	F,M,B	4.50
Aeshna tuberculifera	A_TUBERC	S,M	M,B	5.21
Aeshna umbrosa	A_UMBROS	S,A,M	F,M,S,B	4.37
Basiaeshna janata	B_JANATA	M	B	6.37
Nasiaeshna pentacantha	N_PENTAC	S	S	6.09
Cordulegastridae				
Cordulegaster diastatops	C_DIASTA	A	B	6.24
Macromiidae				
Didymops transversa	D_TRANSV	A,M	H,S,B	5.24
Corduliidae	CORDULII	A	B	5.92
Cordulia shurtleffi	C_SHURTL	S,A,M	F,M,S,B	4.23
Epitheca	EPITHEC_	S,A,M	M,B	5.66
Somatochlora cingulata	S_CINGUL	S,A,M	B	5.08
Somatochlora minor	S_MINOR	S	B	4.87

Table 6 continued on next page

Taxon	Taxonomic Code	Collection Location	Collection Method	Minimum pH
Somatochlora walshii	S_WALSHI	S,A	B	5.83
Somatochlora williamsoni	S_WILLIA	A,M	B	6.08
Libellulidae	LIBELLUL	S,A,M	F,S,B	4.76
Celithemis eponina	C_EPONIN	M	B	5.78
Leucorrhinia	LEUCORR_	A,M	S,B	5.64
Leucorrhinia frigida	L_FRIGID	S,M	M,B	4.87
Leucorrhinia glacialis	L_GLACIA	S,A,M	F,M,S,B	4.23
Leucorrhinia hudsonica	L_HUDSON	S	B	4.55
Leucorrhinia intacta	L_INTACT	A,M	S,B	5.05
Libellula incesta	L_INCEST	M	B	6.37
Libellula julia	L_JULIA	S,A,M	F,M,H,S,B	4.74
Libellula quadrimaculata	L_QUADRI	A,M	B	5.24
Sympetrum	SYMPETR_	S,M	M,S,B	4.76
Sympetrum ambiguum	S_AMBIGU	A	B	5.71
Sympetrum costiferum	S_COSTIF	S	B	5.28
Sympetrum danae	S_DANAE	A	B	6.71
Sympetrum internum	S_INTERN	A	B	6.71
Sympetrum obtrusum	S_OBTRUS	S,M	B	5.35
Sympetrum vicinum	S_VICINU	S	S,B	5.17
Lestidae				
Lestes	LESTES_	S,A,M	S,B	4.37
Lestes disjunctus	L_DISJUN	S	S,B	4.44
Lestes dryas	L_DRYAS	A	B	6.52
Lestes eurinus	L_EURINU	S,A,M	F,M,S,B	5.05
Coenagrionidae	COENAGRI	S,A,M	M,S,B	5.12
Chromagrion conditum	C_CONDIT	A	B	4.87
Enallagma	ENALLAG_	S,A,M	F,M,S,B	4.87
PLECOPTERA				
Leuctridae				
Leuctra	LEUCTRA_	A	B	6.11
HEMIPTERA				
Gerridae				
Gerris	GERRIS_	S	S	4.99
Gerris buenoi	G_BUENOI	S,M	S,B	5.88
Gerris comatus	G_COMATU	S,A,M	S,B	4.37
Metrobates hesperius	M_HESPER	S	S	5.12
Rheumatobates rileyi	R_RILEYI	M	S	4.76
Trepobates inermis	T_INERMI	A,M	S	4.76

Table 6 continued on next page

Taxon	Taxonomic Code	Collection Location	Collection Method	Minimum pH
Mesoveliidae				
Mesovelia mulsanti	M_MULSAN	A,M	S,B	6.04
Corixidae				
Unid. larvae	CORIXIXL	S,A,M	F,S,B	4.23
Dasycorixa hybrida	D_HYBRID	A,M	S	5.09
Hesperocorixa adult	HESPERO_	S,A,M	M,S,B	5.10
Hesperocorixa scabricula	H_SCABRI	S	B	*5.12*
Palmacorixa buenoi	P_BUENOI	S,M	F,S,B	6.36
Sigara adult	SIGARA_	S,M	S,B	*4.53*
Sigara compressoidea	S_COMPRE	S,A,M	S,B	5.53
Sigara decoratella	S_DECORA	S,A,M	S,B	4.74
Sigara defecta	S_DEFECT	S,A,M	S,B	4.74
Sigara dolabra	S_DOLABR	S,M	S,B	4.74
Sigara douglasensis	S_DOUGLA	A	S,B	*5.19*
Sigara johnstoni	S_JOHNST	S,A,M	S,B	5.66
Sigara mackinacensis	S_MACKIN	S,A,M	F,S,B	5.24
Sigara macropala female	S_MACRCF	S,A,M	S,B	4.74
Sigara macropala male	S_MACROP	S,A,M	S,B	4.74
Sigara mulletensis	S_MULLET	S,A,M	S,B	5.24
Sigara penniensis	S_PENNIE	S,A,M	F,S,B	6.05
Sigara signata	S_SIGNAT	A	B	*6.74*
Sigara solensis	S_SOLENS	S,A,M	S	5.24
Notonectidae				
Buenoa adult	BUENO_XA	S	S	*5.72*
Buenoa larva	BUENO_XL	S,A,M	S,B	4.23
Notonecta larva	NOTON_XL	S	S,B	*4.27*
Notonecta borealis	N_BOREAL	S,A,M	S,B	4.50
Notonecta insulata	N_INSULA	S,A,M	F,S,B	4.23
Notonecta undulata	N_UNDULA	S,A,M	F,M,S,B	4.23
Pleidae				
Neoplea striola	N_STRIOL	S	B	*6.52*
Belostomatidae				
Lethocerus americanus	L_AMERIC	S,A,M	F,M,S,B	4.37
Nepidae				
Ranatra larva	RANAT_XL	S	S	*6.82*
Ranatra fusca	R_FUSCA	A	S	5.09
COLEOPTERA				
Haliplidae				
Haliplus canadensis	H_CANADI	A,M	S,B	5.64

Table 6 continued on next page

Taxon	Taxonomic Code	Collection Location	Collection Method	Minimum pH
Haliplus convexus	H_CONVEX	S	S	*6.82*
Haliplus cribrarius	H_CRIBRA	A,M	S,B	5.24
Haliplus immaculicollis	H_IMMACU	M	S,B	5.10
Haliplus pantherinus	H_PANTHE	S	S,B	*6.09*
Peltodytes adult	PELTO_XA	A	S	*6.52*
Dytiscidae				
Unid. larvae	DYTISCXL	A,M	M,B	4.76
Acilius larva	ACILI_XL	S,A,M	S	5.64
Acilius c.f. athabascae	A_ATHABA	S,A,M	F,M,B	5.24
Acilius semisulcatus	S_SEMISU	S,M	F,M	5.17
Acilius sylvanus	A_SYLVAN	S	F	5.88
Agabus adult	AGABU_XA	S,A,M	F	5.63
Agabus larva	AGABU_XL	A	B	*6.74*
Colymbetes adult	COLYM_XA	S,A,M	F,M	5.31
Colymbetes larva	COLYM_XL	S	S	5.35
Coptotomus adult	COPTO_XA	S,A,M	F,S,B	4.23
Coptotomus larva	COPTO_XL	S,M	F,S,B	4.76
Dytiscus larva	DYTIS_XL	S,A,M	F,M,S,B	4.76
Dytiscus alaskanus	D_ALASKA	S,A,M	F,M	5.05
Dytiscus cordieri	D_CORDIE	S	M	5.51
Dytiscus dauricus	D_DAURIC	S	M	5.16
Dytiscus fasciventris	D_FASCIV	S	M	5.29
Dytiscus harrisii	D_HARRIS	S,A,M	M	5.12
Dytiscus verticalis	D_VERTIC	S,A,M	F,M	4.76
Graphoderus larva	GRAPH_XL	S,A,M	M,S,B	4.23
Graphoderus fasciatocollis	G_FASCIA	S,A,M	F,M	4.76
Graphoderus liberus	G_LIBERU	S,A,M	F,M,S,B	4.50
Graphoderus perplexus	G_PERPLE	S,A,M	F,M	4.50
Hydaticus adult	HYDAT_XA	S,M	F	5.10
Hydroporus adult	HYDRO_XA	S,A,M	F,S,B	4.87
Hydroporus larva	HYDRO_XL	S,M	F,S,B	5.77
Hygrotus adult	HYGRO_XA	S,M	S,B	5.09
Ilybius adult	ILYBI_XA	S,A	F	4.87
Ilybius larva	ILYBI_XL	S	B	4.37
Laccophilus adult	LACCO_XA	S,A,M	F,S,B	4.76
Laccophilus larva	LACCO_XL	M	S,B	5.24
Neoscutopterus adult	NEOSC_XA	S	M	4.40
Rhantus adult	RHANT_XA	S,M	F	4.50
Gyrinidae				
Dineutes adult	DINEU_XA	S,A,M	F,S,B	4.76

Table 6 continued on next page

Taxon	Taxonomic Code	Collection Location	Collection Method	Minimum pH
Dineutes larva	DINEU_XL	S,A,M	F,S,B	4.23
Gyrinus adult	GYRIN_XA	S,A,M	F,S,B	4.37
Gyrinus larva	GYRIN_XL	A,M	S,B	5.08
Hydrophilidae				
Helocombus adult	HELOC_XA	M	B	5.35
Tropisternus adult	TROPI_XA	S	S,B	*6.66*
Tropisternus larva	TROPI_XL	M	S,B	5.65
Ptiliidae adult	PTILIIXA	M	B	4.89
Scirtidae				
Scirtes larva	SCIRT_XL	S	S	5.09
Elmidae				
Dubiraphia adult	DUBIR_XA	M	B	5.24
Dubiraphia larva	DUBIR_XL	S,M	S,B	5.71
Macronychus adult	MACRO_XA	M	B	6.56
Chrysomelidae larva	CHRYSOXL	A,M	F,B	5.08
Donacia adult	DONAC_XA	S,A	S	5.24
Neohaemonia adult	NEOHA_XA	A,M	S,B	5.64
Pyrrhalta adult	PYRRH_XA	S	S	6.12
MEGALOPTERA				
Sialidae				
Sialis	SIALIS_	S,A,M	B	4.37
Corydalidae				
Chauliodes	CHAULIO_	M	S,B	5.65
NEUROPTERA				
Sisyridae				
Sisyra	SISYRA_	A,M	S,B	5.24
TRICHOPTERA				
Polycentropodidae pupa	POLYCEXP	S,A,M	H,S,B	5.12
Phylocentropus	PHYLOCE_	A,M	B	5.83
Polycentropus	POLYCEN_	S,A,M	F,H,S,B	4.23
Nyctiophylax	NYCTIOP_	S	B	6.36
Hydroptilidae larva	HYDROPXL	A	B	5.66
Hydroptilidae pupa	HYDROPXP	A	S,B	5.05
Agraylea	AGRAYLE_	A	B	5.66
Hydroptila	HYDROPT_	A	B	5.92
Oxyethira	OXYETHI_	A,M	S,B	5.05
Phryganeidae larva	PHRYGAXL	M	S	5.71

Table 6 continued on next page

Taxon	Taxonomic Code	Collection Location	Collection Method	Minimum pH
Phryganeidae pupa	PHRYGAXP	S,A,M	H,B	4.23
Agrypnia larva	AGRYPNI_	S	S,B	*5.04*
Agrypnia improba	A_IMPROB	S,A,M	F,M,H,B	4.37
Agrypnia c.f. pagetana	A_PAGETA	S	F	4.35
Agrypnia straminea	A_STRAMI	S,A,M	F,H,B	4.87
Agrypnia vestita	A_VESTIT	S	M	4.33
Banksiola	BANKSIO_	S	S,B	*5.12*
Banksiola crotchi	B_CROTCH	S,A,M	F,M,H,B	4.37
Banksiola smithi	B_SMITHI	S,A,M	F,M,H,S,B	4.50
Phryganea	PHRYGAN_	S	M	4.33
Limnephilidae pupa	LIMNEPXP	S,A,M	H,B	4.23
Anabolia	ANABOLI_	S,A,M	F,M,H,S,B	4.87
Glyphopsyche irrorata	G_IRRORA	A,M	H,S,B	5.66
Hydatophylax-Pycnopsyche	HYD_PYC_	S,A,M	F,M,H,B	4.37
Limnephilus	LIMNEPH_	S,A,M	F,M,H,S,B	4.87
Platycentropus amicas	P_AMICUS	S,A,M	F,M,H,S,B	4.37
Lepidostomatidae				
Lepidostoma	LEPIDOS_	A,M	B	6.24
Sericostomatidae pupa	SERICOXP	M	H,B	6.56
Agarodes	AGARODE_	M	B	5.88
Molannidae pupa	MOLANNXP	M	B	5.35
Molanna	MOLANNA_	S,A,M	H,B	4.87
Leptoceridae	LEPTOCXP	S,A,M	H,S,B	5.05
Ceraclea	CERACLE_	A	B	*6.36*
Mystacides	MYSTACI_	S,A,M	H,S,B	5.24
Oecetis	OECETIS_	S,A,M	H,S,B	4.76
Triaenodes	TRIAENO_	S,A,M	F,H,S,B	4.74
LEPIDOPTERA larva	LEPIDOXL	M	S	5.53
LEPIDOPTERA pupa	LEPIDOXP	A	S	*6.67*
Pyralidae				
Acentria	ACENTRI_	A	S	*6.67*
Langessa	LANGESS_	S,M	S,B	6.36
Parapoynx	PARAPOY_	S,A	S	5.24
DIPTERA				
Chironomidae	CHIRONXL	S	S,B	*4.99*
Chaoboridae larva	CHAOB_XL	M	S	5.42
Chaoborus albatus larva	C_ALBAXL	A	B	5.66
Chaoborus albatus pupa	C_ALBAXP	A	B	5.66
Chaoborus americanus larva	C_AMERXL	S,A,M	S,B	4.50

Table 6 continued on next page

Taxon	Taxonomic Code	Collection Location	Collection Method	Minimum pH
Chaoborus americanus **pupa**	C_AMERXP	S,A,M	S,B	4.50
Chaoborus trivittatus **larva**	C_TRIVXL	A	S	5.31
Ceratopogonidae larva	CERATOXL	A,M	S,B	4.76
Ceratopogonidae pupa	CERATOXP	S	S	6.12
Bezzia-Palpomyia **larva**	BE_PA_XL	S,A	B	4.23
Probezzia	PROBEZZ_	A	B	6.54
Tabanidae				
Chrysops **larva**	CHRYS_XL	S,A,M	F,B	4.37
GASTROPODA				
Valvatidae				
Valvata lewisi	V_LEWISI	A,M	F,B	6.94
Hydrobiidae				
Amnicola limosa	A_LIMOSA	S,M	S,B	6.12
Viviparidae				
Campeloma decisum	C_DECISU	M	B	5.71
Ancylidae				
Ferrissia	FERRISS_	S,A,M	S,B	5.24
Planorbidae				
Gyraulus	GYRAULU_	M	S,B	6.37
Gyraulus deflectus	G_DEFLEC	A,M	B	6.24
Helisoma	HELISOM_	S	S,B	*6.48*
Helisoma anceps	H_ANCEPS	S,A,M	S,M,B	5.78
Planorbella campanulata	P_CAMPAN	S	S,B	*7.36*
Planorbella trivolvis	P_TRIVOL	S	S,B	*6.66*
Promenetus exacuous	P_EXACUO	A,M	F,B	6.94
Physidae				
Physella gyrina	P_GYRINA	S,A,M	F,S,B	6.12
BIVALVIA				
Sphaeriidae	SPHAERII	A,M	F,H,S,B	4.76
Pisidium	PISIDIU_	S,A	S,B	4.87
Sphaerium	SPHAERI_	S,A	S,B	5.83

Table 7. A list of fish species collected from three Ontario study areas (Sudbury (S), Algoma (A) and Muskoka (M)), showing the taxonomic code and corresponding minimum pH (based on three year average pH per wetland, excludes 1995).

Taxon	Taxonomic Code	Collection Location	Minimum pH
CLUPEIFORMES			
Salmonidae			
Salvelinus fontinalis (brook trout)	BROOKTRO	S,A	5.82
Umbridae			
Umbra limi (central mudminnow)	CENTRMUD	S	5.12
Esocidae			
Esox lucius (northern pike)	NORTPIKE	S	6.41
CYPRINIFORMES			
Cyprinidae			
Phoxinus eos (northern redbelly dace)	PHOX_EOS	S,A,M	5.08
Phoxinus neogaeus (finescale dace)	PHOX_NEO	S,A,M	5.22
Couesius plumbeus (lake chub)	LAKECHUB	S,A,M	5.53
Hybognathus hankinsoni (brassy minnow)	BRASSMIN	S	5.71
Notemigonus crysoleucas (golden shiner)	GOLDSHIN	S,A,M	4.96
Notropis cornutus (common shiner)	COMSHINR	S,A,M	5.08
Notropis heterodon (blackchin shiner)	BLKSHINR	S,A,M	5.48
Notropis stramineus (sand shiner)	SANDSHIN	S,A	6.63
Pimephales notatus (bluntnose minnow)	BLUNTNOS	S,M	5.22
Pimephales promelas (fathead minnow)	FATHEAD	S,A,M	5.08
Rhinichthys atratulus (blacknose dace)	BLKNOSE	A	5.66
Semotilus atromaculatus (creek chub)	CRKCHUB	S,A,M	4.99
Semotilus margarita (pearl dace)	PEARLDAC	S,A,M	5.21
Catostomidae			
Catostomus commersoni (white sucker)	WHSUCKER	S,A,M	5.24
Ictaluridae			
Ictalurus nebulosus (brown bullhead)	BROWNBUL	S,M	5..62
GASTEROSTEIFORMES			
Gasterosteidae			
Culaea inconstans (brook stickleback)	BROOKSTK	S,A,M	5.13
PERCIFORMES			
Centrarchidae			
Amblopites rupestris (rock bass)	ROCKBASS	S	6.09
Lepomis gibbosus (pumpkinseed)	PUMPKIN	S,M	5.09
Micropterus dolomieui (smallmouth bass)	SMALMOUT	S	6.14
Micropterus salmoides (largemouth bass)	LARGMOUT	M	6.30
Percidae			
Perca flavescens (yellow perch)	YELPERCH	S,M	4.96
Etheostoma exile (Iowa darter)	IOWADART	S,A	4.91

Table 8. A list of amphibian taxa collected from three Ontario study areas (Sudbury (S), Algoma (A) and Muskoka (M)), showing the taxonomic code, collection method (funnel trap (F), minnow trap (M)) and corresponding minimum pH (based on three year average pH per wetland, excludes 1995).

Taxon	Taxonomic Code	Collection Location	Collection Method	Minimum pH
CAUDATA				
Ambystomatidae				
Ambystoma	AMBYSTO_	S	M	6.14
Salamandridae				
Notopthalmus viridescens	N_VIRIDE	S,A,M	M	4.67
ANURA				
Bufonidae				
Bufo americanus	B_AMERIC	S,A	F, M	5.00
Hylidae				
Hyla crucifer	H_CRUCIF	A,M	M	4.61
Hyla versicolor	H_VERSIC	S	M	5.51
Ranidae				
Rana catesbeiana	R_CATESB	S,A,M	M	4.44
Rana clamitans	R_CLAMIT	S,A,M	M	4.35
Rana septentrionalis	R_SEPTEN	S,A,M	M	4.43
Rana sylvatica	R_SYLVAT	S,M	M	4.61

8.1 Aquatic Insects (continued)

○ Corixidae

Hungerford, H. B. 1948. The Corixidae of the Western Hemisphere. University of Kansas Science Bulletin 32: 1-827.

○ Gerridae

Cheng, L. and C. H. Fernando. 1970. The waterstriders of Ontario. Miscellaneous Life Science Publications, Royal Ontario Museum, Toronto 23 pp.

Drake, C. J. and H. M. Harris. 1934. The Gerrinae of the Western Hemisphere (Hemiptera). University of Kansas Science Bulletin 23: 179-241.

Scudder, G. G. E. and G. S. Jamieson. 1972. The immature stages of *Gerris* (Hemiptera) in British Columbia. Journal of the Entomological Society of British Columbia 69: 72-79.

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