Appendix V5-3E

Aquatic Baseline Studies: Doris Hinge Project Data Compilation Report, 1995-2000

AQUATIC BASELINE STUDIES
DORIS HINGE PROJECT
DATA COMPILATION REPORT
1995 - 2000

RL & L Environmental Services Ltd.
A member of the Golder Group of companies

Golder Associates

AQUATIC BASELINE STUDIES
DORIS HINGE PROJECT
DATA COMPILATION REPORT
1995 - 2000

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EXECUTIVE SUMMARY

Introduction

The Hope Bay Belt Project area is located in the Canadian Arctic to the east of Bathurst Inlet, approximately 60 km east of the community of Umingmaktok, Nunavut. The project area consists of three main gold deposit zones: Doris Hinge, Madrid, and Boston. The Doris Hinge zone is the northern-most area and includes several lake systems that drain into Roberts Bay.

Environmental baseline studies were carried out within the Doris Hinge area from 1995 to 1998 and in 2000. As part of the planning to initiate the mining development of the Hope Bay Belt with the Doris Hinge Project, Miramar Hope Bay Ltd., on behalf of the Hope Bay Joint Venture, contracted RL&L Environmental Services Ltd. / Golder Associates Ltd. (RL&L / Golder) to consolidate and synthesize all aquatic environmental baseline information previously collected within the Doris Hinge area. The present synthesis report is based on studies conducted by Klohn Crippen Consultants in 1995 and by Rescan Environmental Services Ltd. during 1996, 1997, 1998 and 2000. The consolidated report is intended to be used in support of an environmental impact assessment and will form the basis for future monitoring programs.

This data compilation report is organized by major disciplines. Environmental disciplines are presented as separate sections in the following order: bathymetry, physical limnology and surface water quality, sediment quality, primary producers, secondary producers, fish communities, and aquatic habitat assessments.

Bathymetry

Lake bathymetric surveys were carried out on Doris, Tail, Ogama, Patch, and Windy lakes; however, only portions of the latter two lakes were surveyed. The purpose of the surveys was to collect detailed hydrographic information (e.g., volume, depth) and to determine fish habitat quality (e.g., overwintering potential).

Most of the lakes surveyed were long and narrow with low shoreline complexity. The shorelines were characterized by low-lying areas covered by tundra vegetation and interspersed with rock outcrops plunging steeply into the lakes. Among the surveyed lakes, Doris Lake was the largest in terms of volume (26.3 million m^3) and had the highest mean (7.4 m) and maximum (20.0 m) depths. Other lakes were considerably more shallow, with mean depths ranging between 2.6 and 3.1 m and maximum depths between 5.8 and 12.9 m.

Physical Limnology and Surface Water Quality

The lakes of the Doris Hinge area were soft water lakes with neutral to slightly acid pH and low to moderate acid sensitivity. Total phosphorus levels were low, indicating oligotrophic to mesotrophic conditions. Chloride, sodium, and potassium concentrations were elevated compared to typical lakes in the Slave Structural Province. Some metal levels (i.e., total aluminum, iron, copper, cadmium, chromium, lead, and manganese) exceeded Canadian Water Quality Guidelines (CWQG) on a seasonal basis in certain lakes. Metal concentrations, however, were generally typical of lakes in undisturbed northern regions.

In summer, the lakes generally were well-mixed; however, thermal stratification occurred occasionally during the hotter part of the summer season. Episodic (wind-driven) mixing events likely played an important role in maintaining well-mixed conditions. In the shallower lakes, these wind events appeared strong enough to cause complete lake turnover. These conclusions were based on the prevalence of isothermal summer temperature profiles for most of the shallow lakes along with the deep, wind-mixed layer in Doris, Patch and Windy lakes during summer 1995.

The under-ice temperature data generally indicated a shallow upper layer of water at or near 0°C, followed by constant temperatures, not exceeding 2 to 3°C, throughout the remainder of the water column.

The lakes were typically well-aerated during the summer; however, depressed near-bottom dissolved oxygen concentrations were recorded during under-ice conditions. With the exception of Ogama Lake, this dissolved oxygen depression occurred in lakes with relatively high total organic carbon (TOC) levels in sediment. This suggested that sediment oxygen demand was the underlying cause.

In general, the water quality of the lake outflows reflected conditions in the lakes. The majority of water quality parameters measured, including metals and nutrients, were within the recommended values of the CWQG.

Most median metal concentrations in Roberts Bay were below detection limits and below the CWQG. The exceptions were total cadmium and total chromium. The Roberts Bay baseline data indicated a thermally stratified and well-aerated water column in summer, with seawater quality typical of coastal environments.

Sediment Quality

Most metal levels in lake sediments were below the Canadian Interim Sediment Quality Guidelines (CISQG). The exceptions were total chromium, total copper, total arsenic and total cadmium. Of these, total chromium values exceeded the CISQG Probable Effect Level (PEL) in four of the eight lakes sampled. Nevertheless, these elevated sediment metal concentrations remained within the range of natural variability for the Slave Structural Province.

Most of the total metal concentrations in Roberts Bay seabed sediments were compliant with sediment quality guidelines. The exceptions were total chromium and total copper. In general, metal concentrations in sediment were inversely proportional to water content.

Phytoplankton

Phytoplankton are small, generally microscopic, free-floating plants that convert sunlight into biological tissues and form part of the lower food chain upon which other life forms depend. Phytoplankton samples were collected from eight lakes within the Doris Hinge area. Between one and four sampling sessions were conducted on each lake between 1996 and 2000.

The phytoplankton samples obtained from the Doris Hinge lakes contained no uncommon or rare species. The phytoplankton communities (i.e., taxonomic composition) among the eight waterbodies showed little differentiation and were similar in many respects to the communities of other small lakes in the Arctic and sub-Arctic. A comparison of mean phytoplankton abundance indicated that Pelvic Lake was the most productive and Windy Lake was the least productive. In general, phytoplankton communities within the Doris Hinge lakes were numerically dominated by the blue-green algae (Cyanophyta) *Oscillatoria* spp. and *Lyngbya limnetica*, as well as the diatoms (Bacillariophyta) *Diatoma tenue* v. *elongatum*, *Asterionella formosa*, and *Tabellaria flocculosa*. The numerical dominance by blue-green algae among the eight Doris Hinge lakes suggested that this group was able to take advantage of existing conditions and substantially increase its population. Blue-green algae also fix atmospheric nitrogen, thereby flourishing during periods when concentrations of available dissolved nitrogen are low. The waters of the Doris Hinge area, and the Arctic/sub-Arctic regions in general, have low nitrate+nitrite nitrogen concentrations. The low available nitrogen levels may be a limiting factor for populations of non blue-green algae.

Periphyton

Periphyton are algae, bacteria, fungi, and associated materials that surround solid surfaces in aquatic systems. Periphyton samples were collected from seven streams within the Doris Hinge area. Two to four sampling sessions were conducted on each stream between 1996 and 2000.

A comparison of periphyton abundance among the study streams suggested that Doris, Ogama, and Windy outflows were highly productive and that Tail Outflow, closely followed by Pelvic Outflow, were the least productive. Based on chlorophyll *a* concentrations, which is a biomass estimate of live algae, Pelvic Outflow was the most productive, whereas Windy Outflow was the least productive. Similar to the phytoplankton, the numerical dominance by Cyanophyta (mainly *Oscillatoria* spp.) among the seven Doris Hinge streams suggested that this group was able to take advantage of existing conditions and substantially increase its population. Bacillariophyta (mainly *Diatoma elongatum*) also were numerically abundant among the study streams. The predominant Cyanophyta and Bacillariophyta were well represented by taxa that form filaments and are able to attach to, or entangle, substrata in flowing waters. The above observations were consistent with those made in other streams of the Arctic and sub-Arctic regions.

Zooplankton

Zooplankton are small animals that inhabit the water column of lakes and consume phytoplankton and other organic matter. In turn, zooplankton are utilized by large invertebrates and fish as a food source. Zooplankton samples were collected from eight lakes within the Doris Hinge area. One to four sampling sessions were conducted on each lake between 1996 and 2000.

The zooplankton samples obtained from the Doris Hinge lakes revealed no uncommon or rare species. The taxonomic composition of the zooplankton among the eight waterbodies showed little differentiation and were similar in many respects to the communities of other small lakes in the Arctic and sub-Arctic. In general, zooplankton communities within the Doris Hinge lakes were numerically dominated by the rotifer (wheel animal) *Kellicottia longispina*. The most common cladoceran (water flea) was *Daphnia longiremis*. A comparison of zooplankton abundance indicated that Tail Lake was the most productive and Windy Lake was the least productive. The presence of large numbers of large-sized zooplankton (i.e., Cladocera) relative to small-sized zooplankton (i.e., Rotifera), suggested that Tail and Ogama lakes had little predation pressure, whereas Windy and Wolverine lakes had high predation pressure.

Benthic Invertebrates in Lakes

Benthic (bottom-dwelling) invertebrates are an important link in aquatic food webs. Many fish species, including early life history stages of piscivorous species, feed upon benthic invertebrates. Benthic invertebrate samples were collected from eight lakes within the Doris Hinge area. One to four sampling sessions were conducted on each lake between 1996 and 2000.

Chironomidae (midges), Nematoda (roundworms), Pelecypoda (clams), Oligochaeta (bristle-worms), and Malacostraca (fairy shrimp, tadpole shrimp, isopods, etc.) dominated the lake benthic invertebrate communities within the Doris Hinge area. The communities in deeper regions of the study lakes appeared to be increasingly dominated by Chironomidae and occasionally Pelecypoda. Due to the close proximity of the Doris Hinge lakes to the Arctic Ocean, the benthic communities of some lakes periodically featured large proportions of the predominantly marine isopod *Saduria entomon*. This species was encountered in all study lakes except Ogama, Patch, and Wolverine lakes.

A comparison of mean benthic macroinvertebrate abundance suggested that Little Roberts Lake was the most productive and Windy Lake was the least productive. With the exception of a few lakes and sample depths, Chironomidae tended to dominate (i.e., contributed more than 50% to total numbers) the benthic communities of the Doris Hinge lakes. The benthic communities of the eight study lakes were similar in many respects to the communities of other small lakes in the Canadian Arctic and sub-Arctic.

Drift Organisms in Streams

Benthic macroinvertebrates in streams can actively or passively enter the water column; this behaviour is known as drift. Also included in the drift are pelagic forms of invertebrates (e.g., zooplankton) that can be entrained from lakes, back-eddies, and calm side-channels of flowing waters. Drift organisms are an important part of the food chain, particularly because they are easily observed and available to fish and other potential predators. Drift samples were collected from seven streams within the Doris Hinge area. Up to three sampling sessions were conducted on each stream between 1997 and 2000.

A comparison of mean total drift abundance among the sampled Doris Hinge streams suggested that Ogama and Pelvic outflows were highly productive, whereas Patch Outflow was the least productive. Chironomidae, Simuliidae (black flies), Ostracoda (seed shrimp), and Cladocera dominated the drift of the Doris Hinge streams. Differences in composition and abundance of drift organisms could largely be ascribed to different physical characteristics among the study streams. For example, the low numbers of drift organisms encountered in Patch Outflow may be due to the low, ephemeral flows encountered at this site. The isopod *Saduria entomon* was occasionally present in considerable proportions (e.g., Patch and Windy outflows). The high proportion of zooplankton in the drift samples from Doris, Little Roberts, and Pelvic outflows may be an artifact of positioning the drift nets in close proximity to a lake and/or high flushing rates from the corresponding lakes.

Benthic Invertebrates in Streams

Stream benthic macroinvertebrates are adapted to living in flowing waters; thus, the species encountered in streams are different than those from lake environments. Stream invertebrates are an important part of the food chain; particularly if they are situated within fish rearing and adult feeding locations. Benthic samples were collected from seven streams within the Doris Hinge area. Two to four sampling sessions were conducted on each stream between 1996 and 2000.

A comparison of mean total benthic abundance among the sampled Doris Hinge streams suggested that Ogama Outflow was the most productive, whereas Little Roberts Outflow was the least productive. Chironomidae and Simuliidae dominated the benthic communities of the Doris Hinge streams. The isopod, *Saduria entomon*, contributed a considerable proportion to the benthos of Patch Outflow. Plecoptera (stonefies, particularly *Podmosta* spp.) contributed a large proportion to the benthos of Little Roberts Outflow in July 1997. Coelenterata (hydras), Nematoda, and Ostracoda also occasionally contributed considerable proportions to the benthos of the Doris Hinge streams (e.g., Patch, Little Roberts, and Pelvic outflows). Differences in composition and abundance of benthic organisms were likely due to seasonal variations in physical and energetic characteristics among the study streams. Except for Patch and Little Roberts outflows, all study streams sampled in July 1997 featured high proportions (more than 63% of total numbers) of Simuliidae (black flies). The dominance of black flies among the majority of Doris Hinge streams during the June to July 1997 colonization period indicated that this group was able to take advantage of sustained high flows and substantially increase its population size relative to the remaining sampling periods.

Benthic Invertebrates in Roberts Bay

Similar to freshwater invertebrates, benthic forms of marine invertebrates are an important link in food webs. Benthic marine invertebrate samples were collected from three sites within Roberts Bay. Two sampling sessions were conducted at each site, one in August 1997 and one in July 1998.

Polychaeta (lugworms, tube worms, and marine bristle worms), Nematoda, Pelecypoda, Cumacea (an Order within the Class Malacostraca), and Amphipoda (scuds) dominated the benthos of Roberts Bay. The composition of benthic communities within Roberts Bay was typical for the Arctic and Antarctic regions of the world. Differences in composition and abundance of the benthos among the sampled sites were ascribed to physicochemical (e.g., water depth, salinity) characteristics at the sampling locations. A comparison of mean benthic macroinvertebrate abundance among the three sites indicated a trend of increasing faunal densities with increasing water depth. Although most taxonomic groups exhibited this trend, one notable exception was the isopod *Saduria entomon*, which exhibited greater densities at shallower depths. With the exception of the samples collected at the most shallow station, polychaetes tended to dominate (i.e., contributed more than 50% to total numbers) the benthic community of Roberts Bay.

Fish Communities in Lakes

In total, 1552 fish representing six species were captured in gill nets and beach seines in seven Doris Hinge lakes during fisheries surveys conducted between 1995 and 2000. The captured species included (in the order of abundance in the total catch) cisco (36%), lake whitefish (34%), lake trout (28%), Arctic char (2%), least cisco (<1%), and broad whitefish (<1%). Ninespine stickleback were also present in most lakes, as recorded from direct observations in Doris Lake and lake trout stomach content data from Tail and Patch lakes.

Fish populations in five of seven surveyed lakes were limited to three species (lake trout, lake whitefish, and cisco); they were recorded in different proportions to each other depending on the lake. Whereas coregonid species (lake whitefish and cisco) accounted for approximately 90% of the catches in Doris, Ogama, and Pelvic lakes, lake trout were considerably more dominant in Patch and Windy lakes (37 and 56 % of respective catches). Tail Lake, although separated from Doris Lake by a very short stream section, did not support coregonids and was inhabited only by lake trout and ninespine stickleback.

Fish populations in Little Roberts Lake were considerably different from the other sampled lakes, because they included Arctic char, broad whitefish, and least cisco in addition to lake trout and lake whitefish. This difference in species diversity was likely caused by a fish passage barrier between Doris and Little Roberts lakes that prevented access of diadromous species (Arctic char and broad whitefish) to lakes farther upstream. Little Roberts Lake likely is used by Arctic char during their migrations between Roberts Lake and the ocean. Although least cisco (*Coregonus sardinella*) were identified only in Little Roberts Lake, it is suspected that they were also captured, and likely misidentified as cisco (*C. artedii*) in Pelvic and Doris lakes.

Index gill nets were used as the primary capture method in all lakes sampled during 1997-2000. The highest mean catch rate (all species combined) was recorded in Pelvic Lake (400 fish/100 m^2/24 h). The overall catch rate in Doris Lake was second highest at 227 fish/100 m^2/24 h, with considerably lower catch rates recorded in the remaining lakes (ranged from 21 to 86 fish/100 m^2/24 h). Lake trout were present in all sampled lakes, but appeared to be more abundant in Tail Lake (86 fish/100 m^2/24 hours) than in the remaining lakes (15 to 29 fish/100 m^2/24 h). Lake whitefish and cisco were most abundant in Pelvic Lake (203 and 168 fish/100 m^2/24 h, respectively), but were also well represented in Doris and Patch lakes.

Fish Communities in Streams

Streams in the Doris Hinge area were inhabited by at least six fish species. Ninespine stickleback was the most common species (66%) in the total catch of 351 fish. This species was also most widely distributed among the sampled streams; it was recorded in 17 of the 20 sampled stream sites. Lake trout was second in abundance (17% of the total catch) and distribution (recorded in 11 streams). Juveniles and adults were present in the catch, suggesting that the larger streams provide both rearing and feeding lake trout habitat.

Arctic char contributed 12% to the total catch; however, this species was recorded only at five sites in close proximity to Roberts Bay (in Doris Outflow below the waterfalls, Little Roberts Outflow, two sites on Glenn Outflow, and one on Windy Outflow). Most (68%) of the Arctic char catch consisted of juvenile fish between 85 and 303 mm in fork length; adult fish were recorded only in Glenn Outflow.

Cisco were captured in small numbers and only at two sites (Doris Outflow and the main Ogama Inflow); the catch included both juveniles and adults. Lake whitefish were captured in Doris Outflow, Ogama Outflow, and the main Ogama Inflow. Similar to cisco, the lake whitefish catch included both juveniles and adults. Slimy sculpin were recorded only in one stream (Glenn Outflow near Roberts Bay).

Fish Tissues

Fish tissue (dorsal muscle, liver, and kidney) samples were collected from lake trout, lake whitefish, and cisco to provide baseline data on metal concentrations. Samples were collected in lakes in close proximity to potential development activities (Doris, Tail, Ogama, Patch, and Windy) and one reference lake (Pelvic). Samples were collected over several years between 1995 and 1998; however, the majority of the samples were collected in 1997 and 1998 and consisted of muscle and liver tissues from lake trout and lake whitefish.

Analyses of fish tissues indicated generally low levels of metal accumulation. Except for arsenic and mercury, mean concentrations of metals exhibited low variability between lakes. The highest mean concentration of arsenic (1.95 µg/g dry weight) was recorded in lake trout livers from Windy Lake; this was approximately one order of magnitude higher than in Doris Lake. Similarly, the highest mean mercury concentration (3.31 µg/g dry weight, recorded in lake trout livers from Patch Lake) was more than ten times higher than in Windy Lake. Concentrations of metals in fish tissues from Pelvic Lake, which was selected as a control basin for long term monitoring, were similar or intermediate to corresponding levels from other study lakes.

A small proportion (7 of 83) of lake trout muscle tissue samples from the study area lakes exceeded the Health Canada food consumption guideline of 0.5 µg/g wet weight (roughly equivalent to 2.5 µg/g dry weight) for mercury. They included six fish from Patch Lake and one from Doris Lake; the maximum concentration was 0.68 µg/g wet weight. Consistent with bioaccumulation up the food chain, older and larger trout had greater concentrations of mercury in their tissues and these fish were most likely to have muscle mercury concentrations above the Health Canada guideline. All lake whitefish muscle tissues contained mercury levels that were below Health Canada guidelines; the maximum concentration was 0.22 µg/g wet weight.

Fish Habitat in Lakes

The shoreline or littoral zones of Doris, Tail, and Little Roberts lakes were aerially assessed and mapped in 2000. The surveys included mapping of near-shore substrate distribution and assessments of habitat quality for lake trout and coregonid fish species.

Doris Lake had the highest diversity of littoral substrate types. Based on the presence of sand, cobble, and boulder substrates that provide fair to high quality habitats for lake trout and coregonid species (e.g., spawning, rearing, and feeding), Doris Lake was considered to have the most suitable shoreline habitat among the three surveyed lakes.

The littoral zone of Tail Lake was rated as poor to fair habitat for lake trout and coregonids, because of the predominance of bedrock substrates. Little Roberts Lake had the least diverse littoral habitat, with silt and sand dominating the substrate. The entire shoreline was rated as fair quality fish habitat, because these fine substrates provide some feeding habitat. Despite the rating of only fair, Little Roberts Lake had the highest diversity of fish species within the sampled Doris Hinge lakes, likely due to the unobstructed passage for diadromous species from Roberts Bay.

Fish Habitat in Streams

Stream habitat assessments were conducted at 17 stream sites between 1996 and 1998. An additional four stream sites were visually assessed from the air. Detailed habitat maps were elaborated for two streams (Roberts Outflow and Little Roberts Outflow) in 2000.

Streams that interconnect lakes or flow into Roberts Bay appeared to support the highest diversity of fish habitat for rearing, adult feeding, spawning, and migration. The associated lakes likely provided overwintering habitat, which was typically lacking within streams due to shallow depths.

Most of the small inflow tributaries that did not feature a lake or pond upstream were found to be either ephemeral, run-off from melt waters, or provided only marginal rearing and feeding habitat near their mouths. Most lake outflows had a wide diversity of instream habitats with riffles and runs dominating, along with lesser quantities of rapids in half of the outflows. Migration habitat was rated as good to excellent in Glenn, Ogama, Little Roberts and Roberts outflows, but was rated as fair in the Windy Outflow. The outflow from Tail Lake provided marginal fish habitat, including virtually no migration corridor to Doris Lake downstream. The outflows from Roberts and Little Roberts lakes also provided adult feeding, rearing, and spawning habitat to populations of Arctic char that are suspected to overwinter in Roberts Lake. Although Doris Outflow was diverse in fish habitat and species, a 2.3 m high waterfall located approximately 400 m downstream of the lake prevented upstream migration. As a result, the fish populations in Doris Lake were isolated from diadromous migrants from Roberts Bay.

Fish Habitat in Roberts Bay

The assessment of habitat quality for fish and benthic marine organisms in near-shore areas of Roberts Bay was mainly based on aerial observations and mapping of substrate distribution.

The rocky nature of the northwest shoreline provided poor to fair habitat for fish and marine benthic organisms. It provided little cover for fish but some substrate for the colonization of small benthic organisms, anemones, and barnacles. Along the southern shoreline, especially around the mouths of Glenn and Little Roberts outflows, habitats were considered good to excellent for fish and marine benthic organisms because of fine substrates that supported benthic growth and provided feeding areas for fish. These areas were deemed particularly important habitat for diadromous fish, as stream waters locally modified the salinity of the marine environment.

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The following RL&L/Golder personnel participated in the preparation of the report:

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Kent Kristensen	-Primary and Secondary Producers Data Analyses
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1.0 INTRODUCTION

1.1 GENERAL

The Hope Bay Belt area is located in the Canadian Arctic to the east of Bathurst Inlet, approximately 60 km east of the community of Umingmaktok, Nunavut (Figure 1.1). The project area consists of three main gold deposit zones: Doris Hinge, Madrid, and Boston. The Doris Hinge zone is the northern-most area and includes several lake systems that drain into Roberts Bay.

Environmental baseline studies were carried out within the Boston area from 1993 to 1998, and within the Doris Hinge area from 1995 to 1998 and in 2000. As part of the planning to start the mining development of the Hope Bay Belt with the Doris Hinge Project, Miramar Hope Bay Ltd., on behalf of the Hope Bay Joint Venture, contracted RL&L Environmental Services Ltd. / Golder Associates Ltd. (RL&L / Golder) to consolidate and synthesize all aquatic environmental baseline information previously collected within the Doris Hinge area. The present synthesis report is based on studies conducted by Klohn Crippen Consultants in 1995 (Klohn Crippen 1995) and by Rescan Environmental Services Ltd. during 1996, 1997, 1998 and 2000 (Rescan 1997, 1998, 1999a, 1999b, 2001). This consolidated report is intended to be used in support of an environmental impact assessment and will form the basis for future monitoring programs.

1.2 1995-2000 SAMPLING PROGRAM

Aquatic baseline studies conducted in the Doris Hinge zone during 1995-2000 included the following major disciplines: bathymetry, physical limnology, water and sediment quality, primary producers (phytoplankton and periphyton), secondary producers (zooplankton, benthos, and drift organisms), fish populations, and fish habitat.

Figure 1.2 provides an overview of the Doris Hinge area. Lakes that were sampled as part of the baseline studies within the project area included Doris, Tail, Ogama, Patch, Wolverine, Windy, and Little Roberts lakes. Also sampled were selected inflow and outflow streams within the lake basins, and the marine environment of Roberts Bay as the main receiving waterbody downstream of the proposed mining development. In addition, sampling was conducted in Pelvic Lake and its outflow. The Pelvic drainage is located outside of the potential zone of impact from the project. As such, it was considered as a control basin and was sampled to provide reference data for future aquatic effects monitoring programs.

The sampling programs conducted in 1995, 1996, 1997, 1998 and 2000 focused on different disciplines and waterbodies each year (Table 1.1). As such, some of the data presented in this report are based on five years of sampling, whereas

100 0 100

SCALE KILOMETRES

REFERENCE
BASE MAP PROVIDED BY RESCAN,
FEBRUARY 17, 1998

HBJV Hope Bay Joint Venture

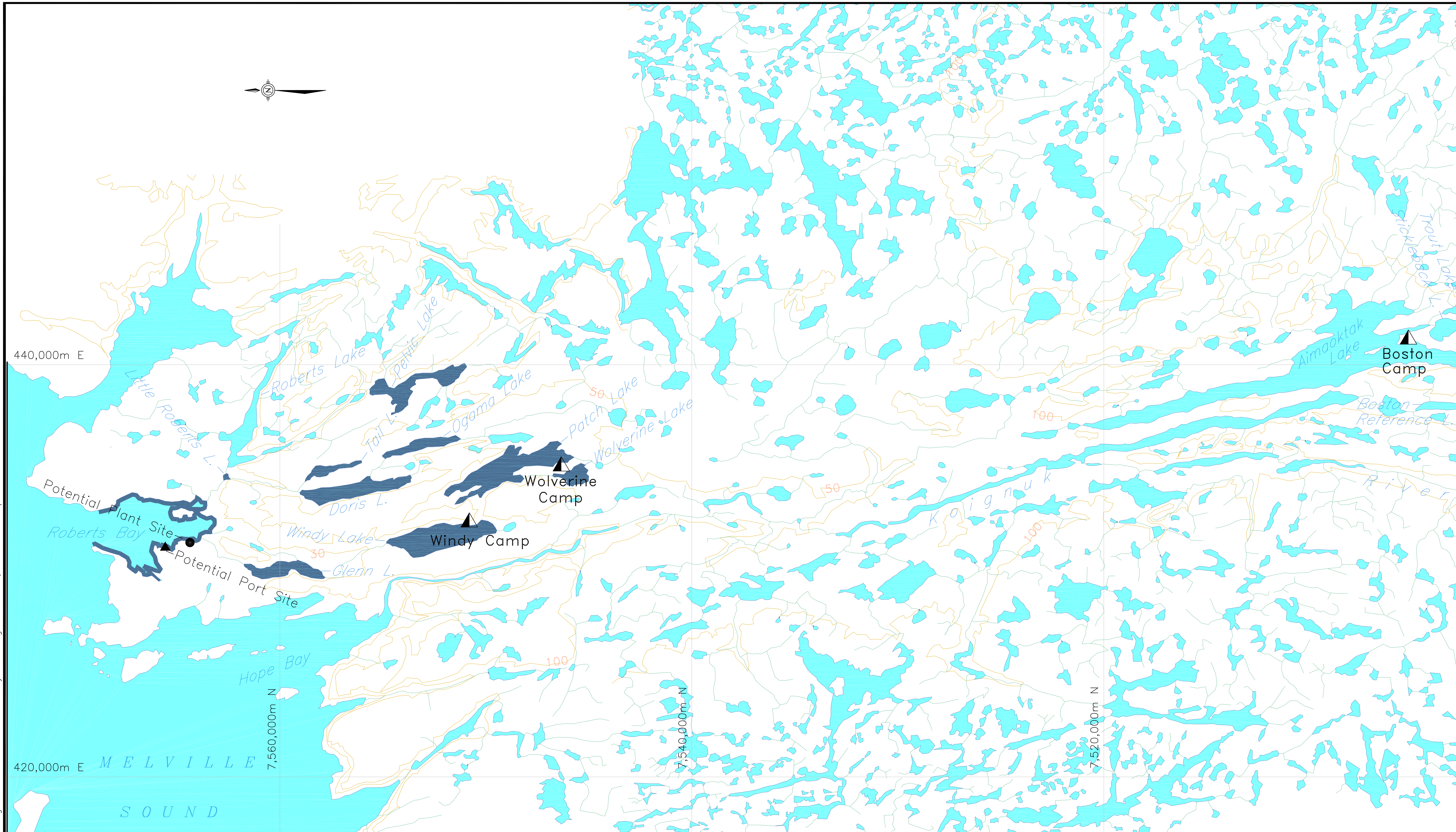
TITLE

HOPE BAY BELT
PROJECT LOCATION MAP

Golder Associates
Calgary, Alberta

PROJECT No. 022–7009.1000			FILE No. Project Location Map	
DESIGN	JP	12/07/02	SCALE 1:4000000	REV. 1
CADD	PSR	17/10/02	**FIGURE: 1-1**	
CHECK	JP	17/10/02		
REVIEW				

R:\CAD\7000\022-7009\ Drawing file: Project Location Map.dwg Jul 12, 2002 - 2:38pm



LEGEND

1995-2000 DORIS HINGE STUDY AREAS

4 0 4

SCALE KILOMETRES

NOTE : CONTOUR INTERVAL 50 m

REFERENCE

BASE MAP PROVIDED BY RESCAN, MARCH 23, 2001

Hope Bay Joint Venture

TITLE

LOCATION OF DORIS HINGE STUDY AREA

Golder Associates
Edmonton, Alberta

PROJECT No. 022-7009.1000			FILE No. Locations 2000 Study	
DESIGN	AH	11/06/02	SCALE AS SHOWN	REV. 0
CADD	RFM	24/07/02	FIGURE: 1.2	
CHECK				
REVIEW				

R:\CAD\7000\022-7009\ Drawing file: Locations of 2000 Study Areas.dwg Jul 24, 2002 - 4:04pm

Table 1.1 Doris Hinge aquatic sampling program, 1995 to 2000.

Waterbody	Bathymetry		Physical Limnology				Water Quality					Sediments				1° & 2° Producers				Fish Populations					Habitat	
	'95	'00	'95	'97	'98	'00	'95	'96	'97	'98	'00	'96	'97	'98	'00	'96	'97	'98	'00	'95	'96	'97	'98	'00	'96	'00
Doris Lake	8		8	4,7,8	4	8	5,6,7,8	4,8	4,7,8	4	7,8	8	7			8	7,8		7	8	8	8				8
Tail Lake	8	7	8	4,7	4	8	8	8	4,7	4	7,8	8	7			8	7		7	8	8			8		8
Ogama Lake		7		4,7	4		5,6,7,8	8	4,7	4		8	7			8	7				8					
Patch Lake	8[a]		8	4,7	4		5,6,7,8	4,8	4,7	4		8	7			8	7			8	8	8				
Wolverine Lake				4,7	4				4,7	4			7				7									
Windy Lake			8	4,7	4		5,6,7,8	8	4,7	4	7	8	7			8	7				8	8				
Little Roberts Lake				7			5,6,7,8	8	7			8	7			8	7							8		8
Pelvic Lake				7	4	8			7	4	7		7				7		7				8			
Roberts Bay				8	7			8	8	7			8	7[b]	7[b]		8	7	7							8
Doris Outflow								6,8	6,7,8		6,9					8	7,8		8	8	7	8		6,8	7	8
Doris Inflow																					7	6				
Tail Outflow								6,8	6,7,8		6,9					8	7,8		8			6		6		6
Ogama Outflow								6,8	6,7,8							8	7,8			8	7	8			7	
Ogama Inflows																				8	7	6			7	
Patch Outflow								6,8	6,7,8							8	8					8				
Patch Inflows																						6				
Windy Outflow								6,8	6,7,8							8	7,8					6			7	
Windy Inflow																						6				
Glenn Outflow																						6,8		6,8		6,8
Little Roberts Outflow								6,8	6,7,8							8	7,8					8		8		6,8
Roberts Outflow																										6,8
Pelvic Outflow									6,7,8		6,9						7,8		8							

NOTE: numbers in the table indicate months when sampling was conducted (e.g., 4 = April)

[a]only the northern half of Patch Lake was surveyed for bathymetry

[b]sediment samples were collected, but not analyzed

other data are based on two or three years of sampling. Sampling details and methodology are provided for each discipline in subsequent chapters.

1.3 OVERVIEW OF REPORT

This report is organized by major disciplines. Environmental disciplines are presented as separate chapters in the following order: bathymetry, physical limnology and surface water quality, sediment quality, primary producers, secondary producers, fish populations, and fish habitat assessment. All original data and analytical results (as presented in the annual data reports) are provided as appendices at the end of the report. In cases where the information in the text of the annual data reports did not agree with the data presented in the corresponding appendices, the appendix values were generally assumed to be correct and were used as bases for all statistical analyses. Where it was obvious that the appendix values were erroneous (e.g., fish lengths that did not agree with the corresponding weights), these data were clearly marked in the appendices (i.e., placed in parenthesis) and were omitted from all statistical analyses.

In the cases of primary and secondary producers, the present report includes only those taxa that were ecologically targeted. For instance, analytical laboratories typically provide results of all specimens encountered. As such, the benthic invertebrate data sets included vertebrates (e.g., fish), non-benthic / non-aquatic invertebrates [e.g., Thysanoptera (thrips), Hymenoptera (ants and bees)] and terrestrial adult forms of aquatic species. Although these non-targeted data were included in the appendices (marked as shaded rows), they were omitted from all statistical analyses. As it was not always apparent how these non-targeted taxa were treated during previous analyses conducted by Rescan (1997, 1998, 2001), summary numbers presented in the present report may not match those provided by Rescan in the annual reports. Based on the consistent treatment of the data during the present analyses, it is suggested that this compilation report be used for subsequent assessment and monitoring purposes.

2.0 BATHYMETRY

2.1 METHODS

Lake bathymetric surveys were carried out in the Doris Hinge area during August 1995 on Doris, Patch, Tail, and Windy lakes and on Ogama and Tail lakes in July 2000. Detailed surveys were carried out within the entire lake area, except for Patch and Windy lakes, which only had portions of their areas surveyed. Bathymetric surveys were conducted to provide detailed volume and hydrographic information in the event that either of Doris, Ogama, or Tail lakes was considered for tailings placement.

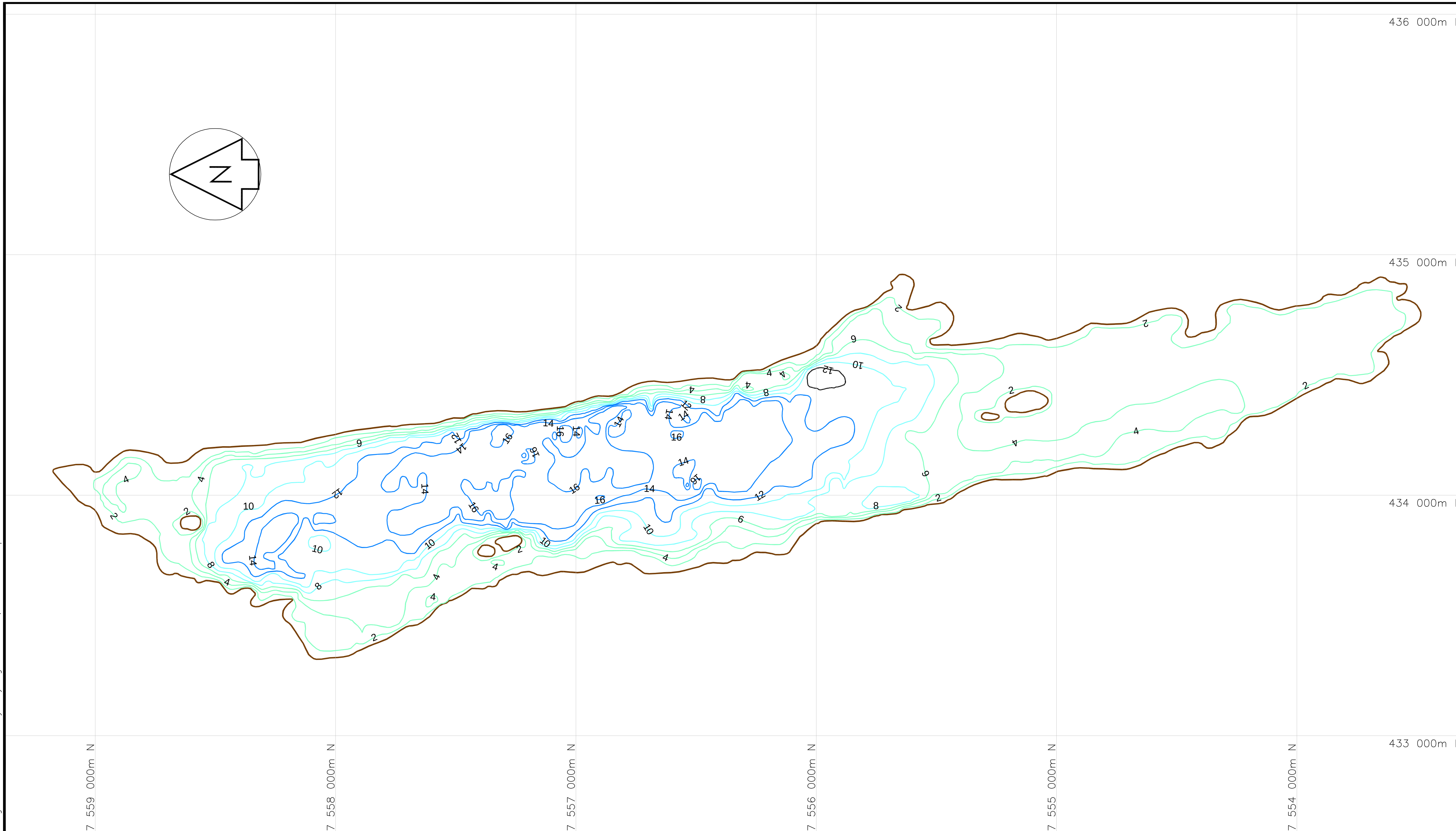
The work predominantly involved the collection of simultaneous global positioning system (GPS) and depth sounder measurements. A Meridata MD100 depth sounder and Trimble Pro XL GPS receiver were used in 1995, whereas a Trimble ProXRS differential global positioning system (DGPS) and a Seamax echosounder were used in 2000. The DGPS position and sounder data streams were merged onto a Trimble TSC1 data logger. To check the correlation of bathymetric data to the lake outlines from NTS data, selected sites around the lake perimeter were marked in the data file as GPS features. These sites generally were areas where the shore was very steep in order that a change in lake elevation would not significantly affect its horizontal extent. Lake areas were calculated based on digitized lake outlines from 1:50 000 scale topographic maps. Lake perimeters were also based on 1:50 000 maps in 1995, whereas they were surveyed by foot with the DGPS in 2000. Differential corrections to GPS data collected in the field were made using data from a portable base station (Trimble 4000SE in 1995, Trimble 4600LS Surveyor in 2000) located on a point with known coordinates. Differential correction of position data was reported to be accurate to within 1 m.

2.2 SURVEYED LAKES

2.2.1 Doris Lake

The bathymetric map of Doris Lake was based on over 30 000 positions and soundings that were collected along two north-south transects, 19 east-west transects (spaced approximately 300 m apart), and the lake perimeter (at approximately 2 m contour).

Doris Lake was approximately 5.5 km long, with an average width of 700 m and a maximum width of 960 m. Besides containing five small islands, the lake had a moderately sized, deep (>14 m), and flat north-central basin approximately 1.5 km in length (Figure 2.1). The southern end of the lake was shallow with depths of 2 to 4 m. Although the continuous maximum depth contour on the



LEGEND

- 2-6 m CONTOUR LINES
- 8-10 m CONTOUR LINES
- 12-16 m CONTOUR LINES

BATHYMETRIC CONTOUR INTERVAL: 2.0 m

300 0 300
SCALE METRES

REFERENCE
DIGITIZED FROM SCAN PROVIDED BY EAGLE MAPPING SERVICES LTD.

Hope Bay Joint Venture

TITLE

BATHYMETRY OF DORIS LAKE

Golder Associates
Edmonton, Alberta

PROJECT No. 022-7009.1000			FILE No. Doris Lake Bath	
DESIGN	AH	11/06/02	SCALE AS SHOWN	REV. 0
CADD	RFM	24/07/02	FIGURE: 2.1	
CHECK				
REVIEW				

R:\CAD\7000\022-7009\ Drawing file: Doris Lake Bathymetry.dwg Jul 24, 2002 – 2:17pm bathymetric map is 16 m, localized depths greater than 18 m and spot depths of 20 m were found. Parts of the northeastern shoreline dropped off steeply, with depths reaching 14 m within 50 m off shore. A similar scenario also existed in a localized area near the eastern shore of the two small islands along the northwest side of the lake. Doris Lake had the third largest perimeter (15.1 km) of the surveyed lakes. It covered an area of 3.54 km^2 and had a volume of 26.3 million m^3 (Table 2.1).

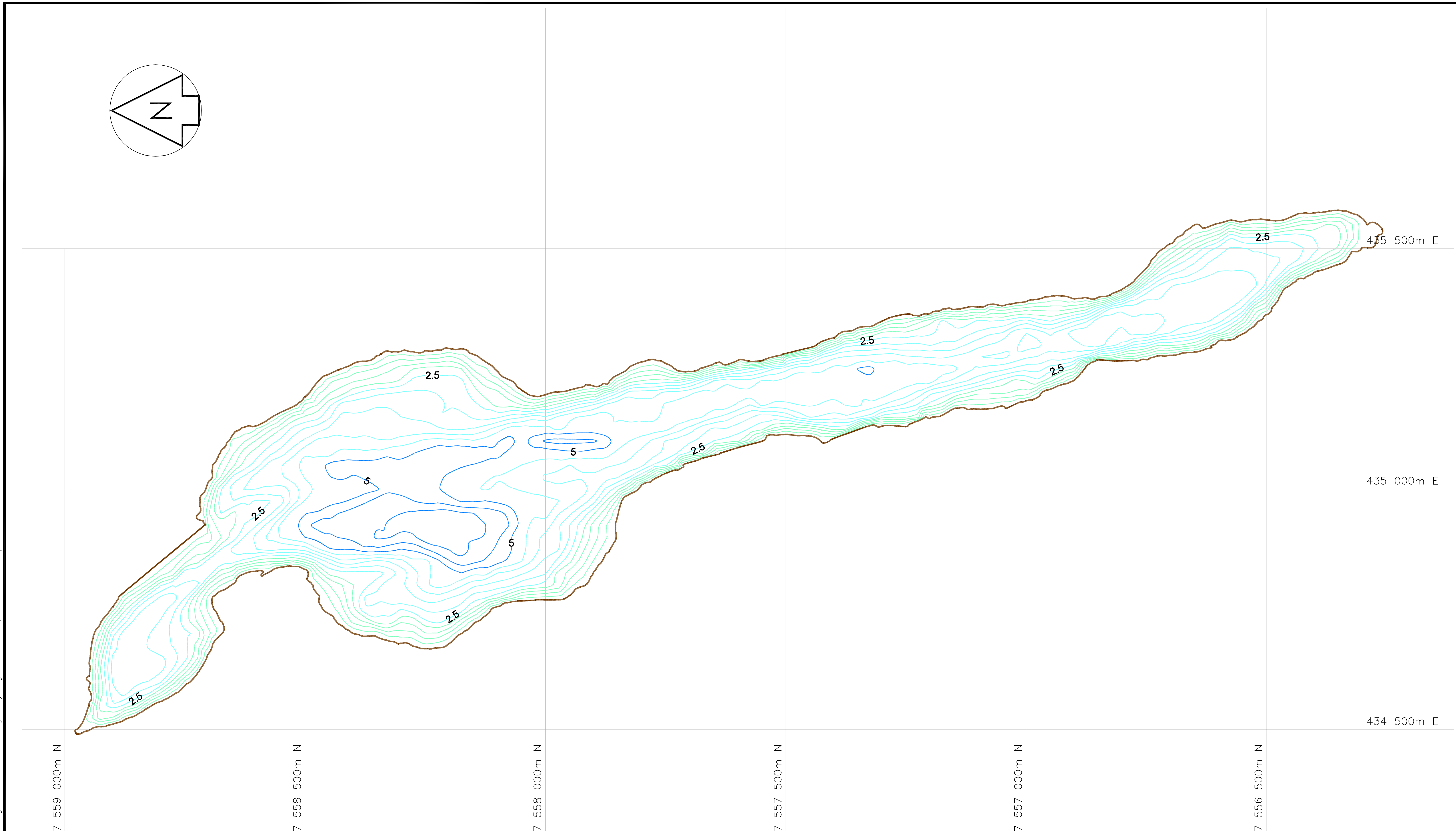
Table 2.1 Physical characteristics of Doris Hinge lakes.

Lake	Survey Year	Length (km)	Maximum Width (km)	Perimeter (m)	Area (m^2)	Volume (m^3)	Mean Depth (m)	Max. Depth (m)
Doris	1995	5.5	0.96	15 055	3 540 053	26 315 362	7.4	20.0
Tail	1995	3.0	0.60	7 152	802 359	2 263 135	2.8	5.8
Tail[a]	2000	2.9	0.61	6 923	766 300	2 380 000	3.1	6.5
Ogama	2000	4.0	0.59	9 803	1 618 667	4 209 800	2.6	7.4
Patch[b]	1995	6.0	1.10	22 109	5 838 535	-	-	12.9
Windy[c]	1995	5.5	1.50	12 640	5 286 112	-	-	9.7
Wolverine[d]	n/a	-	-	5 372	995 381	-	-	-
Glenn[d]	n/a	-	-	10 097	2 230 567	-	-	-
Little Roberts[d]	n/a	-	-	1 344	96 258	-	-	-
Pelvic[d]	n/a	-	-	16 166	3 521 744	-	-	-

[a] The bathymetric survey of Tail Lake conducted in 2000 was considered more accurate than the 1995 survey, because of the greater number of transects conducted.
[b] The maximum depth refers to the surveyed area in the north end. All surface data are for the entire lake.
[c] The maximum depth refers to a small surveyed area in the south end. All surface data are for the entire lake.
[d] Bathymetry surveys were not conducted; perimeter and area calculated from 1:50 000 NTS maps.

2.2.2 Tail Lake

Two bathymetric surveys of Tail Lake were conducted: one in August 1995 and one in July 2000. The 1995 bathymetric map of Tail Lake was based on over 12 500 position and sounding data points that were collected along 18 east-west transects (spaced approximately 150 m apart), one north-south transect, and the lake perimeter (at approximately 2 m contour). The 2000 bathymetric map was based on a total of 9246 data pairs (position and depth) collected along over 40 east-west transects and several longitudinal (north-south) transects. Lake data from the 2000 survey were considered more accurate because a greater number of bathymetric transects were completed and the lake perimeter was surveyed by foot; as such, only the 2000 bathymetric map of Tail Lake is presented in this report (Figure 2.2).



R:\CAD\7000\022-7009\ Drawing file: Tail Lake Bathymetry.dwg Jul 24, 2002 - 2:18pm

LEGEND

- 0.5-2.0 m CONTOUR LINES
- 2.5-4.0 m CONTOUR LINES
- 5.0-6.0 m CONTOUR LINES

BATHYMETRIC CONTOUR INTERVAL: 0.5 m

REFERENCE

BASE MAP PROVIDED BY RESCAN (2001)

150 0 150
SCALE METRES

Hope Bay Joint Venture

TITLE

BATHYMETRY OF TAIL LAKE

Golder Associates
Edmonton, Alberta

PROJECT No. 022-7009.1000			FILE No. Tail Lake Bathymetry	
DESIGN	AH	11/06/02	SCALE AS SHOWN	REV. 0
CADD	RFM	24/07/02	FIGURE: 2.2	
CHECK				
REVIEW				

Physical lake characteristics including length, width, perimeter, area, volume, and mean and maximum depth are presented in Table 2.1. Tail Lake was 2.9 km long along its central axis, with a total perimeter of 6923 m. The maximum measured width of the lake was 608 m at the northern end, with much of the lake averaging less than 300 m in width. The total surface area was 766 300 m^2 (Table 2.1). The lake had a total volume of approximately 2.38 million m^3, with a maximum depth of 6.5 m. Much of the lake was less than 4 m in depth, with the deepest areas (>5 m) located in the north basin. The perimeter had a well-defined area of less than 2.5 m in depth, which dropped off sharply from the shoreline.

2.2.3 Ogama Lake

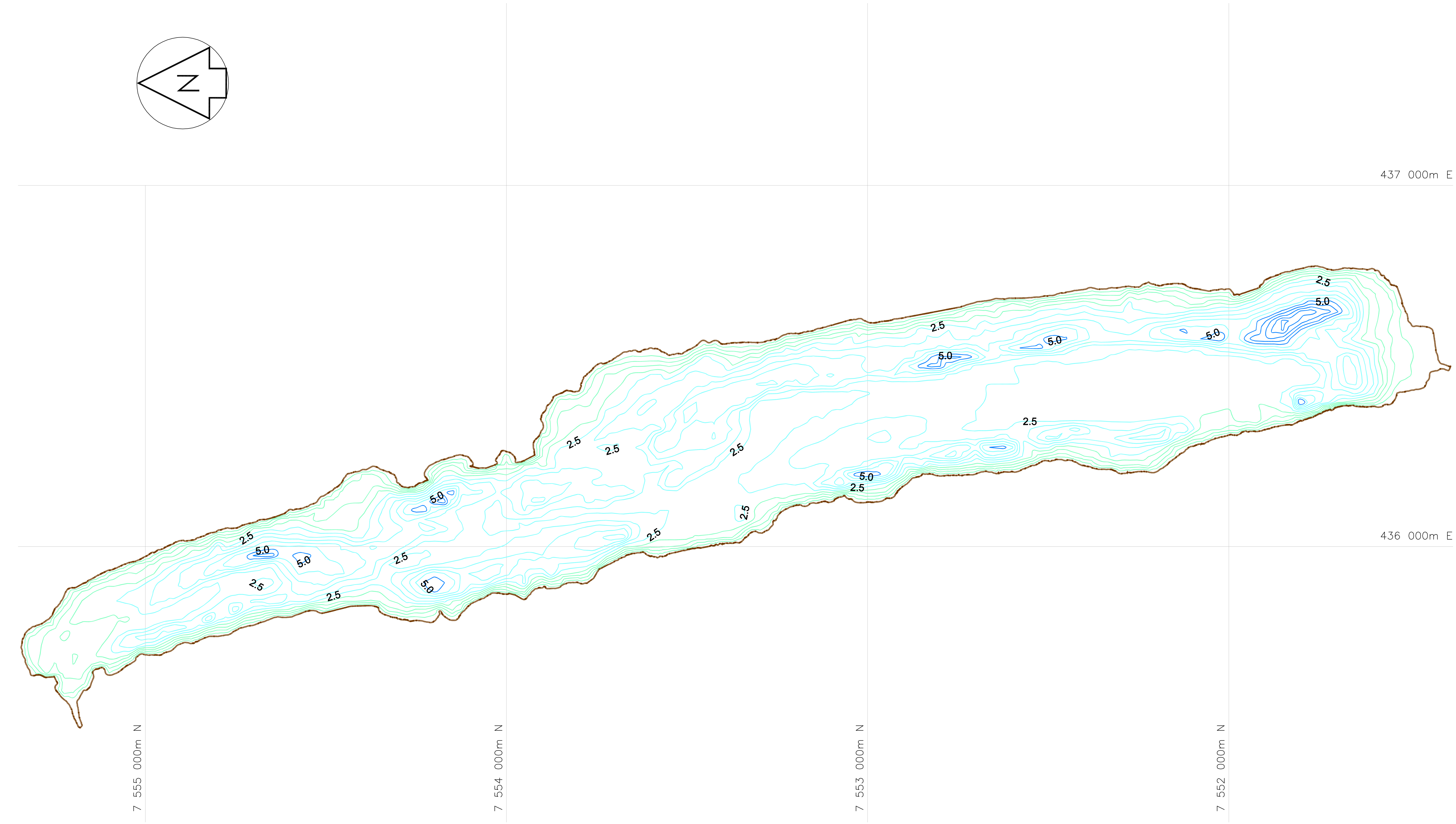
Similar to other lakes in the Doris Hinge area, Ogama Lake is long and narrow with its long axis oriented NNW. The lake was approximately 4.0 km long, with a maximum width of 578 m (Table 2.1; Figure 2.3). In total, 7754 point positions and soundings were collected in July 2000 to generate the bathymetric map. The maximum depth of 7.4 m was recorded in the south basin. Much of the south central area was less than 2.5 m in depth, although several peripheral, small and localized areas reaching 5.0 m in depth were also recorded. Steep drop offs were noted mainly along the west shoreline. Ogama Lake had a perimeter of 9.8 km, an area of 1.6 km^2, and a volume of 4.2 million m^3.

2.2.4 Other Lakes

Patch Lake was approximately 6 km in length and 1.1 km in width. It contained several large islands and bays along its irregular shoreline. A bathymetric survey to provide information for an exploration drilling program was carried out in the north half of Patch Lake in August 1995. The resulting map indicated a maximum depth of 12.9 m off the northwestern shoreline, with depths of less than 4.0 m in the two northern arms (Figure 2.4). Although lake volume data could not be calculated, the lake covered an area of approximately 5.8 km^2 and had a perimeter of 22 km; this was the largest of all surveyed lakes (Table 2.1).

Windy Lake was approximately 5.5 km long with a maximum width of 1.5 km. It covered an area of approximately 5.2 km^2, with a perimeter of approximately 12.6 km. Detailed bathymetry data were not generated for Windy Lake and only a small area near the south end of the lake was surveyed for depth in 1995. The deepest point within this surveyed area was 9.7 m.

Although bathymetric surveys were not conducted in Wolverine, Glenn, Little Roberts, and Pelvic lakes, their perimeters and areas were measured from a 1:50 000 NTS maps. These measurements indicated that perimeter lengths ranged from a minimum of 1.3 km for Little Roberts Lake to a maximum of 16.2 km for Pelvic Lake, whereas surface areas ranged from 0.1 to 3.5 km^2 for these same lakes, respectively (Table 2.1).



LEGEND

- 0.5-2.0 m CONTOUR LINES
- 2.5-4.5 m CONTOUR LINES
- 5.0-7.0 m CONTOUR LINES

BATHYMETRIC CONTOUR INTERVAL: 0.5 m

SCALE 200 0 200 METRES

REFERENCE

BASE MAP PROVIDED BY RESCAN (2001)

Hope Bay Joint Venture

TITLE

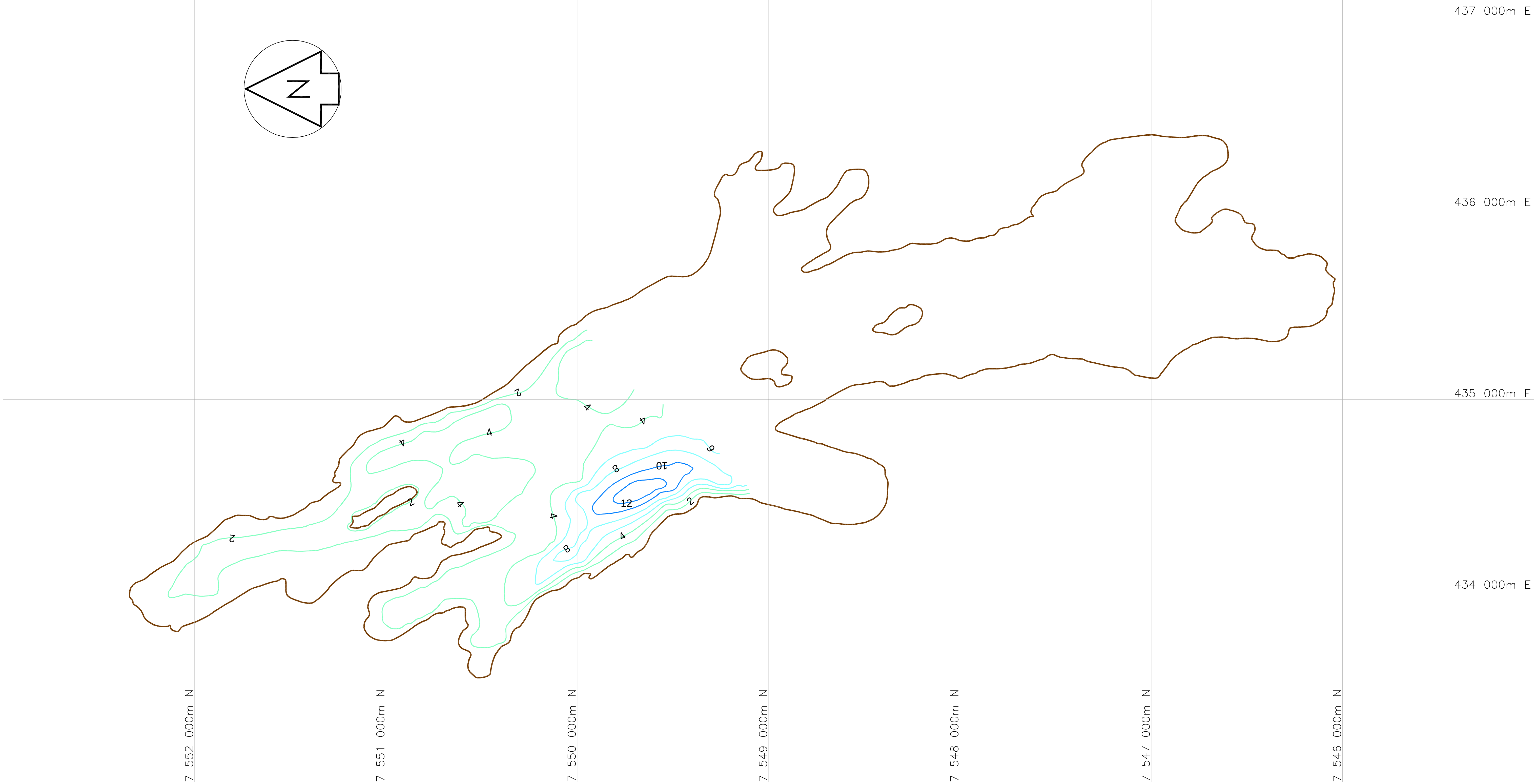
BATHYMETRY OF OGAMA LAKE

Golder Associates
Edmonton, Alberta

PROJECT No. 022-7009.1000			FILE No.	Ogama Lake Bath	
DESIGN	AH	11/06/02	SCALE	AS SHOWN	REV. 0
CADD	RFM	24/07/02			
CHECK					
REVIEW					

FIGURE: 2.3

R:\CAD\7000\022-7009\ Drawing file: Ogama Lake Bathymetry.dwg Jul 24, 2002 - 2:19pm



LEGEND

- 2-4 m CONTOUR LINES
- 6-8 m CONTOUR LINES
- 10-12 m CONTOUR LINES

BATHYMETRIC CONTOUR INTERVAL: 2.0 m

REFERENCE

DIGITIZED FROM SCAN PROVIDED BY EAGLE MAPPING SERVICES LTD.

400 0 400

SCALE METRES

Hope Bay Joint Venture

TITLE

BATHYMETRY OF PATCH LAKE

Golder Associates
Edmonton, Alberta

PROJECT	No. 022-7009.1000	
DESIGN	AH	11/06/02
CADD	RFM	24/07/02
CHECK		
REVIEW		

FILE No. Patch Lake Bath

SCALE AS SHOWN REV. 0

FIGURE: 2.4

3.0 PHYSICAL LIMNOLOGY AND SURFACE WATER QUALITY

This chapter presents information on baseline water quality conditions near the project site. Baseline water quality data for both streams and lakes are presented, as well as for the marine environment in Roberts Bay. The information presented is based on data from various annual project reports including Klohn-Crippen (1995) and Rescan (1997, 1998, 1999a, 2001).

Section 3.1 presents a summary of methods used in the collection of baseline data for both freshwater and marine environments. Sections 3.2 presents the results of the water quality surveys conducted in lakes, streams, and Roberts Bay.

3.1 METHODS

3.1.1 Sampling Locations and Timing

Water quality samples were collected from lakes, streams, and from the marine environment near the project site, between 1995 and 2000. All sampling locations are shown in Figure 3.1. Detailed sampling methodologies are presented in various reports (e.g., Klohn-Crippen 1995; Rescan 1997, 1998, 1999a, 2001); a summary of methodologies is also presented in Appendix A1.

A majority of the initial sampling effort focused on lakes within the Doris Lake watershed including Doris, Tail, Ogama, and Patch lakes and their respective outflows. Other lake sampling locations that were later added to the baseline program included Little Roberts Lake (which receives outflows from Doris Lake and from Roberts Lake), as well as Windy and Pelvic lakes. The latter two lakes are located outside the Doris Lake watershed and were considered as possible reference sites for monitoring potential project influences on the Doris Lake watershed.

In general, water quality samples were collected from a single site in each lake, which was located in the deepest section of the lake. Seasonal samples were collected during under-ice conditions in late winter / early spring (April to June), and during summer open water conditions (July and August). In addition to the collection of discrete water samples for analysis of physical and chemical parameters, vertical temperature and dissolved oxygen (DO) profiles were obtained for each lake using in-situ field-calibrated meters. Field measurements of pH, conductivity and Secchi depth were collected in some lakes. The years in which water quality samples were collected and vertical profiles were measured for all lakes are summarized in Table 3.1.

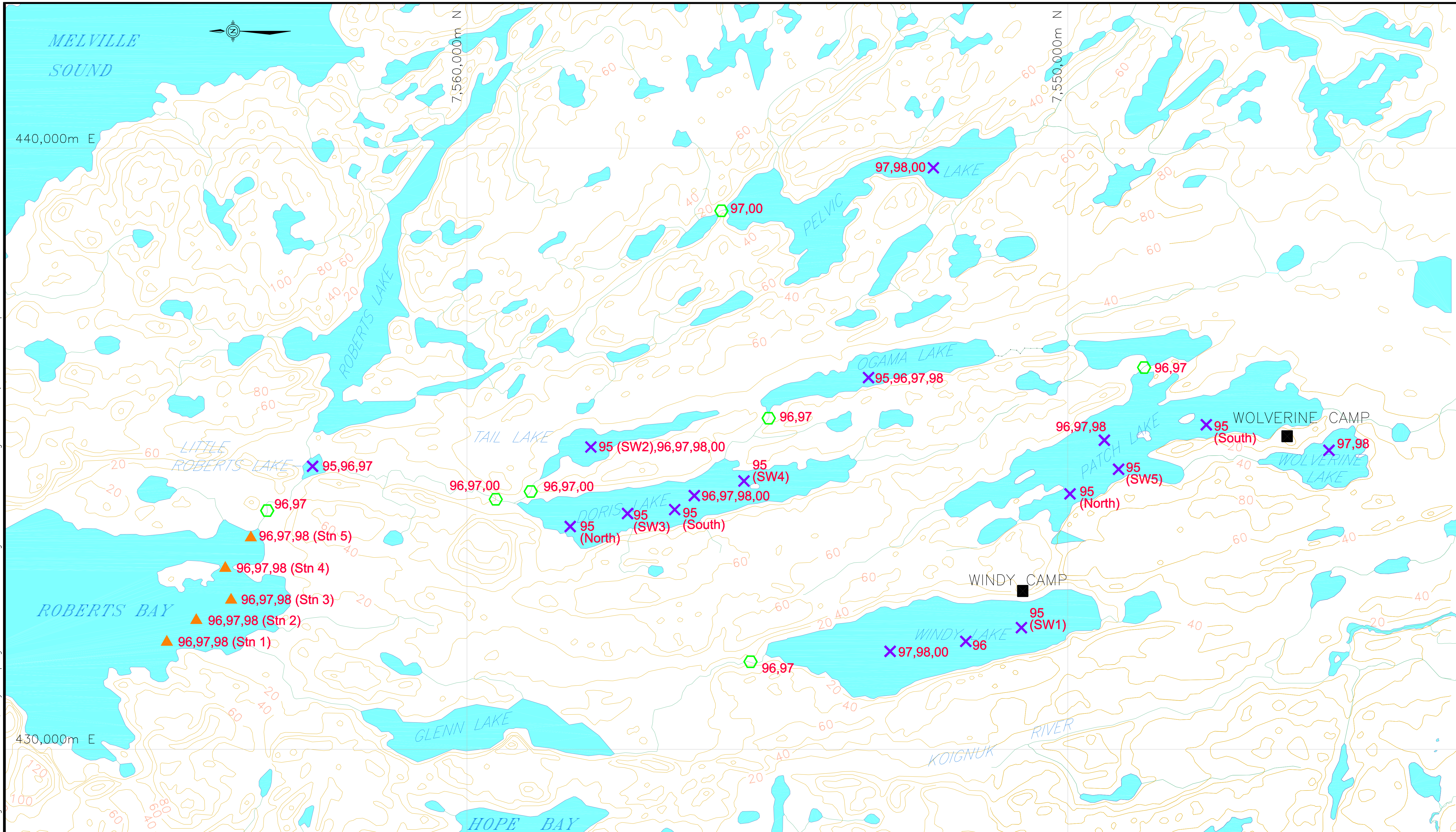
Table 3.1 Summary of water samples (√) and vertical profiles (P) collected from Doris Hinge lakes, 1995 to 2000.

Lake	1995		1996		1997		1998	2000
	Ice Cover	Open Water	Ice Cover	Open Water	Ice Cover	Open Water	Ice Cover	Open Water
Doris	√	√ P	√ P	√ P	√ P	√ P	√ P	√ P
Tail		√ P	P	√ P	√ P	√ P	√	√ P
Ogama	√	√		√	√ P	√ P	√ P	
Patch	√	√ P	√ P	√ P	√ P	√ P	√ P	
Wolverine					√ P	√ P	√ P	
Windy	√	√ P		√ P	√ P	√ P	√ P	√
Little Roberts	√	√		√		√ P		P
Pelvic						√ P	√ P	√ P

Sampling of lake outflows (Doris, Tail, Ogama, Patch, Windy, and Little Roberts) was added to the baseline monitoring program in 1996, with the exception of Pelvic Lake, for which outflow sampling was started in 1997. In general, outflow sampling was conducted during the spring melt conditions (June) and during the summer (July to September). Outflow sampling involved the collection of discrete water samples for the analysis of various physical and chemical parameters. In addition, field parameters including temperature, DO, pH and conductivity were measured during some of the water quality surveys. Table 3.2 presents a summary of stream water quality sampling conducted at the project site between 1995 and 2000.

Table 3.2 Summary of stream water quality sampling sites in Doris Hinge streams, 1996 to 2000.

Stream	1996		1997		2000	
	Spring	Summer	Spring	Summer	Spring	Summer
Doris Outflow	√	√	√	√	√	√
Tail Outflow	√	√	√	√	√	√
Ogama Outflow	√	√	√	√		
Patch Outflow	√	√	√	√		
Windy Outflow	√	√	√	√		
Little Roberts Outflow	√	√	√	√		
Pelvic Outflow			√	√	√	√



LEGEND

×	LAKE SAMPLING LOCATIONS
⬡	STREAM SAMPLING LOCATIONS
▲	MARINE SAMPLING LOCATIONS
95,96 etc.	YEARS OF SAMPLING
(SW1), (North), etc.	STATION NAMES

1.5 0 1.5
SCALE KILOMETRES

NOTE : CONTOUR INTERVAL 20 m

REFERENCE
BASE MAP PROVIDED BY RESCAN, JANUARY 22, 2001

Hope Bay Joint Venture

TITLE

WATER QUALITY SAMPLING LOCATIONS IN DORIS HINGE AREA, 1995-2000

Golder Associates
Edmonton, Alberta

PROJECT No. 022-7009.1000			FILE No. Water Quality Samp	
DESIGN	AH	11/06/02	SCALE AS SHOWN	REV. 0
CADD	RFM	24/07/02		
CHECK				
REVIEW				

FIGURE: 3.1

R:\CAD\7000\022-7009\ Drawing file: revised-Water Quality Sampling Locations in Doris Hinge Area 1995-2000.dwg Jul 24, 2002 - 4:11pm

Baseline marine water quality sampling was also conducted in Roberts Bay, which is the final receiving waterbody of drainage from the Doris Lake watershed. Samples were collected during the summer (i.e., July and August) from 1996 through 1998, at five ocean stations within Roberts Bay (Figure 3.1). Temperature and DO profiles were also obtained at these stations in 1998. In general, methodologies used for the collection of marine samples were similar to those used for lake sampling (see Appendix A1).

3.1.2 Laboratory Analytical Methods

Water samples were analyzed for various physical and chemical parameters including nutrients, major ions, routine water quality parameters (hardness, alkalinity, pH, etc.) as well as dissolved and total metals (refer to Appendix A2 for complete list of analysed parameters).

Analytical methodologies and detection limits used for various parameters varied from year to year, largely because a number of different laboratories were used, including Analytical Service Laboratories (ASL), Elemental Research Inc. (ERI) and University of British Columbia (UBC).

3.1.3 QA/QC Procedures

Various quality control/quality assurance (QA/QC) procedures were followed throughout the five-year baseline monitoring program. In general, QA/QC procedures used during the program included those dealing with field and laboratory components of the program. Field QA/QC included the use of sample replicates, travel blanks and field blanks, while laboratory QA/QC procedures involved the use of sample splits and laboratory method blanks (Appendix A3). The analytical results for QA/QC samples are presented in Appendix A4.

3.2 LAKE WATER QUALITY

Analytical results for all available water quality data from Doris Hinge lakes are presented in Appendices A5 and A6; Secchi depth measurements are summarized in Appendix A7. Seasonal summaries of water quality data for each lake are presented in individual tables in the following sub-sections. Data collected between April and June (under-ice or spring melt conditions) comprise the spring seasonal data. Samples collected in July and August comprise the summer seasonal group (open water conditions).

Wherever possible, data are presented as seasonal medians, minimums and maximums for each waterbody and sampling season. This station and seasonal pooling included all replicates, sample splits, multiple sampling depths, and multiple station sampling sites. Median values of the pooled samples were calculated to obtain seasonal medians. Median values were not calculated if the sample size was less than three. Data were listed in summary tables as medians if sample size was one. Seasonal maximum and minimum values were also presented in summary tables. Details for the derivation of water quality statistics are presented in Appendix A8. The exceptions to this data processing were the temperature and dissolved oxygen profile data, which are discussed in this report on an individual profile basis.

Median, minimum and maximum concentrations were compared to the Canadian Water Quality Guidelines for the protection of aquatic life (CWQG) and Canadian Drinking Water Guidelines (CDWG) (CCME 1999) to provide reference for baseline water quality conditions.

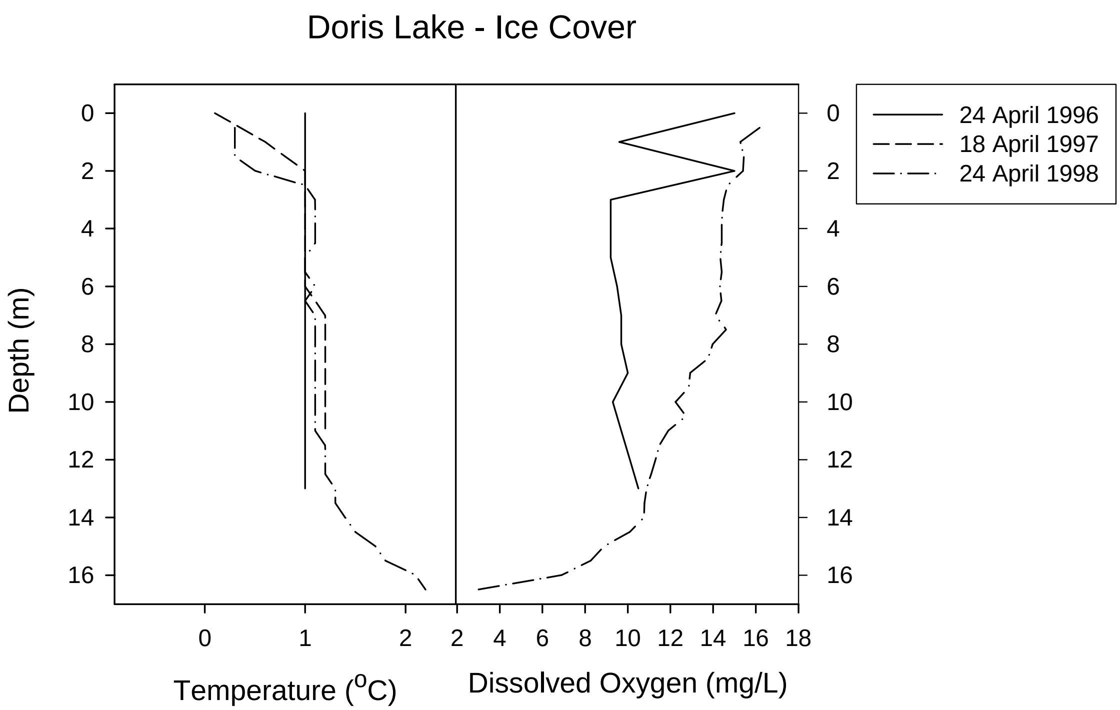
3.2.1 Doris Lake

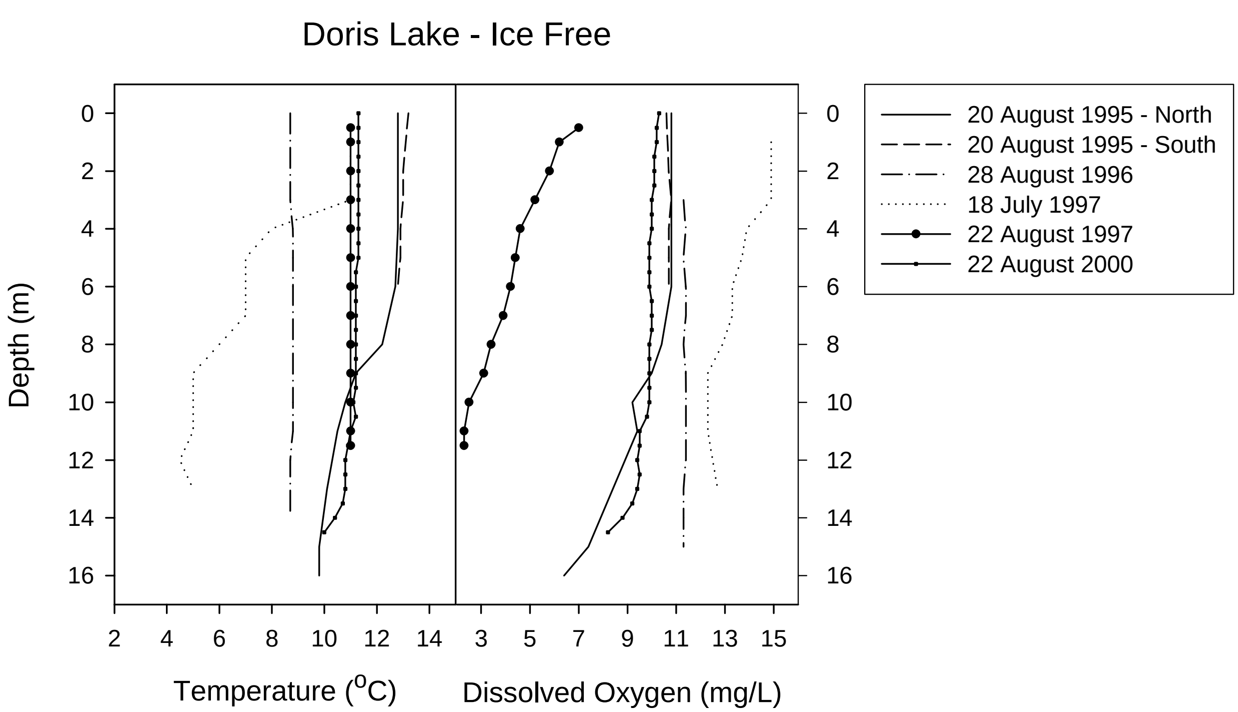
Dissolved oxygen and temperature profiles for Doris Lake are presented in Figure 3.2. Temperature distributions in both the under-ice and summer profiles were variable between years. During winter, temperatures throughout the water column were relatively constant and ranged from 0 to 2°C during the three years surveyed. In one winter dissolved oxygen profile (April 1998), dissolved oxygen concentrations decreased with depth. Values at the bottom of the water column were below the CWQG of 9.5 mg/L for early life stages and 6.5 mg/L for other life stages of cold water biota.

A distinct thermal stratification was only found on one of the six summer profiles measured (Figure 3.2). In the majority of profiles, temperatures were relatively constant with depth, indicating that the water column was thoroughly mixed. Summer oxygen concentrations were either constant throughout the water column or gradually decreased with depth. With few exceptions, dissolved oxygen concentrations remained above the CWQG.

Median turbidity levels in spring and summer were 4.4 and 4.8 NTU, respectively, whereas median TSS was 4 mg/L in both seasons (Table 3.3). The turbidity levels were above the CDWG and above levels typical of other lakes in the Slave Structural Province (Puznicki 1996a). The TSS levels were more characteristic of levels in lakes within the region (Puznicki 1996a).

Figure 3.2 Temperature and dissolved oxygen profiles in Doris Lake, 1995 to 2000.





Median pH levels in spring and summer were 7.06 and 7.32, respectively. The minimum pH for Doris Lake was 5.9 and the maximum was 7.8, which both occurred in the summer (Table 3.3). The minimum pH was below the minimum CWQG of 6.5.

Median total hardness levels in spring and summer were 49 and 36 mg/L, respectively, and median TDS concentrations were 144 and 121 mg/L, respectively (Table 3.3). These values are higher than the typical values for lakes within the region (characteristic total hardness of less than 30 mg/L and characteristic TDS ranging from 10 to 50 mg/L; Puznicki 1996a).

Median concentrations of major ions measured in the spring were 63 mg/L of chloride, 34 mg/L of sodium and 3 mg/L of potassium. Corresponding summer concentrations were 50, 26 and 1.9 mg/L (Table 3.3). These levels are also higher than measured for other lakes in the Slave Structural Province, with Puznicki (1996a) finding a regional characteristic concentration of less than 10 mg/L for chloride and sodium, and less than 1 mg/L for potassium.

The median values of alkalinity in spring and summer were 28 mg/L and 23 mg/L, respectively, with individual values ranging from 1.8 to 34 mg/L throughout the year (Table 3.3). Alkalinity is a common measure of the acid neutralizing capacity (ANC) of water and therefore provides an indication of sensitivity to acid deposition. Acid sensitivity ranges were defined for lakes by Saffran and Trew (1996) based on total alkalinity (as $CaCO_3$) as follows:

- <10 mg/L: high sensitivity
- 11 to 20 mg/L: moderate sensitivity
- 21 to 40 mg/L: low sensitivity
- >40 mg/L: least sensitive

On this basis, Doris Lake has low to moderate susceptibility to acidification.

Median spring and summer ammonia nitrogen concentration (both 0.007 mg/L) and dissolved nitrate+nitrite concentration (0.008 and 0.006 mg/L) are within the normal range for lakes in the Slave Structural Province. The median total phosphorus (TP) concentration in the spring was 0.034 mg/L, and 0.016 mg/L in the summer. These values fall within the normal range for regional lakes (Puznicki 1996a). The ice covered and open water data imply mesotrophic conditions (Wetzel 1983).

Median metal concentrations generally were below the CWQG. The exception was total copper in spring (Table 3.3). Maximum values for several metals, particularly total arsenic, cadmium, chromium, copper, iron, lead, manganese, selenium and zinc were above CWQG.

Table 3.3 Baseline water quality in Doris Lake, 1995 to 2000[a].

	Parameter (units) [c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines [b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Physical Parameters	Conductivity (μS/cm)	265	19	291	11	218	177	258	30		
	Total Dissolved Solids (mg/L)	144	<1	156	11	121	100	140	30	≤ 500 [d]	
	Hardness ($CaCO_3$) (mg/L)	49.0	42.3	50.8	7	35.6	29.0	42.6	26		
	pH (units)	7.06	6.47	7.66	11	7.32	**5.90**	7.80	30	6.5-8.5	6.5-9.0
	Total Suspended Solids (mg/L)	4	<1	11	11	4	<1	11	29		Short-term increase < 25; long term increase < 5
	Turbidity (NTU)	**4.4**	**3.0**	**10.3**	7	**4.8**	**2.1**	**8**	17	1	Short-term increase < 8; long term increase < 2.
Conventional Parameters	Acidity ($CaCO_3$) (mg/L)	4	2	4	7	2	<1	4	16		
	Alkalinity Total ($CaCO_3$) (mg/L)	28.4	1.8	34.0	7	22.7	18.1	24.0	16		
	Alkalinity to pH 4.5 (mg/L)	28.7	28.6	29.3	4	22.5	19.0	26.0	14		
	Bicarbonate Alkalinity (mg/L)	-	-	-	-	22.5	19.0	26.0	14		
	Carbonate Alkalinity (mg/L)	-	-	-	-	<1	<1	<1	14		
Major Ions (dissolved)	Bromide (mg/L)	-	-	-	-	<0.5	<0.5	<0.5	4		
	Chloride (mg/L)	63.0	58.0	66.8	7	50.4	45.4	88.0	26	≤ 250 [d]	230
	Silicate (mg/L)	-	-	-	-	2.6	0.7	4.2	9		
	Fluoride (mg/L)	0.06	0.06	0.08	7	0.06	<0.02	0.14	26	1.5	
	Sulphate (mg/L)	3.0	<1	3.4	11	1.9	1.2	3.0	30	≤ 500 [d]	
	Calcium (mg/L)	7.48	6.79	8.09	5	5.82	4.77	6.31	13		
	Potassium (mg/L)	2.77	2.37	3.10	5	1.89	1.80	2.42	13		
	Magnesium (mg/L)	6.58	6.12	7.00	5	4.94	4.17	5.78	13		
	Sodium (mg/L)	33.7	33.2	34.0	5	25.7	22.5	26.9	7	≤ 200 [d]	
Major Ions (total)	Calcium (mg/L)	8.15	6.86	8.48	8	6.11	5.58	7.00	26		
	Potassium (mg/L)	2.73	2.44	3.17	8	2.14	1.81	3.05	26		
	Magnesium (mg/L)	7.00	6.15	7.20	8	5.29	4.66	6.14	26		
	Sodium (mg/L)	34.0	33.8	35.0	8	26.4	25.0	28.9	21	≤ 200 [d]	

Table 3.3 Baseline water quality in Doris Lake, 1995 to 2000 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines [b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Nutrients	Ammonia Nitrogen (mg/L)	0.007	<0.005	0.039	8	0.007	0.0047	0.040	30		8.9
	Dissolved Nitrate (mg/L)	0.006	<0.005	0.026	8	0.005	0.0017	4.51	30	10	
	Dissolved Nitrite (mg/L)	0.002	0.002	0.003	8	0.001	0.0009	0.017	30	0.97	0.06
	Nitrite/Nitrate (mg/L)	-	-	-	-	-	-	-	-		
	Dissolved Silicate (mg/L)	-	-	-	-	1.29	0.51	1.41	6		
	Dissolved Phosphate (mg/L)	0.002	0.001	0.003	4	0.001	0.001	0.005	6		
	Dissolved ortho-Phosphate (mg/L)	<0.001	<0.001	0.002	4	0.002	<0.001	0.010	20		
	Total Phosphorus – ICP (mg/L)	<0.3	<0.3	<0.3	4	<0.3	0.05	<0.3	15		
	Dissolved Phosphorus - ICP (mg/L)	<0.3	-	-	1	<0.3	0.05	<0.3	7		
	Total Phosphorus (mg/L)	0.034	0.012	0.051	5	0.016	<0.001	0.018	11		
	Total Phosphate (mg/L)	-	-	-	-	0.017	0.013	0.018	6		
	Total Organic Carbon (mg/L)	-	-	-	-	6.9	4.3	7.2	15		
Total Metals	Aluminum (μg/L)	9	5	19	8	42	18	**120**	26		100
	Antimony (μg/L)	<0.1	<0.05	<0.1	8	<0.08	<0.05	<0.2	26	6	
	Arsenic (μg/L)	0.40	0.30	0.62	8	0.50	<0.1	**15**	26	25	5
	Barium (μg/L)	<10	2.7	<10	8	2.6	1.9	<10	26	1000	
	Beryllium (μg/L)	<5	<0.05	<5	8	<0.5	<0.1	<5	26		
	Boron (μg/L)	<100	2	<100	8	44	16	<100	26	5000	
	Cadmium (μg/L)	<0.2	<0.05	**0.42**	12	<0.15	<0.05	<0.2	30	5	0.016
	Chromium (μg/L)	<1	0.4	<1	8	<1.0	<0.5	**3.5**	26	50	1
	Cobalt (μg/L)	<1	<0.1	<1	8	<0.1	<0.1	<1	26		
	Copper (μg/L)	**3.0**	**2.0**	**5.0**	12	1.5	<0.5	**2.3**	30	≤ 1000 [d]	2
	Iron (μg/L)	20	<10	40	8	85	40	**720**	26	≤ 300 [d]	300

Table 3.3 Baseline water quality in Doris Lake, 1995 to 2000 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines [b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Total Metals (cont)	Lead (μg/L)	<1	0.12	**4.00**	12	0.64	<0.05	**1.00**	30	10	1
	Manganese (μg/L)	<5.0	1.8	<5.0	8	10.1	5.2	**191.0**	26	≤ 50 [d]	
	Mercury (μg/L)	<0.03	<0.01	<0.05	4	<0.05	<0.01	<0.05	17	1	0.1
	Molybdenum (μg/L)	<1.0	0.2	<1.0	8	0.4	0.1	<1.0	26		73
	Nickel (μg/L)	<1.0	0.3	<1.0	8	<1.0	0.3	1.7	26		25
	Selenium (μg/L)	<0.50	<0.05	<0.50	8	<1.00	<0.50	**4.00**	26	10	1
	Silicon (μg/L)	1200	990	1370	8	1050	260	1550	24		
	Silver (μg/L)	<0.10	<0.01	<0.10	8	<0.01	<0.01	<0.1	26		0.1
	Strontium (μg/L)	45.0	34.1	47.0	8	32.1	21.9	42.0	20		
	Thallium (μg/L)	<100	<0.05	<200	8	<50	<0.05	<100	20		0.8
	Tin (μg/L)	<30.0	<0.1	<30.0	8	<15.1	<0.1	<30	20		
	Titanium (μg/L)	<10	<10	<10	8	6.5	<0.5	<10	20		
	Uranium (μg/L)	0.03	0.03	0.03	4	0.03	0.01	0.05	20	20	
	Vanadium (μg/L)	<30	<0.1	<30	7	<1	<1	<30	26		
	Zinc (μg/L)	12	2	**118**	5	<5	<1	19	30	≤ 5000[d]	30
Dissolved Metals	Aluminum (μg/L)	4	3	5	5	19	4	33	13		
	Antimony (μg/L)	<0.08	<0.05	<0.10	5	<0.10	<0.05	<0.2	13		
	Arsenic (μg/L)	0.42	0.30	0.62	5	0.73	<0.1	1.00	13		
	Barium (μg/L)	6.3	2.6	<10.0	5	8.4	1.4	<10	13		
	Beryllium (μg/L)	<2.5	<0.05	<5	5	<2.8	<0.1	<5	13		
Dissolved Metals	Boron (μg/L)	61	22	<100	5	78	16	<100	13		
	Cadmium (μg/L)	<0.13	<0.05	<0.2	5	<0.15	<0.05	<0.2	13		
	Chromium (μg/L)	0.8	0.4	<1.0	5	<0.8	<0.1	<1	13		
	Cobalt (μg/L)	<0.6	<0.1	<1.0	5	<0.6	<0.1	<1	13		
	Copper (μg/L)	3.7	2.8	4.0	5	1.0	<0.5	1.3	13		
	Iron (μg/L)	18	10	30	5	40	20	90	13		
	Lead (μg/L)	0.54	0.06	<1.00	5	0.57	0.06	<1	13		

Table 3.3 Baseline water quality in Doris Lake, 1995 to 2000 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Dissolved	Lithium (μg/L)	6.5	3.0	<10	5	<10	2.5	<10	10		
Metals (cont)	Manganese (μg/L)	2.8	0.5	<5	5	7.3	0.13	127	13		
	Mercury (μg/L)	<0.01	-	-	1	<0.03	<0.01	<0.05	3		
	Molybdenum (μg/L)	0.6	0.2	<1	5	0.6	0.1	<1	13		
	Nickel (μg/L)	0.9	0.7	<1	5	0.8	0.2	<1	13		
	Selenium (μg/L)	<0.3	<0.05	<0.5	5	<0.5	<0.5	6.5	13		
	Silicon (μg/L)	1073	970	1170	5	970	770	1210	13		
	Silver (μg/L)	<0.1	<0.1	<0.1	5	<0.06	<0.01	<0.1	13		
	Strontium (μg/L)	39.8	34.5	45.0	5	30.8	20.8	41.0	13		
	Thallium (μg/L)	<50	<0.05	<100	5	<50	<0.05	<100	13		
	Tin (μg/L)	<15	<0.1	<30	5	<15	<0.1	<30	13		
	Titanium (μg/L)	<6	<1	<10	5	<6	<0.5	<10	13		
	Uranium (μg/L)	0.03	0.03	0.03	4	0.04	0.01	<0.05	7		
	Vanadium (μg/L)	<15	<0.1	<30	5	<16	<0.1	<30	13		
	Zinc (μg/L)	7	<1	12	5	4	<1	<5	13		

[a] Values in bold are equal to or greater than guidelines.

[b] All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from the U.S. EPA (1999). Tabled hardness and pH dependent guidelines were determined using median baseline water quality values (analytical results) from all lakes. Similarly, a temperature of 6.0 °C was used to calculate the ammonia guideline. Individual water quality values shown in this table were assessed against guidelines using median hardness and or pH for the period indicated. Average lake temperatures for ice cover (1.2 °C) and open water (10.3 °C) periods were used to assess ammonia concentrations.

[c] The parameters analyzed vary between sampling events. Refer to Appendix A for detailed results.

[d] Aesthetic objective.

Notes:

< = less than analytical detection limit. Statistics (i.e., minimum, median and maximum) were calculated using method outlined in Appendix A.

Median values were not calculated when the sample size was equal to 2. Data were represented as the median if sample size was equal to 1.

μS/cm = micro Seimens per centimetre; NTU = nephelometric turbidity unit; mgCaCO$_3$/L = milligram carbonate per litre; ug/L = microgram per litre.

In summary, Doris Lake was a soft-water lake with near-neutral pH. Major ion concentrations (e.g., sodium, chloride and potassium) were higher than measured in other lakes in the Slave Structural Province. Metal concentrations generally were low and typical for lakes in the region, whereas total phosphorus concentrations indicated moderate nutrient enrichment.

3.2.2 Tail Lake

Temperature and dissolved oxygen profiles for Tail Lake are presented in Figure 3.3. During the two winter surveys, water temperatures were consistently low (i.e., <3°C) throughout the water column but increased slightly with depth during the 1997 survey. Dissolved oxygen values under the ice generally were within CWQG, with the exception of the bottom of the water column measurement during the 1996 survey.

During the summer surveys, temperatures were relatively constant with depth, indicating that the entire water column was thoroughly mixed. Similarly, dissolved oxygen profiles indicated constant concentrations with depth. All summer values were within CWQG, with the exception of the July 1997 survey when values were below 6 mg/L.

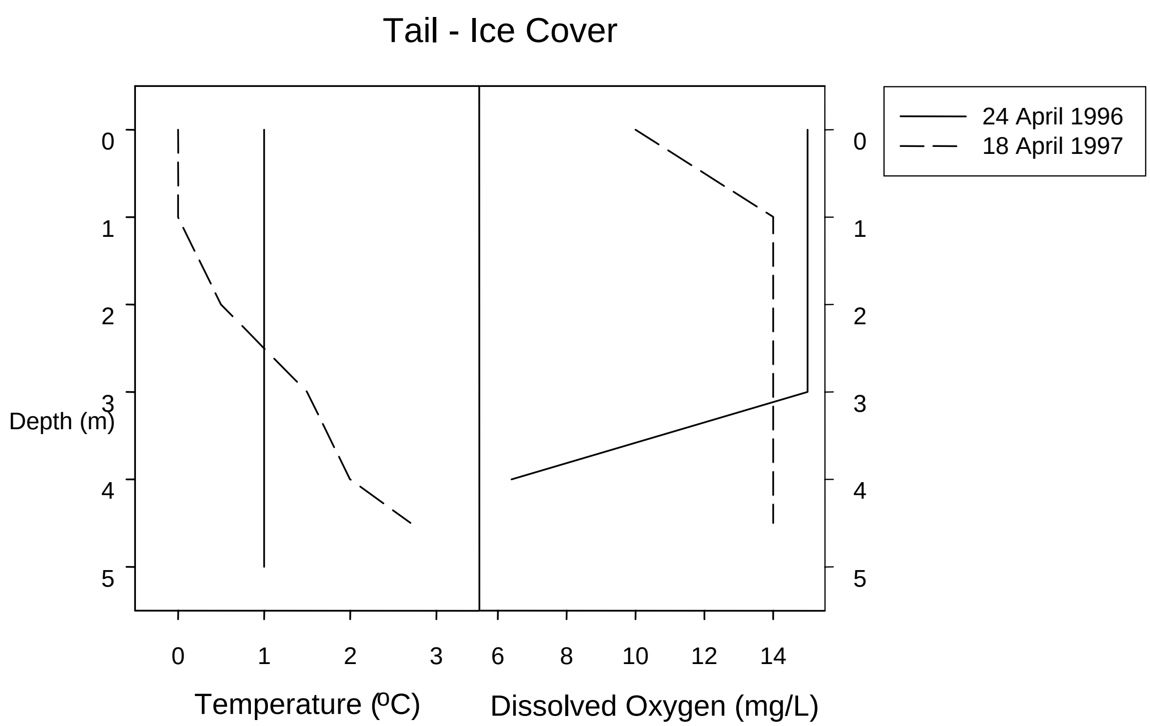
Median turbidity levels were low (3.8 NTU in the spring and 2.2 NTU in the summer). Median TSS concentrations in spring and summer were 2 and 3 mg/L, respectively (Table 3.4).

In spring and summer, median pH levels were 7.15 and 7.31, respectively, median total hardness levels were 57 and 30 mg/L, respectively and median TDS concentrations were 139 and 74 mg/L, respectively. Spring median chloride, sodium and potassium concentrations of 46, 25 and 3.0 mg/L were all elevated compared to typical values for lakes in the region (Puznicki 1996a). Corresponding summer median concentrations indicated that only chloride (27 mg/L) was elevated compared to other lakes in the Slave Structural Province (Table 3.4). Median alkalinity in spring and summer were 46 and 23 mg/L, respectively; therefore, the lake was classified as having a low susceptibility to acidification.

Median summer concentrations of ammonia nitrogen (0.01 mg/L), dissolved nitrate+nitrite (<0.005 mg/L) and TP (0.013 mg/L) are within the normal range for lakes in the Slave Structural Province (Puznicki 1996a). These concentrations indicate a mesotrophic status (Wetzel 1983).

Median metal concentrations generally were below the CWQG. The exceptions were spring values for total aluminum, chromium and copper (Table 3.4).

Figure 3.3 Temperature and dissolved oxygen profiles in Tail Lake, 1995 to 2000.



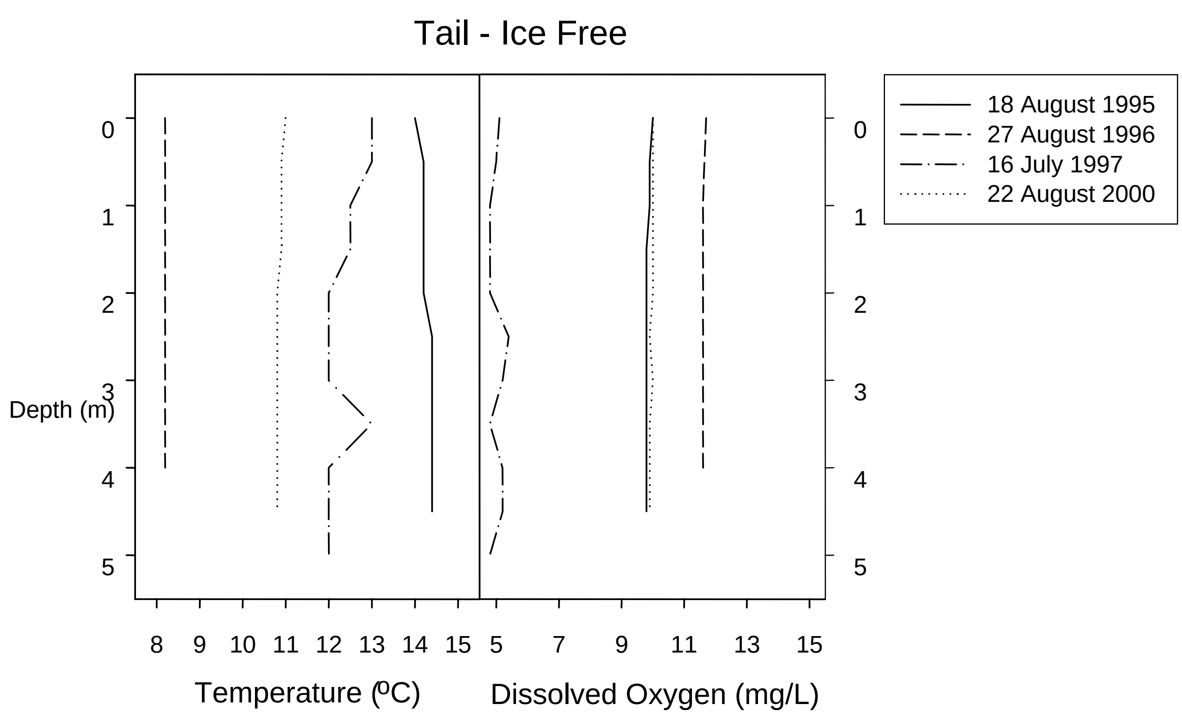


Table 3.4 Baseline water quality in Tail Lake, 1995 to 2000[a]

	Parameter (units) [c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines [b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Physical Parameters	Conductivity (µS/cm)	242	239	244	4	143	120	188	15		
	Total Dissolved Solids (mg/L)	139	136	142	4	74	67	89	15	≤ 500 [d]	
	Hardness ($CaCO_3$) (mg/L)	56.8	53.6	60.4	4	29.8	25.0	34.0	15		
	pH (units)	7.15	6.94	7.39	4	7.31	**5.50**	7.71	15	6.5-8.5	6.5-9.0
	Total Suspended Solids (mg/L)	2	<1	3	4	3	<1	7	15		Short-term increase <25; long term increase <5
	Turbidity (NTU)	**3.8**	0.8	**6.7**	4	**2.2**	0.3	**5.5**	15	1	Short-term increase <8; long term increase <2.
Conventional Parameters	Acidity ($CaCO_3$) (mg/L)	9	7	10	4	2	<1	4	12		
	Alkalinity Total ($CaCO_3$) (mg/L)	46	44	48	4	23	20	24	7		
	Alkalinity to pH 4.5 (mg/L)	-	-	-	-	21	17	24	8		
	Bicarbonate Alkalinity (mg/L)	-	-	-	-	21	17	24	8		
	Carbonate Alkalinity (mg/L)	-	-	-	-	<1	<1	<1	8		
Major Ions (dissolved)	Bromide (mg/L)	-	-	-	-	<0.5	<0.5	<0.5	4		
	Chloride (mg/L)	46.0	45.1	47.1	4	26.9	22.3	29.4	15	≤ 250 [d]	230
	Silicate (mg/L)	-	-	-	-	0.7	0.4	0.8	3		
	Fluoride (mg/L)	0.11	0.08	0.13	4	0.07	0.04	0.14	15	1.5	
	Sulphate (mg/L)	4	3	4	4	2	1	2	15	≤ 500 [d]	
	Calcium (mg/L)	9.13	-	-	1	4.45	4.25	4.71	6		
	Potassium (mg/L)	2.96	-	-	1	1.33	1.24	1.47	6		
	Magnesium (mg/L)	7.47	-	-	1	3.83	3.53	4.21	6		
	Sodium (mg/L)	24.8	-	-	1	12.6	12.1	13.1	6	≤ 200 [d]	
Major Ions (total)	Calcium (mg/L)	9.78	9.30	10.30	3	4.99	4.34	5.61	15		
	Potassium (mg/L)	2.92	2.85	2.97	3	1.58	1.29	2.33	15		
	Magnesium (mg/L)	7.91	7.62	8.40	3	4.19	3.62	4.90	15		
	Sodium (mg/L)	26.0	25.0	27.0	3	14.7	12.7	16.0	15	≤ 200 [d]	

Table 3.4 Baseline water quality in Tail Lake, 1995 to 2000 (continued)

	Parameter (units) [c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines [b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Nutrients	Ammonia Nitrogen (mg/L)	-	-	-	-	0.01	<0.01	0.04	15		8.9
	Dissolved Nitrate (mg/L)	-	-	-	-	<0.005	0.0025	0.011	15	10	
	Dissolved Nitrite (mg/L)	-	-	-	-	<0.001	0.0009	0.001	15	0.97	0.06
	Nitrite/Nitrate (mg/L)	-	-	-	-	-	-	-	-		
	Dissolved Silicate (mg/L)	-	-	-	-	0.639	-	-	1		
	Dissolved Phosphate (mg/L)	-	-	-	-	0.0026	0.0012	0.0060	6		
	Dissolved ortho-Phosphate (mg/L)	-	-	-	-	0.002	0.001	0.012	14		
	Total Phosphorus - ICP (mg/L)	<0.3	<0.3	<0.3	3	<0.2	<0.05	<0.3	4		
	Dissolved Phosphorus- ICP (mg/L)	<0.3	-	-	1	<0.3	-	-	1		
	Total Phosphorus (mg/L)	0.013	-	-	1	0.013	0.011	0.014	6		
	Total Phosphate (mg/L)	-	-	-	-	0.013	0.009	0.018	6		
	Total Organic Carbon (mg/L)	-	-	-	-	6.7	4.4	7.1	9		
Total Metals	Aluminum (μg/L)	**110**	47	**170**	3	29	19	**309**	15		100
	Antimony (μg/L)	<0.1	<0.1	<0.1	3	<0.1	<0.05	<0.2	15	6	
	Arsenic (μg/L)	0.4	0.3	0.4	3	<0.3	<0.1	2	15	25	5
	Barium (μg/L)	<10	<10	<10	3	1.66	1.43	<10	15	1000	
	Beryllium (μg/L)	<5	<5	<5	3	<0.5	<0.1	<5	15		
	Boron (μg/L)	<100	<100	<100	3	13	7	<100	15	5000	
	Cadmium (μg/L)	<0.2	<0.2	**0.2**	3	<0.1	<0.05	<0.2	15	5	0.016
	Chromium (μg/L)	**2**	<1	**3**	3	<0.5	<0.5	**2.3**	15	50	1
	Cobalt (μg/L)	<1	<1	<1	3	<0.1	<0.1	<1	15		
	Copper (μg/L)	**4.8**	**4.0**	**7.0**	3	1.2	0.5	**3.8**	15	≤ 1000 [d]	2
	Iron (μg/L)	213	120	**300**	3	60	40	**300**	15	≤ 300 [d]	300
	Lead (μg/L)	<1	<1	**1**	3	0.1	0.05	<1	15	10	1
	Manganese (μg/L)	5.8	5.0	6.0	3	5.0	2.8	45.0	15	≤ 50 [d]	

Table 3.4 Baseline water quality in Tail Lake, 1995 to 2000 (continued)

	Parameter (units) [c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines [b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Total Metals (cont)	Mercury (µg/L)	<0.03	<0.01	<0.05	3	<0.05	<0.01	<0.05	9	1	0.1
	Molybdenum (µg/L)	<1	<1	<1	3	0.2	0.1	1.4	15		73
	Nickel (µg/L)	1	1	1	3	1.0	0.5	3.2	15		25
	Selenium (µg/L)	<0.5	<0.5	<0.5	3	<1	<0.5	**4**	15	10	1
	Silicon (µg/L)	1638	1280	2020	3	583	150	970	13		
	Silver (µg/L)	<0.1	<0.1	<0.1	3	<0.01	<0.01	<1	15		0.1
	Strontium (µg/L)	39.3	38.0	41.0	3	16.9	14.2	22.0	9		
	Thallium (µg/L)	<150	<100	<200	3	<0.1	<0.05	<100	9		0.8
	Tin (µg/L)	<30	<30	<30	3	<0.2	<0.1	<30	9		
	Titanium (µg/L)	<10	<10	<10	3	<7	<0.5	<10	9		
	Uranium (µg/L))	-	-	-	-	0.03	<0.01	<0.05	14	20	
	Vanadium (µg/L)	<30	<30	<30	3	<1	<1	<30	15		
	Zinc (µg/L)	6	<5	7	3	<1	<1	**85**	15	≤ 5000 [d]	30
Dissolved Metals	Aluminum (µg/L)	110	-	-	1	48	38	55	6		
	Antimony (µg/L)	<0.1	-	-	1	<0.08	<0.05	<0.1	6		
	Arsenic (µg/L)	0.3	-	-	1	<0.6	<0.1	<1	6		
	Barium (µg/L)	<10	-	-	1	5.83	1.54	<10	6		
	Beryllium (µg/L)	<5	-	-	1	<2.8	<0.5	<5	6		
	Boron (µg/L)	<100	-	-	1	55	9	<100	6		
	Cadmium (µg/L)	<0.2	-	-	1	<0.13	<0.05	<0.2	6		
	Chromium (µg/L)	3	-	-	1	1.0	0.8	<1	6		
	Cobalt (µg/L)	<1	-	-	1	<0.6	<0.1	<1	6		
	Copper (µg/L)	3	-	-	1	1.0	0.8	1	6		
	Iron (µg/L)	170	-	-	1	55	1	100	6		

Table 3.4 Baseline water quality in Tail Lake, 1995 to 2000 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Dissolved Metals (cont)	Lead (μg/L)	<1	-	-	1	<0.53	<0.05	<1	6		
	Lithium (μg/L)	<10	-	-	1	<10	-	-	1		
	Manganese (μg/L)	<5	-	-	1	<2.53	<0.05	<5	6		
	Mercury (μg/L)	<0.01	-	-	1	-	-	-	-		
	Molybdenum (μg/L)	<1	-	-	1	<0.53	<0.05	<1	6		
	Nickel (μg/L)	1	-	-	1	<0.55	<0.1	<1	6		
	Selenium (μg/L)	<0.5	-	-	1	<0.5	<0.5	<0.5	6		
	Silicon (μg/L)	1400	-	-	1	545	270	790	6		
	Silver (μg/L)	<0.1	-	-	1	<0.06	<0.01	<0.1	6		
	Strontium (μg/L)	37	-	-	1	18.0	15.6	20.0	6		
	Thallium (μg/L)	<100	-	-	1	<50	<0.05	<100	6		
	Tin (μg/L)	<30	-	-	1	<15	<0.1	<30	6		
	Titanium (μg/L)	<10	-	-	1	<6	<1	<10	6		
	Uranium (μg/L)	-	-	-	-	<0.01	<0.01	0.03	5		
	Vanadium (μg/L)	<30	-	-	1	<15	0.3	<30	6		
	Zinc (μg/L)	12	-	-	1	<3	<1	<5	6		

(a) Values in bold are equal to or greater than guidelines.
(b) All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from the U.S. EPA (1999). Tabled hardness and pH dependent guidelines were determined using median baseline water quality values (analytical results) from all lakes. Similarly, a temperature of 6.0 °C was used to calculate the ammonia guideline. Individual water quality values shown in this table were assessed against guidelines using median hardness and or pH for the period indicated. Average lake temperatures for ice cover (1.2 °C) and open water (10.3 °C) periods were used to assess ammonia concentrations.
(c) The parameters analyzed vary between sampling events. Refer to Appendix A for detailed results.
(d) Aesthetic objective.

Notes:

<= less than analytical detection limit.

Statistics (i.e. minimum, median and maximum) were calculated using method outlined in Appendix A.

Median values were not calculated when the sample size was equal to 2. Data were represented as the median if sample size was equal to 1.

µS/cm = micro Seimens per centimetre; NTU = nephelometric turbidity unit; mg$CaCO_3$/L = milligram carbonate per litre; ug/L = microgram per litre.

Maximum values for total aluminum, cadmium, chromium, copper, iron, selenium and zinc exceeded CWQG.

In summary, Tail Lake was a soft-water lake with a neutral to slightly acidic pH. Turbidity and potassium levels were elevated in the spring. Chloride and sodium levels were elevated in both seasons. However, nutrient and metal concentrations generally were low, as is typical for lakes in undisturbed northern environments.

3.2.3 Ogama Lake

Water temperature increased slightly with depth in both spring profiles to a maximum of just greater than 2°C (Figure 3.4). Dissolved oxygen during the winter profiles was generally greater than 9 mg/L during the 1998 survey. During the 1997 survey, it was consistently at or below 7 mg/L at depths below 1 m. Therefore, some of these values were below the CWQG (9.5 mg/L) for early life stages of cold water biota. The single summer profile indicated constant temperatures of 13°C throughout the well mixed water column. Dissolved oxygen values were low (<5.5 mg/L) and were below CWQG for cold water biota.

Median turbidity levels in spring and summer were 8.8 and 9.5 NTU, respectively. These turbidity levels were above the CDWG and are elevated for the Slave Structural Province (Puznicki 1996a). The elevated turbidity levels were not reflected in the median TSS concentrations of 2 mg/L in spring and 5 mg/L in summer, which were more characteristic for the region (Puznicki 1996a).

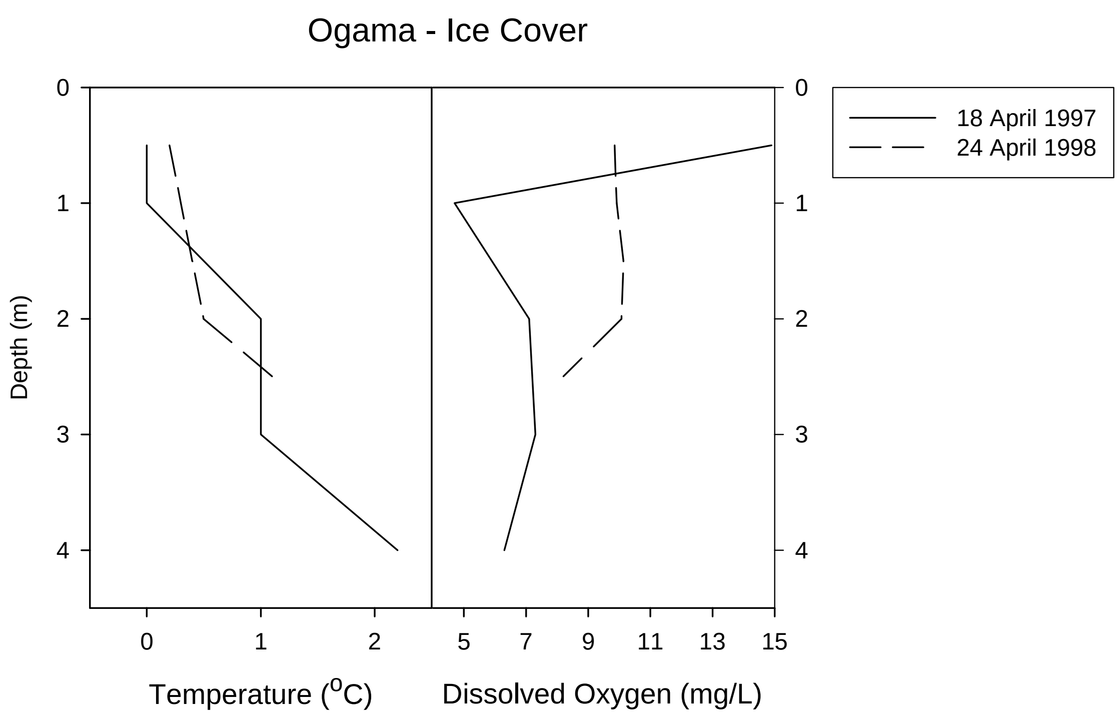
Median pH levels in spring and summer were 6.94 and 7.10, respectively. The minimum pH was 6.43 and the maximum was 7.38 (Table 3.5), with the minimum falling just below the CWQG minimum value of 6.5.

Median total hardness levels in spring and summer were 92 and 35 mg/L, respectively and median TDS levels were 160 and 113 mg/L, respectively. Both parameters were highest in spring (Table 3.5) and were elevated compared to other lakes in the Slave Structural Province (Puznicki 1996a).

Median spring concentrations of chloride, sodium and potassium were 133, 66, and 5.4 mg/L, respectively. The corresponding median summer concentrations were 45, 25, and 1.8 mg/L (Table 3.5). These concentrations were elevated for the Slave Structural Province (Puznicki 1996a).

Median alkalinity in spring and summer were 31 and 20 mg/L, respectively, with individual values ranging from 1.9 to 59 mg/L. Therefore, the lake generally had low to moderate susceptibility to acidification (Table 3.5).

Figure 3.4 Temperature and dissolved oxygen profile in Ogama Lake, 1997 to 1998.



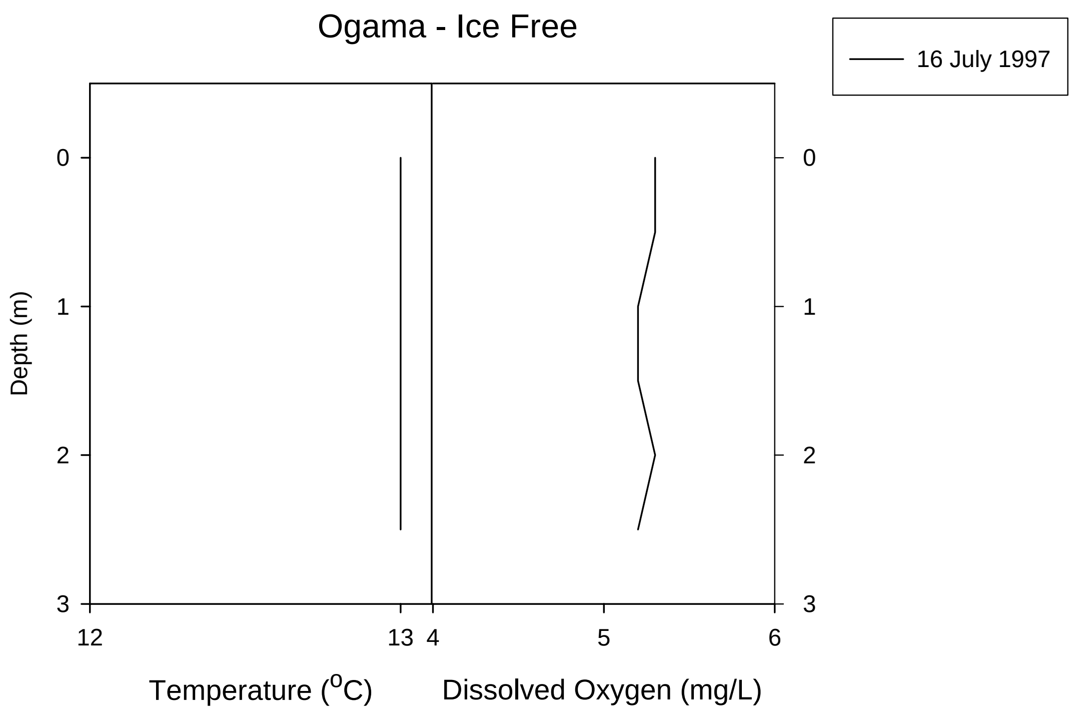


Table 3.5 Baseline water quality in Ogama Lake, 1995-2000[a]

	Parameter (units) [c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines [b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Physical Parameters	Conductivity (µS/cm)	289	20	572	7	219	177	345	6		
	Total Dissolved Solids(mg/L)	160	18	336	7	113	98	125	6	≤ 500 [d]	
	Hardness ($CaCO_3$) (mg/L)	92	83	100	5	35	32	38	4		
	pH (units)	6.94	**6.43**	7.38	7	7.10	6.64	7.35	6	6.5-8.5	6.5-9.0
	Total Suspended Solids (mg/L)	2	<1	12	7	5	4	7	6		Short-term increase <25; long term increase <5
	Turbidity (NTU)	**8.8**	**4.1**	**13.2**	5	**9.5**	**6.3**	**12.1**	4	1	Short-term increase <8; long term increase <2.
Conventional Parameters	Acidity ($CaCO_3$) (mg/L)	12	10	16	5	2	1	3	4		
	Alkalinity Total ($CaCO_3$) (mg/L)	30.7	1.9	59.0	7	20.0	18.9	22.8	3		
	Alkalinity to pH 4.5 (mg/L)	-	-	-	-	23	23	24	3		
	Bicarbonate Alkalinity (mg/L)	-	-	-	-	23	23	24	3		
	Carbonate Alkalinity (mg/L)	-	-	-	-	<1	<1	<1	3		
Major Ions (dissolved)	Bromide (mg/L)	-	-	-	-	-	-	-	-		
	Chloride (mg/L)	133	127	140	5	45	38	52	4	≤ 250 [d]	230
	Silicate (mg/L)	-	-	-	-	-	-	-	-		
	Fluoride (mg/L)	0.12	0.09	0.16	5	0.07	0.06	0.07	4	1.5	
	Sulphate (mg/L)	3	<1	6	7	2	<1	2	6	≤ 500 [d]	
	Calcium (mg/L)	-	11.7	11.9	2	4.74	4.41	5.13	4		
	Potassium (mg/L)	-	5.40	5.43	2	1.82	1.54	2.10	4		
	Magnesium (mg/L)	-	13.1	13.3	2	5.17	4.29	6.14	4		
	Sodium (mg/L)	-	66.0	66.4	2	24.6	22.0	27.4	4	≤ 200 [d]	
Major Ions (total)	Calcium (mg/L)	13.1	11.6	14.4	5	5.1	4.6	5.8	5		
	Potassium (mg/L)	5.46	4.97	6.00	5	1.92	1.74	2.24	5		
	Magnesium (mg/L)	14.5	13.2	15.6	5	5.3	4.5	6.5	5		
	Sodium (mg/L)	71.4	66.3	76.0	5	25.7	22.8	30.1	5	≤ 200 [d]	
Nutrients	Ammonia Nitrogen (mg/L)	-	0.02	0.059	2	0.020	0.008	0.042	6		8.9
	Dissolved Nitrate (mg/L)	-	0.029	0.156	2	0.008	<0.005	0.023	6	10	
	Dissolved Nitrite (mg/L)	-	0.001	0.001	2	<0.002	<0.001	0.002	6	0.97	0.06

Table 3.5 Baseline water quality in Ogama Lake, 1995-2000 (continued)

	Parameter (units) [c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines [b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Nutrients (cont)	Nitrite/Nitrate (mg/L)	-	-	-	-	-	-	-	-		
	Dissolved Silicate (mg/L)	-	-	-	-	0.687	-	-	1		
	Dissolved Phosphate (mg/L)	-	-	-	-	0.0036	0.0012	0.0060	4		
	Dissolved ortho-Phosphate (mg/L)	-	-	-	-	0.002	<0.002	0.004	3		
	Total Phosphorus – ICP (mg/L)	<0.3	<0.3	<0.3	5	<0.3	-	-	1		
	Dissolved Phosphorus - ICP (mg/L)	-	<0.3	<0.3	2	<0.3	-	-	1		
	Total Phosphorus (mg/L)	-	0.03	0.03	2	0.023	0.020	0.024	4		
	Total Phosphate (mg/L)	-	-	-	-	-	-	-	-		
	Total Organic Carbon (mg/L)	-	-	-	-	-	-	-	-		
Total Metals	Aluminum (µg/L)	**261**	**216**	**300**	5	**425**	**334**	**452**	5		100
	Antimony (µg/L)	0.13	<0.1	0.2	5	<0.08	<0.05	<0.1	5	6	
	Arsenic (µg/L)	0.7	0.6	0.8	5	0.6	0.2	<1	5	25	5
	Barium (µg/L)	<10	<10	<10	5	7.9	4.3	<10	5	1000	
	Beryllium (µg/L)	<5	<5	<5	5	<2.8	<0.5	<5	5		
	Boron (µg/L)	<100	<100	<100	5	58	14	<100	5	5000	
	Cadmium (µg/L)	**0.4**	<0.2	**0.8**	7	<0.2	<0.05	<0.2	7	5	0.016
	Chromium (µg/L)	**1.8**	**1.5**	**2**	5	**1.7**	<1	**2.3**	5	50	1
	Cobalt (µg/L)	<1	<1	<1	5	<0.6	<0.1	<1	5		
	Copper (µg/L)	**5**	**2**	**12**	7	**2**	<1	**3.9**	7	≤ 1000 [d]	2
	Iron (µg/L)	**435**	200	**650**	5	**435**	270	**580**	5	≤ 300 [d]	300
	Lead (µg/L)	**1.5**	<1	**3.0**	7	<1	0.2	<1	7	10	1
	Manganese (µg/L)	**170**	17	**329**	5	17	8	25	5	≤ 50 [d]	
	Mercury (µg/L)	<0.03	<0.01	<0.05	5	-	-	-	-	1	0.1
	Molybdenum (µg/L)	<1	<1	<1	5	0.6	0.3	<1	5		73
	Nickel (µg/L)	3	2	3	5	1.3	1	2.2	5		25
	Selenium (µg/L)	0.5	<0.5	0.6	5	<0.53	<0.5	<1	5	10	1

Table 3.5 Baseline water quality in Ogama Lake, 1995-2000 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Total Metals (cont)	Silicon (µg/L)	4063	3970	4110	5	1830	1430	2010	5		
	Silver (µg/L)	<0.1	<0.1	<0.1	5	<0.08	<0.01	<0.1	5		0.1
	Strontium (µg/L)	70	62	80	5	27	25	28	5		
	Thallium (µg/L)	<150	<100	<200	5	<50	<0.05	<100	5		0.8
	Tin (µg/L)	<30	<30	<30	5	<15	<0.1	<30	5		
	Titanium (µg/L)	<10	<10	<10	5	9	6	10	5		
	Uranium (µg/L)	-	-	-	-	<0.01	<0.01	0.06	4	20	
	Vanadium (µg/L)	<30	<30	<30	5	<16	<1	<30	5		
	Zinc (µg/L)	20	11	26	7	<5	<1	13	7	≤ 5000 [d]	30
Dissolved Metals	Aluminum (µg/L)	-	160	220	2	110	78	139	4		
	Antimony (µg/L)	-	<0.1	0.1	2	<0.08	<0.05	<0.1	4		
	Arsenic (µg/L)	-	0.5	0.6	2	0.6	0.1	<1	4		
	Barium (µg/L)	-	<10	10	2	6.4	2.6	<10	4		
	Beryllium (µg/L)	-	<5	<5	2	<2.8	<0.5	<5	4		
	Boron (µg/L)	-	<100	<100	2	58	15	<100	4		
	Cadmium (µg/L)	-	0.3	0.3	2	<0.13	<0.05	<0.2	4		
	Chromium (µg/L)	-	<1	1	2	1.1	<1	1.1	4		
	Cobalt (µg/L)	-	<1	<1	2	<0.6	<0.1	<1	4		
	Copper (µg/L)	-	11	11	2	1.7	1.0	2.8	4		
	Iron (µg/L)	-	300	350	2	110	20	200	4		
	Lead (µg/L)	-	<1	1	2	<0.53	<0.05	<1	4		
	Lithium (µg/L)	-	<10	<10	2	<10	-	-	1		
	Manganese (µg/L)	-	309	314	2	2.6	0.1	<5	4		
	Mercury (µg/L)	-	<0.01	<0.01	2	-	-	-	-		
	Molybdenum (µg/L)	-	<1	<1	2	0.6	0.2	<1	4		
	Nickel (µg/L)	-	2	2	2	0.6	0.2	<1	4		
	Selenium (µg/L)	-	<0.5	0.8	2	<0.5	<0.5	1	4		

Table 3.5 Baseline water quality in Ogama Lake, 1995-2000 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Dissolved Metals (cont)	Silicon (µg/L)	-	4130	4150	2	1150	960	1320	4		
	Silver (µg/L)	-	<0.1	<0.1	2	<0.06	<0.01	<0.1	4		
	Strontium (µg/L)	-	62	62	2	26	25	27	4		
	Thallium (µg/L)	-	<100	<100	2	<50	<0.05	<100	4		
	Tin (µg/L)	-	<30	<30	2	<15	<0.1	<30	4		
	Titanium (µg/L)	-	<10	<10	2	<6	<1	<10	4		
	Uranium (µg/L)	-	-	-	-	<0.01	<0.01	0.03	3		
	Vanadium (µg/L)	-	<30	<30	2	15	0.4	<30	4		
	Zinc (µg/L)	-	12	30	2	<3	<1	<5	4		

[a]Values in bold are equal to or greater than guidelines.

[b]All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from the U.S. EPA (1999). Tabled hardness and pH dependent guidelines were determined using median baseline water quality values (analytical results) from all lakes. Similarly, a temperature of 6.0 °C was used to calculate the ammonia guideline. Individual water quality values shown in this table were assessed against guidelines using median hardness and or pH for the period indicated. Average lake temperatures for ice cover (1.2 °C) and open water (10.3 °C) periods were used to assess ammonia concentrations.

[c] The parameters analyzed vary between sampling events. Refer to Appendix A for detailed results.

[d] Aesthetic objective.

Notes:

<= less than analytical detection limit.

Statistics (i.e. minimum, median and maximum) were calculated using method outlined in Appendix A.

Median values were not calculated when the sample size was equal to 2. Data was represented as the median if sample size was equal to 1.

µS/cm = micro Seimens per centimetre; NTU = nephelometric turbidity unit; mg $CaCO_3$/L = milligram carbonate per litre; ug/L = microgram per litre.

Median spring and summer ammonia nitrogen concentration (0.04 and 0.02 mg/L), dissolved nitrate+nitrite concentration (0.09 and 0.009 mg/L) and TP concentration (0.03 and 0.023 mg/L) were within the normal range for lakes in the Slave Structural Province (Puznicki 1996a) with measured TP concentrations typical of mesotrophic conditions (Wetzel 1983).

Median metal concentrations generally were below the CWQG. The exceptions were spring values for total cadmium, , lead and manganese, and spring/summer values for total aluminum, chromium, copper and iron (Table 3.5).

In summary, Ogama Lake was a soft water lake with a neutral to slightly acidic pH. Turbidity and chloride, sodium and potassium concentrations were elevated. However, nutrient and metal concentrations generally were typical for lakes in undisturbed northern environments. DO concentrations measured in the summer and winter of 1997 were relatively low.

3.2.4 Patch Lake

In 1996, the under ice water temperature remained constant with depth, whereas the 1998 profile indicated an increase in temperature from approximately 0°C at the surface to 1.5°C at 3 m (Figure 3.5). This near-ice layer was underlain by a layer of water at a constant temperature of just under 2°C. Under ice dissolved oxygen profiles generally indicated consistently high concentrations, which remained above the CWQG, except near the bottom of the lake.

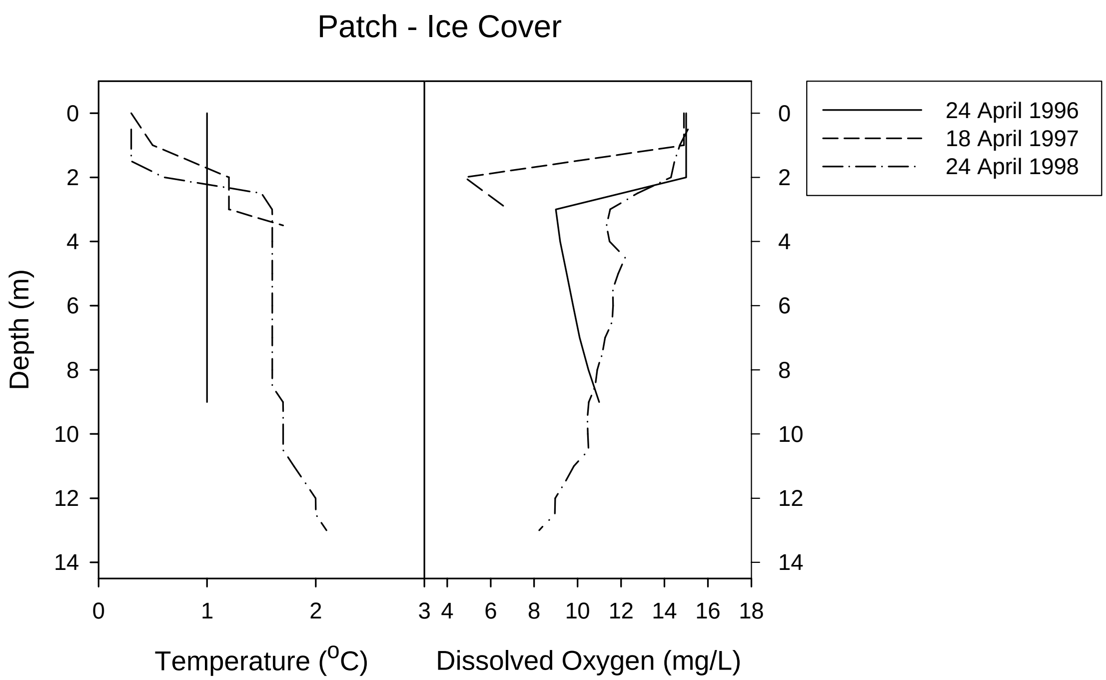
Summer temperature profiles in 1996 suggested a well mixed water column whereas a degree of thermal stratification was observed in 1995 (Figure 3.5). Maximum temperatures were recorded during the 1995 survey and were near 14°C. Summer dissolved oxygen profiles indicated the lake was generally well oxygenated (>10 mg/L).

Median turbidity levels in spring and summer were 0.9 NTU and 3 NTU, respectively. The spring median was the lowest of all project-monitored lakes. Median TSS concentrations were low (<1 mg/L) for both seasons (Table 3.6).

Median pH levels in spring and summer were 7.13 and 7.10, respectively, with a minimum pH of 6.10 and a maximum of 7.82 (Table 3.6). The minimum pH value of 6.10was below the CWQG of 6.5.

Median total hardness levels in spring and summer were 65 and 42 mg/L and median TDS concentrations were 184 and 122 mg/L, respectively (Table 3.6). These levels are elevated compared to other lakes in the Slave Structural Province (Puznicki 1996a). Spring median chloride, sodium and potassium concentrations were 90, 48, and 3.9 mg/L, respectively. Corresponding summer

Figure 3.5 Temperature and dissolved oxygen profiles in Patch Lake, 1995 to 1998.



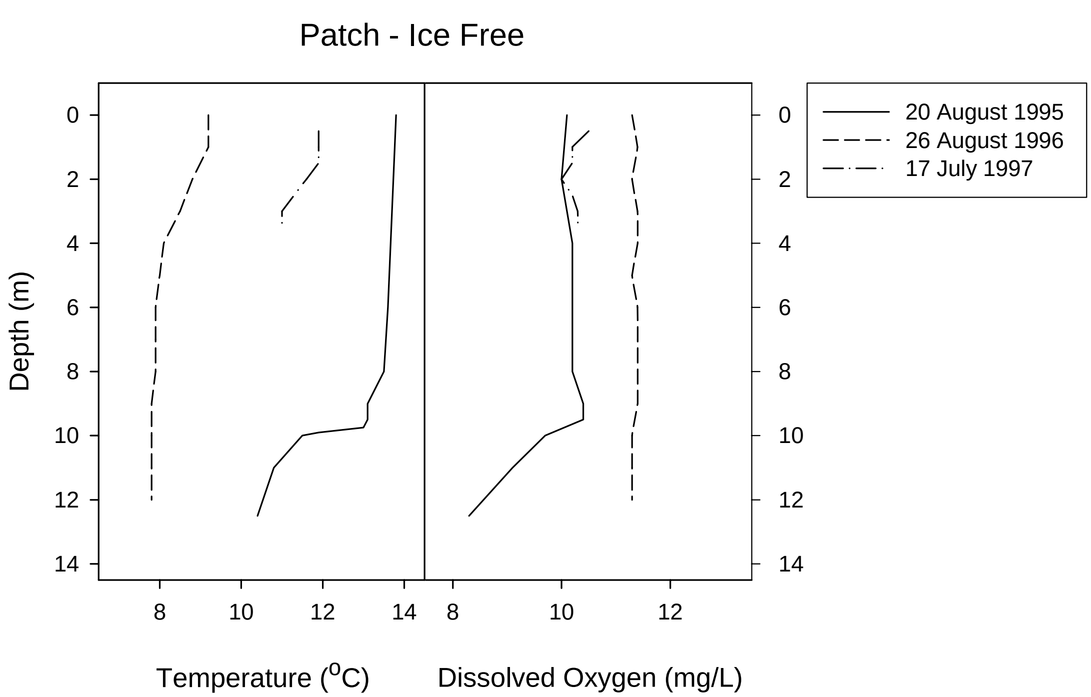


Table 3.6 Baseline water quality in Patch Lake, 1995 to 1998[a]

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines [b]	
		Med	**Min**	**Max**	**n**	**Med**	**Min**	**Max**	**n**	**Drinking Water**	**Aquatic Life**
Physical Parameters	Conductivity (µS/cm)	409	6	434	11	243	184	299	13		
	Total Dissolved Solids(mg/L)	184	<1	227	11	122	98	143	13	≤500 [d]	
	Hardness ($CaCO_3$) (mg/L)	64.7	59.2	77.8	7	42.0	38.2	46.0	9		
	pH (units)	7.13	**6.10**	7.52	11	7.10	**6.10**	7.82	13	6.5-8.5	6.5-9.0
	Total Suspended Solids (mg/L)	1	<1	4	11	1	<1	12	13		Short-term increase <25; long term increase <5
	Turbidity (NTU)	0.9	0.5	**4.4**	7	**3.0**	**2.5**	**4.0**	7	1	Short-term increase <8; long term increase <2
Conventional Parameters	Acidity ($CaCO_3$) (mg/L)	6	4	8	7	2	1	2	7		
	Alkalinity Total ($CaCO_3$) (mg/L)	49	<1	53	7	30	22	33	7		
	Alkalinity to pH 4.5 (mg/L)	51.9	42.6	52.6	4	29.3	28.0	32.0	7		
	Bicarbonate Alkalinity (mg/L)	-	-	-	-	29	28	32	8		
	Carbonate Alkalinity (mg/L)	-	-	-	-	<1	<1	<1	8		
Major Ions (dissolved)	Bromide (mg/L)	-	-	-	-	-	-	-	-		
	Chloride (mg/L)	90.0	59.5	99.8	7	53.5	52.4	54.2	9	≤ 250 [d]	230
	Silicate (mg/L)	-	-	-	-	-	0.2	1.0	2		
	Fluoride (mg/L)	0.09	0.08	0.15	7	0.07	0.04	0.08	8	1.5	
	Sulphate (mg/L)	3	<1	4	11	1	<1	2	13	≤ 500 [d]	
	Calcium (mg/L)	9.93	8.89	11.00	5	6.95	6.11	7.45	7		
	Potassium (mg/L)	3.90	2.49	4.30	5	2.30	2.19	2.50	7		
	Magnesium (mg/L)	9.08	6.55	9.68	5	5.97	5.78	6.64	3		
	Sodium (mg/L)	47.6	27.6	53.8	5	29.7	28.5	30.3	7	≤ 200 [d]	
Major Ions (total)	Calcium (mg/L)	10.85	9.26	13.10	8	6.89	5.94	7.62	10		
	Potassium (mg/L)	4.06	2.49	4.43	8	2.38	2.00	3.26	10		
	Magnesium (mg/L)	9.74	7.14	11.00	8	6.19	5.57	6.96	10		
	Sodium (mg/L)	54.0	28.0	55.6	8	30.6	27.6	32.1	10	≤ 200 [d]	

Table 3.6 Baseline water quality in Patch Lake, 1995 to 1998 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines [b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Nutrients	Ammonia Nitrogen (mg/L)	0.013	<0.005	0.030	8	0.013	0.007	0.02	13		8.9
	Dissolved Nitrate (mg/L)	0.007	<0.005	0.037	8	<0.005	0.003	0.023	13	10	
	Dissolved Nitrite (mg/L)	0.002	0.001	0.002	8	0.001	<0.001	0.001	12	0.97	0.06
	Nitrite/Nitrate (mg/L)	-	-	-	-	0.005	-	-	1		
	Dissolved Silicate (mg/L)	-	-	-	-	0.366	-	-	1		
	Dissolved Phosphate (mg/L)	0.002	0.001	0.005	4	0.002	0.0012	0.002	7		
	Dissolved ortho-Phosphate (mg/L)	0.001	<0.001	0.003	4	0.002	<0.002	0.002	8		
	Total Phosphorus- ICP (mg/L)	<0.3	<0. 3	<0. 3	4	0.18	0.05	<0.3	4		
	Dissolved Phosphorus -ICP (mg/L)	<0.3	-	-	1	<0.3	-	-	1		
	Total Phosphorus (mg/L)	0.009	0.003	0.012	5	0.006	0.004	0.008	7		
	Total Phosphate (mg/L)	-	-	-	-	-	-	-	-		
	Total Organic Carbon (mg/L)	-	-	-	-	-	3.1	4.3	2		
Total Metals	Aluminum (µg/L)	30	7	99	8	69	22	**182**	10		100
	Antimony (µg/L)	<0.1	<0.05	<0.1	8	<0.1	<0.05	<200	10	6	
	Arsenic (µg/L)	0.5	0.3	0.8	8	1	<0.1	2	10	25	5
	Barium (µg/L)	<10	2.5	<10	8	2.6	1.7	<10	10	1000	
	Beryllium (µg/L)	<5	<0.5	<5	8	<0.5	<0.1	<5	10		
	Boron (µg/L)	<100	23	<100	8	22	17	<100	10	5000	
	Cadmium (µg/L)	<0.2	<0.05	**0.2**	12	<0.2	<0.05	<0.2	14	5	0.016
	Chromium (µg/L)	**1**	0.7	**2**	8	<1	0.5	**2.4**	10	50	1
	Cobalt (µg/L)	<1	<0.1	<1	8	<0.1	<0.1	<15	10		
	Copper (µg/L)	**3**	1	**7**	12	1.0	<0.5	2.7	14	≤ 1000 [d]	2
	Iron (µg/L)	40	30	80	8	70	40	120	10	≤ 300 [d]	300
	Lead (µg/L)	<1	0.1	<2	12	<1	0.05	<1	14	10	1
	Manganese (µg/L)	<5	3.6	<5	8	5	1.7	8	10	≤ 50 [d]	
	Mercury (µg/L)	<0.03	<0.01	<0.05	4	<0.01	<0.01	<0.05	3	1	0.1
	Molybdenum (µg/L)	<1	0.2	<1	8	<0.2	0.1	<30	10		73

Table 3.6 Baseline water quality in Patch Lake, 1995 to 1998 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines [b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Total Metals (cont)	Nickel (µg/L)	<1	0.7	<1	8	<1	0.5	<10	10		25
	Selenium (µg/L)	<0.5	<0.5	<0.5	8	<0.5	<0.5	2.2	10	10	1
	Silicon (µg/L)	420	240	730	8	440	90	880	9		
	Silver (µg/L)	<0.1	<0.01	<0.1	8	<0.01	<0.01	<0.1	10		0.1
	Strontium (µg/L)	50.9	35.5	72.0	8	31.2	23.1	41.0	10		
	Thallium (µg/L)	<100	<0.05	<200	8	<0.05	<0.05	<100	10		0.8
	Tin (µg/L)	<30	<0.1	<30	8	<0.1	<0.1	<300	10		
	Titanium (µg/L)	<10	<0.01	<10	8	<3	<0.5	<10	10		
	Uranium (µg/L)	0.04	0.02	0.04	4	0.04	0.01	0.06	8	20	
	Vanadium (µg/L)	<30	0.3	<30	8	<1	<1	<30	10		
	Zinc (µg/L)	9	1	23	12	<5	<1	<5	14	≤ 5000 [d]	30
Dissolved Metals	Aluminum (µg/L)	16	4	26	5	15	12	17	7		
	Antimony (µg/L)	<0.08	<0.05	<0.1	5	<0.08	<0.05	<0.1	7		
	Arsenic (µg/L)	0.52	0.30	0.76	5	<0.6	<0.1	<1	7		
	Barium (µg/L)	6.4	2.5	<10	5	5.8	1.6	<10	7		
	Beryllium (µg/L)	<2.8	<0.5	<5	5	<2.8	<0.5	<5	7		
	Boron (µg/L)	68	23	<100	5	59	16	<100	7		
	Cadmium (µg/L)	0.18	0.07	<0.3	5	<0.13	<0.05	<0.2	7		
	Chromium (µg/L)	0.8	0.4	<1	5	1.05	<1	1.2	7		
	Cobalt (µg/L)	<0.6	<0.1	<1	5	<0.6	<0.1	<1	7		
	Copper (µg/L)	3	2	7	5	0.8	0.5	1	7		
	Iron (µg/L)	20	10	40	5	<10	<10	<10	7		
	Lead (µg/L)	0.54	<0.05	<1	5	<0.54	<0.05	<1	7		
	Lithium (µg/L)	7	4	<10	5	<10	-	-	1		
	Manganese (µg/L)	2.7	0.3	<5	5	<2.5	<0.05	<5	7		
	Mercury (µg/L)	<0.01	-	-	1	-	-	-	-		
	Molybdenum (µg/L)	0.6	0.2	<1	5	<0.5	<0.05	<1	7		
	Nickel (µg/L)	1.1	<1	1.2	5	<0.6	<0.1	<1	7		

Table 3.6 Baseline water quality in Patch Lake, 1995 to 1998 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines [b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Dissolved Metals (cont)	Selenium (µg/L)	<0.5	<0.5	<0.5	5	<0.5	<0.5	<0.5	7		
	Silicon (µg/L)	303	210	690	5	283	210	330	7		
	Silver (µg/L)	<0.06	<0.01	<0.1	5	<0.06	<0.01	<0.1	7		
	Strontium (µg/L)	49	34	51	5	36	28	41	7		
	Thallium (µg/L)	<50	<0.05	<100	5	<50	<0.05	<100	7		
	Tin (µg/L)	<15	<0.1	<30	5	<15	<0.1	<30	7		
	Titanium (µg/L)	<10	<10	<10	5	<6	<1	<10	7		
	Uranium (µg/L)	0.04	0.02	0.04	4	<0.01	<0.01	<0.01	6		
	Vanadium (µg/L)	<15	0.1	<30	5	<15	0.3	<30	7		
	Zinc (µg/L)	8	1	14	5	<3	<1	<5	7		

[a] Values in bold are equal to or greater than guidelines.

[b] All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from the U.S. EPA (1999). Tabled hardness and pH dependent guidelines were determined using median baseline water quality values (analytical results) from all lakes. Similarly, a temperature of 6.0 °C was used to calculate the ammonia guideline. Individual water quality values shown in this table were assessed against guidelines using median hardness and or pH for the period indicated. Average lake temperatures for ice cover (1.2 °C) and open water (10.3 °C) periods were used to assess ammonia concentrations.

[c] The parameters analyzed vary between sampling events. Refer to Appendix A for detailed results.

[d] Aesthetic objective.

Notes:

<= less than analytical detection limit.

Statistics (i.e. minimum, median and maximum) were calculated using method outlined in Appendix A.

Median values were not calculated when the sample size was equal to 2. Data was represented as the median if sample size was equal to 1.

µS/cm = micro Seimens per centimetre; NTU = nephelometric turbidity unit; mg $CaCO_3$/L = milligram carbonate per litre; ug/L = microgram per litre.

concentrations were 54, 30, and 2.3 mg/L. These concentrations were elevated for lakes in the Slave Structural Province (Puznicki 1996a).

Median alkalinity in spring and summer were 49 and 30 mg/L, respectively, with individual values ranging from <1 to 53 mg/L (Table 3.6). These values indicated that the lake had low to moderate susceptibility to acidification.

Median spring and summer ammonia nitrogen concentration (0.013 mg/L for both seasons), dissolved nitrate+nitrite concentration (0.009 and <0.005mg/L) and TP concentration (0.009 mg/L and 0.006 mg/L) were within the normal range for lakes in the Slave Structural Province (Puznicki 1996a). The measured TP concentrations indicate oligotrophic conditions (Wetzel 1983).

Median metal concentrations generally were below the CWQG. The exceptions were spring values for total chromium and total copper (Table 3.6). Maximum values for total aluminum and chromium were also above CWQG.

In summary, Patch Lake was a clear, moderately soft water lake, with a neutral pH. Chloride, sodium and potassium concentrations were elevated. Metal and nutrient concentrations generally were low and typical for lakes in the region.

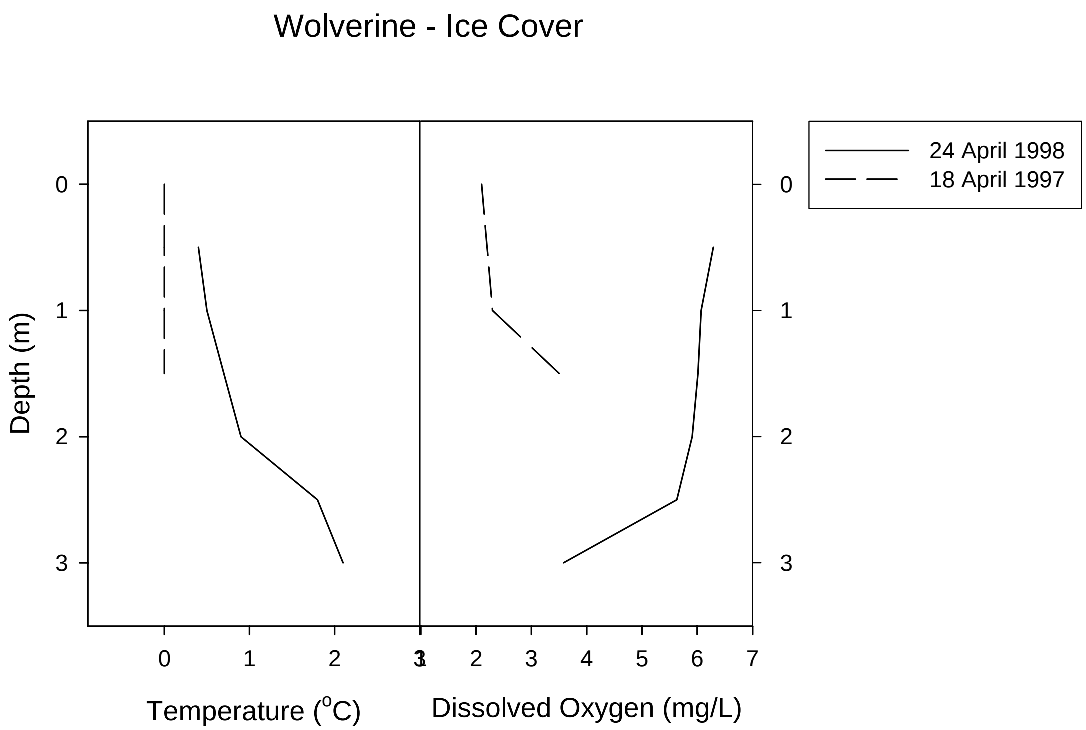
3.2.5 Wolverine Lake

Under ice profiles indicated water temperatures ranging from 0°C at the surface to 2°C at 3 m depth (1998 data; Figure 3.6). Dissolved oxygen concentrations were low in both years samples (<6 mg/L) and were below CWQG for cold water biota. Only one summer profile (1997) was measured. It indicated almost uniform temperatures (12°C) throughout the entire water column. Dissolved oxygen levels were low and remained consistently below 5 mg/L.

Median turbidity levels in spring and summer were 2 and 2.7 NTU, respectively, which generally were lower than other lakes in the Doris Hinge watershed, but within expected ranges for regional lakes (Puznicki 1996a). The median TSS for both spring and summer was 2 mg/L, which was normal for a lake in the Slave Structural Province (Puznicki 1996a).

Median pH levels in spring and summer were 7.18 and 7.02, respectively (Table 3.7). Median total hardness levels in spring and summer were 108 and 46 mg/L, respectively, and median TDS concentrations in spring and summer were 347 and 136 mg/L, respectively. Hardness and TDS were highest in spring (Table 3.7) and generally were elevated for a lake in the Slave Structural Province (Puznicki 1996a). Spring median chloride, sodium and potassium

Figure 3.6 Temperature and dissolved oxygen profiles in Wolverine Lake, 1997 to 1998.



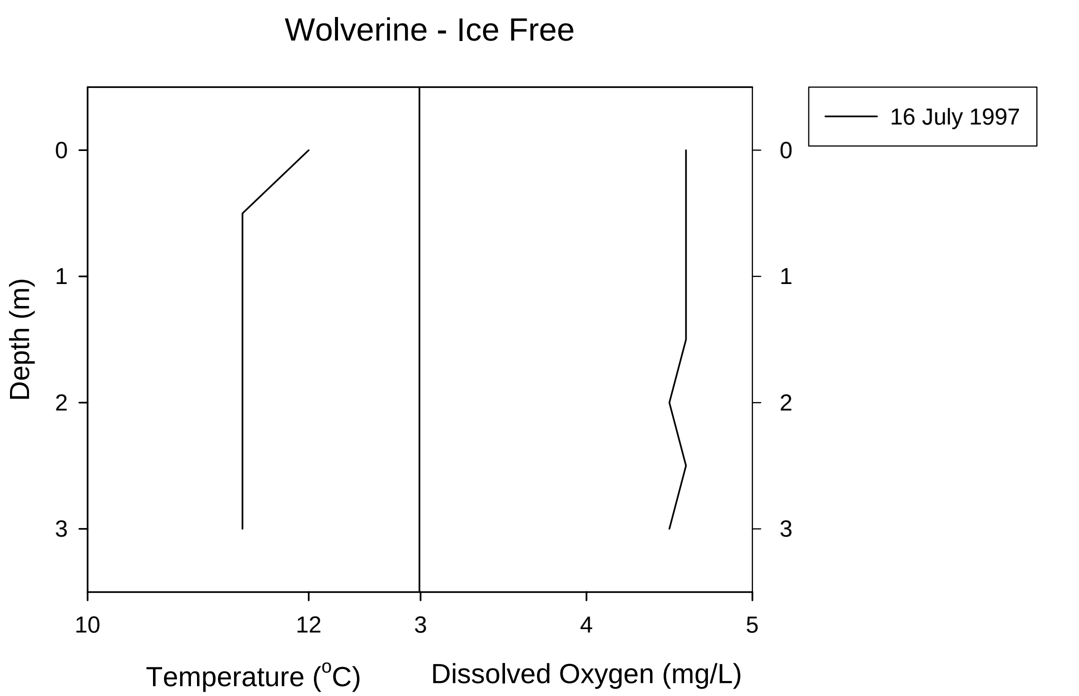


Table 3.7 Baseline water quality in Wolverine Lake, 1996 to 1997[a]

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)	Water Quality Guidelines[b]	
		Med	Min	Max	n	Med (n=1)	Drinking Water	Aquatic Life
Physical Parameters	Conductivity (µS/cm)	629	614	647	4	257		
	Total Dissolved Solids(mg/L)	347	327	366	4	136	≤ 500 [d]	
	Hardness ($CaCO_3$) (mg/L)	108.3	98.5	119.0	4	46.4		
	pH (units)	7.18	6.92	7.46	4	7.02	6.5-8.5	6.5-9.0
	Total Suspended Solids (mg/L)	2	1	5	4	2		Short-term increase <25; long term increase <5
	Turbidity (NTU)	**2.0**	**1.1**	**2.9**	4	**2.7**	1	Short-term increase <8; long term increase <2.
Conventional Parameters	Acidity ($CaCO_3$) (mg/L)	15	11	18	4	4		
	Alkalinity Total ($CaCO_3$) (mg/L)	79	77	79	4	32		
	Alkalinity to pH 4.5 (mg/L)	-	-	-	-			
	Bicarbonate Alkalinity (mg/L)	-	-	-	-			
	Carbonate Alkalinity (mg/L)	-	-	-	-			
Major Ions (dissolved)	Bromide (mg/L)	-	-	-	-			
	Chloride (mg/L)	150	145	155	4	57	≤ 250 [d]	230
	Silicate (mg/L)	-	-	-	-			
	Fluoride (mg/L)	0.15	0.10	0.19	4	0.06	1.5	
	Sulphate (mg/L)	2	1	2	4	<1	≤ 500 [d]	
	Calcium (mg/L)	14.3	-	-	1	6.6		
	Potassium (mg/L)	5.51	-	-	1	1.91		
	Magnesium (mg/L)	15.2	-	-	1	6.2		
	Sodium (mg/L)	74.4	-	-	1	32.3	≤ 200 [d]	
Major Ions (total)	Calcium (mg/L)	16.2	15.0	17.5	4	6.6		
	Potassium (mg/L)	5.30	4.67	5.60	4	1.97		
	Magnesium (mg/L)	17.1	16.1	18.2	4	6.3		
	Sodium (mg/L)	82.2	78.3	86.0	4	32.3	≤ 200 [d]	
Nutrients	Ammonia Nitrogen (mg/L)	-	-	-	-	0.0052		8.9
	Dissolved Nitrate (mg/L)	-	-	-	-	0.0022	10	
	Dissolved Nitrite (mg/L)	-	-	-	-	<0.001	0.97	0.06
	Nitrite/Nitrate (mg/L)	-	-	-	-			

Table 3.7 Baseline water quality in Wolverine Lake, 1996 to 1997 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)	Water Quality Guidelines[b]	
		Med	Min	Max	n	Med (n=1)	Drinking Water	Aquatic Life
Nutrients (cont)	Dissolved Silicate (mg/L)	-	-	-	-	0.637		
	Dissolved Phosphate (mg/L)	-	-	-	-	0.0012		
	Dissolved ortho-Phosphate (mg/L)	-	-	-	-			
	Total Phosphorus - ICP (mg/L)	<0.3	<0.3	<0.3	4	<0.3		
	Dissolved Phosphorus - ICP (mg/L)	<0.3	-	-	1	<0.3		
	Total Phosphorus (mg/L)	0.014	-	-	1	0.01		
	Total Phosphate (mg/L)	-	-	-	-			
	Total Organic Carbon (mg/L)	-	-	-	-			
Total Metals	Aluminum (µg/L)	25	12	34	4	66		100
	Antimony (µg/L)	<0.1	<0.1	<0.1	4	<0.1	6	
	Arsenic (µg/L)	0.8	0.8	0.8	4	<0.1	25	5
	Barium (µg/L)	<10	<10	10	4	<10	1000	
	Beryllium (µg/L)	<5	<5	<5	4	<5		
	Boron (µg/L)	<100	<100	<100	4	<100	5000	
	Cadmium (µg/L)	<0.2	<0.2	<0.2	4	<0.2	5	0.016
	Chromium (µg/L)	<1	<1	<1	4	<1	50	1
	Cobalt (µg/L)	<1	<1	<1	4	<1		
	Copper (µg/L)	**3**	**2**	**3**	4	<1	≤ 1000 [d]	2
	Iron (µg/L)	**360**	**300**	**400**	4	280	≤ 300 [d]	300
	Lead (µg/L)	<1	<1	<1	4	<1	10	1
	Manganese (µg/L)	42	26	**58**	4	12	≤ 50 [d]	
	Mercury (µg/L)	<0.03	<0.01	<0.05	4	-	1	0.1
	Molybdenum (µg/L)	<1	<1	<1	4	<1		73
	Nickel (µg/L)	2	1	2	4	<1		25
	Selenium (µg/L)	<0.5	<0.5	<0.5	4	<0.5	10	1
	Silicon (µg/L)	1080	980	1170	4	520		
	Silver (µg/L)	<0.1	<0.1	<0.1	4	<0.1		0.1
	Strontium (µg/L)	84	79	88	4	37		

Table 3.7 Baseline water quality in Wolverine Lake, 1996 to 1997 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)	Water Quality Guidelines[b]	
		Med	Min	Max	n	Med (n=1)	Drinking Water	Aquatic Life
Total Metals (cont)	Thallium (µg/L)	<150	<100	<200	4	<100		0.8
	Tin (µg/L)	<30	<30	<30	4	<30		
	Titanium (µg/L)	<10	<10	<10	4	<10		
	Uranium (µg/L)	-	-	-	-		20	
	Vanadium (µg/L)	<30	<30	<30	4	<30		
	Zinc (µg/L)	19	13	24	4	<5	≤ 5000 (d)	30
Dissolved Metals	Aluminum (µg/L)	21	-	-	1	19		
	Antimony (µg/L)	<0.1	-	-	1	<0.1		
	Arsenic (µg/L)	0.7	-	-	1	<0.1		
	Barium (µg/L)	<10	-	-	1	<10		
	Beryllium (µg/L)	<5	-	-	1	<5		
	Boron (µg/L)	<100	-	-	1	<100		
	Cadmium (µg/L)	<0.2	-	-	1	<0.2		
	Chromium (µg/L)	<1	-	-	1	<1		
	Cobalt (µg/L)	<1	-	-	1	<1		
	Copper (µg/L)	2	-	-	1	<1		
	Iron (µg/L)	180	-	-	1	90		
	Lead (µg/L)	<1	-	-	1	<1		
	Lithium (µg/L)	<10	-	-	1	<10		
	Manganese (µg/L)	11	-	-	1	<5		
	Mercury (µg/L)	<0.01	-	-	1			
	Molybdenum (µg/L)	<1	-	-	1	<1		
	Nickel (µg/L)	1	-	-	1	<1		
	Selenium (µg/L)	<0.5	-	-	1	<0.5		
	Silicon (µg/L)	1100	-	-	1	410		
	Silver (µg/L)	<0.1	-	-	1	<0.1		
	Strontium (µg/L)	75	-	-	1	36		

Table 3.7 Baseline water quality in Wolverine Lake, 1996 to 1997 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)	Water Quality Guidelines[b]	
		Med	Min	Max	n	Med (n=1)	Drinking Water	Aquatic Life
Dissolved Metals (cont)	Thallium (µg/L)	<100	-	-	1	<100		
	Tin (µg/L)	<30	-	-	1	<30		
	Vanadium (µg/L)	<30	-	-	1	<30		
	Zinc (µg/L)	23	-	-	1	<5		

(a) Values in bold are equal to or greater than guidelines.

(b) All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from the U.S. EPA (1999). Tabled hardness and pH dependent guidelines were determined using median baseline water quality values (analytical results) from all lakes. Similarly, a temperature of 6.0 °C was used to calculate the ammonia guideline. Individual water quality values shown in this table were assessed against guidelines using median hardness and or pH for the period indicated. Average lake temperatures for ice cover (1.2 °C) and open water (10.3 °C) periods were used to assess ammonia concentrations.

(c) The parameters analyzed vary between sampling events. Refer to Appendix A for detailed results.

(d) Aesthetic objective.

Notes:

<= less than analytical detection limit.

Statistics (i.e. minimum, median and maximum) were calculated using method outlined in Appendix A.

Median values were not calculated when the sample size was equal to 2. Data was represented as the median if sample size was equal to 1.

µS/cm = micro Seimens per centimetre; NTU = nephelometric turbidity unit; mg $CaCO_3$/L = milligram carbonate per litre; ug/L = microgram per litre.

concentrations were 150, 74, and 5.5 mg/L, respectively. The corresponding summer concentrations were 57, 32, and 1.9 mg/L (Table 3.7). These levels were elevated compared to other lakes in the region (Puznicki 1996a).

Median alkalinity in spring and summer were 79 mg/L and 32 mg/L, respectively. These values indicated a lake with very low to low susceptibility to acidification.

Median summer ammonia concentration (0.005 mg/L), dissolved nitrate+nitrite concentration (0.002 mg/L) and median spring and summer TP concentration (0.014 and 0.01 mg/L) were within the normal range for lakes in the Slave Structural Province (Puznicki 1996a). The total phosphorus data suggested mesotrophic status in the lake (Wetzel 1983).

Median metal concentrations generally were below the CWQG. The exceptions were spring values for total copper and iron (Table 3.7). The maximum value for manganese in the spring was also above CWQG.

In summary, Wolverine Lake was a relatively clear, moderately soft water lake, with a neutral pH, low nutrients and generally low metal concentrations typical for lakes in the region. Concentrations of chloride, sodium and potassium were elevated compared to other lakes in the area. DO concentrations were low in 1997 and 1998.

3.2.6 Windy Lake

Dissolved oxygen and temperature profiles for Windy Lake are presented in Figure 3.7. Only one comprehensive spring temperature and DO profile was obtained during the study program. This profile indicated a shallow pronounced thermocline and underlying layer of relatively constant temperature up to 2.5°C. Dissolved oxygen was consistently high to a depth of approximately 15 m, after which the concentration decreased to about 2 mg/L. Spring dissolved oxygen concentrations remained above the CWQG at all but the bottom depths.

The summer profiles generally indicated a wind-mixed layer above a pronounced thermocline at approximately 7 m depth. Dissolved oxygen concentrations remained constant and high throughout all depths sampled. Summer dissolved oxygen concentrations remained above the CWQG.

Median turbidity levels in spring and summer were low (1.2 and 1.8 NTU, respectively). Spring and summer median TSS concentrations were <1.0 and 2.0 mg/L, respectively (Table 3.8).

Figure 3.7 Temperature and dissolved oxygen profiles in Windy Lake, 1995 to 1998.

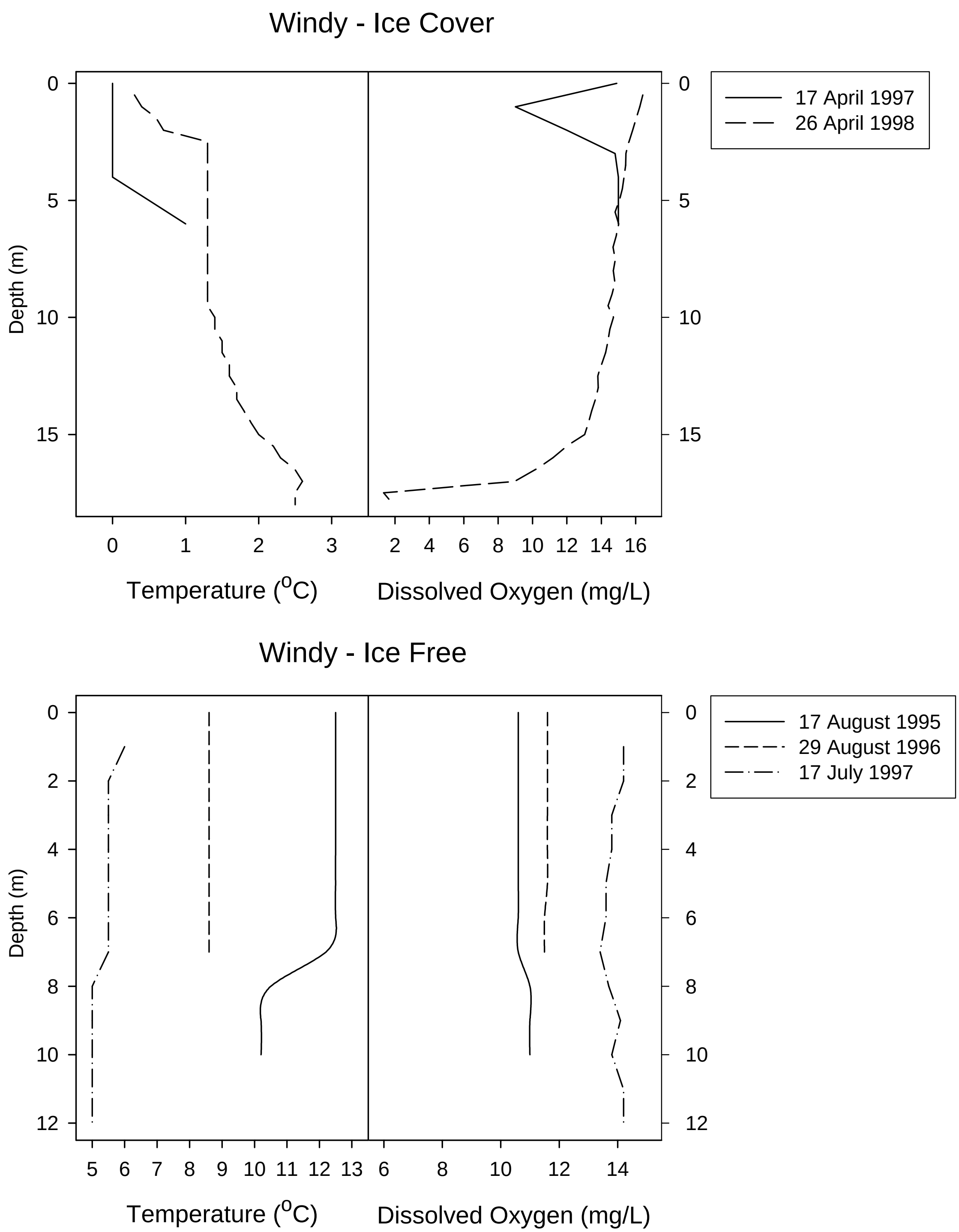


Table 3.8 Baseline water quality in Windy Lake, 1995 to 2000[(a)]

	Parameter (units)[(c)]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines [(b)]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Physical Parameters	Conductivity (µS/cm)	394	20	500	5	414	168	584	13		
	Total Dissolved Solids(mg/L)	209	8	259	5	220	89	237	13	≤ 500 [(d)]	
	Hardness ($CaCO_3$) (mg/L)	62.4	42.2	82.8	3	61.5	52.0	72.7	11		
	pH (units)	7.52	**6.33**	7.73	5	7.58	6.90	8.00	13	6.5-8.5	6.5-9.0
	Total Suspended Solids (mg/L)	<1	<1	2	5	2	<1	19	13		Short-term increase <25; long term increase <5
	Turbidity (NTU)	**1.2**	0.3	**2.1**	3	**1.8**	0.6	**5.0**	10	1	Short-term increase <8; long term increase <2.
Conventional Parameters	Acidity ($CaCO_3$) (mg/L)	5	4	6	3	1	1	2	10		
	Alkalinity Total ($CaCO_3$) (mg/L)	50.9	1.3	56.0	5	45.6	17.9	50.0	8		
	Alkalinity to pH 4.5 (mg/L)	-	-	-	-	46	44	46	5		
	Bicarbonate Alkalinity (mg/L)	-	-	-	-	46	44	46	5		
	Carbonate Alkalinity (mg/L)	-	-	-	-	<1	<1	<1	5		
Major Ions (dissolved)	Bromide (mg/L)	-	-	-	-	<0.5	<0.5	<0.5	4		
	Chloride (mg/L)	103.8	96.0	111.5	3	96.8	94.7	102.0	11	≤ 250 [(d)]	230
	Silicate (mg/L)	-	-	-	-	0.7	-	-	1		
	Fluoride (mg/L)	0.12	0.07	0.18	3	0.08	0.02	0.14	11	1.5	
	Sulphate (mg/L)	7.1	<1	9.0	5	7.0	3.0	8.7	13	≤ 500 [(d)]	
	Calcium (mg/L)	7.5	-	-	1	11.2	9.4	11.7	6		
	Potassium (mg/L)	2.70	-	-	1	3.45	3.15	3.84	6		
	Magnesium (mg/L)	5.7	-	-	1	8.6	7.7	9.4	6		
	Sodium (mg/L)	29.8	-	-	1	-	54.8	57.0	2	≤ 200 [(d)]	
Major Ions (total)	Calcium (mg/L)	9.7	5.4	14.0	4	11.4	10.5	12.9	11		
	Potassium (mg/L)	3.62	2.42	4.81	4	3.93	3.16	5.74	11		
	Magnesium (mg/L)	8.21	4.81	11.60	4	9.08	7.96	11.50	11		
	Sodium (mg/L)	46.3	26.5	67.0	4	52.5	48.5	57.5	7	≤ 200 [(d)]	
Nutrients	Ammonia Nitrogen (mg/L)	-	0.011	0.021	2	0.007	0.0031	<0.02	13		8.9
	Dissolved Nitrate (mg/L)	-	<0.005	0.052	2	0.006	0.004	0.034	13	10	
	Dissolved Nitrite (mg/L)	-	0.001	0.001	2	0.001	0.0009	0.001	13	0.97	0.06
	Nitrite/Nitrate (mg/L)	-	-	-	-	-	-	-	-		

Table 3.8 Baseline water quality in Windy Lake, 1995 to 2000 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines [b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Nutrients (cont)	Dissolved Silicate (mg/L)	-	-	-	-	-	0.357	0.466	2		
	Dissolved Phosphate (mg/L)	-	-	-	-	-	0.001	0.005	2		
	Dissolved ortho-Phosphate (mg/L)	-	-	-	-	0.002	<0.001	0.004	9		
	Total Phosphorus - ICP (mg/L)	<0.3	<0.3	<0.3	4	0.205	0.110	<0.3	3		
	Dissolved Phosphorus - ICP (mg/L)	<0.3	-	-	1	-	<0.3	<0.3	2		
	Total Phosphorus (mg/L)	0.006	-	-	1	0.003	<0.001	0.004	6		
	Total Phosphate (mg/L)	-	-	-	-	0.006	0.006	0.006	4		
	Total Organic Carbon (mg/L)	-	-	-	-	2.3	1.4	3.3	5		
Total Metals	Aluminum (µg/L)	14	9	19	4	42	12	**147**	11		100
	Antimony (µg/L)	<0.1	<0.1	<0.1	4	0.11	0.05	<0.2	11	6	
	Arsenic (µg/L)	0.4	0.2	0.6	4	1.0	0.1	**5**	11	25	5
	Barium (µg/L)	<10	<10	<10	4	2.33	1.97	<10	11	1000	
	Beryllium (µg/L)	<5	<5	<5	4	<0.5	<0.1	<5	11		
	Boron (µg/L)	<100	<100	<100	4	67	43	<100	11	5000	
	Cadmium (µg/L)	<0.2	<0.2	<0.2	6	<0.2	<0.05	<0.2	13	5	0.016
	Chromium (µg/L)	<1	<1	<1	4	**1.8**	<0.5	**5.3**	11	50	1
	Cobalt (µg/L)	<1	<1	<1	4	<0.1	<0.1	<1	11		
	Copper (µg/L)	<2	<1	**2**	6	1	0.8	1.4	13	≤ 1000 [d]	2
	Iron (µg/L)	15	<10	20	4	60	25	150	11	≤ 300 [d]	300
	Lead (µg/L)	**1**	<1	**1**	6	0.64	0.07	<1	13	10	1
	Manganese (µg/L)	<5	<5	<5	4	1.8	0.7	<5	11	≤ 50 [d]	
	Mercury (µg/L)	0.04	0.02	<0.05	4	<0.03	<0.01	<0.05	5	1	0.1
	Molybdenum (µg/L)	<1	<1	<1	4	0.54	<0.2	<1	11		73
	Nickel (µg/L)	<1	<1	<1	4	1.1	0.2	1.5	11		25
	Selenium (µg/L)	<0.5	<0.5	<0.5	4	**2.0**	<0.5	**5**	11	10	1
	Silicon (µg/L)	185	120	250	4	310	270	690	11		
	Silver (µg/L)	<0.1	<0.1	<0.1	4	<0.01	<0.01	<0.1	11		0.1
	Strontium (µg/L)	49	30	69	4	51.1	43.8	57.0	7		
	Thallium (µg/L)	<150	<100	<200	4	<0.05	<0.05	<100	7		0.8
	Tin (µg/L)	<30	<30	<30	4	<0.1	<0.1	<30	7		
	Titanium (µg/L)	<10	<10	<10	4	<4	<0.5	<10	7		

Table 3.8 Baseline water quality in Windy Lake, 1995 to 2000 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Total Metals (cont)	Uranium (µg/L)	-	-	-	-	0.17	0.15	0.19	9	20	
	Vanadium (µg/L)	<30	<30	<30	4	<3	<1	<30	11		
	Zinc (µg/L)	<5	<5	5	6	<5	<1	<5	13	≤ 5000 [d]	30
Dissolved Metals	Aluminum (µg/L)	<5	-	-	1	8	4	10	6		
	Antimony (µg/L)	<0.1	-	-	1	0.08	0.05	0.1	6		
	Arsenic (µg/L)	0.2	-	-	1	<0.6	<0.1	<1	6		
	Barium (µg/L)	<10	-	-	1	5.81	1.62	<10	6		
	Beryllium (µg/L)	<5	-	-	1	<2.8	<0.5	<5	6		
	Boron (µg/L)	<100	-	-	1	86	62	<100	6		
	Cadmium (µg/L)	0.2	-	-	1	<0.13	<0.05	0.2	6		
	Chromium (µg/L)	<1	-	-	1	<0.6	<0.1	<1	6		
	Cobalt (µg/L)	<1	-	-	1	<0.6	<0.1	<1	6		
	Copper (µg/L)	2	-	-	1	0.7	0.3	<1	6		
	Iron (µg/L)	<10	-	-	1	13	<10	20	6		
	Lead (µg/L)	<1	-	-	1	<0.53	<0.05	<1	6		
	Lithium (µg/L)	<10	-	-	1	<10	<10	<10	2		
	Manganese (µg/L)	<5	-	-	1	2.6	0.08	<5	6		
	Mercury (µg/L)	<0.01	-	-	1	-	-	-	-		
	Molybdenum (µg/L)	<1	-	-	1	0.7	0.4	<1	6		
	Nickel (µg/L)	<1	-	-	1	0.6	0.1	<1	6		
	Selenium (µg/L)	<0.5	-	-	1	<0.5	<0.5	0.7	6		
	Silicon (µg/L)	110	-	-	1	265	240	330	6		
	Silver (µg/L)	<0.1	-	-	1	<0.06	<0.01	<0.1	6		
	Strontium (µg/L)	37	-	-	1	50.5	36.1	57.0	6		

Table 3.8 Baseline water quality in Windy Lake, 1995 to 2000 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Dissolved Metals (cont)	Thallium (µg/L)	<100	-	-	1	<50	<0.05	<100	6		
	Tin (µg/L)	<30	-	-	1	<15	<0.1	<30	6		
	Titanium (µg/L)	<10	-	-	1	<6	<1	<10	6		
	Uranium (µg/L)	-	-	-	-	0.14	0.12	0.15	4		
	Vanadium (µg/L)	<30	-	-	1	15	0.4	<30	6		
	Zinc (µg/L)	8	-	-	1	4	2	<5	6		

(a) Values in bold are equal to or greater than guidelines.

(b) All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from the U.S. EPA (1999). Tabled hardness and pH dependent guidelines were determined using median baseline water quality values (analytical results) from all lakes. Similarly, a temperature of 6.0 °C was used to calculate the ammonia guideline. Individual water quality values shown in this table were assessed against guidelines using median hardness and or pH for the period indicated. Average lake temperatures for ice cover (1.2 °C) and open water (10.3 °C) periods were used to assess ammonia concentrations.

(c) The parameters analyzed vary between sampling events. Refer to Appendix A for detailed results.

(d) Aesthetic objective.

Notes:

<= less than analytical detection limit.

Statistics (i.e. minimum, median and maximum) were calculated using method outlined in Appendix A.

Median values were not calculated when the sample size was equal to 2. Data was represented as the median if sample size was equal to 1.

µS/cm = micro Seimens per centimetre; NTU = nephelometric turbidity unit; mg $CaCO_3$/L = milligram carbonate per litre; ug/L = microgram per litre.

Median total hardness in spring and summer was 62 mg/L, whereas median TDS concentrations in spring and summer were 209 and 220 mg/L, respectively (Table 3.8). Summer hardness and TDS were the highest of all the lakes monitored in the Doris Hinge area. Spring median concentrations of chloride, sodium and potassium were 104, 30, and 2.7 mg/L, respectively. Corresponding summer concentrations were 97, 56, and 3.5 mg/L (Table 3.8). These levels were elevated for a lake in the Slave Structural Province (Puznicki 1996a).

Median spring and summer ammonia nitrogen concentration (0.016 and 0.008 mg/L), dissolved nitrate+nitrite concentration (0.029 and 0.006 mg/L) and TP concentration (0.006 and 0.003 mg/L) are in general typical of values measured in lakes in the Slave Structural Province (Puznicki 1996a). The measured TP concentrations indicated oligotrophic conditions (Wetzel 1983).

Median metal concentrations were mostly below the CWQG. The exceptions were total chromium, lead and selenium levels during summer (Table 3.8). The summer maximum total aluminum concentration was also above CWQG.

In summary, Windy Lake was a moderately soft water lake, with a neutral to slightly acidic pH, generally low nutrients and generally low metal concentrations, as is typical for lakes in undisturbed northern environments. However, the concentrations of chloride, sodium, and potassium were elevated compared to other lakes in the Slave Structural Province.

3.2.7 Little Roberts Lake

Two summer dissolved oxygen and temperature profiles were obtained for Little Roberts Lake (Figure 3.8). They indicated a well-mixed water column with high dissolved oxygen concentrations in 2000. Dissolved oxygen values were below CWQG during the 1997 survey (<6 mg/L).

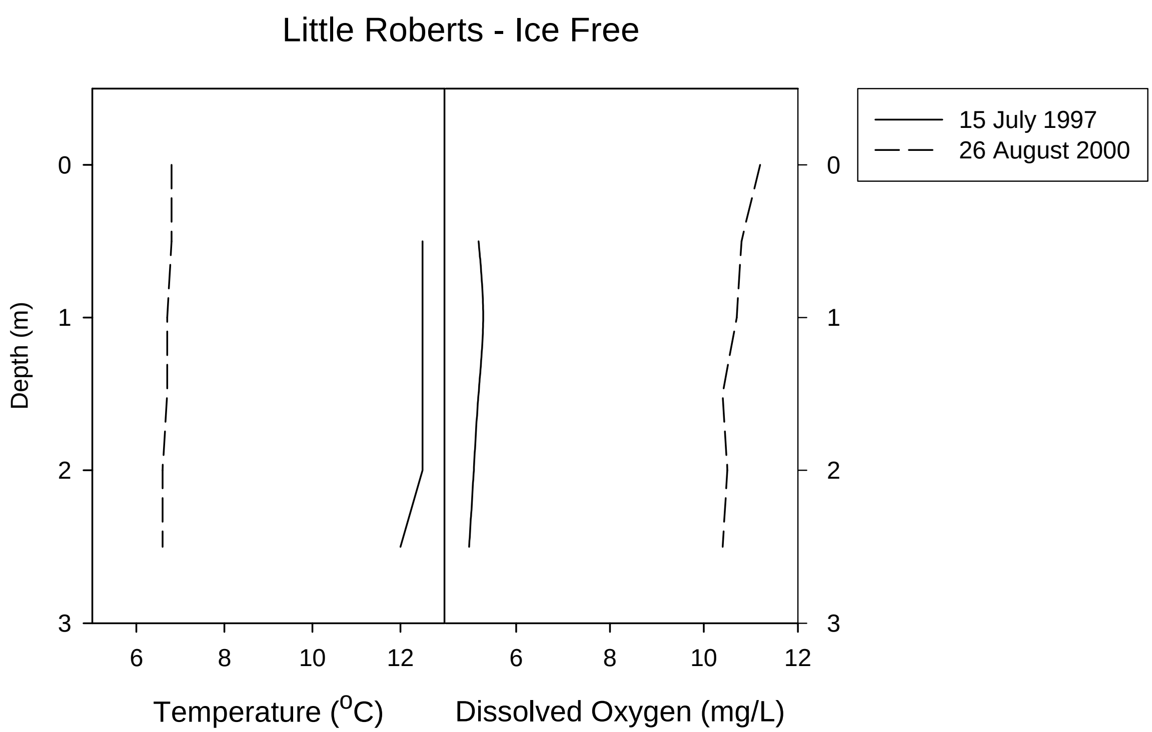
Turbidity was measured only during summer; the median value of 3.4 NTU was low. The corresponding (summer) TSS concentration of 7.5 mg/L and the spring median TSS of 16 mg/L (Table 3.9) were within the normal range for a lake in the Slave Structural Province (Puznicki 1996a).

Median pH levels in spring and summer were 7.03 and 7.08, respectively. The minimum and maximum pH levels were 6.78 and 7.50. All these levels were within the CWQG range.

The summer total hardness level was 32 mg/L, whereas TDS concentrations in spring and summer were 278 and 129 mg/L, respectively (Table 3.9). The hardness levels and TDS concentrations were elevated compared to typical lakes in the Slave Structural Province (Puznicki 1996a). Summer median chloride, sodium and potassium concentrations were 51, 24, and 1.7 mg/L, respectively. These concentrations were elevated for a lake in the Slave Structural Province (Puznicki 1996a).

Median alkalinity levels in spring and summer were 56 and 21 mg/L, respectively. These values indicated that the lake had very low to low susceptibility to acidification.

Figure 3.8 Temperature and dissolved oxygen profiles in Little Roberts Lake, 1997 to 2000.



Median spring and summer ammonia nitrogen concentration (0.058 and 0.013 mg/L, respectively), dissolved nitrate+nitrite concentration (0.029 and 0.006 mg/L) and median summer TP concentration (0.009 mg/L) were within the normal range for lakes in the Slave Structural Province (Puznicki 1996a). The observed TP concentrations imply mesotrophic conditions (Wetzel 1983).

Median metal concentrations generally were below the CWQG. The exceptions were summer values for total aluminum, chromium, copper, lead and selenium (Table 3.9). Spring minimum and maximum concentrations for total copper (3 and 9 mg/L) and maximum concentration for total lead (4 mg/L) and zinc (327 mg/L) were above CWQG.

Table 3.9 Baseline water quality in Little Roberts Lake, 1995 to 1997[a]

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Physical Parameters	Conductivity (µS/cm)	-	84	927	2	230	195	287	6		
	Total Dissolved Solids(mg/L)	-	68	488	2	129	104	173	6	≤ 500 [d]	
	Hardness ($CaCO_3$) (mg/L)	-	-	-	-	32.4	14.3	42.9	4		
	pH (units)	-	7.02	7.04	2	7.08	6.78	7.50	6	6.5-8.5	6.5-9.0
	Total Suspended Solids (mg/L)	-	11	21	2	8	<1	11	6		Short-term increase <25; long term increase <5
	Turbidity (NTU)	-	-	-	-	**3.4**	0.8	**5.8**	4	1	Short-term increase <8; long term increase <2.
Conventional Parameters	Acidity ($CaCO_3$) (mg/L)	-	-	-	-	-	2	2	2		
	Alkalinity Total ($CaCO_3$) (mg/L)	-	20.6	90.3	2	21.0	17.8	23.2	4		
	Alkalinity to pH 4.5 (mg/L)	-	-	-	-	-	20	22	2		
	Bicarbonate Alkalinity (mg/L)	-	-	-	-	-	20	22	2		
	Carbonate Alkalinity (mg/L)	-	-	-	-	-	<1	<1	2		
Major Ions (dissolved)	Bromide (mg/L)	-	-	-	-	-	-	-	-		
	Chloride (mg/L)	-	-	-	-	51.0	42.8	59.4	4	≤ 250 [d]	230
	Silicate (mg/L)	-	-	-	-	-	-	-	-		
	Fluoride (mg/L)	-	-	-	-	0.04	<0.02	0.06	4	1.5	
	Sulphate (mg/L)	-	4.7	10.5	2	2.9	<1	3.7	6	≤ 500 [d]	
	Calcium (mg/L)	-	-	-	-	4.24	1.91	5.10	4		
	Potassium (mg/L)	-	-	-	-	1.72	0.98	2.50	4		
	Magnesium (mg/L)	-	-	-	-	4.68	2.31	7.32	4		
	Sodium (mg/L)	-	-	-	-	-	23.9	24.2	2	≤ 200 [d]	
Major Ions (total)	Calcium (mg/L)	-	-	-	-	5.66	5.07	6.41	4		
	Potassium (mg/L)	-	-	-	-	1.95	1.61	2.50	4		
	Magnesium (mg/L)	-	-	-	-	5.61	4.62	8.18	4		
	Sodium (mg/L)	-	-	-	-	-	24.1	24.3	2	≤ 200 [d]	
Nutrients	Ammonia Nitrogen (mg/L)	-	0.051	0.064	2	0.013	<0.005	0.023	6		8.9
	Dissolved Nitrate (mg/L)	-	0.015	0.023	2	0.005	0.0022	0.020	6	10	
	Dissolved Nitrite (mg/L)	-	0.004	0.007	2	0.001	0.0009	0.002	6	0.97	0.06
	Nitrite/Nitrate (mg/L)	-	-	-	-	-	-	-	-		
	Dissolved Silicate (mg/L)	-	-	-	-	-	1.005	1.250	2		

Table 3.9 Baseline water quality in Little Roberts Lake, 1995 to 1997 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Nutrients (cont)	Dissolved Phosphate (mg/L)	-	-	-	-	-	0.0012	0.0012	2		
	Dissolved ortho-Phosphate (mg/L)	-	-	-	-	-	<0.001	<0.001	2		
	Total Phosphorus- ICP (mg/L)	-	-	-	-	-	<0.3	<0.3	2		
	Dissolved Phosphorus-ICP (mg/L)	-	-	-	-	-	<0.3	<0.3	2		
	Total Phosphorus (mg/L)	-	-	-	-	0.009	<0.001	0.017	4		
	Total Phosphate (mg/L)	-	-	-	-	-	-	-	-		
	Total Organic Carbon (mg/L)	-	-	-	-	-	-	-	-		
Total Metals	Aluminum (µg/L)	-	-	-	-	**242**	**160**	**343**	4		100
	Antimony (µg/L)	-	-	-	-	0.08	0.05	<0.1	4	6	
	Arsenic (µg/L)	-	-	-	-	1.6	0.1	4	4	25	5
	Barium (µg/L)	-	-	-	-	6.8	3.4	<10	4	1000	
	Beryllium (µg/L)	-	-	-	-	<2.8	<0.5	<5	4		
	Boron (µg/L)	-	-	-	-	93	83	<100	4	5000	
	Cadmium (µg/L)	-	<0.2	<0.2	2	<0.2	<0.05	<0.2	6	5	0.016
	Chromium (µg/L)	-	-	-	-	**1.7**	<1	**2.7**	4	50	1
	Cobalt (µg/L)	-	-	-	-	0.6	0.1	<1	4		
	Copper (µg/L)	**-**	**3**	**9**	2	**2**	1	**3.4**	6	≤ 1000 [d]	2
	Iron (µg/L)	-	-	-	-	228	200	260	4	≤ 300 [d]	300
	Lead (µg/L)	**-**	<1	**1**	2	**1**	0.6	**4**	6	10	1
	Manganese (µg/L)	-	-	-	-	8.51	5.07	12	4	≤ 50 [d]	
	Mercury (µg/L)	-	-	-	-	-	-	-	-	1	0.1
	Molybdenum (µg/L)	-	-	-	-	0.6	0.2	<1	4		73
	Nickel (µg/L)	-	-	-	-	1.7	<1	2.5	4		25
	Selenium (µg/L)	-	-	-	-	**1.6**	<0.5	**2.8**	4	10	1
	Silicon (µg/L)	-	-	-	-	1118	1030	1240	4		
	Silver (µg/L)	-	-	-	-	<0.06	<0.01	<0.1	4		0.1
	Strontium (µg/L)	-	-	-	-	33.3	27.5	37.8	4		
	Thallium (µg/L)	-	-	-	-	<50	<0.05	<100	4		0.8
	Tin (µg/L)	-	-	-	-	15	0.2	<30	4		
	Titanium (µg/L)	-	-	-	-	8	6	<10	4		

Table 3.9 Baseline water quality in Little Roberts Lake, 1995 to 1997 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Total Metals (cont)	Uranium (µg/L)	-	-	-	-	-	0.01	0.08	2	20	
	Vanadium (µg/L)	-	-	-	-	15.8	1	<30	4		
	Zinc (µg/L)	**169**	10	**327**	2	<5	<5	8	6	≤ 5000 [d]	30
Dissolved Metals	Aluminum (µg/L)	-	-	-	-	25	<1	46	4		
	Antimony (µg/L)	-	-	-	-	<0.08	<0.05	<0.1	4		
	Arsenic (µg/L)	-	-	-	-	0.8	<0.1	2.0	4		
	Barium (µg/L)	-	-	-	-	5.64	0.59	<10	4		
	Beryllium (µg/L)	-	-	-	-	<3	<0.5	<5	4		
	Boron (µg/L)	-	-	-	-	84	59	<100	4		
	Cadmium (µg/L)	-	-	-	-	<0.13	<0.05	<0.2	4		
	Chromium (µg/L)	-	-	-	-	<0.6	<0.1	<1	4		
	Cobalt (µg/L)	-	-	-	-	<0.6	<0.1	<1	4		
	Copper (µg/L)	-	-	-	-	1.5	0.6	2	4		
	Iron (µg/L)	-	-	-	-	43	20	60	4		
	Lead (µg/L)	-	-	-	-	0.62	0.21	<1	4		
	Lithium (µg/L)	-	-	-	-	-	<10	<10	2		
	Manganese (µg/L)	-	-	-	-	2.59	0.14	<5	4		
	Mercury (µg/L)	-	-	-	-	-	-	-	-		
	Molybdenum (µg/L)	-	-	-	-	0.6	0.09	<1	4		
	Nickel (µg/L)	-	-	-	-	0.7	0.2	<1	4		
	Selenium (µg/L)	-	-	-	-	0.9	<0.5	1.6	4		
	Silicon (µg/L)	-	-	-	-	653	260	800	4		
	Silver (µg/L)	-	-	-	-	<0.06	<0.01	<0.1	4		
	Strontium (µg/L)	-	-	-	-	26.7	10.5	34.0	4		

Table 3.9 Baseline water quality in Little Roberts Lake, 1995 to 1997 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Dissolved Metals (cont)	Thallium (µg/L)	-	-	-	-	<50	<0.05	<100	4		
	Tin (µg/L)	-	-	-	-	15	0.2	<30	4		
	Titanium (µg/L)	-	-	-	-	<6	<1	<10	4		
	Uranium (µg/L)	-	-	-	-	-	0.01	0.01	2		
	Vanadium (µg/L)	-	-	-	-	15.2	0.2	<30	4		
	Zinc (µg/L)	-	-	-	-	3.5	2	<5	4		

[a] Values in bold are equal to or greater than guidelines.

[b] All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from the U.S. EPA (1999). Tabled hardness and pH dependent guidelines were determined using median baseline water quality values (analytical results) from all lakes. Similarly, a temperature of 6.0 °C was used to calculate the ammonia guideline. Individual water quality values shown in this table were assessed against guidelines using median hardness and or pH for the period indicated. Average lake temperatures for ice cover (1.2 °C) and open water (10.3 °C) periods were used to assess ammonia concentrations.

[c] The parameters analyzed vary between sampling events. Refer to Appendix A for detailed results.

[d] Aesthetic objective.

Notes:

<= less than analytical detection limit.

Statistics (i.e. minimum, median and maximum) were calculated using method outlined in Appendix A.

Median values were not calculated when the sample size was equal to 2. Data was represented as the median if sample size was equal to 1.

µS/cm = micro Seimens per centimetre; NTU = nephelometric turbidity unit; mg $CaCO_3$/L = milligram carbonate per litre; ug/L = microgram per litre.

In summary, Little Roberts Lake water quality was similar to the other project lakes, with soft water and neutral pH, as well as low nutrient and metal concentrations. This was typical for lakes in undisturbed northern environments; however, summer concentrations of chloride, sodium, and potassium were elevated for lakes in the region.

3.2.8 Pelvic Lake

Dissolved oxygen and temperatures profiles for Pelvic Lake are provided in Figure 3.9. The single profile taken in under ice conditions in 1998 indicated surface temperatures near 0°C and a relatively constant temperature of 1 to 2°C below 3 m depth. Dissolved oxygen levels declined with depth, but were consistently high (>9 mg/L) to a depth of approximately 10 m.

The summer 1997 temperature profile indicated thermal stratification at 7 m depth, whereas the 2000 profile indicated the lake was well mixed with a constant temperature of approximately 12°C. Similarly, the 2000 dissolved oxygen profile indicated a constant dissolved oxygen concentration of 8 to 9 mg/L. In 1997, dissolved oxygen decreased with depth from 12 mg/L at the surface to 8 mg/L at the lake bottom. For the most part, the water column was well oxygenated with values exceeding 9.5 mg/L.

Median turbidity levels in spring and summer were 6.1 and 8.3 NTU respectively, whereas the corresponding median TSS concentrations were 3 and 7 mg/L. The turbidity levels were above the CDWG, whereas the TSS concentrations were consistent with a lake in the Slave Structural Province (Puznicki 1996a).

Median pH levels in spring and summer were 7.16 and 7.40, respectively (Table 3.10). Median total hardness levels in spring and summer were 44 and 30 mg/L and TDS concentrations were 153 and 104 mg/L, respectively. These hardness levels and TDS concentrations were elevated for a lake in the Slave Structural Province (Puznicki 1996a). The spring median chlorideconcentration was 62 mg/L. The sodium concentration was 35 mg/L and potassium concentrations ranged from 2.41 to 2.47 mg/L (n=2). Corresponding summer concentrations of chloride, sodium, and potassium were 41, 22.9, and 1.97 mg/L. These concentrations were elevated for a lake in the Slave Structural Province (Puznicki 1996a). Median alkalinity ranged from 17 to 25 mg/L and indicated that the lake had moderate susceptibility to acidification.

Figure 3.9 Temperature and dissolved oxygen profiles in Pelvic Lake, 1997 to 2000.

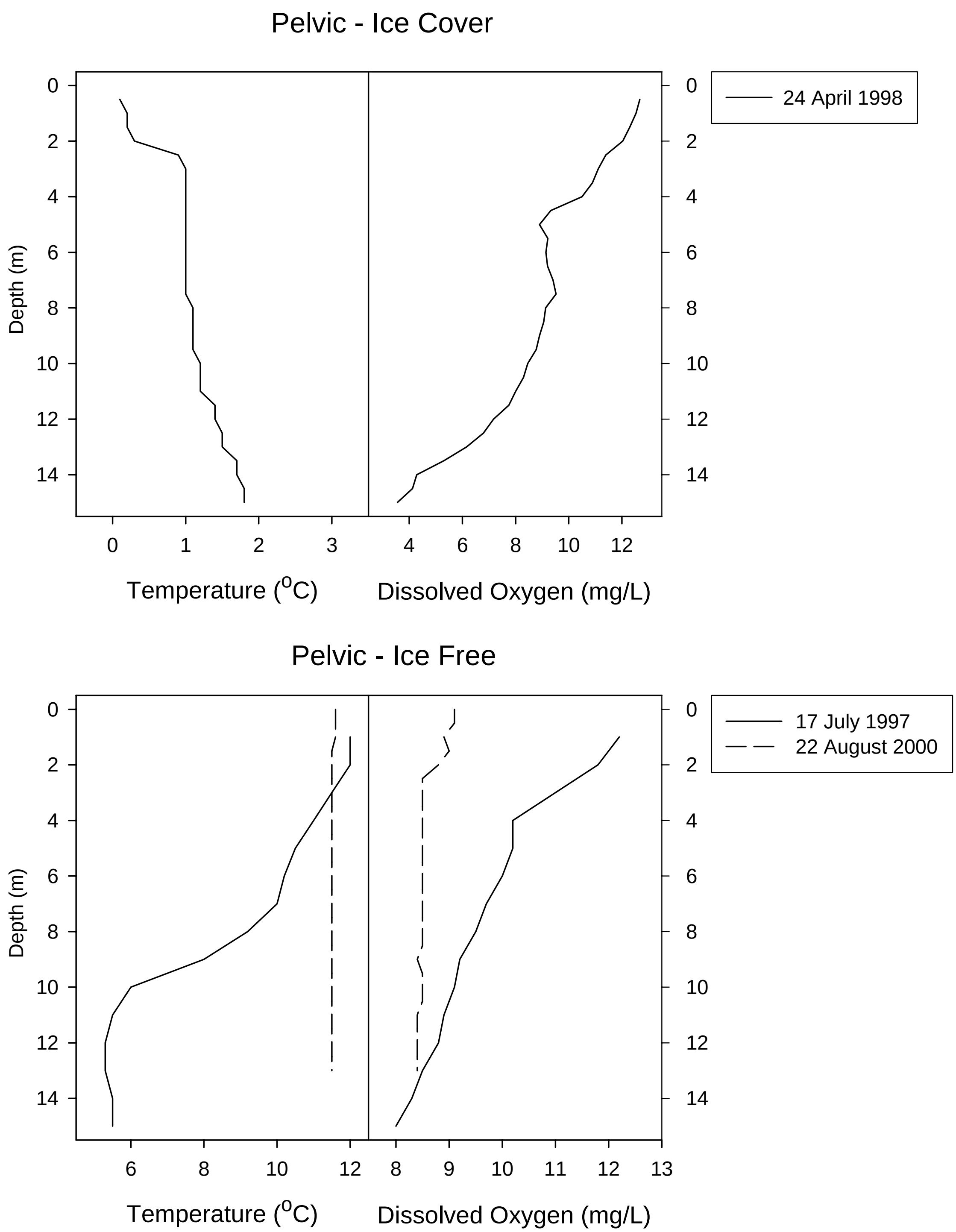


Table 3.10 Baseline water quality in Pelvic Lake, 1997 and 2000[(a)]

	Parameter (units)[(c)]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines[(b)]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Physical Parameters	Conductivity (µS/cm)	260	259	269	3	185	163	208	6		
	Total Dissolved Solids(mg/L)	153	146	185	3	104	91	116	6	≤ 500 [(d)]	
	Hardness ($CaCO_3$) (mg/L)	44.0	43.5	44.1	3	29.7	28.4	30.5	6		
	pH (units)	7.16	7.08	7.19	3	7.40	7.05	7.65	6	6.5-8.5	6.5-9.0
	Total Suspended Solids (mg/L)	3	<1	5	3	7	4	10	6		Short-term increase <25; long term increase <5
	Turbidity (NTU)	**6.1**	**6.0**	**6.3**	3	**8.3**	**5.3**	**11.7**	6	1	Short-term increase <8; long term increase <2.
Conventional Parameters	Acidity ($CaCO_3$) (mg/L)	6	5	6	3	2	1	4	6		
	Alkalinity Total ($CaCO_3$) (mg/L)	25	24	25	3	17	16	17	6		
	Alkalinity to pH 4.5 (mg/L)	-	-	-	-	-	-	-	-		
	Bicarbonate Alkalinity (mg/L)	-	-	-	-	-	-	-	-		
	Carbonate Alkalinity (mg/L)	-	-	-	-	-	-	-	-		
Major Ions (dissolved)	Bromide (mg/L)	-	-	-	-	<0.5	<0.5	<0.5	4		
	Chloride (mg/L)	61.7	61.6	62.8	3	41.0	34.9	47.4	6	≤ 250 [(d)]	230
	Silicate (mg/L)	-	-	-	-	-	-	-	-		
	Fluoride (mg/L)	0.08	0.08	0.09	3	0.06	0.05	0.08	6	1.5	
	Sulphate (mg/L)	4	4	4	3	3	2	3	6	≤ 500 [(d)]	
	Calcium (mg/L)	-	-	-	-	-	3.38	3.39	2		
	Potassium (mg/L)	-	-	-	-	-	1.45	1.48	2		
	Magnesium (mg/L)	-	-	-	-	-	3.97	4.02	2		
	Sodium (mg/L)	-	-	-	-	-	20.5	20.6	2	≤ 200 [(d)]	
Major Ions (total)	Calcium (mg/L)	-	5.55	5.69	2	3.69	3.41	3.94	6		
	Potassium (mg/L)	-	2.41	2.47	2	1.97	1.56	2.30	6		
	Magnesium (mg/L)	-	7.2	7.3	2	4.6	4.1	5.0	6		
	Sodium (mg/L)	-	35.0	35.0	2	22.9	20.5	25.0	6	≤ 200 [(d)]	
Nutrients	Ammonia Nitrogen (mg/L)	-	-	-	-	<0.006	<0.005	0.0074	6		8.9
	Dissolved Nitrate (mg/L)	-	-	-	-	<0.004	0.0019	<0.005	6	10	
	Dissolved Nitrite (mg/L)	-	-	-	-	<0.001	0.0009	0.0017	6	0.97	0.06
	Nitrite/Nitrate (mg/L)	-	-	-	-	-	-	-	-		
	Dissolved Silicate (mg/L)	-	-	-	-	-	0.405	0.556	2		

Table 3.10 Baseline water quality in Pelvic Lake, 1997 to 2000 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines[b]	
										Drinking Water	Aquatic Life
		Med	Min	Max	n	Med	Min	Max	n		
Nutrients (cont)	Dissolved Phosphate (mg/L)	-	-	-	-	-	0.0012	0.0046	2		
	Dissolved ortho-Phosphate (mg/L)	-	-	-	-	0.015	0.013	0.017	4		
	Total Phosphorus - ICP (mg/L)	-	<0.3	<0.3	2	-	<0.3	<0.3	2		
	Dissolved Phosphorus - ICP (mg/L)	-	-	-	-	-	<0.3	<0.3	2		
	Total Phosphorus (mg/L)	-	-	-	-	-	0.026	0.026	2		
	Total Phosphate (mg/L)	-	-	-	-	0.02	0.02	0.026	4		
	Total Organic Carbon (mg/L)	-	-	-	-	6.5	6.3	6.9	4		
Total Metals	Aluminum (µg/L)	-	93	95	2	**147**	66	**338**	6		100
	Antimony (µg/L)	-	<0.1	<0.1	2	<0.08	<0.05	<0.1	6	6	
	Arsenic (µg/L)	-	0.5	0.5	2	0.2	0.1	0.3	6	25	5
	Barium (µg/L)	-	<10	<10	2	6.32	2.61	<10	6	1000	
	Beryllium (µg/L)	-	<5	<5	2	<3	<0.5	<5	6		
	Boron (µg/L)	-	<100	<100	2	59	17	<100	6	5000	
	Cadmium (µg/L)	-	<0.2	<0.2	2	<0.1	<0.05	<0.2	6	5	0.016
	Chromium (µg/L)	-	2.0	2.0	2	<0.8	<0.5	<1	6	50	1
	Cobalt (µg/L)	-	<1	<1	2	<0.6	<0.1	<1	6		
	Copper (µg/L)	-	**13**	**14**	2	1.4	1.0	**2.0**	6	≤ 1000 [d]	2
	Iron (µg/L)	-	80	110	2	298	170	**430**	6	≤ 300 [d]	300
	Lead (µg/L)	-	**1**	**2**	2	**1.5**	0.08	**5**	6	10	1
	Manganese (µg/L)	-	<5	<5	2	23.3	16.1	36.0	6	≤ 50 [d]	
	Mercury (µg/L)	-	<0.05	<0.05	2	<0.05	<0.05	<0.05	4	1	0.1
	Molybdenum (µg/L)	-	<1	<1	2	0.6	0.1	<1	6		73
	Nickel (µg/L)	-	2	2	2	0.7	0.3	<1	6		25
	Selenium (µg/L)	-	<0.5	<0.5	2	<0.8	<0.5	<1	6	10	1
	Silicon (µg/L)	-	1480	1500	2	1460	1200	1790	6		
	Silver (µg/L)	-	<0.1	<0.1	2	<0.06	<0.01	<0.1	6		0.1
	Strontium (µg/L)	-	38	38	2	-	25	25	2		
	Thallium (µg/L)	-	<200	<200	2	-	<100	<100	2		0.8
	Tin (µg/L)	-	<30	<30	2	-	<30	<30	2		
	Titanium (µg/L)	-	<10	<10	2	-	10	10	2		

Table 3.10 Baseline water quality in Pelvic Lake, 1997 to 2000 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Total Metals (cont)	Uranium (µg/L)	-	-	-	-	0.04	0.04	0.04	4	20	
	Vanadium (µg/L)	-	<30	<30	2	<16	<1	<30	6		
	Zinc (µg/L)	-	10	12	2	<3	<1	<5	6	≤ 5000 [d]	30
Dissolved Metals	Aluminum (µg/L)	-	-	-	-	-	99	116	2		
	Antimony (µg/L)	-	-	-	-	-	<0.1	<0.1	2		
	Arsenic (µg/L)	-	-	-	-	-	<0.1	<0.1	2		
	Barium (µg/L)	-	-	-	-	-	<10	<10	2		
	Beryllium (µg/L)	-	-	-	-	-	<5	<5	2		
	Boron (µg/L)	-	-	-	-	-	<100	<100	2		
	Cadmium (µg/L)	-	-	-	-	-	<0.2	<0.2	2		
	Chromium (µg/L)	-	-	-	-	-	<1	<1	2		
	Cobalt (µg/L)	-	-	-	-	-	<1	<1	2		
	Copper (µg/L)	-	-	-	-	-	2	2	2		
	Iron (µg/L)	-	-	-	-	-	120	160	2		
	Lead (µg/L)	-	-	-	-	-	<1	<1	2		
	Lithium (µg/L)	-	-	-	-	-	<10	<10	2		
	Manganese (µg/L)	-	-	-	-	-	<5	11	2		
	Mercury (µg/L)	-	-	-	-	-	-	-	-		
	Molybdenum (µg/L)	-	-	-	-	-	<1	<1	2		
	Nickel (µg/L)	-	-	-	-	-	<1	<1	2		
	Selenium (µg/L)	-	-	-	-	-	<0.5	<0.5	2		
	Silicon (µg/L)	-	-	-	-	-	1100	1290	2		
	Silver (µg/L)	-	-	-	-	-	<0.1	<0.1	2		
	Strontium (µg/L)	-	-	-	-	-	24	25	2		

Table 3.10 Baseline water quality in Pelvic Lake, 1997 to 2000 (continued)

	Parameter (units)[c]	Ice Covered (April to June)				Open Water (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Dissolved Metals (cont	Thallium (µg/L)	-	-	-	-	-	<100	<100	2		
	Tin (µg/L)	-	-	-	-	-	<30	<30	2		
	Titanium (µg/L)	-	-	-	-	-	<10	<10	2		
	Uranium (µg/L)	-	-	-	-	-	-	-	-		
	Vanadium (µg/L)	-	-	-	-	-	<30	<30	2		
	Zinc (µg/L)	-	-	-	-	-	<5	<5	2		

(a) Values in bold are equal to or greater than guidelines.

(b) All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from the U.S. EPA (1999). Tabled hardness and pH dependent guidelines were determined using median baseline water quality values (analytical results) from all lakes. Similarly, a temperature of 6.0 °C was used to calculate the ammonia guideline. Individual water quality values shown in this table were assessed against guidelines using median hardness and or pH for the period indicated. Average lake temperatures for ice cover (1.2 °C) and open water (10.3 °C) periods were used to assess ammonia concentrations.

(c) The parameters analyzed vary between sampling events. Refer to Appendix A for detailed results.

(d) Aesthetic objective.

Notes:

<= less than analytical detection limit.

Statistics (i.e. minimum, median and maximum) were calculated using method outlined in Appendix A.

Median values were not calculated when the sample size was equal to 2. Data was represented as the median if sample size was equal to 1.

µS/cm = micro Seimens per centimetre; NTU = nephelometric turbidity unit; mg $CaCO_3$/L = milligram carbonate per litre; ug/L = microgram per litre.

Median summer ammonia nitrogen concentration (<0.006 mg/L), dissolved nitrate+nitrite concentration (<0.004 mg/L) and TP concentration (0.026 mg/L) were within the normal range for lakes in the Slave Structural Province (Puznicki 1996a). The TP concentrations in the lake imply mesotrophic conditions (Wetzel 1983).

Median metal concentrations generally were below the CWQG. The exceptions were summer values for total aluminum and lead (Table 3.10). The spring sample size was twoand total copper and lead concentrations were above CWQG in both samples.

In summary, Pelvic Lake was a moderately soft water lake, with a neutral pH. Although concentrations of chloride, sodium, and potassium were elevated, nutrient and metal concentrations generally were low and typical for lakes in undisturbed northern environments.

3.2.9 Summary

The lakes of the Doris Hinge area were soft water lakes with neutral to slightly acid pH and low to moderate acid sensitivity. Total phosphorus levels were low, indicating oligotrophic to mesotrophic conditions. Chloride, sodium, and potassium concentrations were elevated compared to lakes typical of the Slave Structural Province. Some metal levels (i.e., total aluminum, iron, copper, cadmium, chromium, lead, and manganese) exceeded Canadian Water Quality Guidelines (CWQG) on a seasonal basis in certain lakes. Metal concentrations, however, were generally typical of lakes in undisturbed northern regions.

In summer, the lakes generally were well-mixed; however, thermal stratification occurred occasionally during the hotter part of the summer season. Episodic (wind-driven) mixing events likely played an important role in maintaining well-mixed conditions. In the shallower lakes, these wind events appeared strong enough to cause complete lake turnover. These conclusions were based on the prevalence of isothermal summer temperature profiles for most of the shallow lakes along with the deep, wind-mixed layer in Doris, Patch and Windy lakes during summer 1995.

The trend in the under ice temperature data was a shallow upper layer of water at or near 0°C followed by constant temperatures, not exceeding 2 to 3°C, throughout the remainder of the water column.

With the exceptions of Ogama and Wolverine, the lakes were typically well aerated during the summer. Depressed near-bottom dissolved oxygen concentrations were recorded during under-ice conditions in most lakes. With the exception of Ogama Lake, this dissolved oxygen depression occurred in lakes with relatively high total organic carbon (TOC) levels in sediment. This suggested that sediment oxygen demand was the underlying cause.

3.3 STREAM WATER QUALITY

The following sections present water quality data collected at the various stream sites (lake outflows) within the Doris Hinge area. Analytical results for all water quality samples collected in Doris, Tail, Ogama, Patch, Windy, Little Roberts, and Pelvic outflows are presented in Appendix A9. A summary of pH, dissolved oxygen, and water temperature field measurements for Doris Hinge streams in 1996 is provided in Table 3.11.

Table 3.11 Field measurements of pH, dissolved oxygen, and water temperature in Doris Hinge streams, 1996.

Sampling Site	Season	pH	Dissolved Oxygen (mg/L)	Water Temperature (^{o}C)
Doris Outflow	Spring	7.2	11.66	6.7
	Summer	7.3	10.88	9.4
Tail Outflow	Spring	7.1	8.71	12.5
	Summer	7.3	10.80	5.2
Ogama Outflow	Spring	7.2	12.44	5.7
	Summer	6.4	11.47	7.4
Patch Outflow	Spring	7.3	14.20	4.9
	Summer	7.7	11.70	6.3
Windy Outflow	Spring	7.2	9.12	13.4
	Summer	7.8	11.24	8.5
Little Roberts Outflow	Spring	7.2	12.18	5.6
	Summer	7.4	12.09	5.9

3.3.1 Doris Outflow

Stream temperatures in spring and summer 1996 were 6.7 and 9.4°C, respectively, dissolved oxygen concentrations in spring and summer were 10.88 and 11.66 mg/L, respectively, and field pH values in spring and summer were 7.2 and 7.3, respectively (Table 3.11). All these values were within the CWQG.

Median turbidity levels in spring and summer were 4.9 and 6.3 NTU, respectively, whereas median TSS values were <3 and 6 mg/L, respectively (Table 3.12). The turbidity levels were above the CDWG of 1 NTU.

Table 3.12 Baseline water quality in Doris Outflow, 1996 to 2000[(a)]

	Parameter (units)[(c)]	Spring (June)				Summer (July to September)				Water Quality Guidelines[(b)]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Physical Parameters	Conductivity (µS/cm)	236	150	269	4	244	211	311	6		
	Total Dissolved Solids(mg/L)	130	86	161	4	140	104	232	6	≤ 500 [(d)]	
	Hardness (CaCO3) (mg/L)	38.1	22.0	49.0	4	47.6	36.6	70.0	6		
	pH (units)	7.20	6.83	7.70	4	7.26	6.99	7.60	6	6.5-8.5	6.5-9.0
	Total Suspended Solids (mg/L)	<3	<1	6	4	6	<1	7	6		Short-term increase <25; long term increase <5
	Turbidity (NTU)	**4.9**	**3**	**6.6**	4	**6.3**	**4.3**	**6.9**	6	1	Short-term increase <8; long term increase <2.
Conventional Parameters	Acidity (CaCO3) (mg/L)	2	1	3	4	2	2	3	6		
	Alkalinity Total (CaCO3) (mg/L)	26	26	26	3	24	23	25	5		
	Alkalinity to pH 4.5 (mg/L)	16	-	-	1	24	-	-	1		
	Bicarbonate Alkalinity (mg/L)	-	-	-	-	24	-	-	1		
	Carbonate Alkalinity (mg/L)	-	-	-	-	<1	-	-	1		
Major Ions (dissolved)	Bromide (mg/L)	-	-	-	-	-	-	-	-		
	Chloride (mg/L)	53.0	30.5	59.3	4	53.4	46.7	87.0	6	≤ 250 [(d)]	230
	Silicate (mg/L)	-	-	-	-	-	-	-	-		
	Fluoride (mg/L)	0.06	0.04	0.07	4	0.07	0.06	0.09	6	1.5	
	Sulphate (mg/L)	3	1	3	4	2	2	4	6	≤ 500 [(d)]	
	Calcium (mg/L)	-	3.97	6.20	2	6.17	5.97	17.4	4		
	Potassium (mg/L)	-	1.20	2.19	2	2.32	1.80	2.42	4		
	Magnesium (mg/L)	-	3.02	5.44	2	5.15	4.84	6.35	4		
	Sodium (mg/L)	-	14.6	26.0	2	25.3	20.9	25.9	4	≤ 200 [(d)]	
Major Ions (total)	Calcium (mg/L)	6.22	4.11	8.48	4	9.10	6.10	18.20	6		
	Potassium (mg/L)	2.23	1.24	3.00	4	2.40	1.95	9.10	6		
	Magnesium (mg/L)	5.44	3.09	6.80	4	5.83	4.93	6.55	6		
	Sodium (mg/L)	26.2	16.4	37.0	4	26.2	21.3	27.9	6	≤ 200 [(d)]	
Nutrients	Ammonia Nitrogen (mg/L)	<0.005	<0.005	0.012	4	0.679	<0.005	1.402	6		8.9
	Dissolved Nitrate (mg/L)	<0.005	<0.005	0.019	4	0.004	0.002	<0.005	6	10	
	Dissolved Nitrite (mg/L)	<0.001	<0.001	0.005	4	0.001	<0.001	0.0012	6	0.97	0.06
	Nitrite/Nitrate (mg/L)	-	-	-	-	-	-	-	-		
	Dissolved Silicate (mg/L)	0.381	-	-	1	0.0044	0.0037	0.0047	3		

Table 3.12 Baseline water quality in Doris Outflow, 1996 to 2000 (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to September)				Water Quality Guidelines [b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Nutrients (cont)	Dissolved Phosphate (mg/L)	-	0.004	0.008	2	0.001	0.0009	0.01	4		
	Dissolved ortho-Phosphate (mg/L)	0.002	<0.001	0.002	3	<0.002	<0.001	<0.002	3		
	Total Phosphorus - ICP (mg/L)	<0.3	-	-	1	<0.3	<0.3	<0.3	3		
	Dissolved Phosphorus- ICP (mg/L)	<0.3	-	-	1	<0.3	<0.3	<0.3	3		
	Total Phosphorus (mg/L)	-	0.006	0.018	2	0.016	0.014	0.022	6		
	Total Phosphate (mg/L)	-	-	-	-	-	-	-	-		
	Total Organic Carbon (mg/L)	-	5.9	6.4	2	-	6.3	6.4	2		
Other	Cyanate (mg/L)	<0.05	-	-	1	-	-	-	-		
	Thiocyanate (mg/L)	0.1	-	-	1	-	-	-	-		
	Total Cyanide (mg/L)	0.005	-	-	1	-	-	-	-	200	5
	WAD Cyanide (mg/L)	<0.005	-	-	1	-	-	-	-		
Total Metals	Aluminum (µg/L)	75	28	**150**	4	72	19	**130**	6		100
	Antimony (µg/L)	<0.05	<0.05	<0.1	4	<0.08	<0.05	<0.1	6	6	
	Arsenic (µg/L)	0.4	0.3	<4	4	0.4	<0.1	3	6	25	5
	Barium (µg/L)	3.13	2.98	<10	4	8.86	3.01	<10	6	1000	
	Beryllium (µg/L)	<0.5	<0.5	<5	4	<2.8	<0.5	<5	6		
	Boron (µg/L)	22	13	<100	4	61	14	<100	6	5000	
	Cadmium (µg/L)	<0.2	<0.05	<0.2	4	<0.13	<0.05	<0.2	6	5	0.016
	Chromium (µg/L)	<0.8	<0.5	<1	4	<1	<0.5	<1	5	50	1
	Cobalt (µg/L)	<0.1	<0.1	<1	4	<0.6	<0.1	<1	6		
	Copper (µg/L)	1.6	1.5	**2**	4	**2.0**	1.6	**2.3**	6	≤ 1000 [d]	2
	Iron (µg/L)	100	60	**310**	4	178	100	210	6	≤ 300 [d]	300
	Lead (µg/L)	0.14	0.09	<1	4	0.61	0.07	<1	6	10	1
	Manganese (µg/L)	8.56	7.93	41.00	4	23.8	13.5	**57.9**	6	≤ 50 [d]	
	Mercury (µg/L)	-	<0.05	<0.05	2	<0.05	<0.05	<0.05	3	1	0.1
	Molybdenum (µg/L)	0.17	0.13	<1	4	0.58	0.14	<1	6		73
	Nickel (µg/L)	0.6	0.4	<1	4	1	0.4	1.3	6		25
	Selenium (µg/L)	<0.6	<0.5	<1	4	<0.5	<0.5	<1	6	10	1
	Silicon (µg/L)	-	710	1500	2	1110	1030	1260	4		
	Silver (µg/L)	<0.02	<0.01	<0.1	4	<0.07	<0.01	<0.1	6		0.1

Table 3.12 Baseline water quality in Doris Outflow, 1996 to 2000 (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to September)				Water Quality Guidelines [b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Total Metals (cont)	Strontium (µg/L)	-	29.2	35	2	45	38	168	4		
	Thallium (µg/L)	-	<0.05	<100	2	<100	0.05	<100	4		0.8
	Tin (µg/L)	-	<0.1	<30	2	<30	<0.1	<30	4		
	Titanium (µg/L)	-	2	<10	2	<10	3	<10	4		
	Uranium (µg/L)	0.02	<0.01	0.03	3	0.02	<0.01	0.04	3	20	
	Vanadium (µg/L)	<1	<1	<30	4	<16	<1	<30	6		
	Zinc (µg/L)	<2	<1	<5	4	<3	<1	<5	6	≤ 5000 [d]	30
Dissolved Metals	Aluminum (µg/L)	-	14	37	2	16	6	24	4		
	Antimony (µg/L)	-	<0.05	<0.1	2	<0.1	<0.05	<0.1	4		
	Arsenic (µg/L)	-	<0.1	<1	2	<0.5	<0.1	<1	4		
	Barium (µg/L)	-	2.27	<10	2	<10	7.7	<10	4		
	Beryllium (µg/L)	-	<0.5	<5	2	<5	<0.5	<5	4		
	Boron (µg/L)	-	11	<100	2	<100	14	<100	4		
	Cadmium (µg/L)	-	<0.05	<0.2	2	<0.2	<0.05	<0.2	4		
	Chromium (µg/L)	-	0.4	<1	2	<1	<1	<1	3		
	Cobalt (µg/L)	-	<0.1	<1	2	<1	<0.1	<1	4		
	Copper (µg/L)	-	0.9	2	2	2	1	2	4		
	Iron (µg/L)	-	40	90	2	40	30	60	4		
	Lead (µg/L)	-	<0.05	<1	2	<1	<0.05	<1	4		
	Lithium (µg/L)	-	2	<10	2	<10	<10	<10	3		
	Manganese (µg/L)	-	1.83	17.00	2	<5	2.07	<5	4		
	Mercury (µg/L)	<0.01	-	-	1	<0.05	-	-	1		
	Molybdenum (µg/L)	-	<0.05	<1	2	<1	0.15	<1	4		
	Nickel (µg/L)	-	0.2	<1	2	<1	0.8	<1	4		
	Selenium (µg/L)	-	<0.5	0.6	2	<0.5	<0.5	<0.5	4		
	Silicon (µg/L)	-	580	1210	2	1050	960	1080	4		
	Silver (µg/L)	-	<0.01	<0.1	2	<0.1	<0.01	<0.1	4		
	Strontium (µg/L)	-	26.5	35.0	2	44	37	168	4		
	Thallium (µg/L)	-	<0.05	<100	2	<100	<0.05	<100	4		

Table 3.12 Baseline water quality in Doris Outflow, 1996 to 2000 (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to September)				Water Quality Guidelines [b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Dissolved Metals (cont)	Tin (µg/L)	-	<0.1	<30	2	<30	<0.1	<30	4		
	Titanium (µg/L)	-	<1	<10	2	<10	<1	<10	4		
	Uranium (µg/L)	<0.01	-	-	1	<0.01	-	-	1		
	Vanadium (µg/L)	-	0.1	<30	2	<30	0.3	<30	4		
	Zinc (µg/L)	-	1	<5	2	<5	<1	<5	4		

[a] Values in bold are equal to or greater than guidelines.

[b] All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from the U.S. EPA (1999). Tabled hardness and pH dependent guidelines were determined using median baseline water quality values (analytical results) from all lakes. Similarly, a temperature of 6.0 °C was used to calculate the ammonia guideline. Individual water quality values shown in this table were assessed against guidelines using median hardness and or pH for the period indicated. Average lake temperatures for ice cover (1.2 °C) and open water (10.3 °C) periods were used to assess ammonia concentrations.

[c] The parameters analyzed vary between sampling events. Refer to Appendix A for detailed results.

[d] Aesthetic objective.

Notes:

<= less than analytical detection limit.

Statistics (i.e. minimum, median and maximum) were calculated using method outlined in Appendix A.

Median values were not calculated when the sample size was equal to 2. Data was represented as the median if sample size was equal to 1.

µS/cm = micro Seimens per centimetre; NTU = nephelometric turbidity unit; mg $CaCO_3$/L = milligram carbonate per litre; ug/L = microgram per litre.

In spring and summer, median pH levels were 7.2 and 7.3, median total hardness levels were 38 and 48 mg/L, and median TDS concentrations were 130 and 140 mg/L, respectively. These concentrations are similar to conditions in the lake proper. The median chloride concentration was 53 mg/L for both seasons, the median sodium concentration in the summer was 26 mg/L and the median potassium concentration was 2.4 mg/L. Sodium and potassium concentrations ranged from 16 to 37 and between 1.2 and 2.4 mg/L, respectively (n=2). These summer concentrations reflected lake conditions, whereas the spring concentrations were lower. The low nutrient concentrations reflected lake conditions, although summer ammonia-nitrogen was elevated in comparison to spring conditions (Table 3.12).

Most of the median metal concentrations were below the CWQG. The single exception was total copper during summer (Table 3.12). Maximum concentrations of total aluminum, copper, iron and manganese were also above CWQG.

3.3.2 Tail Outflow

In spring and summer 1996, stream temperatures were 12.5 and 5.2°C, respectively. Dissolved oxygen concentrations were 8.71 and 10.80 mg/L, and field pH values were 7.1 in spring and summer (Table 3.11). All these values comply with the CWQG.

In spring and summer, median turbidity levels were 0.8 and 3.2 NTU, whereas median TSS concentrations were <2 and 2.5 mg/L, respectively (Table 3.13). The summer turbidity level exceeded the CDWG of 1 NTU.

In spring and summer, median total hardness levels were 17 and 31 mg/L, and median TDS concentrations were 43 and 82 mg/L, respectively. The spring total hardness and TDS concentration was substantially lower than in Tail Lake, as were the spring median concentrations of chloride, sodium, and potassium (13, 8.4, and 1.0 mg/L, respectively). Median nutrient concentrations were characteristically low (Table 3.13).

Median metal concentrations were mostly below the CWQG for aquatic life. The single exception was summer total iron (Table 3.13).

3.3.3 Ogama Outflow

In spring and summer 1996, stream temperatures were 5.7 and 7.4°C, respectively. Dissolved oxygen concentrations were 12.4 and 11.5 mg/L, and field pH ranged from 5.4 to 7.4 throughout the year (Table 3.11).

Table 3.13 Baseline water quality in Tail Outflow, 1996 to 2000[a]

	Parameter (units)[c]	Spring (June)				Summer (July to September)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Physical Parameters	Conductivity (µS/cm)	81	57	98	5	141	127	209	5		
	Total Dissolved Solids(mg/L)	43	32	55	5	82	75	125	5	≤ 500 [d]	
	Hardness ($CaCO_3$) (mg/L)	17.0	13.9	19.0	5	31.4	29.0	43.6	5		
	pH (units)	7.10	6.77	7.34	5	7.10	6.69	7.64	5	6.5-8.5	6.5-9.0
	Total Suspended Solids (mg/L)	<2	<1	<3	5	3	<1	20	5		Short-term increase <25; long term increase <5
	Turbidity (NTU)	0.8	0.7	**1.9**	5	**3.2**	**1.4**	**12.0**	5	1	Short-term increase <8; long term increase <2.
Conventional Parameters	Acidity ($CaCO_3$) (mg/L)	2	<1	3	5	4	2	6	5		
	Alkalinity Total ($CaCO_3$) (mg/L)	12	9	15	4	23	23	25	4		
	Alkalinity to pH 4.5 (mg/L)	20	-	-	1	26	-	-	1		
	Bicarbonate Alkalinity (mg/L)	-	-	-	-	26	-	-	1		
	Carbonate Alkalinity (mg/L)	-	-	-	-	<1	-	-	1		
Major Ions (dissolved)	Bromide (mg/L)	-	-	-	-	-	-	-	-		
	Chloride (mg/L)	13.1	8.1	16.5	5	25.5	22.6	44.0	5	≤ 250 [d]	230
	Silicate (mg/L)	-	-	-	-	-	-	-	-		
	Fluoride (mg/L)	0.04	0.04	0.05	5	0.07	0.06	0.1	5	1.5	
	Sulphate (mg/L)	1	<1	2	5	3	1	6	5	≤ 500 [d]	
	Calcium (mg/L)	3.12	2.96	3.24	3	5.08	4.92	6.25	3		
	Potassium (mg/L)	0.98	0.84	1.12	3	1.30	1.18	1.50	3		
	Magnesium (mg/L)	2.51	2.27	2.73	3	3.70	3.41	4.05	3		
	Sodium (mg/L)	8.36	6.98	9.69	3	12.60	9.15	13.90	3	≤ 200 [d]	
Major Ions (total)	Calcium (mg/L)	3.02	2.55	3.55	5	6.06	4.99	7.81	5		
	Potassium (mg/L)	1.14	0.86	<2.00	5	1.58	1.22	2.42	5		
	Magnesium (mg/L)	2.35	1.80	2.79	5	4.42	3.56	5.90	5		
	Sodium (mg/L)	7.2	5.0	10.6	5	15.5	10.8	26.9	5	≤ 200 [d]	
Nutrients	Ammonia Nitrogen (mg/L)	0.015	<0.005	0.031	5	0.064	<0.005	0.6938	5		8.9
	Dissolved Nitrate (mg/L)	<0.005	<0.001	<0.005	5	0.004	0.0024	0.006	5	10	
	Dissolved Nitrite (mg/L)	<0.001	<0.001	0.004	5	0.001	<0.001	0.0046	5	0.97	0.06
	Nitrite/Nitrate (mg/L)	-	-	-	-	-	-	-	-		
	Dissolved Silicate (mg/L)	-	0.078	0.090	2	-	0.0054	0.0093	2		

Table 3.13 Baseline water quality in Tail Outflow, 1996 to 2000 (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to September)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Nutrients (cont)	Dissolved Phosphate (mg/L)	0.005	0.004	0.006	3	<0.001	<0.001	0.004	3		
	Dissolved ortho-Phosphate (mg/L)	0.004	0.002	0.006	3	<0.002	0.001	<0.002	3		
	Total Phosphorus - ICP (mg/L)	-	<0.3	<0.3	2	-	<0.3	<0.3	2		
	Dissolved Phosphorus – ICP (mg/L)	-	<0.3	<0.3	2	-	<0.3	<0.3	2		
	Total Phosphorus (mg/L)	0.009	0.008	0.009	3	0.007	0.006	0.035	5		
	Total Phosphate (mg/L)	-	-	-	-	-	-	-	-		
	Total Organic Carbon (mg/L)	-	5.2	5.3	2	-	6.0	6.2	2		
Total Metals	Aluminum (µg/L)	31	16	85	5	51	14	64	5		100
	Antimony (µg/L)	<0.05	<0.05	<0.1	5	<0.08	<0.05	<0.1	5	6	
	Arsenic (µg/L)	0.1	0.1	<2	5	<0.3	<0.1	<1	5	25	5
	Barium (µg/L)	1.41	1.22	<10	5	6.4	2.2	<10	5	1000	
	Beryllium (µg/L)	<0.5	<0.5	<5	5	<2.8	<0.5	<5	5		
	Boron (µg/L)	11	5	<100	5	56	8	<100	5	5000	
	Cadmium (µg/L)	<0.05	<0.05	<0.2	5	<0.13	<0.05	<0.2	5	5	0.016
	Chromium (µg/L)	<0.9	<0.5	<1	5	<1	<0.5	<1	4	50	1
	Cobalt (µg/L)	<0.1	<0.1	<1	5	<0.6	<0.1	<1	5		
	Copper (µg/L)	1.0	0.7	1.2	5	1.4	0.7	**3**	5	≤ 1000 [d]	2
	Iron (µg/L)	80	50	120	5	**410**	140	**1110**	5	≤ 300 [d]	300
	Lead (µg/L)	0.09	0.05	<1	5	0.58	0.07	<1	5	10	1
	Manganese (µg/L)	1.48	0.98	<5	5	11.2	5.0	13.8	5	≤ 50 [d]	
	Mercury (µg/L)	-	<0.05	<0.05	2	<0.05	<0.05	<0.05	3	1	0.1
	Molybdenum (µg/L)	0.09	0.06	<1	5	0.54	0.06	<1	5		73
	Nickel (µg/L)	0.5	0.4	<1	5	0.9	0.5	<1	5		25
	Selenium (µg/L)	<0.6	<0.5	<1	5	<0.5	<0.5	<1	5	10	1
	Silicon (µg/L)	450	300	610	3	650	530	1050	3		
	Silver (µg/L)	<0.04	<0.01	<0.1	5	<0.09	<0.01	<0.1	5		0.1
	Strontium (µg/L)	13.1	13.0	13.2	3	24	23	43	3		
	Thallium (µg/L)	<50	<0.05	<100	3	<100	<0.05	<100	3		0.8
	Tin (µg/L)	<15	<0.1	<30	3	<30	<0.1	<30	3		
	Titanium (µg/L)	<6	<1	<10	3	<10	5	<10	3		
	Uranium (µg/L)	0.01	<0.01	0.01	3	<0.01	<0.01	<0.01	3	20	

Table 3.13 Baseline water quality in Tail Outflow, 1996 to 2000 (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to September)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Total Metals (cont)	Vanadium (µg/L)	<1	<1	<30	5	<16	<1	<30	5		
	Zinc (µg/L)	<1	<1	<5	5	<3	<1	<5	5	≤ 5000 [d]	30
Dissolved Metals	Aluminum (µg/L)	23	7	39	3	20	20	29	3		
	Antimony (µg/L)	<0.08	<0.05	<0.1	3	<0.1	<0.05	<0.1	3		
	Arsenic (µg/L)	<0.6	<0.1	<1	3	<0.3	<0.1	<1	3		
	Barium (µg/L)	5.58	1.15	<10	3	<10	1.62	<10	3		
	Beryllium (µg/L)	<2.8	<0.5	<5	3	<5	<0.5	<5	3		
	Boron (µg/L)	56	11	<100	3	<100	6	<100	3		
	Cadmium (µg/L)	<0.13	<0.05	<0.2	3	<0.2	<0.05	<0.2	3		
	Chromium (µg/L)	0.7	0.4	<1	3	-	<1	<1	2		
	Cobalt (µg/L)	<0.6	<0.1	<1	3	<1	<0.1	<1	3		
	Copper (µg/L)	0.9	0.7	1	3	1	0.7	1	3		
	Iron (µg/L)	35	20	50	3	90	50	90	3		
	Lead (µg/L)	<0.53	<0.05	<1	3	<1	<0.05	<1	3		
	Lithium (µg/L)	6	2	<10	3	-	<10	<10	2		
	Manganese (µg/L)	2.56	0.12	<5	3	<5	0.13	<5	3		
	Mercury (µg/L)	-	<0.01	<0.01	2	<0.05	-	-	1		
	Molybdenum (µg/L)	<0.53	<0.05	<1	3	<1	0.08	<1	3		
	Nickel (µg/L)	0.6	0.2	<1	3	<1	0.7	<1	3		
	Selenium (µg/L)	0.6	<0.5	0.6	3	<0.5	<0.5	<0.5	3		
	Silicon (µg/L)	378	290	470	3	520	420	1000	3		
	Silver (µg/L)	<0.06	<0.01	<0.1	3	<0.1	<0.01	<0.1	3		
	Strontium (µg/L)	12.4	11.0	13.2	3	23.0	21.5	26.0	3		

Table 3.13 Baseline water quality in Tail Outflow, 1996 to 2000 (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to September)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Dissolved Metals (cont)	Thallium (µg/L)	<50	<0.05	<100	3	<100	<0.05	<100	3		
	Tin (µg/L)	<15	<0.1	<30	3	<30	<0.1	<30	3		
	Titanium (µg/L)	<6	<1	<10	3	<10	<1	<10	3		
	Uranium (µg/L)	<0.02	-	-	1	<0.01	-	-	1		
	Vanadium (µg/L)	<15	<0.1	<30	3	<30	<0.1	<30	3		
	Zinc (µg/L)	3	1	<5	3	<5	<1	<5	3		

(a) Values in bold are equal to or greater than guidelines.

(b) All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from the U.S. EPA (1999). Tabled hardness and pH dependent guidelines were determined using median baseline water quality values (analytical results) from all lakes. Similarly, a temperature of 6.0 °C was used to calculate the ammonia guideline. Individual water quality values shown in this table were assessed against guidelines using median hardness and or pH for the period indicated. Average lake temperatures for ice cover (1.2 °C) and open water (10.3 °C) periods were used to assess ammonia concentrations.

(c) The parameters analyzed vary between sampling events. Refer to Appendix A for detailed results.

(d) Aesthetic objective.

Notes:

<= less than analytical detection limit.

Statistics (i.e. minimum, median and maximum) were calculated using method outlined in Appendix A.

Median values were not calculated when the sample size was equal to 2. Data was represented as the median if sample size was equal to 1.

µS/cm = micro Seimens per centimetre; NTU = nephelometric turbidity unit; mg $CaCO_3$/L = milligram carbonate per litre; ug/L = microgram per litre.

With the exception of the summer pH value of 5.4, these parameter levels complied with the CWQG.

Turbidity ranged from 5.0 to 16.7 in spring (n=2) and had a median summer value of 10.3 (Table 3.14). The turbidity levels exceeded the CDWG value of 1 NTU.

In spring and summer, respectively, median total hardness levels were 26 and 32 mg/L, median TDS concentrations were 103 and 126 mg/L, median chloride concentrations were 41 and 48 mg/L, median sodium concentrations were 21 and 22 mg/L and median potassium concentrations were 1.8 and 2.0 mg/L (Table 3.14). The summer outflow concentrations were similar to Ogama Lake concentrations, whereas the spring concentrations were substantially lower. With the exception of the elevated summer median ammonia nitrogen (Table 3.14), outflow nutrient concentrations reflected lake nutrient concentrations as well.

Most median metal concentrations were below the CWQG. The exceptions were summer total aluminum, copper and iron levels (Table 3.14). Both values for total aluminum, cadmium, chromium and iron were also above CWQG in the spring (n=2).

3.3.4 Patch Outflow

Patch Outflow temperatures in spring and summer 1996, respectively, were 4.9 and 6.3°C, and dissolved oxygen concentrations were 14.2 and 11.7 mg/L, respectively. Median pH value was 7.49 in summer while spring values ranged from 6.73 to 7.30 (Table 3.11). Spring and summer DO concentrations were all below the CWQG for early life stages.

In summer, the median turbidity level was 7.4 NTU, whereas the median TSS concentration was 4.0 mg/L (Table 3.15). Spring turbidity levels and TSS concentrations ranged from 4.0 to 8.8 NTU and <1 to 6 mg/L, respectively (n=2). Both spring and summer turbidity exceeded the CDWG.

In summer, median hardness was 42 mg/L, median TDS concentrationwas 139 mg/L, median chloride concentrationwas 57 mg/L, median sodium concentrationwas 30 mg/L, and median potassium concentrationwas 2.5 mg/L (Table 3.15). Spring values for hardness ranged from 24 to 25 mg/L, and were between 90 and 106 mg/L for TDS concentrations. Chloride, sodium and potassium concentrations in the spring ranged from 31 to 32 mg/L, 17 to 20 mg/L and 1.6 to 1.8 mg/L, respectively. The summer concentrations were similar to

Table 3.14 Baseline water quality in Ogama Outflow, 1996 and 1997[(a)]

	Parameter (units)[(c)]	Spring (June)				Summer (July to August)				Water Quality Guidelines[(b)]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Physical Parameters	Conductivity (µS/cm)	-	174	194	2	225	200	240	4		
	Total Dissolved Solids(mg/L)	-	88	118	2	126	112	135	4	≤ 500 [(d)]	
	Hardness ($CaCO_3$) (mg/L)	-	24.0	28.7	2	32.0	31.6	35.5	4		
	pH (units)	-	6.63	7.20	2	6.98	**5.40**	7.40	4	6.5-8.5	6.5-9.0
	Total Suspended Solids (mg/L)	-	2	12	2	4	2	13	4		Short-term increase <25; long term increase <5
	Turbidity (NTU)	**-**	**5.0**	**16.7**	2	**10.3**	**6.0**	**10.6**	4	1	Short-term increase <8; long term increase <2.
Conventional Parameters	Acidity ($CaCO_3$) (mg/L)	-	2.3	4	2	2	2	4	4		
	Alkalinity Total ($CaCO_3$) (mg/L)	18	-	-	1	-	20	22	2		
	Alkalinity to pH 4.5 (mg/L)	18	-	-	1	-	22	24	2		
	Bicarbonate Alkalinity (mg/L)	-	-	-	-	-	22	24	2		
	Carbonate Alkalinity (mg/L)	-	-	-	-	-	<1	<1	1		
Major Ions (dissolved)	Bromide (mg/L)	-	-	-	-	-	-	-	-		
	Chloride (mg/L)	-	37.8	44.1	2	47.8	39.5	60.9	4	≤ 250 [(d)]	230
	Silicate (mg/L)	-	-	-	-	-	-	-	-		
	Fluoride (mg/L)	-	0.05	0.05	2	0.07	0.05	0.09	4	1.5	
	Sulphate (mg/L)	-	1	2	2	2.0	1.9	2.0	4	≤ 500 [(d)]	
	Calcium (mg/L)	-	3.55	4.01	2	4.89	4.49	5.19	4		
	Potassium (mg/L)	-	1.49	2.03	2	1.99	1.59	2.50	4		
	Magnesium (mg/L)	-	3.68	4.54	2	4.76	4.37	5.47	4		
	Sodium (mg/L)	-	20.0	22.3	2	22.4	21.0	28.8	4	≤ 200 [(d)]	
Major Ions (total)	Calcium (mg/L)	-	3.67	4.11	2	5.10	4.56	5.16	4		
	Potassium (mg/L)	-	1.65	2.22	2	2.07	1.79	2.66	4		
	Magnesium (mg/L)	-	3.95	4.67	2	4.81	4.51	5.46	4		
	Sodium (mg/L)	-	22.3	22.7	2	22.9	21.5	27.8	4	≤ 200 [(d)]	
Nutrients	Ammonia Nitrogen (mg/L)	-	<0.005	0.022	2	0.682	<0.005	0.9802	4		8.9
	Dissolved Nitrate (mg/L)	-	<0.005	0.042	2	0.005	0.0022	0.014	4	10	
	Dissolved Nitrite (mg/L)	-	<0.001	0.007	2	0.005	<0.001	0.0079	4	0.97	0.06
	Nitrite/Nitrate (mg/L)	-	-	-	-	-	-	-	-		
	Dissolved Silicate (mg/L)	0.238	-	-	1	-	0.004	0.0049	2		

Table 3.14 Baseline water quality in Ogama Outflow, 1996 to 1997 (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Nutrients (cont)	Dissolved Phosphate (mg/L)	-	0.006	0.011	2	0.002	0.0009	0.01	4		
	Dissolved ortho-Phosphate (mg/L)	0.006	-	-	1	-	0.002	0.004	2		
	Total Phosphorus - ICP (mg/L)	<0.3	-	-	1	-	<0.3	<0.3	2		
	Dissolved Phosphorus - ICP (mg/L)	<0.3	-	-	1	-	<0.3	<0.3	2		
	Total Phosphorus (mg/L)	-	0.006	0.032	2	0.022	0.021	0.022	4		
	Total Phosphate (mg/L)	-	-	-	-	-	-	-	-		
	Total Organic Carbon (mg/L)	-	-	-	-	-	-	-	-		
Total Metals	Aluminum (µg/L)	**-**	**179**	**547**	2	**489**	**223**	**499**	4		100
	Antimony (µg/L)	-	0.06	<0.1	2	<0.1	0.05	<0.1	4	6	
	Arsenic (µg/L)	-	0.5	<2	2	0.6	0.2	4.0	4	25	5
	Barium (µg/L)	-	3.66	10	2	10	5	10	4	1000	
	Beryllium (µg/L)	-	<0.5	<5	2	<5	<0.5	<5	4		
	Boron (µg/L)	-	14	<100	2	<100	15	<100	4	5000	
	Cadmium (µg/L)	**-**	**0.13**	<0.2	2	<0.2	<0.05	<0.2	4	5	0.016
	Chromium (µg/L)	**-**	**1.0**	**1.3**	2	-	<1	<1	2	50	1
	Cobalt (µg/L)	-	<0.1	<1	2	<1	<0.1	<1	4		
	Copper (µg/L)	-	1.4	**2**	2	**2**	**2**	**3**	4	≤ 1000 [d]	2
	Iron (µg/L)	**-**	**260**	**1070**	2	**350**	**310**	**710**	4	≤ 300 [d]	300
	Lead (µg/L)	-	0.3	<1	2	<1	0.2	<1	4	10	1
	Manganese (µg/L)	**-**	21.1	**97.0**	2	14	12	27	4	≤ 50 [d]	
	Mercury (µg/L)	-	-	-	-	<0.05	-	-	1	1	0.1
	Molybdenum (µg/L)	-	0.18	<1	2	<1	0.25	<1	4		73
	Nickel (µg/L)	-	0.9	2	2	1	<1	1.8	4		25
	Selenium (µg/L)	**-**	<0.5	**1.6**	2	<0.5	<0.5	<0.5	4	10	1
	Silicon (µg/L)	-	1160	2700	2	1690	1300	2200	4		
	Silver (µg/L)	-	<0.01	<0.1	2	<0.1	0.03	<0.1	4		0.1
	Strontium (µg/L)	-	17.8	23.0	2	31	28	36	4		
	Thallium (µg/L)	-	<0.05	<100	2	<100	<0.05	<100	4		0.8
	Tin (µg/L)	-	<0.1	<30	2	<30	<0.1	<30	4		
	Titanium (µg/L)	-	4	20	2	10	9	20	4		

Table 3.14 Baseline water quality in Ogama Outflow, 1996 to 1997 (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Total Metals (cont)	Uranium (µg/L)	0.02	-	-	1	-	<0.01	0.03	2	20	
	Vanadium (µg/L)	-	<1	<30	2	<30	<1	<30	4		
	Zinc (µg/L)	-	1	<5	2	5	<1	6	4	≤ 5000 [d]	30
Dissolved Metals	Aluminum (µg/L)	-	34	149	2	141	77	159	4		
	Antimony (µg/L)	-	<0.05	<0.1	2	<0.1	<0.05	<0.1	4		
	Arsenic (µg/L)	-	0.1	<1	2	<0.6	<0.1	<1	4		
	Barium (µg/L)	-	2.15	<10	2	<10	2.27	<10	4		
	Beryllium (µg/L)	-	<0.5	<5	2	<5	<0.5	<5	4		
	Boron (µg/L)	-	14	<100	2	<100	13	<100	4		
	Cadmium (µg/L)	-	<0.05	<0.2	2	<0.2	<0.05	<0.2	4		
	Chromium (µg/L)	-	0.7	<1	2	-	<1	<1	2		
	Cobalt (µg/L)	-	<0.1	<1	2	<1	<0.1	<1	4		
	Copper (µg/L)	-	0.9	2	2	2.0	1.2	2.0	4		
	Iron (µg/L)	-	80	410	2	140	30	170	4		
	Lead (µg/L)	-	<0.05	<1	2	<1	0.05	<1	4		
	Lithium (µg/L)	-	2	<10	2	-	<10	<10	2		
	Manganese (µg/L)	-	10.8	23.0	2	<5	0.13	<5	4		
	Mercury (µg/L)	<0.01	-	-	1	<0.05	-	-	1		
	Molybdenum (µg/L)	-	0.1	<1	2	<1	0.21	<1	4		
	Nickel (µg/L)	-	0.4	1	2	<1	<1	1.4	4		
	Selenium (µg/L)	-	<0.5	0.8	2	<0.5	<0.5	<0.5	4		
	Silicon (µg/L)	-	540	1670	2	1210	910	1290	4		
	Silver (µg/L)	-	<0.01	<0.1	2	<0.1	<0.01	<0.1	4		
	Strontium (µg/L)	-	17.2	22.0	2	28	26	35	4		

Table 3.14 Baseline water quality in Ogama Outflow, 1996 to 1997 (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Dissolved Metals (cont)	Thallium (µg/L)	-	<0.05	<100	2	<100	<0.05	<100	4		
	Tin (µg/L)	-	<0.1	<30	2	<30	<0.1	<30	4		
	Titanium (µg/L)	-	<1	<10	2	<10	<1	<10	4		
	Uranium (µg/L)	<0.02	-	-	1	-	<0.01	<0.01	2		
	Vanadium (µg/L)	-	0.2	<30	2	<30	0.3	<30	4		
	Zinc (µg/L)	-	<1	<5	2	<5	1	<5	4		

[a] Values in bold are equal to or greater than guidelines.

[b] All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from the U.S. EPA (1999). Tabled hardness and pH dependent guidelines were determined using median baseline water quality values (analytical results) from all lakes. Similarly, a temperature of 6.0 °C was used to calculate the ammonia guideline. Individual water quality values shown in this table were assessed against guidelines using median hardness and or pH for the period indicated. Average lake temperatures for ice cover (1.2 °C) and open water (10.3 °C) periods were used to assess ammonia concentrations.

[c] The parameters analyzed vary between sampling events. Refer to Appendix A for detailed results.

[d] Aesthetic objective.

Notes:

<= less than analytical detection limit.

Statistics (i.e. minimum, median and maximum) were calculated using method outlined in Appendix A.

Median values were not calculated when the sample size was equal to 2. Data was represented as the median if sample size was equal to 1.

µS/cm = micro Seimens per centimetre; NTU = nephelometric turbidity unit; mg $CaCO_3$/L = milligram carbonate per litre; ug/L = microgram per litre.

Patch Lake concentrations, whereas the spring concentrations were substantially lower. With the exception of the elevated summer ammonia concentration (Table 3.15), median nutrient concentrations generally were as low as in the lake.

Median metal concentrations generally were below the CWQG. The exceptions were total aluminum summer (Table 3.15). Maximum spring concentrations of total aluminum, copper, iron and selenium were above CWQG.

3.3.5 Windy Outflow

In spring and summer 1996, Windy Outflow temperatures were 13.4 and 8.5°C, respectively anddissolved oxygen concentrations were 9.12 and 11.24 mg/L, respectively. Median pH value was 7.61in summerwhile spring values ranged from 7.09 to 7.20 (Table 3.11).

The median turbidity level was 4.5 NTU, whereas the median TSS concentration was 2.0 mg/L in summer (Table 3.16). Turbidity levels and TSS concentrations ranged from 1.1 to 2.6 NTU and <1 to 2 mg/L, respectively (n=2). The spring and summer turbidity levels exceeded the CDWG.

In summer, the median total hardness was 62 mg/L, median TDS was 206 mg/L and median chloride, sodium and potassium concentrations were 93 mg/L, 51 mg/L and 3.9 mg/L, respectively (Table 3.16). Spring hardenss levels ranged from 12 to 18 mg/L and TDS concentrations were between 34 and 61 mg/L. Chloride, sodium and potassium concentrations ranged from 12 to 21 mg/L, 7 to 14 mg/L and 0.8 to 1.1 mg/L, respectively. The summer concentrations were similar to corresponding concentrations in Windy Lake, whereas the spring concentrations were significantly lower. With the exception of elevated ammonia levels during summer (Table 3.16), nutrient levels in Windy Outflow were consistent with Windy Lake levels.

Median metal concentrations generally were below the CWQG. The exceptionwas the summer value for total chromium and the minimum spring value for total cadmium (Table 3.16).

3.3.6 Little Roberts Outflow

Little Roberts Outflow temperatures in 1996 were 5.6 and 5.9°C, and dissolved oxygen concentrations were 12.18 and 12.09 mg/L in spring and summer, respectively (Table 3.11). Median pH values were 7.16 in spring and 7.20 in summer. These parameters were all compliant with the CWQG.

Table 3.15 Baseline water quality in Patch Outflow, 1996 and 1997[a]

	Parameter (units)[c]	Spring (June)				Summer (July to August)				Water Quality Guidelines [b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Physical Parameters	Conductivity (µS/cm)	-	153	165	2	262	245	263	4		
	Total Dissolved Solids(mg/L)	-	90	106	2	139	133	144	4	≤ 500 [d]	
	Hardness ($CaCO_3$) (mg/L)	-	24.0	25.3	2	41.7	36.0	44.9	4		
	pH (units)	-	6.73	7.30	2	7.49	7.08	7.70	4	6.5-8.5	6.5-9.0
	Total Suspended Solids (mg/L)	-	<1	6	2	4	2	20	4		Short-term increase <25; long term increase <5
	Turbidity (NTU)	**-**	**4.0**	**8.8**	2	**7.4**	**3.4**	**26.0**	4	1	Short-term increase <8; long term increase <2.
Conventional Parameters	Acidity ($CaCO_3$) (mg/L)	-	1.8	3.0	2	2	1	212	4		
	Alkalinity Total ($CaCO_3$) (mg/L)	20	-	-	1	-	31	33	2		
	Alkalinity to pH 4.5 (mg/L)	20	-	-	1	-	30	30	2		
	Bicarbonate Alkalinity (mg/L)	-	-	-	-	-	30	30	2		
	Carbonate Alkalinity (mg/L)	-	-	-	-	-	<1	<1	2		
Major Ions (dissolved)	Bromide (mg/L)	-	-	-	-	-	-	-	-		
	Chloride (mg/L)	-	31.5	32.1	2	56.6	53.4	65.1	4	≤ 250 [d]	230
	Silicate (mg/L)	-	-	-	-	-	-	-	-		
	Fluoride (mg/L)	-	0.05	0.05	2	0.07	0.06	0.10	4	1.5	
	Sulphate (mg/L)	-	1	3	2	2.0	2.0	2.1	4	≤ 500 [d]	
	Calcium (mg/L)	-	3.63	3.83	2	6.78	6.16	7.15	4		
	Potassium (mg/L)	-	1.58	1.58	2	2.27	2.19	2.88	4		
	Magnesium (mg/L)	-	3.68	3.82	2	5.82	5.10	6.02	4		
	Sodium (mg/L)	-	16.6	18.5	2	30.4	24.0	30.8	4	≤ 200 [d]	
Major Ions (total)	Calcium (mg/L)	-	3.87	3.93	2	6.79	6.21	7.21	4		
	Potassium (mg/L)	-	1.60	1.77	2	2.46	2.24	2.99	4		
	Magnesium (mg/L)	-	3.68	3.87	2	5.96	5.34	6.07	4		
	Sodium (mg/L)	-	16.7	20.0	2	30.3	25.2	30.8	4	≤ 200 [d]	
Nutrients	Ammonia Nitrogen (mg/L)	-	<0.005	0.02	2	0.252	<0.005	0.4804	4		8.9
	Dissolved Nitrate (mg/L)	-	0.001	<0.005	2	0.002	0.002	<0.005	4	10	
	Dissolved Nitrite (mg/L)	-	<0.001	0.006	2	0.001	<0.001	0.0046	4	0.97	0.06
	Nitrite/Nitrate (mg/L)	-	-	-	-	-	-	-	-		
	Dissolved Silicate (mg/L)	0.3	-	-	1	-	0.0047	0.0079	2		

Table 3.15 Baseline water quality in Patch Outflow, 1996 to 1997 (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to August)				Water Quality Guidelines [b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Nutrients (cont)	Dissolved Phosphate (mg/L)	-	0.004	0.008	2	<0.001	<0.001	0.008	4		
	Dissolved ortho-Phosphate (mg/L)	0.002	-	-	1	-	0.004	0.004	2		
	Total Phosphorus - ICP (mg/L)	<0.3	-	-	1	-	<0.3	<0.3	2		
	Dissolved Phosphorus - ICP (mg/L)	<0.3	-	-	1	-	<0.3	<0.3	2		
	Total Phosphorus (mg/L)	-	0.01	0.021	2	0.015	0.006	0.035	4		
	Total Phosphate (mg/L)	-	-	-	-	-	-	-	-		
	Total Organic Carbon (mg/L)	-	-	-	-	-	-	-	-		
Total Metals	Aluminum (µg/L)	**-**	58	**277**	2	**183**	**105**	**284**	5		100
	Antimony (µg/L)	-	<0.05	0.1	2	<0.1	<0.05	0.1	5	6	
	Arsenic (µg/L)	-	0.4	2.0	2	0.5	<0.1	6	5	25	5
	Barium (µg/L)	-	1.69	<10	2	<10	3.31	<10	5	1000	
	Beryllium (µg/L)	-	<0.5	<5	2	<5	<0.5	<5	5		
	Boron (µg/L)	-	14	<100	2	<100	17	<100	5	5000	
	Cadmium (µg/L)	-	<0.05	<0.2	2	<0.2	<0.05	<0.2	5	5	0.016
	Chromium (µg/L)	-	0.8	<1	2	-	<1	<1	2	50	1
	Cobalt (µg/L)	-	<0.1	<1	2	<1	<0.1	<1	5		
	Copper (µg/L)	-	1.4	**2.0**	2	1.0	1.0	1.2	5	≤ 1000 [d]	2
	Iron (µg/L)	-	70	**480**	2	180	100	270	5	≤ 300 [d]	300
	Lead (µg/L)	-	0.08	<1	2	<1	0.13	<1	5	10	1
	Manganese (µg/L)	-	3.19	19.00	2	8.00	3.73	11.00	5	≤ 50 [d]	
	Mercury (µg/L)	-	-	-	-	<0.05	-	-	1	1	0.1
	Molybdenum (µg/L)	-	0.1	<1	2	<1	0.12	<1	5		73
	Nickel (µg/L)	-	0.3	1.0	2	<1	0.6	<1	5		25
	Selenium (µg/L)	**-**	<0.5	**2.2**	2	<0.5	<0.5	<0.5	5	10	1
	Silicon (µg/L)	-	260	1390	2	610	520	700	5		
	Silver (µg/L)	-	<0.01	<0.1	2	<0.1	0.04	<0.1	5		0.1
	Strontium (µg/L)	-	18.1	21.0	2	42.0	34.2	45.0	5		
	Thallium (µg/L)	-	<0.05	<100	2	<100	<0.05	<100	5		0.8
	Tin (µg/L)	-	<0.1	<30	2	<30	<0.1	<30	5		
	Titanium (µg/L)	-	1	<10	2	<10	<10	12	5		
	Uranium (µg/L)	0.03	-	-	1	0.01	<0.01	0.02	3	20	

Table 3.15 Baseline water quality in Patch Outflow, 1996 to 1997 (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to August)				Water Quality Guidelines [b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Total Metals (cont)	Vanadium (µg/L)	-	<1	<30	2	<30	<1	<30	5		
	Zinc (µg/L)	-	1	<5	2	<5	<1	<5	5	≤ 5000 [d]	30
Dissolved Metals	Aluminum (µg/L)	-	11	85	2	44	22	53	4		
	Antimony (µg/L)	-	<0.05	<0.1	2	<0.1	<0.05	<0.1	4		
	Arsenic (µg/L)	-	<0.1	<1	2	<0.5	<0.1	<1	4		
	Barium (µg/L)	-	1.38	<10	2	<10	1.76	<10	4		
	Beryllium (µg/L)	-	<0.5	<5	2	<5	<0.5	<5	4		
	Boron (µg/L)	-	14	<100	2	<100	15	<100	4		
	Cadmium (µg/L)	-	<0.05	<0.2	2	<0.2	<0.05	<0.2	4		
	Chromium (µg/L)	-	0.5	<1	2	-	<1	<1	2		
	Cobalt (µg/L)	-	<0.1	<1	2	<1	<0.1	<1	4		
	Copper (µg/L)	-	0.8	1	2	1	0.6	1	4		
	Iron (µg/L)	-	20	200	2	<10	<1	<30	4		
	Lead (µg/L)	-	<0.05	<1	2	<1	<0.05	<1	4		
	Lithium (µg/L)	-	2	<10	2	-	<10	<10	2		
	Manganese (µg/L)	-	0.78	<5	2	<5	<0.05	<5	4		
	Mercury (µg/L)	<0.01	-	-	1	<0.05	-	-	1		
	Molybdenum (µg/L)	-	0.05	<1	2	<1	0.09	<1	4		
	Nickel (µg/L)	-	0.3	<1	2	<1	0.3	<1	4		
	Selenium (µg/L)	-	<0.5	1.2	2	<0.5	<0.5	<0.5	4		
	Silicon (µg/L)	-	170	980	2	290	260	350	4		
	Silver (µg/L)	-	<0.01	<0.1	2	<0.1	<0.01	<0.1	4		
	Strontium (µg/L)	-	18.1	19.0	2	42.0	31.7	45.0	4		

Table 3.15 Baseline water quality in Patch Outflow, 1996 to 1997 (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to August)				Water Quality Guidelines [b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Dissolved Metals (cont)	Thallium (µg/L)	-	<0.05	<100	2	<100	<0.05	<100	4		
	Tin (µg/L)	-	<0.1	<30	2	<30	<0.1	<30	4		
	Titanium (µg/L)	-	<1	<10	2	<10	<1	<10	4		
	Uranium (µg/L)	<0.01	-	-	1	-	<0.01	<0.01	2		
	Vanadium (µg/L)	-	0.2	<30	2	<30	0.1	<30	4		
	Zinc (µg/L)	-	1	<5	2	<5	<1	<5	4		

[a] Values in bold are equal to or greater than guidelines.

[b] All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from the U.S. EPA (1999). Tabled hardness and pH dependent guidelines were determined using median baseline water quality values (analytical results) from all lakes. Similarly, a temperature of 6.0 °C was used to calculate the ammonia guideline. Individual water quality values shown in this table were assessed against guidelines using median hardness and or pH for the period indicated. Average lake temperatures for ice cover (1.2 °C) and open water (10.3 °C) periods were used to assess ammonia concentrations.

[c] The parameters analyzed vary between sampling events. Refer to Appendix A for detailed results.

[d] Aesthetic objective.

Notes:

<= less than analytical detection limit.

Statistics (i.e. minimum, median and maximum) were calculated using method outlined in Appendix A.

Median values were not calculated when the sample size was equal to 2. Data was represented as the median if sample size was equal to 1.

µS/cm = micro Seimens per centimetre; NTU = nephelometric turbidity unit; mg $CaCO_3$/L = milligram carbonate per litre; ug/L = microgram per litre.

Table 3.16 Baseline water quality in Windy Outflow, 1996 and 1997[(a)]

	Parameter (units)[(c)]	Spring (June)				Summer (July to August)				Water Quality Guidelines[(b)]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Physical Parameters	Conductivity (µS/cm)	-	70	116	2	410	404	423	5		
	Total Dissolved Solids(mg/L)	-	34	61	2	206	193	211	5	≤ 500 [(d)]	
	Hardness ($CaCO_3$) (mg/L)	-	12.4	18.0	2	62.4	57.0	67.7	5		
	pH (units)	-	7.09	7.20	2	7.61	7.26	7.80	5	6.5-8.5	6.5-9.0
	Total Suspended Solids (mg/L)	-	<1	2	2	2	<1	28	5		Short-term increase <25; long term increase <5
	Turbidity (NTU)	**-**	**1.1**	**2.6**	2	**4.5**	**1.2**	**24.8**	5	1	Short-term increase <8; long term increase <2.
Conventional Parameters	Acidity ($CaCO_3$) (mg/L)	-	2.0	2.2	2	2	<1	3	5		
	Alkalinity Total ($CaCO_3$) (mg/L)	10	-	-	1	49	48	49	4		
	Alkalinity to pH 4.5 (mg/L)	15	-	-	1	44	-	-	1		
	Bicarbonate Alkalinity (mg/L)	-	-	-	-	44	-	-	1		
	Carbonate Alkalinity (mg/L)	-	-	-	-	<1	-	-	1		
Major Ions (dissolved)	Bromide (mg/L)	-	-	-	-	-	-	-	-		
	Chloride (mg/L)	-	12.2	21.2	2	92.7	89.0	102.0	5	≤ 250 [(d)]	230
	Silicate (mg/L)	-	-	-	-	-	-	-	-		
	Fluoride (mg/L)	-	0.03	0.04	2	0.08	0.07	0.13	5	1.5	
	Sulphate (mg/L)	-	2	2	2	7.0	6.0	11.2	5	≤ 500 [(d)]	
	Calcium (mg/L)	-	2.38	3.33	2	10.28	9.85	10.70	5		
	Potassium (mg/L)	-	0.72	1.13	2	3.60	3.48	4.61	5		
	Magnesium (mg/L)	-	1.57	2.31	2	8.42	7.61	9.22	5		
	Sodium (mg/L)	-	6.64	13.00	2	50.55	43.70	55.10	5	≤ 200 [(d)]	
Major Ions (total)	Calcium (mg/L)	-	2.47	3.34	2	10.70	10.20	10.90	5		
	Potassium (mg/L)	-	0.75	1.14	2	3.89	3.67	4.59	5		
	Magnesium (mg/L)	-	1.66	2.34	2	8.90	8.14	9.26	5		
	Sodium (mg/L)	-	6.81	14.10	2	51.50	46.80	54.90	5	≤ 200 [(d)]	
Nutrients	Ammonia Nitrogen (mg/L)	-	<0.005	0.017	2	0.203	<0.005	0.2971	5		8.9
	Dissolved Nitrate (mg/L)	-	0.002	<0.005	2	0.005	0.0026	0.0052	5	10	
	Dissolved Nitrite (mg/L)	-	<0.001	0.006	2	0.003	<0.001	0.0328	5	0.97	0.06
	Nitrite/Nitrate (mg/L)	-	-	-	-	-	-	-	-		
	Dissolved Silicate (mg/L)	0.052	-	-	1	0.005	0.0032	0.009	4		

Table 3.16 Baseline water quality in Windy Outflow, 1996 to 1997 (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Nutrients (cont)	Dissolved Phosphate (mg/L)	-	0.004	0.004	2	<0.001	<0.001	0.006	5		
	Dissolved ortho-Phosphate (mg/L)	0.002	-	-	1	0.002	-	-	1		
	Total Phosphorus - ICP (mg/L)	<0.3	-	-	1	<0.3	<0.3	<0.3	4		
	Dissolved Phosphorus - ICP (mg/L)	<0.3	-	-	1	<0.3	<0.3	<0.3	4		
	Total Phosphorus (mg/L)	-	0.004	0.008	2	0.006	0.005	0.041	5		
	Total Phosphate (mg/L)	-	-	-	-	-	-	-	-		
	Total Organic Carbon (mg/L)	-	-	-	-	-	-	-	-		
Total Metals	Aluminum (µg/L)	-	24	**115**	2	76	42	**797**	5		100
	Antimony (µg/L)	-	<0.1	0.11	2	<0.1	0.08	<0.1	5	6	
	Arsenic (µg/L)	-	0.1	<1	2	0.7	0.2	<1	5	25	5
	Barium (µg/L)	-	1.24	<10	2	10.00	2.37	10.00	5	1000	
	Beryllium (µg/L)	-	<0.5	<5	2	<5	<0.5	<5	5		
	Boron (µg/L)	-	13	<100	2	<100	26	<100	5	5000	
	Cadmium (µg/L)	**-**	**0.15**	<0.2	2	<0.2	<0.2	<0.5	5	5	0.016
	Chromium (µg/L)	-	0.6	<1	2	**1**	<1	**1.5**	4	50	1
	Cobalt (µg/L)	-	<0.1	<1	2	<1	<0.1	<1	5		
	Copper (µg/L)	-	<1	1	2	1.3	<1	**2.0**	5	≤ 1000 [d]	2
	Iron (µg/L)	-	30	120	2	80	60	**810**	5	≤ 300 [d]	300
	Lead (µg/L)	-	0.12	<1	2	<1	0.11	<1	5	10	1
	Manganese (µg/L)	-	0.96	<5	2	5.00	2.33	9.50	5	≤ 50 [d]	
	Mercury (µg/L)	-	-	-	-	-	<0.05	<0.05	2	1	0.1
	Molybdenum (µg/L)	-	0.16	<1	2	<1	0.55	<1	5		73
	Nickel (µg/L)	-	0.2	<1	2	1.0	<1	1.4	5		25
	Selenium (µg/L)	-	<0.5	**1.2**	2	<0.5	<0.5	**2.6**	5	10	1
	Silicon (µg/L)	-	250	540	2	670	315	2100	5		
	Silver (µg/L)	-	<0.01	<0.1	2	<0.1	0.01	<0.1	5		0.1
	Strontium (µg/L)	-	12.0	15.6	2	58.0	56.0	59.5	5		
	Thallium (µg/L)	-	<0.05	<100	2	<100	<0.05	<100	5		0.8
	Tin (µg/L)	-	<0.1	<30	2	<30	<0.1	<30	5		

Table 3.16 Baseline water quality in Windy Outflow, 1996 to 1997 (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Total Metals (cont)	Titanium (µg/L)	-	<1	<10	2	10	4	50	5		
	Uranium (µg/L)	<0.01	-	-	1	0.16	-	-	1	20	
	Vanadium (µg/L)	-	<1	<30	2	<30	<1	<30	5		
	Zinc (µg/L)	-	1	<5	2	<5	<1	<5	5	≤ 5000 [d]	30
Dissolved Metals	Aluminum (µg/L)	-	10	36	2	36	7	51	5		
	Antimony (µg/L)	-	<0.05	<0.1	2	<0.1	0.08	<0.1	5		
	Arsenic (µg/L)	-	0.1	<1	2	<0.7	<0.1	<1	5		
	Barium (µg/L)	-	0.83	<10	2	<10	2.05	<10	5		
	Beryllium (µg/L)	-	<0.5	<5	2	<5	<0.5	<5	5		
	Boron (µg/L)	-	13	<100	2	<100	26	<100	5		
	Cadmium (µg/L)	-	<0.05	<0.2	2	<0.2	<0.05	<0.2	5		
	Chromium (µg/L)	-	0.3	<1	2	<1	<1	<1	4		
	Cobalt (µg/L)	-	<0.1	<1	2	<1	<0.1	<1	5		
	Copper (µg/L)	-	0.6	<1	2	1	<1	1	5		
	Iron (µg/L)	-	10	40	2	25	20	<30	5		
	Lead (µg/L)	-	<0.05	<1	2	<1	<0.05	<1	5		
	Lithium (µg/L)	-	<1	<10	2	<10	<10	<10	4		
	Manganese (µg/L)	-	<0.05	<5	2	<5	0.15	<5	5		
	Mercury (µg/L)	<0.01	-	-	1	-	<0.05	<0.05	2		
	Molybdenum (µg/L)	-	0.12	<1	2	<1	0.55	<1	5		
	Nickel (µg/L)	-	<0.1	<1	2	<1	0.3	<1	5		
	Selenium (µg/L)	-	<0.5	0.5	2	<0.5	<0.5	<0.5	5		
	Silicon (µg/L)	-	200	350	2	375	220	620	5		
	Silver (µg/L)	-	<0.01	<0.1	2	<0.1	<0.01	<0.1	5		
	Strontium (µg/L)	-	11.0	16.1	2	56.5	54.0	59.0	5		

Table 3.16 Baseline water quality in Windy Outflow, 1996 to 1997 (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Dissolved Metals (cont)	Thallium (µg/L)	-	<0.05	<100	2	<100	<0.05	<100	5		
	Tin (µg/L)	-	<0.1	<30	2	<30	<0.1	<30	5		
	Titanium (µg/L)	-	<1	<10	2	<10	<1	<10	5		
	Uranium (µg/L)	<0.01	-	-	1	0.01	-	-	1		
	Vanadium (µg/L)	-	0.2	<30	2	<30	<0.1	<30	5		
	Zinc (µg/L)	-	1	<5	2	<5	<1	<5	5		

[a] Values in bold are equal to or greater than guidelines.

[b] All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from the U.S. EPA (1999). Tabled hardness and pH dependent guidelines were determined using median baseline water quality values (analytical results) from all lakes. Similarly, a temperature of 6.0 °C was used to calculate the ammonia guideline. Individual water quality values shown in this table were assessed against guidelines using median hardness and or pH for the period indicated. Average lake temperatures for ice cover (1.2 °C) and open water (10.3 °C) periods were used to assess ammonia concentrations.

[c] The parameters analyzed vary between sampling events. Refer to Appendix A for detailed results.

[d] Aesthetic objective.

Notes:

<= less than analytical detection limit.

Statistics (i.e. minimum, median and maximum) were calculated using method outlined in Appendix A.

Median values were not calculated when the sample size was equal to 2. Data was represented as the median if sample size was equal to 1.

µS/cm = micro Seimens per centimetre; NTU = nephelometric turbidity unit; mg $CaCO_3$/L = milligram carbonate per litre; ug/L = microgram per litre.

Median turbidity levels were 12 and 4.6 NTU, whereas median TSS concentrations were 8 and 4 mg/L in spring and summer, respectively (Table 3.17). The turbidity levels exceeded the CDWG.

Median total hardness was 29 and 36 mg/L, median TDS concentrations were 104 and 120 mg/L, median chloride concentrations were 40 and 47 mg/L, median potassium concentrations were 1.9 and 2.3 mg/L and median sodium concentrations were 21 and 26 mg/L in spring and summer, respectively (Table 3.17). The summer concentrations for these parameters generally were similar to the concentrations in Little Roberts Lake; however, the spring outflow concentrations were lower than in the lake. Outflow nutrient concentrations were essentially similar to the lake, except for elevated summer ammonia-nitrogen (Table 3.17).

Median metal concentrations generally were below the CWQG. The exceptions were spring values for total chromium, iron and selenium and spring/summer values for total aluminum (Table 3.17).

3.3.7 Pelvic Outflow

Pelvic Outflow field parameters were not measured in 1996. Summary data for 1997 to 2000 indicated that spring and summer median turbidity levels were 5.1 and 7.7 NTU, whereas median TSS concentrations were 4 and 3 mg/L, respectively (Table 3.18). The turbidity levels exceeded the CDWG.

Median pH levels were 6.8 and 7.1 in spring and summer, respectively; they were similar to the corresponding values from Pelvic Lake. In spring and summer, median total hardness levels were 18 and 31 mg/L, median TDS concentrations 63 and 110 mg/L, median chloride concentrations were 24 and 46 mg/L, median sodium concentrations were 13 and 26 mg/L, and median potassium concentrations were 1.8 and 2.2 mg/L, respectively (Table 3.18). The summer concentrations generally were similar to concentrations in Pelvic Lake, although the spring concentrations were lower than lake concentrations. Outflow nutrient concentrations were similar to the lake, except for the median summer ammonia-nitrogen level, which was elevated.

Median metal concentrations in Pelvic Outflow were generally below the CWQG. The exceptions were summer values for total copper and spring/summer values for total aluminum (Table 3.18).

Table 3.17 Baseline water quality in Little Roberts Outflow, 1996 and 1997[a]

	Parameter (units)[c]	Spring (June)				Summer (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Physical Parameters	Conductivity (µS/cm)	186	142	230	3	225	183	286	4		
	Total Dissolved Solids(mg/L)	104	82	127	3	120	108	189	4	≤ 500 [d]	
	Hardness ($CaCO_3$) (mg/L)	29.0	21.0	37.6	3	35.5	29.7	53.0	4		
	pH (units)	7.16	7.08	7.20	3	7.20	6.99	7.40	4	6.5-8.5	6.5-9.0
	Total Suspended Solids (mg/L)	8	4	12	3	4	3	18	4		Short-term increase <25; long term increase <5
	Turbidity (NTU)	**11.9**	**10.8**	**13.0**	3	**4.6**	**4.1**	**18.0**	4	1	Short-term increase <8; long term increase <2.
Conventional Parameters	Acidity ($CaCO_3$) (mg/L)	2.4	1.8	3.0	3	2	2	3	4		
	Alkalinity Total ($CaCO_3$) (mg/L)	-	25	25	2	21	21	21	3		
	Alkalinity to pH 4.5 (mg/L)	16	-	-	1	24	-	-	1		
	Bicarbonate Alkalinity (mg/L)	-	-	-	-	24	-	-	1		
	Carbonate Alkalinity (mg/L)	-	-	-	-	<1	-	-	1		
Major Ions (dissolved)	Bromide (mg/L)	-	-	-	-	-	-	-	-		
	Chloride (mg/L)	40.4	29.0	52.0	3	47	44	74	4	≤ 250 [d]	230
	Silicate (mg/L)	-	-	-	-	-	-	-	-		
	Fluoride (mg/L)	0.06	0.05	0.06	3	0.06	0.05	0.09	4	1.5	
	Sulphate (mg/L)	2	1	4	3	3	2	8	4	≤ 500 [d]	
	Calcium (mg/L)	4.70	3.39	6.19	3	5.45	5.10	11.60	4		
	Potassium (mg/L)	1.76	1.42	2.13	3	1.92	1.47	2.37	4		
	Magnesium (mg/L)	4.20	3.08	5.39	3	4.65	4.11	5.84	4		
	Sodium (mg/L)	20.6	15.6	26.1	3	21.0	14.1	26.9	4	≤ 200 [d]	
Major Ions (total)	Calcium (mg/L)	4.70	3.39	6.20	3	5.75	5.16	12.10	4		
	Potassium (mg/L)	1.88	1.58	2.20	3	2.25	1.83	2.44	4		
	Magnesium (mg/L)	4.38	3.38	5.46	3	5.12	4.70	5.94	4		
	Sodium (mg/L)	20.9	16.2	26.1	3	26.4	24.5	26.8	4	≤ 200 [d]	
Nutrients	Ammonia Nitrogen (mg/L)	0.014	<0.005	0.027	3	0.700	<0.005	0.990	4		8.9
	Dissolved Nitrate (mg/L)	0.003	0.001	<0.005	3	0.003	0.0023	0.026	4	10	
	Dissolved Nitrite (mg/L)	0.003	<0.001	0.006	3	0.0012	<0.001	0.0046	4	0.97	0.06
	Nitrite/Nitrate (mg/L)	-	-	-	-	-	-	-	-		

Table 3.17 Baseline water quality in Little Roberts Outflow, 1996 to 1997 (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Nutrients (cont)	Dissolved Silicate (mg/L)	-	0.506	0.692	2	0.008	0.0042	0.0153	3		
	Dissolved Phosphate (mg/L)	0.007	0.006	0.008	3	<0.001	<0.001	0.006	4		
	Dissolved ortho-Phosphate (mg/L)	<0.002	-	-	1	<0.002	-	-	1		
	Total Phosphorus - ICP (mg/L)	-	<0.3	<0.3	2	<0.3	<0.3	<0.3	3		
	Dissloved Phosphorus - ICP (mg/L)	-	<0.3	<0.3	2	<0.3	<0.3	<0.3	3		
	Total Phosphorus (mg/L)	0.025	0.023	0.026	3	0.02	0.015	0.02	4		
	Total Phosphate (mg/L)	-	-	-	-	-	-	-	-		
	Total Organic Carbon (mg/L)	-	-	-	-	-	-	-	-		
Total Metals	Aluminum (µg/L)	**311**	**211**	**398**	3	**134**	65	**245**	4		100
	Antimony (µg/L)	0.08	<0.05	0.1	3	<0.1	<0.05	<0.1	4	6	
	Arsenic (µg/L)	0.7	0.4	<1	3	0.5	<0.1	4	4	25	5
	Barium (µg/L)	7.84	5.68	<10	3	<10	6.84	<10	4	1000	
	Beryllium (µg/L)	<2.5	<0.05	<5	3	<5	<0.05	<5	4		
	Boron (µg/L)	57	14	<100	3	<100	14	<100	4	5000	
	Cadmium (µg/L)	<0.13	<0.05	<0.2	3	<0.2	<0.05	<0.2	4	5	0.016
	Chromium (µg/L)	**1.4**	<1	**1.8**	3	<1	<1	<1	3	50	1
	Cobalt (µg/L)	0.6	0.1	<1	3	<1	<0.1	<1	4		
	Copper (µg/L)	**2.0**	1.9	**2.0**	3	**2.0**	1.0	**2.3**	4	≤ 1000 [d]	2
	Iron (µg/L)	**418**	**390**	**430**	3	190	140	290	4	≤ 300 [d]	300
	Lead (µg/L)	0.66	0.32	<1	3	<1	0.08	<1	4	10	1
	Manganese (µg/L)	18.3	8.5	29.0	3	8.5	8.0	10.0	4	≤ 50 [d]	
	Mercury (µg/L)	-	-	-	-	-	<0.05	<0.05	2	1	0.1
	Molybdenum (µg/L)	0.57	0.14	<1	3	<1	0.24	<1	4		73
	Nickel (µg/L)	1.0	0.9	<1	3	<1	<1	1.5	4		25
	Selenium (µg/L)	**1.1**	<0.5	**1.7**	3	<0.5	<0.5	<0.5	4	10	1
	Silicon (µg/L)	1550	1490	1650	3	1030	650	2210	4		
	Silver (µg/L)	<0.06	<0.01	<0.1	3	<0.1	0.07	<0.1	4		0.1
	Strontium (µg/L)	29.3	23.1	36.0	3	43	35	108	4		
	Thallium (µg/L)	<50	<0.05	<100	3	<100	<0.05	<100	4		0.8
	Tin (µg/L)	<15	<0.1	<30	3	<30	<0.1	<30	4		
	Titanium (µg/L)	12	<10	13	3	<10	<10	10	4		

Table 3.17 Baseline water quality in Little Roberts Outflow, 1996 to 1997 (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Total Metals (cont)	Uranium (µg/L)	0.05	-	-	1	0.01	-	-	1	20	
	Vanadium (µg/L)	<16	<1	<30	3	<30	<1	<30	4		
	Zinc (µg/L)	4	2	<5	3	<5	4	<5	4	≤ 5000 [d]	30
Dissolved Metals	Aluminum (µg/L)	40	39	42	3	36	15	136	4		
	Antimony (µg/L)	<0.08	<0.05	<0.1	3	<0.1	<0.05	<0.1	4		
	Arsenic (µg/L)	0.6	0.2	<1	3	<0.4	<0.1	<1	4		
	Barium (µg/L)	6.07	2.14	<10	3	<10	5.06	<10	4		
	Beryllium (µg/L)	<2.8	<0.5	<5	3	<5	<0.5	<5	4		
	Boron (µg/L)	57	13	<100	3	<100	12	<100	4		
	Cadmium (µg/L)	<0.13	<0.05	<0.2	3	<0.2	<0.05	<0.2	4		
	Chromium (µg/L)	0.7	0.4	<1	3	<1	<1	<1	3		
	Cobalt (µg/L)	<0.6	<0.1	<1	3	<1	<0.1	<1	4		
	Copper (µg/L)	1.6	1.2	2.0	3	2.0	<1	2.3	4		
	Iron (µg/L)	83	50	120	3	60	30	100	4		
	Lead (µg/L)	<0.5	<0.05	<1	3	<1	<0.05	<1	4		
	Lithium (µg/L)	6	2	<10	3	<10	<10	<10	3		
	Manganese (µg/L)	3.04	1.08	<5	3	<5	0.53	<5	4		
	Mercury (µg/L)	-	<0.01	<0.01	2	-	<0.05	<0.05	2		
	Molybdenum (µg/L)	0.54	0.07	<1	3	<1	0.21	<1	4		
	Nickel (µg/L)	0.7	0.4	<1	3	<1	<1	1.3	4		
	Selenium (µg/L)	0.8	<0.5	1	3	<0.5	<0.5	<0.5	4		
	Silicon (µg/L)	853	530	1190	3	770	510	1580	4		
	Silver (µg/L)	<0.06	<0.01	<0.1	3	<0.1	0.02	<0.1	4		
	Strontium (µg/L)	29	22	36	3	34.5	33.0	97.5	4		

Table 3.17 Baseline water quality in Little Roberts Outflow, 1996 to 1997 (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to August)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Dissolved Metals (cont)	Thallium (µg/L)	<50	<0.05	<100	3	<100	<0.05	<100	4		
	Tin (µg/L)	<15	<0.1	<30	3	<30	<0.1	<30	4		
	Titanium (µg/L)	<6	<1	<10	3	<10	<1	<10	4		
	Uranium (µg/L)	0.01	-	-	1	<0.01	-	-	1		
	Vanadium (µg/L)	15.1	0.2	<30	3	<30	<0.1	<30	4		
	Zinc (µg/L)	3	1	<5	3	<5	2	<5	4		

[a] Values in bold are equal to or greater than guidelines.

[b] All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from the U.S. EPA (1999). Tabled hardness and pH dependent guidelines were determined using median baseline water quality values (analytical results) from all lakes. Similarly, a temperature of 6.0 °C was used to calculate the ammonia guideline. Individual water quality values shown in this table were assessed against guidelines using median hardness and or pH for the period indicated. Average lake temperatures for ice cover (1.2 °C) and open water (10.3 °C) periods were used to assess ammonia concentrations.

[c] The parameters analyzed vary between sampling events. Refer to Appendix A for detailed results.

[d] Aesthetic objective.

Notes:

<= less than analytical detection limit.

Statistics (i.e. minimum, median and maximum) were calculated using method outlined in Appendix A.

Median values were not calculated when the sample size was equal to 2. Data was represented as the median if sample size was equal to 1.

µS/cm = micro Seimens per centimetre; NTU = nephelometric turbidity unit; mg $CaCO_3$/L = milligram carbonate per litre; ug/L = microgram per litre.

Table 3.18 Baseline water quality in Pelvic Outflow, 1997 to 2000[(a)]

	Parameter (units)[(c)]	Spring (June)				Summer (July to September)				Water Quality Guidelines[(b)]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Physical Parameters	Conductivity (µS/cm)	114	87	140	3	208	175	231	4		
	Total Dissolved Solids(mg/L)	63	51	74	3	110	100	139	4	≤ 500 [(d)]	
	Hardness ($CaCO_3$) (mg/L)	18.0	14.4	21.4	3	30.9	26.9	35.3	4		
	pH (units)	6.84	6.67	7.02	3	7.07	6.95	7.63	4	6.5-8.5	6.5-9.0
	Total Suspended Solids (mg/L)	4	<3	5	3	3	2	13	4		Short-term increase <25; long term increase <5
	Turbidity (NTU)	**5.05**	**4.80**	**5.50**	3	**7.7**	**5.7**	**15.9**	4	1	Short-term increase <8; long term increase <2.
Conventional Parameters	Acidity ($CaCO_3$) (mg/L)	3	2	3	3	2	<1	2	4		
	Alkalinity Total ($CaCO_3$) (mg/L)	11	7	15	3	17	16	18	4		
	Alkalinity to pH 4.5 (mg/L)	-	-	-	-	-	-	-	-		
	Bicarbonate Alkalinity (mg/L)	-	-	-	-	-	-	-	-		
	Carbonate Alkalinity (mg/L)	-	-	-	-	-	-	-	-		
Major Ions (dissolved)	Bromide (mg/L)	-	-	-	-	-	-	-	-		
	Chloride (mg/L)	24.1	18.5	29.5	3	45.7	38.8	53.4	4	≤ 250 [(d)]	230
	Silicate (mg/L)	-	-	-	-	-	-	-	-		
	Fluoride (mg/L)	0.04	0.04	0.04	3	0.08	0.05	0.09	4	1.5	
	Sulphate (mg/L)	3	2	3	3	3	3	4	4	≤ 500 [(d)]	
	Calcium (mg/L)	2.78	-	-	1	-	3.34	3.38	2		
	Potassium (mg/L)	1.37	-	-	1	-	1.50	2.12	2		
	Magnesium (mg/L)	3.40	-	-	1	-	4.28	4.50	2		
	Sodium (mg/L)	15.4	-	-	1	-	21.8	25.0	2	≤ 200 [(d)]	
Major Ions (total)	Calcium (mg/L)	2.35	1.89	2.79	3	3.58	3.51	4.44	4		
	Potassium (mg/L)	1.73	1.46	<2	3	2.19	1.59	3.40	4		
	Magnesium (mg/L)	2.91	2.40	3.41	3	4.83	4.44	5.90	4		
	Sodium (mg/L)	13.0	10.0	15.4	3	26.4	22.4	26.8	4	≤ 200 [(d)]	
Nutrients	Ammonia Nitrogen (mg/L)	0.083	0.017	0.15	3	0.598	0.007	1.1231	4		8.9
	Dissolved Nitrate (mg/L)	0.003	0.001	<0.005	3	0.005	0.0021	<0.005	4	10	
	Dissolved Nitrite (mg/L)	0.004	<0.001	0.006	3	0.001	<0.001	0.0012	4	0.97	0.06
	Nitrite/Nitrate (mg/L)	-	-	-	-	-	-	-	-		

Table 3.18 Baseline water quality in Pelvic Outflow, 1997 to 2000[(a)] (continued)

	Parameter (units)[(c)]	Spring (June)				Summer (July to September)				Water Quality Guidelines[(b)]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Nutrients (cont)	Dissolved Silicate (mg/L)	0.111	-	-	1	-	0.0031	0.008	2		
	Dissolved Phosphate (mg/L)	0.007	-	-	1	-	<0.001	<0.001	2		
	Dissolved ortho-Phosphate (mg/L)	-	0.005	0.012	2	-	<0.001	0.002	2		
	Total Phosphorus – ICP (mg/L)	<0.3	-	-	1	-	<0.3	<0.3	2		
	Dissolved Phosphorus - ICP (mg/L)	<0.3	-	-	1	-	<0.3	<0.3	2		
	Total Phosphorus (mg/L)	0.02	-	-	1	0.02	0.019	0.038	4		
	Total Phosphate (mg/L)	-	-	-	-	-	-	-	-		
	Total Organic Carbon (mg/L)	-	6.1	6.1	2	-	6.3	6.5	2		
Total Metals	Aluminum (µg/L)	**112**	99	**124**	3	**172**	92	**184**	4		100
	Antimony (µg/L)	<0.08	<0.05	<0.1	3	<0.1	<0.05	<0.1	4	6	
	Arsenic (µg/L)	0.3	0.2	0.3	3	0.5	0.2	0.5	4	25	5
	Barium (µg/L)	6.23	2.41	<10	3	<10	3.99	<10	4	1000	
	Beryllium (µg/L)	<2.8	<0.5	<5	3	<5	<0.5	<5	4		
	Boron (µg/L)	54	8	<100	3	<100	22	<100	4	5000	
	Cadmium (µg/L)	<0.13	<0.05	<0.2	3	<0.2	<0.05	<0.2	4	5	0.016
	Chromium (µg/L)	<0.8	<0.5	<1	3	<1	<0.5	<1	4	50	1
	Cobalt (µg/L)	0.6	0.2	<1	3	<1	<0.1	1	4		
	Copper (µg/L)	1.5	0.9	**2.0**	3	**2.0**	1.7	**2.0**	4	≤ 1000 [(d)]	2
	Iron (µg/L)	215	160	270	3	140	130	240	4	≤ 300 [(d)]	300
	Lead (µg/L)	0.6	0.1	<1	3	<1	0.15	<1	4	10	1
	Manganese (µg/L)	36.0	26.0	46.4	3	15.0	8.8	15.0	4	≤ 50 [(d)]	
	Mercury (µg/L)	-	<0.05	<0.05	2	<0.05	<0.05	<0.05	3	1	0.1
	Molybdenum (µg/L)	0.5	0.06	<1	3	<1	0.19	<1	4		73
	Nickel (µg/L)	0.8	0.6	<1	3	<1	0.3	<1	4		25
	Selenium (µg/L)	<0.8	<0.5	<1	3	<0.5	<0.5	<1	4	10	1
	Silicon (µg/L)	1060	-	-	1	-	790	1240	2		
	Silver (µg/L)	<0.06	<0.01	<0.1	3	<0.1	<0.01	<0.1	4		0.1
	Strontium (µg/L)	19	-	-	1	-	28	32	2		
	Thallium (µg/L)	<100	-	-	1	-	<100	<100	2		0.8
	Tin (µg/L)	<30	-	-	1	-	<30	<30	2		

Table 3.18 Baseline water quality in Pelvic Outflow, 1997 to 2000[a] (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to September)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Total Metals (cont)	Titanium (µg/L)	<10	-	-	1	-	<10	<10	2		
	Uranium (µg/L)	-	0.02	0.02	2	-	0.05	0.05	2	20	
	Vanadium (µg/L)	<16	<1	<30	3	<30	<1	<30	4		
	Zinc (µg/L)	<3	<1	<5	3	<5	<1	6	4	≤ 5000 [d]	30
Dissolved Metals	Aluminum (µg/L)	45	-	-	1	-	33	58	2		
	Antimony (µg/L)	<0.1	-	-	1	-	<0.1	<0.1	2		
	Arsenic (µg/L)	0.1	-	-	1	-	<0.1	0.5	2		
	Barium (µg/L)	<10	-	-	1	-	<10	<10	2		
	Beryllium (µg/L)	<5	-	-	1	-	<5	<5	2		
	Boron (µg/L)	<100	-	-	1	-	<100	<100	2		
	Cadmium (µg/L)	<0.2	-	-	1	-	<0.2	<0.2	2		
	Chromium (µg/L)	<1	-	-	1	-	<1	<1	2		
	Cobalt (µg/L)	<1	-	-	1	-	<1	<1	2		
	Copper (µg/L)	1	-	-	1	-	2	2	2		
	Iron (µg/L)	110	-	-	1	-	<30	80	2		
	Lead (µg/L)	<1	-	-	1	-	<1	<1	2		
	Lithium (µg/L)	<10	-	-	1		<10	<10	2		
	Manganese (µg/L)	11	-	-	1	-	<5	<5	2		
	Mercury (µg/L)	<0.01	-	-	1	<0.05	-	-	1		
	Molybdenum (µg/L)	<1	-	-	1	-	<1	<1	2		
	Nickel (µg/L)	<1	-	-	1	-	<1	<1	2		
	Selenium (µg/L)	<0.5	-	-	1	-	<0.5	<0.5	2		
	Silicon (µg/L)	880	-	-	1	-	650	950	2		
	Silver (µg/L)	<0.1	-	-	1	-	<0.1	<0.1	2		
	Strontium (µg/L)	19	-	-	1	-	25	29	2		

Table 3.18 Baseline water quality in Pelvic Outflow, 1997 to 2000[a] (continued)

	Parameter (units)[c]	Spring (June)				Summer (July to September)				Water Quality Guidelines[b]	
		Med	Min	Max	n	Med	Min	Max	n	Drinking Water	Aquatic Life
Dissolved Metals (cont)	Thallium (µg/L)	<100	-	-	1	-	<100	<100	2		
	Tin (µg/L)	<30	-	-	1	-	<30	<30	2		
	Titanium (µg/L)	<10	-	-	1	-	<10	<10	2		
	Uranium (µg/L)	-	-	-	-	-	-	-	-		
	Vanadium (µg/L)	<30	-	-	1	-	<30	<30	2		
	Zinc (µg/L)	<5	-	-	1	-	<5	6	2		

[a] Values in bold are equal to or greater than guidelines.

[b] All guidelines are from CCME (1999, with 2000 updates), with the exception of the aquatic life guideline for chloride, which is from the U.S. EPA (1999). Tabled hardness and pH dependent guidelines were determined using median baseline water quality values (analytical results) from all lakes. Similarly, a temperature of 6.0 °C was used to calculate the ammonia guideline. Individual water quality values shown in this table were assessed against guidelines using median hardness and or pH for the period indicated. Average lake temperatures for ice cover (1.2 °C) and open water (10.3 °C) periods were used to assess ammonia concentrations.

[c] The parameters analyzed vary between sampling events. Refer to Appendix A for detailed results.

[d] Aesthetic objective.

Notes:

<= less than analytical detection limit.

Statistics (i.e. minimum, median and maximum) were calculated using method outlined in Appendix A.

Median values were not calculated when the sample size was equal to 2. Data was represented as the median if sample size was equal to 1.

µS/cm = micro Seimens per centimetre; NTU = nephelometric turbidity unit; mg $CaCO_3$/L = milligram carbonate per litre; ug/L = microgram per litre.

3.3.8 Summary

In general, the water quality of the lake outflows reflected conditions in the source lakes. Most of the water quality parameters measured, including metals and nutrients, were within the recommended values of the CWQG.

3.4 MARINE WATER QUALITY

3.4.1 Roberts Bay

Seawater quality samples in Roberts Bay were collected at a total of five sites. Analytical results for individual samples are presented in Appendix A10. Table 3.19 presents summary statistics for the pooled dataset from all sites, along with the Canadian Water Quality Guidelines (CWQG) for the protection of aquatic marine life (CCME 1999).

Temperature and dissolved oxygen profiles measured at the various sites are presented in Figure 3.10. The summer profiles at the deeper-water stations (Stations 1 through 3) were characterized by a thermally structured upper water-column and a general increase in DO concentration with depth. The summer shallow-water profiles (Stations 4 and 5) indicated DO concentrations greater than 11 mg/L and temperatures near 9 °C.

The summer median turbidity and TSS levels were 1.0 NTU and 9 mg/L, respectively (Table 3.19).

Most median metal concentrations in Roberts Bay were below detection limits and below the CWQG. The exceptions were total cadmium and total chromium (Table 3.19).

The Roberts Bay baseline data indicated a thermally stratified, well-aerated water-column in summer with seawater quality typical of coastal marine environments.

Figure 3.10 Temperature and dissolved oxygen profiles in Roberts Bay, 1997.

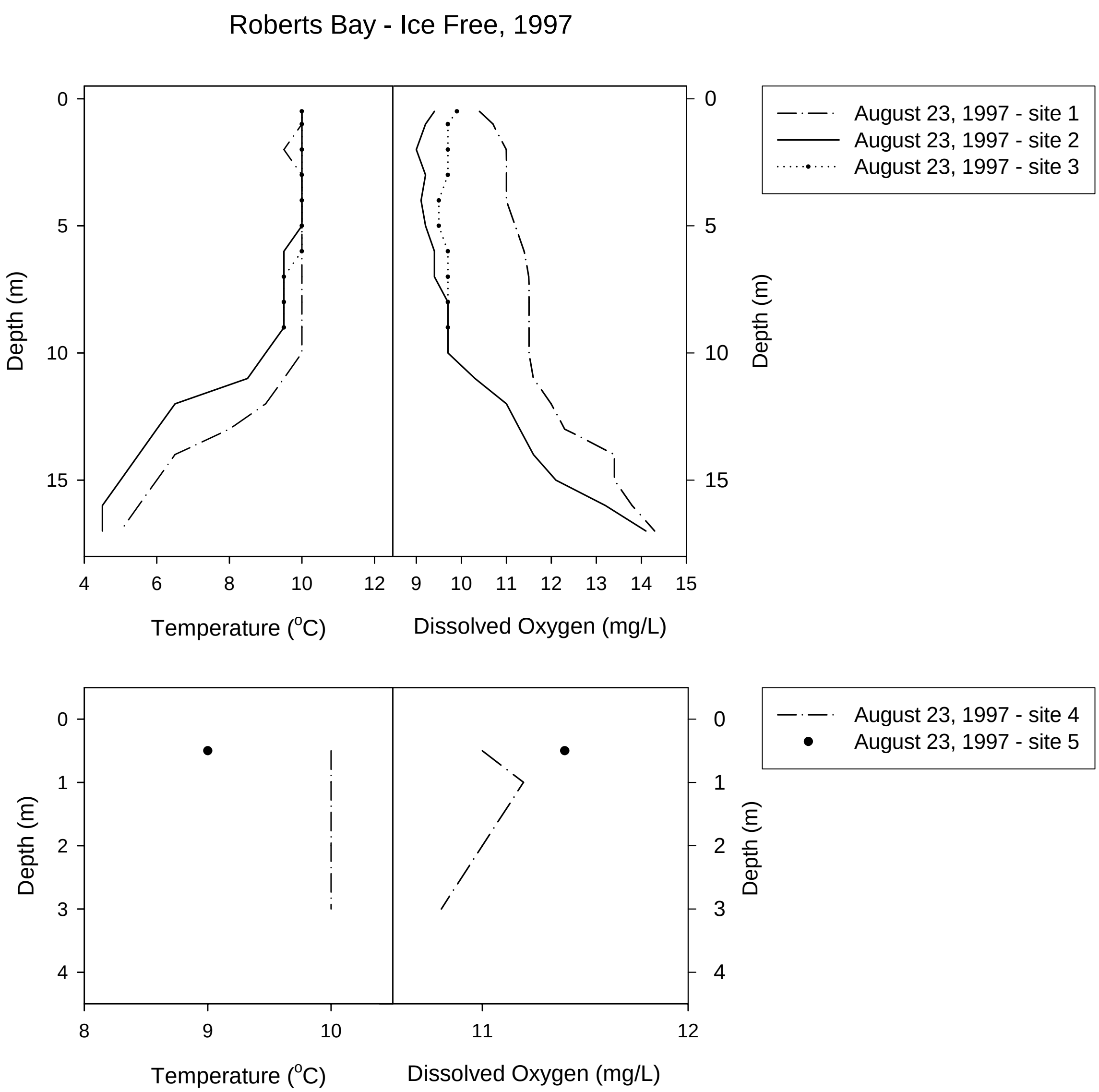


Table 3.19 Baseline water quality in Roberts Bay, 1996 to 1998[(a)].

	Parameter (units)[(b)]	Summer (July to August)				Water Quality Guidelines for Marine Aquatic Life[(c)]
		Med	Min	Max	n	
Physical Parameters	Conductivity (µS/cm)	31172	6610	49900	26	-
	Total Dissolved Solids(mg/L)	23550	3750	36134	26	-
	Hardness ($CaCO_3$) (mg/L)	4106	797	5240	25	-
	pH (units)	7.9	7.8	8.0	26	7.0-8.7 + Narrative
	Total Suspended Solids (mg/L)	9	<1	32	26	-
	Salinity (o/oo)	20	17	26	12	Comparative; > 10% increase
	Turbidity (NTU)	1.0	0.3	7.9	26	Short-term increase <8; long term increase <2.
Conven-tional Parameters	Acidity ($CaCO_3$) (mg/L)	9	2	14	26	-
	Alkalinity Total ($CaCO_3$) (mg/L)	93	43	113	20	-
	Alkalinity to pH 4.5 (mg/L)	86	84	86	6	-
	Bicarbonate Alkalinity (mg/L)	85	83	85	6	-
	Carbonate Alkalinity (mg/L)	1	1	1	6	-
Major Ions (dissolved)	Bromide (mg/L)	-	-	-	-	-
	Chloride (mg/L)	14600	2040	16000	25	-
	Silicate (mg/L)	-	-	-	-	-
	Fluoride (mg/L)	0.7	0.1	<20	26	-
	Sulphate (mg/L)	1570	193	1980	25	-
	Calcium (mg/L)	278	55	326	25	-
	Potassium (mg/L)	264	257	277	5	-
	Magnesium (mg/L)	827	160	1070	25	-
	Sodium (mg/L)	-	-	-	-	-
Major Ions (total)	Calcium (mg/L)	286	276	297	6	-
	Potassium (mg/L)	270	264	279	6	-
	Magnesium (mg/L)	860	826	883	6	-
	Sodium (mg/L)	-	-	-	-	-
Nutrients	Ammonia Nitrogen (mg/L)	1.260	0.002	<5	14	-
	Dissolved Nitrate (mg/L)	<2.5	<0.001	<5	13	-
	Dissolved Nitrite (mg/L)	<0.5	<0.001	<1	13	-
	Nitrite/Nitrate (mg/L)	-	-	-	-	-
	Dissolved Silicate (mg/L)	0.180	0.137	0.540	8	-
	Dissolved Phosphate (mg/L)	0.013	0.005	0.018	8	-
	Diss. ortho-Phosphate (mg/L)	0.019	0.017	0.025	5	-
	Total Phosphorus- ICP (mg/L)	-	-	-	-	-
	Diss. Phosphorus-CP(mg/L)	-	-	-	-	-
	Total Phosphorus (mg/L)	0.024	0.012	0.027	13	-
	Total Phosphate (mg/L)	-	-	-	-	-
	Total Organic Carbon (mg/L)	-	-	-	-	-

Table 3.19 Baseline water quality in Roberts Bay, 1996 to 1998 (continued)

	Parameter (units)[b]	Summer (July to August)				Water Quality Guidelines for Marine Aquatic Life[c]
		Med	Min	Max	n	
Total Metals	Aluminum (µg/L)	166	108	200	6	-
	Antimony (µg/L)	0.35	<0.05	0.85	6	-
	Arsenic (µg/L)	<5	<5	<5	6	12.5
	Barium (µg/L)	4.17	3.23	5.16	6	-
	Beryllium (µg/L)	<0.5	<0.5	<0.5	6	-
	Boron (µg/L)	3090	2790	3440	6	-
	Cadmium (µg/L)	**3.48**	**2.45**	**5.06**	6	0.12
	Chromium (µg/L)	**2.6**	**2.1**	**3.1**	6	1.5
	Cobalt (µg/L)	1.5	1.3	1.9	6	-
	Copper (µg/L)	11.5	9.1	15.5	6	-
	Iron (µg/L)	10	<10	170	6	-
	Lead (µg/L)	0.7	0.4	2.1	6	-
	Manganese (µg/L)	2.7	2.3	2.9	6	-
	Mercury (µg/L)	-	-	-	-	-
	Molybdenum (µg/L)	8.8	6.2	10.4	6	-
	Nickel (µg/L)	21.5	15.5	25.2	6	-
	Selenium (µg/L)	74.4	43.2	113.0	6	-
	Silicon (µg/L)	6920	6760	7530	6	-
	Silver (µg/L)	0.82	0.47	1.41	6	-
	Strontium (µg/L)	4985	4710	5260	6	-
	Thallium (µg/L)	0.27	0.13	0.65	6	-
	Tin (µg/L)	2.5	1.5	3.0	6	-
	Titanium (µg/L)	12	4	21	6	-
	Uranium (µg/L)	1.47	1.19	1.97	6	-
	Vanadium (µg/L)	<0.1	<0.1	<0.1	6	-
	Zinc (µg/L)	7	5	9	6	-
Dissolved Metals	Aluminum (µg/L)	81	20	174	5	-
	Antimony (µg/L)	0.21	<0.1	0.79	25	-
	Arsenic (µg/L)	0.75	0.1	<5	25	-
	Barium (µg/L)	3.24	3.14	4.33	5	-
	Beryllium (µg/L)	<0.5	<0.5	<0.5	5	-
	Boron (µg/L)	2840	2750	3050	5	-
	Cadmium (µg/L)	0.06	<0.02	4.88	25	-
	Chromium (µg/L)	<1	<1	3	25	-
	Cobalt (µg/L)	<0.05	<0.05	1.7	25	-
	Copper (µg/L)	0.8	0.4	13.8	25	-
	Iron (µg/L)	<10	<10	<10	25	-
	Lead (µg/L)	0.47	<0.05	5.03	25	-
	Lithium (µg/L)	-	-	-	-	-
	Manganese (µg/L)	1.19	0.42	2.55	25	-
	Mercury (µg/L)	<0.01	<0.01	0.02	20	-
	Molybdenum (µg/L)	7	2	10	25	-
	Nickel (µg/L)	0.6	0.5	16.4	25	-
	Selenium (µg/L)	<0.5	<0.5	56.0	25	-

Table 3.19 Baseline water quality in Roberts Bay, 1996 to 1998 (continued).

	Parameter (units)[b]	Summer (July to August)				Water Quality Guidelines for Marine Aquatic Life[c]
		Med	Min	Max	n	
Dissolved Metals (cont)	Silicon (µg/L)	6670	6560	6800	5	-
	Silver (µg/L)	<1	0.46	1.15	25	-
	Strontium (µg/L)	4720	4640	4840	5	-
	Thallium (µg/L)	0.26	0.08	0.44	5	-
	Tin (µg/L)	1.9	1.4	2.5	5	-
	Titanium (µg/L)	8	4	10	5	-
	Uranium (µg/L)	1.2	0.1	2.1	25	-
	Vanadium (µg/L)	<10	<10	<10	5	-
	Zinc (µg/L)	1.2	<0.5	7.0	25	-

[a] Values in bold are equal to or greater than guidelines.
[b] The parameters analyzed vary between sampling events. Refer to Appendix A for detailed results.
[c] All guidelines are from CCME (1999, with 2000 updates).

Notes:

< = less than analytical detection limit.

Statistics (i.e., minimum, median and maximum) were calculated using method outlined in Appendix A.

Median values were not calculated when the sample size was equal to 2. Data were represented as the median if sample size was equal to 1.

µS/cm = micro Seimens per centimetre; NTU = nephelometric turbidity unit; mg $CaCO_3$/L = milligram carbonate per litre; ug/L = microgram per litre.

4.0 SEDIMENT QUALITY

This section presents information on baseline sediment quality conditions for Doris Hinge lakes and Roberts Bay. The information presented is based on data from annual data reports (Rescan 1997, 1998).

Sediment quality data were collected in the summer months of 1996 and 1997. Due to small sample sizes, summary statistics were not calculated. The results are discussed in the following sections in terms of individual station data.

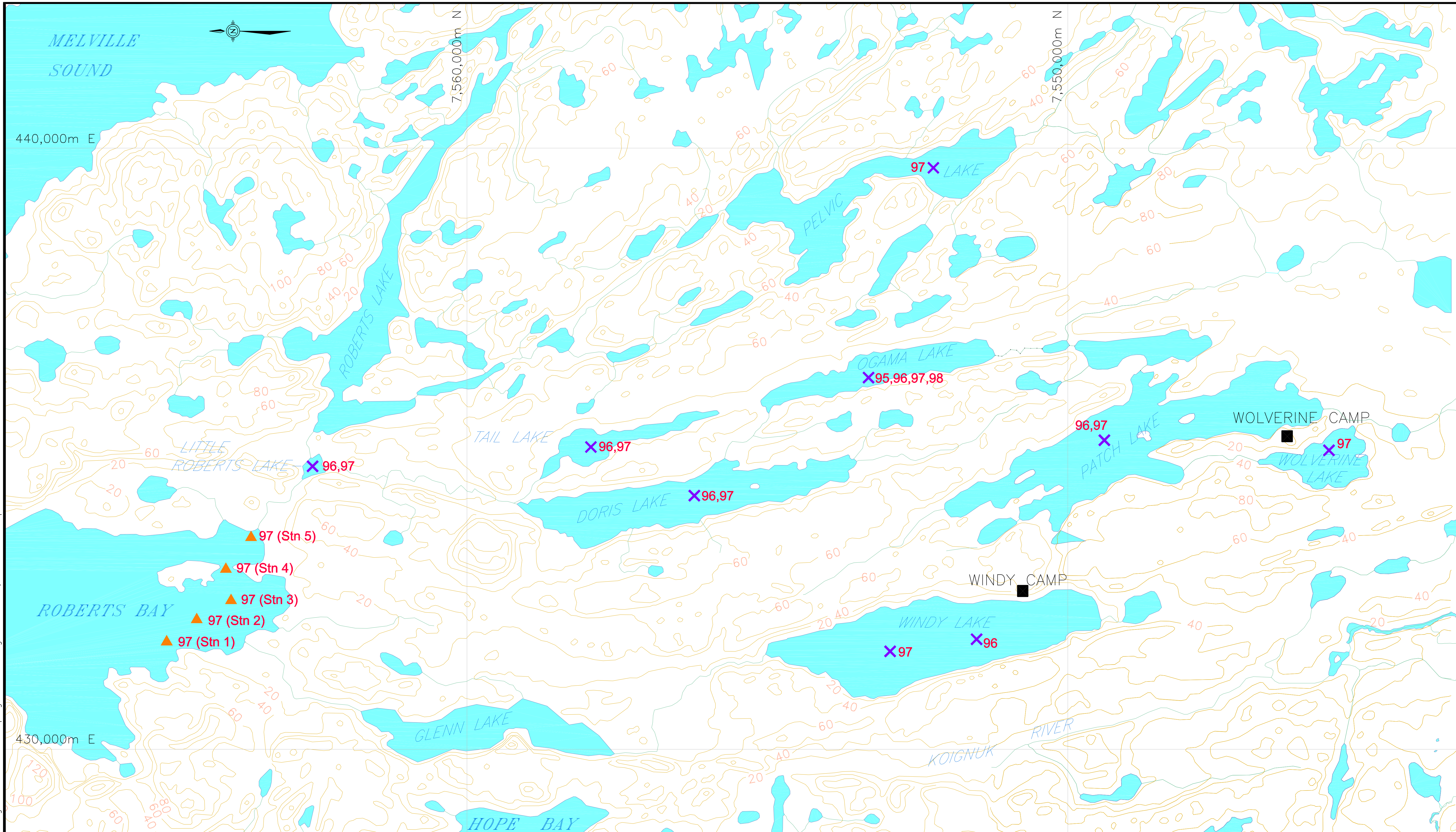
4.1 METHODS

4.1.1 Sampling Locations and Timing

Sediment sampling locations are shown in Figure 4.1 and Table 4.1. Detailed sampling methodologies are presented in various reports (Rescan 1997, 1998). These methodologies are summarized in Appendix A1.

Sediment samples were collected in the lakes during the summer sampling season (i.e., July and August). Bottom sediment samples were collected using an Ekman grab sampler from the deepest parts of the lakes at the same sites used for water quality sampling. Collected sediment grabs were sub-sampled (top 2 to 3 cm) for analysis of various physical and chemical parameters. In addition, sediment grabs were visually examined in the field for color, texture, grain size, presence/absence of biota, etc.

Baseline marine sediment quality sampling was conducted in Roberts Bay, which is the final receiving waterbody of drainage from the Doris Lake watershed. Samples were collected during the summer (August) at five marine stations within Roberts Bay. In general, methodologies used for the collection of marine samples were similar to those used for lake sampling (Appendix A1).



LEGEND

- × LAKE SAMPLING LOCATIONS
- ▲ MARINE SAMPLING LOCATIONS
- 95,96 etc. YEARS OF SAMPLING
- (Stn 1) STATION NAMES

REFERENCE
BASE MAP PROVIDED BY RESCAN, JANUARY 22, 2001

SCALE 1.5 0 1.5 KILOMETRES

NOTE : CONTOUR INTERVAL 20 m

Hope Bay Joint Venture

TITLE

SEDIMENT SAMPLING LOCATIONS IN DORIS HINGE AREA, 1996-1997

Golder Associates
Edmonton, Alberta

PROJECT	No. 022-7009.1000		FILE No.	Sediment Sampling
DESIGN	AH	11/06/02	SCALE AS SHOWN	REV. 0
CADD	RFM	24/07/02		
CHECK				
REVIEW				

FIGURE: 4.1

R:\CAD\7000\022-7009\ Drawing file: Sediment Sampling Locations.dwg Jul 24, 2002 - 4:12pm

Table 4.1 Summary of sediment sampling in Doris Hinge lakes and Roberts Bay, 1996 and 1997.

Waterbody	Summer 1996	Summer 1997
Doris Lake	√	√
Tail Lake	√	√
Ogama Lake	√	√
Patch Lake	√	√
Wolverine Lake		√
Windy Lake	√	√
Little Roberts Lake	√	√
Pelvic Lake		√
Roberts Bay (5 stations)		√
Roberts Bay - Station 2		√
Roberts Bay - Station 3		√
Roberts Bay - Station 4		√
Roberts Bay - Station 5		√

4.1.2 Laboratory Analytical Methods

Sediment quality samples were analysed for moisture content, total organic carbon (TOC), and solid phase metals. Analytical detection limits are presented in Table 4.2.

Table 4.2 Detection limits for sediment quality analysis, 1996 to 1997.

	Parameter (units)	1996 [a]	1997 [b]
Physical Parameters	Moisture (%)	n.s.	0.1
Organic Parameters	Total Organic Carbon (%)	n.s.	0.05
Total Metals	Aluminum (mg/kg)	n.a.	50
	Antimony (mg/kg)	0.05	n.a.
	Arsenic (mg/kg)	n.s.	0.05
	Cadmium (mg/kg)	0.05	0.1
	Cobalt (mg/kg)	n.s.	2.0
	Copper (mg/kg)	n.s.	1.0
	Chromium (mg/kg)	n.s.	2.0
	Iron (mg/kg)	n.s.	50
	Lead (mg/kg)	n.s.	2.0
	Manganese (mg/kg)	n.s.	1.0
	Mercury (mg/kg)	0.05	0.005
	Nickel (mg/kg)	n.s.	2.0
	Selenium (mg/kg)	0.5	0.1
	Silver (mg/kg)	n.s.	0.1
	Zinc (mg/kg)	n.s.	1.0

[a] Detection limits in Rescan (1997).
[b] Detection limits in Rescan (1998).
n.s. = detection limit not specified; n.a. = parameter not analyzed.

It should be noted that analytical methodologies and detection limits used for some parameters varied from year to year, largely because of different laboratories that were involved in the analyses, including Elemental Research Inc. in 1996 and Analytical Service Laboratories in 1997.

4.2 LAKE SEDIMENT QUALITY

Baseline sediment quality information for the various sampled lakes including Doris, Tail, Ogama, Patch, Wolverine, Windy, Little Roberts and Pelvic lakes are presented in the following sections. Sediment samples collected in the various lakes are described based on visual characteristics including color, texture, grain size, etc. Metal concentrations in sediments are compared with the Canadian Interim Sediment Quality Guidelines for the Protection of Aquatic Life (CISQG) (CCME 1999) to assess whether background sediment metal concentrations are within recommended ranges.

The CISQG recommends using two guidelines in assessing sediment quality. The first, referred to as the Threshold Effect Level (TEL), is the concentration below which adverse effects are rare. The second, referred to as the Probable Effect Level (PEL), is the concentration above which adverse effects are likely to occur. This recommended procedure was followed in this report.

4.2.1 Doris Lake

Sediments consisted primarily of clay-sized particles overlain by a surface layer of silt. The interfacial layer was dark greyish-brown in color (10YR 5/2 on the Munsell Color scale), whereas the underlying upper layer was grayish yellow (5Y 5/2) in color (Rescan 1997).

Total organic carbon (TOC) concentration was elevated, compared to other study lakes, ranging from 1.3 to 2.8% dry weight (Table 4.3). The concentration of total chromium (92 to 109 mg/kg) was above the CISQG PEL and total copper (39.5 to 45.0 mg/kg) was above the CISQG TEL, in both the 1996 and 1997 sediment samples. Total arsenic (4.0 to 12.3 mg/kg) was above the CISQG TEL in the 1997 sample only (Table 4.3). Profile sub-sampling carried out in 1996 indicated that total metal concentrations in the interfacial and near-surface layers were essentially indistinguishable (Table 4.3).

Table 4.3 Sediment chemistry in Doris Hinge lakes, 1996 and 1997.

Site	Unit[a]	Doris Lake			Tail Lake			Ogama Lake			Patch Lake			CISQG[b]	
Date		28-Aug-96		18-Jul-97	27-Aug-96		16-Jul-97	27-Aug-96		16-Jul-97	26-Jul-96		18-Jul-97	TEL	PEL
Depth of sample	m	17	17	16	5	5	6	4	4	4	12	12	4.25		
Selected Sediment	cm	0-1	1-3	0-2	0-1	1-3	0-2	0-1	1-3	0-2	0-1	1-3	0-2		
Physical															
Moisture	%	31.2	54.7	57.7	66.8	68.3	58.4	57.8	47.7	56.9	64.2	48	49.9		
Organic															
Tot. Org. Carbon	%	1.29	1.19	2.8	1.94	1.93	3.85	0.89	0.83	1.83	0.82	0.78	1.22		
Total Metals															
Aluminum	mg/kg			36300			33000			32500			31700		
Antimony	mg/kg	<0.05	<0.05		0.26	0.11		<0.05	<0.05		0.08	0.09			
Arsenic	mg/kg	4	4	**12.3**	**7**	3	2.09	**44**	**12**	**12.2**	**12**	4	2.93	5.9	17
Cadmium	mg/kg	0.05	**0.16**	<0.1	0.1	0.14	<0.1	<0.05	0.06	<0.1	**0.15**	**0.11**	<0.1	0.6	3.5
Chromium	mg/kg	**102**	**109**	**92**	**105**	**132**	**81**	**93.6**	**107**	**89**	**108**	**108**	**82**	37.3	90
Cobalt	mg/kg	13.6	14.9	16	16.3	19.3	17	15.6	15.4	16	17.5	16	13		
Copper	mg/kg	**39.5**	**42.4**	**45**	**44.7**	**64**	**46**	30.8	30.1	31	**36.7**	34.4	34	35.7	197
Iron	mg/kg	52100	47600	59700	79800	71300	43900	71600	58700	52700	68400	53100	35900		
Lead	mg/kg	9.86	10.8	14	9.27	11.5	11	9.05	9.76	12	10.1	10.3	12	35	91.3
Manganese	mg/kg	692	750	1080	1390	830	735	4410	1410	856	2150	1000	474		
Mercury	mg/kg	<0.05	<0.05	0.034	<0.05	<0.05	0.023	<0.05	<0.05	0.018	<.05	<.05	0.009	0.17	0.486
Nickel	mg/kg	41.5	43.8	56	41.9	54	48	33.4	40.2	47	44.3	40.7	44		
Selenium	mg/kg	<0.5	0.6	0.3	<0.5	0.9	0.3	<0.5	<0.5	0.2	<0.5	<0.5	0.2		
Silver	mg/kg	0.25	0.16	<0.1	0.27	0.4	0.2	0.14	0.12	<0.1	0.41	0.3	<0.1		
Zinc	mg/kg	91	94	120	90	115	101	74	84	105	84	82	91	123	315

Table 4.3 Sediment chemistry in Doris Hinge lakes, 1996 and 1997 (continued).

Parameter	Unit[a]	Wolverine Lake	Windy Lake			Little Roberts Lake			Pelvic Lake	CISQG[b]	
Date		16-Jul-97	28-Aug-96		17-Jul-97	27-Aug-96		15-Jul-	17-Jul-97	TEL	PEL
Depth of sample	m	3.5	8	8	13	3	3	2	15.75		
Selected Sediment	cm	1-2	0-1	1-3	0-2	0-1	1-3	0-2	0-2		
Physical Parameters											
Moisture	%	65.2	31.3	32.6	63	59	50.3	59.9	54.8		
Organic Parameters											
Tot. Organic Carbon	%	3.86	0.17	0.14	0.95	0.86	0.75	2.17	1.99		
Total Metals											
Aluminum	mg/kg	33200			31100			23300	28800		
Antimony	mg/kg		<0.05	<0.05		<0.05	<0.05				
Arsenic	mg/kg	4.22	**9**	**6**	**13.7**	2	2	2.19	3.25	5.9	17
Cadmium	mg/kg	<0.1	0.07	<0.05	<0.1	0.07	<0.05	<0.1	<0.1	0.6	3.5
Chromium	mg/kg	**82**	**41.1**	**49.5**	**79**	**68.1**	**62.6**	**58**	**74**	37.3	90
Cobalt	mg/kg	13	9.1	8.3	13	10.3	9.9	10	12		
Copper	mg/kg	35	15.8	17.3	**40**	23.8	22	24	32	35.7	197
Iron	mg/kg	42400	25700	26900	43100	38900	35000	28600	41700		
Lead	mg/kg	12	4.67	5.19	12	6.04	5.52	8	9	35	91.3
Manganese	mg/kg	432	590	386	837	395	365	382	500		
Mercury	mg/kg	0.016	<0.05	<0.05	0.011	<0.05	<0.05	0.013	0.017	0.17	0.486
Nickel	mg/kg	42	16.1	24	40	24.4	23.1	28	39		
Selenium	mg/kg	0.3	<0.5	0.5	0.3	<0.5	<0.5	0.2	0.2		
Silver	mg/kg	0.1	0.11	0.09	<0.1	0.07	0.09	<0.1	<0.1		
Zinc	mg/kg	90	25	34	87	60	56	69	83	123	315

[a] Units are expressed as dry weights.

[b] CISQG = Canadian Interim Sediment Quality Guidelines for the Protection of Aquatic Life; TEL = Threshold Effect Level; PEL = Probable Effect Level

NOTE: **Values in bold** are equal or greater than the TEL guidelines.

4.2.2 Tail Lake

The predominantly clay-sized sediment was greyish in color. The TOC concentration was elevated compared to other study lakes, ranging from 1.9 to 3.9% dry weight. The total copper concentration (45 to 64 mg/kg) exceeded the CISQG TEL in both the 1996 and 1997 samples, whereas total chromium (81 to 132 mg/kg) exceeded the PEL in both 1996 samples and the TEL in the 1997 sample. Total arsenic (2.1 to 7.0 mg/kg) exceeded CISQG TEL in the 1996 surficial layer (Table 4.3).

4.2.3 Ogama Lake

The predominantly clay-sized sediment consisted of an orange coloured (5YR 5/6) surficial layer and greyish-blue coloured (5B 5/1) upper layer (Rescan 1997).

The TOC concentration was low and ranged from 0.8 to 1.8% dry weight. The concentration of total arsenic and total chromium exceeded the CISQG TEL in all three samples (Table 4.3). The 1996 sediment profiling indicated that total arsenic, iron and manganese were more abundant in the surficial layer than the underlying upper layer (Table 4.3).

4.2.4 Patch Lake

The fine-grained organic surficial layer was greyish-brown in color (10YR 4/2), whereas the clay-sized upper layer was greyish-yellow in color (Rescan 1997).

The TOC concentration was low compared to other project lakes, ranging from 0.8 to 1.2%. The concentration of total chromium (82 to 108 mg/kg) exceeded the CISQG PEL in both 1996 samples and exceeded the TEL in the single 1997 sample. Total cadmium exceeded the TEL in both 1996 samples, while total copper and total arsenic exceeded the TEL in the surficial 1996 sample (Table 4.3). The 1996 sediment profiling indicated that total arsenic, iron and manganese concentrations were elevated in the surficial layer compared to the underlying upper layer (Table 4.3).

4.2.5 Wolverine Lake

Wolverine Lake sediments were not sampled in 1996. The predominantly clay-sized sediment in the 1997 sample was greyish in color. The TOC concentration of 3.9% dry weight was elevated relative to other project lakes, and total chromium concentration exceeded the CISQG TEL (Table 4.3).

4.2.6 Windy Lake

The clay, fine sand and silt sized surficial layer was greyish-brown in color (10YR 4/2), whereas the clay and fine-sand sized upper layer was greyish yellow in color (5Y 5/2).

The TOC concentration was low compared to other project lakes, ranging from 0.14 to 0.95%. The concentration of total arsenic and total chromium was above the CISQG TEL in both the 1996 and 1997 samples, and total copper exceeded the TEL in 1997. The 1996 profiling indicated that manganese was more abundant in the surficial layer, whereas total nickel was more abundant in the underlying upper layer (Table 4.3).

4.2.7 Little Roberts Lake

The predominantly clay-sized surficial layer was orange (10YR 5/4) in color, whereas the clay-sized underlying upper layer was greyish-yellow (5Y 3/2) in color (Rescan 1997).

The TOC concentrations were moderate compared to other project lakes, ranging from 0.8 to 2.2% dry weight. The concentration of total chromium exceeded the CISQG TEL in 1996 and 1997. The 1996 profiling indicated that metal concentrations were essentially indistinguishable between the two sediment layers (Table 4.3).

4.2.8 Pelvic Lake

The predominantly clay-sized sediment (with a silt particle-sized surface layer) was medium to dark grey in color (Rescan 1997). The TOC concentration (2.0% dry weight) was moderate. Total chromium concentration exceeded the CISQG TEL (Table 4.3).

4.2.9 Summary

Most lake sediment metal levels fell below the CISQG. The exceptions were total chromium, total copper, total arsenic and total cadmium. Of these, total chromium values exceeding the guidelines were the most widespread geographically and temporally, with concentrations exceeding the CISQG PEL in four of the eight lakes. Nevertheless, these sediment metal concentrations remained within the range of natural variability for the Slave Structural Province (Puznicki 1996b).

Sediment TOC levels varied between lakes. For lake sediments with relatively elevated TOC (Doris and Tail lakes), color and mineralogy indicated that reducing conditions were predominant in the surficial layer as well as the underlying sediments. For lake sediments with relatively low to moderate TOC concentrations, and in which profiling had been carried out (Ogama, Patch, Windy and Little Roberts lakes), color and mineralogy indicated a strong redox gradient between an oxic surficial layer and reducing underlying upper layer.

4.3 MARINE SEDIMENT QUALITY

4.3.1 Roberts Bay

The Roberts Bay sediment samples were primarily clay-sized. The exception was the shallowest station (Station S5) sample that consisted primarily of fine sand (Rescan 1997). Concentrations of TOC ranged from <0.05 to 0.72% dry weight, with no apparent relationship between water-column depth and TOC content (Table 4.4). Moisture content varied between samples, ranging from 19% at Station 3 and 47% at Station 5. Total chromium (66 mg/kg) and total copper (26 mg/kg) exceeded the CISQG TEL at Station 1 and 5 (Table 4.4).

4.3.2 Summary

Total metal concentrations in Roberts Bay seabed sediments were, for the most part, within the sediment quality guidelines. The exceptions were total chromium and total copper. Sediment metal concentrations, in general, were inversely proportional to water content, with minimum metal concentrations in the Station 3 sample and maximum concentrations in the Station 1 and 5 samples (Table 4.4). This negative correlation between water content and metal concentration was attributed by Rescan (1997) to an underlying relationship between sediment metal enrichment and particle size.

Table 4.4 Roberts Bay sediment chemistry, 1997.

Parameter	Unit[a]	Station 1	Station 2	Station 3	Station 4	Station 5	CISQG[b] (Marine)	
Date		23-Aug-97	23-Aug-97	23-Aug-97	23-Aug-97	23-Aug-97	TEL	PEL
Depth of sample	m	19.0	19.25	9.5	3.75	0.75		
Selected Sediment	cm	0-2	0-2	0-2	0-2	0-2		
Physical								
Moisture	%	45.8	38.8	19.3	39.5	47.3		
Organic								
Tot. Org. Carbon	%	0.72	0.5	<0.05	0.66	0.8		
Total Metals								
Aluminum	mg/kg	25900	17100	5730	22300	28400		
Arsenic	mg/kg	4.06	2.52	0.78	2.04	4.2	7.24	41.6
Cadmium	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1	0.7	4.2
Chromium	mg/kg	**66**	44	12	52	**66**	52.3	160
Cobalt	mg/kg	11	7	3	8	11		
Copper	mg/kg	**26**	18	9	18	**26**	18.7	108
Iron	mg/kg	36400	22500	8390	28700	35400		
Lead	mg/kg	9	6	<2	7	9	30.2	112
Manganese	mg/kg	376	260	107	305	372		
Mercury	mg/kg	0.009	0.006	<0.005	0.008	0.007	0.13	0.7
Nickel	mg/kg	29	18	7	23	30		
Selenium	mg/kg	0.3	0.2	<0.1	0.1	0.3		
Silver	mg/kg	<0.1	<0.1	<0.1	<0.1	<0.1		
Zinc	mg/kg	74	47	13	56	72	124	271

[a] Units are expressed as dry weights.

[b] CISQG = Canadian Interim Sediment Quality Guidelines for the Protection of Aquatic Life; TEL = Threshold Effect Level; PEL = Probable Effect Level.

NOTE: **Values in bold** are equal or greater than the TEL guidelines.

5.0 PRIMARY PRODUCERS

5.1 PHYTOPLANKTON IN LAKES

In general, phytoplankton are small, microscope free-floating plants. Phytoplankton convert sunlight into biological tissues and form part of the lower trophic level, upon which other life forms depend.

5.1.1 Methods

Phytoplankton samples were collected from eight lakes within the Doris Hinge area (Figure 5.1). One to four sampling sessions were conducted on each lake between 1996 and 2000. Phytoplankton samples were not collected in 1998 and 1999 (Table 5.1).

Table 5.1 Phytoplankton sampling schedule in Doris Hinge lakes, 1996 to 2000.

Waterbody	Date			
	1996	1997	1997	2000
Doris Lake	28 August	18 July	22 August	24 July
Tail Lake	26 August	16 July		19 July
Ogama Lake	27 August	16 July		
Patch Lake	26 August	17 July		
Wolverine Lake		16 July		
Windy Lake	29 August	17 July		
Little Roberts Lake	27 August	15 July		
Pelvic Lake		17 July		24 July

Triplicate phytoplankton samples were collected during each sampling session. Samples were collected from a water depth of 1 m with the use of a 5-L Teflon-lined Go-Flo™ bottle. Each sample was transferred to a clean 250-mL plastic bottle, preserved with Lugol's iodine solution, and labeled. All samples were submitted to Fraser Environmental Services for taxonomic identification and enumeration.

5.1.2 Doris Lake

Four phytoplankton sampling sessions were conducted on Doris Lake during the summer; once in 1996, twice in 1997, and once in 2000. Mean total algal cell numbers [± 1 standard error (SE)] ranged from 18 098 ± 5776 cells/mL on 17 July 1997 to 62 303 ± 5740 cells/mL on 28 August 1996 (Figure 5.2; Appendices B1 and B2).

Cyanophyta, also known as Cyanobacteria and colloquially referred to as blue-green algae, contributed between 94.9 and 99.5% towards the mean total number of cells enumerated per sampling session. The major contributors in this group included *Oscillatoria* spp., *Aphanizomenon flos-aquae*, and *Lyngbya limnetica* (Figure 5.2; Appendices B1 and B2).

5.1.3 Tail Lake

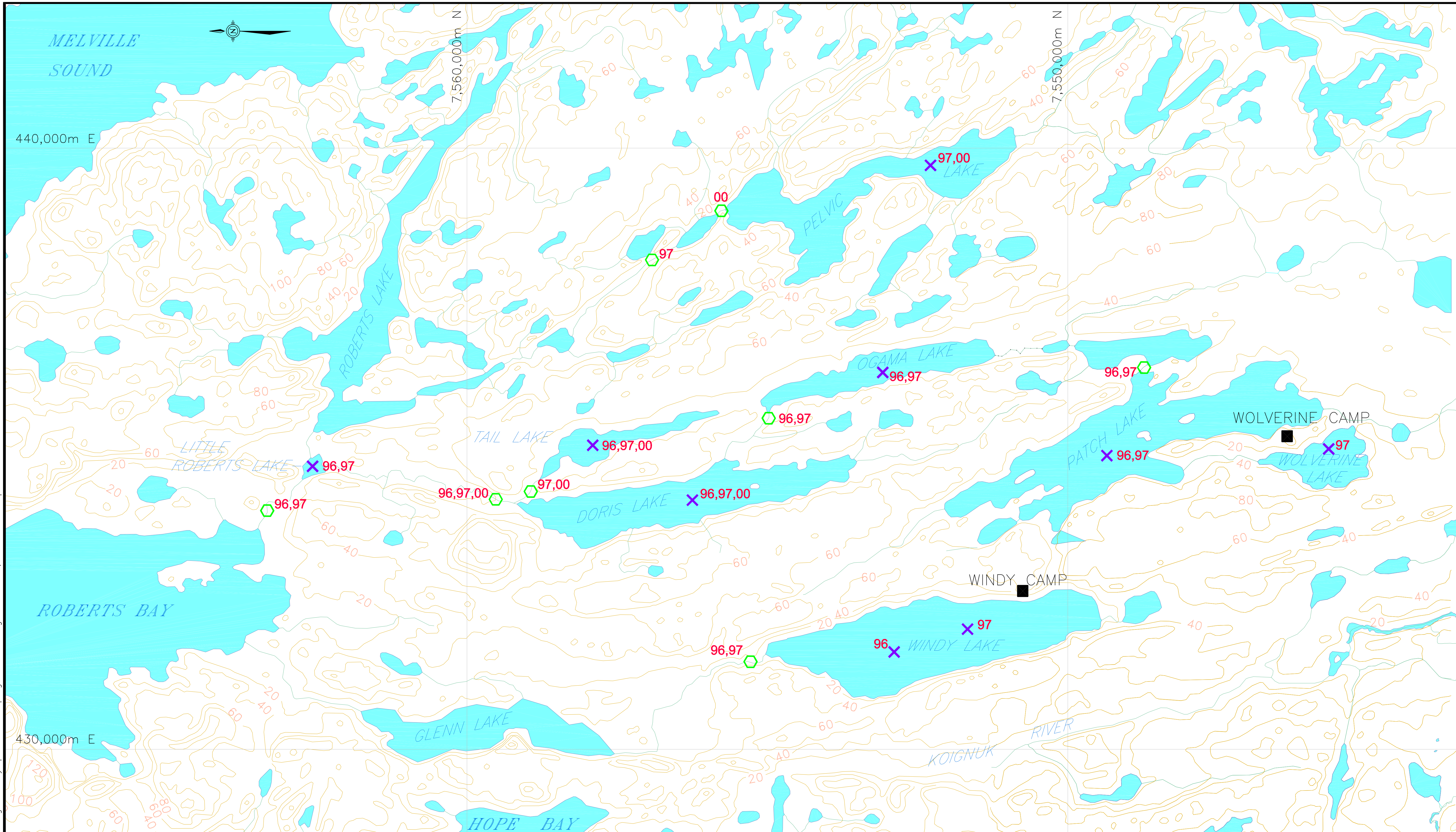
Three phytoplankton sampling sessions were conducted on Tail Lake, once during each summer of 1996, 1997, and 2000. Mean total numbers (± 1 SE) ranged from 122 ± 18 cells/mL on 16 July 1997 to 2365 ± 72 cells/mL on 27 August 1996 (Figure 5.3; Appendices B1 and B2).

In August 1996, the phytoplankton of Tail Lake was dominated by Bacillariophyta (diatoms), which contributed 96.2% towards the total mean cell count in the sample (Figure 5.3; Appendices B1 and B2). The major contributor in this group was *Asterionella formosa*. In July 1997, the phytoplankton community of Tail Lake was dominated by Bacillariophyta (primarily *A. formosa* and *Tabellaria flocculosa*) followed closely by Chrysophyta (golden-brown algae; predominately *Dinobryon sociale* and *Synura* spp.) and Pyrrophyta (dinoflagellates; almost exclusively *Chroomonas acuta*). During the final sampling session (July 2000), the phytoplankton was dominated by Bacillariophyta (49.2% of total cell numbers) and Chrysophyta (42.2%); the Bacillariophyta were represented mainly by *T. flocculosa*, *A. formosa*, and *Fragilaria crotonensis*, whereas the Chrysophyta were represented by *Dinobryon divergens* and *Dinobryon bavaricum*.

5.1.4 Ogama Lake

Two phytoplankton sampling sessions were conducted on Ogama Lake, once in August 1996 and once in July 1997. Mean total numbers (± 1 SE) for these sampling sessions were 16 640 ± 1298 and 2275 ± 197 cells/mL, respectively (Figure 5.4; Appendices B1 and B2).

In August 1996, the phytoplankton of Ogama Lake was dominated by Bacillariophyta, which contributed 97.6% towards the total mean cell count in the sample (Figure 5.4; Appendices B1 and B2). The major contributor in this group was *Melosira* spp. In July 1997, the phytoplankton community of Ogama Lake was dominated by Cyanophyta (52.8% of total cell numbers), followed closely by Bacillariophyta (43.6%). These two major taxonomic groups were represented primarily by *Oscillatoria* spp. and *Diatoma tenue* v. *elongatum*, respectively.



LEGEND

- × PHYTOPLANKTON SAMPLING SITES IN LAKES
- ⬡ PERIPHYTON SAMPLING SITES IN STREAMS
- 95,96 etc. YEARS OF SAMPLING

1.5 0 1.5
SCALE KILOMETRES

NOTE : CONTOUR INTERVAL 20 m

REFERENCE
BASE MAP PROVIDED BY RESCAN, JANUARY 22, 2001

Hope Bay Joint Venture

TITLE
PHYTOPLANKTON AND PERIPHYTON SAMPLING LOCATIONS IN DORIS HINGE AREA, 1996-2000

Golder Associates
Edmonton, Alberta

PROJECT	No. 022-7009.1000		FILE No. Zooplankton Sampling	
DESIGN	AH	11/06/02	SCALE AS SHOWN	REV. 0
CADD	TVS	14/06/02		
CHECK			FIGURE: 5.1	
REVIEW				

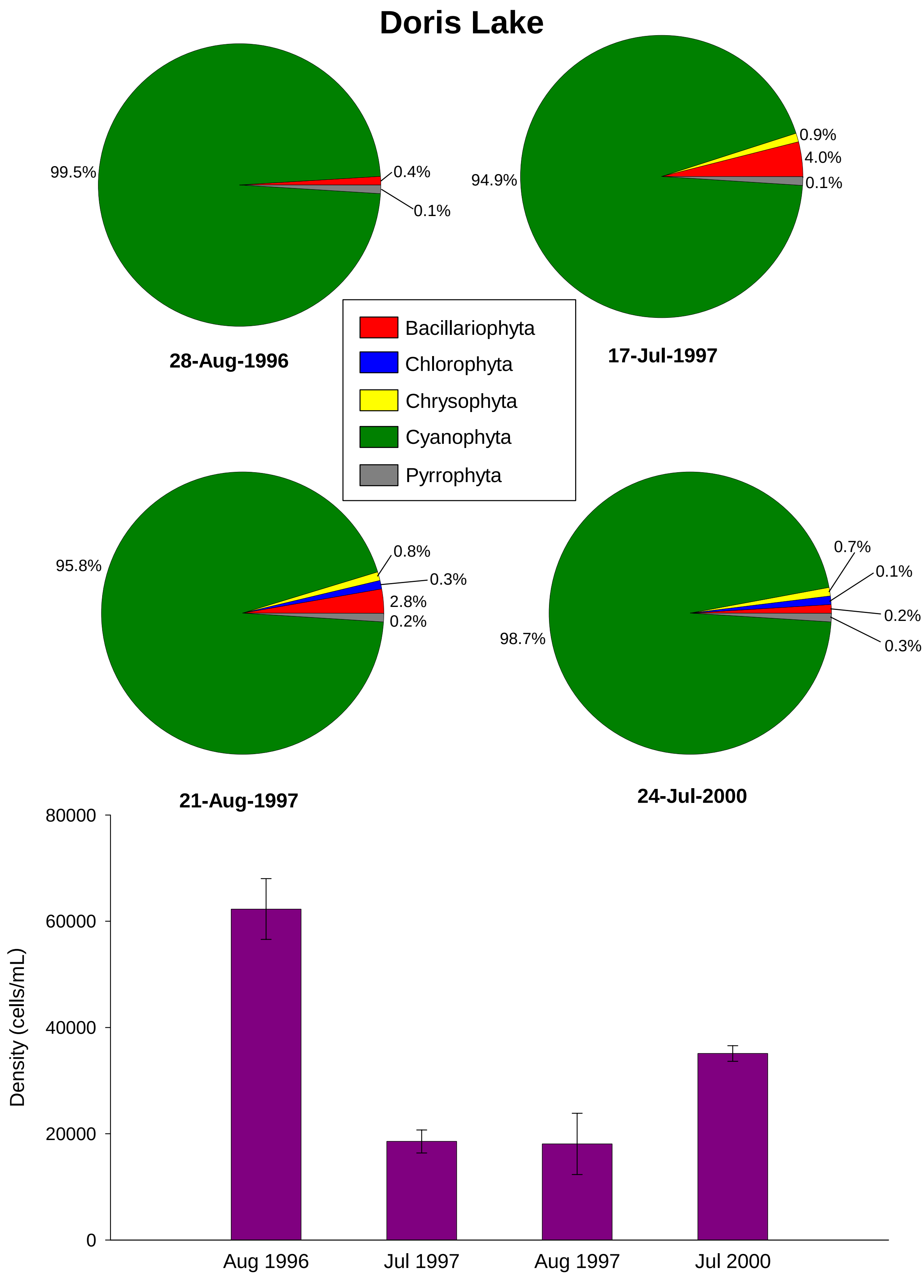


Figure 5.2 Relative abundance of major taxonomic groups and mean total density (± 1SE) of phytoplankton in Doris Lake, 1996 to 2000.

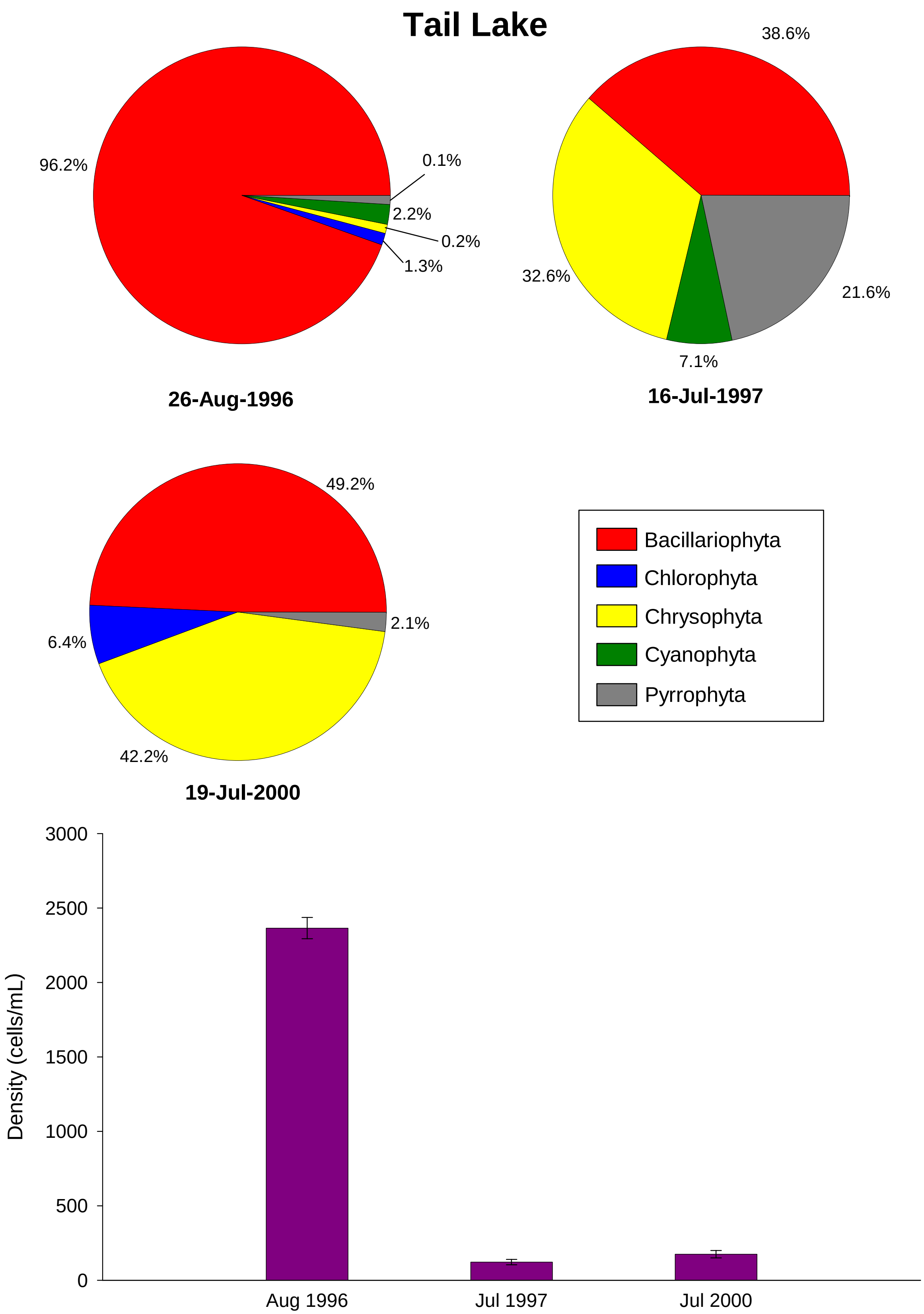
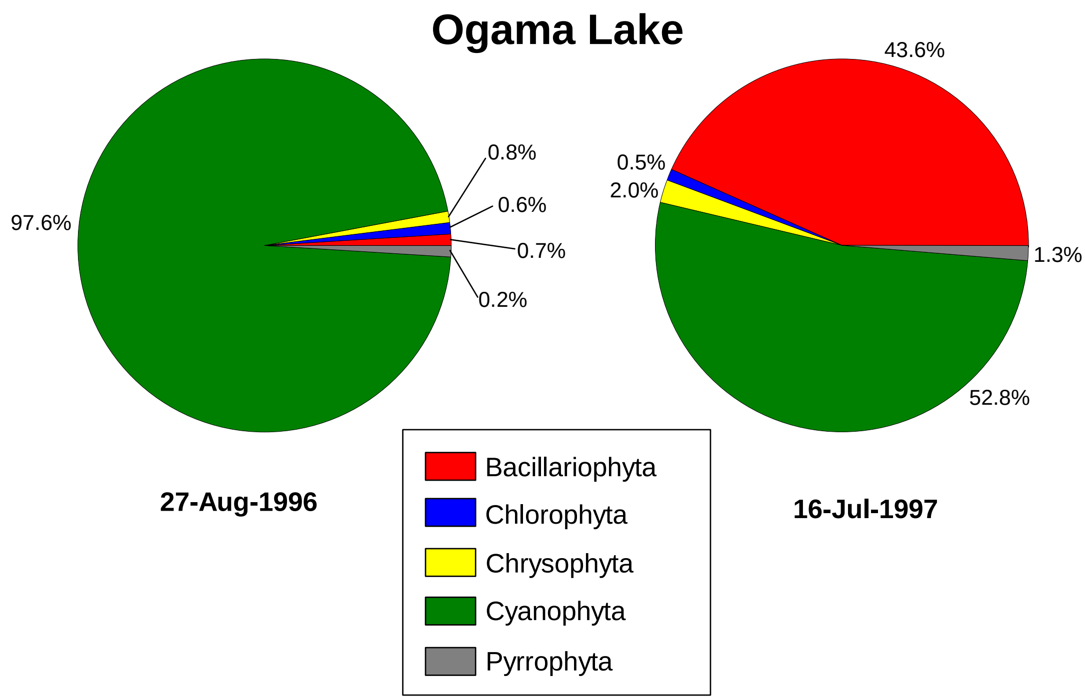


Figure 5.3 Relative abundance of major taxonomic groups and mean total density (± 1SE) of phytoplankton in Tail Lake, 1996 to 2000.



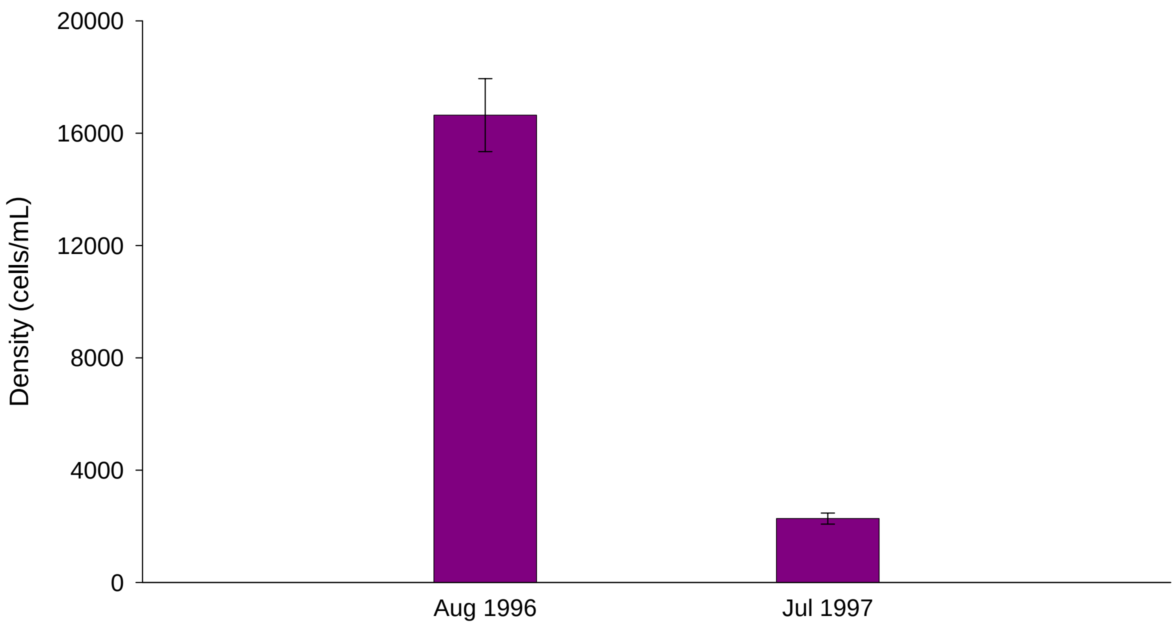


Figure 5.4 Relative abundance of major taxonomic groups and mean total density (± 1SE) of phytoplankton in Ogama Lake, 1996 to 1997.

5.1.5 Patch Lake

Phytoplankton sampling sessions on Patch Lake were conducted once during each of August 1996 and July 1997. Mean total numbers (± 1 SE) in 1996 and 1997 were 224 ± 45 and 200 ± 22 cells/mL, respectively (Figure 5.5; Appendices B1 and B2).

In August 1996, the phytoplankton of Patch Lake was dominated by Cyanophyta, which contributed 41.5% to the total mean cell count in the sample (Figure 5.5; Appendices B1 and B2). The major contributor in this group was *Lyngbya limnetica*. Within the same sampling session, the second and third most abundant major taxa were Bacillariophyta (28.8% of total cell numbers), followed by Chlorophyta (colloquially referred to as green algae; 25.2 % of total cell numbers); these groups were represented primarily by *Asterionella formosa* and *Botryococcus braunii*, respectively. In July 1997, the phytoplankton community of Patch Lake was dominated by Chrysophyta (contributing 45.5% towards the total cell count) followed by Cyanophyta (28.6%) and Bacillariophyta (23.2%). These three major taxonomic groups were represented primarily by *Dinobryon sociale*, *Oscillatoria* spp., and *Diatoma tenue* v. *elongatum*, respectively.

5.1.6 Wolverine Lake

The phytoplankton of Wolverine Lake was collected only on 16 July 1997. The mean total number (± 1 SE) was 840 ± 145 cells/mL (Appendices B1 and B2).

The phytoplankton of Wolverine Lake was dominated by Bacillariophyta, which contributed 77.3% towards the total mean cell count in the sample. The major contributors within this group were *Diatoma tenue* v. *elongatum*, *Achnanthes* spp., and *Nitzschia* spp. The second and third most abundant major taxa were Chrysophyta and Pyrrophyta (13.0 and 7.1% of total cell numbers, respectively); the Chyrsophyta were represented mainly by *Dinobryon sociale*, whereas the Pyrrophyta were represented primarily by *Chryptomonas ovata* (Appendices B1 and B2).

5.1.7 Windy Lake

Phytoplankton sampling sessions on Windy Lake were conducted once in 1996 and once in 1997. Mean total numbers (± 1 SE) for these years were 247 ± 37 and 21 ± 6 cells/mL, respectively (Figure 5.6; Appendices B1 and B2).

In August 1996, the phytoplankton of Windy Lake was dominated by Cyanophyta, which contributed 94.1% towards the total mean cell count in the sample (Figure 5.6; Appendices B1 and B2). The major contributor in this group

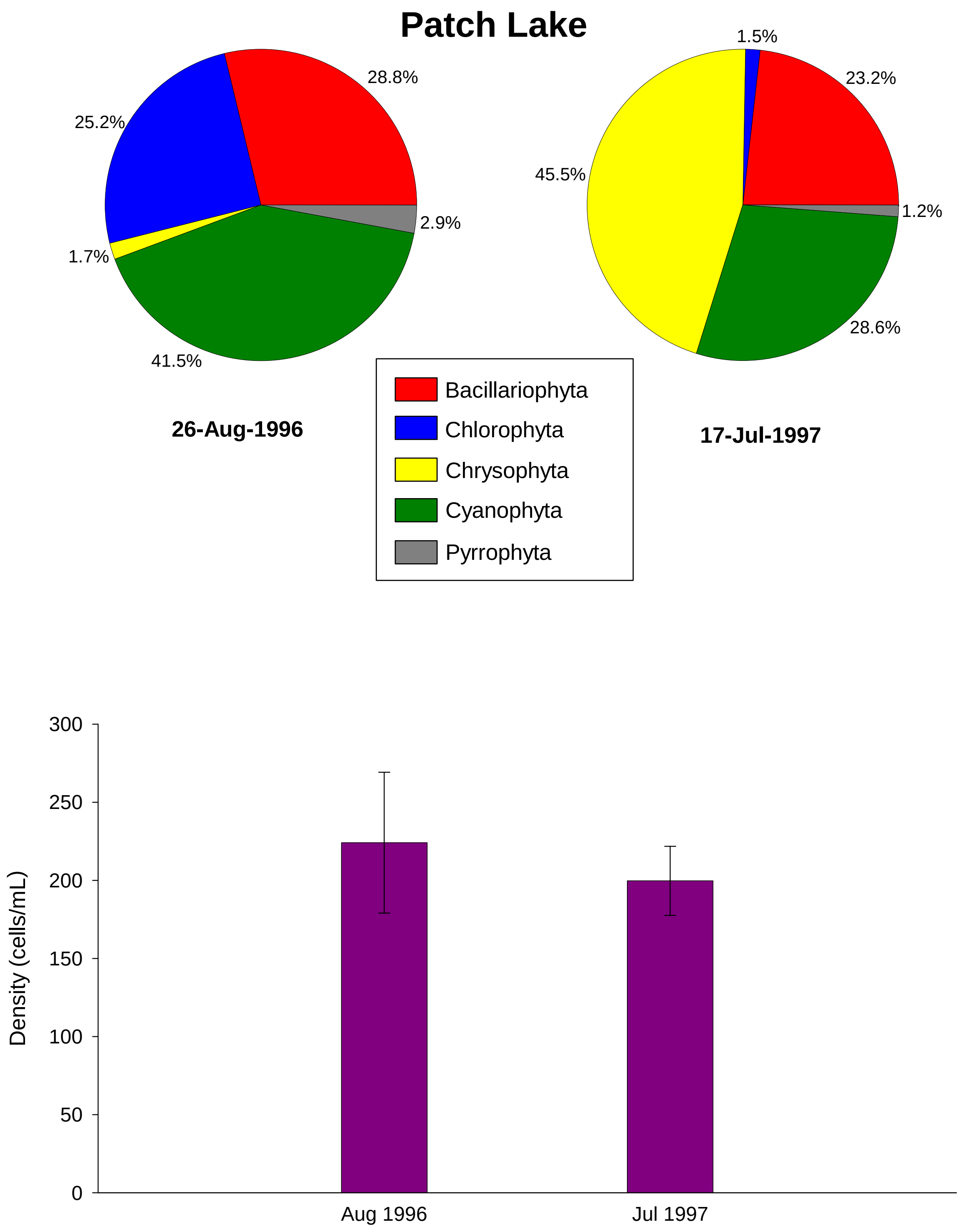
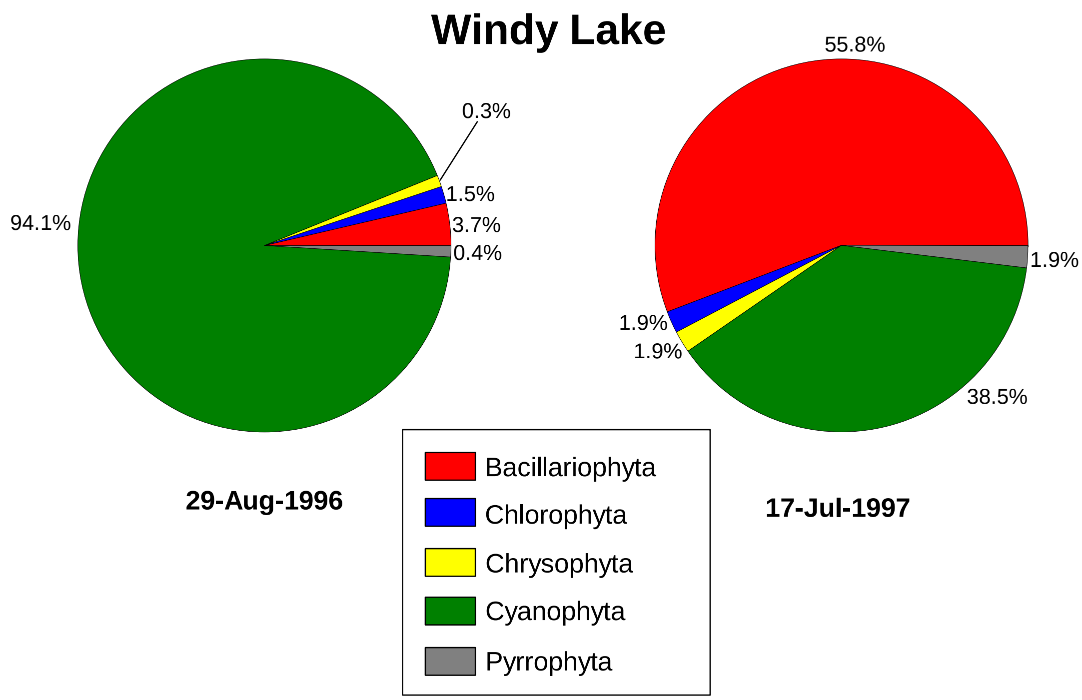


Figure 5.5 Relative abundance of major taxonomic groups and mean total density (± 1SE) of phytoplankton in Patch Lake, 1996 to 1997.



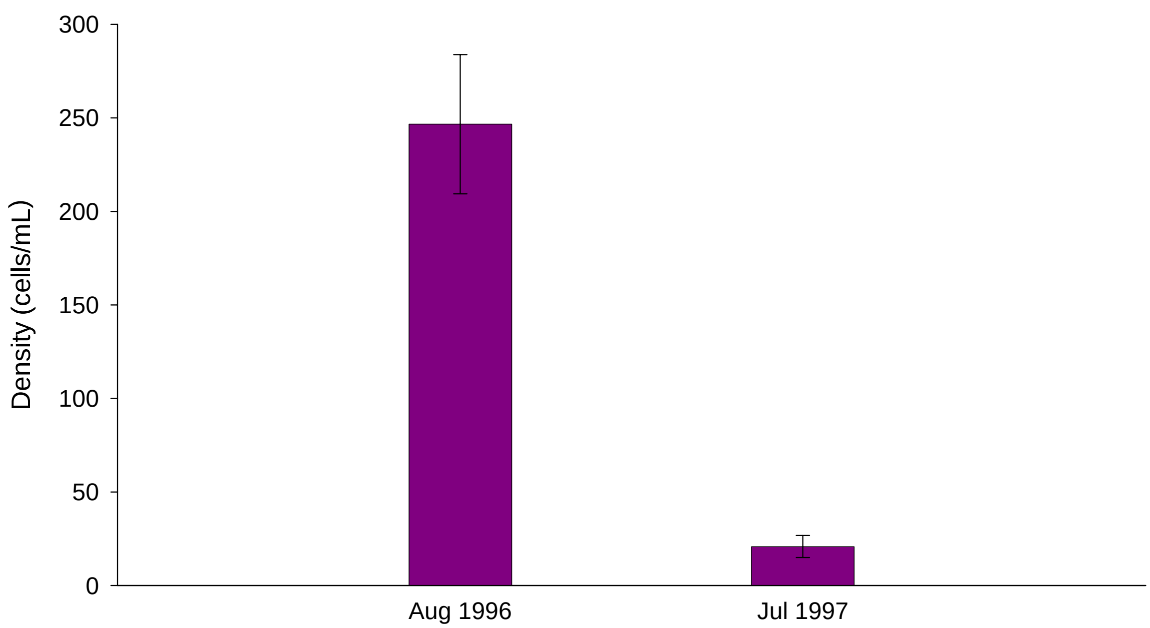


Figure 5.6 Relative abundance of major taxonomic groups and mean total density (± 1SE) of phytoplankton in Windy Lake, 1996 to 1997.

was *Oscillatoria tenuis*. In July 1997, the phytoplankton community of Windy Lake was dominated by Bacillariophyta (55.8% of total cell numbers), followed by Cyanophyta (38.5%); these two major taxonomic groups were primarily represented by *Diatoma tenue* v. *elongatum*, and *Oscillatoria* spp., respectively.

5.1.8 Little Roberts Lake

Phytoplankton sampling sessions on Little Roberts Lake were conducted once during each of 1996 and 1997. Mean total numbers (± 1 SE) during 1996 were 39 508 ± 2685, whereas in 1997 mean total numbers were lower at 10 329 ± 2778 cells/mL (Figure 5.7; Appendices B1 and B2).

The phytoplankton of Little Roberts Lake was dominated by Cyanophyta, which contributed 98.1 and 89.6% towards the mean total cell count within the August 1996 and July 1997 samples, respectively (Figure 5.7; Appendices B1 and B2). The major contributor in this group for both study years was *Oscillatoria* spp.

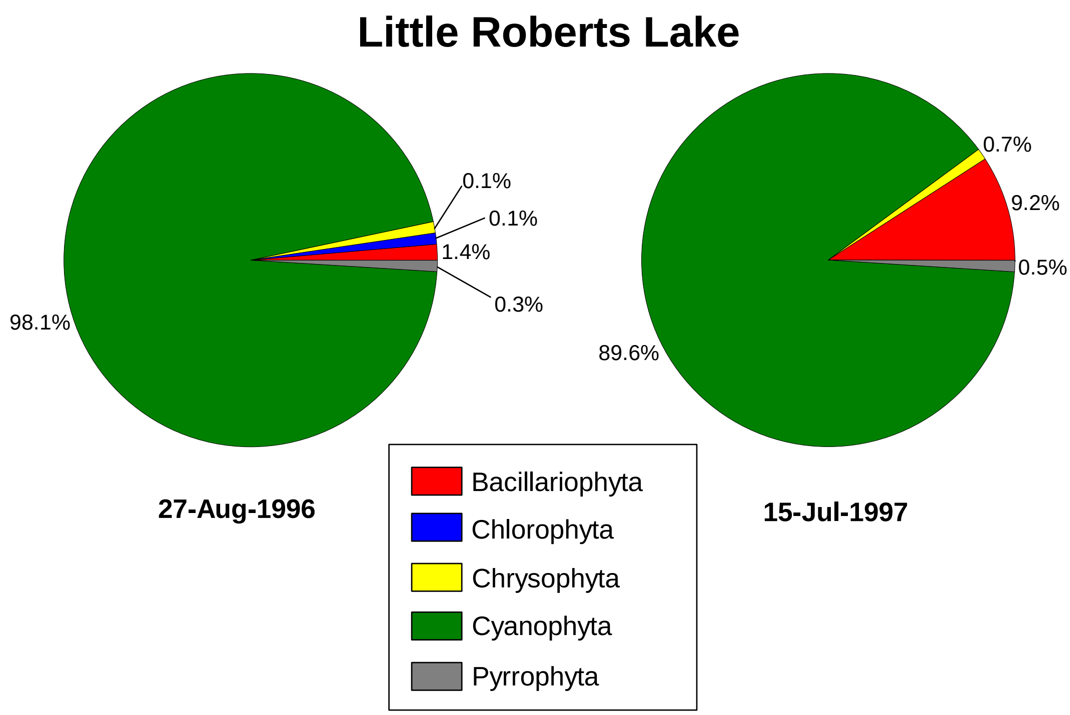
5.1.9 Pelvic Lake

Phytoplankton sampling sessions for Pelvic Lake were conducted on 16 July 1997 and 24 July 2000. Mean total numbers (± 1 SE) on these dates were 24 698 ± 9004 and 63 973 ± 3352 cells/mL, respectively (Figure 5.8; Appendices B1 and B2).

The phytoplankton of Pelvic Lake was dominated by Cyanophyta, which contributed 84.5 and 97.7% towards the total mean cell count within the July 1997 and July 2000 samples, respectively (Figure 5.8; Appendices B1 and B2). The major contributor in this group for both study years was *Oscillatoria* spp.

5.1.10 Summary

The phytoplankton samples obtained from the Doris Hinge lakes revealed no uncommon or rare species. The phytoplankton communities (i.e., taxonomic composition) of the eight waterbodies showed little differentiation and were similar in many respects to the communities of many other small lakes in the Arctic and sub-Arctic (Moore 1978a, 1978b; RL&L 1997, 1998, 1999). In general, phytoplankton within the Doris Hinge lakes were numerically dominated by the blue-green algae (Cyanophyta) *Oscillatoria* spp., and *Lyngbya limnetica*, as well as the diatoms (Bacillariophyta) *Diatoma tenue* v. *elongatum*, *Asterionella formosa*, and *Tabellaria flocculosa*.



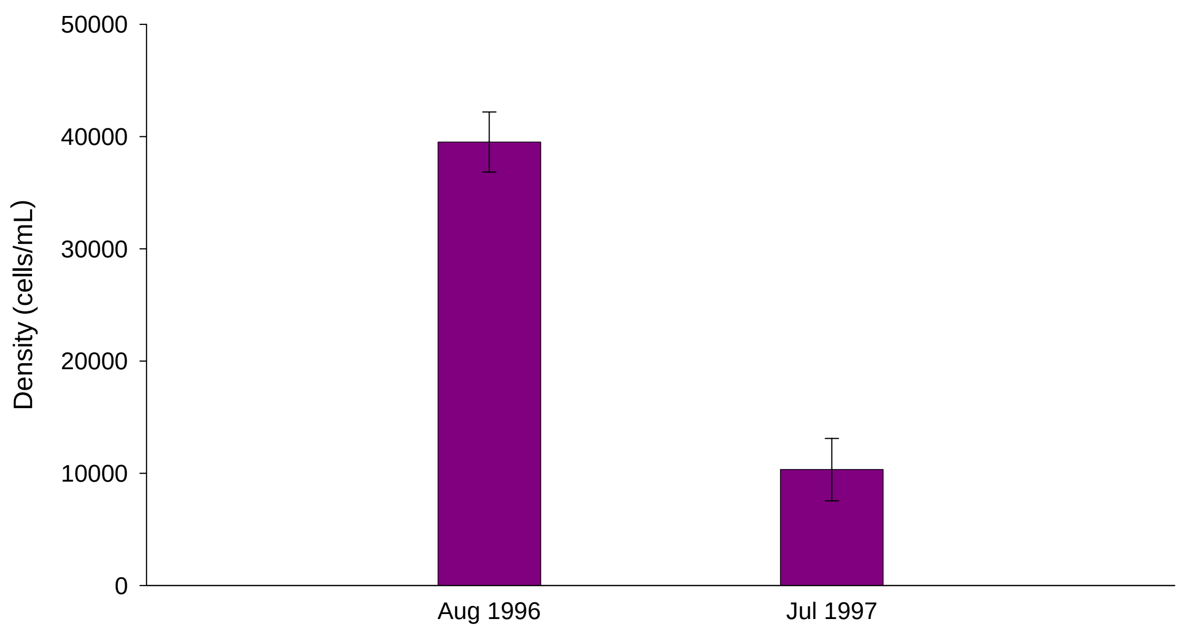
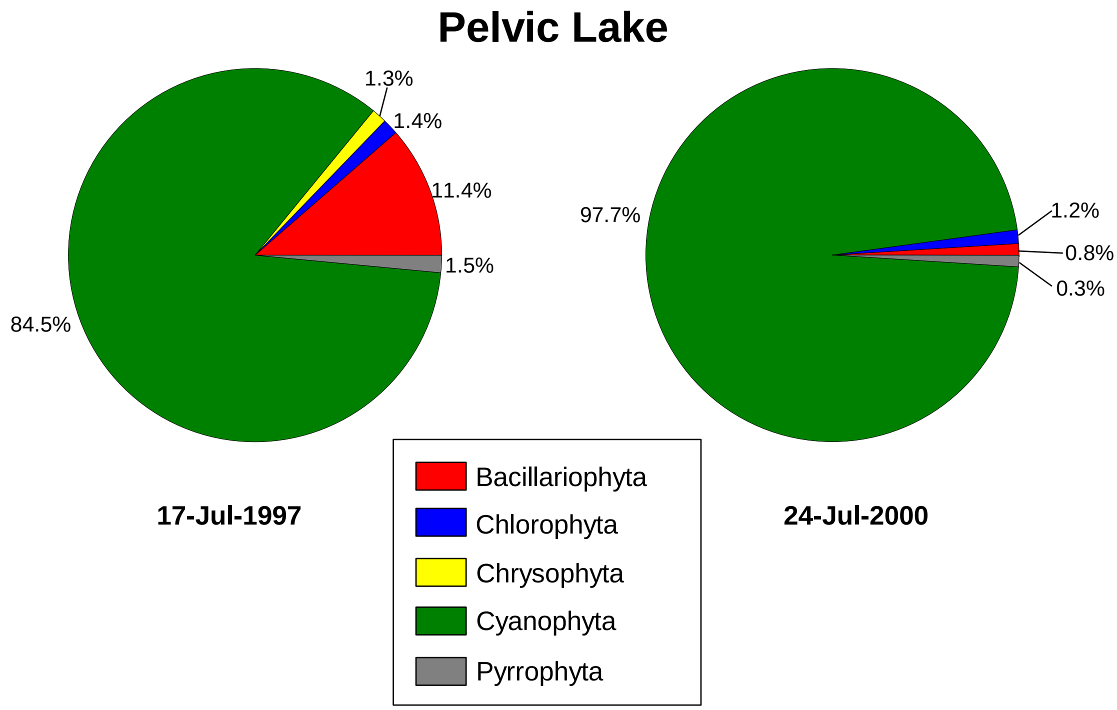


Figure 5.7 Relative abundance of major taxonomic groups and mean total density (± 1SE) of phytoplankton in Little Roberts Lake, 1996 to 1997.



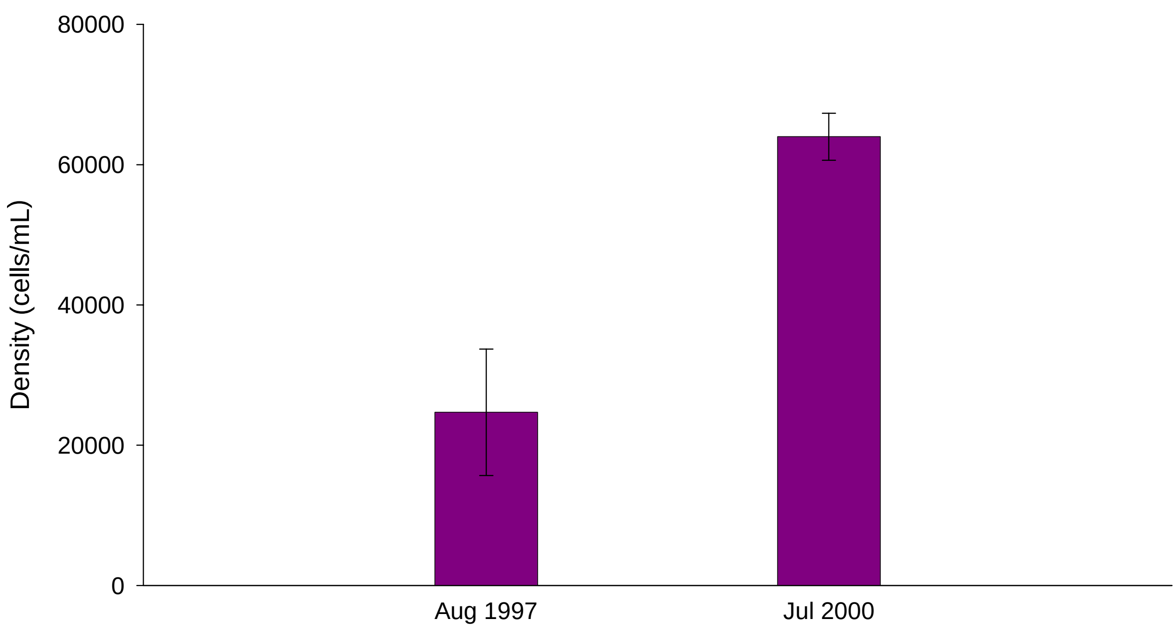


Figure 5.8 Relative abundance of major taxonomic groups and mean total density (± 1SE) of phytoplankton in Pelvic Lake, 1997 to 2000.

For the Doris Hinge lakes, a comparison of phytoplankton abundance indicated that Pelvic Lake was the most productive and that Windy Lake was the least productive (Table 5.2). On an aerial basis, which considers production for the total water column expressed on surface area, Doris Lake was the most productive, whereas Tail Lake was the least productive; however, data were not available for a comparison among all study lakes, because mean depths were not reported for all lakes.

Table 5.2 Summary of phytoplankton abundance in Doris Hinge lakes, 1996 to 2000.

Lake	Surface Area (m^2)	Mean Depth[a] (m)	Number of Sampling Events	Mean Volumetric Cell Numbers (cells/mL)	Mean Aerial Cell Numbers (cells × $10^9/m^2$)
Doris	3 540 000 [a]	7.4	4	33 513	4.53
Tail	766 300 [a]	3.1	3	887	0.285
Ogama	1 618 667 [a]	2.6	3	9 458	3.64
Patch	5 838 535 [a]	--	2	212	--
Wolverine	995 381 [b]	--	1	840	--
Windy	5 286 112 [b]	--	3	134	--
Little Roberts	96 258 [b]	--	2	24 918	--
Pelvic	3 521 744 [b]	--	2	44 336	--

[a]Data obtained from Rescan (1997, 2001).
[b]Calculated from 1:50 000 NTS maps.

The numerical dominance by blue-green algae among the eight Doris Hinge lakes suggested that this group was able to take advantage of existing conditions and substantially increase its population; indeed, many species of blue-green algae exhibit rapid population increases when conditions are suitable (Hoogenhout and Amez 1964). Blue-green algae can regulate their buoyancy (Reynolds 1975), and thus can better maintain themselves near the surface where incident light is greatest, and where the samples were collected (i.e., 1.0 m depth). Large concentrations of algae near the surface also can effectively shade other algae in the deeper waters (Fogg 1966), thereby inhibiting production of those species that cannot regulate their buoyancy and move toward the surface.

Blue-green algae can also fix atmospheric nitrogen, thereby flourishing during periods when concentrations of available dissolved nitrogen are low (Dugdale and Dugdale 1962). Water quality results included in this compilation report (see Section 3) indicated that nitrate + nitrite nitrogen levels were low among the eight lakes and throughout all sampling sessions. The low available nitrogen levels may be a limiting factor for populations of non blue-green algae.

5.2 PERIPHYTON IN STREAMS

Periphyton is the algae, bacteria, fungi, and associated materials that surround solid surfaces in aquatic systems (Lock et al. 1984). The periphytic algal community is often monitored or assessed because of the following: 1) minimal sampling effort, 2) algae are numerically abundant, diverse, and easy to identify, and 3) periphytic algae form part of the lower trophic food chain level (i.e., convert sunlight into biological tissues), upon which other life forms depend.

5.2.1 Methods

Periphyton samples were collected from seven streams within the Doris Hinge area (Figure 5.1). Two to four sampling sessions were conducted on each stream between 1996 and 2000. Periphyton samples were not collected in 1998 and 1999 (Table 5.3).

Table 5.3 Periphyton sampling schedule in Doris Hinge streams, 1996 to 2000.

Stream	Date Sampled			
	1996	1997	1997	2000
Doris Outflow	22 August	19 July	20 August	16 August
Tail Outflow		19 July	19 August	16 August
Ogama Outflow	22 August	18 July	20 August	
Patch Outflow	23 August		21 August	
Windy Outflow	23 August	18 July	21 August	
Little Roberts Outflow	23 August	19 July	19 August	
Pelvic Outflow		19 July	21 August	16 August

Artificial substrates (100-cm^2 plexiglass plates) were used to collect periphytic algal and chlorophyll *a* (the primary photosynthesizing chelate, a biomass estimate of the amount of live plant tissue) samples. At each site, five artificial substrates were anchored in an upright position for approximately one month during June to July period and/or July to August period.

Chlorophyll *a* samples were obtained by gently scraping a known surface area of an artificial substrate into a plastic wide-mouth jar using filtered stream water and a brush. Filtered stream water was added to keep the sample moist and in suspension. Jars were kept cold and in the dark until returned to the field laboratory, where the samples were gently shaken and filtered onto 47-mm diameter membrane filters with a pore size of 0.45 µm. Filters were carefully folded in half, wrapped in aluminum foil, and frozen until analysed by the fluorometric method of Parsons et al. (1984). Chlorophyll *a* samples were collected from one replicate artificial substrate during the latter of two sampling sessions conducted in 1997, whereas in 2000, three replicate chlorophyll *a* samples were collected during one sampling session (raw data not reported by Rescan 2001). Chlorophyll *a* samples were not collected in 1996.

Where possible (e.g., depending on the status and recoverability of the artificial substrates), three replicate periphytic algal samples were collected at each study location. The actual number of replicates recovered from each site ranged between one and three. A known surface area of each artificial substrate was gently scraped into a 500-mL plastic wide-mouth jar using filtered stream water and a brush. Filtered stream water was added to keep the sample in suspension (approximately 100 mL). Samples were then preserved in Lugol's iodine solution and submitted to Fraser Environmental Services for identification and enumeration.

5.2.2 Doris Outflow

Four periphyton sampling sessions were conducted on Doris Outflow during the summer: once in 1996, twice in 1997, and once in 2000. Mean total algal cell numbers (± 1 SE) ranged from 189 ± 16.3 x 10^3 cells/cm^2 on 16 August 2000 to 5653 ± 1595 x 10^3 cells/cm^2 on 22 August 1996. Chlorophyll *a* concentrations were 194 and 0.530 µg/cm^2 on 20 August 1997 and 16 August 2000, respectively (Figure 5.9; Appendices B3 and B4).

Cyanophyta, also known as Cyanobacteria and colloquially referred to as blue-green algae, contributed between 41.3 and 87.9% towards the total mean number of cells enumerated per sampling session (Figure 5.9; Appendices B3 and B4). Bacillariophyta (diatoms) also contributed greatly towards total cell numbers (11.7 to 51.3%). The single most major contributor to Cyanobacteria was *Oscillatoria* spp., whereas Bacillariophyta were primarily represented by *Achnanthes minutissima* in 1996, *Diatoma elongatum* in 1997, and *Achnanthes* spp. in 2000. The 2000 samples included Rhodophyta (red algae) and unidentified groups (contributing 3.2% towards total cell numbers).

5.2.3 Tail Outflow

Three periphyton sampling sessions were conducted on Tail Outflow; artificial substrates were retrieved in July 1997, August 1997, and August 2000. Mean total algal cell numbers (± 1 SE) ranged from 202 ± 34.2 x 10^3 cells/cm^2 on 19 August 1997 to 520 ± 135 x 10^3 cells/cm^2 on 16 August 2000. Periphytic chlorophyll *a* concentrations were 66.9 µg/cm^2 on 19 August 1997 and 0.310 µg/cm^2 on 16 August 2000 (Figure 5.10; Appendices B3 and B4).

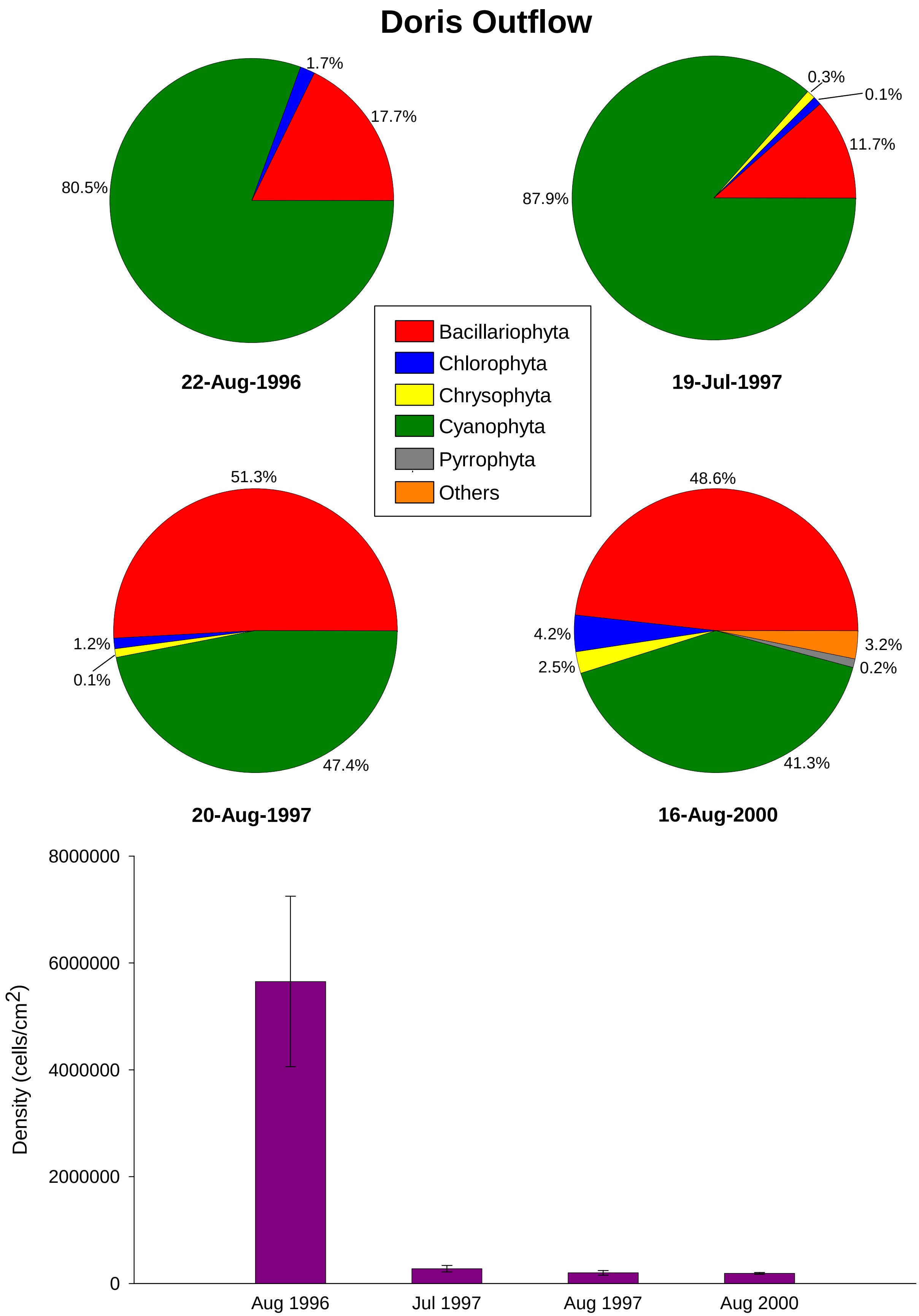
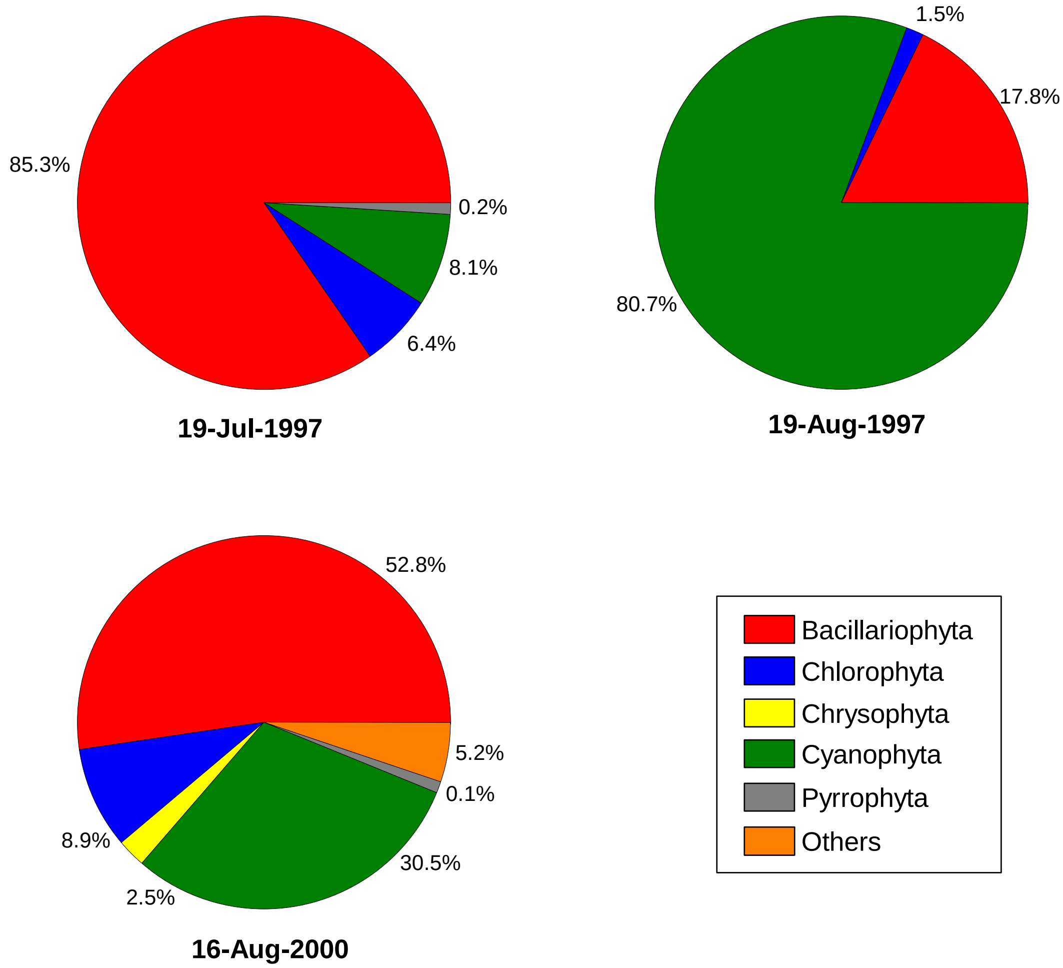


Figure 5.9 Relative abundance of major taxonomic groups and mean total density (± 1SE) of periphyton in Doris Outflow, 1996 to 2000.

Tail Outflow



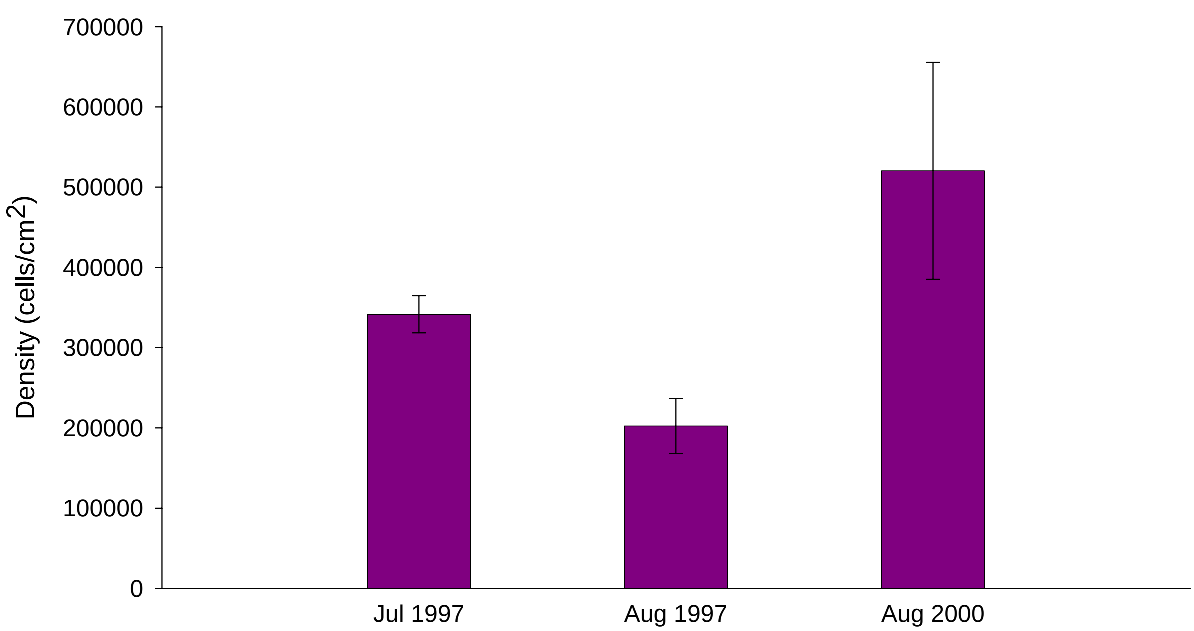


Figure 5.10 Relative abundance of major taxonomic groups and mean total density (± 1SE) of periphyton in Tail Outflow, 1997 to 2000.

In July 1997, the periphyton algal community of Tail Outflow was dominated by Bacillariophyta, which contributed 85.3% towards the total mean cell count in the sample (Figure 5.10; Appendices B3 and B4); the major contributors in this group were *Diatoma elongatum* and *Tabellaria flocculosa*. In August 1997, the periphyton algal community was dominated (80.7% of total cell numbers) by Cyanophyta (primarily *Oscillatoria* spp.). During the final sampling session (August 2000), the periphyton of Tail Outflow was dominated by Bacillariophyta (52.8% of total cell numbers) and Cyanophyta (30.5%); the Bacillariophyta were represented mainly by *Achnanthes* spp. and *Synedra* spp., whereas the Cyanophyta were primarily represented by *Pseudoanabaena catenata*. The 2000 samples included Rhodophyta and unidentified groups (contributing 5.2% towards total cell numbers) that were not identified as such in previous years.

5.2.4 Ogama Outflow

Three periphyton sampling sessions were conducted on Ogama Outflow, once during the summer of 1996 and twice during the summer of 1997. Mean total algal cell numbers (± 1 SE) ranged from 949 ± 264 x 10^3 cells/cm^2 in August 1997 to 3198 ± 621 x 10^3 cells/cm^2 in August 1996. Periphytic chlorophyll *a* concentration was 669 µg/cm^2 on 20 August 1997 (Figure 5.11; Appendices B3 and B4).

In August 1996, the periphyton algal community of Ogama Outflow was dominated by Cyanophyta (49.4% of total cell numbers) closely followed by Bacillariophyta (41.9%) (Figure 5.11; Appendices B3 and B4); these groups were dominated by *Oscillatoria tenuis* and *Fragilaria* spp. In July 1997, the periphyton community was dominated (90.8% of total cell numbers) by Bacillariophyta (primarily *Diatoma elongatum*). During the final sampling session (August 1997), the periphyton was dominated by Cyanophyta and Bacillariophyta (59.1 and 40.6% of total cell numbers, respectively); the Cyanophyta were represented mainly by *Lyngbya* spp., whereas the Bacillariophyta were represented mainly by *Diatoma elongatum* and *Gomphonema* spp.

5.2.5 Patch Outflow

Retrieval of the periphyton artificial substrates from Patch Outflow was conducted on 23 August 1996 and 21 August 1997. Mean total numbers (± 1 SE) on these dates were 768 ± 384 and 136 ± 27.9 x 10^3 cells/cm^2, respectively. On 21 August 1997, the chlorophyll *a* concentration was 46.3 µg/cm^2 (Figure 5.12; Appendices B3 and B4).

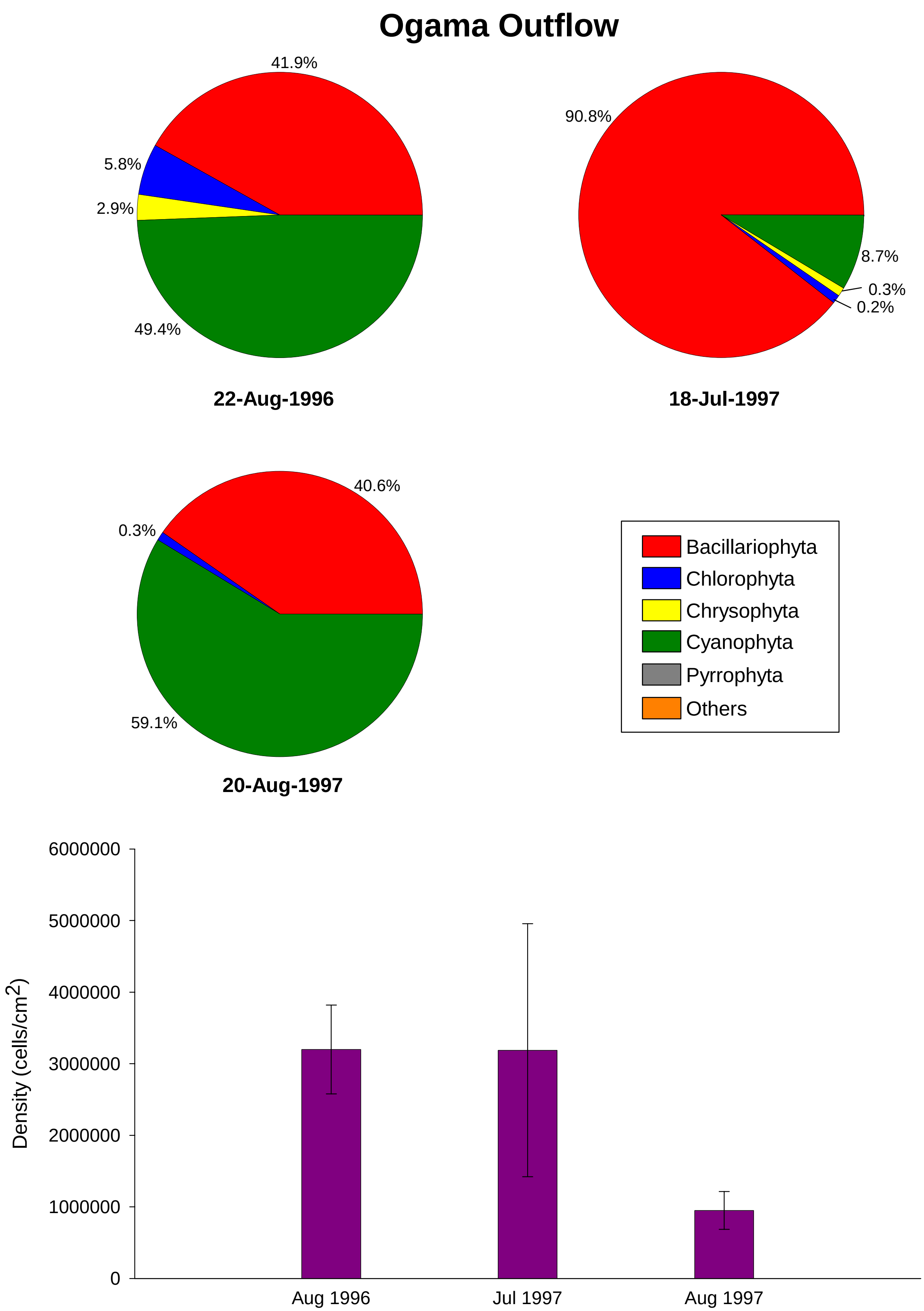


Figure 5.11 Relative abundance of major taxonomic groups and mean total density (± 1SE) of periphyton in Ogama Outflow, 1996 to 1997.

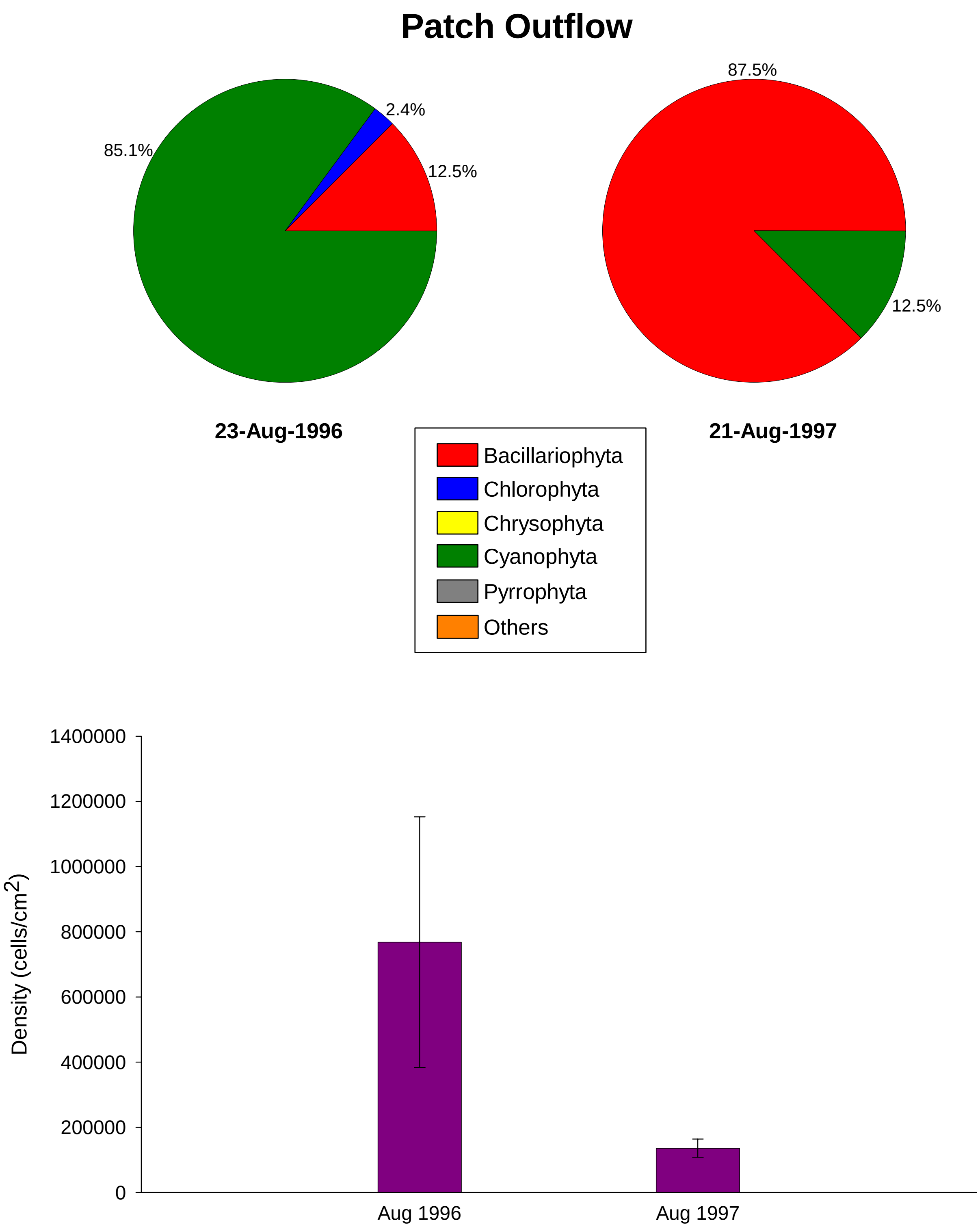


Figure 5.12 Relative abundance of major taxonomic groups and mean total density (± 1SE) of periphyton in Patch Outflow, 1996 to1997.

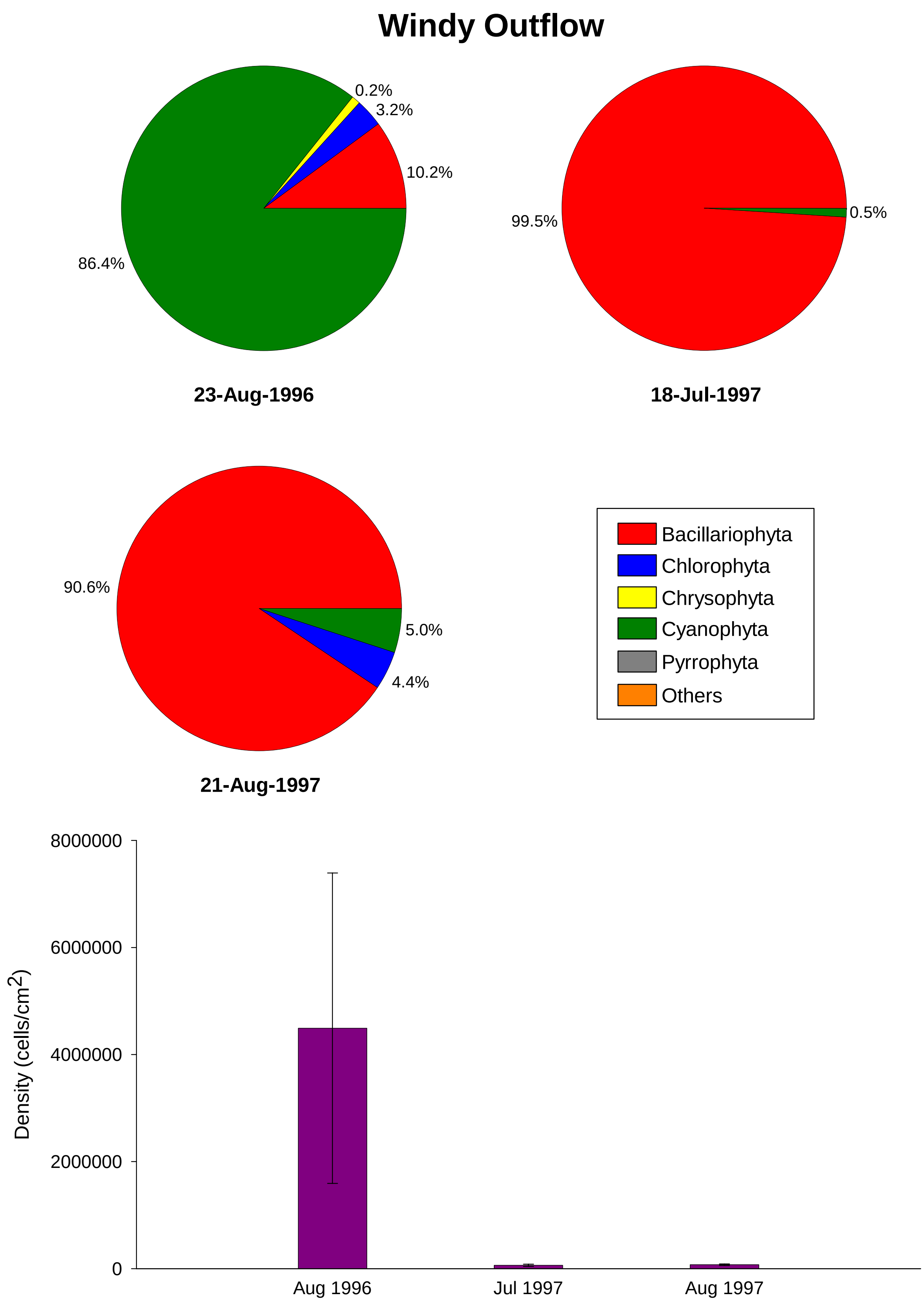


Figure 5.13 Relative abundance of major taxonomic groups and mean total density (± 1SE) of periphyton in Windy Outflow, 1996 to 1997.

In August 1996, the periphyton of Patch Outflow was dominated by Cyanophyta, which contributed 85.1% to the total mean cell count in the sample (Figure 5.12; Appendices B3 and B4). The major contributors in this group were *Lyngbya limnetica* and *Anabaena* spp. Within the same sampling session, the second most abundant major taxon was Bacillariophyta (12.5% of total cell numbers); this group was represented primarily by *Navicula* spp. In August 1997, the periphyton community of Patch Outflow was dominated by Bacillariophyta (contributing 87.5% towards the total cell count); *Diatoma elongatum* dominated this major taxonomic group.

5.2.6 Windy Outflow

Three periphyton sampling sessions were conducted on Windy Outflow; artificial substrates were retrieved once in 1996 and twice in 1997. Mean total algal cell numbers (± 1 SE) ranged from $63.0 \pm 21.7 \times 10^3$ cells/cm^2 on 21 August 1997 to $4493 \pm 2898 \times 10^3$ cells/cm^2 on 23 August 1996. On 21 August 1997, the chlorophyll *a* concentration was 27.5 µg/cm^2 (Figure 5.13; Appendices B3 and B4).

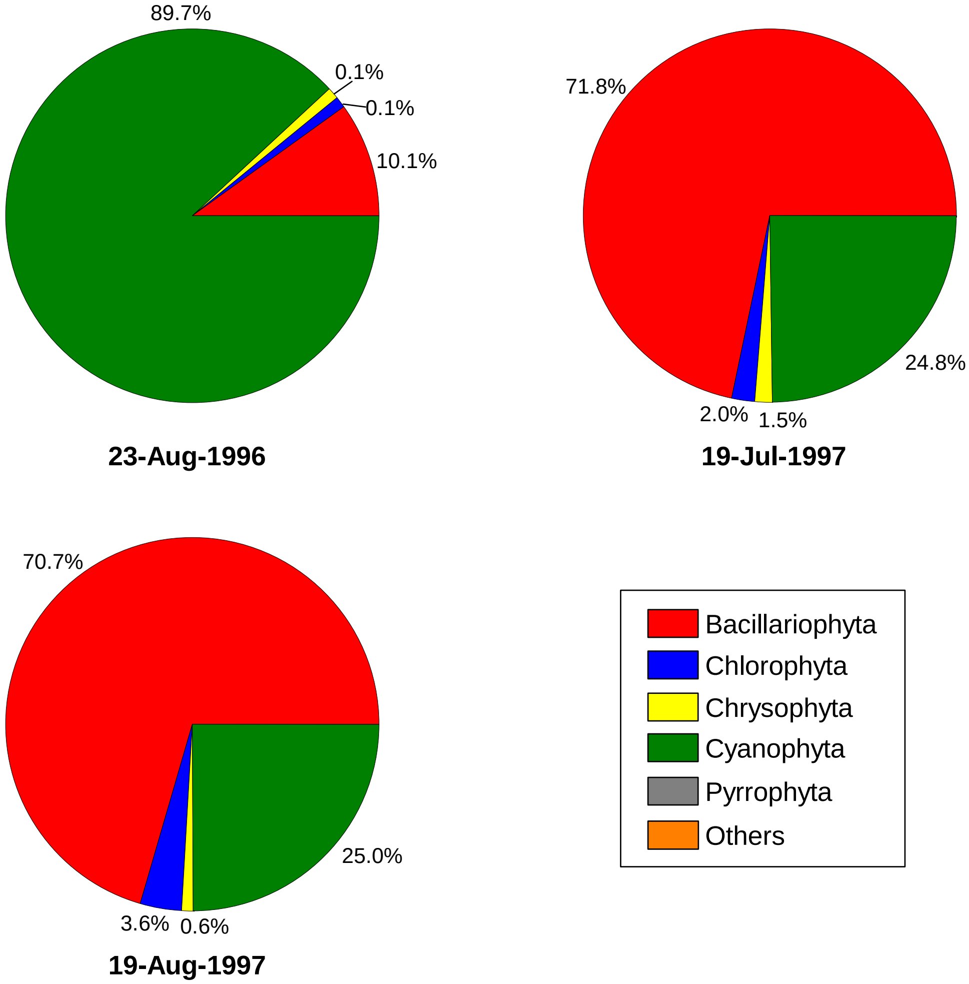
In August 1996, the periphyton algal community of Windy Outflow was dominated by Cyanophyta (86.4% of total cell numbers); this group was represented primarily by *Gloeotrichia* spp. and *Oscillatoria tenuis*. In July 1997, the periphyton algal community was almost exclusively dominated (99.5% of total cell numbers) by Bacillariophyta (primarily *Diatoma elongatum*). During the final sampling session (August 1997), the periphyton of Windy Outflow was dominated by Bacillariophyta (90.6% of total cell numbers), which were represented mainly by *D. elongatum* (Figure 5.13; Appendices B3 and B4).

5.2.7 Little Roberts Outflow

Three periphyton sampling sessions were conducted on Little Roberts Outflow; artificial substrates were retrieved once during the summer of 1996 and twice during the summer of 1997. Mean total algal cell numbers (± 1 SE) ranged from $287 \pm 143 \times 10^3$ cells/cm^2 in 1997 to $766 \pm 108 \times 10^3$ cells/cm^2 in 1996. On 19 August 1997, the chlorophyll *a* concentration was 61.8 µg/cm^2 (Figure 5.14; Appendices B3 and B4).

In August 1996, the periphyton algal community of Little Roberts Outflow was dominated by Cyanophyta (89.7% of total cell numbers); this group was represented primarily by Oscillatoria spp. The July 1997 and August 1997 samples were dominated (71.8 and 70.7% of total cell numbers, respectively) by Bacillariophyta, primarily *Diatoma elongatum* (Figure 5.14; Appendices B3 and B4).

Little Roberts Outflow



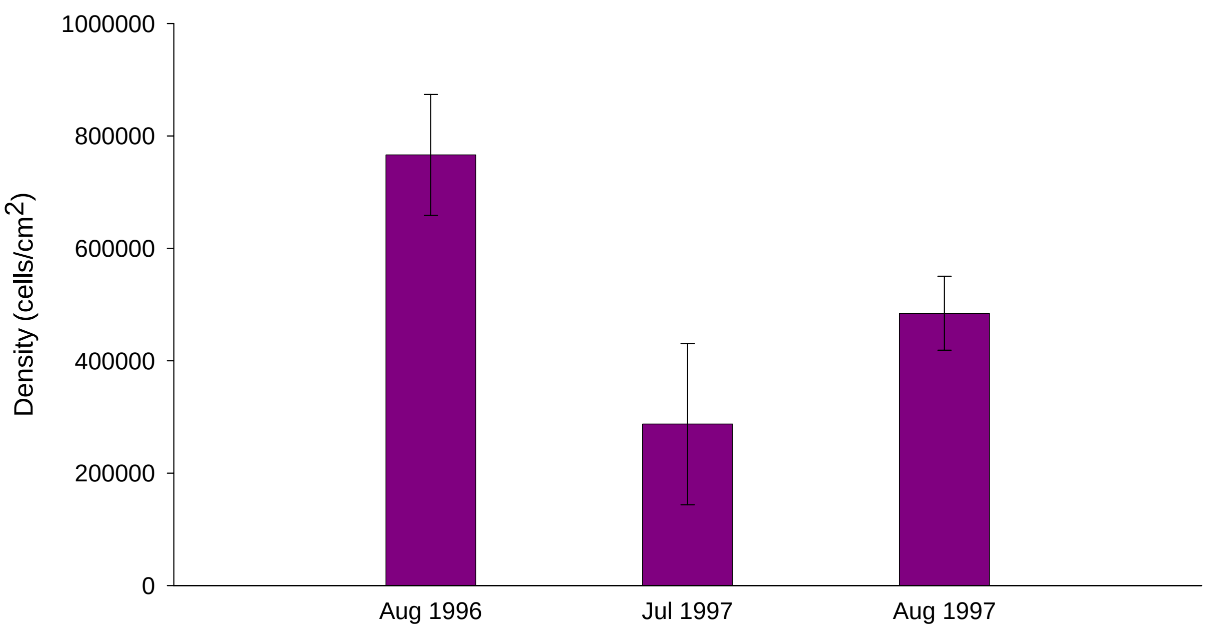


Figure 5.14 Relative abundance of major taxonomic groups and mean total density (± 1SE) of periphyton in Little Roberts Outflow, 1996 to 1997.

5.2.8 Pelvic Outflow

Three periphyton sampling sessions were conducted on Pelvic Outflow; artificial substrates were retrieved twice during the summer of 1997 and once during the summer of 2000. Mean total algal cell numbers (± 1 SE) ranged from 261 ± 120 x 10^3 cells/cm^2 on 16 August 2000 to 453 ± 126 x 10^3 cells/cm^2 on 21 August 1997. Chlorophyll *a* concentrations were 680 and 0.600 µg/cm^2 on 21 August 1997 and 16 August 2000, respectively (Figure 5.15; Appendices B3 and B4).

In July 1997, the periphyton algal community of Pelvic Outflow was dominated by Cyanophyta and Bacillariophyta, which contributed 62.8 and 37.1%, respectively, towards the total mean cell count in the sample (Figure 5.15; Appendices B3 and B4). The major contributors in these groups were *Oscillatoria tenuis* and *Diatoma elongatum*. In August 1997, the Pelvic Outflow periphyton algal community was dominated (69.5% of total cell numbers) by Bacillariophyta (primarily *Diatoma elongatum* and *Achnanthes minutissima*). During the final sampling session (August 2000), the periphyton was dominated by Bacillariophyta (55.3% of total cell numbers) and Cyanophyta (37.0%); the Bacillariophyta were represented mainly by *Achnanthes* spp. and *Fragilaria* spp., whereas the Cyanophyta were primarily represented by *Oscillatoria tenuis*. The 2000 samples included Rhodophyta and unidentified groups (contributing 3.4% towards total cell numbers) that were not identified as such in previous years.

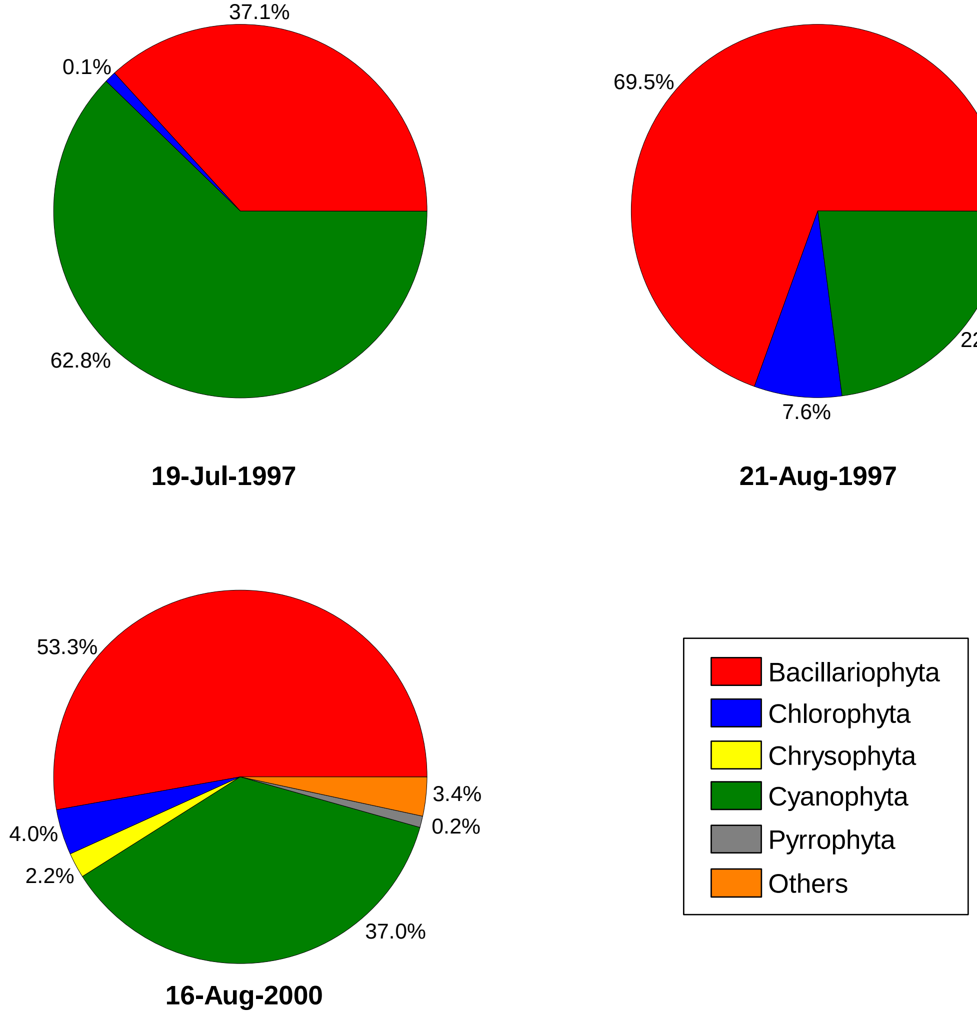
5.2.9 Summary

For the Doris Hinge streams, a comparison of mean periphyton abundance suggested that Doris, Ogama, and Windy outflows were highly productive and that Tail Outflow, closely followed by Pelvic Outflow, were the least productive (Table 5.4). Based on chlorophyll *a* concentrations, which is a biomass estimate of live algae, Pelvic Outflow was the most productive, whereas Windy Outflow was the least productive.

Table 5.4 Summary of periphyton abundance in Doris Hinge streams, 1996 to 2000.

Stream	Number of Sampling Events	Mean Cell Numbers ($\times 10^3$ cells/cm^2)	1997 Chlorophyll *a* (µg/cm^2)	2000 Chlorophyll *a* (µg/cm^2)
Doris Outflow	4	1580	194	0.539
Tail Outflow	3	355	66.9	0.310
Ogama Outflow	3	2445	669	--
Patch Outflow	2	452	46.3	--
Windy Outflow	3	1543	27.5	--
Little Roberts Outflow	3	513	61.8	--
Pelvic Outflow	3	381	680	0.600

Pelvic Outflow



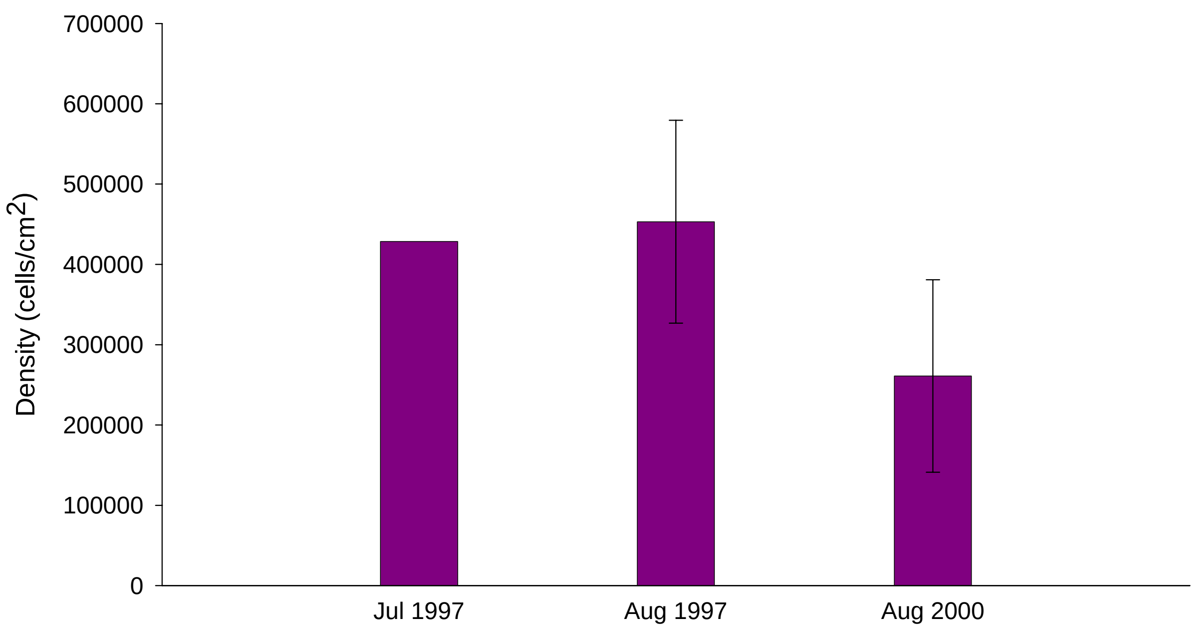


Figure 5.15 Relative abundance of major taxonomic groups and mean total density (± 1SE) of periphyton in Pelvic Outflow, 1997 to 2000.

Similar to the phytoplankton (see Section 5.1), the numerical dominance by Cyanophyta (mainly *Oscillatoria* spp.) among the seven Doris Hinge streams suggested that this group was able to take advantage of existing conditions and substantially increase its population. Blue-green algae can fix atmospheric nitrogen, thereby flourishing during periods when concentrations of available dissolved nitrogen are low (Dugdale and Dugdale 1962). Water quality results from the present study indicated that nitrate+nitrite nitrogen levels generally were low among the seven streams and throughout all sampling sessions. Bacillariophyta (mainly *Diatoma elongatum*) also were numerically abundant among the study streams. The predominant Cyanophyta and Bacillariophyta were represented by taxa that form filaments and are able to attach to, or entangle, substrata in flowing waters. The above observations were consistent with those made in other streams of the Arctic and sub-Arctic (RL&L 1997, 1998, 1999).

6.0 SECONDARY PRODUCERS

6.1 ZOOPLANKTON IN LAKES

In general, zooplankton are small animals that inhabit the water column of lakes. Zooplankton consume phytoplankton and other organic matter. Zooplankton in turn, are utilized by large invertebrates and fish as a food source.

6.1.1 Methods

Zooplankton samples were collected from eight lakes within the Doris Hinge area (Figure 6.1). One to four sampling sessions were conducted on each lake between 1996 and 2000. Zooplankton samples were not collected in 1998 and 1999 (Table 6.1).

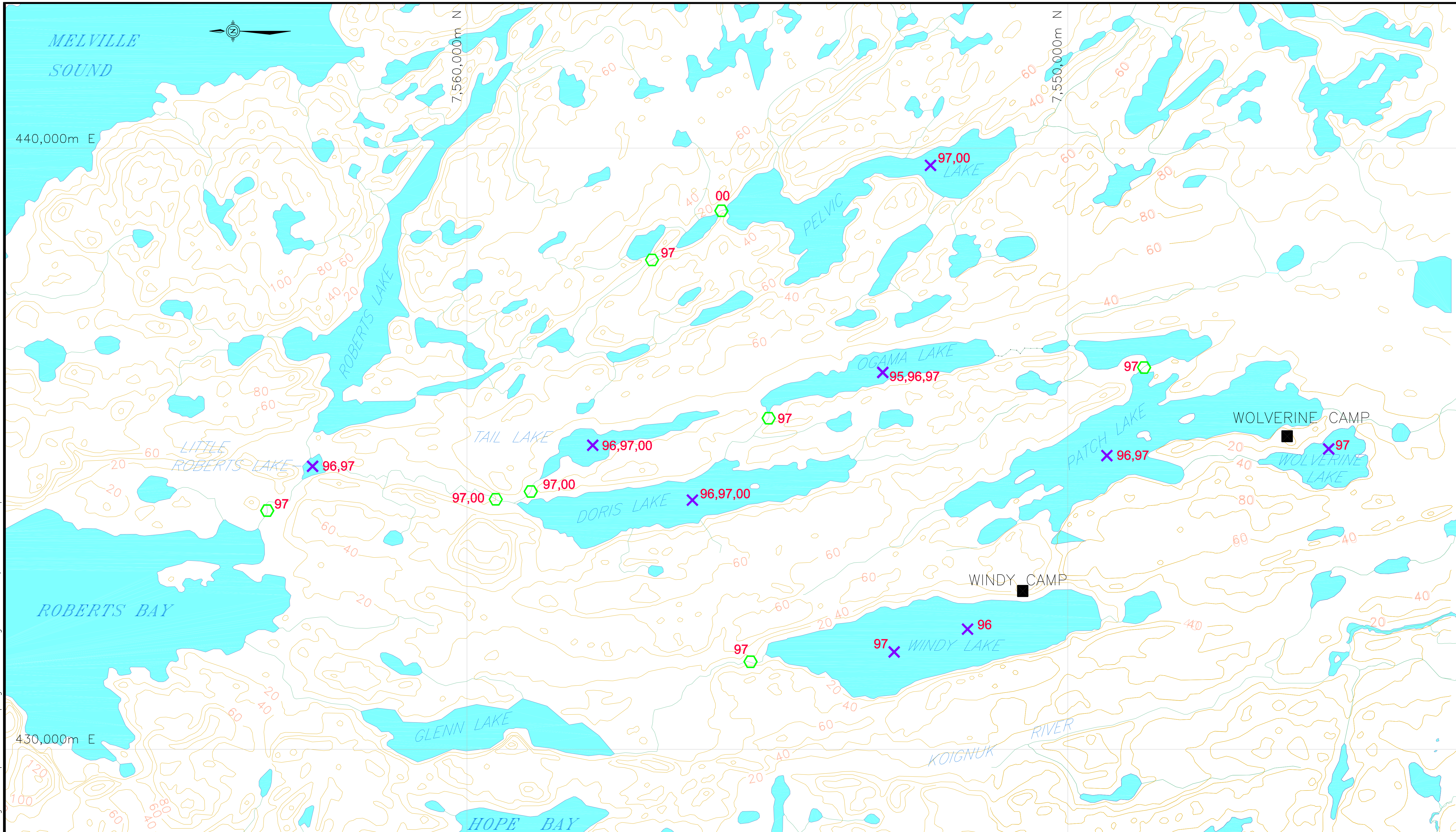
Table 6.1 Zooplankton sampling schedule in Doris Hinge lakes, 1996 to 2000.

Waterbody	Date			
	1996	1997	1997	2000
Doris Lake	28 August	18 July	22 August	19 July
Tail Lake	27 August	16 July		19 July
Ogama Lake	27 August	16 July		
Patch Lake	26 August	17 July		
Wolverine Lake		16 July		
Windy Lake	29 August	17 July		
Little Roberts Lake	27 August	15 July		
Pelvic Lake		17 July		19 July

Triplicate zooplankton samples were collected during each sampling session with a 118 µm mesh net featuring an opening aperture of 0.3 m. At each site, samples were collected from the entire water column beginning at a depth 2 m above the bottom sediments. At each site, a single haul was collected by vertically raising the net at a constant speed of 0.5 m/s. Each sample was transferred to a clean 500-mL plastic bottle, preserved with 10% formalin, and labeled. All samples were submitted to Applied Technical Services, Victoria, BC, for taxonomic identification and enumeration.

6.1.2 Doris Lake

Four zooplankton sampling sessions were conducted on Doris Lake during the summertime: once in 1996, twice in 1997, and once in 2000. Mean total numbers (± 1 SE) ranged from 8861 ± 441 animals/m^3 in August 1997 to 20 166 ± 4098 animals/m^3 in August 2000 (Figure 6.2; Appendices C1 and C2).



LEGEND

- × ZOOPLANKTON SAMPLING SITES IN LAKES
- ⬡ MACROINVERTEBRATE DRIFT SAMPLING LOCATIONS IN STREAMS
- 95,96 etc. YEARS OF SAMPLING

SCALE 1.5 0 1.5 KILOMETRES

NOTE : CONTOUR INTERVAL 20 m

REFERENCE
BASE MAP PROVIDED BY RESCAN, JANUARY 22, 2001

Hope Bay Joint Venture

TITLE
ZOOPLANKTON AND MACROINVERTEBRATE DRIFT SAMPLING LOCATIONS IN DORIS HINGE AREA, 1996-2000.

Golder Associates
Edmonton, Alberta

PROJECT No. 022-7009.1000			FILE No. Zooplankton Sampling	
DESIGN	AH	11/06/02	SCALE AS SHOWN	REV. 0
CADD	RFM	25/07/02	FIGURE: 6.1	
CHECK				
REVIEW				

In 1996, cylclopoid copepods followed by Rotifera (wheel-animals) contributed higher proportions towards the total mean number of zooplankton (50.1 and 43.3%, respectively). During each of the remaining three sampling session (July 1997, August 1997, and July 2000), rotifers dominated the zooplankton community of Doris Lake, contributing 76.1, 45.7, and 52.6% towards total number of animals, respectively. The major contributors to the cyclopoid copepods were immature copepodites (the most abundant species of adult size was *Cyclops scutifer*), whereas the rotifers were primarily represented by *Kellicottia longispina* (Figure 6.2; Appendices C1 and C2).

6.1.3 Tail Lake

Three zooplankton sampling sessions were conducted on Tail Lake, once during each of 1996, 1997, and 2000. Mean total numbers (± 1 SE) ranged from 18 588 ± 1382 animals/m^3 in 1996 to 108 265 ± 1980 animals/m^3 in 2000 (Figure 6.3; Appendices C1 and C2).

Cladocera (water fleas) contributed the most (49.1%) towards total numbers in 1996; rotifers were second in abundance (29.9%). In 1997, the zooplankton was dominated by cyclopoid copepods, closely followed by Cladocera (37.4 and 37.0%, respectively). Rotifers (48.7%) and Cladocera (34.4%) contributed the larger proportions towards total numbers in 2000. The major contributors to the Cladocera were *Daphnia longiremis*, whereas cyclopoid copepods were well represented by *Cyclops scutifer*. *Kellicottia longispina* dominated the rotifers (Figure 6.3; Appendices C1 and C2).

6.1.4 Ogama Lake

Zooplankton sampling sessions on Ogama Lake were conducted on 27 August 1996 and 16 July 1997. Mean total numbers (± 1 SE) on these dates were 15 624 ± 2579 and 13 456 ± 4629 animals/m^3, respectively (Figure 6.4; Appendices C1 and C2).

In August 1996, the zooplankton of Ogama Lake was dominated by Cladocera, which contributed 41.1% towards the total mean animal count in the sample (Figure 6.4; Appendices C1 and C2); cyclopoid copepods were second in abundance at 32.9%. The major contributors in these groups were *Daphnia longiremis* and unidentified copepodites. In July 1997, the zooplankton community was dominated by cyclopoid copepods (39.2% of total numbers), followed closely by Rotifera (38.0%). These two major taxonomic groups were represented primarily by *Cyclops bicuspidatus thomasi* and *Kellicottia longispina*, respectively.

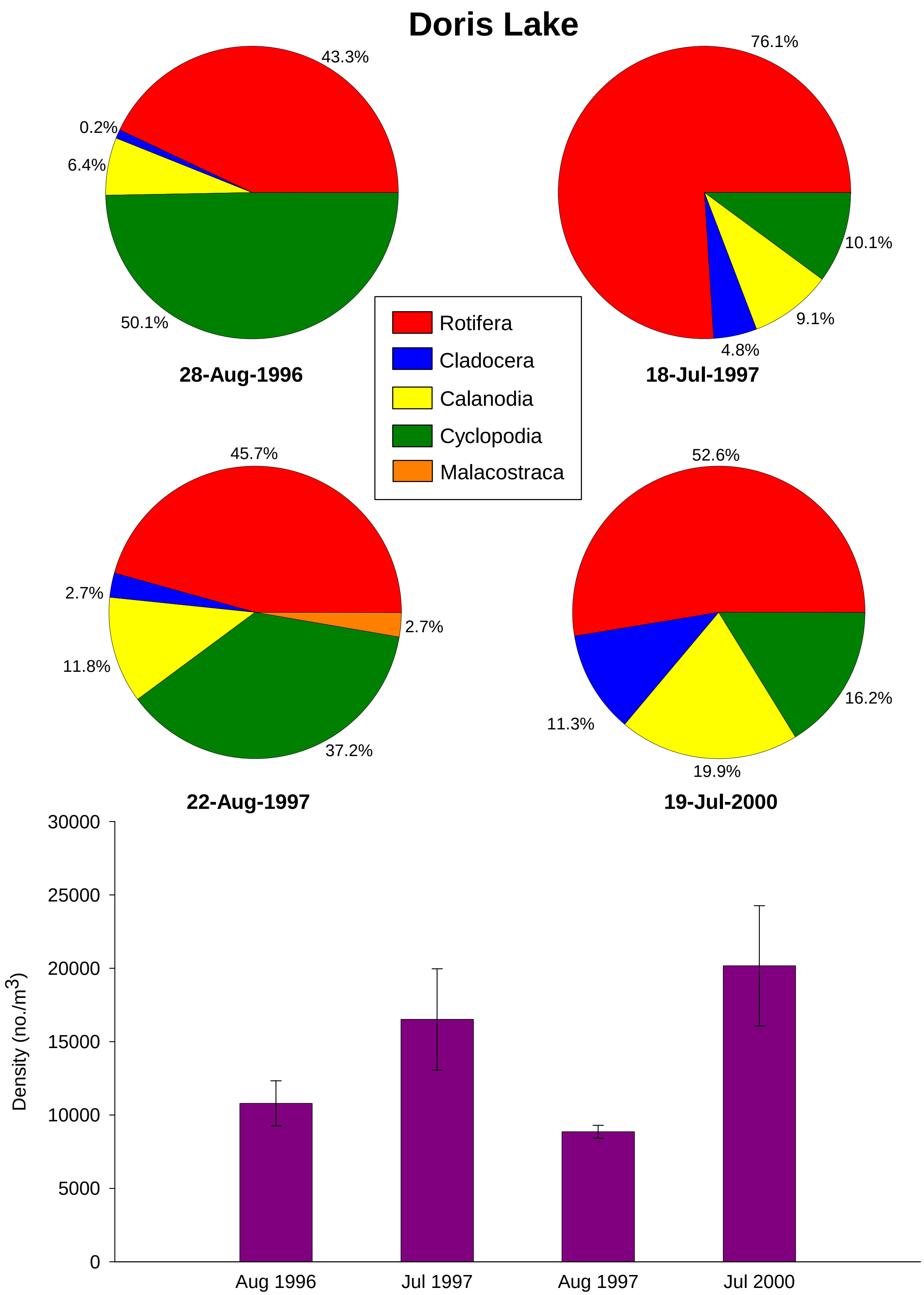


Figure 6.2 Relative abundance of major taxonomic groups and mean total density (± 1SE) of zooplankton in Doris Lake, 1996 to 2000.

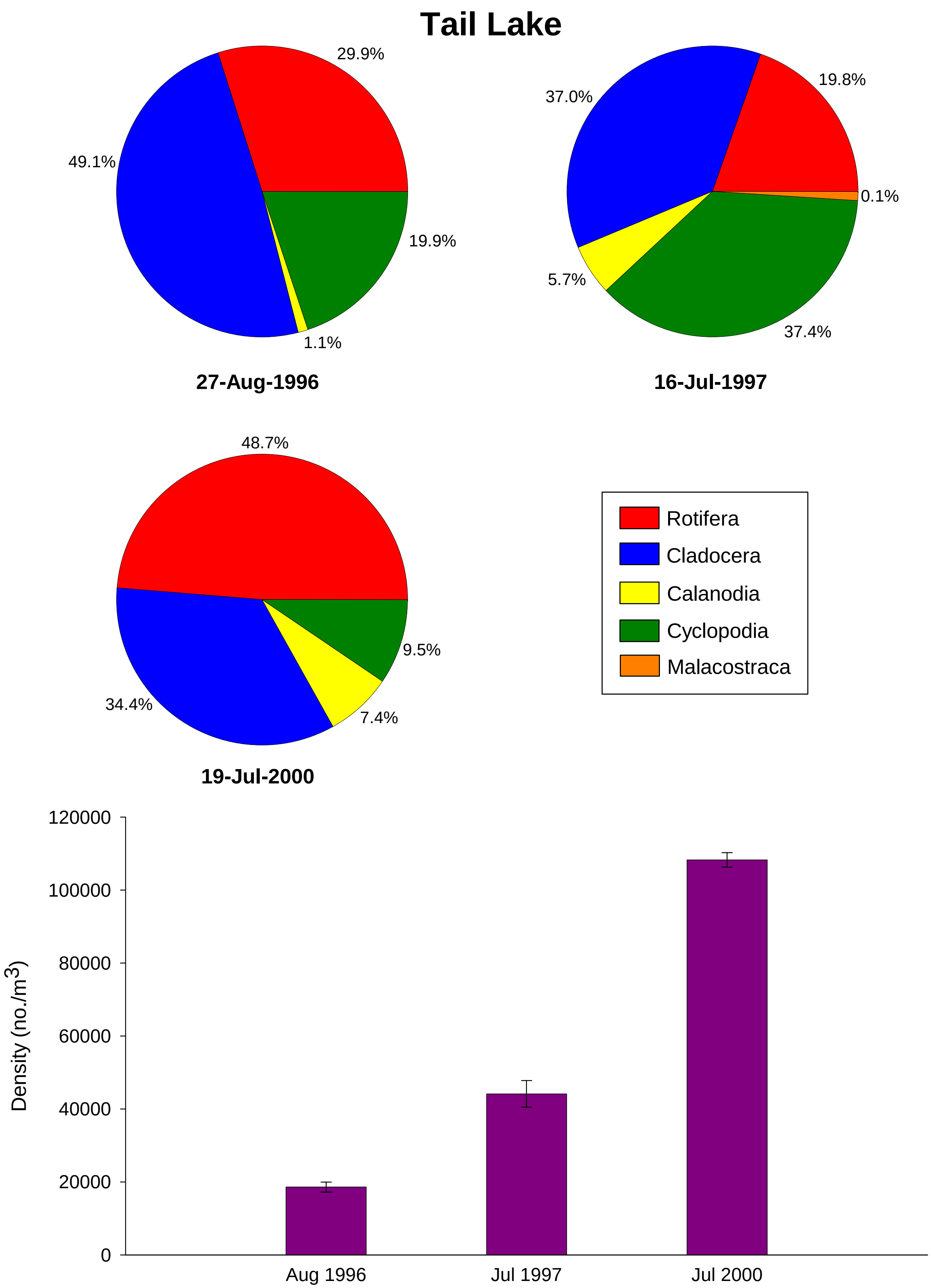
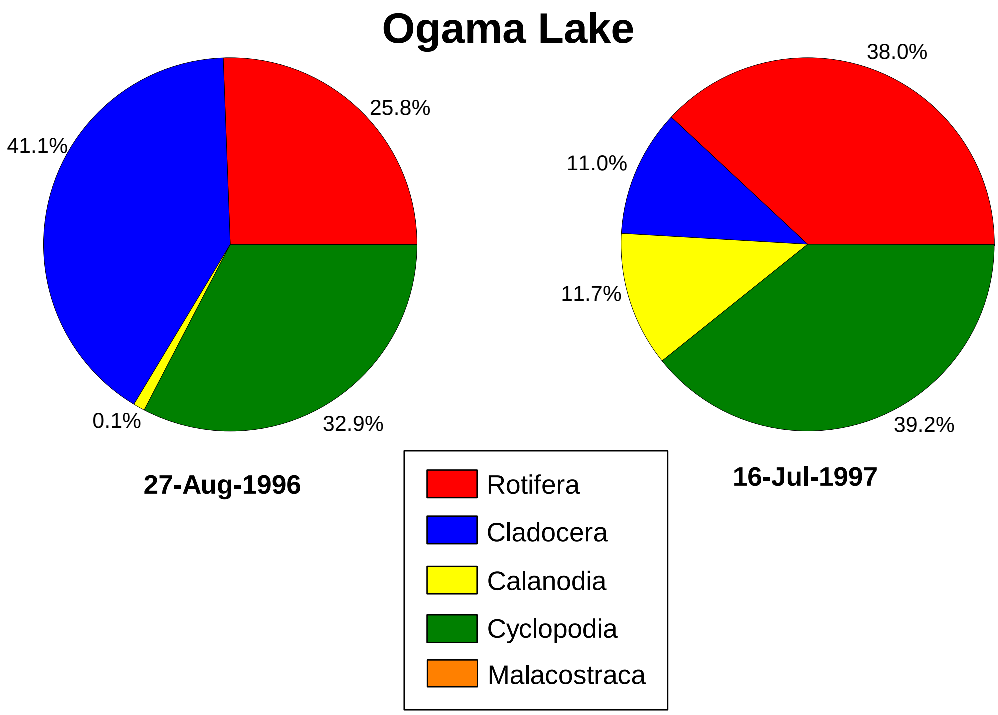


Figure 6.3 Relative abundance of major taxonomic groups and mean total density (± 1SE) of zooplankton in Tail Lake, 1996 to 2000.



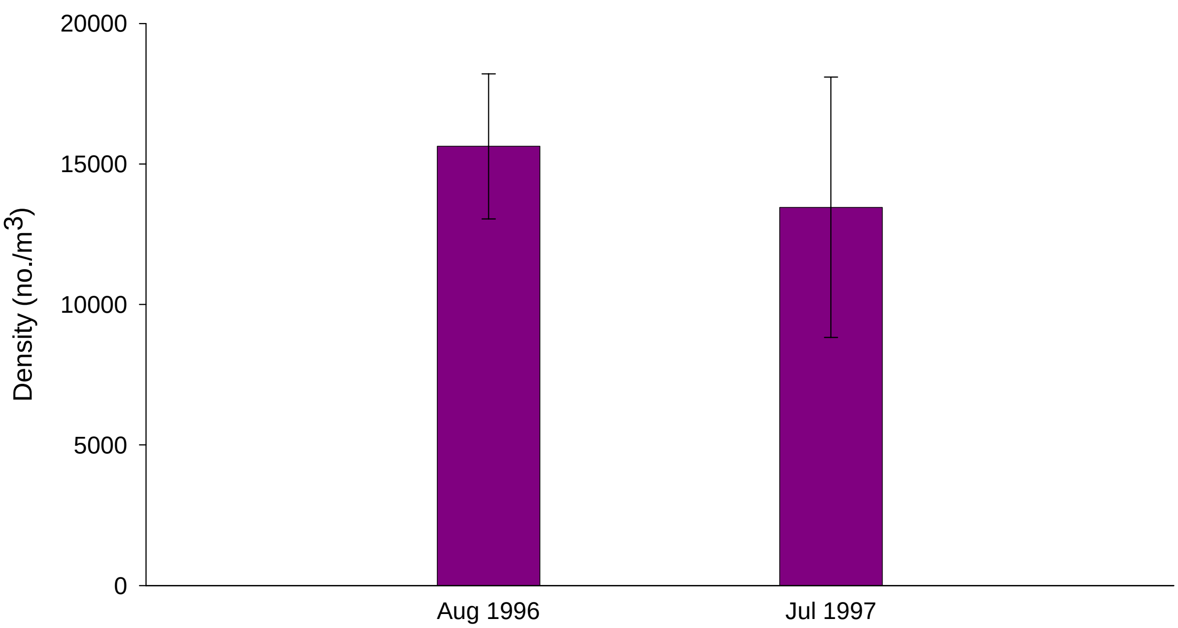


Figure 6.4 Relative abundance of major taxonomic groups and mean total density (± 1SE) of zooplankton in Ogama Lake, 1996 to 1997.

6.1.5 Patch Lake

Zooplankton sampling sessions on Patch Lake were conducted on 26 August 1996 and on 17 July 1997. Mean total numbers (± 1 SE) on these dates were 9907 ± 453 and 18 799 ± 4197 animals/m^3, respectively (Figure 6.5; Appendices C1 and C2).

In August 1996, the zooplankton of Patch Lake was dominated by cyclopoid copepods, which contributed 36.7% to the total mean animal count in the sample (Figure 6.5; Appendices C1 and C2); the major contributors within this major taxonomic group were unidentified copopodites. Within the same sampling session, the second and third most abundant major taxa were Rotifera (31.6% of total numbers) followed by Cladocera (28.6% of total numbers); these groups were represented primarily by *Kellicottia longispina*, and *Daphnia longiremis*, respectively. In July 1997, Rotifera, contributing 61.9% towards the total animal count, dominated the zooplankton community of Patch Lake. This major taxonomic group was represented primarily by *Kellicottia longispina* and *Keratella* spp.

6.1.6 Wolverine Lake

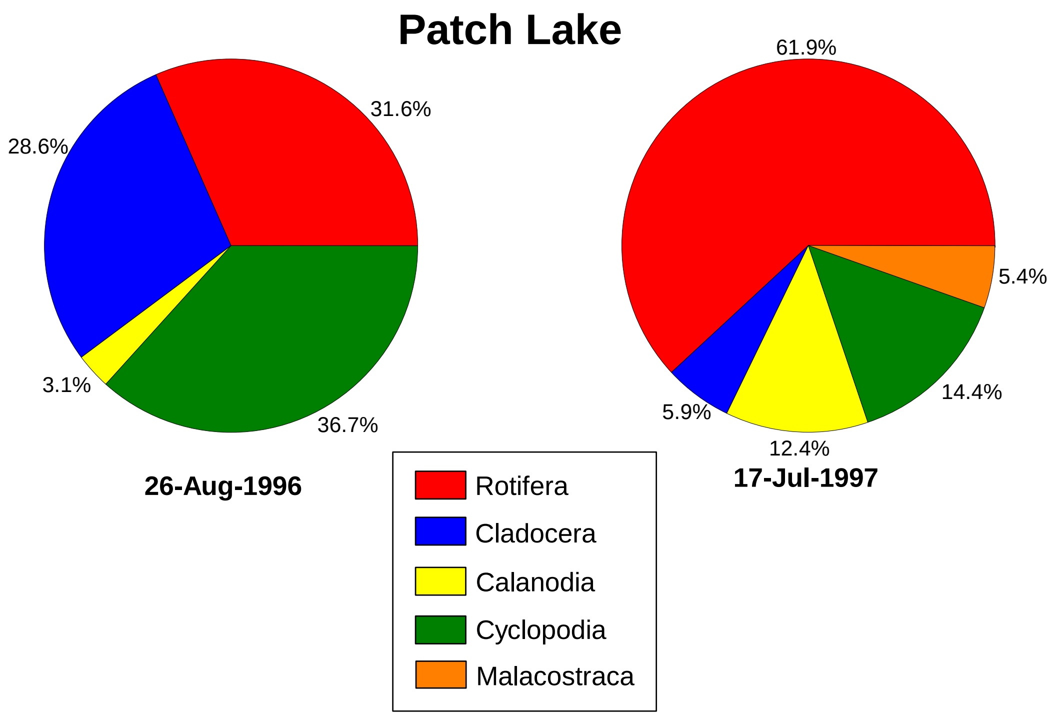
The zooplankton of Wolverine Lake was collected only on 16 July 1997. The mean total number (± 1 SE) was 12 630 ± 1054 animals/m^3 (Appendices C1 and C2).

The zooplankton of Wolverine Lake was dominated by Rotifera, which contributed 52.0% towards the total mean count in the sample. The major contributors within this group were *Kellicottia longispina, Keratella cochlearis*, and *Asplanchna* spp. The second and third most abundant major taxonomic groups were cyclopoid copepods and calanoid copepods (29.7 and 17.6% of total numbers, respectively); these groups were represented mainly by unidentified nauplii (Appendices C1 and C2).

6.1.7 Windy Lake

Zooplankton sampling sessions on Windy Lake were conducted on 29 August 1996 and 17 July 1997. Mean total numbers (± 1 SE) on these dates were 2531 ± 763 and 835 ± 50 animals/m^3, respectively (Figure 6.6; Appendices C1 and C2).

In August 1996, the zooplankton of Windy Lake was almost exclusively represented by Rotifera, which contributed 97.7% towards the total mean count in the sample (Figure 6.6; Appendices C1 and C2). The major contributor in this group was *Kellicottia longispina*. In July 1997, the zooplankton community was



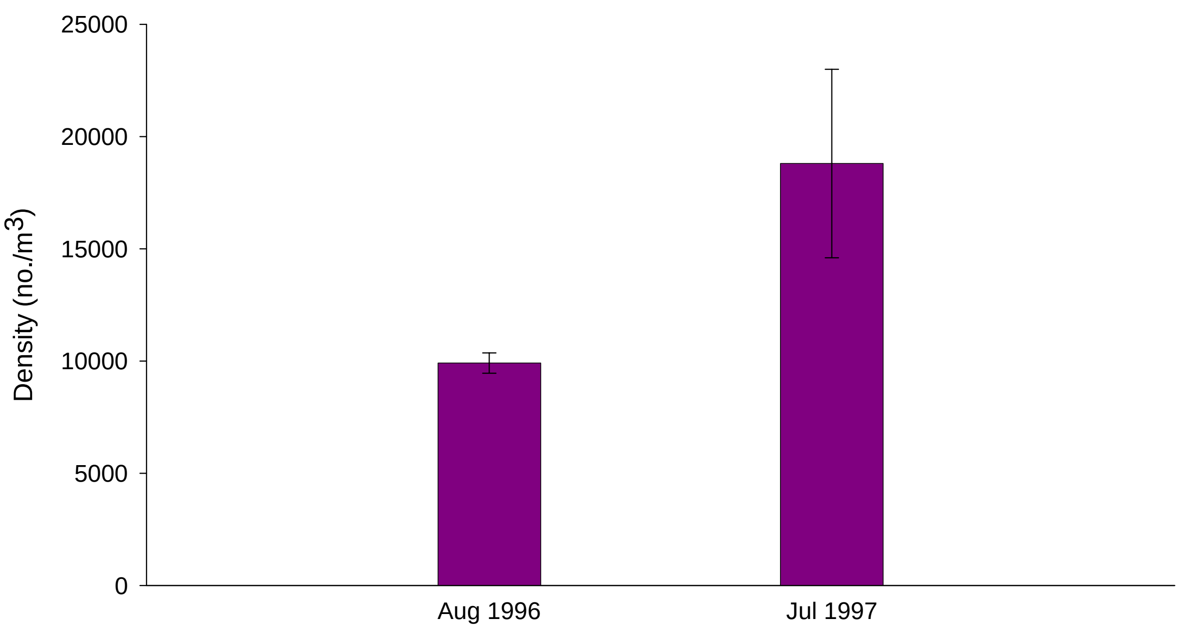
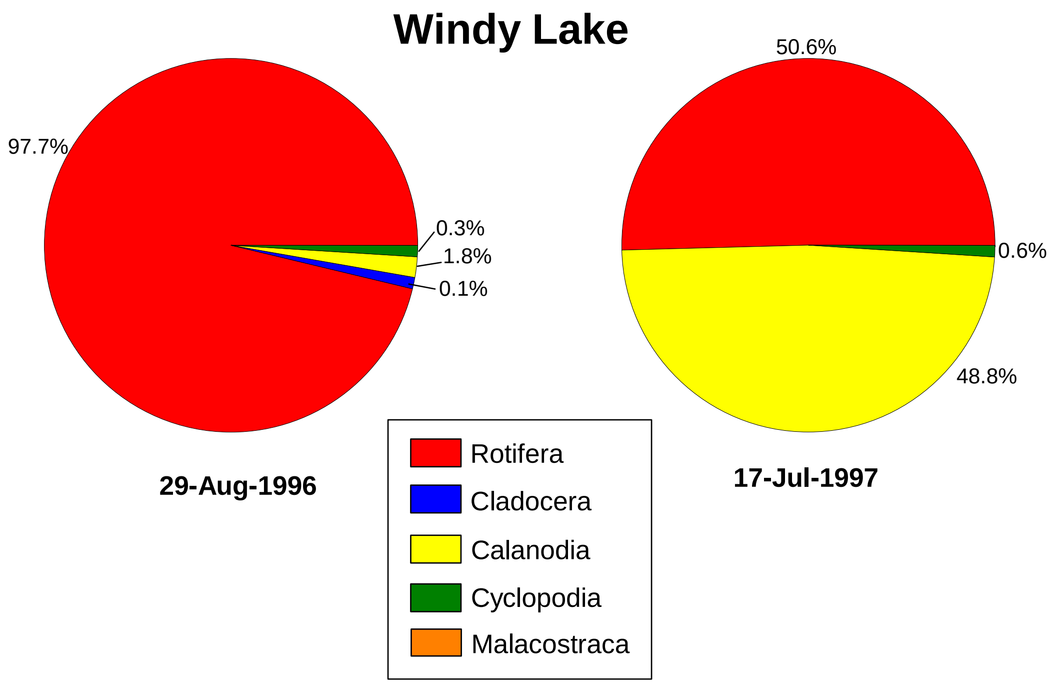


Figure 6.5 Relative abundance of major taxonomic groups and mean total density (± 1SE) of zooplankton in Patch Lake, 1996 to 1997.



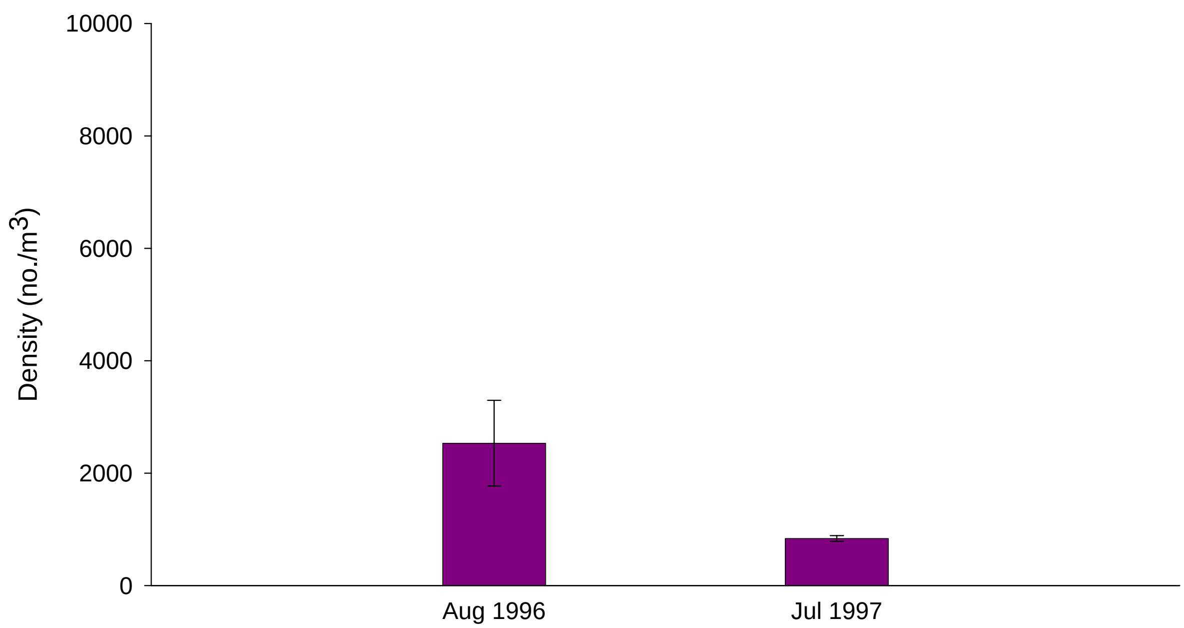


Figure 6.6 Relative abundance of major taxonomic groups and mean total density (± 1SE) of zooplankton in Windy Lake, 1996 to 1997.

dominated by Rotifera (50.6% of total numbers), followed closely by calanoid copepods (48.8%); these two major taxonomic groups were represented primarily by *Conochilus unicornis* and *Limnocalanus macrurus*, respectively.

6.1.8 Little Roberts Lake

Zooplankton sampling sessions on Little Roberts Lake were conducted during August 1996 and July 1997. Mean total numbers (± 1 SE) for these years were 4082 ± 490 and 4903 ± 1122 animals/m^3, respectively (Figure 6.7; Appendices C1 and C2).

The zooplankton of Little Roberts Lake was dominated by Rotifera, which contributed 58.6 and 59.9% towards the total mean cell count within the August 1996 and July 1997 samples, respectively (Figure 6.7; Appendices C1 and C2). The major contributors (in descending order of abundance) in this group for both study years were *Kellicottia longispina*, *Keratella quadrata*, and *Conochilus unicornis*. Cyclopoid copepods, mainly unidentified copepodites and *Cyclops scutifer*, were second in abundance for both study years (23.2 and 15.8% of total numbers in 1996 and 1997, respectively).

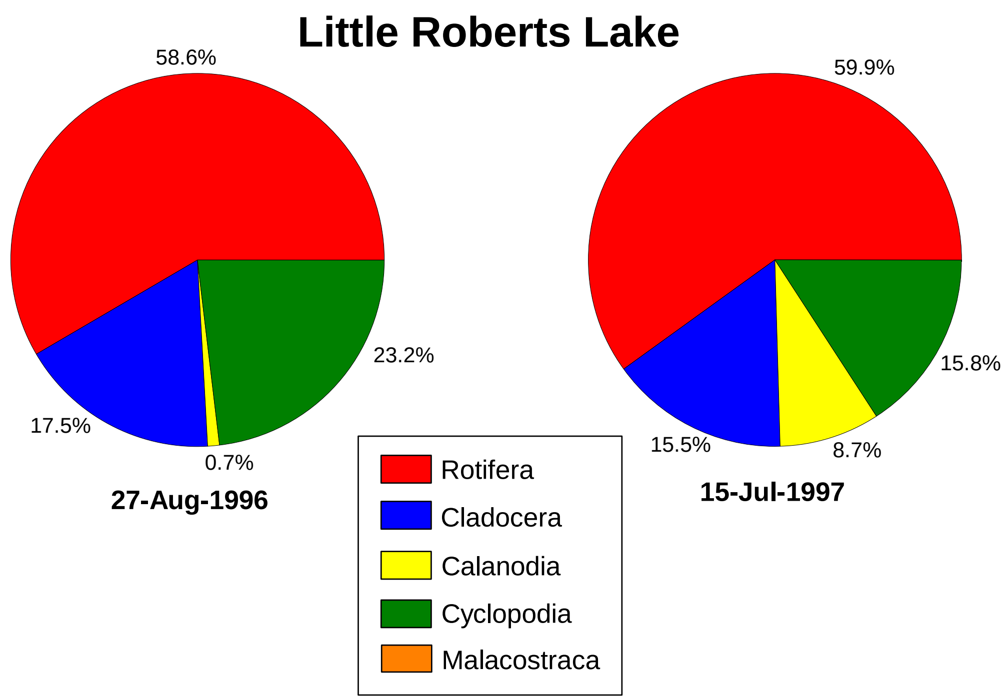
6.1.9 Pelvic Lake

Zooplankton sampling sessions for Pelvic Lake were conducted on 17 July 1997 and 19 July 2000. Mean total numbers (± 1 SE) on these dates were 13 303 ± 957 and 76 290 ± 3691 animals/m^3, respectively (Figure 6.8; Appendices C1 and C2).

The zooplankton of Pelvic Lake was dominated by Rotifera, which contributed 75.3 and 73.7% towards the total mean counts within the July 1997 and July 2000 samples, respectively (Figure 6.8; Appendices C1 and C2). The major contributor in this group for both study years was *Keratella quadrata*. Cylclopoid copepods also were abundant in both study years (18.9 and 17.7% of total numbers in 1997 and 2000, respectively). This group of copepods was represented primarily by unidentified copepodites and nauplii, as well as *Cyclops scutifer* and *Cyclops bicuspidatus thomasi*.

6.1.10 Summary

The zooplankton samples obtained from the Doris Hinge lakes revealed no uncommon or rare species. The zooplankton communities (i.e., taxonomic composition) among the eight waterbodies showed little differentiation and were similar in many respects to the communities of many other small lakes in the Arctic and sub-Arctic (Moore 1978a, 1978b; RL&L 1997, 1998, 1999).



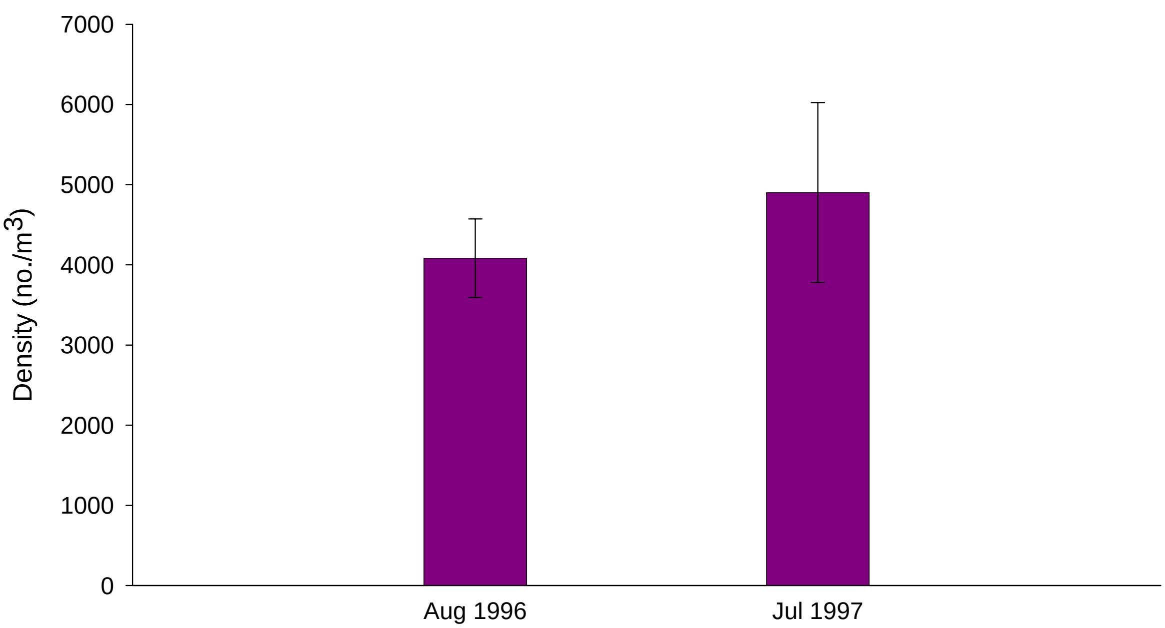
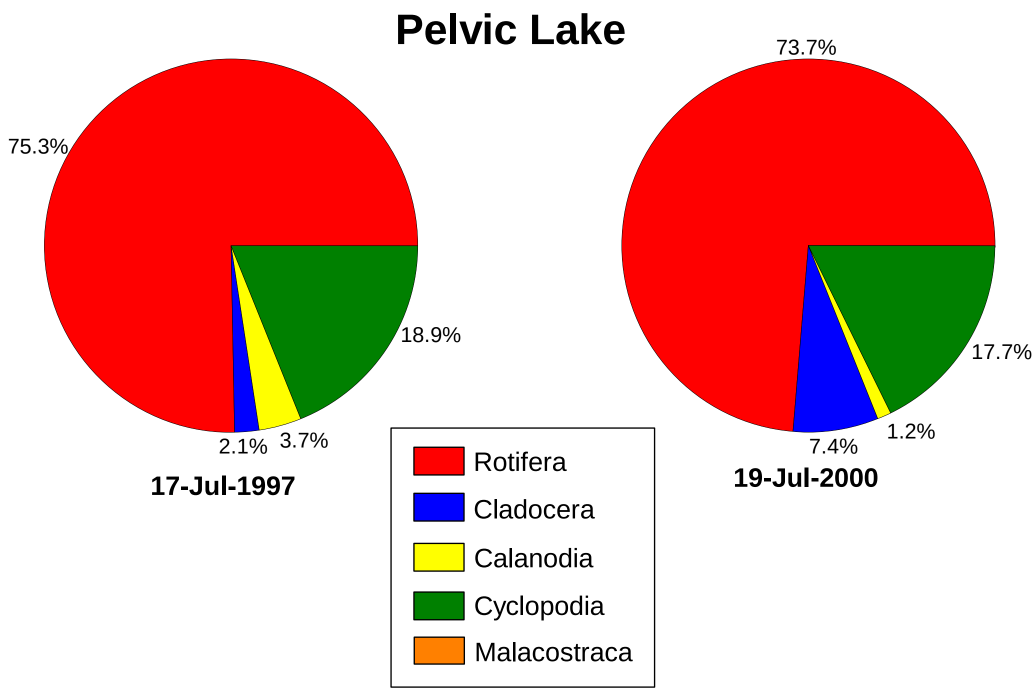


Figure 6.7 Relative abundance of major taxonomic groups and mean total density (± 1SE) of zooplankton in Little Roberts Lake, 1996 to 1997.



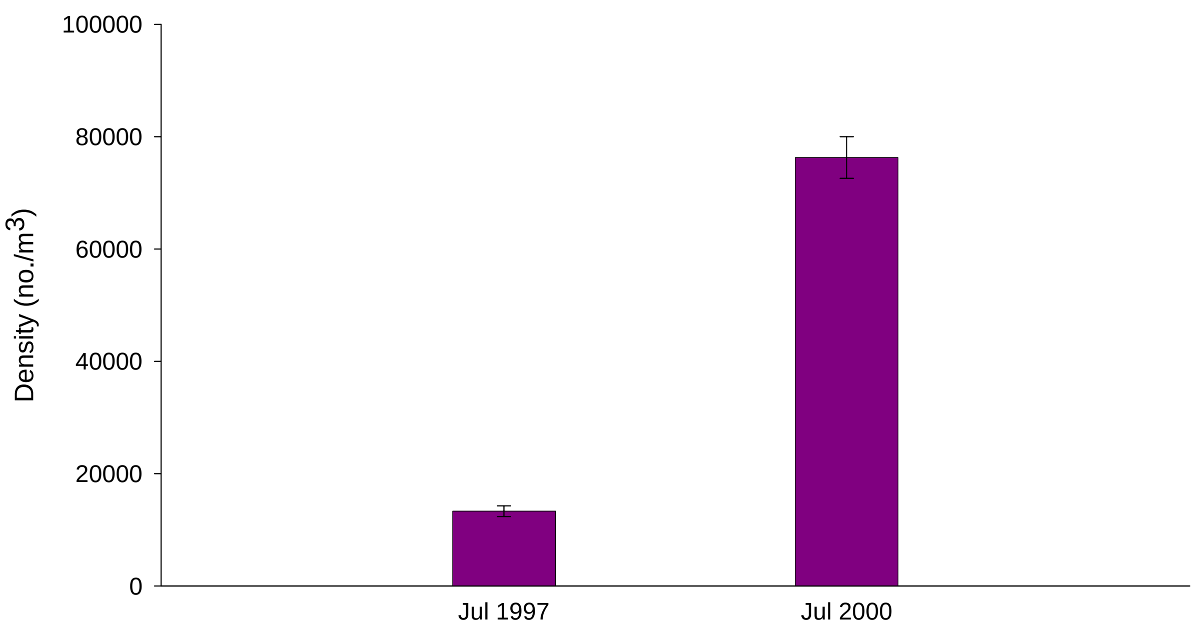


Figure 6.8 Relative abundance of major taxonomic groups and mean total density (± 1SE) of zooplankton in Pelvic Lake, 1997 to 2000.

In general, zooplankton communities within the Doris Hinge lakes were numerically dominated by the rotifer, *Kellicottia longispina*. It should be pointed out, however, that the numbers of rotifers reported were likely underestimated, because the mesh size of the zooplankton net was 118 µm (i.e., smaller rotifers could pass through the mesh). The most common cladoceran was *Daphnia longiremis*.

A comparison of mean zooplankton abundance indicated that Tail Lake was the most productive and that Windy Lake was the least productive; mean total numbers among all sampling sessions in these two lakes were 56 996 and 1683 animals/m^3, respectively (Table 6.2). This observation may be somewhat misleading because biomass data, often reported as wet weight/m^3, were not reported by Rescan (1997, 1998, and 2001). In terms of biomass, large zooplankton species can dominate zooplankton communities, while concurrently remaining numerically subdominant. For example, cladocerans invariably dominated the biomass of eight study lakes located near Rankin Inlet, Nunavut, and six lakes situated near Lupin, Nunavut, despite being overwhelmingly outnumbered by small-sized species of rotifers (RL&L 1997, 1998, 1999). Among zooplankton communities, rotifers have small sized species relative to other groups, copepods have moderately sized species, and cladocerans have species that are large in size (particularly *Daphnia* spp.).

Table 6.2 Summary of zooplankton abundance in Doris Hinge lakes, 1996 to 2000.

Lake	Number of Sampling Events	Mean Total Density (animals/m^3)	Mean Number of Rotifera (animals/m^3)	Mean Number of Cladocera (animals/m^3)	Ratio of Rotifera to Cladocera
Doris	4	14 084	7 974	832	9.58
Tail	3	56 996	22 362	20 895	1.07
Ogama	2	14 540	4 576	3 954	1.16
Patch	2	14 353	7 386	1 977	3.74
Wolverine	1	12 630	6 563	94	69.8
Windy	2	1 683	1 448	1.5	965
Little Roberts	2	4 492	2 665	736	3.62
Pelvic	2	44 796	33 127	2 960	11.2

In the presence of sufficient food and the absence of zooplankton-feeding predators, zooplankton communities tend to be dominated by large-sized species (Lynch et al. 1977a; Vanni 1986a, 1986b), although the species of certain genera such as *Daphnia* (large) and *Kellicottia* (small) may coexist in the absence of predators by partitioning an adequately diverse food source (Kerfoot and DeMott 1980). Many investigators have shown that a shift from large to small species is related to the presence of abundant fish or other vertebrate predators, or large invertebrate predators (Brooks and Dodson 1965; Hrbacek and Novotna-

Dvorakova 1965; Anderson and Raasveldt 1974; Anderson 1980). Conversely, the decline or removal of fish may promote a return to large zooplankton species (Shapiro and Wright 1984). However, other studies have shown that the type and concentration of food available or a combination of a number of environmental factors in addition to food and/or predators may determine the size structure of zooplankton communities (Lynch 1977b, 1980; Vanni 1986a, 1986b). Based on the above, the presence of large numbers of large-sized zooplankton (i.e., Cladocera) relative to small-sized zooplankton (i.e., Rotifera), suggested that Tail and Ogama lakes may have little predation pressure, whereas Windy and Wolverine lakes may have high predation pressure (Table 6.2). Indeed, Tail Lake had no cisco or whitefish species (main predators of zooplankton) at all (see Section 7.1.3).

Although the presence of large numbers of zooplankton-feeding predators (particularly cisco and whitefish species) is the most obvious explanation for the apparent shift from large to small body size in the zooplankton, other causes are possible. Large year-to-year fluctuations do occur in many small lake zooplankton communities, and it would be necessary to gather fish, zooplankton, and other limnological data consistently over a period of several years to be able to determine the exact causes of community structure changes and to ascertain the permanent or cyclical nature of these changes. For example, high flushing rates in small waterbodies are known to have an impact on community structure and abundance (Soballe and Kimmel 1987). In the Doris Hinge lakes, flushing may reduce overall abundance, but not affect zooplankton species composition.

The location (i.e., barren Arctic / sub-Arctic that is notoriously windy; RL&L / Golder field crew observations; Klohn-Crippen 1995; Rescan 1997) and physical nature (i.e., elongated and narrow) of the studied waterbodies suggested that winds likely influenced the distribution of zooplankton, with some species affected more than others (see Teraguchi et al. 1983). This wind factor may explain the considerable differences in abundance of certain species between different stations in the same waterbody or among years.

6.2 BENTHIC INVERTEBRATES IN LAKES

Benthic (bottom-dwelling) invertebrates (also termed macroinvertebrates because of their large size; some species can reach a few centimetres in length) are an important link in aquatic food webs. Most benthic invertebrates are herbivorous, detritivores, or filter feeders and derive much of their energy from aquatic plants and organic materials. Some benthic macroinvertebrates are predacious, generally feeding upon other invertebrates. Many fish species, including early life history stages of piscivorous species, feed upon benthic macroinvertebrates.

6.2.1 Methods

Benthic macroinvertebrates samples were collected from eight lakes within the Doris Hinge area (Figure 6.9). One to four sampling sessions were conducted on each lake between 1996 and 2000. Benthic invertebrate were not collected in 1998 and 1999 (Table 6.3).

Table 6.3 Benthic invertebrate sampling schedule in Doris Hinge lakes, 1996 to 2000.

Waterbody	Date			
	1996	1997	1997	2000
Doris Lake	28 August	18 July	22 August	24 July
Tail Lake	27 August	16 July		19 July
Ogama Lake	27 August	16 July		
Patch Lake	26 August	17 July		
Wolverine Lake		16 July		
Windy Lake	29 August	17 July		
Little Roberts Lake	27 August	15 July		
Pelvic Lake		17 July		24 July

Triplicate benthic invertebrates samples were collected during each sampling session with an Ekman grab sampler (0.0232 m^2). Sample collection depths varied among years. In 1996, the deepest location in each lake was sampled. In 1997, one shallow (littoral zone) location was sampled and one deep (profundal zone) location was sampled, where possible (i.e., not all lakes had water depths greater than 10 m). In 2000, three locations varying in water depth were sampled, where possible, and included one shallow (0 to 5 m), one medium (between 5 and 10 m), and one deep (greater than 10 m) location. Each replicate sample was sieved over 0.493 mm mesh, transferred to a clean 500-mL plastic bottle, preserved with 10% formalin, and labeled. All samples were submitted to Applied Technical Services, Victoria, BC, for taxonomic identification and enumeration.

6.2.2 Doris Lake

Four benthic macroinvertebrate summer sampling sessions were conducted on Doris Lake; these included one in 1996, two in 1997, and one in 2000. Four relatively shallow water depths (equal to or less than 7.5 m) and four deep (greater than 10 m) locations were sampled among the three study years. Mean total numbers (± 1 SE) from the shallow locations ranged from 1778 ± 1045 animals/m^2 in July 1997 to 3481 ± 466 animals/m^2 in August 1997. Mean total number of benthic macroinvertebrates from the deep locations ranged from 1126 ± 286 animals/m^2 in August 1997 to 2059 ± 182 animals/m^2 in August 1996 (Figure 6.10; Appendices C3 and C4).

Shallow Locations

Four taxa dominated the benthos at shallow depths of Doris Lake. Chironomidae (midges) were well represented during all four sampling sessions; this taxon contributed between 57.6 and 97.4% to total numbers. Pelecypoda (clams), exclusively represented by Sphaeriidae (*Pisidium* spp.), appeared in considerable proportions within the two 24 July 2000 sampling locations (36.8 and 23.6% of total numbers at 4.5 and 7.5-m water depths, respectively). Oligochaeta (bristle worms) contributed 17.6% to total number of animals encountered in the samples collected from a depth of 7.5 m on 24 July 2000. Malacostraca, exclusively represented by the isopod *Saduria entomon*, contributed 15.8% to total numbers encountered on 18 July 1997 at water depths of less than 5 m (Figure 6.10; Appendices C3 and C4).

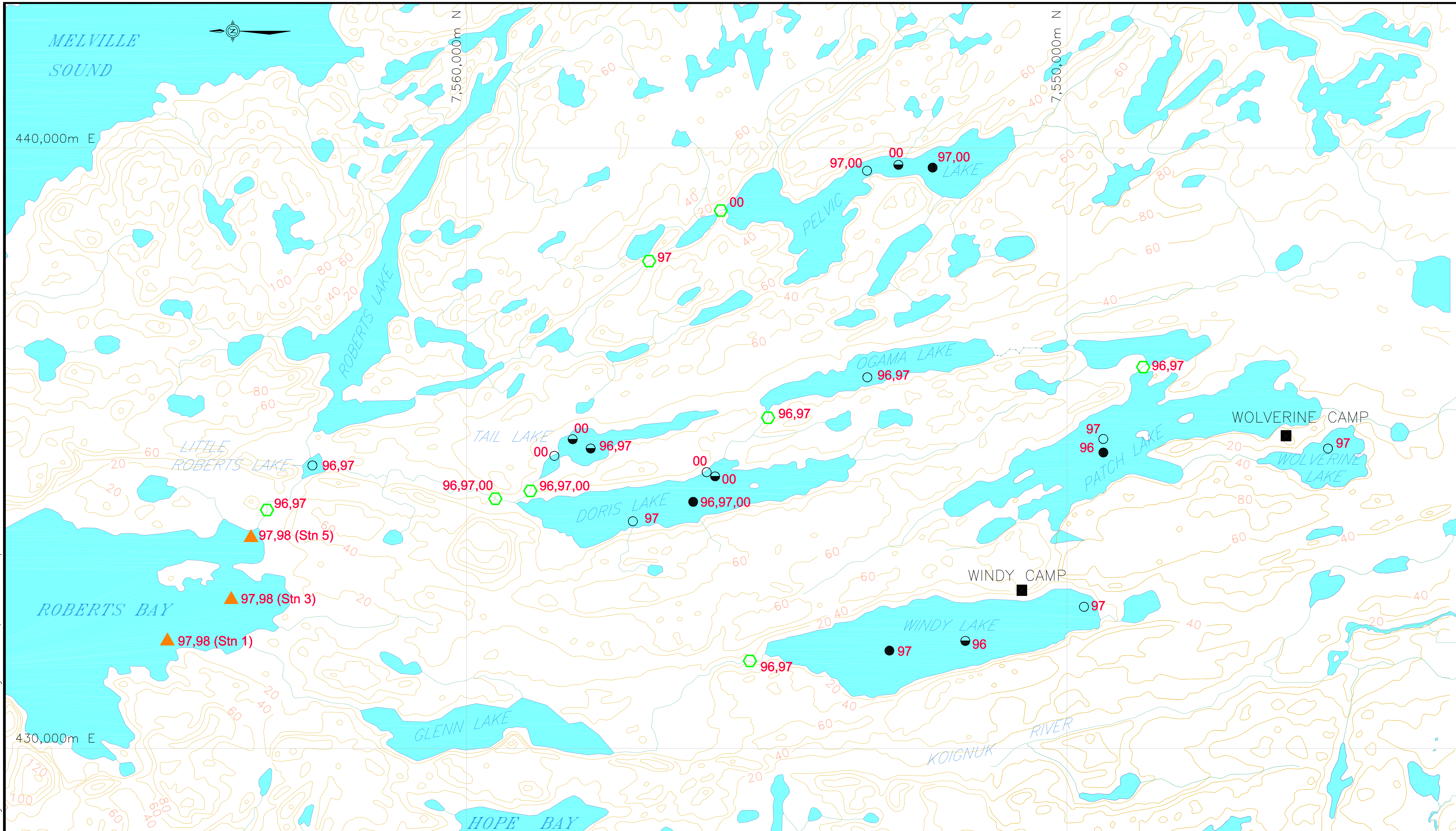
Deep Locations

Chironomidae overwhelmingly dominated the benthos of Doris Lake, at depths greater than 10-m (Figure 6.10; Appendices C3 and C4). This taxon contributed between 92.1 and 97.8% to total mean number of animals among the sample dates and locations. The major contributors to the chironomids were *Phaenopsectra* spp. and *Chironomus* spp.

6.2.3 Tail Lake

Four benthic macroinvertebrate sampling sessions were conducted on Tail Lake in the summer; these included one session in 1996, one in 1997, and two in 2000. Samples were collected from shallow locations (water depths were approximately 5.0 m or less; Tail Lake has a maximum depth of 6.5 m). Mean total numbers (± 1 SE) ranged from 992 ± 281 animals/m^2 in July of 1997 to 4903 ± 1554 animals/m^2 in August of 1996 (Figure 6.11; Appendices C3 and C4).

On each sample date and location, Chironomidae contributed the most (from 41.1 to 75.2%) to total mean numbers of benthic invertebrates within Tail Lake. Pelecypoda (primarily *Pisidium* spp.) were well represented within the samples collected from deeper water (greater than 5.0 m) in July 1997 and July 2000 (28.4 and 20.9% of total numbers, respectively). The August 1996 samples contained considerable proportions of Nematoda (roundworms) and Oligochaeta (19.0 and 22.7% of total numbers, respectively). The July 2000 samples collected at 2.6 m depth contained considerable proportions (greater than 10%) of Oligochaetes and Ostracoda (seed shrimp) (Figure 6.11; Appendices C3 and C4).



LEGEND

- ○ LAKE BENTHOS SAMPLING LOCATIONS (<5 m DEEP)
- ◒ LAKE BENTHOS SAMPLING LOCATIONS (5-10 m DEEP)
- ● LAKE BENTHOS SAMPLING LOCATIONS (>10 m DEEP)
- ⬡ STREAM BENTHOS SAMPLING LOCATIONS
- ▲ MARINE BENTHOS SAMPLING LOCATIONS
- 95,96 etc. YEARS OF SAMPLING
- (Stn 1) STATION NAMES

SCALE 1.5 0 1.5 KILOMETRES

NOTE : CONTOUR INTERVAL 20 m

REFERENCE

BASE MAP PROVIDED BY RESCAN, JANUARY 22, 2001

Hope Bay Joint Venture

TITLE

BENTHIC INVERTEBRATE SAMPLING LOCATIONS IN DORIS HINGE AREA, 1996-2000

Golder Associates
Edmonton, Alberta

PROJECT No. 022-7009.1000			FILE No. Benthic Invertebrate
DESIGN	AH	11/06/02	SCALE 1:60,000 REV. 0
CADD	TVS	19/06/02	
CHECK			
REVIEW			

FIGURE: 6.9

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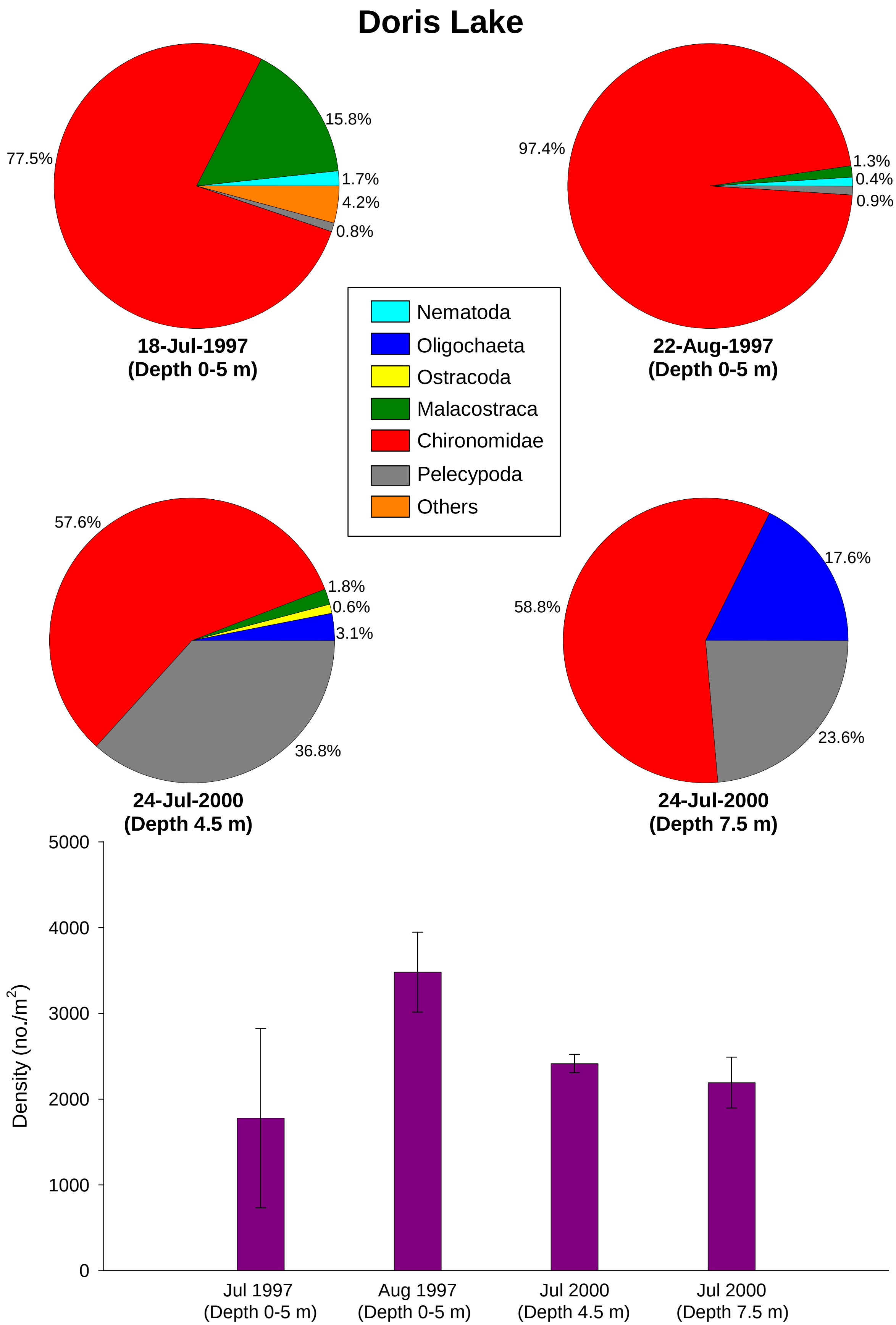


Figure 6.10 Relative abundance of major taxonomic groups and mean total density (± 1SE) of benthic invertebrates in Doris Lake, 1997 to 2000.

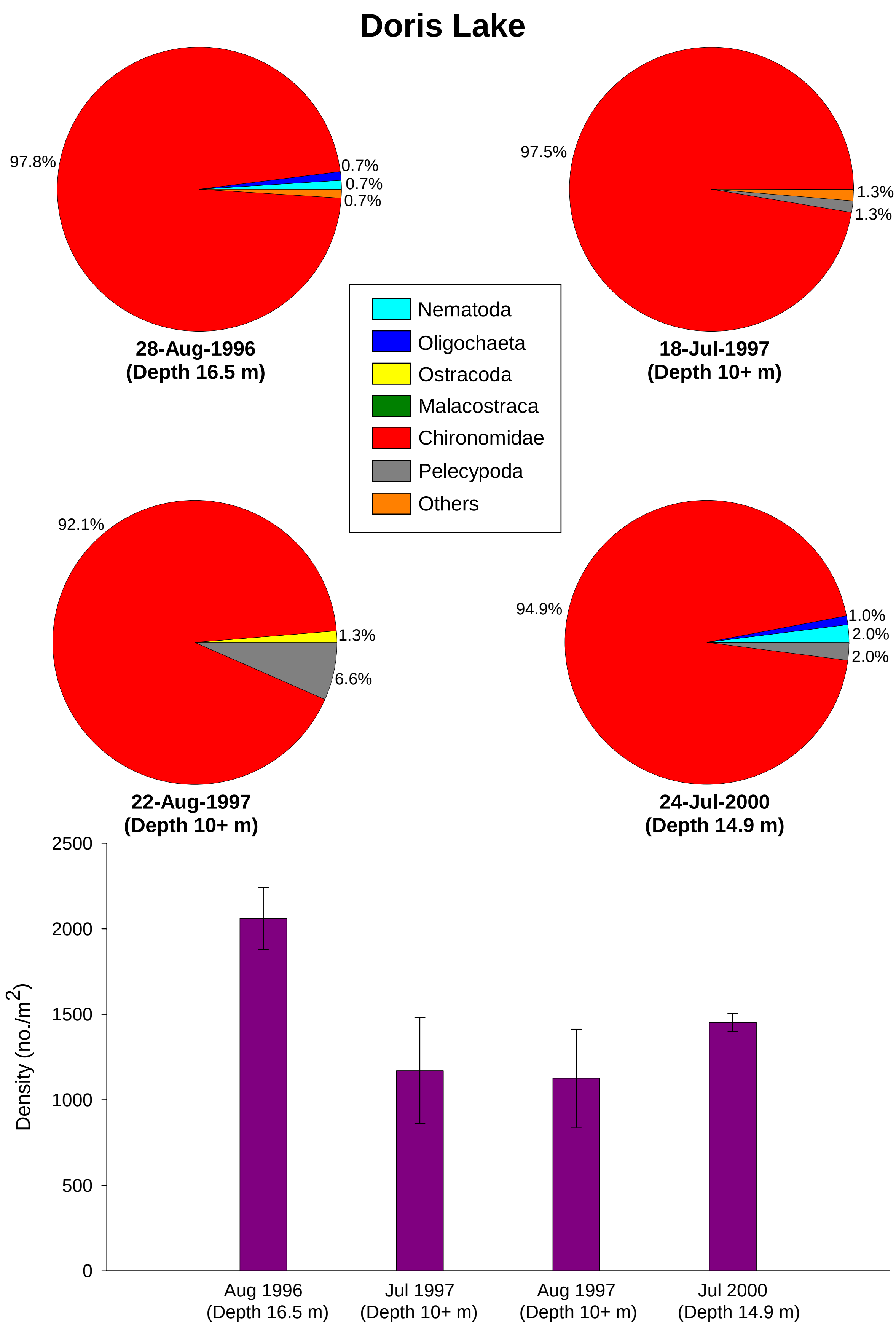


Figure 6.10 (continued). Relative abundance of major taxonomic groups and mean total density (± 1SE) of benthic invertebrates in Doris Lake, 1996 to 2000.

6.2.4 Ogama Lake

Benthic invertebrate sampling sessions on Ogama Lake were conducted on 27 August 1996 and 16 July 1997. During both sessions, samples were collected from shallow waters (less than 5.0 m). Mean total numbers (± 1 SE) on these dates were 5629 ± 360 and 992 ± 295 animals/m^2, respectively (Figure 6.12; Appendices C3 and C4).

In August 1996, Chironomidae, which contributed 88.4% to the total mean animal count, dominated the benthos of Ogama Lake. Nematoda were second in abundance at 8.2% of total numbers. The major contributors for the Chironomidae were *Tanytarsus* spp. and *Phaenopsectra* spp. (nematodes are typically not identified to lower taxonomic levels). In July 1997, the benthic community of Ogama Lake was dominated by Chironomidae (65.7% of total numbers) followed by Pelecypoda (23.9% of total numbers). These two major taxonomic groups were primarily represented by *Procladius* spp. and *Sphaerium* spp., respectively (Figure 6.12; Appendices C3 and C4).

6.2.5 Patch Lake

The benthic community of Patch Lake was sampled on 26 August 1996 (11.5 m water depth) and on 17 July 1997 (<5 m water depth). Mean total numbers (± 1 SE) on these dates were 1866 ± 566 and 1215 ± 602 animals/m^2, respectively (Figure 6.13; Appendices C3 and C4).

In August 1996, the benthos of Patch Lake was co-dominated by Nematoda and Chironomidae, each contributing 44.4% to the total mean animal count. The major contributors to the chironomids were *Tanytarsus* spp. and *Procladius* spp. In July 1997, Chironomidae dominated (contributing 80.5%) the samples collected; this taxonomic group was primarily represented by *Procladius* spp., *Psectrocladius* spp., and *Tanytarsus* spp. Simuliidae (black fly) larvae were reported to have contributed 19.5% to total numbers within the 1997 samples (Figure 6.13; Appendices C3 and C4); however, black fly larvae normally are only found in flowing waters.

6.2.6 Wolverine Lake

The benthos of Wolverine Lake was collected only on 16 July 1997, at water depths less than 5.0 m. The mean total number (± 1 SE) was 3066 ± 1861 animals/m^2 (Appendices C3 and C4).

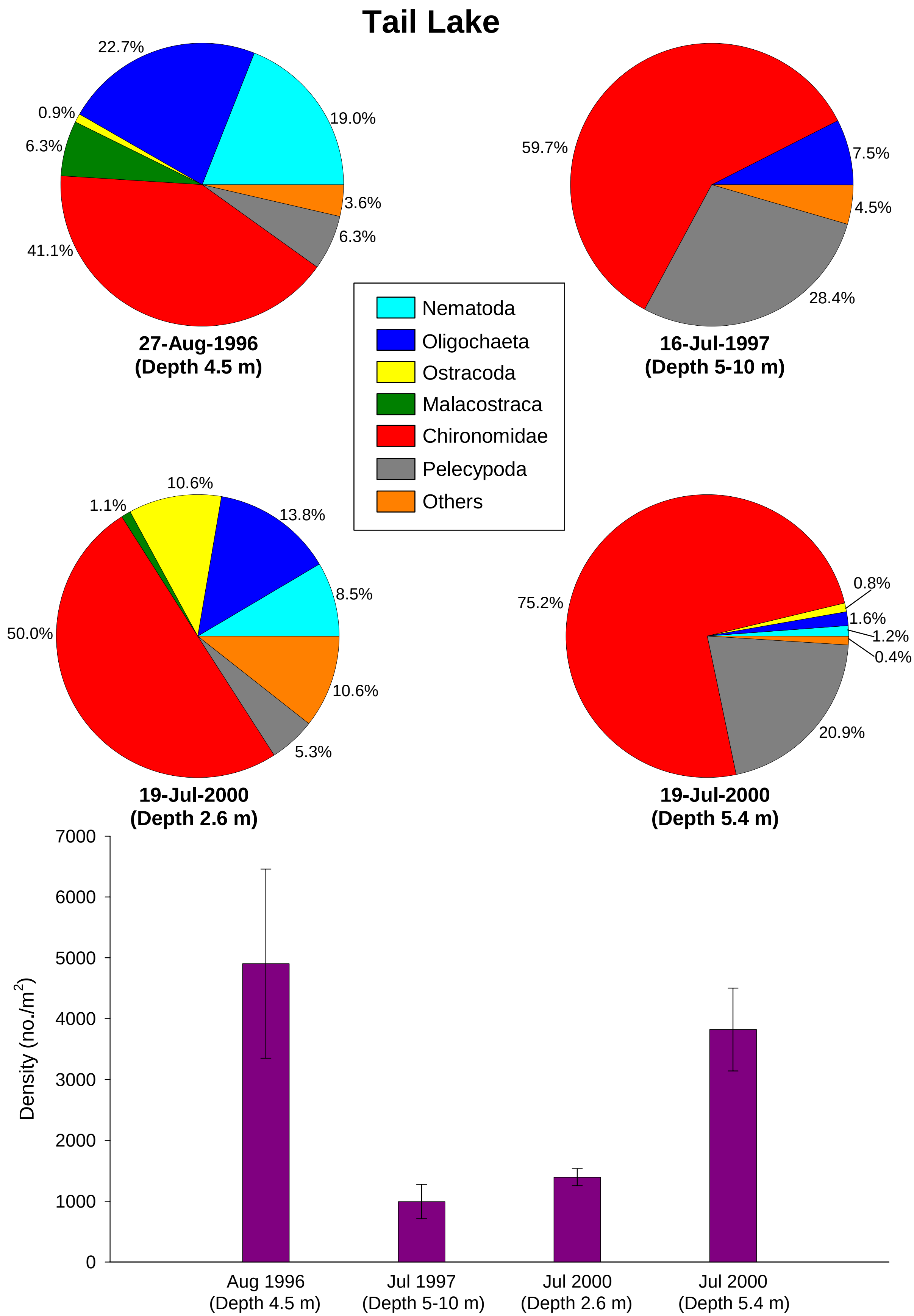
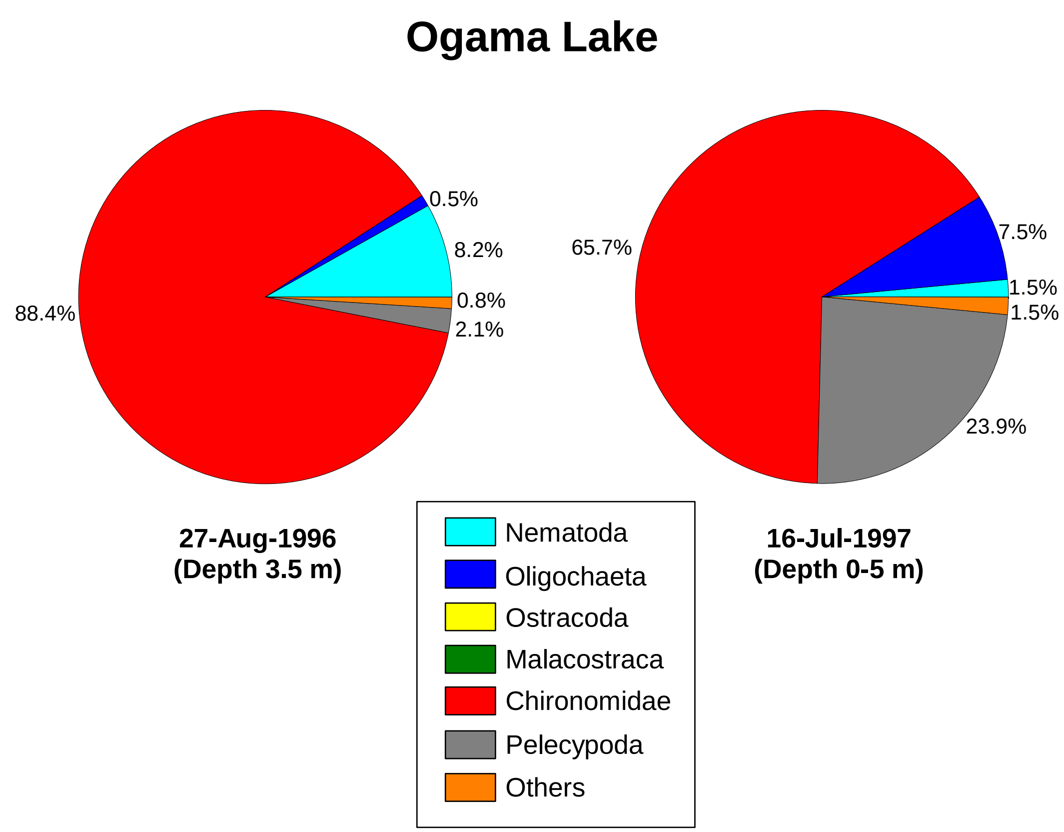


Figure 6.11 Relative abundance of major taxonomic groups and mean total density (± 1SE) of benthic invertebrates in Tail Lake, 1996 to 2000.



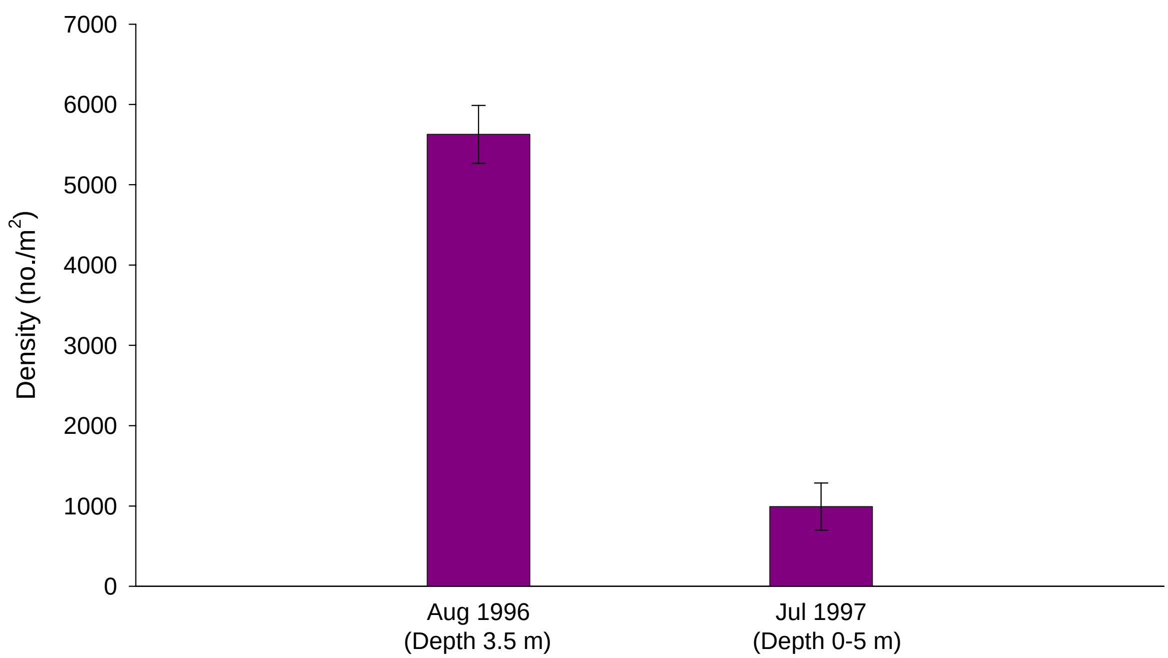
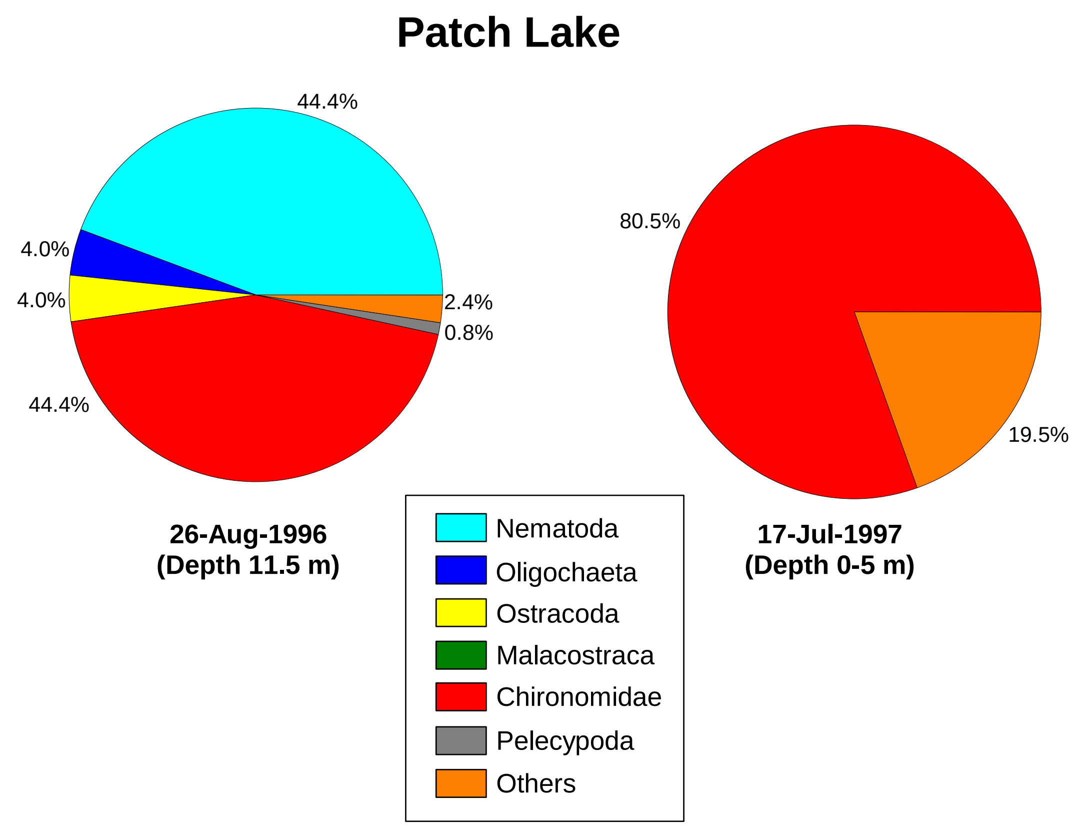


Figure 6.12 Relative abundance of major taxonomic groups and mean total density (± 1SE) of benthic invertebrates in Ogama Lake, 1996 to 1997.



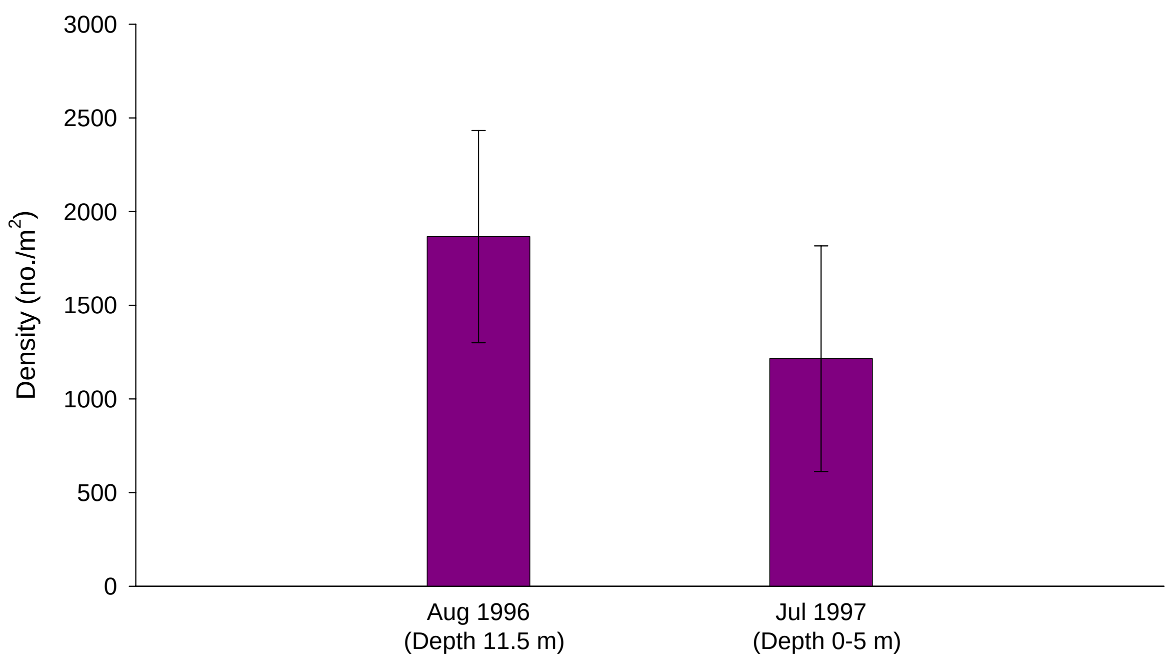


Figure 6.13 Relative abundance of major taxonomic groups and mean total density (± 1SE) of benthic invertebrates in Patch Lake, 1996 to 1997.

Pelecypoda and Chironomidae, contributing 58.9 and 31.8% to total mean numbers, respectively, dominated the benthic community of Wolverine Lake. The major contributors within these groups were *Pisidium* spp. and *Rheotanytarsus* spp. (Appendices C3 and C4).

6.2.7 Windy Lake

Benthic macroinvertebrate sampling sessions on Windy Lake were conducted on 29 August 1996 (7.5 m water depth) and 17 July 1997 (two water depth locations; less than 5.0 m and greater than 10 m). Mean total numbers (± 1 SE) ranged from 89 ± 51 and 518 ± 157 animals/m^2 on 17 July 1997 for the shallow and deeper water locations, respectively (Figure 6.14; Appendices C3 and C4).

In August 1996, the benthos of Windy Lake was comprised of Nematoda and Chironomidae only, contributing 70.6 and 29.4% to total mean numbers, respectively. Nematodes are typically not identified to lower taxonomic levels; the Chironomidae were mainly represented by *Cricotopus* spp. and *Procladius* spp. The shallow (less than 5.0 m) July 1997 benthic community was represented by Chironomidae and Malacostraca only (83.3 and 16.7% of total numbers, respectively); Chironomidae were primarily represented by *Psectrocladius* spp., and Malacostraca consisted only of the isopod, *Saduria entomon*. The deep (greater than 10 m) benthic community of Windy Lake in July 1997 consisted exclusively of Chironomidae, mainly represented by *Psectrocladius* spp. and *Eukeifferiellia* spp. (Figure 6.14; Appendices C3 and C4).

6.2.8 Little Roberts Lake

Benthic invertebrate sampling sessions on Little Roberts Lake were conducted during August 1996 and July 1997; both sampling sessions were from shallow water areas of less than 5.0 m. Mean total numbers (± 1 SE) for these years were 37 493 ± 19 954 and 859 ± 618 animals/m^2, respectively (Figure 6.15; Appendices C3 and C4).

The benthos of Little Roberts Lake was dominated by Chironomidae, which contributed 77.2 and 69.0% to total mean numbers within the 1996 and 1997 samples, respectively. The major contributors (in descending order of abundance) in this group for both study years were *Tanytarsus* spp. and *Cricotopus* spp. In 1997, Pelecypoda (*Pisidium* spp.) contributed a considerable proportion (22.4%) to the benthic community of Little Roberts Lake (Figure 6.15; Appendices C3 and C4).

6.2.9 Pelvic Lake

Two benthic macroinvertebrate sampling sessions were conducted on Pelvic Lake during the summer, one in 1997 and one in 2000. Three relatively shallow water depths (equal to or less than 7.4 m) and two deeper (greater than 10 m) locations were sampled between the two study years. Mean total numbers ($\pm$ 1 SE) from the shallow locations ranged from 1348 $\pm$ 928 animals/m^2 in 1997 to 4237 $\pm$ 1304 animals/m^2 in 2000. Mean total numbers of benthic macroinvertebrates from the deep locations were 281 $\pm$ 90 animals/m^2 and 119 $\pm$ 59 animals/m^2 in 1997 and 2000, respectively (Figure 6.16; Appendices C3 and C4).

Shallow Locations

Two taxa dominated the benthos at shallow depths of Pelvic Lake. Chironomidae were well represented during all sampling sessions; this taxon contributed between 87.5 and 92.3% to total numbers. Pelecypoda, represented exclusively by Sphaeriidae (*Pisidium* spp. and *Sphaerium* spp.), contributed an appreciable proportion (10.9%) to total numbers encountered in the 7.4 m depth samples collected in 2000. The Chironomidae were represented primarily by *Tanytarsus* spp. and *Phaenopsectra* spp. (Figure 6.16; Appendices C3 and C4).

Deep Locations

At depths greater than 10 m, Chironomidae overwhelmingly dominated the benthos of Pelvic Lake. This taxon contributed between 87.5 and 100% to total mean number of animals in 2000 and 1997, respectively. The major contributor to the chironomids was *Chironomus* spp. Pelecypoda, represented exclusively by Sphaeriidae (*Pisidium* spp. and *Sphaerium* spp.), contributed an appreciable proportion (12.5%) to total numbers encountered in the 17.8 m depth samples collected in 2000 (Figure 6.16; Appendices C3 and C4).

6.2.10 Summary

Chironomidae, Nematoda, Pelecypoda, Oligochaeta, and Malacostraca dominated the benthos of the Doris Hinge lakes. Differences in composition and abundance of the benthos could largely be ascribed to physical and energetic characteristics among the sampling locations. The communities in deeper regions of the study lakes appeared to be increasingly dominated by Chironomidae and occasionally Pelecypoda. The benthic invertebrate communities of the eight lakes were similar in many respects to the communities of many other small lakes in the Canadian Arctic and sub-Arctic (RL&L 1997, 1998, 1999).

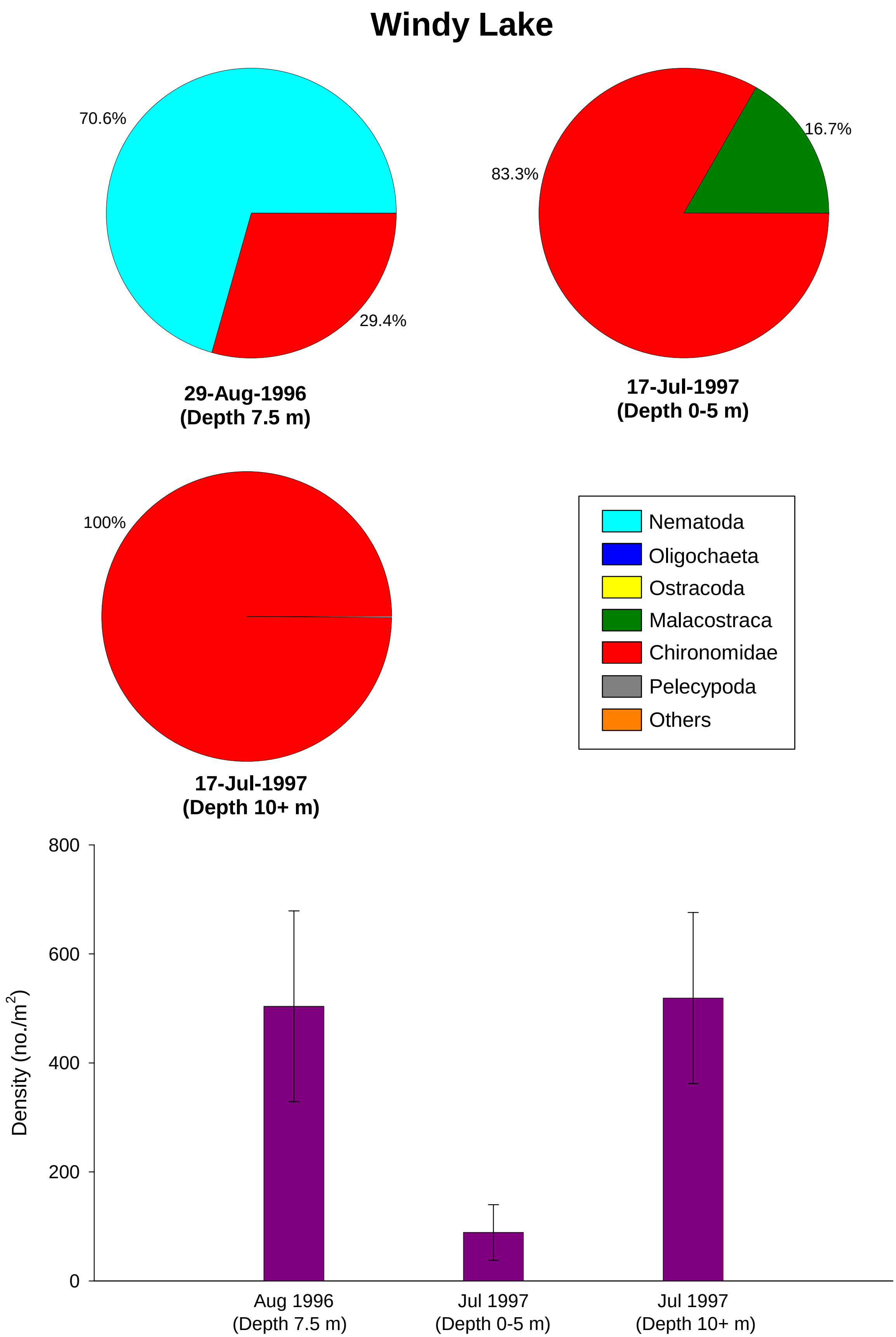
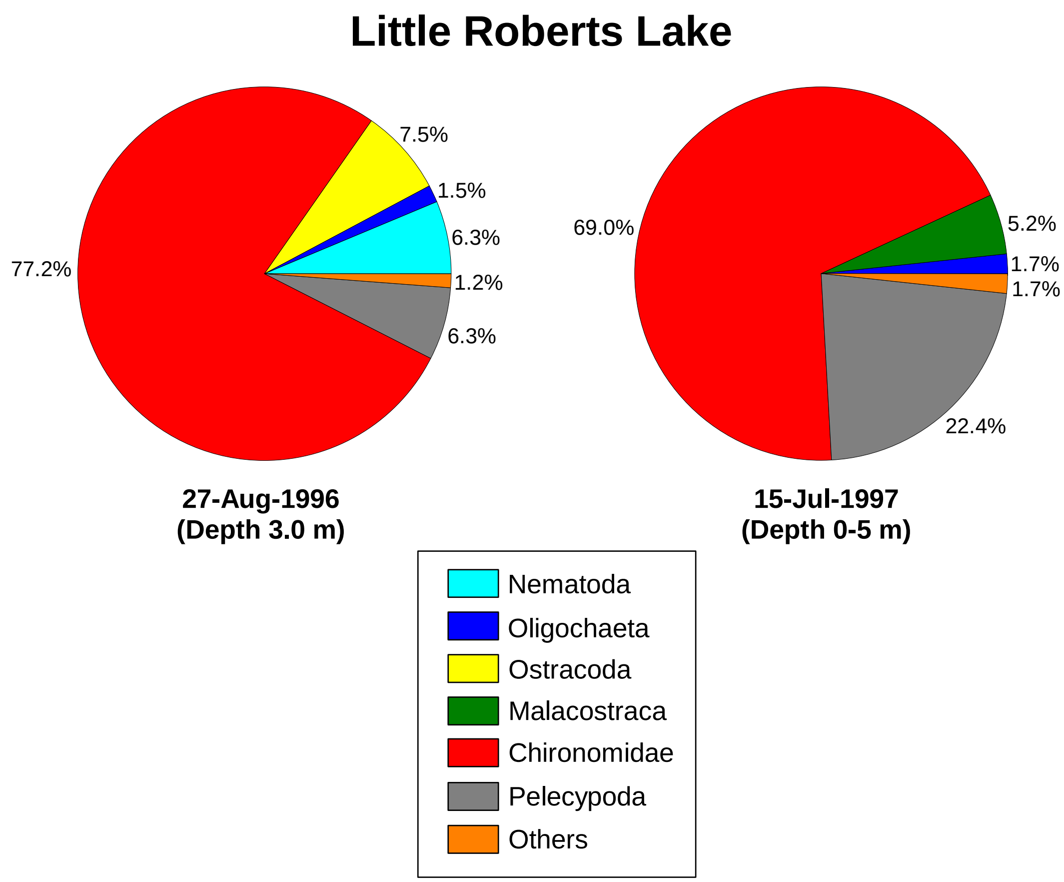


Figure 6.14 Relative abundance of major taxonomic groups and mean total density (± 1SE) of benthic invertebrates in Windy Lake, 1996 to 1997.



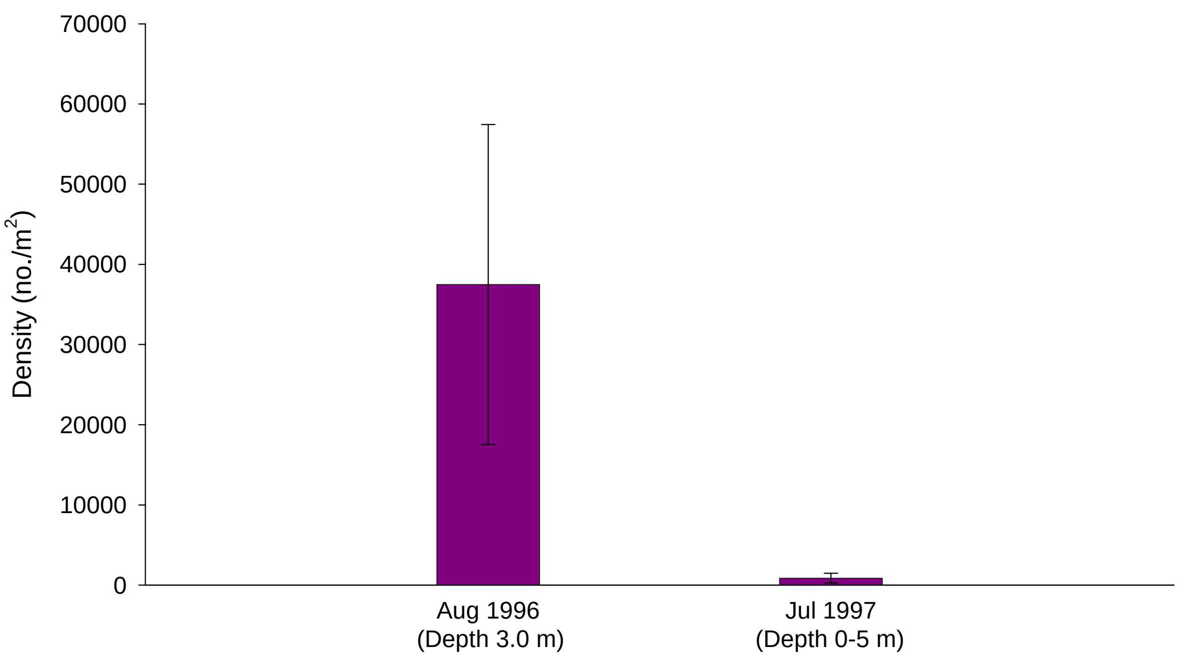


Figure 6.15 Relative abundance of major taxonomic groups and mean total density (± 1SE) of benthic invertebrates in Little Roberts Lake, 1996 to 1997.

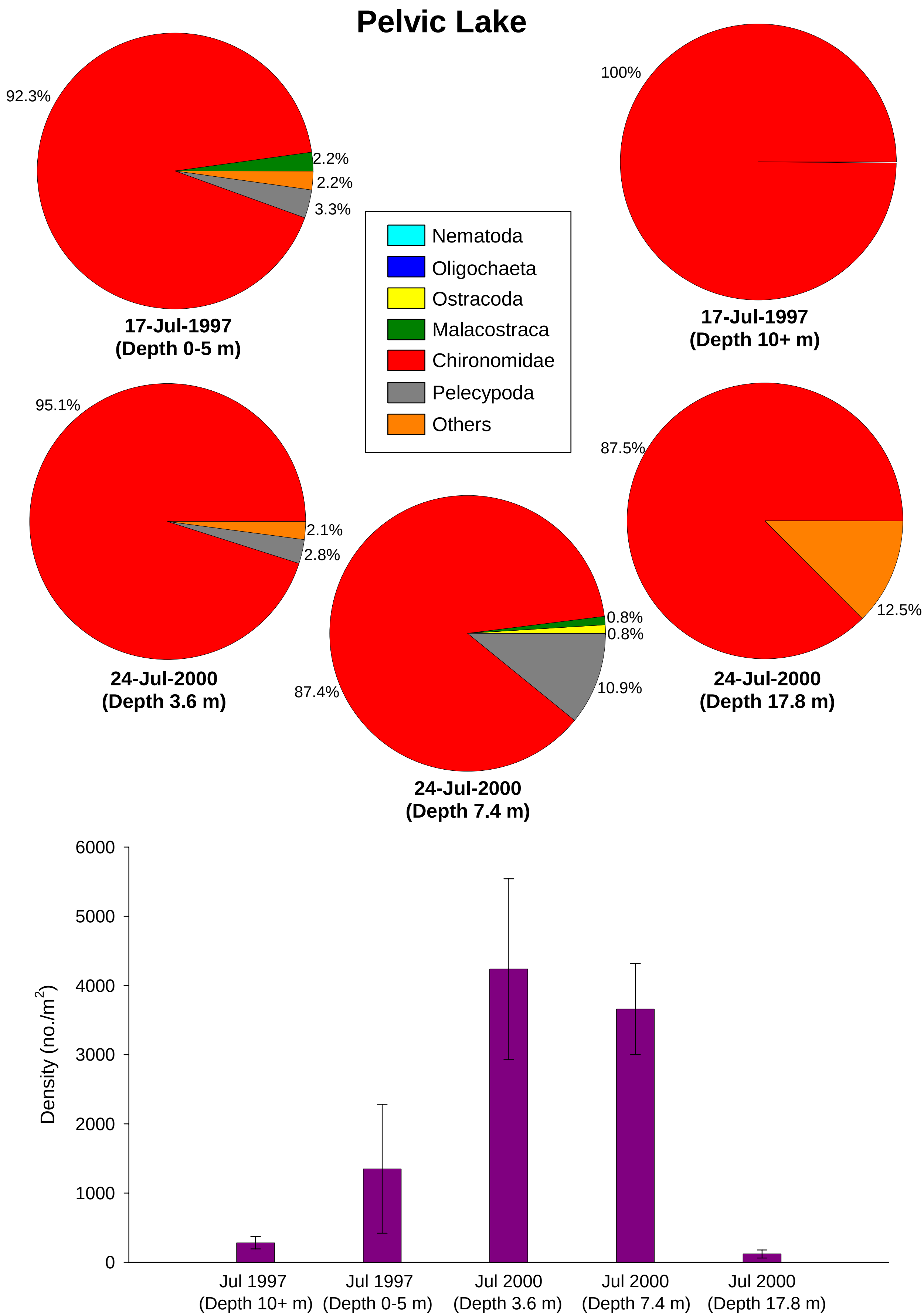


Figure 6.16 Relative abundance of major taxonomic groups and mean total density (± 1SE) of benthic invertebrates in Pelvic Lake, 1997 to 2000.

Due to the close proximity of the Doris Hinge lakes to the Arctic Ocean, the benthic communities of some lakes periodically featured considerable proportions of the normally marine isopod *Saduria entomon*. This species was encountered in all the study lakes except Ogama, Patch, and Wolverine lakes. *Saduria entomon* is known to be able to swim against currents, invade coastal freshwaters, and to feed upon freshwater invertebrates such as other Malacostraca (e.g., scuds, tadpole shrimp) and Chironomidae larvae (Johannesson et al. 2000).

A comparison of mean benthic macroinvertebrate abundance suggests that Little Roberts Lake was the most productive and that Windy Lake was the least productive (Table 6.4). There was no consistent pattern with regard to effects of water depth. Deeper water habitats (i.e., profundal zones) can have anoxic conditions that have important implications for benthic macroinvertebrate communities; such habitat conditions primarily support taxa that can tolerate low oxygen (e.g., certain Chironomidae and Oligochaeta). Anoxia of the profundal zone was not recorded in the study lakes (see Section 3.0) and probably is not a factor in benthic macroinvertebrate production. Oxic conditions are common to Arctic and sub-Artic lakes, and likely reflect the short open water season, low nutrient loading, and windy conditions that tend to keep the lakes from stratifying (e.g., RL&L 1997, 1998, 1999).

Table 6.4 Summary of benthic invertebrate abundance in the Doris Hinge lakes, 1996 to 2000.

Lake	Sample Depth (m)	Number of Sampling Events	Mean Total Density (animals/m^2)	Mean Number of Chironomidae (animals/m^2)	Proportion of Chironomidae to total
Doris	<8.0	4	2 467	1 863	75.5
Doris	>10.0	4	1 452	1 392	95.9
Tail	<6.5	4	2 778	1 544	55.6
Ogama	<5.0	2	3 311	2 814	85.0
Patch	<5.0	1	1 215	978	80.5
Patch	11.5	1	1 866	830	44.5
Wolverine	<5.0	1	3 066	978	31.9
Windy	<8.0	2	296	111	37.5
Windy	>10.0	1	519	519	100.0
Little Roberts	<5.0	2	19 176	14 769	77.0
Pelvic	<7.5	3	3 081	2 825	91.7
Pelvic	>10.0	2	200	193	96.5

With the exception of a few lakes and sample depths, Chironomidae tended to dominate (i.e., greater than 50% of total numbers) the benthic communities of the Doris Hinge lakes (Table 6.4). The family Chironomidae is an ecologically important group of aquatic insects, often occurring in high densities and diversity. Indeed, the number of chironomid species present, and their densities, in most systems often accounts for at least 50% of the total macroinvertebrate species diversity and abundance. The actual number of chironomid species present in a system is the result of the complex of physical, chemical, biological, and biogeographic conditions (Coffman and Ferrington 1996).

6.3 DRIFT ORGANISMS IN STREAMS

Benthic macroinvertebrates can actively or passively enter the water column. This behaviour is known as drift (Resh and Rosenberg 1984). Also included in the drift can be pelagic forms or invertebrates (e.g., zooplankton) that are entrained from lakes, back-eddies, and calm side-channels of flowing waters. Drift organisms are an important part of the food chain, particularly because they are easily observed and available to fish and other potential predators.

6.3.1 Methods

Drift samples were collected from seven streams within the Doris Hinge area (Figure 6.1). Up to three sampling sessions were conducted on each stream between 1997 and 2000. Drift samples were not collected in 1996, 1998, and 1999 (Table 6.5).

Table 6.5 Drift sampling schedule in Doris Hinge streams, 1997 to 2000.

Stream	Date Sampled		
	1997	1997	2000
Doris Outflow	19 July	20 August	23 July
Tail Outflow	19 July		20 July
Ogama Outflow	18 July	20 August	
Patch Outflow		21 August	
Windy Outflow	18 July	21 August	
Little Roberts Outflow	19 July	19 August	
Pelvic Outflow	19 July	21 August	23 July

Two or three replicate drift samples were collected with a cone-shaped net (0.5 mm mesh size) that featured an opening aperture frame of 0.14 m^2. Soak time for the samplers was approximately 24 h. Water flow rates were measured in the streams during sampling and the average flow rate was used to standardize data to volume (animals/1000 m^3). Each sample was transferred to a clean 500 mL plastic bottle, preserved with 10% formalin, and labeled. All samples were submitted to Applied Technical Services, Victoria, BC, for taxonomic identification and enumeration.

6.3.2 Doris Outflow

Three drift sampling sessions were conducted on Doris Outflow, two in 1997 and one in 2000. Mean total drift numbers (± 1 SE) ranged from 68.9 ± 18.2 animals/1000 m^3 on 19 July 1997 to 5389 ± 2353 animals/1000 m^3 on 23 July 2000 (Figure 6.17; Appendices C5 and C6).

Chironomidae contributed 64.8 and 47.4% to the total mean number of animals enumerated during the July and August 1997 sampling sessions, respectively. The July 1997 samples had a considerable proportion (20.8%) of Cladocera, whereas the August 1997 samples had a large proportion (35.3%) of Copepoda. The July 2000 samples were overwhelmingly dominated by zooplankton; Cladocera and Copepoda contributed 51.0% and 45.7% to total numbers, respectively. The Chironomidae were primarily represented by unidentified Orthocladinae species, whereas the Cladocera and Copepoda were well represented by *Holopedium gibberum* and *Limnocalanus macrurus* (Figure 6.17; Appendices C5 and C6).

6.3.3 Tail Outflow

Two drift sampling sessions were conducted on Tail Outflow, one in each of 1997 and 2000. Mean total drift numbers (± 1 SE) were 592 ± 524 and 216 ± 65.3 animals/1000 m^3 in 1997 and 2000, respectively (Figure 6.18; Appendices C5 and C6).

In 1997, Chironomidae and Ostracoda dominated the drift of Tail Outflow, contributing 38.8 and 25.2% to total mean numbers, respectively. The major contributors to these two groups were unidentified Orthocladiinae and *Cypria* spp., respectively. During 2000, the drift of Tail Outflow was dominated by Chironomidae (52.3% of total numbers) and Ostracoda (17.6%); the chironomids were represented mainly by unidentified Orthocladiinae, whereas the ostracods were primarily represented by *Candona* spp. (Figure 6.18; Appendices C5 and C6).

6.3.4 Ogama Outflow

Two drift sampling sessions were conducted on Ogama Outflow in 1997, one in July and one in August. Mean total numbers (± 1 SE) were 6325 ± 3945 and 3351 ± 806 animals/1000 m^3 in the July and August samples, respectively (Figure 6.19; Appendices C5 and C6).

In July, Chironomidae and Simuliidae dominated the drift of Ogama Outflow; these groups contributed 52.7 and 46.6% to total mean numbers, respectively.

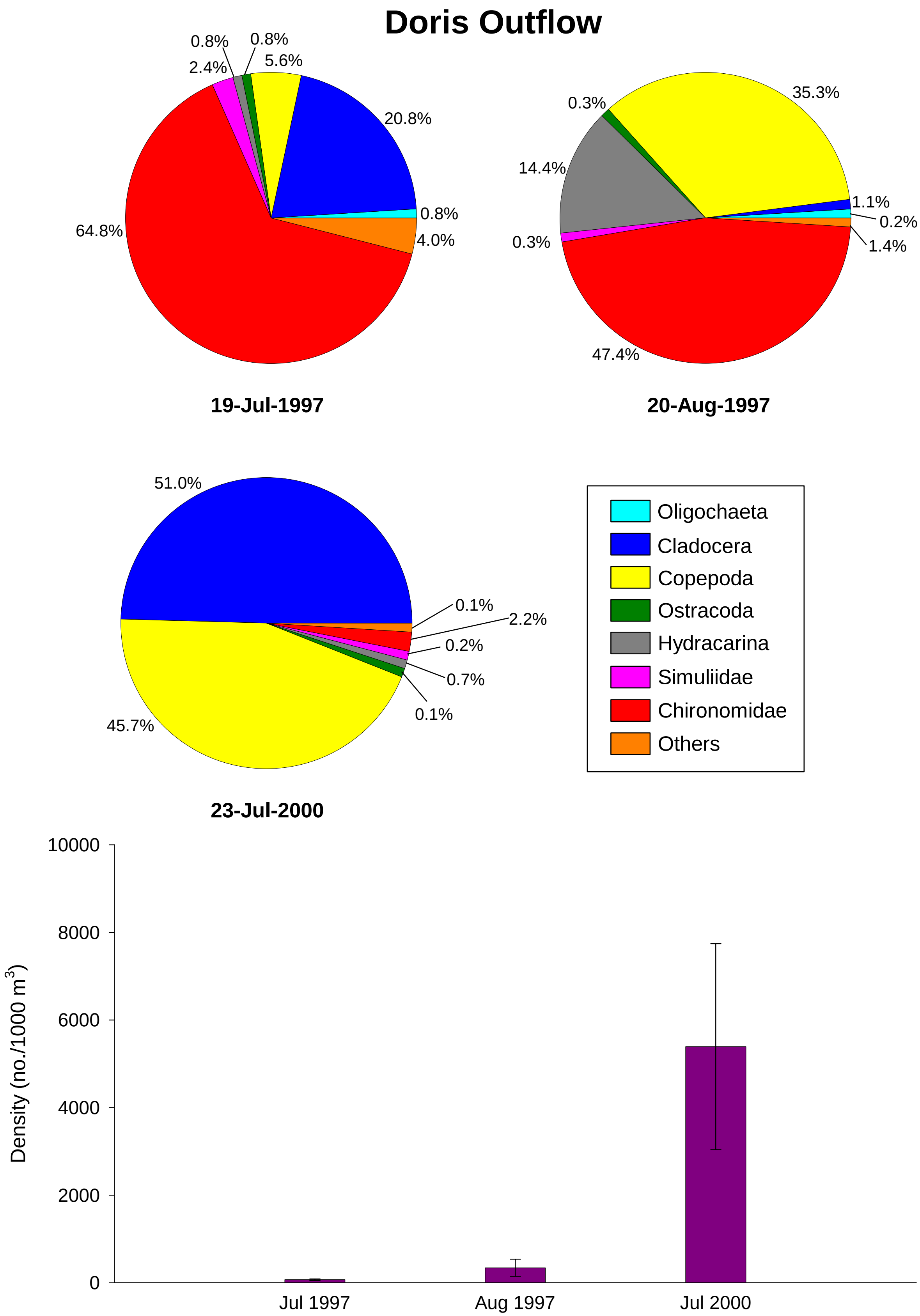


Figure 6.17 Relative abundance of major taxonomic groups and mean total density (± 1SE) of drifting invertebrates in Doris Outflow, 1997 to 2000.

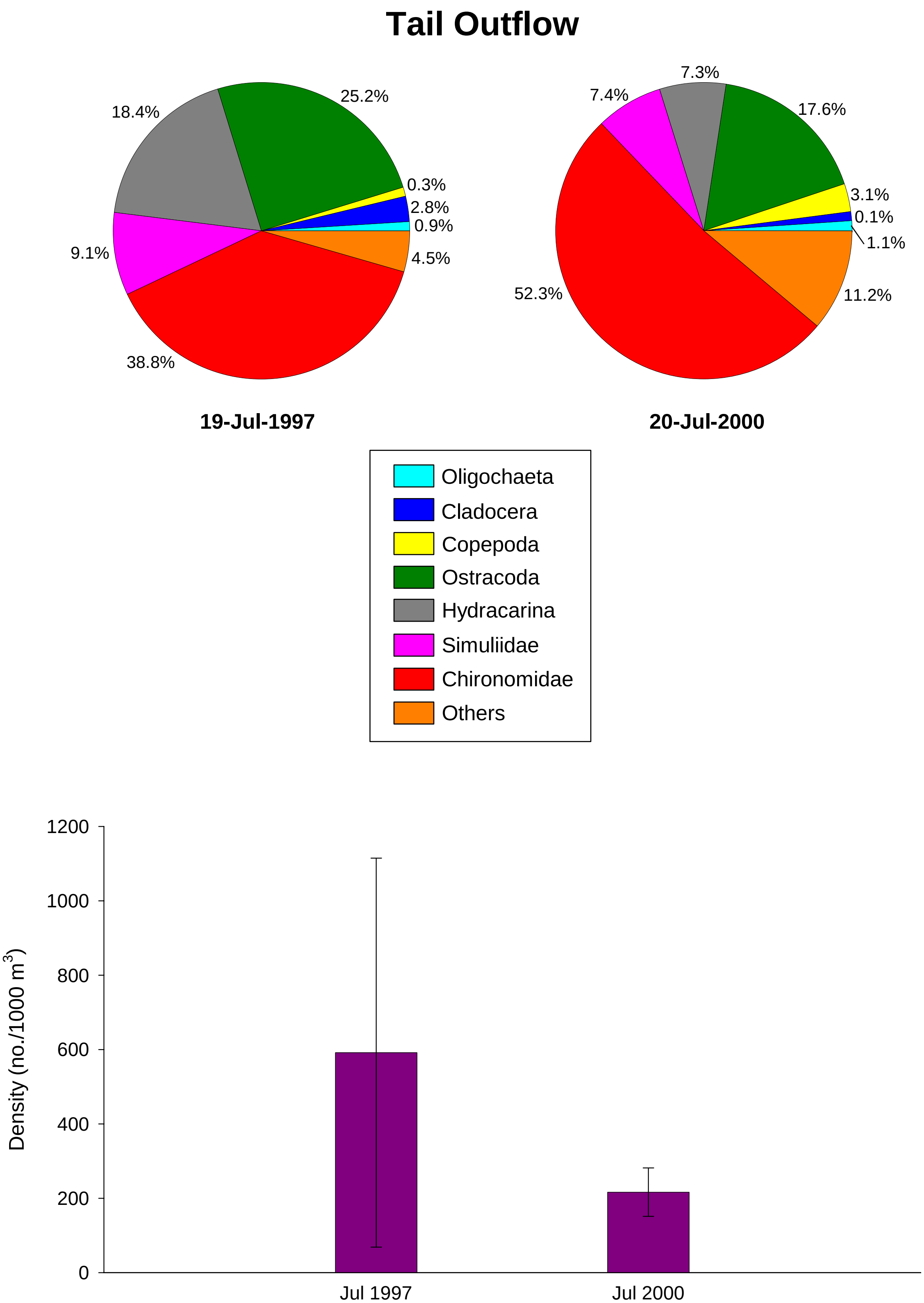


Figure 6.18 Relative abundance of major taxonomic groups and mean total density (± 1SE) of drifting invertebrates in Tail Outflow, 1997 to 2000.

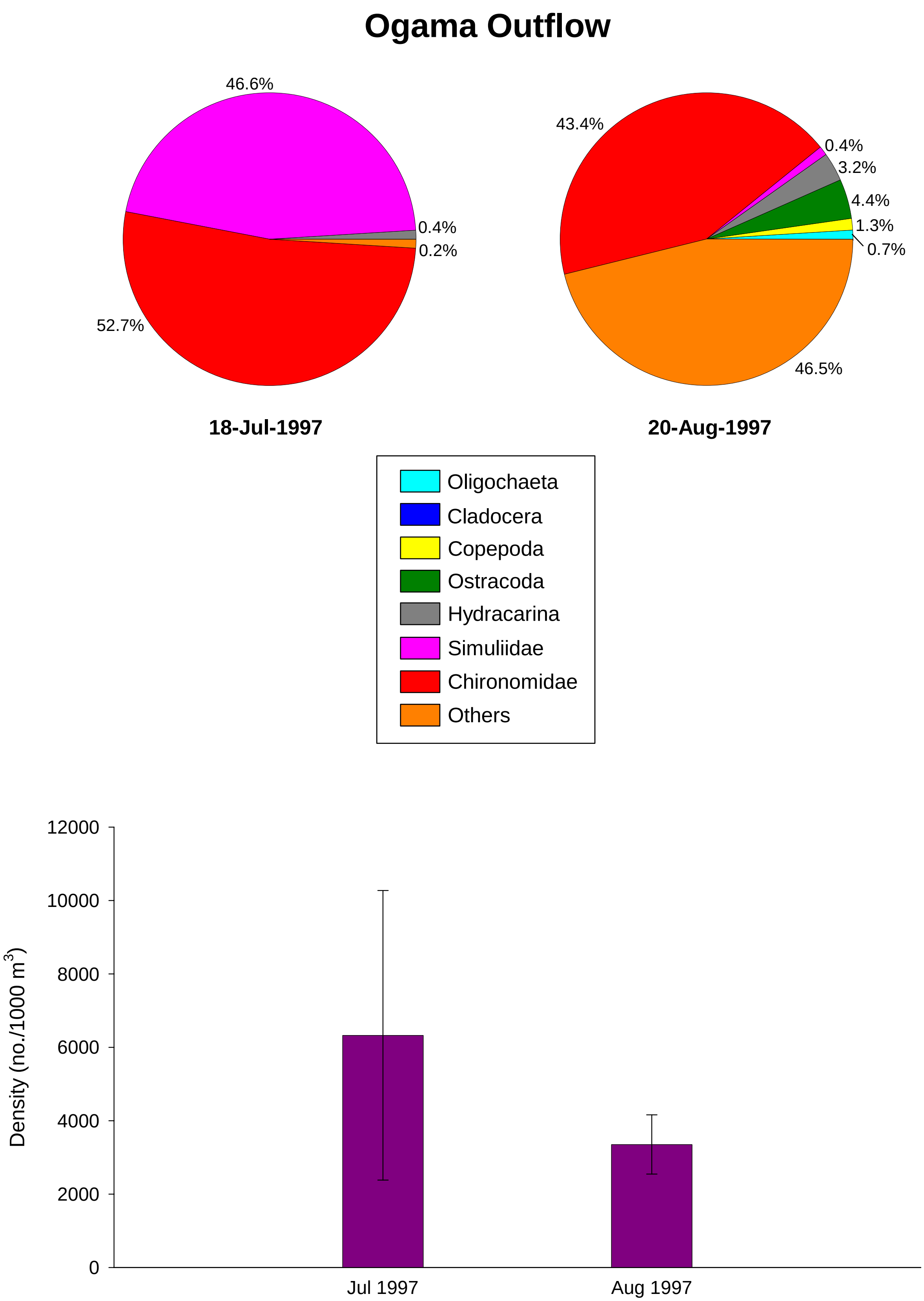


Figure 6.19 Relative abundance of major taxonomic groups and mean total density (± 1SE) of drifting invertebrates in Ogama Outflow, 1997.

The August drift community was dominated by Coelenterata (hydras) and Chironomidae (43.4% and 44.0% of total numbers, respectively). These major taxonomic groups were primarily represented by *Hydra* spp. (Coelenterata), *Simulium* spp. (Simuliidae), and *Rheotanytarsus* spp. (Chironomidae) (Figure 6.19; Appendices C5 and C6).

6.3.5 Patch Outflow

Drift net sampling in Patch Outflow was conducted only on 21 August 1997. Mean total number (± 1 SE) of organisms collected on this date was 6.3 ± 1.8 animals/1000 m^3 (Appendices C5 and C6).

The drift community of Patch Outflow was dominated by Chironomidae, which contributed 62.6% to the total mean count in the sample. The major contributors in this group were *Cricotopus* spp. and *Tanytarsus* spp. Within the same sampling session, the second most abundant major taxon was Malacostraca (18.8% of total numbers); this group was represented exclusively by the isopod *Saduria entomon* (Appendices C5 and C6).

6.3.6 Windy Outflow

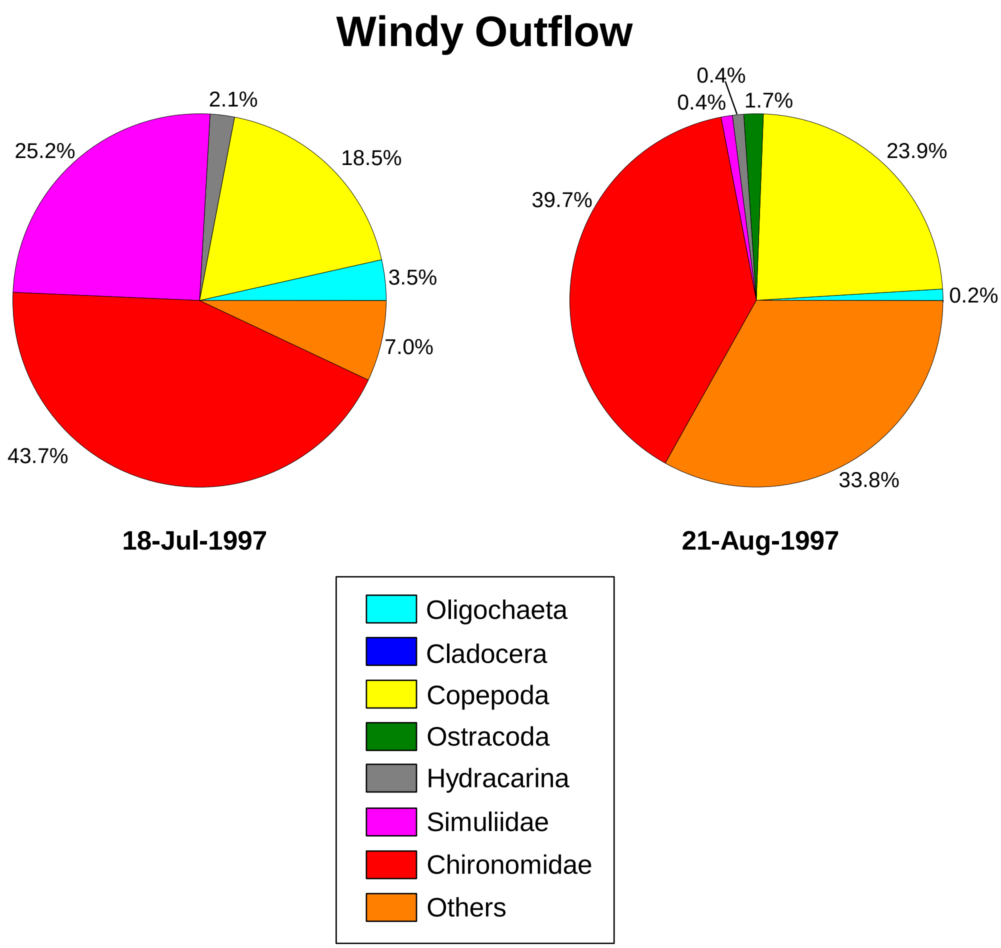
Two drift sampling sessions were conducted on Windy Outflow in 1997, one in July and one in August. Mean total numbers (± 1 SE) were 41.7 ± 5.8 and 560 ± 364 animals/1000 m^3 in the July and August samples, respectively (Figure 6.20; Appendices C5 and C6).

In July, Chironomidae and Simuliidae dominated the drift of Windy Outflow; these groups contributed 53.6 and 30.9% towards total mean numbers, respectively. The August drift community was dominated by Chironomidae and Malacostraca (39.7% and 30.2% of total numbers, respectively). These major taxonomic groups were primarily represented by unidentified species (chironomids), *Prosimulium* spp. and *Simulium* spp. (simuliids), and the isopod S*aduria entomon* (Figure 6.20; Appendices C5 and C6).

6.3.7 Little Roberts Outflow

Two drift sampling sessions were conducted on Little Roberts Outflow in 1997, one in July and one in August. Mean total numbers (± 1 SE) were 982 ± 143 and 160 ± 5 animals/1000 m^3 in the July and August samples, respectively (Figure 6.21; Appendices C5 and C6).

In July, Chironomidae dominated the drift of Little Roberts Outflow; this group contributed 81.3% towards total mean numbers. The August drift community was dominated Cladocera (49.0% of total numbers) and Chironomidae (22.0%).



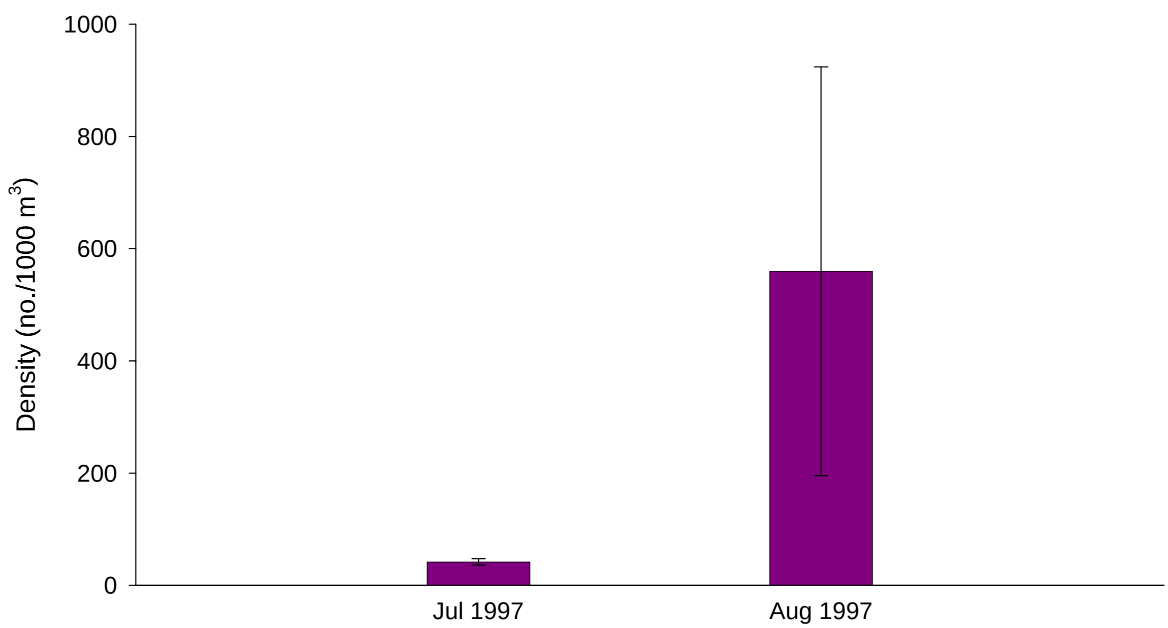


Figure 6.20 Relative abundance of major taxonomic groups and mean total density (± 1SE) of drifting invertebrates in Windy Outflow, 1997.

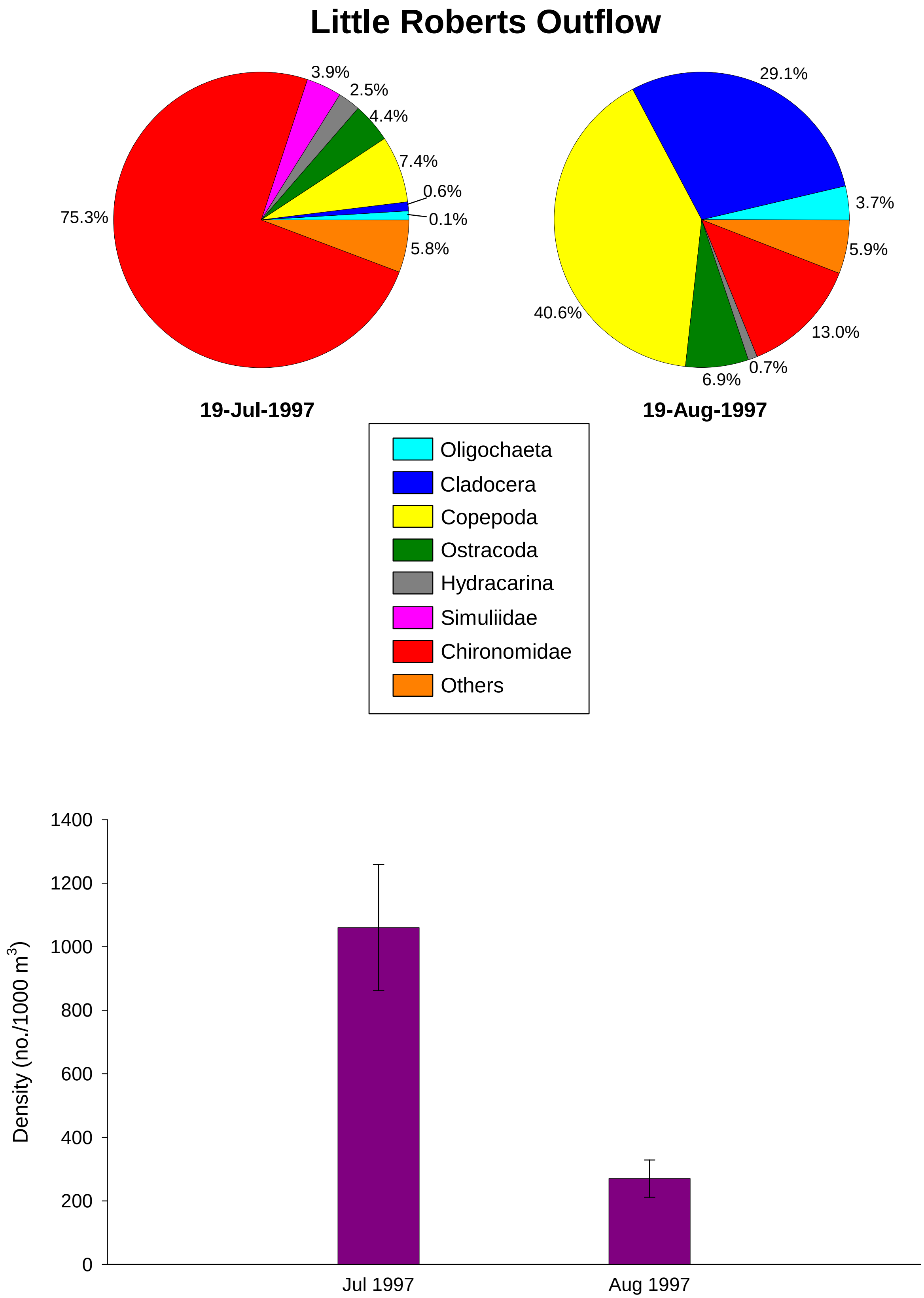


Figure 6.21 Relative abundance of major taxonomic groups and mean total density (± 1SE) of drifting invertebrates in Little Roberts Outflow, 1997.

The chironomids were represented by various unidentified species (specimens were either too immature or too badly damaged for further taxonomic resolution). The Cladocera were represented primarily by *Holopedium gibberum* (Figure 6.21; Appendices C5 and C6).

6.3.8 Pelvic Outflow

Three drift sampling sessions were conducted on Pelvic Outflow, two during summer of 1997 and one during the summer of 2000. Mean total drift numbers (± 1 SE) ranged from 2639 ± 725 animals/1000 m^3 on 19 July 1997 to 14 144 ± 6777 animals/1000 m^3 on 23 July 2000 (Figure 6.22; Appendices C5 and C6).

In July 1997, the drift community of Pelvic Outflow was dominated by Chironomidae, Ostracoda, and Simuliidae, which contributed 38.8, 36.5, and 23.1% towards the total mean count in the samples, respectively. The major contributors in these groups were unidentified species (too immature or damaged to identify further), *Cypria* spp., and *Simulium* spp., respectively. In August 1997, the Pelvic Outflow drift community was dominated by Chironomidae (85.3% of total numbers), the majority of which were not identified to lower taxonomic levels. During the final sampling session (July 2000), Cladocera, contributing 73.4% to mean total numbers, dominated the drift of Pelvic Outflow; this major taxonomic group was represented mainly by *Daphnia longiremis* (Figure 6.22; Appendices C5 and C6).

6.3.9 Summary

For the Doris Hinge streams, a comparison of mean total drift abundance suggests that Ogama and Pelvic outflows were highly productive, and that Patch Outflow was the least productive (Table 6.6). Chironomidae, Simuliidae, Ostracoda, and Cladocera dominated the drift of the Doris Hinge streams. Differences in composition and abundance of drift organisms could largely be ascribed to physical and energetic characteristics among the study streams. For example, the low numbers of drift encountered in Patch Outflow may be due to the low, ephemeral flows encountered at this site (Rescan 1998). The normally marine isopod, *Saduria entomon*, was occasionally present in considerable proportions (i.e., Patch and Windy outflows). The high proportion of zooplankton in the drift of Doris, Little Roberts, and Pelvic outflows may be an artifact of positioning the drift nets in close proximity to a lake and / or high flushing rates of the corresponding lakes. Nonetheless, the capture of zooplankton in the drift of the Doris Hinge streams suggested that they may be an important prey item for stream resident predators.

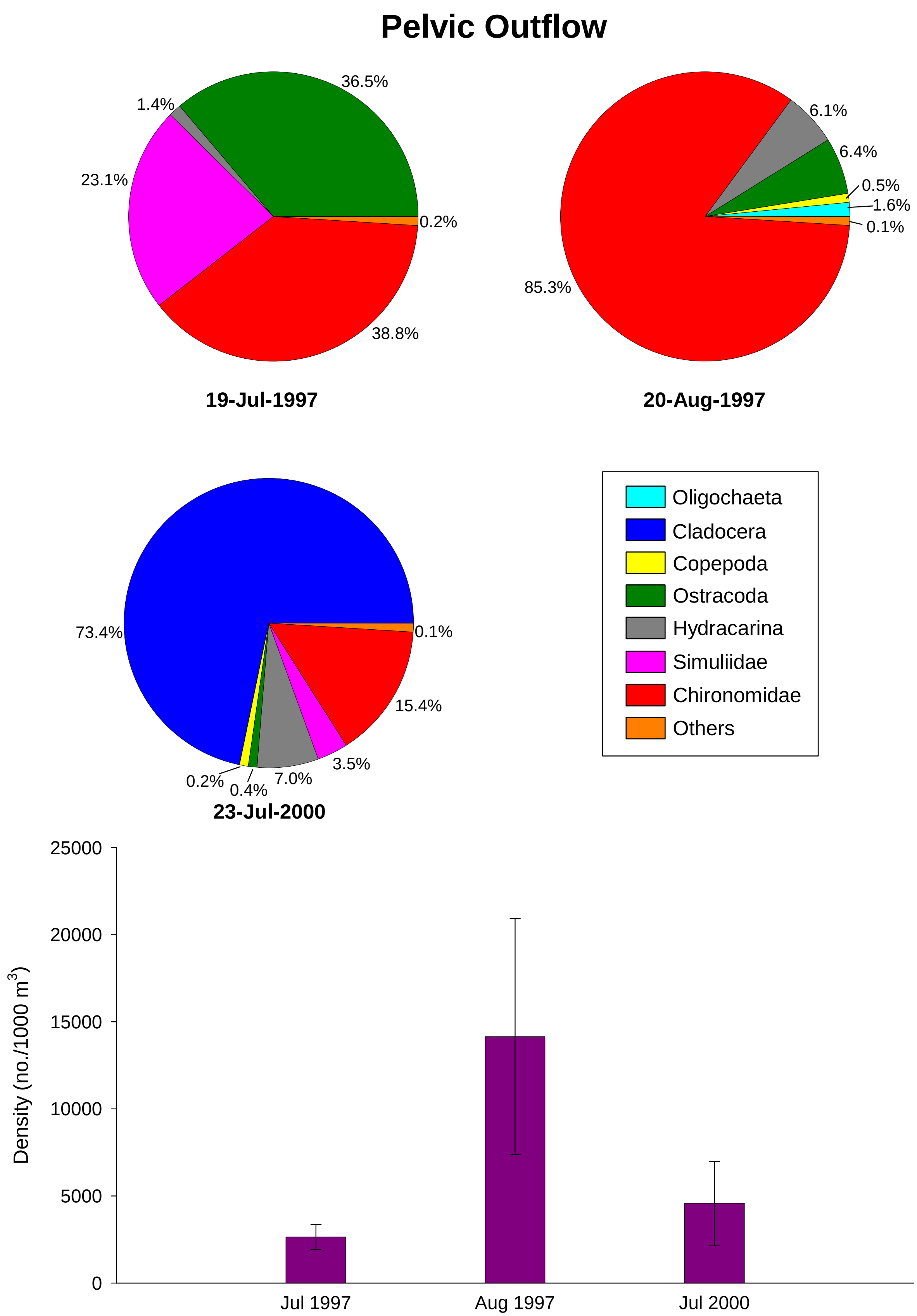


Figure 6.22 Relative abundance of major taxonomic groups and mean total density (± 1SE) of drifting invertebrates in Pelvic Outflow, 1997 to 2000.

Table 6.6 Summary of drift abundance in Doris Hinge streams, 1997 to 2000.

Stream	Number of Sampling Events	Mean Drift Numbers[a] (animals/1000 m^3)
Doris Outflow	3	1 933
Tail Outflow	2	404
Ogama Outflow	2	4 838
Patch Outflow	1	6.3
Windy Outflow	2	301
Little Roberts Outflow	2	665
Pelvic Outflow	3	7 122

[a] all sampling events combined.

6.4 BENTHIC INVERTEBRATES IN STREAMS

Stream benthic macroinvertebrates are adapted to living in flowing waters. Thus, the species encountered in streams are different than those from lake environments (see Section 6.2). Stream invertebrates are an important part of the food chain, particularly if they are located within fish feeding and rearing habitats.

6.4.1 Methods

Benthic samples were collected from seven streams within the Doris Hinge area (Figure 6.9). Two to four sampling sessions were conducted on each stream between 1996 and 2000. Benthic samples were not collected in 1998 and 1999 (Table 6.7).

Artificial substrate samplers (Hester and Dendy 1962) were used to collect stream invertebrates. The artificial substrate samplers consisted of eight 0.064 m^2 plates stacked 0.5 cm apart. Five samplers were set in each stream sampling site to facilitate the collection of a minimum of three replicate samplers at the time of retrieval; in actuality one to five samplers were retrieved per site. Among the study sites, the artificial substrate samplers were placed, exposed, and collected in conditions as nearly identical as possible to reduce site-to-site variability. Invertebrates were allowed to colonize the artificial substrates for approximately 27 to 35 days; however, deployment dates for the 1996 survey were not reported by Rescan (1997).

Table 6.7 Benthic invertebrate sampling schedule in Doris Hinge streams, 1996 to 2000.

Stream	Date Sampled			
	1996	1997	1997	2000
Doris Outflow	25 August	19 July	20 August	16 August
Tail Outflow	2 August	19 July	19 August	16 August
Ogama Outflow	2 August	18 July	20 August	
Patch Outflow	3 August		21 August	
Windy Outflow	1 August	18 July	21 August	
Little Roberts Outflow	3 August	19 July	19 August	
Pelvic Outflow		19 July	21 August	16 August

Prior to sampler removal, a sieve (mesh size not reported) was placed on the downstream side of the sampler to prevent possible loss of organisms. Organisms were then gently brushed from the sampler onto a sieve, transferred to a clean 500-mL plastic bottle, preserved with 10% formalin, and labeled. The 1996 and 1997 samples were submitted to Biologica (Victoria, BC), whereas the 2000 samples were submitted to Applied Technical Services (Victoria, BC) for taxonomic identification and enumeration.

6.4.2 Doris Outflow

Four benthic invertebrate sampling sessions were conducted on Doris Outflow: one in 1996, two in 1997, and one in 2000. Mean total invertebrate numbers (± 1 SE) ranged from 743 animals/m^2 (n=1) in August 1997 to 207 863 ± 3807 animals/m^2 in August 2000 (Figure 6.23; Appendices C7 and C8).

Except for the July 1997 samples, Chironomidae dominated the benthic invertebrate community of Doris Outflow; this taxon contributed from 44.7 to 88.3% towards the total mean number of animals enumerated during the August 1996, August 1997, and August 2000 sampling sessions. Samples from July 1997 were dominated by Simuliidae, which contributed 91.1% to total numbers. The Chironomidae were represented primarily by unidentified species and *Cricotopus* spp., whereas the Simuliidae were represented primarily by *Simulium* spp. (Figure 6.23; Appendices C7 and C8).

6.4.3 Tail Outflow

Four benthic invertebrate sampling sessions were conducted on Tail Outflow: one in 1996, two in 1997, and one in 2000. Mean total numbers (± 1 SE) ranged from 721 ± 148 animals/m^2 in 1996 to 6150 ± 1528 animals/m^2 in 2000 (Figure 6.24; Appendices C7 and C8).

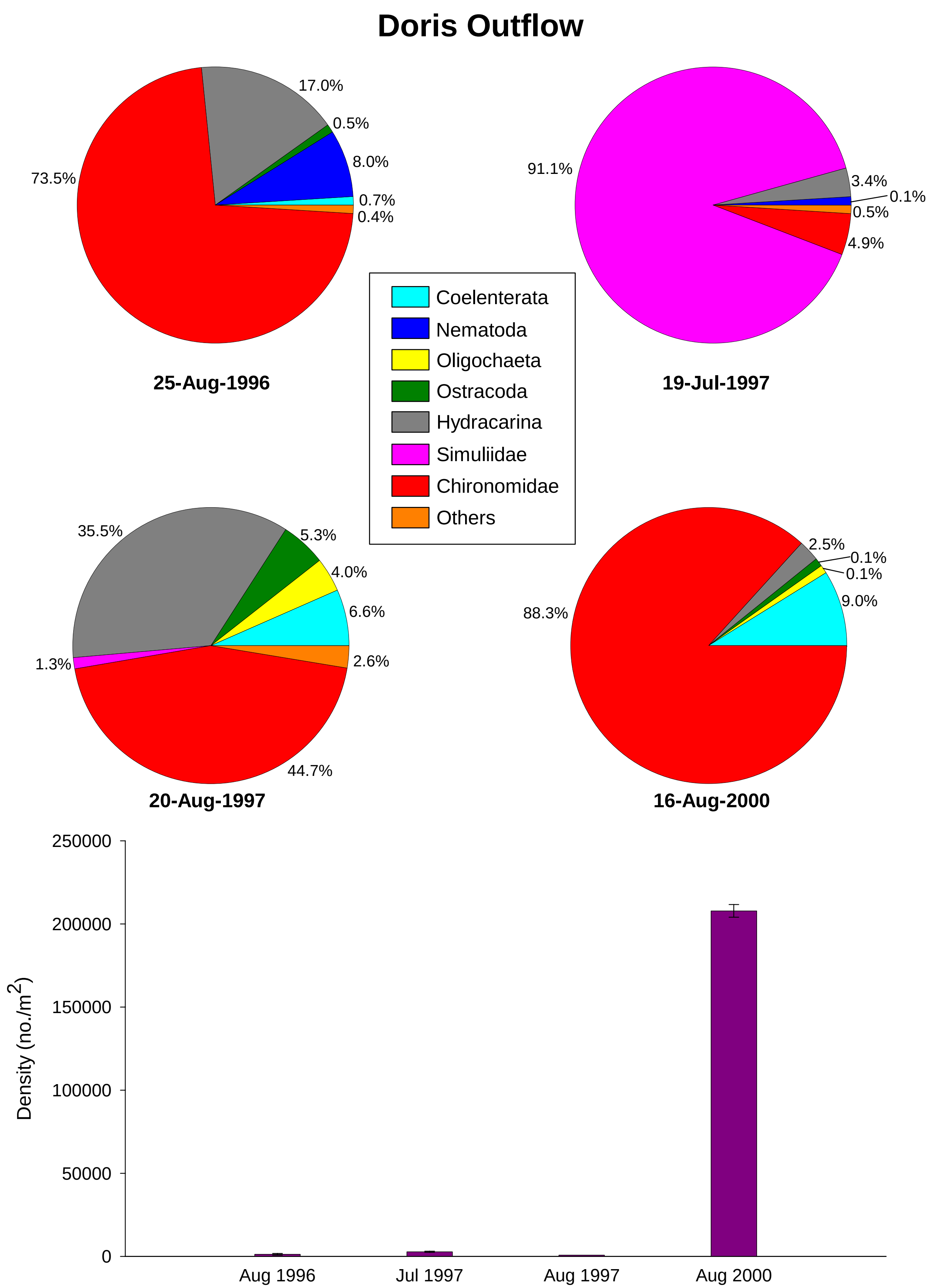


Figure 6.23 Relative abundance of major taxonomic groups and mean total density (± 1SE) of benthic invertebrates in Doris Outflow, 1996 to 2000.

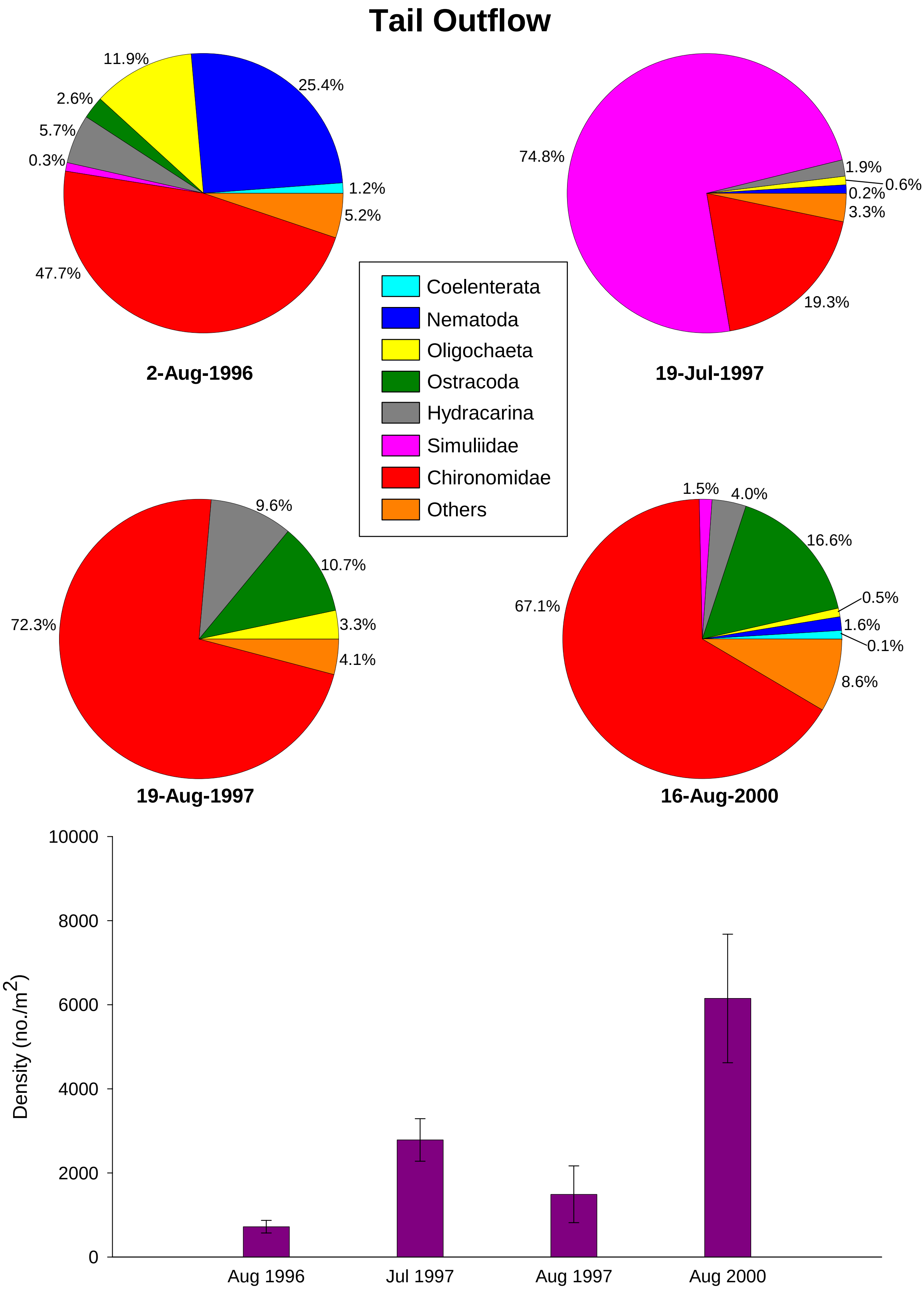


Figure 6.24 Relative abundance of major taxonomic groups and mean total density (± 1SE) of benthic invertebrates in Tail Outflow, 1996 to 2000.

Except for the July 1997 samples, Chironomidae dominated the benthic invertebrate community of Tail Outflow; this taxon contributed between 47.7 and 72.3% to the total mean number of animals enumerated during the August 1996, August 1997, and August 2000 sampling sessions. The July 1997 sampling session was dominated by Simuliidae, which contributed 74.8% to total numbers. Unidentified chironomids, unidentified Tanytarsini, and *Rheotanytarsus* spp. were the main contributors to Chironomidae, whereas the *Simulium* spp. were the dominant Simuliidae (Figure 6.24; Appendices C7 and C8).

6.4.4 Ogama Outflow

Three invertebrate sampling sessions were conducted on Ogama Outflow: one in 1996 and two in 1997. Mean total numbers (± 1 SE) ranged from 7177 ± 185 animals/m^2 in July 1997 to 23 429 ± 13 207 animals/m^2 in August 1996 (Figure 6.25; Appendices C7 and C8).

In August 1996, Chironomidae dominated the benthos of Ogama Outflow; this group contributed 74.1% to total mean numbers. The July 1997 community was dominated by Simuliidae (72.1% of total numbers). The August 1997 community was well represented by Chironomidae (88.3% of total numbers). The chironomids were comprised primarily of *Rheotanytarsus* spp., *Eukiefferiella* spp., and *Cricotopus* spp., whereas the simuliids were comprised of *Simulium* spp. (Figure 6.25; Appendices C7 and C8).

6.4.5 Patch Outflow

Retrieval of the artificial substrates from Patch Outflow was conducted on 3 August 1996 and 21 August 1997. Mean total numbers (± 1 SE) on these dates were 1798 ± 713 and 148 ± 51 animals/m^2 (Figure 6.26; Appendices C7 and C8).

The benthic invertebrate community of Patch Outflow was dominated by Chironomidae, which contributed 52.7 and 68.2% to total mean numbers in 1996 and 1997, respectively. In 1996, Nematoda (round worms) represented a considerable proportion (36.8%) of the benthic community. The Malacostraca, represented exclusively by the isopod *Saduria entomon*, contributed 17.6% toward total numbers encountered in the 1997 samples. The major contributors to the chironomids were *Cricotopus* spp. and *Eukiefferiella* spp. Nematodes are typically not identified to lower taxonomic levels (Figure 6.26; Appendices C7 and C8).

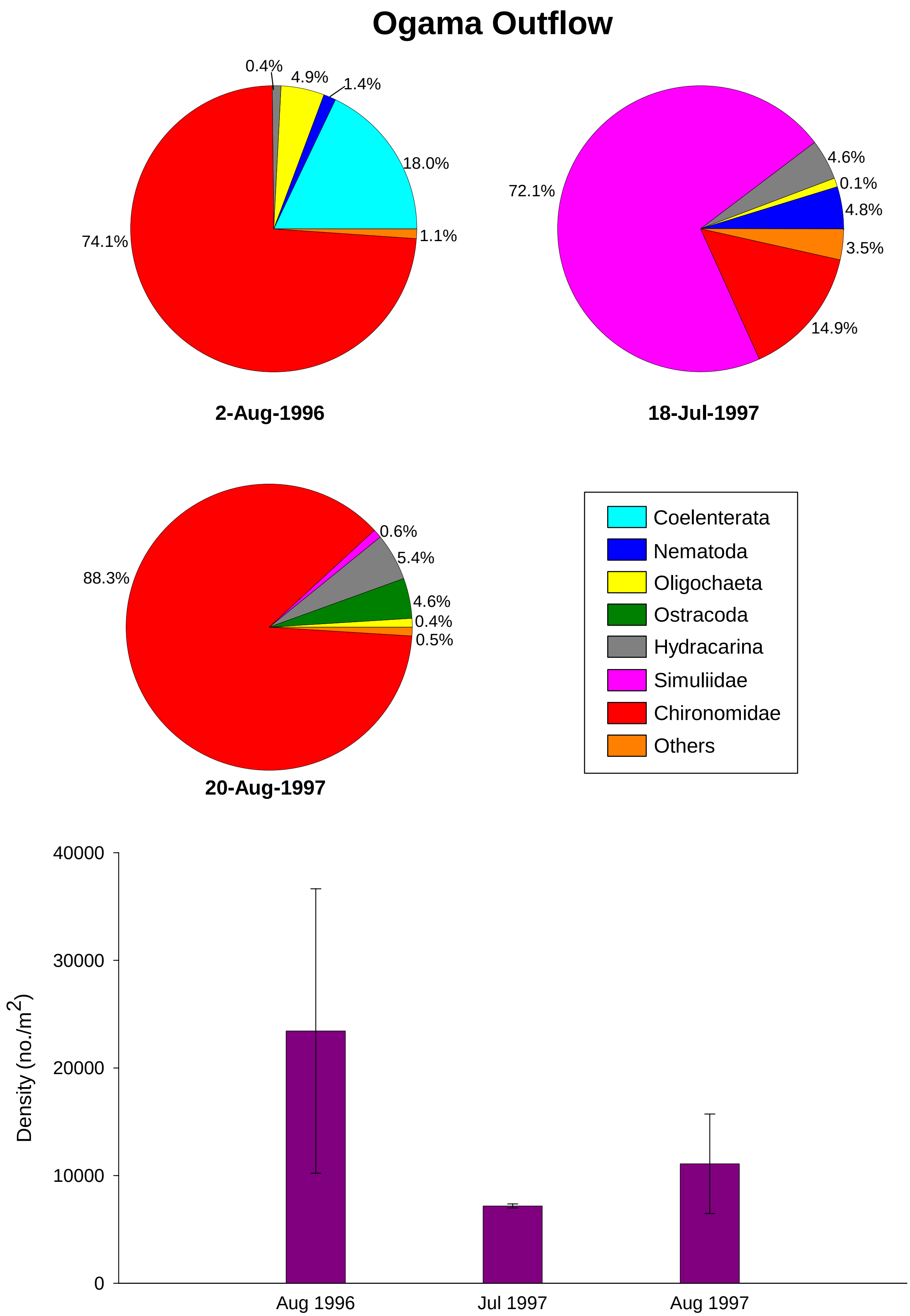


Figure 6.25 Relative abundance of major taxonomic groups and mean total density (± 1SE) of benthic invertebrates in Ogama Outflow, 1996 to 1997.

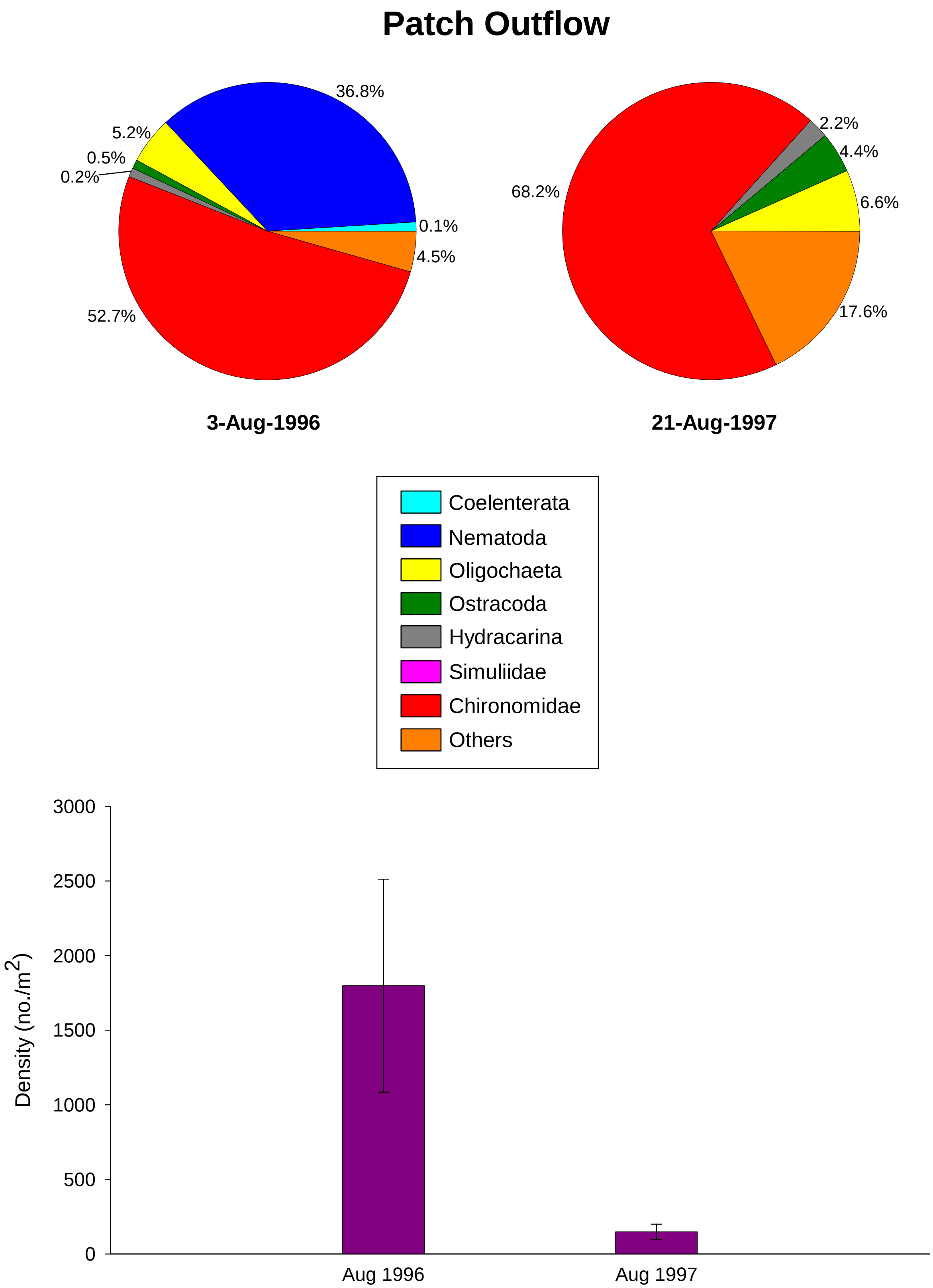


Figure 6.26 Relative abundance of major taxonomic groups and mean total density (± 1SE) of benthic invertebrates in Patch Outflow, 1996 to 1997.

6.4.6 Windy Outflow

Artificial substrates from Windy Outflow were retrieved in August 1996, July 1997, and August 1997. Mean total numbers (± 1 SE) varied from 333 ± 149 animals/m^2 in July 1997 to 3447 ± 2737 animals/m^2 in August 1996 (Figure 6.27; Appendices C7 and C8).

Chironomidae dominated the August 1996 and August 1997 samples from Windy Outflow; this group contributed 69.9 and 48.5% to total mean numbers, respectively. The August 1997 samples also had considerable proportions of Simuliidae (22.6%). The July 1997 stream benthic community was dominated by Simuliidae (63.5% of total numbers). These major taxonomic groups were primarily represented by *Rheotanytarsus* spp. and Tanytarsini spp. (chironomids), and by *Simulium* spp. (simuliids) (Figure 6.27; Appendices C7 and C8).

6.4.7 Little Roberts Outflow

Three benthic sampling sessions were conducted on Little Roberts Outflow. Artificial substrates were retrieved in August 1996, July 1997, and August 1997. Mean total numbers (± 1 SE) varied from 85 ± 65 animals/m^2 in August 1996 to 510 ± 109 animals/m^2 in August 1997 (Figure 6.28; Appendices C7 and C8).

Chironomidae, Coelenterata, and Plecoptera (stoneflies) contributed considerable proportions to the benthic community of Little Roberts Outflow in July 1996 (30.3, 25.0, and 15.8%, respectively). These groups were represented primarily by various unidentified chironomids specimens that were either too immature or too badly damaged for further taxonomic resolution, *Hydra* spp. (coelenterates), and *Podmosta* spp. (plecopterans). The July and August 1997 benthic communities were dominated by Chironomidae (71.9 and 58.8% of total numbers, respectively); the chironomids were represented by various unidentified species and *Eukieffierella* spp. (Figure 6.28; Appendices C7 and C8).

6.4.8 Pelvic Outflow

Three artificial substrate colonization periods were conducted on Pelvic Outflow; samples were collected twice during summer of 1997 and once during the summer of 2000. Mean total benthic invertebrate numbers (± 1 SE) varied from 3071 ± 408 animals/m^2 in August 1997 to 51 736 ± 16 130 animals/m^2 in July 1997 (Figure 6.29; Appendices C7 and C8).

Simulliidae (96.9% of total numbers) overwhelmingly dominated the benthic community of Pelvic Outflow in July 1997; this taxon was represented by

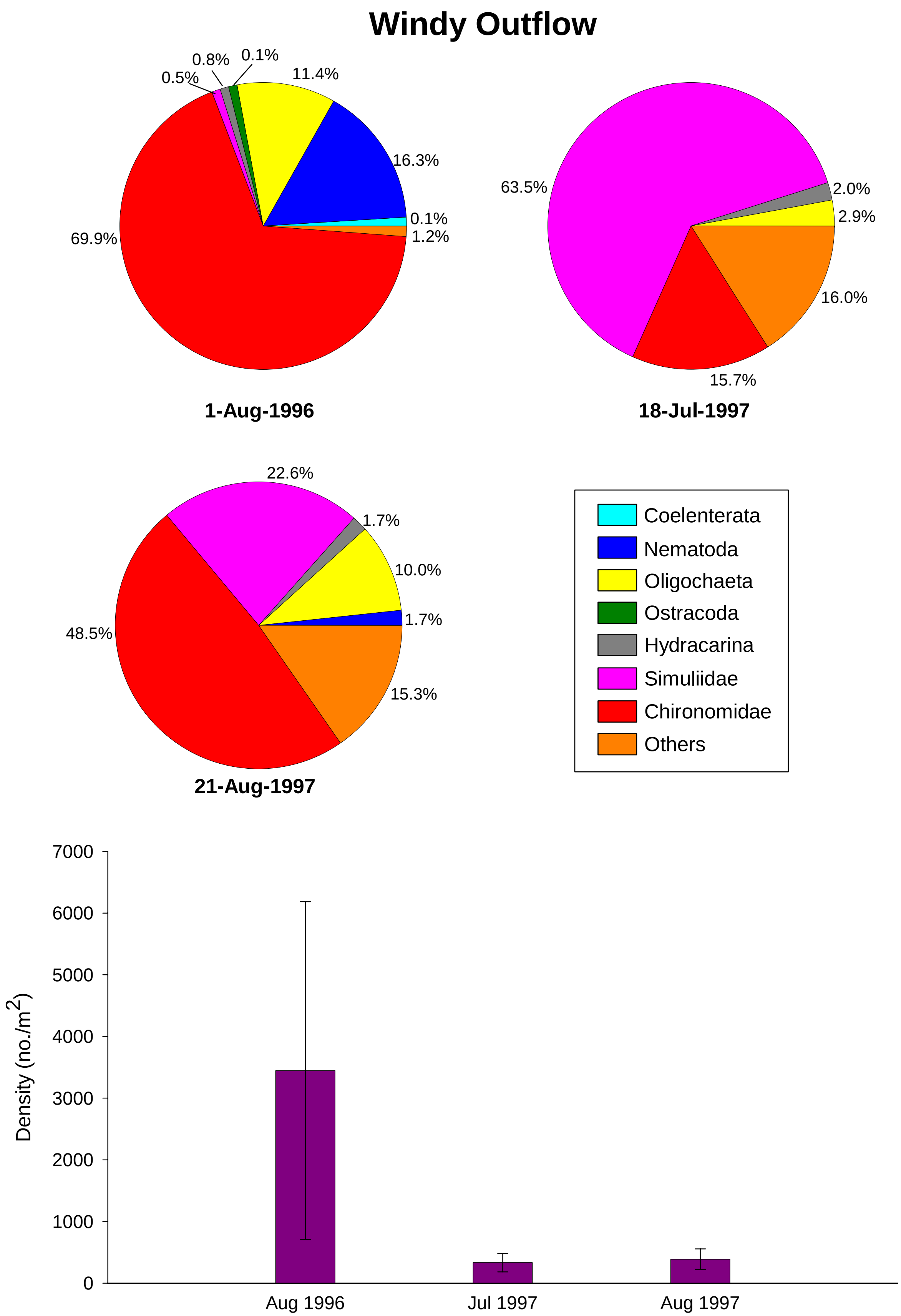


Figure 6.27 Relative abundance of major taxonomic groups and mean total density (± 1SE) of benthic invertebrates in Windy Outflow, 1996 to 1997.

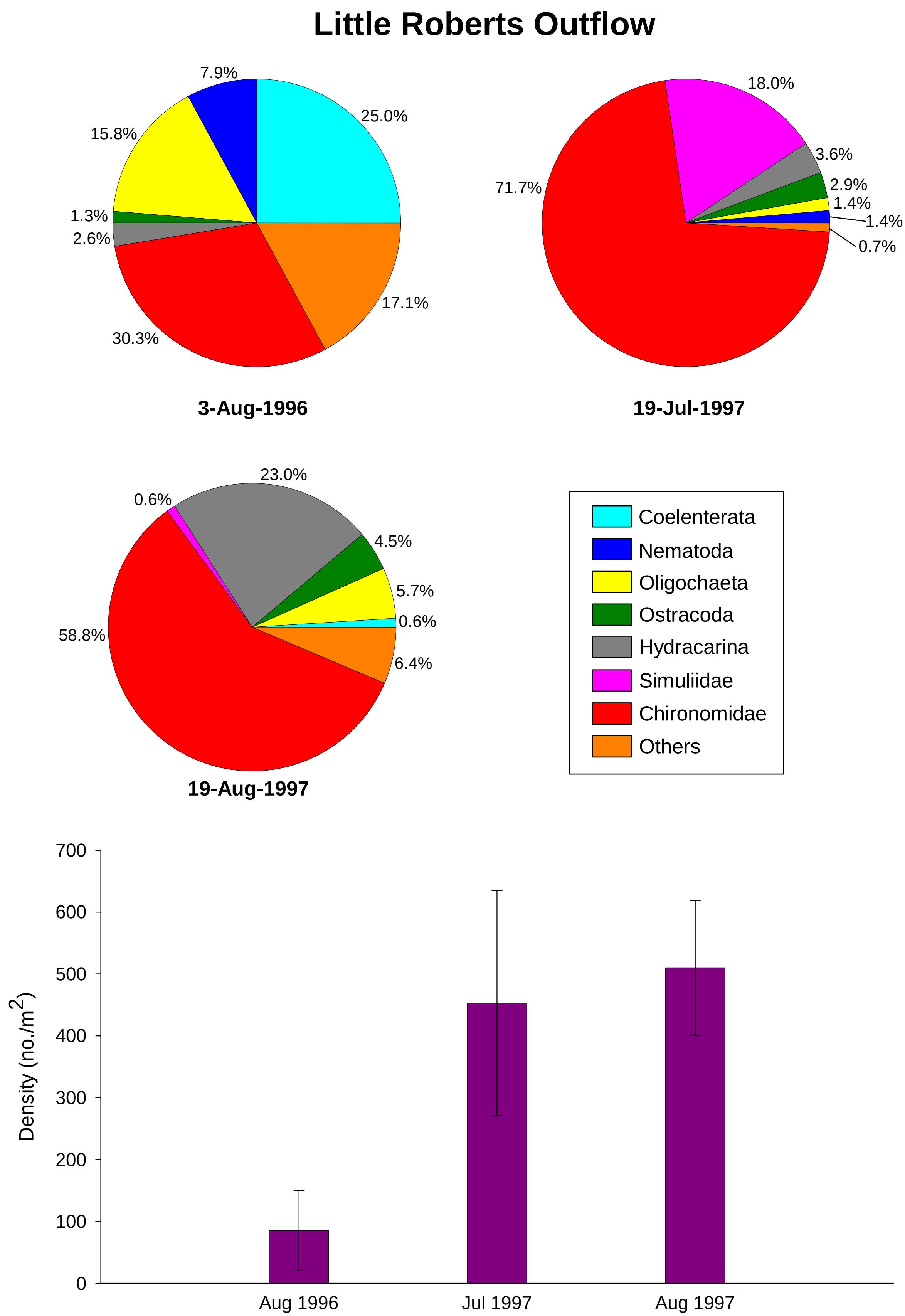


Figure 6.28 Relative abundance of major taxonomic groups and mean total density (± 1SE) of benthic invertebrates in Little Roberts Outflow, 1996 to 1997.

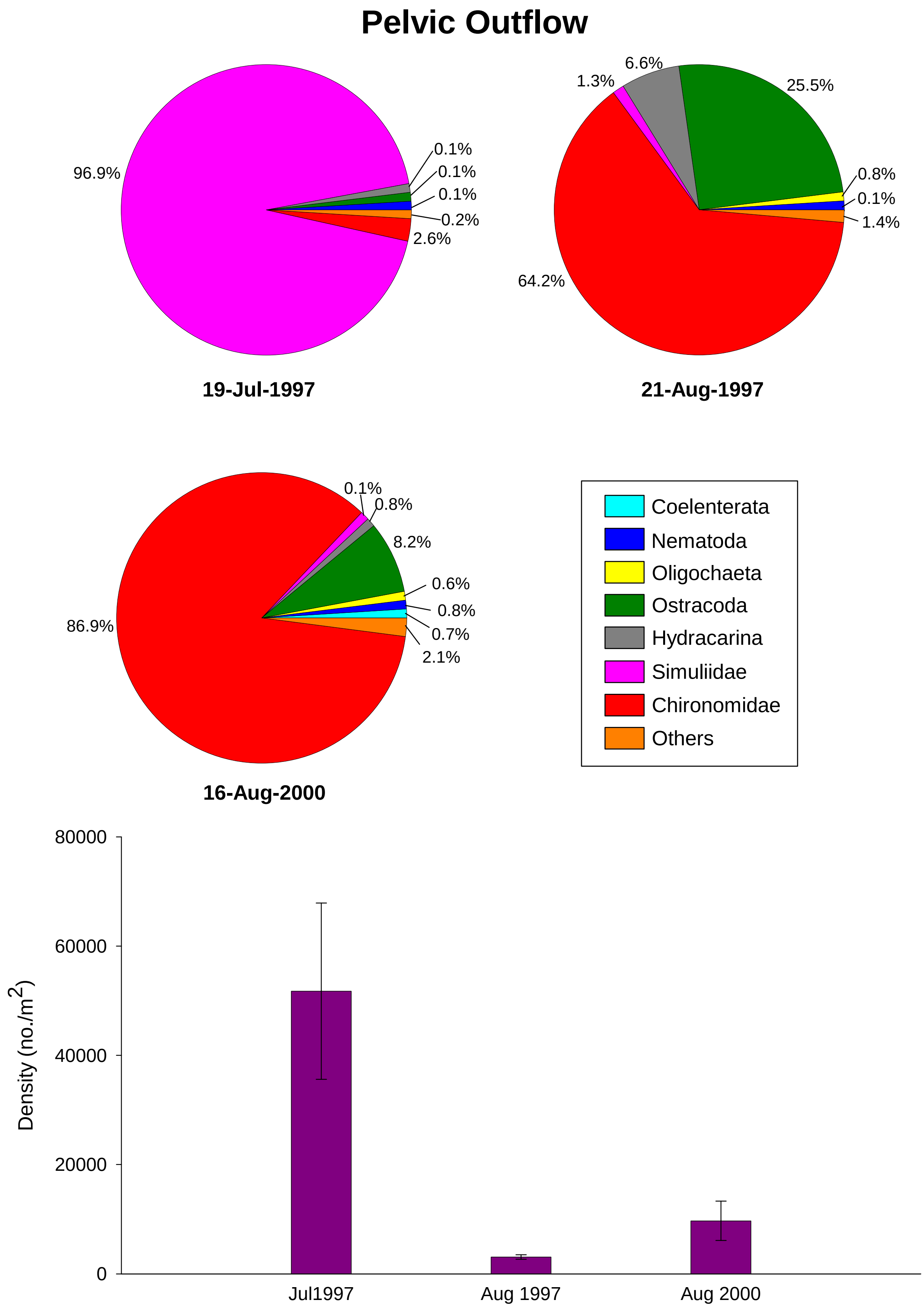


Figure 6.29 Relative abundance of major taxonomic groups and mean total density (± 1SE) of benthic invertebrates in Pelvic Outflow, 1997 to 2000.

Simulium spp. and *Prosimulium* spp. Chironomidae contributed the greatest proportions of the benthic communities in the August 1997 and August 2000 samples (64.2 and 86.9%, respectively). Ostracoda also represented a considerable proportion of the benthos in August 1997 and August 2000 (25.5 and 8.2%, respectively). The chironomids were represented mainly by *Rheotanytarsus* spp. and various unidentifiable species, whereas the ostracods were represented mainly by *Candona* spp. (Figure 6.29; Appendices C7 and C8).

6.4.9 Summary

For the Doris Hinge streams, a comparison of mean total benthic abundance suggested that Ogama Outflow was the most productive, and that Little Roberts Outflow was the least productive (Table 6.8). Chironomidae and Simuliidae dominated the benthic communities of the Doris Hinge streams. The isopod *Saduria entomon* contributed a considerable proportion to the benthos of Patch Outflow. Plecoptera (i.e., *Podmosta* spp.) contributed a large proportion to the benthos of Little Roberts Outflow in July 1997. Coelenterata, Nematoda, and Ostracoda also occasionally contributed considerable proportions to the benthos of the Doris Hinge streams (i.e., Patch, Little Roberts, and Pelvic outflows).

Table 6.8 Summary of benthic invertebrate abundance in Doris Hinge streams, 1996 to 2000.

Stream	Number of Sampling Events	Mean Number of (organisms/m^2)
Doris Outflow	4	53 162
Tail Outflow	4	2 787
Ogama Outflow	3	13 900
Patch Outflow	2	973
Windy Outflow	3	1390
Little Roberts Outflow	3	349
Pelvic Outflow	3	21 504

Differences in composition and abundance of benthic organisms could largely be ascribed to physical and energetic characteristics among the study streams, as well as seasonality. For example, the low numbers of benthos encountered in Little Roberts Outflow may be due to proximity of this sampling site to Roberts Bay (e.g., unknown marine influence, whether physical-chemical or biological). Except for Patch and Little Roberts outflows, all streams sampled in July 1997 featured high proportions (at least 63% of total numbers) of Simuliidae (black flies). Patch Outflow was not sampled in July 1997 and Little Roberts outflows contained relatively lower proportions of simuliids (18.0%). The dominance of black flies among the majority of Doris Hinge streams during the June to July 1997 colonization period suggested that this group was able to take advantage of existing conditions and substantially increase its population, relative to the remaining sampling periods. Larvae and pupae of this taxon are restricted to running waters and use labral fans to capture organic particles suspended in water (Peterson 1996).

6.5 MARINE BENTHIC INVERTEBRATES

As with freshwater invertebrates, benthic forms of marine invertebrates are an important link in food webs. Most marine invertebrates are herbivorous, detritivores, or filter feeders and derive much of their energy from aquatic plants and organic materials. Some benthic macroinvertebrates are predacious, generally feeding upon other invertebrates. Many fish and mammal species feed upon marine invertebrates. The watersheds of the Doris Hinge area empty into Roberts Bay.

6.5.1 Methods

Benthic marine invertebrate samples were collected from three sites within Roberts Bay (Figure 6.9). Two sampling sessions were conducted at each site, one in August 1997 and one in July 1998; attempts were made to collect samples from Roberts Bay in 2000, but discrete, intact samples could not be acquired (Rescan 2001).

Triplicate benthic invertebrate samples were collected at each study location and during each sampling session with an Ekman grab sampler (0.0232 m^2). Three different water depths were sampled; Station 1 was greater than 15 m, Station 3 was approximately 10 m, and Station 5 was approximately 1.0 m. Each replicate sample was sieved over 0.493 mm mesh, transferred to a clean 500-mL plastic bottle, preserved with 10% formalin, and labeled. All samples were submitted to Applied Technical Services, Victoria, BC, for taxonomic identification and enumeration.

6.5.2 Roberts Bay

Mean total numbers (± 1 SE) of benthic marine inhabiting Roberts Bay ranged from 1096 ± 418 animals/m^2 in July 1998 to 41 211 ± 16 719 animals/m^2 in August 1997. There was a trend of increasing densities with water depth (Figures 6.30 to 6.32; Appendices C9 and C10).

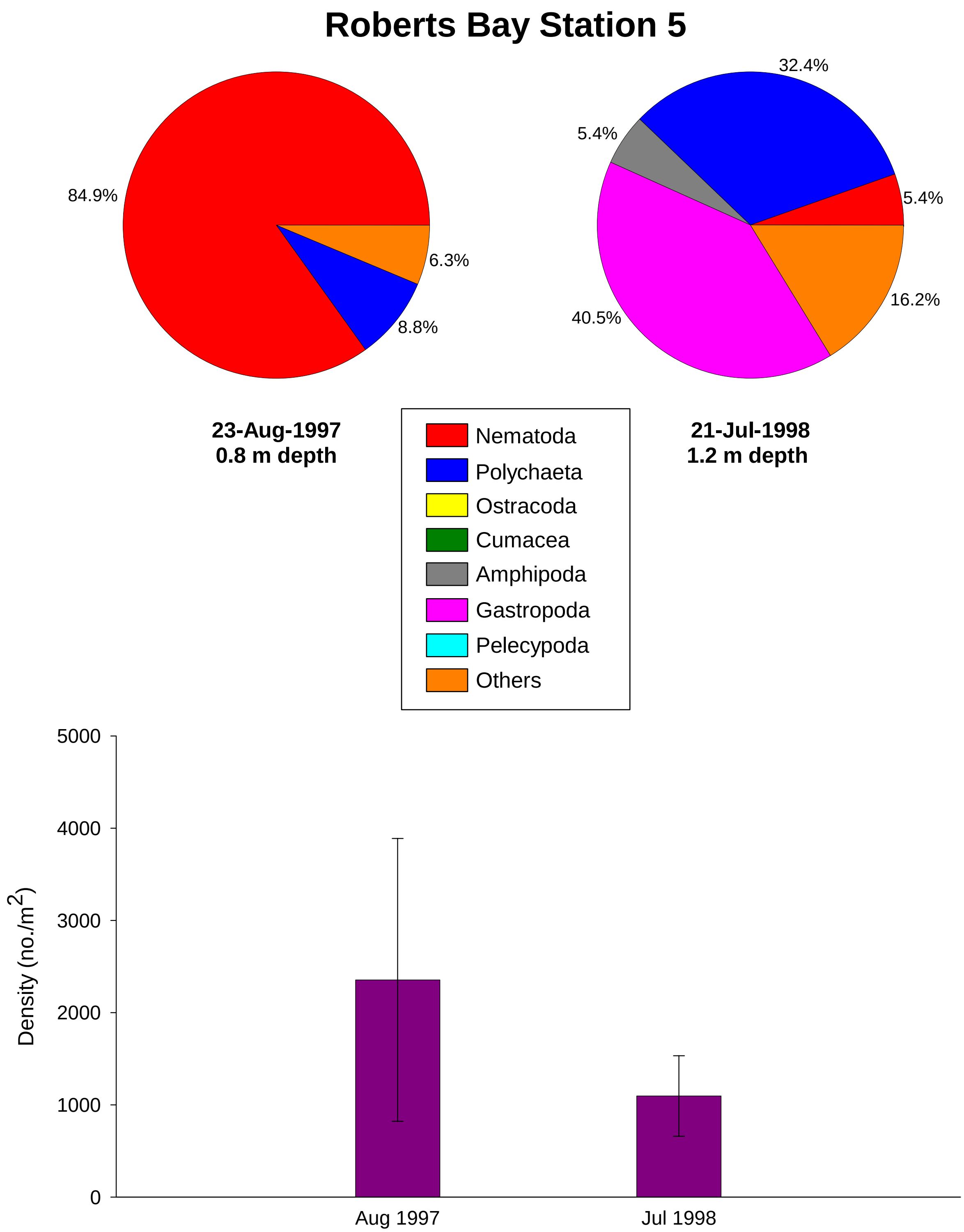


Figure 6.30 Relative abundance of major taxonomic groups and mean total density (± 1SE) of benthic invertebrates in Roberts Bay at Station 5, 1997 to 1998.

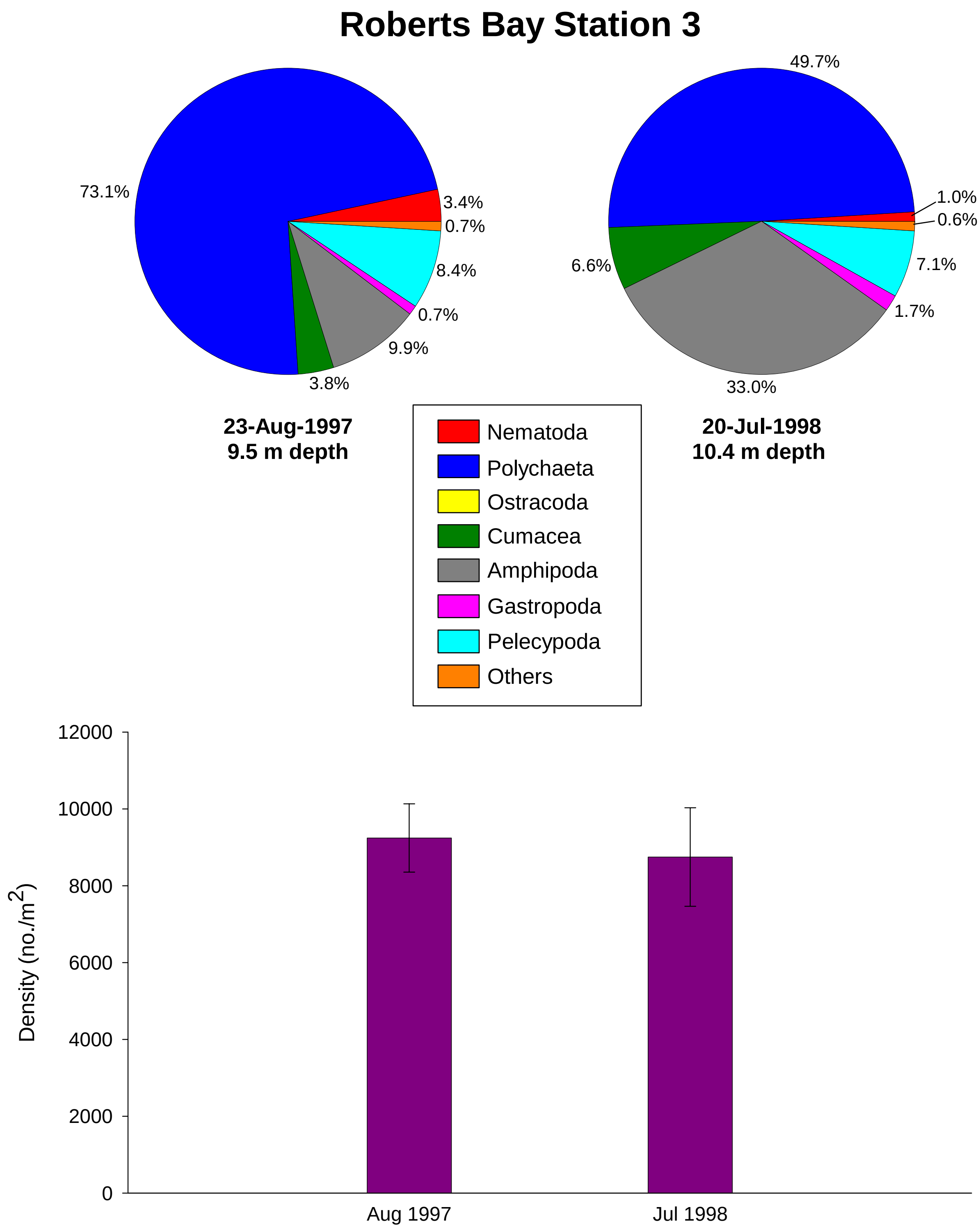


Figure 6.31 Relative abundance of major taxonomic groups and mean total density (± 1SE) of benthic invertebrates in Roberts Bay at Station 3, 1997 to 1998.

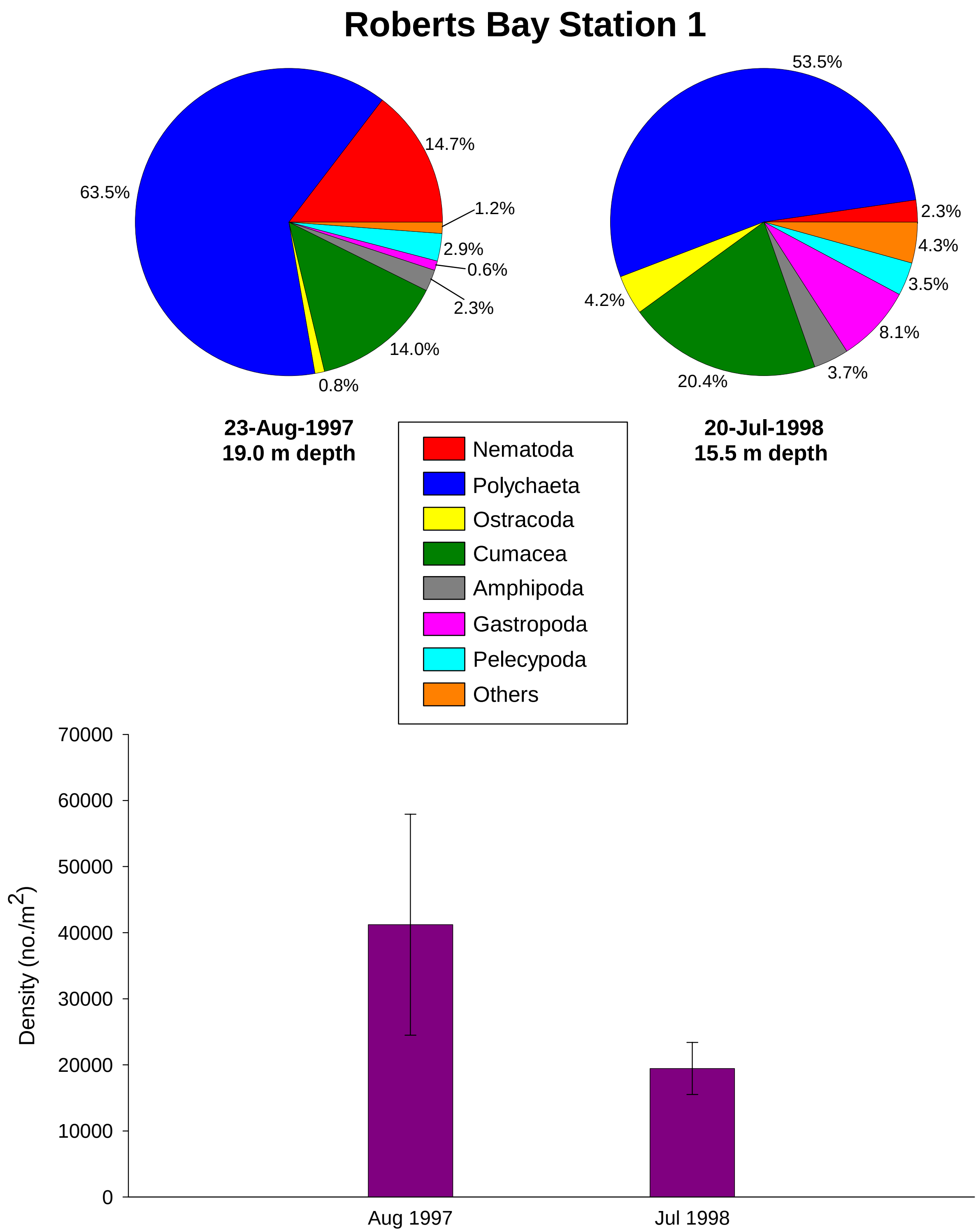


Figure 6.32 Relative abundance of major taxonomic groups and mean total density (± 1SE) of benthic invertebrates in Roberts Bay at Station 1, 1997 to 1998.

Station 5 - Shallow

Nematoda, Pelecypoda, and Polychaeta (lugworms, tube worms, and marine bristle worms) dominated the shallow benthic community of Roberts Bay. Nematodes, contributing 84.9% towards total numbers, dominated the benthic community in August 1997. Pelecypoda contributed 40.5% towards total numbers during the July 1998 sampling session. The proportion of polychaetes in the 1997 samples was lower than that of the 1998 samples (8.8 and 32.4%, respectively). Nematoda typically are not identified to lower taxonomic levels. The pelecypods were represented mainly by *Macoma inquinata*. The polychaetes were represented mainly by the species *Nephytus cornuta* and *Laonice cirrata* (Figure 6.30; Appendices C9 and C10).

Station 3 - Moderate Depth

Polychaetea and Amphipoda (scuds) dominated the benthic community at depths between 9 and 11 m in Roberts Bay (Figure 6.31; Appendices C9 and C10). Polychaetes contributed 73.1 and 49.7% to total mean number of animals in 1997 and 1998, respectively. The main contributors to this major taxonomic group were *Nephtys cornuta* and *Leitoscoloplos pugettensis*. The proportions of amphipods within the benthos of Roberts Bay (moderate depths) were 9.9% in 1997 and 33.0% in 1998; *Pontoporeia femorata* was the most common species encountered.

Station 1 - Deep

At depths greater than 15 m, Polychaetea, Nematoda, and Cumacea (an Order of Malacostraca) dominated the benthic community (Figure 6.32; Appendices C9 and C10). Polychaetes contributed 63.5 and 53.5% to total mean number of animals in 1997 and 1998, respectively. The main contributors to this major taxonomic group were *Nephtys cornuta*, unidentified specimens of the family Cirratulidae, and *Leitoscoloplos pugettensis*. Nematodes contributed 14.7 and 2.3% to the total numbers enumerated in 1997 and 1998, respectively (nematodes were not identified to lower taxonomic levels). The proportions of cumaceans within the deep benthos Roberts Bay were 14.0% in 1997 and 20.4% in 1998; *Diastylis* cf. *abbotti* was the most common species encountered.

6.5.3 Summary

Benthic marine invertebrate samples were collected from three sites (shallow, moderate, and deep) within Roberts Bay. Two sampling sessions were conducted at each site, once in August 1997 and once in July 1998.

Polychaeta (lugworms, tube worms, and marine bristle worms), Nematoda, Pelecypoda, Cumacea (an Order within the Class Malacostraca), and Amphipoda (scuds) dominated the benthos of Roberts Bay. The composition of benthic communities within Roberts Bay was typical for the Arctic and Antarctic regions of the world (Hickman 1973; Johannesson et al. 2000). Differences in composition and abundance of the benthos among the three stations could be ascribed to physicochemical (e.g., water depth, salinity) characteristics at the sampling locations.

A comparison of mean benthic macroinvertebrate abundance among the three Roberts Bay stations indicated a trend of increasing faunal densities with increasing water depth (Table 6.9). Most taxonomic groups followed this trend in abundance among the three study locations. One notable exception included the isopod *Saduria entomon*; shallower depths featured greater densities of this species.

Table 6.9 Summary of benthic invertebrate abundance in Roberts Bay, 1997.

Location	Sample Depth (m)	Number of Sampling Events	Mean Total Density (animals/m^2)	Mean Number of *Saduria entomon* (animals/m^2)	Mean Number of Polychaeta (animals/m^2)
Station 5	<1.5	2	1 726	81	282
Station 3	9.0 - 11.0	2	8 996	7	5 552
Station 1	>15	2	30 331	0	18 286

With the exception of the samples collected at Station 5 (shallow depth), polychaetes tended to dominate (i.e., contributed more than 50% towards total numbers) the benthic communities of Roberts Bay (Table 6.9; Figures 6.30, 6.31, and 6.32). The benthic community at Station 5 featured low numbers and proportions (less than 33%) of polychaetes. The taxonomic Class Polychaeta (within the phylum Annelida) is an ecologically important group of primarily marine worms. More than 10 000 species of these worms exist in nature, displaying an enormous size range (less than 1 mm to 3 m). There are two general forms of polychaetes: those that are free living (Errantia) and those that are sedentary tube dwellers (Sedentaria). The actual number and type of polychaete species present in a system is the result of the complex of physical, chemical, biological, and biogeographic conditions (Hickman 1973).

7.0 FISH POPULATIONS

7.1 LAKE COMMUNITIES

7.1.1 Methods

Field Methods

Fish sampling techniques used in the Doris Hinge lakes between 1995 and 2000 included gill nets, beach seines and visual observations. The primary fish capture method was gill netting (all years), with considerably lesser amounts of beach seining (1996) and visual observations in near-shore areas (1995). All surveys were conducted during August. The lakes sampled during the 1995-2000 period included Doris, Tail, Ogama, Patch, Windy, Little Roberts, and Pelvic (Figure 7.1); some lakes were sampled only once during this period (Little Roberts, Pelvic, and Ogama), whereas others were sampled up to three times (Tail, Doris, and Patch). Detailed descriptions of fish capture methods are provided below.

Standard gill net gangs were used in 1995. These consisted of 76 m long floating and sinking gangs comprised of 15.2 m by 2.4 m panels of monofilament nylon netting of the following stretched mesh sizes: 3.8, 6.4, 8.9, 11.4, and 14.0 cm. This was altered in 1996 when one net had panels of 1.9, 2.5, and 3.8 cm mesh, whereas the second net (set parallel to the first one) consisted of panels with 5.1, 6.4, 8.9, and 12.7 cm mesh. Gang nets had a total length of 45.7 m (smaller meshes) and 61.0 m (larger meshes). In both years the gangs generally were set perpendicular to the shore. Nets were set for 8-12 hour periods and generally were checked hourly to minimize mortality.

Index gill net gangs were used to survey lakes in 1997, 1998, and 2000. Each gang consisted of three panels of 3.8 cm mesh. Each panel was 15.0 m long by 2.44 m deep for a total area of 109.8 m^2 per gang. Index gangs were deployed in what was termed as "rounds". In a round, three to four index gangs were set in succession for approximately one-hour sessions (range of 40-200 minutes). They were then retrieved in the order of setting and re-deployed upon completion of fish sampling.

Beach seining was conducted in Windy, Doris, Ogama, and Patch lakes in August of 1996. The seine was 15.2 m long with 0.2 cm mesh. Except for fish catches in Windy Lake, the results of beach seining in the other lakes were not reported by Rescan (1997), possibly due to nil catches.

Fish life history information was collected from all fish captured. Live fish were identified to species, measured (fork length), weighed (g), sampled for ageing structures, and released. Left pectoral fin clips were taken as ageing structures from 1995 to 1998, whereas left pelvic fin clips were taken in 2000. Between 1997 and 2000, fish larger than 300 mm in fork length were marked with a uniquely numbered Floy anchor tag to assess their movements through subsequent recaptures. Additional data were collected from accidental and euthanized mortalities. These included sex and maturity, reproductive status, stomach contents, collection of otoliths (for ageing), and muscle, liver, and/or kidney tissues for metal analysis.

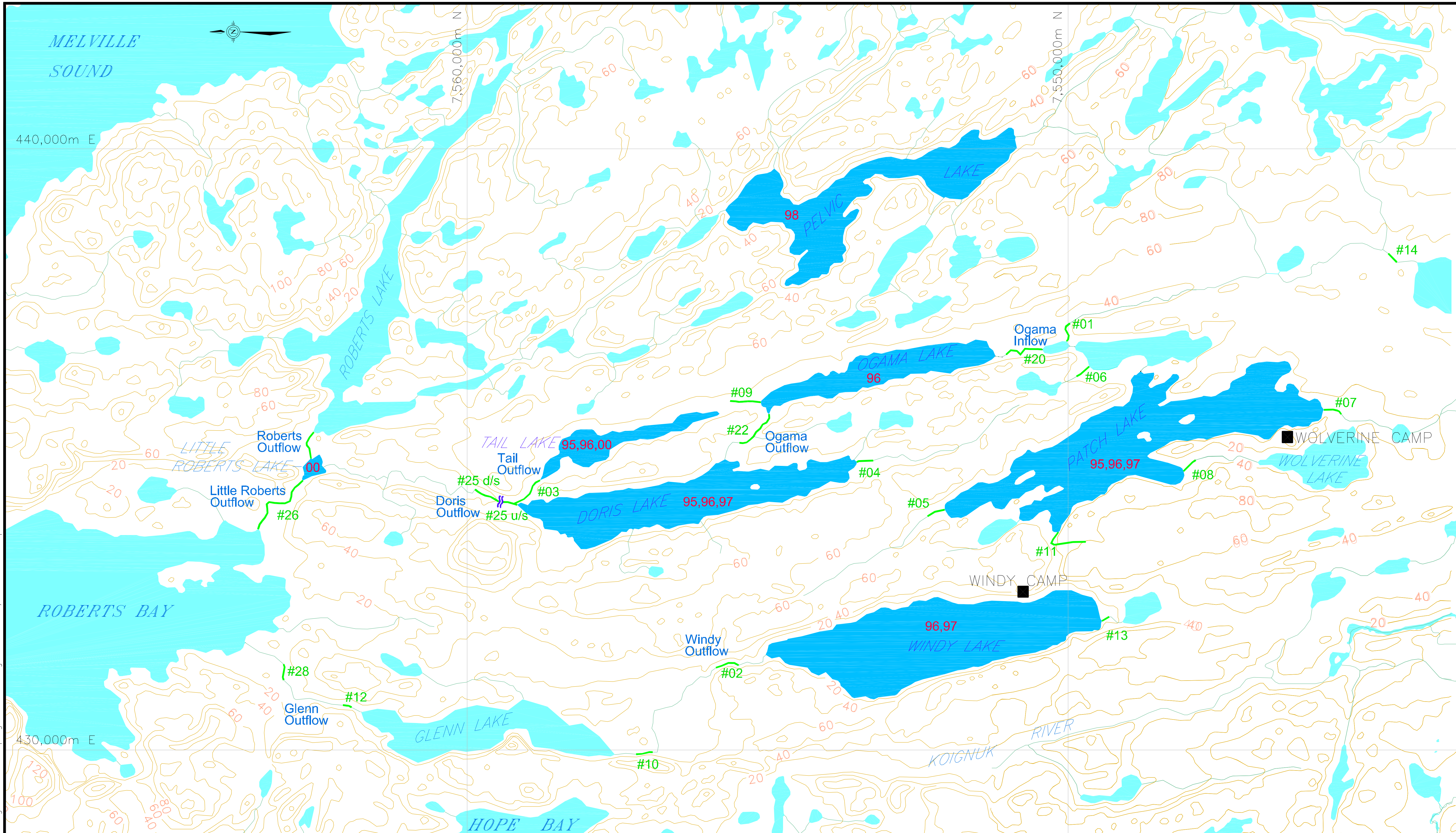
Data Analysis

Data analysis and presentation varied considerably between the five annual data reports. As a result, all raw data have been consolidated into one table (Appendix D8) and submitted to a thorough QA/QC procedure. In cases where fish length did not correspond to its weight (i.e., Fulton's condition factor less than 0.5 or greater than 2.0), both length and weight data were eliminated from life history analyses (these data are reported in quotation marks in Appendix D8). In other cases where fish species were recorded erroneously (e.g., lake trout recorded as lake whitefish), ageing structures were used to verify the true species. Subsequent to filtering out data errors, the raw data were used to calculate life history statistics that included:

- length-frequency distributions,
- length-weight relationships,
- mean, standard deviation, and range of length, weight, age and condition factor data
- age-specific mean length and weight;
- size characteristics for separate sex and maturity categories; and
- diet analyses.

The multi-year data collected from each lake generally were combined during analyses to increase the sample size for each species. In some cases, the data (e.g., length-frequency distributions, mean size statistics) were analyzed separately for each year, if sample sizes were sufficient.

As an index of relative abundance, catch-per-unit-effort (CPUE) values were presented only for 1997, 1998, and 2000 surveys, because of the consistent sampling methods (index gill nets) used during these years. Inconsistent mesh sizes used during 1995 and 1996, as well as the lack of detailed catch and effort information in the early data reports, did not allow for CPUE analyses of 1995 and 1996 data so that it could be compared with the 1997-2000 data. The CPUE values for 1997-2000 gill netting data were reported as number of fish captured per 100 m^2 of 3.8 cm mesh size panel set for 24 hours.



LEGEND

- LAKES SAMPLED FOR FISH POPULATIONS (GILL NETS)
- STREAM SECTIONS SURVEYED FOR FISH POPULATIONS (BACKPACK ELECTROFISHING)
- #01 STREAM SITE DESIGNATIONS (BASED ON RESCAN 1998)
- 95,96 YEARS OF SAMPLING IN LAKES
- WATERFALLS

REFERENCE
BASE MAP PROVIDED BY RESCAN, JANUARY 22, 2001

NOTE : CONTOUR INTERVAL 20 m

Hope Bay Joint Venture

TITLE

FISH SAMPLING LOCATIONS IN DORIS HINGE AREA, 1995-2000

Golder Associates
Edmonton, Alberta

PROJECT No. 022-7009.1000			FILE No.	Fish Sampling
DESIGN	AH	11/06/02	SCALE AS SHOWN	REV. 1
CADD	PSR	17/10/02		
CHECK	JP	17/10/02		
REVIEW				

FIGURE: 7.1

R:\CAD\7000\022-7009\ Drawing file: Fish Sampling Locations.dwg Oct 17, 2002 - 1:12pm

7.1.2 Doris Lake

The catch rates, length-frequency distributions, size and age statistics, age-specific lengths and weights, diet, and sex/maturity data for fish species sampled in Doris Lake during 1995, 1996, and 1997 are summarized in Appendices D1 to D7; data from individual fish are presented in Appendix D8. Gill netting was the main capture method used in Doris Lake; it was complemented with visual observations along the near-shore areas in 1995.

7.1.2.1 Species Composition and Relative Abundance

In total, 573 fish were caught in Doris Lake during 1995-1997 (Table 7.1). They included cisco, lake whitefish, and lake trout; in addition, ninespine stickleback were observed in 1995. Cisco was the predominant species in the overall catch (63%), followed by lake whitefish (27%), and lake trout (10%). Although cisco dominated the 1997 catch, lake whitefish was the dominant species in the 1995 and 1996 catches. This difference was likely influenced by the use of index gill nets in 1997 compared to the varied mesh sizes used in the previous two years. The change in capture methodology, combined with more intensive sampling effort, contributed to the large increase in the total number of fish caught in 1997 (i.e., 91% of the total three-year catch). The CPUE values for cisco, lake whitefish, and lake trout in 1997 were 151, 53, and 24 fish/100 m^2/24 h, respectively.

Table 7.1 Number, percent composition, and catch-per-unit-effort (CPUE) for fish species captured by gill nets in Doris Lake, 1995 to 1997.

Species	1995		1996		1997		Total		1997 CPUE (fish/100m^2/24h)	
	n	%	n	%	n	%	n	%	Mean	SD
Lake trout	1	9.1	4	9.5	56	10.8	**61**	**10.6**	23.7	27.5
Lake whitefish	7	63.6	20	47.6	126	24.2	**153**	**26.7**	52.6	29.9
Cisco[a]	3	27.3	18	42.9	338	65.0	**359**	**62.7**	150.6	132.1
Total	**11**	**100**	**42**	**100**	**520**	**100**	**573**	**100**	**226.9**	**151.9**

[a] likely included *Coregonus artedi* and *C. sardinella* (see Section 7.1.2.2)

Fish marked with Floy tags during the 1997 survey included 23 lake trout, 51 lake whitefish, and 2 cisco. None of these fish were recaptured; however, one lake trout captured in Doris Lake on 16 August 1997 was previously captured and marked on 20 June 1997 in Ogama Inflow (Appendices D8 and D11). This fish moved through Ogama Lake into Doris Lake, indicating that at least one fish utilized different waterbodies during the same year.

7.1.2.2 Life History Data

Lake Trout

Size Distribution

The length distribution of the measured lake trout catch (*n*=51) was wide (ranging from 251 to 945 mm fork length), with a mean of 632 mm. The majority (71%) of the catch was comprised of fish larger than 600 mm in fork length. The length distribution pattern exhibited two distinct modes (Figure 7.2). The smaller mode was centered around 390-480 mm, whereas the larger and wider mode was composed of lake trout in the 600-800 mm size range.

Length-Weight Relationship

The length-weight regression equation for lake trout from Doris Lake (all sampling years combined) was:

log Weight (g) = -4.147 + 2.688 log Fork Length (mm) (n=48; r^2=0.958).

The mean condition factor was 0.98; condition factors for individual fish ranged from 0.61 to 1.42.

Age and Growth

The age-length relationships for lake trout sampled in 1995-1997 are illustrated in Figure 7.2. Age-classes between 8 and 49 were represented in the sample of 30 fish; the mean age was 28.5 years. Mean length-at-age data were highly variable, likely because of the small sample size (i.e., most age-specific means were based on only one fish). Within the aged sample, the fastest rate of growth, averaging about 37 mm/year, was exhibited by fish between 9 and 15 years of age.

Sex and Maturity

Sex and maturity characteristics were determined for 24 lake trout; of these, 15 were female and 9 were male. Twelve females were mature and three were immature, whereas seven mature and two immature males were sampled (Appendix D6). Within this sample, females ranged from 9 to 49 years of age, with a mean fork length of 612 mm and mean condition factor of 0.98. Males ranged from 22 to 45 years of age, with a mean fork length of 617 mm and a mean condition factor of 0.91.

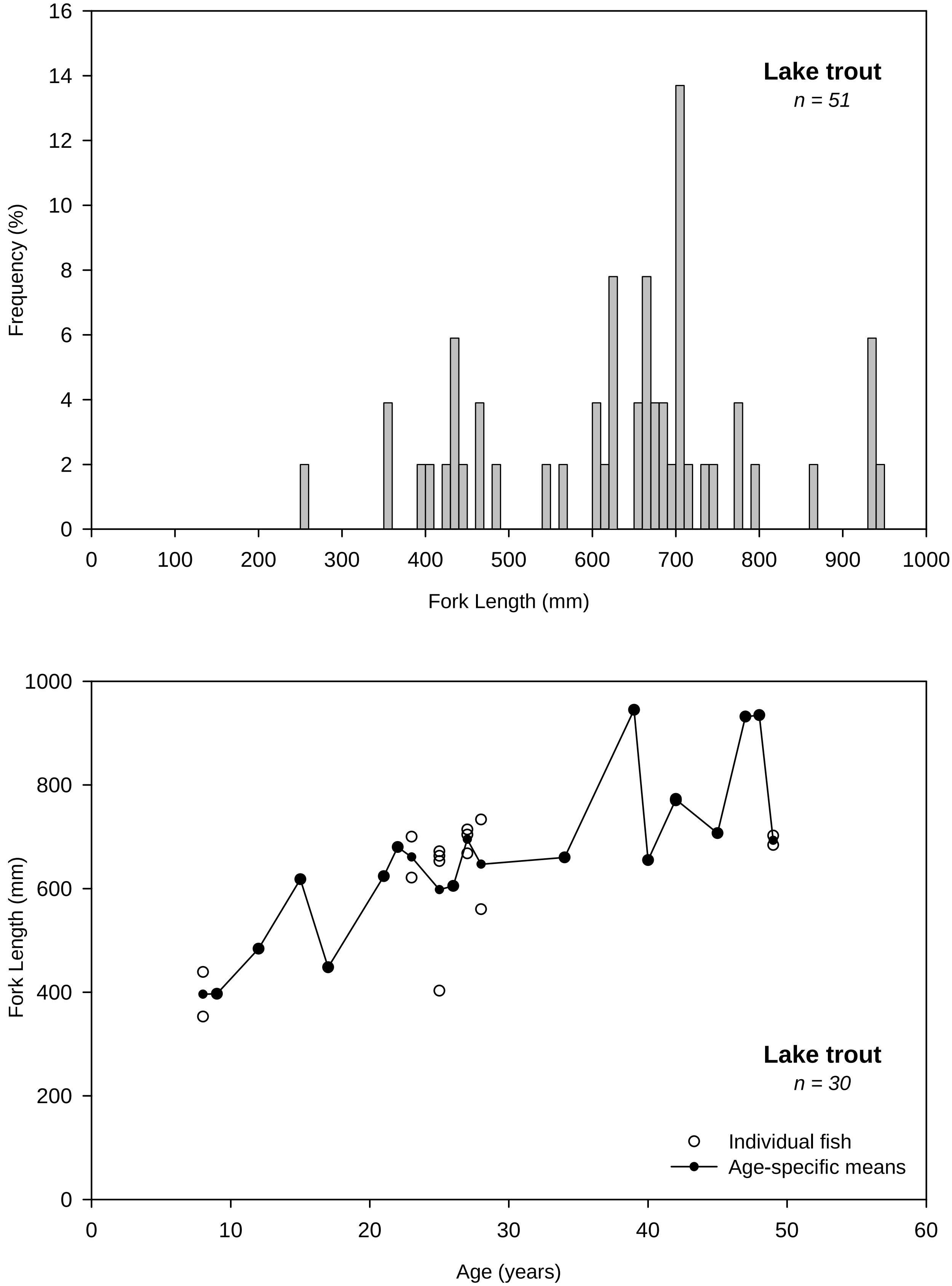


Figure 7.2 Length frequency distribution and age-length relationship for lake trout captured in Doris Lake, 1995-1997.

The largest and oldest immature females were 469 mm in fork length and nine years of age. Within the sample of mature females, the smallest was 403 mm in fork length and the youngest was 23 years old. Although maturity data were limited by small sample sizes, it appeared that maturity in females was reached prior to age 23 at an approximate fork length of 400-470 mm. Similarly, the largest and oldest immature males were 353 mm in length and eight years of age, respectively, whereas the smallest and youngest mature males were 621 mm in fork length and 22 years old, respectively, indicating that males reach maturity prior to age 22 at an approximate length of 360-620 mm.

Diet

Seventeen stomachs were examined from lake trout collected from Doris Lake during 1995-1997. Of these, 11 (65%) were empty; this was reflected in the low mean fullness index of 24.1% (Appendix D7). For the fish with stomach contents, the diet consisted primarily of fish (94%), with the remaining 6% comprised of zooplankton. Coregonid species were the main fish group in the lake trout diet.

Lake Whitefish

Size Distribution

Lake whitefish caught in Doris Lake between 1995 and 1997 (n=146) ranged from 175 to 557 mm in fork length (mean of 370 mm). Most (78%) of the catch was comprised of fish larger than 300 mm in fork length, with 4% of the catch exceeding 500 mm in fork length (Figure 7.3). Three distinct size-class modes were apparent in the catch. The smallest mode was centered around 170-229 mm, whereas the larger two modes were centered around 320-399 mm (33% of catch) and 420-499 mm (36% of catch).

Length-Weight Relationship

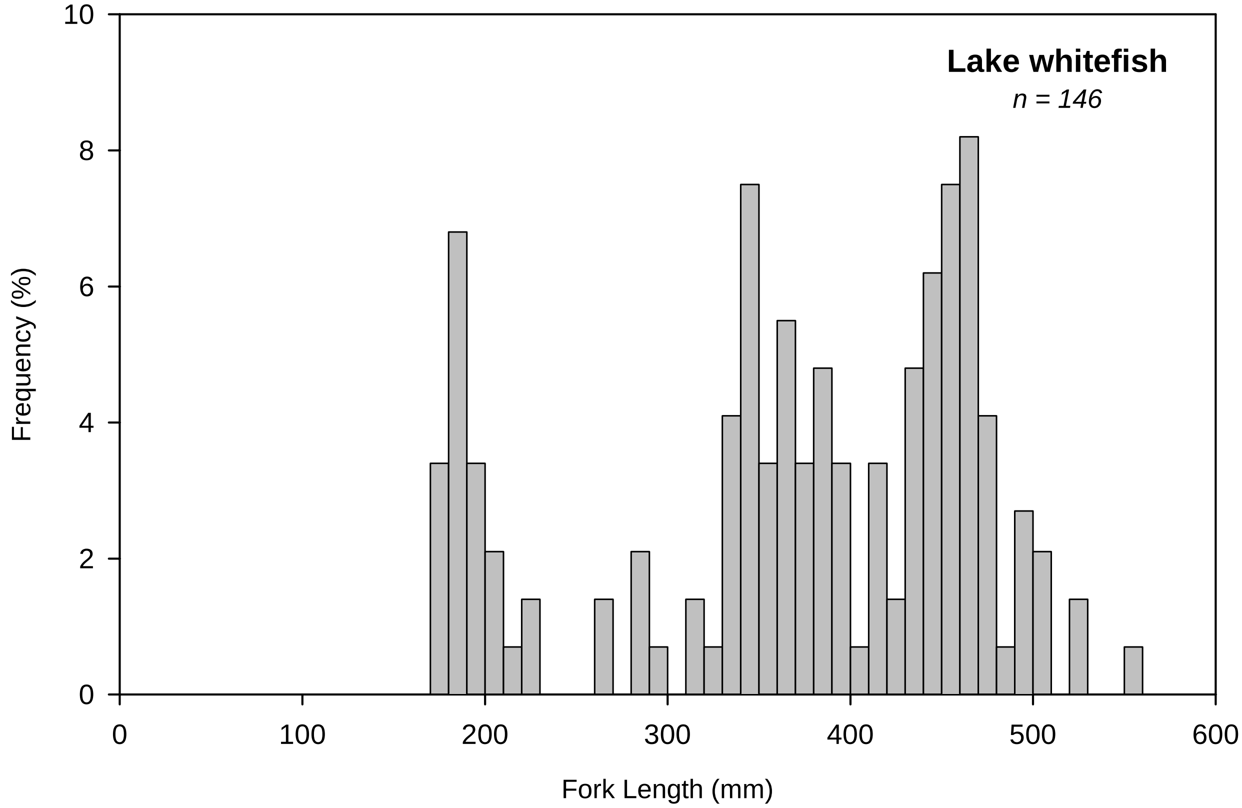
The length-weight regression equation for lake whitefish caught in Doris Lake (all sampling years combined) was:

log Weight (g) = -5.739 + 3.332 log Fork Length (mm) (n=130; r^2=0.991).

The mean condition factor was 1.29; condition factors for individual fish ranged from 0.83 to 1.71 (Appendix D3).

Age and Growth

The age-length relationships for lake whitefish sampled in 1995-1997 are illustrated in Figure 7.3. Within the aged sample of 45 fish, age-classes between 2 and 65 years were represented, with the mean being 22.5 years. It appeared that



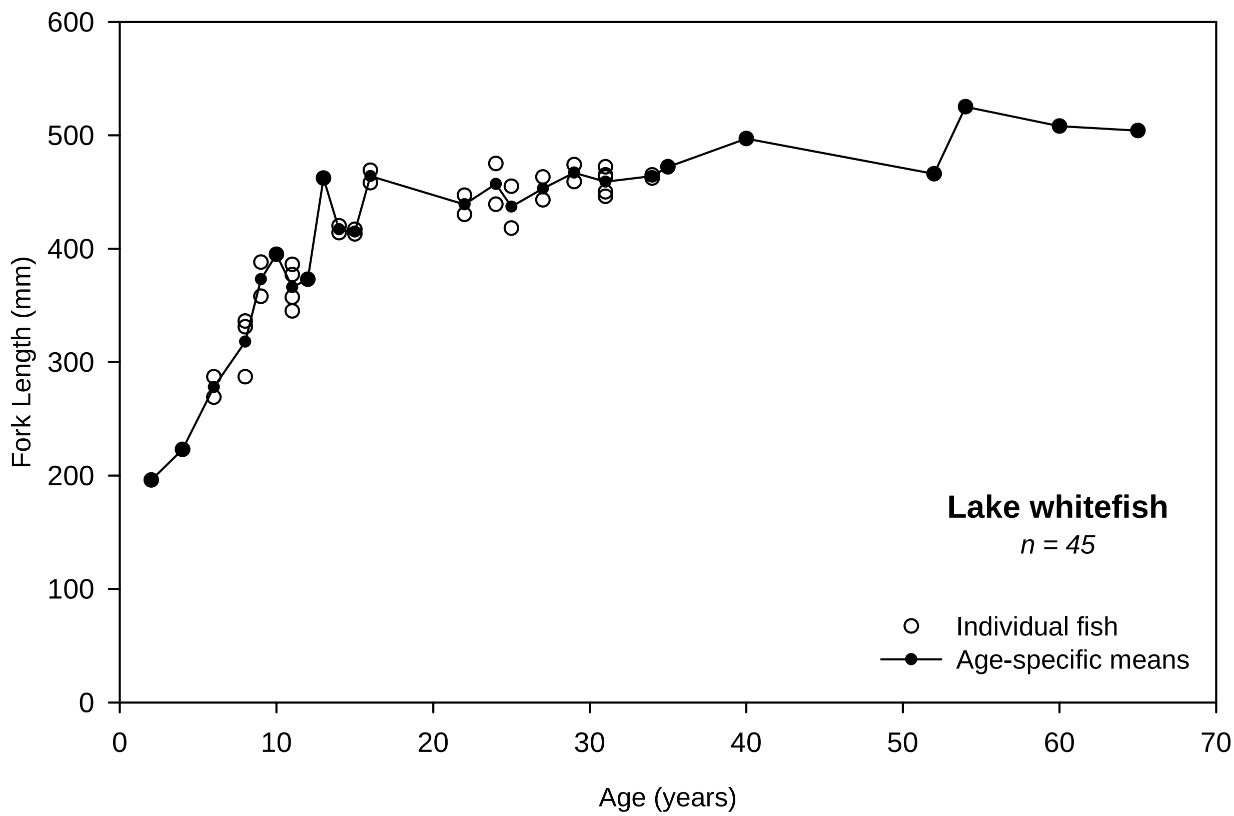


Figure 7.3 Length frequency distribution and age-length relationship for lake whitefish captured in Doris Lake, 1995-1997.

the oldest age-classes (52 to 65 years) were likely overestimates, because maximum reported age for this species is 50 years (www.fishbase.org). However, without being able to verify the collected ageing structures, the lake whitefish age data are presented here the same as reported by Rescan (1998).

Growth increments in early life (ages 2 to 10) were the highest, averaging approximately 25 mm per year; older fish grew much slower and averaged only a few millimetres of growth per year. The asymptotic fork length appeared to be approximately 500 mm.

Sex and Maturity

Seventy-one lake whitefish were sampled for sex and maturity characteristics. Of these, 24 were female and 47 were male. Females were evenly split across maturity categories at 12 each, whereas there were 22 mature and 25 immature males (Appendix D6). Sampled females ranged from 8 to 54 years old, with a mean fork length of 357 mm, whereas males were 4 to 65 years old, with a mean fork length of 352 mm. Mean condition factors were 1.30 for females and 1.22 for males.

The smallest mature male was 377 mm in fork length and 11 years old. The smallest mature female was 357 mm in fork length and 11 years old (Appendix D8). The largest and oldest immature males and females were 420 and 386 mm in fork length, and 15 and 11 years of age, respectively. These data suggest that males mature between 11 and 15 years of age (370-420 mm fork length), whereas females mature around 11 years of age, at fork lengths between 350 and 390 mm.

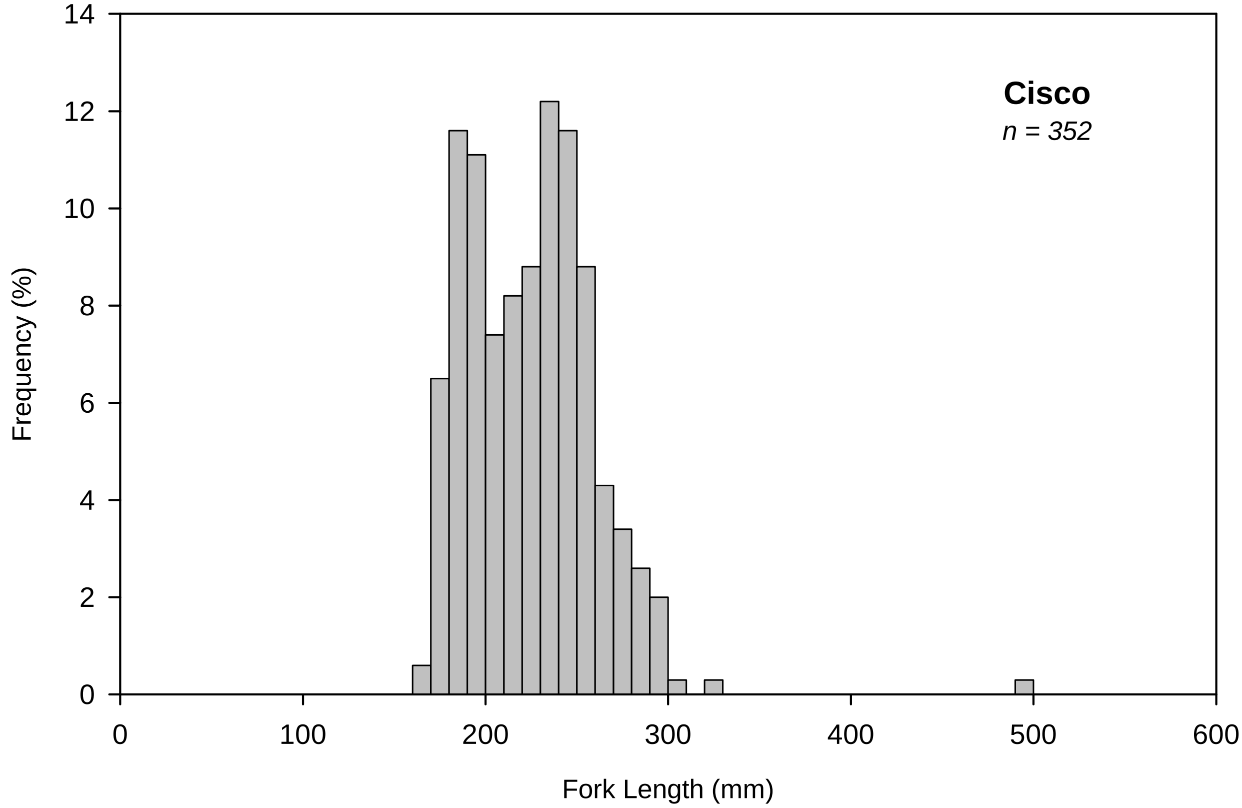
Diet

Aquatic invertebrates from three different taxa accounted for all the food items found in the nine stomachs examined. Freshwater shrimp, blood worms, and isopods were all represented, with the latter forming the majority of the diet. Six of the examined stomachs (67%) were empty; the overall mean fullness index was 25% (Appendix D7).

Cisco

Size Distribution

Cisco captured in Doris Lake during 1995-1997 (*n*=352) ranged from 163 to 498 mm in fork length, with a mean of 225 mm (Figure 7.4). Most (57%) of the catch was contributed by fish in the 200-259 mm size-class, with 1% of the catch exceeding 300 mm in fork length.



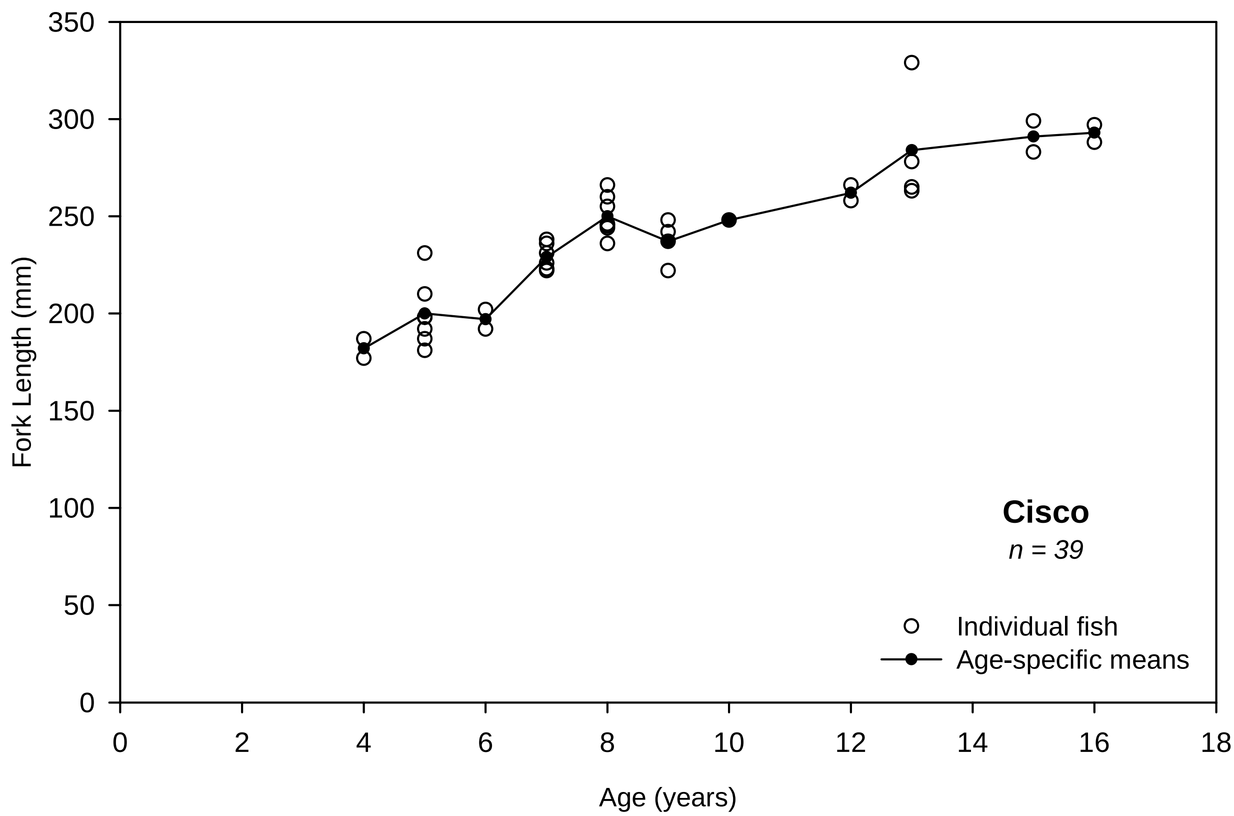


Figure 7.4 Length frequency distribution and age-length relationship for cisco captured in Doris Lake, 1995-1997.

Length-Weight Relationship

The length-weight regression equation for cisco caught in Doris Lake (all sampling years combined) was:

log Weight (g) = -5.040 + 3.012 log Fork Length (mm) (n=340; r^2=0.932).

The mean condition factor was 0.98; condition factors for individual fish ranged from 0.50 to 1.53 (Appendix D3).

Age and Growth

The age-length data for cisco are presented in Appendix D5 and Figure 7.4. Fish in the aged sample (n=39) were between 4 and 16 years of age, with a mean of 8.6 years. Although the youngest age-classes were not represented in the catch, the fastest growth rates of approximately 17 mm per year occurred between the ages of 4 and 8, with slower growth continuing through to age 16.

Sex and Maturity

In total, 222 cisco were sampled for sex and maturity characteristics. Sampled males ranged from 5 to 16 years in age and between 165 and 288 mm in fork length. Females were between 172 and 329 mm in length and were 4 to 15 years old. Mean condition factors were similar for both sexes (0.99 and 0.97 for males and females, respectively).

The maturity data indicated that some fish reached sexual maturity at fork lengths as small as 183 and 195 mm (females and males, respectively), whereas immature fish were recorded to be as large as 270 and 288 mm in fork length (females and males, respectively). Overall, 11% of mature fish were smaller than 210 mm in fork length, whereas 12% of immature fish exceeded 250 mm in fork length. This large overlap in size-at-maturity data suggested that one part of the cisco population in Doris Lake may have been comprised of least cisco (*Coregonus sardinella*), that were misidentified as cisco (*Coregonus artedi*). Similar indications of two subpopulations or different species of cisco were reported by Rescan (1999a) in Pelvic Lake (see Section 7.1.8).

Diet

Only three cisco stomachs were examined during the 1995-1997 studies. Chironomids (blood worms) were the only food item encountered. The mean fullness index was 10% (Appendix D7).

7.1.3 Tail Lake

The catch rates, length-frequency distributions, size and age statistics, age-specific lengths and weights, diet, and sex/maturity data for fish species sampled in Tail Lake during 1995, 1996, and 2000 are summarized in Appendices D1 to D7; data from individual fish are presented in Appendix D8. Gill netting was the only capture method used in Tail Lake.

7.1.3.1 Species Composition and Relative Abundance

Lake trout was the only fish species captured in Tail Lake during the three years of sampling (Appendix D1). Unlike other lakes in the Doris Hinge area, Tail Lake did not appear to support lake whitefish and cisco populations. Based on diet analyses of lake trout in Tail Lake (Appendix D7), ninespine stickleback also inhabited this waterbody.

In total, 163 lake trout were captured over the three sampling years (Table 7.2). Most (82%) were caught on 17-19 August 2000, during a three-day program of intensive netting with index (3.8 cm mesh) gill nets. A total of 24 gill nets (109.8 m^2 each) set for the combined duration of 34.3 hours captured 134 fish (mean CPUE of 85.6 fish/100 m^2/24 h). This catch rate of lake trout was approximately three to six times higher than the catch rates recorded in other Doris Hinge lakes between 1997 and 2000 (corresponding CPUE values ranged from 15.2 fish/100 m^2/24 h in Little Roberts Lake to 28.5 fish/100 m^2/24 h in Pelvic Lake).

Table 7.2. Number and catch-per-unit-effort (CPUE) for fish species captured by gill nets in Tail Lake, 1995 to 2000.

Species	Number Captured				2000 CPUE (fish/100 m^2/24 h)	
	1995	1996	2000	Total	Mean	SD
Lake trout	13	16	134	**163**	85.6	61.6

Lake trout were marked with Floy tags during the 2000 survey in an attempt to derive a population estimate through subsequent recaptures. Although 128 lake trout were marked during the three-day survey (19, 65, and 44 fish on the first, second, and third day, respectively), no recaptures were recorded. This suggested a very large population size within a relatively small lake; however, the survey did not allow sufficient time for the marked fish to disperse or recover from the stress of the marking procedure. As such, the marked fish likely did not have the same probability of capture as unmarked fish.

7.1.3.2 Life History Data

Lake Trout

Size Distribution

The sample of lake trout from Tail Lake (n=163) ranged between 284 and 665 mm in fork length, with a mean of 556 mm (Figure 7.5; Appendix D3). The mean weight was 1623 g (maximum of 2830 g). Although the overall length distribution of the catch was widespread, most (52%) of the fish were within a narrow 550-589 mm size-class. Fish smaller than 450 mm contributed less than 4% to the total catch, suggesting limited recruitment (i.e., these size-classes should be fully vulnerable to 3.8 cm mesh sizes). In contrast to most of the other Doris Hinge lakes where lake trout exceeding 900 mm in fork length were captured (all except Ogama and Little Roberts lakes), the largest lake trout captured in Tail Lake was considerably smaller at 665 mm in fork length.

Length-Weight Relationship

The length-weight regression equation for sampled lake trout was:

log Weight (g) = -3.316 + 2.375 log Fork Length (mm) (n=150; r^2=0.808).

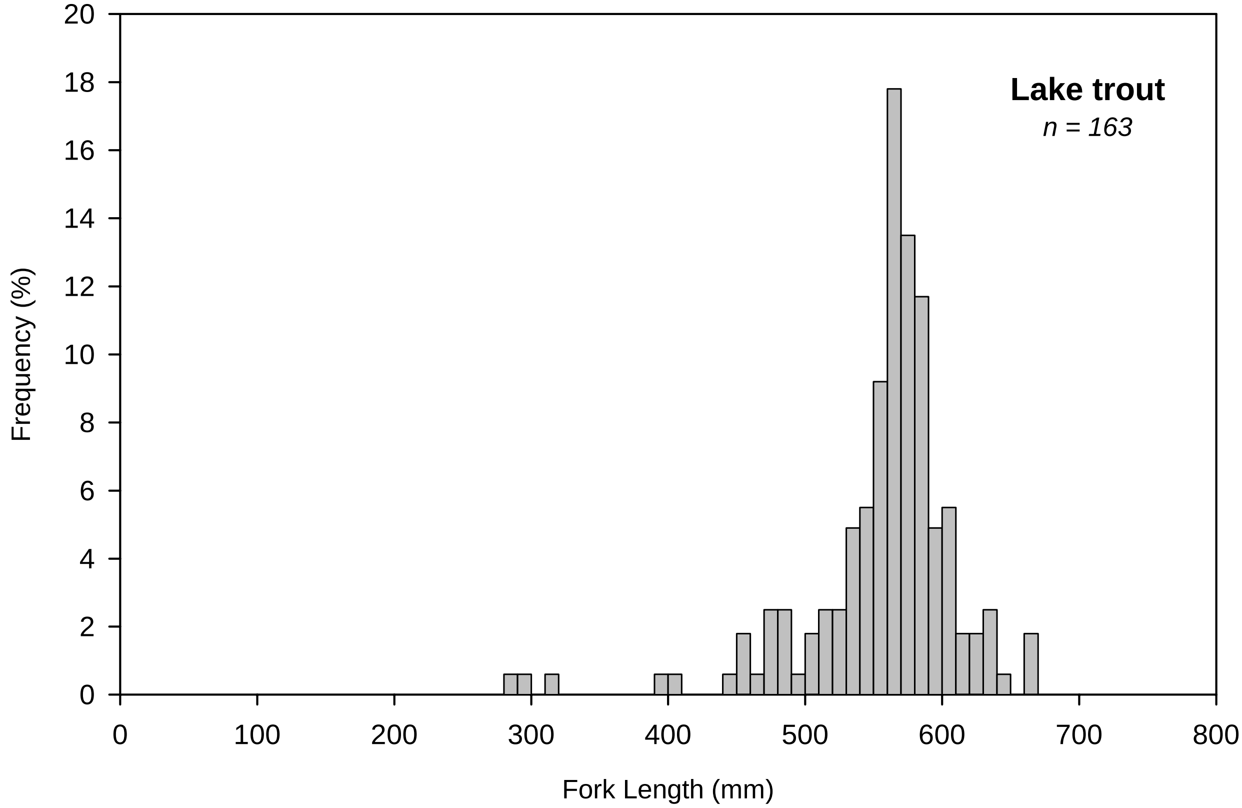
The relatively low coefficient of correlation (r^2=0.808) suggested high variability in length-weight relationship among individual fish. The mean condition factor was 0.94; condition factors for individual fish ranged from 0.66 to 1.77 (Appendix E2).

Age and Growth

The age-length relationship for lake trout sampled in 1995-2000 is illustrated in Figure 7.5. Age-classes between 4 and 33 years were represented in an aged sample of 131 fish. The fastest rate of growth within this sample (averaging approximately 37 mm/year) occurred among fish between 6 and 12 years of age. The growth rate was considerably slower after age 13, with an average increase of about 3 mm/year over the next 20-year period.

Sexual Maturity

Of the 20 lake trout sampled for sex and maturity, 14 were females and 6 were males. Except for two immature females, all examined fish were mature. One of the immature females was 553 mm in fork length and 14 years of age suggesting that the attainment of sexual maturity is a slow process. The presence of six mature females as young as 11 or 13 years (557 to 601 mm in fork length) suggested that females mature between 11 and 14 years of age at an approximate size of 550 mm in fork length. Based on the smallest mature male in the sample



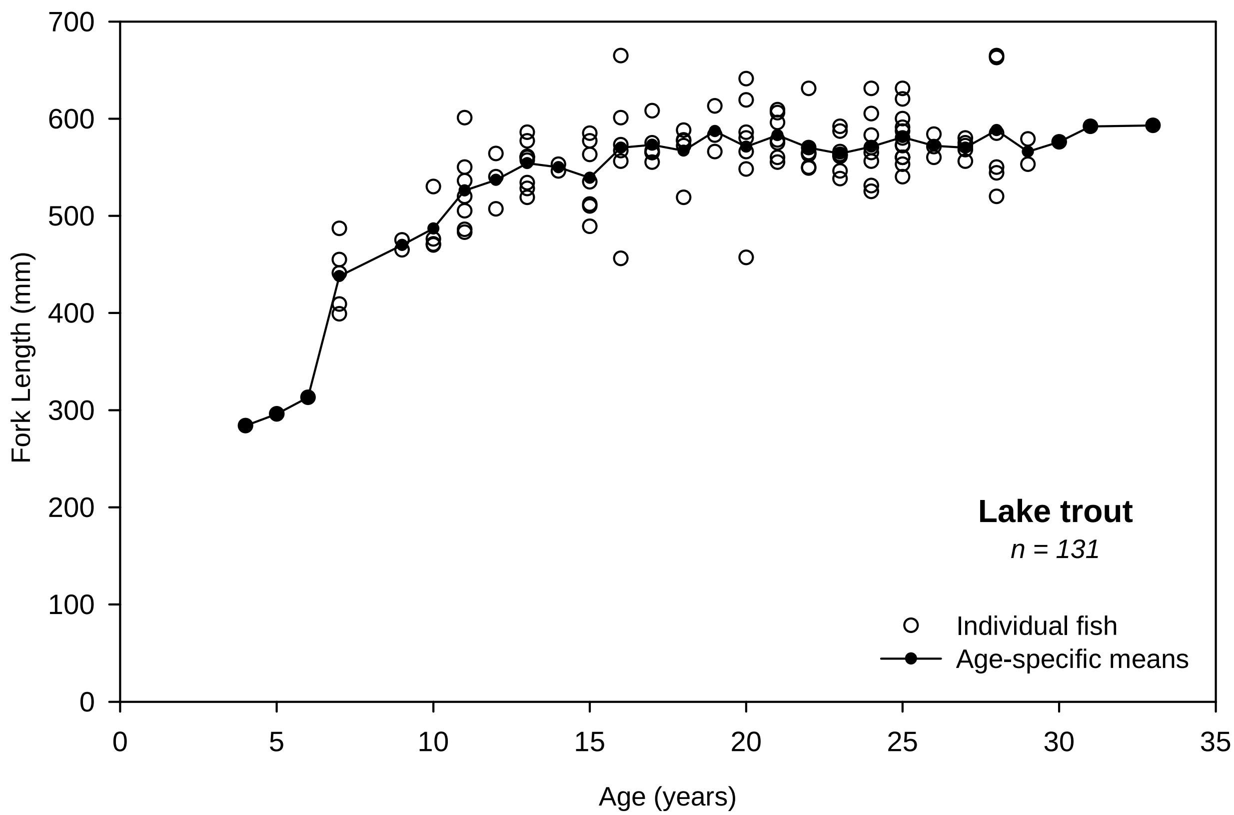


Figure 7.5 Length frequency distribution and age-length relationship for lake trout captured in Tail Lake, 1995-2000.

(471 mm fork length and 10 years old), males appeared to mature at a younger age and smaller size.

Diet

Lake trout diet in Tail Lake was comprised of a large variety of aquatic invertebrates and ninespine stickleback. Within 15 stomachs examined, only three were empty, and the mean fullness index (38%) was the highest among lake trout populations in Doris Hinge lakes (Appendix D7). Ninespine stickleback contributed 32% to the total volume of food items encountered. Caddis fly larvae (Trichoptera) and tadpole shrimp (Notostraca) were also important in lake trout diet (21 and 19%, respectively). Other identified invertebrates included clams, isopods, blood worms, amphipods and zooplankton.

7.1.4 Ogama Lake

Catch, length-frequency distributions, size and age statistics, age-specific lengths and weights, and sex/maturity data for fish species sampled in Ogama Lake during 1996 are summarized in Appendices D1 to D7; data from individual fish are presented in Appendix D8.

7.1.4.1 Species Composition and Relative Abundance

Unlike other lakes in the Doris Hinge area, which were intensively sampled with index gill nets (38 mm mesh size), fish sampling in Ogama Lake was limited to a one-day survey on 4 August 1996 during which a variety of mesh sizes were used. As such, the catch rates are not comparable with the other sampled lakes, and the number of fish captured was much lower than reported elsewhere.

The total catch in Ogama Lake included 4 lake trout, 29 lake whitefish, and 5 cisco (Appendix D1). Lake whitefish contributed 76% to the total catch, followed by lake trout (13%) and cisco (10%).

7.1.4.2 Life History Data

Lake Trout

The four lake trout caught in Ogama Lake in 1996 were between 440 and 772 mm in fork length, with a mean of 556 mm (Appendix D3). Only one lake trout (475 mm fork length) was aged; it was 10 years old and a mature female.

Lake Whitefish

The measured catch of lake whitefish from Ogama Lake in 1996 (n=22) ranged from 193 to 420 mm in fork length, with a mean of 327 mm (Appendix D3).

Most (82%) of the sampled fish were larger than 300 mm in fork length, with 9% exceeding 400 mm in fork length (Appendix D4).

The length-weight regression equation for sampled lake whitefish was:

log Weight (g) = -4.450 + 2.830 log Fork Length (mm) (n=9; r^2=0.982).

The mean condition factor was 1.32; condition factors for individual fish ranged from 1.20 to 1.40 (Appendix D3).

Age-classes between 7 and 24 were represented within an aged sample of 11 fish (Appendix D5). The mean age was 11.1 years.

Of 10 lake whitefish sampled for sex and maturity, seven were female and three were male. All the females and one male were immature, whereas two of the males were mature (Appendix D6). The immature females ranged from 7 to 13 years in age and 282 to 340 mm in fork length. The smallest mature male was 392 mm in fork length, whereas the youngest was 12 years old. The immature male was 318 mm in fork length and 12 years old. These data suggest that males mature around 12 years of age.

Cisco

Cisco captured in Ogama Lake (n=5) ranged from 210 to 354 mm in fork length, with a mean of 291 mm (Appendix D3). Most (60%) were larger than 300 mm in fork length.

The length-weight regression equation for cisco was:

log Weight (g) = -3.742 + 2.544 log Fork Length (mm) (n=3; r^2=0.770).

The mean condition factor was 1.36; condition factors for individual fish ranged from 1.16 to 1.53 (Appendix D3). Within the limited sample that was aged (n=3), cisco ranged from 8 to 21 years of age (Appendix D3).

7.1.5 Patch Lake

The catch rates, length-frequency distributions, size and age statistics, age-specific lengths and weights, diet, and sex/maturity data for fish species sampled in Patch Lake during 1995, 1996, and 1997 are summarized in Appendices D1 to D7; data from individual fish are presented in Appendix D8. Gill netting was the only capture method used in Patch Lake.

7.1.5.1 Species Composition and Relative Abundance

In total, 187 fish were caught in Patch Lake during 1995-1997 (Table 7.3). They included lake whitefish, lake trout, and cisco. Lake whitefish was the predominant species in the overall catch (43%), followed by lake trout (38%) and cisco (19%). Although lake whitefish dominated the 1997 catch, lake trout was the dominant species in the 1995 and 1996 catches. This difference was likely influenced by the use of index gill nets in 1997 compared to the varied mesh sizes used in the previous two years. The change in capture methodology, combined with more intensive sampling effort, contributed to the large increase in the total number of fish caught in 1997 (i.e., 87% of the total three-year catch). The CPUE values for lake whitefish, lake trout, and cisco in 1997 (36, 24, and 16 fish/100 m^2/24 h, respectively) were indicative of moderate abundance in relation to other Doris Hinge lakes.

Table 7.3 Number, percent composition, and catch-per-unit-effort (CPUE) for fish species captured by gill nets in Patch Lake, 1995 to 1997.

Species	1995		1996		1997		Total		1997 CPUE (fish/100 m^2/24 h)	
	n	%	n	%	n	%	n	%	Mean	SD
Lake trout	2	100.0	14	63.6	54	33.1	**70**	**37.4**	24.3	18.0
Lake whitefish			3	13.6	78	47.9	**81**	**43.3**	35.7	33.2
Cisco			5	22.7	31	19.0	**36**	**19.3**	16.0	31.9
Total	**2**	**100**	**22**	**100**	**163**	**100**	**187**	**100**	**75.9**	**53.5**

Fish marked with Floy tags during the 1997 survey included 28 lake trout and 37 lake whitefish. None of these fish were recaptured.

7.1.5.2 Life History Data

Lake Trout

Size Distribution

The length distribution of the measured lake trout catch (*n*=68) was widespread (ranging from 199 to 915 mm fork length), with a mean of 598 mm (Appendix D3). The majority (71%) of the catch was comprised of fish larger than 550 mm

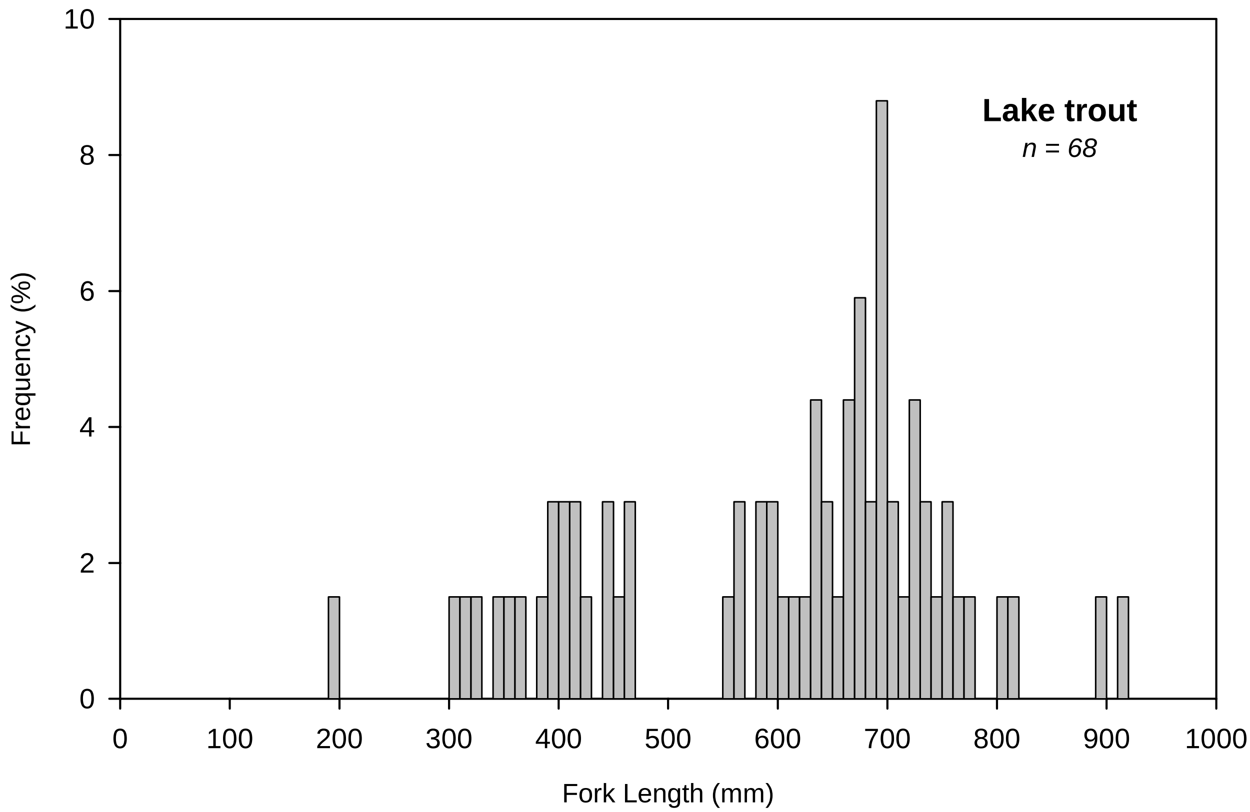


Figure 7.6 Length frequency distribution and age-length relationship for lake trout captured in Patch Lake, 1995-1997.

in fork length. The length distribution pattern exhibited two distinct modes (Figure 7.6). The smaller mode was centered around 380-469 mm, whereas the larger and wider mode was composed of lake trout in the 550-759 mm size range.

Length-Weight Relationship

The length-weight regression equation for lake trout from Patch Lake (all sampling years combined) was:

log Weight (g) = -4.749 + 2.898 log Fork Length (mm) (n=47; r^2=0.978).

The overall mean condition factor was 0.95; condition factors for individual fish ranged from 0.58 to 1.35 (Appendix D3).

Age and Growth

The age-length relationships for lake trout sampled in 1995-1997 are illustrated in Figure 7.6. Age-classes between 7 and 40 years (mean of 20.8 years) were represented in the aged sample of 33 fish. Length-at-age data were variable, likely because of the small sample size (i.e., most age-specific means were based on one or two fish). The presence of three fish that were much smaller (440-464 mm in fork length) than their counterparts in the 22 to 29 year age-class (600-700 mm size range) suggested that part of the populations might have been stunted.

Sex and Maturity

Sex and maturity characteristics were determined for 28 lake trout. Of these, 11 were female and 17 were male (Appendix D6). The only immature female within this sample was 357 mm in fork length and eight years of age. The smallest mature female was 453 mm in fork length and the youngest was 18 years old. The largest and oldest immature male was 397 mm fork length and 15 years of age, whereas the smallest mature male was 380 mm in fork length and 11 years old. Although data were limited, it appeared that females reached maturity between 8 and 18 years of age at an approximate fork length of 355-455 mm, whereas males reached maturity between ages 11 and 15, at an approximate fork length of 380-400 mm.

Diet

Three fish species (ninespine stickleback, lake whitefish, and cisco), aquatic invertebrates (isopods and amphipods), and plant matter accounted for all identifiable food items encountered in 24 lake trout stomachs examined (Appendix D7). Fish accounted for 71% of the total food volume, with smaller amounts contributed by invertebrates (28%) and plant matter (1%). Of the 24 stomachs examined, 11 were empty; the mean fullness index was 23%.

Lake Whitefish

Size Distribution

Lake whitefish captured in Patch Lake during 1996 and 1997 (n=81) ranged from 269 to 504 mm in fork length (mean of 409 mm). The majority (61%) of the sampled fish were within a relatively narrow size-class between 390 to 459 mm in fork length (Figure 7.7; Appendix D4).

Length-Weight Relationship

The length-weight regression equation for lake whitefish from Patch Lake (all sampling years combined) was:

log Weight (g) = -5.666 + 3.290 log Fork Length (mm) (n=79; r^2=0.910).

The overall mean condition factor was 1.25; condition factors for individual fish ranged from 0.84 to 1.73 (Appendix D3).

Age and Growth

Age-classes between 8 and 43 years were represented within an aged sample of 34 fish (Figure 7.7). Although data were limited for younger age-classes, fish between ages 8 and 25 exhibited steady annual growth of approximately 8 mm in fork length. Older age-classes did not appear to grow as fast and reached an asymptotic size of about 500 mm in fork length.

Sex and Maturity

Sex and maturity characteristics were determined for 43 lake whitefish. Within this sample, 19 were females and 24 were males. The smallest mature male was 423 mm in fork length and 23 years of age, whereas the largest immature male was 432 mm in fork length and 30 years old. The smallest mature female was 406 mm in fork length and the youngest mature female was 17 years old. These data suggest that males reach maturity between ages 23 and 30 years at an approximate fork length of 420-435 mm, whereas females may reach maturity at an earlier age and smaller size (17 years and 400 mm in fork length).

Diet

Isopods and zooplankton were the only two food items found in the five lake whitefish stomachs examined (Appendix D7). Isopods were the predominant food item and accounted for 96% of the total food volume. Only one of the five

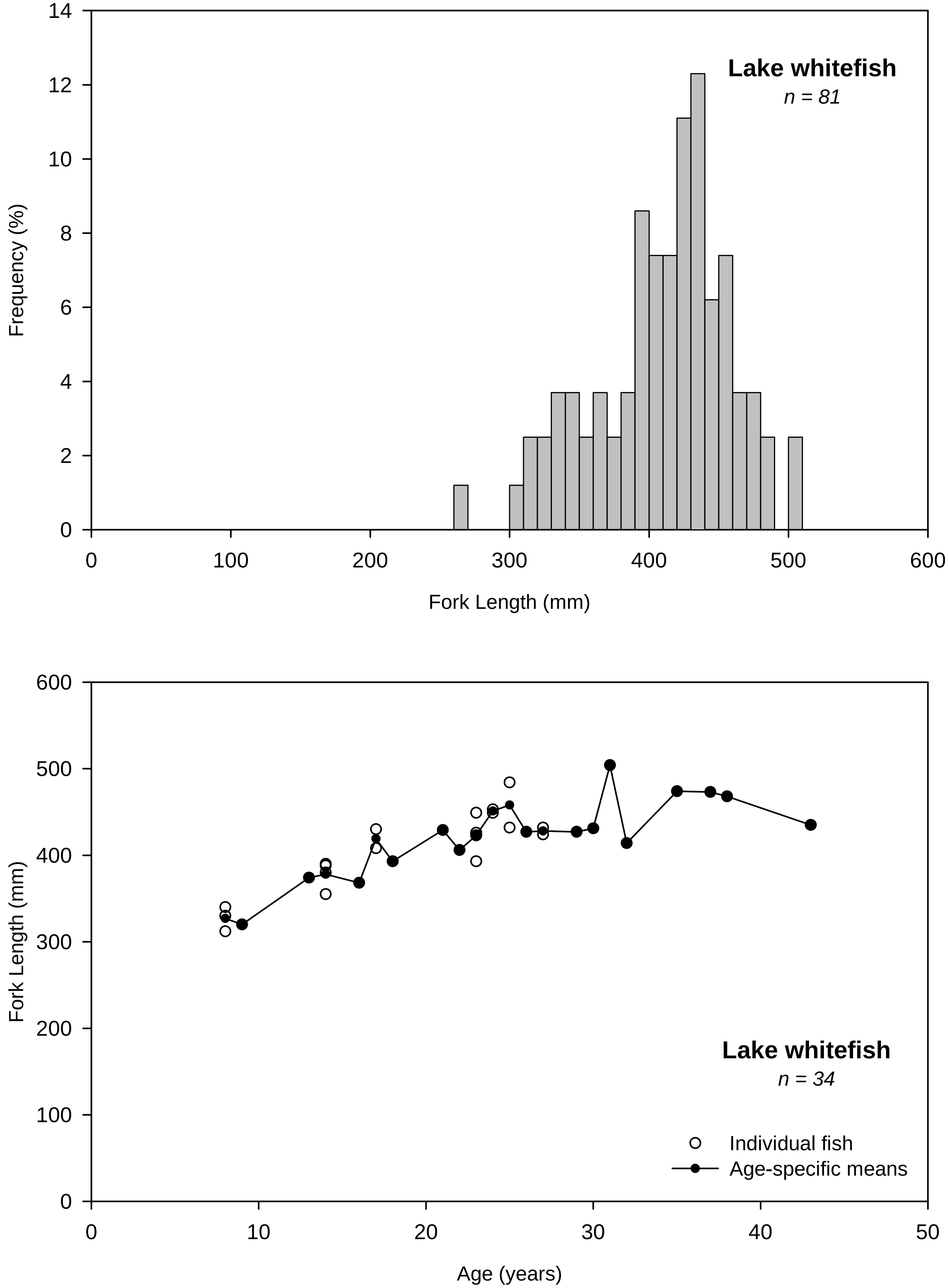


Figure 7.7 Length frequency distribution and age-length relationship for lake whitefish captured in Patch Lake, 1995-1997.

stomachs examined was empty, resulting in a relatively high mean fullness index of 46%.

Cisco

Size Distribution

The measured sample of cisco captured in Patch Lake in 1996 and 1997 (*n*=35) ranged from 141 to 310 mm in fork length, with a mean of 249 mm (Appendix D3). More than half (54%) of the sampled fish were within a relatively narrow size-class between 250 to 299 mm in fork length (Appendix D4). The length-frequency histogram (Figure 7.8) illustrates bimodal distribution with the smaller peak corresponding to 180-209 mm size-class.

Length-Weight Relationship

The length-weight regression equation for Patch Lake cisco (all sampling years combined) was:

log Weight (g) = -5.126 + 3.048 log Fork Length (mm) (*n*=32; r^2=0.964).

The overall mean condition factor was 0.98; condition factors for individual fish ranged from 0.82 to 1.18 (Appendix D3).

Age and Growth

The age-length data for cisco are presented in Appendix D6 and illustrated in Figure 7.8. Fish in the aged sample (*n*=12) ranged from 7 to 17 years of age. The age-length data were highly variable and attributed to the small sample size.

Sexual Maturity

Sex and maturity data were collected from 23 cisco. Within this sample, 15 were females and eight were males. Data from this small sample suggested that both males and females mature around age 9 at a fork length of approximately 260 mm.

7.1.6 Windy Lake

The catch rates, length-frequency distributions, size and age statistics, age-specific lengths and weights, diet, and sex/maturity data for fish species sampled in Windy Lake during 1996 and 1997 are summarized in Appendices D1 to D7; data from individual fish are presented in Appendix D8. Gill netting was the main capture method used during both years; however, beach seining was also employed in 1996.

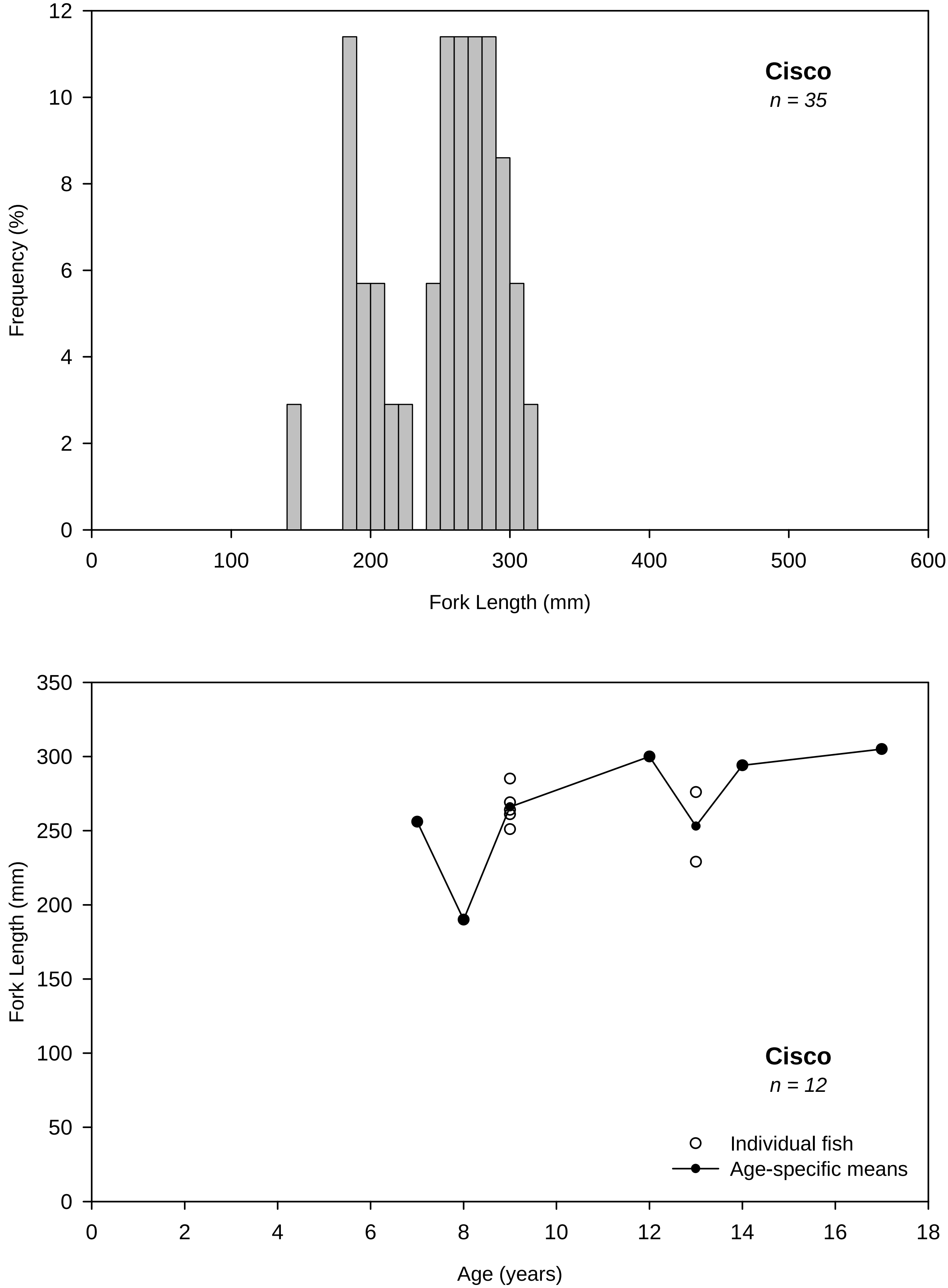


Figure 7.8 Length frequency distribution and age-length relationship for cisco captured in Patch Lake, 1995-1997.

7.1.6.1 Species Composition and Relative Abundance

In total, 137 fish were caught in Windy Lake during 1996 and 1997 (Table 7.4). Most (61%) were captured by gill nets; the remainder consisted of 53 juvenile lake whitefish captured by beach seine in August 1996. The combined gill net catch was comprised mostly of lake trout (92%), with small numbers of cisco and lake whitefish also present (6 and 2% of the total catch, respectively). The most intensive gill netting effort (32 nets set for a total of 66.3 h) occurred in 1997 (Appendix D2). The mean CPUE value for all species combined in 1997 was 21.3 fish/100 m^2/24 h; it was the lowest overall catch rate among all Doris Hinge lakes sampled with index gill nets in 1997-2000 (Appendix D1). The CPUE values for lake trout and cisco caught in 1997 were 19.7 and 1.6 fish/100 m^2/24 h, respectively.

Table 7.4 Number, percent composition, and catch-per-unit-effort (CPUE) for fish species captured by gill nets and beach seines in Windy Lake, 1996 to 1997.

Species	1996[a]		1997		Total		1997 CPUE (fish/100m²/24h)	
	n	%	n	%	n	%	Mean	SD
Lake trout	19	25.7	58	92.1	**77**	**56.2**	19.7	16.9
Lake whitefish	55	74.3			**55**	**40.1**		
Cisco			5	7.9	**5**	**3.6**	1.6	7.5
Total	**74**	**100**	**63**	**100**	**137**	**100**	**21.3**	**19.3**

[a] includes 53 lake whitefish captured in beach seines.

Fish marked with Floy tags during the 1997 survey included 31 lake trout and two cisco. None of these fish were recaptured.

7.1.6.2 Life History Data

Lake Trout

Size Distribution

The length distribution of the lake trout catch (*n*=77) was widespread (ranging from 202 to 980 mm fork length), with a mean of 476 mm (Figure 7.9; Appendix D3). The majority (91%) of the catch was comprised of fish in the 340-529 mm size range. The other size-classes included one juvenile fish (202 mm fork length) and six very large fish in the 931 to 980 mm size range (Figure 7.9). Rescan (1998) suggested that the lake trout population in Windy

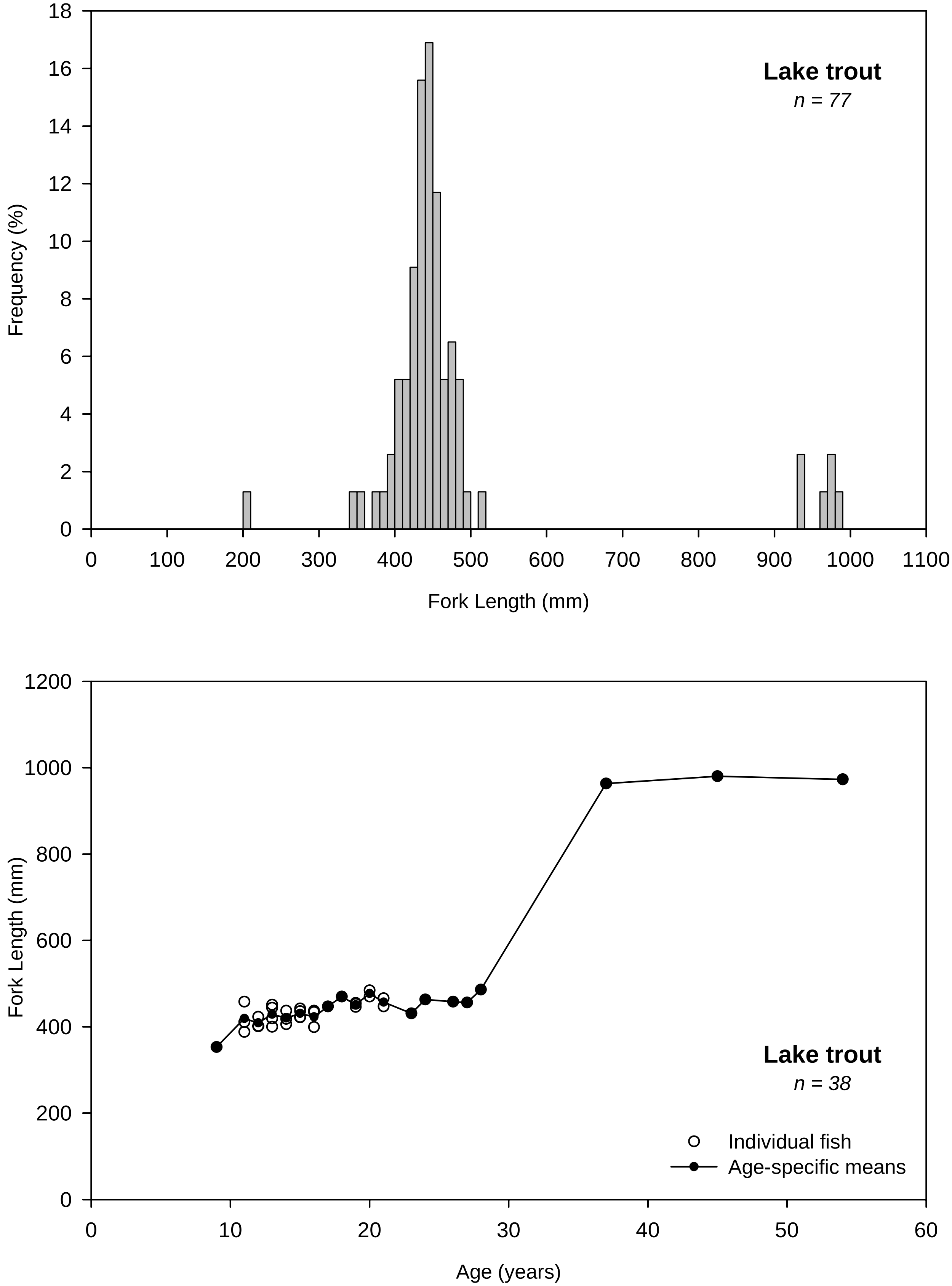


Figure 7.9 Length frequency distribution and age-length relationship for lake trout captured in Windy Lake, 1996-1997.

Lake has stratified into two size groups because of the lack of forage fish. The smaller, more populous group represented invertebrate feeders, with the less abundant and larger fish foraging on the smaller lake trout.

Length-Weight Relationship

The length-weight regression equation for lake trout from Windy Lake (all sampling years combined) was:

log Weight (g) = -4.807 + 2.940 log Fork Length (mm) (n=65; r^2=0.936).

The mean condition factor was 1.10; condition factors for individual fish ranged from 0.54 to 1.94.

Age and Growth

The age-length relationships for lake trout sampled in 1996-1997 are illustrated in Figure 7.9. Age-classes between 9 and 54 years were represented in the aged sample of 38 fish; the mean age was 18.9 years. Within the sample of 11 to 28 year old fish, mean fork lengths ranged between 419 and 486 mm, indicating limited annual growth increments (less than 4 mm per year). The small sample of aged large fish (n=3; 963-980 mm fork length) ranged from 37 to 54 years of age, suggesting a sharp increase in growth rates in fish between 28 and 37 years old.

Sex and Maturity

In total, sex and maturity characteristics were determined for 35 lake trout. Of these, 19 were females and 16 were males. Eighteen females were mature and one was immature, whereas nine males were mature and seven were immature (Appendix D6). Although data are limited, it appeared that females reached maturity between 11 and 13 years of age at an approximate fork length of 400-460 mm, whereas the onset of maturity in males appeared to occur later (between ages 12 and 19), but at a similar size range as the females.

Diet

Three lake trout stomachs from Windy Lake were examined. All were empty (Appendix D7).

Lake Whitefish

Size Distribution

Lake whitefish were caught in Windy Lake only in 1996. The measured catch (n=55) ranged from 48 to 419 mm in fork length, with a mean size of 98 mm. Most (96%) of the fish consisted of juveniles caught by beach seining. These juveniles exhibited two distinct size-classes: 48-58 mm fork length (27% of the total catch; likely young-of-the-year) and 80-160 mm fork length (69%; likely yearlings or older). The remaining two fish were captured by gill nets; they were 399 and 419 mm in fork length.

Length-Weight Relationship

Length-weight relationship for lake whitefish captured in Windy Lake could not be determined because of the small sample size (weights were available for only two fish captured in gill nets).

Age and Growth

Only two lake whitefish were aged. One fish was aged at 17 years (399 mm in fork length) and the other was 20 years old (419 mm in fork length).

Sex and Maturity

Sex and maturity characteristics were determined for only one lake whitefish caught. It was a mature female that was 17 years old and 399 mm in fork length.

Cisco

Size Distribution

Five cisco were captured by index gill nets in Windy Lake in 1997. They ranged from 274 to 409 mm in fork length, with a mean of 344 mm (Appendix D3).

Length-Weight Relationship

The length-weight regression equation for Windy Lake cisco was:

$$\log \text{Weight (g)} = -3.742 + 2.544 \log \text{Fork Length (mm)} \qquad (n=3;\ r^2=0.770).$$

The low correlation coefficient reflected the small sample size of weighed fish (n=3). The mean condition factor was 1.05; condition factors for individual fish ranged from 0.94 to 1.15 (Appendix D3).

Age and Growth

Within the limited sample that was aged (n=5), cisco ranged from 7 to 17 years of age (Appendix D3). The 7-8 year old fish were 274-303 mm in fork length, whereas the 14-17 year old fish were 364-409 mm in fork length (Appendix D5). The corresponding age-classes of cisco in Doris Lake were considerably smaller (222-266 mm and 283-289 mm, respectively).

Sex and Maturity

Sex and maturity data were collected from three Windy Lake cisco; all were mature females. They ranged from 7 to 14 years in age and from 274 to 368 mm in fork length. Although data were limited, they suggested that females matured prior to age 7.

7.1.7 Little Roberts Lake

The catch rates, length-frequency distributions, size and age statistics, age-specific lengths and weights, diet, and sex/maturity data for fish species sampled in Little Roberts Lake during 2000 are summarized in Appendices D1 to D7; data from individual fish are in Appendix D8. All fish sampling in Little Roberts Lake was carried out using index gill nets (3.8 cm mesh size).

7.1.7.1 Species Composition and Relative Abundance

The total catch in 20 gill nets set on 26 and 27 August 2000 (for a total duration of 28.5 h) was 64 fish (Table 7.5). The catch was comprised of five species (Arctic char, lake trout, lake whitefish, broad whitefish, and least cisco). As such, Little Roberts Lake represented the most diverse fish community within the studied Doris Hinge lakes. Three species (Arctic char, broad whitefish and least cisco) were captured in Little Roberts Lake, but not in the other lakes. This was a reflection the lake's proximity to the marine environment of Roberts Bay and the diadromous nature of these three species. The presence of a major migration barrier between Little Roberts and Doris lakes (see Section 8.2.2) prevents access of the diadromous species to Doris Lake and other lakes farther upstream.

Arctic char contributed almost half (45%) to the combined catch in Little Roberts Lake. Lake trout was the second most abundant species (33%), followed by lake whitefish (11%), least cisco (9%), and broad whitefish (2%). The overall mean CPUE of 45.5 fish/100 m^2/24 h (Appendix D1) was the second lowest catch rate among the Doris Hinge lakes sampled with index gill nets between 1997 and 2000. The mean catch rate for lake trout (15.3 fish/100 m^2/24 h) was the lowest among all sampled lakes.

Table 7.5 Number, percent composition, and catch-per-unit-effort (CPUE) for fish species captured by gill nets in Little Roberts Lake, 2000.

Species	Number Caught	% of Total Catch	CPUE (fish/100 m^2/24 h)	
			Mean	SD
Arctic char	29	45.3	21.2	27.8
Lake trout	21	32.8	15.3	17.8
Lake whitefish	7	10.9	4.6	20.5
Broad whitefish	1	1.6	0.7	3.1
Least cisco	6	9.4	3.6	9.1
Total	**64**	**100**	**45.5**	**57.9**

Fish marked with Floy tags during the 2000 survey included 19 lake trout, nine Arctic char and one broad whitefish. Except for one lake trout recaptured by the field crew one day after release, none of the remaining fish were recaptured.

7.1.7.2 Life History Data

Arctic Char

Size Distribution

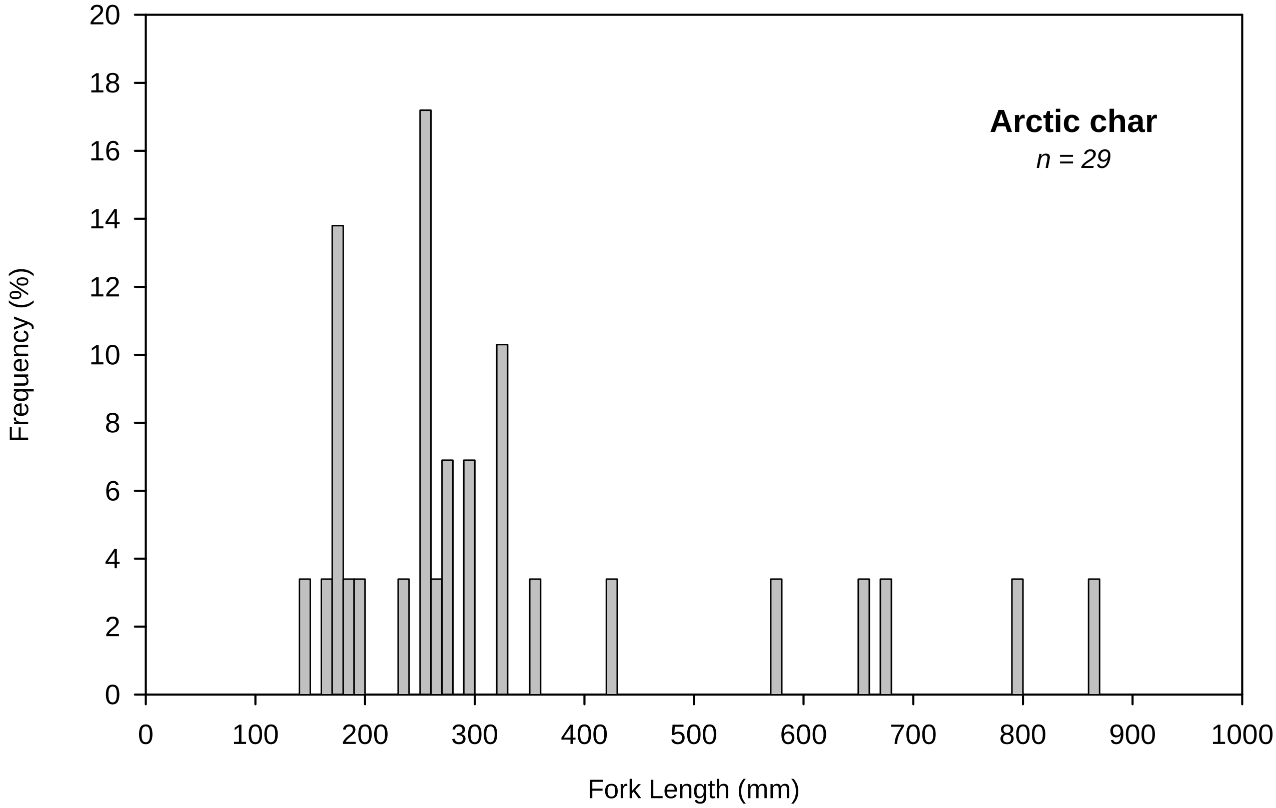
The length distribution of the Arctic char catch in Little Roberts Lake (*n*=29) was wide; fork lengths ranged from 149 to 869 mm, with a mean of 332 mm (Appendix D3). The length distribution pattern exhibited two distinct modes (Figure 7.10). The most notable mode was centered around 230-279 mm and was composed mainly of 3-4 year old fish. The second mode was smaller and focused around 140-149 mm fork length; it was composed mainly of 2 year old fish. Although the majority of the catch (79%) was comprised of fish smaller than 400 mm in fork length, fish larger than 650 mm in fork length were also represented (14% in the total catch).

Length-Weight Relationship

The length-weight regression equation for Arctic char from Little Roberts Lake was:

log Weight (g) = -4.714 + 2.941 log Fork Length (mm) (n=28; r^2=0.995).

The mean condition factor was 1.30; condition factors for individual fish ranged from 1.10 to 1.58 (Appendix D3).



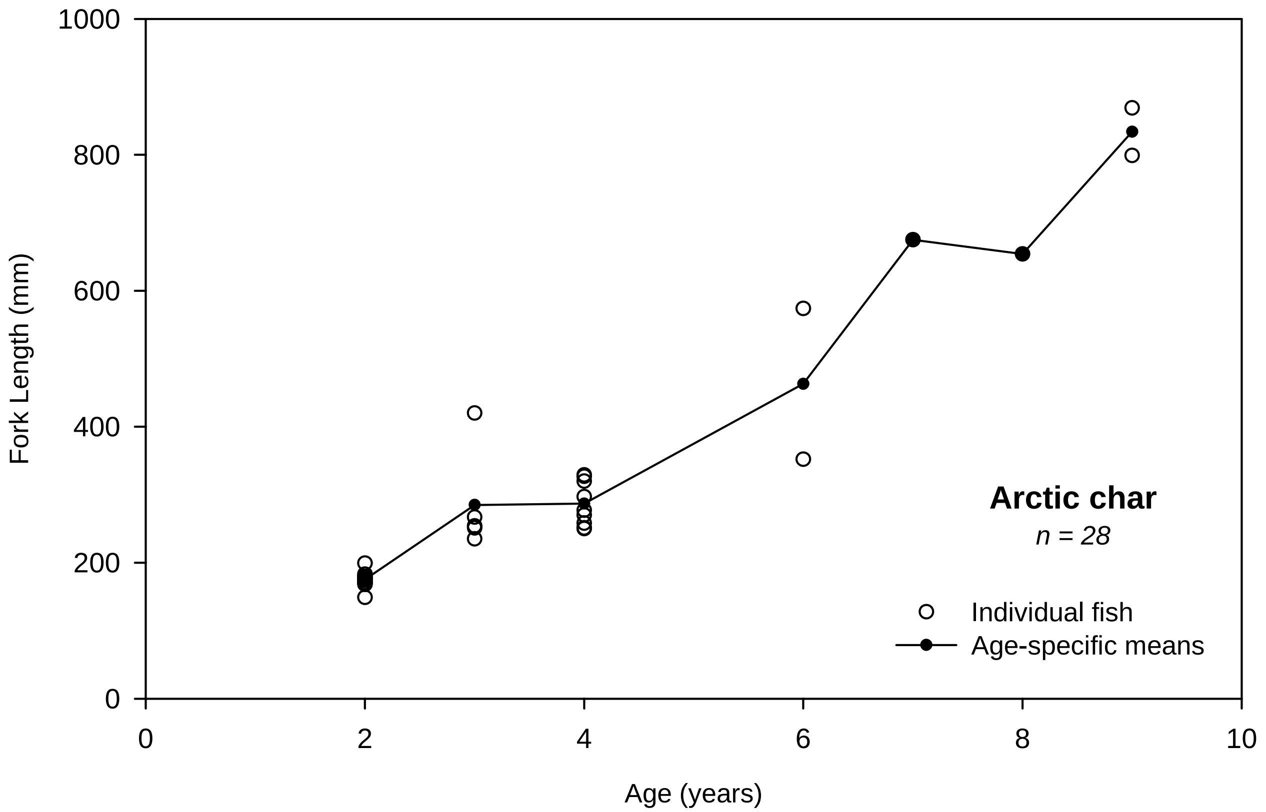


Figure 7.10 Length frequency distribution and age-length relationship for Arctic char captured in Little Roberts Lake, 2000.

Age and Growth

The age-length relationship for Arctic char is illustrated in Figure 7.10. Seven age-classes between 2 and 9 years were represented in the aged sample of 28 fish; the mean age was 4.0 years. The fastest rate of growth within the aged sample (approximately 90 mm/year) occurred between ages 4 and 6; this likely corresponds to the period when smolts start to undergo summer feeding migrations to the sea (Johnson 1980, Moshenko et al. 1984).

Sex and Maturity

Sex and maturity characteristics were determined for eight Arctic char. Males and females were equally represented and each sex-class contained three immature and one mature fish (Appendix D6). The immature fish were smaller than 280 mm in fork length, except for one large male (675 mm), which may have been misidentified as immature (Arctic char are alternate year spawners and their gonads are very small during non-spawning years).

Diet

Out of six Arctic char stomachs examined, four contained food. Tadpole shrimp (Order Notostraca) was the only food item identified in the diet (Appendix D7). The mean fullness index was 53%.

Lake Trout

Size Distribution

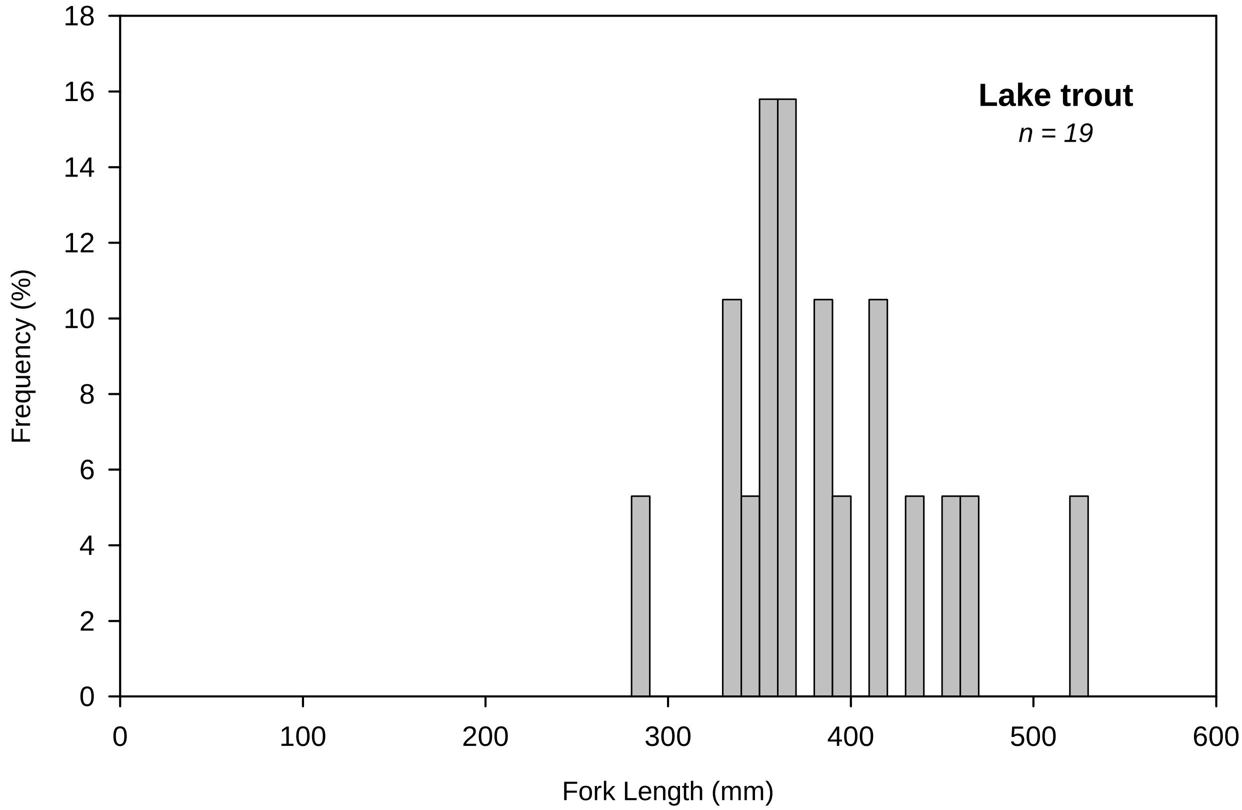
The measured sample of 19 lake trout caught in Little Roberts Lake ranged between 288 and 523 mm in fork length, with a mean length of 385 mm (Figure 7.11; Appendix D3). The majority of the catch (74%) was comprised of fish within the 336-419 mm size-class.

Length-Weight Relationship

The length-weight regression equation for lake trout from Little Roberts Lake was:

$$\log \text{Weight (g)} = -3.416 + 2.432 \log \text{Fork Length (mm)} \qquad (n=19;\ r^2=0.771).$$

The low correlation coefficient likely reflected the small sample size of weighed fish (n=19). The mean condition factor was 1.33; condition factors for individual fish ranged from 0.65 to 1.55 (Appendix D3).



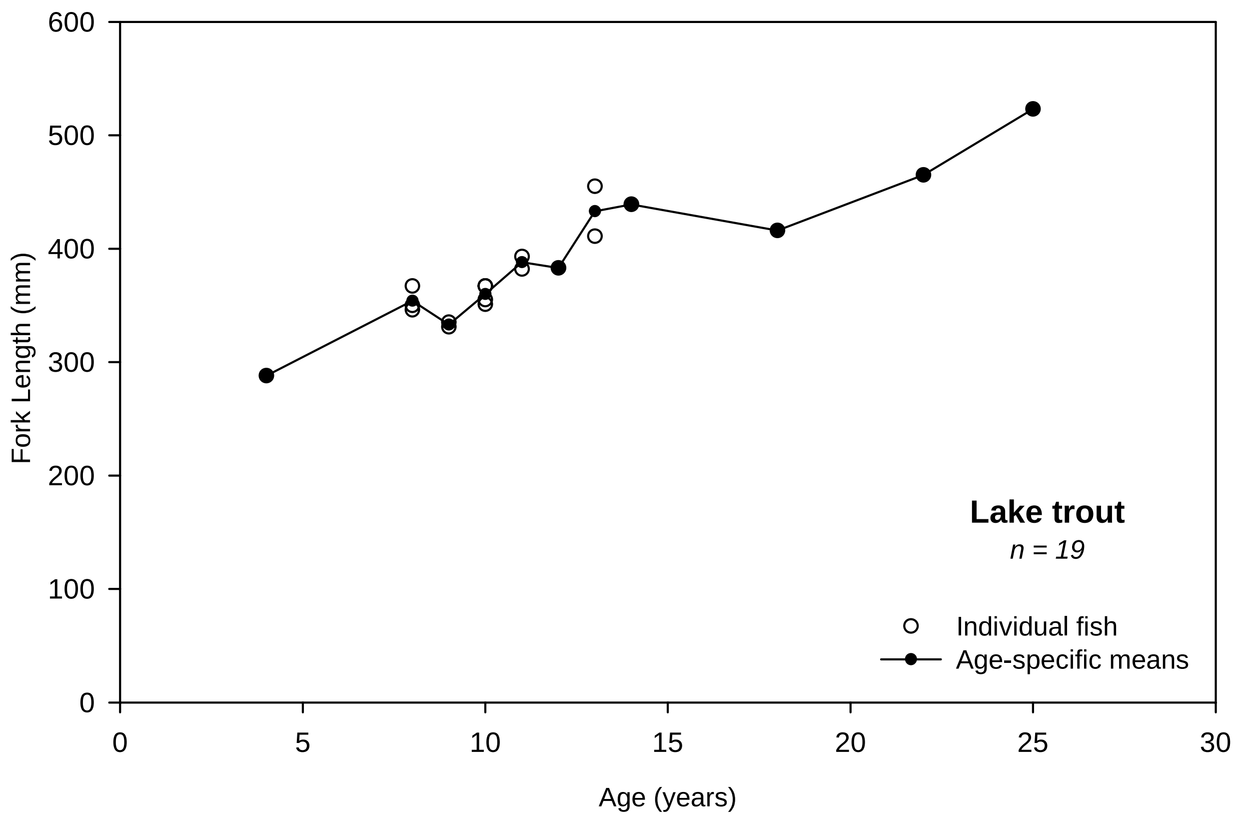


Figure 7.11 Length frequency distribution and age-length relationship for lake trout captured in Little Roberts Lake, 2000.

Age and Growth

The age-length relationship for lake trout from Little Roberts Lake is illustrated in Figure 7.11. Age-classes between 4 and 25 were represented in the aged sample of 19 fish; the mean age was 11.9 years (Appendix D3). Within the sample of 8 to 13 year old fish, annual growth increments were low (less than 16 mm per year).

Lake Whitefish

Size Distribution

Seven juvenile lake whitefish were captured in Little Roberts Lake in 2000. Within the measured catch (n=6), the fish ranged from 174 to 213 mm in fork length, with a mean length of 198 mm (Appendix D3).

Length-Weight Relationship

The length-weight regression equation for lake whitefish from Little Roberts Lake was:

log Weight (g) = -4.412 + 2.796 log Fork Length (mm) (n=6; r^2=0.950).

The mean condition factor was 1.32; condition factors for individual fish ranged from 1.24 to 1.41 (Appendix D3).

Age and Growth

Within the limited sample that was aged (n=7), lake whitefish were represented by two age-classes: age 4 and age 6. The four-year old fish ranged from 174-203 mm in fork length, whereas the six-year olds were 208 and 213 mm in fork length (Appendix D5). The corresponding age-classes of lake whitefish in Doris Lake were considerably larger (220-280 mm in fork length).

Sex and Maturity

Sex and maturity characteristics were determined for six lake whitefish. Within this sample, one was an immature female and five were immature males (Appendix D6).

Diet

Plant matter was the only identified food item in the six lake whitefish stomachs examined (Appendix D7). Half of the stomachs examined were empty, resulting in a low mean fullness index of 27%.

Least Cisco

Size Distribution

The limited sample of least cisco (n=6) ranged from 169 to 221 mm in fork length, with a mean of 191 mm (Appendix D3). One half of the catch was between 180 and 199 mm in fork length.

Length-Weight Relationship

The length-weight relationship of least cisco caught in Little Roberts Lake was:

log Weight (g) = -3.249 + 2.271 log Fork Length (mm) (n=6; r^2=0.894).

The mean condition factor was 1.23; condition factors of individual fish ranged from 1.07 to 1.34.

Broad Whitefish

One adult broad whitefish was caught in Little Roberts Lake in 2000. It was 533 mm in fork length, weighed 2000 g, and was 12 years old (Appendix D3).

7.1.8 Pelvic Lake

The catch rates, length-frequency distributions, size and age statistics, age-specific lengths and weights, diet, and sex/maturity data for fish species sampled in Pelvic Lake during 1998 are summarized in Appendices D1 to D7; data from individual fish are presented in Appendix D8. Gill netting was the only capture method used in Pelvic Lake.

7.1.8.1 Species Composition and Relative Abundance

In total, 390 fish were caught in Pelvic Lake during 1998 (Table 7.6). They included lake whitefish, cisco, and lake trout. Lake whitefish was the dominant species in the overall catch (51%), followed by cisco (41%), and lake trout (8%).

A total of 16 index gill nets set in Pelvic Lake during 15 to 17 August 1998 (total effort of 20.8) resulted in an overall mean CPUE value of 400 fish/100 m^2/24 h (Appendix D2). This was the highest overall catch rate among of all the Doris Hinge lakes sampled with index gill nets during 1997-2000. The CPUE values for lake whitefish, cisco, and lake trout were 203, 169, and 29 fish/100 m^2/24 h, respectively.

Fish marked with Floy tags during the 1998 survey included 34 lake whitefish, nine lake trout, and three cisco. None of these fish were recaptured.

Table 7.6 Number, percent composition, and catch-per-unit-effort (CPUE) for fish species captured by gill nets in Pelvic Lake, 1998.

Species	Number Caught	% of Total Catch	CPUE (fish/100m^2/24h)	
			Mean	SD
Lake trout	32	8.2	28.5	29.1
Lake whitefish	198	50.8	203.0	86.5
Cisco[a]	160	41.0	168.5	154.6
Total	**390**	**100**	**400.1**	**153.5**

[a] likely includes *Coregonus artedi* and *C. sardinella* (see Section 7.1.8.2)

7.1.8.2 Life History Data

Lake Trout

Size Distribution

The measured catch of lake trout in Pelvic Lake (*n*=31) exhibited a widespread length distribution, ranging from 159 to 915 mm in fork length (mean of 525 mm; Appendix D3), and indicating that most life stages of lake trout were present in the lake. The length-frequency histogram (Figure 7.12) exhibited one distinct mode centered on the 400 to 479 mm size-class, which represented 58% of the total catch. Fish larger than 620 mm in fork length contributed 32% to the total catch (Appendix D4).

Length-Weight Relationship

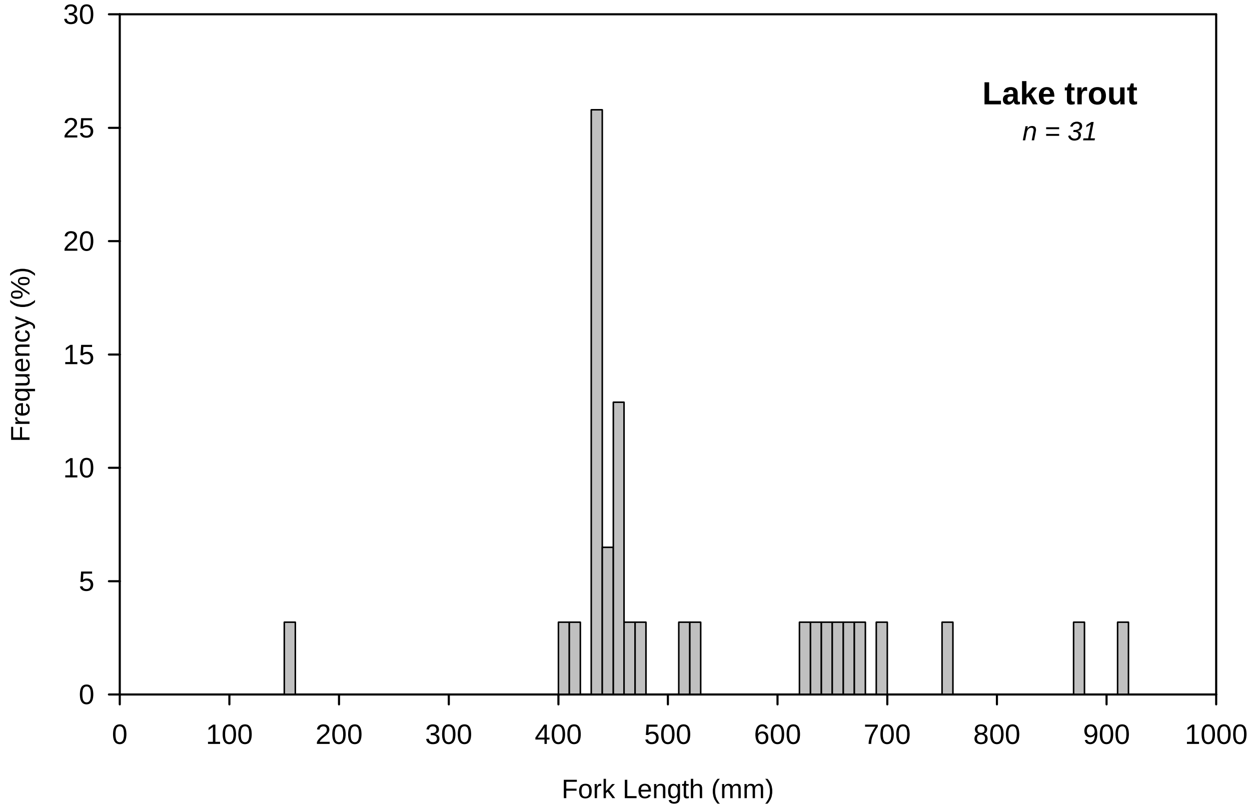
The length-weight regression equation for lake trout from Pelvic Lake was:

log Weight (g) = -4.759 + 2.922 log Fork Length (mm) (n=31; r^2=0.977).

The mean condition factor was 1.08; condition factors for individual fish ranged from 0.62 to 1.39.

Age and Growth

The age-length relationships for lake trout from Pelvic Lake are illustrated in Figure 7.12. Age-classes between 8 and 39 years were represented in the aged sample of 30 fish; the mean age was 22.2 years (Appendix D3). Large differences in individual fork lengths among cohorts within the 23 to 25 year age-classes (between 430 and 753 mm) suggested the presence of two distinct populations of lake trout in Pelvic Lake: one that stops growing prior to reaching



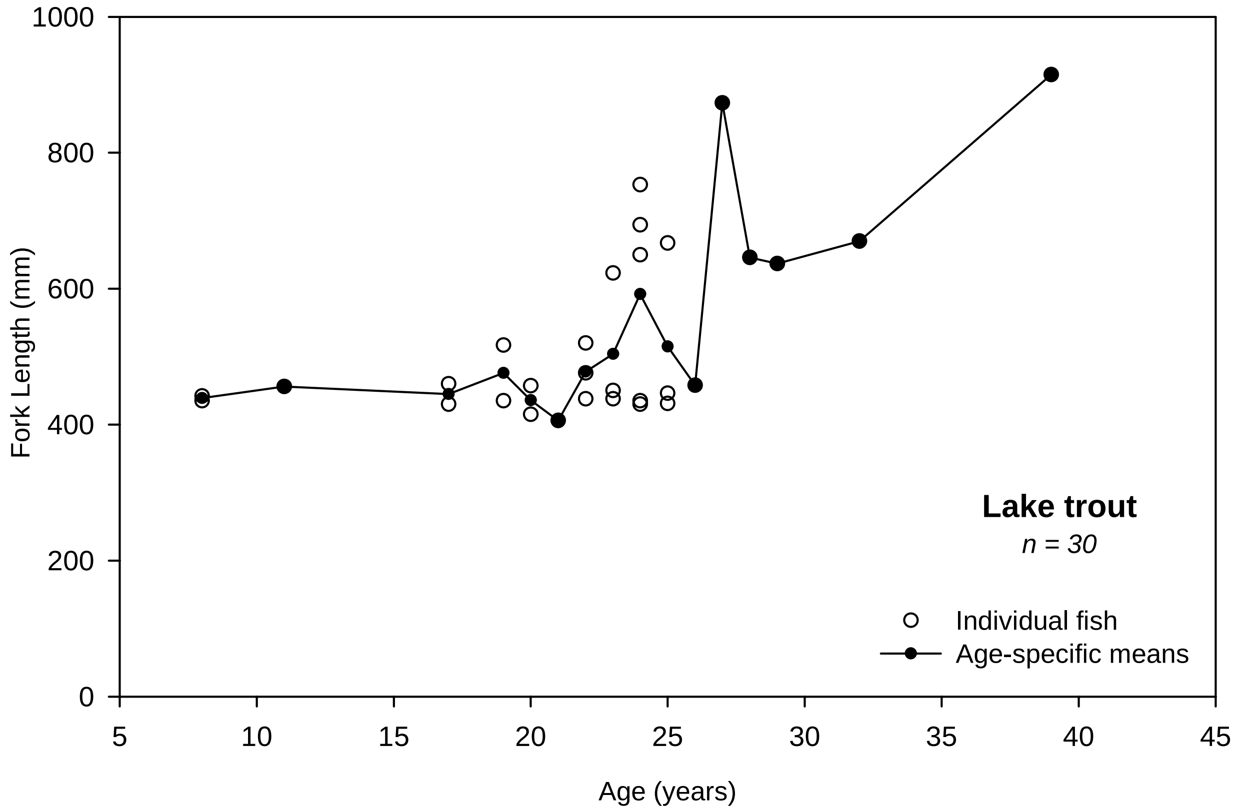


Figure 7.12 Length frequency distribution and age-length relationship for lake trout captured in Pelvic Lake, 1998.

approximately 500 mm in fork length, and one that continues to grow in excess of 900 mm in fork length. Similar patterns of growth were exhibited by lake trout in Windy and Patch lakes.

Sex and Maturity

In total, sex and maturity characteristics were determined for 21 lake trout (Appendix D6). Of these, 12 were females and nine were males. Although data were limited, it appeared that females could reach maturity at age 11 at an approximate fork length of 400 mm, whereas the onset of maturity in males appeared to occur later (the smallest mature male was 17 years old and 430 mm in fork length).

Diet

Twenty lake trout stomachs from Pelvic Lake were examined (Appendix D7). Cisco and lake whitefish accounted for 68 and 25% of the total food volume, respectively; the remainder was contributed by unidentified fish remains and unidentified matter. Most (60%) of the examined stomachs were empty, resulting in a low mean fullness index of 20%.

Lake Whitefish

Size Distribution

The measured catch of lake whitefish from Pelvic Lake (n=194) ranged from 153 to 420 mm in fork length (mean of 290 mm). Most (59%) of the catch was composed of fish smaller than 300 mm in fork length, with 12% of the catch exceeding 400 mm in fork length (Figure 7.13). Three distinct size-class modes were apparent in the catch. The smallest mode (12% of the catch) was centered around 150-179 mm in fork length, whereas the larger two modes were focused around 210-299 mm (46% of catch) and 370-419 mm (30% of catch).

Length-Weight Relationship

The length-weight regression equation for lake whitefish caught in Pelvic Lake was:

log Weight (g) = -5.054 + 3.057 log Fork Length (mm) (n=193; r^2=0.991).

The mean condition factor was 1.22; condition factors for individual fish ranged from 0.66 to 1.51 (Appendix D3).

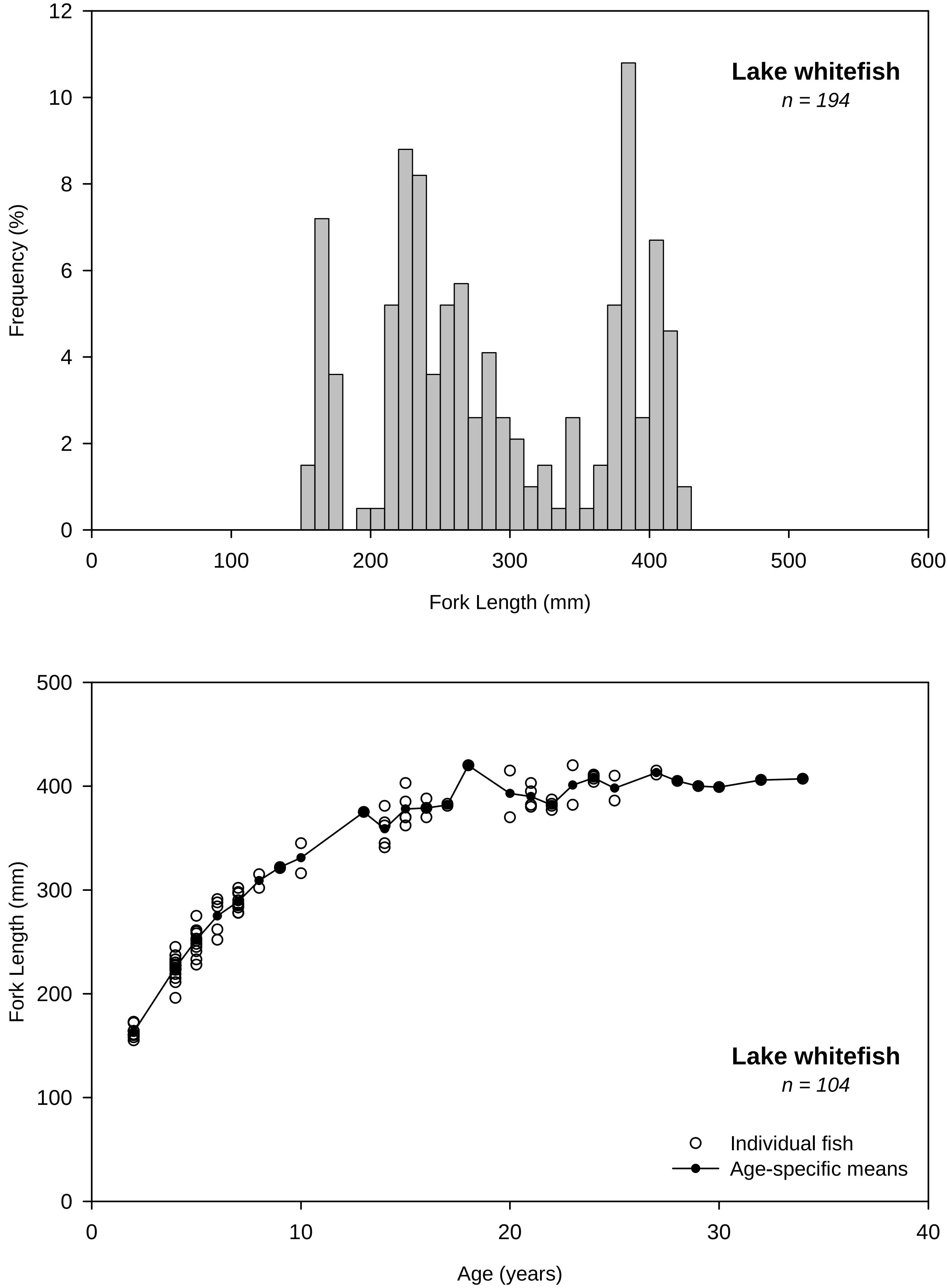


Figure 7.13 Length frequency distribution and age-length relationship for lake whitefish captured in Pelvic Lake, 1998.

Age and Growth

The age-length relationships for lake whitefish from Pelvic Lake are illustrated in Figure 7.13. Within the aged sample of 104 fish, age-classes between 2 and 35 years were represented (mean of 11.7 years). Growth increments in early life (ages 2 to 10) were the highest, averaging approximately 19 mm per year; older fish grew much slower and averaged only a few millimetres of growth per year. The asymptotic fork length appeared to be approximately 420 mm.

Sexual Maturity

Sex and maturity characteristics were determined for 134 lake whitefish. Within this sample, 52 fish were females and 82 were males (Appendix D6). Both sexes consisted mainly of immature fish (67% of females and 88% of males). The smallest and youngest mature females were 370 mm in fork length and 14 years old. The smallest mature male was 377 mm in fork length and 22 years old; however, immature males of up to 30 years old were recorded (Appendix D8).

The data suggested that females mature between 14 and 16 years of age (370 to 420 mm fork length), whereas males mature later, but at a similar size range.

Cisco

Size Distribution

The measured sample of cisco captured in Pelvic Lake in 1998 (n=155) ranged from 157 to 337 mm in fork length, with a mean of 214 mm (Appendix D3). Most (75%) of the catch was composed of fish smaller than 230 mm in fork length; however, larger fish in the 270-339 mm size-class were also well represented (16% of the total catch; Figure 7.14).

Length-Weight Relationship

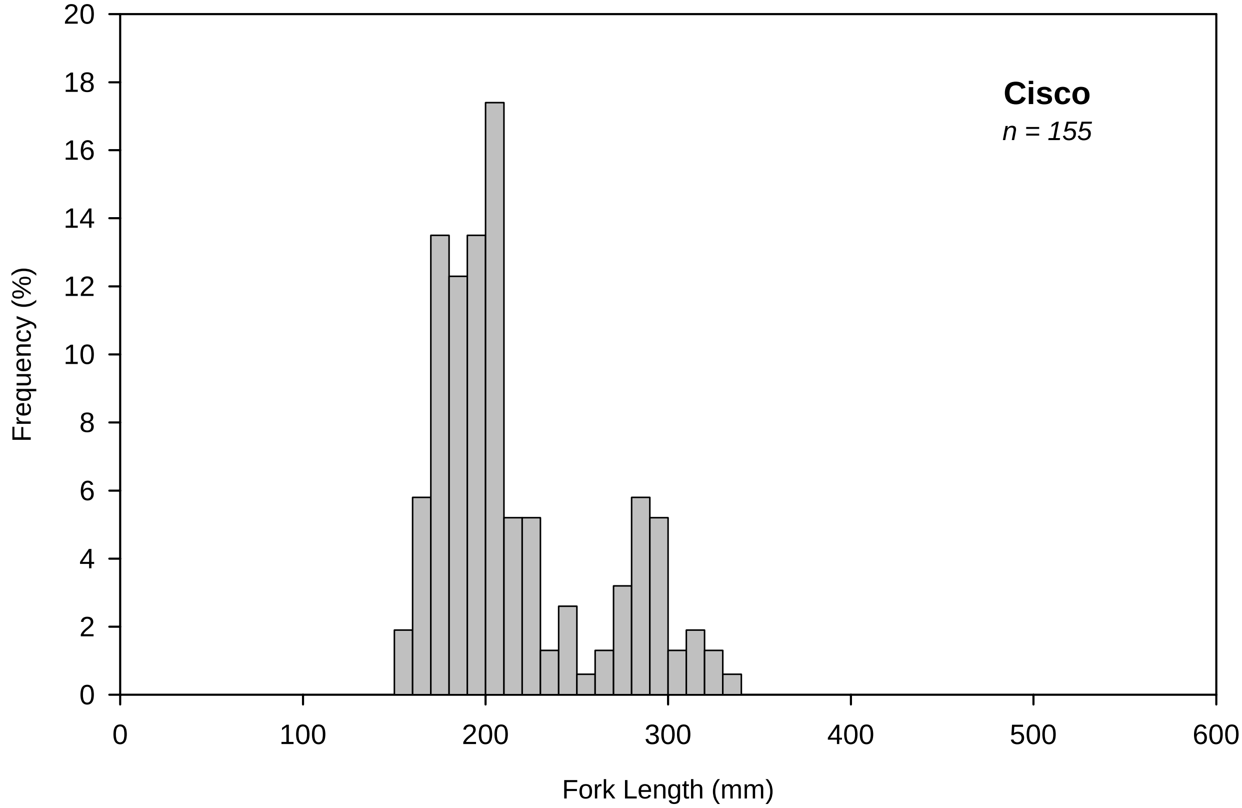
The length-weight regression equation for Pelvic Lake cisco was:

log Weight (g) = -5.238 + 3.111 log Fork Length (mm) (n=155; r^2=0.937).

The mean condition factor was 1.06; condition factors for individual fish were widespread and ranged from 0.60 to 1.68 (Appendix D3).

Age and Growth

The age-length data for cisco are presented in Appendix D5 and Figure 7.14. Fish in the aged sample (n=60) were between 3 and 18 years of age, with a mean of 9.0 years. Large differences in individual fork lengths among cohorts within the 5 to 7 year-classes (between 157 and 293 mm in fork length) suggested the



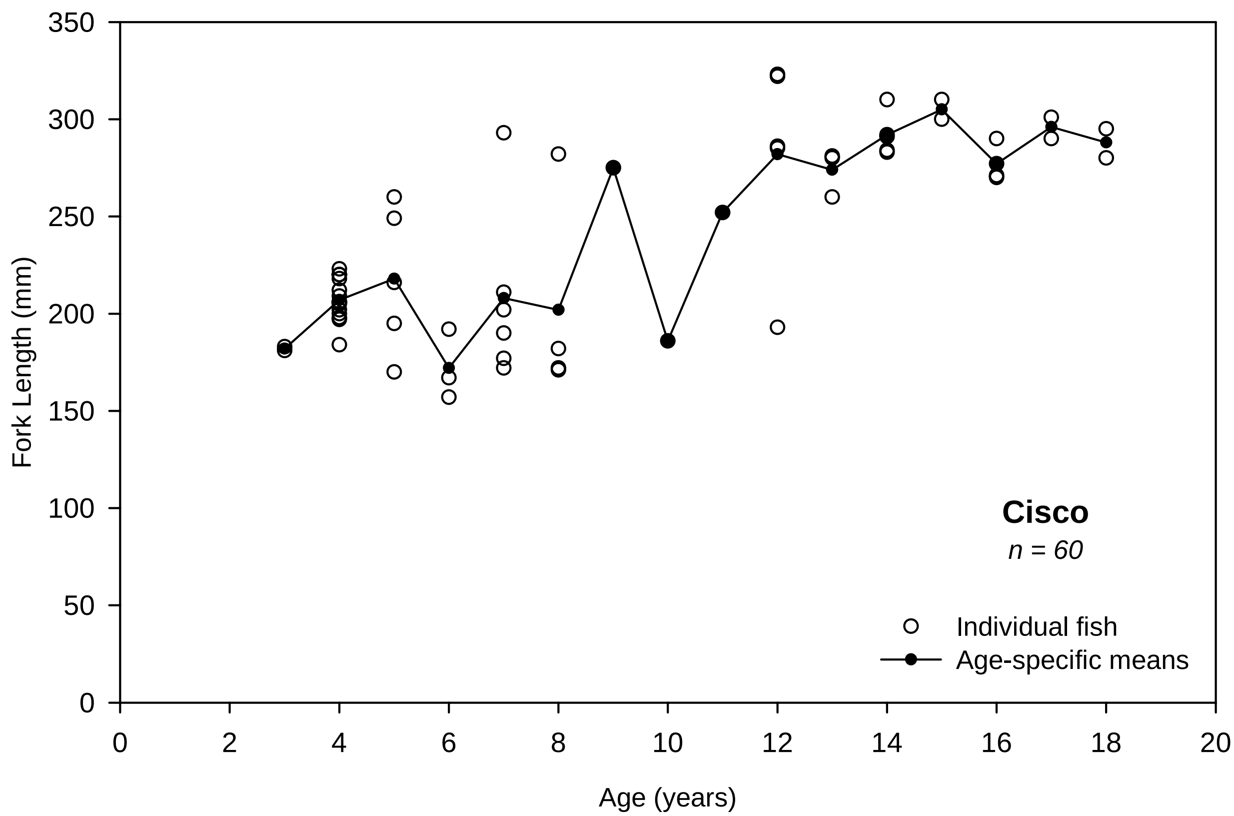


Figure 7.14 Length frequency distribution and age-length relationship for cisco captured in Pelvic Lake, 1998.

presence of two distinct growth patterns among cisco in Pelvic Lake. This may have been due to misidentification of least cisco (*Coregonus sardinella*) individuals among the catch of *Coregonus artedi* (see below).

Sex and Maturity

In total, 141 cisco were sampled for sex and maturity characteristics; they included 77 females and 64 males. The maturity data indicated that some fish reached sexual maturity at fork lengths as small as 162 and 157 mm (females and males, respectively), whereas immature fish were recorded to be as large as 221 and 271 mm in fork length (females and males, respectively). Overall, 51% of mature fish were smaller than 200 mm in fork length, whereas 21% of immature fish exceeded 220 mm in fork length.

This large overlap in size-at-maturity data suggested that one part of the cisco population in Pelvic Lake may have been comprised of least cisco (*Coregonus sardinella*) that were misidentified as cisco (*Coregonus artedi*). Rescan (1999a) noted these differences in growth and maturity indices and attributed them to the likely presence of two subpopulations or two different species of cisco in Pelvic Lake. Known external differences between these two species (e.g., the position of the pelvic fin relative to the snout and caudal peduncle) were not assessed by Rescan (1999a); therefore, it is likely that the cisco sample collected from Pelvic Lake in 1998 was a mixture of two species. Similar results from Doris Lake (see Section 7.1.2) also suggested the presence of two cisco populations in that lake.

7.1.9 Summary

In total, 1552 fish representing six species were captured in gill nets and beach seines in seven Doris Hinge lakes during fisheries surveys conducted between 1995 and 2000 (Table 7.7). The captured species included (in the order of abundance in the total catch) cisco (36%), lake whitefish (34%), lake trout (28%), Arctic char (2%), least cisco (<1%), and broad whitefish (<1%). Ninespine stickleback were also present in most lakes, as recorded from direct observations in Doris Lake and lake trout stomach content data from Tail and Patch lakes.

Fish populations in five of seven surveyed lakes were limited to three species (lake trout, lake whitefish, and cisco); they were recorded in different proportions to each other depending on the lake. Whereas coregonid species (lake whitefish and cisco) accounted for approximately 90% of the catches in Doris, Ogama, and Pelvic lakes, lake trout were considerably more dominant in Patch and Windy lakes (37 and 56 % of respective catches). Tail Lake, although separated by a very short stream section from Doris Lake, did not support coregonids and was inhabited solely by lake trout (and ninespine stickleback, as recorded from lake trout stomach analyses).

Table 7.7 Summary of fish species composition in Doris Hinge lakes, 1995 to 2000.

Lake	Total Catch	Dominant Species (% of total catch)		Co-dominant Species (% of total catch)		Other Species (% of total catch)	
Doris	573	Cisco[a]	(62.7)	Lake whitefish	(26.7)	Lake trout	(10.6)
Tail	163	Lake trout	(100.0)				
Ogama	38	Lake whitefish	(76.3)	Cisco	(13.2)	Lake trout	(10.5)
Patch	187	Lake whitefish	(43.3)	Lake trout	(37.4)	Cisco	(19.3)
Windy	137	Lake trout	(56.2)	Lake whitefish	(40.1)	Cisco	(3.6)
Little Roberts	64	Arctic char	(45.3)	Lake trout	(32.8)	Lake whitefish	(10.9)
						Least cisco	(9.4)
						Broad whitefish	(1.6)
Pelvic	390	Lake whitefish	(50.8)	Cisco[a]	(41.0)	Lake trout	(8.2)
Total	**1552**						

[a] likely included *Coregonus artedi* and *C. sardinella* (see Sections 7.1.2.2 and 7.1.8.2)

Fish populations in Little Roberts Lake were considerably different from the other sampled lakes because they included Arctic char, broad whitefish, and least cisco in addition to lake trout and lake whitefish. This difference in species diversity was likely caused by a fish passage barrier between Doris and Little Roberts lakes that prevented access of diadromous species (Arctic char and broad whitefish) to lakes farther upstream. Little Roberts Lake likely is used by Arctic char during their migrations between Roberts Lake and the ocean. Although least cisco (*Coregonus sardinella*) were identified only in Little Roberts Lake, it is suspected that they were also captured, and possibly misidentified as cisco (*C. artedii*) in Pelvic and Doris lakes.

Index gill nets (38 mm mesh size) were used as the primary capture method in all lakes sampled during 1997-2000. As such, catch rate data from these standardized sampling events were used to compare fish abundance between the lakes (Table 7.8). The highest mean catch rate (all species combined) was recorded in Pelvic Lake (400 fish/100 m^2/24 h). The overall catch rate in Doris Lake was second highest at 227 fish/100 m^2/24 h, with considerably lower catch rates recorded in the remaining lakes (ranged from 21 to 86 fish/100 m^2/24 h).

Lake trout were present in all sampled lakes, but appeared to be more abundant in Tail Lake (86 fish/100 m^2/24 h) than in the remaining lakes (15 to 29 fish/100 m^2/24 h). Lake whitefish and cisco were most abundant in Pelvic Lake (203 and 168 fish/100 m^2/24 h, respectively), but were also well represented in Doris and Patch lakes.

Table 7.8 Summary of sampling effort and catch-per-unit-effort (CPUE) for fish species captured by index gill nets in Doris Hinge lakes, 1997 to 2000.

Lake	Total Effort		CPUE (fish/100 m^2 of 3.8 mm gill net/24 h)						
	No. Sets	No. Hours	Arctic char	Lake trout	Lake whitefish	Broad whitefish	Cisco	Least cisco	Total
Doris	27	52.4		23.7	52.6		150.6		**226.9**
Tail	25	34.3		85.6					**85.6**
Patch	33	49.2		24.3	35.7		16.0		**75.9**
Windy	32	66.3		19.7			1.6		**21.3**
Little Roberts	20	28.5	21.2	15.3	4.6	0.7		3.6	**45.5**
Pelvic	16	20.8		28.5	203.0		168.5		**400.1**

7.2 STREAM COMMUNITIES

7.2.1 Methods

Field Methods

Fish sampling techniques used in streams within the Doris Hinge area included backpack electrofishing, angling, and visual observations. The primary fish capture method was backpack electrofishing. Stream surveys were conducted from June to August during the 1995-2000 period. Sampled watercourses included the outflows of Doris, Tail, Ogama, Windy, Glenn, and Little Roberts lakes as well as several small inflows to Doris, Ogama, Windy, and Patch lakes (Figure 7.1; Appendix D9). Larger inflows from upstream lakes were considered as outflows (e.g., stream connection between Ogama and Doris lakes was designated as Ogama Outflow). The outflows were sampled on at least two occasions during the 1995-2000 period (except for Windy Outflow sampled only in 1997), whereas the inflows were sampled only once during 1997 (except for Ogama Inflow sampled yearly from 1995 to 1997). Detailed descriptions of fish capture methods are provided below.

Backpack electrofishing was conducted by a two-person crew using either a gas-powered Smith-Root model 15A POW (Programmable Output Waveforms) or model 15C backpack electrofisher. Working in an upstream direction, both single and double pass electrofishing were used on accessible portions of selected streams (Rescan 1997, 1998, 2001). Crews sampled three consecutive 100 m sections of stream in 1996, whereas surveyed sections varied between 100 and 1250 m in 2000. Data recorded during backpack electrofishing events included location, effort, amperage, voltage, water temperature, and habitat conditions. After the fishing survey, a habitat assessment of the surveyed stream section was conducted. All stream site reference numbers (e.g., Site #20, Site #22, etc.; Figure 7.1) are based on Rescan (1998).

Fish life history data were collected from the captured fish. Live fish were identified to species, measured (fork length in mm), weighed (g), and released. Non-lethal ageing structures were also collected from sub-samples of the captured fish. Left pectoral fin clips were taken as ageing structures from 1995 to 1998, whereas left pelvic fin clips were taken in 2000. Scales were also occasionally taken for ageing in 1995 and 2000. Between 1997 and 2000, fish larger than 300 mm in fork length were marked with a uniquely numbered Floy anchor tag to assess their movements through subsequent recaptures. Additional data were collected from accidental and euthanized mortalities; these included sex and maturity, reproductive status, stomach contents, and collection of otoliths (for ageing).

Data Analysis

The presentation of fish population data for Doris Hinge streams varied considerably between the four annual data reports in which they were discussed. To facilitate data presentation in this report, all data were consolidated into one table (Appendix D11) and analyzed for life history characteristics based on multi-year catches combined. Where data were available, mean fork length, weight, condition factor, and age (with corresponding standard deviations and ranges) were calculated for each stream and each species on a yearly basis (Appendix D10). The multi-year data collected from each stream were also combined to maximize the sample sizes.

As an index of relative abundance, catch-per-unit-effort (CPUE) values are presented here only for 1996 and 1997 surveys. Previous data reports had recorded CPUE as either the number of fish encountered per 100 m of stream electrofished (Klohn Crippen 1995), per 300 m/hour (Rescan 1997), per minute of sampling (Rescan 1998), or were not recorded (Rescan 2001). Because effort data (i.e., total time and distance sampled) were not consistently reported in the annual data reports, CPUE values could not be recalculated to a common unit nor verified for their accuracy. As such, the CPUE data presented in Appendix D9 are based on the reported CPUE values for 1996 and 1997, when fish captured or observed per minute of active sampling were used as a CPUE unit (hours were converted to minutes for the 1996 data).

7.2.2 Doris Outflow (Sites #25u/s and #25d/s)

The Doris Outflow traverses approximately 3.4 km from the north end of Doris Lake to Little Roberts Lake. Two sites were sampled along this stream: one upstream and one downstream of a 2.3 m high waterfall located approximately 400 m downstream of Doris Lake (Sites #25u/s and #25d/s; Figure 7.1). The sites were sampled during July of 1996, and during August of 1995, 1997, and 2000. Where reported, the electrofished stream sections ranged from 150 to 300 m in length. Both one pass and two pass (1996 only) electrofishing methodology was used.

Five fish species were captured or observed in Doris Outflow. They included Arctic char, lake whitefish, lake trout, cisco, and ninespine stickleback; in addition, two unidentified fish were recorded in 1996 (Appendix D9). Ninespine stickleback were not enumerated during 1996 surveys because of time constraints and the large numbers caught (Rescan 1997).

In total, 71 fish were captured or observed in Doris Outflow during 1995-2000. Ninespine stickleback contributed almost half to the total catch (49%). Arctic char (*n*=12) and lake trout (*n*=12) dominated the sportfish catch, with smaller numbers of cisco (*n*=8) and lake whitefish (*n*=2) also present. Arctic char and cisco were captured only at Site #25d/s (downstream of the waterfall), whereas lake trout and lake whitefish were captured at both upstream and downstream of the waterfall. The waterfall (2.3 m high) is a physical barrier to upstream fish migration; as such, the populations of lake trout and lake whitefish in Doris Lake were considered to be resident and isolated from downstream reaches (Rescan 1997).

Four lake trout and one lake whitefish were marked with Floy tags in August 1997 at Site #25d/s in an attempt to monitor fish movements. None of these fish were recaptured. One cisco caught on 14 August 1997 at Site #25d/s was recorded as a recapture; however, its tag number was not recorded. Based on similarities in fork length and weight, it was likely that this fish was one of two cisco that were tagged in Doris Lake one day earlier.

Arctic Char

The Arctic char catch (*n*=12) ranged from 91 to 303 mm in fork length, with a mean of 189 mm (Appendix D10). The majority of the catch (58%) was composed of fish smaller than 200 mm in fork length (Appendix D11). The capture of three fish in the 91-93 mm size-class on 14 August 1997 (likely young-of-the-year fish) suggested that Doris Outflow was used for Arctic char rearing. All Arctic char in Doris Outflow were captured downstream of the waterfall.

Four fish (captured on 14 August 1997 and ranging from 195 to 243 mm in fork length) were aged; all were two years old. Two year old Arctic char caught on 26-27 August 2000 in Little Roberts Lake were considerably smaller in size (149 to 199 mm in fork length; *n*=8). These data, although limited by small sample sizes and different years of sampling, suggested that the stream habitat of Doris

Outflow may have provided faster growth conditions for juvenile Arctic char than the lake habitat in Little Roberts Lake.

Sex and maturity characteristics were determined for two Arctic char. One was a male and the other a female; both were immature (Appendix D11). The largest of the two fish (the male) was 303 mm in fork length; its stomach was 100% full of invertebrate larvae.

Lake Trout

Eleven of the 12 lake trout captured in Doris Outflow were measured; fork length ranged from 71 to 447 mm, with a mean of 216 mm (Appendix D10). Almost half (46%) of the catch consisted of juvenile fish in the 78 to 92 mm size-class, which were all caught on 7 July 1996 upstream of the waterfalls. The remainder of the catch, composed of six lake trout larger than 200 mm in fork length, were caught downstream of the waterfall on 14 August 1997.

All lake trout exceeding 200 mm in fork length (*n*=6) were weighed; weights ranged from 84 to 800 grams (mean of 391 g). The mean condition factor was 0.99, with the condition factors of individual fish ranging from 0.90 to 1.07 (Appendix D10).

Lake Whitefish

One of two lake whitefish caught in Doris Outflow was 78 mm in fork length; this juvenile was caught upstream of the waterfall. The other fish was an adult (493 mm in fork length) that was captured downstream of the waterfall (Appendix D11).

Cisco

The cisco catch from Doris Outflow (*n*=10) ranged from 130 to 276 mm in fork length, with a mean of 227 mm (Appendix D10). Most (80%) were larger than 200 mm in fork length. Although cisco were captured both downstream and upstream of the waterfall, the smallest individuals (130 and 165 mm in fork length) were captured upstream of the falls. These two fish were aged at two and three years old, respectively. The largest cisco (276 mm in fork length) was a mature female.

Ninespine Stickleback

The measured ninespine stickleback catch from Doris Outflow (*n*=35) ranged from 24 to 81 mm in total length (mean of 44 mm; Appendix D10).

7.2.3 Doris Inflow (Site #04)

This stream is approximately 2.6 km long and flows into the southern end of Doris Lake. It was sampled with a backpack electrofisher on 21 June 1997 (Site #04, Figure 7.1). The total catch consisted of three ninespine stickleback; they were captured over a 310 m survey distance near the mouth of the stream. The stickleback ranged from 38 to 52 mm in total length, with a mean length of 45 mm (Appendix D10). The CPUE value was 0.2 fish/min (Appendix D9).

7.2.4 Tail Outflow (Site #03)

This outlet stream from Tail Lake to Doris Lake is approximately 0.6 km in length (Figure 7.1). It was sampled in June 1997 and June 2000 for a distance of 270 and 100 m, respectively. A single ninespine stickleback was captured in 1997 (CPUE of 0.2 fish/min) and no fish were recorded in 2000 (Appendix D9).

7.2.5 Ogama Outflow (Site #22)

This stream is approximately 1.3 km long and connects Ogama and Doris lakes (Figure 7.1). Fish sampling at Site #22 included angling in August 1995 and backpack electrofishing in July 1996 and August 1997 (section lengths of 300 and 200 m, respectively). In total, 33 fish were captured or observed during these surveys; they included six lake trout, two lake whitefish, and 25 ninespine stickleback (Appendix D9). No fish were caught during the July 1996 survey.

Lake Trout

Five of the six lake trout captured in Ogama Outflow were caught by angling in 1995, and one was caught by backpack electrofishing in 1997. All lake trout were measured; they ranged from 463 to 647 mm in fork length, with a mean of 542 mm. One lake trout was marked with a Floy tag in 1997, but was not recaptured.

Lake Whitefish

Two lake whitefish were captured at Site #22; they were captured by electrofishing on 15 August 1997 (CPUE of 0.2 fish/min; Appendix D9). They were 287 and 316 mm in fork length and weighed 280 and 360 g, respectively. Both fish were marked with Floy tags, but were not recaptured.

Ninespine Stickleback

Of the 25 ninespine stickleback recorded from Ogama Outflow, 10 were measured for fork length. Their lengths ranged from 18 to 72 mm, with a mean of 56 mm (Appendix D10).

7.2.6 Ogama Inflows (Sites #01, #06, #09, #14, and #20)

Five sites on tributaries that drain into Ogama Lake were surveyed during 1995, 1996, and 1997. The longest inflow originates from an unnamed lake approximately 8 km south of Ogama Lake; it was sampled at Sites #14, #01, and #20 (in downstream direction; Figure 7.1). Site #20 was downstream of the confluence with the drainage from Patch Lake. The remaining two sites (#09 and #06) were located on small tributaries (less than 0.5 km in length). Site #09 was on a stream that flows into the north end of Ogama Lake and Site #06 was on a stream that flows into an unnamed lake before draining into the south end of Ogama Lake. Three of the surveyed sites (#01, #14, and #06) were located more than 1 km upstream of Ogama Lake and above one or more unnamed lakes; Site #09 was near the stream's inlet to Ogama Lake and Site #20 was within 0.5 km of Ogama Lake.

Electrofishing surveys were conducted at Site #20 in August 1995, July 1996 (300 m section surveyed), and August 1997 (100 m section surveyed). The remaining sites were surveyed only in June 1997 for a combined sampled length of 500 m.

A total of 51 fish comprised of four species were captured or observed during surveys in the Ogama Inflows. They included 16 lake trout, one lake whitefish, one cisco, and 33 ninespine stickleback (Appendix D9).

Lake trout were captured or observed at Site #01 (14 fish) and Site #20 (two fish). Of six lake trout that were measured, fork lengths ranged from 563 to 750 mm (mean of 681 mm). The largest fish weighed 4400 g. Four lake trout were marked with Floy tags at Site #01 on 20 June 1997; one of these (tag #95) was recaptured in Doris Lake on 16 August 1997. This indicated that at least part of the lake trout population moves between lake systems (i.e., the recaptured fish traversed one unnamed lake and Ogama Lake in less than two months). Two more lake trout were tagged at Site #20 on 14 August 1997, but were not recaptured.

Other sportfish species captured in the Ogama inflows included one lake whitefish (323 mm in fork length) and one cisco (206 mm in fork length); both were captured at Site #20. Ninespine stickleback were captured at Sites #20 (n=29), #09 (n=2) and #14 (n=2); they were the only species encountered at the latter two sites. Ninespine stickleback ranged from 35 to 63 mm in total length (mean of 49 mm). No fish were captured at Site #06.

7.2.7 Patch Inflows (Sites #05, #07, #08, and #11)

Four sites on tributaries that drain into Patch Lake were sampled on 21-22 June 1997. The longest inflow is approximately 4 km in length and passes through an unnamed lake approximately 1.5 km south of Patch Lake; it was sampled at Site #07, immediately upstream of its inlet into Patch Lake (Figure 7.1). Site #08 was located near the mouth of the stream that drains Wolverine Lake into Patch Lake. The remaining two sites (#05 and #11) were located on small watercourses (approximately 2.5 and 0.7 km in length, respectively) that flow into the north and northwest bays of Patch Lake. All sampled sites were within 200 m of Patch Lake.

Apart from four observed lake trout in Patch Lake in the immediate vicinity of Site #11, ninespine stickleback (n=68) represented the entire catch in all surveyed inflows to Patch Lake. Ninespine stickleback CPUE values were highest at Site #11 (12.2 fish/min) and lowest at Site #07 (0.2 fish/min). Ninespine stickleback ranged from 28 to 71 mm in total length (mean of 46 mm).

7.2.8 Windy Outflow (Site #02 and 10)

The outflow from Windy Lake flows for approximately 3.2 km before draining into Glenn Lake. Two sites on the stream were sampled with a backpack electrofisher on 20 and 22 June 1997. The upstream site (#02) was within 500 m of Windy Lake, whereas the downstream site (#10) was within 500 m of Glenn Lake.

In total, one juvenile Arctic char (185 mm in fork length) and 11 adult lake trout were captured or observed (Appendix D9). Whereas the Arctic char was caught at Site #02 (near Windy Lake), most (78%) of the lake trout were captured or observed at Site #10 (near Glenn Lake).

Among six lake trout that were measured, fork lengths ranged from 444 to 744 mm (mean of 546 mm). The largest fish weighed 3600 g. All six lake trout were marked with Floy tags, but none were recaptured.

7.2.9 Windy Inflow (Site #13)

This stream is the only inflow to Windy Lake and its mouth is located at the south end of the lake. The stream is approximately 1.8 km in length and originates upstream of a small unnamed lake (Figure 7.1). Backpack electrofishing was conducted of this stream (within 100 m of Windy Lake) on 23 June 1997.

The catch consisted entirely of ninespine stickleback (*n*=51). The CPUE of 75 fish/min was the highest catch rate among the surveyed Doris Hinge streams (Appendix D9). The measured fish (*n*=8) ranged from 24 to 62 mm in total length (mean of 38 mm).

7.2.10 Glenn Outflow (Sites #12 and #28)

The outflow from Glenn Lake flows for approximately 2.6 km before draining into Roberts Bay. Two sites on this stream were sampled with a backpack electrofisher in 1997 and 2000. The upstream site (#12) was within 100 m of Glenn Lake; it was sampled on 23 June 1997. The downstream site (#28) was approximately 800 m upstream of Roberts Bay, and was likely influenced by the marine environment (Figure 7.1). This site was sampled three times: 15 August 1997, 25 June 2000, and 20 August 2000.

In total, 31 fish were caught or observed during electrofishing surveys at the two sites. The catch was comprised of 18 Arctic char, six lake trout, four ninespine stickleback, and three slimy sculpin (Appendix D9).

Within the sample of five Arctic char that were measured, fork lengths ranged from 194 to 820 mm (Appendix D10). The largest fish weighed 5150 g; it was caught at Site #28 in August 2000. Three juvenile Arctic char captured at Site #28 in August 1997 ranged from 194 to 215 mm in fork length. One adult Arctic char captured at Site #12 in June 1997 was marked with a Floy tag, but was not recaptured. In addition to the captured fish, 12 adult Arctic char were observed (but not captured) in a pool at Site #28 in August 2000.

Of two lake trout that were measured, one was a juvenile (142 mm in fork length; caught at Site #28 in August 2000) and the other was an adult (390 mm in fork length; caught at Site #12 in June 1997). The larger lake trout was marked with a Floy tag, but was not recaptured. In addition to the one lake trout caught at Site #12 in June 1997, four larger lake trout were observed (but not captured) at the same site.

Three slimy sculpin were recorded at Site #28 in August 2000; however, they were not measured. Site #28 was the only site within the Doris Hinge streams where slimy sculpin were recorded. Ninespine stickleback were observed in Glenn Outflow, but were not counted.

7.2.11 Little Roberts Outflow (Site #26)

The outflow from Little Roberts Lake flows for approximately 1.3 km before draining into Roberts Bay. Backpack electrofishing in this stream was conducted on two occasions: 14 August 1997, when a 150 m long section near the mouth was sampled, and 25 August 2000, when the entire stream (1250 m) was sampled.

Although 24 fish were captured in 1997, none were caught in 2000. The 1997 catch included 10 juvenile Arctic char, three juvenile lake trout, and 11 ninespine stickleback (Appendix D9).

Arctic char fork lengths ranged from 85 to 200 mm (mean of 146 mm). Although they were not aged, the two smallest fish (85 and 93 mm in fork length) were likely young-of-the-year fish, whereas the remaining eight fish (123-200 mm) were likely comprised of age 1 and 2 fish (based on similar sizes for the aged Arctic char samples from Little Roberts Lake and the Doris Outflow). The presence of juvenile Arctic char in Little Roberts Outflow indicated that this stream provides rearing habitat for this species.

Three juvenile lake trout captured in 1997 were 208, 249, and 303 mm in fork length. The largest lake trout was marked with a Floy tag on 14 August 1997, but was not recaptured. The remainder of the 1997 catch included 11 ninespine stickleback that ranged from 38 to 54 mm in total length (mean of 47 mm).

7.2.12 Summary

Streams in the Doris Hinge area were inhabited by at least six fish species. Ninespine stickleback was the most common species (66%) in the total catch of 351 fish. This species was also most widely distributed among the sampled streams, being recorded in 17 of the 20 stream sites. Lake trout was second in abundance (17% of the total catch) and distribution (recorded in 11 sites). Juveniles and adults were present in the catch, suggesting that the larger streams provide both rearing and feeding habitat for lake trout.

Arctic char contributed 12% to the total catch; however, this species was recorded only at five sites in close proximity to Roberts Bay (in Doris Outflow below the waterfall, Little Roberts Outflow, two sites on Glenn Outflow, and one on Windy Outflow). Most (68%) of the Arctic char catch was composed of juvenile fish between 85 and 303 mm in fork length; adult fish were recorded only in Glenn Outflow.

Cisco were captured in small numbers and only at two sites (Doris Outflow and the main Ogama Inflow); the catch included both juveniles and adults. Lake whitefish were captured in Doris Outflow, Ogama Outflow, and the main Ogama Inflow. Similar to cisco, the captured lake whitefish included both juveniles and adults. Slimy sculpin were recorded only in one stream (Glenn Outflow near Roberts Bay).

7.3 FISH TISSUES

To provide baseline data on metal concentrations in fish tissues, dorsal muscle, liver, and kidney samples were collected from lake trout, lake whitefish, and cisco from selected lakes (Figure 7.1). The selected lakes included those in close proximity to potential development activities (Doris, Tail, Ogama, Patch, and Windy) and one reference lake (Pelvic).

In total, 385 tissue samples were collected and analyzed. Table 7.9 shows the distribution of the samples in terms of species, tissue types, lakes, and sampling years. Preliminary analyses of small numbers of fish tissue samples were carried out in 1995 (Klohn Crippen 1995) and 1996 (Rescan 1997); however, most (88%) of the samples were collected in 1997 and 1998 (Rescan 1999b). As such, the following discussion of the results will focus on muscle and liver samples from lake trout and lake whitefish collected in 1997 and 1998; the data for 1995 and 1996 samples are included in Appendices D12 and D13.

Table 7.9 Number of fish tissue samples analyzed for metals concentrations, Doris Hinge lakes, 1995 to 1998.

Lake	Species	1995			1996		1997		1998	
		Muscle	Liver	Kidney	Muscle	Liver	Muscle	Liver	Muscle	Liver
Doris	Lake trout	1	1	1	1		22	22		
	Lake whitefish	3	3	3	1	1	29	29		
	Cisco				1					
Tail	Lake trout	5	5	5	1	1				
Ogama	Lake trout				1	1				
Patch	Lake trout	1	1	1	1	1	25	25		
	Lake whitefish				1	1	26	26		
Windy	Lake trout				1		25	25		
	Lake whitefish				1	1				
Pelvic	Lake trout								21	21
	Lake whitefish								22	22

Because most of the analyzed metal constituents are not potential contaminants associated with the Doris Hinge Project, they are not included in the detailed analyses, but are presented in Appendices D12 and D13. Metal constituents that were deemed to be suitable indicators included aluminum, arsenic, cadmium, copper, lead, mercury, nickel, selenium, and zinc. These metals were included because they are of potential concern in gold mining developments and from a human consumption perspective. The following sections briefly outline the significance of these constituents to aquatic environments and human health.

Aluminum

The availability of aluminum to aquatic organisms has been correlated with the pH of the aquatic environment (Holtze and Hutchinson 1989); however, it is unclear at what pH threshold or concentration aluminum becomes toxic to fish. Aluminum can be acutely toxic at high exposure levels, but it does not bioaccumulate in aquatic organisms (Neville 1985).

Arsenic

Arsenic is more common in the earth's crust than is mercury or cadmium, and is more toxic to plants than to animals (Demayo et al. 1979). It does not appear to biomagnify through different trophic levels. Demersal (bottom dwelling) fish species are more likely to accumulate arsenic than pelagic (open water) species (Demayo et al. 1979). Arsenic concentrates mainly in the liver and is a cumulative toxin (Falk et al. 1973). Background concentrations of arsenic in most aquatic organisms generally are less than 1 µg/g wet weight (Eisler 1988) or less than 5 µg/g dry weight (assuming 80% moisture content). The Canadian Food Inspection Agency’s guidelines indicate that arsenic levels in fish tissues should not exceed 3.5 µg/g wet weight (http://www.inspection.gc.ca/english/anima/fispoi/guide/chme.shtml).

Cadmium

Cadmium is a relatively rare element, and is most often associated with copper, lead, and zinc. In sufficient concentrations, cadmium is toxic to plants and animals (Health Canada 1992). The rate of cadmium uptake in aquatic organisms is generally faster in hard waters, although cadmium toxicity decreases in hard water (Reeder et al. 1979). Cadmium does not bioaccumulate in the food web (Reeder et al. 1979). Cadmium concentrations exceeding 3 µg/L in water lead to high mortality of aquatic organisms, reduced growth, and inhibited reproduction (Eisler 1985a). The main sources of cadmium pollution are industrial and municipal wastes. Other anthropogenic sources of cadmium include smelter dusts and fumes and fossil fuel incineration products (Health Canada 1992).

Copper

In contrast to the non-essential trace metals (e.g., arsenic, cadmium, mercury, lead), copper is an essential element with important biochemical functions; however, excessive amounts of copper are toxic to freshwater fish (Forstner and Wittman 1979). The toxicity of copper varies not only with the species of fish, but also with ambient water characteristics such as pH and alkalinity. Copper is not considered to be a cumulative systematic poison as most of it is excreted from the body (Falk et al. 1973). The main areas of the body where it concentrates are liver, muscle, and brain tissues (Demayo and Taylor 1981).

Lead

Lead is the most common of the heavy metals and is toxic to all forms of life. Lead does not appear to bioaccumulate. In aquatic ecosystems, lead concentrations are generally higher in benthic organisms and lower in organisms at higher trophic levels. Lead tends to deposit in bone (hard tissue) as a cumulative toxin (Falk et al. 1973). It is more toxic in soft water than in hard water (Demayo et al. 1980). Solid and liquid wastes account for a large percentage of the lead discharged into the Canadian environment, usually into landfills, but lead has been dispersed more widely in the general environment though atmospheric emissions (Health Canada 1992). The federal guidelines state that lead levels should not exceed 0.5 µg/g wet weight (http://www.inspection.gc.ca/english/anima/fispoi/guide/chme.shtml).

Mercury

Mercury is a toxic element, which in fish tissue is most commonly present in the form of methyl mercury. Under anaerobic conditions in sediments, inorganic mercury can be processed by microorganisms into organic mercury compounds (most commonly in the form of methyl mercury). Methyl mercury can readily associate with suspended and organic matter and be taken up by aquatic organisms. It has a high affinity for lipids and is distributed to the fatty tissues of living organisms (Health Canada 1992). As such, methyl mercury bioaccumulates in the food chain and tissues of the top predators may contain mercury levels that are unacceptable for human consumption (Health Canada 1992).

The average proportion of methyl mercury to total mercury increases from 10% in the water column to 15% in phytoplankton, 30% in zooplankton, and 90% or more in fish (Huckabee et al. 1979, Morel et al. 1998). High levels of mercury are common in reservoirs as flooded terrestrial vegetation, which are rich in organic material, decompose and stimulate the production of methyl mercury. Environmental conditions can influence the rate of methylation; these environmental conditions include water temperature, pH, dissolved oxygen, and sediment chemistry (Rudd and Turner 1983).

Mercury may enter the water column from three principal sources: 1) by direct deposition from the atmosphere, 2) in runoff from the drainage basin, or 3) by solubilization or suspension from the benthic sediments. Erosion of mercury-bearing rocks is the ultimate geological source of mercury, and also contributes to mercury loads in rivers.

Long-term daily ingestion of mercury has been found to cause the onset of neurological symptoms (Health Canada 1992). The maximum allowable level of mercury in muscle tissue of fish sold in Canada for human consumption is

0.5 µg/g (wet weight), which is comparable to about 2.5 µg/g dry weight (assuming 80% moisture content).

Nickel

The toxicity of nickel increases with decreasing water hardness and increasing acidity (CCREM 1996). Nickel toxicity also increases when it is present with copper, likely as a result of synergism (Taylor et al. 1979). Nickel does not biomagnify in the food web (Taylor et al. 1979). Hutchinson et al. (1975) reported that nickel concentrations were highest in plants and lowest in top predators. Bowen (1966) considered 1 µg/g (dry weight) of nickel in fish tissue to be in the range of natural background levels.

Nickel concentrations tend to be highest in the vicinity of nickel smelters, sewage outfalls, coal ash disposal basins, and heavily populated areas (Eisler 1998). In fish, signs of nickel poisoning include rapid opercular and mouth movements, and surfacing. Loss of equilibrium and convulsions occur prior to death (Khangarot and Ray 1990).

Selenium

Selenium is an essential nutrient in low concentrations (Eisler 1985b); however it is also a toxicant for humans and animals at concentrations slightly higher than those required (Chen 2000). Selenium is a naturally occurring trace element found commonly in rocks and soil, particularly in deposits of coal and other fossil fuels (Lemly and Smith 1987). Selenium is usually present in water as selenate or selenite; however the elemental form may be carried in suspension (Health Canada 1992). Anthropogenic sources of selenium include irrigation waters from seleniferous soils, municipal and industrial wastewaters, fuel (coal and oil) combustion, mining, smelting, and refining (Nagpal and Howell 2001; Health Canada 1992).

Selenium has been found to bioaccumulate within the food chain (Nagpal and Howell 2001; Lemly and Smith 1987). In aquatic environments, organisms accumulate selenium from both water and food. The bioaccumulation of selenium through the diet, however, is usually greater than the direct uptake from water (Nagpal and Howell 2001; Lemly and Smith 1987). Most selenium (90%) that enters an aquatic ecosystem is taken up by organisms or bound to particulate matter, which results in its deposition and accumulation in the top layer of sediments and detritus.

Toxic effects of selenium include mortality of juvenile and adult fish and reproductive effects (Lemly and Smith 1987). Selenite tends to be more toxic at early life history stages (i.e., eggs and juveniles) and these effects are more pronounced when water temperature is elevated. Selenium concentrations greater than 0.005 mg/L in water can be bioconcentrated in food chains and cause toxicity and reproductive failure in fish (Lemly and Smith 1987). Juvenile and adult fish usually require higher concentrations of selenium in water before mortality occurs. The bioaccumulation of selenium through the diet is usually greater than the direct uptake from water (Nagpal and Howell 2001; Lemly and Smith 1987). Signs of selenium toxicity include losses of equilibrium, lethargy, muscle spasms, liver degeneration, reduction in erythrocytes and blood haemoglobin, and an increase in white blood cells (Eisler 1985b).

Lemly and Smith (1987) provided selenium levels of concern for fish and wildlife. They suggested that concentrations in water should not exceed 2 to 5 µg/L to protect fish and waterfowl. For food ingested by fish, they suggested that concentrations of 5 µg/g (dry weight) could cause toxic effects. Reproductive failure was found to occur in fish when concentrations exceeded 12 µg/g (dry weight) in whole body residue, 16 µg/g in visceral residue, and 8 µg/g in skeletal muscle residue.

Zinc

Zinc primarily affects gill epithelial tissues. In excessive amounts, it can cause outright mortality or induce stress that leads to death (Falk et al. 1973). Zinc, however, is essential for plant and animal health. Zinc toxicity increases with increasing pH and decreasing water hardness. Zinc concentrations are usually greater in omnivorous than in piscivorous species, and greater in benthic invertebrates than in fish (CCME 1999).

7.3.1 Methods

Field Methods

Tissue samples were collected opportunistically from fish mortalities encountered during the gill netting surveys of the Doris Hinge lakes. Most fish were captured during the lake survey programs in 1997 and 1998 using index (38 mm mesh size) gill nets. In 1995 and 1996, other mesh sizes were also used (see Section 7.1.1).

All fish selected for tissue analyses were identified to species, measured for fork length (mm), weighed (g), examined for sex, maturity, and reproductive status, and dissected for ageing structures (otoliths) and tissues. The 1997-1998 samples were collected following the procedures outlined in the British Columbia Field Sampling Manual (MELP 1996). A minimum of 100 gm of muscle tissue was collected from each fish, as well as the complete liver, minus the bile gland. Samples were individually stored in labelled, clean plastic Whirl-Pac bags and frozen until analysis. All 1997-1998 samples were held in storage for analysis in February 1999.

Of 14 muscle and liver samples collected in 1996, 12 were composite samples of each tissue collected for each species and each lake. The numbers or sizes of fish included in each composite sample were not specified. The remaining two tissue samples were collected from a single lake trout captured in Ogama Lake.

All samples collected in 1995 (n=30) were from individual fish. In addition to muscle and liver tissues, kidneys were also collected from each sampled fish. The 1995 samples were placed individually in 120 mL sterile, acid-washed specimen containers.

Laboratory

Analyses for fish collected in 1997-1998 were conducted by Analytical Services Laboratories Ltd. (Vancouver, BC). The 1995 samples were analyzed by Elemental Research Inc. laboratory (North Vancouver, BC). The laboratory used for analyses of the 1996 samples was not specified.

The detection limits and methods used for metal analyses are listed for each sampling year in Table 7.10. All results were reported as micrograms per gram on a ‘wet weight’ basis.

Data Analyses

To provide a standardized value for future comparisons, all wet weight values were converted to dry weight, using the reported moisture content of each sample. In cases where the moisture content was not reported in the raw data appendices (Appendix D13), the percent moisture was assumed to be 79% (mean of all reported moisture values).

To allow statistical analyses of all sample data, metal constituent values that were below analytical detection limits were replaced with values that equaled one half the detection limit (Helsel and Hirsch 1992).

As concentration of mercury in fish tissues tends to increase with increasing fish size and age (Bodaly et al. 1988), mercury concentrations were described in relation to fork length and age of fish. Mercury concentrations were presented on the dependent axis (Y) and the fork length and age of the fish on the independent axis (X). Because growth of fish (irrespective of age, weight, or length) is curvilinear, it would be inappropriate to apply linear regression techniques against non-linear data without first transforming the data. As such, length, age, and mercury data were transformed into logarithmic values prior to calculating the regression equations and the associated r^2 values.

Table 7.10 Detection limits (µg/g wet weight) and methods used to analyze fish tissues for metals concentrations, Doris Hinge lakes, 1995 to 1998.

Metal	1995		1996	1997-1998	
	Det. Limit	Method	Det. Limit	Det. Limit	Method
Aluminum				5	ICP
Arsenic	0.01	ICPMS	0.05	0.05	HVAAS
Barium				0.5	ICP
Beryllium				0.2	ICP
Cadmium	0.002	ICPMS	0.02	0.02	ICP
Calcium				10	ICP
Chromium				0.5	ICP
Cobalt				0.5	ICP
Copper	0.01	ICPMS	0.1	0.5	ICP
Iron				1	ICP
Lead	0.002	ICPMS	0.05	0.05	GFAAS
Magnesium			1	0.05	ICP
Manganese			0.1	0.2	ICP
Mercury	0.002	ICPMS	0.005	0.005	CVAAS
Molybdenum				1	ICP
Nickel	0.002	ICPMS	0.2	1	ICP
Selenium			0.2	0.1	HVAAS
Silver			0.01	0.1	ICP
Tellurium			0.2		
Zinc	0.01	ICPMS	0.1	0.3	ICP

CVAAS = Cold Vapor Atomic Absorption Spectrophotometry
GVAAS = Graphite Furnace Atomic Absorption Spectrophotometry
HVAAS = Hydride Vapor Atomic Absorption Spectrophotometry
ICP = Inducively Coupled Argon Plasma / Atomic Emission Spectrophotometry
ICPMS = Inducively Coupled Argon Plasma / Mass Spectrometer
Lab methods used in 1996 were Atomic Absorption Spectrophotometry and/or ICP, but were not specified for each metal.

7.3.2 Doris Lake

The following discussion is based on muscle and liver tissues collected in 1997 from 22 lake trout and 29 lake whitefish in Doris Lake. Additional samples collected in 1995 (muscle, liver and kidney tissues from one lake trout and three lake whitefish) and 1996 (single composite muscle and/or liver samples from lake trout, lake whitefish and cisco) are presented in Appendix D13.

Lake trout captured for tissue analyses in Doris Lake ranged from 353 to 932 mm in fork length and from 8 to 49 years in age (Table 7.11). Lake whitefish ranged from 358 to 525 mm in fork length and from 9 to 65 years in age (see Section 7.1.2.2 for discussion of age data).

Table 7.11 Fork length, weight and age of lake trout and lake whitefish sampled for metal concentrations in Doris Lake, 1997.

Species	*n*	Fork Length (mm)			Weight (g)			Age (years)		
		Mean	SD[a]	Range	Mean	SD	Range	Mean	SD	Range
Lake trout	*22*	637	136	353-932	2772	1899	406-9900	29.5	12.7	8-49
Lake whitefish	*29*	448	37	358-525	1240	354	534-1975	29.1	14.3	9-65

[a]standard deviation

The concentrations of 19 metal elements in individual tissue samples are presented in Appendix D12. Mean metal concentrations (including standard deviation, range, and number of samples below analytical detection limits) are provided for each species and tissue type in Appendix D11. The average concentrations of some of the potentially toxic trace metals (i.e., aluminum, arsenic, cadmium, copper, lead, mercury, nickel, selenium, and zinc) are summarized in Table 7.12.

Aluminum

All lake trout and lake whitefish muscle tissue samples contained aluminum levels below the detection limit (5 µg/g wet weight). Aluminum concentrations in liver samples were slightly higher, with 14% and 34% of lake trout and lake whitefish samples, respectively, exhibiting concentrations above the detection limit (Table 7.12). The highest aluminum levels were 61.9 and 81.2 µg/g dry weight in lake trout and lake whitefish livers, respectively.

Arsenic

Arsenic levels in lake trout from Doris Lake ranged from 0.11 to 0.53 µg/g. Mean concentrations were higher in muscle than in liver tissues (0.29 and 0.18 µg/g dry weight, respectively). The percentages of samples below the detection limit were 36% for muscle and 68% for liver.

In lake whitefish, the mean concentrations of arsenic were higher in liver than in muscle tissues (0.41 and 0.13 µg/g, respectively). The highest arsenic level (0.94 µg/g) was recorded in a liver tissue. Whereas all lake whitefish muscle samples were below the detection limit, only 17% of liver samples were below detection.

Cadmium

All lake trout and lake whitefish muscle tissue samples contained cadmium levels below the detection limit. Cadmium concentrations in liver samples were slightly higher, with 50% and 79% of lake trout and lake whitefish samples, respectively, exhibiting concentrations above the detection limit (Table 7.12). The highest

Table 7.12 Metal concentrations in lake trout and lake whitefish tissues from Doris Lake, 1997.

Species	Tissue	Parameter	Metal Concentrations (µg/g dry weight)								
			Al	As	Cd	Cu	Pb	Hg	Ni	Se	Zn
Lake trout	Muscle *n=22*	*n < D.L.*[a]	*22*	*8*	*22*	*22*	*22*	*0*	*22*	*0*	*0*
		Mean	12.6	0.29	0.05	1.3	0.13	1.45	2.53	0.98	14.5
		SD[b]	1.2	0.15	0.00	0.1	0.01	0.77	0.25	0.11	1.4
		Minimum	10.7	0.11	0.04	1.1	0.11	0.36	2.14	0.63	12.4
		Maximum	15.8	0.53	0.06	1.6	0.16	3.37	3.16	1.26	17.7
	Liver *n=22*	*n < D.L*	*19*	*15*	*11*	*0*	*22*	*0*	*22*	*0*	*0*
		Mean	16.9	0.18	0.09	63.0	0.12	2.44	2.38	5.23	138.6
		SD	14.1	0.11	0.06	30.3	0.01	1.49	0.27	1.38	23.2
		Minimum	9.1	0.11	0.04	17.7	0.09	0.43	1.81	3.64	90.0
		Maximum	61.9	0.45	0.22	144.3	0.15	6.23	3.03	7.88	187.6
Lake whitefish	Muscle *n=29*	*n < D.L.*[a]	*29*	*29*	*29*	*29*	*29*	*0*	*29*	*0*	*0*
		Mean	12.5	0.13	0.05	1.3	0.13	0.36	2.51	0.98	13.1
		SD	1.1	0.01	0.00	0.1	0.01	0.19	0.22	0.13	1.2
		Minimum	10.8	0.11	0.04	1.1	0.11	0.07	2.16	0.60	10.3
		Maximum	16.6	0.17	0.07	1.7	0.17	0.85	3.31	1.42	16.1
	Liver *n=29*	*n < D.L*	*19*	*5*	*6*	*0*	*29*	*0*	*29*	*0*	*0*
		Mean	23.0	0.41	0.18	20.6	0.13	0.86	2.57	5.10	105.7
		SD	18.3	0.22	0.11	9.8	0.01	0.45	0.21	1.17	10.7
		Minimum	10.2	0.11	0.05	7.1	0.10	0.19	2.03	2.78	86.1
		Maximum	81.2	0.94	0.47	41.1	0.15	1.87	2.92	7.39	123.2

[a]number of samples below detection limit
[b]standard deviation

cadmium levels were 0.22 and 0.47 µg/g dry weight in lake trout and lake whitefish livers, respectively.

Copper

All lake trout and lake whitefish muscle tissue samples contained copper levels below the detection limit of 0.5 µg/g wet weight. Copper concentrations in liver samples were considerably higher, with all lake trout and lake whitefish samples exhibiting concentrations above the detection limit (Table 7.12). Mean levels of copper in lake trout liver samples (63.0 µg/g dry weight) were approximately three times higher than in lake whitefish liver samples (20.6 µg/g). The maximum copper concentrations in individual samples were 144.3 and 41.1 µg/g in lake trout and lake whitefish livers, respectively.

Lead

All muscle and liver tissue samples collected from lake trout and lake whitefish in Doris Lake in 1997 had lead concentrations below the detection limit (0.05 µg/g wet weight). With much lower detection limits (0.002 µg/g wet weight) used to analyze three lake whitefish samples in 1995, the maximum lead concentrations were 0.06, 0.10, and 0.26 µg/g dry weight (muscle, liver, and kidney samples, respectively; Appendix D13). The maximum lead concentration in kidney tissues, corresponded to 0.05 µg/g wet weight; this was 10 times lower than the federal guideline of 0.5 µg/g wet weight.

Mercury

Total mercury levels in lake trout muscle tissues ranged from 0.36 to 3.37 µg/g dry weight.; the mean concentration within 22 samples was 1.45 µg/g dry weight. The maximum mercury level recorded corresponded to 0.64 µg/g wet weight and was the only lake trout sample that exceeded the maximum levels allowed for human consumption (0.5 µg/g wet weight).

Mercury levels in lake trout liver tissues were higher than in muscle tissues and ranged from 0.43 to 6.23 µg/g dry weight.; the mean concentration was 2.44 µg/g dry weight. Nine of 22 liver samples (41%) exceeded the maximum levels allowed for human consumption (0.5 µg/g wet weight).

Lake whitefish mercury concentrations were considerably lower than in lake trout, with mean levels of 0.36 and 0.84 µg/g dry weight (muscle and liver samples, respectively). The highest mercury level was equivalent to 0.37µg/g wet weight and was lower than the maximum levels allowed for human consumption.

Because mercury is known to bioaccumulate in fish, mercury concentrations in muscle and liver tissues were regressed against age and fork length to determine the strength of these relationships and to allow comparisons with future monitoring studies (Figure 7.15). The correlation coefficients (r^2; the closer to 1, the better the relationship) ranged between 0.63 (lake trout muscle versus fork length) and 0.77 (lake whitefish muscle versus both age and fork length).

Nickel

All muscle and liver tissue samples collected from lake trout and lake whitefish in Doris Lake in 1997 had nickel concentrations below the detection limit (1.0 *µ*g/g wet weight). With much lower detection limits (0.002 µg/g wet weight) used to analyze three lake whitefish samples in 1995, the maximum nickel concentrations were 0.05, 0.37, and 1.10 µg/g dry weight (muscle, liver, and kidney samples, respectively; Appendix D13).

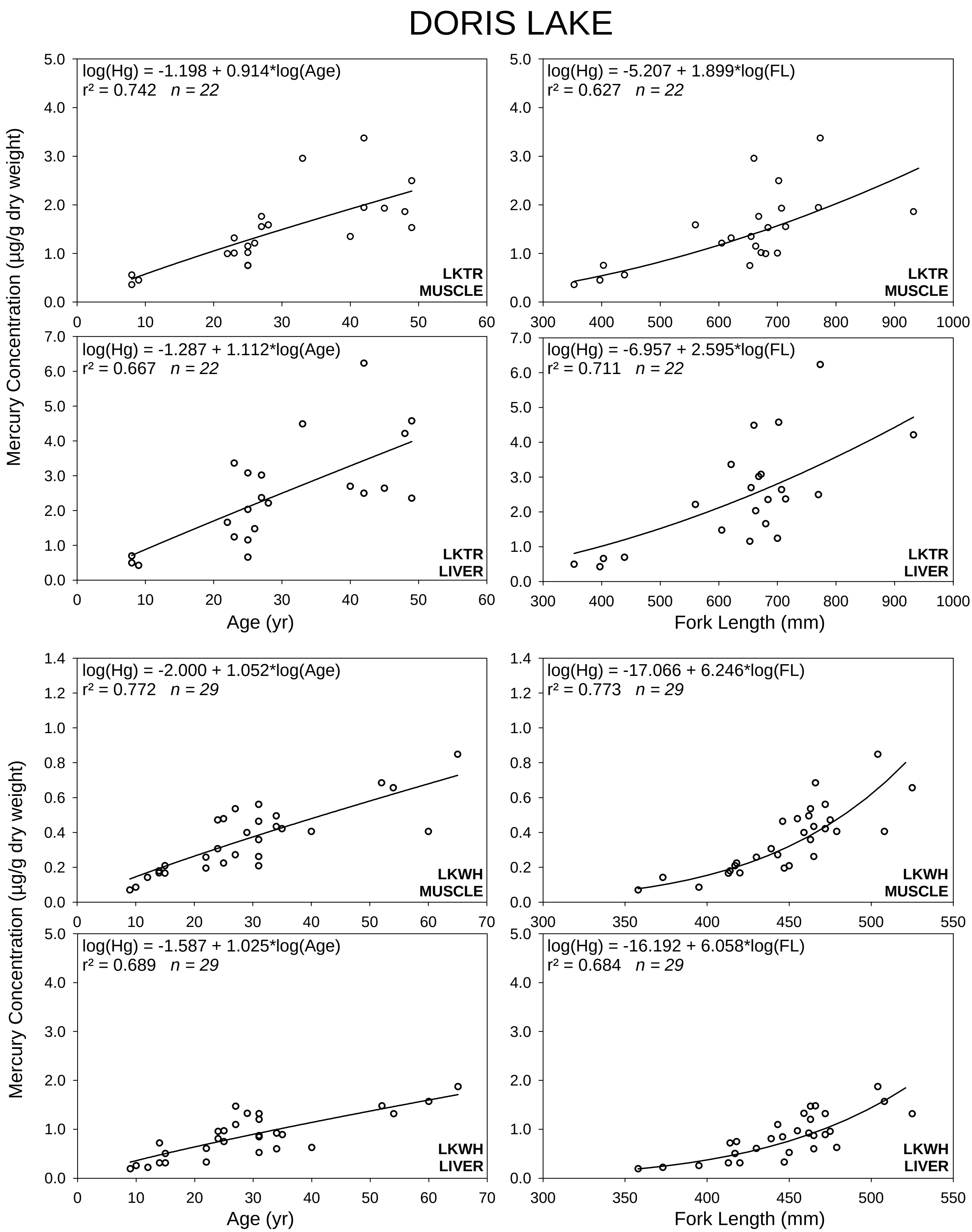


Figure 7.15 Mercury concentrations in lake trout (LKTR) and lake whitefish (LKWH) muscle and liver tissues from Doris Lake, 1997(note changes between scales).

Selenium

Selenium levels in lake trout muscle tissues ranged from 0.63 to 1.26 µg/g dry weight; the mean concentration was 0.98 µg/g dry weight. In lake trout liver tissues, selenium concentrations were approximately five times higher than in muscle tissues and ranged from 3.64 to 7.88 µg/g dry weight (mean of 5.23 µg/g dry weight).

Lake whitefish selenium concentrations were similar to those recorded in lake trout, with mean levels of 0.98 and 5.10 µg/g dry weight (muscle and liver samples, respectively). The highest selenium level in lake whitefish was 7.39 µg/g dry weight (in liver).

Zinc

Zinc levels in lake trout muscle tissues ranged from 12.4 to 17.7 µg/g dry weight; the mean concentration was 14.5 µg/g dry weight. In lake trout liver tissues, mean zinc concentrations (138.6 µg/g dry weight) were approximately ten times higher than in muscle tissues. The maximum zinc level recorded in lake trout was 187.6 µg/g dry weight.

Lake whitefish zinc concentrations were slightly lower than those recorded in lake trout, with mean levels of 13.1 and 105.7 µg/g dry weight (muscle and liver samples, respectively). The highest zinc level in lake whitefish was 123.2 µg/g dry weight (in liver).

7.3.3 Tail Lake

Tissue samples from Tail Lake were collected in 1995 and 1996. The 1995 samples were limited to muscle, liver and kidney tissues from five lake trout whereas single composite liver and muscle tissues from an unspecified number of lake trout were collected in 1996 (Appendices D12 and D13). The 1995 lake trout ranged from 560 to 601 mm in fork length and from 13 to 16 years in age (Table 7.13).

Table 7.13 Fork length, weight and age of lake trout sampled for metal concentrations in Tail Lake, 1995.

Species	*n*	Fork Length (mm)			Weight (g)			Age (years)		
		Mean	SD[a]	Range	Mean	SD	Range	Mean	SD	Range
Lake trout	*5*	577	17	560-601	2099	456	1722-2830	14.0	1.4	13-16

[a]standard deviation

The concentrations of seven metal elements in individual tissue samples are presented in Appendix D13. Mean metal concentrations (including standard deviation, range, and number of samples below analytical detection limits) are provided for each tissue type in Appendix D12. The average concentrations of some of the potentially toxic trace metals (i.e., arsenic, cadmium, copper, lead, mercury, nickel, and zinc) are summarized in Table 7.14. The tissue samples collected from Tail Lake were not analyzed for aluminum or selenium.

Table 7.14 Metal concentrations in lake trout tissues from Tail Lake, 1995.

Species	Tissue	Parameter	Metal Concentrations (µg/g dry weight)						
			As	Cd	Cu	Pb	Hg	Ni	Zn
Lake trout	Muscle *n=5*	*n < D.L.*[a]	*3*	*5*	*0*	*0*	*0*	*2*	*0*
		Mean	0.04	0.005	1.4	0.12	0.69	0.08	13.4
		SD[b]	0.03	0.001	0.3	0.06	0.23	0.12	3.0
		Minimum	0.02	0.004	1.1	0.06	0.36	0.004	10.4
		Maximum	0.10	0.005	1.7	0.18	0.94	0.28	18.2
	Liver *n=5*	*n < D.L*	*5*	*0*	*0*	*0*	*0*	*0*	*0*
		Mean	0.03	0.33	56.3	0.13	0.68	0.16	204.7
		SD	0.00	0.19	46.9	0.06	0.32	0.11	46.0
		Minimum	0.02	0.09	9.8	0.07	0.35	0.03	144.0
		Maximum	0.03	0.58	128.9	0.20	1.02	0.34	257.5
	Kidney *n=5*	*n < D.L.*[a]	*2*	*0*	*0*	*0*	*0*	*0*	*0*
		Mean	0.78	2.67	12.2	0.12	1.50	1.55	148.8
		SD	1.05	2.10	8.6	0.06	0.74	1.06	21.6
		Minimum	0.02	0.55	5.1	0.06	0.65	0.48	122.6
		Maximum	2.49	5.65	25.2	0.21	2.32	3.08	182.5

[a]number of samples below detection limit
[b]standard deviation

Arsenic

Arsenic levels in lake trout from Tail Lake ranged from 0.02 to 2.49 µg/g dry weight. Mean concentrations were highest in kidney tissues (0.78 µg/g dry weight) and considerably lower in muscle and liver tissues (0.04 and 0.03 µg/g, respectively). The percentages of samples below the detection limit were 60% for muscle, 100% for liver, and 40% for kidney.

Cadmium

Although all lake trout muscle tissue samples contained cadmium levels below the detection limit, all liver and kidney samples were above detectable levels. Mean cadmium concentrations were highest in the kidneys (2.67 µg/g dry weight) and considerably lower in liver and muscle tissues (0.33 and 0.005 µg/g, respectively). The highest cadmium levels were 5.65 and 0.58 µg/g in kidney and liver tissues, respectively.

Copper

Copper levels in lake trout from Tail Lake ranged from 1.1 to 128.9 µg/g dry weight. Mean concentrations were highest in liver tissues (56.3 µg/g dry weight) and considerably lower in kidney and muscle tissues (12.2 and 1.4 µg/g dry weight, respectively). All copper concentrations were above the detection limit of 0.01µg/g wet weight.

Lead

All tissue samples collected from lake trout in Tail Lake in 1995 had detectable lead concentrations (>0.002 µg/g wet weight). Mean levels were low and did not differ between tissue types (ranged from 0.12 to 0.13 µg/g dry weight. The maximum lead concentration (0.21 µg/g in kidney tissue), was equivalent to 0.05 µg/g wet weight; this was 10 times lower than the federal guideline of 0.5 µg/g wet weight.

Mercury

Total mercury levels in lake trout muscle tissues ranged from 0.36 to 0.94 µg/g dry weight (mean of 0.69 µg/g). The maximum mercury level recorded corresponded to 0.20 µg/g wet weight and was well below the maximum levels allowed for human consumption (0.5 µg/g wet weight).

Mercury levels in lake trout liver tissues (ranged from 0.35 to 1.02 µg/g dry weight; mean of 0.68 µg/g) were similar to those in muscle tissues, but less than half of the mercury levels in kidneys (mean of 1.50 µg/g dry weight). The maximum mercury level in kidneys was equivalent to 0.48 µg/g wet weight and was slightly lower than the maximum level allowed for human consumption (0.5 µg/g wet weight).

Because of the small sample size (n=5) and a narrow range of sizes and ages within the analyzed fish, mercury concentrations in lake trout tissues were not regressed against age and fork length.

Nickel

Except for two muscle samples, all tissue samples collected from lake trout in Tail Lake had detectable nickel concentrations (>0.002 µg/g wet weight). Mean nickel concentrations in kidneys (1.55 µg/g dry weight) were much higher than those in liver and muscle samples (0.16, and 0.08 µg/g, respectively). The maximum nickel concentration in kidneys was 3.08 µg/g dry weight).

Zinc

All tissue samples collected from lake trout in Tail Lake in 1995 had detectable zinc concentrations (>0.01 µg/g wet weight). Mean levels were considerably higher in liver and kidney tissues (204.7 and 148.8 µg/g dry weight, respectively) than in the muscle tissue (13.4 µg/g dry weight). The maximum zinc concentration (257.5 µg/g dry weight in liver tissue) was the highest recorded among all fish tissue samples collected in Doris Hinge lakes.

7.3.4 Ogama Lake

Tissue samples from Ogama Lake were collected only in 1996 and were limited to muscle and liver samples from a single lake trout (Appendix D12). This lake trout was 475 mm in fork length, 1100 in weight, and 10 years old.

The concentrations of 12 metal elements in both tissue samples are presented in Appendix D13. Arsenic, cadmium, and nickel concentrations were below detection limits in both liver and muscle tissues. Copper concentration was much higher in the liver sample than in the muscle (9.7 and 0.2 µg/g wet weight, respectively). A lead level of 0.07 µg/g wet weight was recorded in the liver tissue, but lead was below the detection limit in the muscle tissue.

Mercury concentrations were within the maximum levels allowed for human consumption (0.5 µg/g wet weight) in both muscle and liver tissues (0.14 and 0.10 µg/g wet weight, respectively). A selenium level of 0.9 µg/g wet weight was recorded in the liver tissue, but was below the detection limit in the muscle tissue. Zinc was more concentrated in the liver than in the muscle tissue (26.9 and 3.1 µg/g wet weight, respectively).

7.3.5 Patch Lake

The following discussion is based on muscle and liver tissues collected in 1997 from 25 lake trout and 26 lake whitefish in Patch Lake. Additional samples collected in 1995 (muscle, liver and kidney tissues from one lake trout) and 1996 (single composite muscle and liver samples from lake trout and lake whitefish) are presented separately in Appendix D13.

Lake trout captured for tissue analyses in Patch Lake in 1997 ranged from 357 to 897 mm in fork length and from 8 to 40 years in age (Table 7.15). Lake whitefish ranged from 368 to 484 mm in fork length and from 13 to 43 years in age.

Table 7.15 Fork length, weight and age of lake trout and lake whitefish sampled for metal concentrations in Patch Lake, 1997.

Species	*n*	Fork Length (mm)			Weight (g)			Age (years)		
		Mean	SD[a]	Range	Mean	SD	Range	Mean	SD	Range
Lake trout	*25*	625	128	357-897	2524	1442	418-7294	23.0	7.1	8-40
Lake whitefish	*26*	425	29	368-484	1012	239	592-1674	24.2	7.3	13-43

[a]standard deviation

The concentrations of 19 metal elements in individual tissue samples are presented in Appendix D12. Mean metal concentrations (including standard deviation, range, and number of samples below analytical detection limits) are provided for each species and tissue type in Appendix D11. The average concentrations of some of the potentially toxic trace metals (i.e., aluminum, arsenic, cadmium, copper, lead, mercury, nickel, selenium, and zinc) are summarized in Table 7.16.

Table 7.16 Metal concentrations in lake trout and lake whitefish tissues from Patch Lake, 1997.

Species	Tissue	Parameter	Metal Concentrations (µg/g dry weight)								
			Al	As	Cd	Cu	Pb	Hg	Ni	Se	Zn
Lake trout	Muscle *n=25*	*n < D.L.*[a]	*25*	*6*	*25*	*25*	*25*	*0*	*25*	*0*	*0*
		Mean	12.0	0.39	0.05	1.2	0.12	1.91	2.41	1.06	12.6
		SD[b]	1.1	0.21	0.00	0.1	0.01	0.90	0.22	0.21	1.2
		Minimum	10.2	0.11	0.04	1.0	0.10	0.51	2.05	0.82	10.1
		Maximum	15.6	0.77	0.06	1.6	0.16	4.19	3.13	1.53	15.6
	Liver *n=25*	*n < D.L*	*14*	*6*	*9*	*1*	*25*	*0*	*25*	*1*	*0*
		Mean	38.5	0.43	0.14	59.7	0.12	3.31	2.41	7.75	135.1
		SD	51.1	0.40	0.12	34.5	0.01	1.77	0.22	2.82	34.6
		Minimum	9.3	0.12	0.04	1.5	0.09	0.99	1.85	0.29	12.9
		Maximum	186.6	1.96	0.48	156.9	0.15	6.59	2.92	12.92	209.6
Lake whitefish	Muscle *n=26*	*n < D.L.*[a]	*26*	*6*	*26*	*26*	*26*	*0*	*26*	*0*	*0*
		Mean	12.2	0.34	0.05	1.2	0.12	0.59	2.45	1.05	12.2
		SD	0.7	0.15	0.00	0.1	0.01	0.30	0.14	0.18	0.7
		Minimum	11.0	0.11	0.04	1.1	0.11	0.20	2.20	0.88	11.1
		Maximum	13.4	0.63	0.05	1.3	0.13	1.13	2.69	1.52	13.7
	Liver *n=26*	*n < D.L*	*6*	*0*	*1*	*0*	*26*	*0*	*26*	*0*	*0*
		Mean	33.6	1.19	0.30	21.0	0.12	1.82	2.32	7.52	125.0
		SD	18.3	0.70	0.19	11.8	0.01	0.92	0.22	1.56	16.0
		Minimum	9.5	0.29	0.05	11.0	0.09	0.66	1.81	4.74	101.8
		Maximum	89.9	2.78	0.86	68.9	0.14	3.80	2.81	11.00	176.6

[a]number of samples below detection limit
[b]standard deviation

Aluminum

All lake trout and lake whitefish muscle tissue samples contained aluminum levels below the detection limit (5 µg/g wet weight). Aluminum concentrations in liver samples were slightly higher, with 44% and 77% of lake trout and lake whitefish samples, respectively, exhibiting concentrations above the detection limit (Table 7.16). The highest aluminum levels were 186.6 and 89.9 µg/g dry weight in lake trout and lake whitefish livers, respectively.

Arsenic

Arsenic levels in lake trout from Patch Lake ranged from 0.11 to 1.96 µg/g dry weight. Mean concentrations were similar in both muscle and liver tissues (0.39 and 0.43 µg/g, respectively); however, the maximum level in muscle tissues was less than half of the maximum level in livers (0.77 and 1.96 µg/g, respectively). The percentage of samples below the detection limit was 24% each for both muscle and liver samples.

In lake whitefish, the mean concentrations of arsenic were five times higher in liver than in muscle tissues (1.19 and 0.34 µg/g, respectively). The highest arsenic level (2.78 µg/g) was recorded in a liver tissue. Although arsenic levels were detectable in all lake whitefish liver samples, they were below detection limits (0.05 µg/g wet weight) in 24% of muscle samples.

Cadmium

All lake trout and lake whitefish muscle tissue samples from Patch Lake contained cadmium levels below the detection limit (0.02 µg/g wet weight). Cadmium concentrations in liver samples were higher, with 64% and 96% of lake trout and lake whitefish samples, respectively, exhibiting concentrations above the detection limit (Table 7.16). The highest cadmium levels were 0.48 and 0.86 µg/g in lake trout and lake whitefish livers, respectively.

Copper

All lake trout and lake whitefish muscle tissue samples contained copper levels below the detection limit of 0.5 µg/g wet weight. Copper concentrations in liver samples were considerably higher, with 96% of lake trout and all lake whitefish samples exhibiting concentrations above the detection limit (Table 7.16). Mean levels of copper in lake trout liver samples (59.7 µg/g dry weight) were approximately three times higher than in lake whitefish liver samples (21.0 µg/g). The maximum copper concentrations in individual samples were 156.9 and 68.9 µg/g in lake trout and lake whitefish livers, respectively.

Lead

All muscle and liver tissue samples collected from lake trout and lake whitefish in Patch Lake in 1997 had lead concentrations below the detection limit (0.05 µg/g wet weight). With much lower detection limits (0.002 µg/g wet weight) used to analyze samples from one lake trout in 1995, the maximum lead concentrations were <0.002, 0.12 and 0.28 µg/g wet weight (muscle, liver, and kidney samples, respectively; Appendix D13). The maximum lead concentration in kidney tissues was approximately one half of the federal guideline for maximum allowable human consumption (0.5 µg/g wet weight).

Mercury

Total mercury levels in lake trout muscle tissues ranged from 0.51 to 4.19 µg/g dry weight; the mean concentration was 1.91 µg/g dry weight. The maximum mercury level recorded corresponded to 0.68 µg/g wet weight and was among six lake trout samples (24%) that exceeded the maximum levels allowed for human consumption (0.5 µg/g wet weight).

Mercury levels in lake trout liver tissues were higher than in muscle tissues and ranged from 0.99 to 6.59 µg/g dry weight; the mean concentration was 3.31 µg/g dry weight. Most (64%) of lake trout liver samples exceeded the maximum levels allowed for human consumption (0.5 µg/g wet weight), with 28% exceeding levels of 1.0 µg/g wet weight. The maximum mercury level in lake trout from Patch Lake was 1.39 µg/g wet weight.

Lake whitefish mercury concentrations were lower than in lake trout, with mean levels of 0.59 and 1.82 µg/g dry weight (muscle and liver samples, respectively). Whereas none of lake whitefish muscle samples exceeded the maximum levels allowed for human consumption (0.5 µg/g wet weight), 31% of liver samples exceeded the guideline. The maximum mercury levels in lake whitefish from Patch Lake were 0.80 and 0.21 µg/g wet weight for liver and muscle tissues, respectively (Appendix D13).

Both lake trout and lake whitefish from Patch Lake exhibited the highest mercury levels (in both muscle and liver tissues) among the tested lakes in the Doris Hinge area. The reasons for these elevated mercury levels in relation to other lakes are not known.

Because mercury is known to bioaccumulate in fish, mercury concentrations in muscle and liver tissues were regressed against age and fork length to determine the strength of these relationships and to allow comparisons with future monitoring studies (Figure 7.16). The correlation coefficients for lake trout (r^2 between 0.35 and 0.63) generally were lower than those determined for lake whitefish (between 0.50 and 0.71). Whereas, mercury concentrations in lake trout

PATCH LAKE

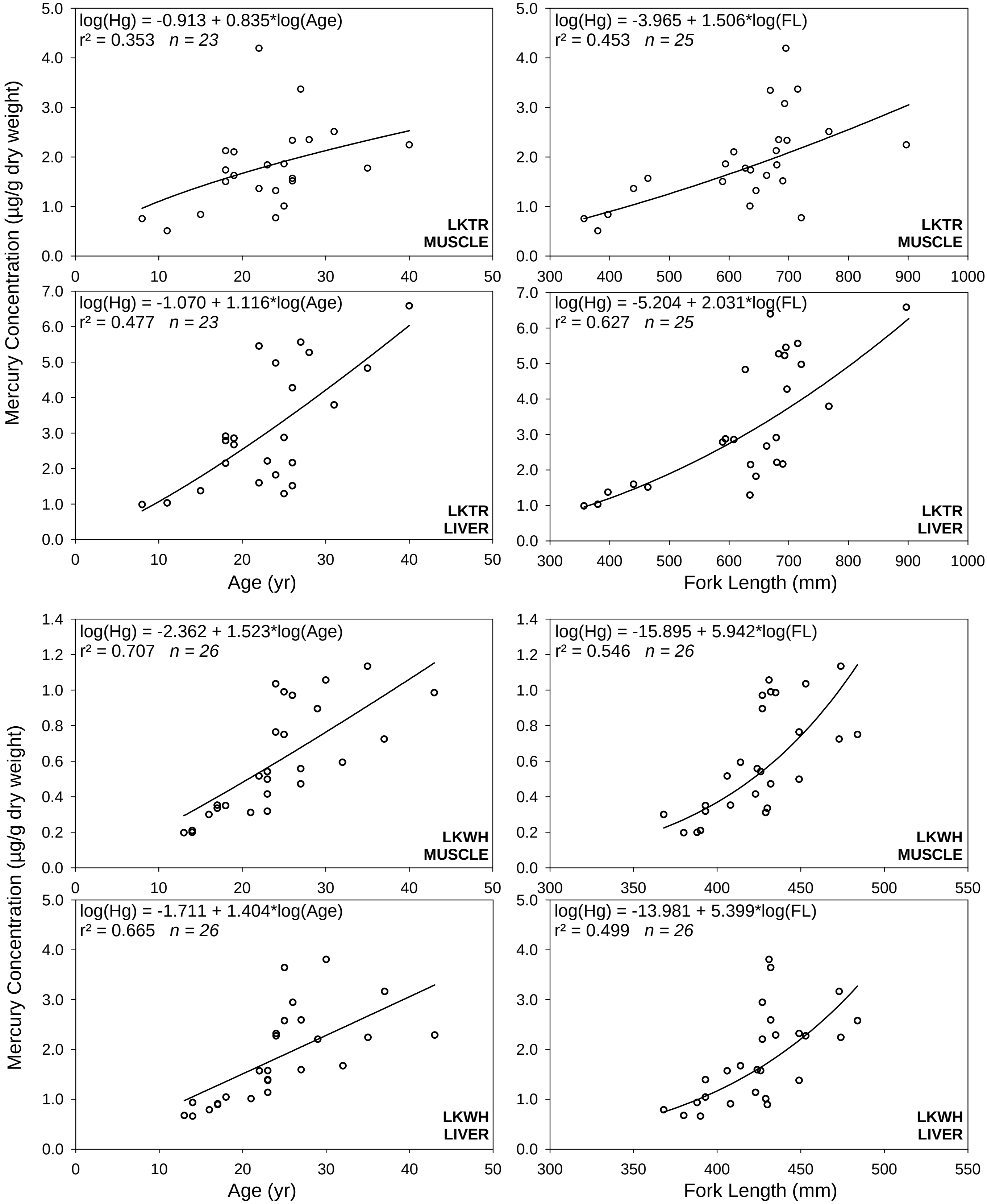


Figure 7.16 Mercury concentrations in lake trout (LKTR) and lake whitefish (LKWH) muscle and liver tissues from Patch Lake, 1997(note changes between scales).

appeared to be better correlated with age than with fork length, an opposite relationship was recorded for lake whitefish (i.e., length was a better indicator of mercury levels than age).

Nickel

All muscle and liver tissue samples collected from lake trout and lake whitefish in Patch Lake in 1997 had nickel concentrations below the detection limit (1.0 µg/g wet weight). With much lower detection limits (0.002 µg/g wet weight) used to analyze samples from one lake trout in 1995, the nickel concentrations were 0.01, 0.02, and 0.10 µg/g wet weight (muscle, liver, and kidney samples, respectively; Appendix D13).

Selenium

Selenium levels in lake trout muscle tissues ranged from 0.82 to 1.53 µg/g dry weight; the mean concentration was 1.06 µg/g dry weight. In lake trout liver tissues, selenium concentrations were approximately seven times higher than in muscle tissues and ranged from 0.29 to 12.9 µg/g dry weight (mean of 7.75 µg/g dry weight).

Lake whitefish selenium concentrations were similar to those recorded in lake trout, with mean levels of 1.05 and 7.52 µg/g dry weight (muscle and liver samples, respectively). The highest selenium level in lake whitefish was 11.0 µg/g dry weight (in liver tissue).

Zinc

Zinc levels in lake trout muscle tissues from Patch Lake ranged from 10.1 to 15.6 µg/g dry weight; the mean concentration was 12.6 µg/g dry weight. In lake trout liver tissues, mean zinc concentrations (135.1 µg/g dry weight) were approximately ten times higher than in muscle tissues. The maximum zinc level recorded in lake trout liver was 209.6 µg/g dry weight.

Lake whitefish zinc concentrations were similar to those recorded in lake trout, with mean levels of 12.2 and 125.0 µg/g dry weight (muscle and liver samples, respectively). The highest zinc level in lake whitefish from Patch Lake was 176.6 µg/g dry weight (in liver).

7.3.6 Windy Lake

The following discussion is based on muscle and liver tissues collected in 1997 from 25 lake trout in Windy Lake. Additional samples collected in 1996 (one composite liver sample from lake trout and single composite liver and muscle samples from lake whitefish) are presented separately in Appendix D13.

Lake trout captured for tissue analyses in Windy Lake in 1997 ranged from 399 to 470 mm in fork length and from 12 to 36 years in age (Table 7.17).

Table 7.17 Fork length, weight and age of lake trout sampled for metal concentrations in Windy Lake, 1997.

Species	*n*	Fork Length (mm)			Weight (g)			Age (years)		
		Mean	SD[a]	Range	Mean	SD	Range	Mean	SD	Range
Lake trout	*25*	434	22	399-470	845	120	620-1106	18.0	5.8	12-36

[a]standard deviation

The concentrations of 19 metal elements in individual tissue samples are presented in Appendix D13. Mean metal concentrations (including standard deviation, range, and number of samples below analytical detection limits) are provided for each tissue type in Appendix D12. The average concentrations of some of the potentially toxic trace metals (i.e., aluminum, arsenic, cadmium, copper, lead, mercury, nickel, selenium, and zinc) are summarized in Table 7.18.

Table 7.18 Metal concentrations in lake trout tissues from Windy Lake, 1997.

Species	Tissue	Parameter	Metal Concentrations (µg/g dry weight)								
			Al	As	Cd	Cu	Pb	Hg	Ni	Se	Zn
Lake trout	Muscle *n=25*	*n < D.L.*[a]	*25*	*25*	*25*	*25*	*25*	*0*	*25*	*0*	*0*
		Mean	12.1	0.38	0.05	1.2	0.12	0.18	2.42	2.36	12.8
		SD[b]	0.9	0.10	0.00	0.1	0.01	0.08	0.18	0.22	1.0
		Minimum	10.6	0.14	0.04	1.1	0.11	0.08	2.12	1.86	10.8
		Maximum	14.0	0.58	0.06	1.4	0.14	0.36	2.81	2.84	15.6
	Liver *n=25*	*n < D.L*	*1*	*1*	*6*	*0*	*24*	*0*	*25*	*0*	*0*
		Mean	72.5	1.95	0.15	104.5	0.13	0.27	2.40	9.25	161.4
		SD	59.3	0.69	0.09	51.5	0.04	0.15	0.29	2.54	21.0
		Minimum	12.3	0.77	0.05	18.9	0.09	0.11	1.89	3.98	97.5
		Maximum	227.3	3.61	0.34	266.8	0.32	0.73	2.84	15.44	204.9

[a]number of samples below detection limit
[b]standard deviation

Aluminum

All lake trout muscle tissue samples contained aluminum levels below the detection limit (5 µg/g wet weight). Aluminum concentrations in the liver samples were considerably higher, with 96% of samples exhibiting levels above the detection limit (Table 7.18). The mean aluminum level in lake trout livers was 72.5 µg/g dry weight, whereas the maximum value recorded in an individual sample was 227.3 µg/g dry weight. Both of these values (i.e., mean and maximum) represented the highest aluminum levels among all fish tissue samples collected in Doris Hinge lakes.

Arsenic

Arsenic levels in lake trout from Windy Lake ranged from 0.14 to 3.61 µg/g dry weight. Mean concentrations were approximately five times higher in liver than in muscle tissues (1.95 and 0.38 µg/g, respectively). The percentages of samples below the detection limit were 4% for liver and 100% for muscle.

Cadmium

Whereas all lake trout muscle tissue samples contained cadmium levels below the detection limit of 0.02 µg/g wet weight, most 76% of liver samples exhibited concentrations above the detection limit. Mean cadmium concentration in liver samples was 0.15 µg/g dry weight. The highest cadmium level was 0.34 µg/g dry weight.

Copper

All lake trout muscle tissue samples contained copper levels below the detection limit of 0.5 µg/g wet weight. Copper concentrations in the liver tissues were considerably higher, with all samples exhibiting concentrations above the detection limit (Table 7.18). Mean level of copper in the liver samples (104.5 µg/g dry weight) was the highest among all fish tissue samples collected in Doris Hinge lakes. Similarly, the maximum copper level in an individual sample (266.8 µg/g dry weight) was the highest recorded copper concentration in fish tissues from the Doris Hinge lakes.

Lead

All muscle tissue samples and 96% of liver samples collected from lake trout in Windy Lake in 1997 had lead concentrations below the detection limit (0.05 µg/g wet weight). Lead concentration in the only liver sample that was within the detectable range was 0.32 µg/g dry weight (0.08 µg/g wet weight); this was six times lower than the federal guideline of 0.5 µg/g wet weight.

Mercury

Total mercury levels in lake trout muscle tissues ranged from 0.08 to 0.36 µg/g dry weight; the mean concentration was 0.18 µg/g dry weight. The maximum mercury level recorded corresponded to 0.07 µg/g wet weight and was well below the maximum levels allowed for human consumption (0.5 µg/g wet weight).

Mercury levels in lake trout liver tissues were higher than in muscle tissues and ranged from 0.11 to 0.73 µg/g dry weight; the mean concentration was 0.27 µg/g dry weight. The maximum level recorded corresponded to 0.15 µg/g wet weight and was well below the maximum levels allowed for human consumption (0.5 µg/g wet weight).

Lake trout from Windy Lake exhibited the lowest mercury levels (in both muscle and liver tissues) among the tested lakes in the Doris Hinge area. Mean concentrations in both tissues were more than 10 times lower than the corresponding concentrations in lake trout from Patch Lake. The reasons for these large differences in mercury levels between Windy Lake lake trout and lake trout from other lakes are not known, although Rescan (1999b) suggested that it was likely due to differences in diet. Because Windy Lake supported low densities of forage fish relative to most other lakes, Rescan (1999b) suggested that they fed primarily on invertebrates and thus were exposed to lower mercury levels in their diet than the more piscivorous fish in other lakes. Unfortunately, only three lake trout stomachs were examined in Windy Lake and they were all empty. Other factors that confound this hypothesis are higher lake trout mercury levels in Tail Lake (about three to five times higher than in Windy Lake), even though Tail Lake supports no forage fish other than ninespine stickleback.

Because mercury is known to bioaccumulate in fish, mercury concentrations in muscle and liver tissues were regressed against age and fork length to determine the strength of these relationships and to allow comparisons with future monitoring studies (Figure 7.17). The correlation coefficients (r^2; the closer to 1, the better the relationship) were very low and ranged between 0.06 (lake trout liver versus fork length) and 0.29 (lake trout liver versus age). This suggested that mercury concentrations in Windy Lake lake trout were not related to fish size and, to a slightly lesser extent, to fish age.

Nickel

All muscle and liver tissue samples collected from lake trout in Windy Lake in 1997 had nickel concentrations below the detection limit (1.0 µg/g wet weight). With lower detection limits (0.2 µg/g wet weight) used to analyze one composite sample of lake trout in 1996, the nickel concentrations were also below detection limit in both muscle and liver samples (Appendix D13).

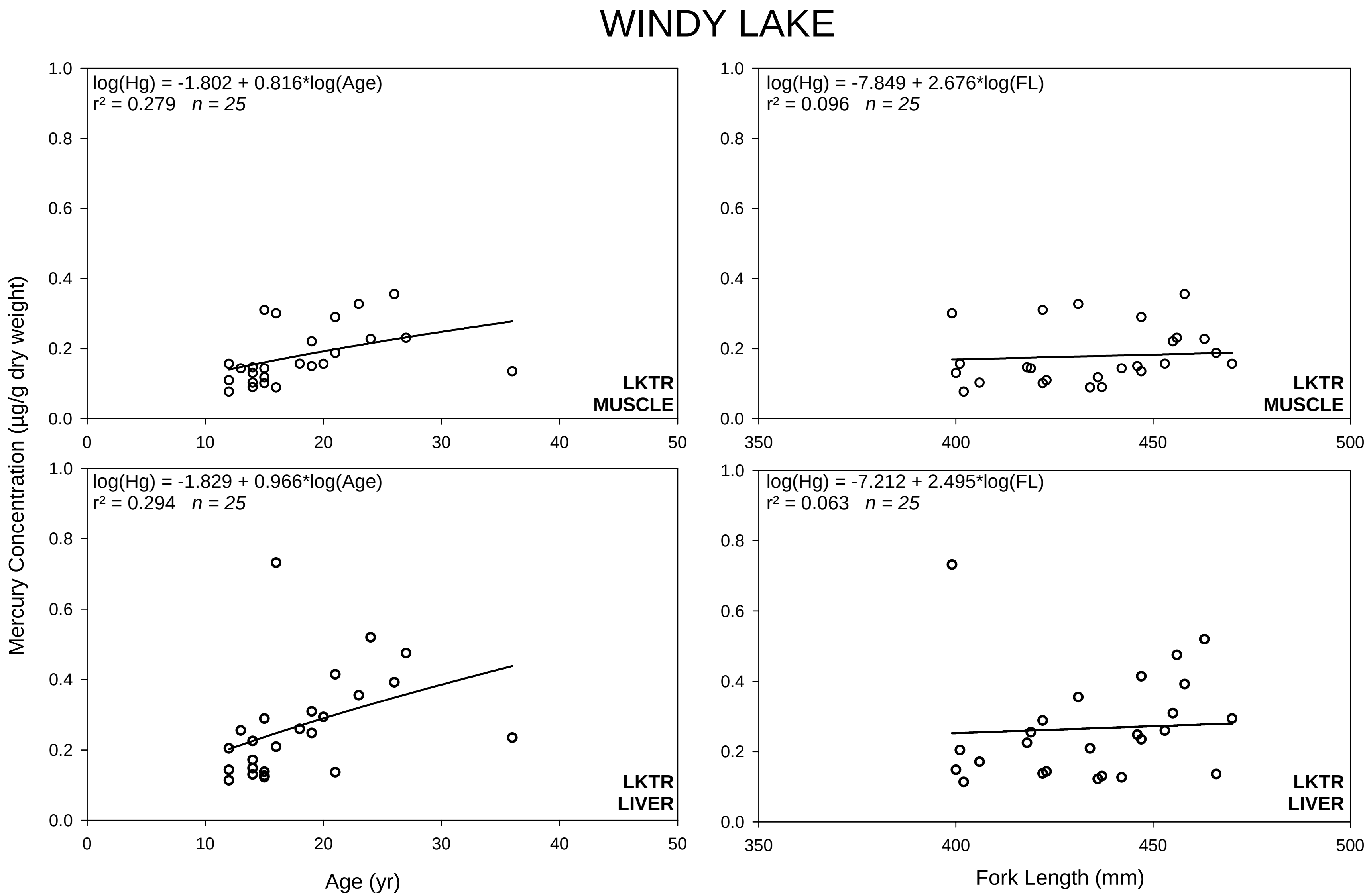


Figure 7.17 Mercury concentrations in lake trout (LKTR) muscle and liver tissues from Windy Lake, 1997.

Selenium

Selenium levels in lake trout muscle tissues ranged from 1.86 to 2.84 µg/g dry weight; the mean concentration was 2.36 µg/g dry weight. In lake trout liver tissues, selenium concentrations were approximately four times higher than in muscle tissues and ranged from 3.98 to 15.44 µg/g dry weight (mean of 9.25 µg/g dry weight).

In direct contrast to mercury concentrations, mean levels of selenium in lake trout from Windy Lake were the highest (in both muscle and liver tissues) among the tested lakes in the Doris Hinge area. The reasons for these opposite trends in mercury and selenium levels are not known.

Zinc

Zinc levels in lake trout muscle tissues from Windy Lake ranged from 10.8 to 15.6 µg/g dry weight; the mean concentration was 12.8 µg/g dry weight. In lake trout liver tissues, mean zinc concentrations (161.4 µg/g dry weight) were approximately 13 times higher than in muscle tissues. The maximum zinc level recorded in a lake trout liver from Windy Lake was 204.9 µg/g dry weight.

7.3.7 Pelvic Lake

The following discussion is based on muscle and liver tissues collected in 1998 from 21 lake trout and 22 lake whitefish in Pelvic Lake. Lake trout captured for tissue analyses in Pelvic Lake ranged from 406 to 753 mm in fork length and from 8 to 32 years in age (Table 7.19). Lake whitefish ranged from 316 to 411 mm in fork length and from 10 to 34 years in age.

Table 7.19 Fork length, weight and age of lake trout and lake whitefish sampled for metal concentrations in Pelvic Lake, 1997.

Species	*n*	Fork Length (mm)			Weight (g)			Age (years)		
		Mean	SD[a]	Range	Mean	SD	Range	Mean	SD	Range
Lake trout	*21*	529	115	406-753	1789	1053	856-4250	21.5	6.1	8-32
Lake whitefish	*22*	382	23	316-411	733	125	412-954	21.5	6.3	10-34

[a]standard deviation

The concentrations of 19 metal elements in individual tissue samples are presented in Appendix D13. Mean metal concentrations (including standard deviation, range, and number of samples below analytical detection limits) are provided for each species and tissue type in Appendix D11. The average concentrations of some of the potentially toxic trace metals (i.e., aluminum, arsenic, cadmium, copper, lead, mercury, nickel, selenium, and zinc) are summarized in Table 7.20.

Table 7.20 Metal concentrations in lake trout and lake whitefish tissues from Pelvic Lake, 1997.

Species	Tissue	Parameter	Metal Concentrations (µg/g dry weight)								
			Al	As	Cd	Cu	Pb	Hg	Ni	Se	Zn
Lake trout	Muscle *n=21*	*n < D.L.*[a]	*21*	*17*	*21*	*21*	*21*	*0*	*21*	*0*	*0*
		Mean	12.1	0.15	0.05	1.2	0.12	1.48	2.42	0.97	12.7
		SD[b]	0.6	0.06	.00	0.1	0.01	0.35	0.12	0.05	0.9
		Minimum	11.0	0.11	0.04	1.1	0.11	0.73	2.20	0.88	10.7
		Maximum	13.2	0.29	0.05	1.3	0.13	1.96	2.63	1.05	14.0
	Liver *n=21*	*n < D.L*	*9*	*10*	*8*	*0*	*21*	*0*	*21*	*0*	*0*
		Mean	34.1	0.21	0.14	53.6	0.11	1.64	2.29	4.81	123.0
		SD	28.9	0.11	0.11	32.0	0.02	0.49	0.35	1.43	27.1
		Minimum	9.8	0.10	0.03	4.4	0.08	0.58	1.63	2.94	87.6
		Maximum	96.5	0.46	0.38	119.8	0.14	2.29	2.87	7.34	173.0
Lake whitefish	Muscle *n=22*	*n < D.L.*[a]	*22*	*21*	*22*	*22*	*22*	*0*	*22*	*0*	*0*
		Mean	12.4	0.13	0.05	1.2	0.12	0.42	2.49	1.31	12.5
		SD	0.6	0.04	0.00	0.1	0.01	0.28	0.12	0.26	0.9
		Minimum	11.7	0.12	0.05	1.2	0.12	0.15	2.34	0.93	11.3
		Maximum	14.3	0.30	0.06	1.4	0.14	1.10	2.86	1.91	14.4
	Liver *n=22*	*n < D.L*	*13*	*8*	*0*	*0*	*22*	*0*	*22*	*0*	*0*
		Mean	25.3	0.23	0.42	23.0	0.13	1.19	2.40	5.92	114.7
		SD	18.4	0.09	0.25	6.9	0.04	0.60	0.19	1.46	13.9
		Minimum	10.4	0.11	0.10	6.3	0.10	0.27	2.04	3.43	84.4
		Maximum	63.1	0.38	1.00	33.5	0.33	2.66	2.86	9.09	135.9

[a]number of samples below detection limit
[b]standard deviation

Aluminum

All lake trout and lake whitefish muscle tissue samples contained aluminum levels below the detection limit (5 µg/g wet weight). Aluminum concentrations in liver samples were slightly higher, with 57% and 41% of lake trout and lake whitefish samples, respectively, exhibiting concentrations above the detection limit (Table 7.20). The highest aluminum levels were 96.5 and 63.1 µg/g dry weight in lake trout and lake whitefish livers, respectively.

Arsenic

Arsenic levels in lake trout from Pelvic Lake ranged from 0.10 to 0.46 µg/g dry weight. Mean concentrations were slightly higher in liver than in muscle tissues

(0.21 and 0.15 µg/g, respectively). The percentages of samples below the detection limit were 81% for muscle and 48% for liver samples.

In lake whitefish, the mean concentrations of arsenic were also higher in liver than in muscle tissues (0.23 and 0.13 µg/g dry weight, respectively). The highest arsenic level (0.38 µg/g) was recorded in a liver tissue. Whereas 95% of lake whitefish muscle samples were below the detection limit, only 36% of liver samples were below detection.

Cadmium

All lake trout and lake whitefish muscle tissue samples contained cadmium levels below the detection limit. Cadmium concentrations in liver samples were higher, with 62% and 100% of lake trout and lake whitefish samples, respectively, exhibiting detectable concentrations. The highest cadmium levels were 0.38 and 1.00 µg/g dry weight in lake trout and lake whitefish livers, respectively.

Copper

All lake trout and lake whitefish muscle tissue samples contained copper levels below the detection limit of 0.5 µg/g wet weight. Copper concentrations in liver samples were considerably higher, with 62% of lake trout and all lake whitefish samples exhibiting concentrations above the detection limit (Table 7.20). Mean levels of copper in lake trout liver samples (53.6 µg/g dry weight) were more than two times higher than in lake whitefish liver samples (23.0 µg/g dry weight). The maximum copper concentrations in individual samples were 119.8 and 33.5 µg/g in lake trout and lake whitefish livers, respectively.

Lead

All muscle and liver tissue samples collected from lake trout and lake whitefish in Pelvic Lake had lead concentrations below the detection limit (0.05 µg/g wet weight), which was 10 times lower than the federal guideline for maximum allowable levels for human consumption (0.5 µg/g wet weight).

Mercury

Total mercury levels in lake trout muscle tissues ranged from 0.73 to 1.96 µg/g dry weight; the mean concentration was 1.48 µg/g. The maximum mercury level recorded was equivalent to 0.41 µg/g wet weight and did not exceed the maximum allowable level for human consumption (0.5 µg/g wet weight).

Mercury levels in lake trout liver tissues were slightly higher than in muscle tissues and ranged from 0.58 to 2.29 µg/g dry weight; the mean concentration was 1.64 µg/g dry weight. Three of 21 liver samples (14%) exceeded the maximum levels allowed for human consumption (0.5 µg/g wet weight).

Lake whitefish mercury concentrations were lower than in lake trout, with mean levels of 0.42 and 1.19 µg/g dry weight (muscle and liver samples, respectively). The highest mercury level in livers was equivalent to 0.56µg/g wet weight and was among two samples (9%) that exceeded the maximum levels allowed for human consumption (0.5 µg/g wet weight). The highest mercury level in muscle tissues was equivalent to 0.22 µg/g wet weight and did not exceed the maximum levels allowed for human consumption.

Because mercury is known to bioaccumulate in fish, mercury concentrations in muscle and liver tissues were regressed against age and fork length to determine the strength of these relationships and to allow comparisons with future monitoring studies (Figure 7.18). The correlation coefficients (r^2; the closer to 1, the better the relationship) were relatively high for lake trout muscle and liver versus age (0.68 and 0.82, respectively), but were much lower for lake trout muscle and liver versus fork length (0.16 and 0.07, respectively) and for all lake whitefish regressions (ranged from 0.23 for liver versus fork length to 0.48 for liver versus age).

Nickel

All muscle and liver tissue samples collected from lake trout and lake whitefish in Pelvic Lake had nickel concentrations below the detection limit (1.0 µg/g wet weight).

Selenium

Selenium levels in lake trout muscle tissues ranged from 0.88 to 1.05 µg/g dry weight; the mean concentration was 0.97 µg/g dry weight. In lake trout liver tissues, selenium concentrations were approximately five times higher than in muscle tissues and ranged from 2.94 to 7.34 µg/g dry weight (mean of 4.81 µg/g dry weight).

Lake whitefish selenium concentrations were slightly higher than those recorded in lake trout, with mean levels of 1.31 and 5.92 µg/g dry weight (muscle and liver samples, respectively). The highest selenium level in lake whitefish was 9.09 µg/g dry weight (in liver).

Zinc

Zinc levels in lake trout muscle tissues from Pelvic Lake ranged from 10.7 to 14.0 µg/g dry weight; the mean concentration was 12.76 µg/g dry weight. In lake trout liver tissues, mean zinc concentrations (123.0 µg/g dry weight) were

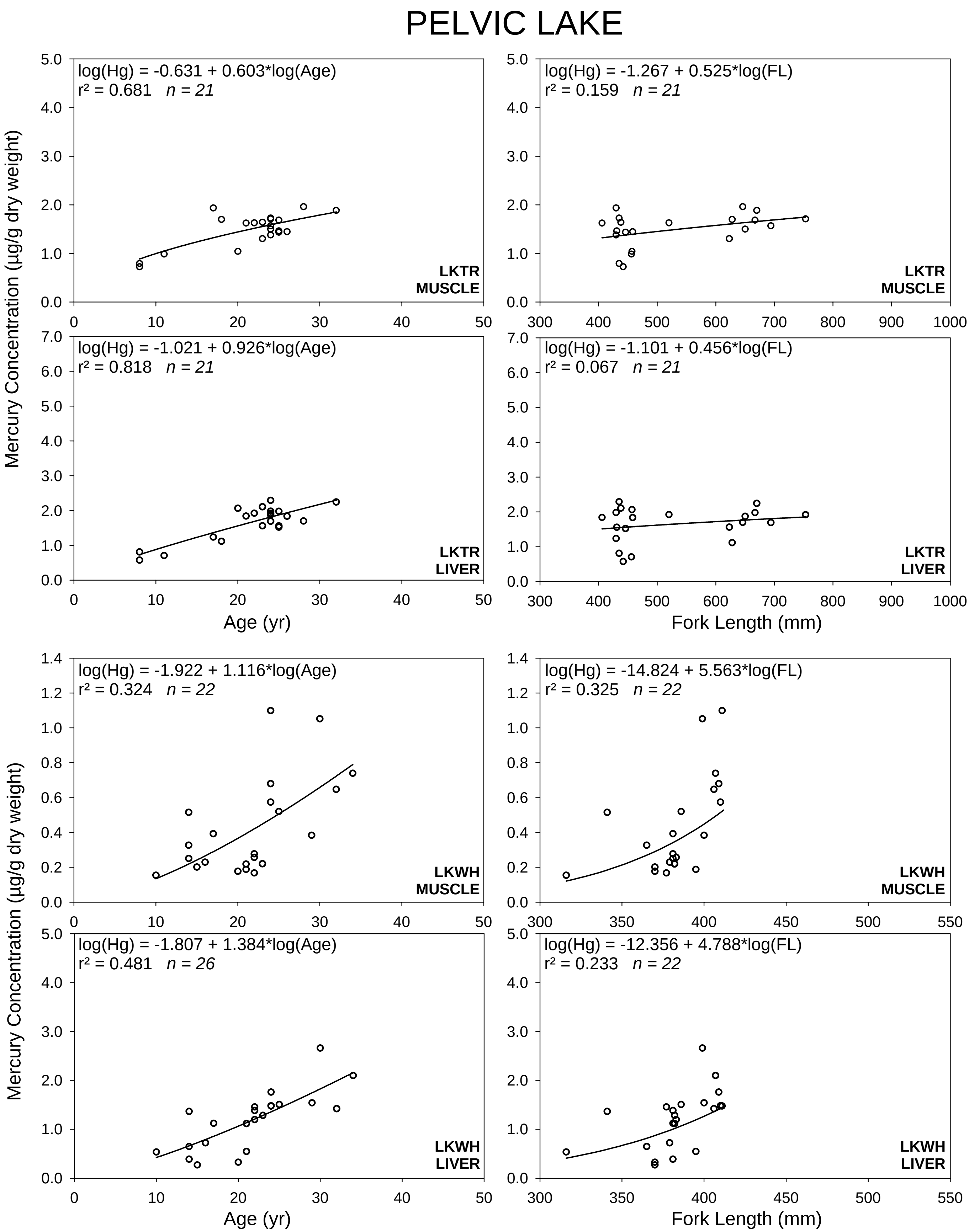


Figure 7.18 Mercury concentrations in lake trout (LKTR) and lake whitefish (LKWH) muscle and liver tissues from Pelvic Lake, 1997(note changes between scales).

approximately ten times higher than in muscle tissues. The maximum zinc level recorded in lake trout liver was 173.0 µg/g dry weight.

Lake whitefish zinc concentrations were similar to those recorded in lake trout, with mean levels of 12.5 and 114.7 µg/g dry weight (muscle and liver samples, respectively). The highest zinc level in lake whitefish from Pelvic Lake was 135.9 µg/g dry weight (in liver).

7.3.8 Summary

Fish tissue (dorsal muscle, liver, and kidney) samples were collected from lake trout, lake whitefish, and cisco to provide baseline data on metal concentrations. Samples were collected in lakes in close proximity to potential development activities (Doris, Tail, Ogama, Patch, and Windy) and one reference lake (Pelvic). Samples were collected over several years between 1995 and 1998; however, the majority of the samples were collected in 1997 and 1998 and consisted of muscle and liver tissues from lake trout and lake whitefish.

Analyses of fish tissues indicated generally low levels of metal accumulation. Except for arsenic and mercury, mean concentrations of metals exhibited low variability between lakes. The highest mean concentration of arsenic (1.95 µg/g dry weight) was recorded in lake trout livers from Windy Lake; this was approximately one order of magnitude higher than in Doris Lake. Similarly, the highest mean mercury concentration (3.31 µg/g dry weight, recorded in lake trout livers from Patch Lake) was more than ten times higher than in Windy Lake. Concentrations of metals in fish tissues from Pelvic Lake, which was selected as a control basin for long term monitoring, were similar or intermediate to corresponding levels from other study lakes.

A small proportion (7 of 83) of lake trout muscle tissue samples from the study area lakes exceeded the Health Canada food consumption guideline of 0.5 µg/g wet weight (roughly equivalent to 2.5 µg/g dry weight) for mercury. They included six fish from Patch Lake and one from Doris Lake; the maximum concentration was 0.68 µg/g wet weight. Consistent with bioaccumulation up the food chain, older and larger trout had greater concentrations of mercury in their tissues and these fish were most likely to have muscle mercury concentrations above the Health Canada guideline. All lake whitefish muscle tissues contained mercury levels that were below Health Canada guidelines; the maximum concentration was 0.22 µg/g wet weight.

8.0 FISH HABITAT ASSESSMENT

8.1 LAKES

8.1.1 Methods

Lake habitat assessments were done at an overview level for Doris, Tail, Ogama, Patch, and Windy lakes in August 1995, and at a more detailed reconnaissance level for Doris, Tail, and Little Roberts lakes in August 2000 (Figure 8.1). The following habitat assessment methodologies and discussions are based on descriptions given in Klohn-Crippen (1995) and Rescan (2001).

In 1995, habitat characteristics were visually assessed through field surveys and aerial observations during overflights. Habitat was described based on its potential to support fish populations. Lake assessments included relative size, depth (bathymetric surveys), extent of littoral zone, near-shore substrate types, and the relative abundance of aquatic vegetation, periphyton, and benthic invertebrates.

The objective of the reconnaissance level lake habitat assessments conducted in August 2000 was to assess substrate composition along the littoral zone. This zone is important to fish populations for critical life history requirements such as spawning, rearing, and adult feeding. Substrate classification was conducted by helicopter, and a topographic map outlining the lake perimeter was used to identify transition areas of different substrate composition. These zones were marked on the map during low altitude flights. Once the zones were delineated, the substrate composition of each zone was recorded as a percent coverage (e.g., 25% cobble, 75% boulder). Substrate types were classified into five categories: silt, sand, cobble, boulder, and bedrock. The resulting map illustrated the substrate composition of each zone along the perimeter of the lake.

Habitat quality ratings were based on the habitat classification system outlined in Table 8.1. This table rates the ability of different substrates to provide critical habitat for the primary fish species found in area lakes. These ratings are qualitative in nature because a large area was surveyed without detailed groundwork. All five primary substrate types were classified as poor, fair, good, or excellent for each life history requisite and each group of species. For example, lake trout spawn over cobble and boulders; therefore, both substrate types were rated as good for spawning. Cobble and sand were rated as good and fair, respectively, for coregonid spawning because coregonids spawn over cobble and sometimes over sand (lake whitefish). Boulders and cobble were classified as good rearing habitat because of their excellent provision of cover, whereas all other substrate types were rated as poor rearing habitat. Sand and silt bottoms are good forage areas for coregonids, as they provide good habitat for benthic invertebrates. Lake trout primarily feed on coregonids and smaller lake trout; thus, areas where these prey species are likely to be present were classified as good habitat. Based on an overall average of all habitat rankings for lake trout and coregonids, lake habitat quality for silt and sand was classified as fair, cobble as excellent, boulders as good, and bedrock as poor. By using the map illustrating zonal substrate composition, a subsequent lake map depicting habitat quality was produced. If two substrate types were present, the most abundant substrate was used for rating habitat quality. Where three or more substrates were present, a weighted average was used to rank habitat quality.

Table 8.1 Lake substrate habitat classification scheme for lake trout and coregonid species in Doris Hinge lakes, 2000 (from Rescan 2001).

Substrate Type	Potential Habitat Use						Overall Habitat Quality
	Spawning		Rearing (cover)		Feeding		
	Lake Trout	Coregonids	Lake Trout	Coregonids	Lake Trout	Coregonids	
Silt	Poor	Poor	Poor	Poor	Good	Good	Fair[a]
Sand	Poor	Fair	Poor	Poor	Good	Good	Fair
Cobble	Excellent	Good	Good	Good	Good	Fair	Excellent[b]
Boulder	Good	Poor	Good	Good	Good	Poor	Good
Bedrock	Poor	Poor	Poor	Poor	Poor	Poor	Poor

[a] Rated as fair (instead of poor) to reflect the fact that silt can be a good substrate type for feeding.
[b] Rated as excellent (instead of good) to reflect the fact that cobble can be an excellent substrate for spawning.

8.1.2 Doris Lake

Bathymetric survey data from 1995 indicated that this 5.5 km long lake had an area of 3.5 km^2, a mean depth of 7.4 m, and a maximum depth of 20 m. During the helicopter habitat reconnaissance in 2000, approximately 50% of the Doris Lake shoreline was found to consist of sections of bedrock (Figure 8.2), whereas the remainder was very diverse. The southern end of the lake was dominated by sand along approximately 1 km of shoreline. The small inlet stream located at the south end of the lake may have been contributing to this build up of sand.

Cisco, lake whitefish, and lake trout were captured in Doris Lake (Rescan 1997, 1998, 2001). Cobble and boulders generally provide fair to good spawning, feeding and rearing habitat for these species. Therefore, areas containing a high percentage of coverage by these substrate types were classified as good lake trout and coregonid habitat. Approximately half of the east shore of Doris Lake was ranked as good to excellent lake trout and coregonid habitat (Figure 8.3). The southern half of the littoral zone on a small island at the south end was also rated as excellent lake trout and coregonid habitat. As sand dominated the southern