Fishery Data Series No. 11-58

Lake Characteristics and Species Inventory and Distribution for 11 Interior Alaska Lakes, 2005–2008

by

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and

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December 2011

Alaska Department of Fish and Game **Divisions of Sport Fish and Commercial Fisheries**

Symbols and Abbreviations

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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LAKE CHARACTERISTICS AND SPECIES INVENTORY AND DISTRIBUTION FOR 11 INTERIOR ALASKA LAKES, 2005–2008

by

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ABSTRACT

Eleven lakes in Interior Alaska (Birch Lake, Donna Lake, Donnelly Lake, Dune Lake, Little Donna Lake, Quartz Lake, Rainbow Lake, Triangle Lake, West Iksgiza Lake, West Twin Lake, and Wilderness Lake) were sampled on three occasions each during 2005–2008 to gather information on species inventory and distribution, limnology, and watershed characteristics. Sampling was conducted during mid-summer (July), fall (September), and late winter (March). Species presence was examined during mid-summer and fall; physical, chemical, and climatic features were examined during mid-summer, fall, and late-winter; and lake morphometry was examined during mid-summer. Lakes varied in size from 18 to 683 ha, in maximum depth from 7 to 34 m, and in elevation from 208 to 2,424 m. Nine lakes were sampled for fish species present. Three lakes contained at least one native fish species (Alaska blackfish *Dallia pectoralis,* northern pike *Esox lucius*, or burbot *Lota lota*) and seven lakes contained stocked species (Arctic char Salvelinus alpinus, Arctic grayling, *Thymallus arcticus*, or rainbow trout *Oncorhynchus mykiss*). The most common submergent, emergent, and floating macrophytes found in study lakes were pond weed *Potomogeton* spp., sedges *Carex* spp., and yellow pond lily *Nymphaeceae nuphar*, respectively. Chironimids dominated most macroinvertebrate samples, and copepods were most prevalent in eight of the 11 lakes sampled during summer. Chlorophyll samples were collected from eight lakes and the average chlorophyll-*a* concentrations ranged from 1.14 mg/m^3 to 3.18 mg/m^3. In July, recorded water temperatures did not exceed 20°C for any of the lakes, and in March, eight lakes had dissolved oxygen levels greater than 5 mg/L in the upper 6 m of the water column. The pH ranged from 6.15 to 9.13 in study lakes and nine lakes had clear water. Resulting data will be used to assess impacts of current and proposed development, stocking, and regulation changes.

Key words: Alaska lakes, limnology, lake morphometry, fish, zooplankton, macroinvertebrates, macrophytes, bathymetry, Arctic char, Arctic grayling, rainbow trout, Alaska blackfish, burbot, northern pike, Birch Lake, Donna Lake, Donnelly Lake, Dune Lake, Little Donna Lake, Quartz Lake, Rainbow Lake, Triangle Lake, West Iksgiza Lake, West Twin Lake, Wilderness Lake

INTRODUCTION

Alaska's constitution requires that the state's natural resources be managed for utilization, development, and conservation on the sustained yield principal for the maximum benefit of Alaskans. These resources are important to and used by many different groups who depend on them for subsistence, recreation, and economic needs. Various land use activities, however, can unintentionally compromise the habitat quality that is necessary to sustain fish stocks, other aquatic resources, and their use. Many lakes in Interior Alaska will be impacted by current or proposed exploration and development activities, and all are affected by episodic climate variability on decadal time scales. Yet, except for a few locations, minimal or no information has been collected on species presence, their distributions, or the changing status of the aquatic habitats they depend on. Accurate and current information is needed for responsible resource management.

Recently, a number of efforts have been made to inventory fish and collect aquatic habitat data throughout Alaska. Some of these efforts focus on river systems, while others explore lake and/or pond habitats.

Currently ADF&G Division of Sport Fish is conducting a project to inventory fish in river systems (Mike Wiedmer, Unpublished. 2005 Operational Plan; *Synoptic Inventory of Fish Distribution in Seward Peninsula and Middle Yukon River Freshwaters*). The goal of this project is to document resident and anadromous fish distribution and to update the Anadromous Waters Catalog. Information on fish abundance and distribution is collected, along with stream and riparian habitat features.

The National Park Service is currently creating a monitoring program for surveying shallow lakes within the national parks and preserves of central Alaska. Spot sampling is conducted at each selected lake once during the summer for two consecutive years, and repeat sampling will be conducted 8 years later. The focus of this program is water quantity, water quality, and macroinvertebrates; however, fish species are noted as being present or absent.

Previously, University of Alaska researchers have conducted several limnological studies on Interior Alaska lakes. Some findings have shown that Interior lakes are not homogenous in terms of biological, physical, or chemical characteristics (LaPerriere et al. 2003b). There are noted differences among lakes in the same general watershed. These studies did not investigate fish or invertebrate species in great detail, but researchers did note that fish were present in these systems.

In 2005 this project was designed to gather current information on species inventory and distribution along with limnology and watershed characteristics of Interior lake systems. Information from this project will be used to map distributions of fish and other aquatic species and to describe the habitat and watershed characteristics. This project will also provide baseline data for monitoring the status of species and habitat over time. Resource managers need this information to make informed decisions and to develop plans for current and future activities that impact land and water resources. The information from this project will provide resource managers with a powerful tool for managing aquatic resources to ensure healthy fish populations and their continued use.

This project provides a uniform approach for sampling and monitoring fish populations and their aquatic habitats in Interior Alaska lakes. Consistency in sampling methodology will ensure that data are comparable across years for multiple lakes. This report summarizes data collected in 2005–2008.

OBJECTIVES

The objective of this project was to investigate 11 Interior Alaska lakes and document species inventory and distribution, and physical, chemical, climatic, and morphological features at each location:

1. Species inventory and distribution: Identify and characterize the aquatic species present in each lake during mid-summer (July) and fall (September).

    Task 1: in each lake, use a variety of sampling gear to capture and identify all fish species present;

    Task 2: in each lake, describe the area of lake covered by each of three types of macrophytes (submergent, emergent, and floating);

    Task 3: in each lake, sample different habitat areas to capture and identify all macroinvertebrate orders present;

    Task 4: in each lake, collect water samples to determine chlorophyll-*a* concentrations using laboratory techniques; and,

    Task 5: in each lake, collect zooplankton samples to investigate relative abundance of copepods, cladocerans, and rotifers in specified sample areas.

2. Physical, chemical and climatic features: Describe the physical and chemical properties of each lake during midsummer (July) and fall (September), and late winter (March).

    Task 1: in each lake, measure water clarity, temperature, dissolved oxygen, pH, total dissolved solids, specific conductivity, and alkalinity; and,

    Task 2: at each lake, document weather conditions at the time surveys are made (air temperature, cloud cover, precipitation, etc).

3. Lake morphometry: Describe the morphometry of each lake during midsummer (July).

Task 1: in each lake, survey the lake bottom to obtain depth readings for producing bathymetric maps;

Task 2: in each lake, describe the lake watershed and the immediate surroundings, such as tree/shrub cover, and inlets and outlets; and,

Task 3: for each lake, take photographs with a digital camera of the area from north and south locations on the lake, and, if flown into a lake, take aerial photographs.

STUDY AREA

The criteria for selecting lakes for this study included: 1) the importance of the information for management needs; 2) the number of public inquiries or requests for development of a fishery, or for information about the lake or species present in the lake; and, 3) proximity to other lakes under consideration to reduce transportation costs. The four lakes chosen for 2005–2006 were Donna Lake (23.5 ha), Donnelly Lake (19 ha), Little Donna Lake (18 ha) and Rainbow Lake (35 ha) (Figure 1). The four lakes chosen for 2006–2007 were Dune Lake (76.5 ha), Rainbow Mountain Lake (2.3 ha), Triangle Lake (44 ha), and West Iksgiza Lake (25.5 ha) (Figure 1). Only three out of four lakes chosen for 2006–2007 were actually examined (see Results and Discussion). The four lakes chosen for 2007–2008 were Birch Lake (315 ha), Quartz Lake (584 ha), West Twin Lake (683 ha), and Wilderness Lake (79 ha) (Figure 1). All lakes are in the Tanana River Management Area.

DONNA LAKE

Donna Lake is located 5.6 km south of the Alaska Highway at Mile 1,391.8. The lake covers 23.5 surface ha, has a maximum depth of 10 m was first stocked with rainbow trout *Oncorhychus mykiss* fingerlings in 1962 and since 1999 has been stocked alternate years with rainbow trout. (Donna Lake was stocked in 2003 and 2004 to switch stocking events to even years). Sampling was conducted at Donna Lake because it is relatively close to other lakes being sampled in 2005 and managers wished to compare collected data among neighboring lakes.

DONNELLY LAKE

Donnelly Lake is located approximately 0.8 km east of the Richardson Highway at Mile 244.6. The lake covers 19 ha, has a maximum depth of 12.4 m and has been stocked with multiple fish species since 1973. Species previously stocked include rainbow trout, Arctic char *Salvelinus alpinus*, coho salmon *O. kisutch*, Chinook salmon *O. tshawytscha*, and Arctic grayling *Thymallus arcticus*. Since 1999, rainbow trout have been stocked alternate years and Arctic char were last stocked in 1999. Previous studies conducted at Donnelly Lake documented angler reports of large rainbow trout; however, only 1%–2% of fish captured during sampling were ≥ 300 mm (Behr et al. 2005). In 2004 the Board of Fish classified Donnelly Lake as a special management lake, and corresponding bag restrictions were implemented in 2005. Managers speculated that this regulatory change, combined with reduced stocking numbers, may promote larger fish within the fishery. Sampling in 2005 was conducted to establish baseline information to possibly identify the affects of these actions in the future.

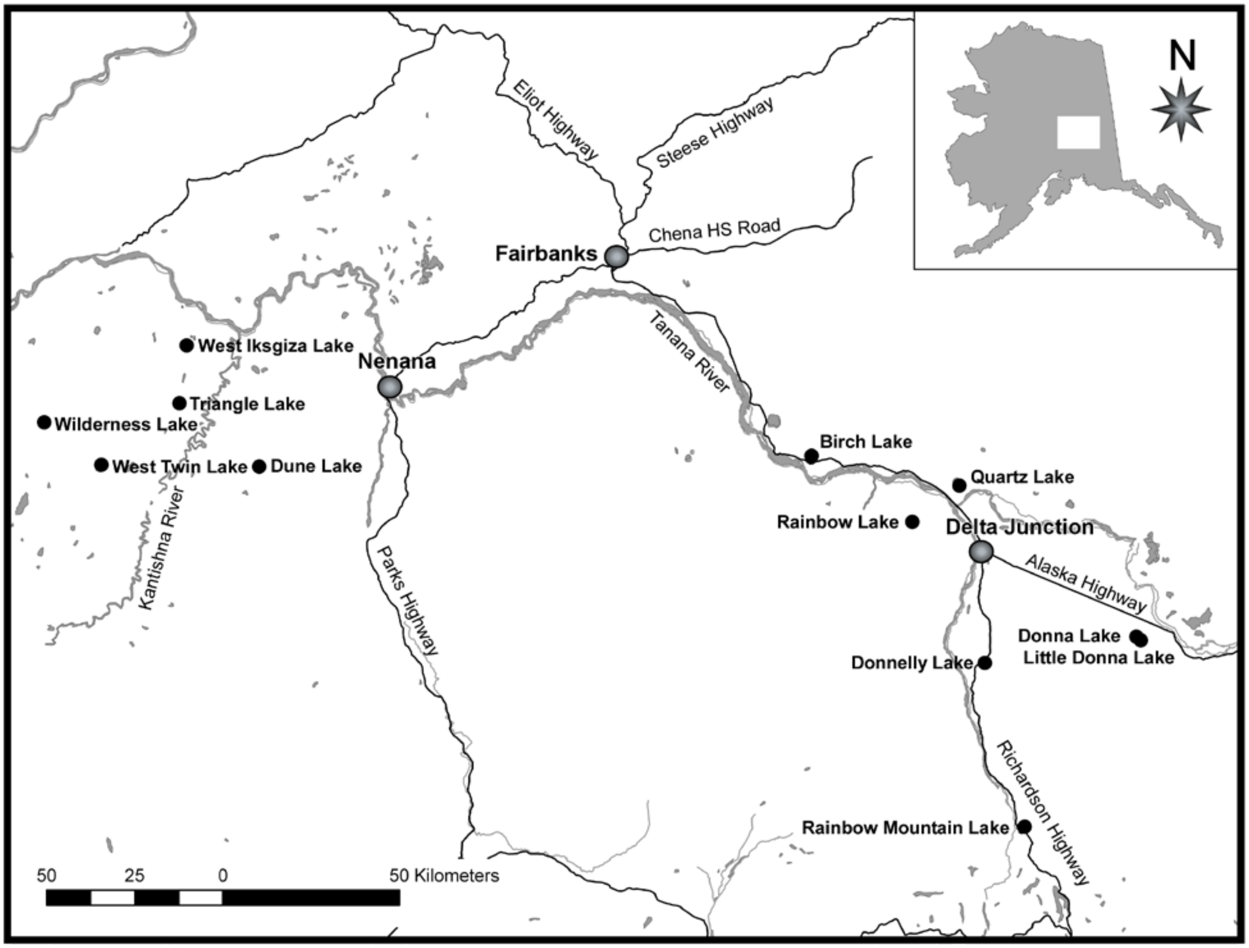

Figure 1.–Location of lakes sampled in 2005–2006 (Donna Lake, Donnelly Lake, Little Donna Lake, and Rainbow Lake), lakes sampled in 2006–2007 (Dune Lake, Rainbow Mountain Lake, Triangle Lake, and West Iksgiza Lake), and lakes sampled in 2007–2008 (Birch Lake, Quartz Lake, West Twin Lake, and Wilderness Lake).

Little Donna Lake

Little Donna Lake is located near Donna Lake, 7.2 km south of the Alaska Highway at Mile 1,391.8. The lake covers 18 ha, has a maximum depth of 7 m and was first stocked with rainbow trout fingerlings in 1963 and has been stocked alternate years since 1999. (Little Donna Lake was stocked in 2003 and 2004 to switch stocking events to even years). Sampling at Little Donna Lake was conducted in 2005 because of the lake's proximity to neighboring lakes being sampled.

Rainbow Lake

Rainbow Lake is located approximately 16 km SW of Quartz Lake near Delta Junction. The lake covers 35 ha, has a maximum depth of 9.2 m and has been stocked with rainbow trout fingerlings since 1971 and since 1999 (with the stocking schedule switching to even years in 2004) are stocked alternate years. Rainbow Lake was classified as a Special Management lake by the Alaska Board of Fisheries in 2004 and corresponding bag restrictions were implemented in 2005. Rainbow trout up to 500 mm have been observed in Rainbow Lake (Behr and Skaugstad 2006), and anglers have expressed interest in maintaining large fish in this fishery. Managers were interested in distinguishing habitat characteristics that may contribute to maintaining fish of this size.

Dune Lake

Dune Lake is located west of Nenana. The lake covers 76.5 ha, has a maximum depth of 8 m and has been stocked with multiple species since 1976. Species currently stocked since 1999 are rainbow trout, coho salmon, and Arctic grayling. Recently, rainbow trout were stocked on odd years and coho salmon were stocked on even years. Arctic grayling stockings were not consistent biennial events. Dune Lake is listed under Conservative Management and was last sampled in 2000 (Skaugstad and Fish 2002). Dune Lake is known for producing large fish and many anglers have expressed interest in maintaining this type of fishery. Managers wished to identify potential habitat characteristic contributing to the notable growth this lake is known for.

Rainbow Mountain Lake

Rainbow Mountain Lake is located on the Richardson Highway near Black Rapids Glacier. The lake is approximately 2.3 ha and has not been stocked. Rainbow Mountain Lake was nominated by a member of the public for stocking in 2005. Managers wished to collect habitat information for this lake to determine stocking feasibility and suitable species and life stages to stock.

Triangle Lake

Triangle Lake is located west of Nenana, across the Kantishna River, near West Iksgiza Lake and Dune Lake. The lake covers 44 ha, has a maximum depth of 13 m and has been stocked with multiple species since 1988. Species previously stocked include rainbow trout, Arctic grayling and lake trout *Salvelinus namaycush*. Since 1999 rainbow trout have been stocked alternate years. Managers wished to compare habitat characteristics of Triangle Lake to neighboring lakes.

WEST IKSGIZA LAKE

West Iksgiza Lake is located near Iksgiza Lake, west of Nenana, across the Kantishna River. The lake covers 25.5 surface ha, has a maximum depth of 10 m and was first stocked with rainbow trout fingerlings in 2004 and again in 2005. West Iksgiza Lake was nominated for stocking by a member of the public in 2004. Preliminary investigations prior to stocking found dissolved oxygen levels exceeded 6 mg/L in February[1]. As a result, managers anticipated adequate overwinter survival and proceeded with stocking activities. Sampling in 2006 was conducted to evaluate this newly established rainbow trout population and to characterize the aquatic habitat and food resources available.

BIRCH LAKE

Birch Lake is located along the Richardson Highway about 97 kilometers south of Fairbanks. The lake covers 315 ha, has a maximum depth of 14 m and has been stocked since 1966. Species previously stocked include rainbow trout, Arctic char, Chinook salmon, coho salmon, and Arctic grayling. Birch Lake is relatively large in size and appears to have adequate littoral vegetation for fish habitat; however, fish growth is slower than that observed in Quartz Lake, which is about 40 km east of Birch Lake. Managers wished to identify possible distinguishing characteristics between these two lake systems that may influence growth of stocked fishes.

QUARTZ LAKE

Quartz Lake is located 21 kilometers north of Delta Junction on the Richardson Highway. It is the largest roadside stocked fishery in Interior Alaska (584 ha), has a maximum depth of 13 m and has been stocked since 1971. Species currently stocked include rainbow trout, Arctic char, Chinook salmon, and coho salmon. Quartz Lake is known for producing large rainbow trout (≥ 460 mm) and managers wished to identify possible distinguishing characteristics that may contribute to this notable growth.

WEST TWIN LAKE

West Twin Lake is located approximately 88 km west of Nenana. The lake covers 683 ha and has a maximum depth of 34 m. Lake trout were stocked in 1989 but anglers have not reported catching lake trout. Managers selected West Twin Lake for evaluation because they wished to gain a better understanding of the species composition and habitat characteristics of lakes in this area.

WILDERNESS LAKE

Wilderness Lake is located approximately 100 km west of Nenana. The lake covers 79 ha, has a maximum depth of 21 m, and has not been stocked. This lake is relatively close to West Twin Lake and managers wished to gain a better understanding of the species composition and habitat characteristics of lakes in this area.

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1 ADF&G lake limnology records archived at 1300 College Rd. Fairbanks, provided by April Behr and Cal Skaugstad.

METHODS

Sampling of biotic and abiotic features was conducted at each study lake during midsummer (July), autumn (September), and late winter (March). These times were selected because environmental conditions often approach critical biological limits in summer and late winter when many species become stressed. Species presence and abundance also fluctuate during the year and multiple sampling events documented seasonal shifts in community structure. Midsummer sampling consisted of measuring physical and chemical lake properties, surveying lake morphometry, and sampling the macroinvertebrate, macrophyte, zooplankton, and phytoplankton communities. Autumn sampling consisted of measuring physical and chemical lake properties, identifying fish species present, and sampling the macroinvertebrate, macrophyte, zooplankton, and phytoplankton communities. Late winter sampling consisted of measuring physical and chemical properties.

SPECIES INVENTORY AND DISTRIBUTION

Fish

Fyke nets, tangle nets, and hoop nets were used to capture fish species present in each lake. The area of the lake determined the number of nets fished and duration of sampling (Table 1).

Table 1.–Sampling effort (days) by gear type for lakes of three size categories.

Hectare (Acre)	Effort (days)	No. of Fyke Nets	No. of Tangle Nets	No. of Hoop Traps
0 to 20 (50)	2	2	2	4
21 to 100 (250)	2	4	2	6
>100	3	4	2	6

Fyke nets were set near shore on the lake bottom in approximately 1 to 2 m of water. Fyke nets had openings that were either 0.9 or 1.2 m^2, the body length from opening to cod end was about 5 m, hoop size was 0.9 m diameter, and mesh size was 9 mm^2. Wings were 7.3 m long by 1.2 m deep and were attached to each side of the open end. The net body was positioned parallel to shore and the wings set to form a "V". Each fyke net was pulled taut from the cod end and held in position with a weight. The location and spacing of nets was determined by the field crew leader based on lake morphology, presence or absence of aquatic vegetation, knowledge of past netting activities, knowledge of fish behavior, limnology information, and weather.

Tangle nets were set perpendicular to shore in water deeper than 2 meters. Nets measured 45 m long by 4.9 m deep and were made of 13 mm bar fine thread monofilament. Mesh size was small to ensure that fish were captured by entanglement around the mouth and not by the gill covers. Generally, tangle nets were checked every 20 min. The time was shortened or extended depending on an assessment of the condition of the fish.

Hoop traps were set offshore in water deeper than 2 m. Traps were 0.5 m diameter and 1.6 m long with a throat at each end. Netting was 6.4 mm Delta weave. Each trap was attached to a vertical line that had a float on one end and a weight on the other. Traps were positioned horizontally in the water column, baited with unsalted salmon roe, and set to avoid depths where dissolved oxygen was less than 2 ppm.

Captured fish were anesthetized, marked with an upper caudal (UC) fin clip, and measured to the nearest millimeter fork length (FL). Recaptured fish were not measured again. A solution of 100 mg spearmint oil per ml of non-denatured ethanol was used to anesthetize fish. This solution was further diluted with lake water to a concentration of 120 mg/L.

Macrophytes

A handheld GPS (GARMIN® GPSMAP 76 chart plotting receiver)[2] was used to record boundaries of submergent, emergent, and floating aquatic vegetation in each lake. Areas of each vegetation type were calculated using ArcGIS 9.1. Predominant macrophytes within each area were identified in the field to family and genus if possible. Digital aerial photographs of each lake were taken if an aircraft was used to access the lake.

Macroinvertebrates

A D-frame dip net with 600 μm mesh was used to sample macroinvertebrates in near shore areas of each lake (≤ 2 m deep). At each sample station, a one-meter sweep was made with the dip net through macrophytes and across the lake bottom. Three sweeps at each station were combined to form one composite sample. Samples were preserved in polyethylene bottles with 70% ETOH (ethanol) and the invertebrates were later identified to order.

The number of habitat types (emergent, submergent, and floating vegetation) and their relative size determined the number of stations sampled in each lake. A minimum of two stations and a maximum of four stations were sampled within each habitat type. Two stations were sampled within habitats comprising less than 50% of the total habitat area, three in habitats comprising 50%–75% of the total, and four in habitats comprising greater than 75% of the total habitat area. Stations were distributed evenly within each habitat type. Shallow areas were visually inspected for freshwater mussels and samples collected if present.

In a laboratory, a 100-organism sub sample was prepared from each composite sample by evenly distributing the whole sample in a white pan having a grid of 30 squares. A square was randomly selected using a random number generator and all organisms within the selected square were removed until 100 organisms were selected from the sample. If less than 100 organisms were found in the first square, then another square was randomly selected and so on. Each of the 100 organisms was identified using a dissecting stereomicroscope to order or a lower taxonomic level if feasible (Hafele and Hinton 2003). Remaining squares not selected were examined to determine if other species were present.

Chlorophyll-*a*

Phytoplankton was sampled by measuring chlorophyll-*a*. A 1 L water sample was taken directly over each major basin and within prominent arms or extensions of each lake. Water samples at all study lakes were taken at approximately the same time of day. The samples were collected with a Van Dorn water sampler 1 m below the surface on the last day of sampling. Each sample of lake water was run through a glass fiber filter attached to a hand vacuum pump as described by LaPerriere et al. (2003a). About 1 ml of $MgCO_3$ was added to the filter to prevent

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2 Product names used in this publication are included for scientific completeness but do not constitute product endorsement.

chlorophyll-*a* from converting to phaeophytin. The sample was wrapped in a larger paper filter (coffee filter) with a silicon gel desiccant, sealed in a plastic bag, and stored in an insulated container until it could be frozen.

In the laboratory the concentration of chlorophyll-*a* in each sample was measured using spectrophotometry following the instructions outlined in USEPA Method 446.0[3] (Arar 1997).

Zooplankton

A two-stage sampling design was used to estimate zooplankton density. Two (n) sampling sites were selected in each lake, directly over each major basin and within prominent arms or extensions (same as phytoplankton samples). These sites were the 1st stage units. At each site, two (m) tows were conducted, which were the 2nd stage units.

A 20-cm diameter conical plankton net with 153 μm mesh was used for collecting zooplankton. The net was lowered to 50 m or to just above the lake bottom and pulled vertically to the surface at a speed of 0.5 m/s. The net was rinsed by immersing it in lake water several times to just below the net collar until all contents were flushed into the net bucket. The contents were transferred into a 125 ml polyethylene bottle with 70% ETOH (procedure adopted from American Public Health Association 1992-Section 10-8).

Samples at all study lakes were taken at approximately the same time of day.

In the laboratory, zooplankton samples from each tow were diluted with tap water until approximately 100–150 organisms were present in 1ml of water. A 1ml sub sample was extracted using a Hansen-Stemple pipette following procedures outlined in Koenings et al. (1987). Zooplankton in each sub sample were transferred to a counting dish and divided into three major groups (k) (copepods, cladocerans, and rotifers) under a dissecting stereomicroscope. Copepods were identified to subclass, rotifers were identified to phylum and cladocerans to family.

Density for each major group (y_{ijk}) was calculated for the jth 2nd stage unit of the ith 1st stage unit following procedures outlined by Koenings et al. 1987:

$$y_{ijk} \quad = \quad Zooplankter_k / m^3 = \frac{n_k \times s}{v} \qquad (1)$$

where:

n_k = number of group k zooplankter per 1 ml sub sample;

s = total ml in diluted sample; and,

v = volume of water sampled (m^3) (depth of tow × area of net).

Total density (y_{ij}) was calculated for the jth 2nd stage unit of the ith 1st stage unit by summing the calculated densities for all three groups observed:

$$y_{ij} = \sum_{k=1}^{3} y_{ijk} \ . \qquad (2)$$

[3] *In Vitro* Determination of Chlorophyll-*a*, *b*, *c1+c2* and Pheopigments in Marine and Freshwater Algae by Visible Spectrophotometry

The mean total density for each 1st stage unit (sample site) was estimated (Sukhatme et al. 1984):

$$\bar{y}_i = \frac{1}{m}\sum_{j=1}^{m} y_{ij} \tag{3}$$

with sample variance

$$s_i^2 = \frac{1}{m-1}\sum_{j=1}^{m}\left(y_{ij} - \bar{y}_i\right)^2 \tag{4}$$

and sampling variance of the estimated mean

$$\hat{\text{var}}(\bar{y}_i) = \frac{1}{m} s_i^2 \tag{5}$$

The mean total density for each lake was also estimated:

$$\bar{\bar{y}} = \frac{1}{n}\sum_{i=1}^{n} \bar{y}_i \tag{6}$$

with sample variance between 1st stage units calculated

$$s_b^2 = \frac{1}{n-1}\sum_{j=1}^{m}\left(\bar{y}_i - \bar{\bar{y}}\right)^2 \tag{7}$$

When N is the total number of 1st stage units available for sampling and M is the total number of 2nd stage units available for sampling at each 1st stage unit, Sukhatme et al. (1984) provides an unbiased estimate of the sampling variance of the overall mean for the lake:

$$\hat{\text{var}}(\bar{\bar{y}}) = \left(\frac{1}{n} + \frac{1}{N}\right) s_b^2 + \frac{1}{N}\left(\frac{1}{m} + \frac{1}{M}\right) s_w^2 \tag{8}$$

where

$$s_w^2 = \frac{1}{n}\sum_{i=1}^{n} s_i^2 \tag{9}$$

Due to the logistics of sampling on the lakes, N and M are considered to be effectively ∞ so that equation (8) simplifies to

$$\hat{\text{var}}(\bar{\bar{y}}) = \frac{1}{n} s_b^2 \tag{10}$$

PHYSICAL, CHEMICAL, AND CLIMATIC FEATURES

Physical and chemical samples were collected at two stations in each lake. One station was situated at the maximum depth of each major basin present in the lake. The other station was located equal distance between the maximum depth and shore (along the long axis of the lake; Koenings et al. 1987).

A *YSI Incorporated Environmental Monitoring System 6600 Sonde* or *Hydrolab MiniSonde 4a* was used to measure temperature, pH, dissolved oxygen, percent dissolved oxygen, specific conductivity, and total dissolved solids. Readings were recorded at 0.5 m intervals from the surface down to 5 m, and then at 1 m intervals until the lake bottom was reached.

A 1 L sample of lake water was taken from a depth of 0.3m and later titrated at room temperature to determine total alkalinity.

Water transparency was measured using a Secchi disk, following methods outlined by Koenings et al. (1987).

Lake type (glacial, organically stained, or clear-water), water color (Table 2), GPS coordinates, date, time, and weather conditions (e.g., cloud cover, air temperature) were also noted at the time of sampling.

Table 2.–Descriptions of water color.

Code	Description	Definition
CLR	Clear	Transparent water, or nearly so.
FER	Ferric	Rust- (orange) stained.
GHT	Glacial, High Turbidity	High turbidity waters (visibility ≤ 30 cm (12 in) typical of streams originating directly from glaciers (e.g., Matanuska River).
GLT	Glacial, Low Turbidity	Low turbidity waters (visibility > 30 cm) typical of systems with large la (settling basins) below glacial discharge (e.g., Kenai River). These wate are frequently turquoise-colored.
HUM	Humic	Tea-colored water (tannic)
MUD	Muddy	Dark water with high suspended particulate load.

LAKE MORPHOMETRY

Position and depth data for bathymetry mapping were collected using a Lowrance LCX-15MT sonar unit equipped with a GPS receiver mounted in a small skiff. Latitude and longitude were recorded in decimal degrees to the fifth decimal place (Alaska State Plane 1 geographic projection, NAD 1927). Data were collected along multiple transects. The first transect followed the shoreline within 5 m where adequate depth allowed (>0.5 m). When shallow water was encountered (<0.5 m), data were collected further from shore until water depth was adequate to maneuver the skiff. The remaining transects were equally spaced and parallel to the long axis of each lake. The number of transects was determined by lake size. Lakes that were less than 40 ha had a minimum of 6 transects, lakes between 40 and 200 ha had a minimum of 10 transects, and lakes that were 200 to 800 ha had a minimum of 15 transects. If the lake bottom appeared to be highly variable more transects were added after the initial survey was complete. Position and depth data were recorded every 2 s and saved to a laptop computer. Lake maps were later generated using ArcGIS 9.1 and *Surfer* (Golden Software), a computer application designed to create contour and three dimension surface maps from random XYZ survey data. The algorithms and methods used to generate contour maps are described in the user's guide for *Surfer*[4]. Surface area, mean depth, maximum depth, volume, maximum length, and shoreline length were also calculated using ArcGIS.

The immediate surroundings (up to 5 m from shore) of the lake were described through visual observations. This included documenting inlets and outlets and noting the general vegetation cover as tundra, shrub (willow), deciduous, coniferous, or a combination of these types.

[4] Golden Software, Inc., 809 14th Street, Golden, Colorado 80401-1866

At each lake, a minimum of two digital photographs were taken: One photograph was taken from the south shore looking north, and one photograph was taken from the north shore looking south. Additional photographs were taken of notable habitat features or other subjects of interest at each lake.

RESULTS AND DISCUSSION

All four study lakes selected for sampling during 2005–2006 were examined; Donna Lake, Donnelly Lake, Little Donna Lake and Rainbow Lake. Three of the four study lakes selected for sampling during the 2006–2007 season were examined; Dune Lake, Triangle Lake and West Iksgiza Lake. Sampling was not conducted at Rainbow Mountain Lake due to inclement weather prohibiting aerial transport of the field crew and equipment. All four study lakes selected for sampling during 2007–2008 were examined; Birch Lake, Quartz Lake, West Twin Lake, and Wilderness Lake; however, fish sampling was not performed at Birch Lake and Quartz Lake due to recent fish stock assessments. Data pertaining to results presented in this report were archived as described in Appendix G.

SPECIES INVENTORY AND DISTRIBUTION

Fish

Both wild and stocked fish were present in lakes sampled during 2005–2008. Catches consisted primarily of stocked fish (Arctic char, Arctic grayling, and rainbow trout). Alaska blackfish *Dallia pectoralis* were captured in one lake (Triangle Lake), northern pike *Esox lucius* were captured in two lakes (West Twin Lake and Wilderness Lake), and burbot *Lota lota* were captured in one lake (West Twin Lake) (Table 3). Stocking histories for all stocked lakes sampled during 2005–2008 are listed in Appendix A. Length frequency distributions for both wild and stocked fish captured in each study lake are listed in Appendix B.

In all stocked lakes, rainbow trout were the largest species present and the most frequently captured. The largest rainbow trout were observed in Triangle, Rainbow, and Dune lakes, (Table 3) and had an average length of 356, 376, and 432 mm FL, respectively.

Large fish have been observed in Dune Lake during previous studies, but not in Triangle Lake. A mark recapture experiment conducted in 2000 at Dune Lake found rainbow trout up to 621 mm in length (Skaugstad and Fish 2002). The maximum length for fish captured in Triangle Lake during 2006 (568 mm) was greater than that observed in 2000 (325 mm) (Behr et al. 2005).

Rainbow trout in Rainbow Lake were slightly smaller than previously observed. The maximum length for fish captured in Rainbow Lake during 2004 was 500 mm (Behr and Skaugstad 2006), compared to 477 mm in 2005. Additionally, field personnel noted that 12 of the 70 fish captured in Rainbow Lake during 2005 were thinner than usual. This may suggest that food availability or other habitat factors are affecting fish growth.

Rainbow trout age cohorts could be indentified from length frequency distributions for five study lakes (Donna Lake, Donnelly Lake, Dune Lake, Triangle Lake, and West Iksgiza Lake) (Appendix B). Mean length of age-1 rainbow trout ranged from 150 mm (Dune Lake) to 268 mm (Triangle Lake). West Iksgiza Lake was first stocked in 2004 (Appendix A) and rapid growth of age-1 fish may be partially attributed to the abundance of macroinvertebrate forage species often present in fishless lakes prior to stocking.

A detailed summary and analysis of the stocked fish captured during this study can be found in Behr and Skaugstad 2006, Behr et al. *In prep*, Skaugstad et al 2010 and Skaugstad and Behr 2010.

Macrophytes

Submergent, emergent, and floating vegetation were present in all but two lakes sampled during 2005–2008. Donnelly Lake and West Twin Lake did not have floating vegetation. Rainbow Lake and Quartz Lake had the most vegetation (97% of total surface area), while Wilderness Lake had the least (15%) (Table 4). Submergent vegetation was most prevalent in six of the 11 study lakes, emergent vegetation was most prevalent in one, and floating vegetation was most prevalent in four. Pond weed *Potomogeton* spp. was the most common submergent vegetation (found in all study lakes), sedges were the most common emergent vegetation *Carex* spp. (found in all but one study lake), and yellow pond lily *Nymphaeceae nuphar* was the most common floating vegetation (found in eight of the 11 study lakes).

In the littoral zone macrophytes provide essential habitat for aquatic invertebrates and juvenile fishes. This is the most productive and important part of a lake (Holdren et al. 2001). In Central Ontario lakes researchers found a correlation between the abundance of pumpkinseed and bluegill (*Lepomis*) fishes and nearshore macrophyte cover (Hinch and Collins 1993). Perhaps a similar correlation exists between macrophyte cover and fish growth. Historically large fish have been caught in Rainbow, Dune, and Quartz lakes. In this study, Rainbow Lake was one of the study lakes with the most macrophyte coverage, and, although distinct age classes is unclear from the length frequency histogram, the age-1 and age-6 fish had the second largest average length of rainbow trout. It is unclear how macrophyte coverage influenced average fish length in Dune Lake. Age-1 rainbow trout in Dune Lake were not as large when compared to the other study lakes, but had the greatest average length of all age classes combined. In order to better understand the influence macrophyte coverage has on fish length, a separate study will need to be conducted.

Macroinvertebrates

Macroinvertebrate orders identified in lakes sampled during 2005–2008 are summarized in Table 5 and Appendix C. Ten unique macroinvertebrate orders were identified in three of the 11 study lakes (Donna Lake, Rainbow Lake, and West Iksgiza) (Table 5). Caddis flies Tricoptera, damselflies Odonata Zygoptera, mayflies Ephemeroptera, midges Diptera *Chironomidae*, mussels and clams Bivalvia, segmented worms Annelida, snails Gastropoda, and water mites Acari were present in all study lakes (Appendix C). Midges were most prevalent in all samples except those collected from West Twin Lake. Dragonflies Odonata Anisoptera were present in all but one study lake (West Twin Lake) and scuds Amphipoda were present in all but one study lake (Donnelly Lake).

No apparent trends were observed in macroinvertebrate orders present; however, midges dominated most samples. This supports previous findings in which chironomids were found to be an abundant group “that dominates aquatic macroinvertebrate assemblages in the north” (Nyman and Korhola 2005). Chironomids have also been used to categorize lake trophic status (LaPerriere 1975; Saether 1979), and specific species of chironomids, in conjunction with other lake parameters, have been found to be indicators for trophic status (e.g., eutrophic, oligotrophic) (Saether 1979; Brodersen et al. 2001). Although detailed analyses were not preformed during this study, collected data did indicate that on average more invertebrate orders were identified in summer samples than in fall samples.

Table 3.–Species, number, length range, and average length for fish captured during 2005–2008 sampling.

Fish: common name	scientific name	Donna Lake	Donnelly Lake	Little Donna Lake	Rainbow Lake	Dune Lake	Triangle Lake	West Iksgiza Lake	Birch Lake [b]	Quartz Lake [b]	West Twin Lake	Wilderness Lake
Alaska blackfish[a]	*Dallia pectoralis*											
	number captured	-	-	-	-	-	6	-	-	-	-	-
	min length (mm)	-	-	-	-	-	42	-	-	-	-	-
	max length (mm)	-	-	-	-	-	95	-	-	-	-	-
	average length (mm)	-	-	-	-	-	64	-	-	-	-	-
Arctic char	*Salvelinus alpinus*											
	number captured	-	13	-	-	-	-	-	-	-	-	-
	min length (mm)	-	151	-	-	-	-	-	-	-	-	-
	max length (mm)	-	376	-	-	-	-	-	-	-	-	-
	average length (mm)	-	268	-	-	-	-	-	-	-	-	-
Arctic grayling	*Thymallus arcticus*											
	number captured	-	-	-	-	399	-	-	-	-	-	-
	min length (mm)	-	-	-	-	306	-	-	-	-	-	-
	max length (mm)	-	-	-	-	512	-	-	-	-	-	-
	average length (mm)	-	-	-	-	394	-	-	-	-	-	-
burbot[a]	*Lota lota*											
	number captured	-	-	-	-	-	-	-	-	-	6	-
	min length (mm)	-	-	-	-	-	-	-	-	-	92	-
	max length (mm)	-	-	-	-	-	-	-	-	-	105	-
	average length (mm)	-	-	-	-	-	-	-	-	-	98	-
northern pike	*Esox lucius*											
	number captured	-	-	-	-	-	-	-	-	-	3	2
	min length (mm)	-	-	-	-	-	-	-	-	-	114	367
	max length (mm)	-	-	-	-	-	-	-	-	-	713	371
	average length (mm)	-	-	-	-	-	-	-	-	-	326	369
rainbow trout	*Oncorhynchus mykiss*											
	number captured	122	120	43	70	569	15	150	-	-	-	-
	min length (mm)	166	81	145	226	108	241	184	-	-	-	-
	max length (mm)	415	383	462	477	656	568	468	-	-	-	-
	average length (mm)	273	184	325	376	432	356	277	-	-	-	-

[a] Total length listed.

[b] Fish sampling was not performed at Birch Lake or Quartz Lake due to recent fish stock assessments.

Table 4.–Macrophytes present and percent coverage of submergent, emergent, and floating vegetation for lakes sampled during 2005–2008.

Macrophytes			Donna Lake	Donnelly Lake	Little Donna Lake	Rainbow Lake	Dune Lake	Triangle Lake	West Iksgiza Lake	Birch Lake	Quartz Lake	West Twin Lake	Wilderness Lake
common name	family	genus	macrophytes present (marked with X) and % surface area coverage[a]										
submergent			14%	20%	11%	60%	19%	21%	40%	11%	17%	8%	1%
bladderwort	Lentibulariaceae	*Utricularia*	-	-	-	-	-	X	-	-	-	-	-
hornwort/coontai	Ceratophyllaceae	*Ceratophyllum*	-	-	-	-	X	-	-	X	X	-	-
pond weed	Potamogeton	multiple	X	X	X	X	X	X	X	X	X	X	X
water milfoil	Haloragaceae	*Myriophyllum*	-	-	-	-	X	-	X	-	-	X	-
emergent			13%	11%	13%	24%	5%	7%	12%	5%	12%	9%	6%
bur reed	Spaganiaceae	*Sparganium*	X	-	X	-	-	-	X	-	-	-	-
cattail	Typhaceae	*Typha*	-	-	-	-	X	-	-	-	-	-	-
creeping spike ru	Cyperaceae	*Eleocharis*	-	-	-	-	X	-	-	-	-	-	-
Iris			-	-	-	-	-	-	-	X	-	-	-
knotted rush	Juncaceae	*Juncus*	-	-	-	-	-	-	X	-	-	-	-
mare's tail	Haloragaceae	*Hippuris*	X	-	X	-	-	-	-	-	X	X	X
rushes	Juncaceae	multiple	-	-	-	-	-	-	-	-	X	X	X
sedge	Carex	multiple	X	X	X	X	X	X	X	X	X	-	X
vernal water-star	Callitriche	Verna	-	-	-	-	-	-	-	X	-	-	-
floating			10%	0%	15%	13%	5%	9%	15%	15%	68%	0%	8%
yellow pond lily	Nymphaeaceae	*Nuphar*	X	-	X	X	X	-	X	X	X	-	X
water smartweed	Polygonaceae	*Polygonum*	-	-	-	X	X	X	-	-	X	-	X
white water-lily	Nymphaeaceae	*Nymphaea*	-	-	-	-	-	X	-	-	-	-	-
TOTAL % coverage			37%	31%	39%	97%	29%	37%	67%	31%	97%	17%	15%

[a] Percent of total lake surface area covered in submergent, ermergent, or floating vegetation.

Table 5.–Number of macroinvertebrate orders identified in submergent, emergent, and floating vegetation for lakes sampled during 2005–2008.

Macroinvertebrates		Donna Lake	Donnelly Lake	Little Donna Lake	Rainbow Lake	Dune Lake	Triangle Lake	West Iksgiza Lake	Birch Lake	Quartz Lake	West Twin Lake	Wilderness Lake
habitat	season	number of orders present in samples										
submergent	summer	9	4	6	7	7	6	7	7	7	8	8
	fall	5	4	5	7	-[b]	7	8	6	5	6	8
emergent	summer	9	7	9	9	7	7	10	7	7	8	8
	fall	8	4	6	8	-[b]	7	8	7	5	7	7
floating	summer	10	-[a]	6	5	9	7	6	7	8	-[a]	8
	fall	5	-[a]	5	7	-[b]	7	8	7	6	-[a]	9
Total unique orders identified		10	7	9	10	9	7	10	9	8	8	9

[a] No floating vegetation present in lake.

[b] Sampling was not conducted in September because aircraft and field personnel were not available.

Chlorophyll-*a*

Chlorophyll-*a* concentrations were calculated for eight of the 11 study lakes (Table 6). Samples collected in 2006 were filtered and stored at the Fairbanks ADF&G office, but mistakenly discarded during laboratory cleaning. Average chlorophyll-*a* concentrations ranged from 1.14 mg/m^3 (Donna Lake and Little Donna Lake) to 3.18 mg/m^3 (Birch Lake) (Table 6). Rainbow Lake had the highest July concentration (2.05 mg/m^3) and Donna Lake and Little Donna Lake had the lowest (1.14 mg/m^3). Birch Lake had the highest September concentration (3.14 mg/m^3) and Little Donna Lake had the lowest (1.15 mg/m^3). No apparent trends were observed between July and September sampling in all study lakes.

Zooplankton

Copepoda, Cladocera, and Rotifera were found in all 11 lakes sampled during 2005–2008 (Table 7). Total zooplankton sample densities (plankters/m^3) ranged from 204 (Wilderness Lake) to 2,124 (Donnelly Lake) during summer sampling, and from 213 (Wilderness Lake) to 956 (Donnelly Lake) during fall sampling. Copepods were most prevalent in samples collected from eight of the 11 lakes sampled during summer and most prevalent in eight of the 10 lakes sampled during fall. Cladocerans were most prevalent in samples collected from Donnelly Lake during both summer and fall. Rotifers were most prevalent in West Iksgiza Lake and Birch Lake samples collected during the summer, and in Little Donna Lake samples collected in the fall. No trends were apparent between sample stations or within sample lakes and observed zooplankton densities varied greatly (Table 7 and Appendix D). This could be attributed to poor zooplankton density estimates and variances from a small samples size.

Previous studies have found that copepods usually outnumber cladocerans in unproductive lakes (Horne and Goldman 1994). Donnelly Lake and West Iksgiza Lake were the only two sample locations in which copepods did not dominate fall and/or summer samples (Table 7). Donnelly Lake had the least growth of age-1 rainbow trout and West Iksgiza had the second highest growth observed, which is somewhat inconsistent. Because of a small sample size, estimates are poor, so conclusions drawn from comparisons are to be heeded. With that in mind, it is interesting to note, Donnelly Lake had over two times the density of zooplankton than any other study lake.

West Iksgiza Lake was the only lake in which rotifers were dominant. Of the stocked lakes sampled (West Twin Lake and Wilderness Lake are not stocked), West Iksgiza Lake has been stocked the shortest time. The dominance of this assemblage in a relatively new stocked lake, and the lower densities in established stocked lakes, may indicate that stocked rainbow trout target this assemblage first.

PHYSICAL, CHEMICAL, AND CLIMATIC FEATURES

Temperature, pH, dissolved oxygen, percent dissolved oxygen, specific conductivity, and total dissolved solids were measured along depth profiles for each study lake sampled during 2005–2008. Table 8 lists ranges for these and other parameters including alkalinity, Secchi reading, and water color. Physical and chemical properties of each lake were recorded during three different visits (July, September, and March). Appendix E lists temperature and dissolved oxygen profiles observed during these sampling events for measurements from the deepest basin. Although this approach provides a general picture of seasonal lake conditions, it does not capture daily fluctuations.

Table 6.–Average chlorophyll-*a* concentration (mg/m^3) for samples collected during 2005–2008.

Chlorophyll-a (average mg/m^3)	Donna Lake	Donnelly Lake	Little Donna Lake	Rainbow Lake	Dune Lake	Triangle Lake	West Iksgiza Lake	Birch Lake	Quartz Lake	West Twin Lake	Wilderness Lake
July	1.14	1.60	1.14	2.05	-[a]	-[a]	-[a]	1.18	1.96	1.45	1.47
September	1.48	1.37	1.15	2.05	-[a]	-[a]	-[a]	3.18	1.54	1.96	2.47

[a] Samples in 2006 were collected, filtered, and stored at the Fairbanks ADF&G office. Samples were mistakenly discarded during laboratory cleaning and could not be analyzed.

Table 7.–Average zooplankton density (plankters/m3) for samples collected during 2005–2008.

Zooplankton		Donna Lake	Donnelly Lake	Little Donna Lake	Rainbow Lake	Dune Lake	Triangle Lake	West Iksgiza Lake	Birch Lake	Quartz Lake	West Twin Lake	Wilderness Lake
group	season	average density (plankters/m^3)										
copepods	summer	203	949	255	270	812	217	54	70	378	453	187
	fall	343	233	70	569	-[a]	311	425	408	287	285	162
cladocerans	summer	66	1,174	37	22	1	10	112	113	83	155	1
	fall	104	457	113	57	-[a]	3	5	184	176	169	0
rotifers	summer	44	0	252	75	5	53	606	175	55	295	16
	fall	116	266	175	86	-[a]	5	357	303	195	236	51
TOTAL	summer	312	2,124	544	367	818	280	772	358	517	903	204
	fall	563	956	358	711	-[a]	319	787	894	658	690	213

[a] Sampling was not conducted in September because aircraft and field personnel were not available.

Table 8.–Physical and chemical features for lakes sampled during 2005–2008. Data ranges reported for water color, Secchi, alkalinity, conductivity, pH, and TDS summarize readings made in summer and fall. Data ranges reported for temperature and DO summarize seasonal profiles.

Physical and Chemical Features	Donna Lake	Donnelly Lake	Little Donna Lake	Rainbow Lake	Dune Lake	Triangle Lake	West Iksgiza Lake	Birch Lake	Quartz Lake	West Twin Lake	Wilderness Lake
water color	clear	clear	clear	clear	clear	clear	humic	clear	clear	clear	stained
Secchi reading (m)	2.9-3.45	4.0-8.1	3.05-5.4	2.65-3.95	2.75	2.75-3.13	2.63-2.88	3.25-5.1	2.38-4.75	4.75-6.75	2.75-4.375
alkalinity (mg/L $CaCO^{3}$)	33-38	14	15-16	29-36	-[a]	-	-	58-70	262-348	56-66	13-22
conductivity (mS/cm)	0.067-0.115	0.022-0.320	0.038-0.095	0.063-0.104	0.152-0.196	0.039-0.094	0.058-0.085	0.127-0.275	0.495-0.842	0.109-0.125	0.026-0.036
pH	6.35-7.46	6.64-8.23	6.15-7.23	6.23-7.60	7.16-8.78	6.45-7.75	6.36-8.00	7.02-8.83	7.54-8.94	7.21-9.13	6.55-8.22
TDS (ppm)	0.036-0.075	0.014-0.035	0.022-0.046	0.041-0.068	0.098-0.125	0.023-0.600	0.037-0.065	0.081-0.176	0.317-0.541	0.070-0.081	0.019-0.020
temperature range (°C)											
summer	6.28-20.33	10.76-17.55	6.76-19.48	5.51-19.16	10.73-18.33	4.96-19.78	3.85-22.28	4.32-22.08	7.06-26.41	5.67-20.25	7.37-21.77
fall	6.54-9.73	6.20-6.32	8.95-9.20	5.90-11.20	-[a]	5.12-11.84	4.11-11.46	5.2-11.9	9.95-10.75	4.49-16.42	7.71-16.77
winter	1.67-3.84	0.59-4.49	2.50-4.50	1.73-3.26	0.02-4.37	0.90-3.80	0.00-3.50	1.94-3.78	2.85-3.48	1.29-3.13	2.12-3.96
DO range (mg/L)											
summer	2.50-9.63	6.39-8.18	4.37-8.80	0.40-7.70	0.25-9.69	2.16-9.45	0.14-9.38	0.66-10.93	0.13-9.38	9.35-12.61	2.64-9.24
fall	0.23-9.07	10.03-10.26	8.95-9.69	-	-[a]	0.81-12.5	0.29-11.92	0.45-9.08	9.01-9.82	3.11-10.2	1.02-9.18
winter	4.38-8.56	0.6-12.88	1.37-8.81	5.04-10.48	1.52-10.23	5.3-12.54	4.47-8.15	1.37-10.06	0.53-5.79	6.01-12.78	8.30-10.54

[a] Sampling was not conducted in September because aircraft and field personnel were not available.

Alkalinity ranged from 13 mg/L at Wilderness Lake to 348 mg/L at Quartz Lake, Secchi readings ranged from 2.38 m at Quartz Lake to 8.1 m at Donnelly Lake, and conductivity ranged from 0.022 in Donnelly Lake to 0.842 in Quartz Lake (Table 8).

In general, seasonal temperature and dissolved oxygen profiles observed during this study were consistent with previous findings. Thermal stratification was observed during summer sampling in all study lakes and thermoclines ranged in depth from 2 to 3 m at West Iksgiza Lake to 8 m at Donnelly Lake and West Twin Lake. Fall profiles indicated that complete mixing had occurred in Donnelly Lake, Little Donna Lake, and Quartz Lake. All other fall profiles indicated thermoclines deeper than those observed during summer sampling. A reverse thermal profile, where cool temperatures are near the surface and warmer temperatures are at the lake bottom, and smaller temperature range were present during winter sampling for all study lakes. These were found at 3.5 to 4 m in West Iksgiza Lake and 8 m in Donna Lake. This is typical of lakes in cold climates that have ice covering the entire lake surface, usually permanently throughout the season (Horne and Goldman 1994).

Dissolved oxygen concentrations decreased with depth during summer, fall, and winter sampling; however, dissolved oxygen concentrations within Donnelly Lake, Little Donna Lake, and Quartz Lake showed little change with depth during fall indicating that complete mixing had occurred. Donnelly Lake, Little Donna Lake, Birch Lake, and West Twin Lake had unique summer dissolved oxygen profiles showing highest concentrations near the thermocline and decreasing concentrations with increasing distance above and below the thermocline. This could be a result of input from stream water or a natural spring (Horne and Goldman 1994). However, Donnelly Lake and Little Donna Lake had no inlets and dissolved oxygen readings were taken from the middle of the lake. Another explanation is solubility of oxygen in water depends upon the water temperature and pressure. Cooler temperatures and higher pressure tend to result in higher dissolved oxygen levels (Wetzel 1975; Horne and Goldman 1994). This means that water above the thermocline was not able to hold as much dissolved oxygen because the temperature was higher and pressure was lower. Quartz Lake displayed a unique dissolved oxygen profile in March. A spike of about 4 mg/L of dissolved oxygen was observed near 8 m below the surface. Similar results were found on Quartz Lake during 2000 and 2001 (Cal Skaugstad, ADF&G fisheries biologist, Fairbanks, Alaska, personal communication,).

In northern latitude lakes, extended periods of ice and snow cover can reduce the contribution of oxygen by photosynthetic organisms and prolong the depletion of oxygen by decomposers (Wetzel 1975; Horne and Goldman 1994; Danylchuk and Tonn 2003; LaPerriere et al. 2003a). These conditions increase the likelihood of winterkill when fish die due to low levels of dissolved oxygen. Low dissolved oxygen levels can have either a positive or negative impact on invertebrate abundance and community structure during this time. Insects may be directly affected and die due to low oxygen levels, or indirectly affected by a reduction in the number of fish that prey on them (Tonn et al. 2004). Although dissolved oxygen profiles did not indicate a winterkill event, it could become a potential problem for lakes similar to Quartz Lake where aquatic vegetation covers approximately 97% of the lake (Table 4).

High temperatures and low dissolved oxygen levels can approach and may possibly exceed critical limits for some aquatic species during summer months. Upper thermal critical limits for rainbow trout (>24°C; Bear et al. 2007) were not exceeded in any of the study lakes, although several lakes had surface temperatures that reached 20°C in July. The dissolved oxygen lower critical limit for rainbow trout (<3 mg/L DO; Dean and Richardson 1999) was exceeded in all but one study lake for at least one of the sampling months. These low dissolved oxygen readings occurred most often at the deepest portions of the lake, with acceptable dissolved oxygen levels present higher in the water column.

Climatic observations were also noted during each sampling event, summarized, and archived with limnological data (Appendix G).

LAKE MORPHOMETRY

Each lake bottom was mapped with a GPS and sonar unit to collect depth data. These data were converted to bathymetric maps. Lake maps are being stored at the regional office and are available to the public (Appendix F). Table 9 summarizes surface area (ha), elevation (m), and maximum depth (m) for each study lake. Surrounding riparian and upland descriptions (vegetation, inlets/outlets, and shore development) are summarized in Table 10.

Lake level appeared to have dropped in Rainbow Lake and Donnelly Lake. Aerial views of Rainbow Lake revealed a prevalent treeless perimeter with sedges in dry areas outlining the previous water level. Earlier bathymetric maps of Donnelly Lake show the water level higher than that observed during 2005. The photographs taken at each study lake were archived as described in Appendix G.

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April Behr, Jessica Mitchell, Jake Hughes, and Nadine Carroll assisted with the field work. William Morris assisted with chlorophyll samples, and Brian Taras and Anton Antonovich provided biometric review.

Table 9.–Morphometry of lakes sampled during 2005-2008.

Morphometry	Donna Lake	Donnelly Lake	Little Donna Lake	Rainbow Lake	Dune Lake	Triangle Lake	West Iksgiza Lake	Birch Lake	Quartz Lake	West Twin Lake	Wilderness Lake
surface area (ha)	23.5	19.0	18.0	35.0	76.5	44.0	25.5	315.0	584.0	683.0	79.0
elevation (m)	506	739	493	339	134	160	172	251	293	228	208
max depth (m)	10	12	7	9	8	13	10	14	13	34	21
mean depth (m)	9.6	8.6	6.9	5.5	4.4	6.6	7.2	10.3	10.4	21.5	16.1
shoreline length (m)	2380	2798	1835	2302	4073	2582	1953	8316	10399	10768	3642
max length (m)	869	543	688	834	1753	946	745	2820	3155	4050	1497
volume (m^3)	2261488	1631638	1248485	1941111	3338784	2910962	1840742	32531521	60672867	147033043	12733538

Table 10.–Surrounding riparian and upland description for lakes sampled during 2005–2008.

Riparian and Upland Description	Donna Lake	Donnelly Lake	Little Donna Lake	Rainbow Lake	Dune Lake	Triangle Lake	West Iksgiza Lake	Birch Lake	Quartz Lake	West Twin Lake	Wilderness Lake
inlets	none	none	none	none	none	none	1	2	1	1	none
outlets	none	none	none	none	none	none	none	1	none	1	none
grasses	-	X	X	X	X	X	X	X	X	X	X
shrubs	X	X	-	X	-	X	X	X	X	X	X
spruce	X	X	X	X	X	-	X	X	X	X	X
birch	-	-	-	X	X	-	-	X	-	X	X
forest fire in watershed	none	none	none	yes	none	none	none	none	none	none	none
access											
road	-	-	-	-	-	-	-	X	X	-	-
summer trail	X	X	X	-	-	-	-	-	-	-	-
winter trail	X	X	X	X	X	X	X	-	-	X	-
aerial	-	-	-	X	X	X	-	-	-	X	X
development	tent	none	none	1 cabin	cabins	none	cabins	cabins	cabins	cabins	3 cabins

Note:"X" refers to presence at the site.

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APPENDIX A
LAKE STOCKING HISTORIES

Appendix A1.–Stocking histories of currently stocked lakes (1999–2007) and one historically stocked lake (1989) sampled during 2005–2008.

Lake	Species	Date	Number	Avg. Length (mm)
Donna L	RT	7/26/1999	11,488	57
Donna L	RT	8/3/2001	7,600	47
Donna L	RT	8/20/2003	7,600	54
Donna L	RT	7/14/2004	7,600	52
Donna L	RT	8/21/2006	7,600	50
Donnelly L	RT	8/9/1999	13,278	59
Donnelly L	AC	9/22/1999	4,939	115
Donnelly L	RT	8/1/2000	13,000	50
Donnelly L	RT	8/14/2002	11,522	53
Donnelly L	RT	8/17/2004	6,513	58
Donnelly L	RT	8/28/2006	6,141	53
Little Donna L	RT	7/26/1999	6,000	57
Little Donna L	RT	8/3/2001	4,000	47
Little Donna L	RT	8/20/2003	4,000	54
Little Donna L	RT	7/14/2004	4,000	52
Little Donna L	RT	8/21/2006	4,000	50
Rainbow L	RT	7/26/1999	7,000	57
Rainbow L	RT	8/8/2001	8,600	49
Rainbow L	RT	7/14/2004	12,000	52
Rainbow L	RT	7/1/2006	2,000	100
Rainbow L	RT	7/6/2006	2,000	100
Rainbow L	RT	9/5/2006	12,500	52
Dune L	RT	7/22/1999	10,000	54
Dune L	SS	6/27/2000	8,836	79
Dune L	GR	8/29/2000	10,794	53
Dune L	RT	8/29/2000	5,009	74
Dune L	RT	8/3/2001	15,000	47
Dune L	RT	8/6/2001	15,000	47
Dune L	SS	7/9/2002	3,000	74
Dune L	GR	7/9/2002	10,000	24
Dune L	GR	8/6/2003	9,000	47
Dune L	RT	8/6/2003	10,016	49
Dune L	GR	7/29/2004	10,000	44
Dune L	SS	6/24/2004	3,962	64
Dune L	RT	8/3/2005	11,000	45
Dune L	GR	7/18/2006	5,495	33
Dune L	SS	7/18/2006	6,199	56
Dune L	GR	8/15/2007	10,000	57
Dune L	RT	8/15/2007	20,000	47
Triangle L	RT	7/22/1999	10,133	54
Triangle L	RT	8/6/2001	10,000	47
Triangle L	RT	8/6/2003	10,001	49
Triangle L	RT	8/3/2005	10,000	45
Triangle L	RT	8/15/2007	10,000	47

-continued-

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Lake	Species	Date	Number	Avg. Length (mm)
West Iksgiza (Gap L)	RT	7/29/2004	10,033	47
West Iksgiza (Gap L)	RT	9/13/2005	10,796	62
Birch L	RT	6/1/1999	16,849	156
Birch L	SS	6/1/1999	24,666	136
Birch L	RT	6/30/1999	1,981	202
Birch L	AC	9/29/1999	2,360	117
Birch L	AC	9/29/1999	11,712	118
Birch L	RT	7/21/1999	9,580	145
Birch L	SS	9/8/1999	24,306	136
Birch L	GR	5/18/2000	4,181	180
Birch L	RT	5/18/2000	13,322	208
Birch L	RT	7/6/2000	2,778	202
Birch L	SS	7/20/2000	27,471	93
Birch L	SS	8/3/2000	15,365	97
Birch L	RT	5/29/2001	16,468	214
Birch L	GR	6/19/2001	4,148	172
Birch L	AC	8/31/2001	7,034	108
Birch L	SS	6/13/2002	40,000	72
Birch L	GR	6/13/2002	5,000	176
Birch L	RT	6/13/2002	8,278	217
Birch L	KS	9/17/2002	8,895	176
Birch L	KS	10/23/2002	3,020	203
Birch L	RT	5/22/2003	5,886	228
Birch L	AC	5/22/2003	6,261	222
Birch L	RT	5/30/2003	2,631	238
Birch L	RT	7/2/2003	2,027	235
Birch L	GR	8/20/2003	7,500	53
Birch L	KS	9/18/2003	9,926	186
Birch L	RT	5/25/2004	3,833	214
Birch L	RT	5/26/2004	4,788	226
Birch L	RT	8/26/2004	1,013	254
Birch L	KS	9/20/2004	10,550	193
Birch L	RT	2/10/2004	290	249
Birch L	AC	5/13/2005	5,982	222
Birch L	RT	5/13/2005	4,886	216
Birch L	RT	5/13/2005	3,497	211
Birch L	KS	9/22/2005	10,977	206
Birch L	RT	4/21/2006	25,313	93
Birch L	RT	5/25/2006	4,494	262
Birch L	RT	8/16/2007	93,981	46
Birch L	RT	8/21/2007	12,247	50
Birch L	AC	8/23/2007	7,390	95
Birch L	GR	9/13/2007	23,235	67
Birch L	RT	3/10/2008	22,933	122
Quartz L	SS	6/3/1999	78,727	77

-continued-

Lake	Species	Date	Number	Avg. Length (mm)
Quartz L	RT	8/25/1999	647	159
Quartz L	AC	8/25/1999	11,047	102
Quartz L	RT	7/26/1999	228	57
Quartz L	RT	7/27/1999	294,593	57
Quartz L	RT	10/11/1999	50,172	83
Quartz L	SS	6/12/2000	84,321	78
Quartz L	SS	8/3/2000	14,978	97
Quartz L	RT	8/3/2000	66,369	50
Quartz L	RT	8/3/2000	286,362	57
Quartz L	KS	9/22/2000	10,000	187
Quartz L	RT	6/11/2001	2,507	211
Quartz L	RT	6/11/2001	2,500	215
Quartz L	SS	6/11/2001	58,000	69
Quartz L	RT	6/11/2001	85	293
Quartz L	RT	6/28/2001	2,745	208
Quartz L	RT	7/5/2001	2,705	207
Quartz L	RT	7/5/2001	6,982	207
Quartz L	RT	8/8/2001	78,705	50
Quartz L	RT	8/8/2001	146,884	50
Quartz L	RT	8/8/2001	46,772	52
Quartz L	AC	8/31/2001	9,065	108
Quartz L	RT	8/31/2001	27,775	66
Quartz L	RT	8/31/2001	13,108	66
Quartz L	RT	6/3/2002	6,682	197
Quartz L	RT	6/13/2002	2,883	192
Quartz L	RT	6/27/2002	7,005	236
Quartz L	RT	8/14/2002	85,726	52
Quartz L	RT	8/14/2002	167,767	54
Quartz L	RT	8/14/2002	75,674	53
Quartz L	AC	9/4/2002	6,285	94
Quartz L	RT	5/27/2003	13,294	196
Quartz L	SS	6/3/2003	61,826	69
Quartz L	RT	6/25/2003	1,590	203
Quartz L	RT	7/9/2003	2,952	203
Quartz L	RT	7/9/2003	2,755	233
Quartz L	RT	8/20/2003	76,712	57
Quartz L	RT	9/23/2003	14,387	83
Quartz L	RT	9/23/2003	13,516	62
Quartz L	RT	9/23/2003	821	58
Quartz L	RT	7/19/2004	51,746	52
Quartz L	RT	6/22/2004	2,000	218
Quartz L	RT	5/14/2004	6,291	217
Quartz L	SS	5/14/2004	30,407	62
Quartz L	SS	5/28/2004	2,782	61
Quartz L	RT	6/4/2004	9,519	212

-continued-

Lake	Species	Date	Number	Avg. Length (mm)
Quartz L	RT	8/17/2004	60,071	56
Quartz L	AC	8/19/2004	9,504	70
Quartz L	RT	8/26/2004	75,196	61
Quartz L	RT	8/26/2004	49,397	61
Quartz L	KS	9/22/2004	5,000	198
Quartz L	RT	11/3/2004	318	194
Quartz L	RT	11/3/2004	11,000	69
Quartz L	RT	9/30/2004	27,166	71
Quartz L	RT	9/30/2004	7,664	61
Quartz L	RT	9/30/2004	438	-
Quartz L	RT	1/25/2005	3,846	92
Quartz L	RT	9/21/2005	8,245	67
Quartz L	RT	9/21/2005	3,691	62
Quartz L	RT	2/11/2005	3,693	93
Quartz L	SS	6/8/2005	29,615	49
Quartz L	RT	5/27/2005	3,000	209
Quartz L	RT	5/27/2005	13,889	211
Quartz L	AC	8/24/2005	9,536	93
Quartz L	RT	8/16/2005	41,724	52
Quartz L	RT	8/16/2005	26,962	51
Quartz L	RT	8/16/2005	15,823	50
Quartz L	RT	9/13/2005	19,133	62
Quartz L	RT	4/21/2006	15,122	93
Quartz L	RT	4/21/2006	21,670	87
Quartz L	RT	6/6/2006	8,742	237
Quartz L	SS	6/14/2006	84,168	48
Quartz L	RT	7/6/2006	39,504	100
Quartz L	RT	3/23/2007	1,420	156
Quartz L	RT	3/23/2007	3,339	123
Quartz L	RT	3/28/2007	4,145	123
Quartz L	RT	3/29/2007	4,099	123
Quartz L	RT	3/30/2007	4,147	123
Quartz L	RT	4/2/2007	1,202	156
Quartz L	RT	4/2/2007	2,857	123
Quartz L	RT	4/3/2007	3,422	123
Quartz L	RT	4/25/2007	12,670	156
Quartz L	RT	5/24/2007	9,370	151
Quartz L	RT	5/30/2007	15,750	139
Quartz L	AC	6/12/2007	2,925	188
Quartz L	SS	6/18/2007	35,555	54
Quartz L	SS	6/19/2007	53,161	62
Quartz L	AC	8/23/2007	9,586	74
Quartz L	RT	9/13/2007	30,968	60
Quartz L	RT	9/13/2007	120,170	55
Quartz L	RT	9/13/2007	142,349	55

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Appendix A1.–Page 5 of 5.

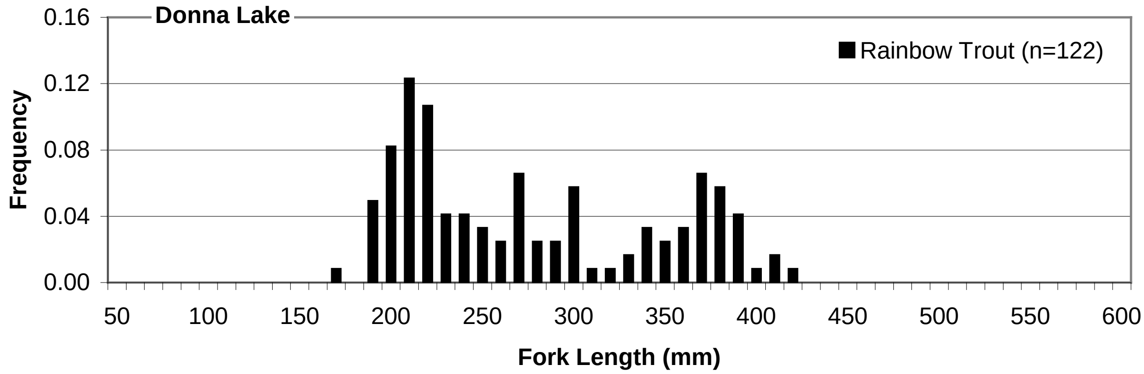
Lake	Species	Date	Number	Avg. Length (mm)
West Twin L	LT	8/28/1989	5,952	128
West Twin L	LT	8/31/1989	4,986	128
West Twin L	LT	8/29/1989	7,936	128
West Twin L	LT	8/16/1989	6,702	124

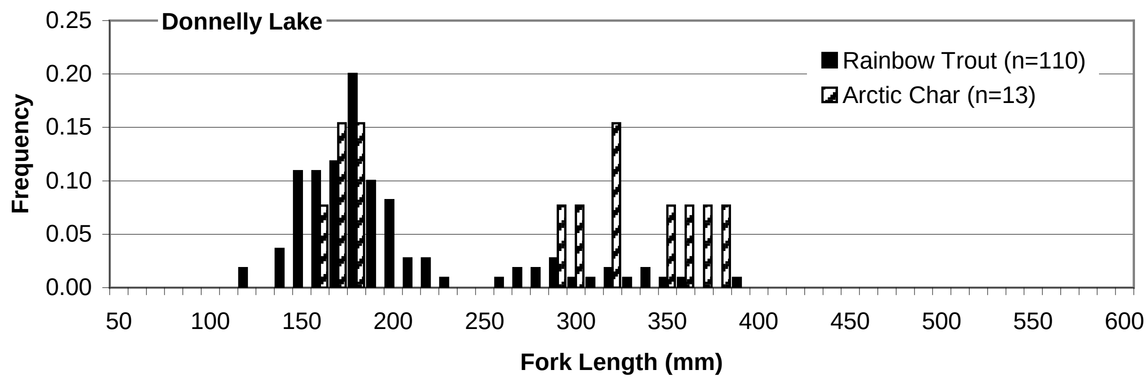
Note: Abbreviations used in this table:

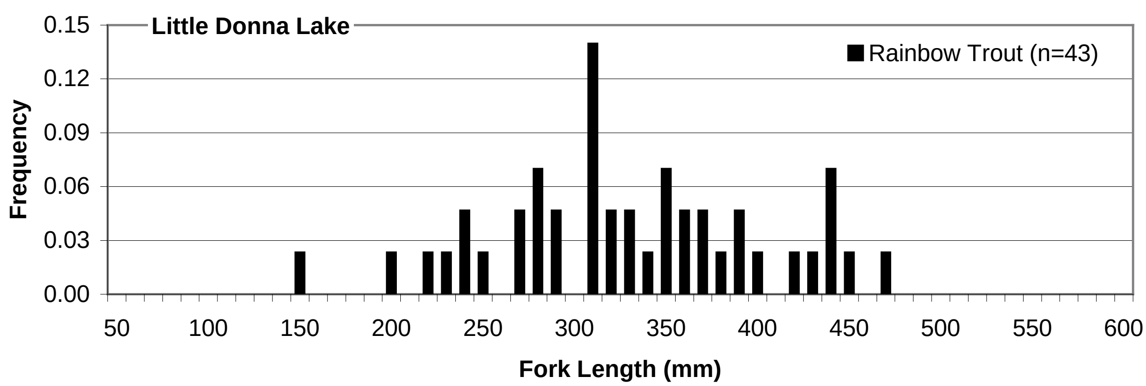
AC	Arctic char	*Salvelinus alpinus*
GR	Arctic grayling	*Thymallus arcticus*
KS	Chinook salmon	*Oncorhynchus tshawytscha*
RT	rainbow trout	*Oncorhynchus mykiss*
SS	coho salmon	*Oncorhynchus kisutch*

APPENDIX B
FISH LENGTH FREQUENCY DISTRIBUTIONS

Appendix B1.–Length frequency distributions for fish captured in lakes sampled during 2005–2008.







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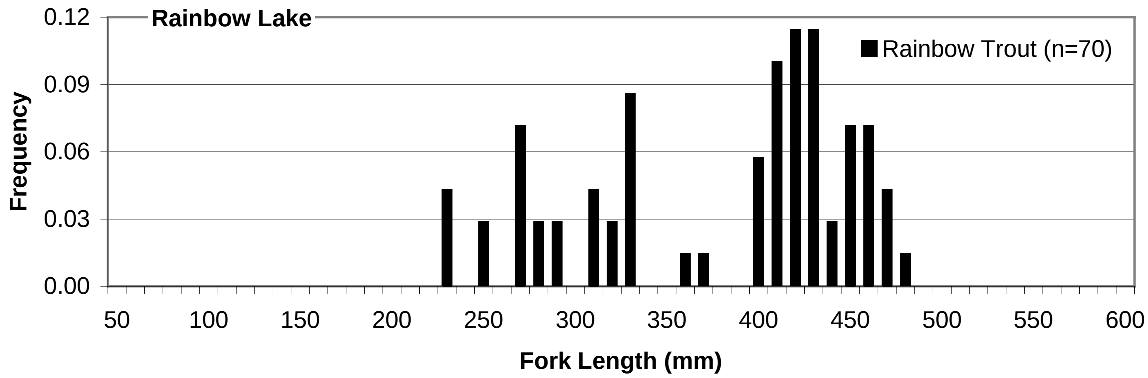
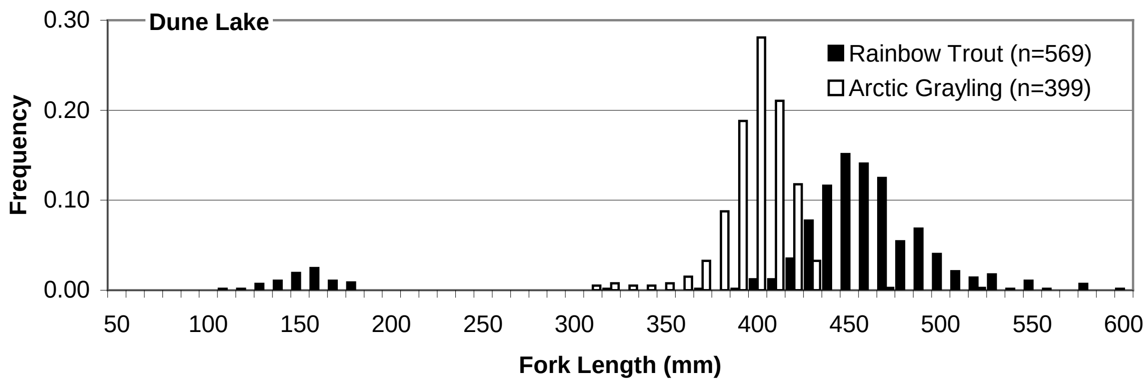
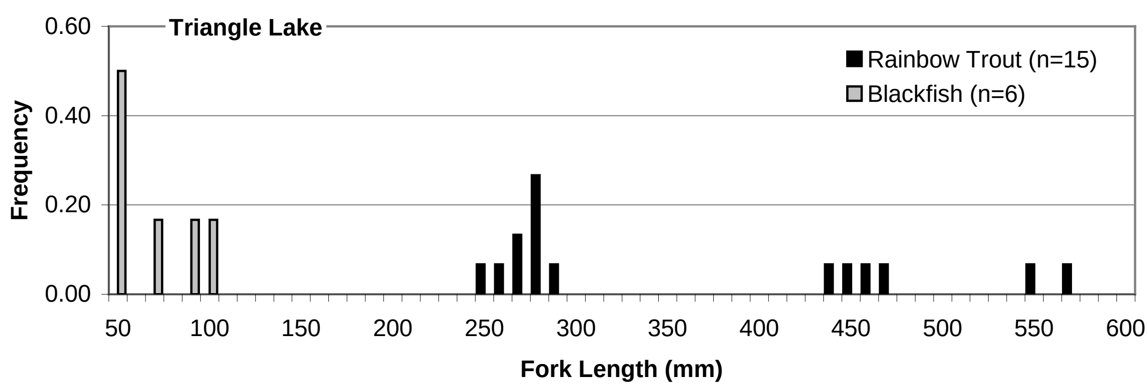
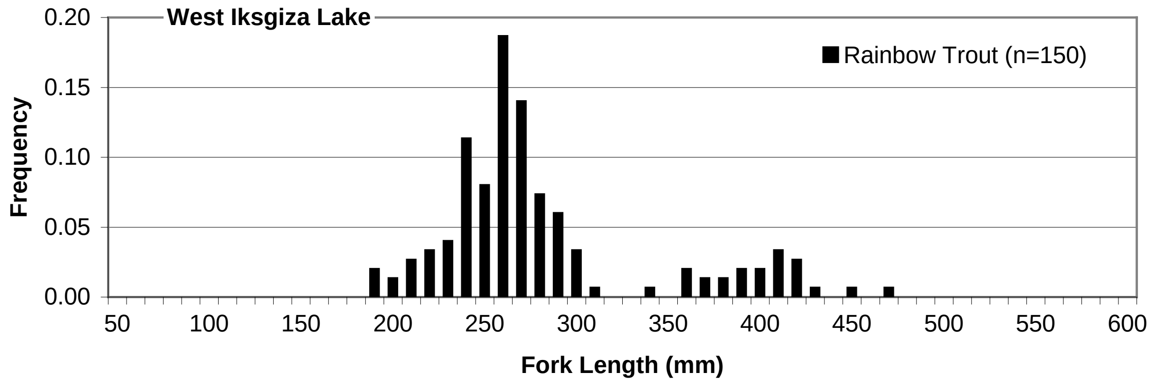
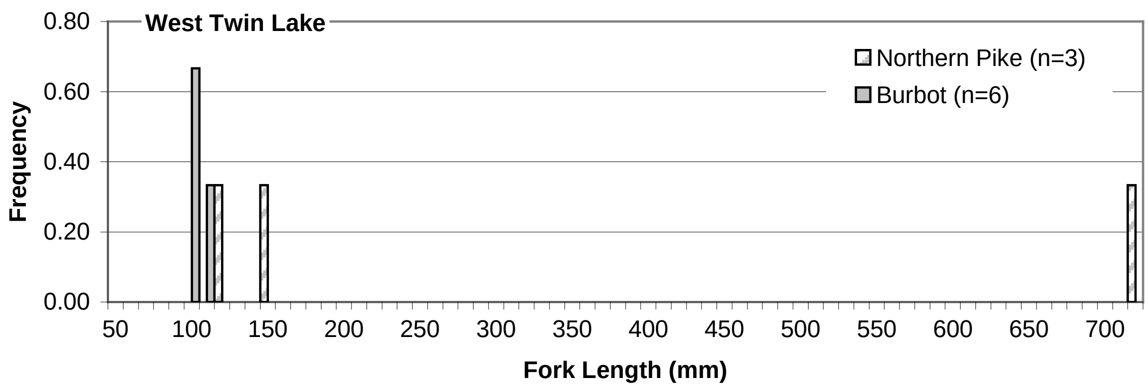

Rainbow Lake
Rainbow Trout (n=70)
Frequency
0.12
0.09
0.06
0.03
0.00
50
100
150
200
250
300
350
400
450
500
550
600
Fork Length (mm)

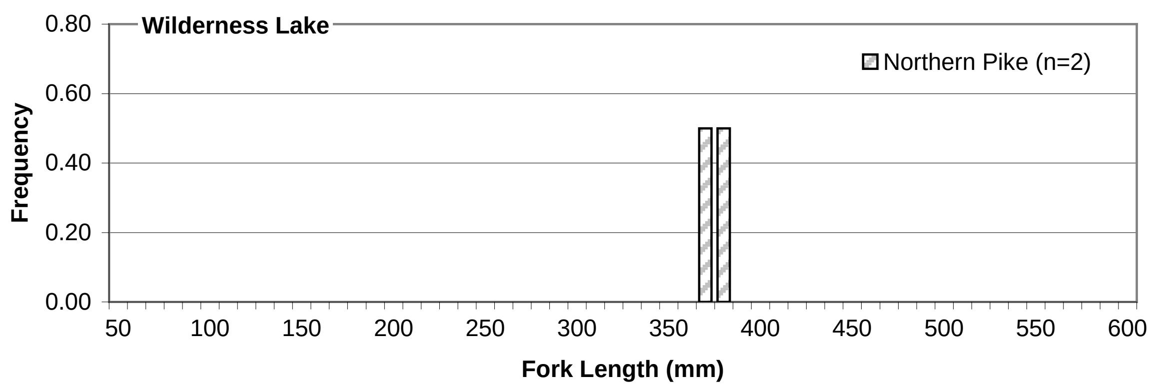

Dune Lake
Rainbow Trout (n=569)
Arctic Grayling (n=399)
Frequency
0.30
0.20
0.10
0.00
50
100
150
200
250
300
350
400
450
500
550
600
Fork Length (mm)


Triangle Lake
Rainbow Trout (n=15)
Blackfish (n=6)
Frequency
0.60
0.40
0.20
0.00
50
100
150
200
250
300
350
400
450
500
550
600
Fork Length (mm)

-continued-


West Iksgiza Lake
Rainbow Trout (n=150)
Frequency
0.00
0.05
0.10
0.15
0.20
50 100 150 200 250 300 350 400 450 500 550 600
Fork Length (mm)


West Twin Lake
Northern Pike (n=3)
Burbot (n=6)
Frequency
0.00
0.20
0.40
0.60
0.80
50 100 150 200 250 300 350 400 450 500 550 600 650 700
Fork Length (mm)


Wilderness Lake
Northern Pike (n=2)
Frequency
0.00
0.20
0.40
0.60
0.80
50 100 150 200 250 300 350 400 450 500 550 600
Fork Length (mm)

APPENDIX C
MACROINVERTEBRATES

Appendix C1.–Macroinvertebrate orders present in lakes sampled during 2005–2008.

Macroinvertebrates common name	order suborder	family (if known)	Donna Lake	Donnelly Lake	Little Donna Lake	Rainbow Lake	Dune Lake	Triangle Lake	West Iksgiza Lake	Birch Lake	Quartz Lake	West Twin Lake	Wilderness Lake
aphids	Hemiptera	Aphididae	-	X	-	X	-	X	-	-	-	-	-
beetles	Coleoptera (spp.)		X	X	X	-	-	-	X	X	X	X	X
biting midges	Diptera	Ceratopogonidae	X	X	X	X	-	X	X	X	X	-	X
caddis fly	Tricoptera		X	X	X	X	X	X	X	X	X	X	X
damselfly	Odonata Zygoptera		X	X	X	X	X	X	X	X	X	X	X
dragonfly	Odonata Anisoptera		X	X	X	X	X	X	X	X	X	-	X
flies	Diptera (spp.)		X	X	X	X	X	X	X	X	X	X	X
leeches	Hirudinea (ID to class only)		X	X	-	X	-	-	-	-	-	X	X
mayfly	Ephemeroptera		X	X	X	X	X	X	X	X	X	X	X
mensicus midges	Diptera	Dixidae	-	X	-	-	-	-	-	-	-	-	-
midges	Diptera	Chironomidae	X	X	X	X	X	X	X	X	X	X	X
mosquitos	Diptera	Culicidae	-	-	-	-	-	X	-	X	-	-	-
moths and Butterflies	Lepidoptera		X	-	-	X	-	-	-	-	-	-	-
mussels and clams	Bivalvia (ID to class only)		X	X	X	X	X	X	X	X	X	X	X
phantom midges	Diptera	Chaoboridae	-	-	-	X	-	-	X	X	X	-	-
predaceous diving beetle	Coleoptera	Dytisidae	-	X	X	-	-	-	X	-	-	X	X
round worm unknown	Nematoda (ID to phylum only)		-	-	-	-	-	-	-	-	X	-	X
scuds	Amphipoda		X	-	X	X	X	X	X	X	X	X	X
segmented worms unknown	Annelida (ID to phylum only)		X	X	X	X	X	X	X	X	X	X	X
snails	Gastropoda		X	X	X	X	X	X	X	X	X	X	X
spiders	Aracnid (ID to class only)		X	-	X	X	-	-	X	X	X	-	X
springtails	Collembola		X	-	-	X	-	-	1	-	-	-	-
true bugs (unknown)	Hemiptera (spp.)		X	X	X	X	X	X	X	X	X	-	-
wasps	Hymenoptera		X	-	X	X	X	-	X	X	-	-	X
water mites	Acari (ID to subclass only)		X	X	X	X	X	X	X	X	X	X	X
water strider	Hemiptera	Gerridae	X	-	X	X	-	-	X	-	-	-	X
waterboatman	Hemiptera	Corixidae	X	X	X	X	X	X	X	X	X	X	X
whirligig beetle	Coleoptera	Gyrinidae	-	-	-	-	X	-	X	-	-	-	X

APPENDIX D
ZOOPLANKTON

Appendix D1.–Zooplankton mean density and variance by lake and sample site for lakes sampled during 2005–2008.

Zooplankton Mean Density (plankters/m3)

	sample site	sample mean density	variance	lake mean density	variance
Donna Lake					
summer	1	225	63	312	5,210
	2	400	318		
fall	1	638	1,895	563	5,095
	2	487	2,060		
Donnelly Lake					
summer	1	2,423	79,602	2,124	86,869
	2	1,824	1,099		
fall	1	1,288	6,545	956	76,150
	2	624	1,537		
Little Donna Lake					
summer	1	575	10,957	544	4,357
	2	512	165		
fall	1	360	1,538	358	1,814
	2	356	3,898		
Rainbow Lake					
summer	1	253	761	367	10,159
	2	481	3,615		
fall	1	711	4,053	711	1,362
	2	712	33		
Dune Lake					
summer	1	915	29,545	818	18,226
	2	721	6,403		
fall	1	-[a]	-[a]	-[a]	-[a]
	2	-[a]	-[a]		
Triangle Lake					
summer	1	285	2,314	280	1,137
	2	275	1,051		
fall	1	310	32	319	518
	2	327	1,379		
West Iksgiza Lake					
summer	1	782	6,617	772	3,721
	2	762	4,347		
fall	1	658	4,671	787	29,031
	2	916	49,058		

[a] Sampling was not conducted in September because aircraft and field personnel were not available.

-continued-

Appendix D1.–Page 2 of 2.

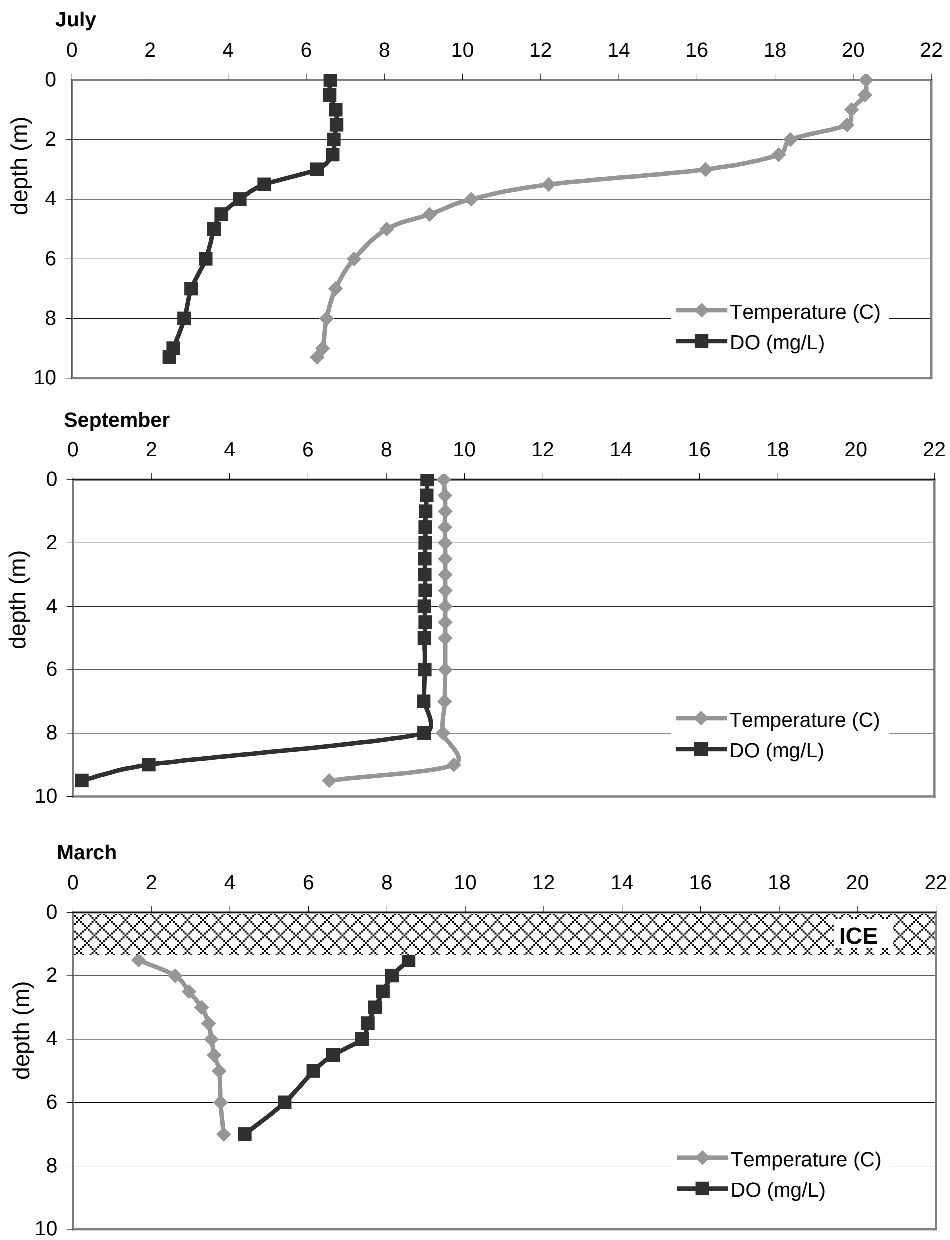
	sample site	sample mean density	variance	lake mean density	variance
Birch Lake					
summer	1	2,313	15,449	2,368	11,221
	2	2,423	12,226		
fall	1	902	89,427	894	29,875
	2	886	70		
Quartz Lake					
summer	1	420	153	517	14,614
	2	614	3,015		
fall	1	451	4,435	658	68,751
	2	865	12,859		
West Twin Lake					
summer	1	917	20,922	903	7,645
	2	889	1,626		
fall	1	680	585	690	1,367
	2	701	3,299		
Wilderness Lake					
summer	1	215	99	204	302
	2	192	554		
fall	1	183	340	213	799
	2	242	340		

APPENDIX E
TEMPERATURE AND DISSOLVED OXYGEN PROFILES

Appendix E1.–July, September, and March temperature and dissolved oxygen profiles over the deepest basin of lakes sampled during 2005–2008.

Temperature and dissolved oxygen readings were taken in the same general area in July, September, and March, but sometimes the same exact location was not achieved, which is why there is a discrepancy in the deepest reading for each month.

DONNA LAKE



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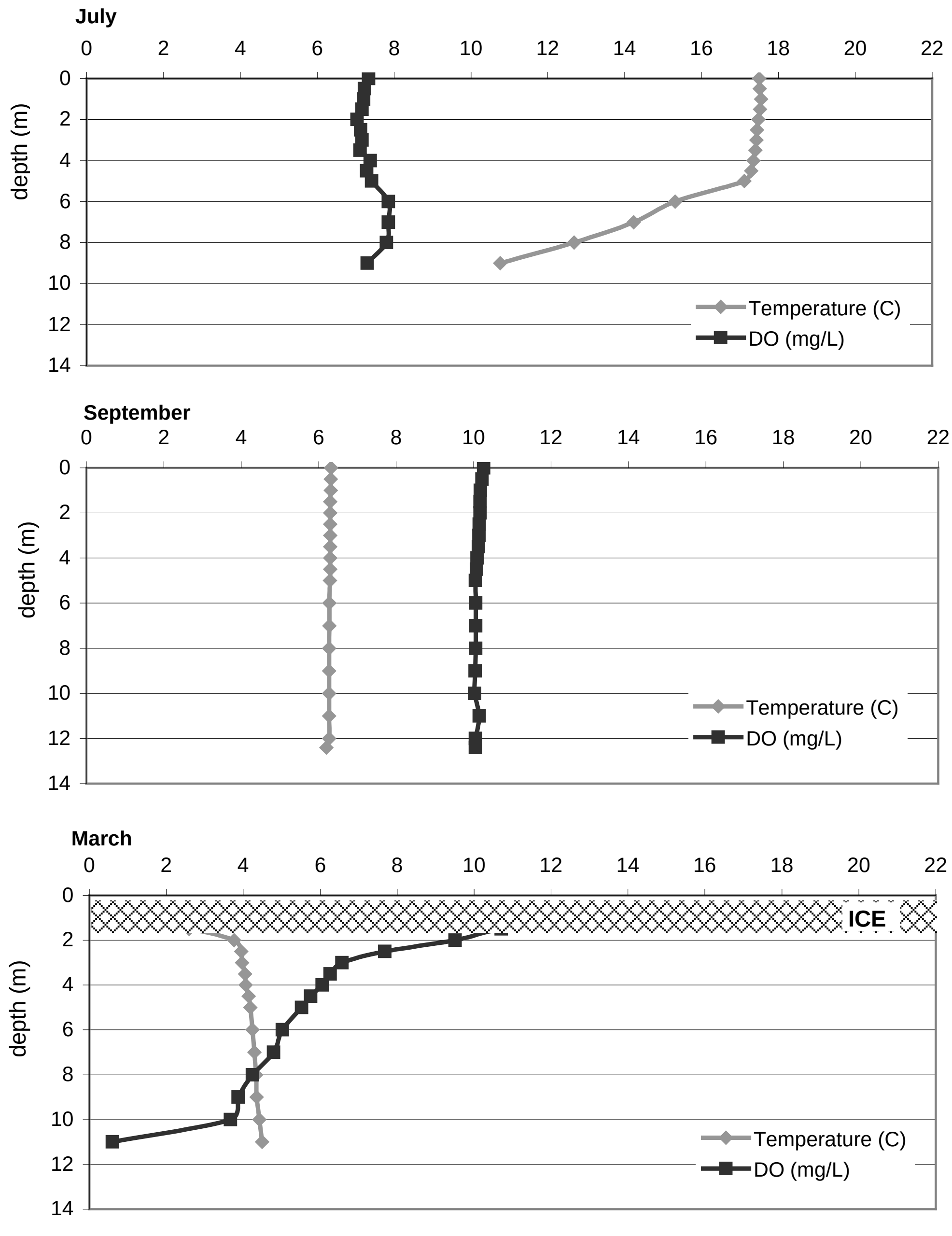
Temperature and dissolved oxygen readings were taken in the same general area in July, September, and March, but sometimes the same exact location was not achieved, which is why there is a discrepancy in the deepest reading for each month.

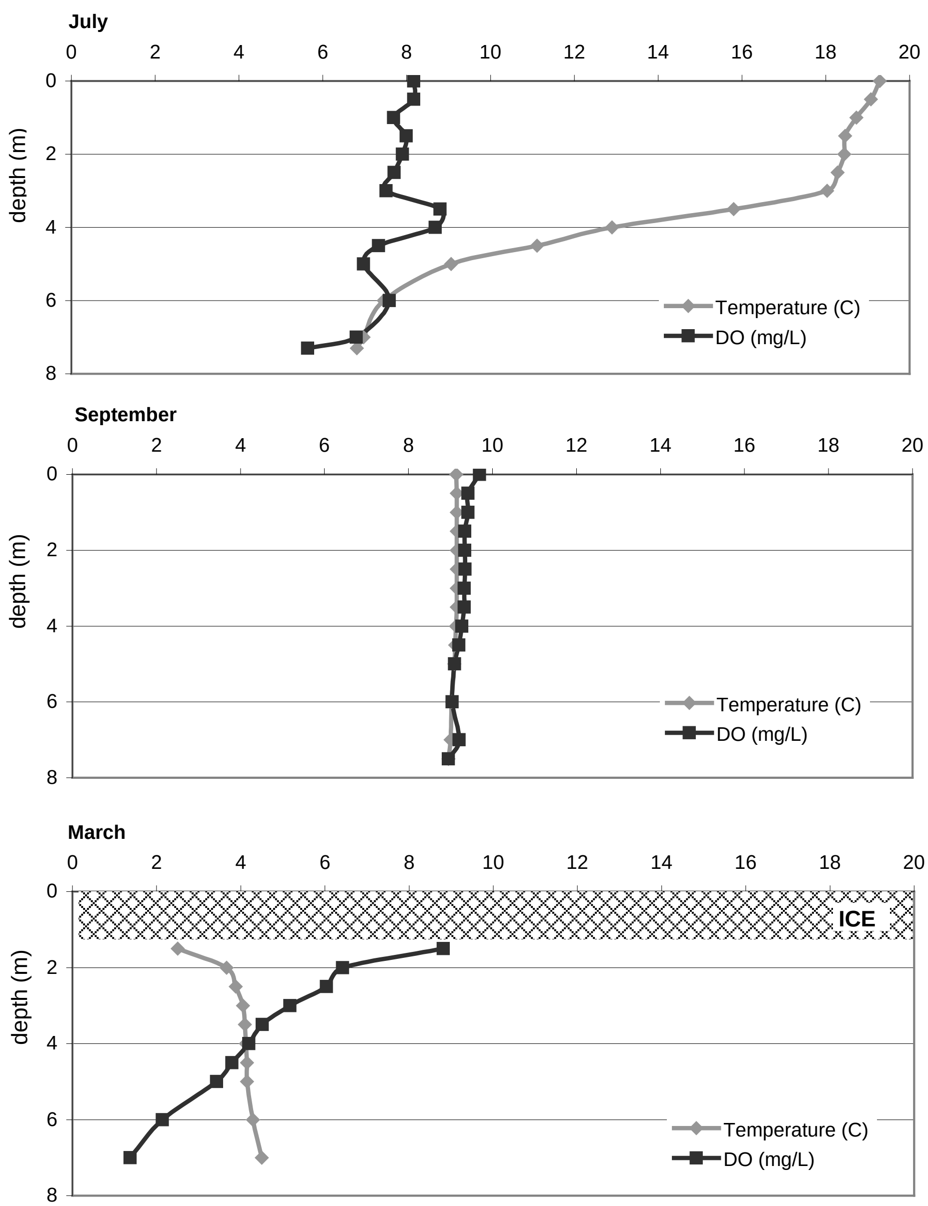
DONNELLY LAKE



-continued-

Temperature and dissolved oxygen readings were taken in the same general area in July, September, and March, but sometimes the same exact location was not achieved, which is why there is a discrepancy in the deepest reading for each month.

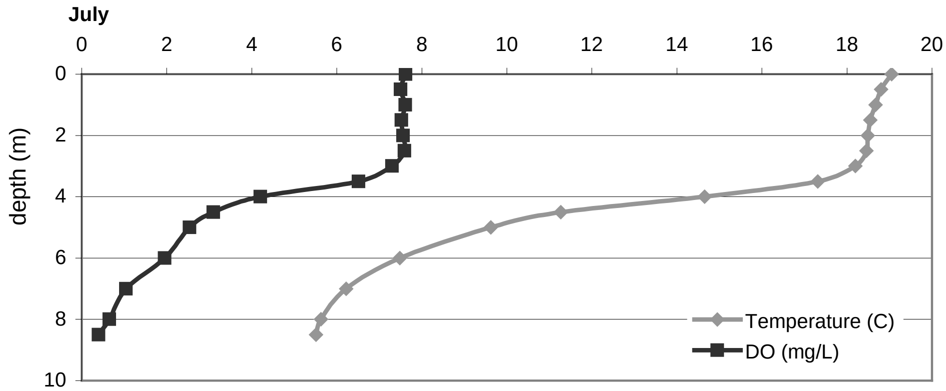
LITTLE DONNA

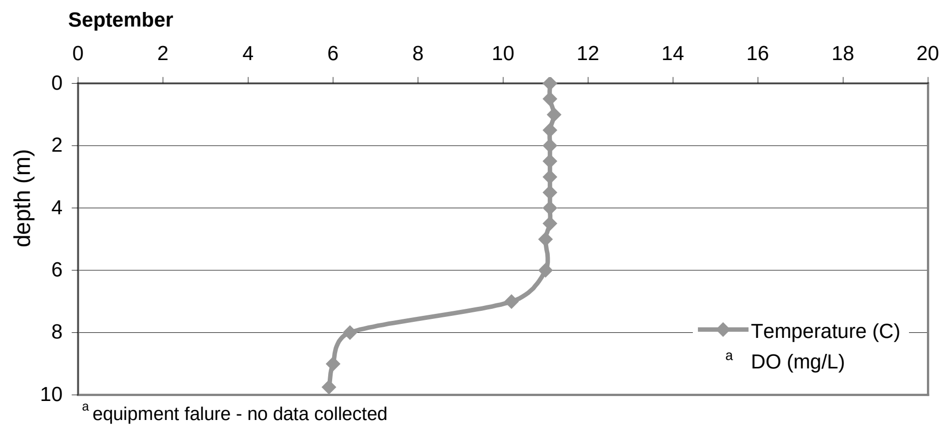


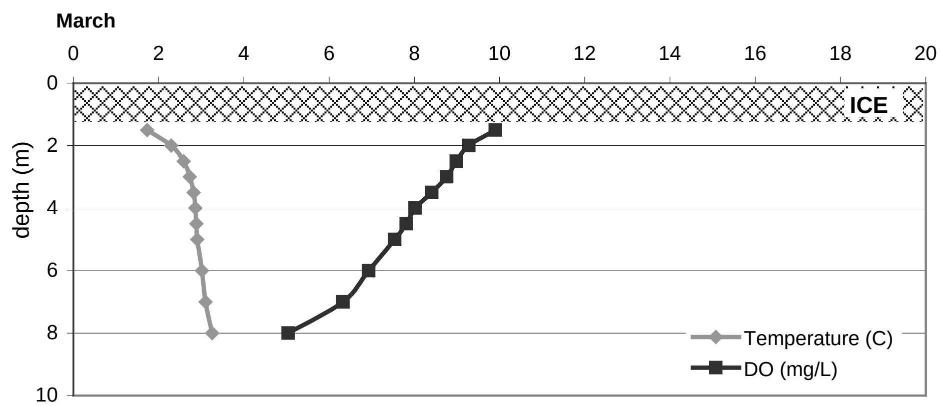
-continued-

Temperature and dissolved oxygen readings were taken in the same general area in July, September, and March, but sometimes the same exact location was not achieved, which is why there is a discrepancy in the deepest reading for each month.

RAINBOW LAKE







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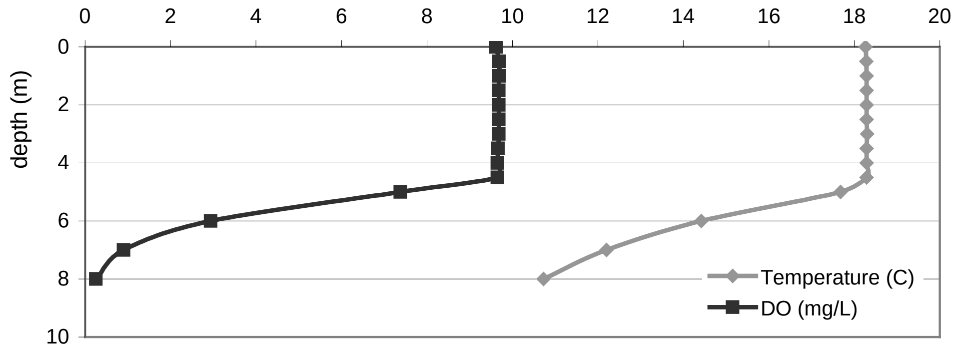
Temperature and dissolved oxygen readings were taken in the same general area in July, September, and March, but sometimes the same exact location was not achieved, which is why there is a discrepancy in the deepest reading for each month.

DUNE LAKE

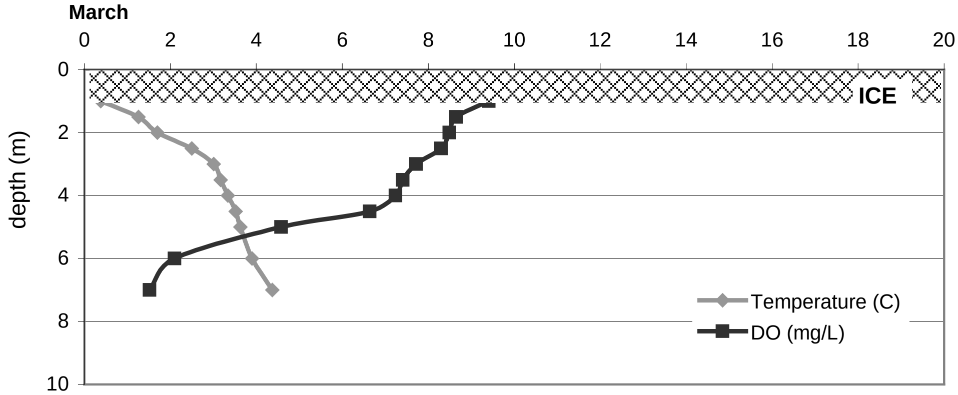
July



September

No sampling conducted.

March



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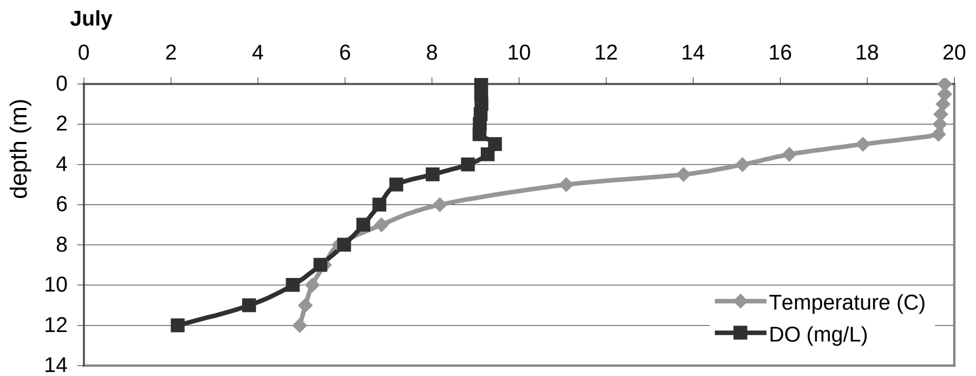
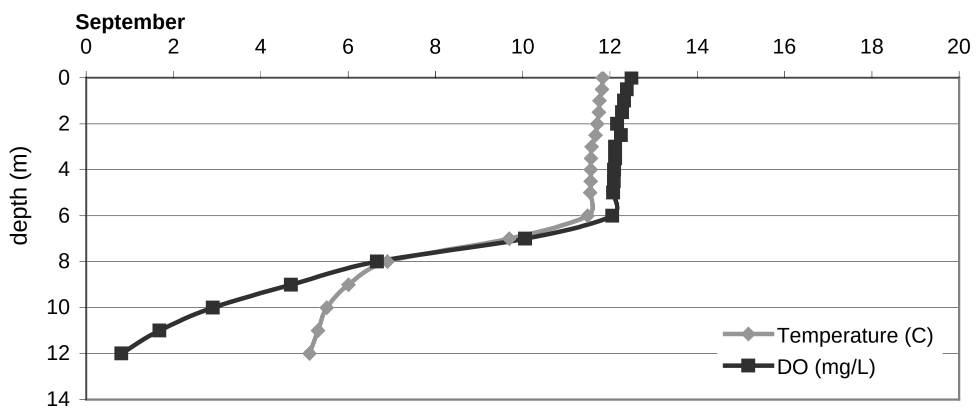
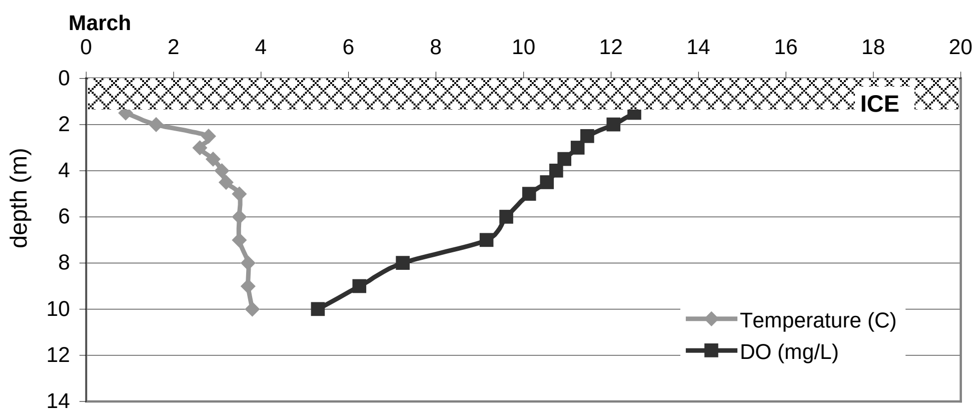
Temperature and dissolved oxygen readings were taken in the same general area in July, September, and March, but sometimes the same exact location was not achieved, which is why there is a discrepancy in the deepest reading for each month.

TRIANGLE LAKE







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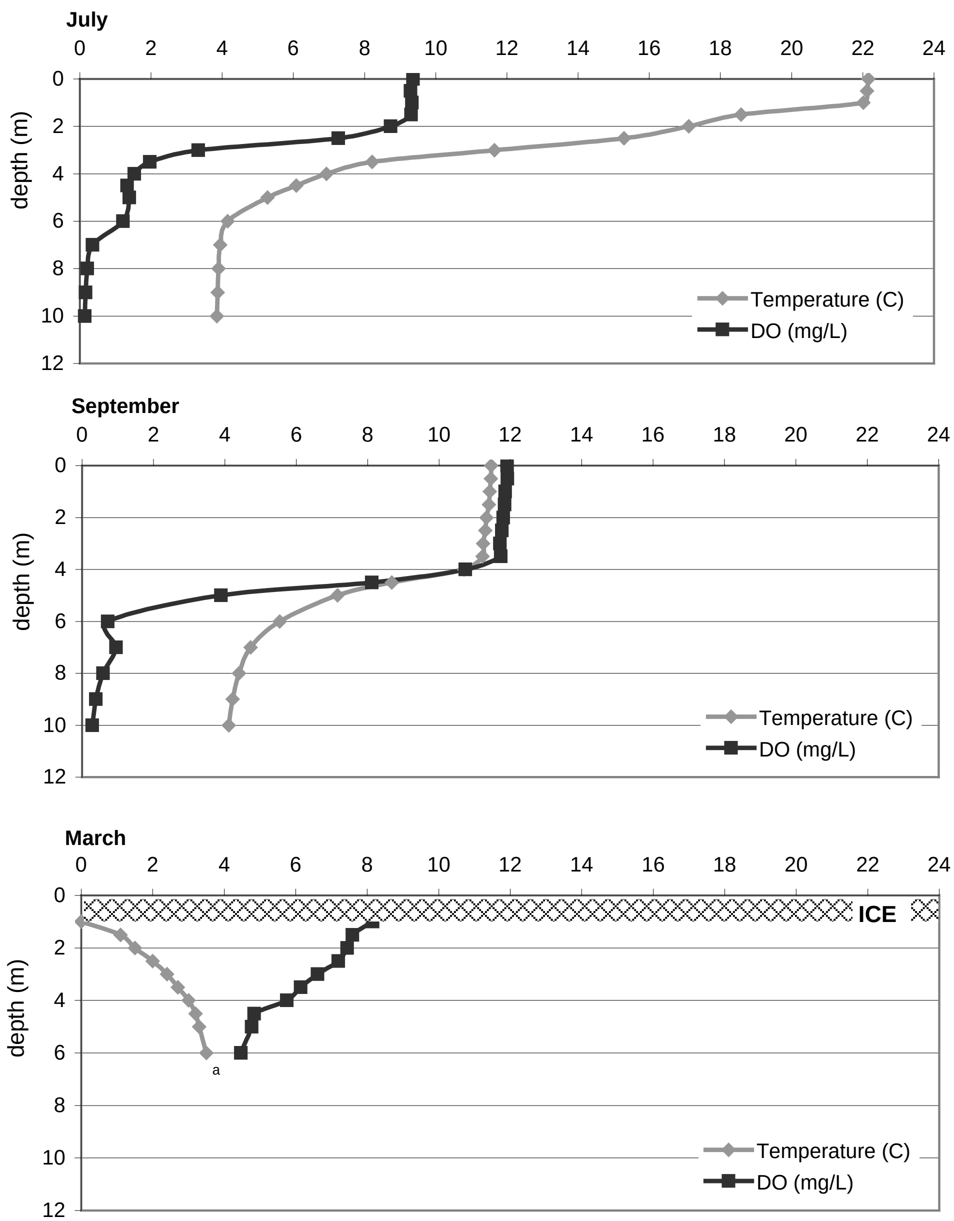
Temperature and dissolved oxygen readings were taken in the same general area in July, September, and March, but sometimes the same exact location was not achieved, which is why there is a discrepancy in the deepest reading for each month.

WEST IKSGIZA

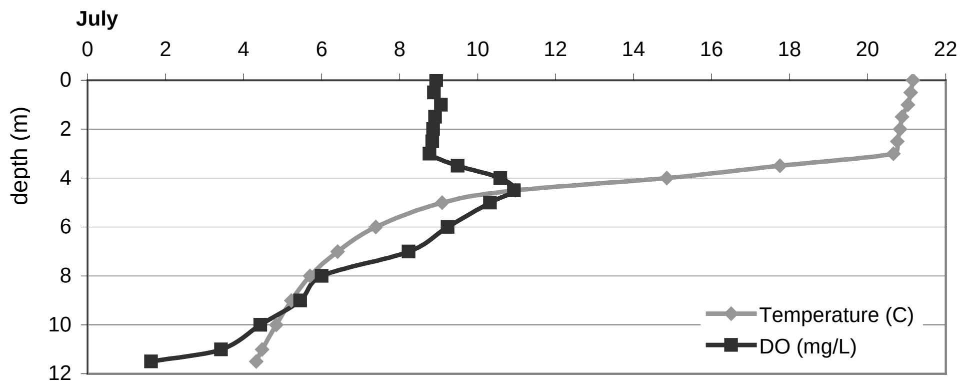


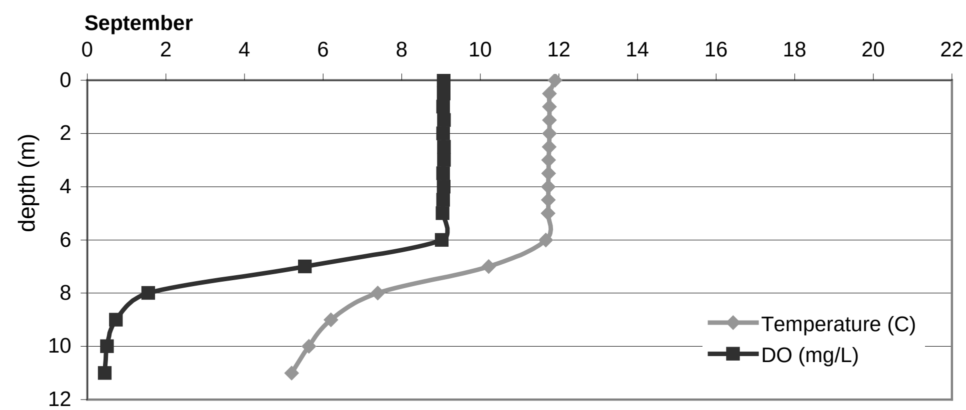
[a] Readings were only taken down to 6 m (approximately half the depth of the lake) due to equipment difficulties caused by cold weather.

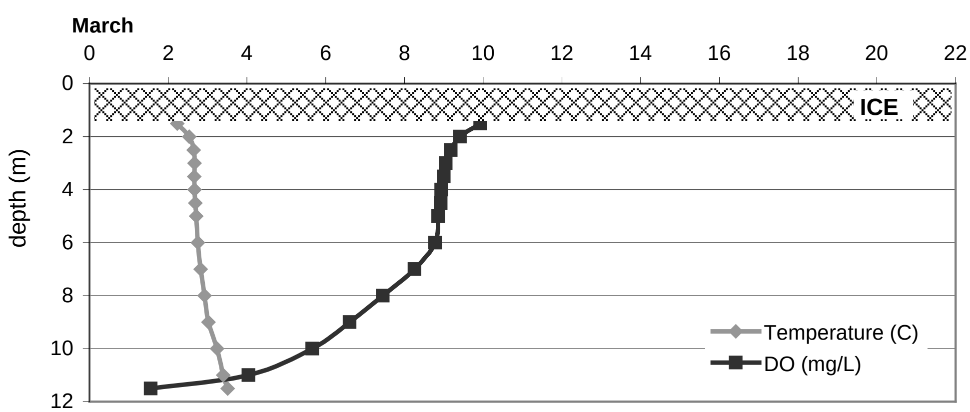
-continued-

Temperature and dissolved oxygen readings were taken in the same general area in July, September, and March, but sometimes the same exact location was not achieved, which is why there is a discrepancy in the deepest reading for each month.

BIRCH LAKE







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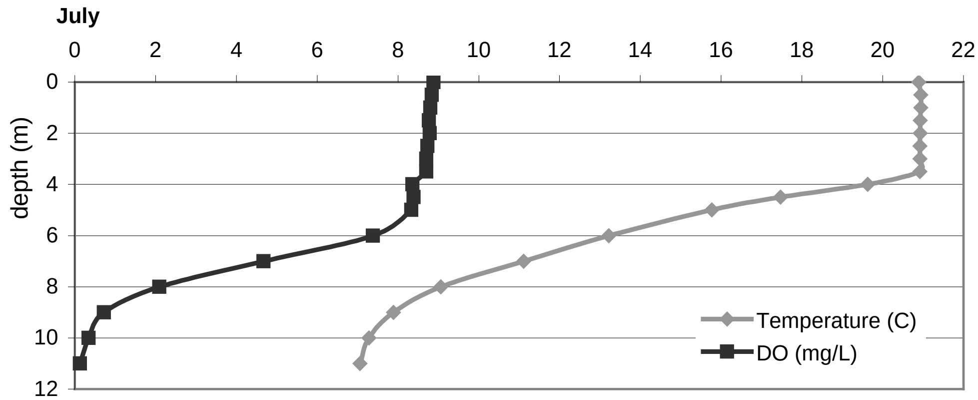
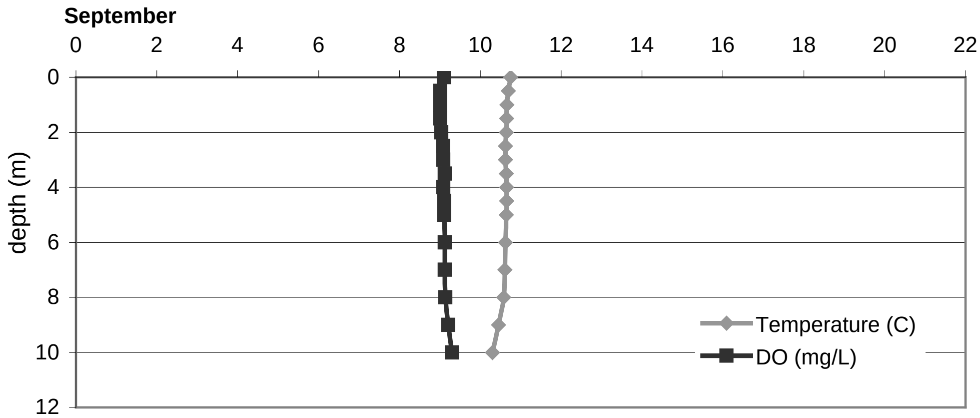
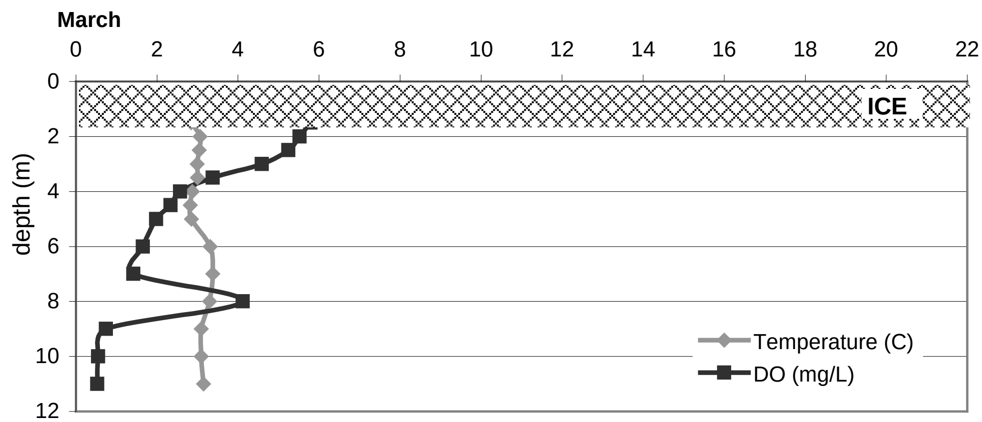
Temperature and dissolved oxygen readings were taken in the same general area in July, September, and March, but sometimes the same exact location was not achieved, which is why there is a discrepancy in the deepest reading for each month.

QUARTZ LAKE







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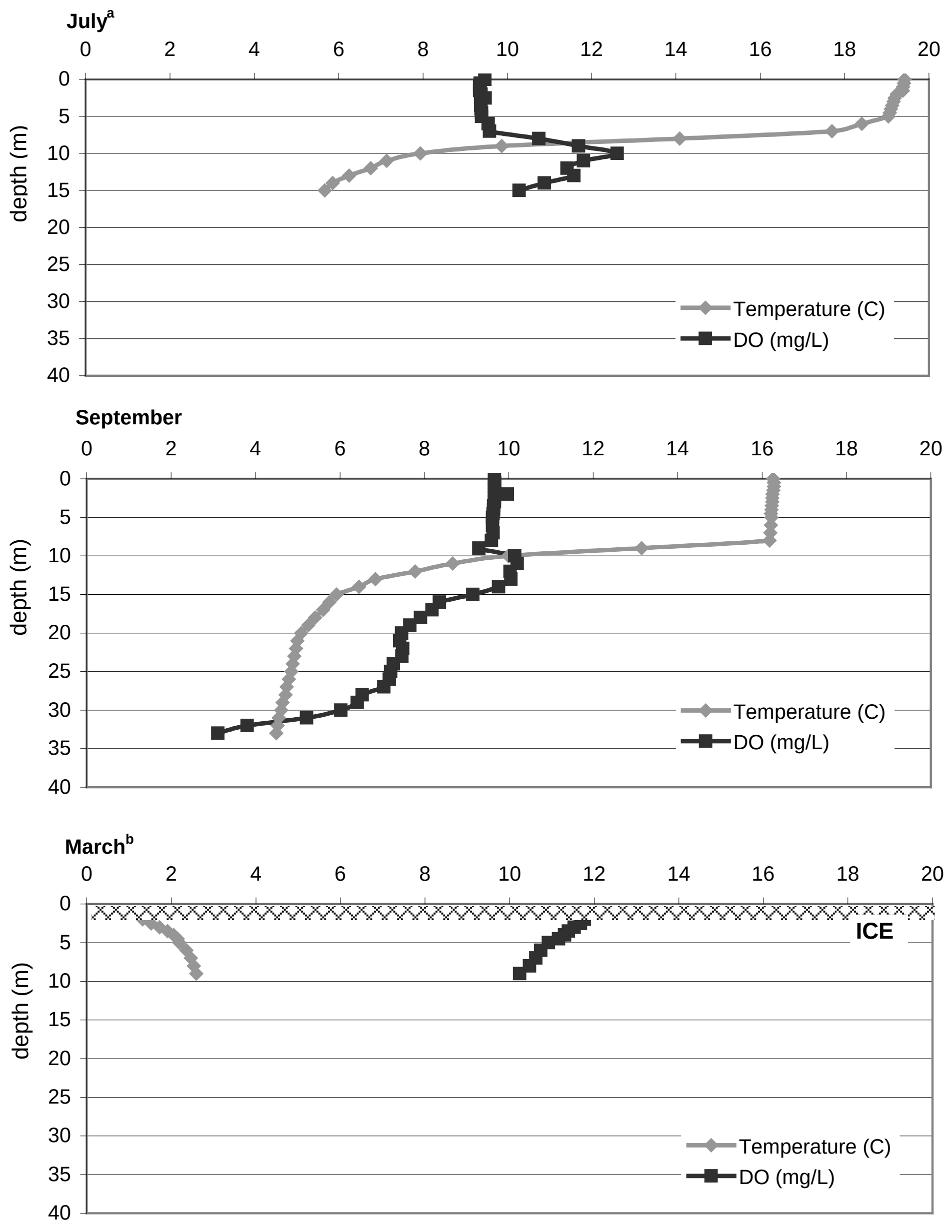
Temperature and dissolved oxygen readings were taken in the same general area in July, September, and March, but sometimes the same exact location was not achieved, which is why there is a discrepancy in the deepest reading for each month.

WEST TWIN LAKE



[a] Readings were only taken down to15 m due to equipment limitations (the cord measured 15 m).

[b] Readings were only taken down to 9 m due to winter logistics.

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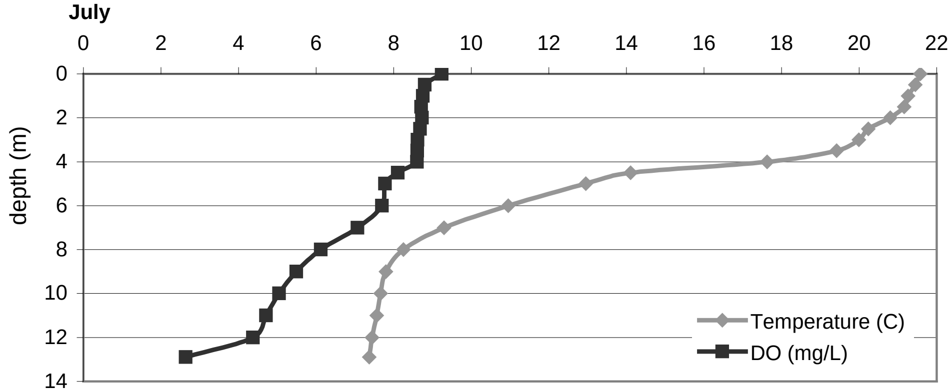
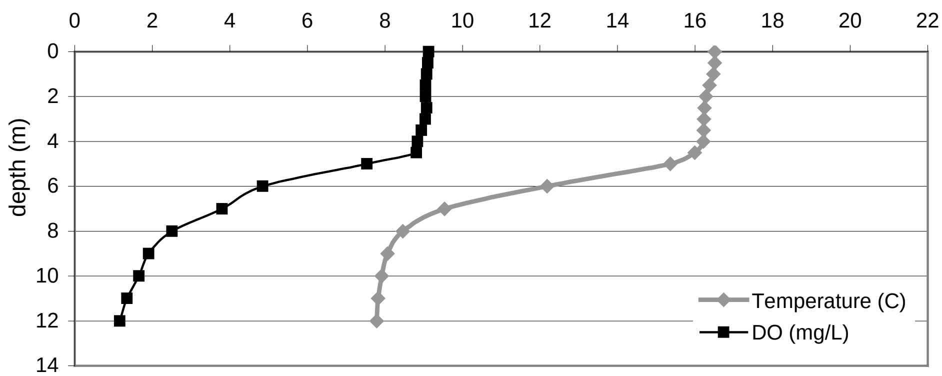
Temperature and dissolved oxygen readings were taken in the same general area in July, September, and March, but sometimes the same exact location was not achieved, which is why there is a discrepancy in the deepest reading for each month.

WILDERNESS LAKE

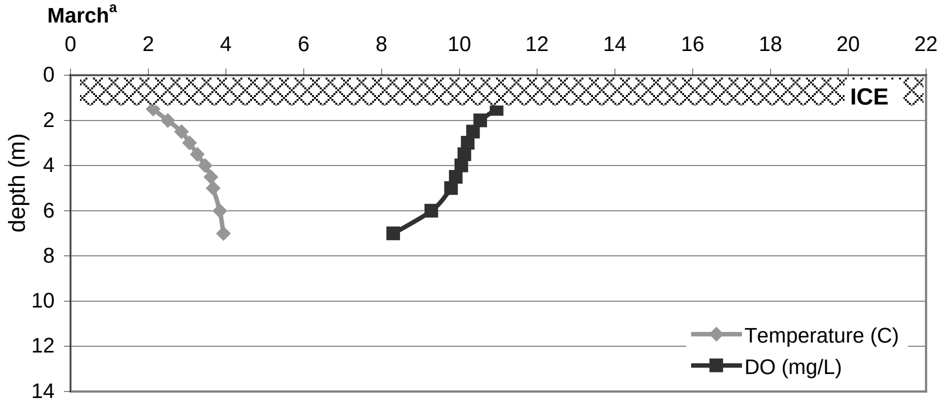
July



September



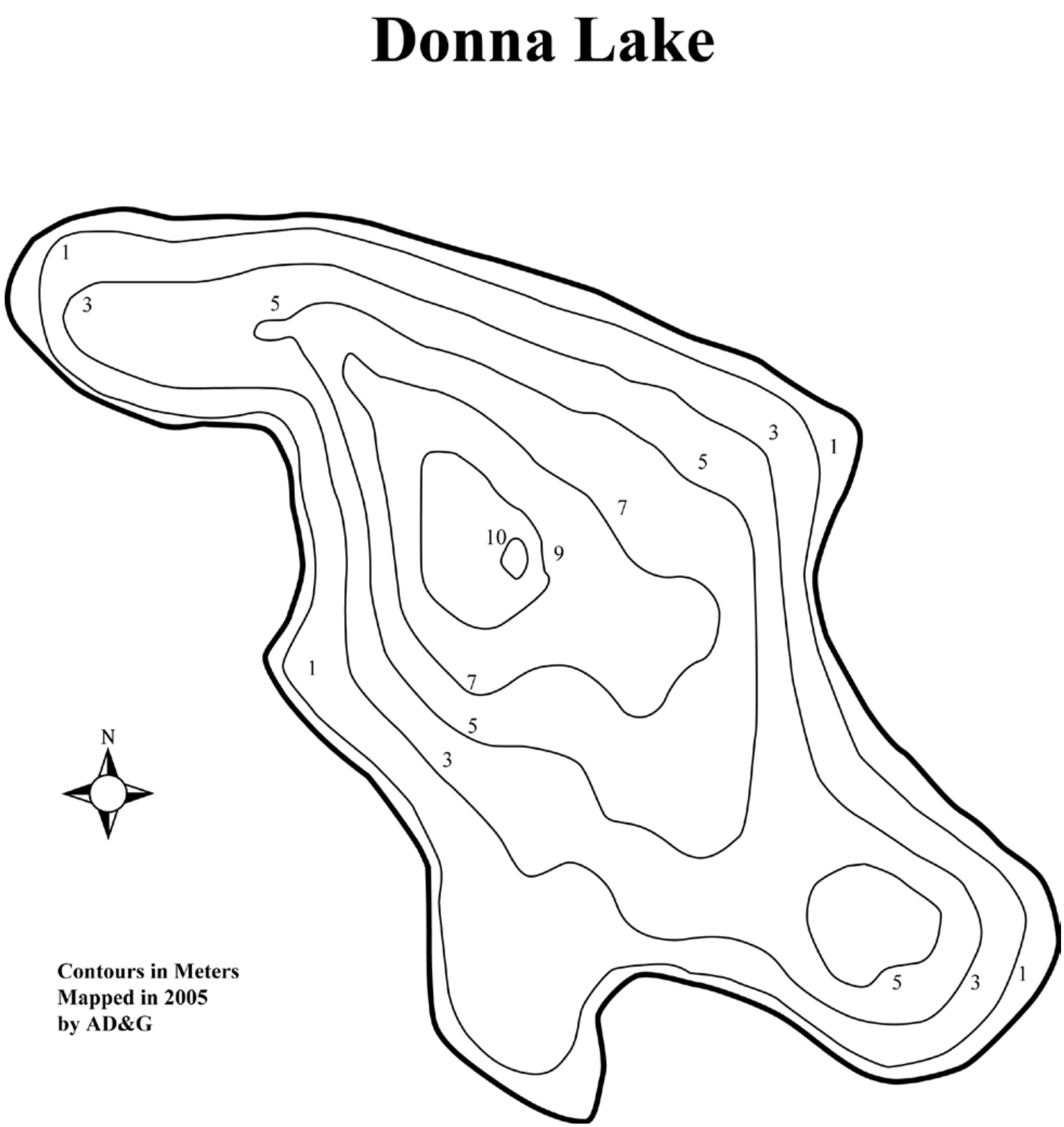
March[a]



[a] Readings were only taken down to 7 m due to winter logistics.

APPENDIX F
BATHYMETRIC MAPS

Appendix F1.–Bathymetric maps for lakes sampled in 2005–2006.



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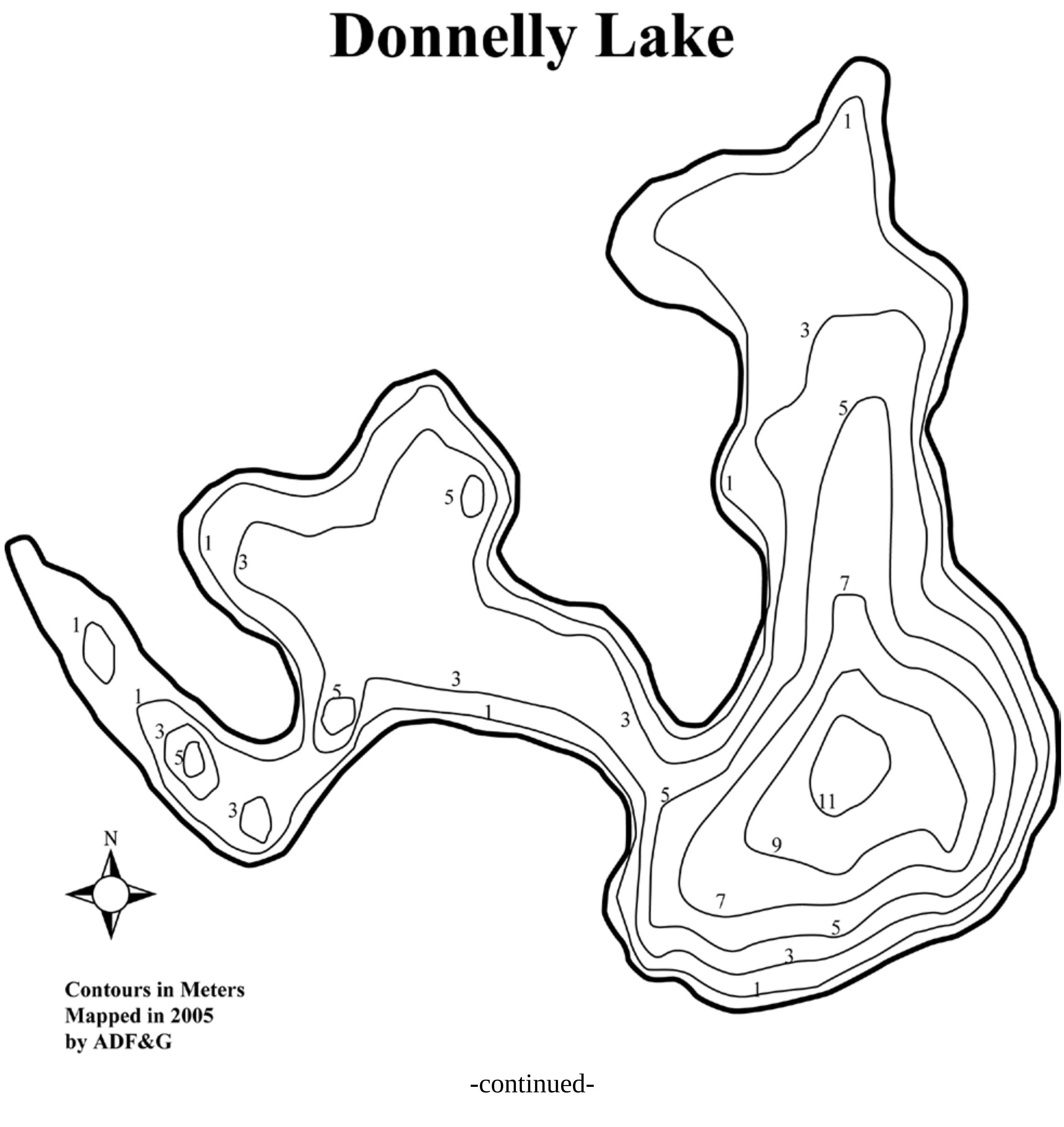
Donnelly Lake
N
Contours in Meters
Mapped in 2005
by ADF&G
1
3
5
7
9
11

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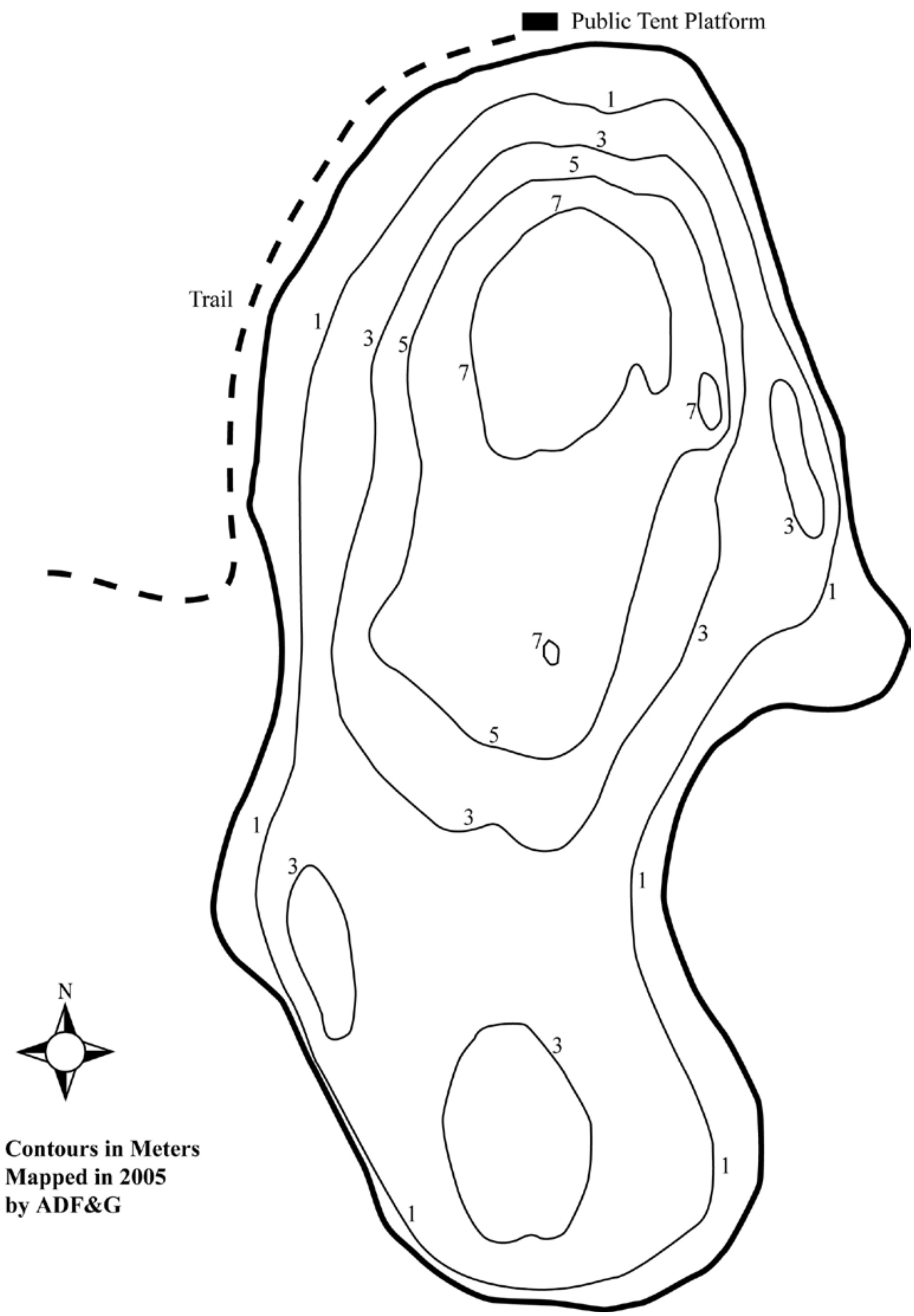
Little Donna Lake



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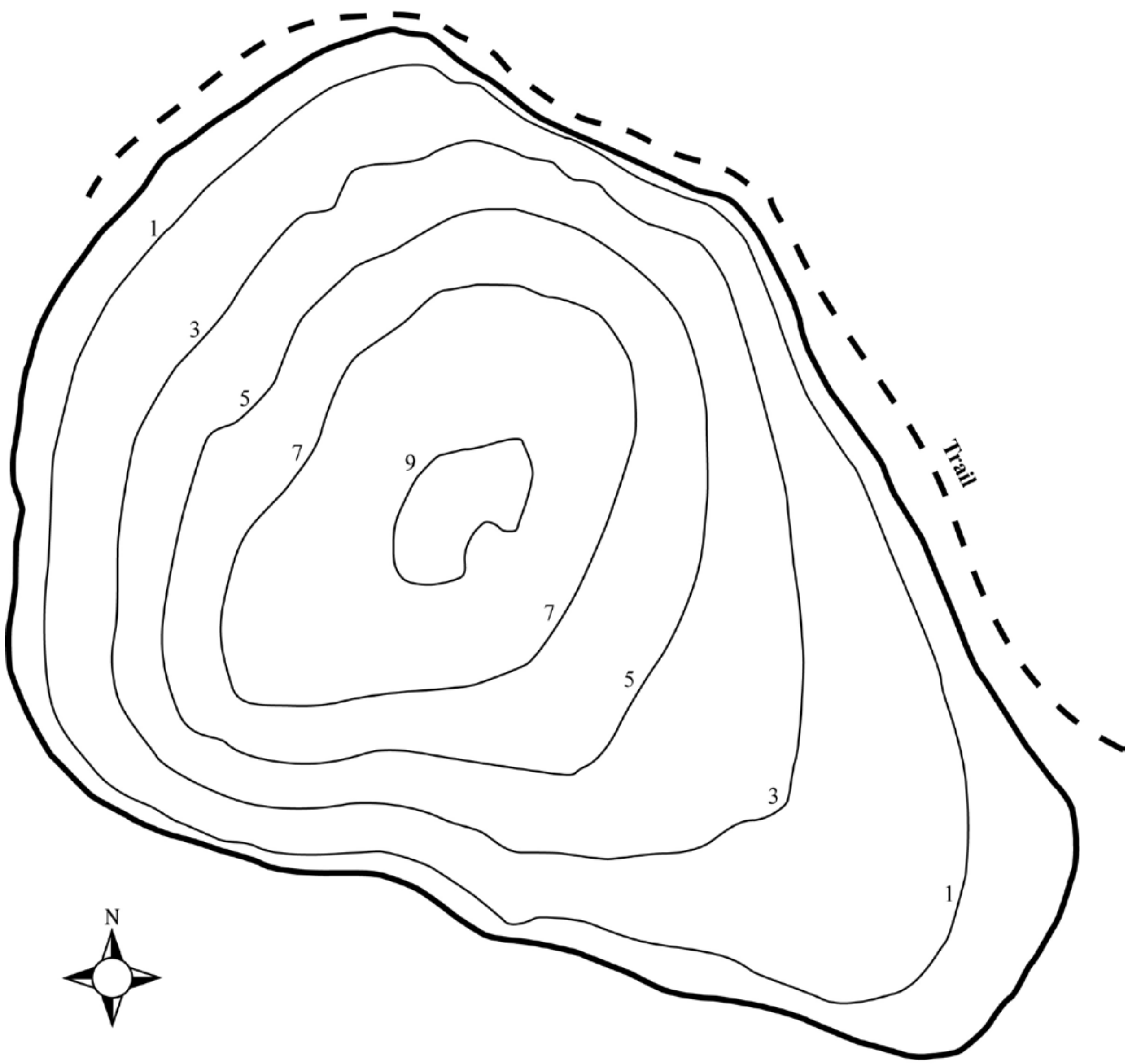
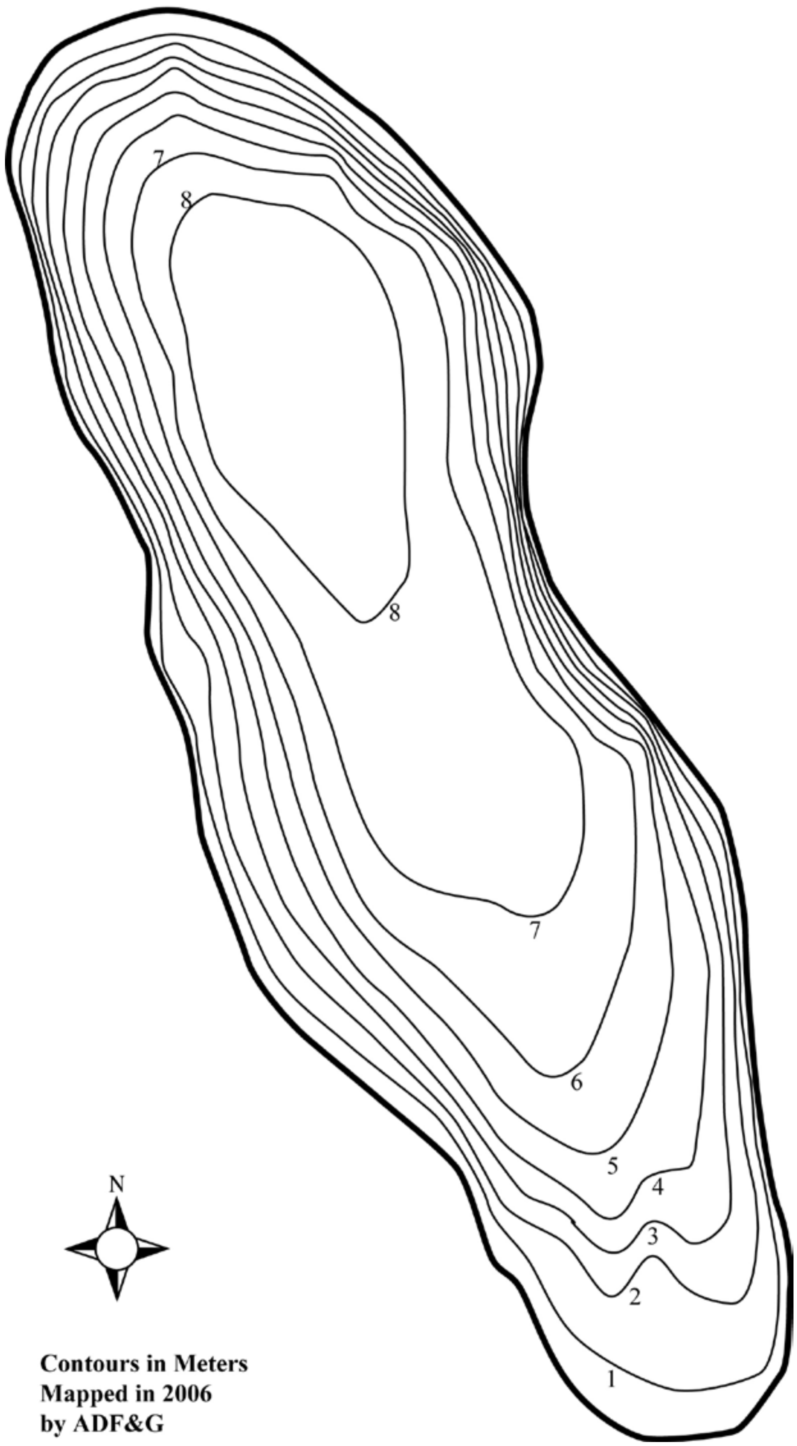
Rainbow Lake



Contours in Meters
Mapped in 2005
by ADF&G

-continued-

Dune Lake



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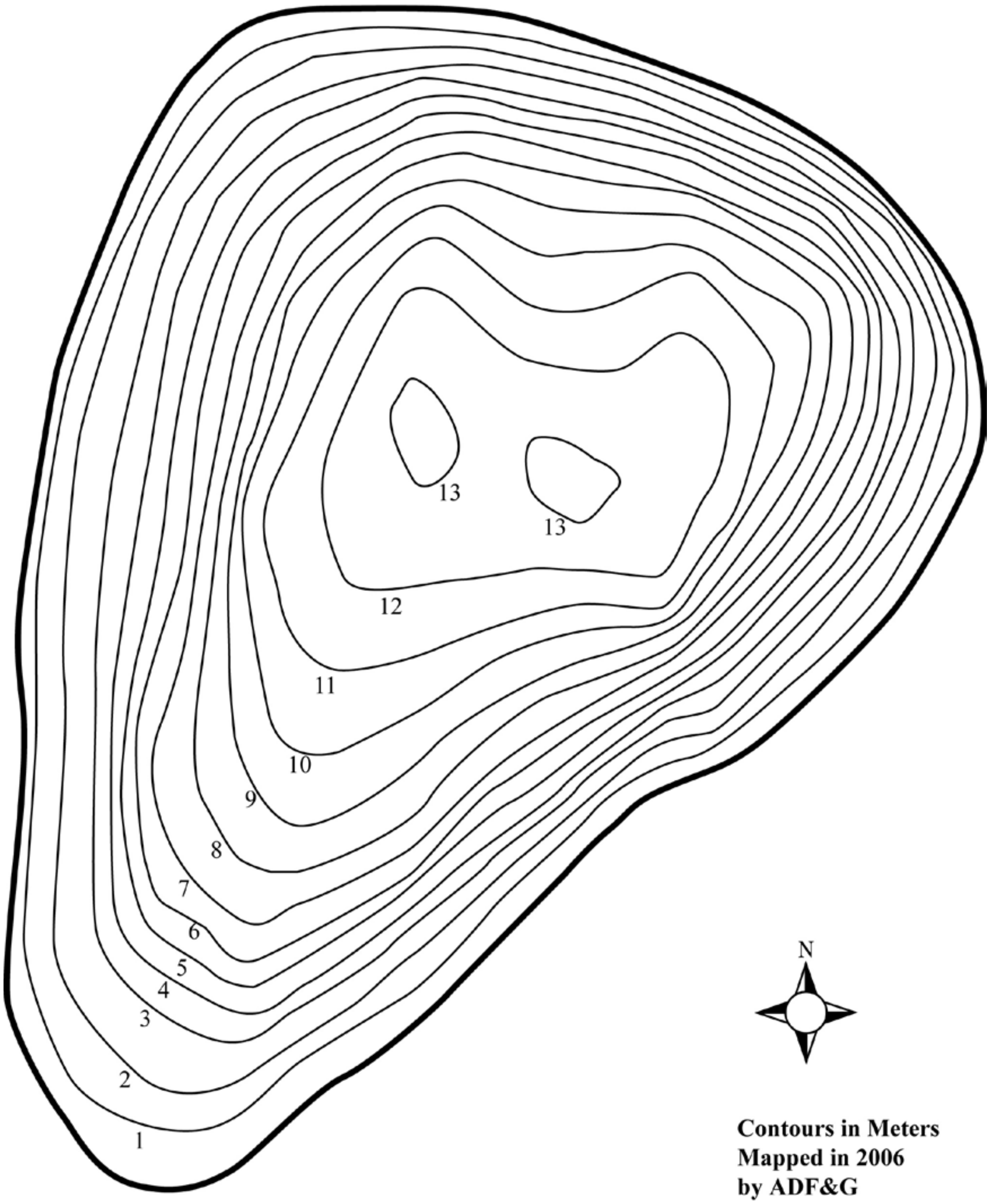
Triangle Lake



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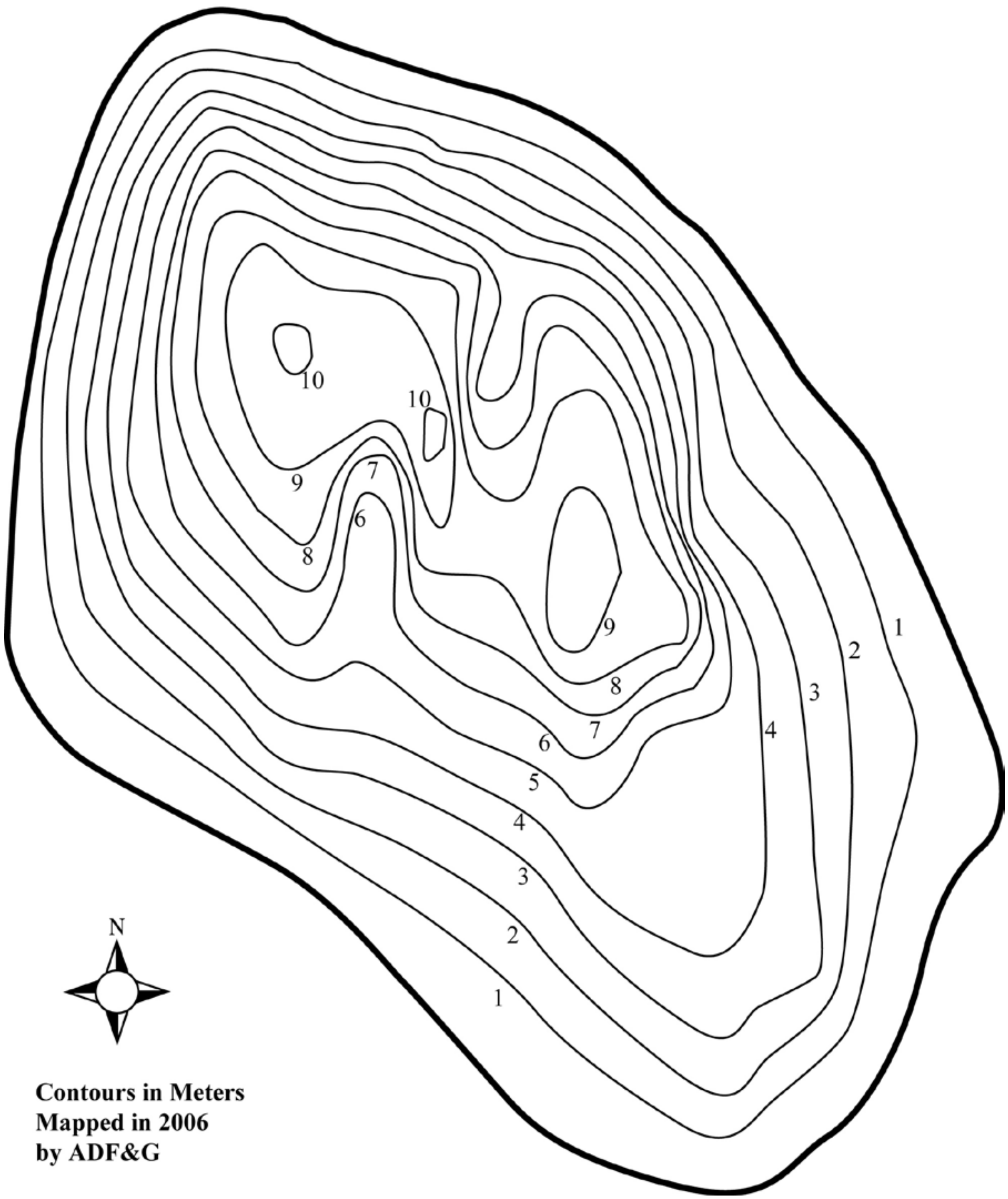
West Iksgiza Lake



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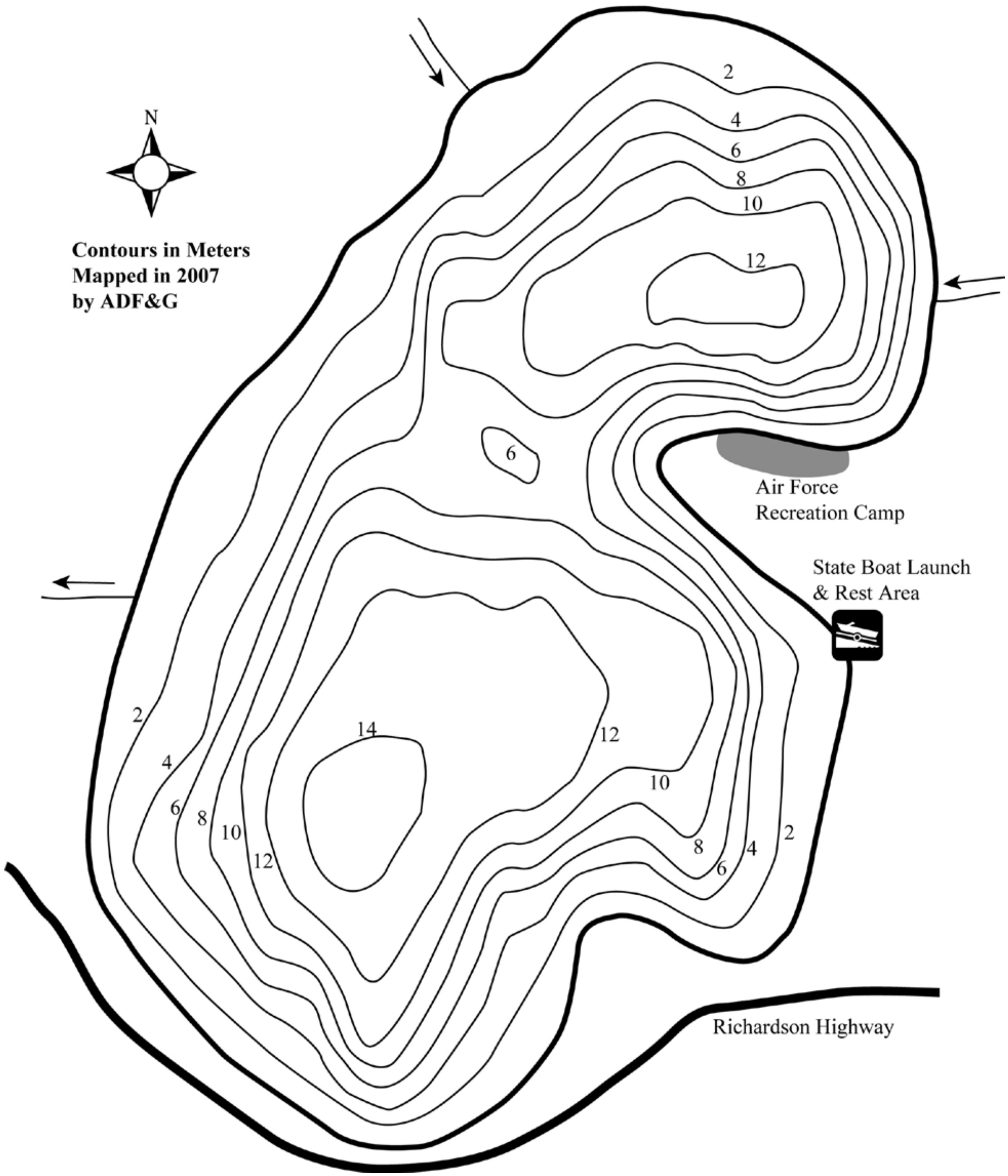
Birch Lake



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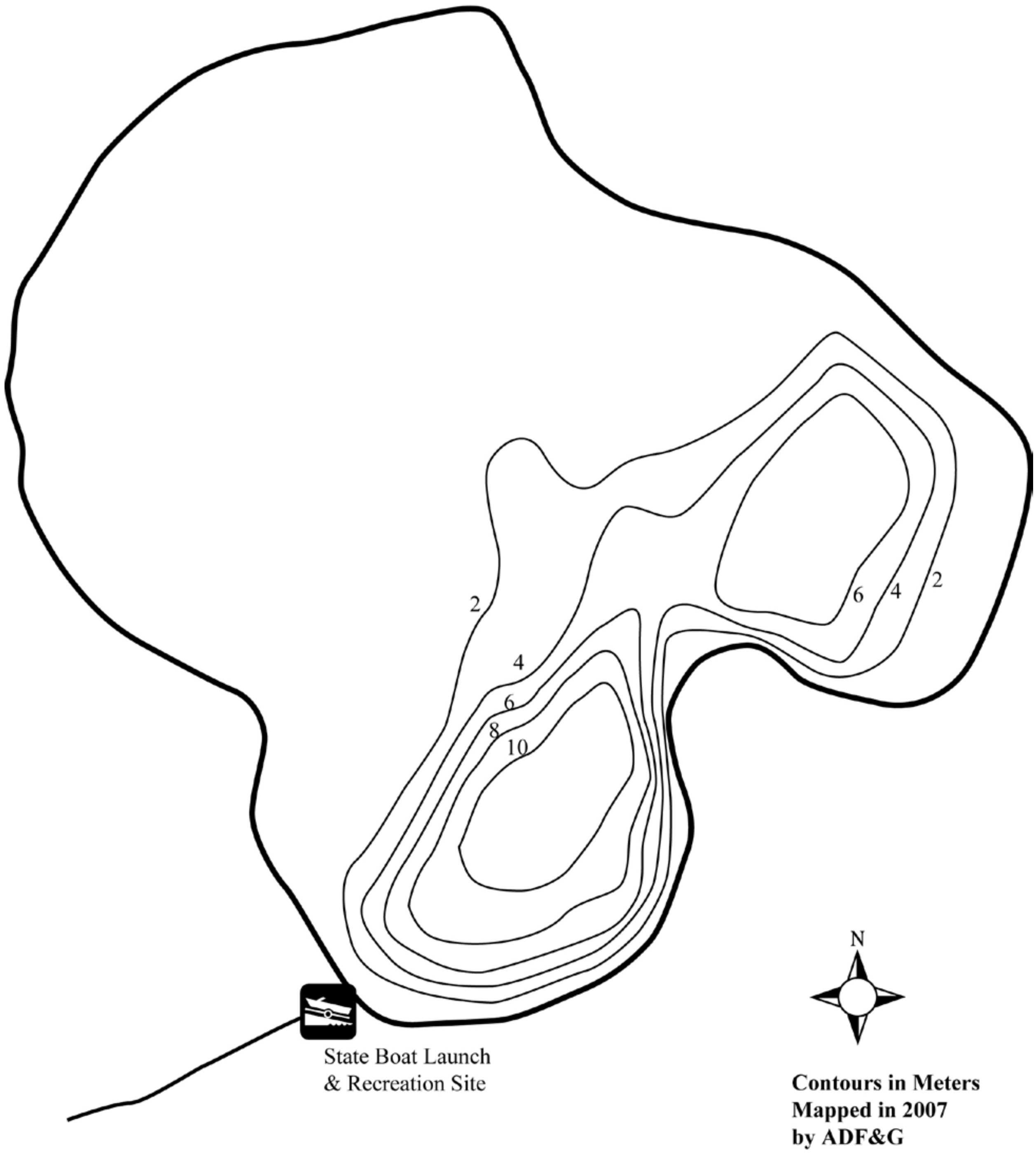
Quartz Lake



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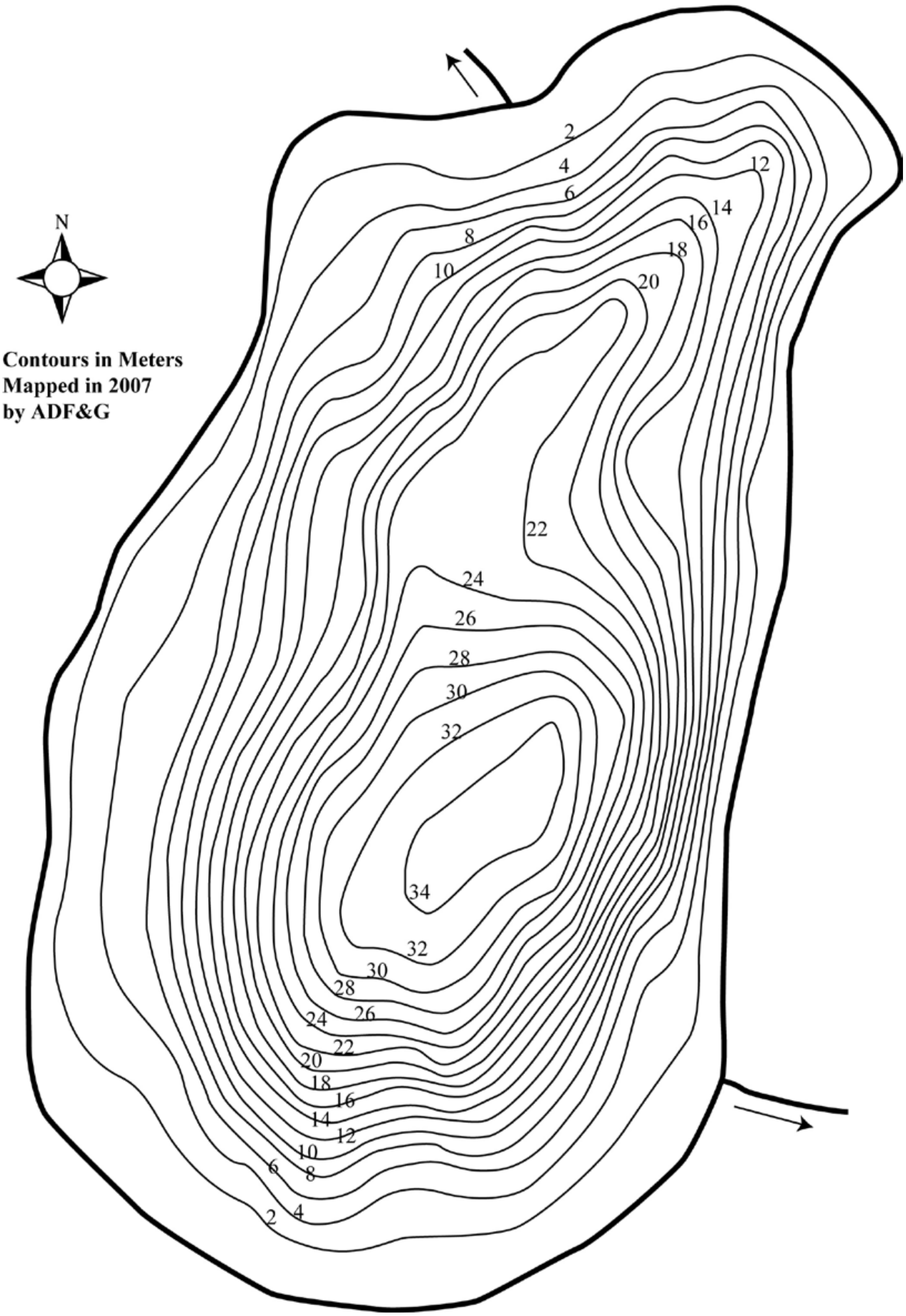
West Twin Lake



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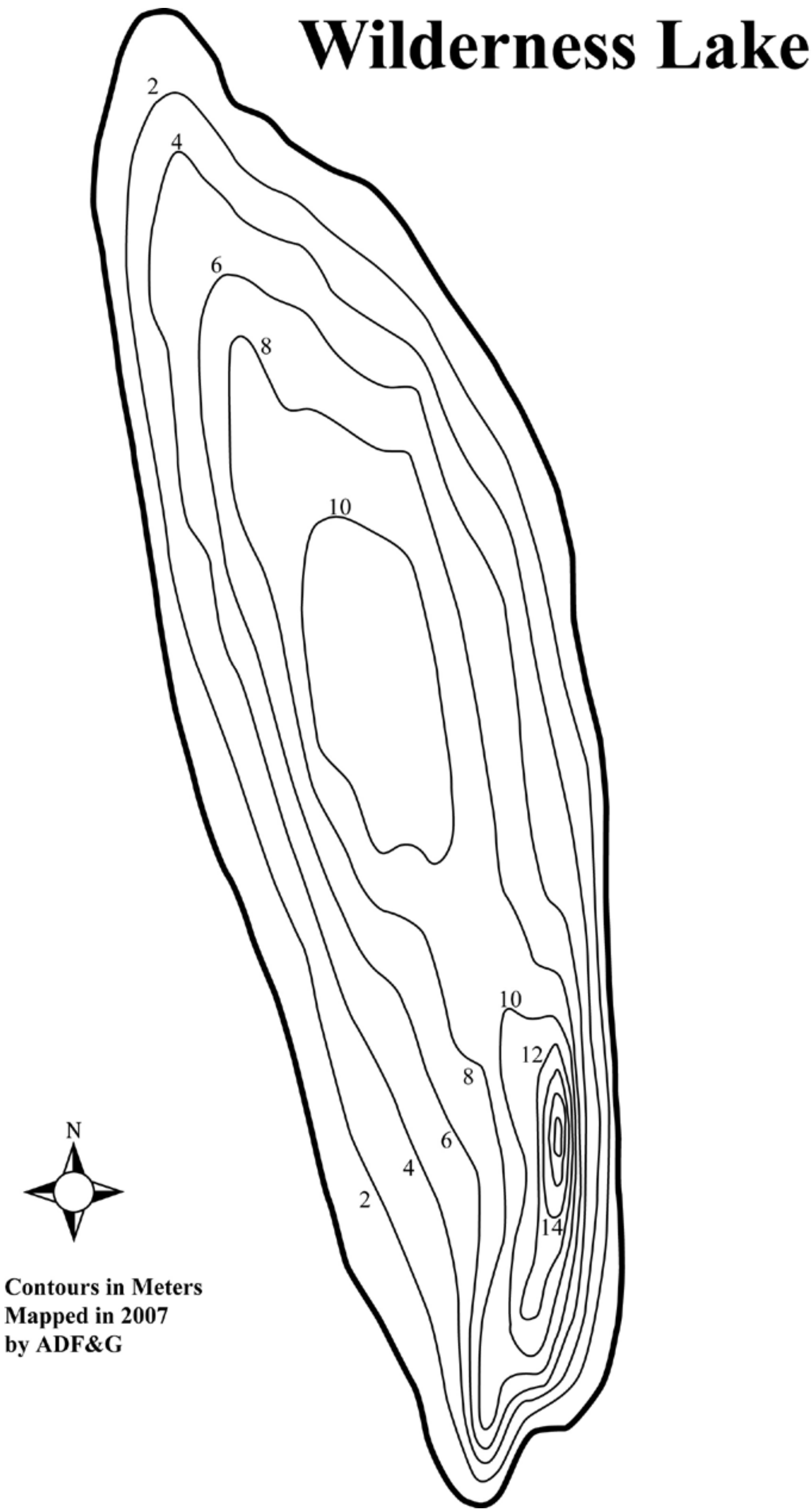
Appendix F1.–Page 11 of 11.



APPENDIX G
DATA FILES

Appendix G1.–Archived data files pertaining to this report available from the authors at ADF&G, 1300 College Road, Fairbanks, AK, 99701.

Data File	Description
Limnology 2005-2008 AB.xls	Limnology data from sample lakes for 2005–2008.
Macroinvertebrates 2005-2008 AB.xls	Macroinvertebrate sample data that includes counts of organisms for 2005–2008.
Macrophytes 2005-2008 AB.xls	Macrophyte data from sample lakes for 2005–2008.
Zooplankton 2005-2008 AB.xls	Zooplankton data that includes counts of organisms for 2005–2008.
Fish Data Summary 2005-2008 AB.xls	Fish length and count data for sample lakes for 2005–2008.
Photographs of Lakes 2005-2007 (folder)	JPEG files of lake photographs for each sample lake during summer for 2005–2008.