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Stock Assessment and Biological Characteristics of Burbot in Tanada Lake, 2007 and Copper Lake, 2008

Final Report for Study 07-501

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Fishery Information Service

by

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and

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October 2010

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

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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

FISHERY DATA REPORT NO. 10-62

STOCK ASSESSMENT AND BIOLOGICAL CHARACTERISTICS OF BURBOT IN TANADA LAKE, 2007 AND COPPER LAKE, 2008

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ABSTRACT

Stock assessments of burbot *Lota lota* were conducted at Tanada Lake in 2007 and at adjacent Copper Lake in 2008. Burbot were captured using baited hoop traps systematically set along equally spaced transects and soaked for two nights (approximately 48 h). Sampling was conducted twice at each lake as part of a two-event mark-recapture experiment. Mean CPUE, length composition and abundance were estimated.

At Tanada Lake, the first event occurred from 25 June to 6 July 2007 and 388 traps were set. The second event took place from 12 to 19 September 2007 and 333 traps were set. Mean CPUE of fully recruited burbot (i.e., ≥450 mm TL) for the first event was 1.17 (SE = 0.19) burbot/trap and was 0.89 (SE = 0.13) burbot/trap for the second event. A pooled Chapman-modified Petersen estimator was used to estimate the abundance of fully recruited burbot at 2,217 (90% CI = 1,821–2,613). Burbot from 450 to 549 mm TL composed 77% of the total estimated abundance of fully recruited burbot. Measurements (1.0 m depth increments) of water temperature (°C), conductivity (µS/cm), dissolved oxygen (DO) and pH were recorded at several occasions during the spring, summer and fall and all measurements were within expected ranges.

At Copper Lake, the first event occurred from 7 to 15 June 2008 and 382 traps were set. The second event took place from 10 to 17 September 2008 and 311 traps were set. Mean CPUE of fully recruited burbot for the first event was 0.041 (SE = 0.016) burbot/trap and was 0.096 (SE = 0.031) burbot/trap for the second event. A length-stratified, Chapman-modified Petersen estimator was used and the abundance estimate of burbot ≥315 mm TL was 943 (90% CI = 550–1,337). Smaller sized fish (315–425 mm TL) dominated the catches. Measurements (1.0 m depth increments) of water temperature (°C), conductivity (µS/cm), dissolved oxygen (DO) and pH were recorded at several occasions during the spring, summer, and fall. DO and temperature readings in the deeper zones of the lake indicate that Copper Lake does not turn over annually.

Key words: Burbot, *Lota lota,* abundance, length composition, catch per unit effort, hoop traps, mean length, Copper Lake, Tanada Lake.

INTRODUCTION

Burbot *Lota lota* in Tanada and Copper lakes (Figure 1) had never been studied and have always been managed under the general sport fishing regulations. The present daily bag and possession limit under state regulations is five burbot. Estimated annual harvest from Tanada Lake from the Alaska Department of Fish and Game (ADF&G) Statewide Harvest Survey has ranged from 0 to 637, and averaged 14 burbot during the last five years (2004–2008; Figure 2). For Copper Lake, estimated annual harvest has ranged from 0 to 450 burbot, and the most recent 5-year (2004–2008) annual mean harvest is 46 burbot (Jennings et al. 2006a-b, 2007, 2009a-b, 2010a-b; Figure 2). Both lakes lie within the Wrangell-St. Elias National Park/Preserve (WRST), and subsistence fishing opportunities exist for federally qualified users. Currently, no federal subsistence harvest limits have been established for freshwater fish species in the Copper River drainage.

While federal subsistence fishing permits have recently been issued, no harvests have been reported. It is possible that federally qualified subsistence users are already meeting their needs from these lakes by fishing under State of Alaska sport fish regulations. However, this situation could change if qualified users decide to fish under Federal subsistence fishing regulations that provide greater harvest opportunities. To examine the status of the burbot populations, assessment projects in both Tanada and Copper lakes were undertaken by the ADF&G and WRST during 2007 and 2008. Information on abundance and size structure of the burbot population will allow managers to determine sustainable harvest levels for this resource.

Specific objectives for 2007 and 2008 were to:

1. estimate the length composition of fully recruited burbot (≥450 mm TL) at Tanada Lake (2007) and Copper Lake (2008) such that the estimated proportions were within ±10 percentage points of the actual values 95% of the time;
2. estimate mean catch per unit of effort (CPUE) of fully recruited burbot (≥450 mm TL) in Tanada Lake (2007) and Copper Lake (2008) such that the estimated mean CPUE was within ±50% of its asymptotic value 90% of the time;
3. estimate the abundance of fully recruited burbot (≥450 mm TL) in Tanada Lake for spring 2007 and in Copper Lake for spring 2008 such that the estimated abundances were within ±25% of the true abundance 90% of the time; and,
4. collect limnological information from Tanada and Copper lakes through a hole in the ice during April and on a monthly basis during the open water period, 2007 and 2008.

The objectives, as well as the study design, were adjusted since the Investigation Plan (IP) was approved. The original study design was changed from conducting concurrent (i.e., sampling both Tanada and Copper lakes each spring) three-year Jolly-Seber experiments to conducting a two-event mark-recapture experiment at each lake. This change was made to obtain more precise estimates of abundance. In addition, only one lake would be assessed in a given year with first event sampling occurring in spring and second event sampling occurring in fall. Tanada Lake was assessed in 2007 and Copper Lake was assessed in 2008. Also, the limnological sampling was added as an objective. This sampling was discussed in the methods of the IP, but was omitted from the list of objectives. Lastly, leftover monies from the 2010 fiscal year were used to purchase archival tags which were surgically implanted into burbot at Tanada Lake during spring 2009. These tags will be used to evaluate seasonal depth use and temperature preferences. The goals of this graduate study and a summary of archival tag implanting at Tanada Lake are discussed in this report (i.e., how the FY10 money for this contract was used). The archival tag study will continue for two additional years and will expand to Copper Lake in spring 2010. Final results will be published as a Master's thesis in a cooperative study between the University of Alaska Fairbanks, WRST and ADF&G.

METHODS

STUDY AREA

Tanada Lake (62°25' N, 143°22' W; Figure 1) is located within the Wrangell-St. Elias National Park/Preserve in the upper Copper River drainage. Its surface area is 1,100 ha, it has a maximum depth of 60 m and an elevation of 835 m. At present there are no public recreational facilities on the lake, although Tanada Lake Lodge began operations with new owners in 2008. Tanada Lake supports burbot, lake trout S*alvelinus namaycush*, Arctic grayling *Thymallus arcticus*, round whitefish *Prosopium cylindraceum*, longnose sucker *Catostomus catostomus*, and anadromous sockeye salmon *Oncorynchus nerka*. Tanada Lake has four inlet streams (Grayling, Goat, Sawmill and one that is unnamed) and one outlet stream (Tanada Creek) which flows directly into the Copper River.

Copper Lake (62°25' N, 143°30' W; Figure 1) is located within the WRST about 3 km west of Tanada Lake. Its surface area is 730 ha, maximum depth is 70 m, and elevation is 884 m. There are no public recreational facilities on the lake, although a lodge does operate on the lake with cabin and boat rentals available. Copper Lake supports burbot, lake trout, Arctic grayling,

whitefish, longnose sucker, and sockeye salmon (both anadromous and resident forms). Copper Lake has three small inlet streams and one short outlet stream which flows directly into the Copper River.

STUDY DESIGN AND FISH CAPTURE

Two separate two-event mark-recapture experiments were conducted to estimate abundance and length composition of burbot in Tanada Lake (2007) and Copper Lake (2008). Burbot were captured in 3-m long baited hoop traps with 25-mm mesh netting set on the bottom as described in Bernard et al. (1991). Burbot ≥450 mm TL were assumed to be fully recruited to this gear. Traps were positioned according to a systematic sampling design as described in Bernard et al. (1993) to minimize competition among the gear while still covering the bottom of the lake. A grid system was used with traps placed along transects at approximately 125-m intervals; transects were also spaced at approximately 125-m intervals. These spacing intervals serve as a guideline and were estimated by the field crews on a trap by trap, transect by transect basis. For each event at each lake, a second series of transects were set down the length of the lake after the first pass was completed to improve sample sizes. For each lake, the number of traps set per complete pass varied with the experience of the crew. For example, during the first pass down Copper Lake in spring 2008 the field crew underestimated the spacing distance and ended up setting many more traps during the first pass. No traps were set deeper than 15 m in either lake to avoid decompression-induced mortality associated with burbot captured at greater depths (Bernard et al. 1993). A set was defined as a single hoop trap baited with Pacific herring *Clupea pallasi* fished for approximately 48 hours. On a daily basis, the crew would bait and place approximately 60-70 traps. Two days later these traps were lifted, rebaited and reset along new transects.

After lifting a hoop trap, the catch was emptied into a holding tank and all burbot were measured for total length (to the nearest 1 mm) and examined for previous tags and secondary marks. All captured fish >300 mm TL that were not previously tagged were marked with an individually numbered T-bar anchor tag (Floy™ FD-94)[1] inserted in the musculature beneath the dorsal fin and given a secondary mark in the form of a fin clip. For each lake, a partial left ventral fin clip was used in the spring and a partial right ventral clip was used in the fall. All tags were checked to ensure that they were locked between the pterygiophores of the dorsal fin.

Individual trap and associated catch information were recorded on standard hoop-net mark-sense forms (Heineman 1998) for all lakes. Data forms were optically scanned and electronic data files (ASCII format) were produced and imported into Microsoft Excel™ spreadsheets for data analysis. Trap information included: hoop trap number, location of set, depth of set, hour set and pulled, and number of fish caught by species. Total length, tag number and color, secondary mark, fate, and recapture status were recorded on mark-sense forms for each burbot caught in each set. All edited ASCII files derived from the hoop-net forms were archived (Appendix A1).

The first event (spring sampling) at Tanada Lake commenced on 25 June and ended on 6 July 2007. The lake became ice free <5 days prior to the initiation of sampling. Sampling near the time of ice-out is essential because burbot have the highest catchability at these times and experiments can be repeated more easily to ensure accurate CPUE comparisons with future projects (Bernard et al. 1993). Two complete passes were made down the entire length of the

[1] Product names used in this report are included for scientific completeness, but do not constitute product endorsement.

lake using the transect protocol described in Bernard et al. (1993). During the first pass, 200 hoop traps were set and during the second pass, 188 traps were set (Table 1).

The second event at Tanada Lake took place from 12 to 19 September 2007. After an initial first pass in which 218 hoop traps were set the entire length of the lake (Table 1), it was determined that the objective criteria for both the length distribution and abundance estimate would be easily attained so making another complete pass was not necessary. Instead only half the transects were set (i.e., every other transect; 115 traps) to catch additional fish to improve the precision of the abundance estimate, as well as to increase the number of recaptured fish for diagnostic testing.

The first event (spring sampling) at Copper Lake commenced on 7 June and ended on 15 June 2008 (Table 1). The lake became ice free <5 days prior to the initiation of sampling. Two passes were made down the entire length of the lake using the transect protocol described in Bernard et al. (1993). During the first pass, 250 hoop traps were set and during the second pass, 132 traps were set (Table 1). The discrepancy in the total number of traps per pass down the lake is due to the crew underestimating 125-m intervals during the first pass.

Fall sampling at Copper Lake took place from 10 to 17 September 2008. As in the spring event, two complete passes were made along all transects (Table 1). During the first pass 161 traps were set, and during the second pass 150 traps were set.

The sampling strategy for these studies was to: 1) place our sampling gear in an attempt to subject all fish to an equal probability of capture during the first event (i.e., to the extent possible, distribute marks in proportion to abundance throughout the study area); 2) facilitate mixing of marked and unmarked fish within the lake with a long hiatus; and, 3) repeat step "1" for the second event. The study lakes were arbitrarily divided into nearly equal sized sections prior to sampling to serve as initial strata for performing diagnostic tests (i.e., examine movement and capture probabilities). Tanada Lake was divided into 7 strata and Copper Lake was divided into 3 strata (Figures 3 and 4).

Abundances were estimated using a two-event Petersen mark-recapture experiment (Seber 1982) designed to satisfy the following assumptions:

1. the populations were closed (burbot did not enter the populations, via growth or immigration, or leave the populations, via death or emigration, during the experiment);
2. all burbot had similar probabilities of capture in the first event or in the second event, or marked and unmarked burbot mixed completely between events;
3. marking of burbot in the first event did not affect the probabilities of capture in the second event;
4. marked burbot were identifiable during the second event; and,
5. all marked burbot were reported when examined during the second event.

The experiment was designed to allow us to test these assumptions. The specific form of the population estimator used was based on results of the diagnostic tests performed to evaluate whether assumptions concerning size selectivity, mixing, and capture probability were met (Appendices B1 and B2).

Evaluation of Assumptions

Assumption 1: It was unlikely that burbot exited either lake during the study. For both lakes, all inlet streams were unsuitable burbot habitat. It was unlikely that burbot entered or exited Tanada Lake via Tanada Creek. WRST operates a weir on the creek and have never passed a burbot through it. The outlet creek at Copper Lake is small, shallow and swift thus not suitable for burbot. It was recognized that growth recruitment would likely occur during the three month hiatus needed to promote mixing. Marking fish with individually numbered tags permitted an evaluation of growth using lengths of recaptured fish. These growth data were used to determine whether adjustments to the abundance estimate or the population of inference were needed to eliminate related bias. It was known that some natural mortality would occur, but as with growth, this can be addressed when considering the population of inference. Angling-induced mortality during the hiatus was assumed to be insignificant because Copper and Tanada lakes have a very small reported harvest (i.e., 40 annually), the lakes are remote and burbot typically are not harvested in the summer months.

Assumption 2: Sampling with hoop traps was limited to water depths ≤15 m. Efforts were made to subject all fish within sampled portions of the lake to an equal probability of capture during each event to the best of our ability by uniformly setting areas within the transect/grid system for deploying hoop traps (Bernard et al. 1993). This design promoted similar trap densities for each pass down the lake throughout all waters ≤15 m. These experiments rely on ensuring equal probability of capture during at least one event, or complete mixing of marked and unmarked fish so that event specific probabilities of capture are equal. We hoped that the three month hiatus between events would allow for complete mixing. We used diagnostic tests to identify heterogeneous capture probabilities (Appendix B2) and then selected an appropriate method to correct for any biases that were detected.

Assumption 3: The hiatus of almost three months between the first and second events were assumed to be long enough to allow marked fish to recover from handling and marking-induced behavioral effects from the first event.

Assumptions 4 and 5**:** Burbot captured during the first events were double marked with an individually numbered Floy™ FD-94 T-bar anchor tag and the removal of the tip of the left ventral fins. In the second events, the tip of the right ventral fins were removed from all fish and served as an identifying mark to prevent duplicate sampling. All fish were carefully examined for these marks.

Limnological Sampling

Limnological measurements were collected near the deepest area of each lake. Sampling locations were generally near 62.4219° N, 143.3740° W at Tanada Lake and at 62.4251° N, 143.5472° W at Copper Lake. Measurements of the following parameters were made at 1.0 m depth increments from the surface (0 m) to the bottom: water temperature (°C), conductivity (µS/cm), dissolved oxygen (DO) and pH. Measurements were scheduled to be taken once each month throughout the open water period (June–September), and once when the lake was ice-covered (March–May). Measurements were taken with a Quantra Series Hydrolab.

DATA ANALYSIS

CPUE

CPUE was defined as the number of fish caught per trap fished for a 48-h period (two nights). Mean CPUE of partially (<450 mm TL) and fully recruited burbot (≥450 mm TL) was estimated for each of the passes down the lakes following a two-stage sampling design with transects as first-stage units and sets along transects as second-stage units (Bernard et al. 1993; Sukhatme et al. 1984). Burbot captured during the second passes that were previously captured during the first passes were used in the CPUE analysis for each of the passes; however, these fish were not used in the estimation of length composition or abundance. Although all transects had an equal probability of being included in sample events, they were of different lengths due to the shape of the lakes. Under these conditions, an unbiased estimate of mean CPUE was:

$$\overline{CPUE} = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{m_i}\sum_{j=1}^{m_i}\omega_i c_{ij} \qquad (1)$$

where:

c_{ij} = catch of burbot from the jth set on the ith transect;

n = number of transects;

m_i = number of sets sampled on the ith transect;

$\omega_i = M_i / \overline{M}$;

M_i = maximum possible sets on the ith transect; and,

$\overline{M}$ = mean of possible sets across all transects.

Although the M_i and $\overline{M}$ are unknown, the m_i and $\overline{m}$ were used as substitutes because both M and m are directly related to the length of transects. Thus $\varpi_i = m_i / \overline{m}$ was used to estimate ω_i. Because few burbot enter traps during daylight (Bernard et al. 1991), catches were not adjusted for the few hours deviation in soak times from the standard 48-h for most sets. A two-stage resampling procedure (Efron 1982; Rao and Wu 1988) was used to generate an empirical distribution of mean CPUE for each sample event from which variance of mean CPUE and bias from using ω_i were estimated. In resampling procedures, sets were chosen randomly within each transect although the original selection of sets was systematic. Systematically drawn data can be treated as randomly drawn with little concern for bias in the resultant statistics only so long as these data are not auto-correlated or follow a trend (Wolter 1984). Analysis of data from surveys in other Alaska lakes has revealed no meaningful trends or autocorrelations among catches along transects (Bernard et al. 1993). Estimates of mean CPUE for two size groups of burbot (≥450 mm and <450 mm TL) were calculated for each sample event using procedures described in Bernard et al. (1993). The computer program RAOWU.EXE was used to estimate mean CPUE, approximate its variance, and estimate inherent bias in the estimate according to a two-stage bootstrap procedure based on a model in Rao and Wu (1988). Individual burbot captured more than once in a given year were considered different fish each time captured in calculation of mean CPUE. Conditions for the accurate calculation of mean CPUE as an index of abundance were:

1. gear do not compete for burbot;
2. burbot do not saturate the gear; and,
3. gear is not size-selective.

Bernard et al. (1993) showed that the spacing of sets used in these studies (125 m) were sufficient to avoid competition among gear for burbot and that saturation of gear by burbot was negligible. Because hoop traps fished in this project were size-selective for burbot (Bernard et al. 1991, 1993), only mean CPUE for fully recruited burbot were considered as a valid index of abundance. Also, because captured burbot take as many as 2–3 weeks to fully adjust to the effects of capture and handling (Bernard et al. 1991), CPUE from only the first pass of each event should be used for future CPUE comparisons.

Length Composition

Based on results of the K-S tests outlined in Appendix B1 (i.e., to stratify by length or not), length composition of the pooled population or individual length strata were estimated as the following proportion(s):

$$\hat{p}_{jk} = \frac{n_{jk}}{n_j} \tag{2}$$

where:

n_j = the number sampled from length stratum j in the mark-recapture experiment;

n_{jk} = the number sampled from length stratum j that were in length category k; and,

$\hat{p}_{jk}$ = the estimated proportion of length category k in length stratum j.

Each length category was 50 mm wide at Tanada Lake and 10 mm wide at Copper Lake.

Variances were estimated as (Cochran 1977):

$$\hat{V}\left[\hat{p}_{jk}\right] = \frac{\hat{p}_{jk}\left(1-\hat{p}_{jk}\right)}{n_j - 1}. \tag{3}$$

Results of the same K-S two-sample tests used to determine procedures for calculating population abundances were also used to determine whether the length composition estimates for the populations needed to be adjusted for differential capture probabilities (Appendix B1). If length stratification was warranted (Case IV), strata were formed based on the x-value (length) of the maximum vertical deviation between the two curves being compared (D statistic of K-S test), number of recaps for each potential length strata, and capture probabilities of probable length strata. K-S tests were then performed on each group to determine whether additional stratification was needed.

Abundance Estimates

Relative to Assumption 2 (equal probability of capture or complete mixing), variations in capture probability related to size, location, and time were examined. Violations of Assumption 2 relative to size-selective sampling were tested by using results of two Kolmogorov-Smirnov (K-S) two-sample tests ($\alpha = 0.05$) that compared length frequency distributions of 1) fish captured during the first event and recaptured fish; and, 2) fish captured during the second event and recaptured fish. A third test, comparing fish captured during the first event with those of the second event can be used to interpret questionable results of the first two tests. There are four possible combinations of outcomes of these two tests, each of which requires using different procedures to calculate a population abundance estimate (Appendix B1).

Violations of Assumption 2 were tested using consistency tests described by Seber (1982; Appendix B2). The documentation of release locations for each fish permitted the examination of multiple geographic stratification schemes and capture probabilities. Criteria considered when defining geographic strata included number of recaptures per stratum and stratum size relative to anticipated movements. If at least one of the three consistency tests resulted in a failure-to-reject the null hypothesis, then we concluded that at least one of the conditions in Assumption 2 was satisfied (Appendix B2). If all three of these tests reject the null hypothesis, then depending on the extent of movement, a partially or completely stratified estimator would be used. If marked burbot moved differently between strata (incomplete mixing), then a partially stratified abundance estimate was computed using Darroch's (1961) methods. If no movement of marked burbot between geographic strata occurred, then a completely stratified abundance estimate was computed using Chapman's modification of the Petersen estimator (Seber 1982; Appendix B3).

RESULTS

TANADA LAKE

Summary of Fish Captured

A total of 1,110 burbot were captured during this project, and of these 377 were partially recruited and 733 were fully recruited to the gear (Table 2). Four hundred and forty-seven (447) fully recruited burbot were captured and released during the first event and 286 fully recruited burbot were captured and examined during the second event. Fifty-seven (57) of the 286 burbot examined during the second event were recaptures marked during the first event, six of which had experienced tag loss (10%). Overall mean length of captured fully recruited burbot for the first and second events were 538 (SD = 65.9) and 523 (SD = 55.7) mm TL, respectively (Table 2).

CPUE

The first pass of the first event yielded a mean CPUE of 0.194 (SE = 0.048) and 1.170 (SE = 0.187) for partially and fully recruited burbot, respectively (Table 3). During the second event of the experiment, the first pass down the lake resulted in a mean CPUE of 0.837 (SE = 0.143) partially recruited burbot and a mean CPUE of 0.884 (SE = 0.126) fully recruited burbot. In both events, the second pass resulted in slightly higher mean CPUE for fully recruited burbot than the first pass (Table 3). Generally, CPUE was higher in the deeper water sets for both events (Appendix C1 and C2).

Length Composition

K-S test results indicated there was no size selectivity during the second sampling event, but that there was during the first event (Figure 5; Appendix B1; Case III). Therefore, only lengths from the second event were used to estimate length composition of the population. The largest 50-mm length category was 500-549, which represented 42% of the population (Figure 6). The next largest length class was 450-499 mm TL. Together, these two length categories represented 77% of the population.

Abundance

K-S tests indicated that size stratification was not necessary for fully recruited burbot (Case III; Appendix B1). The M vs. R test failed to reject the null hypothesis while the C vs. R test rejected the null hypothesis (Figure 5).

Consistency tests indicated that geographic stratification was not necessary. Using the seven original equal sized strata (Figure 3), these tests indicated that the probabilities of capture during the first event were equal (Table 4) and probabilities of capture during the second event were equal (Table 5). Although the complete mixing matrix had limited sample sizes per cell, the null hypothesis was not rejected indicating mixing was sufficient (Table 6). Furthermore, visual examination indicated substantial movement among sampling sections. Only 11% of recaptured fish stayed in the section they were marked, while 60% of recaptured fish moved across two or more section boundaries and 30% moved across five or more section boundaries.

An empirical examination of the change in depth at the time of initial capture vs. recapture suggested that substantial mixing throughout the water column occurred. Therefore it appeared unlikely that many fish (i.e., fish remaining below 15 m) were isolated from the experiment (Figure 7).

The estimated abundance of burbot ≥450 mm TL was 2,217 (SE = 241; 90% CI = 1,821-2,613).

Limnological Sampling

Monthly measurements (1.0-m depth increments) of water temperature (°C), conductivity (µS/cm), dissolved oxygen (DO) and pH were taken in Tanada Lake during April, and then intermittently during the open water period in 2007 and 2008 (Appendix D). Measurements for April 2007 were obtained while the lake was still covered with ice, and temperatures ranged from 0.10°C at the surface to about 4.00°C at the bottom of the water column (45 m). Water temperatures at depths where burbot were captured (~1–15 m) probably ranged from about 4°C to 3°C during the first sampling event in June, and from about 12°C to 4°C during the second event in September. Dissolved oxygen levels at these depths ranged from 13 to 14 mg/L during the first event, and were steady around 10 mg/L during the second event.

COPPER LAKE

Summary of Fish Captured

A total of 391 burbot of all sizes were captured. Of these, 188 burbot were 315–424 mm TL and 44 were ≥425 mm TL (Table 2). During the first event, 100 burbot ≥315 mm TL were captured and only 19 were ≥425 mm TL. During the second event, 132 burbot ≥315 mm TL were captured and only 25 were ≥425 mm TL. A total of 9 burbot 315–424 mm TL and a total of 8 burbot ≥425 mm TL were captured during both events. Mean length of all burbot captured was 349 (SD = 77.8) mm TL for the first event and 348 mm (SD = 72.7) mm TL for the second event (Table 7).

CPUE

During the first sampling event of the experiment, the first pass down the lake yielded a mean CPUE of 0.371 (SE = 0.063) for partially recruited burbot and 0.041 (SE = 0.016) for fully recruited burbot (Table 8). During the second event, the first pass down the lake resulted in a mean CPUE of 0.788 (SE = 0.100) for partially recruited burbot and 0.096 (SE = 0.031) for fully recruited burbot. Generally, CPUE was higher in the deeper water sets for partially recruited burbot, and no partially recruited burbot were captured at depths <4 m (Appendix C3 and C4). There was no apparent trend in depth at capture for fully-recruited burbot (Appendix B3 and B4). However, unlike partially recruited burbot, fully recruited burbot were captured at depths <4 m during both sampling events.

Abundance and Length Composition

Because so many burbot <450 mm TL were captured in this project, abundance estimates were generated for smaller sized fish. The size of the smallest recaptured fish (315 mm TL) was chosen as the lower bound of size range for the abundance estimate. Results of the pooled K-S tests (Figure 8; Appendix B1: Case IV) indicated that length-stratification was required and two length strata were formed: one for burbot 315–424 mm TL and a second for burbot ≥425 mm TL. Since sample sizes of recaptured burbot were limited, the cutoff length of 425 mm was chosen not only because of the relatively high D statistic at this length on the cumulative relative frequency curve, but also because it evenly divided the number of recaptured fish among length strata. Additional K-S tests for the smaller length stratum indicated that additional stratification was not needed (Figure 9, Appendix B1: Case I). Therefore, the length composition of fish in the smaller length stratum was estimated by pooling samples from both sampling events and calculating proportions and standard deviations in 10 mm-length increments (Figure 10). Additional K-S tests were not done for the larger length stratum due to small sample sizes, but visual examination of graphed data suggested that length frequencies of marked, recaptured, and event two captured fish were similar (Figure 11). Since the sample size was small, we simply plotted the length frequency histogram of captured fish ≥425 mm TL in 50 mm TL increments from both events rather than calculating proportions (Figure 12).

Consistency tests using the three original geographic sections (A–C, Figure 4; Appendix B2) indicated that geographic stratification was not necessary for either of the length strata. However, these results were based on small sample sizes. For fish within the smaller length stratum, the tests indicated that the probabilities of capture during both events were equal (Tables 9 and 10). While the test for complete mixing did not have a sufficient number of recaptured fish within the geographic sections to provide meaningful statistical results, some movement among the three sections occurred (3 of 8 fish; Table 11). For fish within the larger length strata the probabilities of capture during both events were also equal (Tables 12 and 13). Again, while the test for complete mixing did not have a sufficient number of recaptured fish within the geographic sections to provide meaningful statistical results, some movement among the three sections occurred (2 of 5 fish; Table 14).

Since sample sizes were limited to evaluate movement with the contingency tables, movement was also examined by measuring 1) the difference between capture and recapture depth; and, 2) the straight line distance between capture and recapture locations. All but two burbot were recaptured in shallower water during the second sampling event than during the first sampling event (Figure 13). The change in capture depth for all but one recaptured burbot was <5 m.

Horizontal movements suggest that at least partial mixing occurred because the mean straight line distance between capture and recapture locations was 1,600 m (Figure 14). Nine fish moved <1,000 m, while four moved >2,000 m.

The total abundance estimate for the population sampled in Copper Lake was 944 burbot ≥315 mm TL (SE = 238; 90% CI = 550-1,337). This estimate was the sum of estimates for burbot between 315 and 424 mm TL (886 total; SE = 238; 90% CI = 494-1,278) and burbot ≥425 mm TL (58 total; SE = 11; 90% CI = 40-76). Relative precision (RP) of the total estimate was 0.42, which was less precise than our objective of 0.25.

Limnological Sampling

Monthly measurements (1.0-m depth increments) of water temperature (°C), conductivity (µS/cm), dissolved oxygen (DO) and pH were taken in Copper Lake during April, and then intermittently during the open water period in 2007 and 2008 (Appendix E). Measurements for April 2008 were obtained while the lake was still covered with ice, and temperatures ranged from 0.05°C at the surface to about 4.00°C at the bottom of the water column (70 m). Water temperatures at depths where burbot were captured (3 to 15 m) ranged from 8°C to 4°C during the first sampling event in June, and from about 9°C to 4°C during the second event in September. Dissolved oxygen levels at these depths ranged from 9.0 to 10.3 mg/L during the first event, and from 7.1 to 9.1 mg/L during the second event.

Archival Tag Study

From 29 June to 14 July 2009, 70 burbot of various sizes ranging from 352 to 728 mm TL were captured at depths ranging from 2 to 30 m and were surgically implanted with archival tags (Table 15). These tags were programmed to record depth and water temperature every 15 minutes for 15 months. Recovery efforts for Tanada Lake will take place during spring and fall 2010. Seventy burbot will also be tagged at Copper Lake in spring 2010 and recovery efforts will take place in spring and fall 2011. Data will be analyzed to determine depth and temperature preferences of burbot, the results of which can be used to evaluate assumptions of mark-recapture experiments for burbot in deep lakes.

DISCUSSION

TANADA LAKE

The study design for estimating the abundance of burbot ≥450 mm TL in Tanada Lake was successful and resulted in an unbiased estimate and a relative precision of 18%, exceeding the objective criteria of 25%. If stock assessments are needed in the future, a similar design is recommended.

The burbot population ≥450 mm TL in Tanada Lake appeared healthy and there is no evidence that the lake is being overexploited. The length frequency distributions were somewhat unexpected because the proportion (approximately 77%) of the population composed of fish between 450 and 550 mm TL was unusually large. Statewide harvest reports did not indicate that the lake was ever overexploited and the lack of larger sized fish in the population is most likely natural. The most plausible explanation is simply the presence of a strong cohort having just recruited into the sampled population.

COPPER LAKE

Our efforts to estimate the abundance of burbot in Copper Lake had mixed results because in contrast to other lakes studied in Alaska, Copper Lake yielded adequate sample sizes of smaller sized burbot (i.e., 315–425 mm TL) to estimate their abundance, however the relative precision (0.42) of the estimate was less than desired (0.25). Nevertheless, our results did conclusively demonstrate that the density of fully recruited burbot in Copper Lake was unusually small.

Copper Lake was a challenging lake to sample because its bathymetry required the study design to rely heavily upon mixing between the sampled areas (i.e., <15 m or ~20% of the lake) and unsampled areas of the lake. Evidence from the small numbers of recaptured fish suggested that adequate mixing had not occurred because vertical and horizontal movements were both small relative to the lakes depth and surface area. (Figures 13 and 14). However, the limnological data strongly suggested that relative to the amount of suitable habitat available, adequate mixing did in fact occur. During the spring sampling event DO levels were <2.0 mg/L at a depths ≥60 m. In fall DO levels were <2.0 mg/L at depths ≥35 m, and virtually no oxygen was detected in the deepest zones of the lake during both events. Therefore, we estimated over 75% of the suitable habitat above the 35-m contour interval was sampled, and that any bias associated from inadequate mixing (i.e., fish being isolated from the experiment) was acceptable (e.g., <20%) for evaluating the populations status.

The observed population structure of burbot in Copper Lake was interesting because the smaller sized burbot dominated the catch and very few large fish were present. The structure could be an artifact of the lakes limnology. For example, Copper Lake might be unproductive because it has a very limited littoral zone and the temperature and DO data suggested that the lake does not mix in the fall and spring. The graduate study being conducted from 2010–2012 will help to address these questions needed prior to another stock assessment. For example, the archival tags will provide detailed movement information relative to unsampled depths, growth information will be collected using otoliths and previously tagged burbot, and more comprehensive limnological information will be collected.

Some local anglers claim there was historically more large burbot in Copper Lake, while others claim that burbot in Copper Lake have always been relatively small. Past overexploitation could have affected the present size of the burbot, but the remoteness of the lake and reported harvest does not support this. Due to the current scarcity of large burbot and the relatively small abundance of smaller sized burbot, it is recommended that Federal subsistence bag limits not exceed state regulation bag limits at this lake.

ACKNOWLEDGEMENTS

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FIGURES

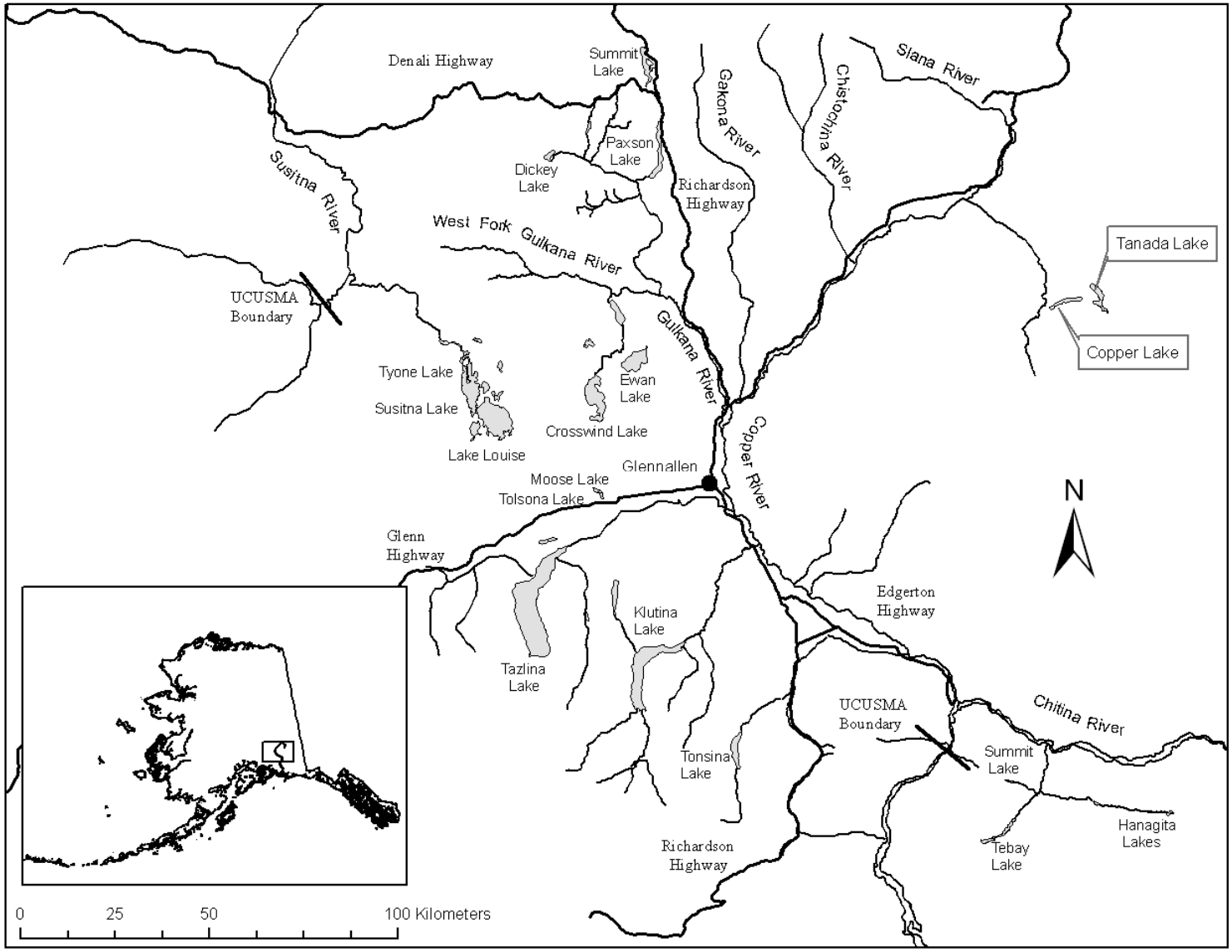


Figure 1.–Location of Copper and Tanada lakes in the Upper Copper/Upper Susitna Management Area.

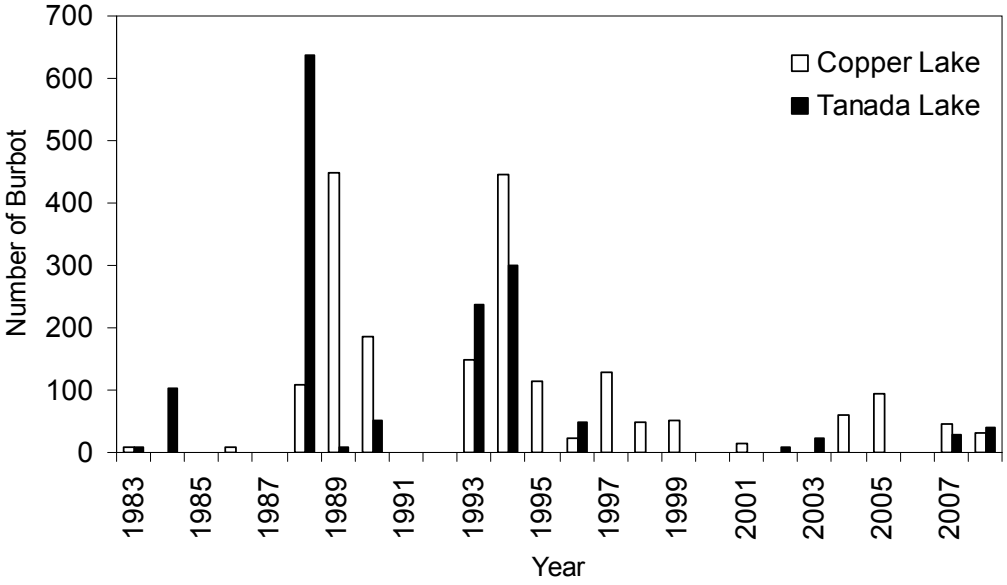


Figure 2.–Estimated harvest of burbot from Copper and Tanada lakes (data from Mills 1985-1994; Howe et al. 1995, 1996, 2001a-d; Jennings et al. 2004, 2006a-b, 2007, 2009a-b, 2010a-b; and Walker et al. 2003).

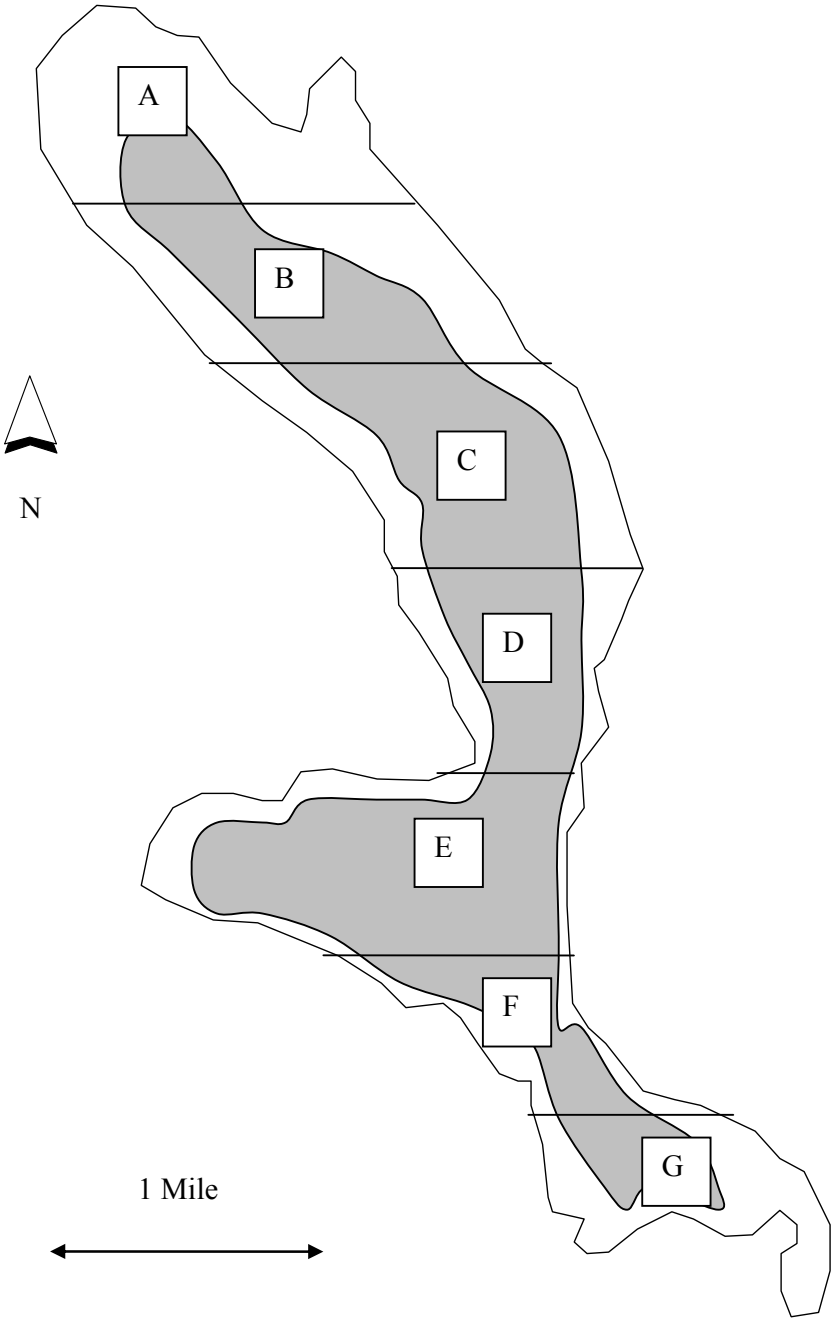


Figure 3.–Map of Tanada Lake with section boundaries. Shaded area represents water that is >15 m deep.

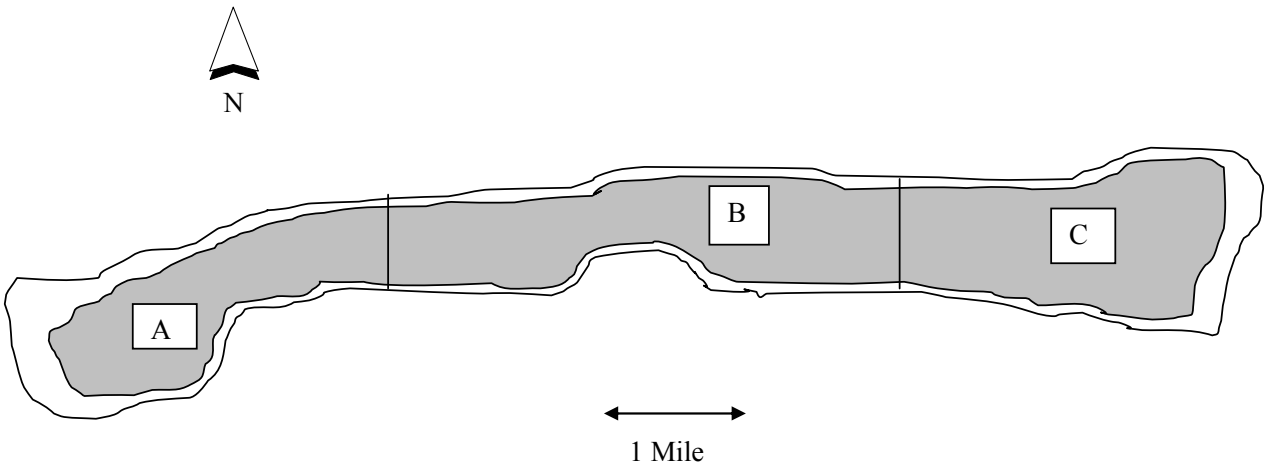


Figure 4.–Map of Copper Lake with section boundaries. Shaded area represents water that is >15 m deep.

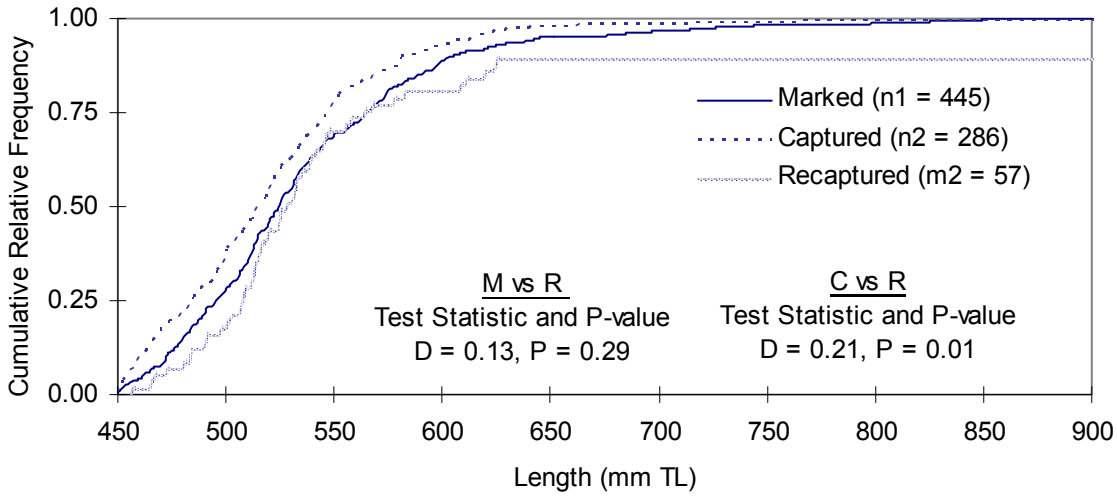


Figure 5.–Cumulative relative frequency distributions of fully recruited burbot, Tanada Lake, 2007.

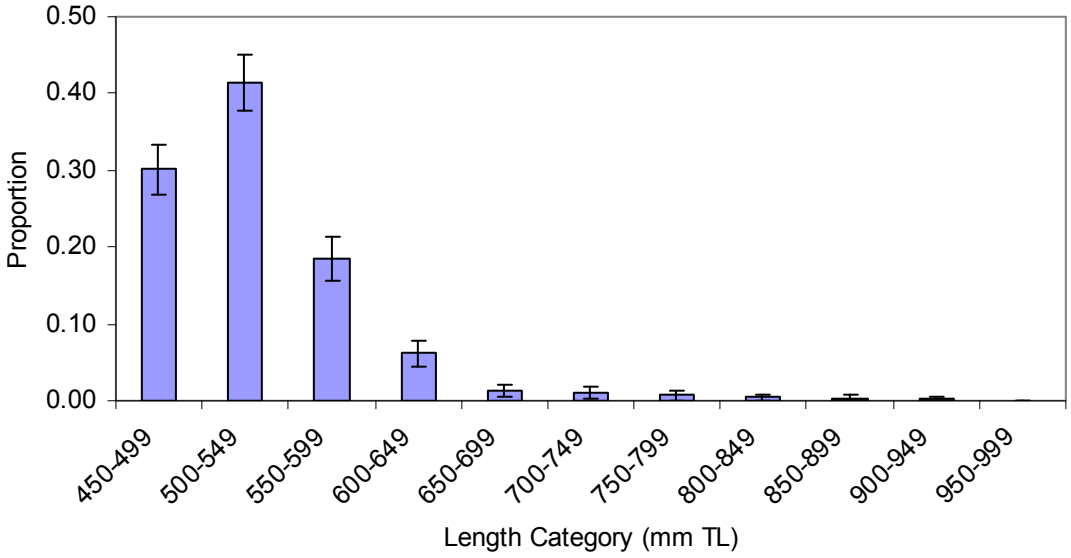


Figure 6.–Estimated length frequency of fully recruited burbot in Tanada Lake, 2007. Vertical bars represent 95% confidence intervals.

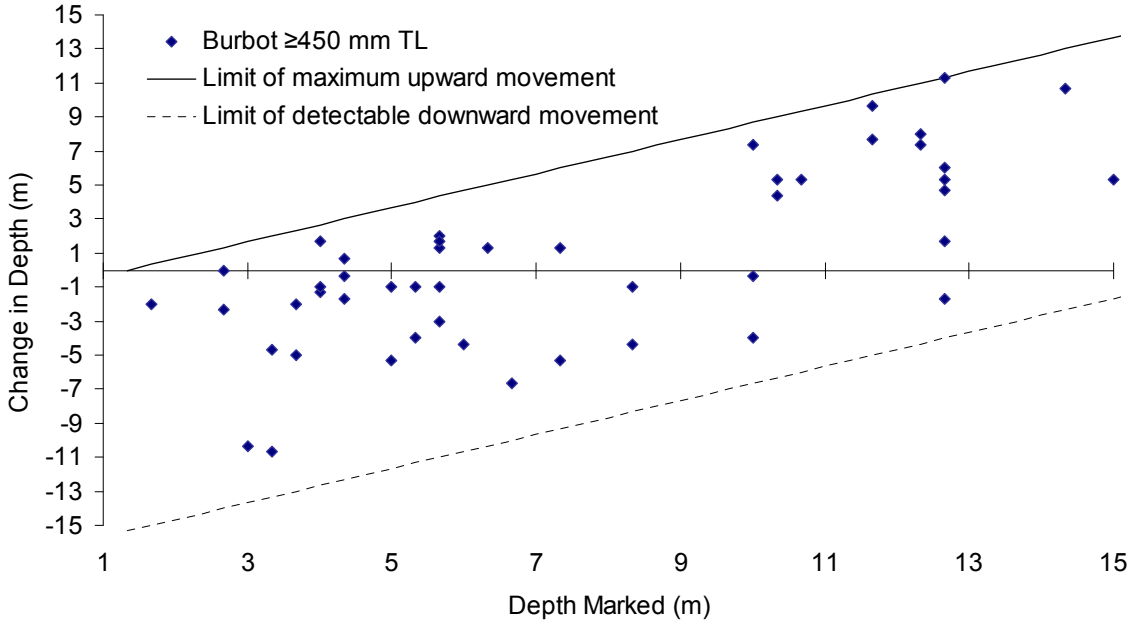


Figure 7.–Change in depth (m) of recaptured burbot between the time marked (spring) and recaptured (fall), Tanada Lake, 2007.

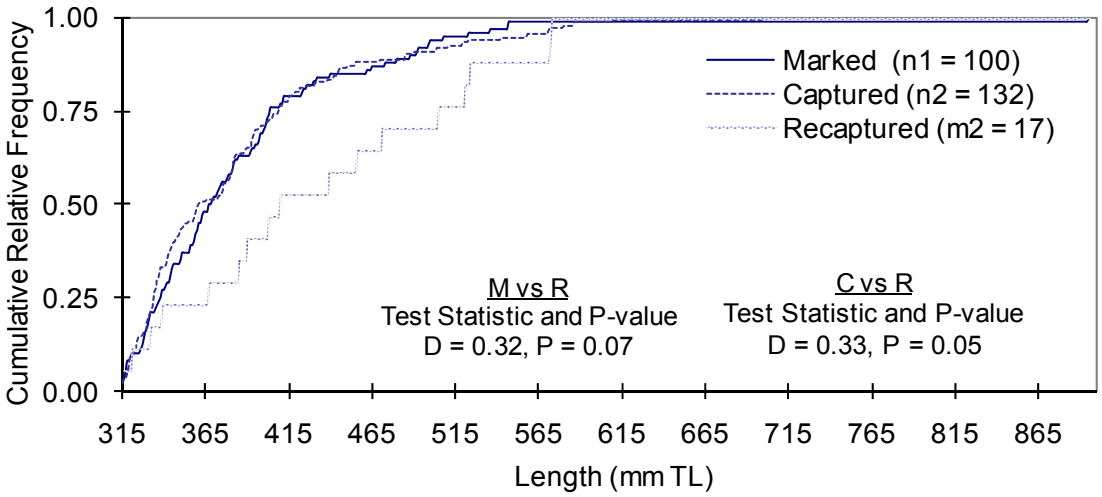


Figure 8.–Cumulative relative frequency distributions of burbot ≥315 mm TL, Copper Lake, 2008.

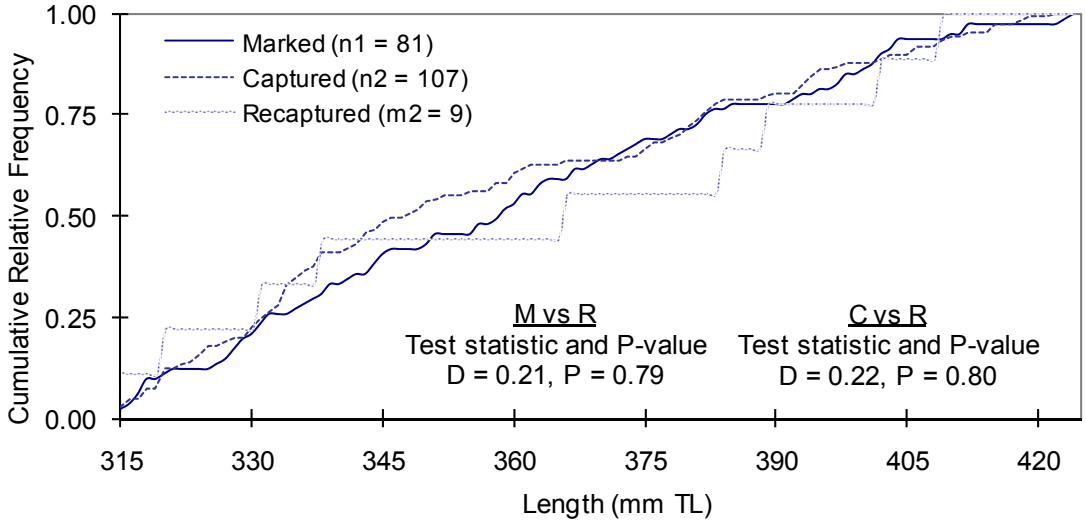


Figure 9.–Cumulative relative frequency distributions of burbot 315–424 mm TL, Copper Lake, 2008.

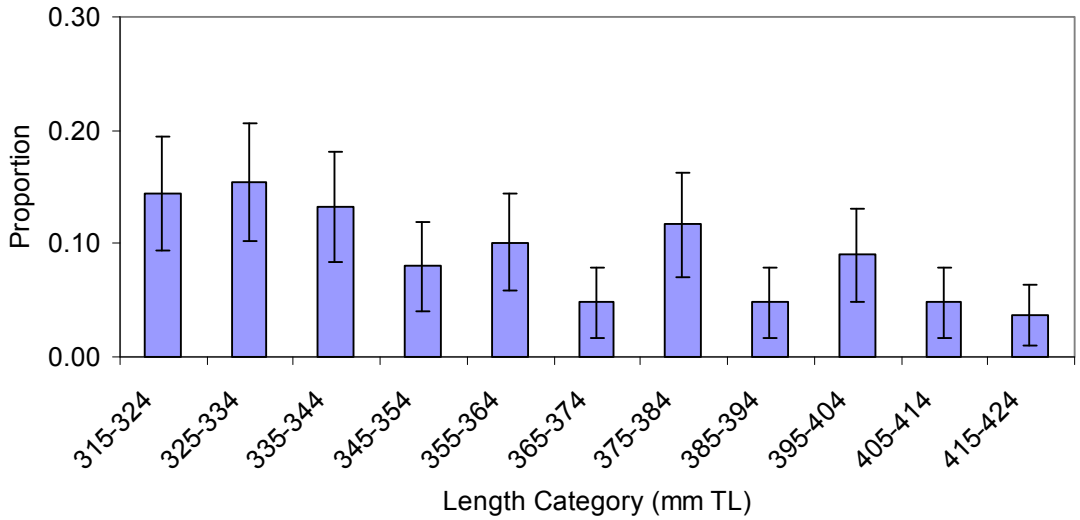


Figure 10.–Estimated length composition of burbot 315–424 mm TL in Copper Lake, 2008. Vertical bars represent 95% confidence intervals.

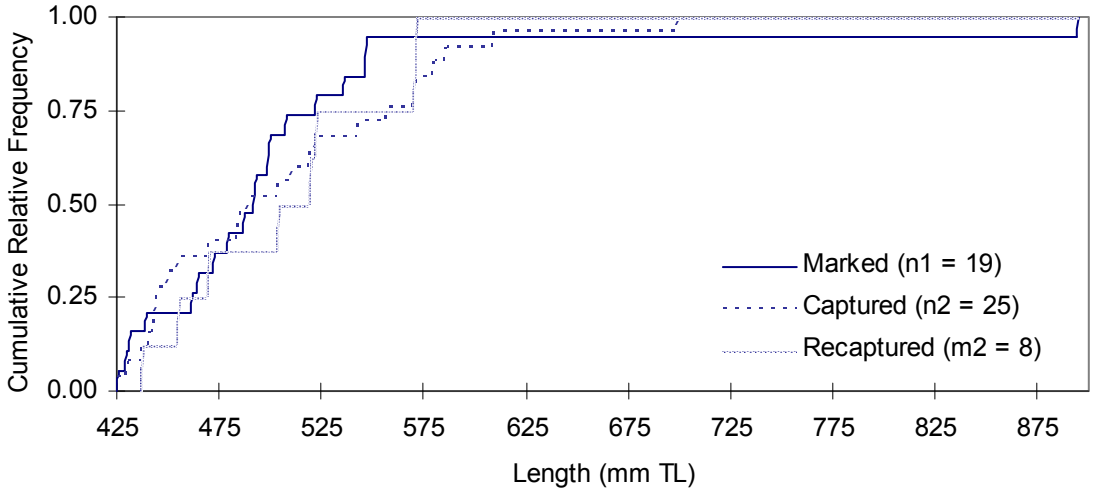


Figure 11.–Cumulative relative length frequency distributions of burbot ≥425 mm TL, Copper Lake, 2008.

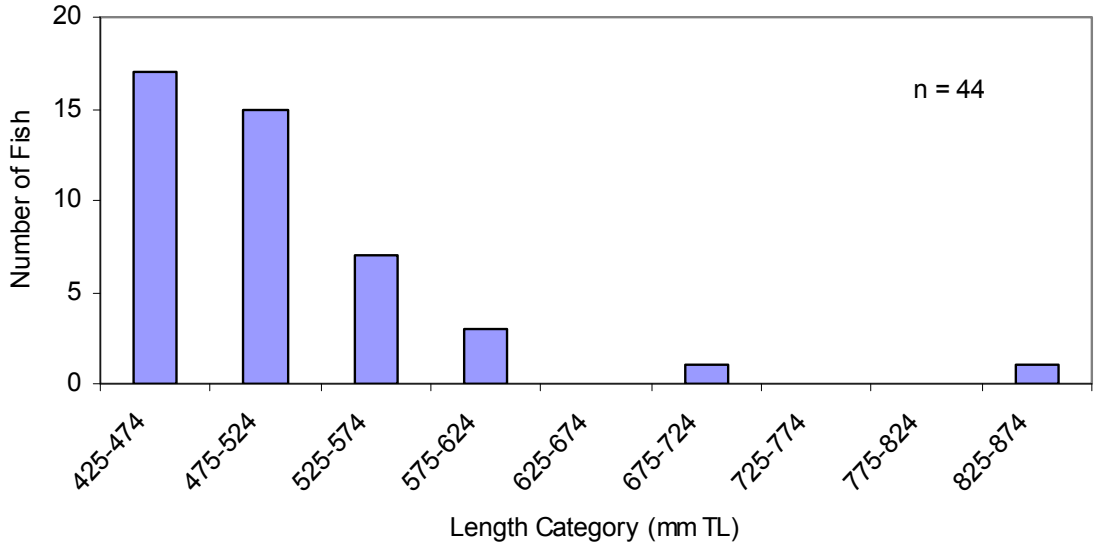


Figure 12.–Length frequency of burbot ≥425 mm TL captured during both events in Copper Lake, 2008.

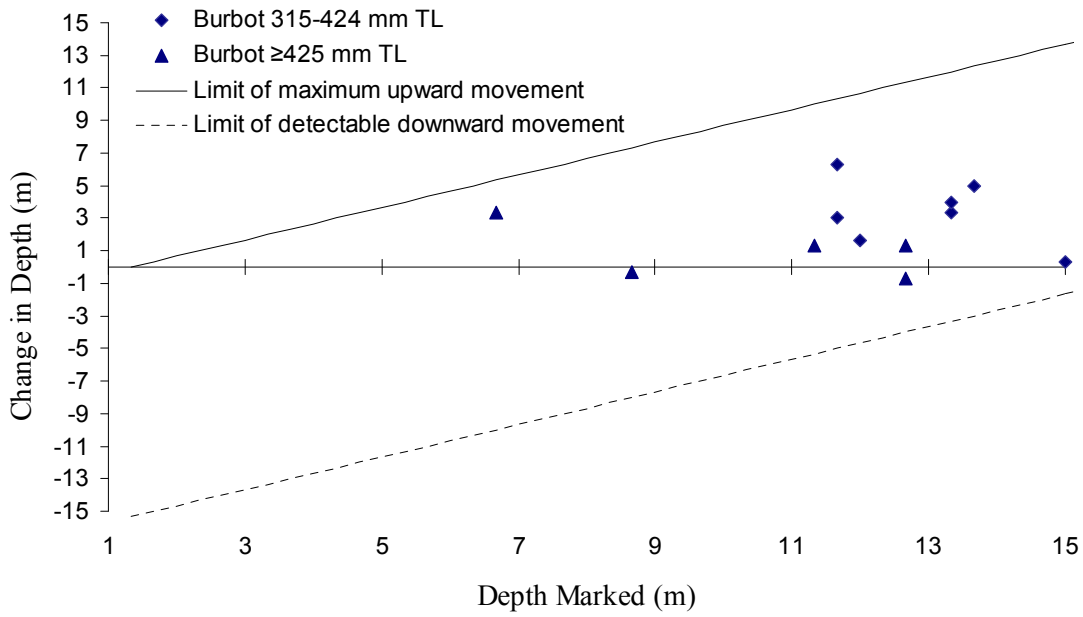


Figure 13.–Change in depth (m) of recaptured burbot between the time marked (spring) and recaptured (fall), Copper Lake, 2008.

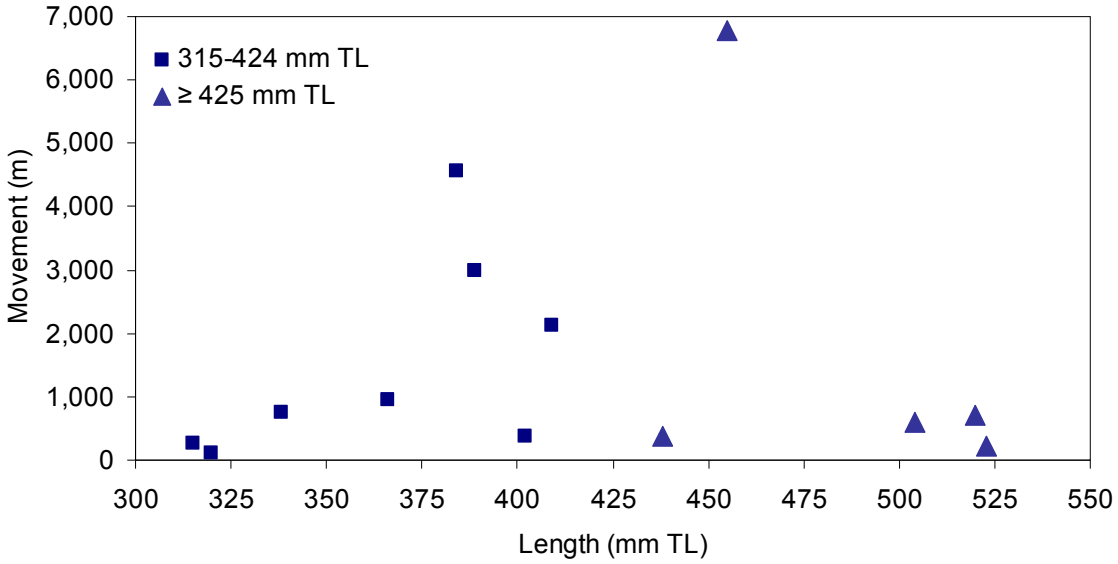


Figure 14.–Movement of recaptured burbot, determined by straight line distances between marked and recaptured locations, Copper Lake, 2008.

TABLES

Table 1.–Number of sets and dates of sampling events for the stock assessment of burbot in Tanada Lake, 2007 and Copper Lake, 2008.

Lake	Year – Event – Pass #	Dates of Sampling Events	Number of Sets
Tanada	2007 - Spring - Pass 1	6/25–6/30	200
	2007 - Spring - Pass 2	6/28–7/06	188
	2007 - Fall – Pass 1	9/12–9/17	218
	2007 - Fall – Pass 2	9/16–9/19	115
Copper	2008 - Spring–Pass 1	6/07–6/12	250
	2008 - Spring–Pass 2	6/11–6/15	132
	2008 - Fall–Pass 1	9/10–9/14	161
	2008 - Fall–Pass 2	9/13–9/17	150

Table 2.–Mean length (mm TL) of burbot measured during both sampling events at Tanada Lake, 2007.

Date of sampling	Statistic	Partially Recruited[a]	Fully Recruited[b]	All
6/25 – 7/06	Mean	391	538	510
	SD	45.9	65.9	85.2
	Sample size	104	447	549
9/12 – 9/19	Mean	383	523	454
	SD	43.2	55.7	85.8
	Sample size	273	286	561

[a] burbot <450 mm TL and considered partially recruited

[b] burbot ≥450 mm TL are considered fully recruited burbot

Table 3.–Hoop trap and catch information for burbot from Tanada Lake, 2007. All sets were made at depths ≤15 m.

Dates	Sets	Tran-sects	Mean CPUE Bootstrapped	Mean CPUE Arithmetic	Mean CPUE %Δ	Bootstrapped SE	Bootstrapped CV
			First Sampling Event				
Pass 1	200	55					
6/25 – 6/30	Fully Recruited[a]:		1.170	1.165	0.4%	0.187	16.0%
	Partially Recruited[b]:		0.194	0.195	-0.3%	0.048	24.6%
Pass 2	188	54					
6/28 – 7/6	Fully Recruited[a]:		1.238	1.228	0.8%	0.201	17.7%
	Partially Recruited[b]:		0.401	0.399	0.5%	0.086	24.7%
			Second Sampling Event				
Pass 1	218	73					
9/12 – 9/17	Fully Recruited[a]:		0.884	0.875	1.0%	0.126	14.2%
	Partially Recruited[b]:		0.837	0.833	0.5%	0.143	17.0%
Pass 2	115	37					
9/16 – 9/19	Fully Recruited[a]:		0.983	0.973	1.0%	0.176	17.9%
	Partially Recruited[b]:		0.908	0.902	0.7%	0.223	24.6%

[a] burbot <450 mm TL and considered partially recruited

[b] burbot ≥450 mm TL are considered fully recruited burbot

Table 4.–Test for equal probability of capture during the first event for burbot ≥450 mm TL. Number of marked and unmarked burbot examined during the second event by section (A–G) of Tanada Lake, 2007.

Category	Section Where Examined							All Sections
	A	B	C	D	E	F	G	
Marked (m_2)	12	13	4	5	5	10	8	57
Unmarked (n_2-m_2)	25	36	13	33	22	55	45	229
Examined (n_2)	37	49	17	38	27	65	53	286
$P_{capture}$ 1st event (m_2/n_2)	0.32	0.27	0.24	0.13	0.19	0.15	0.15	0.20

χ^2 = 7.84, df = 6, P-value = 0.25, fail to reject H_0.

Table 5.–Test for equal probability of capture during the second event for burbot ≥450 mm TL. Number of burbot marked by section (A–G) during the first event that were recaptured and not recaptured during the second event, Tanada Lake, 2007. **Six burbot were recaptured that had lost their tags and could not be assigned the sections where they were marked.**

Category	Section Where Marked							All Sections
	A	B	C	D	E	F	G	
Recaptured (m_2)	7	13	0	7	2	15	7	51
Not Recaptured (n_1-m_2)	70	87	10	42	37	103	47	396
Marked (n_1)	77	100	10	49	39	118	54	447
$P_{capture}$ 2nd event (m_2/n_1)	0.09	0.13	0.00	0.14	0.05	0.13	0.13	0.11

χ^2 = 4.19, df = 4, P-value = 0.65, fail to reject H_0.

Table 6.–Test for complete mixing. Number of burbot ≥450 mm TL marked in each section (A–G) and recaptured or not recaptured in each section of Tanada Lake, 2007.

Section Where Marked	Section Where Recaptured							Not Recaptured	Total Marked
	A	B	C	D	E	F	G	(n_1-m_2)	(n_1)
A	**0**	0	0	2	0	5	0	70	77
B	3	**5**	1	0	1	1	2	87	100
C	0	0	**0**	0	0	0	0	10	10
D	1	2	1	**0**	1	2	0	42	49
E	0	0	0	0	**0**	1	1	37	39
F	4	2	1	1	3	**0**	4	103	118
G	1	3	1	1	0	0	**1**	47	54
Total	9	12	4	4	5	9	8	396	447

χ^2 = 41, df = 42, P-value = 0.50, fail to reject H_0.

Table 7.–Mean length (mm TL) of burbot measured during both sampling events at Copper Lake, 2008.

Date of sampling	Statistic	Partially Recruited[a]	Fully Recruited[b]	All
6/7–6/15	Mean	332	538	349
	SE	47.0	105.3	77.8
	Sample size	154	15	169
9/10–9/17	Mean	331	534	348
	SE	45.4	63.0	72.7
	Sample size	204	18	222

[a] burbot <450 mm TL and considered partially recruited

[b] burbot ≥450 mm TL are considered fully recruited burbot

Table 8.–Hoop trap and catch information for all captured burbot from Copper Lake, 2008. All sets were made at depths ≤15 m.

Sample Dates	Sets	Transects	Mean CPUE			Bootstrapped	
			Bootstrapped	Arithmetic	%Δ	SE	CV
			First Sampling Event				
Pass 1	250	113					
6/7–6/12	Fully Recruited[a]:		0.041	0.041	0.0%	0.016	39.4%
	Partially Recruited[b]:		0.371	0.369	-0.3%	0.063	17.1%
Pass 2	132	59					
6/11–6/15	Fully Recruited[a]:		0.067	0.069	-2.0%	0.028	42.0%
	Partially Recruited[b]:		0.529	0.527	0.5%	0.099	18.8%
			Second Sampling Event				
Pass 1	161	73					
9/10–9/14	Fully Recruited[a]:		0.096	0.093	2.6%	0.031	32.3%
	Partially Recruited[b]:		0.788	0.789	-0.1%	0.100	12.6%
Pass 2	150	75					
9/13–9/17	Fully Recruited[a]:		0.060	0.060	0.0%	0.024	40.0%
	Partially Recruited[b]:		0.604	0.600	0.7%	0.093	15.4%

[a] burbot <450 mm TL and considered partially recruited

[b] burbot ≥450 mm TL are considered fully recruited burbot

Table 9.–Test for equal probability of capture during the first event for burbot 315-424 mm TL. Number of marked and unmarked burbot examined during the second event by section (A–C) of Copper Lake, 2008.

Category	Section Where Examined			
	A	B	C	All
Marked (m_2)	4	0	5	9
Unmarked (n_2-m_2)	25	27	46	98
Examined (n_2)	29	27	51	107
$P_{capture}$ 1st event (m_2/n_2)	0.14	0.00	0.10	0.08

$\chi^2 = 3.69$, df = 2, P-value = 0.16, fail to reject H_0.

Table 10.–Test for equal probability of capture during the second event for burbot 315–424 mm TL. Number of burbot marked by section (A–C) during the first event that were recaptured or not recaptured during the second event, Copper Lake, 2008. One burbot was recaptured that had lost its tag and could not be assigned to the section where it was marked.

Category	Section Where Marked			
	A	B	C	All Sections
Recaptured (m_2)	1	3	4	8
Not Recaptured (n_1-m_2)	14	29	30	73
Marked (n_1)	15	32	34	81
$P_{capture}$ 2nd event (m_2/n_1)	0.07	0.09	0.12	0.10

$\chi^2 = 0.32$, df = 2, P-value = 0.85, fail to reject H_0.

Table 11.–Test for complete mixing. Number of burbot 315–424 mm TL marked in each section (A–C) and either recaptured or not recaptured in each section of Copper Lake, 2008.

Section Where Marked	Section Where Recaptured			Not Recaptured	Total Marked
	A	B	C	(n_1-m_2)	(n_1)
A	**1**	0	0	14	15
B	2	**0**	1	29	32
C	0	0	**4**	30	34
Total	3	0	5	73	81

Table 12.–Test for equal probability of capture during the first event for burbot ≥425 mm TL. Number of marked and unmarked burbot examined during the second event by section (A-C) of Copper Lake, 2008.

Category	Section Where Examined			All Sections
	A	B	C	
Marked (m_2)	3	3	2	8
Unmarked (n_2-m_2)	2	7	8	17
Examined (n_2)	5	10	10	25
$P_{capture}$ 1st event (m_2/n_2)	0.60	0.30	0.20	0.36

χ^2 = 2.48, df = 2, P-value = 0.29, fail to reject H_0.

Table 13.–Test for equal probability of capture during the second event for burbot ≥425 mm TL. Number of burbot marked by section (A-C) during the first event that were either recaptured or not recaptured during the second event, Copper Lake, 2008. Three burbot were recaptured that had lost their tags and could not be assigned the sections where they were marked.

Category	Section Where Marked			All Sections
	A	B	C	
Recaptured (m_2)	1	1	3	5
Not Recaptured (n_1-m_2)	3	4	7	14
Marked (n_1)	4	5	10	19
$P_{capture}$ 2nd event (m_2/n_1)	0.25	0.20	0.30	0.26

χ^2 = 5.89, df = 2, P-value = 0.75, fail to reject H_0.

Table 14.–Test for complete mixing. Number of burbot ≥425 mm TL marked in each section (A–C) and either recaptured or not recaptured in each section of Copper Lake, 2008.

Section Where Marked	Section Where Recaptured			Not Recaptured	Total Marked
	A	B	C	(n_1-m_2)	(n_1)
A	**1**	0	0	3	4
B	0	**1**	0	4	5
C	1	1	**1**	7	10
Total	2	2	1	14	19

Table 15.–Summary of archival tagging, Tanada Lake, 29 June–14 July, 2009.

Size Category (mm)	Shallow (<9 m)	Deep (>18 m)	Total
350–400	3	10	13
401–450	6	5	11
451–500	7	6	13
501–550	8	7	15
551–600	5	6	11
601–650	6	1	7
Total	35	35	70

APPENDIX A:
SUMMARY OF DATA FILE ARCHIVES

Appendix A1 .–Summary of data archives.

Location	Project leader	Storage Software
Fairbanks	Corey Schwanke 822-3309	Delimited ASCII files, Microsoft EXCEL workbook

Lake	File Name	Data Format	Software
Tanada Lake	i-027100h012007.dta	Hoop net	RTS-ASCII
	i-027100h022007.dta	Hoop net	RTS-ASCII
Copper Lake	i-004000h012008.dta	Hoop net	RTS-ASCII
	i-004000h022008.dta	Hoop net	RTS-ASCII

Definition of data formats:

Hoop net: a mark-sense form developed by Alaska Department of Fish and Game, Division of Sport Fish Research and Technical Services (RTS) for the recording of trap, catch, and tagging information. Specific codes and organization of columns for data format is available on request.

APPENDIX B
METHODS FOR TESTING ASSUMPTIONS OF THE PETERSON ESTIMATOR AND ESTIMATING ABUNDANCE

Appendix B1.–Procedures for detecting and adjusting for size or sex selective sampling during a 2-sample mark recapture experiment.

Overview

Size and sex selective sampling may result in the need to stratify by size and/or sex in order to obtain unbiased estimates of abundance and composition. In addition, the nature of the selectivity determines whether the first, second or both event samples are used for estimating composition. The Kolmogorov-Smirnov two sample (K-S) test (Conover 1980) is used to detect significant evidence that size selective sampling occurred during the first or second sampling events and contingency table analysis (Chi-square test) is generally used to detect significant evidence that sex selective sampling occurred during the first or second sampling events.

K-S tests are used to evaluate the second sampling event by comparing the length frequency distribution of all fish marked during the first event (M) with that of marked fish recaptured during the second event (R), using the null test hypothesis (H_o) of no difference. The first sampling event is evaluated by comparing the length frequency distribution of all fish inspected for marks during the second event (C) with that of R. Chi-square tests are used to compare the counts of observed males to females between M&R and C&R according to the null hypothesis that the probability that a sampled fish is male or female is independent of the sample. When the proportions by gender are estimated for a subsample (usually from C), rather than observed for all fish in the sample, contingency table analysis is not appropriate and the proportions of females (or males) are compared using a two sample test (e.g. Student's t-test).

Mark-recapture experiments are designed to obtain sample sizes sufficient to 1) achieve precision objectives for abundance and composition estimates and 2) ensure that the diagnostic tests (i.e., tests for selectivity) have power adequate for identifying selectivity that could result in significantly biased estimates. Despite careful design, experiments may result in inadequate sample sizes leading to unreliable diagnostic test results due to low power. As a result, detection and adjusting for size and sex selectivity involves evaluating the power of the diagnostic tests.

The protocols that follow are used to classify the experiment into one of four cases. For each case the following are specified: 1) whether stratification is necessary, 2) which sample event's data should be used when estimating composition, and 3) the estimators to be used for composition estimates when stratifying. The first protocols assume adequate power. These are followed by supplemental protocols to be used when power is suspect and guidelines for evaluating power.

Protocols given Adequate Power

Case I:

M vs. R	**C vs. R**
Fail to reject H_o	Fail to reject H_o

There is no size/sex selectivity detected during either sampling event. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated after pooling length, sex, and age data from both sampling events.

Case II:

M vs. R	**C vs. R**
Reject H_o	Fail to reject H_o

There is no size/sex selectivity detected during the first event but there is during the second event sampling. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the first sampling event without stratification. If composition is estimated from second event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the M vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type formula.

-continued-

Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case III:

M vs. R	**C vs. R**
Fail to reject H_o	Reject H_o

There is no size/sex selectivity detected during the second event but there is during the first event sampling. Abundance is calculated using a Petersen-type model from the entire data set without stratification. Composition parameters may be estimated using length, sex, and age data from the second sampling event without stratification. If composition is estimated from first event data or after pooling both sampling events, data must first be stratified to eliminate variability in capture probability (detected by the C vs. R test) within strata. Composition parameters are estimated within strata, and abundance for each stratum needs to be estimated using a Petersen-type type formula. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance according to the formulae below.

Case IV:

M vs. R	**C vs. R**
Reject H_o	Reject H_o

There is size/sex selectivity detected during both the first and second sampling events. The ratio of the probability of captures for size of sex categories can either be the same or different between events. Data must be stratified to eliminate variability in capture probability within strata for at least one or both sampling events. Abundance is calculated using a Petersen-type model for each stratum, and estimates are summed across strata to estimate overall abundance. Composition parameters may be estimated within the strata as determined above, but only using data from sampling events where stratification has eliminated variability in capture probabilities within strata. If data from both sampling events are to be used, further stratification may be necessary to meet the condition of capture homogeneity within strata for both events. Overall composition parameters are estimated by combining stratum estimates weighted by estimated stratum abundance.

When stratification by sex or length is necessary prior to estimating composition parameters, overall composition (p_k) is estimated by combining within stratum composition estimates using:

$$\hat{p}_k = \sum_{i=1}^{j} \frac{\hat{N}_i}{\hat{N}_\Sigma} \hat{p}_{ik} \text{, and} \tag{B1-1}$$

$$\hat{V}[\hat{p}_k] \approx \frac{1}{\hat{N}_\Sigma^2} \left(\sum_{i=1}^{j} \hat{N}_i^2 \hat{V}[\hat{p}_{ik}] + \left(\hat{p}_{ik} - \hat{p}_k \right)^2 \hat{V}[\hat{N}_i] \right) \tag{B1-2}$$

where:

j	=	the number of sex/size strata;
$\hat{p}_{ik}$	=	the estimated proportion of fish that were age or size k among fish in stratum i;
$\hat{N}_i$	=	the estimated abundance in stratum i;
$\hat{N}_\Sigma$	=	sum of the $\hat{N}_i$ across strata.

-continued-

Protocols when Power Suspect (re-classifying the experiment)

When sample sizes are small (guidelines provided in next section) power needs to be evaluated when diagnostic tests fail to reject the null hypothesis. If this failure to identify selectivity is due to low power (that is, if selectivity is actually present) data will be pooled when stratifying is necessary for unbiased estimates. For example, if the both the M vs. R and C vs. R tests failed to identify selectivity due to low power, Case I may be selected when Case IV is true. In this scenario, the need to stratify could have been overlooked leading to biased estimates. The following protocols should be followed when sample sizes are small.

Case I:

M vs. R	**C vs. R**	**Implication**
Fail to reject Ho	Fail to reject Ho	re-evaluate both tests
Power OK/retain test result	Power OK/retain test result	Case I
Power suspect/change to Reject Ho	Power OK/retain test result	Case II
Power OK/retain test result	Power suspect/change to Reject Ho	Case III
Power suspect/change to Reject Ho	Power suspect/change to Reject Ho	Case IV

Case II:

M vs. R	**C vs. R**	**Implication**
Reject Ho	Fail to reject Ho	re-evaluate C vs. R
	Power OK/retain test result	Case II
	Power suspect/change to Reject Ho	Case IV

Case III:

M vs. R	**C vs. R**	**Implication**
Fail to reject Ho	Reject Ho	re-evaluate M vs. R
Power OK/retain test result		Case III
Power suspect/change to Reject Ho		Case IV

-continued-

Guidelines for evaluating power:

The following guidelines to assess power are based upon the experiences of Sport Fish biometricians; they have not been comprehensively evaluated by simulation. Because some "art" in interpretation remains these guidelines are not intended to be used in lieu of discussions with biometricians when possible. When the evaluation does not lead to a clear choice, a stratified estimator should be selected (i.e., the experiment should be classified as Case IV) in order to minimize potential bias.

The reliability of M vs. R and C vs. R tests that fail to reject H_o are called into question when 1) sample sizes M or C are < 100 and the sample size for R is < 30, 2) p-values are not large (~0.20 or less), and the D statistics are large (≥ 0.2). If sample sizes are small, the p-value is not large, and the D statistic is large then the power of the test is suspect and, when re-classifying the experiment, the test should be considered as having rejected the null hypothesis. If for example, sample sizes are marginal (close to the recommended values), the p-value is large, and the D-statistic is not large then the test result may be considered reliable. It is when results are close to the recommended "cutoffs" that interpretation becomes somewhat more complicated.

Apparent inconsistencies between the combination of the M vs. R and C vs. R test results and the M vs. C test results may also arise from low power. For example, if one of the tests involving R rejects the null hypothesis and the other fails to reject one could infer a difference between M & C; however, the M vs. C test may still fail to reject the null indicating no difference between the M & C. In this case, the apparent inconsistency may be due to low power in the test involving R that failed to reject the null. Finally, an additional Case I scenario is flagged by an apparent inconsistency between test results, this time resulting from power being too high. Under this scenario both the M vs. R and C vs. R tests fail to reject the null hypothesis and their power is thought to be sufficient; however, the M vs. C test rejects H_o: no difference between the M & C. The apparent inconsistency may result from the M vs. C test being so powerful as to detect selectivity that would result in insignificant bias when estimating abundance and composition. The reliability of M vs. C tests that reject are called into question when 1) sample sizes M or C are > 500, 2) p-values are not extremely small (~0.010-0.049), and the D statistics are small (<0.08). In general all three K-S tests should be performed to permit these evaluations.

Appendix B2.–Tests of consistency for the Petersen estimator (from Seber (1982), page 438).

TESTS OF CONSISTENCY FOR PETERSEN ESTIMATOR

Of the following conditions, at least one must be fulfilled to meet assumptions of a Petersen estimator:

1. Marked fish mix completely with unmarked fish between events;
2. Every fish has an equal probability of being captured and marked during event 1; or,
3. Every fish has an equal probability of being captured and examined during event 2.

To evaluate these three assumptions, the chi-square statistic will be used to examine the following contingency tables as recommended by Seber (1982). At least one null hypothesis needs to be accepted for assumptions of the Petersen model (Bailey 1951, 1952; Chapman 1951) to be valid. If all three tests are rejected, a geographically stratified estimator (Darroch 1961) should be used to estimate abundance.

I.-Test For Complete Mixing

Ho: movement probabilities (θ) from section i (i = 1, 2, ...s) to section j (j = 1, 2, ...t) are the same among sections: H_0: $\theta_{ij} = \theta_j$

Section Where Marked	Section Where Recaptured				Not Recaptured
	1	**2**	**…**	**t**	$(n_1\text{-}m_2)$
1					
2					
…					
s					

II.-Test For Equal Probability of capture during the first event[a]

H_0: $\Sigma_i a_i \theta_{ij} = kU_j$, where k = total marks released/total unmarked in the population, U_j = total unmarked fish in stratum j at the time of sampling, and a_i = number of marked fish released in stratum i.

	Section Where Examined			
	1	**2**	**…**	**t**
Marked (m_2)				
Unmarked ($n_2\text{-}m_2$)				

III.-Test for equal probability of capture during the second event[b]

H_0: $\Sigma_j \theta_{ij} p_j = d$, where p_j is the probability of capturing a fish in section j during the second event, and d is a constant.

	Section Where Marked			
	1	**2**	**…**	**s**
Recaptured (m_2)				
Not Recaptured ($n_1\text{-}m_2$)				

[a] Tests the hypothesis of homogeneity on the columns of the 2-by-t contingency table with respect to the marked to unmarked ratio among river sections

[b] Tests the hypothesis of homogeneity on the columns of this 2-by-s contingency table with respect to recapture probabilities among the river sections .

Appendix B3.–Equations for calculating estimates of abundance and its variance using the Chapman-modified Petersen estimator.

The abundance of fully recruited burbot was estimated as:

$$\hat{N} = \frac{(n_2 + 1)(n_1 + 1)}{(m_2 + 1)} - 1, \tag{B3-1}$$

where:

n_1 = the number of fully recruited burbot marked and released alive during the first event;

n_2 = the number of fully recruited burbot examined for marks during the second event; and,

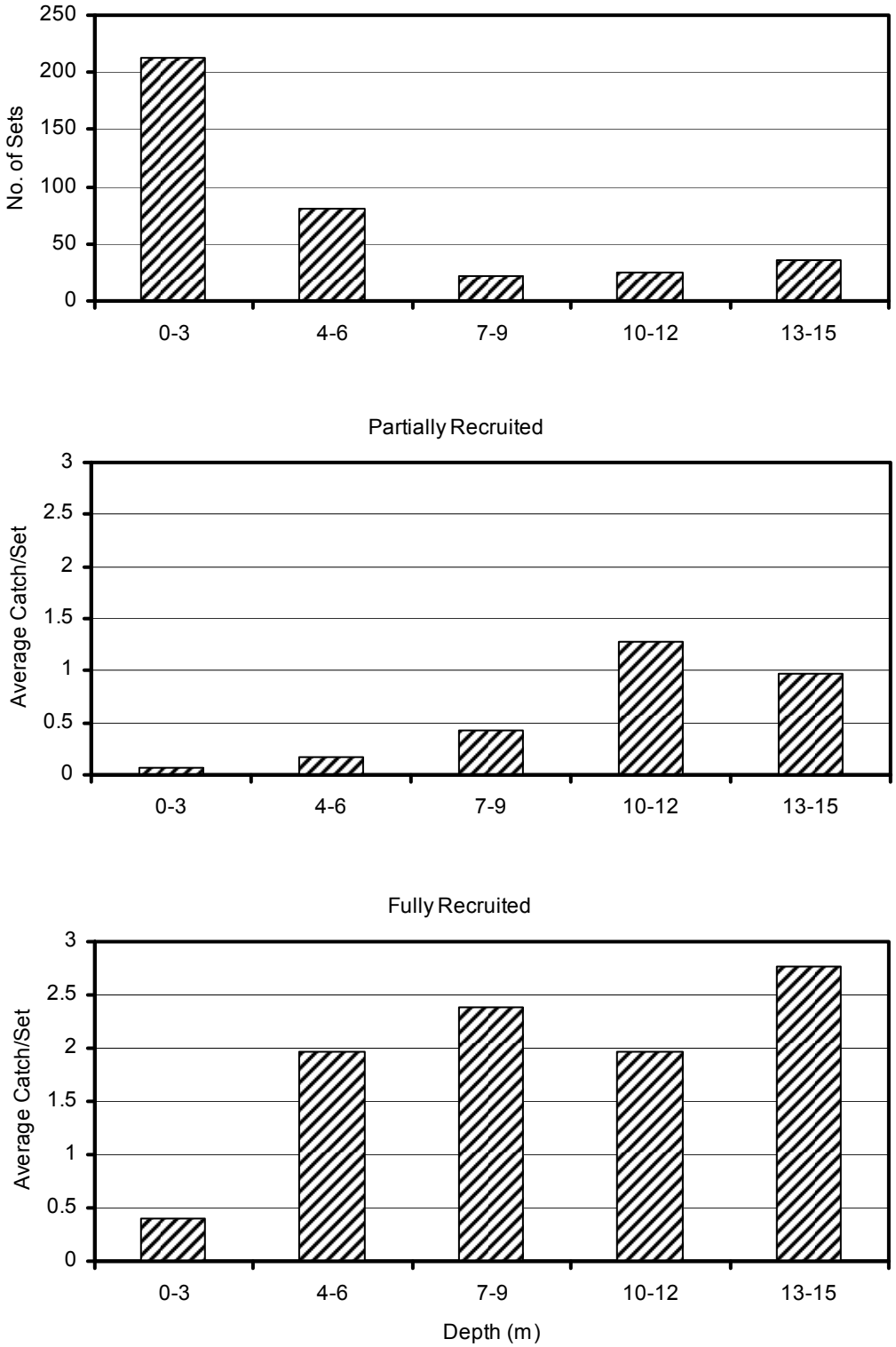
m_2 = the number of fully recruited burbot marked in the first event that were recaptured during the second event; and,

The variance was estimated as (Seber 1982):

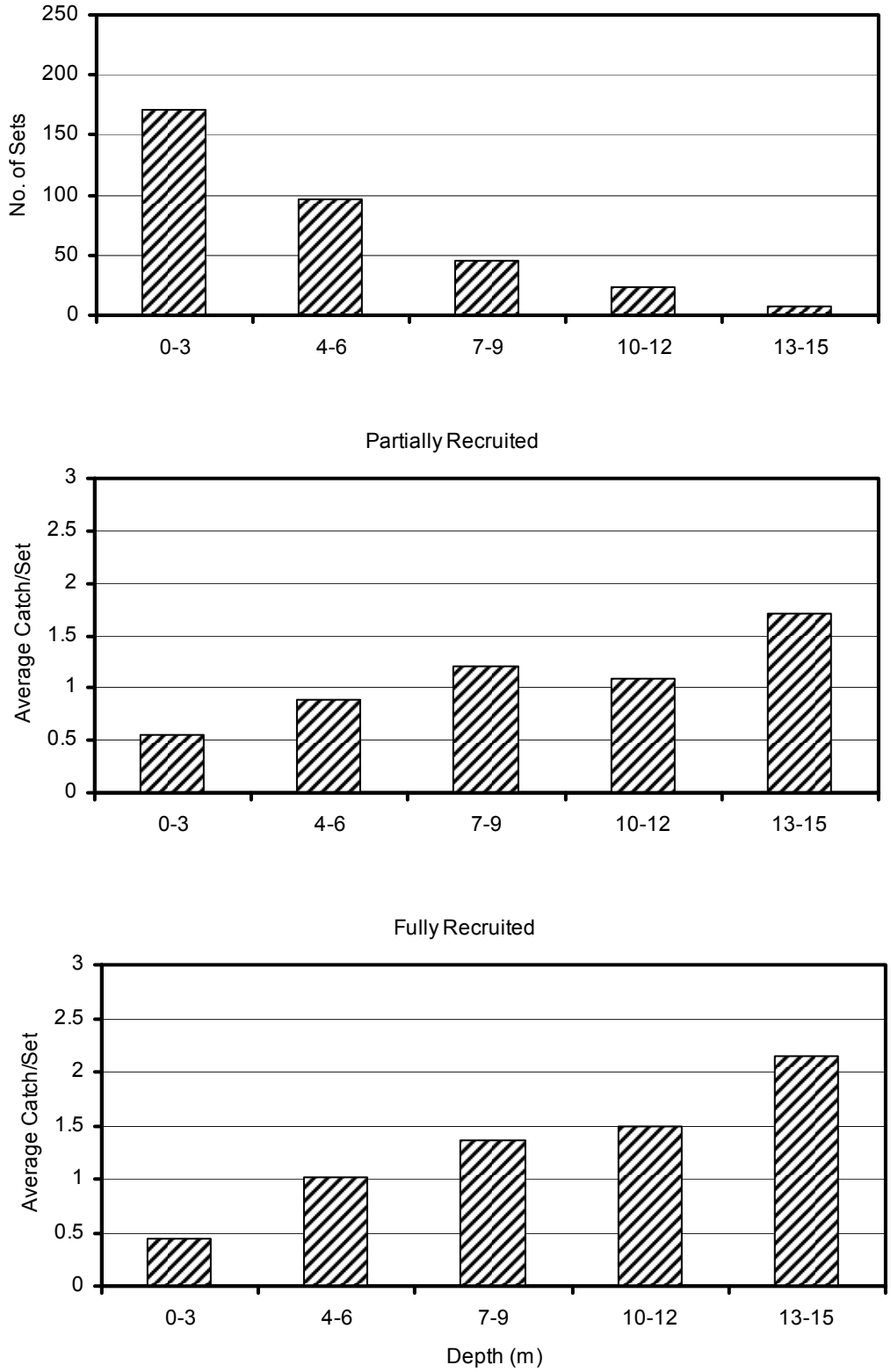
$$\hat{V}[\hat{N}] = \frac{(n_1 + 1)(n_2 + 1)(n_1 - m_2)(n_2 - m_2)}{(m_2 + 1)^2 (m_2 + 2)}. \tag{B3-2}$$

APPENDIX C
HOOP TRAP CATCH INFORMATION

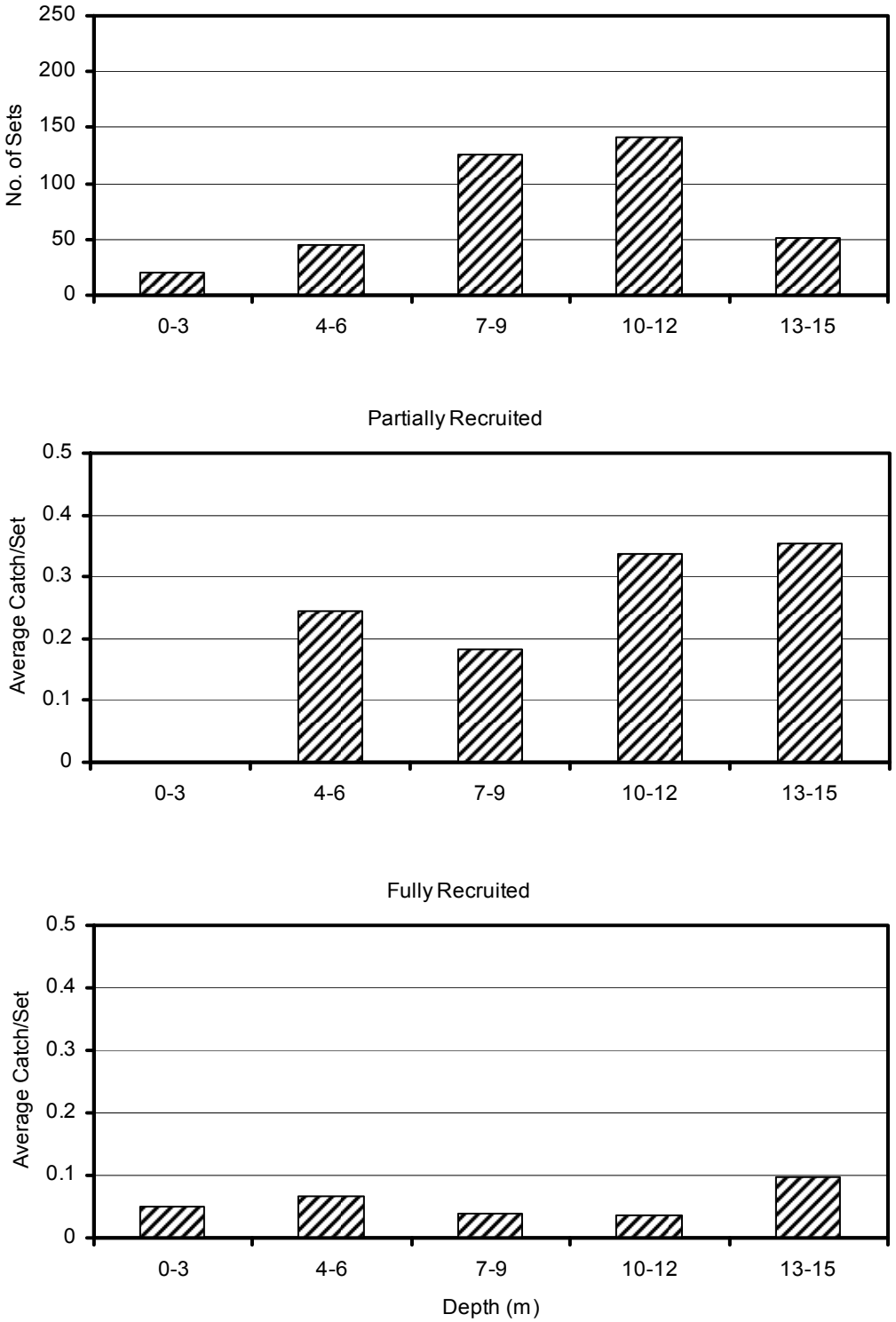
Appendix C1.–Catch information for hoop trap sets in spring, Tanada Lake, 2007.



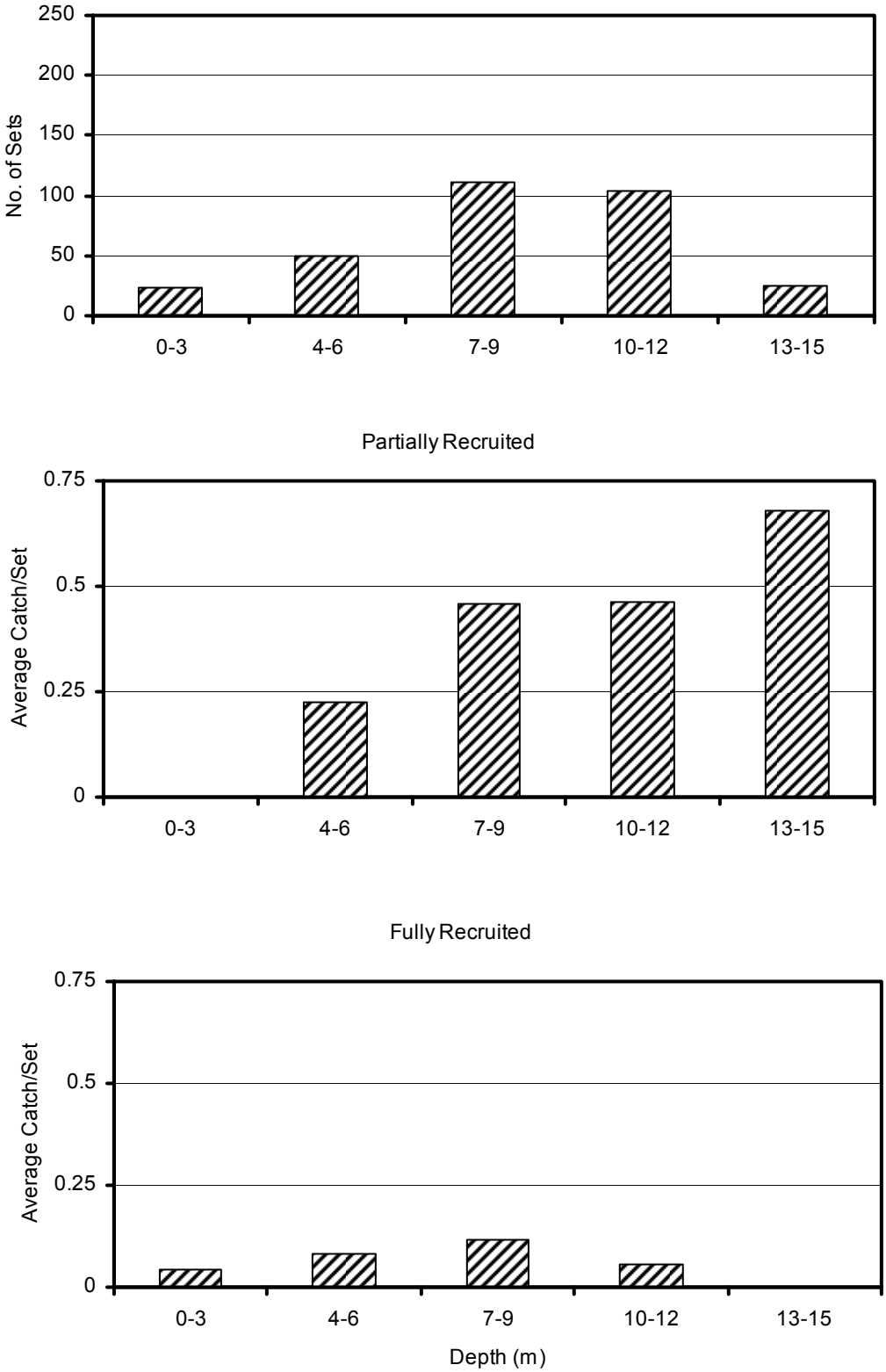
Appendix C2.–Catch information for hoop trap sets in fall, Tanada Lake, 2007.



Appendix C3.–Catch information for hoop trap sets in spring, Copper Lake, 2008.



Appendix C4.–Catch information for hoop trap sets in fall, Copper Lake, 2008.



APPENDIX D
LIMNOLOGICAL INFORMATION FOR TANADA LAKE

Appendix D1.–Limnological data collected on 1 May 2007, Tanada Lake (62.4219° N, 143.3740° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	0.10	0.134	12.03	7.53
1	0.20	0.140	11.92	7.59
2	1.05	0.149	11.57	7.64
3	1.10	0.148	11.21	7.68
4	1.09	0.149	11.57	7.71
5	1.08	0.149	11.57	7.75
6	1.08	0.149	11.64	7.75
7	1.08	0.149	11.58	7.76
8	1.08	0.148	11.47	7.75
9	1.08	0.148	11.49	7.75
10	1.12	0.148	11.01	7.73
11	1.08	0.148	11.34	7.73
12	1.08	0.149	11.20	7.71
13	1.08	0.149	10.82	7.72
14	1.07	0.148	10.81	7.72
15	1.07	0.148	11.02	7.73
16	1.07	0.148	10.99	7.74
17	1.07	0.148	11.04	7.75
18	1.07	0.148	11.11	7.74
19	1.07	0.148	11.07	7.75
20	1.07	0.148	11.13	7.74
21	1.07	0.148	11.23	7.74
22	1.07	0.148	10.96	7.77
23	1.07	0.148	11.11	7.76
24	1.07	0.148	11.22	7.76
25	1.07	0.148	11.07	7.76
26	1.07	0.148	10.93	7.76
27	1.07	0.148	11.06	7.76
28	1.07	0.148	11.15	7.76
29	1.07	0.148	11.04	7.75
30	1.07	0.148	11.10	7.74
31	1.08	0.148	11.17	7.74
32	1.09	0.148	11.21	7.76
33	1.11	0.147	11.04	7.76
34	1.12	0.147	11.32	7.77
35	1.12	0.147	11.48	7.77
36	1.13	0.147	11.46	7.77
37	1.13	0.147	11.40	7.78
38	1.13	0.147	11.35	7.79
39	1.14	0.147	11.47	7.79
40	1.14	0.147	11.50	7.79
41	1.14	0.147	11.25	7.79
42	1.14	0.147	11.59	7.79
43	1.14	0.147	11.49	7.79
44	1.14	0.147	11.50	7.79
45	1.14	0.146	11.43	7.79
46	1.15	0.146	11.48	7.80
47	1.14	0.148	11.40	7.82
48	1.15	0.149	11.31	7.84
49	1.16	0.149	7.97	7.68

Appendix D2.–Limnological data collected on 28 June 2007, Tanada Lake (62.4219° N, 143.3740° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	9.59	0.135	12.86	8.24
1	3.72	0.138	14.11	8.03
2	3.71	0.139	13.66	8.09
3	3.74	0.138	13.58	8.11
4	3.67	0.138	13.50	8.14
5	3.64	0.139	13.37	8.14
6	3.64	0.139	13.24	8.14
7	3.63	0.139	13.14	8.15
8	3.62	0.139	13.10	8.15
9	3.63	0.138	13.09	8.15
10	3.65	0.139	13.09	8.15
11	3.62	0.138	13.05	8.15
12	3.63	0.138	13.03	8.15
13	3.66	0.138	13.02	8.15
14	3.67	0.138	13.06	8.16
15	3.68	0.138	13.09	8.15
16	3.64	0.138	13.07	8.15
17	3.66	0.138	13.05	8.15
18	3.67	0.138	13.06	8.14
19	3.66	0.138	13.04	8.14
20	3.68	0.138	13.05	8.13
21	3.67	0.138	13.03	8.13
22	3.63	0.137	12.98	8.12
23	3.63	0.138	12.95	8.11
24	3.62	0.138	12.95	8.10
25	3.63	0.138	12.88	8.10
26	3.63	0.138	12.90	8.10
27	3.66	0.138	12.95	8.09
28	3.66	0.138	12.93	8.09
29	3.66	0.137	12.92	8.09
30	3.67	0.138	12.93	8.08
31	3.66	0.138	12.92	8.08
32	3.67	0.137	12.90	8.07
33	3.67	0.138	12.89	8.05
34	3.66	0.137	12.90	8.07
35	3.66	0.137	12.92	8.06
36	3.67	0.137	12.88	8.06
37	3.66	0.137	12.88	8.06
38	3.66	0.137	12.88	8.06
39	3.66	0.137	12.89	8.05
40	3.67	0.137	12.90	8.05
41	3.67	0.137	12.89	8.06
42	3.67	0.137	12.89	8.05
43	3.67	0.137	12.93	8.05
44	3.66	0.137	12.90	8.04
45	3.66	0.137	12.88	8.04

Appendix D3.–Limnological data collected on 28 June 2007, Tanada Lake (62.4219° N, 143.3740° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	16.03	0.128	9.63	8.00
1	14.14	0.128	9.99	8.02
2	14.15	0.128	10.00	7.98
3	13.08	0.129	10.30	8.04
4	12.61	0.129	10.46	8.02
5	10.69	0.129	10.87	8.00
6	8.15	0.132	7.89	7.87
7	7.68	0.132	11.13	7.78
8	5.83	0.133	11.12	7.69
9	8.22	0.134	11.01	7.56
10	4.42	0.135	10.94	7.51
11	4.34	0.137	11.02	7.48
12	4.11	0.137	11.00	7.44
13	4.02	0.137	10.99	7.45
14	3.43	0.137	10.99	7.43
15	3.41	0.137	10.97	7.42
16	3.42	0.137	10.96	7.41
17	3.41	0.137	10.95	7.41
18	3.40	0.138	10.98	7.40
19	3.43	0.137	10.92	7.40
20	3.44	0.137	10.93	7.39
21	3.45	0.137	10.91	7.38
22	4.03	0.137	10.86	7.38
23	4.07	0.137	10.78	7.36
24	4.10	0.137	10.60	7.36
25	4.10	0.137	10.64	7.33
26	4.10	0.137	10.57	7.34
27	4.12	0.137	10.56	7.33
28	4.12	0.137	10.52	7.31
29	4.10	0.138	10.47	7.31
30	4.10	0.137	10.40	7.29
31	4.04	0.138	10.37	7.28
32	4.10	0.137	10.43	7.27
33	4.10	0.137	10.47	7.28
34	4.10	0.137	10.41	7.26
35	4.10	0.137	10.41	7.26
36	4.08	0.137	10.32	7.26
37	4.10	0.137	10.29	7.25
38	4.06	0.136	9.78	7.23
39	4.05	0.137	9.35	7.04

Appendix D4.–Limnological data collected on 7 September 2007, Tanada Lake (62.4219° N, 143.3740° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	12.27	0.130	11.02	8.91
1	12.00	0.130	10.80	8.88
2	11.85	0.131	10.80	8.80
3	11.78	0.130	10.80	8.84
4	11.67	0.130	10.76	8.81
5	11.59	0.131	10.45	8.78
6	11.51	0.130	10.59	8.77
7	11.41	0.131	10.56	8.70
8	11.23	0.133	10.53	7.62
9	9.69	0.135	10.24	7.05
10	8.21	0.135	10.00	7.72
11	6.81	0.135	10.07	7.67
12	5.22	0.136	10.16	7.64
13	4.60	0.136	10.18	7.60
14	4.40	0.137	10.10	7.56
15	4.31	0.137	10.08	7.55
16	4.24	0.137	10.03	7.53
17	4.20	0.137	10.04	7.51
18	4.13	0.137	10.08	7.51
19	4.07	0.137	10.17	7.51
20	4.06	0.137	10.19	7.50
21	4.06	0.137	10.18	7.49
22	4.06	0.137	10.20	7.50
23	4.06	0.137	10.16	7.46
24	4.06	0.137	10.13	7.48
25	4.04	0.137	10.07	7.46
26	4.10	0.137	10.02	7.45
27	4.08	0.137	9.88	7.44
28	4.09	0.137	9.82	7.43
29	4.04	0.137	9.78	7.42
30	4.09	0.137	9.66	7.40
31	4.09	0.137	9.63	7.39
32	4.10	0.137	9.53	7.38
33	4.09	0.137	9.50	7.37
34	4.10	0.137	9.46	7.37
35	4.09	0.137	9.45	7.35
36	4.09	0.137	9.44	7.35
37	4.07	0.137	9.24	7.34
38	4.07	0.137	9.08	7.32
39	4.07	0.137	8.99	7.31
40	4.08	0.137	8.94	7.30
41	4.06	0.137	8.75	7.29
42	4.05	0.137	8.54	7.27
43	4.04	0.137	8.35	7.26
44	4.02	0.138		7.26

Appendix D5.–Limnological data collected on 29 August 2008, Tanada Lake (62.4219° N, 143.3740° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	11.03	0.106	9.77	10.26
1	10.98	0.106	9.64	10.14
2	10.81	0.106	9.66	10.10
3	10.78	0.106	9.60	10.03
4	10.76	0.106	9.55	9.95
5	10.45	0.107	9.40	9.71
6	10.22	0.107	9.31	9.50
7	9.85	0.108	8.97	9.29
8	9.36	0.111	8.46	9.10
9	8.01	0.116	8.27	8.96
10	7.62	0.117	8.11	8.88
11	6.40	0.122	7.78	8.84
12	6.01	0.123	7.54	8.79
13	5.80	0.124	7.39	8.75
14	5.33	0.126	7.27	8.72
15	5.06	0.127	7.00	8.71
16	4.90	0.128	7.05	8.68
17	4.86	0.128	7.02	8.66
18	4.67	0.129	6.78	8.66
19	4.45	0.130	6.66	8.63
20	4.39	0.130	6.59	8.61
21	4.34	0.131	6.58	8.59
22	4.30	0.130	6.34	8.59
23	4.25	0.131	6.37	8.57
24	4.24	0.131	6.48	8.56
25	4.17	0.132	6.35	8.56
26	4.15	0.132	6.47	8.54
27	4.13	0.132	6.45	8.52
28	4.07	0.133	6.31	8.51
29	4.00	0.133	6.27	8.50
30	3.96	0.134	6.06	8.49
31	3.92	0.133	6.07	8.48
32	3.90	0.134	5.80	8.47
33	3.88	0.135	5.74	8.46
34	3.87	0.135	5.70	8.45
35	3.86	0.135	5.69	8.45
36	3.83	0.135	5.62	8.44
37	3.83	0.135	5.46	8.44
38	3.83	0.135	5.47	8.43
39	3.78	0.135	5.40	8.42
40	3.77	0.136	5.17	8.41
41	3.76	0.136	4.89	8.40
42	3.73	0.137	4.62	8.46
43	3.70	0.137	4.13	8.40
44	3.69	0.137	3.68	8.36
45	3.68	0.138	3.38	8.33
46	3.65	0.138	3.32	8.32
47	3.69	0.138	3.32	8.31
48	3.67	0.138	3.04	8.30
49	3.66	0.140	1.87	8.27
50	3.64	0.141	1.41	8.25
51	3.64	0.141	1.20	8.24
52	3.64	0.339	0.43	8.27

Appendix D6.–Limnological data collected on 23 September 2008, Tanada Lake (62.4219° N, 143.3740° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	8.48	0.112	9.73	9.17
1	8.43	0.112	9.53	9.27
2	7.93	0.112	9.63	9.33
3	7.90	0.112	9.47	9.28
4	7.84	0.112	9.37	9.26
5	7.88	0.112	9.31	9.25
6	7.86	0.113	9.30	9.24
7	7.83	0.113	9.17	9.16
8	7.71	0.114	8.83	9.05
9	7.58	0.116	8.47	8.92
10	7.48	0.116	8.35	8.85
11	7.46	0.118	8.26	8.82
12	7.16	0.118	8.11	8.79
13	6.73	0.121	7.74	8.74
14	6.16	0.124	7.43	8.66
15	5.74	0.125	7.12	8.61
16	5.50	0.127	6.87	8.60
17	5.15	0.129	6.68	8.56
18	5.11	0.028	6.57	8.55
19	4.94	0.130	6.40	8.53
20	4.85	0.130	6.31	8.50
21	4.57	0.133	6.05	8.50
22	4.41	0.132	5.86	8.48
23	4.38	0.132	5.85	8.47
24	4.22	0.133	5.82	8.47
25	4.16	0.133	5.71	8.47
26	4.14	0.134	5.67	8.46
27	4.12	0.134	5.60	8.46
28	4.08	0.134	5.56	8.45
29	4.08	0.134	5.52	8.45
30	4.06	0.134	5.51	8.45
31	4.07	0.134	5.51	8.45
32	4.04	0.134	5.49	8.45
33	4.05	0.134	5.43	8.44
34	4.03	0.134	5.43	8.43
35	3.98	0.135	5.40	8.44
36	3.95	0.134	5.29	8.43
37	3.95	0.135	5.24	8.43
38	3.92	0.135	5.22	8.43
39	3.92	0.135	5.17	8.42
40	3.92	0.135	5.16	8.42
41	3.91	0.134	5.13	8.42
42	3.91	0.136	5.08	8.42
43	3.88	0.136	5.04	8.42
44	3.86	0.135	4.84	8.40
45	3.86	0.135	4.80	8.40
46	3.86	0.135	4.78	8.40
47	3.80	0.135	4.71	8.40
48	3.78	0.136	4.50	8.54
49	3.79	0.136	4.33	8.54
50	3.82	1.360	4.03	8.43
51	3.78	0.137	1.93	8.39

Appendix D7.–Limnological data collected on 8 April 2009, Tanada Lake (62.4219° N, 143.3740° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	-0.09	0.145	9.12	pH probe
1	-0.05	0.146	9.32	broken
2	1.15	0.140	8.90	
3	1.87	0.136	8.70	
4	1.91	0.135	8.38	
5	1.92	0.135	8.05	
6	1.91	0.136	8.32	
7	1.91	0.136	8.24	
8	1.91	0.135	7.98	
9	1.93	0.135	8.28	
10	1.96	0.135	8.18	
11	1.96	0.135	8.12	
12	1.97	0.134	8.12	
13	1.98	0.134	7.99	
14	1.99	0.135	7.78	
15	2.02	0.134	7.76	
16	2.04	0.133	7.82	
17	2.05	0.133	8.03	
18	2.09	0.133	8.02	
19	2.10	0.133	8.01	
20	2.11	0.133	7.97	
21	2.11	0.133	7.44	
22	2.12	0.132	7.77	
23	2.13	0.132	7.73	
24	2.16	0.132	7.73	
25	2.18	0.132	7.61	
26	2.19	0.132	7.56	
27	2.20	0.132	7.57	
28	2.23	0.132	7.55	
29	2.23	0.132	7.47	
30	2.27	0.131	7.40	
31	2.30	0.132	7.16	
32	2.30	0.132	7.06	
33	2.30	0.132	7.02	
34	2.29	0.132	7.00	
35	2.28	0.133	6.87	
36	2.26	0.134	6.75	
37	2.28	0.134	6.86	
38	2.30	0.134	6.80	
39	2.31	0.134	6.57	
40	2.32	0.135	6.40	
41	2.34	0.135	6.32	
42	2.36	0.135	5.95	
43	2.36	0.135	5.88	
44	2.37	0.135	5.75	
45	2.37	0.136	5.57	
46	2.40	0.136	5.22	
47	2.40	0.137	4.49	
48	2.47	0.137	4.11	
49	2.52	0.138	2.85	
50	2.56	0.138	1.14	
51	2.70	0.148	0.44	
52	2.85	0.177	0.35	

Appendix D8.–Limnological data collected on 8 July 2009, Tanada Lake (62.4219° N, 143.3740° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	17.81	0.118	7.35	8.38
1	15.37	0.118	7.57	8.37
2	13.80	0.117	8.07	8.43
3	12.10	0.117	8.41	8.48
4	7.97	0.120	9.27	8.45
5	6.93	0.120	9.17	8.35
6	6.28	0.122	8.93	8.26
7	5.70	0.122	8.49	8.22
8	5.27	0.124	8.14	8.19
9	5.13	0.124	7.90	8.18
10	4.62	0.125	7.71	8.15
11	4.47	0.125	7.50	8.14
12	4.34	0.126	7.44	8.12
13	4.14	0.126	7.38	8.06
14	4.02	0.127	7.25	8.07
15	3.93	0.127	7.25	8.07
16	3.81	0.127	7.19	8.05
17	3.81	0.128	7.13	8.04
18	3.76	0.128	7.11	8.01
19	3.72	0.128	7.08	8.02
20	3.67	0.128	7.08	8.00
21	3.96	0.128	7.06	7.99
22	3.63	0.128	7.02	7.99
23	3.60	0.128	7.01	7.98
24	3.60	0.128	6.99	7.98
25	3.57	0.128	6.96	7.95
26	3.56	0.129	6.94	7.96
27	3.57	0.129	6.92	7.94
28	3.56	0.129	6.87	7.92
29	3.56	0.129	6.85	7.92
30	3.55	0.129	6.82	7.91
31	3.57	0.129	6.79	7.89
32	3.58	0.130	6.77	7.89
33	3.58	0.130	6.76	7.87
34	3.57	0.129	6.75	7.87
35	3.57	0.130	6.69	7.87
36	3.63	0.130	6.62	7.84
37	3.60	0.131	6.57	7.85
38	3.59	0.131	6.48	7.85
39	3.57	0.132	6.38	7.84
40	3.51	0.130	6.11	7.84
41	3.51	0.131	6.25	7.83
42	3.51	0.131	6.24	7.82
43	3.52	0.132	6.22	7.81
44	17.81	0.118	7.35	8.38

Appendix D9.–Limnological data collected on 4 August 2009, Tanada Lake (62.4219° N, 143.3740° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	16.85	0.120	6.40	9.57
1	16.15	0.120	6.59	9.47
2	15.80	0.119	6.63	9.44
3	15.55	0.120	6.65	9.41
4	15.36	0.119	6.46	9.39
5	15.26	0.119	6.58	9.39
6	14.20	0.119	6.71	9.40
7	11.43	0.121	7.06	9.30
8	8.74	0.123	7.25	9.25
9	7.58	0.123	7.17	9.25
10	6.40	0.123	7.30	9.25
11	5.88	0.124	7.07	9.22
12	5.66	0.124	6.88	9.21
13	5.51	0.124	6.75	9.20
14	5.27	0.125	6.60	9.19
15	4.80	0.126	6.69	9.10
16	4.41	0.127	6.54	9.10
17	4.26	0.128	6.50	9.10
18	4.10	0.128	6.47	9.09
19	3.99	0.128	6.46	9.08
20	3.92	0.128	0.64	9.07
21	3.85	0.128	6.38	9.06
22	3.82	0.129	6.30	9.05
23	3.72	0.130	6.27	9.04
24	3.73	0.129	6.27	9.03
25	3.74	0.130	6.24	9.04
26	3.69	0.130	6.23	9.02
27	3.66	0.130	6.16	9.00
28	3.68	0.129	6.15	9.00
29	3.75	0.130	6.15	8.99
30	3.79	0.130	6.14	8.98
31	3.76	0.130	6.11	8.97
32	3.75	0.130	6.04	8.96
33	3.75	0.130	6.05	8.94
34	3.74	0.131	6.04	8.94
35	3.74	0.131	6.00	8.93
36	3.74	0.131	5.99	8.93
37	3.72	0.131	5.98	8.92
38	3.71	0.131	5.88	8.92
39	3.68	0.131	5.85	8.92
40	3.68	0.132	5.75	8.91
41	3.67	0.133	5.68	8.90
42	3.67	0.132	5.60	8.88
43	3.68	0.132	5.60	8.89
44	3.67	0.133	5.58	8.88
45	3.66	0.133	5.52	8.87
46	3.66	0.132	5.38	8.87
47	3.65	0.133	5.29	8.85
48	3.63	0.133	5.26	8.86
49	3.62	0.133	5.19	8.85
50	3.48	0.142	4.90	8.87
51	3.39	0.152	1.54	8.73
52	3.35	0.181	0.91	8.81

Appendix D10.–Limnological data collected on 2 September 2009, Tanada Lake (62.4219° N, 143.3740° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	11.38	0.120	6.27	9.51
1	11.38	0.120	6.16	9.43
2	11.36	0.120	6.23	9.38
3	11.35	0.120	6.27	9.36
4	11.32	0.120	6.27	9.34
5	11.29	0.120	6.31	9.32
6	10.80	0.121	6.23	9.20
7	10.45	0.121	5.92	9.01
8	9.94	0.122	5.94	8.90
9	9.19	0.123	5.98	8.84
10	8.47	0.125	5.79	8.77
11	7.82	0.124	5.82	8.75
12	7.21	0.126	5.69	8.72
13	6.73	0.126	5.66	8.68
14	6.26	0.127	5.63	8.69
15	6.07	0.127	5.59	8.69
16	5.41	0.127	5.64	8.66
17	5.07	0.128	5.58	8.64
18	4.80	0.128	5.57	8.64
19	4.67	0.129	5.53	8.64
20	4.54	0.129	5.53	8.64
21	4.38	0.131	5.48	8.61
22	4.33	0.130	5.41	8.62
23	4.24	0.130	5.40	8.60
24	4.18	0.130	5.42	8.61
25	4.10	0.130	5.41	8.59
26	4.09	0.130	5.41	8.60
27	3.99	0.130	5.42	8.60
28	4.02	0.131	5.39	8.58
29	4.00	0.131	5.32	8.58
30	3.97	0.131	5.27	8.58
31	3.96	0.131	5.22	8.58
32	3.95	0.132	5.15	8.58
33	3.94	0.131	5.10	8.55
34	3.90	0.131	5.08	8.55
35	3.90	0.131	5.04	8.54
36	3.88	0.131	4.97	8.54
37	3.88	0.133	4.92	8.54
38	3.85	0.133	4.75	8.52
39	3.83	0.133	4.70	8.52
40	3.81	0.133	4.60	8.50
41	3.81	0.134	4.47	8.50
42	3.80	0.133	4.38	8.48
43	3.80	0.133	4.33	8.47
44	3.77	0.134	4.08	8.46
45	3.76	0.134	3.85	8.44
46	3.74	0.135	3.74	8.44
47	3.73	0.135	2.95	8.43
48	3.71	0.136	2.88	8.41
49	3.70	0.137	2.66	8.40
50	3.69	0.138	2.29	8.38
51	3.68	0.138	1.98	8.37
52	3.67	0.139	1.21	8.37

APPENDIX E
LIMNOLOGICAL INFORMATION FOR COPPER LAKE

Appendix E1.–Limnological data collected on 28 June 2007, Copper Lake (62.4251° N, 143.5472° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	15.20	0.074	10.32	8.29
1	13.90	0.074	10.62	8.34
2	13.22	0.074	10.85	8.34
3	12.80	0.075	11.18	8.36
4	12.26	0.075	11.39	8.35
5	10.84	0.075	11.80	8.32
6	9.82	0.076	12.02	8.28
7	7.26	0.077	12.44	8.19
8	5.83	0.078	12.72	8.11
9	5.59	0.078	12.53	8.10
10	5.20	0.079	14.48	8.09
11	4.73	0.079	12.11	8.05
12	4.46	0.079	11.75	8.03
13	4.11	0.081	11.45	8.03
14	3.98	0.082	11.00	8.03
15	3.97	0.084	10.73	8.03
16	3.95	0.086	10.50	8.03
17	3.94	0.087	10.24	8.04
18	3.89	0.088	10.05	8.04
19	3.86	0.088	9.92	8.04
20	3.86	0.088	9.81	8.05
21	3.84	0.088	9.70	8.05
22	3.81	0.088	9.61	8.04
23	3.80	0.088	9.53	8.05
24	3.80	0.088	9.48	8.04
25	3.80	0.088	9.39	8.05
26	3.80	0.088	9.00	8.05
27	3.78	0.088	8.84	8.05
28	3.78	0.088	8.68	8.05
29	3.78	0.089	8.52	8.05
30	3.79	0.089	8.44	8.05
31	3.79	0.089	8.41	8.05
32	3.79	0.089	8.25	8.05
33	3.78	0.089	8.05	8.04
34	3.77	0.090	7.97	8.05
35	3.85	0.091	7.97	8.05
36	3.90	0.091	6.53	8.05
37	3.90	0.091	6.83	8.05
38	3.82	0.092	6.85	8.05
39	3.83	0.092	6.79	8.05
40	3.83	0.092	6.40	8.04
41	3.81	0.093	6.59	8.04
42	3.80	0.093	6.60	8.04
43	3.83	0.093	6.43	8.05
44	3.82	0.094	6.56	8.04
45	3.82	0.095	6.11	8.05
46	3.83	0.095	6.14	8.05
47	3.85	0.095	5.61	8.04
48	3.90	0.096	4.96	8.04
49	3.89	0.097	4.62	8.06

-continued-

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
50	3.90	0.097	4.45	8.04
51	3.89	0.097	4.35	8.04
52	3.89	0.098	4.20	8.04
53	3.88	0.099	4.17	8.03
54	3.88	0.099	4.09	8.04
55	3.87	0.099	4.02	8.03
56	3.87	0.099	3.77	8.04
57	3.88	0.100	3.53	8.03
58	3.89	0.101	3.05	8.03
59	3.90	0.102	2.72	8.03
60	3.89	0.103	2.25	8.02
61	3.90	0.103	1.93	8.02
62	3.90	0.104	1.53	8.03
63	3.90	0.104	1.44	8.03
64	3.90	0.105	0.30	8.00

Appendix E2.–Limnological data collected on 30 July 2007, Copper Lake (62.4251° N, 143.5472° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	16.57	0.071	9.06	7.30
1	16.02	0.072	9.12	7.33
2	15.75	0.072	9.11	7.41
3	15.35	0.071	9.15	7.40
4	14.45	0.072	9.34	7.38
5	12.88	0.073	9.64	7.30
6	10.89	0.073	10.10	7.31
7	8.51	0.075	10.40	7.16
8	6.43	0.077	11.08	7.31
9	5.27	0.079	10.01	7.24
10	4.95	0.078	9.66	7.21
11	4.52	0.081	8.90	7.17
12	4.29	0.082	8.54	7.11
13	4.10	0.085	8.30	7.04
14	4.02	0.086	8.05	7.01
15	3.94	0.087	7.89	7.00
16	3.92	0.087	7.84	6.99
17	3.89	0.087	7.85	6.98
18	3.89	0.087	7.84	6.95
19	3.89	0.087	7.84	6.94
20	3.85	0.087	8.81	6.94
21	3.82	0.087	7.78	6.91
22	3.82	0.088	7.71	6.90
23	3.81	0.088	7.43	6.90
24	3.80	0.088	7.11	6.84
25	3.84	0.088	6.73	6.85
26	3.83	0.088	6.48	6.80
27	3.83	0.089	6.23	6.79
28	3.87	0.089	5.89	6.74
29	3.88	0.090	5.81	6.74
30	3.88	0.090	5.70	6.74
31	3.89	0.091	5.63	6.70
32	3.88	0.092	5.12	6.70
33	3.93	0.092	4.95	6.69
34	3.93	0.092	4.69	6.69
35	3.91	0.093	4.91	6.66
36	3.91	0.093	4.83	6.67
37	3.94	0.094	4.33	6.65
38	3.92	0.094	4.44	6.64
39	3.99	0.094	3.71	6.75
40	3.96	0.095	4.01	6.70
41	3.99	0.096	3.27	6.69
42	4.02	0.096	2.60	6.61
43	4.01	0.096	2.62	6.59
44	4.01	0.096	2.62	6.58
45	4.01	0.097	2.60	6.57
46	4.06	0.096	3.36	6.58
47	4.08	0.097	3.50	6.58
48	4.04	0.097	2.72	6.57
49	4.02	0.097	3.41	6.58

-continued-

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
50	4.06	0.097	3.47	6.57
51	4.04	0.098	3.42	6.57
52	4.04	0.098	2.91	6.57
53	4.05	0.098	2.88	6.55
54	4.03	0.099	2.62	6.56
55	4.03	0.099	2.55	6.55
56	4.13	0.098	2.85	6.55
57	4.14	0.098	2.89	6.55
58	4.15	0.098	2.93	6.56
59	4.14	0.098	2.94	6.55
60	4.15	0.098	2.95	6.55
61	4.12	0.098	2.39	6.55
62	4.03	0.100	1.97	6.54
63	4.12	0.100	1.97	6.51
64	4.15	0.102	1.35	6.52
65	4.12	0.103	0.92	6.51
66	3.98	0.109	0.38	6.49
67	3.98	0.111	0.33	6.48
68	4.03	0.113	0.29	6.47
69	4.03	0.114	0.28	6.48

Appendix E3.–Limnological data collected on 7 September 2007, Copper Lake (62.4251° N, 143.5472° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	12.58	0.074	9.46	7.78
1	12.59	0.074	9.60	7.71
2	12.57	0.074	9.40	7.72
3	12.55	0.074	9.38	7.75
4	12.52	0.073	9.34	7.72
5	12.51	0.074	9.33	7.73
6	12.48	0.074	9.33	7.71
7	12.45	0.074	9.34	7.71
8	10.24	0.076	9.26	7.45
9	7.40	0.079	9.39	7.37
10	5.13	0.088	9.14	7.33
11	4.80	0.085	8.25	7.31
12	4.44	0.085	7.90	7.27
13	4.28	0.086	7.80	7.26
14	4.18	0.086	7.79	7.21
15	4.12	0.086	7.76	7.20
16	4.02	0.087	7.68	7.21
17	3.98	0.087	7.64	7.18
18	3.94	0.087	7.63	7.18
19	3.93	0.087	7.57	7.18
20	3.89	0.087	7.49	7.16
21	3.89	0.087	7.45	7.15
22	3.87	0.088	7.22	7.14
23	3.88	0.085	6.77	7.09
24	3.86	0.088	6.79	7.09
25	3.86	0.089	6.59	7.07
26	3.88	0.090	6.29	7.01
27	3.88	0.090	6.22	7.04
28	3.89	0.090	6.12	7.04
29	3.91	0.091	6.06	7.02
30	3.91	0.091	5.94	7.01
31	3.92	0.091	5.81	7.01
32	3.95	0.092	5.78	7.00
33	3.95	0.092	5.43	6.99
34	3.96	0.092	5.65	6.97
35	3.96	0.093	5.67	6.98
36	3.96	0.093	5.24	6.95
37	3.97	0.094	5.14	6.94
38	3.98	0.094	4.77	6.94
39	3.99	0.095	3.62	6.92
40	4.00	0.095	3.38	6.88
41	4.00	0.095	3.00	6.84
42	4.00	0.095	2.80	6.83
43	4.01	0.096	2.75	6.99
44	4.01	0.096	2.55	6.92
45	4.01	0.096	2.49	6.89
46	4.01	0.097	2.46	6.87
47	4.02	0.098	3.59	6.88
48	4.02	0.098	2.85	6.85
49	4.02	0.098	2.84	6.85

-continued-

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
50	4.03	0.098	2.67	6.83
51	4.04	0.098	2.67	6.84
52	4.03	0.098	2.55	6.83
53	4.03	0.099	2.55	6.83
54	4.05	0.098	2.63	6.84
55	4.04	0.099	2.63	6.82
56	4.04	0.099	2.58	6.82
57	4.03	0.100	3.24	6.82
58	4.02	0.101	3.07	6.83
59	4.02	0.101	2.82	6.81
60	4.02	0.101	2.21	6.81
61	4.06	0.102	0.93	6.79
62	4.04	0.102	0.87	6.76
63	4.04	0.104	0.32	6.75
64	4.04	0.107	0.18	6.76
65	4.03	0.112	0.16	6.73
66	4.03	0.118	0.14	6.75

Appendix E4.–Limnological data collected on 23 April 2008, Copper Lake (62.4251° N, 143.5472° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	0.05	0.086	10.26	7.41
1	0.06	0.085	9.85	7.49
2	1.16	0.082	9.31	7.50
3	1.68	0.081	8.92	7.51
4	2.07	0.081	8.67	7.45
5	2.25	0.080	8.52	7.45
6	2.40	0.079	8.35	7.45
7	2.50	0.079	8.28	7.46
8	2.66	0.079	8.22	7.47
9	2.76	0.079	8.16	7.48
10	2.87	0.077	8.04	7.49
11	2.98	0.078	7.90	7.49
12	3.06	0.077	7.83	7.49
13	3.20	0.077	7.70	7.49
14	3.29	0.077	7.64	7.49
15	3.37	0.077	7.67	7.49
16	3.46	0.077	7.55	7.49
17	3.53	0.077	7.41	7.49
18	3.60	0.077	7.07	7.47
19	3.63	0.077	6.89	7.46
20	3.68	0.078	6.66	7.45
21	3.77	0.078	6.18	7.43
22	3.79	0.078	6.12	7.42
23	3.84	0.079	5.56	7.40
24	3.87	0.080	5.44	7.38
25	3.91	0.081	5.38	7.36
26	3.93	0.082	5.13	7.35
27	3.96	0.083	4.90	7.34
28	3.97	0.084	4.63	7.33
29	3.99	0.084	4.44	7.32
30	3.99	0.084	4.08	7.30
31	4.00	0.085	3.93	7.30
32	4.01	0.085	3.71	7.29
33	4.01	0.086	3.57	7.28
34	4.01	0.087	3.45	7.27
35	4.01	0.087	3.22	7.27
36	4.02	0.087	3.11	7.26
37	4.02	0.087	2.83	7.26
38	4.02	0.088	2.64	7.26
39	4.02	0.088	2.55	7.26
40	4.02	0.089	2.49	7.26
41	4.02	0.089	2.43	7.26
42	4.02	0.090	2.31	7.25
43	4.02	0.090	2.21	7.26
44	4.02	0.090	2.11	7.25
45	4.02	0.091	1.99	7.37
46	4.02	0.091	1.93	7.35
47	4.01	0.091	1.82	7.33
48	4.01	0.092	1.68	7.31
49	4.01	0.091	1.44	7.27

-continued-

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
50	4.01	0.092	1.54	7.29
51	4.00	0.092	1.38	7.28
52	3.99	0.093	1.34	7.27
53	3.99	0.094	1.12	7.27
54	3.98	0.094	1.10	7.26
55	3.98	0.094	1.03	7.26
56	3.98	0.094	0.81	7.26
57	3.98	0.095	0.68	7.25
58	3.99	0.095	0.42	7.24
59	4.00	0.095	0.22	7.24
60	4.00	0.096	0.07	7.24
61	4.01	0.097	0.06	7.24
62	4.01	0.098	0.05	7.24
63	4.01	0.099	0.04	7.25
64	4.02	0.100	0.04	7.26
65	4.02	0.101	0.04	7.26
66	4.02	0.103	0.04	7.27
67	4.01	0.106	0.04	7.27
68	4.01	0.114	0.03	7.28
69	4.01	0.147	0.03	7.35
70	4.00	0.308	0.03	7.51

Appendix E5.–Limnological data collected on 19 June 2008, Copper Lake (62.4251° N, 143.5472° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	7.85	0.069	9.79	8.53
1	7.49	0.710	9.98	8.54
2	6.45	0.710	10.29	8.58
3	6.24	0.710	10.25	8.61
4	6.06	0.710	10.31	8.63
5	5.90	0.710	10.32	8.64
6	5.63	0.072	10.35	8.58
7	5.16	0.073	10.25	8.55
8	4.55	0.076	9.88	8.43
9	4.50	0.074	9.83	8.40
10	4.35	0.074	9.87	8.37
11	4.31	0.075	9.52	8.30
12	4.30	0.076	9.48	8.27
13	4.28	0.077	9.21	8.22
14	4.23	0.077	9.13	8.20
15	4.04	0.078	9.04	8.17
16	3.43	0.078	8.57	8.14
17	3.88	0.079	8.59	8.09
18	3.86	0.078	8.51	8.09
19	3.84	0.078	8.52	8.07
20	3.84	0.079	8.46	8.06
21	3.81	0.079	8.40	8.05
22	3.80	0.079	8.34	8.03
23	3.87	0.080	7.72	8.00
24	3.88	0.080	6.66	7.96
25	3.87	0.082	6.12	7.84
26	3.88	0.083	5.48	7.80
27	3.80	0.082	5.20	7.75
28	3.88	0.084	4.68	7.73
29	3.92	0.085	4.44	7.71
30	3.92	0.085	4.43	7.70
31	3.95	0.086	4.11	7.69
32	3.96	0.085	4.09	7.68
33	3.96	0.086	4.04	7.68
34	3.98	0.087	3.80	7.67
35	3.98	0.087	3.76	7.66
36	4.00	0.088	3.45	7.65
37	3.99	0.088	3.35	7.65
38	3.99	0.089	3.30	7.64
39	3.99	0.089	3.13	7.64
40	3.98	0.089	3.11	7.63
41	3.96	0.089	3.09	7.64
42	3.95	0.090	3.08	7.64
43	3.94	0.090	3.04	7.63
44	3.90	0.091	3.12	7.64
45	3.87	0.091	3.35	7.80
46	3.85	0.092	3.37	7.85
47	3.86	0.091	3.36	7.74
48	3.86	0.092	3.34	7.73
49	3.86	0.092	3.16	7.72

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Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
50	3.91	0.093	2.48	7.68
51	3.09	0.094	2.54	7.66
52	3.87	0.094	2.64	7.66
53	3.86	0.096	2.66	7.66
54	3.85	0.095	2.64	7.66
55	3.84	0.095	2.57	7.65
56	3.84	0.096	2.56	7.65
57	3.84	0.097	2.36	7.64
58	3.84	0.096	2.23	7.64
59	3.85	0.097	1.92	7.63
60	3.90	0.097	1.08	7.60
61	3.91	0.098	0.70	7.58
62	3.91	0.099	0.36	7.56
63	3.94	0.101	0.15	7.54
64	3.94	0.106	0.12	7.52
65	3.96	0.110	0.09	7.54
66	3.96	0.115	0.08	7.56
67	3.96	0.118	0.08	7.59
68	3.91	0.121	0.08	7.62
69	3.91	0.124	0.07	7.67

Appendix E6.–Limnological data collected on 29 July 2008, Copper Lake (62.4251° N, 143.5472° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	14.24	0.064	8.70	8.71
1	11.59	0.064	8.75	8.79
2	11.30	0.064	8.82	8.83
3	11.16	0.064	8.78	8.86
4	11.10	0.064	8.79	8.86
5	11.04	0.064	8.73	8.86
6	10.73	0.064	8.72	8.79
7	9.15	0.066	8.85	8.78
8	8.16	0.068	8.88	8.64
9	6.67	0.071	9.00	8.63
10	5.82	0.073	9.00	8.62
11	5.00	0.075	8.52	8.59
12	4.60	0.076	8.35	8.55
13	4.31	0.077	8.13	8.52
14	4.18	0.078	8.00	8.49
15	4.04	0.079	7.85	8.47
16	3.97	0.079	7.58	8.44
17	3.94	0.080	7.53	8.41
18	3.91	0.080	7.16	8.39
19	3.92	0.081	6.68	8.35
20	3.92	0.081	6.20	8.29
21	3.92	0.081	5.89	8.25
22	3.94	0.082	5.63	8.21
23	3.95	0.083	5.30	8.18
24	3.96	0.083	7.93	8.15
25	3.97	0.084	4.57	8.10
26	3.98	0.085	4.21	8.08
27	3.99	0.086	3.95	8.05
28	3.99	0.086	3.82	8.03
29	3.99	0.086	3.75	8.00
30	3.99	0.086	3.74	8.00
31	4.00	0.086	3.57	7.99
32	4.01	0.087	3.27	7.98
33	4.01	0.088	2.96	7.95
34	4.01	0.089	2.69	7.93
35	4.01	0.089	2.54	7.92
36	4.01	0.089	2.47	7.90
37	4.01	0.089	2.43	7.91
38	4.01	0.089	2.38	7.90
39	4.01	0.090	2.22	7.89
40	4.01	0.090	2.16	7.88
41	4.02	0.090	2.08	7.87
42	4.02	0.091	1.91	7.87
43	4.04	0.091	1.91	7.87
44	4.03	0.091	1.87	7.86
45	4.04	0.091	1.83	7.85
46	4.05	0.091	1.78	7.85
47	4.06	0.092	1.75	7.85
48	4.07	0.091	1.71	7.85
49	4.08	0.092	1.67	7.84

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Appendix E6.–Page 2 of 2.

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
50	4.09	0.093	1.69	7.95
51	4.09	0.092	1.65	7.92
52	4.10	0.092	1.62	7.91
53	4.10	0.092	1.60	7.90
54	4.10	0.092	1.59	7.89
55	4.10	0.092	1.48	7.88
56	4.10	0.092	1.44	7.86
57	4.09	0.093	1.16	7.86
58	4.10	0.093	1.09	7.84
59	4.09	0.094	1.08	7.84
60	4.10	0.093	1.02	7.83
61	4.09	0.093	0.97	7.83
62	4.09	0.093	0.93	7.82
63	4.10	0.093	0.88	7.82
64	4.10	0.094	0.80	7.82
65	4.10	0.094	0.71	7.82
66	4.10	0.094	0.68	7.80
67	4.10	0.095	0.44	7.80
68	4.09	0.096	0.16	7.80
69	4.09	0.099	0.10	7.79
70	4.08	0.106	0.08	7.79

Appendix E7.–Limnological data collected on 29 August 2008, Copper Lake (62.4251° N, 143.5472° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	11.22	0.065	8.67	8.30
1	10.92	0.065	8.76	8.45
2	10.82	0.065	8.86	8.56
3	10.76	0.065	8.87	8.65
4	10.65	0.065	8.60	8.69
5	10.57	0.065	8.74	8.73
6	10.39	0.065	8.67	8.73
7	9.91	0.065	8.51	8.74
8	9.05	0.066	8.40	8.72
9	8.58	0.067	8.43	8.68
10	7.71	0.070	8.14	8.66
11	6.84	0.071	7.96	8.63
12	6.12	0.073	7.96	8.59
13	5.50	0.075	8.01	8.58
14	5.13	0.076	7.55	8.57
15	4.85	0.077	7.36	8.53
16	4.35	0.077	7.48	8.52
17	4.09	0.079	7.01	8.50
18	4.04	0.080	6.61	8.47
19	4.00	0.080	6.61	8.43
20	3.97	0.081	5.92	8.42
21	3.97	0.082	5.60	8.38
22	3.97	0.083	5.39	8.35
23	3.96	0.082	5.08	8.33
24	3.97	0.083	4.99	8.31
25	3.95	0.084	4.78	8.29
26	3.97	0.084	4.54	8.29
27	3.98	0.086	4.16	8.26
28	3.99	0.085	3.99	8.24
29	4.00	0.086	3.98	8.22
30	4.01	0.087	3.50	8.21
31	4.01	0.087	3.50	8.19
32	4.02	0.087	3.24	8.19
33	4.02	0.088	3.12	8.26
34	4.02	0.088	3.14	8.24
35	4.03	0.088	2.71	8.22
36	4.03	0.089	2.71	8.18
37	4.04	0.089	2.65	8.17
38	4.04	0.090	2.40	8.17
39	4.05	0.090	2.11	8.15
40	4.05	0.091	2.15	8.13
41	4.05	0.090	2.16	8.12
42	4.06	0.091	2.09	8.13
43	4.06	0.091	2.02	8.12
44	4.06	0.091	1.91	8.12
45	4.06	0.091	1.90	8.11
46	4.06	0.092	1.87	8.11
47	4.07	0.091	1.87	8.10
48	4.08	0.092	1.83	8.10
49	4.08	0.092	1.69	8.10

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Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
50	4.07	0.092	1.55	8.10
51	4.09	0.092	1.53	8.08
52	4.08	0.092	1.50	8.08
53	4.09	0.092	1.44	8.08
54	4.09	0.093	1.48	8.08
55	4.08	0.093	1.29	8.07
56	4.09	0.093	1.34	8.07
57	4.09	0.094	1.23	8.07
58	4.09	0.093	1.18	8.06
59	4.09	0.093	1.13	8.06
60	4.09	0.093	1.09	8.06
61	4.09	0.093	0.97	8.06
62	4.09	0.094	0.68	8.05
63	4.09	0.094	0.59	8.05
64	4.09	0.095	0.30	8.03
65	4.09	0.097	0.19	8.03
66	4.09	0.098	0.15	8.03
67	4.09	0.102	0.14	8.03
68	4.09	0.104	0.12	8.04
69	4.08	0.110	0.12	8.16

Appendix E8.–Limnological data collected on 23 September 2008, Copper Lake (62.4251° N, 143.5472° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	9.30	0.067	9.06	8.76
1				
2	8.95	0.066	9.10	8.83
3	8.65	0.067	9.09	8.89
4	8.59	0.067	8.98	8.90
5	8.58	0.066	8.72	8.92
6	8.57	0.066	8.85	8.91
7	8.56	0.066	8.86	8.93
8	8.54	0.066	8.90	8.93
9	8.50	0.067	8.81	8.93
10	8.20	0.068	8.22	8.81
11	7.04	0.072	7.68	8.68
12	6.54	0.073	7.58	8.61
13	5.21	0.077	7.58	8.56
14	4.44	0.078	7.46	8.55
15	4.10	0.080	7.10	8.52
16	4.03	0.081	6.45	8.48
17	4.02	0.081	6.23	8.45
18	4.03	0.082	5.73	8.41
19	4.03	0.084	5.28	8.36
20	4.02	0.084	4.87	8.33
21	4.03	0.085	4.47	8.32
22	4.02	0.086	4.09	8.29
23	4.03	0.087	3.87	8.26
24	4.03	0.086	3.75	8.26
25	4.03	0.087	3.52	8.23
26	4.04	0.087	3.34	8.25
27	4.05	0.088	3.18	8.22
28	4.06	0.089	2.96	8.20
29	4.06	0.089	2.68	8.18
30	4.08	0.091	2.25	8.19
31	4.10	0.092	2.75	8.20
32	4.09	0.092	2.68	8.21
33	4.09	0.092	2.71	8.19
34	4.09	0.092	2.65	8.18
35	4.09	0.092	2.62	8.18
36	4.07	0.092	1.82	8.16
37	4.08	0.092	1.99	8.24
38	4.08	0.092	1.49	8.22
39	4.08	0.092	1.45	8.17
40	4.08	0.093	1.29	8.17
41	4.08	0.093	1.26	8.16
42	4.08	0.093	1.30	8.14
43	4.08	0.094	1.20	8.14
44	4.09	0.094	1.24	8.13
45	4.08	0.094	0.99	8.12
46	4.08	0.094	1.00	8.11
47	4.10	0.094	1.07	8.12
48	4.08	0.094	1.04	8.11
49	4.08	0.094	1.00	8.11

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Appendix E8.–Page 2 of 2.

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
50	4.08	0.095	0.91	8.11
51	4.08	0.095	0.68	8.10
52	4.08	0.095	0.68	8.09
53	4.08	0.096	0.21	8.09
54	4.08	0.096	0.18	8.29
55	4.09	0.096	0.14	8.20
56	4.08	0.098	0.14	8.19
57	4.08	0.099	0.13	8.18
58	4.08	0.103	0.13	8.18
59	4.08	0.106	0.13	8.19
60	4.07	0.112	0.13	8.18
61	4.07	0.260	0.11	8.42

Appendix E9.–Limnological data collected on 8 April 2009, Copper Lake (62.4251° N, 143.5472° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	0.05	0.082	8.08	pH probe
1	0.25	0.082	8.72	broken
2	1.48	0.079	8.54	
3	2.29	0.077	8.12	
4	2.62	0.077	7.95	
5	2.74	0.076	7.94	
6	2.81	0.076	7.87	
7	2.87	0.076	7.84	
8	2.93	0.075	7.89	
9	2.98	0.075	7.96	
10	3.03	0.074	7.83	
11	3.10	0.075	7.75	
12	3.17	0.074	7.77	
13	3.21	0.074	7.79	
14	3.30	0.074	7.68	
15	3.36	0.075	7.57	
16	3.39	0.075	7.57	
17	3.51	0.075	7.37	
18	3.57	0.075	7.25	
19	3.65	0.076	6.88	
20	3.72	0.078	6.57	
21	3.78	0.079	6.26	
22	3.84	0.080	5.89	
23	3.91	0.082	5.48	
24	3.95	0.084	4.71	
25	3.99	0.086	4.31	
26	4.03	0.088	3.90	
27	4.03	0.088	3.55	
28	4.04	0.088	3.34	
29	4.04	0.090	3.16	
30	4.05	0.089	3.02	
31	4.05	0.090	2.81	
32	4.05	0.090	2.68	
33	4.05	0.091	2.53	
34	4.07	0.091	2.37	
35	4.06	0.091	2.27	
36	4.05	0.091	2.16	
37	4.06	0.092	2.05	
38	4.06	0.092	1.98	
39	4.06	0.092	1.92	
40	4.06	0.093	1.86	
41	4.07	0.093	1.82	
42	4.06	0.093	1.82	
43	4.06	0.094	1.77	
44	4.06	0.094	1.74	
45	4.06	0.094	1.71	
46	4.05	0.094	1.66	
47	4.05	0.093	1.75	
48	4.05	0.094	1.79	
49	4.05	0.094	1.79	

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Appendix E9.–Page 2 of 2.

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
50	4.05	0.095	1.75	
51	4.04	0.095	1.70	
52	4.05	0.095	1.60	
53	4.05	0.096	1.64	
54	4.03	0.096	1.61	
55	4.03	0.096	1.65	
56	4.02	0.096	1.60	
57	3.99	0.097	1.75	
58	3.98	0.095	1.89	
59	3.99	0.097	1.90	
60	4.03	0.097	0.95	
61	4.05	0.098	0.81	
62	4.05	0.098	0.51	
63	4.06	0.100	0.39	
64	4.06	0.102	0.37	
65	4.06	0.104	0.36	
66	4.06	0.106	0.36	
67	4.05	0.110	0.36	

Appendix E10.–Limnological data collected on 4 August 2009, Copper Lake (62.4251° N, 143.5472° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	17.38	0.068	5.92	8.69
1	17.06	0.068	6.06	8.83
2	16.78	0.067	6.22	8.88
3	16.66	0.067	6.31	8.95
4	16.50	0.068	6.42	9.04
5	13.01	0.068	6.91	9.13
6	10.27	0.070	7.29	9.31
7	8.90	0.070	7.42	9.37
8	7.92	0.071	7.45	9.47
9	7.50	0.071	7.34	9.54
10	6.48	0.072	7.38	9.64
11	5.63	0.073	7.41	9.67
12	5.12	0.074	7.24	9.70
13	4.65	0.074	7.04	9.72
14	4.40	0.075	6.86	9.73
15	4.28	0.075	6.76	9.71
16	4.11	0.075	6.60	9.72
17	4.08	0.076	6.49	9.69
18	4.07	0.077	6.14	9.69
19	3.98	0.079	5.74	9.63
20	3.97	0.080	5.26	9.60
21	3.97	0.081	5.06	9.56
22	3.96	0.082	4.83	9.53
23	3.96	0.082	4.32	9.48
24	3.98	0.083	4.23	9.45
25	3.99	0.085	3.99	9.42
26	3.99	0.087	3.58	9.40
27	4.00	0.087	3.27	9.38
28	4.01	0.088	3.05	9.36
29	4.02	0.089	2.74	9.33
30	4.02	0.089	7.55	9.33
31	4.02	0.089	2.44	9.30
32	4.02	0.090	2.33	9.30
33	4.03	0.090	2.19	9.27
34	4.04	0.091	2.01	9.26
35	4.04	0.092	1.88	9.25
36	4.04	0.092	1.80	9.24
37	4.03	0.092	1.69	9.23
38	4.03	0.092	1.64	9.21
39	4.03	0.093	1.58	9.21
40	4.03	0.093	1.51	9.19
41	4.03	0.093	1.44	9.18
42	4.03	0.093	1.41	9.17
43	4.03	0.093	1.37	9.15
44	4.02	0.094	1.31	9.15
45	4.02	0.094	1.37	9.14
46	4.02	0.094	1.23	9.12
47	4.02	0.095	1.14	9.11
48	4.01	0.095	1.05	9.10
49	17.38	0.068	5.92	8.69

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Appendix E10.–Page 2 of 2.

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
50	4.01	0.095	0.98	9.10
51	4.01	0.096	0.89	9.07
52	4.01	0.096	0.86	9.06
53	4.01	0.096	0.77	9.06
54	4.01	0.097	0.62	9.05
55	4.00	0.097	0.57	9.04
56	4.01	0.097	0.46	9.02
57	4.01	0.097	0.32	9.02
58	4.00	0.098	0.24	8.99
59	4.00	0.099	0.23	8.90
60	4.00	0.100	0.20	8.97
61	4.01	0.100	0.21	8.96
62	4.00	0.101	0.18	8.17
63	4.01	0.102	0.19	8.96
64	4.00	0.102	0.18	8.96
65	4.00	0.104	0.18	8.94
66	4.01	0.107	0.17	8.92
67	4.01	0.109	0.17	8.93
68	4.01	0.111	0.18	8.90
69	4.01	0.126	0.17	8.98

Appendix E11.–Limnological data collected on 2 September 2009, Copper Lake (62.4251° N, 143.5472° W).

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
0	11.36	0.069	5.85	8.64
1	11.40	0.069	5.83	8.69
2	11.40	0.068	5.81	8.75
3	11.39	0.069	5.83	8.78
4	11.37	0.068	5.83	8.86
5	11.35	0.069	5.83	8.86
6	11.30	0.068	5.85	8.89
7	10.86	0.069	5.85	8.87
8	10.44	0.069	5.80	8.86
9	9.32	0.070	5.78	8.84
10	7.51	0.072	5.88	8.86
11	6.23	0.073	5.73	8.88
12	6.23	0.073	5.73	8.88
13	5.50	0.074	5.72	8.89
14	4.98	0.074	5.60	8.88
15	4.61	0.074	5.62	8.87
16	4.46	0.075	5.62	8.86
17	4.31	0.074	5.61	8.87
18	4.20	0.075	5.58	8.85
19	4.10	0.076	5.53	8.86
20	4.06	0.077	5.16	8.82
21	4.09	0.078	4.95	8.77
22	4.07	0.081	4.33	8.71
23	4.05	0.082	4.01	8.67
24	4.00	0.083	3.76	8.64
25	3.98	0.084	3.66	8.62
26	3.98	0.084	3.35	8.58
27	3.99	0.085	3.17	8.57
28	4.00	0.086	3.03	8.55
29	4.00	0.088	2.65	8.54
30	4.00	0.088	2.57	8.51
31	4.01	0.089	2.46	8.50
32	4.01	0.089	2.35	8.49
33	4.02	0.090	2.23	8.48
34	4.02	0.099	2.17	8.48
35	4.02	0.091	1.91	8.46
36	4.03	0.091	1.78	8.45
37	4.03	0.093	1.73	8.44
38	4.03	0.092	1.54	8.45
39	4.02	0.093	1.53	8.43
40	4.03	0.093	1.50	8.43
41	4.02	0.093	1.42	8.43
42	4.02	0.094	1.40	8.42
43	4.02	0.094	1.37	8.42
44	4.02	0.094	1.33	8.42
45	4.01	0.095	1.23	8.41
46	4.01	0.095	1.17	8.41
47	4.01	0.096	1.00	8.38
48	4.01	0.096	0.87	8.38
49	4.01	0.096	0.78	8.39

-continued-

Depth (m)	Temperature (°C)	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	pH
50	4.01	0.096	0.58	8.36
51	4.01	0.096	0.54	8.36
52	4.01	0.097	0.53	8.37
53	4.01	0.097	0.54	8.33
54	4.01	0.097	0.51	8.36
55	4.01	0.097	0.51	8.36
56	4.00	0.098	0.53	8.36
57	4.00	0.098	0.56	8.35
58	4.00	0.098	0.54	8.34
59	4.00	0.099	0.33	8.35
60	4.00	0.100	0.30	8.34
61	4.00	0.101	0.31	8.34
62	4.00	0.101	0.29	8.32
63	4.00	0.102	0.25	8.34
64	4.00	0.104	0.28	8.34
65	4.00	0.105	0.28	8.35
66	4.00	0.106	0.29	8.35
67	4.00	0.109	0.26	8.33
68	4.01	0.116	0.27	8.31
69	4.01	0.120	0.28	8.31
70	4.01	0.127	0.28	8.58

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