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Stock Assessment and Biological Characteristics of Burbot in Paxson, Sucker, and Tolsana Lakes, 2001

by

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and

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

Symbols and Abbreviations

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Weights and measures (metric)

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

Weights and measures (English)

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

Time and temperature

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

Physics and chemistry

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

General

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

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

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 SERIES NUMBER 04-16

STOCK ASSESSMENT AND BIOLOGICAL CHARACTERISTICS OF BURBOT IN PAXSON, SUCKER, AND TOLSONA LAKES, 2001

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ABSTRACT

Abundance, mean CPUE, and length composition were estimated for the population of burbot *Lota lota* in Tolsona Lake and mean CPUE in Paxson and Sucker lakes in Southcentral Alaska. Sampling occurred in May and September 2001. Bootstrapped mean catch per unit of effort of fully recruited burbot (≥450 mm total length) per 48-hour set was 1.85 (SE = 0.464) in Tolsona Lake, 0.95 (SE = 0.122) in Paxson Lake, and 0.75 (SE = 0.085) in Sucker Lake. Mean CPUE of fully recruited burbot in Paxson Lake in 2001 was significantly greater than the estimate from 1990, and mean CPUE was greater in Sucker Lake in 2001 than in 1988, which prior to this study were the most recent estimates for those lakes. Abundance during 2000 of fully recruited burbot in Tolsona Lake estimated with mark-recapture experiments was 2,006 fish (SE = 597), the fourth highest estimate since assessment was initiated 1986. Estimated annual survival rate for fully recruited burbot in Tolsona Lake was 98.4% (SE = 28.6%) between 1999 and 2000. Estimated length composition indicated few large (>675 mm TL) burbot present, but that average size of burbot in Tolsona Lake had increased. Water quality measurements in Tolsona Lake were outside critical zones for temperature, dissolved oxygen, pH, and water clarity during August, but dissolved oxygen and pH were within critical zones in April. Estimated abundance of burbot (≥450 mm) in 2001, by expansion of CPUE, was 12,941 (SE = 2,248) in Paxson Lake, 628 burbot in Sucker Lake, and 545 burbot (SE = 254) in Tolsona Lake. Regulatory actions taken in the late 1980s and early 1990s appeared to have allowed burbot populations in Paxson and Sucker lakes to recover from overexploitation that occurred in the mid-1980s.

Key words: Burbot, *Lota lota,* abundance, length composition, catch per unit effort, hoop traps, mean length, survival rate, recruitment, fishery management.

INTRODUCTION

Historically, the lakes of the Upper Copper/Upper Susitna Management Area (UCUSMA) supported the largest burbot fishery in the state. Harvests from the UCUSMA averaged over 9,000 burbot or 60% of the statewide burbot harvest from 1977 to 1986 (Taube 2000). Harvest from the fishery peaked in 1985 when over an estimated 19,000 burbot were harvested from the UCUSMA, accounting for 71% of the statewide burbot harvest (Mills 1993, Jennings et al. *In prep*; Figure 1). The Tyone River drainage (consisting of Lake Louise, Susitna and Tyone lakes; Figure 2) produced over half of the burbot harvested in the Glennallen area (UCUSMA) prior to 1987. Concerns about overexploitation resulted in the Alaska Department of Fish and Game (ADF&G) initiating research in 1986 to collect basic life history information necessary to assess stock status and to estimate sustained yield of burbot in interior Alaskan lakes. In 1988, the Board of Fisheries adopted a lake burbot management plan into regulation (AAC 2001). This plan directs the ADF&G to manage burbot stocks in lakes of the UCUSMA to permit maximum sustainable harvests on healthy stocks, rebuild depressed stocks, and maintain opportunity for anglers to participate in the fishery.

The ADF&G has managed UCUSMA burbot fisheries through bag limits, gear restrictions, and lake closures. Since 1988, bag and possession limits have been reduced to 5 burbot per day on most lakes, and 2 burbot per day on some heavily fished, road-accessible lakes. The use of setlines has been prohibited by emergency order in the Tyone River drainage and in Tolsona and Moose lakes from 1989 to 1991, and by regulation since 1991 in the entire UCUSMA. Hudson Lake was closed in 1988, but stock assessment in May 1993 indicated the population had recovered sufficiently to open the lake to harvest in November 1993. The fishery in Lake Louise was also closed in 1988 due to continued declines in abundance of burbot, and stock assessment in 1999 indicated that the population had not increased to historical levels. An incomplete recovery during this 11-year closure suggested that a lower carrying capacity equilibrium of the population was established. If so, some surplus production is available for harvest, just not as

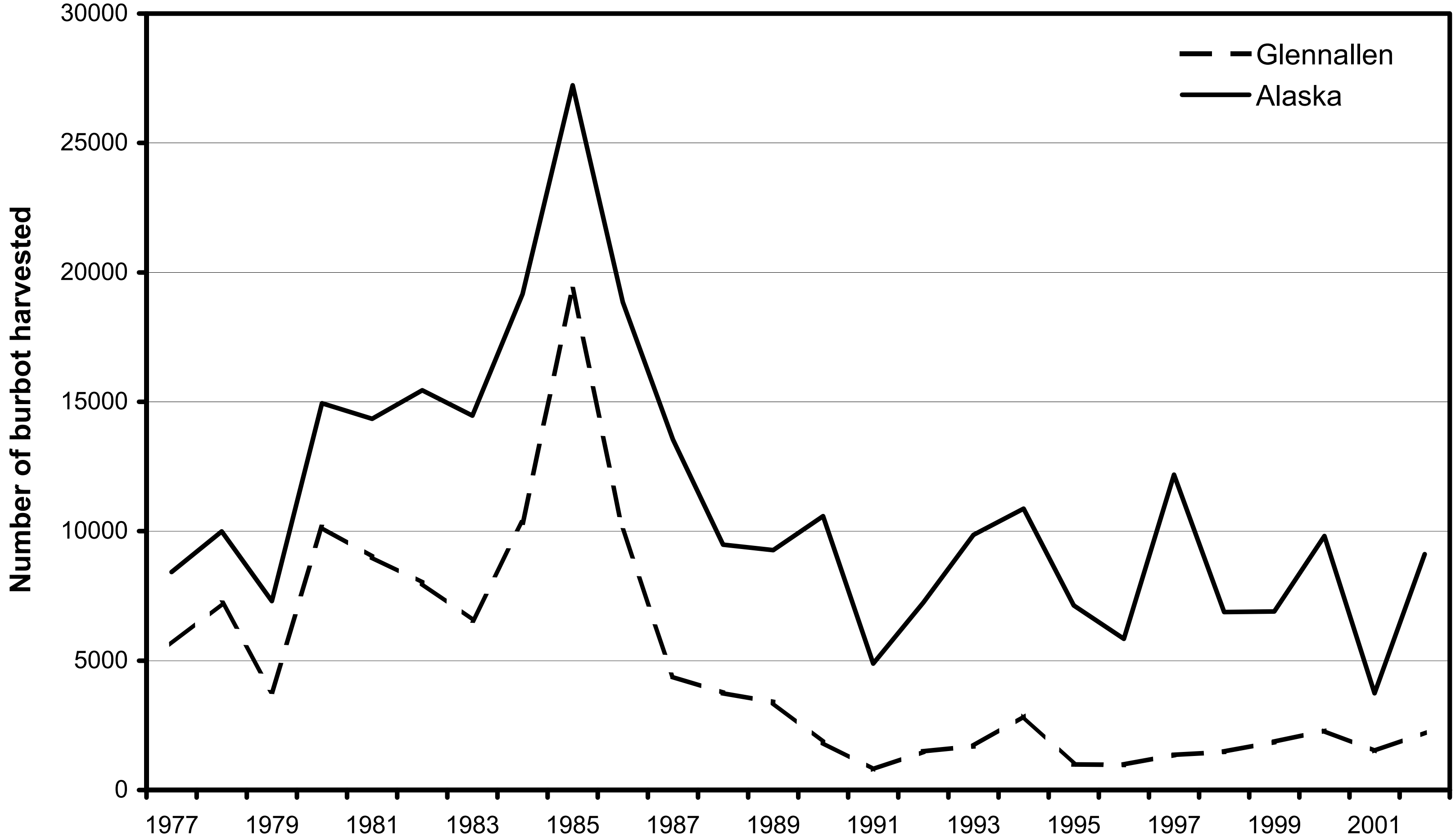

Figure 1.–Harvest of burbot in sport fisheries of the Glennallen Area (UCUSMA) compared to all burbot harvested in Alaska, 1977-2002.

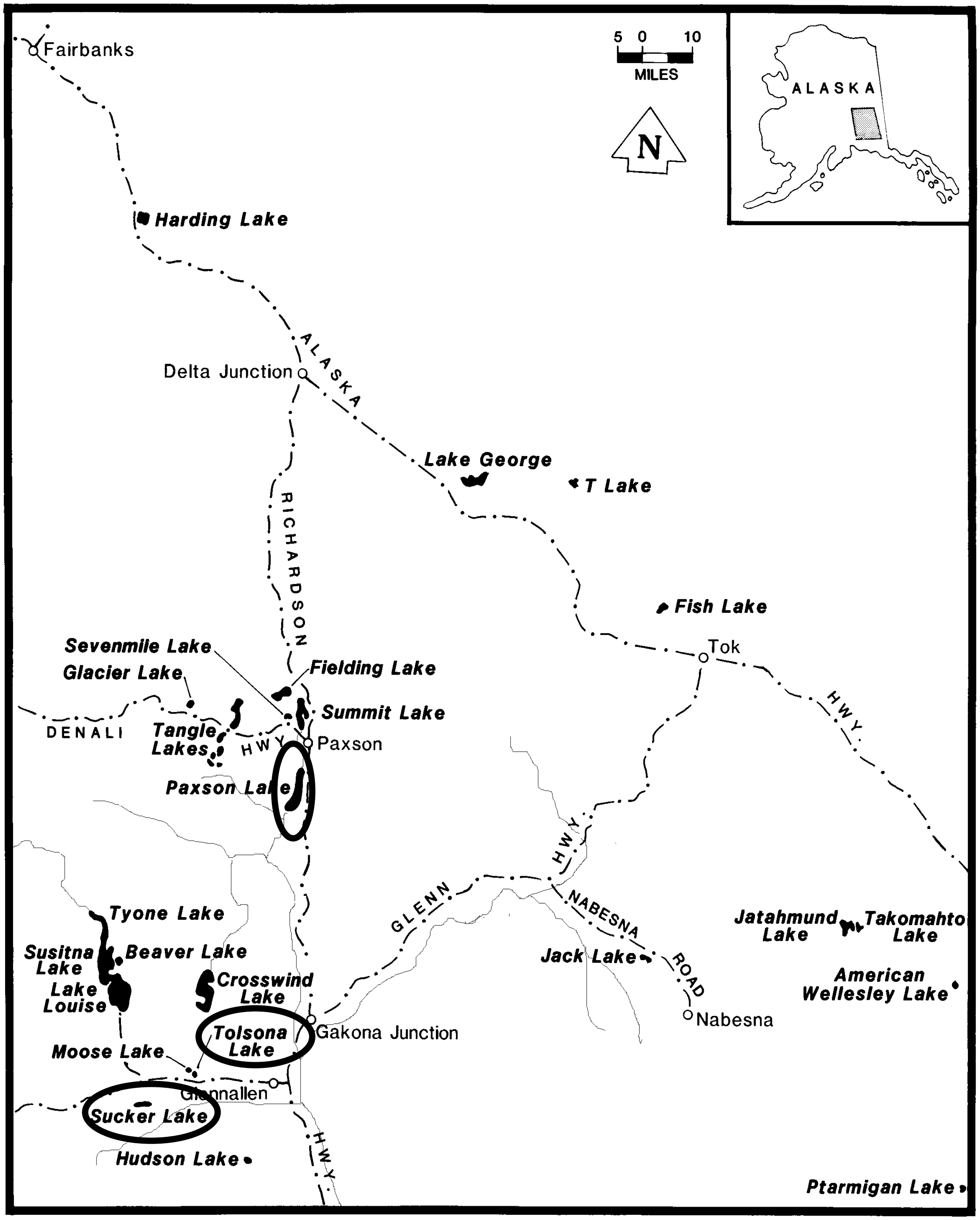

Figure 2.–Locations of burbot lakes in the UCUSMA that were sampled during 2001.

much as was available prior to 1990. Assuming a new equilibrium had been established, the Board of Fisheries in 2003 passed an ADF&G proposal reopening Lake Louise to a one burbot per day bag limit (Taube *In prep*).

Populations in Paxson and Sucker lakes were last sampled in 1990 and 1988, respectively (Lafferty et al. 1991; Parker et al. 1989). Both lakes have had sport fisheries for burbot, though the fishery at Sucker Lake has primarily occurred as a winter fishery due to limited accessibility during the snow-free months. As regulations became restrictive, harvests on these lakes declined. Harvests at Paxson and Sucker lakes from 1985 to 1990 averaged 384 and 216 burbot, respectively. From 1991 to 2002, 269 burbot were harvested from Paxson Lake on average, and 90 burbot from Sucker Lake during the same period (Mills 1986-1994; Howe et al. 1995-1996, 2001a-d, Jennings et al. 2004, *In prep;* Walker et al. 2003). Assessments in 2001 were conducted to determine if the reduced bag limits and gear restrictions in place since 1990 have permitted the burbot populations in these lakes to increase.

The burbot population in Tolsona Lake has been assessed annually since 1986 as part of a long-term study on an exploited population (Parker et al. 1987-1989; Lafferty et al. 1990-1992; Lafferty and Bernard 1993; Taube et al. 1994, 2000; and Taube and Bernard 1995, 1999, 2001). Tolsona Lake was closed to burbot fishing in 1998. This was due to a dramatic decline in burbot abundance and poor summer survival that occurred in 1996 (Figure 3). A combination of factors contributed to this decline, but it appears the high summer water temperatures may have been most significant. To date, Tolsona Lake remains closed, as the burbot population has not recovered to a level capable of sustaining expected harvests. In 2001, the burbot population in Tolsona Lake was sampled to estimate abundance, length composition, and mean catch per unit of effort (CPUE). In addition, data on water temperature profiles and water chemistry were collected.

The objectives for the project during 2001 were to:

1. estimate the length composition of burbot (≥ 450 mm TL) for each sampling event in Paxson, Sucker, and Tolsona lakes;

2. estimate the abundance of burbot (≥ 450 mm TL) in Tolsona Lake;

3. estimate mean catch-per-unit of effort (CPUE) of burbot (≥ 450 mm TL) in Paxson. Sucker, and Tolsona lakes;

4. test the hypothesis that mean CPUE of burbot (≥ 450 mm TL) in Paxson Lake had increased since 1990; and,

5. test the hypothesis that mean CPUE of burbot (≥450 mm TL) in Sucker Lake had increased since 1988.

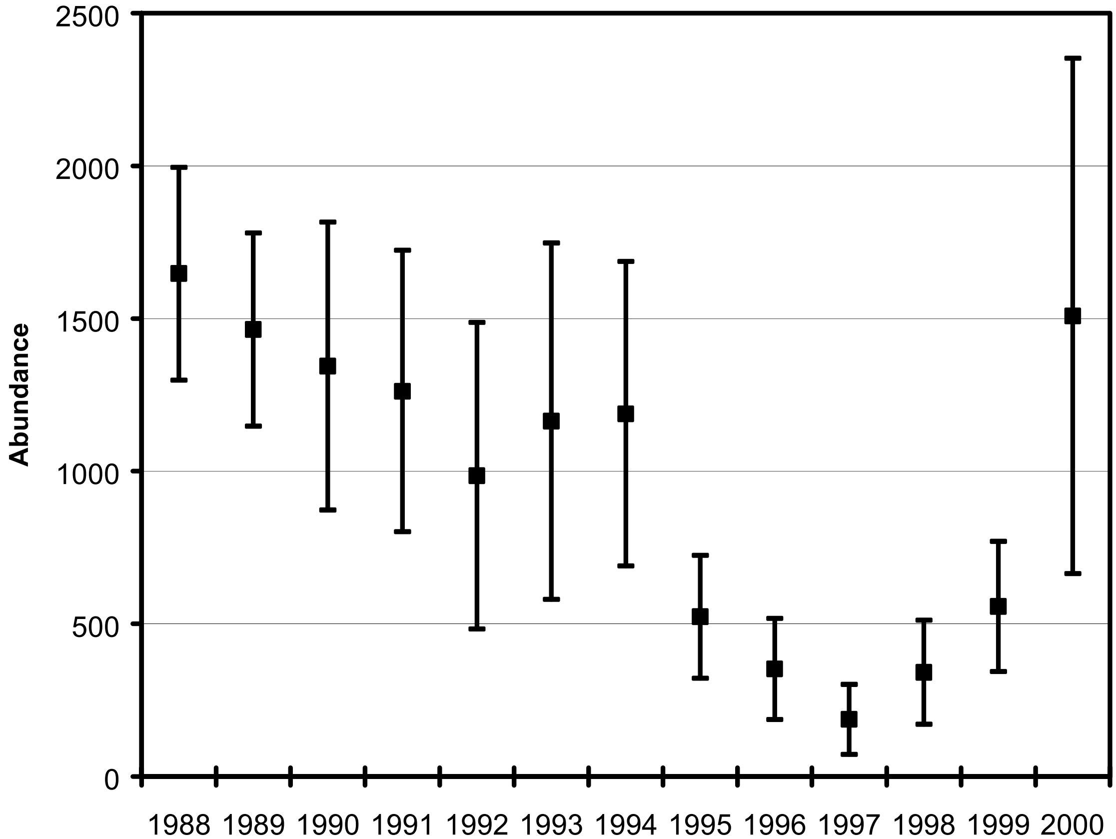

Figure 3.–Estimated abundance (solid squares) and 95% confidence intervals (vertical bars) of fully recruited (≥ 450 mm TL) burbot in Tolsona Lake, 1988-2000.

Project tasks for 2001 were to:

1. measure water temperatures to provide a temperature profile of Tolsona Lake during the open-water period;
2. collect water quality data at one-month intervals in Tolsona Lake from May through September;
3. measure dissolved oxygen from Tolsona and area lakes during March; and,
4. estimate the abundance of fully recruited burbot (≥ 450 mm TL) in Paxson, Sucker, and Tolsona lakes for 2001 from expansion of mean CPUE and estimated average catchability.

METHODS

STUDY DESIGN

Burbot were captured by deploying baited hoop traps (3-m long and constructed with 25-mm mesh netting) on the lake bottom as described in Bernard et al. (1991). Burbot ≥ 450 mm TL were fully recruited to this gear (burbot of this size are approximately 6 years of age and are usually sexually mature). Traps were positioned according to a systematic sampling design as described in Bernard et al. (1993) to minimize competition among the gear and to provide sufficient coverage of the lake bottom. Sampling at Tolsona Lake occurred immediately after the lake became ice-free and at Paxson and Sucker lakes just prior to ice forming because during these periods catch per set is maximized (Bernard et al. 1993; Table 1). A set was defined as fishing ("soaking") a single hoop trap for 48-hours. Traps were systematically placed along randomly chosen transects across each lake, however in Paxson Lake no traps were placed in waters > 15 m deep. Traps in Paxson Lake were restricted to shallow waters to reduce mortalities of burbot that can result from decompression. Past studies showed such restrictions had little effect on estimates of mean CPUE (Bernard et al. 1993). The Jolly-Seber model (Seber 1982) was used to estimate abundance of burbot in Tolsona Lake for 2000. Estimates of mean CPUE were expanded to obtain estimates of abundance in all three lakes for 2001.

Table 1.–Number of sets and dates of sampling events for the stock assessment of burbot populations in Paxson, Sucker, and Tolsona lakes, 2001.

Lake	Surface Area (ha)	Dates of Sampling Events	Number of Sets
Paxson	1,575	9/12 – 20/2001	420
Sucker	283	9/24 – 28/2001	180
Tolsona	130	5/29 – 31/2001	60

After lifting a hoop trap, the catch was emptied into a holding tank, where burbot were inspected for marks, tagged (if necessary), measured for total length (to the nearest 5 mm), and then returned to the lake. At Tolsona Lake, each unmarked burbot was tagged with an individually numbered internal anchor tag (Floy FD 94) inserted in the musculature beneath the dorsal fin. All tags were checked to insure that they were locked between the pterygiophores of the dorsal fin. Each burbot also received a second mark in the form of a left ventral finclip. This second mark was used to evaluate loss of anchor tags. The left ventral fin clip (1998, 2001), right ventral fin clip (1999), and opercular punch (2000) have been used as secondary marks in a three-year rotation in Tolsona Lake. A recaptured burbot without a tag was recorded as being captured in the year in which the secondary mark was last used. Since only CPUE was estimated at Paxson and Sucker lakes, no tags or secondary marks were used. Individual trap and associated catch information was recorded on standard hoopnet mark-sense forms (Heineman *Unpublished*). Hoop trap information included: trap number, location of set, depth of set, hour set and hour pulled, and number of fish caught by species. Tag number and color, secondary mark, and total length were recorded on the mark-sense form for each burbot caught in each set. In the event of sampling-induced mortalities, otoliths were extracted, and ages were determined at a later date. Processing and reading of otoliths followed the procedures described by Chilton and Beamish (1982). Age information was added to the database record of each burbot aged.

Temperature and water quality data for Tolsona Lake were collected through the ice in April and during the open water period in August 2001. Statistics on water clarity (determined by use of a secchi disk), conductivity, and pH were collected for comparison to data from 1993 (Simpson 1997). Measurements of water temperatures and dissolved oxygen were compared with published thresholds for physiological stress as they relate to survival of burbot (Scott and Crossman 1973).

DATA ANALYSIS

Abundance, survival rate, and recruitment statistics were generated for the burbot population in Tolsona Lake (1986-2000) with the Jolly-Seber model (Seber 1982) using the computer program JOLLY (Model A) developed by Brownie et al. (1986) and described by Pollock et al. (1990). Model A is the most general form of the Jolly-Seber model and assumed capture probabilities and survival rates varied over time. Individual burbot captured more than once in 2001 were only considered captured once in this analysis. Conditions needed for producing accurate statistics with the Jolly-Seber model were:

1. all burbot had the same probability of capture during each sample event (probability of capture can vary among events), or marked burbot completely mixed with unmarked burbot between sample events;
2. no marks were lost between sample events;
3. marked burbot behaved (entered traps) similarly to unmarked burbot;
4. marked burbot had the same mortality rate as unmarked burbot; and,
5. immigration and emigration were permanent.

Because burbot < 450 mm TL were not fully recruited to the sampling gear used in this project (Bernard et al. 1991), statistics were only generated for burbot ≥ 450 mm TL. The probability of capturing extremely large burbot (> 900 mm TL) was less than the probability of capturing burbot < 900 mm TL in the hoop traps used in this project (Bernard et al. 1991). This was not considered significant since there were few burbot (e.g., < 1.0%) larger than this size in this population. Traps were distributed uniformly to homogenize the probability of capture of burbot across Tolsona Lake. Over the span of a year, burbot should have completely mixed throughout Tolsona Lake. Double marking of burbot (tag and fin clip) permitted correction of bias in estimates due to loss of tags. Previous studies indicated little change in behavior (trap happiness or trap shyness) of captured burbot (Bernard et al. 1991). Although an intermittent stream connects Moose and Tolsona lakes, only one of several thousand burbot recaptured from 1986 - 2001 was recaptured in a lake in which it was not marked.

Mean CPUE was estimated for fully and partially (< 450 mm TL) recruited burbot in Paxson, Sucker, and Tolsona lakes from a two-stage sampling design with transects as first-stage units and sets along transects as second-stage units (Sukhatme et al. 1984). Although all transects had an equal probability of being included in a sample event, they were of different lengths depending upon the shape of the lake. Under these conditions, the 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;

$\overline{m}$ = mean number of sets sampled across all transects;

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

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

$\overline{M}$ = mean number 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 were directly related to the length of transects. Thus $\hat{\varpi}_i = m_i/\overline{m}$ 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 (bootstrapping) 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 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 autocorrelated or follow a trend (Wolter 1984). Analysis of data from surveys has revealed no meaningful trends or autocorrelations among catches along transects (Bernard et al. 1993). Estimates of mean CPUE for two 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 2001 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 did not compete for burbot;
2. burbot did not saturate the gear; and,
3. gear was not size-selective.

Bernard et al. (1993) showed that the spacing of sets used in this project was sufficient to avoid competition among gear for burbot and that saturation of gear by burbot is negligible. Because hoop traps as fished in this project are size-selective for burbot (Bernard et al. 1991, 1993), mean CPUE for only fully recruited burbot was considered as a valid index of abundance.

Mean CPUE was used to estimate abundance of fully recruited burbot in Paxson, Sucker, and Tolsona lakes in 2001 using the relationship:

$$\hat{N} = A(\overline{CPUE})\hat{q}^{-1} \tag{2}$$

$$v(\hat{N}) \cong \hat{N}^2\left[\frac{v(\overline{CPUE})}{\overline{CPUE}^2} + \frac{v(\hat{q})}{\hat{q}^2}\right] \tag{3}$$

where A is the surface area of the lake (ha) and q is the catchability coefficient (the fraction of the population removed instantaneously with one unit of sampling effort). Estimates of q were obtained from previous sampling at Paxson and Sucker lakes (Lafferty and Bernard 1993).

For a given lake, Kolmogorov-Smirnov two-sample tests were used to compare length distributions of burbot between sampling events.

RESULTS

TOLSONA LAKE

Estimated abundance of burbot ($\geq$ 450 mm TL) for 2000 at Tolsona Lake was 2,006 (SE = 597), which was the largest since sampling began in 1986 (Table 2). Estimated recruitment from 1999 to 2000 was 1,155 (SE = 407), which was also the largest since the inception of the assessment program. The annual survival rate of burbot from 1999 to 2000 was 98.4% (SE = 28.6).

Estimated density of fully recruited burbot in 2000 was 15.43 burbot/ha (SE = 4.59) in Tolsona Lake. Of the fully recruited burbot released in previous years and recaptured in 2001, 5% were recovered without tags. Two of the 44 fish recaptured from previous years were identified by secondary marks. Both secondary marks were half dorsal, which was the secondary mark used from 1995 to 1997. As these burbot could not be assigned to the specific year they were marked, these fish were excluded from the analysis. Another nine of the burbot recaptured from previous years had been marked or recaptured at lengths less than 450 mm, and were also excluded from the abundance analysis. The mark-recapture histories for burbot captured in Tolsona Lake are found in Appendix B.

Table 2.–Estimates of abundance, survival rate, and recruitment for fully recruited (≥450 mm TL) burbot by date residing in Tolsona Lake.

	Days Between	Abundance			Survival Rate %		Recruitment	
Date	Events	Estimate	SE	CV %	Estimate	SE	Estimate	SE
9/26/86		1,901[a]	120	21.6				
	235				60.0	4.6	138	209
6/25/87		1,291	120	9.3				
	335				77.9	7.1	645	144
5/26/88		1,647	178	10.8				
	95				66.6	7.4	45	111
9/01/88		1,142	132	11.5				
	263				77.8	9.1	576	124
5/24/89		1,464	162	11.1				
	110				100.0[b]	17.6	277	174
9/13/89		1,846	311	16.8				
	251				47.9	9.8	460	153
5/24/90		1,344	240	17.9				
	104				36.0	6.6	88	69
9/07/90		572	89	15.6				
	255				63.5	12.0	856	186
5/22/91		1,220	231	18.9				
	109				33.4	6.1	96	80
9/12/91		503	96	19.1				
	273				85.3	23.1	478	163
6/11/92		906	247	27.3				
	341				24.6	6.2	1,127	368
5/20/93		1,350	389	28.8				
	375				90.9	17.7	-30	435
6/01/94		1,193	261	21.9				
	354				32.6	7.2	177	82
5/23/95		565	114	20.2				
	377				37.7	9.2	199	69
6/05/96		411	99	24.1				
	354				69.8	25.1	549	246
5/27/97		821	317	38.6				
	355				29.1	9.9	969	361
5/19/98		1,205	396	32.9				
	375				43.7	7.8	339	292
6/01/99		865	185	21.4				
	367					28.6	1,155	407
6/06/00		2,006	597	29.8				

[a] Estimate obtained from Parker et al. (1987).

[b] Actually computed above 100. Since this value is not valid, this estimate was truncated at 100.

Mean CPUE of fully recruited burbot in Tolsona Lake in 2001 was 1.83 (Table 3), which was the lowest since 1997 and the second lowest since stock assessment began. Expansion of CPUE resulted in an estimated abundance of burbot in 2001 of 539 (SE = 252; Table 4). Statistics concerning mean CPUE for partially recruited burbot are listed in Table 5. The frequency of sets by depth and average catch of burbot by depth for sampling in 2001 are shown in Appendix C1.

Water quality data was collected under ice in April and in open water during August 2001 (Table 6). Water temperature, pH, and dissolved oxygen were all greater during August. During sampling in April, dissolved oxygen and pH were within critical zones. These were the first readings within critical zones since water quality sampling began in 2000. There were no reports of fish kill after ice-out in 2001.

Length composition of all burbot sampled in 2001 was similar to burbot sampled in 2000 (DN = 0.11, P = 0.17; Figure 4). The 525-mm length category was the predominant size category of burbot captured in 2000 and 2001. The mean length of fully recruited burbot was 558 in 2001 (Table 7) and was larger than the mean length of fully recruited burbot captured from 1998-2000 (Figure 4; Taube and Bernard 1999, 2001, Taube et al. 2000).

PAXSON LAKE

Mean CPUE of fully recruited burbot in Paxson Lake in 2001 was 0.95 (Table 3). There was a significant 90% increase between mean CPUE in 2001 compared to mean CPUE in the fall of 1990 (Z = -3.70, P = 0.0002). Expansion of mean CPUE resulted in an estimated abundance of burbot in 2001 of 12,941 (SE = 530), compared to 6,818 (SE = 839) in 1990 (Table 4). Statistics concerning mean CPUE for partially recruited burbot are listed in Table 5. The frequency of sets by depth and average catch of burbot by depth for sampling in 2001 are shown in Appendix C2.

There was a significant, though slight, difference between the length distribution of burbot captured in 2001 and 1990 (D=0.109, P=0.015; Figure 5). The 575-mm length category was the predominant size category of burbot captured in both 2001 and 1990 (Figure 6). Burbot captured in 2001 were generally larger, as indicated by the mean length of fully recruited burbot. Mean length of fully recruited burbot in 2001 was 595 mm, which was greater than the 580 mm mean length of burbot captured in 1990 (Table 7; Lafferty et al. 1991).

SUCKER LAKE

Mean CPUE of fully recruited burbot in Sucker Lake in 2001 was 0.75 (Table 3). There was a significant 74% increase in mean CPUE in 2001 compared to mean CPUE in the spring of 1988 (Z=-3.41 P=0.0002). Expansion of mean CPUE results in an estimated abundance of burbot in 2001 of 628, compared to 362 in 1988 (Table 4). Statistics concerning mean CPUE for partially recruited burbot are listed in Table 5. The frequency of sets by depth and average catch of burbot by depth for sampling in 2001 are shown in Appendix C.

There was no significant difference between the length distribution of burbot captured in 2001 and fall 1988 (D=0.102, P=0.431; Figure 5). The 525-mm length category was the predominant size category of burbot (≥ 450 mm) captured in both 2001 and 1988 (Figure 7). Burbot in 1988 were generally larger, as indicated by the mean length of fully recruited burbot. Mean length of fully recruited burbot in 2001 was 590 mm, which was less than the 599 mm mean length of burbot captured in 1988 (Table 7; Parker et al. 1989).

Table 3.–Estimated mean CPUE of fully recruited (≥450 mm TL) burbot in Paxson, Sucker, and Tolsona lakes, 2001.

Lakes and Dates	Strata	Sets	Transects	Mean CPUE Bootstrapped	Mean CPUE Arithmetic	Mean CPUE %Δ	Bootstrapped SE	Bootstrapped CV
Paxson								
9/12-20/01	All depths	418	71	0.949	0.952	-0.3%	0.122	12.8%
Sucker								
9/24-28/01	All depths	178	37	0.747	0.753	-0.7%	0.085	11.3%
Tolsona								
5/29-31/01	All depths	60	8	1.832	1.850	-1.0%	0.464	25.4%

Table 4.–Estimated abundance of fully recruited burbot (≥450 mm TL) by expansion of CPUE for Paxson, Sucker, and Tolsona lakes, 2001 and the year most recently sampled.

Lake	Year	Surface Area (ha)	Mean CPUE	SE	Catchability Coefficient	SE	Estimated Abundance	SE
Paxson	2001	1,575	0.95	0.122	0.116	0.029	12,941	2,248
	1990		0.50	0.020	0.116	0.029	6,818	839
Sucker	2001	283	0.75	0.085	0.337	0.127	628	[a]
	1988		0.43	0.040	0.337	0.127	362	[a]
Tolsona	2001	130	1.83	0.464	0.441	0.173	539	252
	2000		6.25	0.740	0.441	0.173	1,841	755

[a] No standard error was calculated for the estimated abundance of burbot in Sucker Lake because only one value of q was available for the calculations.

Table 5.–Estimated mean CPUE of partially recruited (<450 mm TL) burbot in Paxson, Sucker, and Tolsona lakes, 2001.

Lakes and Dates	Strata	Sets	Transects	Mean CPUE Bootstrapped	Mean CPUE Arithmetic	Mean CPUE %Δ	Bootstrapped SE	Bootstrapped CV
Paxson								
9/12-20/01	All depths	418	71	0.135	0.134	1.0%	0.024	17.6%
Sucker								
9/24-28/01	All depths	178	37	0.281	0.281	0.2%	0.052	18.4%
Tolsona								
5/29-31/01	All depths	60	8	0.320	0.317	1.0%	0.115	36.0%

Table 6.–Critical zones and measurements of water quality by depth and date at Tolsona Lake, 2001.

Measurement	Critical Zones[a]	Depth (m) 0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.3
					April 11				
Temperature (C°)	> 18°C	0.05	0.01	0.43	1.61	2.75	3.46	4.24	4.74
Dissolved Oxygen	< 2.0 ppm	1.97	1.92	1.72	1.44	1.07	0.32	0.12	0.00
PH	< 7 or > 9	6.94	6.95	6.97	6.97	6.95	6.95	6.84	6.73
Water Clarity	none established	nd[b]							
					August 31				
Temperature (C°)	> 18°C	14.27	13.23	12.90	12.77	12.72	nd	nd	nd
Dissolved Oxygen	< 2.0 ppm	8.49	8.59	8.80	8.77	8.75	nd	nd	nd
PH	< 7 or > 9	8.43	8.47	8.50	8.44	8.43	nd	nd	nd
Water Clarity	none established	2.4 m							

[a] From Simpson 1997 and Scott and Crossman 1973.

[b] nd = no data

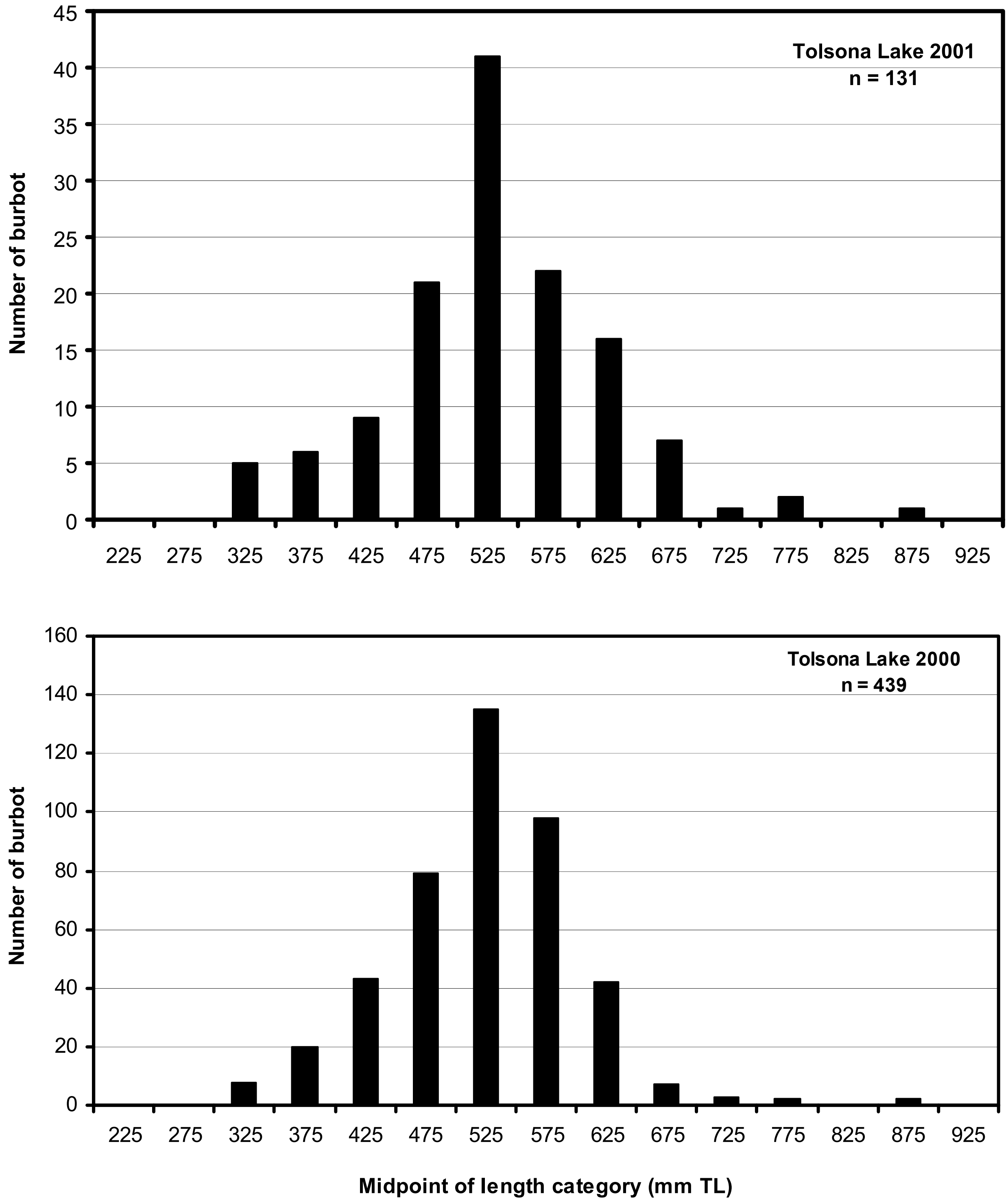

Figure 4.–Length distributions of burbot captured in Tolsona Lake in 2001 and 2000.

Table 7.–Mean length (mm TL) of burbot measured during sampling events in Paxson, Sucker, and Tolsona lakes, 2001.

Lake	Statistic	Partially Recruited[a]	Fully Recruited	All
Paxson	Mean	349	595	563
	SE	7	9	10
	Sample size	58	398	456
Sucker	Mean	359	590	525
	SE	7	11	12
	Sample size	53	136	189
Tolsona	Mean	389	558	533
	SE	7	9	10
	Sample size	19	112	131

[a] Burbot partially recruited to the gear were < 450 mm TL and fully recruited burbot were ≥ 450 mm TL.

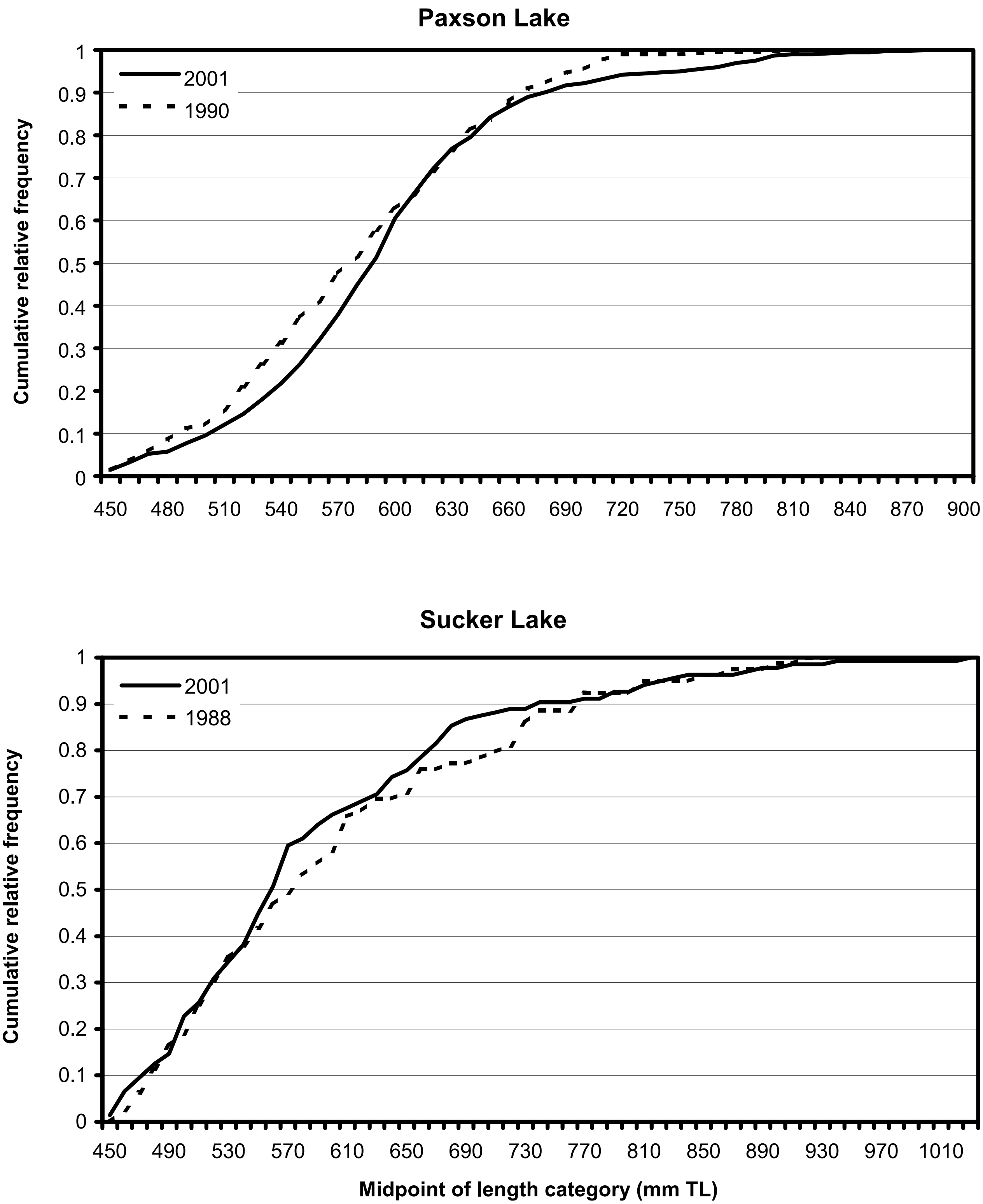

Figure 5.–Comparison of cumulative relative frequencies of length frequency of burbot in Paxson Lake in 2001 and 1990 and in Sucker Lake in 2001 and 1988.

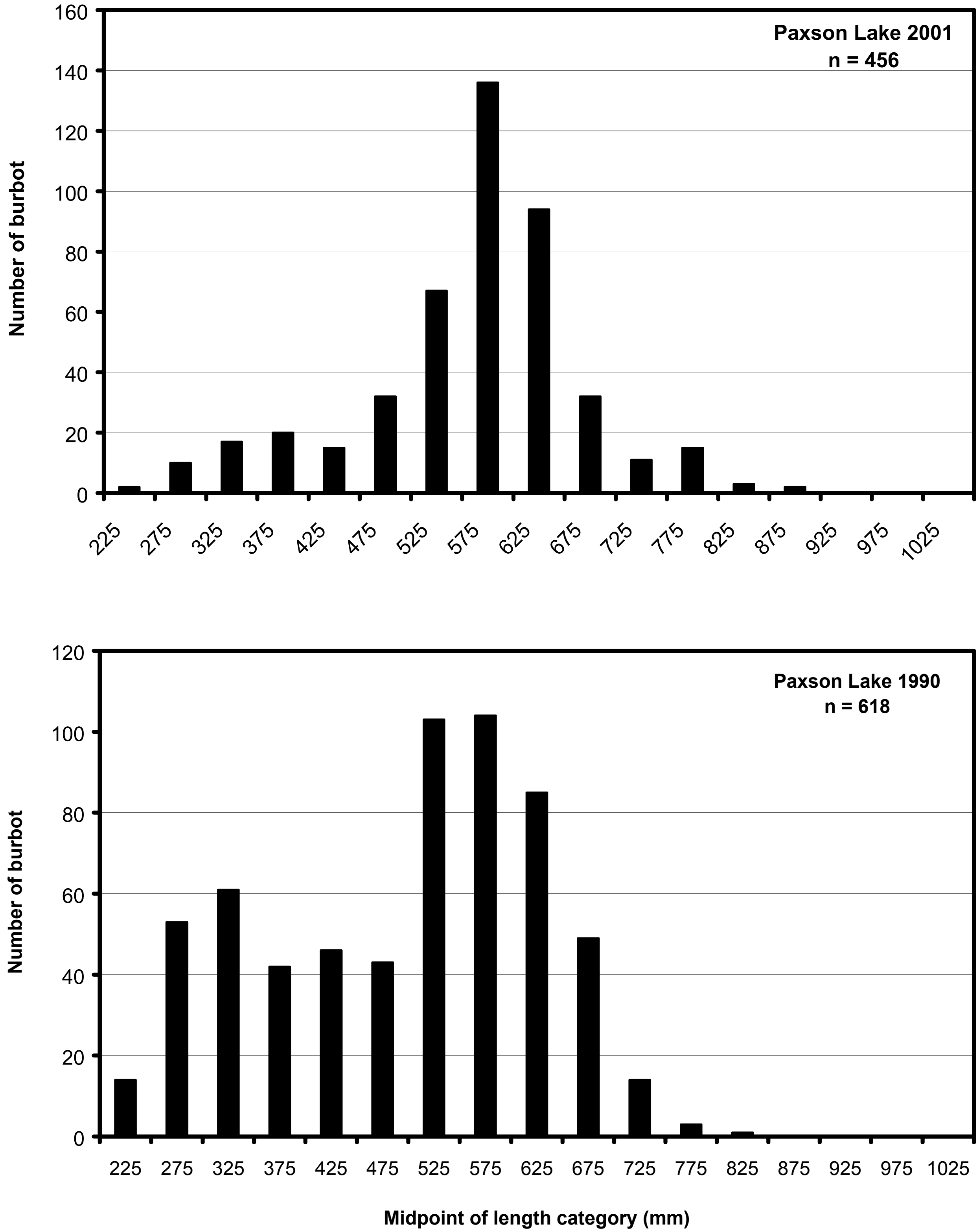

Figure 6.–Length distributions of burbot captured in Paxson Lake in 2001 and 1990.

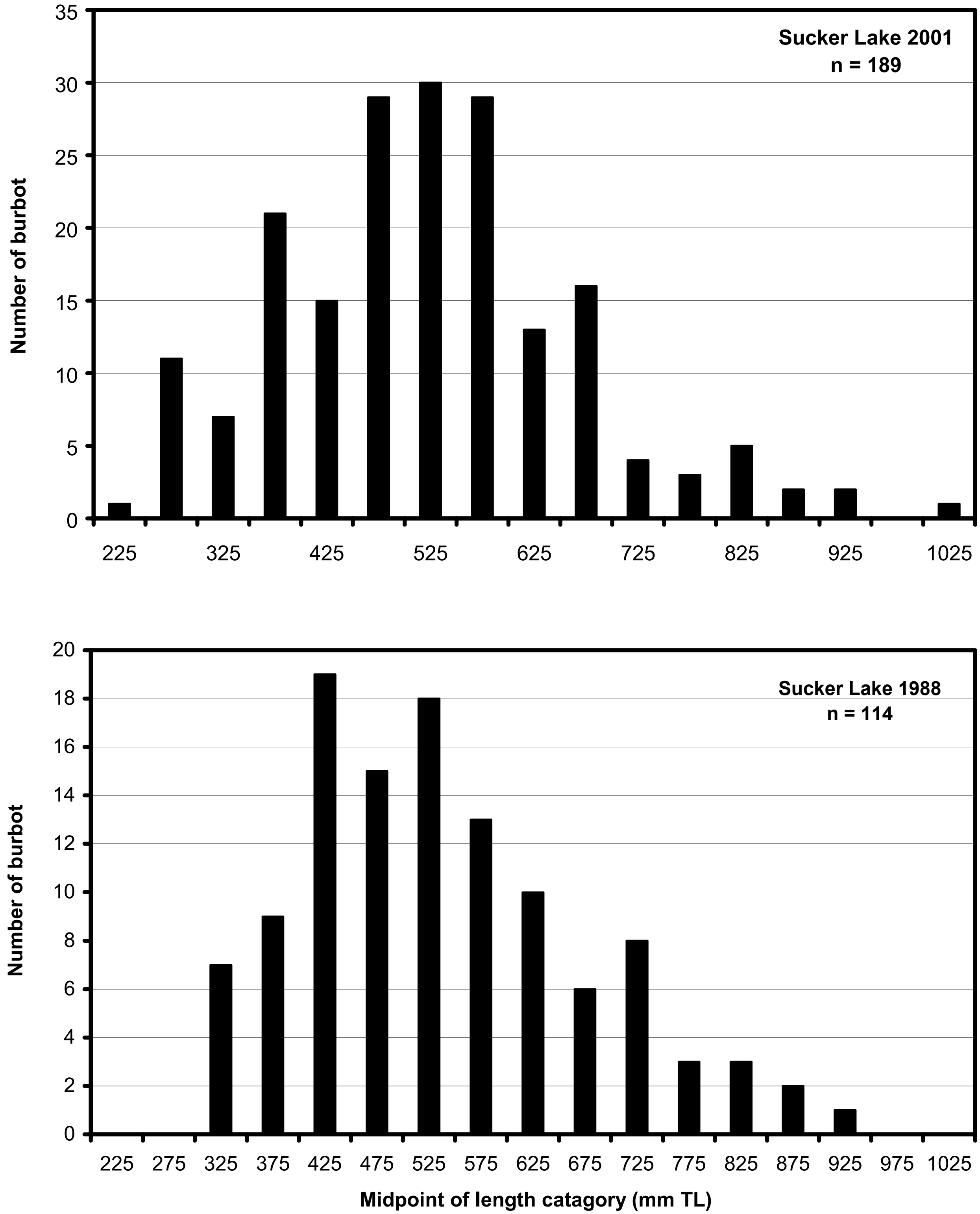

Figure 7.–Length distributions of burbot captured in Sucker Lake in 2001 and 1988.

Electronic data files used for these analyses were archived as described in Appendix D.

DISCUSSION

In Tolsona Lake, it would appear that the fishery closure and the favorable climate and environmental conditions experienced in the Copper Basin between 1999 and 2000 may have resulted in a temporary increase in the burbot population. Survival from the 1999-2000 period was the highest estimated since 1989. The apparent increase in abundance should be tempered with the fact that this most recent estimate from the Jolly-Seber model has the greatest amount of uncertainty. Estimated abundance by expansion of CPUE for 2001 indicated a decline in burbot abundance. Sampling in 2002 will corroborate this decline and provide estimates of survival and recruitment from the Jolly-Seber model. Currently, a management action to reopen the burbot fishery on Tolsona Lake will require that the estimated abundance exceed 1,500 fully recruited burbot for two consecutive years. This two-year requirement was implemented to account for the inherent uncertainly in the abundance estimates and the observed variability in survival possibly due to climatic variables.

In Sucker Lake, there is reason to believe that the increase in mean CPUE from 1988 to 2001 may not accurately reflect a similar increase in abundance due to differences in catchability. Bernard et al. (1993) demonstrated that catchability increases in the fall as formation of ice cover (freeze up) nears. In 2001, freeze up was later than normal and sampling occurred on September 24-28. In 1988 the timing of freeze up was considered normal and sampling occurred from September 30 to October 4. Because of the variability in catchability during the fall, and because date of ice cover each year is variable and unpredictable, future sampling in Sucker and other lakes to estimate CPUE should be conducted during the summer when catchability is more stable.

Estimating abundance for Paxson and Sucker lakes by expansion of mean CPUE required catchability coefficients (q) estimated from previous sampling events. When estimating lake-specific catchability coefficients, temporal variation in catchability should be accounted for by deriving estimates using multiple sampling events within a year that are temporally similar or from sampling events conducted annually on similar dates. For example, Bernard et al. (1993) demonstrated that catchability is higher within 30 days of ice out or ice formation. For Sucker Lake, the only available abundance estimate was from spring (June 10-14) of 1987 (Parker et al. 1988). Because only this one estimate of q was available for estimating the abundance of burbot in Sucker Lake in 2001, there was no variance for the abundance calculation.

Evidence suggested that burbot populations in Tolsona, Paxson, and Sucker lakes rebounded under more restrictive regulations. The fishery at Tolsona Lake has been closed, and fisheries in Paxson and Sucker lakes were included in the area-wide regulations prohibiting the use of setlines and reducing the daily bag limit from 15 to 5 fish. The restrictive regulations were probably successful for populations in Paxson and Sucker lakes due to their distance from population centers, lack of development, and remoteness. Paxson Lake is at least a 4-hour drive from Anchorage and Fairbanks and development on the lake is limited (only a BLM campground and no lodges). Paxson Lake probably did not receive the level of exploitation that the Tyone River drainage lakes (Lake Louise, Susitna and Tyone lakes) and some of the smaller lakes around the Glennallen area experienced. Sucker Lake has no on-site development and is off the road system.

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APPENDIX A

Appendix A.–Description of lakes with burbot populations sampled in 2001.

PAXSON LAKE (62º50’ N, 145º35’ W) is directly accessible from the Richardson Highway 8 km south of Paxson. Paxson Lake is 1,575 ha with a maximum depth of 29 m and an elevation of 778 m. There are numerous cabins along the shore and the Bureau of Land Management maintains a public campground and boat launch. Paxson Lake is the start of a popular float trip on the Gulkana River to Sourdough. This lake is popular for its wide variety of fishing as well as hunting opportunities. Paxson Lake contains lake trout *Salvelinus namaycush*, burbot, sockeye salmon *Oncorhynchus nerka*, Arctic grayling *Thymallus arcticus*, round whitefish *Prosopium cylindraceum*, humpback whitefish *Coregonus clupeaformis*, and other species.

SUCKER LAKE (62º01’ N, 146º20’ W) is 6.5 km south of milepost 158 on the Glenn Highway. Sucker Lake is 283 ha with a maximum depth of 7 m and an elevation of 616 m. There are no private or public facilities at the lake, but it does support a large winter ice fishery for burbot. Sucker Lake contains burbot, Arctic grayling, round whitefish and longnose suckers *Catostomus catostomus*.

TOLSONA LAKE (62º06’ N, 146º04’ W) is accessible from the Glenn Highway. Tolsona Lake is 130 ha with a maximum depth of 4 m and an elevation of 625 m. Tolsona Lake has numerous cabins and one lodge. No public recreational facilities are available. This lake has had a popular burbot fishery during the winter in the past. Tolsona Lake has burbot, Arctic grayling, longnose suckers, and other species Tolsona Lake had been stocked with rainbow trout *Oncorhynchus mykiss*, coho salmon *Oncorhynchus kisutch* and chinook salmon *Oncorhynchus tshawytscha* prior to 2000.

APPENDIX B

Appendix B.–Mark-recapture histories of fully recruited (≥450 mm TL) burbot by year for the population in Tolsona Lake.

Category	Number of Recaptures by Sampling Date: Year and Dates												
	1986 (9/23-10/10)	1987 (6/02-6/04)	1988 (5/25-5/27)	1988 8/30 9/01	1989 (5/22-5/24)	1989 9/11 9/13	1990 (5/22-5/24)	1990 (9/05-9/07)	1991 (5/20-5/23)	1991 (9/09-9/12)	1992 (6/11-6/13)	1993 (5/20-5/22)	1994 (6/01-6/03)
Recaptured from Event 1	0	123	35	14	5	3	5	9	0	0	0	0	0
Recaptured from Event 2		0	79	32	33	18	11	5	1	1	0	0	0
Recaptured from Event 3			0	51	36	11	8	6	0	0	0	0	0
Recaptured from Event 4				0	47	12	10	5	3	0	0	0	0
Recaptured from Event 5					0	62	16	11	10	2	0	0	0
Recaptured from Event 6						0	22	11	3	1	0	0	0
Recaptured from Event 7							0	21	12	2	2	0	0
Recaptured from Event 8								0	33	5	7	0	1
Recaptured from Event 9									0	35	12	6	1
Recaptured from Event 10										0	27	3	3
Recaptured from Event 11											0	6	6
Recaptured from Event 12												0	37
Recaptured from Event 13													0
Recaptured from Event 14													
Recaptured from Event 15													
Recaptured from Event 16													
Recaptured from Event 17													
Recaptured from Event 18													
Recaptured from Event 19													
Captured with tags	0	123	114	97	121	106	72	68	62	46	48	15	48
Captured without tags	531	379	236	118	237	143	143	112	301	91	148	214	162
Captured	531	502	350	215	358	249	215	180	363	137	196	229	210
Released with tags	531	497	350	215	358	249	215	180	362	136	196	225	209

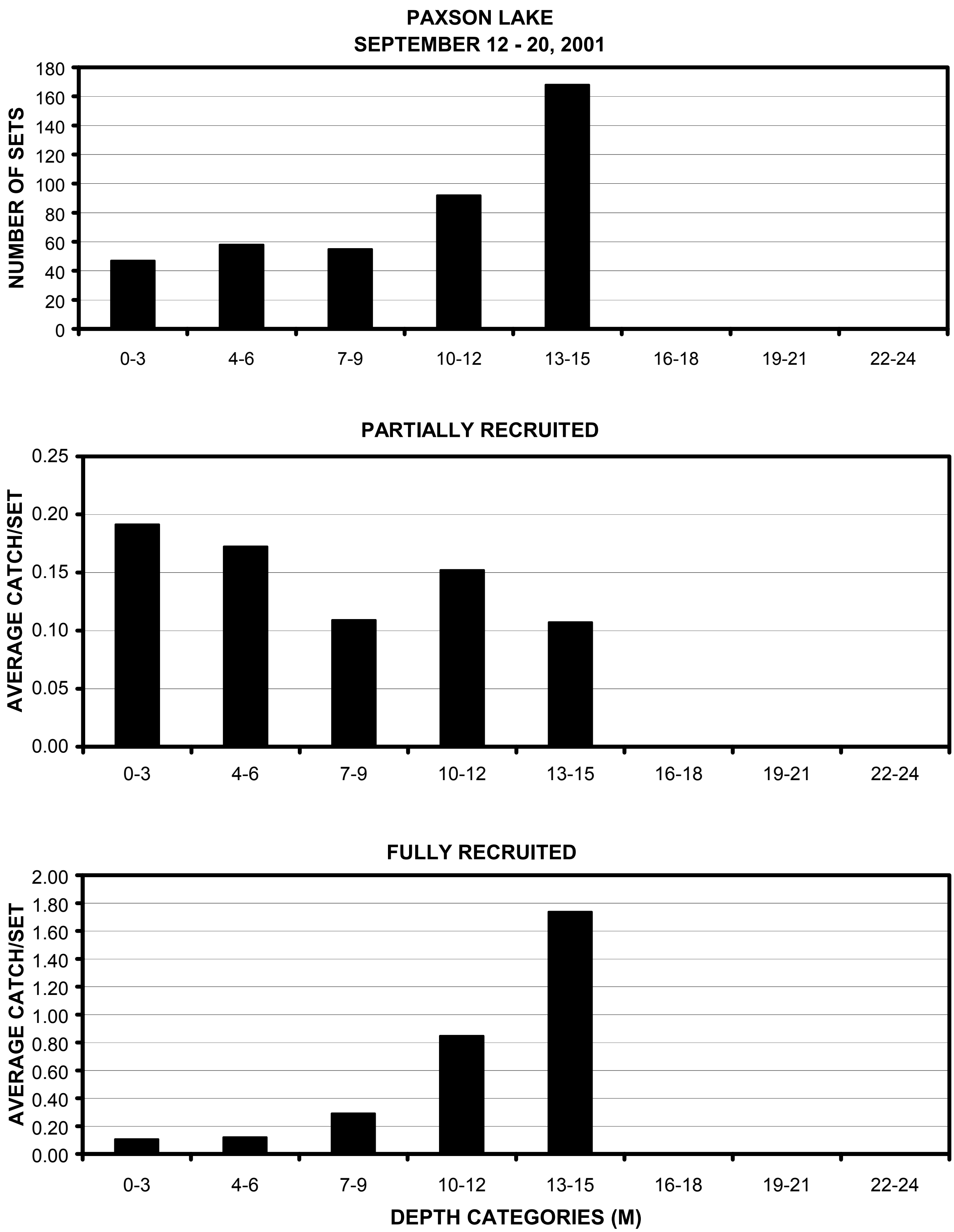
-continued-

Appendix B.–Page 2 of 2.

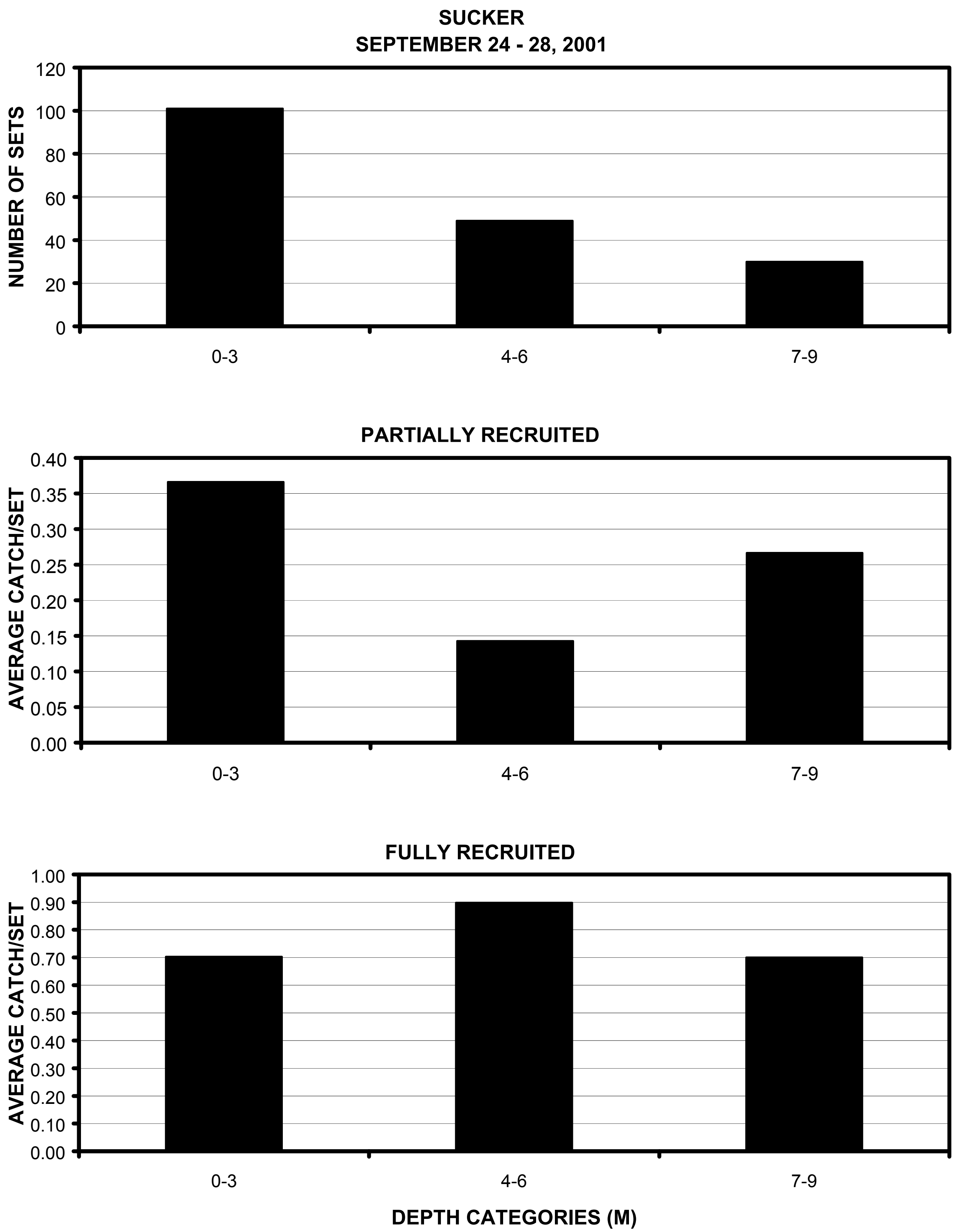
Category	Number of Recaptures by Sampling Date: Year and Dates						
	1995 (5/23-5/25)	1996 (6/05-6/07)	1997 (5/27-5/29)	1998 (5/19-5/21)	1999 (6/01-6/03)	2000 (6/06-6/08)	2001 (5/29-5/31)
Recaptured from Event 1	0	0	0	0	0	0	0
Recaptured from Event 2	0	0	0	0	0	0	0
Recaptured from Event 3	0	0	0	0	0	0	0
Recaptured from Event 4	0	0	0	0	0	0	0
Recaptured from Event 5	1	0	0	0	0	0	0
Recaptured from Event 6	0	0	0	0	0	0	0
Recaptured from Event 7	1	0	0	0	0	0	0
Recaptured from Event 8	0	0	0	0	0	0	0
Recaptured from Event 9	0	1	0	0	0	0	0
Recaptured from Event 10	1	0	0	0	0	0	0
Recaptured from Event 11	5	0	1	1	0	0	0
Recaptured from Event 12	16	7	2	0	0	0	0
Recaptured from Event 13	27	3	2	0	0	0	0
Recaptured from Event 14	0	29	3	2	0	1	0
Recaptured from Event 15		0	11	6	3	1	0
Recaptured from Event 16			0	6	5	0	0
Recaptured from Event 17				0	24	23	4
Recaptured from Event 18					0	41	8
Recaptured from Event 19						0	21
							0
Captured with tags	51	40	19	15	32	66	33
Captured without tags	151	111	96	264	163	373	97
Captured	202	151	115	279	195	439	130
Released with tags	198	129	104	279	195	438	130

APPENDIX C

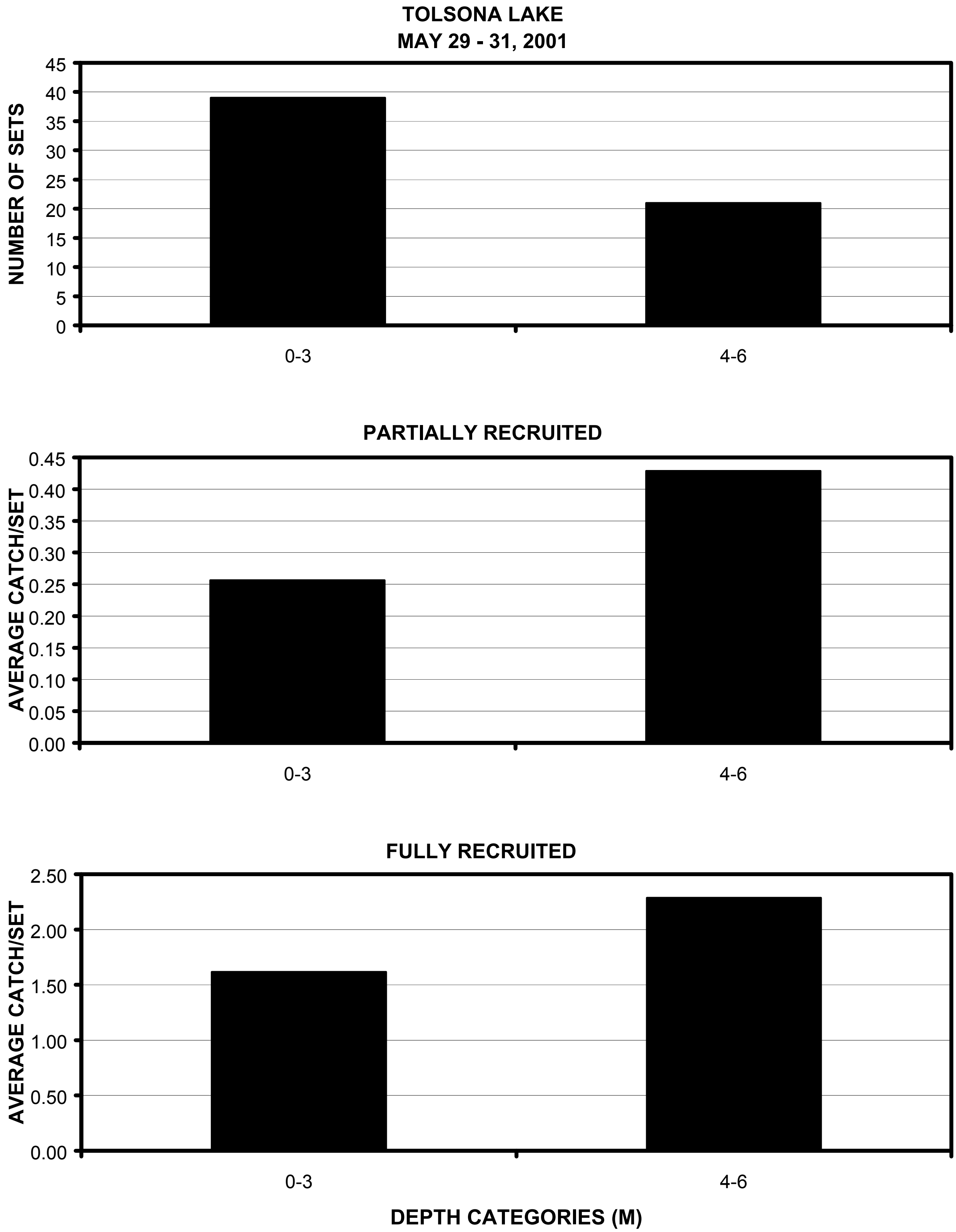
Appendix C1.–Frequency of sets by depth and average catch of burbot by depth in Paxson Lake in 2001.



Appendix C2.–Frequency of sets by depth and average catch of burbot by depth in Sucker Lake in 2001.



Appendix C3.–Frequency of sets by depth and average catch of burbot by depth in Tolsona Lake in 2001.



APPENDIX D

Appendix D.–Summary of data archives.

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

Lake	File name	Data format	Software
Paxson	i-013000h012001.dta	Hoop net	RTS-ASCII
Sucker	i-026600h012001.dta	Hoop net	RTS-ASCII
Tolsona	i-039800h012001.dta	Hoop net	RTS-ASCII
	2001 Tolsona BB tag history.xls	Tag history	Microsoft EXCEL

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.

Tag history: an EXCEL file that contains lake specific historical tagging information by individual tags and recaptures by sampling events.