Fishery Data Series No. 07-24

Stock Assessment and Biological Characteristics of Burbot in Susitna Lake 2002, Tolsona Lake 2002, 2004 and 2005, and Lake Louise 2005

by

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and

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April 2007

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 REPORT NO. 07-24

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ABSTRACT

Stock assessments of burbot *Lota lota* were conducted at Susitna Lake in 2002, at Lake Louise in 2005 and at Tolsona Lake in 2002, 2004 and 2005. In all three lakes baited hoop traps were systematically set along randomly selected transects during the spring shortly after ice-out. Mean CPUE of fully recruited burbot (≥ 450 mm TL) per 48 h set was 0.48 (SE = 0.086) at Susitna Lake in 2002, an increase of 60% since the lake was last sampled in 1990. Mean CPUE of fully recruited burbot was 0.48 (SE = 0.052) at Lake Louise in 2005, an increase of 20% since the lake was last sampled in 1999. At Tolsona Lake mean CPUE of fully recruited burbot was 2.04 (SE = 0.366) in 2002, 3.35 (SE = 0.518) in 2004 and 3.44 (SE 0.709) in 2005. Abundance of fully recruited burbot at Tolsona Lake was estimated as 662 (90% CI = 437 - 887), 1,119 (90% CI = 642 – 1,596), 1,018 (90% CI = 530 –1,504) and 855 (90% CI = 471 – 1,238) during spring 2001, 2003, 2004 and 2005. Abundance was estimated for 2001, 2003 and 2004 with Jolly-Seber mark-recapture models and for 2005 with CPUE expansion. Point estimates of abundance for fully recruited burbot at Tolsona Lake increased from 1997 to 2003, but have decreased since 2003. Annual estimated survival ranged from 35% to 51% at Tolsona Lake and annual estimated recruitment ranged from 161 to 574 fish. Water quality measurements were recorded periodically during open water periods at Tolsona Lake in 2002, 2004 and 2005. All measurements of temperature, dissolved oxygen and pH were within preferred ranges of burbot except water temperature in 2004 that exceeded 18° C throughout the entire water column during two readings. Estimated abundance from CPUE expansion at Lake Louise was 4,827 (90% CI = 3,500 – 6,154) in 2005 and was 6,151 (90% CI = 1,345 – 10,956) at Susitna Lake in 2002. Both point estimates were higher than the last year those lakes were sampled (1990 for Susitna Lake and 1999 for Lake Louise), but not significantly different at the 90% confidence level. A conservative management strategy has been in place at Susitna Lake since the late 1980s, and despite the more restrictive regulations, a significant increase in mean CPUE for fully recruited burbot since 1990 did not occur and a liberalization of fishing regulations was not advised.

Key words: Burbot, *Lota lota*, Jolly-Seber, abundance, length composition, catch per unit effort, hoop traps, mean length, Tolsona Lake, Susitna Lake, Lake Louise.

INTRODUCTION

The lakes of the Upper Copper/Upper Susitna Management Area (UCUSMA; Figure 1) have supported the largest burbot fishery in the state. Annual harvests from the UCUSMA averaged over 8,000 burbot, or 57% of the statewide burbot harvest from 1977 – 1988 (Taube 2002). Harvest from the fishery peaked in 1985 when over 19,000 burbot were harvested from the UCUSMA, accounting for 71% of the statewide burbot harvest (Mills 1986; Figure 2). Concerns of overexploitation resulted in the Alaska Department of Fish and Game (ADF&G) initiating a continuing research study in 1986 to assess stock status and to estimate the sustained yield of burbot in interior Alaska lakes. Many studies have been conducted on lake burbot throughout the UCUSMA since 1986 (Lafferty and Bernard 1993; Lafferty et al. 1990-1992; Parker et al. 1987-1989; Schwanke and Bernard 2005; Taube and Bernard 1995, 1999, 2001, 2004; Taube et al. 1994, 2000). In 1987, the bag and possession limit of burbot caught in the UCUSMA was reduced from 15 fish to 5 fish in most lakes, and was reduced even further to 2 fish per day in more accessible lakes. In 1988 the Alaska Board of Fisheries adopted as regulation (5 AAC 52.045, 1988) a lake burbot management plan that directs the lake burbot fisheries in the UCUSMA to be managed for maximum sustained yield.

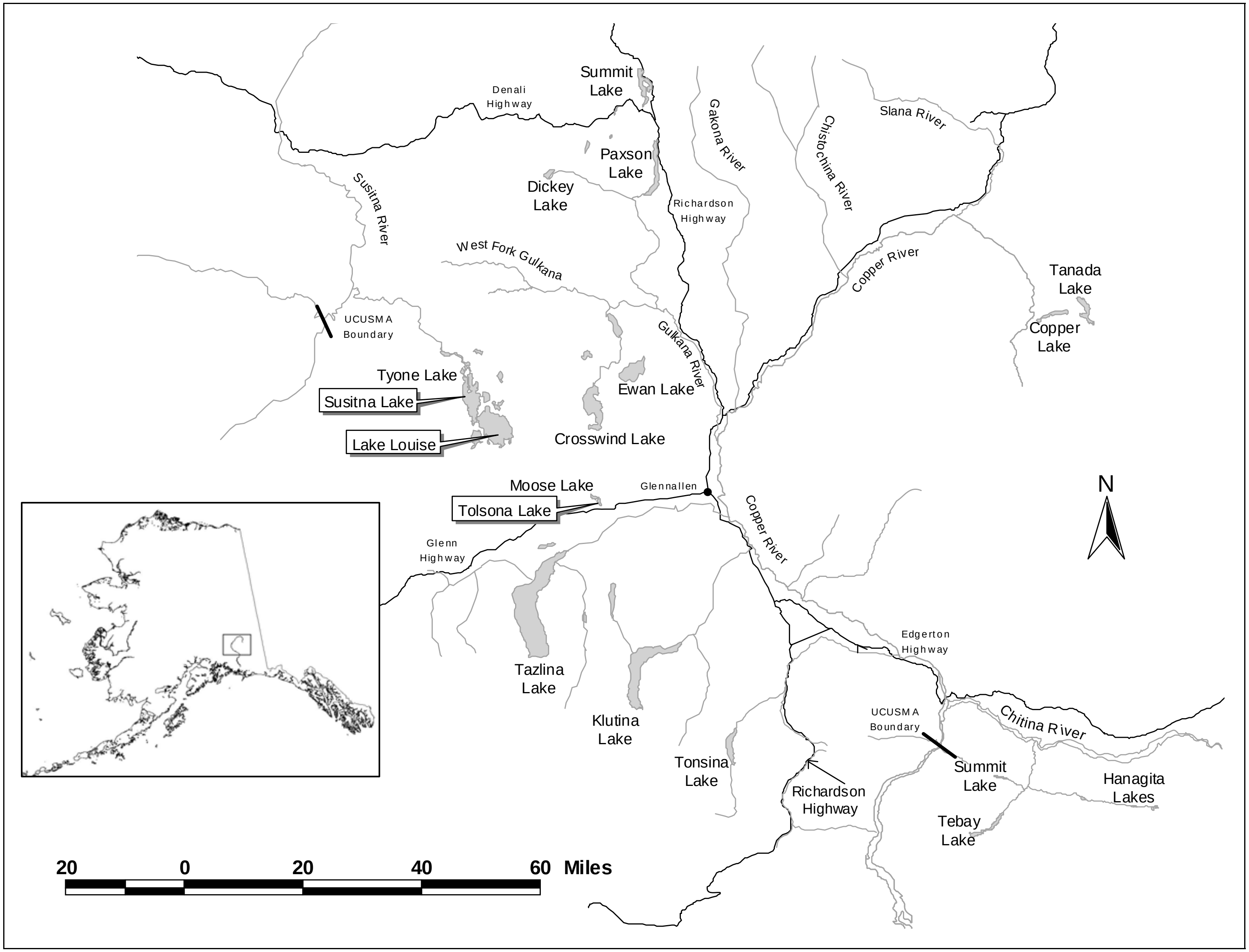

Figure 1.-Location of Lake Louise, Susitna Lake and Tolsona Lake within the Upper Copper/Upper Susitna Management Area.

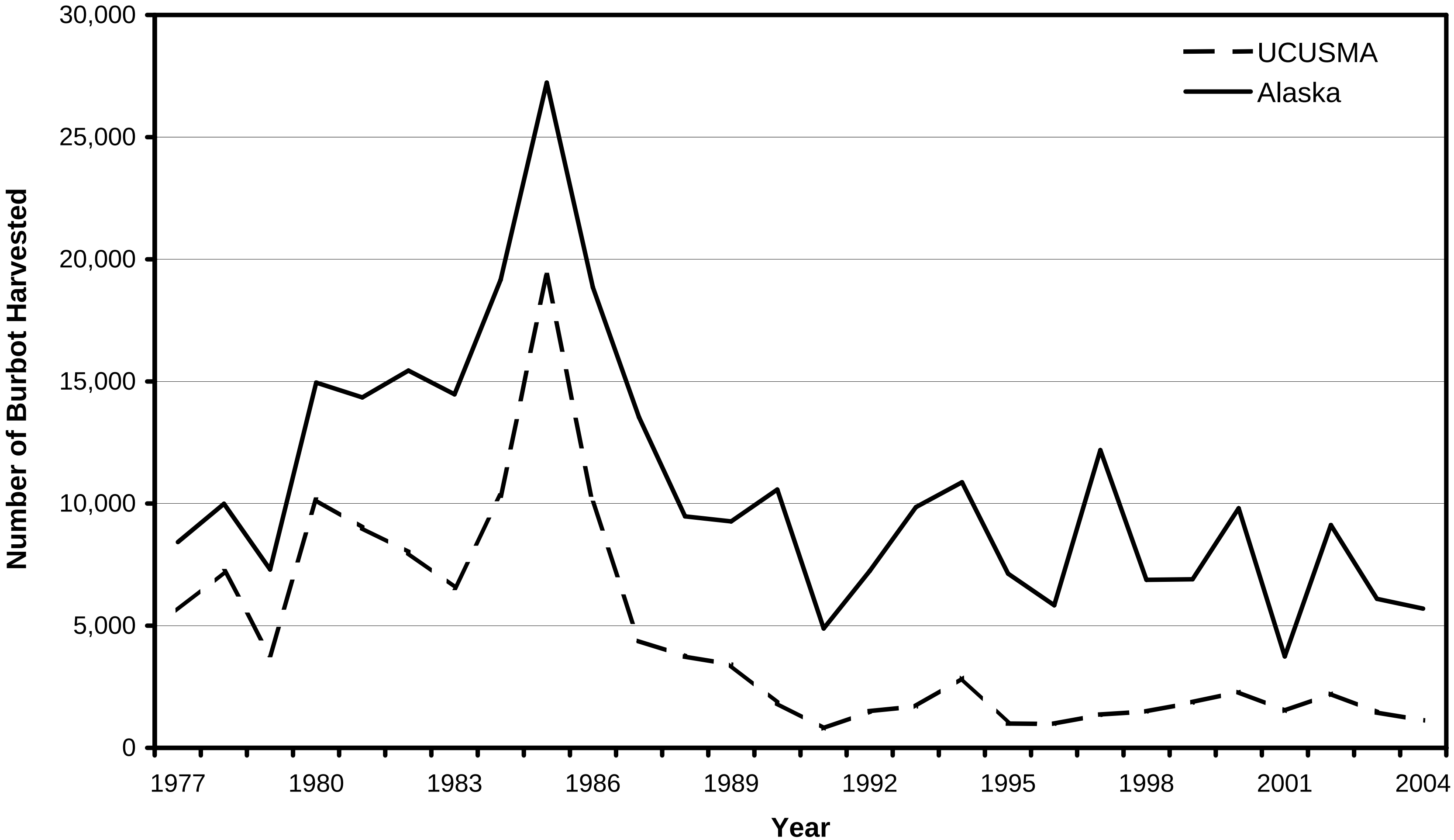

Figure 2.–Annual sport fish harvest (Jennings 2006 b, *In prep*; Taube 2006) of burbot in the UCUSMA compared to total Alaskan sport harvest, 1977-2004.

ADFG has since managed harvest of burbot in fisheries in the UCUSMA through reduced bag limits, gear restrictions and lake closures. In 1988 the use of setlines was prohibited by emergency order in the Tyone River drainage and in Tolsona and Moose lakes. In 1991 a regulation was adopted that prohibited the use of setlines in the entire UCUSMA. Since the elimination of setlines in the UCUSMA, annual burbot harvests have remained relatively stable, ranging between 1,000 and 3,000 burbot. Various bag and possession limits have been enacted since 1987. Presently, the bag and possession limit for burbot for most lakes remains at five. Tolsona Lake is presently closed to burbot fishing. Lake Louise presently has a bag and possession limit of one burbot, and several road accessible lakes have bag and possession limits of two burbot (Susitna, Tyone, Hudson, Moose and Summit lakes).

Stock assessments of burbot at Tolsona Lake (Table 1; Figure 3; Appendix A) have been conducted annually since 1986 (Lafferty and Bernard 1993; Lafferty et al. 1990-1992; Parker et al. 1987-1989; Schwanke and Bernard 2005; Taube and Bernard 1995, 1999, 2001, 2004; Taube et al. 1994, 2000) to determine the population's status relative to prescribed management objectives. The continuous and long-term nature of this project has provided an improved understanding of population dynamics on a burbot stock that resides in a shallow, productive lake, atypical of burbot habitat in Alaska. In 1998 Tolsona Lake was closed to burbot fishing due to a significant decline in burbot abundance and poor summer survival (Table 1; Figure 3). This decline was likely due to a combination of factors, but high summer water temperatures may have contributed most to this decline (Taube and Bernard 2001). Dissolved oxygen, temperature, pH, conductivity and water clarity have been measured in Tolsona Lake since 1998.

This monitoring program was initiated after the observed decline in burbot abundance from 1995 to 1997, which was more attributed to lethal water quality conditions than to exploitation. Tolsona Lake is relatively small and shallow and has approached the critical temperature level (> 20º C) for burbot in the past, and may be prone to reaching the critical level for dissolved oxygen (< 2.0 ppm) in late winter (Simpson 1997).

Burbot stock assessments similar to those of Tolsona Lake have been conducted in Lake Louise (Figure 4; Table 1; Appendix A) from 1986-1996 and in 1999 (Parker et al. 1987-1989; Lafferty et al. 1990-1992; Lafferty and Bernard 1993; Taube et al. 1994, 2000; Taube and Bernard 1995). Results of mark-recapture experiments show that the population of burbot ≥ 450 mm TL declined from about 7,000 burbot in 1986 to about 3,800 in 1987 and stabilized at a level of about 4,000 burbot from 1989 to 1994 (Figure 4). Population sizes estimated using CPUE expansion show a similar trend from the last time the population was studied in 1995, 1996 and 1999 (Taube et al. 2000). Population abundance in Lake Louise prior to 1986 is unknown. However, it is believed that the population was much larger then based on estimated harvests from the annual Statewide Harvest Survey in 1984 (1,129 burbot; Mills 1985), 1985 (3,710 burbot; Mills 1986) and 1986 (2,945 burbot; Mills 1987), and in years prior to 1984,when harvest was estimated for the Lake Louise, Susitna Lake, and Tyone Lake complex. For example, the 1985 reported harvest was over half of the 1986 population estimate, and equivalent to the 1987 population estimate, a strong indication that the population size was higher prior to 1986 (Figure 4).

Table 1.–Estimates of population parameters of fully recruited (≥ 450 mm TL) burbot at Tolsona Lake, Susitna Lake and Lake Louise.

		Days Between Events		Abundance[a]			Survival Rate %[a]		Recruitment[a]	
Lake	Date		CPUE	Estimate	SE	CV %	Estimate	SE	Estimate	SE
Tolsona Lake[b]	9/26/86		3.98	1,901	120	6.3				
		235					60.0	4.6	138	209
	6/25/87		2.79	1,291	120	9.3				
		335					77.9	7.1	645	144
	5/26/88		5.93	1,647	178	10.8				
		95					66.6	7.4	45	111
	9/01/88		3.58	1,142	132	11.5				
		263					77.8	9.1	576	124
	5/24/89		5.86	1,464	162	11.1				
		110					95.1	17.6	277	174
	9/13/89		4.08	1,846	311	16.8				
		251					47.9	9.8	460	153
	5/24/90		3.59	1,344	240	17.9				
		104					35.0	6.3	86	67
	9/07/90		2.95	556	85	15.3				
		255					67.0	12.2	890	191
	5/22/91		3.62	1,262	235	18.6				
		109					35.9	6.5	96	87
	9/12/91		1.14	549	105	19.1				
		273					87.5	22.6	505	171
	6/11/92		3.14	985	256	26.0				
		341					25.2	6.0	915	275
	5/20/93		3.83	1,164	298	25.6				
		375					95.1	18.2	86	349
	6/01/94		3.50	1,188	255	21.5				
		354					31.8	7.0	150	74
	5/23/95		3.44	528	104	19.7				
		377					38.3	9.3	149	56
	6/05/96		2.19	352	84	23.9				
		354					37.6	11.6	54	37
	5/27/97		0.80	187	58	31.0				
		355					35.3	10.0	257	74
	5/19/98		2.19	323	79	24.5				
		375					74.5	10.1	301	119
	6/01/99		2.57	541	98	18.1				
		367					106.7	18.1	836	208
	6/08/00		6.25	1,413	262	18.5				
		356					35.5	6.5	161	111
	5/31/01		1.83	662	138	20.8				
		371					100.0	24.6	108	127
	6/06/02		2.03	771	189	29.4				
		348					51.3	14.8	724	222
	5/21/03		4.02	1,119	290	24.5				
		364					39.5	11.1	576	225
	5/20/04		3.36	1,018	296	29.1				
		363								
	5/18/05		3.45	855	233	27.3				

-continued-

Table 1.–Page 2 of 2.

		Days Between		Abundance[a]			Survival Rate %[a]		Recruitment[a]	
Lake	Date	Events	CPUE	Estimate	SE	CV %	Estimate	SE	Estimate	SE
Lake Louise[c]	6/25/86		0.97	6,990	2,131	30.5				
		358					30.9	5.8	1,864	2,032
	7/06/87		0.61	3,788	1,028	27.1				
		330					89.2	14.2	2,718	1,370
	6/11/88		0.58	5,843	1,318	22.6				
		357					55.5	7.0	1,280	851
	6/01/89		0.42	4,473	703	15.7				
		360					58.5	5.6	1,076	489
	6/04/90		0.50	3,688	418	11.3				
		360					85.0	8.4	1,843	501
	6/04/91		0.44	4,997	583	11.7				
		372					68.1	7.7	834	409
	6/16/92		0.41	4,220	496	11.8				
		356					80.4	10.8	985	391
	6/07/93		0.45	4,374	579	13.2				
		349					65.0	11.6	1,859	491
	6/06/94		0.37	4,698	811	17.3				
		NA								
	6/05/95		0.40	4,022	576	14.3				
		NA								
	6/11/96		0.45	4,525	895	19.8				
		NA								
	6/19/99		0.38	3,821	686	18.0				
		NA								
	6/01/05		0.48	4,827	807	16.7				
Susitna Lake[d]	6/27/86		0.40	5,125	2,439	47.6				
		355								
	8/21/87		0.12	3,471	1,954	56.3				
		323					19.2	9.2	1,433	1,539
	6/11/88		0.34	2,929	1,554	53.6				
		355					96.6	36.7	1,852	2,423
	6/15/89		0.21	4,659	1,950	41.8				
		NA								
	6/17/90		0.30	3,844	1,746	45.4				
		NA								
	6/13/02		0.48	6,151	2,921	48.0				

[a] Data from Lafferty et al. 1990-1992; Lafferty and Bernard 1993; Parker et al. 1987-1989; Schwanke and Bernard 2005; Taube and Bernard 1995, 1999, 2004; Taube et al. 1994, 2000.

[b] Abundance estimate for 1986 is from a same year Petersen mark-recapture experiment, estimates from 1987-2004 are from the Jolly-Seber method, and estimated abundance in 2005 is from CPUE expansion.

[c] Abundance estimate for 1986 is from a same year Petersen mark-recapture experiment, abundance estimates from 1987-1994 are from the Jolly-Seber method, and abundance estimates from 1995, 1996, 1999 and 2005 are from CPUE expansion.

[d] Abundance estimates for 1986, 1990 and 2002 are from CPUE expansion, and estimates for 1987-1989 are from the Jolly-Seber method.

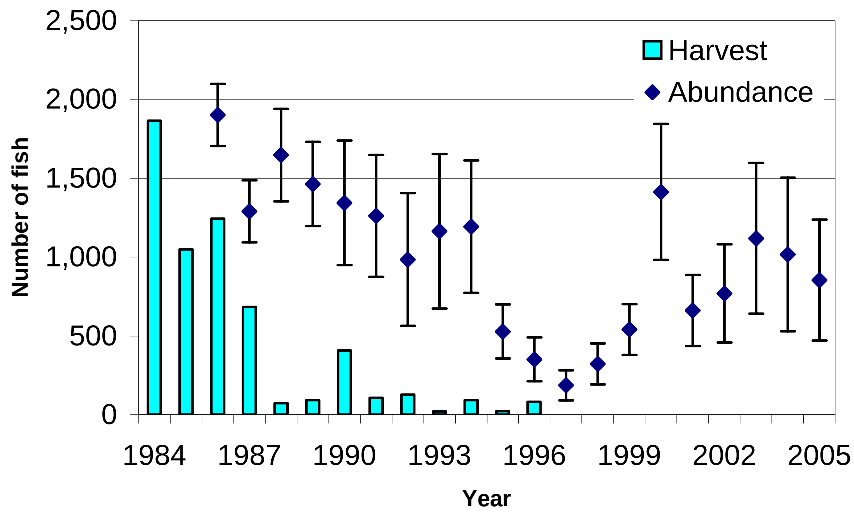

Figure 3.–Estimated harvest and abundance with 90% confidence intervals of fully recruited (≥ 450 mm TL) burbot in Tolsona Lake, 1984-2005

Source: (Mills 1985-1994; Howe et al. 1995, 1996, 2001a-d; Jennings et al. 2004, 2006 a-b, *In prep;* Walker et al. 2003).

Note: Abundance estimate for 1986 is from a within-season Petersen mark-recapture experiment. Estimates from 1987 to 2004 are from the Jolly-Seber method, and estimated abundance in 2005 is from CPUE expansion.

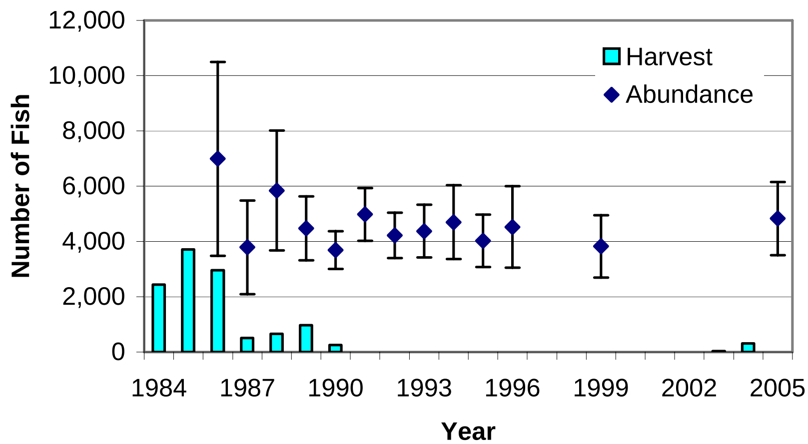

Figure 4.–Estimated harvest and abundance with 90% confidence intervals of fully recruited (≥ 450 mm TL) burbot in Lake Louise, 1984-2005.

Source: (Mills 1985-1994; Howe et al. 1995, 1996, 2001a-d; Jennings et al. 2004, 2006 a-b *In prep;* Walker et al. 2003)

Note: Abundance estimate from 1986 is from a within-season Petersen mark-recapture experiment, abundance estimates from 1987 to 1994 are from the Jolly-Seber method, and abundance estimates from 1995, 1996, 1999 and 2005 are from CPUE expansion.

The Lake Louise burbot fishery was closed in 1991 because of the decline in abundance and harvest. The burbot population had not responded to this regulation change as of 1999, as demonstrated by a CPUE expanded population estimate of 3,821 (90% CI = 2.692 – 4,950) burbot ≥ 450 mm TL (Taube et al. 2000). It was hypothesized that the burbot population reached a new equilibrium after the decline. In 2002 the fishery was opened with a bag limit of one burbot. Estimated annual harvests since the fishery reopened are 0, 32 and 317 burbot in 2002, 2003 and 2004, respectively (Jennings et al. 2006 a-b, *In prep*).

Stock assessments of burbot at Susitna Lake (Table 1; Figure 5; Appendix A) were assessed annually from 1986 – 1990 (Parker et al. 1987-1989; Lafferty et al. 1990 and 1991). Multiple event, open population models were used to estimate abundance for 1987, 1988 and 1989, but were imprecise: 3,471 (90% CI = 256 – 6,685), 2,929 (90% CI = 498 – 5,360) and 4,114 (90% CI = 1,682 – 6,545) burbot ≥ 450 mm, respectively (Lafferty et al. 1991; Figure 5). Consequentially, abundance estimates derived from CPUE expansions from 1989 and 1990 also had poor precision (Table 1; Figure 5). Presently, the bag and possession limit for burbot in Susitna Lake is two fish. Sampling was conducted in 2002 to provide data helpful in determining if a greater bag limit could be sustained.

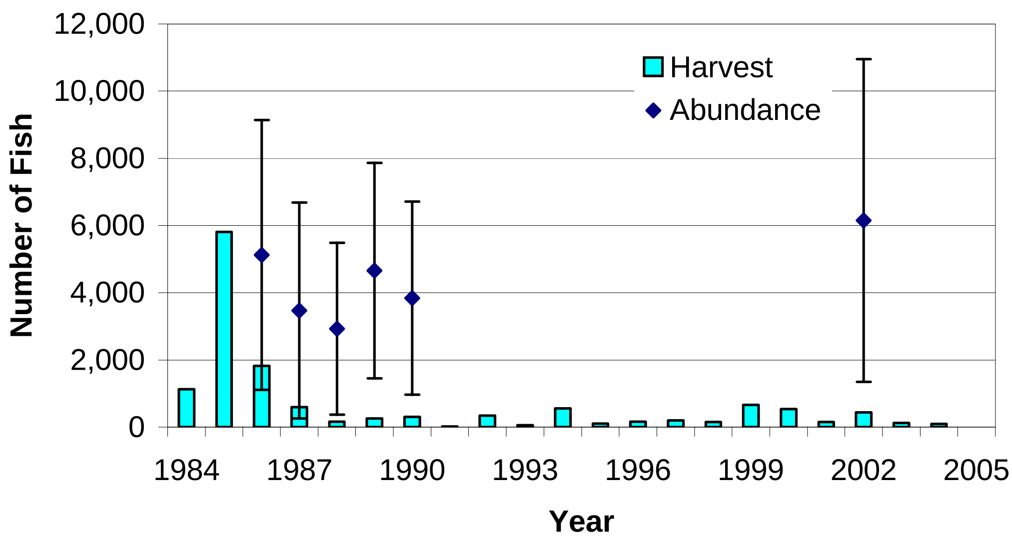

Figure 5.–Estimated harvest **and** abundance with 90% confidence intervals of fully recruited (≥ 450 mm) burbot in Susitna Lake, 1984-2005.

Source: (Mills 1985-1994; Howe et al. 1995, 1996, 2001a-d; Jennings et al. 2004, 2006 a-b, *In prep;* Walker et al. 2003)

Note: Abundance estimates for 1986, 1990 and 2002 are from CPUE expansion, and estimates for 1987-1989 are from the Jolly-Seber method.

OBJECTIVES

The objectives for the projects during 2002, 2004 and 2005 were to:

1. estimate the length composition of fully recruited burbot (≥ 450 mm TL) at Susitna Lake in June 2002, Tolsona Lake in May 2002, 2004 and 2005, and at Lake Louise in June 2005 such that the estimated proportions were within ± 10 percentage points of the actual values 95% of the time;
2. estimate mean CPUE of burbot (≥ 450 mm TL) at Tolsona Lake in May 2002, 2004 and 2005 and at Susitna Lake in June 2002 such that the estimated mean CPUE was within ± 50% of their asymptotic values 90% of the time;
3. estimate the abundance of fully recruited burbot (≥ 450 mm TL) in Tolsona Lake for May 2001, 2003 and 2004 such that the estimated abundances were within ± 50% of the true abundances 90% of the time;
4. estimate abundance of fully recruited burbot in Tolsona Lake and Lake Louise for spring 2005 such that the estimated abundances were within 50% and within 30%, respectively, of the true abundances 90% of the time;
5. test the hypothesis that mean CPUE of fully-recruited burbot in Susitna Lake has increased by at least 0.3 burbot per set since 1990 with a power of 0.80 and 5% probability of a Type I error; and,
6. test the hypothesis that the burbot population at Lake Louise in 2005 has decreased by 50% from the average population abundance from 1989-1996 and 1999 with a power of 0.80 and a 10% probability of a Type I error.

Project tasks for 2002, 2004 and 2005 were to:

1. measure water temperature, dissolved oxygen, pH, conductivity and clarity in Tolsona Lake in 2002 and 2004 through the ice in April, and for one month intervals during the open water period;
2. measure DO levels in Tolsona Lake in April, on a weekly basis immediately after ice-out, on a monthly basis during the open water period and also during non-scheduled periods in 2005 when levels were suspected of reaching the critical level for fish (< 2.0 ppm); and,
3. measure water temperature in 2005 at Tolsona Lake throughout the open water period.

METHODS

STUDY DESIGN

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 are 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 each lake. No traps were set deeper than 15 m in Susitna Lake and Lake Louise to avoid decompression-induced mortality associated with burbot captured at greater depths (Bernard et al. 1993). Maximum depth of sets in Tolsona Lake was 5 m. Sampling at all lakes commenced within a few days after each lake became ice-free to maximize the catch per set and to ensure accurate CPUE comparisons with past experiments (Bernard et al. 1993). A set was defined as a single hoop trap baited with Pacific herring *Clupea pallasi* fished for approximately 48 hours. In Tolsona Lake, 60, 62 and 61 sets were fished in 2002, 2004 and 2005, respectively. In Susitna Lake, 420 sets were fished in 2002, and in Lake Louise, 490 sets were fished in 2005 (Table 2).

Table 2.–Number of sets and dates of sampling events for the stock assessment of burbot populations in Susitna Lake 2002, Tolsona Lake 2002, 2004 and 2005, and Lake Louise 2005.

Lake	Year	Area (ha)	Dates of Sampling Events	Number of Sets
Susitna	2002	3,816	6/13 – 6/21	420
Tolsona	2002	130	6/04 – 6/06	60
Tolsona	2004	130	5/18 – 5/20	62
Tolsona	2005	130	5/16 – 5/18	61
Louise	2005	6,519	6/01 – 6/09	492

After lifting a hoop trap, the catch was emptied into a holding tank and all burbot were measured for total length (to the nearest 5 mm). Burbot sampled from Susitna Lake were inspected for old tags and released immediately after measuring. Burbot captured from Lake Louise were measured and marked with an individually numbered internal anchor tag (Floy^{TM} FD-94) inserted in the musculature beneath the dorsal fin. All tags were checked to ensure that they were locked between the pterygiophores of the dorsal fin. Burbot captured from Tolsona Lake were inspected for previous tags and secondary marks. If marked with a tag, the tag number was recorded. If no tag was present, the fish was tagged as described for Lake Louise and given a secondary mark. Specific secondary marks have been used with Tolsona Lake burbot in a three year rotation to allow tag loss to be accounted for: partial excision of the left ventral fin (2002), a hole cut with a paper punch in the left operculum (2003), partial excision of the right ventral fin (2004) and again, partial excision of the left ventral fin (2005). These marks have been used at Tolsona Lake since 1990, except for 1995-1997 when the dorsal fin clip was used. A recaptured burbot exhibiting a secondary mark(s), but missing its tag, was considered to have been last captured in the most recent year the secondary mark was used. Individual trap and associated catch information were recorded on standard hoop-net mark-sense forms (Heineman *Unpublished*) for all lakes. Data forms were optically scanned and electronic data files (ASCII format) were produced for archival purposes (Appendix B) and were imported into 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. Tag number and color, secondary mark, and total length were recorded on the mark-sense form for each burbot caught in each set, unless the burbot was too small to tag (< 300 mm TL).

Monthly measurements (0.5 m depth increments) of water temperature, conductivity, dissolved oxygen (DO), pH and clarity at Tolsona Lake were planned for 2002 and 2004 beginning with first effort through the ice in April and continuing through the open water period. All measurements were recorded with a YSI® 556 MPS recorder[1]. In 2005, protocol changed for limnological sampling at Tolsona Lake. A DO measurement was taken through a hole in the ice in April, but the monthly recording of conductivity, dissolved oxygen, pH and clarity was discontinued. Instead, water temperature was recorded hourly throughout the open water period with Hobo® Water Temp Pro[1] temperature loggers. Using a rope and buoy tethered to an anchor, a series of three temperature data loggers were suspended off the lake bottom over the deepest part of the lake for the entire open water period. One temperature data logger was suspended just off the lake bottom, one in the lower third of the water column and one in the upper third of the water column. Another temperature logger was placed in a different location near the lake bottom in case the other three were tampered with. Water DO was to be examined more closely immediately after ice out if the presence of a hypolimnetic oxygen deficit was established because the lake failed to mix following break up. Since the first temperature and DO readings immediately after break up were uniform, subsequent weekly measurements were abandoned. DO was measured periodically (e.g., one-month intervals) during the open water period and also early in the morning proceeding extremely warm sunny days. This is when DO was likely to be lowest due to diurnal fluctuations when oxygen is consumed at night through plant respiration but not produced through photosynthesis.

DATA ANALYSIS

Length-frequency distributions of captured burbot from Tolsona Lake, Susitna Lake and Lake Louise were summarized in 50-mm increments. For each lake sampled, cumulative length-frequency distributions of captured burbot between two consecutive years of sampling were compared using Kolmogorov-Smirnov two-sample tests to help identify a significant change in the length of the population. For example, a shift in a curve towards smaller sized fish coupled with an increase in abundance indices (i.e., mean CPUE) would reflect a strong recruitment.

CPUE is defined as the number of fish caught per trap fished for a 48-h period. Mean CPUE was estimated for fully and partially recruited burbot in all three 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 and 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 each lake. Under these conditions, an unbiased estimate of mean CPUE was:

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

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.

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

Although the M_i and $\overline{M}$ are unknown, the m_i and m were used as substitutes because both M and m are directly related to the length of transects. Thus $\varpi_i = m_i/m$ 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 previous 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 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 are:

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 this project (125 m) was 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 was considered as a valid index of abundance.

Abundance, survival rate and recruitment statistics were generated for the burbot population in Tolsona Lake with the Jolly-Seber model (Seber 1982) using the computer program JOLLY (Model A) developed by Brownie et al. (1986)[2]. Model A is the most general form of the Jolly-Seber model and assumes capture probabilities and survival rates vary over time. Individual burbot captured more than once in an event during 2002, 2004 and 2005 were considered caught only once in this analysis to estimate abundance. Estimates of abundance are lagged 1-year and estimates of survival and recruitment are lagged 2 years from the most recent sampling event due to the nature of the model. Conditions for producing accurate statistics with the Jolly-Seber model are:

1. all burbot have the same probability of capture during each sample event (probability of capture can vary among events) or marked burbot must completely mix with unmarked burbot between sample events;
2. no marks are lost between sample events;
3. marked burbot must behave (enter traps) as do unmarked burbot;
4. marked burbot must have the same mortality rate as unmarked burbot; and,
5. immigration and emigration are permanent.

[2] see Pollock et al. (1990) for a description of JOLLY.

Statistics were only generated for burbot ≥ 450 mm TL because Bernard et al. (1991) demonstrated that burbot < 450 mm TL are not fully recruited to the hoop traps used in this project. Although the probability of capturing extremely large burbot (> 900 mm TL) is less than the probability of capturing other burbot between 450 and 900 mm TL in the hoop traps used in this project (Bernard et al. 1991), the proportion of fish over 900 mm TL is negligible. Traps were distributed uniformly to homogenize the probability of capture of burbot across Tolsona Lake. Over the span of a year, burbot should completely mix 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 evidence of capture-induced behavior (trap happiness or trap shyness) with a sampling hiatus of 1 year (Bernard et al. 1991). Although an intermittent stream connects Moose and Tolsona lakes, only one of over a thousand burbot recaptured from 1986 - 2005 had moved between lakes.

For Susitna Lake 2002, Tolsona Lake 2005, and Lake Louise 2005, mean CPUE was used to estimate abundance of fully recruited burbot using:

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

where

A = surface area of the lake (ha); and,

$\bar{q}$ = expected catchability coefficient (the fraction of the population removed instantaneously with one unit of sampling effort) as estimated from previous surveys.

Estimated variance of $\hat{N}$ was approximated with the delta method (Seber 1982) as:

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

where

$v(\overline{\text{CPUE}})$ = obtained from Raouw.exe.

Estimates of the catchability coefficient (q_i) from previous surveys was calculated by:

$$\hat{q}_i = \frac{A(\overline{CPUE}_i)}{\hat{N}_i} \tag{4}$$

where:

$\hat{q}_i$ = estimated catchability coefficient for the *i*th survey prior to the sampling event in 2002 or 2005;

$\hat{N}_i$ = estimated abundance during the ith survey prior to sampling in 2002 or 2005; and,

$\overline{CPUE}_i$ = estimated mean CPUE during the ith survey prior to sampling in 2002 or 2005.

Catchability coefficient (q_i) were calculated only for those past surveys that were conducted during the same time period relative to ice-out. Statistics for use in equation (2) were:

$$\overline{q} = \frac{\sum_{i=1}^{k} \hat{q}_i}{k} \tag{5}$$

Estimated variance of $(\hat{q}_i)$ is from Bernard et al. (1993):

$$v(\hat{q}_i) \approx \hat{q}_i^2 \left[\frac{v(\hat{N})_i}{\hat{N}_i^2} + \frac{v(\overline{CPUE}_i)}{\overline{CPUE}_i^2} \right]. \tag{6}$$

For Tolsona Lake, *i* encompassed years 1987 through 2003; for Lake Louise, *i* encompassed years 1989 through 1994, and for Susitna Lake, *i* encompassed years 1988 and 1989.

The CPUE expansion technique generally does not have the precision, nor does it garner the information that the Jolly-Seber model does, but it allows the estimation of abundance the same year the lakes were sampled. Jolly-Seber estimates are presented in this report when available. When they were not available, CPUE expansion abundance estimates are reported. The methods used to estimate abundances were noted in the titles of figures or as footnotes in tables. The management objective of two consecutive years with an estimated population abundance of at least 1,500 fully recruited burbot in Tolsona Lake is evaluated based exclusively on estimates from the Jolly-Seber method (Taube and Bernard 2001).

RESULTS

SUSITNA LAKE CPUE, LENGTH COMPOSITION AND ABUNDANCE, 2002

A total of 231 burbot were captured from Susitna Lake, 203 of which were fully recruited to the gear. The mean length of fully recruited burbot was 574 mm TL (SE = 6.1), while the mean length of the 28 partially recruited burbot was 358 mm TL (SE = 12.5; Table 3). The length distribution was unimodal with the mode occurring at 525 mm TL (midpoint of 50-mm length category; Figure 6). Cumulative length distributions of all burbot sampled in 1990 and 2002 were found to be significantly different from each other (DN = 0.23, P < 0.01; Figure 7; Table 4). The length distribution shifted towards larger fish in 2002.

Mean CPUE of fully recruited burbot at Susitna Lake in 2002 was 0.48 (SE = 0.09), while mean CPUE of partially recruited burbot was 0.07 (SE = 0.02; Table 5). Relative to Objective 5, mean CPUE of fully recruited burbot did not increase by 0.30 or more (Z = -1.03, P = 0.85), but the point estimate increased by 0.18 between 1990 and 2002. Mean CPUE for fully recruited burbot was higher in the shallow sets (0-3 m) than in the deep sets (4-6 m; Appendix C).

Table 3.–Mean length (mm TL) of burbot measured during sampling events at Susitna Lake 2002, at Tolsona Lake, 2002, 2004 and 2005, and at Lake Louise 2005.

Lake	Year	Statistic	Partially Recruited[a]	Fully Recruited	All
Susitna	2002	Mean	358	574	548
		SE	12.5	6.1	7.2
		Sample size	28	203	231
Tolsona	2002	Mean	399	575	535
		SE	6.9	6.8	8.0
		Sample size	36	122	158
Tolsona	2004	Mean	380	555	540
		SE	14.4	3.9	5.0
		Sample size	19	208	227
Tolsona	2005	Mean	386	600	592
		SE	24.7	4.3	5.0
		Sample size	8	210	218
Louise	2005	Mean	338	642	616
		SE	15.1	4.9	6.9
		Sample size	20	236	256

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

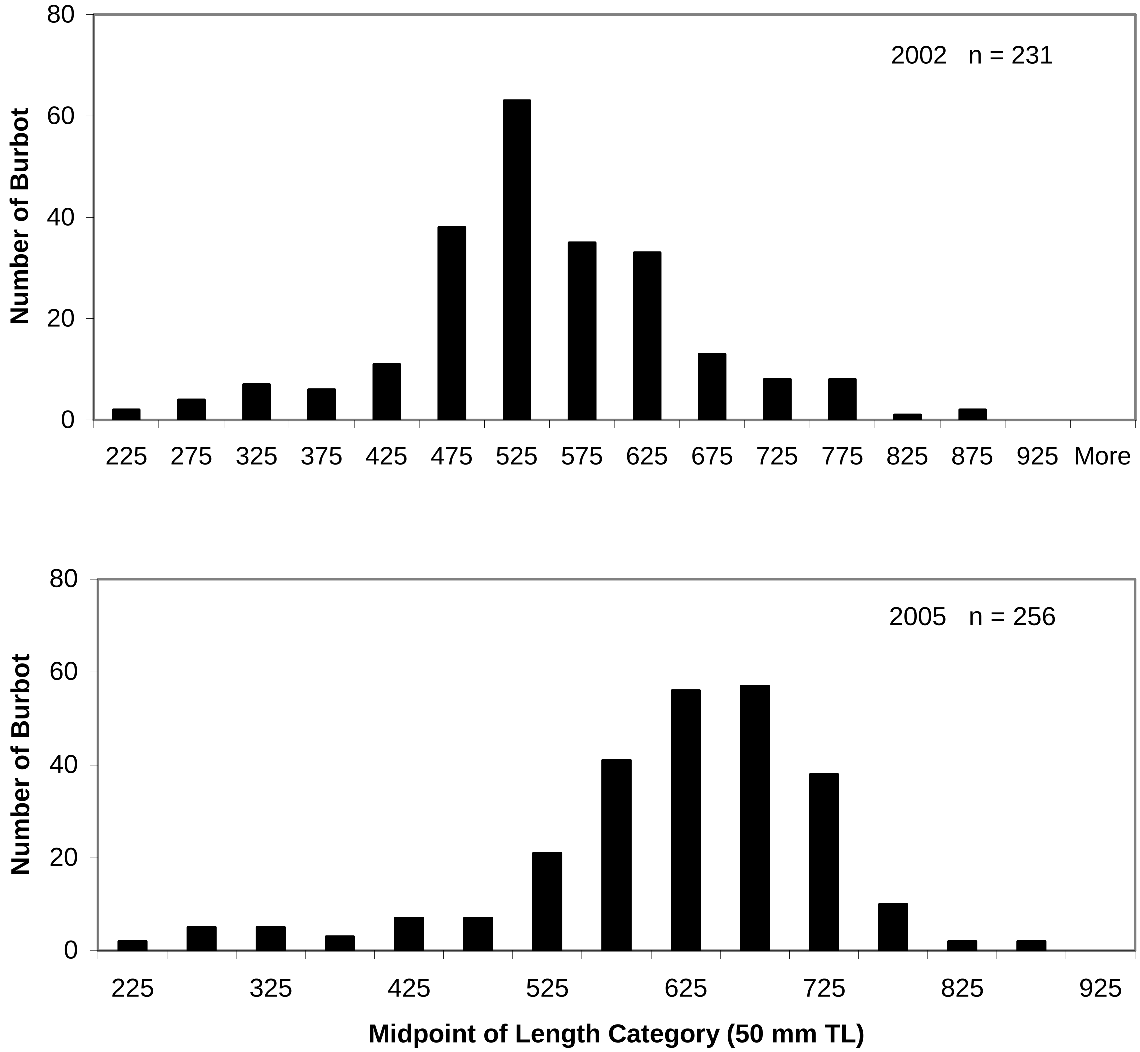

Figure 6.–Length-frequency of burbot captured in Susitna Lake, 2002 (upper graph) and Lake Louise, 2005 (lower graph).

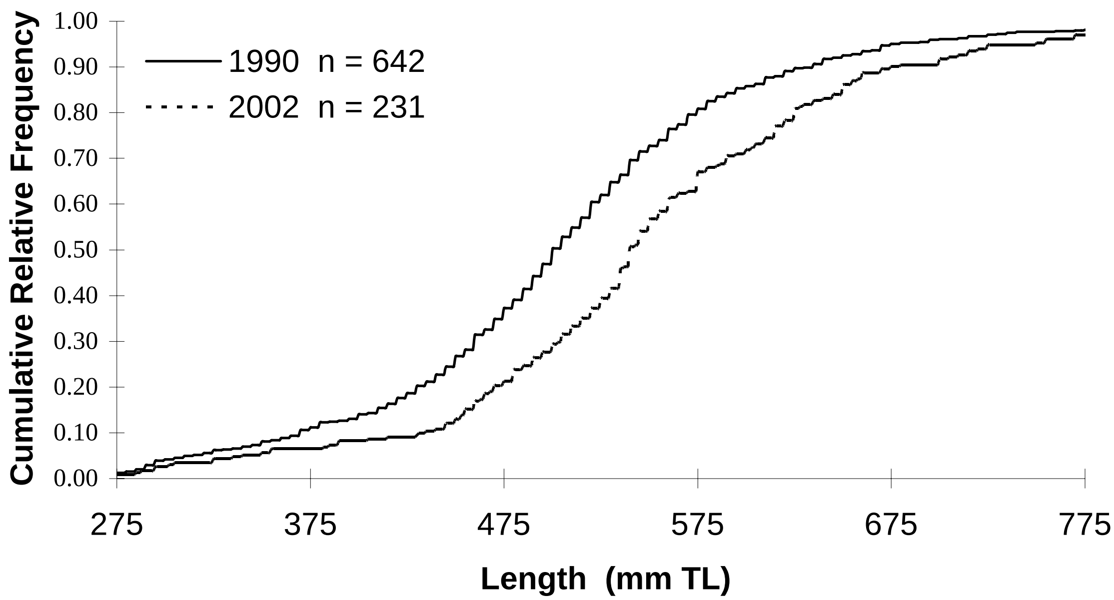

Figure 7.–Comparison of cumulative length frequency distributions of all burbot sampled from Susitna Lake, 1990 and 2002.

Table 4.–Results of Kolmogorov-Smirnov two sample tests.

Comparisons	*D*-statistic	P-value	Result
Tolsona Lake			
2001 vs. 2002	0.11	0.35	Not Significant
2002 vs. 2003	0.21[a]	< 0.01[a]	Significant
2003 vs. 2004	0.29	< 0.01	Significant
2004 vs. 2005	0.34	< 0.01	Significant
Susitna Lake			
1990 vs. 2002	0.23	< 0.01	Significant
Lake Louise			
1999 vs. 2005	0.17	< 0.01	Significant

[a] Data from Schwanke and Bernard (2005).

Table 5.–Estimated mean CPUE of fully recruited (≥ 450 mm TL) and partially recruited (< 450 mm TL) burbot in Susitna Lake 2002, Tolsona Lake 2002, 2004 and 2005, and Lake Louise 2005.

Lake and Date	Strata	Sets	Transects		Mean CPUE Bootstrapped	Mean CPUE Arithmetic	%Δ	Bootstrapped SE	Bootstrapped CV
Susitna Lake									
6/13 – 6/21, 2002	< 15 m	420	49						
				Fully recruited:	0.483	0.484	2.1%	0.086	17.9%
				Partially recruited:	0.067	0.067	0.0%	0.019	28.6%
Tolsona Lake									
6/04 – 6/06, 2002	1 - 5 m	60	9						
				Fully recruited:	2.033	2.043	0.5%	0.366	18.0%
				Partially recruited:	0.611	0.600	1.8%	0.145	23.7%
Tolsona									
5/18 – 5/20, 2004	1 - 5 m	62	12						
				Fully recruited:	3.316	3.355	1.2%	0.518	15.6%
				Partially recruited:	0.299	0.306	2.3%	0.097	32.5%
5/16 – 5/18, 2005	1 - 5 m	61	11						
				Fully recruited:	3.445	3.443	0.0%	0.709	20.6%
				Partially recruited:	0.133	0.131	0.0%	0.071	53.2%
Louise									
6/01 – 6/09, 2005	< 15 m	492	20						
				Fully Recruited:	0.479	0.480	-0.2%	0.052	10.9%
				Partially Recruited:	0.041	0.041	0.0%	0.014	33.2%

Estimated abundance from CPUE expansion for fully recruited burbot in Susitna Lake for spring 2005 was 6,151 (90% CI = 1,345 – 10,956; Table 6).

Table 6.–Estimated abundance and density of fully recruited (≥ 450 mm TL) burbot in Susitna Lake 2002, Tolsona Lake 2001, 2003-2005, and Lake Louise 2005.

Lake	Date	Abundance[a]	SE	Lake Area (ha)	Density (burbot/ha)	SE
Susitna	6/13/02 – 6/21/02	6,151	2,921	3,816	1.61	0.76
Tolsona	5/29/01 – 5/31/01	662	138	130	5.09	1.06
	5/19/03 – 5/21/03	1,119	290	130	8.67	2.23
	5/18/04 – 5/20/04	1,018	296	130	7.83	2.27
	5/16/05 – 5/18/05	855	233	130	6.57	1.79
Louise	6/01/05 – 6/09/05	4,827	807	6,519	0.74	0.12

[a] Abundance estimates at Tolsona Lake for 2001, 2003 and 2004 were derived with the Jolly-Seber model and incorporate information collected up to and including 2005. Abundance estimates for Susitna Lake 2002, Tolsona Lake 2005 and Lake Louise 2005 are from CPUE expansion.

TOLSONA LAKE CPUE AND LENGTH COMPOSITION, 2002

One hundred fifty-eight burbot were captured from Tolsona Lake in 2002, 122 of which were fully recruited to the gear (Appendix D). Fifty-one of the burbot had been previously captured, but seven were too small (i.e., < 450 mm TL) at the time of previous capture to be included in the abundance estimate as recaptured fish. Five of the 51 previously captured fish experienced tag loss, but all were assigned a year of previous capture based on secondary marks. Four fish were previously captured in 1999 and one was previously captured in 2001.

The mean length of fully recruited burbot captured in 2002 was 575 mm TL (SE = 6.8; Table 3). Mean length of partially recruited burbot was 399 mm TL (SE = 6.9). Length distribution was unimodal with the mode occurring at 575 mm TL (midpoint of 50-mm length category; Figure 8). Cumulative length distributions of all sampled burbot (Figure 9) were not significantly different between 2002 and 2001 (DN = 0.11, P = 0.35; Table 4).

Mean CPUE of fully recruited burbot at Tolsona Lake in 2002 was 2.04 (SE = 0.37), while mean CPUE of partially recruited burbot was 0.60 (SE = 0.15; Table 5). Mean CPUE for fully recruited burbot was higher in the deep sets (4-6 m) than the shallow sets (0-3 m; Appendix C).

TOLSONA LAKE CPUE AND LENGTH COMPOSITION, 2004

Two hundred twenty-seven burbot were captured from Tolsona Lake in 2004, 208 of which were fully recruited to the gear (Appendix D). Of the 227 total burbot sampled, 33 had been previously captured. Five of the 33 recaptured fish (15.1%) experienced tag loss, but all five were assigned a capture year based on the presence of secondary marks. Three were previously captured in 2003 and two were previously captured in 2001. Two of the 33 recaptured fish were not included in the mark-recapture experiment because their lengths at previous capture were < 450 mm.

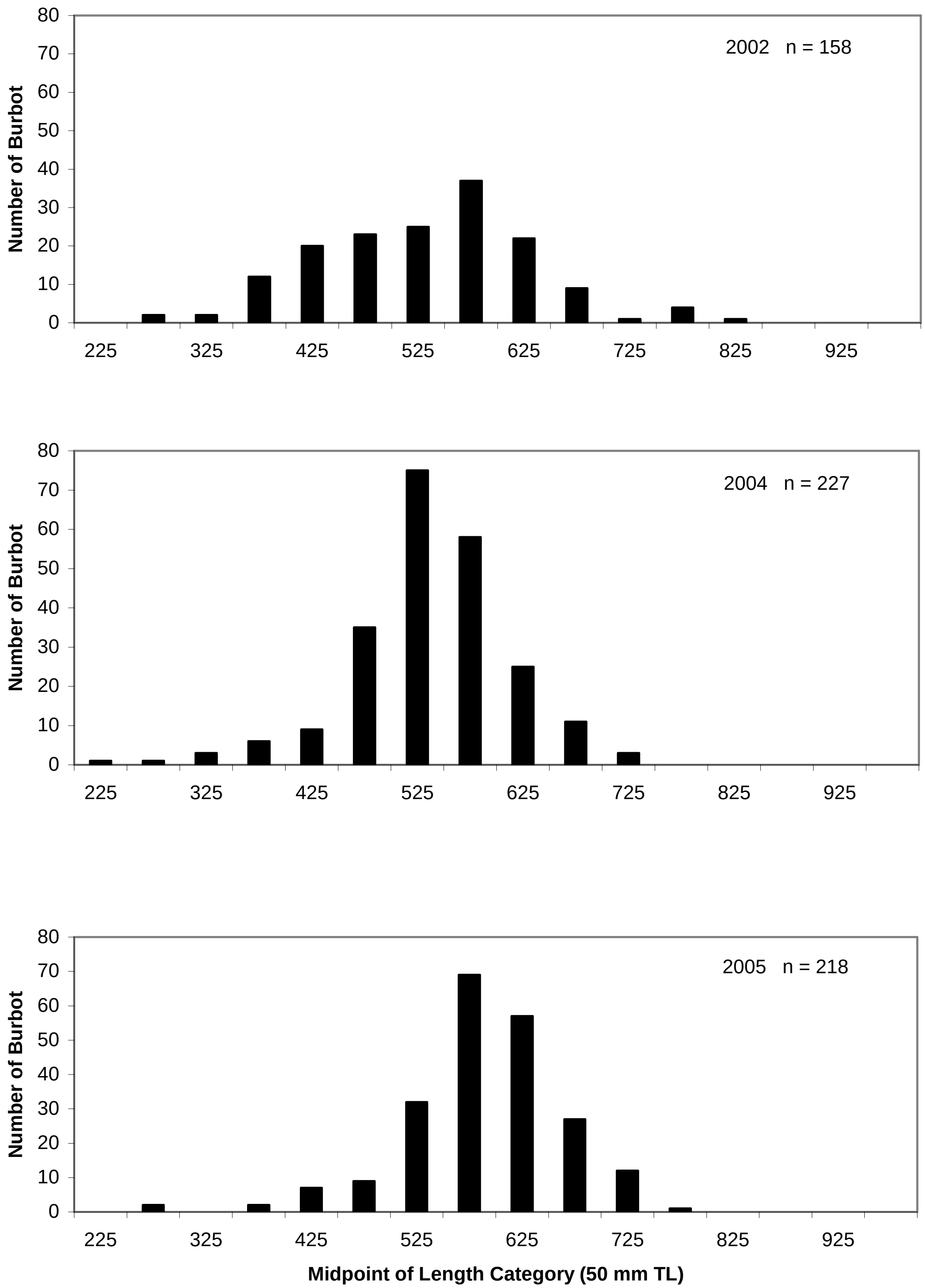

Figure 8.–Length-frequency of burbot captured in Tolsona Lake, 2002, 2004 and 2005.

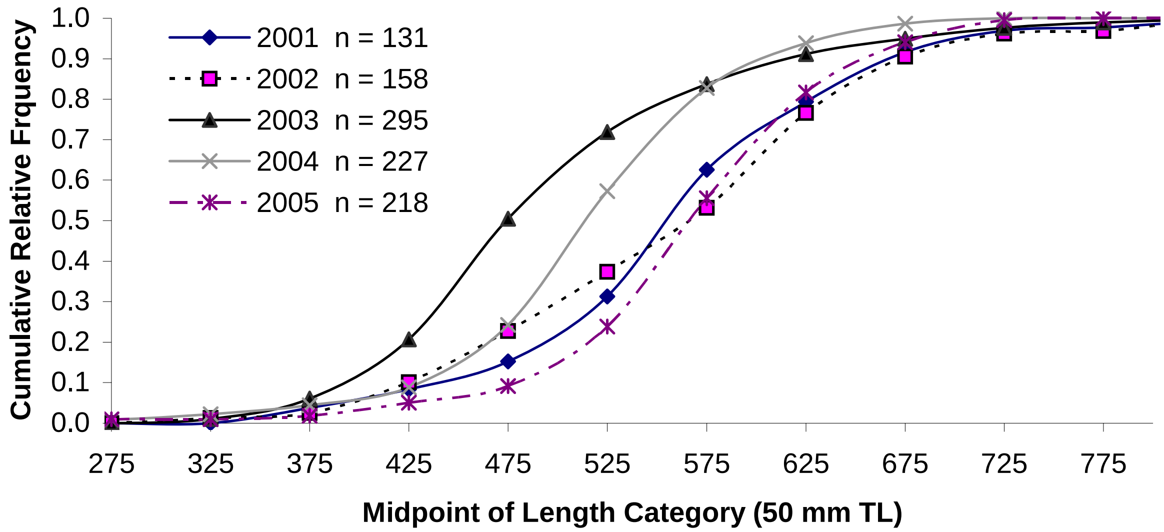

Figure 9.–Comparison of cumulative length frequency distributions of all burbot sampled from Tolsona Lake, 2001-2005.

The mean length of fully recruited burbot captured in 2004 was 555 mm TL (SE = 3.9; Table 3). Mean length of partially recruited burbot was 380 mm TL (SE = 14.2). Length distribution of all captured burbot was unimodal with the mode occurring at 525 mm TL (midpoint of 50-mm length category; Figure 8). Cumulative length distributions of all sampled burbot (Figure 9) were significantly different between 2003 and 2004 (DN = 0.29, P < 0.01; Table 4).

Mean CPUE of fully recruited burbot at Tolsona Lake in 2004 was 3.36 (SE = 0.52), while mean CPUE of partially recruited burbot was 0.31 (SE = 0.10; Table 5). Mean CPUE for fully recruited burbot in the deep sets (4-6 m) was nearly identical to that of the shallow sets (0-3 m; Appendix C).

TOLSONA LAKE CPUE AND LENGTH COMPOSITION, 2005

Two hundred eighteen burbot were captured from Tolsona Lake in 2005, 210 of which were fully recruited to the gear (Appendix D). Of the 218 total burbot sampled, 42 had been previously captured. Three of these recaptured fish were not used in the mark-recapture analysis because they were too small at the time of previous capture. Three of the 42 recaptured fish (7.1%) experienced tag loss. As evident by secondary marks, two of these fish were previously captured in 2003 and the other was previously captured in 2004.

The mean length of fully recruited burbot captured in 2005 was 600 mm TL (SE = 4.3; Table 3). Mean length of partially recruited burbot was 386 mm TL (SE = 24.7). Length distribution was unimodal with the mode occurring at 550 mm TL (midpoint of 50-mm length category; Figure 8). Cumulative length distributions of all sampled burbot (Figure 9) were significantly different between 2004 and 2005 (DN = 0.34, P < 0.01; Table 4).

Mean CPUE of fully recruited burbot at Tolsona Lake in 2005 was 3.44 (SE = 0.71), while mean CPUE of partially recruited burbot was 0.13 (SE = 0.07; Table 5). Average catch per set for fully recruited burbot was higher in the deep sets (4-6 m) than the shallow sets (0-3 m; Appendix C).

TOLSONA LAKE ABUNDANCE, 2001, 2003, AND 2004

Using the Jolly-Seber method, abundance of fully recruited burbot in 2001, 2003 and 2004 was estimated as 662 (90% CI = 437 – 887), 1,119 (90% CI = 642 – 1,596) and 1,018 (90% CI = 530 – 1,504) burbot, respectively (Table 1; Figure 3). Survival between the years listed and the previous year ranged from 35% to 51%, while recruitment during the same time periods ranged from 161 to 724 burbot (Table 1).

Expansion of CPUE resulted in a population estimate of 855 (90% CI = 471 – 1,238) fully recruited burbot for spring 2005 (Table 1; Figure 3). For the last 4 years, the CPUE expansion estimate has been tracking about 20% lower than the Jolly-Seber estimate (Figure 10). The Jolly-Seber estimate for 2005 is expected to be similar to that of 2004 because of the high Pearson correlation coefficient between mean CPUE expansion abundance estimates and Jolly-Seber mark-recapture abundance estimates (r=0.85; Figure 10).

TOLSONA LAKE LIMNOLOGICAL SAMPLING

Limnological information was collected from Tolsona Lake on three occasions in 2002: 15 April, 16 August and 23 October (Table 7). No measurements were outside the preferred range for burbot or markedly different from what Simpson (1997) reported.

Monthly limnological measurements were collected from Tolsona Lake from May through September 2004 (Table 8). No April measurements were collected because the measuring device was not available. All open water measurements were within preferred ranges for burbot (Simpson 1997; Scott and Crossman 1973), except temperature measurements from 30 June and 20 August (Table 8). Although not substantiated in the water samples collected, based on unusually warm air temperatures experienced throughout the summer, the entire water column was probably over the preferred range of burbot for at least 30 days.

From 16 May through 2 October 2005, water temperature in Tolsona Lake ranged from 5º to 21º C near the surface, and from 5º to 18º C near the bottom (Figure 11). None of the temperatures reached the critical level for burbot, and were only briefly above the preferred range for burbot. DO measurements were uniform a few days after ice-out indicating no hypolimnetic oxygen deficit and subsequent DO measurements were abandoned (Table 9). The exploratory DO sampling during times when DO might be low (i.e., early in the morning after a hot sunny day; see August 10 and 11) revealed that the lakes DO levels fluctuated little diurnally (Table 9). While recording DO, the measuring device also recorded pH, conductivity and temperature (Table 9).

LAKE LOUISE CPUE, LENGTH COMPOSITION AND ABUNDANCE, 2005

Two hundred fifty-six burbot were captured at Lake Louise in 2005, 236 of which were fully recruited to the gear. The mean length of these fully recruited burbot was 642 mm TL (SE = 4.9), while the mean length of the 20 partially recruited burbot was 338 mm (SE = 15.1; Table 3). Length distribution was unimodal with the mode occurring at 625 mm TL (midpoint of

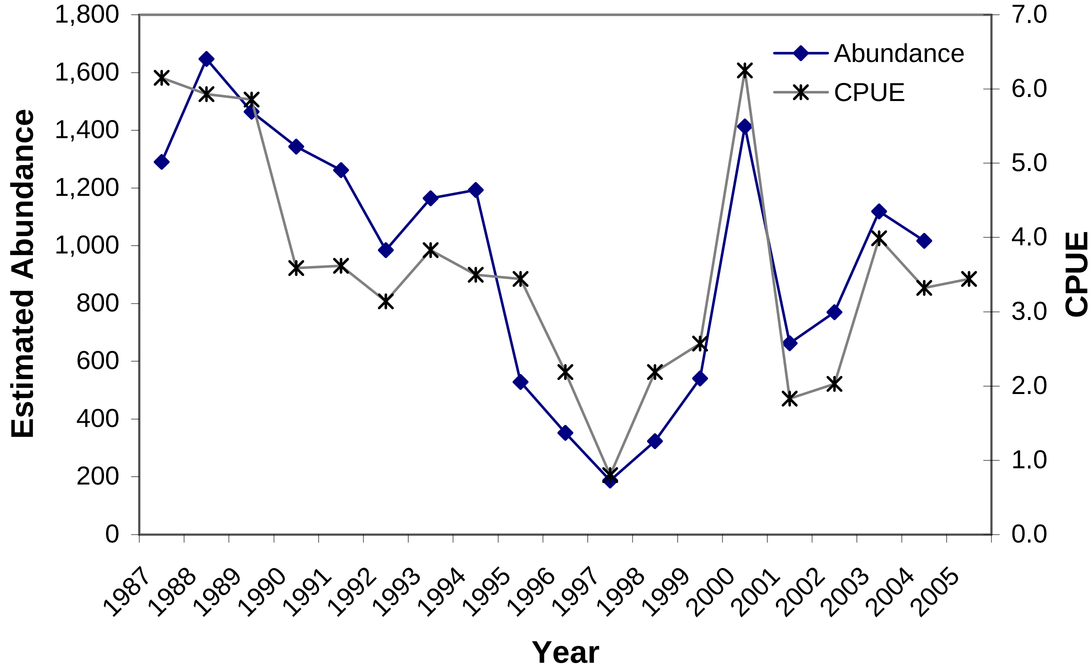

Figure 10.–Comparison of Jolly-Seber abundance estimates and mean CPUE of fully recruited burbot in Tolsona Lake, 1987-2005.

Table 7.–Measurements of limnological parameters from Tolsona Lake, 2002.

Measurement	Preferred Range[a]	Depth[b] (m)							
		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
		April 15, 1400 hours							
Temperature (C°)	<18°C	0.1	0.5	1.6	2.6	3.9	4.3		
Dissolved Oxygen	>2.0 mg/L	0.1	6.5	6.1	5.0	0.6	1.1		
PH	6.5 - 9	7.2	7.2	7.2	7.2	7.1	7.1		
Conductivity (µS/cm)	NA	364	364	362	361	337	383		
		August 16, 1710 hours							
Temperature (C°)	<18°C	14.6	14.5	14.4	14.4	14.2	13.9	13.9	
Dissolved Oxygen	>2.0 mg/L	9.2	9.3	9.3	9.5	9.8	10.2	10.4	
PH	6.5 - 9	8.1	8.1	8.2	8.2	8.2	8.24	8.27	
Conductivity (µS/cm)	NA	274	274	274	274	272	270	270	
		October 23, 1200 hours							
Temperature (C°)	<18°C	2.4	2.4	2.5	2.4	2.4	2.4	2.4	2.4
Dissolved Oxygen	>2.0 mg/L	11.2	10.9	10.7	10.8	10.7	10.7	10.8	10.7
PH	6.5 - 9	7.8	7.9	7.9	7.9	7.9	7.9	7.9	7.9
Conductivity (µS/cm)	NA	269	269	269	270	269	269	269	269

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

[b] The deepest measurements for each date were within 0.5 meters of the bottom.

Table 8.-Measurements of limnological parameters from Tolsona Lake, 2004.

Measurement	Preferred Range[a]	Depth [b] (m)								
		0.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
		May 20								
Temperature (C°)	<18°C	11.5	11.5	11.4	11.1	11.0	11.0			
Dissolved Oxygen[c]	>2.0 mg/L	15.2	15.3	13.2	15.3	15.7	15.6			
PH	6.5 - 9	8.0	8.0	8.0	8.1	8.1	8.1			
Conductivity (µS/cm)	NA	245	245	245	244	244	244			
		June 30								
Temperature (C°)	<18°C	21.7	20.8	20.6	20.5	20.4	20.4	20.4	20.4	
Dissolved Oxygen[c]	>2.0 mg/L	13.7	13.7	13.7	13.5	13.4	13.8	13.6	14.8	
PH	6.5 - 9	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.9	
Conductivity (µS/cm)	NA	502	499	499	499	500	498	498	498	
		July 26								
Temperature (C°)	<18°C	16.9	16.9	16.9	16.9	16.8	16.8	16.8	16.8	16.8
Dissolved Oxygen	>2.0 mg/L	13.8	13.7	13.7	13.7	13.6	13.6	13.6	13.6	13.6
PH	6.5 - 9	8.9	8.9	8.9	8.9	8.8	8.8	8.8	8.8	8.8
Conductivity (µS/cm)	NA	455	455	456	456	456	456	456	457	457
		August 20								
Temperature (C°)	<18°C	19.1	19.1	19.0	18.9	18.9	18.9	18.9	18.9	
Dissolved Oxygen[c]	>2.0 mg/L	16.4	16.5	16.5	16.6	16.6	16.5	16.6	16.7	
PH	6.5 - 9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	
Conductivity (µS/cm)	NA	445	445	445	445	445	444	444	444	
		September 29								
Temperature (C°)	<18°C	3.4	3.4	3.4	3.4	3.4	3.4	3.5	3.4	
Dissolved Oxygen	>2.0 mg/L	14.2	13.9	13.9	13.9	13.6	13.6	13.3	13.3	
PH	6.5 - 9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	8.9	
Conductivity (µS/cm)	NA	386	385	384	381	383	384	380	381	

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

[b] The deepest measurements for each date were within .5 meters of the bottom.

[c] Dissolved oxygen levels were abnormally high. The measuring device may not have been working properly.

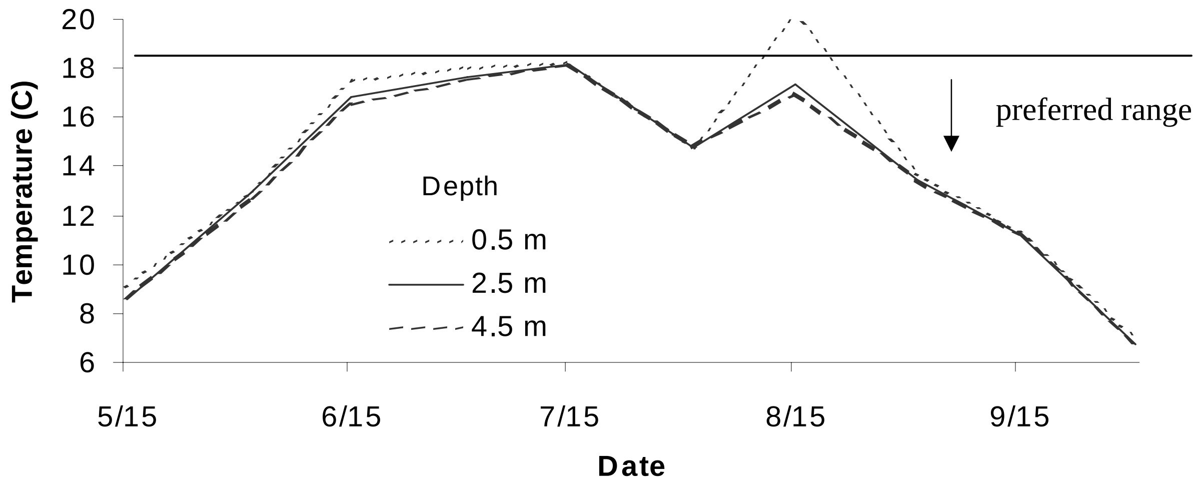

Figure 11.–Water temperature measurements from Tolsona Lake, 2005.

Table 9.–Measurements of limnological parameters from Tolsona Lake, 2005.

Measurement	Preferred Range[a]	Depth[b] (m)							
		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
		April 6, 0745 hours							
Temperature (C°)	<18°C	0.1	0.9	2.2	3.1	3.1	3.4	3.4	3.5
Dissolved Oxygen	>2.0 mg/L	8.5	6.9	3.4	2.8	1.5	1.4	1.2	1.3
PH	6.5 - 9	7.2	7.3	7.4	7.4	7.3	7.2	7.2	7.1
Conductivity (µS/cm)	NA	265	257	254	260	278	284	286	283
		May 19, 0900 hours							
Temperature (C°)	<18°C	10.6	10.6	10.5	10.4	10.4	10.	10.1	9.9
Dissolved Oxygen	>2.0 mg/L	12.6	12.4	12.4	12.5	12.5	12.4	12.2	11.9
PH	6.5 - 9	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
Conductivity (µS/cm)	NA	223	223	222	221	221	221	220	220
		June 30, 0800 hours							
Temperature (C°)	<18°C	18.5	18.4	18.4	17.9	17.5	17.2	17.2	16.8
Dissolved Oxygen	>2.0 mg/L	13.1	12.8	12.8	12.5	14	14.6	15.1	13.7
PH	6.5 - 9	8.4	8.5	8.4	8.5	8.5	8.6	8.6	8.5
Conductivity (µS/cm)	NA	250	248	245	243	239	237	235	238
		July 31, 1000 hours							
Temperature (C°)	<18°C	19.7	18.4	17.7	17.2	16.8	16.4	16.0	15.8
Dissolved Oxygen	>2.0 mg/L	14.0	14.7	14.8	15.1	15.5	15.2	14.6	13.6
PH	6.5 - 9	7.9	8.1	8.2	8.3	8.4	8.4	8.5	8.4
Conductivity (µS/cm)	NA	248	246	245	245	245	244	243	246
		August 10, 2100 hours							
Temperature (C°)	<18°C	19.8	18.4	17.8	17.0	16.6	16.2	16.0	15.9
Dissolved Oxygen	>2.0 mg/L	14.2	14.3	14.6	15.3	15.8	16.2	16.7	15.2
PH	6.5 - 9	8.0	8.2	8.3	8.3	8.3	8.3	8.4	8.2
Conductivity (µS/cm)	NA	248	247	245	245	244	243	242	244

Table 9.-Page 2 of 2

Measurement	Preferred Range[a]	Depth[b] (m)							
		0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0
		August 11, 0700 hours							
Temperature (C°)	<18°C	18.8	18.6	18.1	17.4	16.9	16.6	16.0	15.8
Dissolved Oxygen	>2.0 mg/L	14.3	14.2	15.0	14.9	15.2	16.1	16.6	15.5
PH	6.5 - 9	8.3	8.4	8.5	8.4	8.5	8.5	8.5	8.4
Conductivity (µS/cm)	NA	241	242	240	240	239	238	236	239
		October 2, 1700 hours							
Temperature (C°)	<18°C	6.8	6.7	6.7	6.7	6.7	6.7	6.7	6.7
Dissolved Oxygen	>2.0 mg/L	16.9	16.2	15.7	15.6	15.4	15.3	15.2	15.2
PH	6.5 - 9	7.9	7.8	7.9	7.8	7.9	7.9	7.9	7.9
Conductivity (µS/cm)	NA	244	242	241	241	241	241	240	240

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

[b] The deepest measurements for each date were within .5 meters of the bottom.

50-mm length category; Figure 6). Cumulative length distributions of all sampled burbot (Figure 12) were significantly different between 1999 and 2005 (DN = 0.17, $P < 0.01$; Table 4).

Mean CPUE of fully recruited burbot captured in 2005 was 0.48 (SE = 0.05), while mean CPUE of partially recruited burbot was 0.04 (SE = 0.01; Table 5). Mean CPUE for fully recruited burbot was higher in the deep sets (4-6 m) than the shallow sets (0-3 m; Appendix C).

Using the CPUE expansion method, abundance of fully recruited burbot in Lake Louise was estimated as 4,827 (90% CI = 3,500 – 6,154; Table 6; Figure 4). This estimate is not significantly different from the spring 1999 estimate, but the point estimate is greater by approximately 1,000 fish. Relative to Objective 6, the population estimate did not decrease by 50% or more from the average of estimates from 1989 to 1996 and 1999.

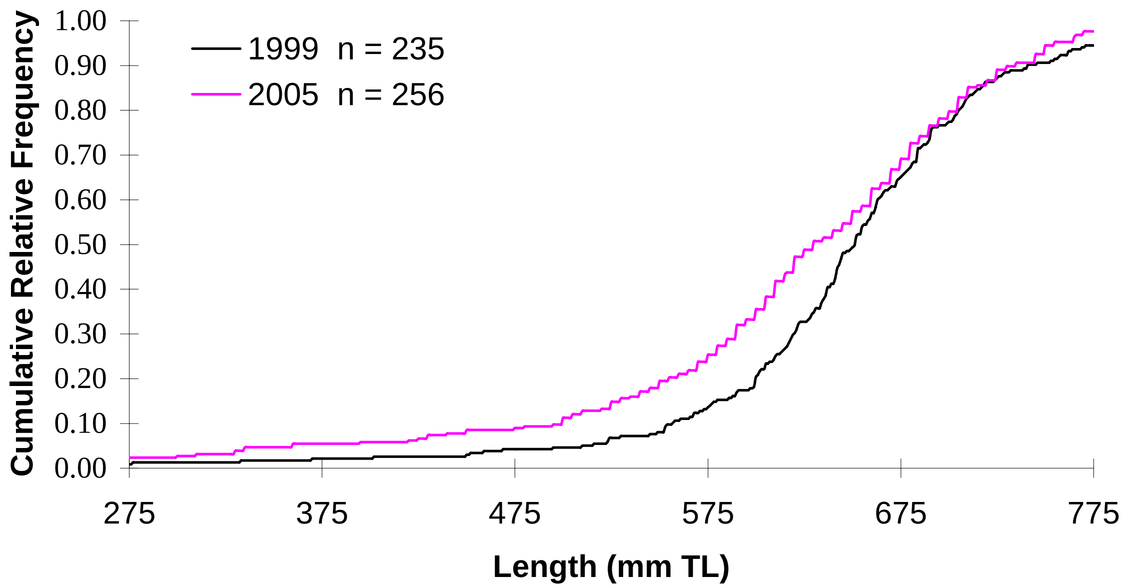

Figure 12.–Comparison of cumulative length frequency distributions of all burbot sampled from Lake Louise, 1999 and 2005.

DISCUSSION

SUSITNA LAKE

A conservative management strategy has been in place at Susitna Lake since the late 1980s. Harvest levels were measurably reduced after 1987 (Figure 5) when the bag limit was reduced from 15 burbot per day and in possession (no size limit) to just 2 burbot, size limit. This bag limit still remains in effect. The use of setlines was made illegal in the Tyone River drainage in 1988. Despite these changes a significant increase in mean CPUE for fully recruited burbot of 0.3 or more since 1990 did not occur (i.e., Objective 5) and a liberalization of fishing regulations was not advised. However, mean CPUE of fully recruited burbot did increase by approximately 60% (0.18) from 1990, and although changes in CPUE are not always indicative of changes in abundance, this increase in CPUE coupled with the increase in frequency of larger burbot suggested the population might be recovering from likely over-exploitation that occurred in the early to mid 1980s.

Past abundance estimates from mark-recapture experiments for Susitna Lake burbot have had relatively high standard errors (see 1987, 1988 and 1989 in Table 1). Only two of the 3-years abundance estimates were calculated from mark-recapture experiments conducted in the spring; therefore, only two data points could be used to calculate catchability coefficients (q) in relation to spring sampling. Additionally, these two estimates of q were quite different (0.391 for 1988 and 0.205 for 2005). The end results are imprecise abundance estimates through CPUE expansion. The 2002 estimate had a relative precision of 78%. Without expending considerable time and effort in the future to estimate abundance in consecutive years with mark-recapture methods, CPUE derived abundances will continue to be imprecise for Susitna Lake burbot.

TOLSONA LAKE

Estimated abundance of fully recruited burbot in Tolsona Lake was generally increasing from 1998 to 2003. This increase in abundance was likely due to a combination of reduced harvest (fishery closure since March 1998) and favorable environmental conditions. However, since 2003 it appears this trend may have ceased (Figure 3).

Examination of length frequencies, mean CPUE of partially recruited burbot and recapture rates of tagged burbot in 2005 raised concerns over the health of the stock. Few small, mature burbot (i.e., 450 - 500 mm) were captured in 2005 (Figure 8), indicating poor recruitment between spring 2004 and spring 2005. Mean CPUE of partially recruited (i.e., < 450 mm TL) burbot was also the lowest since 1995 when it was 0.10 (SE = 0.06; Taube and Bernard 1999), the year the population started a significant decline. This low CPUE of partially recruited burbot may be an indication of poor recruitment of fully recruited burbot in future years. If survival was poor between 2004 and 2005, or is poor in the next couple of years, the population may experience another significant decline.

The summer of 2004 was characterized as being abnormally warm and dry. For example, the average maximum temperature for the summer months (June through August) was the highest recorded since temperatures have been annually recorded at the Gulkana Airport beginning in 1943 (ACRC 2006). This weather pattern resulted in Tolsona Lake warming to above 20º C. Since measurements were only collected roughly once a month in 2004, maximum daily temperatures and number of days the water column exceeded 18ºC are unknown. However, based on air temperatures, it is reasonable to believe that Tolsona Lake was warmer than 18ºC for over half the summer, and may have exceeded 20ºC for over a month. It is yet to be seen if this adversely affected the burbot population. If it did have a negative effect on survival, Tolsona Lake burbot may experience a significant decline in abundance in 2005 (Jolly-Seber model will determine this after sampling in spring 2006). The indications of poor recruitment between 2004 and 2005 may be related to the unusually warm water in the summer of 2004. Other than above normal water temperatures in 2004, none of the limnological parameters collected in 2002, 2004 or 2005 were outside historical ranges or the preferred range for burbot. It is recommended that temperature data loggers be placed in Tolsona Lake throughout the open water period as long as the burbot sampling program continues. In addition, given the record high temperatures observed in 2004, it is also recommended that a potential relationship(s) between air temperature recorded at the Gulkana Airport and estimated parameters such as survival and recruitment be explored.

Continuous monitoring of Tolsona Lake burbot is warranted until the population reaches a level where a moderate harvest can be sustained. Currently this level has been established at an estimated 1,500 fully recruited burbot for two consecutive years (Taube and Bernard 2000).

LAKE LOUISE

Using mean CPUE to estimate abundance can be problematic. Catchability of burbot in hoop traps during the open water period is highest immediately after ice out, then drops rapidly to a low level during summer, then increases as the water cools and ice forms (Bernard et al. 1993; Taube and Bernard 2004). However, CPUE estimates from 1999 and 2005 are comparable because the sampling start dates are nearly identical relative to ice-out. In 1999 sampling commenced ten days after the lake became ice free, and in 2005, sampling commenced eight days after the lake became ice free.

Estimated CPUE and abundance estimates from CPUE expansion for 1999 and 2005 were not significantly different and provided no evidence that the burbot population in Lake Louise has declined. This may be partially attributed to the opening of the fishery to harvest (i.e., one burbot per day and in possession). The CPUE expansion abundance estimates reveal approximately a 26% increase in the point estimate of abundance from 1999 to 2005 (Table 5). However, these estimates are imprecise, with overlapping 90% confidence intervals (Figure 4).. In fact, none of the estimates have been significantly different since the inception of the monitoring program on Lake Louise. Reasons why the population has not rebounded are unclear and likely complex. Taube and Bernard (2000) speculated that the burbot population may have reached a new equilibrium, with part of their old niche being filled by lake trout. Some residents of Lake Louise also believe predation by a rapidly growing double-crested cormorant *Phalacrocorax auritus* population at Lake Louise is a contributing factor.

It is unlikely that harvesting burbot out of Susitna Lake while Lake Louise was closed to burbot fishing had an impact on the Lake Louise burbot abundance indices. There is evidence of burbot moving from Lake Louise to Susitna Lake and vice versa, but all the evidence (i.e., tag return information) suggests that this movement is minimal and has been deemed inconsequential (Lafferty and Bernard 1993). Also, burbot harvests were relatively low at Susitna Lake while Lake Louise was closed to the retention of burbot (Figure 5).

In the absence of precise abundance information, the difference in cumulative length frequencies of captured burbot from 1999 and 2005 is difficult to interpret. The difference between those 2 years appears to be because more small fish were captured in 2005, and not necessarily because there were fewer large fish in 2005. Although harvest has increased annually since the fishery was reopened, it still remains very low relative to the size of the lake and its estimated abundance of fully recruited burbot (Figure 4). Thus, the low percentage of large fish in the 2005 sample is likely not an artifact of excessive exploitation. If effort and harvest continue to increase, changes in relative abundance and length composition might be detected in future sampling.

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APPENDIX A

Appendix A.–Description of lakes with burbot populations sampled in 2002, 2004 and 2005.

TOLSONA LAKE (62°06’ N, 146°04’ W) is accessible from the Glenn Highway. Tolsona Lake is 130 ha with a maximum depth of 5 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 in the winter in past years. Tolsona Lake has burbot, Arctic grayling *Thymallus arcticus*, longnose sucker *Catostomus catostomus* and was stocked rainbow trout *Oncorhynchus mykiss* in the past.

LAKE LOUISE (62°20’ N, 146°04’ W) is the largest lake in a three-lake system that drains into the Susitna River, and is accessible by the Glenn Highway via an approximately 32-km gravel road. Lake Louise is 6,519 ha with a maximum depth of 51 m and an elevation of 720 m. A state campground with a boat launch is available. Four lodges are on the south end of the lake, and numerous cabins are located on the lakes perimeter and islands. Lake Louise has burbot, Arctic grayling, lake trout *Salvelinus namaycush*, humpback whitefish *Coregonus clupeaformis*, longnose sucker and round whitefish *Prosopium cylindraceum*.

SUSITNA LAKE (62°25’ N, 146°38’ W) is the second largest lake in a three-lake system that drains into the Susitna River, and is accessible through a narrow approximately 100-m long channel on the north end of Lake Louise. Susitna Lake is 3,816 ha with a maximum depth of 37 m and an elevation of 720 m. No lodges or public facilities exist on the lake, but numerous private recreation cabins exist. Susitna Lake has burbot, Arctic grayling, lake trout, humpback whitefish, longnose sucker and round whitefish.

APPENDIX B

Appendix B.–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
Tolsona	i-039800h012002.dta	Hoop net	RTS-ASCII
	i-039800h012004.dta	Hoop net	RTS-ASCII
	i-039800h012005.dta	Hoop net	RTS-ASCII
	2005 Tolsona BB tag history.xls	Tag history	Microsoft EXCEL
Susitna	i-001100h012002.dta	Hoop net	RTS-ASCII
Louise	i-001000h012005.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.

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

APPENDIX C

Appendix C.-Number of sets by depth category, and CPUE of partially and fully recruited burbot by depth category at Tolsona Lake in 2002, 2004 and 2005, at Susitna Lake in 2002, and at Lake Louise in 2005.

Lake & Year	Number of sets		CPUE of fully recruited burbot		CPUE of partially recruited burbot	
	0-3 m	4-15 m	0-3 m	4-15 m	0-3 m	4-15 m
Tolsona Lake 2002	23	37	1.35	2.50	0.74	0.51
Tolsona Lake 2004	33	29	3.36	3.35	0.45	0.14
Tolsona Lake 2005	29	32	2.45	4.34	0.21	0.06
Susitna Lake 2002	182	238	0.70	0.32	0.07	0.06
Lake Louise 2005	83	409	0.33	0.51	0.02	0.04

APPENDIX D

Appendix D.–Mark-recapture histories of fully recruited (≥ 450 mm TL) burbot, Tolsona Lake, 1989-2005.

Event	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Date : Year	1989	1989	1990	1990	1991	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Beginning	5/22	9/11	5/22	9/05	5/20	9/09	6/11	5/20	6/01	5/23	6/05	5/27	5/19	6/01	6/06	5/29	6/04	5/19	5/18	5/16
Ending	5/24	9/13	5/24	9/07	5/23	9/12	6/13	5/22	6/03	5/25	6/07	5/29	5/21	6/03	6/08	6/31	6/06	5/21	5/20	5/18
Number of Fully Recruited Burbot:																				
Recaptured from Event 1	0	63	14	8	10	2	0	0	0	1	0	0	0	0	0	0	0	0	0	0
Recaptured from Event 2		0	22	9	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Recaptured from Event 3			0	21	15	2	2	0	0	1	0	0	0	0	0	0	0	0	0	0
Recaptured from Event 4				0	33	7	8	2	1	0	0	0	0	0	0	0	0	0	0	0
Recaptured from Event 5					0	35	14	8	1	0	1	0	0	0	0	0	0	0	0	0
Recaptured from Event 6						0	27	3	3	1	0	0	0	0	0	0	0	0	0	0
Recaptured from Event 7							0	6	7	6	0	1	1	0	0	0	0	0	0	0
Recaptured from Event 8								0	39	17	7	2	0	0	0	0	0	0	0	0
Recaptured from Event 9									0	27	3	2	0	0	0	0	0	0	0	0
Recaptured from Event 10										0	29	3	2	0	1	0	0	0	0	0
Recaptured from Event 11											0	11	6	3	1	0	0	0	0	0
Recaptured from Event 12												0	6	5	0	0	0	0	0	0
Recaptured from Event 13													0	24	23	4	5	0	0	0
Recaptured from Event 14														0	41	8	7	4	0	0
Recaptured from Event 15															0	21	16	10	6	2
Recaptured from Event 16																0	16	13	3	1
Recaptured from Event 17																	0	13	3	3
Recaptured from Event 18																		0	19	9
Recaptured from Event 19																			0	24
Recaptured from Event 20																				0
Captured with tags	0	63	36	38	63	48	51	19	51	53	40	19	15	32	66	33	44	40	31	39
Captured without tags	358	186	179	142	300	89	145	210	159	142	89	29	118	120	308	79	78	201	177	171
Captured	358	249	215	180	363	137	196	229	210	195	129	48	133	152	374	112	122	241	208	210
Released with tags	358	249	215	180	362	136	196	225	209	195	129	48	133	151	372	112	121	240	207	209

a Data was collected prior to 1989, but our current Jolly-Seber program is limited to 20 events. The lack of this information has no effect on the current abundance estimates.