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Stock Assessment and Biological Characteristics of Burbot in Tolsona Lake, 2008–2011.

by

Corey J. Schwanke

February 2014

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. 14-11

STOCK ASSESSMENT AND BIOLOGICAL CHARACTERISTICS OF BURBOT IN TOLSONA LAKE, 2008–2011.

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ABSTRACT

Stock assessments of burbot *Lota lota* were conducted annually at Tolsona Lake from 1986–2011. This report describes results of assessments conducted from 2008–2011, the final years of scheduled stock assessments for this population. Baited hoop traps were systematically set along random transects each spring to capture fish and to estimate abundance, CPUE, and length composition. Mean CPUE of fully recruited burbot (≥450 mm TL) per 48-h set was 6.00 (SE=0.70) in 2008, 8.34 (SE=0.82) in 2009, 5.53 (SE=0.73) in 2010 and 4.01 (SE=0.72) in 2011. Mean length of all burbot sampled was 517 mm TL (SD=75.4) in 2008, 535 mm TL (SD=65.4) in 2009, 537 mm TL (SD=63.0) in 2010 and 486 mm TL (SD=98.0) in 2011. Abundance of fully recruited burbot was estimated using a Jolly-Seber open population model. The model provides estimates lagged one year from date of sampling. Estimates were 1,080 (90% CI=828-1,332) in 2007, 1,847 (90% CI =1,429-2,265) in 2008, 3,291 (90% CI=2,519-4,063) in 2009 and 1,091 (90% CI=841-1,341) in 2010. The estimated abundance in 2009 was more than 1,200 fish than the previous highest abundance estimate for the lake. Since the abundance estimates exceeded 1,500 burbot in both 2008 and 2009, the Alaska Department of Fish and Game proposed reopening Tolsona Lake to sport fishing for burbot with a daily bag and possession limit of 2 fish, and in December 2011 the Alaska Board of Fisheries adopted the proposal reopening the lake to burbot retention starting 15 April 2012.

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

INTRODUCTION

OVERVIEW

Tolsona Lake lies within the Tazlina River drainage and is a relatively small and shallow lake with a surface area of 130 ha and a maximum depth of 5 m (Figure 1). Stock assessments of burbot at Tolsona Lake have been conducted annually since 1986 (Lafferty et al. 1990-1992; Lafferty and Bernard 1993; Parker et al. 1987-1989; Schwanke and Bernard 2005; Schwanke and Perry-Plake 2007; Schwanke 2009, Taube et al. 1994, 2000; Taube and Bernard 1995, 1999, 2001, 2004). These annual assessments were conducted to determine the population's status relative to prescribed management objectives.

Since 1986, several changes have been made to fishery regulations in Tolsona Lake, not all being exclusive to Tolsona Lake. Both bag limits and the number of allowable lines were reduced from 15 to 5 in 1987. The use of setlines was prohibited by emergency order in 1989 and by regulation in 1991. In 1998, Tolsona Lake was closed to burbot fishing by emergency order because of a significant decline in burbot abundance from 1994 to 1997. Annual sampling has indicated that the population has increased from the lows experienced in 1997 (Schwanke 2009). Continued assessment was recommended at Tolsona Lake until the burbot population recovered to a prescribed level capable of sustaining harvest.

The management strategy was that ADF&G would recommend reopening the fishery when the estimated abundance of fully recruited burbot was at least 1,500 for two consecutive years. It was estimated that 1,500 burbot could support a daily bag limit of 2 burbot. The Jolly-Seber model is the method used to estimate abundance and these estimates are lagged one year. For example, an annual sampling event conducted in 2009 would generate an abundance estimate for 2008 and information related to CPUE and length composition in 2009.

Tolsona Lake is relatively small (130 ha) and shallow (<5 m) and has the potential to frequently exceed the preferred temperature for burbot during summer, which is 18^{o}C (Scott and Crossman 1973). The lake may also be prone to reaching the lethal range for dissolved oxygen (DO) in late winter and early spring (Simpson 1997).

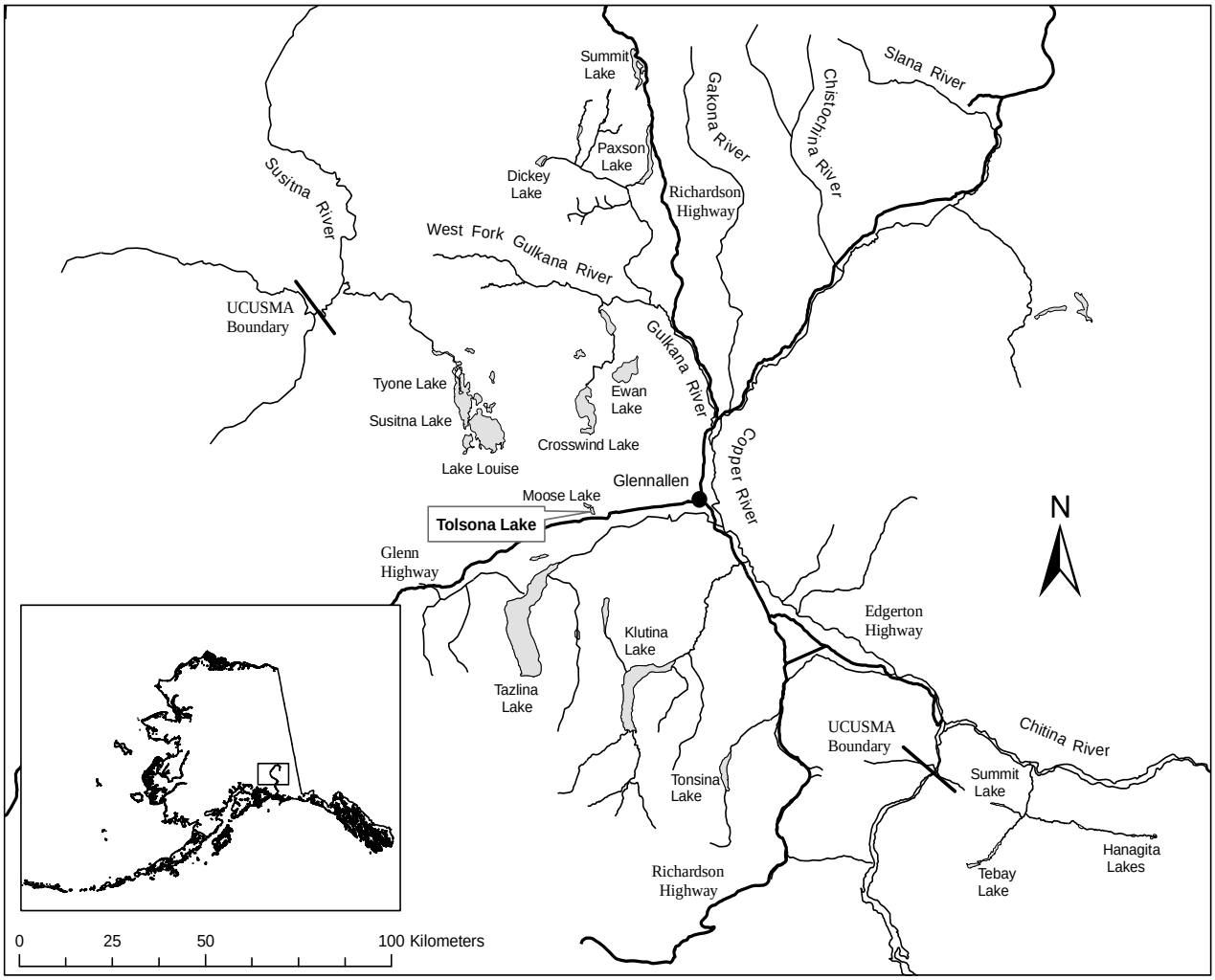

Figure 1.–Location of Tolsona Lake within the Upper Copper Upper Susitna Management Area.

OBJECTIVES AND TASKS

Specific objectives for 2008–2011 were to:

1. estimate the abundance of fully recruited burbot (≥450 mm TL) in Tolsona Lake for spring 2007–2010 such that the estimated abundance is within 30% of the true abundance 90% of the time;
2. estimate mean catch-per-unit of effort (CPUE) of burbot (≥450 mm TL) in Tolsona Lake for spring 2008–2011 such that the estimated mean CPUE is within ±50% of its asymptotic value 90% of the time; and,
3. describe the length composition of sampled fully recruited burbot (≥450 mm TL) at Tolsona Lake in spring 2008–2011.

Project tasks for 2008–2011 were to:

1. measure water temperature in Tolsona Lake throughout the open water period in all years.

METHODS

FISH CAPTURE

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 the lake. The number of transects selected to be sampled depended upon the number of traps to be set. Transects were randomly removed until the desired number of possible sets was equal to the number of sets planned to be made for that event (i.e., 60). All potential transects were approximately 125 m apart, and traps along transects were set approximately 125 m apart. A set was defined as a single hoop trap baited with Pacific herring *Clupea pallasi* fished for approximately 48 h.

After lifting a hoop trap, the catch was emptied into a holding tank and all burbot were measured for total length (TL) to the nearest 5 mm and examined for previous tags and secondary marks. All captured fish that were not previously tagged were marked with an individually numbered internal anchor tag (Floy™ FD-94) inserted into the musculature beneath the dorsal fin and given a secondary mark in the form of a fin clip. All fish that were previously tagged were still given a secondary mark for that sampling event. All tags were checked to ensure that they were locked between the pterygiophores of the dorsal fin. Specific secondary marks have been used in a three–year rotation to allow tag loss to be accounted for: partial excision of the right ventral fin (2008), a hole cut with a paper punch in the left operculum (2009), a partial excision of the left ventral fin (2010), and back to a partial excision of the right ventral fin (2011). A recaptured burbot exhibiting a secondary mark(s), but missing a tag, was considered to have been last captured during the most recent year the secondary mark was used.

Individual trap and associated catch information were recorded on standard hoop-net mark-sense forms (unpublished ADF&G manuscript, Anchorage, Alaska). Data forms were optically scanned and electronic data files (ASCII format) were produced for archival (Appendix A1) 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. Total length, tag number and color, secondary mark, fate, and recapture status 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).

STUDY DESIGN

From 1992–2006, Tolsona Lake was sampled once a year following a protocol: set approximately 60 traps in the spring as close to ice-out as possible and retrieve them approximately 48 hours later (Schwanke and Perry-Plake 2007). Annual catch data were used to estimate abundance for the previous year using the Jolly-Seber Model, as well as describe the length composition and estimate CPUE for the current year. This protocol changed during 2007–2011 when effort was doubled to improve precision (Table 1). Approximately 60 sets were still set after ice-out and were retrieved two days later (i.e., first pass). Once the last trap was pulled and the last captured fish released back into the lake, the sixty traps were reset on different transects for another two days (i.e., second pass). The first pass mimicked sampling protocol from prior years and were used to make the inter-annual comparisons of CPUE and length composition, and sets from both passes were pooled to estimate abundance.

Table 1.–Number of sets and dates of sampling events at Tolsona Lake, 2008–2011.

Year	Dates of Sampling Events	Pass #[a]	Number of Sets	Secondary Mark
2008	5/20-5/22	1	59	Right Ventral Fin
	5/22-5/24	2	55	Right Ventral Fin
2009	5/19-5/21	1	62	Opecular Punch
	5/21-5/23	2	57	Opecular Punch
2010	5/17-5/19	1	60	Left Ventral Fin
	5/19-5/21	2	60	Left Ventral Fin
2011	5/24-5/26	1	59	Right Ventral Fin
	5/26-5/28	2	60	Right Ventral Fin

[a] Two passes were made down the lake. The first was on random transects down the entire length of the lake. The second pass was on the remaining transects.

Abundance of fully recruited burbot during May of 2007–2010 was estimated by continuation of the Jolly-Seber model. The model also produced estimates of annual survival and recruitment rates between May of 2006, 2007, 2008, 2009 and 2010. Conditions for producing unbiased abundance, survival, and recruitment estimates with the Jolly-Seber model were:

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

Evaluation of Assumptions

Assumption 1: The year-long hiatus between events benefited the experiment by increasing mixing of marked and unmarked fish. Bernard et al. (1993) showed that adult burbot showed no depth preference during the open water period, that distribution across lakes was generally random (not aggregated), and that adult burbot moved rapidly and randomly across depths between surveys within the same season. They found that marked and unmarked burbot can completely mix in as little as 2–3 weeks with crude sampling densities of 0.9–3.6 ha/set. Traps at Tolsona Lake were placed approximately 125 meters apart, a sampling density of roughly 1 ha/set.

Assumption 2: This assumption was addressed by double marking each burbot with Floy tags and partial fin clips.

Assumption 3: Based on a meta-analysis from the sampling of several lakes over several years within the drainage, Bernard et al. (1991 and 1993), did not find any evidence of trap-induced behavior after 2–3 weeks.

Assumption 4: Bernard et al. (1993) found that burbot captured in traps set in water depths <15 m (Tolsona Lake is <5 m deep) showed no ill effects from being sampled and no evidence was

found indicating higher post sampling mortality with marked vs. unmarked burbot. There is no evidence to suggest that handling and tagging burbot affects their growth for any substantial period of time.

Assumption 5: Tolsona Lake no longer has passable inlets or outlets and these burbot are considered a closed population.

Water temperature was recorded hourly throughout the open water period with Hobo® Water Temp Pro temperature loggers. The loggers were suspended in the water column using a rope and buoy tethered to an anchor at the deepest part of the lake: one just off the lake bottom (~5 m), one mid column (~2.5 m) and one under the surface (~0.5 m). These temperatures were then plotted and compared to cited preferred and lethal temperatures for burbot.

DATA ANALYSIS

CPUE

CPUE was 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 for each pass down the lake following a two-stage sampling design with transects as first-stage units and sets along transects as second-stage units (Bernard et al. 1993; Sukhatme et al. 1984). Burbot that were captured in the second pass that were previously captured in the first pass were used in the CPUE analysis for each pass; however, these fish were not counted twice for the length composition or abundance estimation. 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:

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

where:

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

n = number of transects;

m_i = number of sets sampled on the ith transect;

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

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

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

Although the M_i and $\overline{M}$ are unknown, the m_i and 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 were:

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

Bernard et al. (1993) showed that the spacing of sets used in 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 and 1993), only mean CPUE for fully recruited burbot was considered as a valid index of abundance. However, mean CPUE of partially recruited burbot has provided insight to relative abundance of small fish in Tolsona Lake, likely because the lake is shallow and the entire lake bottom is sampled. CPUE from only the first pass of each event was used for annual comparisons, because captured burbot may require 2–3 weeks to fully adjust to the effects of capture and handling (Bernard et al. 1991).

Abundance Estimation

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). 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 were considered caught only once in this analysis to estimate abundance. Estimates of abundance are lagged one year and estimates of survival and recruitment are lagged two years from the most recent sampling event due to the nature of the model. Sampling during 2008–2011 (along with previous year's sampling) produced abundance estimates relative to 2007–2010.

RESULTS

2008

Burbot were sampled during 20–24 May 2008 (Table 1). A total of 549 burbot were sampled, 477 of which were fully recruited (Table 2). Of these fully recruited burbot, 76 had been previously captured at a fully recruited length (≥450 mm TL; Appendix B1). Five of these recaptured burbot exhibited tag loss, but the presence of secondary marks allowed the assignment of the year of last capture.

Table 2.–Mean length (mm TL) of burbot measured during sampling at Tolsona Lake, 2008–2011.

Date	Statistic	Partially Recruited[a]	Fully Recruited[a]	All
5/20–5/24, 2008	Mean	423	531	517
	SD	28.5	70.0	75.4
	Sample size	72	477	549
5/19–5/23, 2009	Mean	413	541	535
	SD	34.5	60.4	65.4
	Sample size	35	702	737
5/17–5/21, 2010	Mean	405	546	537
	SD	50.9	52.5	63.0
	Sample size	36	515	551
5/24–5/28, 2011	Mean	362	543	486
	SD	40.4	53.4	98.0
	Sample size	149	323	472

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

The mean length of fully recruited burbot was 531 mm TL (SD=70.0) and mean length of partially recruited burbot was 423 mm TL (SD=28.5; Table 2). The length frequency distribution of all fish captured during the first pass revealed the highest number of fish captured were 450-499 mm TL (Figure 2). There was a significant difference between the cumulative length frequency distribution of fully recruited burbot sampled between 2007 and 2008 (K-S two sample test; D=0.28, P<0.001; Figure 3). Mean CPUE of fully recruited burbot at Tolsona Lake during the first pass in 2008 was 6.00 (SE=0.70), while mean CPUE of partially recruited burbot was 0.93 (SE=0.28; Table 3). Mean CPUE for both fully and partially recruited burbot during the second pass dropped by 46% and 59%, respectively.

After the final sampling event conducted in spring 2011, the abundance of fully recruited burbot for spring 2008 was estimated at 1,847 (90% CI=1,429-2,265; Table 4; Figure 4). Survival between spring 2007 and spring 2008 was estimated as 58.9% (SE=7.0), while recruitment was estimated at 1,211 (SE=224; Appendix B2).

Hourly water temperatures were collected from 30 May to 29 September. Two of the water temperature loggers were missing so only temperatures from the middle of the water column were recovered. Water temperatures briefly exceeded the preferred temperature (i.e., <18°C) of burbot from 5–7 July with a maximum temperature of 19.03°C recorded (Figure 5). The water temperature was likely at least one degree cooler on the bottom.

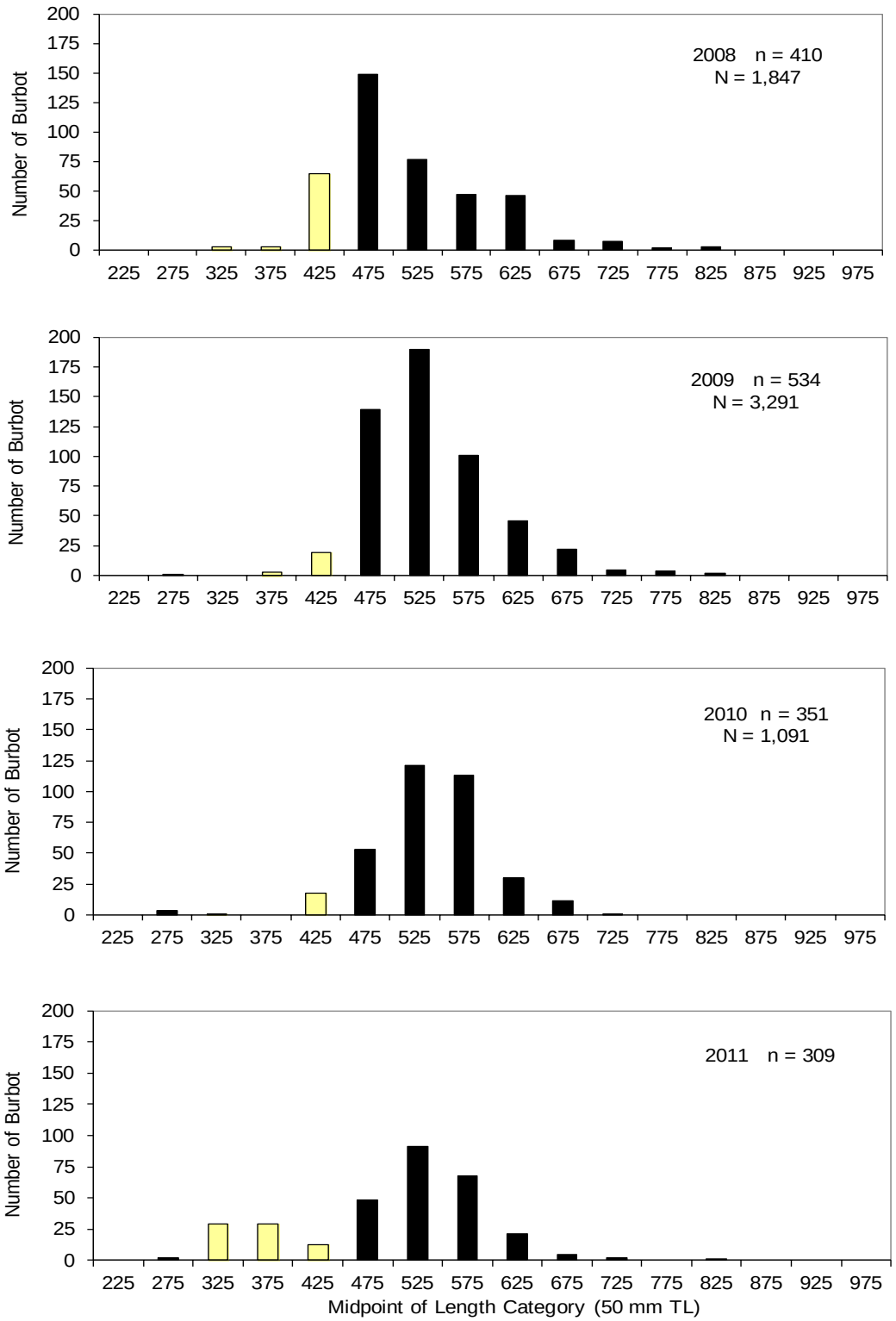

Figure 2.–Length histogram of burbot sampled from the first pass down Tolsona Lake, 2008–2011. Black bars represent fish fully recruited to the gear and light bars represent fish not fully recruited to the gear. N is the abundance estimate, n is the sample size.

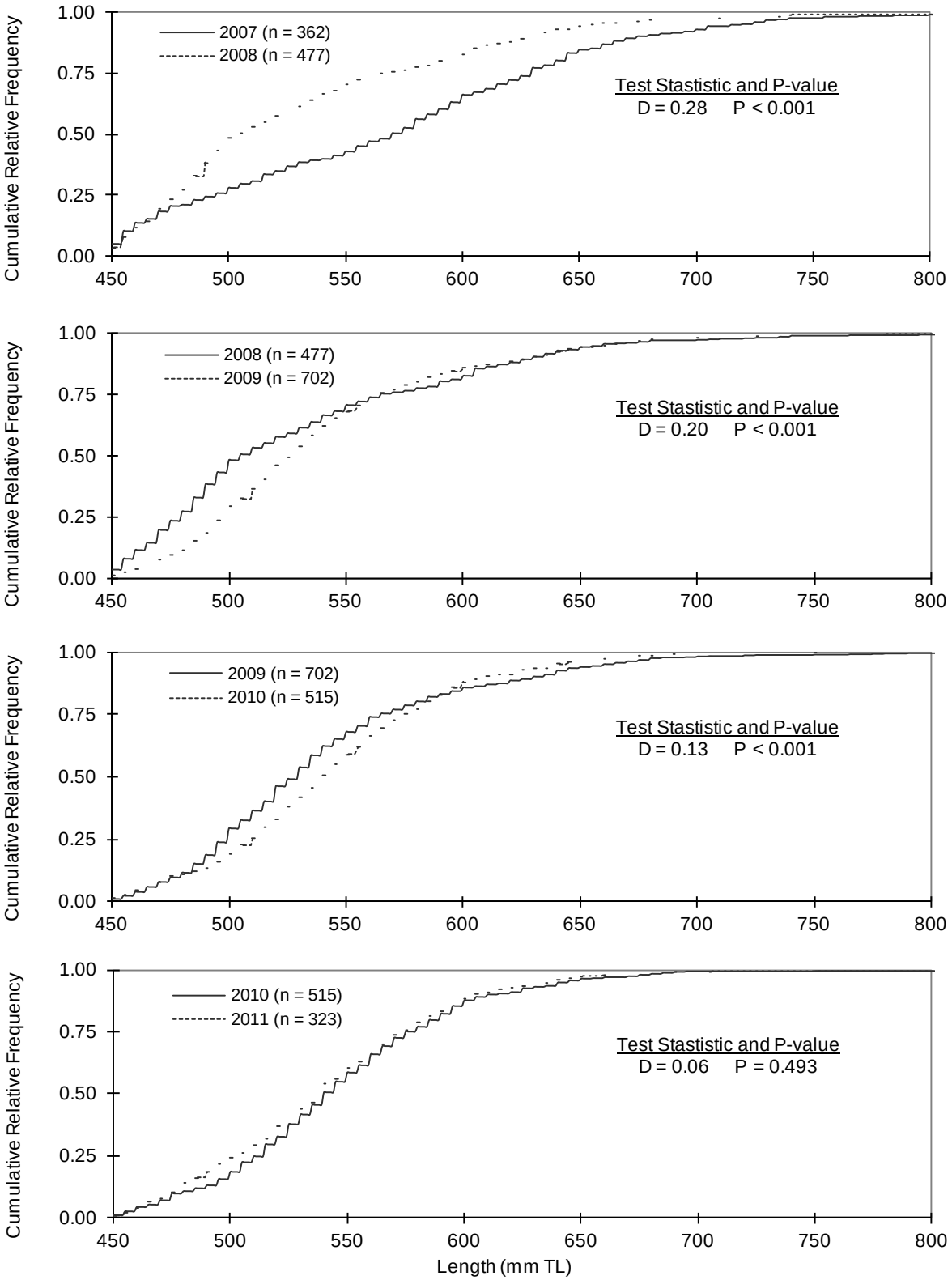

Figure 3.–Comparisons of cumulative relative frequency distributions of fully recruited burbot, 2008–2011.

Table 3.–Estimated mean CPUE of fully recruited (≥450 mm TL) and partially recruited (<450 mm TL) burbot in Tolsona Lake, 2008–2011.

				Mean CPUE		Bootstrapped	
Date and Pass #		Sets	Transects	Bootstrapped	Arithmetic	SE	CV
5/20/08–5/22/08	Fully recruited	59	10	6.05	6.00	0.70	11.6%
Pass 1	Partially recruited			0.92	0.93	0.28	30.8%
5/22/08–5/24/08	Fully recruited	55	9	3.20	3.22	0.44	13.8%
Pass 2	Partially recruited			0.39	0.38	0.14	35.2%
5/19/09–5/21/09	Fully recruited	62	10	8.32	8.34	0.82	9.9%
Pass 1	Partially recruited			0.29	0.29	0.12	40.4%
5/21/09–5/23/09	Fully recruited	57	9	4.55	4.56	0.68	14.9%
Pass 2	Partially recruited			0.30	0.30	0.08	25.2%
5/17/10–5/19/10	Fully recruited	60	11	5.51	5.53	0.73	13.3%
Pass 1	Partially recruited			0.32	0.32	0.13	40.2%
5/19/10–5/21/10	Fully recruited	60	9	4.06	4.07	0.42	10.4%
Pass 2	Partially recruited			0.28	0.28	0.08	45.7%
5/24/11–5/26/11	Fully recruited	59	10	4.02	4.01	0.72	17.9%
Pass 1	Partially recruited			1.22	1.21	0.26	21.2%
5/26/11–5/28/11	Fully recruited	60	10	1.63	1.65	0.29	17.6%
Pass 2	Partially recruited			1.28	1.28	0.25	19.5%

Table 4.–Estimated abundance and density of fully recruited (≥450 mm TL) burbot in Tolsona Lake, 2007–2010.

Date	Abundance	SE	90% CI	RP	Density (burbot/ha)
5/25/07–5/29/07	1,080	153	828-1,332	0.23	8.3
5/20/08–5/24/08	1,847	254	1,429-2,265	0.23	14.2
5/19/09–5/23/09	3,291	469	2,519-4,063	0.24	25.0
5/17/10–5/21/10	1,091	152	841-1,341	0.23	8.4

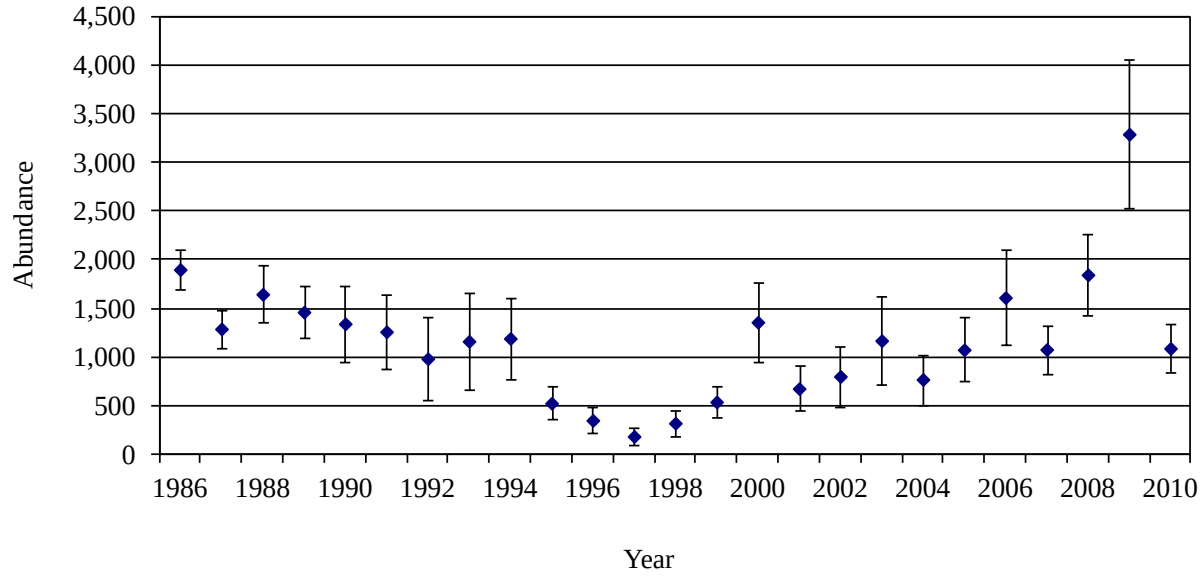

Figure 4.–Estimated abundance with 90% confidence intervals of fully recruited (≥450 mm TL) burbot in Tolsona Lake, 1986–2010. Abundance estimate for 1986 is from a within-season Petersen mark-recapture experiment. Estimates from 1987 to 2010 are from the Jolly-Seber method.

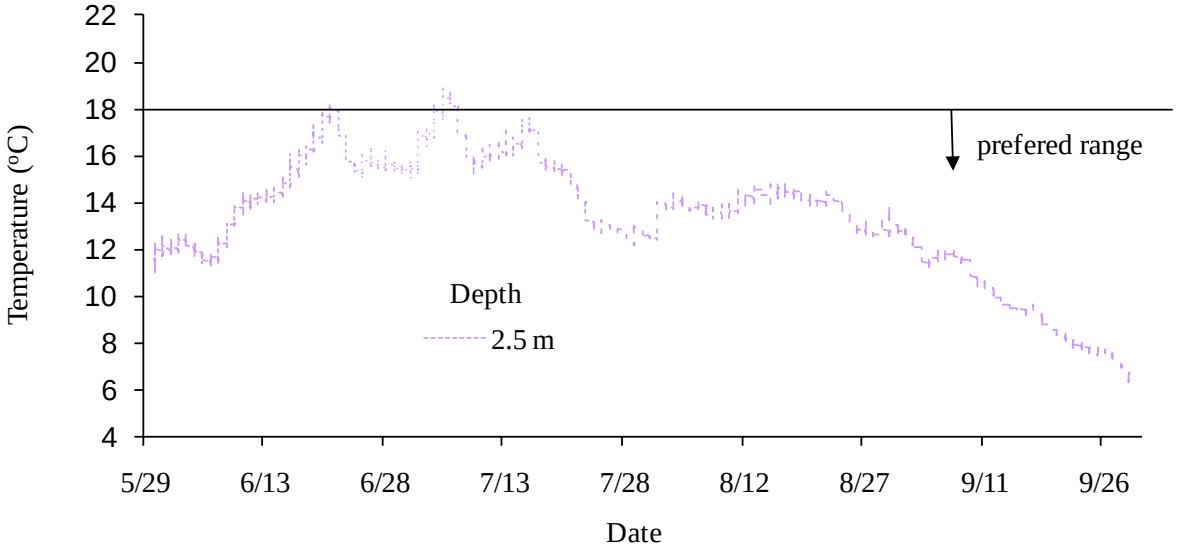

Figure 5.–Water temperature measurements from Tolsona Lake, 2008.

2009

Hoop traps were set from 19–23 May 2009 and 737 burbot were captured (Tables 1 and 2). Fully recruited burbot comprised 702 of these fish, 119 of which were previously tagged at a length ≥450 mm TL (Table 2; Appendix B1). Of these recaptured burbot, 14 exhibited tag loss but all had discernable secondary marks to determine the time they were last captured.

The mean length of fully recruited burbot was 541 mm TL (SD=60.4) and the mean length of partially recruited burbot was 413 mm TL (SD=34.5; Table 2). Burbot between 500 and 549 mm were the most frequent length category of all burbot sampled in the first pass (Figure 2). There was a significant difference in the cumulative length frequency distribution of burbot sampled in 2008 and 2009 (K-S two sample test; D=0.20; P<0.001; Figure 3). Mean CPUE of fully recruited burbot at Tolsona Lake during the first pass in 2009 was 8.34 (SE=0.82), while mean CPUE of partially recruited burbot was 0.29 (SE=0.12; Table 3). Mean CPUE for both fully and partially recruited burbot during the second pass dropped by 45% and increased by 3%, respectively.

After the final sampling event conducted in spring 2011, the abundance of fully recruited burbot for spring 2009 was estimated at 3,291 (90% CI=2,519-4,063; Table 4; Figure 4). Survival and recruitment between spring 2008 and spring 2009 was estimated as 80.2% (SE=10.5) and 1,808 (SE=367), respectively (Appendix B2).

Hourly water temperatures were collected from 21 May to 1 October 2009 from three positions in the water column: the bottom (4.5 m), the middle (2.5 m) and the top (0.5 m). There were two periods when the entire water column warmed to above 18°C: during 11–12 June and 9–21 July 2011 (Figure 6). The maximum temperature on the bottom (4.5 m) was recorded on 15 July as20.96°C, while the maximum reading for the middle of the water column (2.5 m) was recorded at 21.80°C on 14 July.

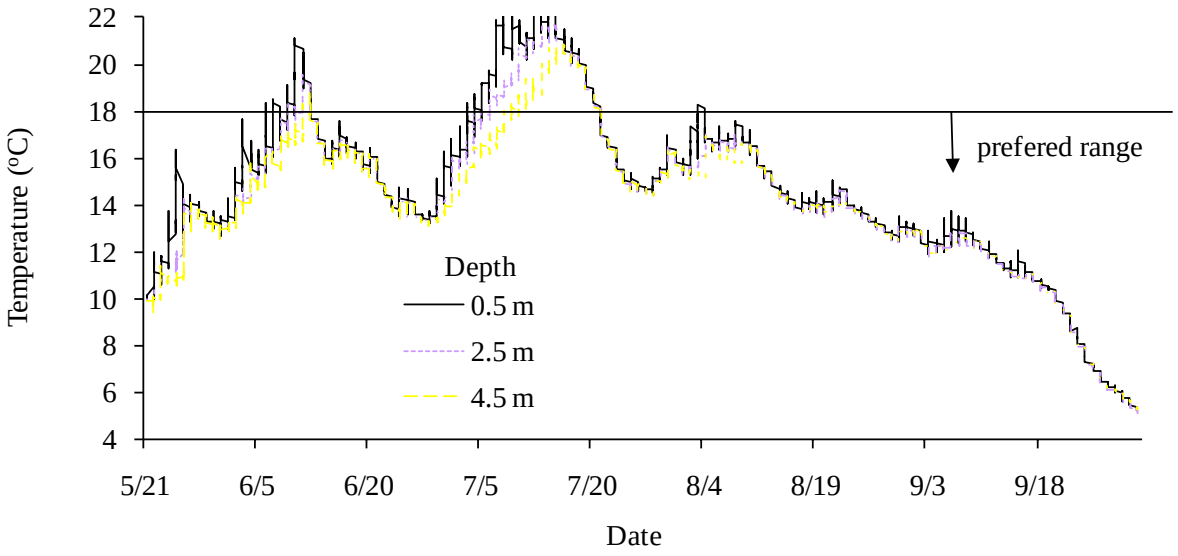

Figure 6.–Water temperature measurements from Tolsona Lake, 2009.

2010

Sampling took place during 17–21 May 2010 (Table 1). A total of 551 burbot were sampled, 515 of which were fully recruited (Table 2). Of these, 134 had been previously captured at a length ≥450 mm TL (Appendix B1), including 23 of which had tag loss, but year of last capture was assigned according to the presence of secondary marks.

Mean length of fully recruited burbot was 546 mm TL (SD=52.5) and mean length of partially recruited burbot was 405 mm TL (SD=50.9; Table 2). Burbot between 500 and 599 mm TL comprised about 75% of the entire catch during the first pass (Figure 2). A significant difference existed between the cumulative relative frequency of fully recruited burbot sampled in 2009 and 2010 (K-S two sample test; D=0.13, P<0.001; Figure 3). Mean CPUE during the first pass of the lake was 5.53 (SE=0.73) for fully recruited burbot and was 0.32 (SE=0.13) for partially recruited burbot (Table 3). Mean CPUE dropped for fully and partially recruited burbot during the second pass by 26% and 13%, respectively.

The final abundance estimate of fully recruited burbot was attained for spring 2010 (after sampling in 2011) and was 1,091 (90% CI=841-1,341; Table 4; Figure 4). Survival between spring 2009 and spring 2010 was estimated as 24.9% (SE=3.7), while recruitment was estimated at 272 (SE=106; Appendix B2).

In 2010, three water temperature recorders were deployed on 21 May and were all recovered on 27 September. During this time period, bottom depth (4.5 m) attained a maximum temperature of 16.75°C on 3 June (Figure 7). The middle of the water column (2.5 m) experienced a maximum temperature of 18.30°C on 3 August and remained above 18°C for only 5 hours.

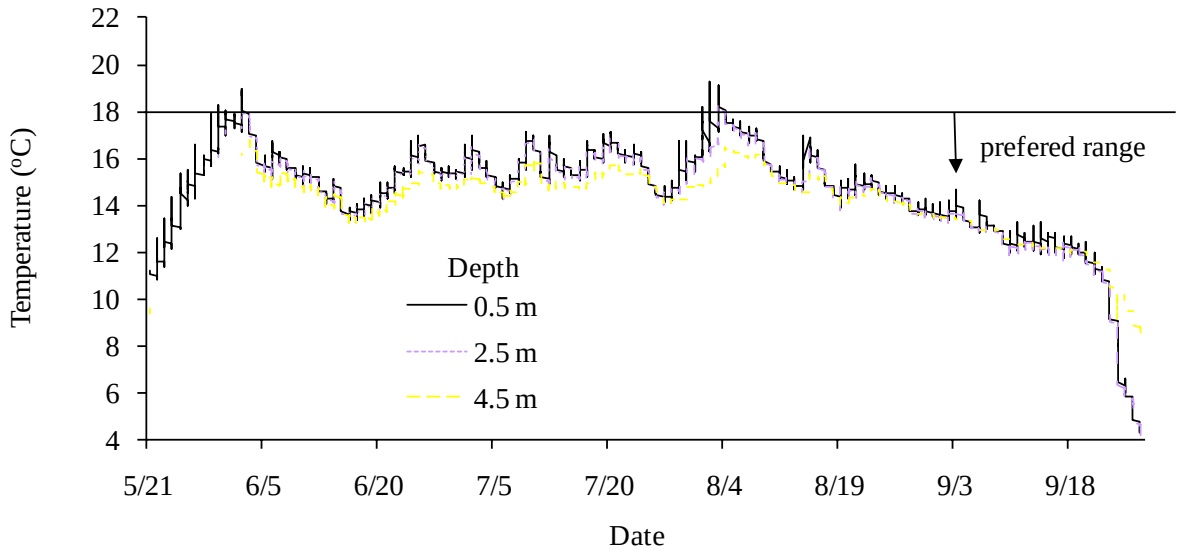

Figure 7.–Water temperature measurements from Tolsona Lake, 2010.

2011

Burbot were sampled during 24–28 May 2011 (Table 1). A total of 472 burbot were sampled, 323 of which were fully recruited burbot (Table 2). Of these, 87 had been previously captured at a fully recruited length (≥450 mm TL; Appendix B1). Six of these recaptured burbot experienced tag loss, but the presence of secondary marks allowed the determination of the last year of capture.

The mean length of fully recruited burbot was 543 mm TL (SD=53.4) and mean length of partially recruited burbot was 362 mm TL (SD=40.4; Table 2). Length distribution was bimodal with the largest peak occurring at the 500-549 mm TL category and a smaller peak of partially recruited burbot in the 300-399 mm TL class (Figure 2). There was not a significant difference between the cumulative length frequency distribution of fully recruited burbot sampled between 2010 and 2011 (K-S two sample test; D=0.06, P=0.493; Figure 3). Mean CPUE of fully recruited burbot at Tolsona Lake during the first pass in 2011 was 4.01 (SE=0.72), while mean CPUE of partially recruited burbot was 1.21 (SE= 026; Table 3). Mean CPUE of fully recruited burbot during the second pass dropped by 59%, but increased by 5% for partially recruited burbot.

No abundance estimate was attained for 2011 due to the one year lag in the Jolly-Seber model, nor were annual survival and recruitment estimates during spring 2009-2011.

In 2011, three water temperature recorders were deployed from 29 May and were all recovered on 29 September. During this time period, bottom depth (4.5 m) attained a maximum temperature of 17.03 °C on 23 July (Figure 8). The middle of the water column (2.5 m) experienced a maximum temperature of 19.13°C on 22 July and remained above 18°C for 22 hourly measurements during a two day period.

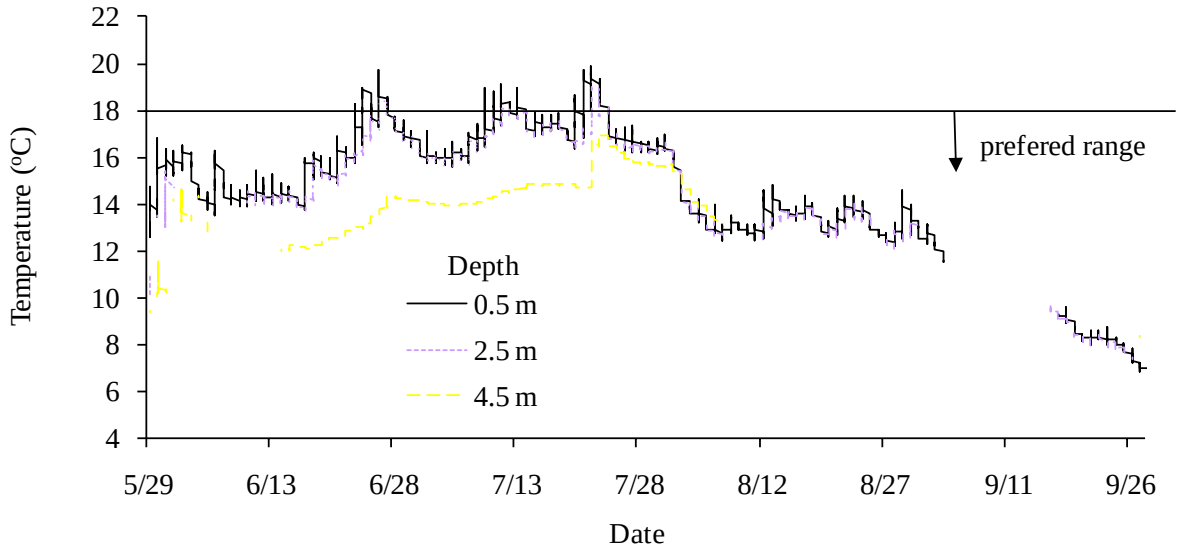

Figure 8.–Water temperature measurements from Tolsona Lake, 2011.

DISCUSSION

This report concludes the monitoring and estimation of fully recruited burbot at Tolsona Lake using the Jolly-Seber model. The abundance of fully recruited burbot in Tolsona Lake exceeded the threshold guideline (established in 2001) of 1,500 fish for two consecutive years (2008 and 2009; Table 4 and Figure 4) and the lake was reopened to sport fishing for burbot in April 2012 with a daily bag and possession limit of 2 burbot. After 26 consecutive years, no further stock assessments are scheduled because it is assumed that future harvests will be sustainable under the new fishing regulations.

The data accumulated since 1986 provide some insight relative to the factors affecting population size of fully recruited burbot in Tolsona Lake. The estimated abundances of fully recruited burbot have experienced considerable variation during a period with exploitation (1986–1997) and without exploitation (1998–2011; Figure 4; Appendix B2). During 1986–1994 abundance estimates appeared relatively stable with a slight downward trend until a dramatic decline was observed in 1995 continuing to 1997 when only 187 fully recruited burbot were estimated. After closing fishing for burbot in 1998, the population increased and far greater variation was seen with an impressive peak of 3,291 fully recruited burbot in 2009. The variables responsible for these observed variations (e.g., exploitation, competition, water temperature, dissolved oxygen, predation, etc.) and their interdependency are still unknown and cannot be accurately assessed. However, when examined together, the data relative to recapture histories, length frequency, CPUE of partially and fully recruited burbot, estimated abundance of fully recruited fish, and the parameter estimates from the Jolly-Seber model (i.e., recruitment and survival) are revealing.

Burbot in Tolsona Lake seem to be relatively short-lived with very few fish living past the ages of approximately 9–11 years. Burbot typically reach a sexually mature size of 450 mm TL at an age of 5 or 6 years old (Lafferty et al. 1990-1991; Parker et al. 1987-1989). In Tolsona Lake, the length histograms and individual recapture histories indicate that these burbot typically only live 4–5 years once reaching maturity (i.e., ≥450 mm TL; Figures 3 and 9). This relatively short life span in a small lake is likely contributing to the population swings documented at Tolsona Lake. Burbot appear longer lived in larger lakes and can commonly reach ages in the teens (Lafferty et al. 1990-1991; Parker et al. 1987-1989).

The catch of partially recruited burbot appeared to be a good predictor of cohort strength and the future recruitment of burbot ≥450 mm TL in Tolsona Lake (Figure 9), especially since the decline of the mid-1990s. The observed increases in the number and proportional catch of partially recruited burbot from 1997–1998, 2002–2003, 2006–2007 all translated to higher future abundances. If this predictor holds true, then the catch in 2011 indicated a very strong cohort of fish soon to be recruiting into population. In 2011, the proportion of fish 300-400 mm FL was relatively high, and more burbot <450 mm TL were sampled than during 2008, 2009, and 2010 combined (Table 2 and Figure 5).

The drastic decline in estimated abundance from 1994 to 1998 appears to have been caused by an aging population combined with poor recruitment. For the years 1994–1996, the length frequencies indicated very few burbot <450 mm present in the population (Figure 9), and by 1996, the majority of the sampled catch was composed of large fish (i.e., >600 mm TL). By 1997, these relatively old fish essentially disappeared, likely due to natural mortality, and no new fish ≥450 had recruited into the population. A strong push of smaller burbot 325-400 mm TL

appeared in the 1997 sample, but this cohort did not start recruiting into the population until 1999 and 2000 when the estimated abundance of burbot ≥450 mm TL increased to over 1,300 fish (Figures 4 and 9).

The Jolly-Seber model's estimates of recruitment support recruitment failure as the primary cause of the declines from 1995–1997. From 1993–1997, estimated recruitment was extremely low with an estimated 440 burbot recruiting to the population combined (Appendix B2). It is not known what caused this dismal recruitment. It may have been a result of unfavorable environmental conditions during spawning or the rearing period, fishing pressure, or a combination of both. Tolsona Lake was a popular burbot fishery in the 1980s through the early 1990s and estimated harvest was high at times (Table 5). The early harvest data (1983–1985) is not precise though because even though the lake was popular, it is a small lake and the number of respondents to the statewide mail in survey was relatively low. Further complicating our understanding of burbot harvest rates from Tolsona Lake, Moose Lake was combined with Tolsona Lake from 1986–1988 so estimated harvest from Tolsona Lake is undeterminable. Whether it was natural or human caused, it is evident that from 1987–1993 very few burbot >600 mm TL were present in the population (Figure 9). Regardless of the cause, this general lack of large, highly fecund fish may have contributed to poor reproduction and consequently poor recruitment that contributed to the abundance declines in the mid-1990s.

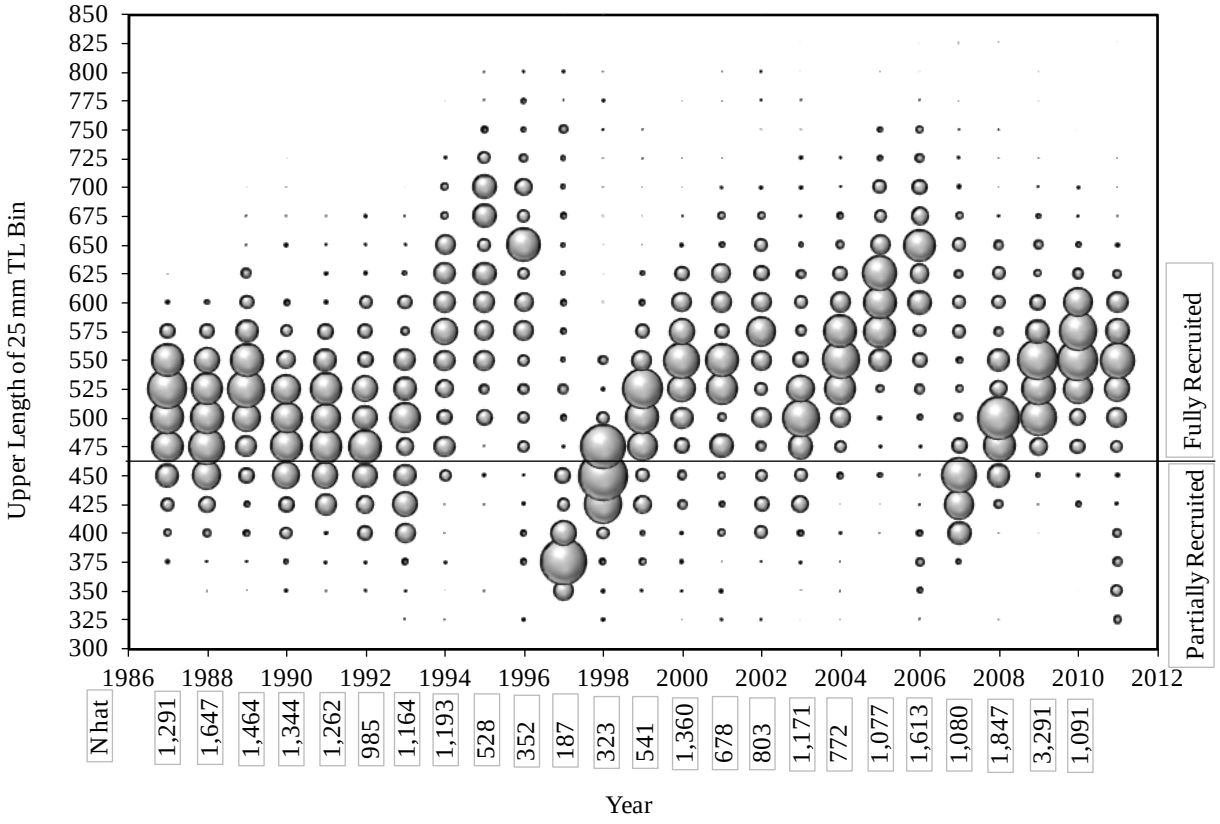

Figure 9.–Length composition of burbot sampled from spring sampling, 1987–2011. Diameter of the circles represent the proportion of the spring catch in a 25 mm TL category.

Table 5.–Estimated harvest of burbot, and number of respondents to the annual Statewide Harvest Survey, Tolsona Lake, 1983–1998.

Year	Estimated Harvest	Number of Respondents
1983	713	3
1984	1,864	4
1985	1,050	3
1986 [a]	1,243	15
1987 [a]	684	14
1988 [a]	73	18
1989	94	17
1990	408	13
1991	102	18
1992	127	23
1993	21	17
1994	93	18
1995	23	17
1996	81	14
1997	0	5
1998	0	9

[a] For these years, Moose Lake was grouped with Tolsona Lake so the estimates of harvest and number of respondents are for both lakes combined. Data is from Mills (1984-1994) and Howe et al. (1995-1996, 2001a-c).

In the absence of adequate data (e.g., age structure or biomass of juvenile fish) carrying capacity is difficult to determine, even more so when environmental conditions that can easily affect carrying capacity on such a small lake are unknown as well. However, our data did provide insight. In 2009 when the population of fully recruited burbot eclipsed 3,000 fish, there was an almost 70% decrease in the estimated abundance the following year when the lake was closed to burbot fishing. It is doubtful that senescence of older fish was a significant factor since the majority of the fish sampled in 2009 were between 450 and 550 mm TL (Figure 2) and had only recently recruited to the population of inference (i.e., 450 mm TL). It is probable that carrying capacity was breeched in 2009.

The annual sampling for the Jolly-Seber model was discontinued after May of 2011, but if the burbot population is ever monitored again, it is recommended that CPUE be initially used as an index of abundance. Catch per unit effort of 60 hoop traps set for approximately 48 hours in spring immediately after ice-out has proven to be a good index of abundance of fully-recruited burbot in Tolsona Lake (Figure 10). If a future spring sampling event reveals a weak index, a fall sampling event should take place and abundance be assessed with a Petersen two-event mark recapture technique. A CPUE of <2.2 was attained during spring sampling at Tolsona Lake on five occasions (1996–1998 and 2001–2002) and the corresponding abundances ranged from 187-803 fully recruited burbot. Any spring CPUE near this level should serve as a trigger point to warrant fall sampling to conduct an unbiased abundance estimate.

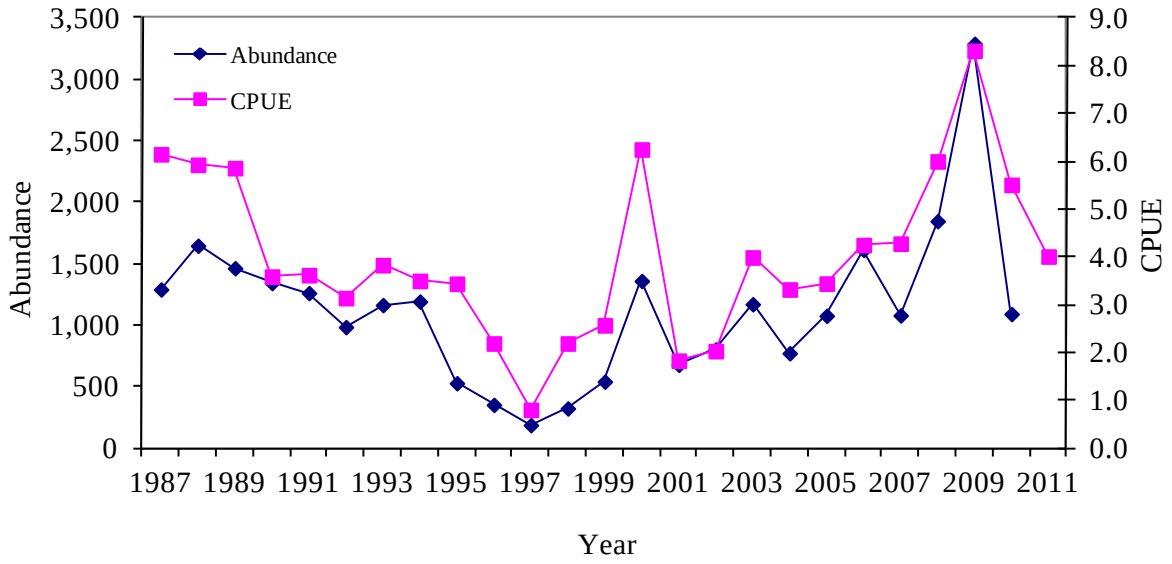

Figure 10.–Comparisons of Jolly-Seber abundance estimates and CPUE estimates, Tolsona Lake, 1987–2011.

Prior to any changes in fishing regulations, the department should consider other things than merely abundance. Sampling from 1998–2011 documented the propensity of Tolsona Lake burbot abundances to experience swings in abundance due to natural variations. The population has demonstrated that it can readily recover from a disturbingly small population size, as was observed in 1997, and that short term, reactionary changes in the regulations are unnecessary. In hindsight, the population may have easily recovered from what was observed in 1997 and carrying capacity may not have been exceeded had harvest been permitted all along. Natural variation, the length composition of the catch, particularly for burbot <450 mm TL (i.e., predictor of future recruitment), estimated harvests from the SWHS, and anecdotal information from the angling public are good metrics to consider prior to any regulatory actions.

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APPENDIX A:
DATA FILE ARCHIVES

Appendix A1.–Summary of data archives.

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

File Name	Data Format	Software
i-039800h012008.dta	Hoop net	RTS-ASCII
i-039800h012009.dta	Hoop net	RTS-ASCII
i-039800h012010.dta	Hoop net	RTS-ASCII
i-039800h012011.dta	Hoop net	RTS-ASCII
2011 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.

APPENDIX B:
HISTORICAL TOLSONA LAKE SAMPLING INFORMATION

Appendix B1.–Mark-recapture histories of fully recruited (≥450 mm TL) burbot for the last 20 sampling events, Tolsona Lake, 1992–2011.

Date : Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Beginning	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	5/31	5/25	5/20	5/19	5/17	5/24
Ending	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	6/02	5/29	5/24	5/23	5/21	5/28
Recaptured from Event 1	0	6	7	6	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Recaptured from Event 2		0	39	17	7	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Recaptured from Event 3			0	27	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Recaptured from Event 4				0	29	3	2	0	1	0	0	0	0	0	0	0	0	0	0	0
Recaptured from Event 5					0	11	6	3	1	0	0	0	0	0	0	0	0	0	0	0
Recaptured from Event 6						0	6	5	0	0	0	0	0	0	0	0	0	0	0	0
Recaptured from Event 7							0	24	23	4	5	0	0	0	0	0	0	0	0	0
Recaptured from Event 8								0	41	8	7	4	0	0	0	0	0	0	0	0
Recaptured from Event 9									0	21	16	10	6	2	2	1	0	0	0	0
Recaptured from Event 10										0	16	13	3	1	0	0	1	0	0	0
Recaptured from Event 11											0	13	3	3	1	0	0	0	0	0
Recaptured from Event 12												0	19	9	4	1	1	0	0	0
Recaptured from Event 13													0	24	21	9	3	3	0	1
Recaptured from Event 14														0	23	22	13	1	1	0
Recaptured from Event 15															0	38	8	4	2	0
Recaptured from Event 16																0	50	35	9	1
Recaptured from Event 17																	0	76	43	3
Recaptured from Event 18																		0	79	15
Recaptured from Event 19																			0	67
Recaptured from Event 20																				0
Captured with tags	0	6	46	50	39	19	15	32	66	33	44	40	31	39	51	71	76	119	134	87
Captured without tags	196	223	164	145	90	29	118	120	308	79	78	201	177	171	205	291	401	583	381	236
Captured	196	229	210	195	129	48	133	152	374	112	122	241	208	210	256	362	477	702	515	323
Released with tags	196	225	209	195	129	48	133	151	372	112	121	240	207	209	255	361	477	700	514	320

Appendix B2.–Estimates of population parameters of fully recruited (≥450 mm TL) burbot in Tolsona Lake, 1986–2011.

	Days between		Abundance			Survival Rate %		Recruitment	
Date	events	CPUE	Estimate	SE	CV %	Estimate	SE	Estimate	SE
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					102.7	17.1	805	197
6/08/00		6.25	1,360	247	18.2				

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Date	Days between events	CPUE	Abundance			Survival Rate %		Recruitment	
			Estimate	SE	CV %	Estimate	SE	Estimate	SE
	356					37.0	6.6	176	114
5/31/01		1.83	678	139	20.5				
	371					102.5	24.5	108	133
6/06/02		2.03	803	192	23.9				
	348					52.1	13.8	753	219
5/21/03		4.02	1,171	279	23.8				
	364					29.4	5.7	428	142
5/20/04		3.36	772	157	20.3				
	363					69.2	10.4	544	188
5/18/05		3.45	1,077	200	18.6				
	377					86.7	14.2	679	249
5/31/06		4.25	1,613	298	18.5				
	361					40.1	6.1	434	135
5/27/07		4.29	1,080	153	14.2				
	358					58.9	7.0	1,211	224
5/20/08		6.00	1,847	254	13.8				
	364					80.2	10.5	1,808	367
5/19/09		8.34	3,291	469	14.2				
	363					24.9	3.7	272	106
5/17/10		5.53	1,091	152	13.9				
	370								
5/22/11		4.01							