Fishery Data Series No. 96-30

Burbot Research in Rivers of the Tanana River Drainage and at Fort Knox, 1995

by

Matthew J. Evenson

October 1996

Alaska Department of Fish and Game

Division of Sport Fish

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
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd
Spell out acre and ton.	

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s
Spell out year, month, and week.	

Physics and chemistry

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

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
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
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

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	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
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.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
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
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES NO. 96-30

BURBOT RESEARCH IN RIVERS OF THE TANANA RIVER DRAINAGE AND AT FORT KNOX, 1995

by

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ABSTRACT

As part of an ongoing stock assessment program, burbot were sampled in two river sections (approximately 25 km in length), one each in the Tanana and Chena rivers, representing the area where most fishing harvest occurs. These sections have been sampled annually since 1986 and 1988, respectively. A systematic sampling design was used, whereby hoop traps were set and moved daily over an eight day period. Estimates of mean catch per unit effort, mean length, length distributions, and proportions of catch for three size categories were calculated. Estimates for each were within the range of observed values from previous sampling years. Seasonal variations in catch rate and composition was cited as a problem in interpreting these annual estimates. Suggestions for improving the study design to alleviate seasonal catch variability are given.

Catch-age analysis was used to combine harvest estimates from a statewide mail survey and age composition from catch sampling with auxiliary information in the form of angler effort to estimate exploitable abundance of burbot in the Tanana River drainage. The CAGEAN model results showed a decreasing trend in exploitable abundance from 1987 to 1994, which corresponds to a trend in increased fishing mortality during that time. Catch-age analysis appears to be a promising method for estimating trend in abundance for burbot in the Tanana River drainage, but improvements in the catch sampling program and more accurate estimates of fishing effort are needed to improve accuracy of the estimates.

Mark-recapture experiments were conducted in two small settling ponds in the Fort Knox gold mining project to estimate abundance of burbot. The settling pond complex in the Fish Creek drainage was developed into a 67 ha reservoir, and was completed in May, 1996. These estimates represent the total abundance of burbot in the reservoir prior to its completion. Estimated abundance of burbot greater than 120 mm total length was 360 (SE = 90) in Polar #1 Pond, and 486 (SE = 63) in Polar #2 Pond. Total abundance in waters comprising the freshwater reservoir was 846 (SE = 91) burbot. Mean length at age (ages 2-5) and length frequency distributions are presented.

Key words: burbot, *Lota lota*, hoop traps, Tanana River, Chena River, catch per unit effort, mean length, mark-recapture, catch-age analysis, CAGEAN, exploitable abundance, fishing mortality.

CHAPTER 1. INDEX SAMPLING IN THE CHENA AND TANANA RIVERS, 1995

INTRODUCTION

Research concerning burbot *Lota lota* stocks in flowing waters of the Tanana River system has been ongoing since 1983. The objectives of this research program have been to determine biological characteristics such as size, age, and density distributions, identify migratory and reproductive behavior, examine spawning characteristics, monitor harvests, and determine characteristics of the sport fishery. Results of this research have been published in a number of documents (Hallberg 1984 - 1986; Hallberg et al. 1987; Guinn and Hallberg 1990; Evenson 1988, 1989, 1990a, 1990b, 1991, 1992, 1993a, 1993b, 1994, Evenson and Hansen 1991; Evenson and Merritt 1995; Clark et al. 1991; Bernard et al. 1991).

Initially, this research sought to identify individual stocks by studying movements throughout the system in an attempt to delineate ranges. This was accomplished through a rigorous sampling program which marked and subsequently recaptured burbot in the mainstream Tanana River and in many tributary streams. More recently (Evenson 1993b), radio telemetry was used to monitor seasonal movements and identify spawning concentrations in attempt to refine stock definitions. This information indicated that movements were frequent and extensive throughout the system, and that for management purposes, the entire drainage should be considered a single stock (Evenson 1989 and 1990a).

Assessment of this stock has been accomplished by estimating abundance through mark-recapture experiments, relative abundance through mean catch per unit effort (CPUE) and length compositions for many river sections throughout the system using a standardized design. These estimates have been obtained annually or semi-annually for important river sections (areas of large harvest such as the Chena and Tanana rivers near the city of Fairbanks). This assessment has indicated that annual exploitation is low relative to abundance for the entire system. Thus, the stock assessment research has been reduced, and is focused toward those river sections where a substantial harvest occurs.

Since 1986, when extensive stock assessment sampling began, a number of estimates of abundance, CPUE, and mean length have been obtained. Estimates from 1986 through 1994 are summarized by Evenson and Merritt (1995). The purpose of this investigation was to continue stock monitoring in the Tanana and Chena rivers near Fairbanks. The specific objective was to estimate mean CPUE of burbot for each of three length categories (small: 300-449; medium: 450-799; and, large: 800 mm TL and larger) in one 24 km section of the Tanana River and in one 24 km section of the Chena River. In addition, other statistics regarding length compositions are presented and compared to previous years data.

STUDY AREA

The Tanana River is of glacial origin flowing over 900 km and draining 115,255 sq. km. The study areas in this investigation included a 24 km section of the Tanana River extending downstream from the confluence of the Chena River, and a 27 km section of the Chena River extending upstream from it's confluence with the Tanana River (Figure 1). These same two sections have been sampled annually since 1986 and 1988, respectively, using a similar sampling design.

METHODS

Gear Description

Burbot were captured in commercially available hoop traps. Two sizes of traps have been used during the past eight years. The larger of the two traps were used during all years prior to 1988, while the smaller traps were used in all following years. Bernard et al. (1991) provides a comprehensive account of the efficacy of both large and small traps. In general, both sizes are effective at catching burbot greater than 300 mm total length (TL), however burbot do not fully recruit to either gear until 450 mm TL. For all lengths 800 mm and larger, large traps are more effective than small traps. Small hoop traps were chosen as a sampling gear beginning in 1988 because they are more easily transported, and more traps can be deployed during a sampling day.

Small hoop traps were 3.05 m long with seven 6.35 mm steel hoops (Figure 2). Hoop diameters tapered from 0.61 m at the entrance to 0.46 m at the cod end. Each trap had a double throat (tied to the second and fourth hoops) which narrows to an opening 10 cm in diameter. All netting was knotted nylon woven into 25 mm bar mesh, bound with No. 15 cotton twine, and treated with an asphaltic compound. Each trap was kept stretched with two sections of 19 mm polyvinyl chloride (PVC) pipe attached by snap clips to the end hoops.

Large hoop traps were of similar design, but were 3.66 m long, and had fiberglass hoops with inside diameters tapering from 0.91 to 0.69 m (Figure 2). Throat diameters were 0.36 m. Spreader bars made from PVC were also used to keep the traps stretched.

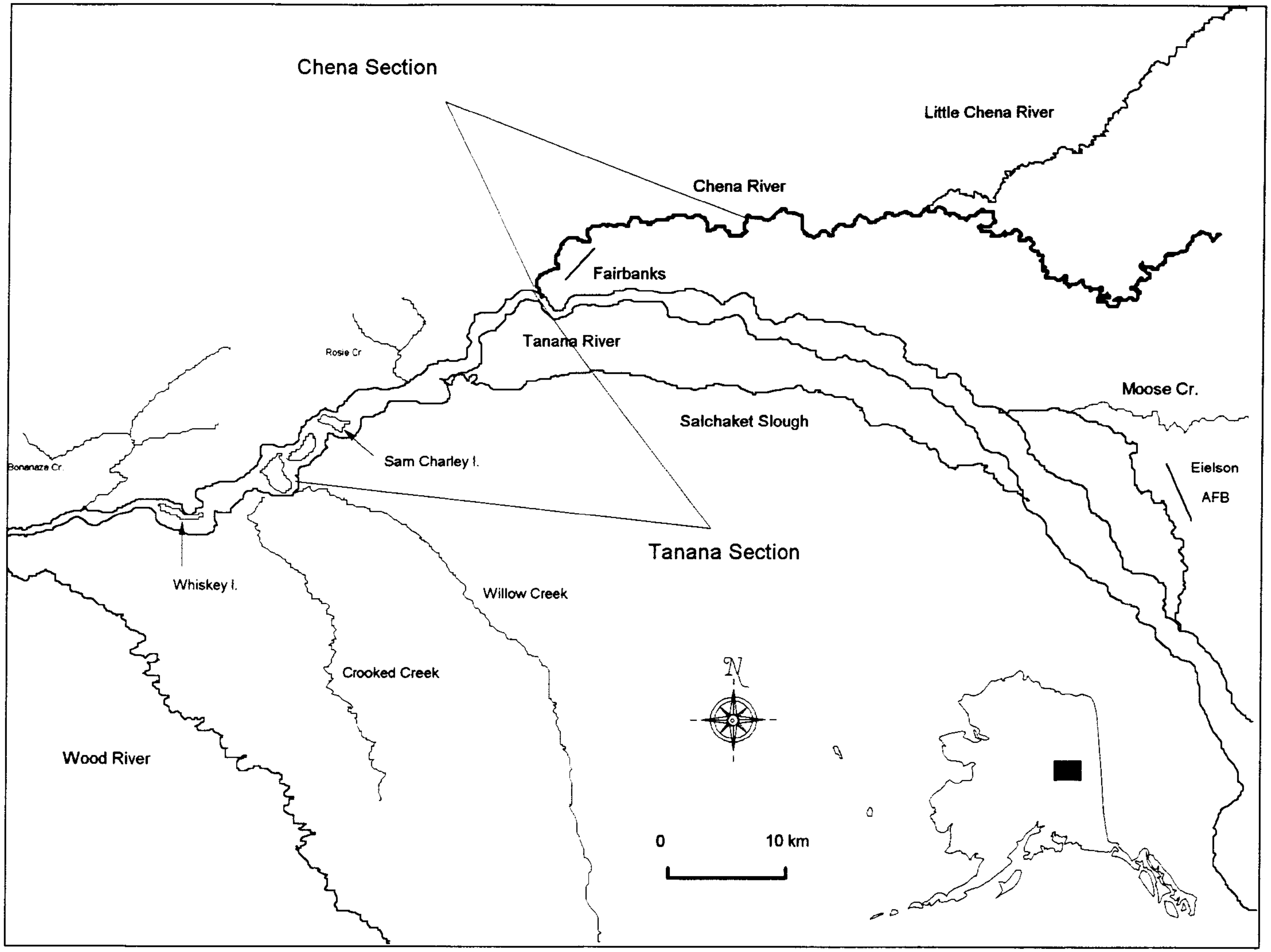

Figure 1.-Map of the Tanana River drainage showing sample sections during 1995.

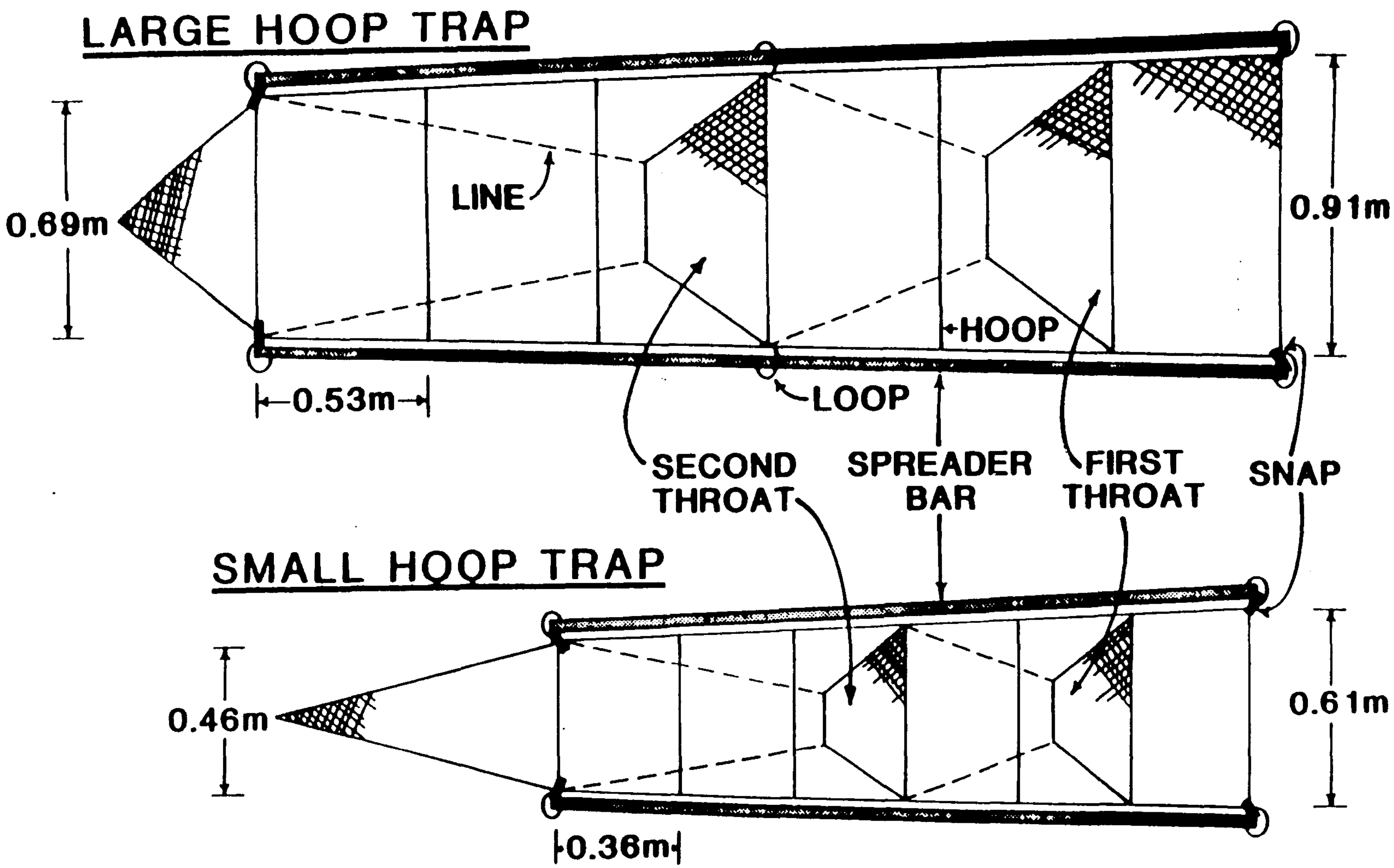

Figure 2.-Diagrams of large and small hoop traps used to catch burbot in flowing waters of the Tanana River drainage.

Hoop traps were baited with cut Pacific herring *Clupea harengus* placed in perforated plastic containers. One end of a five to 10 m section of polypropylene rope was tied to the cod end of each trap, while the other end was tied off to shore. The traps then fished on the river bottom near shore with the opening facing downstream. An outboard-powered riverboat was used to set, move, and retrieve the traps.

Study Design

The sampling design used one crew of two persons over a period of two weeks. A systematic sampling design was used whereby traps were set along both shores at near equal intervals beginning at the most downstream end of the section and progressing to the most upstream end of the section. Traps were set at a density of 1.5 traps per kilometer per day. All traps were fished for approximately 24 hours, were rebaited, and were moved each day. All trap locations were marked on 1:63,360 USGS maps and were recorded to the nearest kilometer. All burbot captured were measured for total length (TL) to the nearest millimeter, and were tagged using individually numbered Floy internal anchor tags. All fish were released at the capture site.

Data Analysis

Due to the size selectivity of hoop traps described above, estimates of mean CPUE and length composition statistics described below are given for three length strata: "small" (≤450 mm TL) "medium" (450-799 mm TL) and "large" (≥800 mm TL).

Catch per Unit Effort

Mean CPUE for each river section and its associated variance were calculated from the number of burbot caught per net-night for all traps set during each sampling period based upon the following equations from Wolter (1984):

$$\overline{CPUE_c} = \overline{X}_c = \frac{\sum_{h=1}^{t} X_{ch}}{t} \qquad (1)$$

$$V\left[\overline{CPUE_c}\right] = \frac{\sum_{h=2}^{t} (X_{ch} - X_{ch-1})^2}{2t(t-1)} \qquad (2)$$

where:

X_{ch} = catch of burbot of size class c in hoop trap h (h=1 to t where h=1 the most downstream set and h=t the most upstream); and,

t = the total number of hoop traps in a river section.

All estimates of mean CPUE are given in units of number of burbot per net per overnight set, or burbot per net-night (bb/nn).

Length Composition

Length compositions of burbot sampled in these two sections were examined using three methods. Mean lengths and proportions of total catch for each of the three size categories were calculated. In addition, length distributions for various sampling years were plotted and compared.

Mean length and its associated variance was also calculated for three length categories as:

$$\bar{l}_a = \sum_{b=1}^{n} \frac{l_{ab}}{n_a} \tag{3}$$

$$V[\bar{l}_a] = \sum_{b=1}^{n} \frac{(l_{ab} - \bar{l}_a)^2}{n_a(n_a - 1)} \tag{4}$$

where:

l_{ab} = length of burbot b in category a; and,
n_a = number of samples in length category a.

All estimates of mean length are expressed to the nearest millimeter of total length (TL).

Proportions of total catch for each length category and associated variances were calculated as:

$$\hat{P}_z = \frac{n_z}{n} \tag{5}$$

$$V[\hat{P}_z] = \frac{\hat{P}_z(1 - \hat{P}_z)}{n - 1} \tag{6}$$

$\hat{P}_z$ = the estimated proportion of burbot in category z;
n_z = number of samples in length category z; and,
n = the total number of burbot in the sample.

Data files regarding burbot stock assessment in these two river sections for all sampling done since 1986 are listed in Appendix A.

RESULTS

In the Tanana River during 1995, a total of 383 burbot were caught with 303 net-nights of effort. Estimates of mean CPUE were 0.61 bb/nn (SE = 0.07) for small burbot, 0.64 bb/nn (SE = 0.06) for medium burbot, and 0.01 bb/nn (SE = 0.01) for large burbot. In the Chena River, a total of 334 burbot were caught with 273 net-nights of effort. Estimates of mean CPUE were 0.28 bb/nn (SE = 0.04) for small burbot, 0.91 bb/nn (SE = 0.08) for medium burbot, and 0.03 (SE = 0.01) for large burbot.

A summary of annual CPUE estimates for these two sections is shown in Table 1. The mean CPUE estimates from 1995 in the Tanana River section for medium burbot was greater than the 1994 estimate, but was within the range of estimates from previous years. The mean CPUE estimate for small burbot was among the highest on record. Mean CPUE estimates for large burbot are typically low compared to those of medium and small burbot, however the 1995 estimate was at the lower end of observed values. Mean CPUE estimates in the Chena River in 1995 were also within the observed range of estimates from previous years for all size categories, but were all higher than the previous four years' estimates.

Table 1.-Catch per unit effort (CPUE) estimates of burbot sampled in sections of the Tanana and Chena rivers, 1986-1995.

River Sampling Dates	Year	km Sampled	Trap Size	Net Nights	Small (300-449 mm TL) Catch	CPUE	SE	Medium (450-799 mm TL) Catch	CPUE	SE	Large (≥800 mm TL) Catch	CPUE	SE	Medium + Large (≥450 mm TL) Catch	CPUE	SE
Tanana River																
07/29-08/02	1986[a]	334-352	Large	99	51	0.52	NA[b]	94	0.95	NA	7	0.07	NA	101	1.02	NA
08/11-08/15	1986[a]	334-352	Large	128	42	0.33	NA	57	0.45	NA	3	0.02	NA	60	0.47	NA
07/22-07/25	1987[a]	339-354	Large	77	22	0.29	0.02	41	0.53	NA	6	0.08	NA	47	0.61	0.09
07/28-07/31	1987[a]	339-354	Large	106	70	0.66	0.10	73	0.69	NA	6	0.06	NA	79	0.75	0.09
08/04-08/07	1987[a]	339-354	Large	79	24	0.30	0.08	45	0.57	NA	2	0.03	NA	47	0.59	0.10
08/18-08/21	1987[a]	339-354	Large	183	46	0.25	0.05	178	0.97	NA	14	0.08	NA	192	1.05	0.11
07/06-07/09	1988	312-376	Small	268	159	0.59	0.05	144	0.54	NA	1	<0.01	NA	145	0.54	0.05
06/13-06/16	1989	317-374	Small	237	137	0.58	0.06	125	0.53	NA	6	0.03	NA	131	0.55	0.05
08/14-08/16	1990	344-376	Small	90	44	0.49	0.10	96	1.07	NA	4	0.04	NA	100	1.11	0.12
07/11-07/17	1991	336-360	Small	310	97	0.31	0.04	247	0.80	0.07	3	0.01	0.01	250	0.81	0.07
08/24-08/28	1992	336-360	Small	277	57	0.21	0.03	266	0.96	0.08	16	0.06	0.01	282	1.02	0.08
06/08-06/11	1993	336-360	Small	257	85	0.32	0.04	175	0.67	0.05	6	0.02	<0.01	181	0.70	0.05
06/07-06/17	1994	336-360	Small	317	157	0.50	0.05	173	0.55	0.05	4	0.01	0.01	177	0.56	0.05
06/13-06/23	1995	330-360	Small	303	184	0.61	0.07	195	0.64	0.06	4	0.01	0.01	199	0.66	0.06
Chena River																
09/07-09/09	1988	0-24	Small	88	23	0.32	0.08	65	0.90	0.13	0	0	0	65	0.90	0.13
06/12-06/15	1990[a]	0-24	Small	232	14	0.06	0.02	16	0.07	NA	0	0	0	16	0.07	0.02
08/21-08/24	1990[a]	0-24	Small	204	41	0.20	0.04	82	0.40	NA	1	<0.01	NA	83	0.41	0.06
08/27-08/31	1990[a]	0-24	Small	203	59	0.29	0.04	204	1.00	NA	1	<0.01	NA	205	1.01	0.11
09/06-09/07	1990[a]	0-24	Small	73	26	0.36	0.03	90	1.23	NA	0	0	0	90	1.23	0.09
09/27-09/28	1990[a]	0-24	Small	80	9	0.11	0.03	66	0.83	NA	2	0.03	NA	68	0.85	0.05
08/27-08/30	1991[a]	0-24	Small	268	35	0.13	0.03	218	0.81	0.09	0	0	0	218	0.81	0.09
09/04-09/07	1991[a]	0-24	Small	248	28	0.11	0.03	171	0.69	0.08	3	0.01	<0.01	174	0.70	0.08
08/31-09/04	1992	0-24	Small	272	19	0.07	0.02	111	0.41	0.05	1	<0.01	<0.01	112	0.41	0.05
08/17-08/20	1993	0-24	Small	257	23	0.08	0.01	127	0.49	0.09	0	0	0	127	0.49	0.09
08/31-09/09	1994	0-27	Small	200	38	0.19	0.03	137	0.69	0.08	4	0.02	0.01	141	0.71	0.08
08/29-09/08	1995	0-27	Small	273	77	0.28	0.04	249	0.91	0.08	8	0.03	0.01	257	0.94	0.08

[a] Data used as part of a mark-recapture experiment to estimate abundance.

[b] Data is not available for this estimate.

Estimates of mean length for burbot sampled from the Tanana River section were 375 mm TL (SE = 4) for small burbot, 534 mm TL (SE = 5) for medium burbot, and 849 mm TL (SE = 30) for large burbot. Estimates of mean length for burbot sampled from the Chena River section were 385 mm TL (SE = 5) for small burbot, 563 mm TL (SE = 5) for medium burbot, and 836 (SE = 28) for large burbot. A summary of annual mean length estimates for these two sections is shown in Table 2.

Due to size selectivity of the hoop traps, proportions of total catch attributed to each of the three size categories do not represent true population proportions, but do provide a means of comparison among years. Also, due to seasonal variations in sampled size composition, only estimates from similar time frames are compared. Large burbot are caught in low proportions in both sections (less than 5% using small hoop traps) (Table 3). In the Tanana River section, the proportion of medium burbot for any one sampling event has ranged from 0.47 to 0.78 since 1986. The 1995 estimate of 0.51 (SE = 0.03) is similar to estimates from other June sampling events. Correspondingly, the proportion of small burbot in the 1995 sample was at the upper end of the observed range, which may be indicative of strong recruitment. Estimates of the proportions of medium burbot in the Chena River section are generally higher than those in the Tanana River section, and have ranged from 0.53 to 0.86 since 1988. The 1995 estimate was 0.75 (SE = 0.02).

Statistical comparisons among cumulative length frequency distributions for sample years 1988-1993 indicated that distributions were not homogenous in either river section (Evenson 1994). Plotted length frequencies indicate that distributions are more variable in the Tanana River section than in the Chena River section (Figures 3 and 4). This is likely attributed to the more variable times of sampling in the Tanana River section (See Table 1 for dates of sampling).

DISCUSSION

Accurate stock assessment of burbot in this system is difficult for a number of reasons. Because it is so large, only a small portion can be sampled during the open water period. Information from tag recoveries and from radio telemetry investigations have indicated that there is substantial interchange among burbot in river sections over the span of one year or more (Evenson 1990a, 1993b). Thus, stock structure (size composition and density) can vary annually as well as seasonally within a section as a result of movements into and out of the section Also, there are seasonal fluctuations in both catch rates and in size composition of sampled catches which can be attributed to changes in catchability. Similar fluctuations occur in lacustrine systems as well (Bernard et al. 1991) where immigration and emigration are unlikely.

While mark/recapture experiments are an accurate method of stock assessment, this method has met with limited success in past investigations. Due to the low probability of capture using hoop traps, abundance estimates require substantial effort (twice as much as is needed to estimate mean CPUE) and in the past have been marginally precise (relative precision of seven estimates has ranged between 58%-87%; Evenson, 1993a).

To alleviate problems associated with seasonal fluctuations in catch rates and size compositions, sampling was modified (beginning in 1994) to cover a two week period instead of a one week period as was the case in years prior to 1994. Standard errors of 1995 estimates were similar to those obtained in previous years. This slightly longer sampling period may reduce some of the seasonal variation in catchability, thus providing CPUE and length composition estimates which

Table 2.-Mean length estimates of burbot sampled in sections of the Tanana and Chena rivers, 1986-1995.

River Sampling Dates	Year	River km Sampled	Hoop Trap Size	Length Range (mm TL)	Small (300-449 mm TL) Catch	Small Mean	Small SE	Medium (450-799 mm TL) Catch	Medium Mean	Medium SE	Large (≥800 mm TL) Catch	Large Mean	Large SE	Medium + Large (≥450 mm TL) Catch	Medium + Large Mean	Medium + Large SE
Tanana River																
07/29-08/02	1986	334-352	Large	260-863	51	382	6	94	552	8	7	839	9	101	572	10
08/11-08/15	1986	334-352	Large	266-905	42	379	7	57	556	14	3	846	29	60	570	13
07/22-07/25	1987	339-354	Large	315-1,025	22	400	7	41	544	12	6	888	41	47	588	21
07/28-07/31	1987	339-354	Large	304-1,079	70	396	5	73	552	9	6	885	45	79	578	13
08/04-08/07	1987	339-354	Large	308-1,028	24	399	7	45	569	12	2	937	92	47	584	16
08/18-08/21	1987	339-354	Large	311-1,000	46	411	4	178	570	7	14	882	17	192	593	9
07/06-07/09	1988	312-376	Small	235-855	159	388	3	144	520	5	1	855	ID[a]	145	523	5
06/13-06/16	1989	317-374	Small	278-895	137	381	4	125	535	6	6	849	13	131	549	8
08/14-08/16	1990	344-376	Small	300-900	44	393	6	96	540	8	4	856	23	100	553	8
07/11-07/17	1991	336-360	Small	238-922	97	386	5	247	530	4	3	893	19	250	534	4
08/24-08/28	1992	336-360	Small	277-1,040	57	398	6	266	557	5	16	864	16	282	574	6
06/08-06/11	1993	336-360	Small	280-902	86	375	5	174	552	6	6	841	14	180	562	7
06/07-06/17	1994	336-360	Small	265-915	158	382	4	169	529	6	4	864	23	173	537	7
06/13-06/23	1995	330-360	Small	259-937	184	375	4	195	534	5	4	849	30	199	540	6
Chena River																
09/07-09/09	1988	0-24	Small	306-754	23	394	8	65	557	8	0	ID	ID	65	557	8
06/27-06/30	1989	0-40	Small	295-802	30	366	6	74	568	10	1	802	ID	75	571	10
06/12-06/15	1990	0-24	Small	265-600	14	375	14	16	510	12	0	ID	ID	16	510	12
08/21-08/24	1990	0-24	Small	302-873	41	400	7	82	540	8	1	873	ID	83	544	8
08/27-08/31	1990	0-24	Small	294-852	59	409	5	204	555	5	1	852	ID	205	556	5
09/06-09/07	1990	0-24	Small	316-762	26	391	9	90	554	7	0	ID	ID	90	554	7
09/27-09/28	1990	0-24	Small	315-905	9	381	18	66	554	9	2	888	18	68	564	9
08/27-08/30	1991	0-24	Small	288-785	35	385	8	218	562	5	0	ID	ID	218	562	5
09/04-09/07	1991	0-24	Small	295-895	28	382	9	171	565	5	3	850	27	174	569	5
08/31-09/04	1992	0-24	Small	307-843	19	388	10	111	575	7	1	843	ID	112	577	7
08/17-08/20	1993	0-24	Small	295-760	23	371	11	126	565	7	0	ID	ID	126	565	7
08/31-09/09	1994	0-27	Small	303-910	38	395	7	136	573	6	4	839	28	140	581	7
08/29-09/08	1995	0-27	Small	275-897	77	385	5	249	563	5	8	836	13	257	571	6

[a] Insufficient data.

Table 3.-Estimates of proportions of small, medium, and large burbot sampled in sections of the Tanana and Chena rivers, 1986-1995.

Sampling Date	Year	River km Sampled	Hoop Trap Size	Catch Total	Small	Catch Proportion	SE	Medium	Catch Proportion	SE	Large	Catch Proportion	SE
Tanana River													
07/29-08/02	1986	334-352	Large	152	51	0.34	0.04	94	0.62	0.04	7	0.05	0.02
08/11-08/15	1986	334-352	Large	102	42	0.41	0.05	57	0.56	0.05	3	0.03	0.02
07/22-07/25	1987	339-354	Large	69	22	0.32	0.06	41	0.59	0.06	6	0.09	0.03
07/28-07/31	1987	339-354	Large	149	70	0.47	0.04	73	0.49	0.04	6	0.04	0.02
08/04-08/07	1987	339-354	Large	71	24	0.34	0.06	45	0.63	0.06	2	0.03	0.02
08/18-08/21	1987	339-354	Large	238	46	0.19	0.03	178	0.75	0.03	14	0.06	0.02
07/06-07/09	1988	312-376	Small	304	159	0.52	0.03	144	0.47	0.03	1	0	0
06/13-06/16	1989	317-374	Small	268	137	0.51	0.03	125	0.47	0.03	6	0.02	0.01
08/14-08/16	1990	344-376	Small	144	44	0.31	0.04	96	0.67	0.04	4	0.03	0.01
07/11-07/17	1991	336-360	Small	347	97	0.28	0.02	247	0.71	0.02	3	0.01	0
08/24-08/28	1992	336-360	Small	339	57	0.17	0.02	266	0.78	0.02	16	0.05	0.01
06/08-06/11	1993	336-360	Small	266	86	0.32	0.03	174	0.65	0.03	6	0.02	0.01
06/07-06/17	1994	336-360	Small	331	158	0.48	0.03	169	0.51	0.03	4	0.01	0.01
06/13-06/23	1995	330-360	Small	383	184	0.48	0.03	195	0.51	0.03	4	0.01	0.01
Chena River													
09/07-09/09	1988	0-24	Small	88	23	0.26	0.05	65	0.74	0.05	0	0	0
06/27-06/30	1989	0-24	Small	105	30	0.29	0.04	74	0.70	0.04	1	0.01	0.01
06/12-06/15	1990	0-24	Small	30	14	0.47	0.09	16	0.53	0.09	0	0	0
08/21-08/24	1990	0-24	Small	124	41	0.33	0.04	82	0.66	0.04	1	0.01	0.01
08/27-08/31	1990	0-24	Small	264	59	0.22	0.03	204	0.77	0.03	1	0	0
09/06-09/07	1990	0-24	Small	116	26	0.22	0.04	90	0.78	0.04	0	0	0
09/27-09/28	1990	0-24	Small	77	9	0.12	0.04	66	0.86	0.04	2	0.03	0.02
08/27-08/30	1991	0-24	Small	253	35	0.14	0.02	218	0.86	0.02	0	0	0
09/04-09/07	1991	0-24	Small	202	28	0.14	0.02	171	0.85	0.03	3	0.01	0.01
08/31-09/04	1992	0-24	Small	131	19	0.15	0.03	111	0.85	0.03	1	0.01	0.01
08/17-08/20	1993	0-24	Small	149	23	0.15	0.03	126	0.85	0.03	0	0	0
08/31-09/09	1994	0-27	Small	178	38	0.21	0.03	136	0.76	0.03	4	0.02	0.01
08/29-09/08	1995	0-27	Small	334	77	0.23	0.02	249	0.75	0.02	8	0.02	0.01

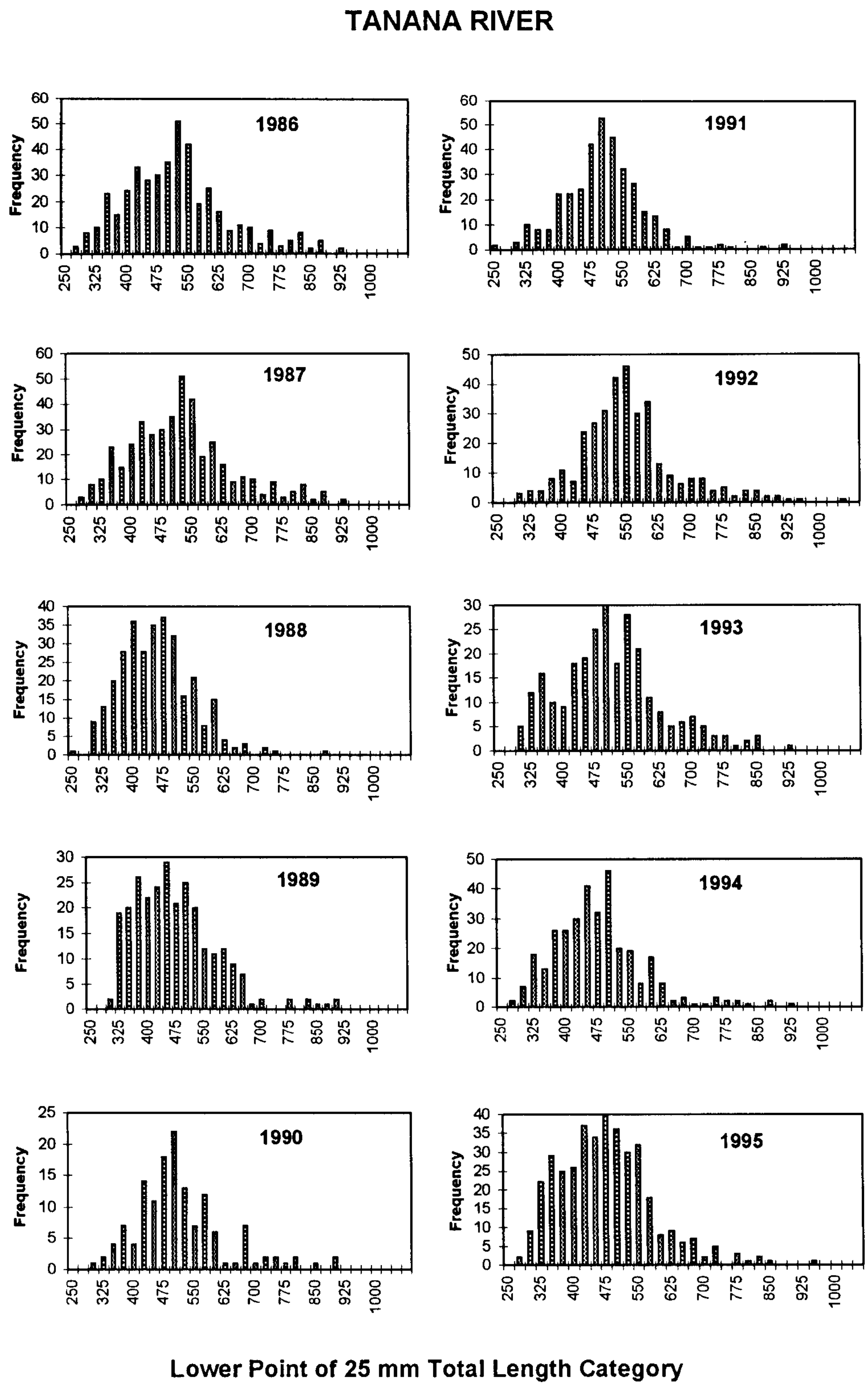

Figure 3.-Length frequency distributions of burbot sampled in the Tanana River, 1986-1995.

CHENA RIVER

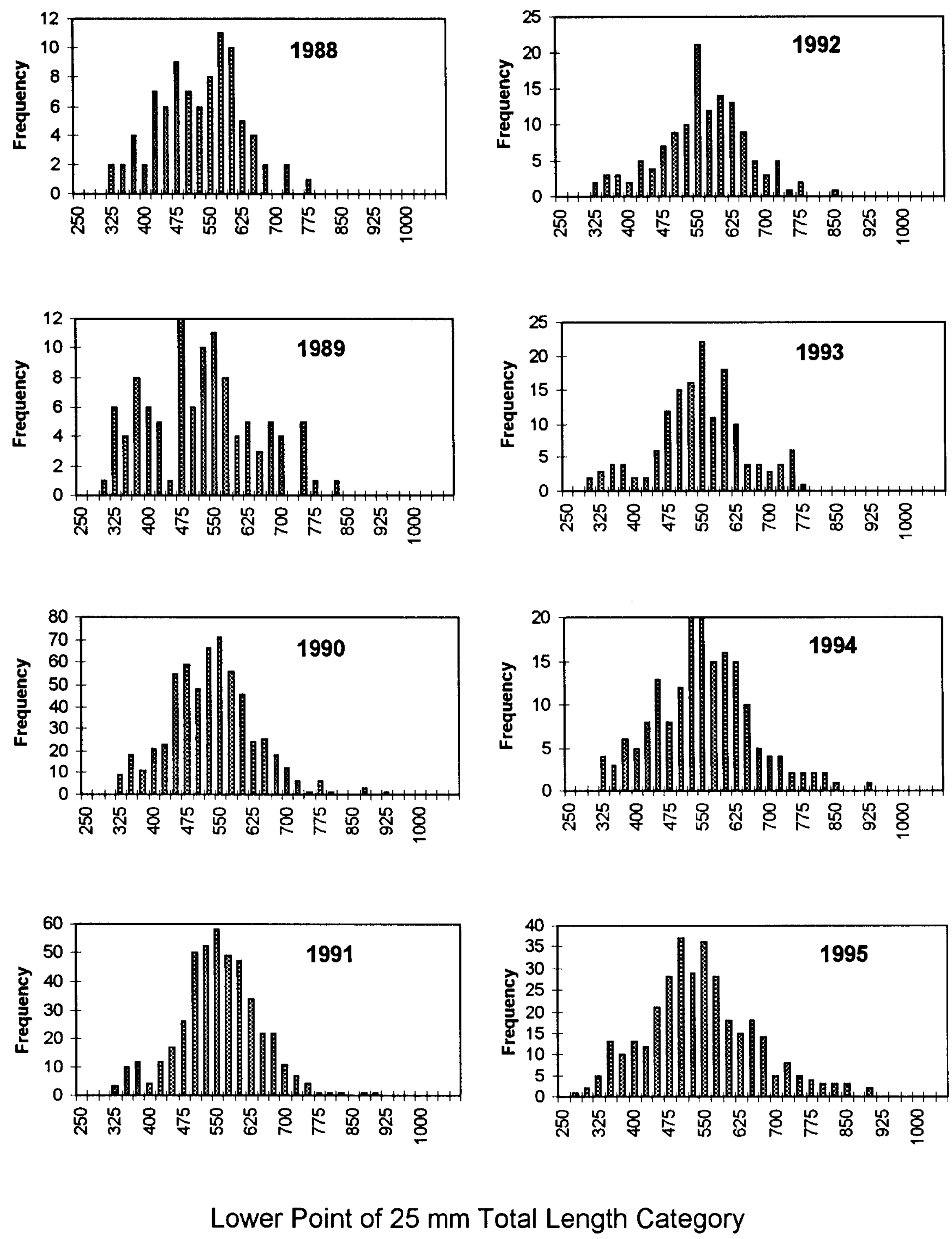

Figure 4.-Length frequency distributions of burbot sampled in the Chena River, 1988-1995.

are more comparable among years. In addition, a standard sampling time was established for each section. In the Tanana River section sampling times varied from early June to late August from 1986-1992. Beginning in 1993, a standard sampling time of early to mid June was established. In the Chena River section, sampling times have been more consistent. With the exception of one sampling event in 1990, all sampling has taken place between late August and late September. These same time frames should be used in future years.

CHAPTER 2. CATCH-AGE ANALYSIS OF BURBOT IN THE TANANA RIVER DRAINAGE

INTRODUCTION

Estimates of mean CPUE for burbot in the Tanana River are difficult to interpret due to seasonal variations in catch rate and composition. Additionally, CPUE estimates have not correlated well with mark/recapture estimates of abundance (Evenson 1993a). Catch-age analysis was examined as an alternative method of assessing the population of burbot in the Tanana River beginning in 1994 (Evenson and Merritt 1995). Catch-age analysis uses an age-structured approach to population abundance estimation by combining harvest at age information with auxiliary data (Deriso et al. 1989) to generate abundance estimates by year and age class. Catch-age techniques require a long series of well sampled catches before meaningful estimates can be generated (Megrey 1989). This analysis includes only eight years of catch samples (1987-1994), and therefore the parameter estimates presented below should not be considered definitive. The purpose of this analysis is to present the development of the CAGEAN model for these data and to identify bias and problems with the model so that it can be improved and fine tuned with additional years data.

METHODS

The computer program CAGEAN (Deriso et al. 1985) was used to solve for a non-linear least-squares solution (Marquardt 1963) to parameters related to the population and sport fishery. CAGEAN couples a simulation model of the population dynamics with data generated from various estimation procedures, and compares predicted parameters with observed data. Using a minimization criterion, CAGEAN seeks the set of parameters that minimize differences between predicted and observed values. Standard deviations of calculated parameter estimates are obtained using the Monte Carlo (bootstrap) technique. Two observed data sources were used: total sport harvest estimates for the Tanana River from 1987-1994[1] (Mills 1988 - 1994 and Howe et al. 1995); and estimated age composition of the harvest (ages 4 - 16+) from voluntary angler returns and catch sampling. Auxiliary information in the form of fishing effort (angler days; Mills 1988 - 1994 and Howe et al. 1995) was introduced to stabilize parameter estimation. Initial values generated by CAGEAN were used for initial parameter estimates. Input files for the CAGEAN analysis are given in Appendix B.

Model Assumptions

The assumptions of the CAGEAN model are as follows (summarized from Megrey 1989):

1) the age composition of the stock is not constant from year to year;
2) the age composition data are independent of the total catch estimate;

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[1] No harvest samples were collected for 1990 so harvest at age information is missing for that year.

3) errors are associated with estimating the total catch;

4) all significant components of mortality are accounted for in F (fishing mortality) and M (natural mortality);

5) M does not vary by age, year, or size of the stock and represents all components of mortality not associated with the directed fishery;

6) F does not vary with respect to stock size;

7) F and M operate concurrently and independent of one another;

8) M is known or can be estimated independently;

9) F can vary between years, and within one year it can vary by age;

10) variation in F can be represented as the product of an age and a year factor;

11) exploitation can change between years, but not within a year;

12) catchability (q) of the gear is constant and does not vary by age within a year;

13) there is no gear saturation or competition;

14) the population is closed to immigration and emigration; and,

15) the fishery operates on a single unit stock over its entire geographic range.

Notation

Notation used to define parameters follows. A caret (^) is used to denote parameter estimates from data (e.g. age composition and harvest); parameter estimates from catch age models are topped with (˜).

$\hat{H}_{a,y}$ = harvest by age in year y as estimated from samples of otoliths and information from the statewide harvest survey;

$\tilde{H}_{a,y}$ = estimated harvest of fish of age a in year y from the catch age model.

$\hat{p}_a$ = observed proportion of age a fish in the sample;

$\hat{L}_a$ = length at age a;

$\hat{L}_\infty$ = asymptotic length of burbot;

$\hat{K}$ = von Bertalanffy growth coefficient;

$\hat{t}_o$ = theoretical age at length zero;

$\hat{t}_{mb}$ = 0.38 of the maximum observed age;

$\hat{Z}$ = estimated total mortality;

$\hat{M}$ = instantaneous natural mortality;

$\hat{F}$ = estimated fishing mortality;

$\hat{E}_y$ = calculated fishing effort in year y for burbot;

$\hat{AD}$ = estimated angler days from the statewide harvest survey;

$\tilde{\varepsilon}_y$ = error in relationship between fishing mortality and fishing effort in year y;

q = catchability coefficient;

$\tilde{N}_{a,y}$ = estimated number of fish in the cohort at age a in year y;

λ = effort lambda or weighting factor for effort; and,

μ = exploitation fraction or rate.

Harvest at Age

Total harvests estimated from the statewide harvest survey (Mills 1988-1994 and Howe et al. 1995) were computed by summing harvests from all discrete flowing waters draining into the Tanana River[2] (see Figure 5). Harvest at age from 1987-1989 and from 1991-1994 (no catch samples were obtained in 1990) was estimated by multiplying the estimated proportion by age class from angler-returned carcasses and catch sampling (Table 4) and the estimated harvest from the statewide harvest survey (Table 5):

$$\hat{H}_{a,y} = \hat{H}_y \hat{p}_a. \quad (7)$$

Catch samples were obtained from burbot harvested primarily in the winter fishery. Most samples were collected from the middle mainstem Tanana River near Fairbanks and the lower Chena River. The majority of the annual harvest (ranging from 60 to 80%) occurs in the middle portion of the Tanana River drainage (Appendix C). For this analysis, these age samples were assumed to represent total annual harvests within the Tanana River drainage.

Age Determination

A pair of otoliths (sagittae bones) were removed from each fish for age analysis. Otoliths were stored dry and were soaked in distilled water for 4 hours prior to reading. Otoliths were surface read under a dissecting microscope using reflected light. Magnification varied between 1.0X and 4.0X depending upon the size of the otolith. An aging study conducted previously (Evenson and Merritt 1995) indicated that surface reading techniques provided similar, but more precise estimates of age than did break and burn techniques.

Gear Description and Vulnerability

Anglers typically use fish bait to capture burbot. Baited hooks are fished both actively (rod and reel) or passively using lines set over night. Regulations require a minimum hook size (distance between point of hook and shank) of 19 mm (3/4 inch). Most samples for this analysis were collected from anglers fishing during the winter using set-lines.

The range of ages used in the analysis was 4 - 20. Although not fully recruited to the fishery, burbot of age 4 begin to show in significant numbers in harvest samples. Bias in determining age increases with age. Therefore, burbot of age 16 and older were pooled into a single 16+ group as

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2 Areas in the statewide harvest survey which were summed to provide estimates of total harvest were: upper and lower Chena River, lower, middle and upper Tanana River, Nenana River, Salcha River, Shaw Creek, Goodpaster River, Piledriver Slough, Chatanika River, Delta Clearwater River, Minto Flats, and other streams in the Tanana River drainage not specifically listed in the statewide harvest survey.

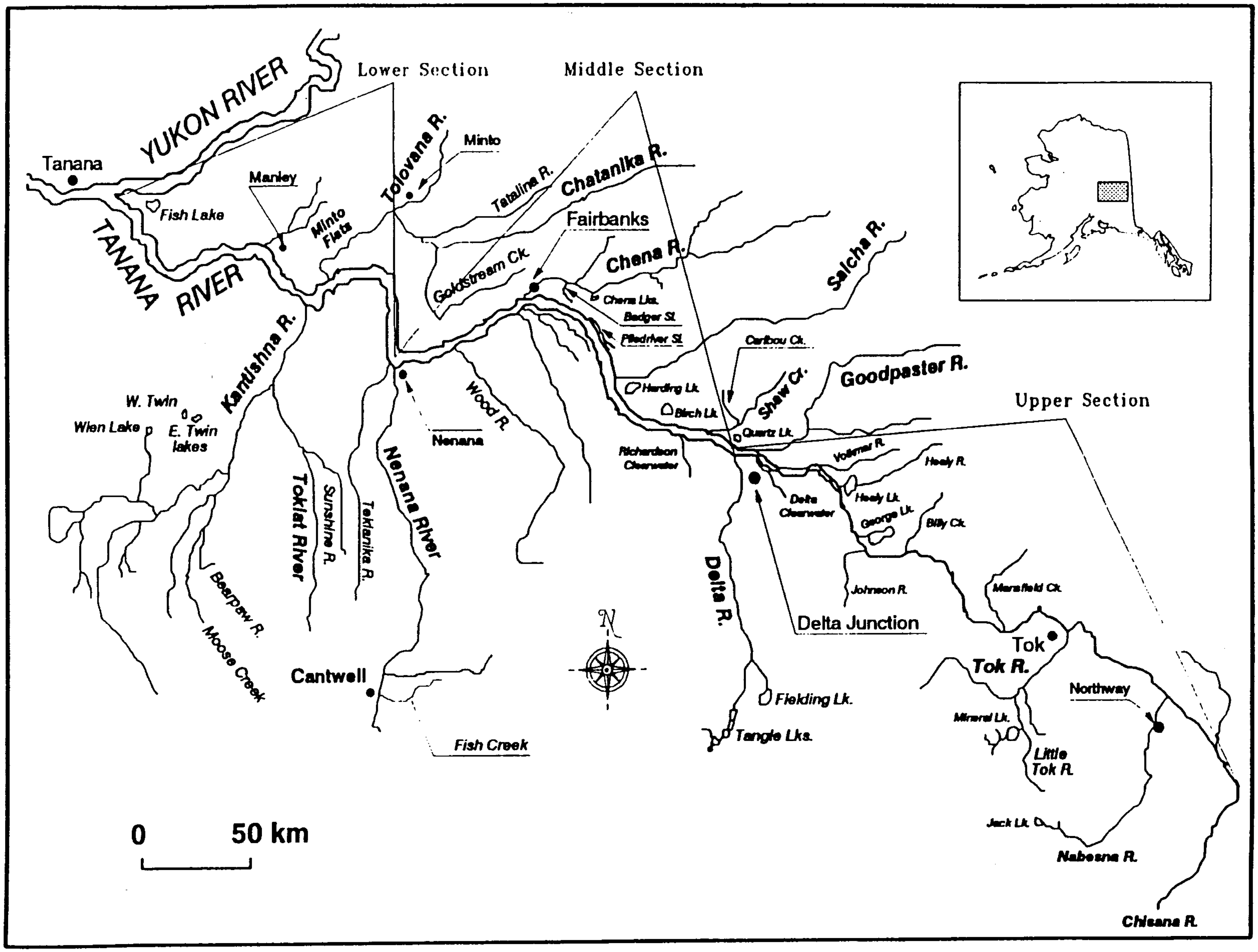

Figure 5.-Map of the Tanana River drainage, with the lower, middle and upper sections of the Tanana River demarcated.

Table 4.-Proportion at age of burbot in the Tanana River, estimated from carcasses collected during the winter sport harvest, for the years 1987-1994.

		Year								
Age	Statistic	1987	1988	1989	1990	1991	1992	1993	1994	Total
4	Sample Size	0	3	1	0	0	1	0	0	5
	Proportion	0.000	0.018	0.008	0.000	0.000	0.002	0.000	0.000	0.004
	SE	0.000	0.010	0.008	0.000	0.000	0.002	0.000	0.000	0.002
	CV	0	57	100	0	0	100	0	0	45
5	Sample Size	4	7	4	0	6	23	0	0	44
	Proportion	0.059	0.041	0.030	0.000	0.025	0.040	0.000	0.000	0.032
	SE	0.029	0.015	0.015	0.000	0.010	0.008	0.000	0.000	0.005
	CV	49	37	49	0	40	20	0	0	15
6	Sample Size	7	14	7	0	38	88	4	5	191
	Proportion	0.103	0.082	0.053	0.000	0.105	0.094	0.009	0.000	0.079
	SE	0.037	0.021	0.019	0.000	0.020	0.012	0.009	0.000	0.007
	CV	36	26	37	0	19	13	100	0	9
7	Sample Size	9	25	22	0	38	88	4	5	191
	Proportion	0.132	0.146	0.165	0.000	0.160	0.154	0.034	0.074	0.140
	SE	0.041	0.027	0.032	0.000	0.024	0.015	0.017	0.032	0.009
	CV	31	19	20	0	15	10	49	43	7
8	Sample Size	4	21	19	0	35	85	4	5	173
	Proportion	0.059	0.123	0.143	0.000	0.147	0.149	0.034	0.074	0.127
	SE	0.029	0.025	0.030	0.000	0.023	0.015	0.017	0.032	0.009
	CV	49	20	21	0	16	10	49	43	7
9	Sample Size	9	30	14	0	30	73	18	8	176
	Proportion	0.132	0.175	0.105	0.000	0.126	0.128	0.154	0.118	0.133
	SE	0.041	0.029	0.027	0.000	0.022	0.014	0.033	0.039	0.009
	CV	31	17	25	0	17	11	22	33	7
10	Sample Size	4	22	18	0	32	75	17	8	176
	Proportion	0.059	0.129	0.135	0.000	0.134	0.131	0.145	0.118	0.129
	SE	0.029	0.026	0.030	0.000	0.022	0.014	0.033	0.039	0.009
	CV	49	20	22	0	16	11	23	33	7
11	Sample Size	6	21	18	0	16	64	24	12	161
	Proportion	0.088	0.123	0.135	0.000	0.067	0.112	0.205	0.176	0.118
	SE	0.035	0.025	0.030	0.000	0.016	0.013	0.037	0.047	0.009
	CV	39	20	22	0	24	12	18	26	7
12	Sample Size	9	15	11	0	27	43	13	10	128
	Proportion	0.132	0.088	0.083	0.000	0.113	0.075	0.111	0.147	0.094
	SE	0.041	0.022	0.024	0.000	0.021	0.011	0.029	0.043	0.008
	CV	31	25	29	0	18	15	26	29	8
13	Sample Size	4	4	9	0	18	27	13	6	81
	Proportion	0.059	0.023	0.068	0.000	0.076	0.047	0.111	0.088	0.059
	SE	0.029	0.012	0.022	0.000	0.017	0.009	0.029	0.035	0.006
	CV	49	50	32	0	23	19	26	39	11

-continued-

Table 4.-Page 2 of 2.

Age	Statistic	Year								Total
		1987	1988	1989	1990	1991	1992	1993	1994	
14	Sample Size	4	4	6	0	6	16	6	9	51
	Proportion	0.059	0.023	0.045	0.000	0.025	0.028	0.051	0.132	0.037
	SE	0.029	0.012	0.018	0.000	0.010	0.007	0.020	0.041	0.005
	CV	49	50	40	0	40	25	40	31	14
15	Sample Size	3	3	3	0	6	16	6	9	51
	Proportion	0.044	0.018	0.023	0.000	0.017	0.023	0.060	0.044	0.026
	SE	0.025	0.010	0.013	0.000	0.008	0.006	0.022	0.025	0.004
	CV	57	57	57	0	50	27	37	57	16
16	Sample Size	5	2	1	0	1	10	10	2	31
	Proportion	0.074	0.012	0.008	0.000	0.004	0.017	0.085	0.029	0.023
	SE	0.032	0.008	0.008	0.000	0.004	0.005	0.026	0.021	0.004
	CV	43	71	100	0	100	31	30	70	18
Total	Sample Size	68	171	133	0	238	572	117	68	1,367

Table 5.-Estimated harvest of burbot and angler days of fishing effort in flowing waters of the Tanana River drainage from the statewide harvest survey, 1987-1994.

Year	Harvest[a]	SE[Harvest]	Effort[b]
1987	3,749	NA[c]	3,026
1988	3,406	NA	1,666
1989	4,225	NA	2,421
1990	3,579	NA	3,225
1991	2,187	561	2,748
1992	3,231	624	1,721
1993	5,181	1,017	4,329
1994	4,915	NA	2,968

[a] Summed from: lower and upper Chena River, lower, middle, and upper Tanana River, Nenana River, Salcha River, Shaw Creek, Goodpaster River, Piledriver Slough, Chatanika River, Delta Clearwater River, Minto Flats, and other flowing waters not specifically listed in the statewide harvest survey.

[b] Specific estimates of effort towards burbot in the Tanana River are not available. Effort was calculated as the product of the proportion of burbot harvest to total harvest and total angler days of effort in the Tanana River drainage from the statewide harvest survey.

[c] Estimate not available.

recommended by Fournier and Archibald (1982). The age of full vulnerability to the fishery was determined to be 9 from initial CAGEAN model output (Figure 6).

Catchability

The regulation regime (i.e. gear restrictions, seasons, and bag limits) for this sport fishery was constant during all years of analysis (1987-1994). Additionally, because the fishery is continuous (occurs year round), environmental factors which might influence catchability are minimal compared to discrete fisheries. For these reasons catchability was assumed to be constant among all years.

Instantaneous Natural Mortality

The von Bertalanffy growth model (von Bertalanffy 1938) was used in the estimation of the following life history parameters: K, L_∞, and t_o. Estimates of these parameters were obtained using a modified Marquardt non-linear least squares procedure contained in a FORTRAN program. The equation used was:

$$\hat{L}_a = \hat{L}_\infty(1 - e^{-\hat{K}(a-\hat{t}_0)}). \quad (8)$$

The oldest age consistently present in samples was 16, which was used as the maximum age of burbot for purposes of estimating instantaneous natural mortality[3]. Alverson and Carney (1975) have shown that the age at which a cohort reaches its maximum biomass (T_{mb}) is about 0.38 of the maximum age. Alverson and Carney reasoned that because the time at which cohort biomass is maximized is a function of growth and mortality, natural mortality could be estimated by:

$$\hat{M} = \frac{3\hat{K}}{e^{\hat{t}_{mb}\hat{K}} - 1}. \quad (9)$$

Equation 8 was used with results from the von Bertalanffy models for the years in which individual age data were available (1987 - 1994). The average was used as the estimate of natural mortality for all ages.

Total mortality was estimated as:

$$\hat{Z}_{a,y} = \hat{F}_{a,y} + \hat{M}_{a,y}. \quad (10)$$

Fishing Effort Source File, Effort Lambda

Estimated total angler days from the statewide harvest survey could not be used as a direct measure of fishing effort because data are collected by waterbody, not by species targeted. To obtain an estimate of fishing effort it was assumed that the fraction of burbot harvested from the mainstem Tanana River relative to total fish harvested is proportional to the fraction of angler days expended for burbot, relative to total angler days:

$$\hat{E}_y = \frac{\hat{H}_{burbot,y}}{\hat{H}_{total,y}} \times \hat{AD}_y. \quad (11)$$

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[3] Maximum age should be determined through observation of an unfished population; however Tanana River burbot are not heavily exploited. Thus, relatively little error will be introduced by assuming that maximum age of fish in samples have not been reduced through exploitation.

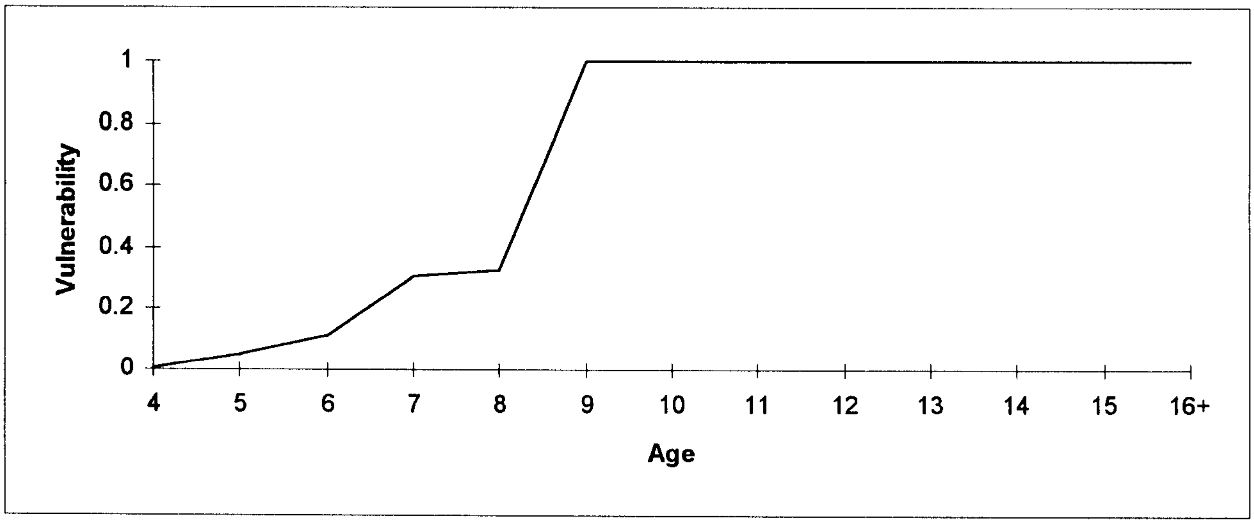


Figure 6.-Estimated gear vulnerability at age for the burbot sport fishery in the Tanana River.

Fishing effort in terms of angler days was used as an auxiliary data source to aid in the estimation of fishing mortality.

Because there is no direct measure of effort for the burbot sport fishery in the Tanana River, there is less confidence in the reliability of effort information, as opposed to harvest information, so an upper limit of 0.9 was imposed on the search for the effort lambda (λ). An effort lambda of 0.4 was derived by running CAGEAN models over a range of lambdas (0.1 to 0.9 at 0.1 increments) and examining: (1) the stability of the fishing mortality, after Deriso et al. (1985); (2) total abundance and variance estimates; and, (3) the residual root mean square (unexplained variability).

Error Structure

A log normal error structure was assumed for harvest at age data. This is similar to other catch-age analyses (Deriso et al. 1985, Doubleday 1976) which assume logarithms of harvest age compositions to be normally distributed. Angler days (fishing effort) is measured with error, so the relationship between fishing effort and fishing mortality is not exact. The difference between these two terms can be modeled by the log normal distribution:

$$\tilde{\varepsilon}_y = \ln \hat{F}_y - \ln(q\hat{E}_y). \tag{12}$$

Population Dynamic Models

Because the Tanana River burbot fishery occurs essentially year-round, and fishing mortality is continuous, the following equation was used to model abundance of one cohort to the next year:

$$\tilde{N}_{a+1,y+1} = \tilde{N}_{a,y} e^{-Z_{a,y}}. \tag{13}$$

Older ages were pooled into a single group (16+) and the abundance of this group was calculated as:

$$\tilde{N}_{16+,y+1} = \tilde{N}_{15,y} + \tilde{N}_{16+,y} e^{-Z_{16+,y}}. \tag{14}$$

Estimated harvest was modeled as a function of:

$$\tilde{H}_{a,y} = \mu_{a,y} \tilde{N}_{a,y} \tag{15}$$

which assumes that exploitation and vulnerability are separable.

Statistical Models

A given sum of squares component (SSQ) represents estimation error. The sum of squares which compared differences between observed and estimated log-harvest at age data was computed as:

$$SSQ_{harvest} = \sum_{y,a} [(\ln \tilde{H}_{y,a}) - (\ln \hat{H}_{y,a})]^2. \tag{16}$$

The sum of squares which modeled the inexact relationship between fishing effort and fishing mortality was computed as:

$$SSQ_{effort} = \lambda \sum_{y} (\tilde{\varepsilon}_y)^2. \tag{17}$$

Objective Function

The objective is to minimize total prediction error (O_{total}) which is computed in the program algorithm by adding each of the error components:

$$O_{total} = SSQ_{harvest} + SSQ_{effort}. \quad (18)$$

The value of the objective function is to measure how well the model fits observed data. A smaller objective function signifies a better fit.

RESULTS

Estimated Abundance

Exploitable abundance, the number of fish that are potentially vulnerable to the fishery, showed a decreasing trend from 1987 to 1994 (Table 6 and Figure 7). As expected, the coefficient of variation for the most recent (1994) abundance estimate was high (27%) compared to prior years because cohort information for CAGEAN estimation is missing after 1994.

Pre-fishery abundance is defined as fish at large, without consideration of the gear selectivity adjustment. Pre-fishery abundance at age estimates decreased markedly from 1987 to 1994 for young, partially-recruited fish (Table 7). Whereas, abundance of older fish (ages 12+) did not vary to the same extent during this time frame. Thus, the decreasing trend in total exploitable abundance may be more attributable to decreased numbers of young, partially-recruited fish than to a substantial depletion of older, large fish.

Estimated Fishing Mortality

Overall, estimated fishing mortality is relatively low. However, estimated fishing mortality of fully recruited burbot (ages 9+) increased markedly from 1987 through 1994 (Table 8). The highest estimated fishing mortality rate was 12% during 1994 for fully recruited burbot. Fishing mortality of pre-recruits (age 4-8) has remained low (below 4%) for all ages and years.

Model Bias

Predictions of harvest from the CAGEAN model track well with harvest estimates, while the predictions of effort show considerable disparity from computed effort (Figure 8). Effort predictions showed no consistent pattern of either over or under estimating fishing effort.

The difference between the model estimate of abundance and the mean bootstrap estimate of abundance was higher for recent estimates (19% for the 1994 estimate) than for earlier estimates (7% for the 1988 estimate; Table 6). This is similar in trend to the estimates of variance for the abundance estimates.

DISCUSSION

Catch-age analysis appears to be a promising method for estimating trends in abundance and fishing mortality for burbot in Tanana River drainage. The estimates of abundance appear reasonable (within an order of magnitude) compared to expansions of mark-recapture estimates of small index areas throughout the drainage (Evenson 1993a), and the precision of the estimates is adequate for management purposes (typically ±25% of the true abundance is the regional goal for abundance estimates). The relatively small statistical bias associated with the abundance estimates indicates that the model fits the data reasonably well.

The model portrays a dramatic, decreasing trend in total exploitable abundance from 1987 to 1993, especially with ages 4-9. This decline may be attributed to one or more causes. The first

Table 6.-Total estimated and bootstrapped mean exploitable abundance with coefficients of variation and percent bias for Tanana River burbot, 1987-1994.

Year	Total Exploitable Abundance		Coefficient of Variation	Percent Bias
	Estimated	Mean		
1987	149,207	161,363	16	8
1988	137,753	148,483	14	7
1989	125,551	136,568	14	8
1990	109,489	120,313	14	9
1991	96,161	108,270	15	11
1992	75,559	84,507	15	11
1993	60,401	71,329	21	15
1994	43,311	53,767	27	19

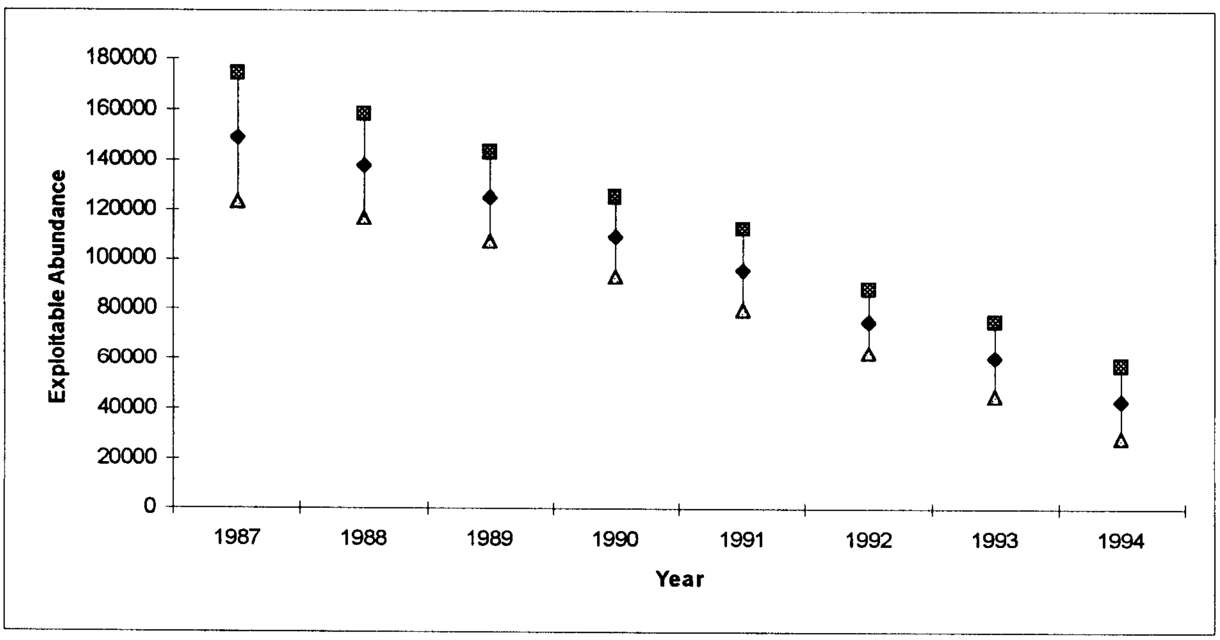


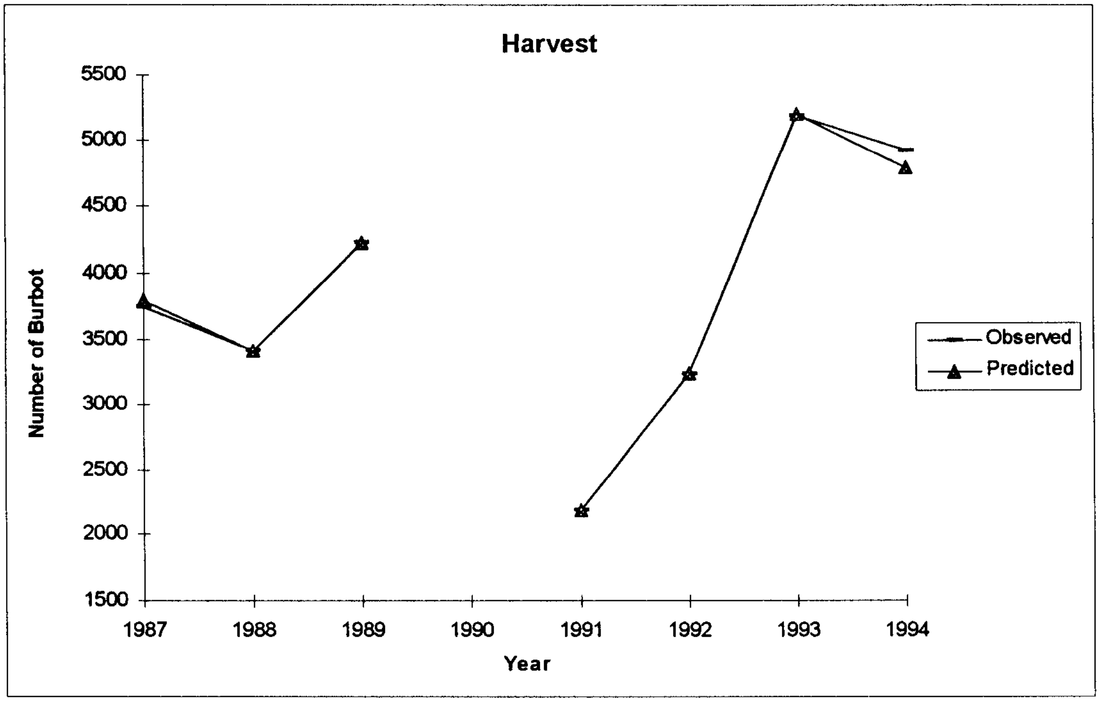
Figure 7.-Total estimated exploitable abundance (± 1 SD) of burbot in the Tanana River by year.

Table 7.-Estimated pre-fishery abundance at age for burbot in the Tanana River, 1987-1994.

	Age												
Year	4	5	6	7	8	9	10	11	12	13	14	15	16+
1987	113,050	145,869	110,554	72,870	47,050	34,094	17,321	15,875	7,219	4,303	4,208	1,844	5,006
1988	148,546	72,061	92849	70,225	45,978	29,671	21,020	10,679	9,787	4,450	2,653	2,595	4,223
1989	93,894	94,689	45,873	58,992	44,337	29,013	18,329	12,985	6,597	6,046	2,749	1,639	4,212
1990	67,358	59845	60,240	29,106	37,104	27,865	17,706	11,186	7,925	4,026	3,690	1,678	3,571
1991	28,013	42,937	38,096	38,273	18,375	23,412	17,212	10,937	6,910	4,895	2,487	2,279	3,242
1992	1,960	17,858	27,342	24,222	24,211	11,619	14,554	10,700	6,799	4,296	3,043	1,546	3,432
1993	1,752	1,249	11,349	17,310	15,144	15,121	6,957	8,714	6,407	4,071	2,572	1,822	2,981
1994	3,017	1,116	792	7,155	10,695	9,340	8,715	4,010	5,023	3,693	2,346	1,482	2,768

Table 8.-Estimated fishing mortality at age for burbot in the Tanana River, 1987-1994.

	Age					
Year	4	5	6	7	8	9+
1987	0.0003	0.0017	0.0038	0.0105	0.0111	0.0337
1988	0.0003	0.0016	0.0036	0.0099	0.0104	0.0317
1989	0.0004	0.0023	0.0049	0.0137	0.0144	0.0438
1990	0.0003	0.0016	0.0036	0.0099	0.0105	0.0318
1991	0.0002	0.0013	0.0029	0.0079	0.0084	0.0254
1992	0.0006	0.0033	0.0071	0.0196	0.0207	0.0629
1993	0.0009	0.0052	0.0114	0.0315	0.0333	0.1010
1994	0.0011	0.0062	0.0135	0.0373	0.0394	0.1195



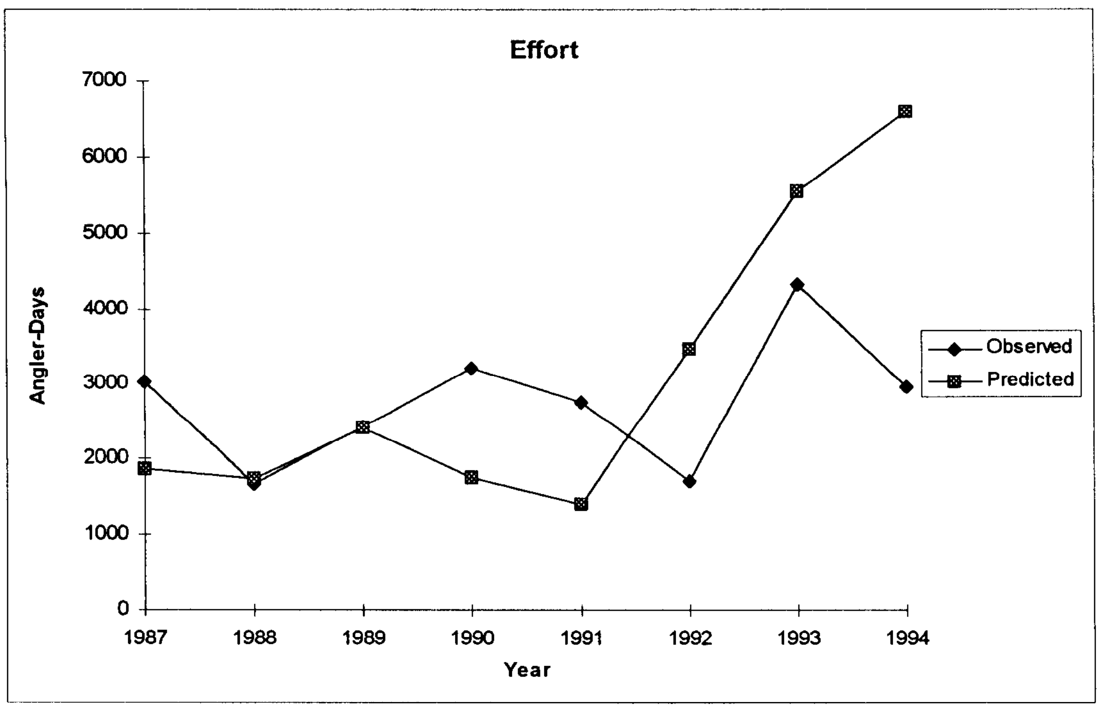


Figure 8.-Comparison of observed harvest and effort with estimates predicted from the CAGEAN model, Tanana River, 1987-1994.

cause may be an actual decline in the number of young partially recruited fish. This is generally corroborated by changes in length frequency distributions in the Tanana and Chena rivers generated during independent catch sampling during the same time frame. These distributions show a decline in catch frequency of burbot < 450 mm TL (corresponding to approximately age 6 or younger) after 1989 (see Figures 3 and 4). However, the magnitude of decline is not as dramatic as the CAGEAN estimates. Another cause may be an artifice of CAGEAN. In a retrospective catch-age analysis of Pacific halibut *Hippoglossus stenolepus*, Parma (1993) found that estimates of stock abundance tended to be autocorrelated, with the stock consistently being overestimated or underestimated for a series of consecutive years. Hightower (1996) noted a similar autocorrelation of errors in estimated stock size of widow rockfish *Sebastes entomelas*, and indicated that these errors were large in early years, but decreased considerably once 12-15 years of data were available. Such errors could be stock-specific, so it is unknown whether these errors exist in this analysis. However, because this study was comprised of only eight years of data, and because age-structured models generally require a long term data set, the estimates and trends given in this report should not be considered definitive.

In addition to the possibility of autocorrelation in errors and a short time series of data, the catch-age analysis used in this study was constrained in other respects. Foremost is the tenuous quality of the catch sampling data which is used to generate harvest at age information. This data suffers from two major shortfalls. The first is imprecise estimates of age composition due to small sample sizes. Sample sizes have ranged from 68-572 burbot per calendar year (however, no samples were collected in 1990). The larger sample was supplemented extensively with additional catch sampling (non-sport harvest) to examine burbot reproductive characteristics. Coefficients of Variation (CV) for many of the proportions of harvest by age estimates were quite large (see Table 4). The second shortfall is that the harvest samples have been temporally and spatially discrete. Most samples were collected from the winter fishery in the middle Tanana River area. Although most of the harvest occurs in this area, a substantial portion is harvested during open water periods (Evenson and Hansen 1991). Bias would result if the age composition of the open water and ice-cover harvests are substantially different. A more aggressive catch sampling program is planned for 1996 which will attempt to collect a larger sample, and samples from both open water and ice cover periods in order to determine if age compositions from the two seasons differ.

Another constraint of the CAGEAN model is the indirect measure of effort. Beginning in 1995, a direct measure of fishing effort for burbot in the Tanana River will be estimated through a statewide postal survey. These direct measures of effort will undoubtedly increase the precision of parameter estimates.

CHAPTER 3. FORT KNOX BURBOT INVESTIGATIONS

INTRODUCTION

This research involved population assessment and an age validation study of burbot at the Fort Knox mining project located in the Fish Creek drainage near Fairbanks (Figure 9). The study area in 1995 consisted of two small settling ponds (0.9-1.2 ha) connected by a small creek stretch. Recent development of the Fort Knox gold mine has created a freshwater reservoir approximately 67 surface ha (165 ac) in size, which has encompassed the two settling ponds sampled during this study. The reservoir was created via a freshwater impoundment dam in Fish Creek.

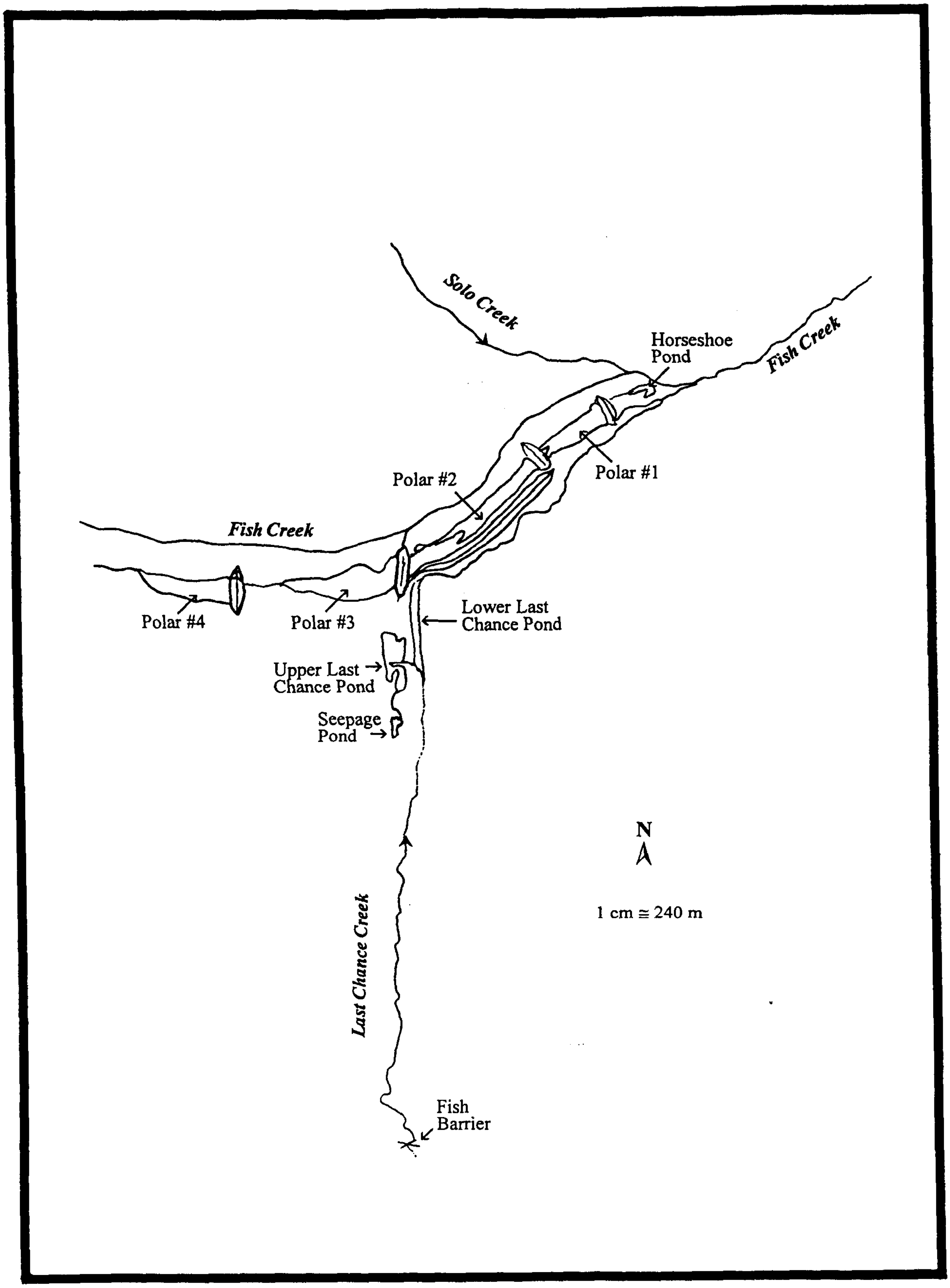


Figure 9.-Fort Knox pond complex in the Fish Creek drainage.

Impoundment of water began November, 1995. Sampling conducted by the Division of Habitat during 1994 indicated that young burbot (ages 0-4) inhabited the area, and were present in relatively high densities. Because the system is small, access and fishing are restricted, and a large proportion of the population can be captured, it represents an ideal location to investigate an age validation study. Upon completion of mining activities (approximately 2002), the area will be turned over to the state and developed into a public recreation area. Therefore, baseline estimates of age compositions and population abundance were desired.

The specific objectives of this research were to estimate abundance of all burbot 120 mm TL and larger in the area of the proposed Fort Knox reservoir; estimate mean length at age for all age classes captured; and, capture, mark, and release burbot in the Fort Knox system with an injection of oxytetracycline (OTC) to fluoresce the bone structure, and subsequently estimate the proportion of correctly aged (either one, two or three annuli after the fluorescent mark dependent upon the year of recapture) otoliths from recaptured burbot (one, two, and three years later).

METHODS

Sampling was conducted in Polar #1 and #2 Ponds in the Last Chance Creek drainage (Figure 9). A two sample mark-recapture experiment was conducted in each pond to estimate abundance. Four sampling gears were used to capture burbot. Two fyke nets were set in each pond. These nets were 3.7 m long with two 0.9 m square entrance frames, five hoops, a 1.8 m cod end, and 0.9m by 7.6 m net wings attached to the entrance frame. The center lead was 30.4 m. The nets were set with the center lead perpendicular to the pond bank. Minnow traps baited with salmon roe were also set in each pond. These traps were 42 cm long and 22 cm in diameter. Traps were wire mesh construction, with two 2.5 cm entrance holes on each end. Fifteen minnow traps were set in each pond. Two sizes of hoop traps baited with cut herring were also used. The small traps were 1.6 m long with 4 hoops 54 cm in diameter. These traps had two throats (tied to the first and second throats) which narrowed to square openings 11 cm on a side. Netting was 8.5 mm bar mesh. The large traps were 3.05 m long with seven 6.35 mm steel hoops. Hoop diameters tapered from 0.61 m at the entrance to 0.46 m at the cod end. Each trap had a double throat (tied to the second and fourth hoops) which narrows to an opening 10 cm in diameter. All netting was knotted nylon woven into 25 mm bar mesh, bound with No. 15 cotton twine, and treated with an asphaltic compound. Each trap was kept stretched with two sections of 19 mm polyvinyl chloride (PVC) pipe attached by snap clips to the end hoops. Two large traps and three small traps were set in each pond. Minnow traps and hoop traps were set along transect lines spaced 25 m apart. Traps were spaced at 25 m intervals along each transect line with the first locations chosen randomly. The two fyke traps were set on opposite ends of the ponds.

All gear for the marking event was deployed on 8 May in each pond and was pulled on 10 May. All burbot captured were measured for total length. All burbot 150 mm and larger were tagged with an individually numbered Floy internal anchor tag. A right ventral fin clip was given to all burbot captured in Polar #1 Pond, and a left ventral fin clip was given to all burbot captured in Polar #2 Pond to detect tag loss and to mark burbot smaller than 150 mm.

The recapture event was conducted similarly. All gear was deployed on 16 May and was pulled on 18 May. All burbot captured were measured and inspected for tags and fin clips. Because no recaptured burbot had migrated between ponds, abundance was estimated for each pond separately. The unbiased Petersen estimator and associated sampling variance (Chapman 1951) was used to estimate abundance for each pond:

$$\hat{N}^* = \left[\frac{(n_1+1)(n_2+1)}{(m_2+1)}\right] - 1 \quad (19)$$

$$V(\hat{N}^*) = \frac{(n_1+1)(n_2+1)(n_1-m_2)(n_2-m_2)}{(m_2+1)^2(m_2+2)} \quad (20)$$

where:

$\hat{N}^*$ = the estimated abundance of burbot;
n_1 = the number of burbot marked during the first event;
n_2 = the number of burbot examined during the second event; and,
m_2 = the number of marked burbot collected during the second event.

The assumptions of a two-event mark-recapture experiment and the methods for alleviating bias due to gear selectivity are described by Seber (1982) and are summarized in Appendix D.

All first-captured burbot were given an interperitoneal injection of 25 mg/kg OTC (McFarlane and Beamish 1987) to induce a permanent fluorescent mark on bony structures. This mark will subsequently be used to validate ages. Attempts will be made to recapture burbot during open water periods of 1996-1998 to obtain a sample of these marked fish one, two, and three years after marking. A correctly aged fish will be designated as one which the number of annuli noted after the fluorescent mark equals the time elapsed between mark and recapture.

During the recapture event, a sample of burbot which were not handled during the marking event (tagged or clipped fish) was collected and sacrificed for determining mean length at age. Otoliths (Sagittae) were removed from each fish. Two fish from each 10 mm length interval of the entire sample were collected. Otoliths were stored dry and were soaked in distilled water for 4 hours prior to reading. Otoliths were surface read under a dissecting microscope using reflected light. Magnification varied between 1.0X and 4.0X depending upon the size of the otolith. Mean length and its associated variance for each age class were calculated as:

$$\bar{l}_a = \sum_{b=1}^{n} \frac{l_{ab}}{n_a} \quad (21)$$

$$V[\bar{l}_a] = \sum_{b=1}^{n} \frac{(l_{ab} - \bar{l}_a)^2}{n_a(n_a - 1)} \quad (22)$$

where:

l_{ab} = length of burbot b in age category a; and,
n_a = number of samples in age category a.

RESULTS

During the first event of the mark-recapture experiment, 83 burbot in Polar #1 Pond and 72 burbot in Polar #2 Pond were captured, marked and released. During the second event, 72 burbot were captured and examined in Polar #1 Pond. Of these, 16 were recaptures from the first event. In Polar #2 Pond, 138 burbot were examined, and 23 were recaptures from the first event. Samples ranged in length from 106-334 mm TL.

Tests to investigate size selective sampling indicated that length distributions were similar during both sampling events in both ponds (Kolmogorov-Smirnov two sample tests: DN = 0.08; P = 0.98 for Polar #1 Pond; and, DN = 0.13; P = 0.40 for Polar #2 Pond; Figure 10). Test statistics comparing length distributions of all fish marked during the first sampling event to all fish recaptured in the second sampling event were also nonsignificant (DN = 0.28; P = 0.26 for Polar #1 Pond; and, DN = 0.33; P = 0.05 for Polar #2 Pond). However, the plotted length distributions were examined and in both ponds it was noted that the shapes of the distributions were similar, but the distributions of the recaptured fish were shifted slightly to the right (Figure 10). These results indicated that there was likely size selective sampling during both events and that small burbot were captured at a lower frequency than were large burbot. To alleviate this bias, both sampling events were stratified to estimate abundance. A reasonable length break point on both plots appeared to be at 200 mm. The stratified estimates were then compared to the unstratified estimates to determine the extent of the bias in terms of the overall abundance estimates.

The stratified estimate of abundance for Polar #1 Pond was 215 (SE = 83) small burbot (less than 200 mm) and 177 (SE = 33) large burbot (200 mm and larger). The total estimate by combining the two stratified estimates was 392 burbot (SE = 90). This compares very closely to the unstratified estimate of 360 burbot (SE = 66).

The stratified estimate of abundance for Polar #2 Pond was 192 (SE = 98) small burbot (less than 200 mm) and 278 (SE = 40) large burbot (200 mm and larger). The total estimate obtained by combining the two stratified estimates was 470 burbot (SE = 105). This also compares very closely to the unstratified estimate of 486 burbot (SE = 63). Because the test statistics were nonsignificant, the unstratified estimates were very similar to the stratified estimates in both ponds. The unstratified estimates were chosen as the most appropriate because the variances were much smaller than variances of the stratified estimates.

The two estimates (unstratified estimate from each pond) were summed to provide a total estimate of abundance in waters which will be encompassed by the freshwater reservoir. Total abundance was 846 (SE=91) burbot.

A total of 33 burbot were collected for age analysis. Samples ranged in length from 141 to 330 mm. Ages ranged from 2-5 years. Mean length at age increased with age (Table 9).

DISCUSSION

Age 0 and age 1 fish were absent from the sample, as were fish older than age 5. The dearth of young burbot (smaller than 150 mm) in this sample may be indicative of poor recruitment, rather than problems with gear selectivity. A sample of 71 burbot caught in Polar #1 and #2 ponds in 1994 using baited minnow traps ranged in length from 110-210 mm, and half were smaller than 150 mm (Ott et al. 1995). The absence of large burbot suggests that the ponds were only recently inhabited. Given that burbot in the Tanana River drainage do not become sexually mature until

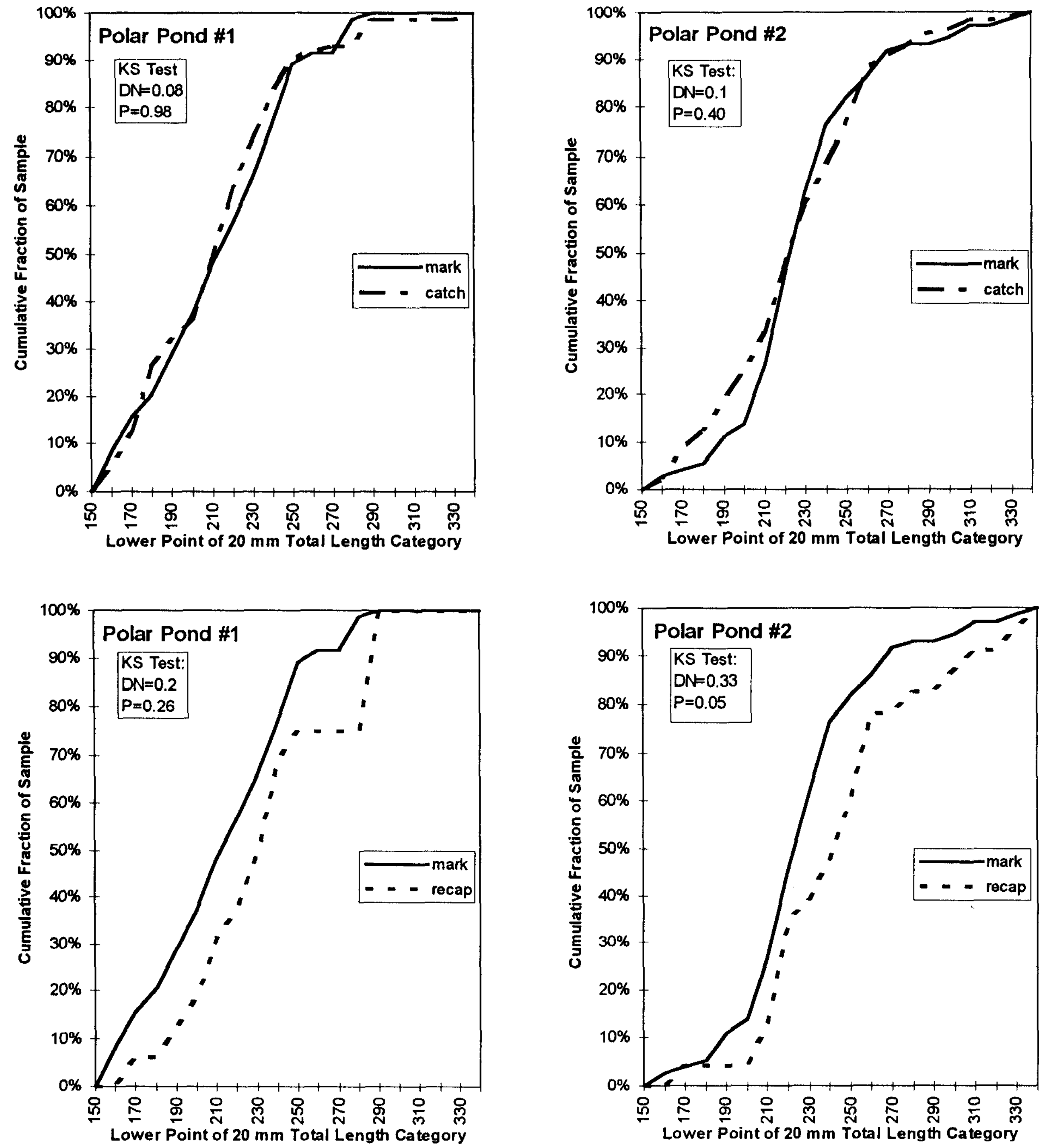


Figure 10-Length frequency distributions and results of Kolmogorov-Smirnov (KS) two sample tests comparing lengths of burbot marked during the first event (mark), lengths of burbot captured during the second event (catch) and lengths of burbot captured during the first and second event (recap) during the mark-recapture experiment in Polar Ponds #1 and #2.

Table 9.-Mean length at age of burbot captured in the Fort Knox settling ponds during 1995.

Age	Sample Size	Mean Length	SE	Minimum Length	Maximum Length
2	16	178	6	141	217
3	11	243	5	214	267
4	3	270	9	252	280
5	3	308	11	297	330

age 4 with males and age 6 with females (Evenson 1990), then either burbot in this system mature at a much earlier age than do burbot in other parts of the Tanana River drainage, or recruitment of young fish occurred through immigration from spawning areas outside of this system.

ACKNOWLEDGMENTS

Roy Perry, Dave Stoller, Jim Fish, Al Ott, and Al Townsend expertly assisted with collecting data. Peggy Merritt ran the CAGEAN program and provided much assistance with the catch-age analysis. Pat Hansen and Mike Wallendorf provided biometric support and technical reviews. Sara Case finalized the document for publication.

LITERATURE CITED

Alverson, D. L. and M. J. Carney. 1975. A graphic review of the growth and decay of population cohorts. Journal du Conseil International pour lExploration de la Mer 36:133-143.

Bernard, D. R., G. Pearse, and R. Conrad. 1991. Hoop traps as a means to capture burbot. North American Journal of Fisheries Management 11:91-104.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological censuses. University of California Publications in Statistics. No.1:131-160.

Clark, J. H., M. J. Evenson, and R. R. Riffe. 1991. Ovary size, mean egg diameters, and fecundity of Tanana River burbot. Alaska Department of Fish and Game. Fishery Data Series No. 91-64, Anchorage.

Deriso, R. B., T. J. Quinn II, and P. R. Neal. 1985. Catch-age analysis with auxiliary information. Canadian Journal of Fisheries and Aquatic Sciences 42:815-824.

Deriso, R. B., P. R. Neal, and T. J. Quinn II. 1989. Further aspects of catch-age analysis with auxiliary information. Pages 127-135 *in* R. J. Beamish, and G. A. Mcfarlane, eds. Effects of ocean variability on recruitment and an evaluation of parameters used in stock assessment models. Canadian Special Publication of Fisheries Aquatic Science 108.

Doubleday, W. G. 1976. A least squares approach to analyzing catch at age data. Research Bulletin of the International Commission on Northwest Atlantic Fisheries 12:69-81.

Evenson, M. J. 1988. Movement, abundance and length composition of Tanana River burbot stocks during 1987. Alaska Department of Fish and Game. Fishery Data Series No. 56, Juneau.

Evenson, M. J. 1989. Biological characteristics of burbot in rivers of interior Alaska during 1988. Alaska Department of Fish and Game. Fishery Data Series No. 109, Juneau.

Evenson, M. J. 1990a. Movement, abundance, and length composition of burbot in rivers of interior Alaska during 1989. Alaska Department of Fish and Game. Fishery Data Series No. 90-3, Anchorage.

Evenson, M. J. 1990b. Age and length at sexual maturity of burbot in the Tanana River, Alaska. Alaska Department of Fish and Game, Fishery Data Series No. 90-2, Anchorage.

Evenson, M. J. 1991. Abundance and size composition of burbot in rivers of interior Alaska during 1990. Alaska Department of Fish and Game. Fishery Data Series No. 91-33, Anchorage.

Evenson, M. J. 1992. Abundance and size composition of burbot in rivers of interior Alaska during 1991. Alaska Department of Fish and Game. Fishery Data Series No. 92-12, Anchorage.

Evenson, M. J. 1993a. A summary of abundance, catch per unit effort, and mean length estimates of burbot sampled in rivers of interior Alaska, 1986-1992. Alaska Department of Fish and Game. Fishery Data Series No. 93-15, Anchorage.

Evenson, M. J. 1993b. Seasonal movements of radio-implanted burbot in the Tanana River Drainage. Alaska Department of Fish and Game. Fishery Data Series No. 93-47, Anchorage.

LITERATURE CITED (Continued)

Evenson, M. J. 1994. Stock assessment of burbot in the Tanana and Chena rivers, 1993. Alaska Department of Fish and Game. Fishery Data Series No. 94-11, Anchorage.

Evenson, M. J. and P. Hansen. 1991. Assessment of harvest characteristics of the Tanana River burbot sport fishery in 1990 using a postal questionnaire. Alaska Department of Fish and Game, Fishery Data Series No. 91-67, Anchorage.

Evenson, M. J. and M. F. Merritt. 1995. CPUE estimates and catch-age analysis of burbot in the Tanana River drainage, 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-37, Anchorage.

Fournier, D. and C. P. Archibald. 1982. A general theory for analyzing catch at age data. Canadian Journal of Fisheries and Aquatic Sciences 39:1195-1207.

Guinn, D. A. and J. E. Hallberg. 1990. Precision of estimated ages of burbot using vertebrae and otoliths. Alaska Department of Fish and Game. Fishery Data Series No. 90-17, Juneau. 17 pp.

Hallberg, J. E. 1984. Evaluation of Interior Alaska waters and sport fish with emphasis on managed waters - Fairbanks District. Juneau, AK: Alaska Department of Fish and Game, Performance Report 25(G-III-H): p 63, 66-68.

Hallberg, J. E. 1985. Evaluation of Interior Alaska waters and sport fish with emphasis on managed waters - Fairbanks District. Juneau, AK: Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1984-1985, Project F-9-17, 26(G-III): 26 pp.

Hallberg, J. E. 1986. Interior burbot study. Part A: Tanana burbot study. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1985-1986, Project F-10-1, 27(N-8): 16 pp.

Hallberg, J. E., R. A. Holmes, and R. D. Peckham. 1987. Movement, abundance and length composition of 1986 Tanana River burbot stocks. Juneau, AK: Alaska Department of Fish and Game. Fishery Data Series No. 13. 21 pp.

Hightower, J. E. 1996. Comparison of reliability of catch-at-age analyses using auxiliary survey estimates of relative or absolute recruitment. Canadian Journal of Fisheries and Aquatic Sciences 53: 70-79.

Howe, A. L., G. Fidler, and M. J. Mills. 1995. Harvest, catch and participation in Alaska sport fisheries during 1994. Alaska Department of Fish and Game. Fishery Data Series No. 95-24, Anchorage.

Marquardt, D. W. 1963. An algorithum for least-squares estimation of nonlinear parameters. Journal for the Society of Industrial and Applied Mathematics 11:431-441.

McFarlane, G. and R. Beamish. 1987. Selection of dosages of oxytetracycline for age validation studies. Canadian Journal of Fisheries and Aquatic Sciences 44:905-909.

Megrey, B. A. 1989. Review and comparison of age-structured stock assessment models from theoretical and applied points of view. American Fisheries Society Symposium 6: 8-48.

Mills, M. J. 1988. Alaska statewide sport fisheries harvest report (1987). Alaska Department of Fish and Game, Fishery Data Series Number 52, Juneau.

Mills, M. J. 1989. Alaska statewide sport fisheries harvest report (1988). Alaska Department of Fish and Game, Fishery Data Series Number 122, Juneau.

Mills, M. J. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series Number 90-44, Anchorage.

Mills, M. J. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series Number 91-58, Anchorage.

Mills, M. J. 1992. Harvest, catch, and participation in Alaska sport fisheries during 1991. Alaska Department of Fish and Game, Fishery Data Series Number 92-40, Anchorage.

Mills, M. J. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series Number 93-42, Anchorage.

Mills, M. J. 1994. Harvest, catch, and participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series Number 94-28, Anchorage.

Ott, A. G., P. Weber-Scannell, and A. H. Townsend. 1995. Aquatic Habitat and fisheries studies, upper Fish Creek, 1992-1994. Alaska Department of Fish and Game, Habitat and Restoration Division. Technical Report No. 95-4.

Parma, A. M. 1992. Retrospective catch-at-age analysis of Pacific halibut: implication on assessment of harvesting policies, p. 247-265 *in* Management Strategies for Exploited Fish Populations, University of Alaska Sea Grant Report No. 93-02.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters. Charles Griffin and Company, Ltd. 654 pp.

von Bertalanffy, L. 1938. A quantitative theory of organic growth. Human Biology 10:181-213.

Wolter, K. M. 1984. An investigation of some estimators of variance for systematic sampling. Journal of the American Statistical Association 79 (388):781-790.

APPENDIX A

Appendix A.-Data files regarding burbot stock assessment in sections of the Tanana and Chena rivers archived by the Research and Technical Services of the Alaska Department of Fish and Game-Sport Fish Division[a].

Year	Data File	River (River Kilometer)
1986	U0275ETA.DTA	Tanana River (334-352)
1986	U0275ETB.DTA	Tanana River (334-352)
1986	U0275ETC.DTA	Tanana River (334-352)
1987	U0275CBA.DTA	Tanana River (339-354)
1987	U0275DBA.DTA	Tanana River (339-354)
1987	U0275EBA.DTA	Tanana River (339-354)
1987	U0275EBB.DTA	Tanana River (339-354)
1987	U0275EBC.DTA	Tanana River (339-354)
1988	U275CLA8.DTA	Tanana River (312-376)
1988	U0020LA8.DTA	Chena River (0-24)
1989	U275BLA9.DTA	Tanana River (317-374)
1989	U0020LA1.DTA	Chena River (0-40)
1990	U2750HA0.DTA	Tanana River (344-376)
1990	U0020HA0.DTA	Chena River (0-24)
1990	U0020HB0.DTA	Chena River (0-24)
1990	U0020HC0.DTA	Chena River (0-24)
1990	U0020HD0.DTA	Chena River (0-24)
1990	U0020HE0.DTA	Chena River (0-24)
1991	U2750HA1.DTA	Tanana River (336-360)
1991	U0020HA1.DTA	Chena River (0-24)
1992	U2750HA2.DTA	Tanana River (336-360)
1992	U0020HA2.DTA	Chena River (0-24)
1993	U2750HA3.DTA	Tanana River (336-360)
1993	U0210HA3.DTA	Chena River (0-24)
1994	U2750HA4.DTA	Tanana River (336-360)
1994	U0020HA4.DTA	Chena River (0-24)
1995	U2750LA5.DTA	Tanana River (336-360)
1995	U0020LA5.DTA	Chena River (0-24)

[a] Files for other river sections sampled since 1986 are given in Evenson (1994).

APPENDIX B. COMMAND AND DATA FILES USED TO RUN CAGEAN

Appendix B1.-Command File: initial values (CAGINIT.DAT).

TANANA BURBOT 1987-1994	
caginit.out	
1987 1994	range of years for analysis
4 16	range of ages for analysis
1	number of gear types
1	code number for gear type 1
1	number of selectivity groups
1987 1994	range of years of first selectivity group
9 16	range of ages of full selectivity first group
1	number of catchability groups
1987 1994	first and last years of catchability group 1
100	TIMES TO DO THE BOOT
0.45000	NATURAL MORTALITY
0.0	TO STOP NATURAL MORTALITIES
OK	OK TO PARAMETERS OK
Y	TO FULL LISTING
0	no fixing of variables - fix catchability
1	pooling of data (1=YES)
catch.dat	
weight.dat	
effort.dat	
.4	EFFORT OR CATCHABILITY LAMBDA GEAR TYPE 1
NONE	
bbinits.dat	
NONE	
kboot.out	
Y	PRINT LABELED RESIDS
Y	PRINT RESIDUALS

Appendix B2.-Command File: first run (CAGFRST.OUT).

TANANA BURBOT 1987-1994	
cagfrst.out	
1987 1994	range of years for analysis
4 16	range of ages for analysis
1	number of gear types
1	code number for gear type 1
1	number of selectivity groups
1987 1994	range of years of first selectivity group
9 16	range of ages of full selectivity first group
1	number of catchability groups
1987 1994	first and last years of catchability group 1
100	TIMES TO DO THE BOOT
0.45000	NATURAL MORTALITY
0.0	TO STOP NATURAL MORTALITIES
OK	OK TO PARAMETERS OK
Y	TO FULL LISTING
0	no fixing of variables - fix catchability
1	pooling of data (1=YES)
catch.dat	
weight.dat	
effort.dat	
0.4	EFFORT OR CATCHABILITY LAMBDA GEAR TYPE 1
NONE	
COHORT	
0.5	
NONE	
kboot.out	
Y	PRINT LABELED RESIDS
Y	PRINT RESIDUALS

Appendix B3.-Effort file (EFFORT.DAT).

1987	1	3026
1988	1	1666
1989	1	2421
1990	1	3225
1991	1	2748
1992	1	1721
1993	1	4329
1994	1	2968

Appendix B4.-Harvest file (CATCH.DAT).

4	1987	1	1
5	1987	1	5.4066
6	1987	1	5.9663
7	1987	1	6.2176
8	1987	1	5.4066
9	1987	1	6.2176
10	1987	1	5.4066
11	1987	1	5.8121
12	1987	1	6.2176
13	1987	1	5.4066
14	1987	1	5.4066
15	1987	1	5.1190
16	1987	1	5.6298
4	1988	1	4.0902
5	1988	1	4.9375
6	1988	1	5.6307
7	1988	1	6.2105
8	1988	1	6.0362
9	1988	1	6.3928
10	1988	1	6.0827
11	1988	1	6.0362
12	1988	1	5.6997
13	1988	1	4.3779
14	1988	1	4.3779
15	1988	1	4.0902
16	1988	1	3.6848
4	1989	1	3.4584
5	1989	1	4.8447
6	1989	1	5.4043

-continued-

7	1989	1	6.5495
8	1989	1	6.4029
9	1989	1	6.0975
10	1989	1	6.3488
11	1989	1	6.3488
12	1989	1	5.8563
13	1989	1	5.6556
14	1989	1	5.2502
15	1989	1	4.5570
16	1989	1	3.4584
4	1990	1	0.0
5	1990	1	0.0
6	1990	1	0.0
7	1990	1	0.0
8	1990	1	0.0
9	1990	1	0.0
10	1990	1	0.0
11	1990	1	0.0
12	1990	1	0.0
13	1990	1	0.0
14	1990	1	0.0
15	1990	1	0.0
16	1990	1	0.0
4	1991	1	1
5	1991	1	4.0098
6	1991	1	5.4369
7	1991	1	5.8556
8	1991	1	5.7734
9	1991	1	5.6192

-continued-

10	1991	1	5.6838
11	1991	1	4.9906
12	1991	1	5.5139
13	1991	1	5.1084
14	1991	1	4.0098
15	1991	1	3.6043
16	1991	1	2.2180
4	1992	1	1.7314
5	1992	1	4.8669
6	1992	1	5.7204
7	1992	1	6.2087
8	1992	1	6.1741
9	1992	1	6.0219
10	1992	1	6.0489
11	1992	1	5.8903
12	1992	1	5.4926
13	1992	1	5.0272
14	1992	1	4.5040
15	1992	1	4.2964
16	1992	1	4.0340
4	1993	1	1
5	1993	1	1
6	1993	1	3.7906
7	1993	1	5.1769
8	1993	1	5.1769
9	1993	1	6.6810
10	1993	1	6.6238
11	1993	1	6.9686

-continued-

12	1993	1	6.3555
13	1993	1	6.3555
14	1993	1	5.5823
15	1993	1	5.7365
16	1993	1	6.0932
4	1994	1	1
5	1994	1	1
6	1994	1	1
7	1994	1	5.8600
8	1994	1	5.8600
9	1994	1	6.3300
10	1994	1	6.3300
11	1994	1	6.7355
12	1994	1	6.5532
13	1994	1	6.0424
14	1994	1	6.4478
15	1994	1	5.3492
16	1994	1	4.9437

Appendix B5.-Weight file (WEIGHT.DAT).

4	1987	1	1
5	1987	1	1
6	1987	1	1
7	1987	1	1
8	1987	1	1
9	1987	1	1
10	1987	1	1
11	1987	1	1
12	1987	1	1
13	1987	1	1
14	1987	1	1
15	1987	1	1
16	1987	1	1

This Format was repeated for all years 1989-1994.

APPENDIX C. TANANA RIVER BURBOT HARVEST, 1977-1994, BY RIVER SECTION

Appendix C.-Tanana River burbot harvest 1977-1994.

River	Annual Harvest[a] (Number of Burbot)																	
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
Mainstem Tanana River																		
Lower Tanana R.[b]	0	0	0	0	0	0	0	0	0	0	40	218	130	236	113	93	11	180
Middle Tanana R.[b]	0	0	0	0	0	0	0	0	0	0	1,873	1,692	1,764	912	834	1,286	2,460	2,191
Upper Tanana R.[b]	0	0	0	0	0	0	0	0	0	0	409	509	411	641	654	338	685	823
Total Tanana R.[cd]	0	0	0	0	0	0	0	1,921	1,365	2,948	2,322	2,419	2,325	1,789	1,602	1,717	3,156	3,194
Lower Tanana River Tributaries																		
Chatanika R.	34	18	9	50	5	42	21	13	175	40	13	55	10	17	0	8	0	0
Nenana R.[d]	0	0	0	0	0	0	0	0	0	0	53	0	60	68	11	76	11	0
Minto Flats	37	72	45	9	32	21	0	39	105	32	132	0	20	0	56	0	0	208
Middle Tanana River Tributaries																		
Chena R.	642	389	807	1,127	1,317	1,457	1,055	1,233	2,065	889	149	386	1,322	304	225	1,032	1,135	737
Salcha R.	0	0	0	0	0	0	0	0	35	296	0	18	0	203	23	25	64	21
Piledriver Sl.[d]	0	0	0	0	0	0	0	84	0	0	79	55	100	456	203	195	568	73
Shaw Cr.[d]	0	0	0	0	0	0	0	415	175	120	607	0	170	354	45	161	161	93
Upper Tanana River Tributaries																		
DCR	0	0	0	29	0	0	0	13	0	0	26	0	0	0	0	0	0	0
Goodpaster R.[d]	0	0	0	0	0	0	0	221	350	88	13	109	120	0	0	17	86	0
Other Areas[e]	829	832	966	1,285	2,257	1,866	3,146	935	245	441	355	364	100	388	23	93	289	589
% Total											9.5	10.7	2.4	10.8	1.1	2.8	5.3	12.0
Total Lower River											238	273	220	321	180	177	22	388
% Total											6.3	8.0	5.2	9.0	8.2	5.3	0.4	7.9
Total Middle River											2,708	2,151	3,356	2,229	1,330	2,695	4,388	3,115
% Total											72.2	63.2	79.4	62.3	60.8	81.2	80.2	63.4
Total Upper River											448	618	531	641	654	355	771	823
% Total											11.9	18.1	12.6	17.9	30.0	10.7	14.1	16.7
Total All Areas	1,542	1,311	1,827	2,500	3,611	3,386	4,306	4,790	4,515	4,854	3,749	3,406	4,225	3,579	2,187	3,320	5,470	4,915

[a] Data from Alaska statewide harvest survey (Mills 1978-1995).

[b] River sections were not described as specific areas on the survey form until 1987.

[c] Includes harvests from upper, middle, lower, and unspecified sections.

[d] was not described as a specific area until 1984. Any harvest that may have occurred in this area would have been listed in the "Other this Areas" category.

[e] Was described as "Other Waters" on the survey form until 1984, and may have included harvests from lakes and ponds. Beginning in 1984, this category is listed as "Other Streams" on the survey form.

APPENDIX D-STATISTICAL TESTS FOR ANALYZING DATA FOR GEAR BIAS OF A TWO-EVENT MARK-RECAPTURE EXPERIMENT.

Appendix D.-Statistical tests for analyzing data for gear bias of a two-event mark-recapture experiment.

The following statistical tests will be used to analyze the data for significant bias due to gear selectivity by length:

1. Tests for significant gear bias by size will be based on: (A) Kolmogorov-Smirnov goodness of fit test comparing the distributions of the lengths of all fish that were marked during the first event and all marked fish that were collected during the second event; and, (B) Kolmogorov-Smirnov two sample test comparing the distributions of the lengths of all fish that were captured during the first event and all fish that were collected during the second event. The null hypothesis is no difference between the distributions of lengths for Test A or for Test B.

For these two tests there are four possible outcomes:

Case I:

Accept $H_o(A)$ Accept $H_o(B)$

There is no size-selectivity during the first or second sampling events.

Case II:

Accept $H_o(A)$ Reject $H_o(B)$

There is no size-selectivity during the second sampling event but there is size-selectivity during the first sampling event.

Case III:

Reject $H_o(A)$ Accept $H_o(B)$

There is size-selectivity during both sampling events.

Case IV:

Reject $H_o(A)$ Reject $H_o(B)$

There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.

Depending on the outcome of the tests, the following procedures will be used to estimate the abundance of the population:

-continued-

Case I: Calculate one unstratified estimate of abundance, and pool lengths from both sampling events to improve precision of proportions in estimates of compositions.

Case II: Calculate one unstratified estimate of abundance, and only use lengths from the second sampling event to estimate proportions in compositions.

Case III: Completely stratify both sampling events, and estimate the abundance for each stratum. Add the estimates of abundance across strata to get a single estimate for the population. Pool lengths from both sampling events to improve precision of proportions in estimates of composition, and correct for size bias to the pooled data.

Case IV: Completely stratify both sampling events and estimate the abundance for each stratum. Add the estimates of abundance across strata to get a single estimate for the population. Also, calculate a single estimate of abundance without stratification.

Case IVa: If the stratified and unstratified estimates of abundance for the entire population are dissimilar, discard the unstratified estimate. Only use the lengths, ages, and sexes from the second sampling event to estimate proportions in composition, and correct for size bias to data from the second event.

Case IVb: If the stratified and unstratified estimates of abundance for the entire population are similar, discard the estimate with the larger variance. Only use the lengths, ages, and sexes from the first sampling event to estimate proportions in compositions, and do not correct for size bias.