Fishery Data Series No. 95-4

Stock Assessment and Biological Characteristics of Burbot in Fielding Lake During 1994

by

James F. Parker

May 1995

Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Division of Sport Fish Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications without definition. All others must be defined in the text at first mention, as well as in the titles or footnotes of tables and in figures or figure captions.

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. 95-4

STOCK ASSESSMENT AND BIOLOGICAL CHARACTERISTICS OF BURBOT IN FIELDING LAKE DURING 1994

by
James F. Parker
Division of Sport Fish, Delta Junction

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

May 1995

This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-10, Job R-3-4(a).

The Fishery Data Series was established in 1987 for the publication of technically-oriented results for a single project or group of closely related projects. Fishery Data Series reports are intended for fishery and other technical professionals. Distribution is to state and local publication distribution centers, libraries and individuals and, on request, to other libraries, agencies, and individuals. This publication has undergone editorial and peer review.

James F. Parker
Alaska Department of Fish and Game, Division of Sport Fish
P.O. Box 605, Delta Jct., AK 99737-0605, USA

This document should be cited as:
Parker, J. F. 1995. Stock assessment and biological characteristics of burbot in Fielding Lake during 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-4, Anchorage.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

Abundance and index of abundance were estimated for a population of burbot *Lota lota* in Fielding Lake. Burbot were captured in baited hoop traps. Traps were set in a systematic pattern across Fielding Lake. Sampling occurred during June of 1994. Estimated mean CPUE per 48-hour set of fully (450 millimeters total length and longer) and partially (300 to 449 millimeters total length) recruited burbot in Fielding Lake was 0.52 (SE = 0.08) and 0.54 (SE = 0.07), respectively. Abundance of fully recruited burbot estimated with multiple year mark-recapture experiments was 302 (SE = 59) in Fielding Lake in 1993. Fully recruited burbot surviving from 1992 to 1993 was estimated at 65.9% (SE = 12.5).

Key words: burbot, *Lota lota*, lakes, abundance, hoop traps, systematic design, mean length, catch-per-unit of effort, abundance estimates, survival rates, recruitment.

INTRODUCTION

Harvests of burbot *Lota lota* from Interior lakes increased, on average, 30% annually from 1977 to 1983, with the largest harvest occurring during the years 1984 to 1986 (Mills 1994). The lakes in the Glennallen area (south-central Alaska) have historically supported the largest component of this harvest. Harvest of burbot in the Tanana River drainage has been stable (Figure 1).

Burbot harvests have declined in lakes of interior Alaska since peak harvests in the mid-1980's. This decline in harvests can be attributed to decreasing abundance of burbot in lakes due to overfishing and more restrictive regulations governing sport fisheries. Emergency regulations adopted in 1987 and other regulations since restricted bag and possession limits to two fish and eliminated the use of set lines as a legal method of sport fishing from the Upper-Copper/Upper Susitna management area, Fielding, T, and Harding lakes, and throughout the Tangle Lakes system. Regulations for other populations in the Tanana River drainage are a daily bag and possession limit of five burbot and a maximum of five hooks fished at any one time.

No recorded burbot harvest occurred in Fielding Lake (63°10' N, 145° 42' W) from 1989-1991 (Mills 1990-1992). During 1992 and 1993 there were 51 and 32 burbot harvested from Fielding Lake (Mills 1993, 1994), respectively. The recent decline in the population from 569 fully recruited burbot in 1991 to 256 fully recruited burbot in 1992 (Parker 1994) is attributed to low survival, possibly affected by increased unreported harvests between 1991 and 1992. This prompted the Department of Fish and Game to issue an emergency order on May 26, 1994, closing Fielding Lake to the taking of burbot until further notice.

In 1986, the Sport Fish Division of the Alaska Department of Fish and Game initiated a stock assessment program for burbot populations in the Upper Copper/Upper Susitna basin (Region II) and in the Tanana River drainage (Region III; Parker et al. 1987-1989, Parker 1993-1994, Lafferty et al. 1990-1992, Lafferty and Bernard 1993, Taube et al. 1994). This document is the ninth report of the findings from this research in Region III. The objectives of the program in 1994 are as follows:

1. to estimate the abundance in 1993 and survival rate from 1992 to 1993 for burbot greater than 449 mm total length (TL) in Fielding Lake; and,
2. to index abundance of burbot greater than 449 mm TL in Fielding Lake in 1994 with mean catch-per-unit effort (CPUE).

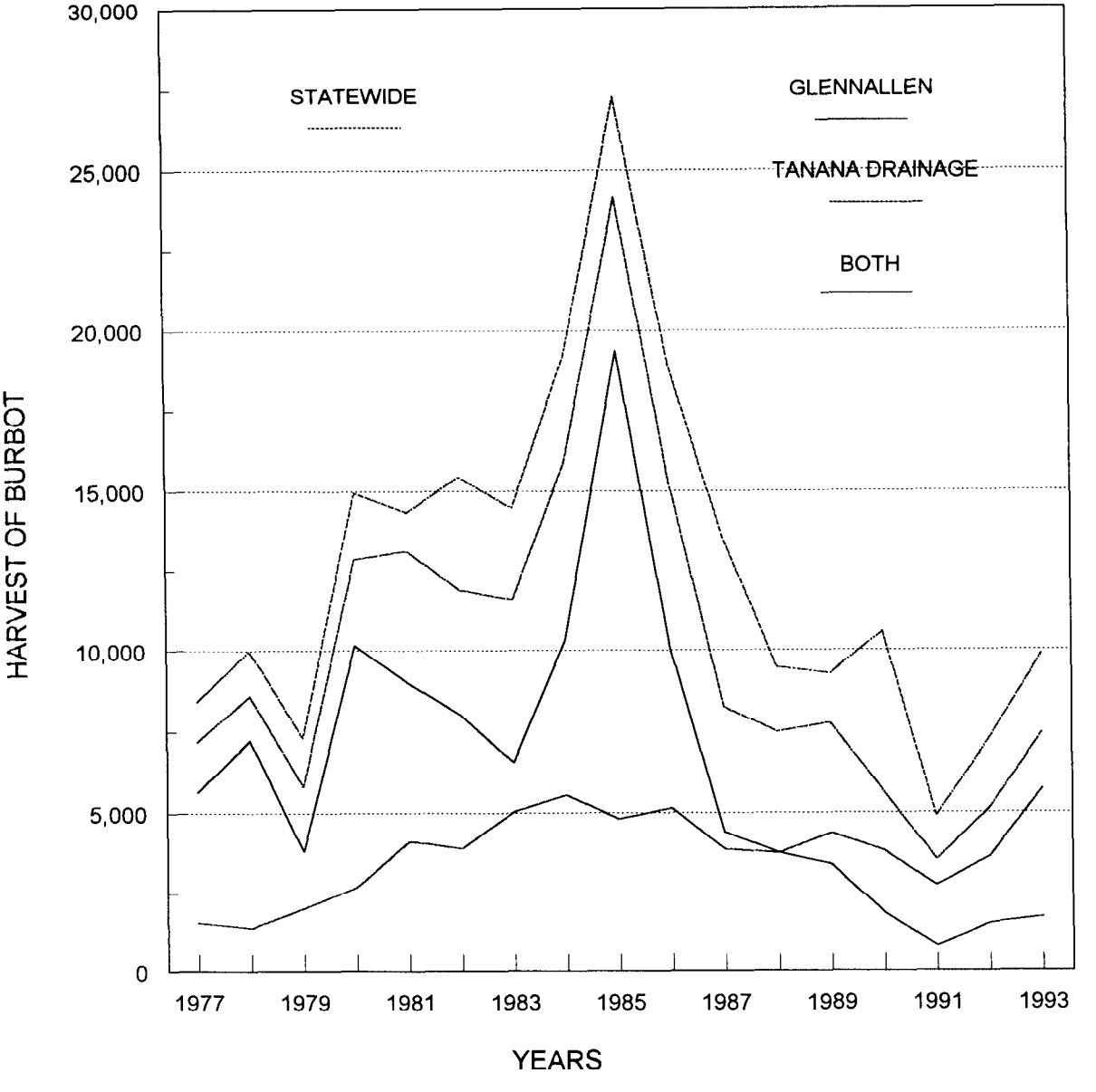

Figure 1.-Harvest in Alaskan burbot fisheries, 1977-1993.

A popular sport fishery was directed at Fielding Lake burbot stocks. Fielding Lake burbot are geographically isolated from other lakes by a lengthy river and accessible by road via the Richardson Highway (Figure 2). The lake surface area is 538 ha with a maximum depth of 24 m and an elevation of 906 m. The lake is fed by three inlet streams and the outlet stream is located on the north end of the lake. The lake begins to freeze by mid-October and breakup occurs from June 15 to July 1. Campground and boat launch facilities are located near the lakes' outlet, with several recreational cabins located along the south shore. In addition to burbot, Fielding Lake contains Arctic grayling *Thymallus arcticus*, lake trout *Salvelinus namaycush*, and round whitefish *Prosopium cylindraceum*.

METHODS

GEAR DESCRIPTION

Burbot were captured in hoop traps 3.05 m in length with seven 6.35 mm steel hoops (Figure 3). Hoop diameters tapered from 0.61 m at the entrance to 0.46 m at the cod end. Each trap was double throated (tied to the first and third hoop) with throats narrowing to an opening 10 cm in diameter. All netting material was knotted nylon 25 mm bar meshes, held together with No. 15 cotton twine, and treated with an asphaltic compound. Each trap was stretched with two sections of 12 mm galvanized steel conduit that was attached by snap clips to the end hoops of the trap. A numbered buoy was attached to the cod end of the trap with a polypropylene rope. Each trap was baited with Pacific herring *Clupea harengus pallasi* cut into chunks and placed in a 500 ml perforated plastic, screw-top container. Bait containers were placed unattached in the cod end of the hoop trap. Each hoop trap was soaked for approximately 48 hours (hereafter referred to as a set) to maximize the catch of burbot (Bernard et al. 1991).

STUDY DESIGN

Mean CPUE was estimated with a two-stage, systematic survey of 300 sets from June 16-20. First, an overlay with parallel lines was placed across a map of Fielding lake at a randomly chosen position but with the lines in the overlay perpendicular to the long axis of the lake. Distances between adjacent lines[1] in the overlay represented 125 m. Each parallel line had tick marks that represented a distance of 125 m. Next, the desired number of sets was compared with the tick marks that were over the water on the map; parallel lines were randomly excluded until the tick marks and the desired number of sets were similar. Traps were set in transects corresponding to the position of each remaining parallel line. However, the location of the first set along each transect was randomly chosen, and every subsequent set was along that transect at 125 m from the last set. The desired number of sets for each survey in mark-recapture experiment was estimated by dividing an a *priori* estimate of mean CPUE into sample size in numbers of burbot needed for the associated mark-recapture experiment. Sample size for the mark-recapture experiment is based on a previous abundance estimate. The desired number of sets to estimate mean CPUE as an index of abundance was calculated with procedures in Cochran (1977) for

[1] The distance between traps of 125 m was chosen to eliminate gear competition. The effective fishing area of a baited trap was estimated at 0.45 ha by dividing the average CPUE of burbot caught per 48-hour set in 1985 in Fielding Lake by the density of burbot per ha from the mark-recapture experiment (Pearse and Conrad 1986). This estimated fishing area was arbitrarily increased to 1.25 ha to ensure elimination of gear competition; this area corresponds to traps set at a distance of 125 m.

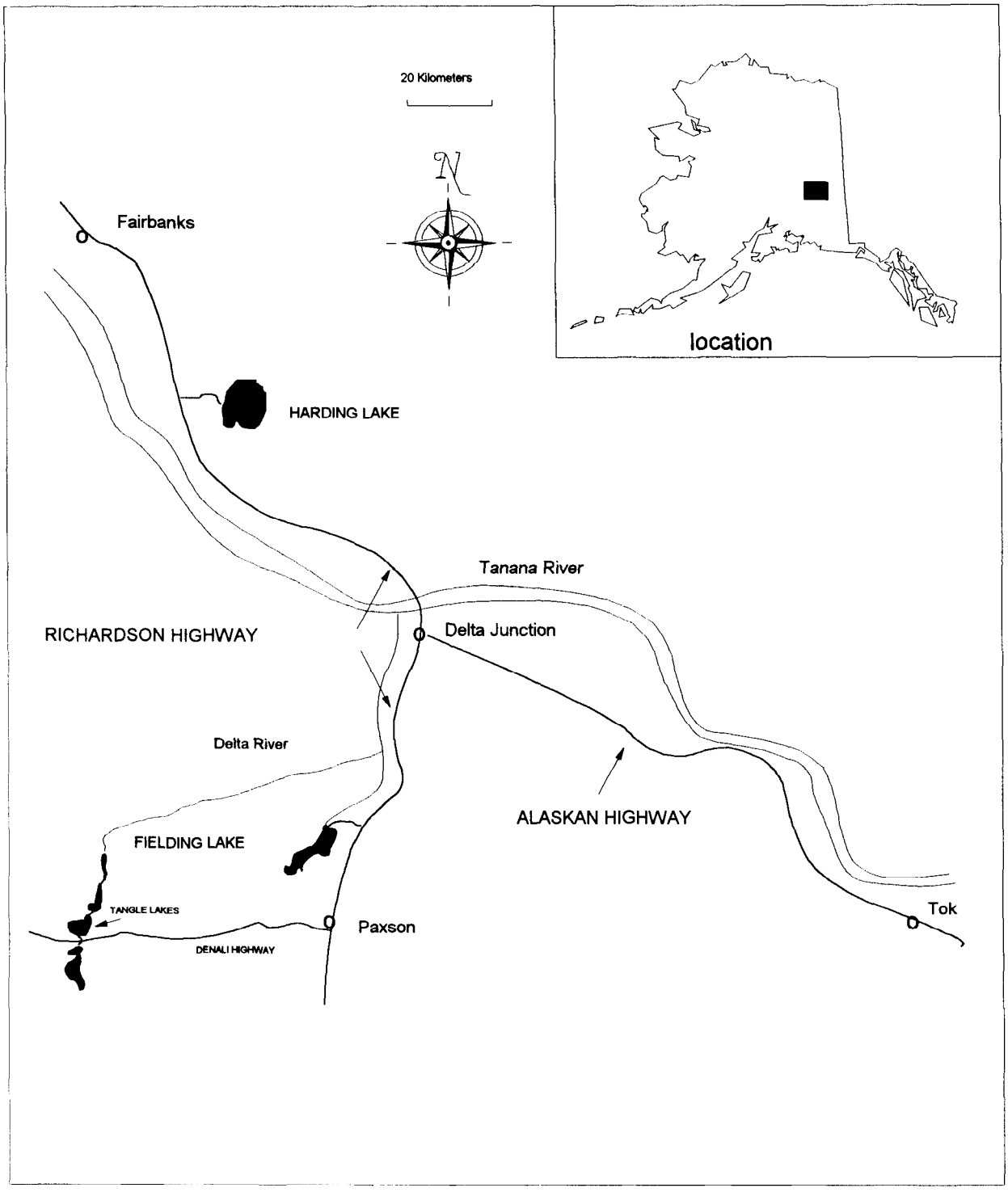

Figure 2.-Location of Fielding Lake in the Tanana River drainage.

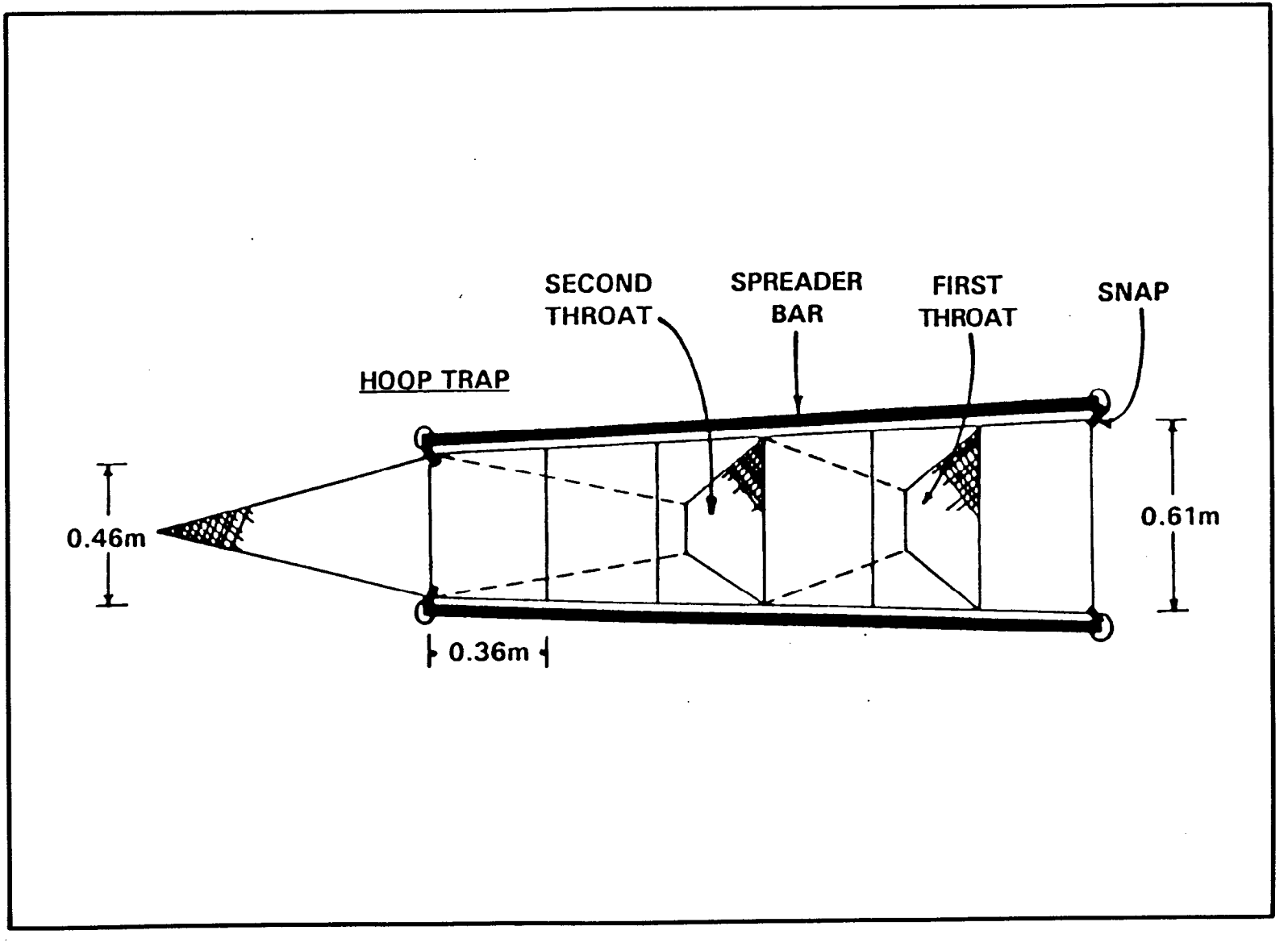

Figure 3.-Schematic drawing of hoop traps used to catch burbot during 1994.

determining sample size to estimate the mean of a continuous variable. Desired sample sizes for both mean CPUE and abundance was calculated, and the larger number was used.

Traps were immersed and retrieved during daylight hours beginning on one end of the lake and progressing to the other end. A single crew of three (one person piloted the boat and recorded data while the other two handled traps and measured and tagged captured burbot) immersed and retrieved traps simultaneously. The crew immersed and retrieved 60 traps in an 8-hour work day. Every new set received fresh bait, and old bait was discarded on shore.

Captured fish from each trap were placed into a plastic tank during sampling. Each burbot was measured and those greater than 300 mm TL was doubly marked. Burbot were tagged with an individually numbered Floy tag inserted in the musculature beneath the dorsal fin. Throughout the mark-recapture experiments, tags were used in serial order to allow easy recognition of specific locations and sampling events. The second mark, which was used to evaluated loss of Floy tags, was a left ventral finclip. Any burbot that was stressed from deep-water removal (usually an expanded gas bladder) or had trap-inflicted injuries was killed and dissected. Otoliths were removed, and the sex and maturity of these burbot were recorded. Ages were estimated from whole, polished otoliths by counting annuli according to the method of Beamish and McFarlane (1987) and Chilton and Beamish (1982). Burbot in Fielding Lake were separated into two groups for analysis: those fully recruited to the hoop traps ($\geq$ 450 mm TL) and those partially recruited ($<$ 450 mm TL). Bernard et al. (1991) showed that burbot recruited fully to the hoop trap gear between 450 and 500 mm TL in most populations.

MEAN CPUE

Mean CPUE was estimated in Fielding Lake for fully ($\geq$ 450 mm TL) and partially ($<$ 450 mm TL) recruited burbot following a two-stage sampling design with transects as first-stage units and sets along transects as second-stage units (Sukhatme et al. 1984). Although all transects had an equal probability of being included in a survey, they were of different sizes (lengths) depending upon the shape of the lake. Under these conditions, an unbiased estimate of mean CPUE is:

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

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;

x_i = $M_i \overline{M}$; and

M_i = maximum possible sets on the ith transect.

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

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

Thus $\hat{x}_i = m_i / \overline{m}$ was inserted for. x_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 hours for most sets. Although the distribution of burbot can be related to depth (Odell 1932; Kennedy 1940; Rawson 1951; Dryer 1966), estimate of mean CPUE was not post-stratified by depth because sampling effort was proportionally (or near proportionally) allocated across depths within the survey design. A two-stage, resampling procedure (Efron 1982, Rao and Wu 1988) was used to generate an empirical distribution of mean CPUE for each survey from which variance of mean CPUE and bias from using x were estimated (Bernard et al. 1993).

ABUNDANCE, SURVIVAL RATES, AND RECRUITMENT

Abundance, survival rates, and surviving recruitment of fully recruited burbot (≥450 mm TL) were estimated using the mark-recapture histories of fish according to the models of Jolly (1965) and Seber (1965, 1982). The computer program Jolly (model A) as described in Pollock et al. (1985, 1990) was used to do the calculations. Mark-recapture histories for the population are listed in Appendices A1 and A2. In earlier years, two-event mark-recapture experiments based on closed populations were use to estimate abundance of burbot; both events were a few weeks apart. Data from these experiments were pooled to form the annual sampling events used in the multi-year mark-recapture experiment as recommended by Pollock (1982). Since mark-recapture experiments of this type do not produce estimates of abundance for the current year of sampling, mean CPUE was used to estimate abundance of burbot in 1994 using the relationship:

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

where A is the surface area the lake, and q is the catchability coefficient (the fraction of the population removed instantaneously with one unit of sampling effort). Estimates of q were obtained from previous sampling in Fielding Lake (see Lafferty and Bernard 1993; Parker 1994). Since catchability of burbot in hoop traps is about 1.5 times higher just after lakes become ice-free than later in the summer (Bernard et al., 1993), only information from past sampling events that matched the scheduling with the sampling event in 1994 was used to estimate an average q.

RESULTS

Length distributions of fully recruited burbot in 1994 were significantly different than in 1993 (Kolmogorov-Smirnov two-sample test, $P < 0.05$; Figure 4). Results of this hypothesis test indicate fewer burbot were recruited into this size group than in the previous year. The mean length of fully recruited burbot in 1993 was 520 mm TL (Parker 1994) which increased to 571 mm TL in 1994 (Table 1), as a result of fewer recruits. Fully recruited burbot released in 1993 and recaptured in 1994 grew an average of 41 mm (n=27). The length distribution in 1993 had a steep ascending left limb from 300 to 400 mm (Parker 1993). There was a less abrupt left ascending limb from 300 to 425 mm in 1994 (Figure 5). The mode of the distribution (420 mm) is less than the length at full recruitment for the sampling gear (450 mm TL).

In 1994, estimated mean CPUE (bootstrapped) of fully and partially recruited burbot was 0.53 burbot and 0.54 burbot per set, respectively (Table 2). Estimated bias in mean CPUE as

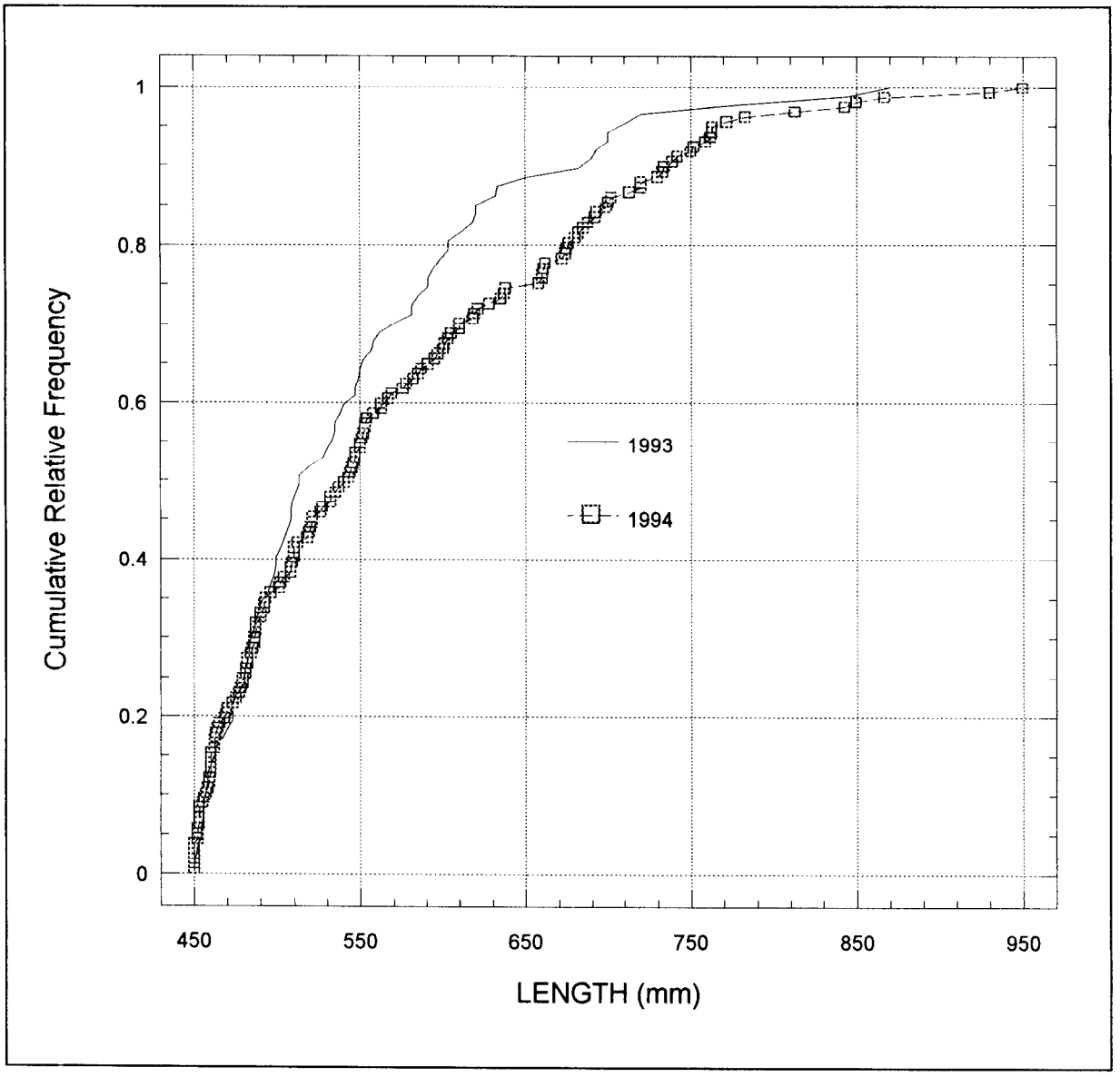

Figure 4.-Cumulative length frequency of burbot captured during 1993 and 1994.

Table 1.-Mean lengths (mm TL) of measured burbot during the 1994 sampling event.

		Recruitment to the gear[a]		
Lake	Statistic	Partially	Fully	All
Fielding	Mean	385	571	477
	SE	3	9	7
	Samples	161	157	318

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

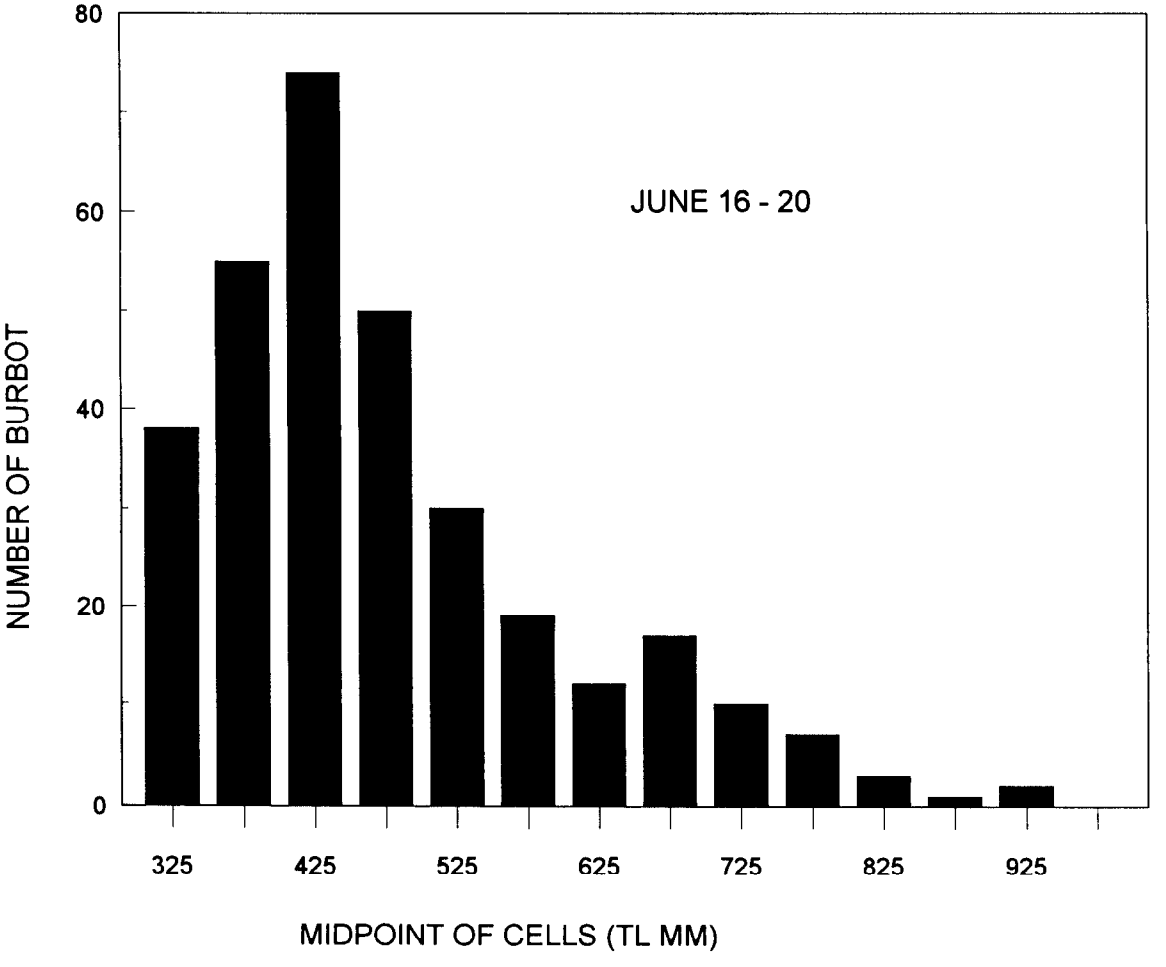

Figure 5.-Length-frequency histogram of burbot captured in 1994.

Table 2.-Estimated mean CPUE of fully recruited (≥ 450 mm TL) and partially recruited (< 450 mm TL) from systematic sampling of the population in 1994.

Dates	Strata	Number of Sets and Transects		Mean CPUE Bootstrapped	Mean CPUE Arithmetic	%D	SE	CV
Full Recruits:								
6/16-22	All depths	299	43	0.53	0.52	0.7	0.08	15.0
Full Recruits:								
6/16-22	All depths	299	43	0.54	0.54	0.0	0.07	13.8

calculated through bootstrapping was negligible (< 0.7%). Estimated mean CPUE for fully recruited burbot has declined from 0.71 in 1991 (Lafferty et al. 1992) to 0.47 in 1992 (Parker 1993), and 0.32 in 1993 (Parker 1994). The CPUE of partially recruited burbot increased from 0.42 in 1992 to 0.62 in 1993 but declined slightly in 1994 (Figure 6). Sets were most numerous between 6-10 m with burbot being caught at all depths (Figure 7).

Abundance in 1993 of fully recruited burbot was estimated at 302 fish and abundance in 1994 was estimated at 371. Annual survival rate from 1992-1993 was estimated at 66%, and surviving recruitment was estimated at 107 (Table 3). Density of fully recruited burbot in 1993 was 0.56 fish per hectare (SE = 0.11) which is considerably less than the 1991 estimate of 1.06 fish per hectare (SE = 0.18, Parker 1993; Table 4). Rate of overwinter tag loss was 3.1% for fully recruited burbot. Throughout the mark-recapture experiment, there was no evidence of regenerated fins on any of the recaptured burbot with tags. Table 4 contains statistics on catchability coefficients that were used for the 1994 estimate of abundance. In 1994, two fish were killed incidental to sampling, age, weight, and length information collected from these fish are found in the Appendix A3. Voluntary tag returns from sport anglers from other population studied in past years are listed in Appendix A4. Finally, Appendix A5 provides a listing of the data archives.

DISCUSSION

Potential bias in the estimate of abundance, survival rate, and recruitment from the mark-recapture experiment was negligible. Only three of the 40 fully recruited recaptured burbot, marked in 1993, lost their tags. Secondary marks allowed these recaptures to be identified to the marking event. No immigration or emigration has ever been observed from Fielding Lake. Sampling recommendations in Bernard et al. (1991) have been followed closely to avoid other potential bias in estimates mentioned above.

High fishing mortality prior to 1984 resulted in poor recruitment of juveniles. These fish enter the fully recruited population in low numbers beginning in 1992 (Parker 1994). Harvest in 1992 and 1993 even though small, has a high exploitation of 17% and 10%, respectively. Harvest during low recruitment will contribute to variable abundance of fully recruited burbot.

The abundance of fully recruited burbot in Fielding Lake between 1992 and 1993 remained nearly the same. Also survival of fully recruited burbot increased to an average level during the same time. While current estimates of abundance, recruitment, and survival rates from the mark-recapture experiment will change as time passes (statistics will become more accurate as data accumulate), the mean CPUE in 1994 indicates that abundance will increase in 1994. Fielding and Harding lakes are the only two roadside lakes in the Tanana River drainage that are productive enough to support a burbot fishery. A small sustainable level of harvest can be allowed in Fielding Lake once the population increases to past abundance levels.

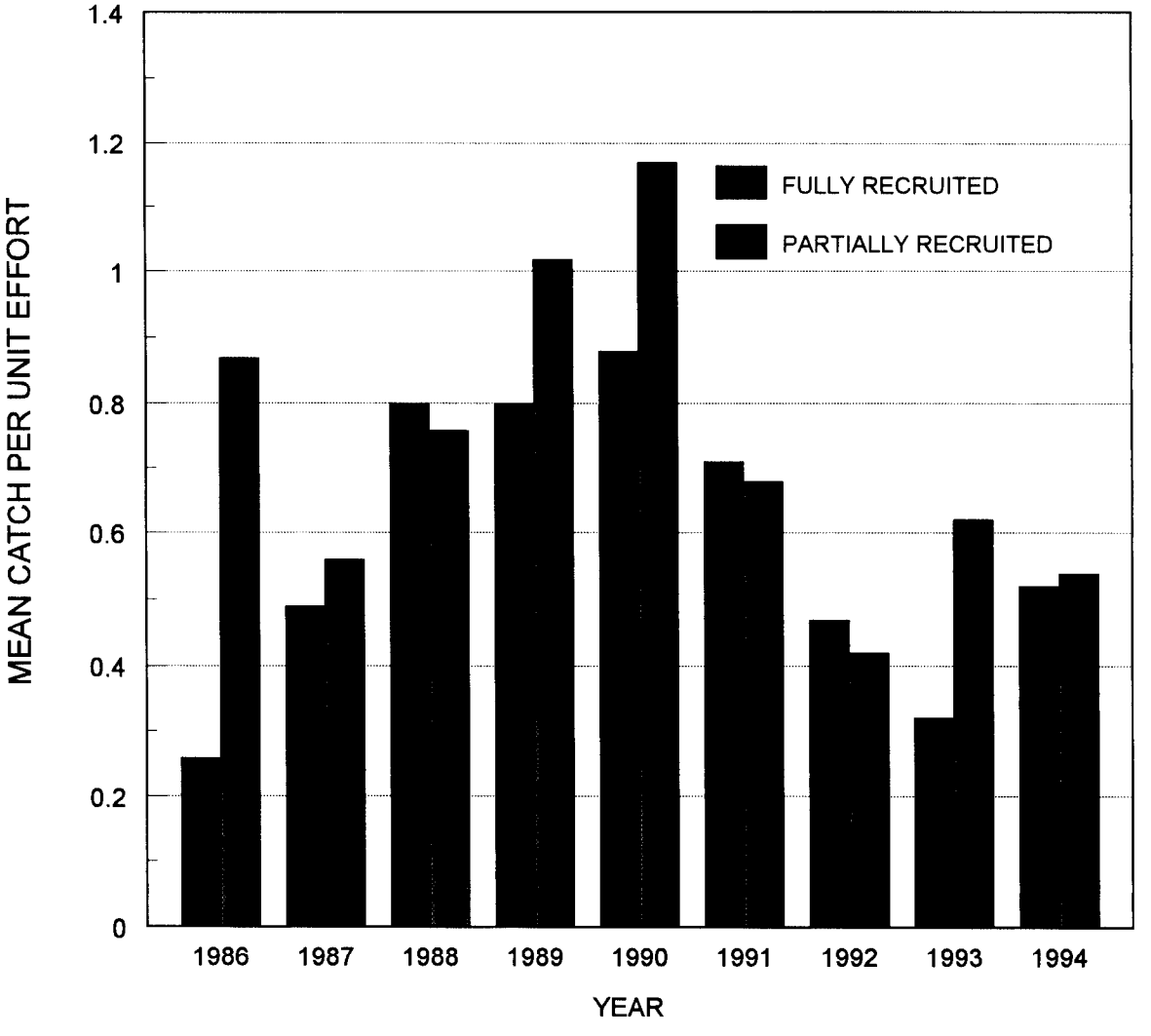

Figure 6.-Mean CPUE of fully recruited (≥ 450 mm TL) burbot captured during spring sampling events from 1988 - 1994.

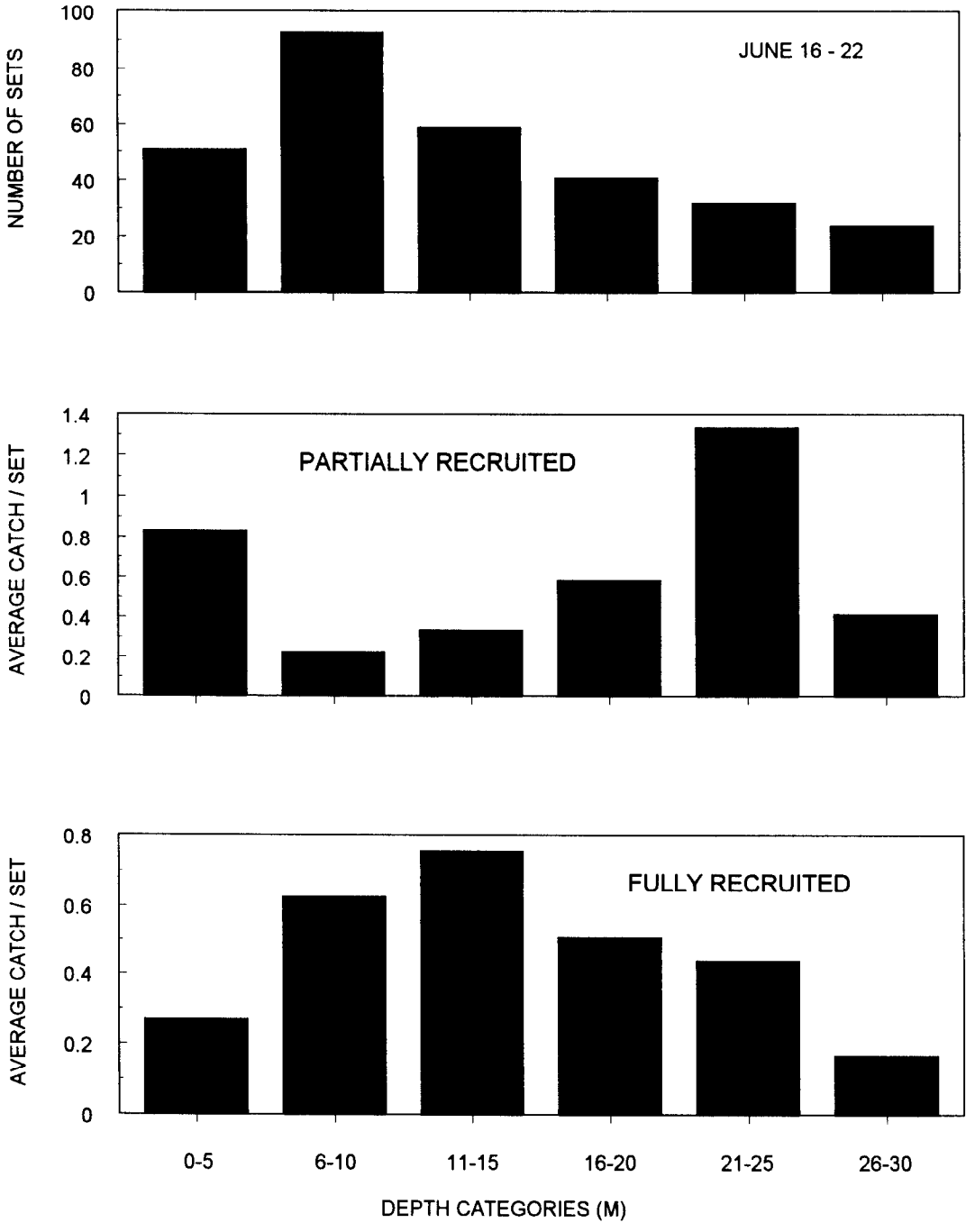

Figure 7.-Frequency of sets by depth and average catch of burbot by depth in 1994.

Table 3.-Estimates of abundance, survival rate, and recruitment for fully recruited (≥ 450 mm TL) burbot.

		Days				Survival			
	Midway	Between	Abundance			Rate %		Recruitment	
Lake	Date	Events	Est.	(SE)	CV %	Est.	(SE)	Est.	(SE)
Fielding	7/14/84		N/A						
		403				64.9	13.7	N/A	
	8/21/85		325	83	25.7				
		355				54.7	7.0	170	72
	8/11/86		335	55	16.5				
		360				67.0	7.0	38	35
	8/06/87		234	23	9.6				
		343				93.6	8.8	246	46
	7/15/88		444	54	12.2				
		365				78.8	9.1	227	61
	7/15/89		556	72	13.0				
		367				69.5	8.3	267	68
	7/17/90		651	81	12.5				
		368				69.7	9.3	140	60
	7/20/91		592	82	13.8				
		335				43.2	6.3	42	28
	6/27/92		297	38	12.9				
		361				65.9	12.5	107	36
	6/23/93		302	59	19.6				
		360							
	6/19/94		371						

Table 4.-Spring catchability coefficients for fully recruited burbot (≥ 450 mm TL) from 1988 - 1993.

Lakes and Dates	Mean CPUE	Abundance[a]	Density	Catchability Coefficient[b]
Fielding Lake:				
6/29/88	0.81	445	0.83	0.99
6/26/89	0.81	567	1.05	0.77
6/16/90	0.88	667	1.24	0.71
6/24/91	0.71	569	1.06	0.67
6/27/92	0.46	256	0.48	0.97
6/23/93	0.32	302	0.56	0.58
Spring Average				0.78

[a] Jolly-Seber multi-year mark-recapture estimate, unless otherwise noted.

[b] Mean CPUE multiplied by surface area (538 ha) divided by abundance.

ACKNOWLEDGMENTS

I would like to thank Doug Edwards, Pat Houghton, Roy Perry and Isaac Parker who assisted with the Lake Burbot Project. My thanks to Frank and Donna Seigwart, camp host (Park Service), at Fielding Lake, for their hospitality and enthusiasm in collecting information from anglers catching tagged fish. Finally, I appreciate the editorial comments from Dave Bernard and Peggy Merritt.

LITERATURE CITED

Beamish, R. J. and G. A. McFarlane. 1987. Current trends in age determination methodology, Pages 15-42 in R.C. Summerfelt and G.E. Hall ed. The Age and Growth of Fish. Iowa State University Press, Ames, Iowa. 544pp.

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

Bernard, D. R., J. F. Parker, and R. Lafferty. 1993. Stock assessment of burbot populations in small and moderately sized lakes. North American Journal of Fisheries Management 13:657-675.

Chilton, D. E. and R. J. Beamish. 1982. Age determination methods for fishes studied by the groundfish program at the Pacific Biological Station. Canadian Special Publication of Fisheries and aquatic Sciences, No. 60:102pp

Cochran, W. G. 1977. Sampling techniques, 3rd ed. John Wiley and Sons, Inc. New York. 428 pp.

Dryer, W. R. 1966. Bathymetric distribution of fish in the Apostle Islands region, Lake Superior. Transactions of the American Fisheries Society 95(3):248-259.

Efron, B. 1982. The jackknife, the bootstrap, and other resampling plans. Society of Industrial and Applied Mathematics, Philadelphia. 92 pp.

Jolly, G. M. 1965. Explicit estimates from capture-recapture data with both death and immigration - stochastic model. Biometrika 52:225-247.

Kennedy, W. A. 1940. The migration of fish from a shallow to a deep lake in spring and early summer. Transactions of the American Fisheries Society 70(1940):391-396.

Lafferty, R., J. F. Parker, and D. R. Bernard. 1990. Stock assessment and biological characteristics of burbot in lakes of interior Alaska during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-48, Anchorage.

Lafferty, R., J. F. Parker, and D. R. Bernard. 1991. Stock assessment and biological characteristics of burbot in lakes of interior Alaska during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-57, Anchorage.

Lafferty, R., J. F. Parker, and D. R. Bernard. 1992. Stock assessment and biological characteristics of burbot in lakes of interior Alaska during 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-20, Anchorage.

Lafferty, R., and D. R. Bernard. 1993. Stock assessment and biological characteristics of Burbot in Lake Louise, Moose, and Tolsona Lakes, Alaska, 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-19, Anchorage.

Mills, M. J. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-44, Anchorage.

Mills, M. J. 1991. Harvest and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-58, Anchorage.

LITERATURE CITED (Continued)

Mills, M. J. 1992. Harvest and participation in Alaska sport fisheries during 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-40, Anchorage.

Mills, M. J. 1993. Harvest and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-42, Anchorage.

Mills, M. J. 1994. Harvest and participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 93-28, Anchorage.

Odell, T. T. 1932. The depth distribution of certain species of fish in some of the lakes of New York. Transactions of the American Fisheries Society 62:333.

Parker, J. F., W. D. Potterville, and D. R. Bernard. 1987. Stock assessment and biological characteristics of burbot in lakes of interior Alaska during 1986. Alaska Department of Fish and Game, Fishery Data Series No. 14, Juneau.

Parker, J. F., W. D. Potterville, and D. R. Bernard. 1988. Stock assessment and biological characteristics of burbot in lakes of interior Alaska during 1987. Alaska Department of Fish and Game, Fishery Data Series No. 65, Juneau.

Parker, J. F., R. Lafferty, W. D. Potterville, and D. R. Bernard. 1989. Stock assessment and biological characteristics of burbot in lakes of interior Alaska during 1988. Alaska Department of Fish and Game, Fishery Data Series No. 98, Juneau.

Parker, J. F. 1993. Stock assessment and biological characteristics of burbot in Fielding and Harding Lakes During 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-9, Anchorage.

Parker, J. F. 1994. Stock assessment and biological characteristics of burbot in Fielding Lake, Round and Upper Tangle Lakes During 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-22, Anchorage.

Pearse, G. A. and R. Conrad. 1986. Interior burbot study, part c: hoop trap catch per unit effort standardization. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1985-1987, Project N-8-1. 51 pp.

Pollock, K. H. 1982. A capture-recapture design robust to unequal probability of capture. J. Wildlife Management 46(3):752-757.

Pollock, K. H., J. E. Hines, and J. D. Nichols. 1985. Goodness-of-fit tests for open capture-recapture models. Biometrics 41:399-410.

Pollock, K. H., J. D. Nichols, C. Brownie, and J. E. Hines. 1990. Statistical inference for mark-recapture experiments. Wildlife Monograph 107. 97 p.

Rao, J. N. K. and C. F. J. Wu. 1988. Resampling inference with complex survey data. J. American Statistical Association. 83(401) 231-241.

Rawson, D. S. 1951. Studies of the fish of Great Slave Lake. Journal of the Fisheries Research Board of Canada 8(4):207-240.

Seber, G. A. F. 1965. A note on the multiple-recapture census. Biometrika 52:249-259.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, 2nd. Griffin & Co., Ltd. London.

Sukhatme, P. B., B. V. Sukhatme, S. Sukhatme, and C. Asok. 1984. Sampling theory of survey applications. Iowa State University Press. Ames, Iowa. 526 pp.

Taube, T., Bernard, D. R., and Lafferty R. 1994. Stock assessment and biological characteristics of burbot in Lake Louise, Hudson, and Tolsona Lakes, Alaska, 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-4, Anchorage.

APPENDIX A

Appendix A1.-Mark-recapture histories of fully recruited[a] burbot by year (by sampling event in 1994).

Fielding Lake											
Date:	Year	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
	Beginning	7/20	7/16	7/28	7/21	6/29	6/26	6/16	6/22	6/24	6/20	6/16
	Ending	10/8	9/27	8/25	8/22	7/31	8/04	8/17	8/18	6/30	6/26	6/22
NUMBER OF FULLY RECRUITED BURBOT:												
Recaptured from Event 1		0	13	2	2	0	2	0	0	0	0	0
Recaptured from Event 2			0	27	23	1	1	1	2	0	0	0
Recaptured from Event 3				0	30	9	2	1	0	2	0	0
Recaptured from Event 4					0	48	18	4	6	4	0	0
Recaptured from Event 5						0	38	16	7	7	2	0
Recaptured from Event 6							0	51	13	5	0	2
Recaptured from Event 7								0	52	18	3	6
Recaptured from Event 8									0	38	8	6
Recaptured from Event 9										0	29	16
Recaptured from Event 10											0	24
Recaptured from Event 11												0
Captured with Tags		0	13	29	55	58	61	73	80	74	42	54
Captured without Tags		43	149	90	93	117	120	152	108	67	45	103
Captured		43	162	119	148	175	181	225	188	141	87	157
Released with Tags		43	138	76	126	149	177	223	187	140	87	156

[a] Fully recruited burbot are ≥450 mm TL.

Appendix A2.-Mark-recapture histories of partially recruited[a] burbot by year (by sampling event in 1994).

Fielding Lake											
Date:	Year	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
	Beginning	7/20	7/16	7/28	7/21	6/29	6/26	6/16	6/22	6/24	6/20	6/16
	Ending	10/8	9/27	8/25	8/22	7/31	8/04	8/17	8/18	6/30	6/26	6/20
NUMBER OF FULLY RECRUITED BURBOT:												
Recaptured from Event 1		0	19	6	0	1	0	0	0	0	0	0
Recaptured from Event 2			0	50	23	4	4	0	0	0	0	0
Recaptured from Event 3				0	29	13	2	0	0	0	0	0
Recaptured from Event 4					0	28	5	2	0	0	0	0
Recaptured from Event 5						0	31	5	0	0	0	0
Recaptured from Event 6							0	38	5	0	0	0
Recaptured from Event 7								0	24	2	4	0
Recaptured from Event 8									0	12	6	0
Recaptured from Event 9										0	13	7
Recaptured from Event 10											0	11
Recaptured from Event 11												0
Captured with Tags		0	19	56	52	46	42	45	29	14	23	18
Captured without Tags		65	432	278	230	175	244	274	168	112	142	143
Captured		65	451	334	282	221	286	319	197	126	165	161
Released with Tags		65	404	233	163	152	279	308	194	121	158	160

[a] Partially recruited burbot are <450 mm TL.

Appendix A3.-Weights, lengths and estimated ages of burbot killed in 1994.

Date Killed	Tag Number	Sex	Age	Length (mm)	Weight (kg)	Maturity
6/20/94	8767	M	5	410	0.55	Immature
6/21/94	8806	F	7	450	0.60	Immature

Appendix A4.-Voluntary returns of tags by sport anglers from other populations studied in past years.

Lake	Date Tagged	Tag Number	Date Caught	Recapture Location
Harding	9/19/90	71305	07/08/94	Harding Lake
Harding	9/17/90	71296	04/09/94	Harding Lake
Harding	6/20/87	24929	05/24/94	Harding Lake
Harding	9/20/91	72645	12/31/93	Harding Lake
Landlock Tangle	7/20/86	37566	07/??/94	Landlock Tangle Lake

Appendix A5.-Summary of data archives.

Location	Project Leader	Storage Software and version
Region III	J.F. Parker	Comma delimited
Delta Junction	895-4632	ASCII files Standard
		RTS Archive format [a]

	Data Map		
Lake	File Name	Data Format	Software
Fielding	U0130HA4.DTA	Hoopnet	RTS-ASCII
	FIEL94TD.DBF	Tag History	DBASE

Definitions of Data Formats:

Hoopnet: 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.

Tag History: a Dbase file that contains lake specific historical tagging information by individual tags and recaptures by sampling events.

Specific codes and organization of columns for each data format are available on request from RTS.

[a] Alaska Department of Fish and Game - Sport Fish Division - Research and Technical Services (RTS).