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Stock Assessment and Biological Characteristics of Burbot in Fielding Lake, Round and Upper Tangle Lakes During 1993

by

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CHARACTERISTICS OF BURBOT IN FIELDING LAKE,
ROUND AND UPPER TANGLE LAKES DURING 1993[1]

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

Abundance and/or indices of abundance were estimated for populations of burbot *Lota lota* in three lakes in the Tanana River drainage. Burbot were captured in baited hoop traps set in a systematic pattern across each lake sampled during June of 1993. Estimated mean catch per unit of effort 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 0.32 (SE = 0.06) and 0.62 (SE = 0.11), respectively. Mean catch per unit of effort of all burbot ($\geq$ 300 millimeters total length) was 0.58 (SE = 0.15) burbot in Upper Tangle Lake and 1.03 (SE = 0.17) burbot in Round Tangle Lake. Abundance of fully recruited burbot estimated with multiple year mark-recapture experiments was 256 (SE = 39) in Fielding Lake in 1992. Estimated rate of survival of fully recruited burbot from 1991 to 1992 was 38.2% (SE - 6.7) in Fielding Lake.

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 1993). The lakes in the Glennallen area (southcentral Alaska) have historically supported the largest component of this harvest. Harvest of burbot in the Tanana drainage has been stable (Figure 1).

Since the peak harvests in the mid-1980's, harvests of burbot in lakes of interior Alaska have declined. 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.

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, Lafferty et al. 1990-1992, Lafferty and Bernard 1993). This document is the eighth in a series of annual reports of the findings from lake burbot research in Region III. The objectives of the program in 1993 are as follows:

1. to estimate the abundance in 1992 and survival rate from 1991 to 1992 for burbot greater than 449 mm total length (TL) in Fielding Lake;

2. to index abundance of burbot greater than 449 mm TL in Fielding Lake in 1993 with mean catch per unit of effort (CPUE); and,

3. to index abundance of burbot greater than 299 mm TL in 1993 in Round and Upper Tangle lakes treated as a single unit with mean CPUE.

In addition, incremental growth and density of burbot in Fielding Lake were estimated. Each of the populations studied in 1993 has (or had) a popular sport fisheries for burbot. Study populations reside in lakes that are either geographically isolated or are separated from other lakes by lengthy rivers (Figure 2). Descriptions of each study lake are presented in Appendix A.

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 mesh, held together with No. 15

ALASKA BURBOT HARVEST 1977 - 1992

HARVEST OF BURBOT
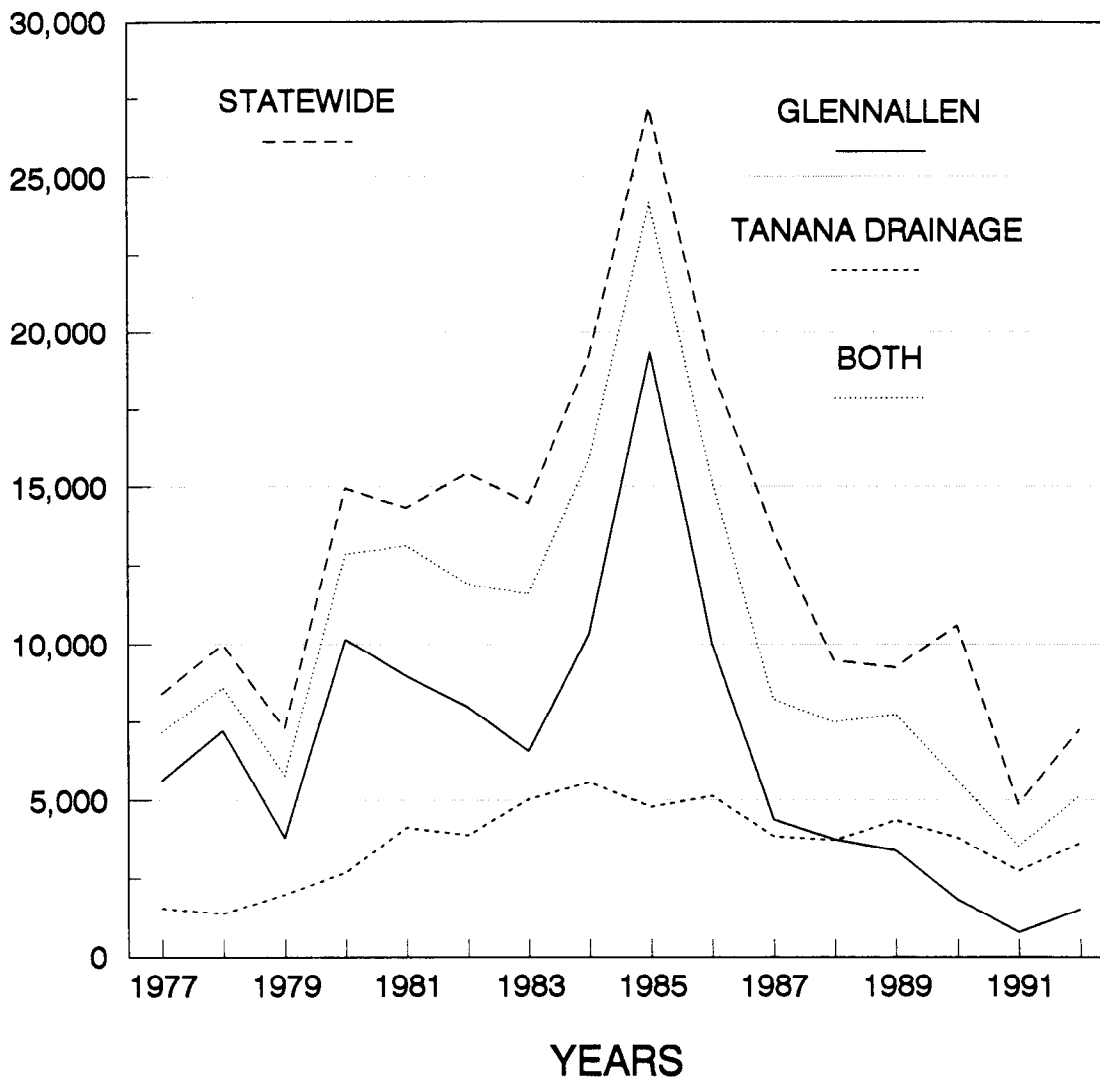
Figure 1. Harvests for Alaskan burbot fisheries, 1977-1992.
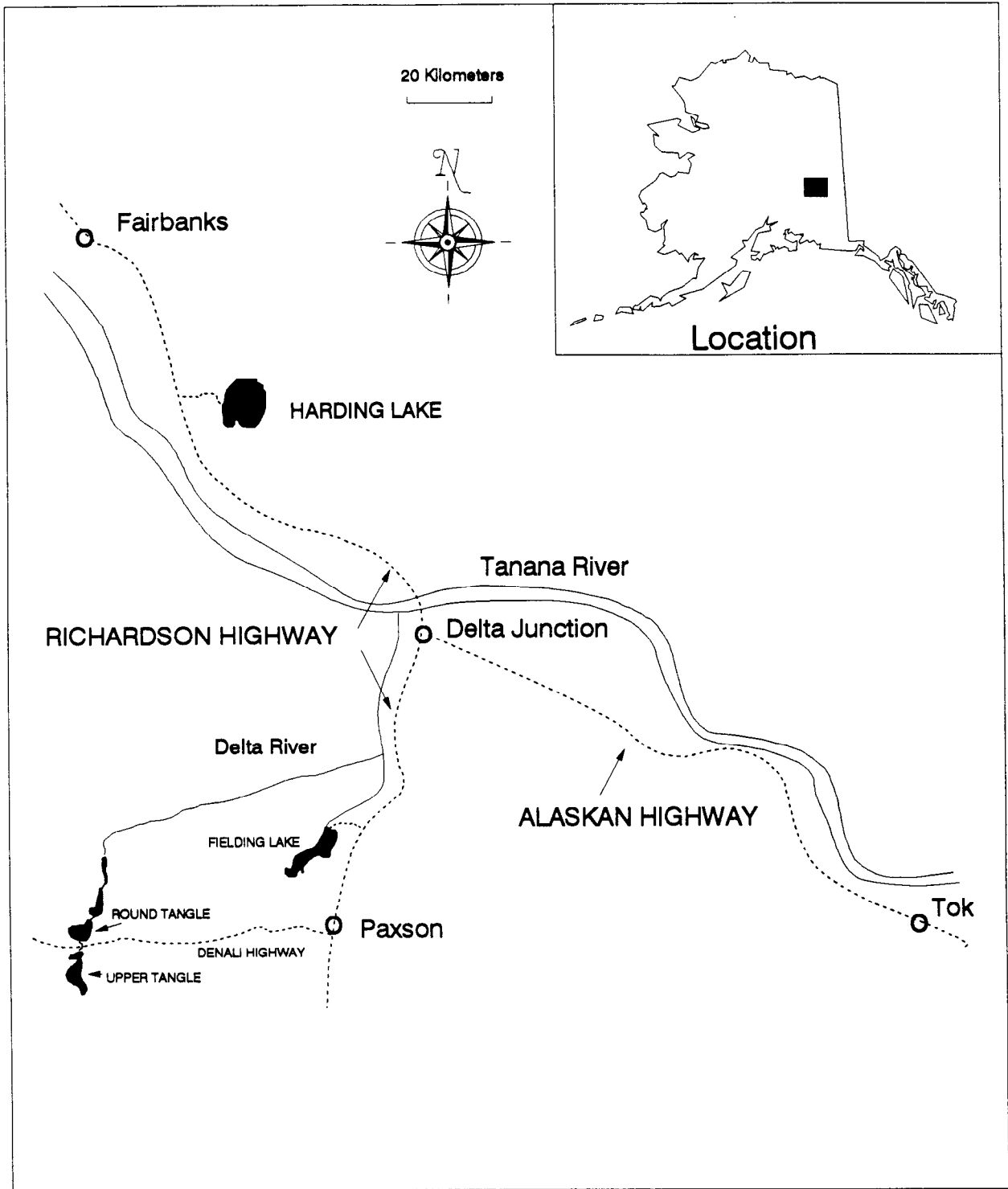
Figure 2. Location of lakes in the Tanana River drainage in which burbot populations were studied in 1993.

SECOND THROAT · SPREADER BAR · FIRST THROAT · SNAP

HOOP TRAP

0.46m

0.61m

0.36m
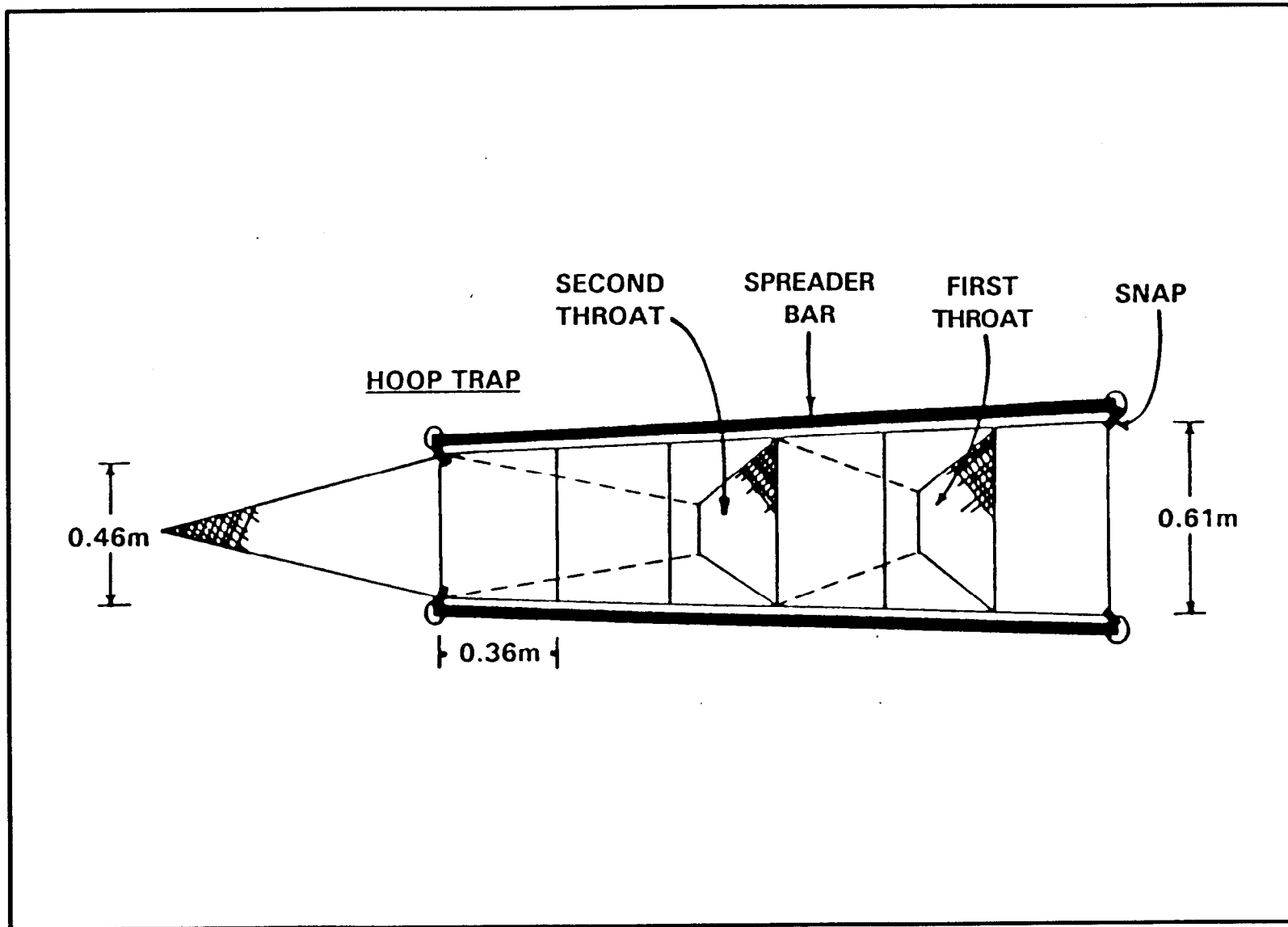
Figure 3. Schematic drawing of hoop traps used to catch burbot during 1993.

cotton twine, and treated with an asphaltic compound. Each trap was stretched with two sections of 12 mm galvanized steel conduit which were 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 in Fielding Lake, and Round and Upper Tangle lakes with two-stage, systematic surveys (Table 1). First, an overlay with parallel lines was placed across a map of each 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 experiments 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 sizes for mark-recapture experiments were based on previous abundance estimates. The desired number of sets to estimate mean CPUE as an index of abundance was calculated with procedures in Cochran (1977) for determining sample sizes to estimate the mean of a continuous variable. Desired sample sizes for both mean CPUE and abundance were calculated, and the larger number was used. To reduce sampling-induced mortality (often caused by decompression) sets were limited to depths less than 15 m in Upper Tangle Lake where maximum depth is 30 m.

Traps were immersed and retrieved during daylight hours beginning on one end of the lake and progressing to the other end. For each study lake 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. Each crew usually immersed and retrieved 60 traps in an 8-hour work day. Every new set received fresh bait, and old bait was discarded on shore.

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[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.

Table 1. Numbers of sets and dates of sampling events for the stock assessment of burbot populations in Fielding, Round and Upper Tangle lakes in 1993.

Lake	Area (ha)	Sampling Dates	Number of Sets
Fielding	538	6/20-26	240
Round Tangle	155	6/16-19	120
Upper Tangle	142	6/18-21	120
TOTAL			480

Captured fish from each trap were placed into a plastic tank during sampling. Each burbot was measured and those greater than 300 mm TL were 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 dorsal finclip in Fielding Lake, Round and Upper Tangle lakes. 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. Burbot in Round and Upper Tangle lakes are exceptions, these populations have few burbot over 450 mm to conduct accurate estimates of abundance (Lafferty et al. 1990). As a result, the size groups are combined and estimates reflect burbot over 300 mm in length. Determination of sample sizes for the mark-recapture experiment in Fielding Lake was based on fully recruited burbot. Due to the size of the two Tangle lakes, sample sizes were set at the maximum number of sets allowed to avoid trap competition (Bernard et al. 1991).

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). For Round and Upper Tangle lakes, mean CPUE was estimated for all burbot over 300 mm in length. In addition, CPUE for fully and partially recruited burbot were estimated for each of the Tangle lakes. 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:

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

where:

c_{ij} = catch of burbot from the jth set on the ith transect;
n   = number of transects;
m_i = number of sets sampled on the ith transect;

ω_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 $\hat{\omega}_i = m_i/\overline{m}$ was inserted for ω_i. Because few burbot enter traps during daylight (Bernard et al. 1991), catches were not adjusted for the few hours deviation in soak times from the standard 48 hours for most sets. Although the distribution of burbot can be related to depth (Odell 1932; Kennedy 1940; Rawson 1951; Dryer 1966), estimates of mean CPUE were not post-stratified by depth because sampling effort was proportionally (or near proportionally) allocated across depths with 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 ω were estimated (see Appendix B). In resampling procedures, sets were chosen randomly even though the original selection of sets was systematic. Systematically drawn data can be treated as if it was randomly drawn with little concern for bias in the resultant statistics only so long as these data are not autocorrelated nor follow a trend (Wolter 1984), as has been the case for past surveys (Bernard et al. *In press*).

Abundance, Survival Rates, and Recruitment

Abundance, annual survival rates, and annual estimates of surviving recruitment of fully recruited (≥ 450) and partially recruited (< 450) burbot in Fielding Lake were estimated using the mark-recapture history 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 Appendix C. 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 1993 using the relationship:

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

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) and in the Tangle lakes (Parker et al. 1989; Lafferty et al. 1990, 1991, 1992). 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. *In press*), only information from past sampling events that matched the scheduling with the sampling event in 1993 was used to estimate an average q.

RESULTS

Length distributions of fully recruited burbot in Fielding Lake in 1993 were significantly different than in 1992 (Kolmogorov-Smirnov two-sample test, P < 0.05; Figure 4). Results of this hypothesis test indicate more burbot were recruited into this size group than in the previous year. The mean length of fully recruited burbot in Fielding Lake in 1992 was 589 mm TL (Parker 1993) which decreased to 520 mm TL in 1993 (Table 2), as a result of recruitment and loss of fully recruited burbot in the population. Fully recruited burbot released in Fielding Lake in 1992 and recaptured in 1993 grew an average of 26 mm (n=29). The length distribution for Fielding Lake in 1992 had a descending left limb starting from 300 mm in 1992 (Parker 1993). There was a steep left ascending limb from 300 to 400 mm in 1993 (Figure 5). The mode of the distribution in Fielding Lake is less than the length at full recruitment for the sampling gear (450 mm TL). Length distribution for burbot in Round Tangle Lake displayed a steep left descending limb starting at 300 mm (Figure 5). In Upper Tangle Lake the length distribution for burbot had a slight ascending left limb which then descended at 375 mm. Average length of burbot in Round Tangle Lake between spring sampling events in 1991 and 1993 decreased slightly from 396 mm in 1991 (Lafferty et al. 1992) to 385 mm in 1993 (Table 2).

Estimated mean CPUE (bootstrapped) of fully and partially recruited burbot for Fielding Lake was 0.32 burbot and 0.62 burbot per set, respectively, in 1993 (Tables 3 and 4). Mean CPUE of all burbot ($\geq$ 300 mm) was 0.58 burbot per set in Upper Tangle Lake and 1.03 burbot per set in Round Tangle Lake (Table 5). Estimated bias in mean CPUE as calculated through bootstrapping was negligible (< 1.5%). Estimated mean CPUE for fully recruited burbot in Fielding Lake has declined from 0.71 in 1991 (Lafferty et al. 1992) to 0.47 in 1992 (Parker 1993). The CPUE of partially recruited burbot increased from 0.42 in 1992 to 0.62 in 1993 (Figure 6). Estimated mean CPUE for all burbot in Round Tangle Lake declined from 1.32 in 1991 (Lafferty et al. 1992) to 1.03 in 1992 (Table 5), indicating an overall decline in abundance since 1991. Mean CPUE of fully recruited burbot in Round Tangle Lake remained unchanged from mean CPUE in 1987 (Parker et al. 1988).

Abundance in 1992 of fully recruited burbot in Fielding Lake was estimated at 256 fish, abundance in 1993 was estimated at 213, annual survival rate from 1991-1992 was estimated at 38.2%, and surviving recruitment was estimated at 39 (Table 6); estimated abundance of burbot $\geq$ 300 mm TL in Round Tangle Lake in 1993 is 746 (Table 7 contains statistics for partially recruited burbot in Fielding Lake. Density of fully recruited burbot in Fielding Lake in 1992 was 0.48 fish per hectare (SE = 0.07) which fell considerably from the 1991 estimate of 1.10 fish per hectare (SE = 0.18, Parker 1993; Table 8). Density of partially recruited burbot for Fielding Lake in 1992 was 1.59 fish per hectare (SE = 0.66) which is more than the density in 1991 of 0.72 fish per hectare (SE = 0.29; Parker 1993). Rate of tag loss was insignificant in the marked population in Fielding Lake (< 1%). Throughout the mark-recapture experiments, there was no evidence of regenerated fins on any of the recaptured burbot with tags. Table 8 contains statistics on catchability coefficients for populations in Fielding and Round Tangle lakes. In 1993, seven fish in Fielding Lake were killed incidental to sampling; age, weight, and length information collected from these fish are found in Appendix C4.

FIELDING LAKE
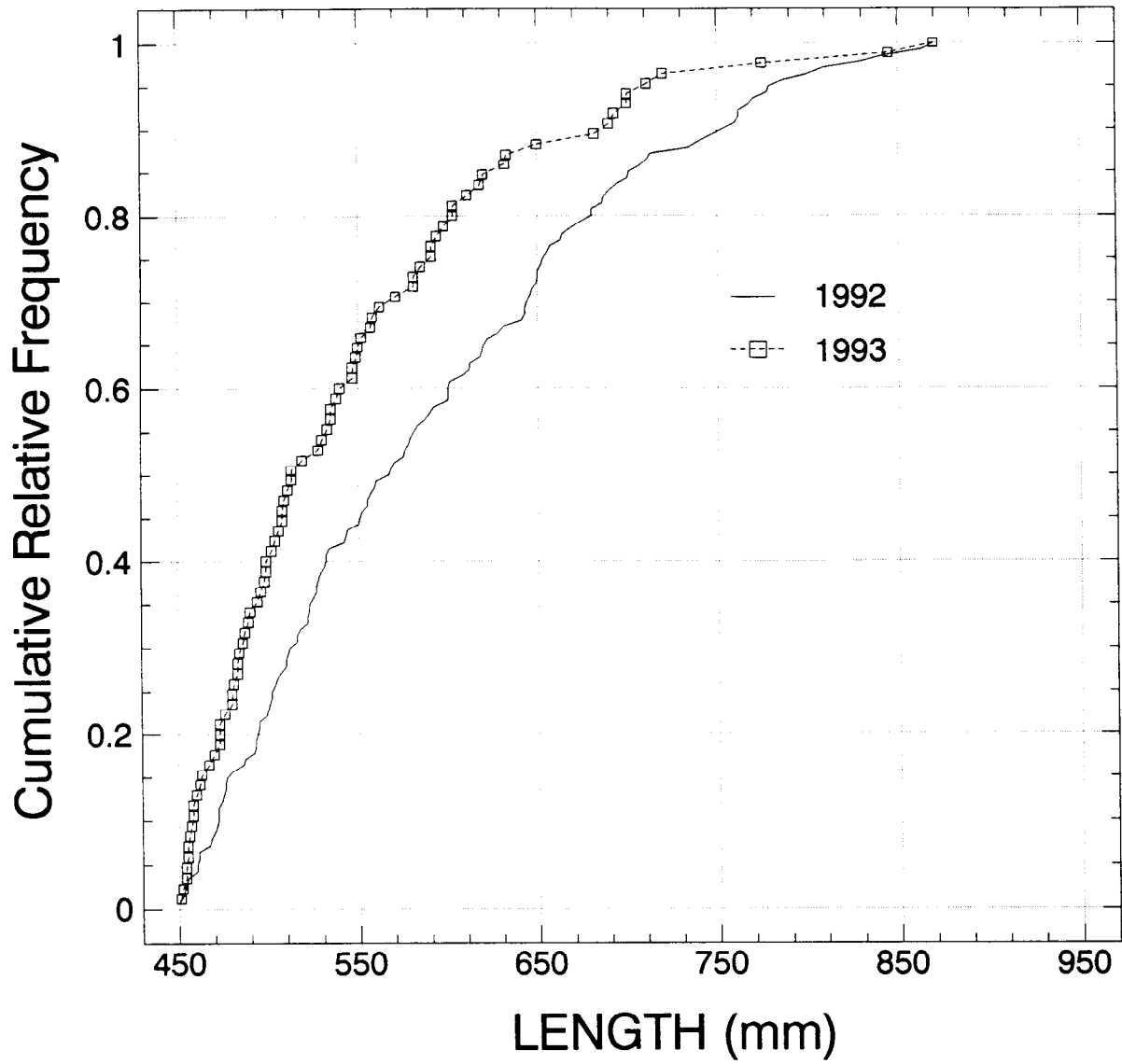
Figure 4. Cumulative length frequency of burbot captured in Fielding Lake during 1992 and 1993.

Table 2. Mean lengths (mm TL) of burbot measured during sampling events in Fielding, Round and Upper Tangle lakes in 1993.

Lake	Statistic	Recruitment to the gear[a]		
		Partially	Fully	All
Fielding	Mean	373	520	433
	SE	3	10	6
	Samples	148	103	251
Round Tangle	Mean	360	520	385
	SE	4	13	7
	Samples	104	20	124
Upper Tangle	Mean	370	508	406
	SE	6	9	9
	Samples	51	18	69

[a] Burbot partially recruited to the gear are less than 450 mm TL and fully recruited burbot are greater than or equal to 450 mm TL.
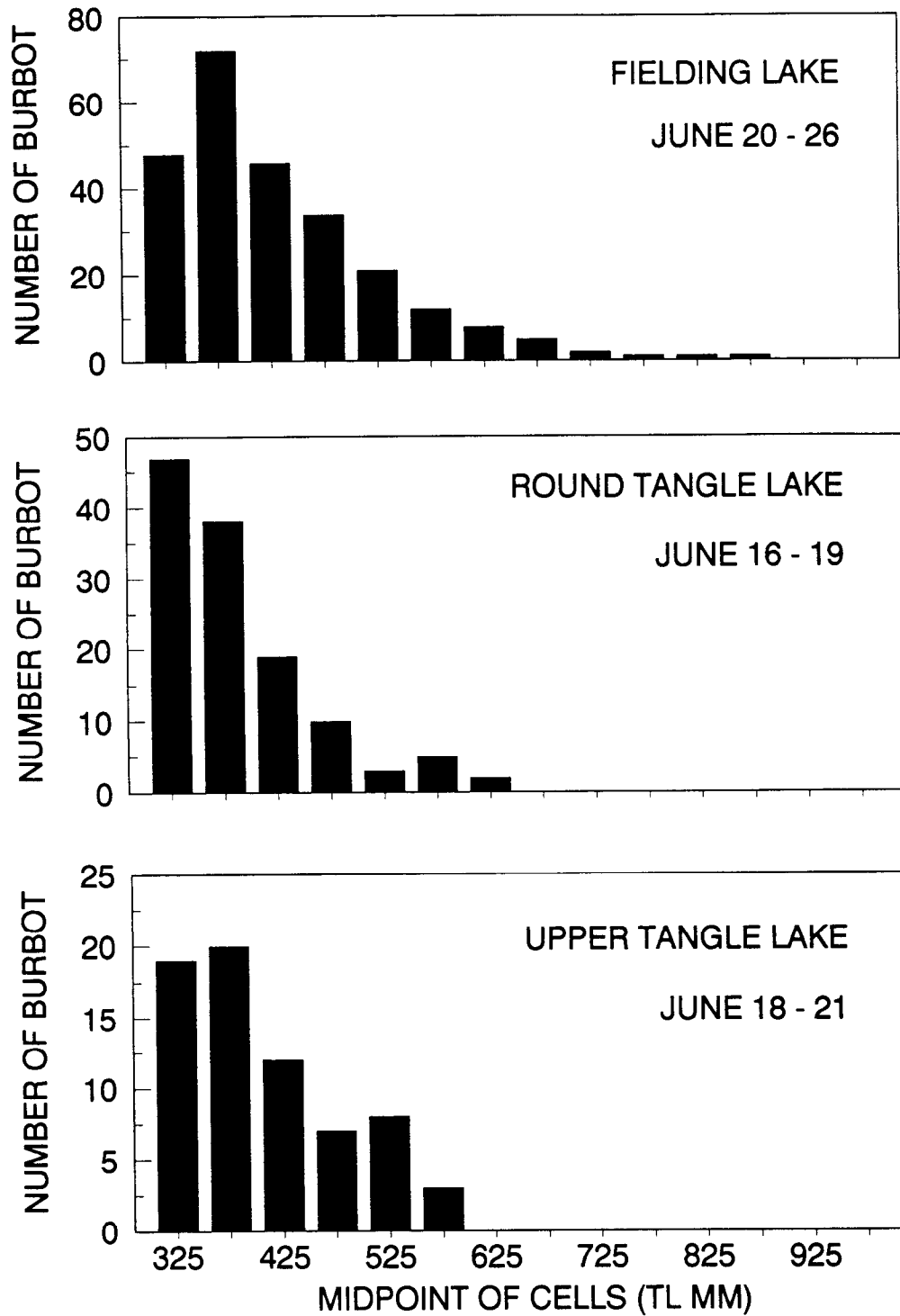
Figure 5. Length-frequency histograms of burbot captured in Fielding, Round and Upper Tangle lakes in 1993.

Table 3. Estimated mean CPUE of fully recruited (≥ 450 mm TL) burbot from systematic sampling of populations studied in 1993.

Lakes and Dates	Strata	Number of Sets and Transects		Mean CPUE				
				Bootstrapped	Arithmetic	%Δ	SE	CV
Fielding 6/20-26	All depths	239	42	0.32	0.32	0.6%	0.06	18.4%
Round Tangle 6/16-19	All depths	119	19	0.17	0.17	0.2%	0.05	30.0%
Upper Tangle 6/18-21	≤15 meters	115	33	0.16	0.16	2.5%	0.06	36.5%

Table 4. Estimated mean CPUE of partially recruited (< 450 mm TL) burbot from systematic sampling of populations studied in 1993.

Lakes and Dates	Strata	Number of Sets and Transects		Mean CPUE			SE	CV
				Bootstrapped	Arithmetic	%Δ		
Fielding								
6/20-26	All depths	239	42	0.62	0.61	1.0%	0.11	17.7%
Round Tangle								
6/16-19	All depths	119	19	0.85	0.87	-1.3%	0.17	20.1%
Upper Tangle								
6/18-21	≤15 meters	115	33	0.42	0.43	-2.8%	0.12	27.6%

Table 5. Estimated mean CPUE of all recruited burbot (≥ 300 mm TL) from systematic sampling of populations studied in Round and Upper Tangle lakes in 1993.

Lakes and Dates Strata	Number of Sets and Transects		Mean CPUE				
			Bootstrapped	Arithmetic	%Δ	SE	CV
Round Tangle							
6/16-19 All depths	119	19	1.03	1.03	-0.4%	0.17	16.9%
Upper Tangle							
6/18-21 ≤15 meters	115	33	0.58	0.59	-1.5%	0.15	25.5%
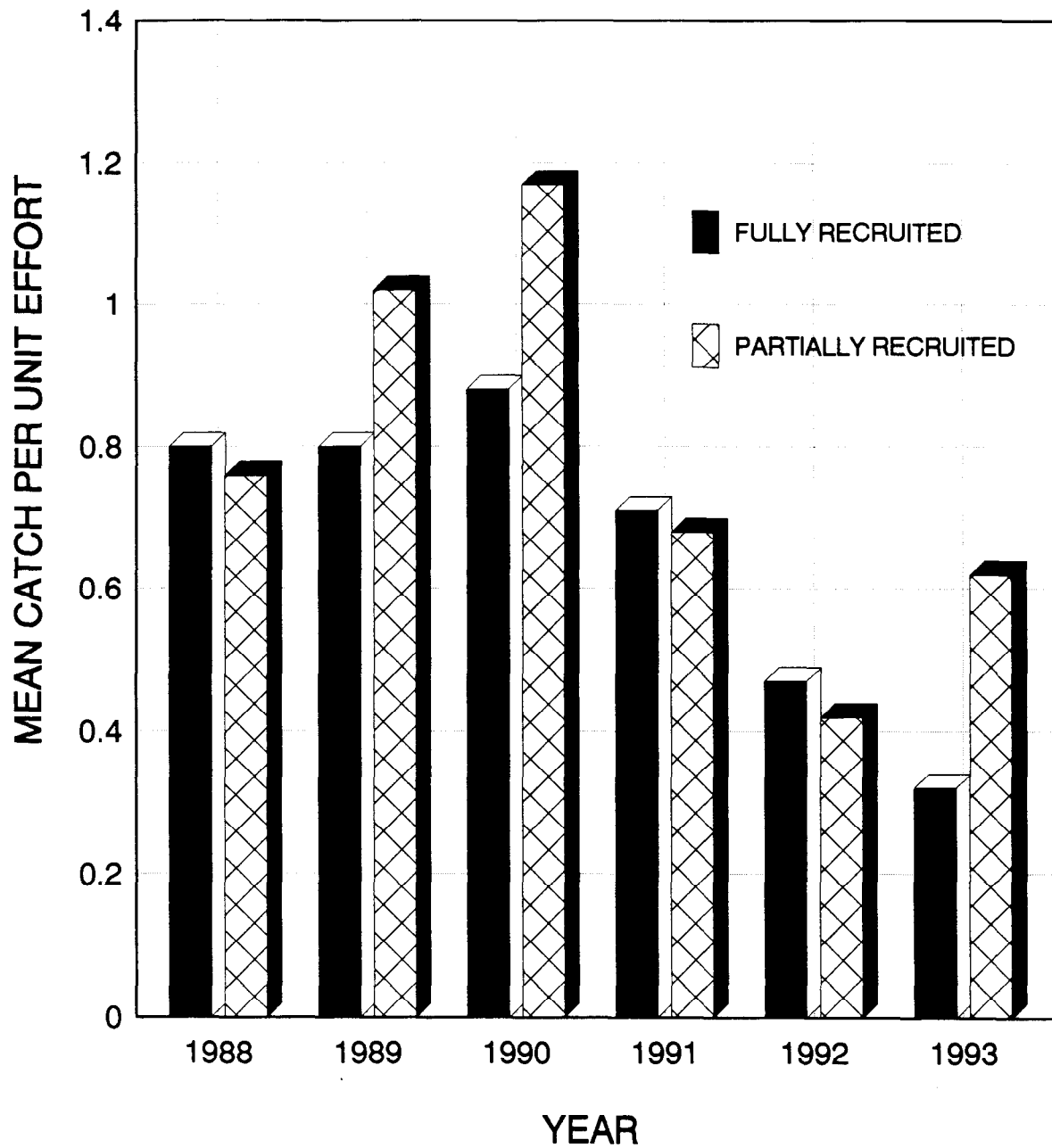
Figure 6. Mean CPUE of fully recruited (≥ 450 mm TL) burbot captured during spring sampling events at Fielding Lake from 1988-1993.

Table 6. Estimates of abundance, survival rates, and recruitment for fully recruited (≥ 450 mm TL) burbot residing in Fielding Lake.

Lake	Midway Date	Days Between Events	Abundance			Survival Rate %		Recruitment	
			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)	25.5				
		355				54.7	(7.0)	170	(72)
	8/11/86		335	(55)	16.4				
		360				67.0	(7.0)	38	(35)
	8/06/87		234	(23)	9.6				
		343				93.6	(8.8)	256	(46)
	7/15/88		444	(54)	12.2				
		365				80.3	(9.4)	231	(63)
	7/15/89		567	(75)	13.2				
		367				70.3	(8.7)	271	(70)
	7/17/90		667	(86)	12.9				
		368				66.0	(9.5)	131	(59)
	7/20/91		569	(83)	14.6				
		335				38.2	(6.7)	39	(24)
	6/27/92		256	(39)	15.2				
		361							
	6/23/93		213						

-18-

Table 7. Estimates of abundance and recruitment for partially recruited
(> 450 mm TL) burbot residing in Fielding Lake.

Lake	Midway Date	Days between events	Abundance			Recruitment	
			Est.	(SE)	CV %	St.	(SE)
Fielding	7/14/84		N/A				
		403				N/A	
	8/21/85		1211	(348)	28.7		
		355				717	(282)
	8/11/86		1307	(248)	18.9		
		360				378	(126)
	8/06/87		861	(164)	19.1		
		343				202	(69)
	7/15/88		471	(86)	18.2		
		365				409	(103)
	7/15/89		578	(126)	21.9		
		367				493	(141)
	7/17/90		660	(173)	26.2		
		368				434	(162)
	7/20/91		598	(203)	33.9		
		335				624	(299)
	6/27/92		856	(358)	41.8		
		361					
	6/23/93		N/A				

Table 8. Spring catchability coefficients for fully recruited burbot ($\geq$ 450 mm TL) in Fielding Lake from 1988-1992, and all recruited burbot ($\geq$ 300 mm TL) in Round Tangle Lake from 1988-1991.

Lakes and Dates	Mean CPUE	Surface Area (ha)	Abundance[a]	Density	Catchability Coefficient[b]
Fielding Lake:					
6/29/88	0.81	538	445	0.827	0.985
6/26/89	0.81		567	1.054	0.765
6/16/90	0.88		667	1.240	0.707
6/24/91	0.71		569	1.058	0.670
6/27/92	0.46		256	0.476	0.973
Spring Average					0.820
Round Tangle:					
6/17/88	1.12	155	619	3.994	0.280
6/25/89	1.35		893	5.761	0.234
6/25/90	1.26		1,644	10.606	0.119
6/18/91	1.32		912[c]	5.884	0.224
Spring Average					0.214

[a] Jolly-Seber multi-year mark-recapture estimate, unless otherwise noted.
[b] Mean CPUE multiplied by surface area divided by abundance.
[c] Single year Petersen mark-recapture estimate.

Additional Appendices (C1 - C4 and D) provide continuity between previous annual reports or summarize information that could be useful to the reader. Historical voluntary tag returns from sport anglers are listed in Appendix C3. Appendix C5 is a listing of the data archives for each study lake. Finally, Appendix D provides a graphic presentation of the catch by depth for partially and fully recruited burbot.

DISCUSSION

Although sampling in waters < 15 m deep in Upper Tangle Lake prevented deaths of burbot from decompression (none died), such sampling compromised the use of mean CPUE as an index of abundance. In past surveys, burbot have been distributed nearly equally across the depths in Upper Tangle Lake in some years (Parker et al. 1989; Lafferty et al. 1990, 1991) and have been absent from waters $\geq$ 15 m in other years (Parker et al. 1988, 1989; Lafferty et al. 1992). If burbot are concentrated at particular depths, mean CPUE must be corrected to be an unbiased index of abundance (Bernard et al. *In press*). If burbot are distributed across depths, no correction in mean CPUE is needed when sampling is concentrated in shallow waters. Since the distribution of burbot across depths in 1993 during sampling is unknown, there is no way of knowing whether mean CPUE should be corrected or not. Since partially and fully recruited burbot have had similar distributions across depths in past years, sampling only in water < 15 m should not have affected estimates of length distributions for the population in Upper Tangle Lake.

The decline in abundance of fully recruited burbot in Fielding Lake between 1991 and 1992 is different than the decline between 1986 and 1987. Both declines were caused in part by negligible recruitment. However, the fishery was closed before 1987. The contrast in the survival rates between 1986 and 1987 and 1991 and 1992 (67% vs. 38%) is testament to the presence of a fishery during the latter period. 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 low mean CPUE in 1993 indicates that abundance remained low in 1993. In contrast, the estimated abundance doubled between 1987 and 1988 with increased recruitment and better survival rates.

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APPENDIX A

Appendix A. Description of Fielding, Round and Upper Tangle lakes.

FIELDING LAKE (63°10' N, 145°42' W) is accessible by road 3 km southwest of
the Richardson Highway. Fielding Lake is 538 ha with a maximum depth of 24 m
and an elevation of 906 m. Three major inlets enter Fielding Lake with the
outlet on the north end of the lake entering Phelan Creek. The lake begins to
freeze by mid-October and breakup occurs from June 15th to July 1st.
Campground and boat launch facilities are located at the mouth of the outlet,
and 15 to 20 recreational cabins are located along the south shore. Fielding
Lake contains Arctic grayling *Thymallus arcticus*, burbot *Lota lota*, lake trout
Salvelinus namaycush, and round whitefish *Prosopium cylindraceum*,.

ROUND TANGLE LAKE (63°02' N, 145°48' W) is located north of the Denali
Highway. Round Tangle Lake is 155 ha with a maximum depth of 29 m and an
elevation of 851 m. A public boat launch, campground facilities, and lodge
accommodations are available through the spring and fall. During the winter
months, the Denali Highway is closed and the Tangle lakes receive very little
fishing pressure. Round Tangle Lake has Arctic grayling, burbot, lake trout,
longnose suckers *Catostomus catostomus*, and round whitefish.

UPPER TANGLE LAKE (63°00' N, 146°04' W) is located south of the Denali Highway
but drains through a 500 m long river into Round Tangle Lake. Upper Tangle
Lake is 142 ha with a maximum depth of 30 m and an elevation of 868 m. A boat
launch and campground facilities are available at the mouth of this lake.
Upper Tangle Lake has Arctic grayling, lake trout, round whitefish, burbot,
and longnose suckers.

APPENDIX B

Appendix B. Bias and variance of mean CPUE.

Variance of mean CPUE, its empirical distribution, and its bias were estimated for each survey with the resampling techniques of Efron (1982). Each survey produced data $\{c_{ij}\}$ in which c_{ij} is the catch of burbot in set j on transect i of the survey where $i=1,n$ and $j=1,m_i$. One thousand bootstrap samples (B=1000) were drawn by resampling these original data with replacement. For each bootstrap sample, n transects were randomly chosen with replacement from the n transects in each survey, then from each chosen transect, m_i catches were randomly drawn from the m_i sets on that transect. Although sets were selected systematically on each transect to produce the original data, catches were presumed to be independently distributed along each transect, a situation for which random selection of catches would be unbiased (Wolter 1985). Each bootstrap sample can be expressed as $\{c^*_{ij}\}_b$ in which c^*_{ij} is the catch of burbot in set j on transect i of the survey where $i=1,n$ and $j=1,m^*_i$ and $b=1,B$. Since transects were chosen during the resampling with equal probability even though they were of different sizes, the $\{c^*_{ij}\}$ were scaled appropriately with the technique suggested by Rao and Wu (1988):

$$\tilde{c}_{ij} = \overline{CPUE} + \left\{\frac{n}{n-1}\right\}^{1/2} (\hat{\omega}^*_i \bar{c}^*_i - \overline{CPUE}) + \hat{\omega}^*_i \left\{\frac{m^*_i}{m^*_i-1}\right\}^{1/2} (c^*_{ij} - \bar{c}^*_i) \qquad (B.1)$$

where $\hat{\omega}^*_i = m^*_i/\bar{m}^*$, $\overline{CPUE}$ = mean CPUE from the original data (from Equation 1), and $\{c_{ij}\}$ = appropriately weighted, resampled catch statistics. The estimate of mean CPUE from the bootstrap estimate is calculated as:

$$\overline{CPUE}^* = \frac{1}{n} \sum_{i=1}^{n} \frac{1}{m^*_i} \sum_{i=1}^{m_i} \tilde{c}_{ij} \qquad (B.2)$$

The B bootstrap estimates of mean CPUE comprise the empirical distribution F(mean $CPUE^*_1,\ldots$.mean $CPUE^*_B$) for the original estimate mean CPUE from Equation 1 as obtained through resampling. Variance of mean CPUE from the original data can be estimated as the population variances of the bootstrap samples:

$$V[\overline{CPUE}] = \frac{\sum_{b=1}^{B} (\overline{CPUE}^*_b - \overline{\overline{CPUE}}^*)^2}{B-1} \qquad (B.3)$$

-28-

Appendix B. (Page 2 of 2).

where:

$$\overset{=====*}{CPUE} = \frac{\displaystyle\sum_{b=1}^{B} \overline{CPUE}_b^{*}}{B} \tag{B.4}$$

The difference between $\overset{=====*}{CPUE}$ and the original statistic $\overline{CPUE}$ is an esti-mate of bias in the original statistic.

The $\{c_{ij}\}$ were resampled with a computer program based on Microsoft™ Fortran that included subroutines from IMSL, Inc. of Houston, TX for the generation of uniformly distributed random numbers.

APPENDIX C

Appendix C1. Mark-recapture histories of fully recruited[a] burbot by year (by sampling event in 1993) for the population in Fielding Lake.

FIELDING LAKE

Date:	Year	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
	Beginning	7/20	7/16	7/28	7/21	6/29	6/26	6/16	6/22	6/24	6/20
	Ending	10/8	9/27	8/25	8/22	7/31	8/04	8/17	8/18	6/30	6/26

NUMBER OF FULLY RECRUITED BURBOT:

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Recaptured from Event 1	0	13	2	2	0	2	0	0	0	0
Recaptured from Event 2		0	27	23	1	1	1	2	0	0
Recaptured from Event 3			0	30	9	2	1	0	2	0
Recaptured from Event 4				0	48	18	4	6	4	0
Recaptured from Event 5					0	38	16	7	7	2
Recaptured from Event 6						0	51	13	5	0
Recaptured from Event 7							0	52	18	3
Recaptured from Event 8								0	38	8
Recaptured from Event 9									0	29
Recaptured from Event 10										0
Captured with Tags	0	13	29	55	58	61	73	80	74	42
Captured without Tags	43	149	90	93	117	120	152	108	67	45
Captured	43	162	119	148	175	181	225	188	141	87
Released with Tags	43	138	76	126	149	177	223	187	140	87

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

Appendix C2. Mark-recapture histories of partially recruited[a] burbot by year (by sampling event in 1993) for the population in Fielding Lake.

FIELDING LAKE

Date: Year	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Beginning	7/20	7/16	7/28	7/21	6/29	6/26	6/16	6/22	6/24	6/20
Ending	10/8	9/27	8/25	8/22	7/31	8/04	8/17	8/18	6/30	6/26

NUMBER OF PARTIALLY RECRUITED BURBOT:

	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993
Recaptured from Event 1	0	19	6	0	1	0	0	0	0	0
Recaptured from Event 2		0	50	23	4	4	0	0	0	0
Recaptured from Event 3			0	29	13	2	0	0	0	0
Recaptured from Event 4				0	28	5	2	0	0	0
Recaptured from Event 5					0	31	5	0	0	0
Recaptured from Event 6						0	38	5	0	0
Recaptured from Event 7							0	24	2	4
Recaptured from Event 8								0	12	6
Recaptured from Event 9									0	13
Recaptured from Event 10										0
Captured with Tags	0	19	56	52	46	42	45	29	14	23
Captured without Tags	65	432	278	230	175	244	274	168	112	142
Captured	65	451	334	282	221	286	319	197	126	165
Released with Tags	65	404	233	163	152	279	308	194	121	158

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

Appendix C3. Voluntary returns of tags by sport anglers.

Lake	Date Tagged	Tag Number	Date Caught	Recapture Location
Round Tangle	6/17/91	71554	10/16/91	Round Tangle

Appendix C4. Estimated ages, weights, and lengths of burbot killed in 1993.

Lake	Date Killed	Tag Number	Sex	Age	Length (mm)	Weight (kg)	Maturity
Fielding	6/23/93	9604	?	4	315	0.10	Immature
	6/23/93	9619	?	4	377	0.55	Immature
	6/24/93	9108	?	5	383	0.55	Immature
	6/24/93	9628	?	5	402	0.70	Immature
	6/25/93	9693	?	5	360	0.50	Immature
	6/25/93	9690	?	4	365	0.50	Immature
Round Tangle	6/16/93	9401	?	na	381	NA	NA
Harding	9/??/93	64179	?	?	675	?	Mature

Appendix C5. Summary of data archives.

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

Lake	Data Map		
	File Name	Data Format	Software
Fielding	U0130HA3.DTA FIEL93TD.DBF	Hoopnet Tag History	RTS-ASCII DBASE
Round Tangle	U015CHA3.DTA	Hoopnet	RTS-ASCII
Upper Tangle	U015DHA3.DTA	Hoopnet	RTS-ASCII

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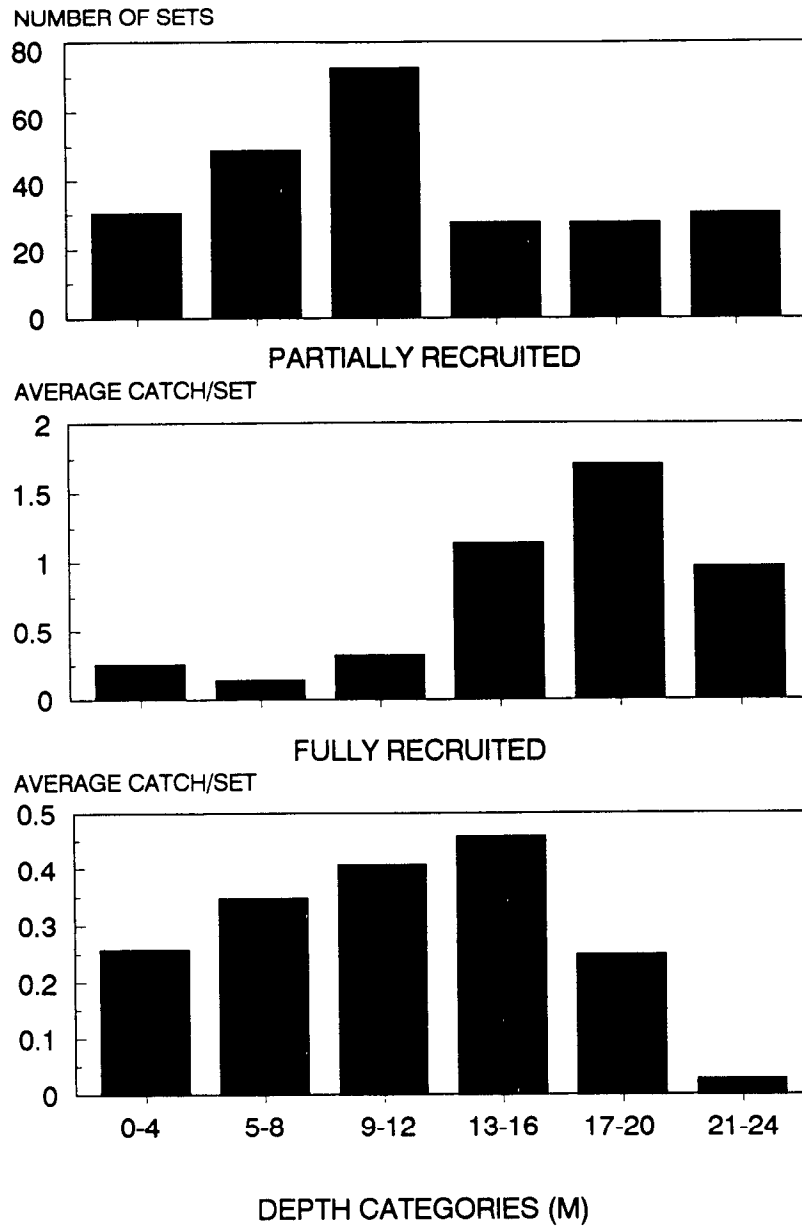
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[a] Alaska Department of Fish and Game - Sport Fish Division - Research and Technical Services (RTS).
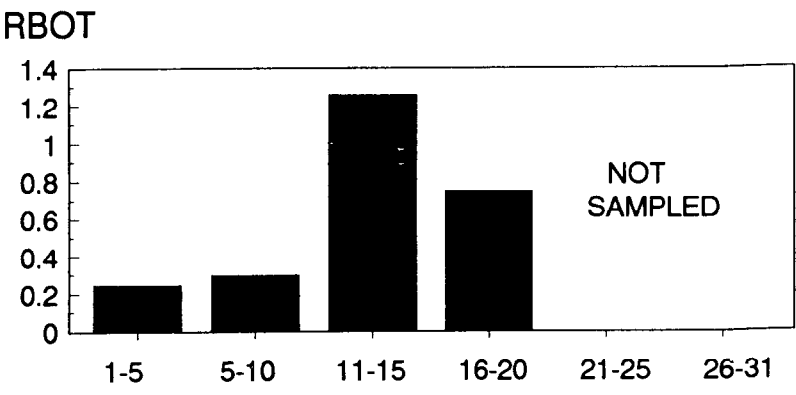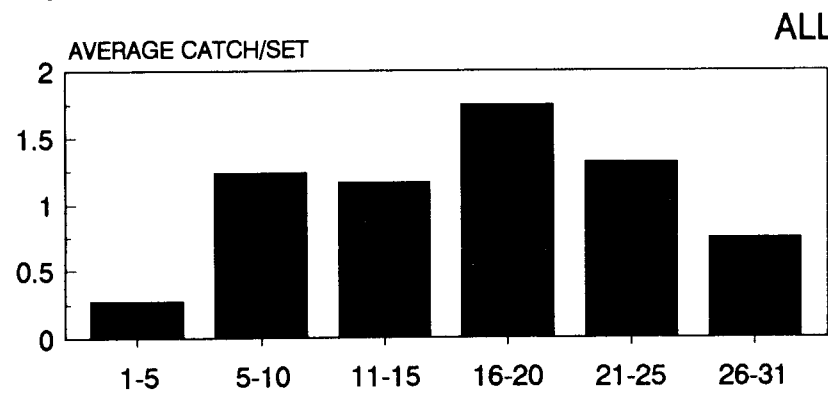
APPENDIX D

FREQUENCY OF SETS BY DEPTH AND AVERAGE CATCH
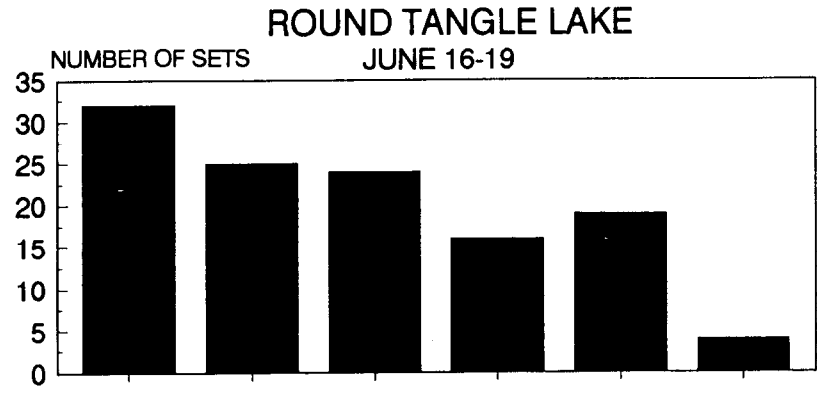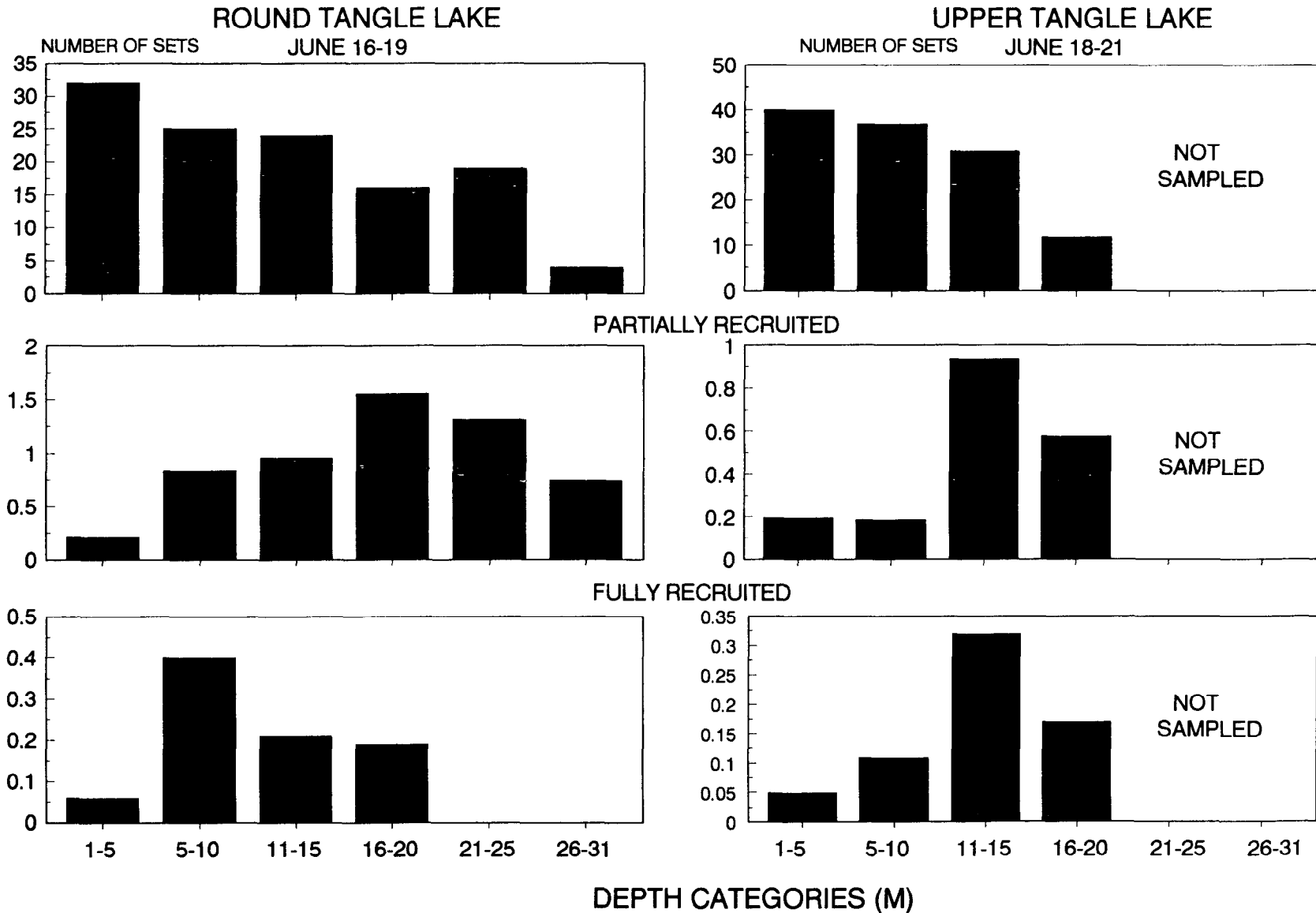
FIELDING LAKE
JUNE 20-26

NUMBER OF SETS

PARTIALLY RECRUITED

AVERAGE CATCH/SET

FULLY RECRUITED

AVERAGE CATCH/SET

DEPTH CATEGORIES (M)

Appendix D1. Frequency of sets by depth and average catch of burbot by depth for Fielding Lake in 1993.

ROUND TANGLE LAKE
JUNE 16-19

NUMBER OF SETS

AVERAGE CATCH/SET

UPPER TANGLE LAKE
JUNE 18-21

NOT SAMPLED

ALL BURBOT

NOT SAMPLED
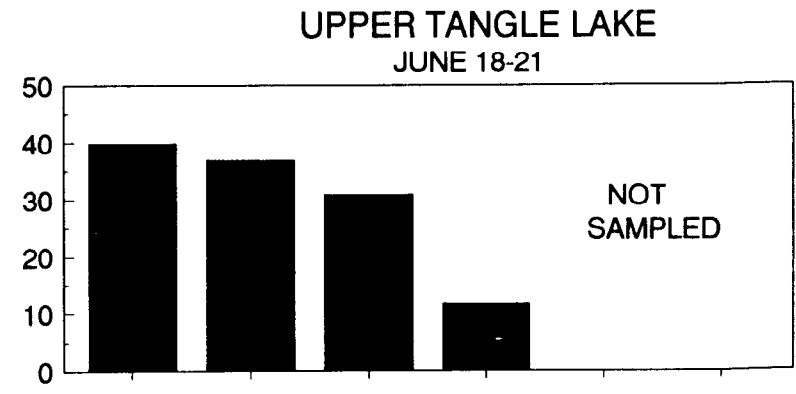
DEPTH CATEGORIES (M)

Appendix D2. Frequency of sets by depth and average catch of burbot ($\geq$ 300 mm TL) by depth for Round and Upper Tangle lakes in 1993.

ROUND TANGLE LAKE
JUNE 16-19

NUMBER OF SETS

UPPER TANGLE LAKE
JUNE 18-21

NUMBER OF SETS

NOT SAMPLED

PARTIALLY RECRUITED

NOT SAMPLED

FULLY RECRUITED

NOT SAMPLED

DEPTH CATEGORIES (M)

Appendix D3. Frequency of sets by depth and average catch of fully recruited burbot ($\geq$ 450 mm TL) and partially recruited burbot (< 450 mm TL) for Round and Upper Tangle lakes in 1993.