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Stock Assessment and Biological Characteristics of Burbot in Fielding and Harding Lakes During 1992

by

James F. Parker

March 1993

Alaska Department of Fish and Game

Division of Sport Fish

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ABSTRACT

Abundance and/or indices of abundance were estimated for populations of burbot *Lota lota* for two lakes in the Tanana River drainage. Adult (450 millimeters total length and longer) and juvenile (300 to 449 millimeters total length) burbot were captured in baited hoop traps set in a systematic pattern across each lake sampled. Sampling occurred from June through September 1992. Mean catch-per-unit of effort of fully recruited burbot (450 millimeters total length and larger) per 48-hour set was 0.20 (SE = 0.03) in Harding Lake and 0.47 (SE = 0.07) in Fielding Lake. Abundance of fully recruited burbot estimated with multiple year mark-recapture experiments was 535 in Harding Lake (SE = 201) and 592 in Fielding Lake (SE = 95) in 1991. Annual rates of survival were 49.9% (SE = 19.1) in Harding Lake and 68.6% (SE = 10.9) in Fielding Lake.

KEY WORDS: burbot, *Lota lota*, Harding Lake, Fielding Lake, abundance, hoop traps, 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 1992). 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 the sport fishery. Emergency regulations adopted in 1987 and other regulations since, restricted 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 drainage are a daily bag and possession limit of five burbot and a maximum of five hooks fished at any one time.

Lakes in the upper Tanana drainage having burbot populations and easy access to anglers, are few. Those lakes in the upper Tanana drainage are small in size, high in elevation, less productive, and very susceptible to over exploitation even at a low level of harvest. Like populations throughout the state, burbot are slow to grow and mature. While harvest of burbot in Tanana drainage lakes decreased in 1985, harvest of burbot in the Tanana River increased. In 1991, only 22% of the burbot harvested in the Tanana River drainage came from lakes (Mills 1992). In the Interior, the Alaska Department of Fish and Game (ADF&G) continues to monitor Fielding and Harding lakes to determine the recovery (if any) of depressed lake burbot populations, and the possibility of developing sustained yield burbot fisheries in the future. A major sport fishery for burbot occurred in Harding and Fielding lakes of interior Alaska (Figure 2) during the winter months from November to April. These populations of burbot have been exploited in recreational set-line and jig fisheries. Set lines are baited hooks (attached to jugs in open water or placed through the ice in winter) left overnight on the bottom of the lake.

In 1986, staff of Sport Fish Division of the ADF&G 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, 1988, 1989 and Lafferty et al. 1990, 1991, 1992). This document is the seventh in a series of annual reports of the findings from lake burbot research in Region III. The objectives of the program in 1992 are as follows:

<u>Project N-8-2, Job Number R-3-4a:</u>

1. estimate the abundance of burbot greater than 449 mm total length (TL) in Fielding Lake;

2. estimate the abundance of burbot greater than 449 mm total length (TL) in Harding Lake;

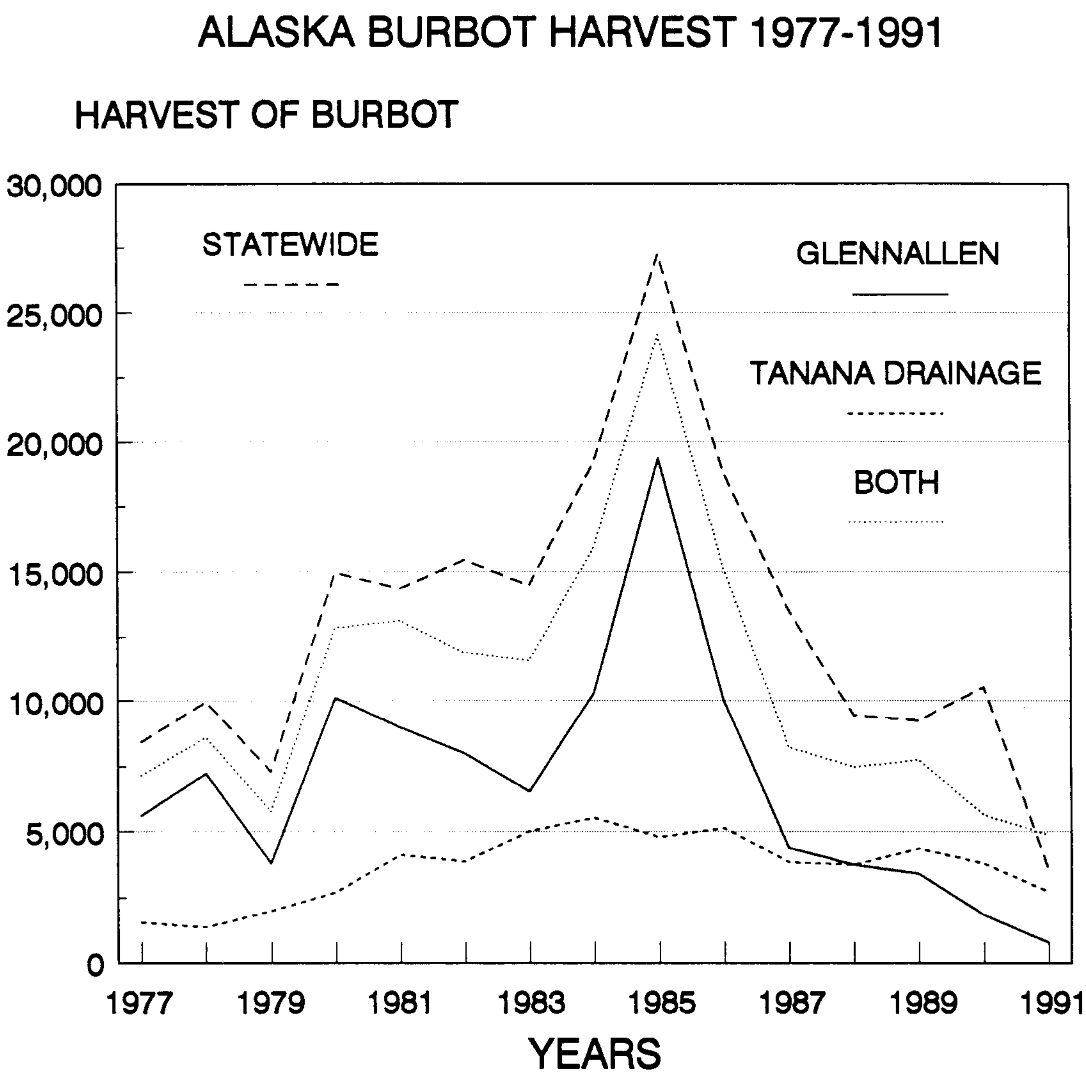

Figure 1. Harvests for Alaskan burbot fisheries, 1977-1991.

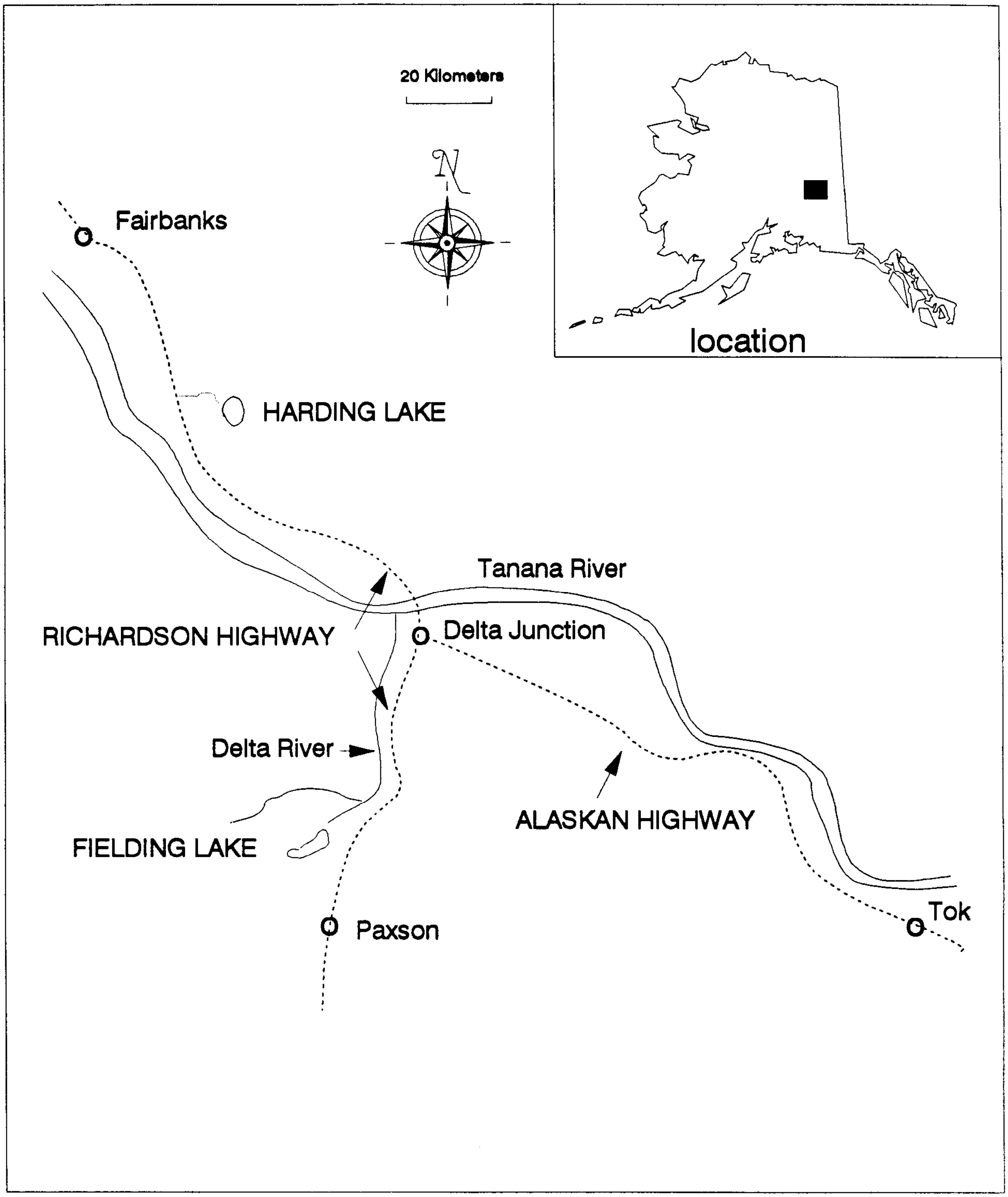

Figure 2. Location of Harding and Fielding lakes in the Tanana River drainage in which burbot populations were studied in 1992.

3. index abundance with mean catch-per-unit-effort (CPUE) statistics for burbot greater than 449 mm TL in Fielding and Harding lakes, and;

4. estimate annual survival rates of the burbot population in Fielding Lake.

In addition, incremental growth and density of burbot were estimated. Each of the populations studied in 1992 are exploited in sport fisheries. Both populations reside in lakes that are either geographically isolated or are separated from other lakes by lengthy rivers. 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 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 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

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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.

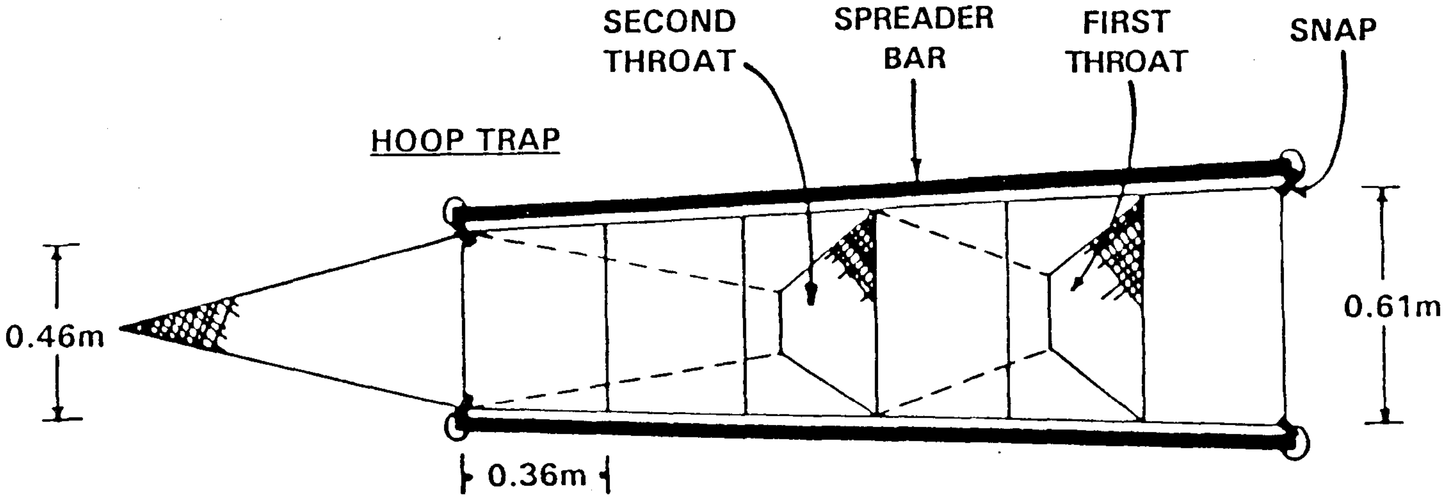

Figure 3. Schematic drawing of hoop traps used to catch burbot in Harding and Fielding lakes during 1992.

Table 1. Numbers of sets and dates of sampling events for the stock assessment of burbot populations in Fielding and Harding lakes in 1992.

Lake	Area (ha)	Sampling Dates	Number of Sets
Fielding	538	6/24-30	298
Harding	1,000	9/14-24	477
TOTAL			775

parallel line. However, the location of the first set along each transect was randomly chosen with every subsequent set along that transect at 125 m. 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 (see Robson and Regier 1964). 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.

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.

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 evaluate loss of Floy tags, was a right ventral finclip in Fielding Lake and a left ventral finclip in Harding Lake. 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 methodologies of Beamish and McFarlane (1987) and Chilton and Beamish (1982).

Burbot 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. Determination of sample sizes for surveys and mark-recapture experiments was based solely on fully recruited burbot for each study lake.

Abundance, Survival Rates, and Recruitment

Abundance, annual survival rates, and annual estimates of surviving recruitment of burbot in Fielding and Harding lakes were estimated with mark-recapture histories of fish according to the models of Jolly (1965) and Seber (1965). The computer program Jolly (model A) as described in Pollock et al. (1985, 1990) was used to do the calculations. Mark-recapture histories for both populations are listed in Appendix B. In earlier years, two-event mark-recapture experiments based on closed populations were used 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).

Mean CPUE

Mean CPUE was estimated for fully (≥ 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:

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

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 = $M_i/\bar{M}$; and
M_i = maximum possible sets on the ith transect.

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

Thus $\hat{\omega}_i = m_i/\bar{m}$ 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 $\hat{\omega}_i$ were estimated (see Appendix C). In resampling procedures, sets were chosen randomly even though the original selection of sets was systematic. Systematically drawn data can be treated as randomly drawn with little concern for bias in the resultant statistics only so long as these data are not autocorrelated nor follow a trend (Wolter 1984), as has been the case for past surveys (Bernard et al. in press).

RESULTS

Length Distributions

Length distributions of fully recruited burbot in both Fielding and Harding lakes in 1992 were significantly different than those in 1991 (Kolmogorov-Smirnov two-sample test, $P < 0.05$; Figure 4). Results of these hypothesis

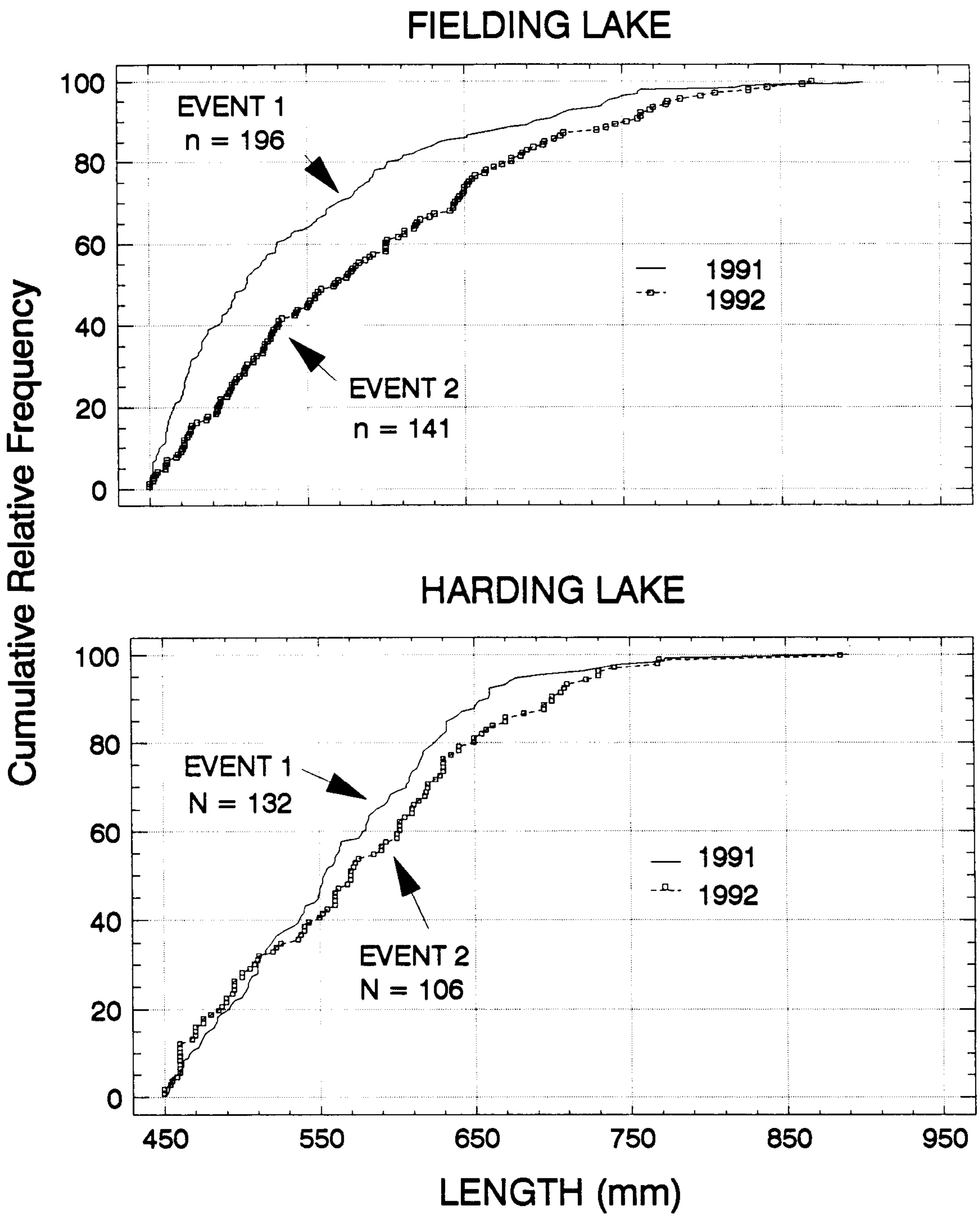

Figure 4. Cumulative length frequency of burbot captured in Fielding and Harding lakes during 1991 and 1992.

tests indicate fewer burbot were recruited into this size group as in previous years. The mean length of fully recruited burbot in Fielding Lake in 1991 was 544 mm and in Harding Lake was 563 mm (Lafferty et al. 1992) which increased to 589 mm and 579 mm respectively, in 1992 (Table 2). The mean increment of growth in fully recruited burbot released in Fielding and Harding lakes in 1991 and recaptured in 1992 was 30 mm (n=41) and 57 mm (n=14), respectively. The length distribution of burbot in Fielding Lake in 1991 had a steep ascending left limb from 300 - 450 mm (Lafferty et al. 1992). There was a descending left limb starting from 300 mm in 1992 (Figure 5). The reverse was demonstrated in Harding Lake, which had no ascending left limb in 1991 (Lafferty et al. 1992), yet was present in 1992 (Figure 5). Length distributions of burbot populations in Fielding and Harding lakes have modes of 600 and 460 mm, respectively, which is more than the length at full recruitment to the sampling gear (450 mm TL).

In Fielding Lake mean length of fully recruited burbot sampled in the population increased from 521 in 1986 (Parker et al. 1987) to 589 mm in 1992 (Table 2), an average increase of 11 mm per year. In Harding Lake mean length of fully recruited burbot sampled in the population increased from 532 mm in 1986 (Parker et al. 1987) to 579 mm in 1992 (Table 2), an average increase of 8 mm per year.

Mean CPUE

Estimates of bootstrapped mean CPUE of fully recruited burbot 1992 ranged from 0.20 burbot per set in Harding Lake to 0.47 burbot per set in Fielding Lake (Table 3). Mean CPUE of partially recruited burbot (≥ 300 mm but < 450 mm) ranged from 0.30 burbot per set in Harding Lake to 0.42 burbot per set in Fielding Lake (Table 4). Estimated bias in mean CPUE as calculated through bootstrapping was negligible (< 2%). Estimated mean CPUE for fully recruited burbot in Fielding Lake declined from 0.71 in 1991, also partially recruited burbot declined from 0.68 (Lafferty et al. 1992). Estimates of mean CPUE for fully recruited burbot in Harding Lake declined slightly from 0.27 in 1991 to 0.20 in 1992, partially recruited burbot increased from 0.22 to 0.30.

Mark-Recapture Experiments

Rates of tag loss ranged from 0% for overwinter at Fielding Lake to 7.5% (SE = 3.6%) for the Harding Lake experiments. Rates in each lake are significantly different (t test, $\alpha = 0.05$) from those previously reported (Lafferty et al. 1992). Technique of tag placement has improved on Fielding Lake, whereas in Harding Lake, tag loss exists from a combination of increasing numbers of recaptures and use of inexperienced crew members. Throughout the mark-recapture experiments, there was no evidence of regenerated fins on any of the recaptured burbot with tags.

Abundance of fully recruited (≥ 450 mm) burbot ranged from 535 fish in Harding Lake to 592 fish in Fielding Lake in 1991 (Table 5). Abundance of burbot 300 mm to 449 mm in Fielding Lake (Table 6) was 389 fish in 1991. None of the 1991 abundance estimates are significantly different (t test, $\alpha = 0.05$) than the 1990 abundance estimates. Density of fully recruited burbot in 1991 ranged from 0.545 fish per hectare (SE = 0.20) in Harding Lake to 1.10 fish

Table 2. Mean lengths (mm TL) of burbot measured during sampling in Fielding and Harding lakes in 1992.

Lake	Statistic	Recruitment to the Gear[a]		
		Partially	Fully	All
Fielding	Mean	370	589	485
	SE	4	9	8
	Samples	126	141	267
Harding	Mean	380	579	462
	SE	3	9	7
	Samples	155	109	264

[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.

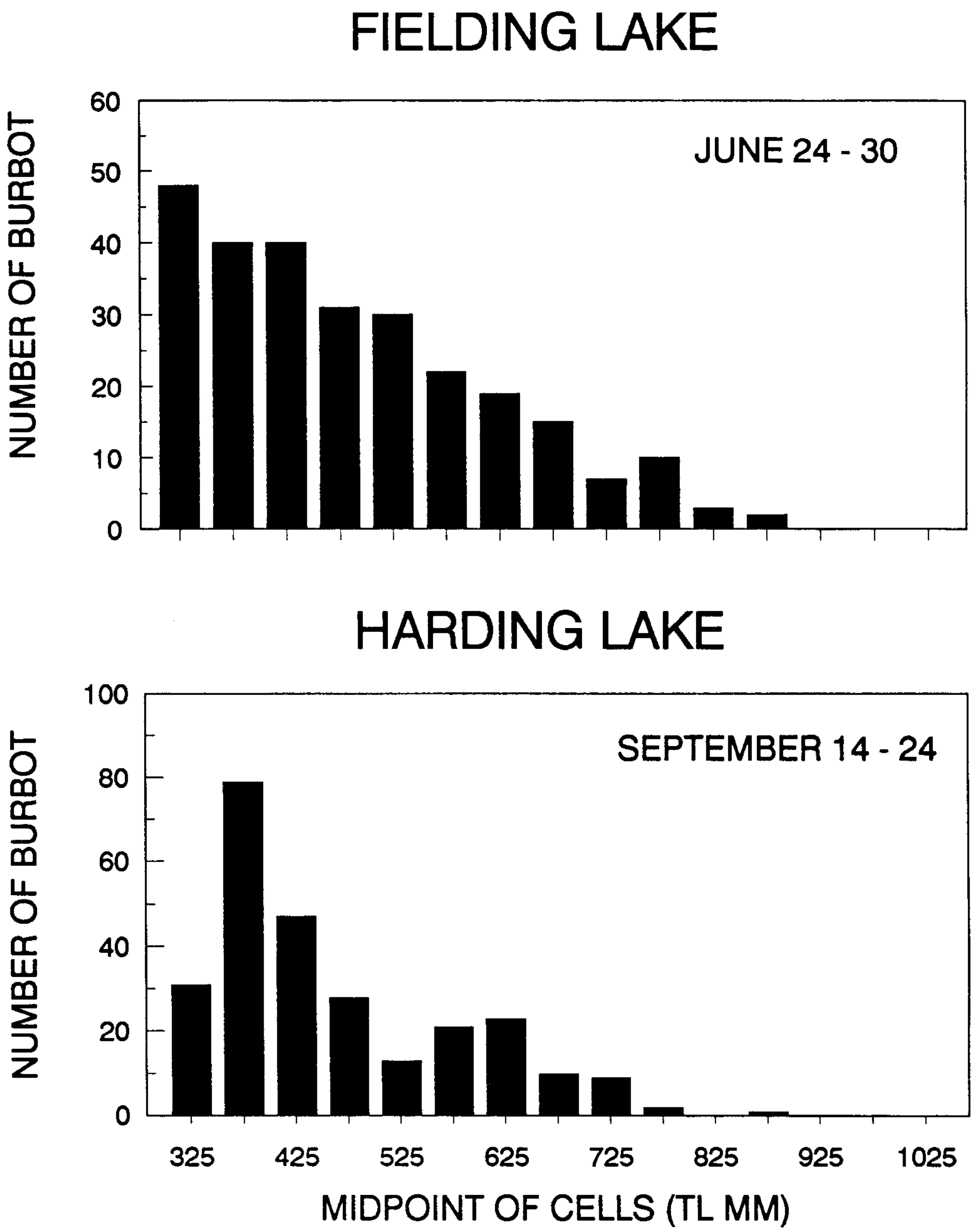

Figure 5. Length-frequency histograms of burbot captured in Fielding and Harding lakes in 1992.

Table 3. Estimated mean CPUE of fully recruited ($\geq$ 450 mm TL) burbot from systematic sampling of populations studied in 1992.

Lakes & Dates	Strata	Number of Sets and Transects		Mean CPUE Bootstrapped	Mean CPUE Arithmetic	%Δ	SE[a]	CV[a]
<u>Fielding</u>:								
6/24-30	All depths	298	43	0.47	0.46	0.7%	0.07	14.2%
<u>Harding</u>:								
9/14-24	All depths	477	25	0.20	0.20	-0.6%	0.03	16.5%

[a] Estimates were obtained from bootstrapping.

Table 4. Estimated mean CPUE of partially recruited (≤ 450 mm TL) burbot from systematic sampling of populations studied in 1992.

Lakes & Dates	Strata	Number of Sets and Transects		Mean CPUE Bootstrapped	Mean CPUE Arithmetic	%Δ	SE[a]	CV[a]
Fielding:								
6/24-30	All depths	298	43	0.42	0.42	-0.7%	0.07	17.6%
Harding:								
9/18-27	All depths	477	25	0.30	0.30	0.3%	0.48	15.8%

[a] Estimates were obtained from bootstrapping.

Table 5. Estimates of abundance, survival rates, and recruitment for fully recruited (≥ 450 mm TL) burbot residing in Fielding and Harding lakes.

	Midway	Days Between	Abundance			Survival Rate %		Recruitment	
Lake	Date	Events	Est.	(SE)	CV %	Estimate	(SE)	Estimate	(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	(7.1)	38	(35)
	8/06/87		234	(23)	9.8				
		343				95.2	(9.1)	250	(47)
	7/15/88		452	(56)	12.4				
		365				77.3	(9.1)	223	(61)
	7/15/89		552	(73)	13.2				
		367				71.5	(9.0)	274	(70)
	7/17/90		666	(88)	13.2				
		368				68.6	(10.9)	136	(62)
	7/20/91		592	(95)	16.0				
		342							
	6/27/92		N/A						
Harding	9/11/86		N/A						
		324				76.5	(20.4)	N/A	
	6/18/87		287	(92)	32.1				
		468				77.8	(23.8)	377	(187)
	9/28/88		583	(219)	37.6				
		357				36.6	(10.3)	-10	(72)
	9/20/89		199	(57)	28.6				
		349				134.4	(39.2)	612	(253)
	9/04/90		880	(299)	34.0				
		349				49.9	(19.1)	99	(134)
	9/20/91		535	(201)	37.6				
		363							
	9/18/92		N/A						

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

Lake	Midway Date	Days Between Events	Abundance Estimate	Abundance (SE)	Abundance CV %	Recruitment Estimate	Recruitment (SE)
Fielding	7/14/84		N/A				
		403				N/A	
	8/21/85		1,211	(347)	28.7		
		355				717	(282)
	8/11/86		1,307	(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				531	(162)
	7/17/90		711	(201)	28.3		
		368				277	(119)
	7/20/91		389	(157)	40.2		
		342					
	6/27/92		N/A				

per hectare (SE = 0.18) in Fielding Lake. Density of partially recruited burbot in Fielding Lake was 0.72 fish per hectare (SE = 0.29). In both Fielding and Harding lakes six fish were incidentally killed during sampling; age, weight, and length information collected from these fish are found in Appendix B4.

Survival Rates and Recruitment

Annual survival rates for fully recruited burbot were 68.6% in Fielding Lake and 49.9% in Harding Lake between the sampling events of 1990 and 1991 (Table 5). Annual recruitment of burbot ≥ 450 mm TL was 136 in Fielding Lake and 99 in Harding Lake (Table 5). Recruitment of burbot between 300 mm and 449 mm TL was 277 in Fielding Lake (Table 6).

Additional Appendices (B1 - B4 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 is provided in Appendix B3. Appendix B4 is age, weight, and length data collected in 1992. Appendix B5 is a listing of the data for each study lake. Finally, Appendix D provides a graphic presentation of the catch by depth for partially and fully recruited burbot.

DISCUSSION

Fielding and Harding lakes are oligatrophic and support several species of fish (Appendix A). Because both lakes are located along major highways, their burbot populations have been subjected to unregulated fishing pressure prior to 1987. The population of burbot in Fielding is recovering from high exploitation rates during the 1980s. The Fielding Lake population was depressed to its lowest point of 234 fully recruited burbot in 1987. Abundance in Fielding Lake has since increased to 666 in 1990 then declined slightly to 592 in 1991. Annual survival of burbot, ranged from 54.7 - 95.2 and averaging 71% since 1985 has aided the recovery of the population. Mean length of fully recruited burbot has increased annually as fish become larger in Fielding Lake. A discouraging indicator of stock status is mean CPUE (spring events): for fully recruited burbot in 1990 and 1991; mean CPUE was 0.88 and 0.71, respectively. In 1992 the mean CPUE was nearly half or 0.47. An estimate for the population of fully recruited burbot for 1992 (contingent on sampling effort occurring in 1993) may see a decline in numbers of fully recruited burbot. Continued restrictive regulations of this fishery is recommended to minimize harvest.

Estimates of abundance in Harding Lake show variability over the years. In 1990 the estimate was 880 fully recruited burbot, the largest to date (Table 5). However, there was a significant decrease in 1991 to an estimated 535 fully recruited burbot. The CPUE has followed the decrease in numbers of large burbot as well. Average CPUE decreased from 0.41 in 1990 to 0.27 in 1991. A further decrease in CPUE to 0.20 in 1992 indicates the population of fully recruited burbot will be further reduced. A similar reduction of partially recruited burbot occurred at the same time. However, CPUE of smaller burbot increased from 0.22 to 0.30 in 1992. Of 33 fully recruited burbot recaptured in 1992, only 19 (Appendix B1) were used in the Jolly-Seber estimate. The remaining 14 burbot were tagged as partially recruited into the full recruit size group in 1992. These newly recruited tagged burbot were not treated as recaptures. The average annual growth of partially recruited recaptured burbot in 1992 was 49 mm (n=18). A maximum of three years growth is required for a 300 mm burbot to become fully recruited. Of the 18 partially recruited burbot captured in 1992 only three were from 1990, the rest were tagged in 1991. The average annual growth of fully recruited recaptured burbot in Harding Lake is nearly double that of Fielding Lake burbot.

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APPENDIX A

DESCRIPTION OF FIELDING AND HARDING LAKES

Appendix A. Description of Fielding and Harding 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*,.

HARDING LAKE (64°25′ N, 146°50′ W) is accessible by road, located 72 km southeast of Fairbanks along the Richardson Highway. Harding Lake is 1,000 ha with a maximum depth of 47 m and an elevation of 218 m. Two small inlets from Little Harding and Spencer Lakes enter Harding Lake, but no outlet exists. The lake begins to freeze by late October and breakup occurs from May 15th to the first week of June. Access to the lake is provided by three roads that turn in off the Richardson Highway, which passes just to the west of the lake. one of the roads leads to a campground and boat launch facility maintained by the Alaska Department of Natural Resources. The other two access roads connect with Salchacket Drive, which encircles approximately three fourths of the shoreline. Recreational cabins and houses are located along the access road to the shoreline. Indigenous species in Harding Lake are burbot, least cisco, northern pike, and slimy sculpin *Cottus cognatus*. Transplanted species include Arctic char *Salvelinus alpinus*, Arctic grayling, coho salmon *Oncorhynchus kisutch*, lake trout, rainbow trout *Oncorhynchus mykiss*, sheefish *Stenodus leucicthys*, and sockeye salmon *Oncorhynchus nerka*.

APPENDIX B

MARK - RECAPTURE HISTORIES BY YEAR

and

DATA ARCHIVES

Appendix B1. Mark-recapture histories of fully recruited[a] burbot by year (by sampling event in 1992) for the populations in Fielding and Harding lakes.

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

HARDING LAKE								
DATE: Year		1986	1987	1988	1989	1990	1991	1992
Beginning		9/08	6/16	9/26	9/18	8/18	9/18	9/14
Ending		9/14	6/20	9/30	9/22	9/22	9/27	9/24
NUMBER OF FULLY RECRUITED BURBOT:								
Recaptured from Event	1	0	14	3	2	0	1	1
Recaptured from Event	2		0	9	4	4	3	0
Recaptured from Event	3			0	8	5	2	0
Recaptured from Event	4				0	8	9	2
Recaptured from Event	5					0	13	5
Recaptured from Event	6						0	11
Recaptured from Event	7							0
Captured with Tags		0	14	12	14	17	28	19
Captured without Tags		55	87	76	38	98	104	90
Captured		55	103	88	52	115	132	109
Released with Tags		54	81	77	52	110	132	104

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

Appendix B2. Mark-recapture histories of partially recruited[a] burbot by year (by sampling event in 1992) for the populations in Fielding and Harding lakes.

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

HARDING LAKE							
DATE: Year	1986	1987	1988	1989	1990	1991	1992
Beginning	9/08	6/16	9/26	9/18	8/18	9/18	9/14
Ending	9/14	6/20	9/30	9/22	9/22	9/27	9/24
NUMBER OF PARTIALLY RECRUITED BURBOT:							
Recaptured from Event 1	0	3	1	0	0	0	0
Recaptured from Event 2		0	3	1	0	0	0
Recaptured from Event 3			0	1	2	0	0
Recaptured from Event 4				0	4	0	0
Recaptured from Event 5					0	1	3
Recaptured from Event 6						0	15
Recaptured from Event 7							0
Captured with Tags	0	3	4	2	6	1	18
Captured without Tags	59	108	76	70	92	105	137
Captured	59	111	80	72	98	106	155
Released with Tags	47	80	69	67	87	103	153

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

Appendix B3. Voluntary returns of tagged burbot by sport anglers.

Lake	Date Tagged	Tag Number	Date Caught	Recapture Location
Fielding	6/16/90	70325	7/05/92	Fielding
Jatahmumd	8/15/88	61182	3/28/92	Jatahmund
Harding	9/17/90	71289	6/01/92	Harding
Harding	9/25/91	72763	12/29/91	Harding
Harding	9/18/90	71351	12/10/92	Harding

Appendix B4. Estimated ages, weights, and length information of burbot killed in 1992.

Lake	Date Killed	Tag Number	Sex	Age	Length (mm)	Weight (kg)	Maturity
Fielding							
	6/30/92	9135	F	7	525	1.20	mature
	6/28/92	9074	?	4	306	0.32	immature
	6/30/92	9077	F	5	421	0.60	immature
	6/30/92	71939	?	4	330	0.32	immature
	6/30/92	9130	M	5	402	0.51	mature
	6/30/92		F	4	285	0.31	immature
Harding							
	9/02/92		F	6	590		mature
	8/25/92		F	7	703		mature
	8/28/92	72591	M	7	550		mature
	8/25/92		?	5	435		immature
	8/26/92	72655	M	7	552		mature
	9/02/92		F	8	730		mature

Appendix B5. 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[1]

Lake	Data Map File Name	 Data Format	 Software
Fielding	U0130HA2.DTA	Hoopnet	RTS-ASCII
	FIEL92TD.DBF	Tag History	DBASE
Harding	U1890HA2.DTA	Hoopnet	RTS-ASCII
	HARD92TD.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.

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

APPENDIX C

BIAS AND VARIANCE OF MEAN CPUE

Appendix C. 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 1984). 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):

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

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

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

The B bootstrap estimates of mean CPUE comprise the empirical distribution F(mean $CPUE^*_1$,....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:

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

-continued-

where:

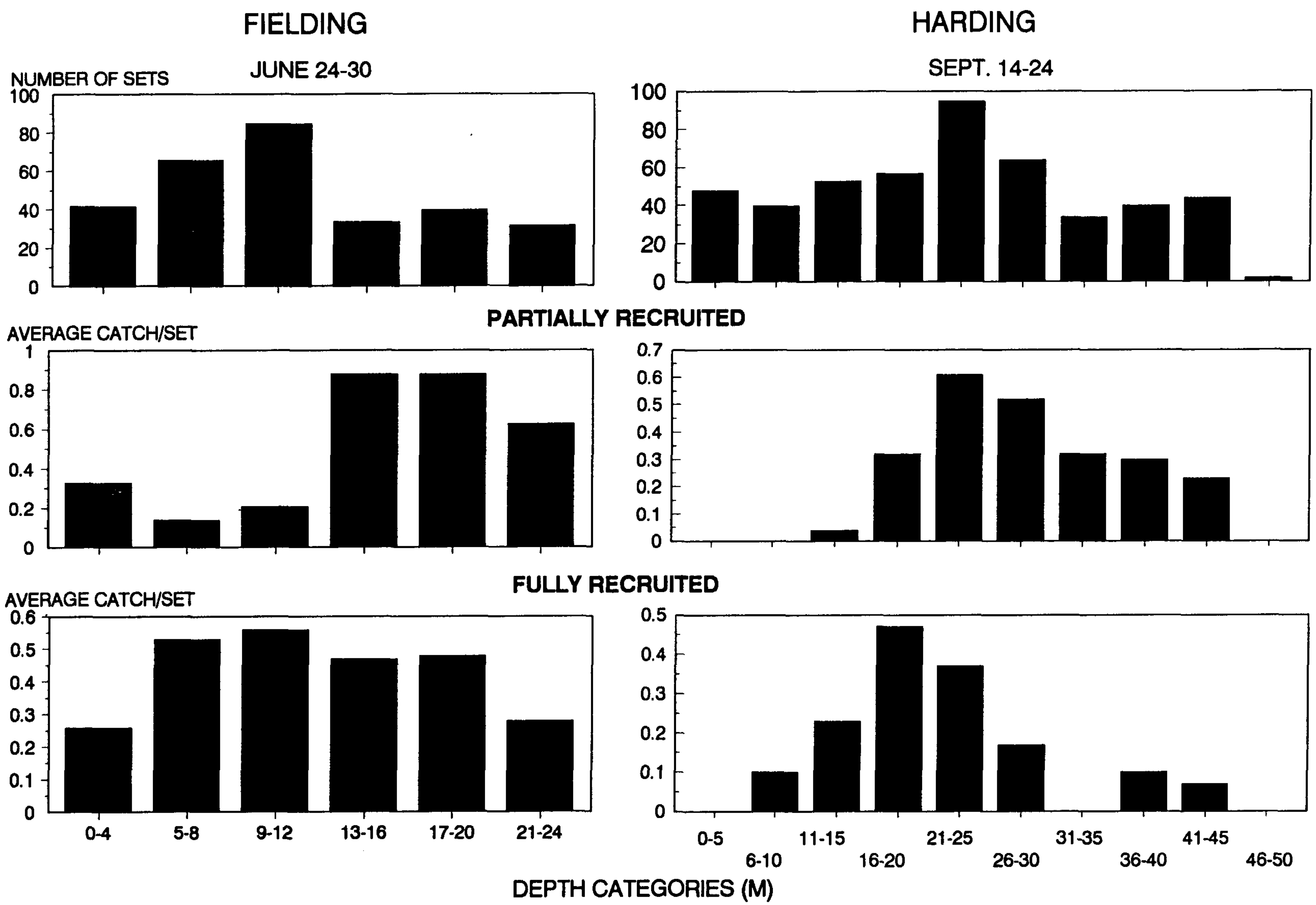
$$\overline{\overline{CPUE}}^{*} = \frac{\sum_{b=1}^{B} \overline{CPUE}_b^{*}}{B} \qquad (C.4)$$

The difference between $\overline{\overline{CPUE}}^{*}$ and the original statistic $\overline{CPUE}$ is an estimate 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 D

FREQUENCY OF SETS BY DEPTH AND AVERAGE CATCH



Appendix D. Frequency of sets by depth and average catch of burbot by depth for Fielding and Harding lakes sampled in 1992.