Fishery Data Series No. 92-20

# Stock Assessment and Biological Characteristics of Burbot in Lakes of Interior Alaska during 1991

by

Robert Lafferty,
James F. Parker,
and
David R. Bernard

July 1992

Alaska Department of Fish and Game

Division of Sport Fish

FISHERY DATA SERIES NO. 92-20

# STOCK ASSESSMENT AND BIOLOGICAL CHARACTERISTICS OF BURBOT IN LAKES OF INTERIOR ALASKA DURING 1991[1]

By

Robert Lafferty,
James F. Parker,
and
David R. Bernard

Alaska Department of Fish and Game
Division of Sport Fish
Anchorage, Alaska

July 1992

[1] This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-7, Jobs R-2-4 and R-3-4a.

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.

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 16 lakes in interior Alaska. Sampling occurred from May through October 1991. Mean catch per unit of effort of fully recruited burbot (450 mm total length and larger) per 48-hour set ranged from 0.03 (SE = 0.02) in Nancy Lake to 3.62 (SE = 0.42) in Tolsona Lake. Abundance of fully recruited burbot estimated with mark-recapture experiments was greatest in Paxson Lake (7,435; SE = 1,685) and lowest in T Lake (134 fish; SE = 39). Catchability coefficients from spring surveys (0.636) were greater than summer surveys (0.428).

KEY WORDS: burbot, *Lota lota*, lakes, abundance, hoop traps, systematic design, random design, stratified design, mean length, catch per unit of effort, abundance estimates, survival rates, recruitment, catchability coefficients.

## INTRODUCTION

A major sport fishery for burbot *Lota lota* occurs in the lakes of interior Alaska (Figures 1 and 2). Historically, the typical gear to harvest burbot through the ice included baited setlines or jigging, whereas jigs or baited hooks were used during the open water season. Harvests of burbot from these lakes increased, on average, 30% annually from 1977 to 1983, with the largest harvest occurring during the years 1984 to 1986 (Mills 1991). Lakes in the Glennallen area (Southcentral Alaska) have supported the largest component of this harvest. During 1984-1986, burbot harvests from the Glennallen area were greater than 10,000 annually, with a peak harvest of over 19,000 burbot occurring during 1985 (Figure 3). Within the Glennallen area, the lakes of the Tyone River drainage (consisting of Lake Louise and Susitna and Tyone lakes) have historically supported over half the harvest.

Recent harvests of burbot in the interior lakes of Alaska have declined because of reduced abundance of burbot from overfishing and more restrictive regulations governing these sport fisheries. Emergency regulations adopted in 1987 for many populations reduced the daily bag and possession limits for burbot to a maximum of five fish and reduced the number of simultaneously fished hooks to a maximum of five. Also during 1987, setlines were banned as a legal method of sport fishing in Fielding, T, and Harding lakes as well as throughout the Tangle lakes system. During the 1988 Board of Fisheries meeting, further reductions were made in daily bag and possession limits for those road-accessible lakes (Lake Louise, Tyone, Susitna, Tolsona, Moose, Summit, Fielding, Harding, and T lakes, and the Tangle lakes system) where anglers were restricted to two hooks and a possession limit of two burbot. Continued declines of burbot were documented in Lake Louise and Hudson Lake prompting the closure of these sport fisheries during the fall of 1988. To disperse angler effort and conserve existing burbot stocks of the Tyone River drainage further restrictions (prohibiting the use of setlines) were implemented to reduce harvest. The Alaska Board of Fisheries eliminated setlines as a legal manner of sport fishing throughout the Upper Copper/Upper Susitna management area during the 1991 meeting. Specific historical perspectives of these burbot fisheries can be found in the annual management reports for the Arctic-Yukon-Kuskokwim and Upper Copper/Upper Susitna management areas (Arvey 1989, Whitmore and Vincent-Lang 1991). Further detailed interpretation of changes in burbot stock status of the Upper Copper/Upper Susitna management area is presented in a report to the Board of Fisheries (Lafferty and Vincent-Lang 1991).

In the mid-1980s, Division of Sport Fish 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 drainage (Region III). During 1991, two populations in Big and Nancy lakes in the Matanuska-Susitna management area were included in this assessment program. This document is the sixth in a series of annual reports of the findings from this program and partially fulfills the contract requirements for two Federal Aid projects. The objectives of the program in 1991 were as follows:

Upper Copper/Upper Susitna Basin (Region II):

1. Estimate length composition of fully recruited burbot (≥ 450 mm TL) in Moose, Tolsona, Big, Nancy, and Paxson lakes and Lake Louise;

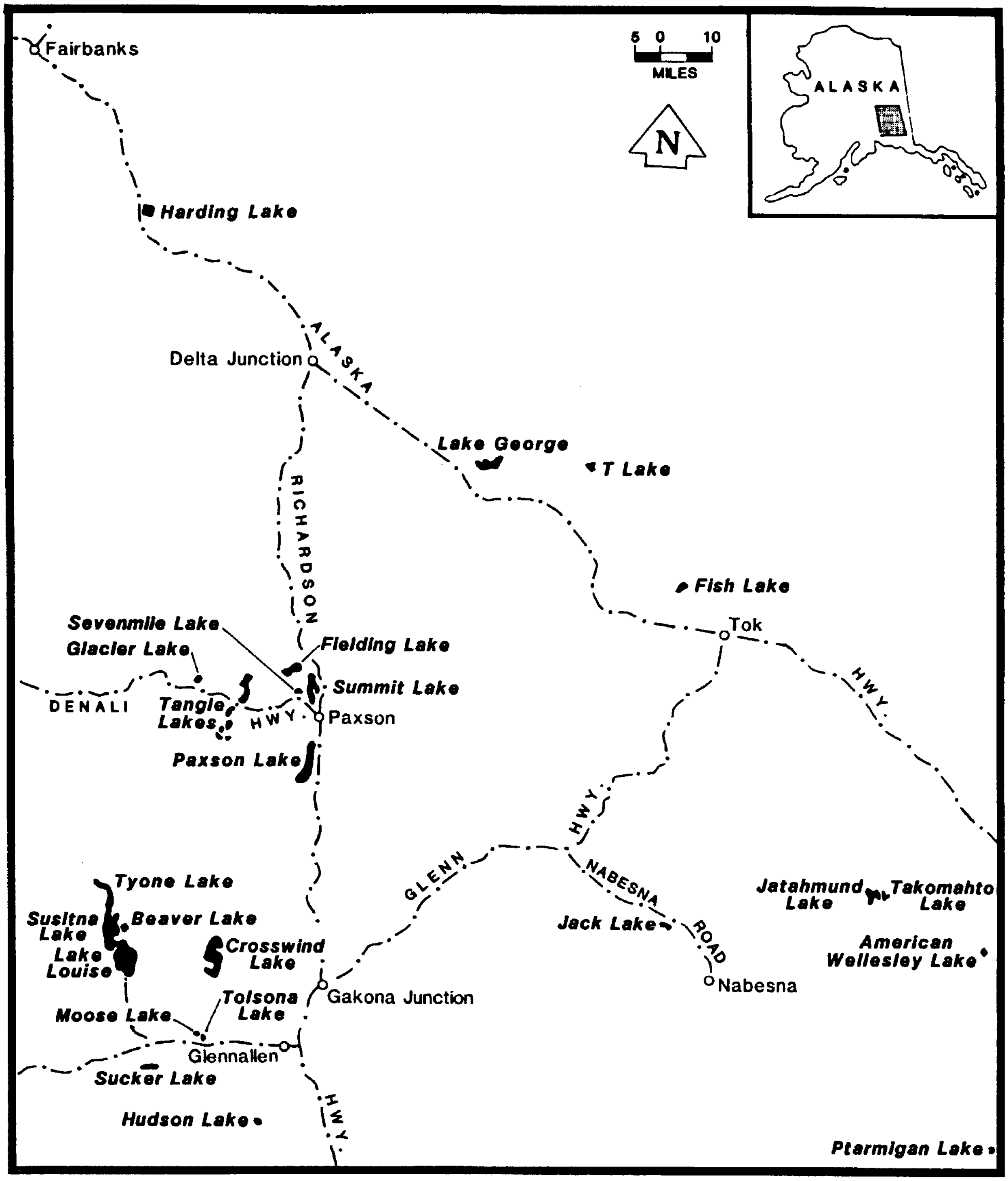



Figure 1. Location of lakes in the Tanana River drainage and near Glennallen with burbot populations that were studied in interior Alaska in 1991.

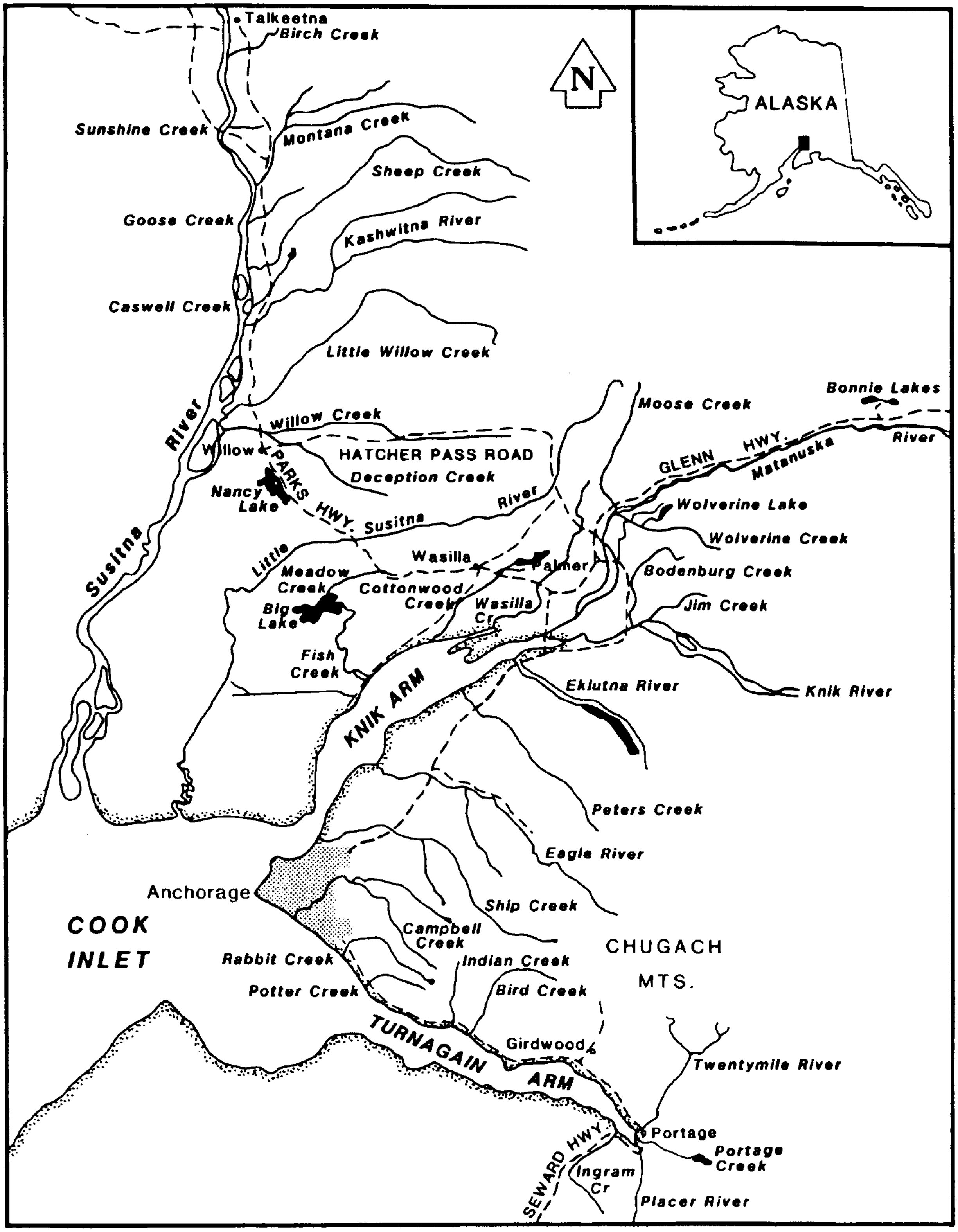



Figure 2. Location of Big and Nancy lakes in the Matanuska/Susitna River valley.

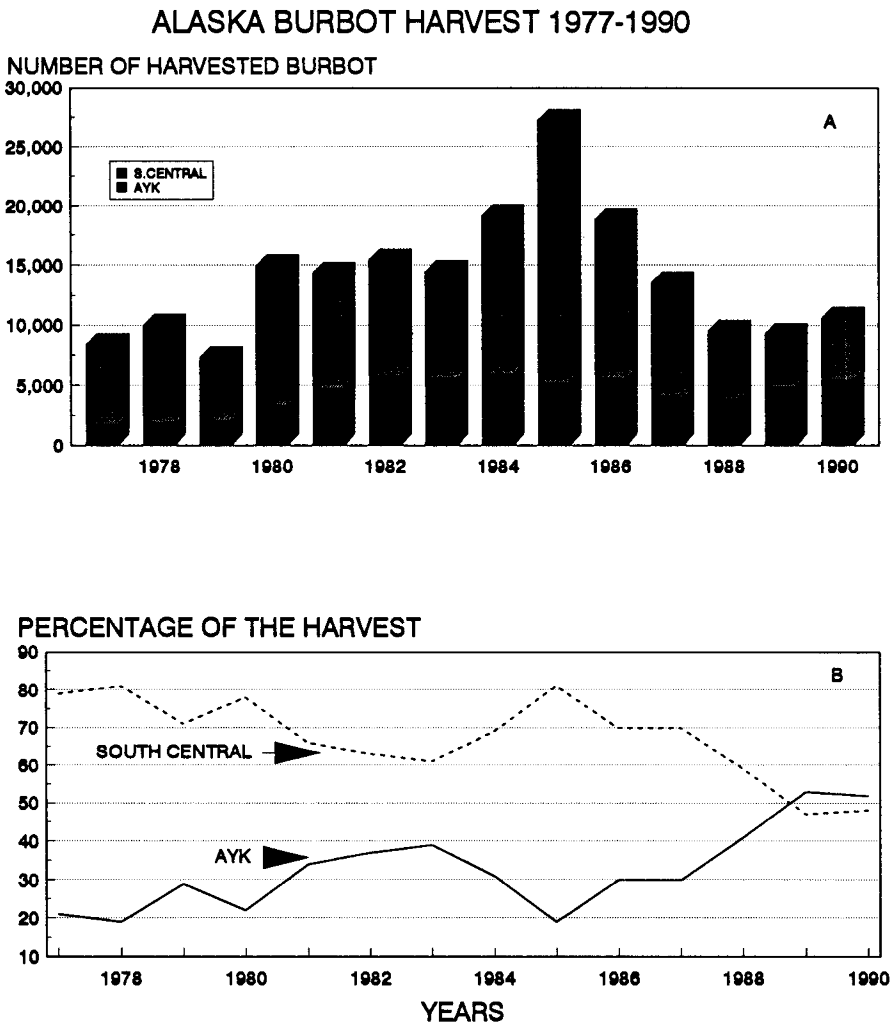



Figure 3. Harvests of burbot in Alaskan sport fisheries, 1977-1990 (A) and percentage of burbot harvested by region (B).

2. Estimate abundance of fully recruited burbot (≥ 450 mm TL) in Lake Louise and Moose, Tolsona, Big, Nancy and Paxson lakes;

3. Estimate annual survival rates for fully recruited burbot (≥ 450 mm TL) in Moose, Tolsona, and Paxson lakes and Lake Louise;

4. To index abundance of fully recruited burbot (≥ 450 mm TL) with mean CPUE (catch per unit of effort) in Moose, Tolsona, Big, Nancy, and Paxson lakes and Lake Louise; and

5. Detect the onset and duration of burbot spawning in Moose Lake.

Tanana Drainage (Region III):

1. Estimate abundance, survival rates, and recruitment of burbot in Fielding, Harding, T, Landlocked Tangle, Round Tangle, and Upper Tangle lakes;

2. Index abundance of burbot with mean CPUE (catch per unit of effort) in Fielding, Harding, George, T, Summit, Landlocked Tangle, Round Tangle, Upper Tangle, and Sevenmile lakes.

Each of the populations studied in 1991 has (or had) a popular sport fishery that targeted burbot. Most of these populations resided in lakes that were either geographically isolated or separated by lengthy rivers. The exceptions were the populations in the: (1) Lake Louise complex (consisting of Lake Louise and Susitna and Tyone lakes), (2) Summit and Paxson lakes, and (3) the Tangle lakes complex (lakes sampled in 1991 in this complex included Landlock, Round, and Upper Tangle lakes). These lakes are connected by short 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 4). 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 with 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).

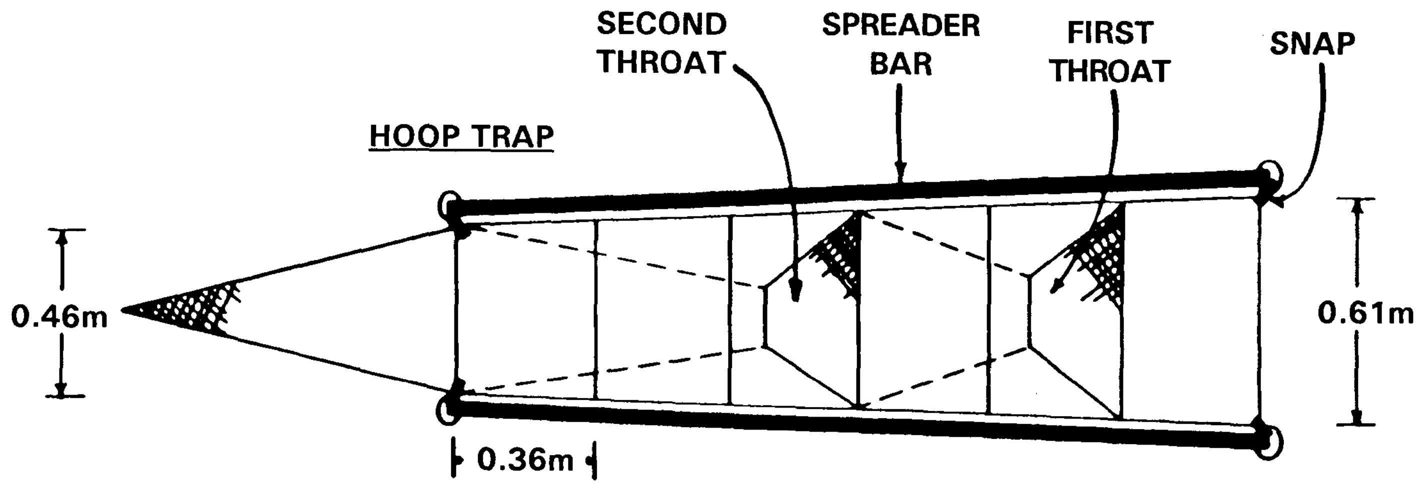



Figure 4. Schematic drawing of hoop traps used to catch burbot in interior Alaska in 1991.

Study Design

Mean CPUE was estimated in 16 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 within 125 m of shore 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 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. When both parameters (mean CPUE and abundance) were to be estimated, desired sample sizes for both statistics were calculated and the larger was used.

To reduce sampling-induced mortality (decompression) no traps were set deeper than 15 m in several deep lakes, unless an estimate of mean CPUE of partially recruited (≤ 300 mm TL) burbot was an objective. Parker et al. (1989) determined that fully recruited burbot in high altitude, deep lakes are equally distributed across depths from early spring throughout the summer. This uniform distribution allows restricting sampling to shallow waters without compromising the accuracy of the mean CPUE as an index of abundance. Mixing of fully recruited burbot across depths occurs within a few weeks (Bernard et al. *In prep*). Selection of sampling locations in these deep lakes followed the same procedure as in other lakes, only a bathymetric map was used, and all locations below 15 m were not considered for sampling. Because partially recruited burbot, < 450 mm total length (TL), are not evenly distributed across depths during summer (Parker et al. 1989), restricting sampling to less than 15 m in depth biased estimates of mean CPUE for that group. For this reason, deep-water sampling in some high altitude lakes occurred when mean CPUE estimates of partially recruited burbot were desired (Summit Lake for example).

Traps were immersed and retrieved during daylight hours beginning on one end of the lake and progressing to the other end. On larger lakes, multiple crews (three members per crew: one person piloted the boat and recorded data while the other two handled traps and measured and tagged captured burbot) immersed

---

[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 hectare by dividing the average CPUE of burbot caught per 48-hour set in 1985 in Fielding Lake by the density of burbot per hectare from the mark-recapture experiment (Pearse and Conrad 1986). This estimated fishing area was arbitrarily increased to 1.25 hectare 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 16 lakes in interior Alaska in 1991.

| Region III | | | | | Region II | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Lake | Area (hectare) | Sampling: Event | Sampling: Dates | Number of Sets | Lake | Area (hectare) | Sampling: Event | Sampling: Dates | Number of Sets |
| Fielding | 538 | 1 | 6/22-26 | 180 | Big[a] | 1,296 | 1 | 9/26-10/7 | 672 |
| | | 2 | 8/12-18 | 240 | | | | | |
| | | | | | Louise[a] | 6,519 | 1 | 6/3-14 | 1,409 |
| George | 1,863 | 1 | 5/27-6/2 | 300 | | | | | |
| | | | | | Moose | 130 | 1 | 5/22-25 | 100 |
| Harding | 1,000 | 1 | 9/18-27 | 480 | | | 2 | 9/11-14 | 120 |
| Ptarmigan | 251 | 1 | 8/14-18 | 80 | Nancy | 327 | 1 | 9/19-25 | 296 |
| Sevenmile | 34 | 1 | 7/7-9 | 40 | Paxson[a] | 1,575 | 1 | 6/17-25 | 1,036 |
| Summit | 1,651 | 1 | 7/15-21 | 300 | Tolsona | 130 | 1 | 5/20-23 | 100 |
| | | | | | | | 2 | 9/9-12 | 118 |
| T | 162 | 1 | 5/18-22 | 99 | | | | | |
| Landlock Tangle[a] | 219 | 1 | 7/03-08 | 220 | | | | | |
| | | 2 | 8/2-7 | 220 | | | | | |
| Round Tangle | 155 | 1 | 6/17-20 | 120 | | | | | |
| | | 2 | 7/29-8/1 | 120 | | | | | |
| Upper Tangle | 142 | 1 | 6/19-22 | 119 | | | | | |
| | | 2 | 7/31-8/3 | 120 | | | | | |
| TOTALS | | | 5/20 thru 10/07 | | | | | | 6,916 |

[a] Sets were restricted to depths < 15 m.

and retrieved traps simultaneously. On smaller lakes, a single crew was used to immerse and retrieve traps. Each crew usually immersed and retrieved from 50 to 80 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 Floy tags were attached 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 finclip or a hole punched through the opercle. 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). Age composition is reported when sufficient (25) mortalities occurred within a survey.

Burbot were separated into two groups for analysis: those fully recruited to the hoop traps (≥ 450 mm TL) and those partially recruited (< 450 mm TL). Bernard et al. (1991) showed that burbot recruited fully to hoop traps between 450 and 500 mm TL in most populations. Exceptions to this rule are burbot populations in Landlock Tangle, Round Tangle, Upper Tangle, and Sevenmile lakes (Lafferty et al. 1990), for which a single estimate of abundance for burbot ≥ 300 mm TL was computed for each population. Recaptures during a single annual survey were considered captured only once to estimate abundance with the mark-recapture experiments, but were considered captured "k" times to estimate mean CPUE.

Abundance, Survival Rates, and Recruitment

Abundance of fully recruited burbot was estimated with mark-recapture experiments using the multi-event model of Jolly (1965) and Seber (1965). Capitalizing on low sampling costs associated with smaller lakes, several surveys were designed for 1-year, two-sample experiments using Chapman's (1951) modification of the Petersen model. The Jolly-Seber models were applied when a population had been sampled for at least three consecutive events. Mark-recapture histories for all populations studied in 1991 are in Appendices B1 and B2.

Chapman's modification of the Petersen model (Seber 1982) is:

$$\hat{N} = \frac{(M+1)(C+1)}{(R+1)} - 1; \qquad (1)$$

and,

$$V(\hat{N}) = \frac{\hat{N}(M-R)(C-R)}{(R+1)(R+2)}; \qquad (2)$$

where:

$\hat{N}$ = estimated abundance;

M = number of marked burbot released alive into the population during the earlier sampling event;

C = number of burbot caught in the later sampling event; and,

R = number of burbot marked in the earlier event and recaptured during the later event.

The open population model of Jolly (1965) and Seber (1965) is:

$$\hat{M}_{i,i+1} = \frac{R_{i,i+2}\, M_{i+1}}{R_{i+1,i+2}} + R_{i,i+1} + D_{i,i+1} \quad (i=2,3,\ldots,s-1) \tag{3}$$

where:

s = the sum of sampling events i;

$M_s$ = number of marked burbot released alive into the population during sampling event "s";

$M_{s,t}$ = number of marked burbot released alive into the population during sampling event "s" that are still alive just prior to sampling event "t";

$R_{s,t}$ = number of marked burbot released in sampling event "s" and recaptured during event "t"; and,

$D_{s,t}$ = number of marked burbot released in sampling event "s", recaptured during event "t", and not returned to the population (usually due to death).

An estimate of the survival rate between sampling events "s" and "t" was calculated as:

$$\hat{S}_{i,i+1} = \frac{\hat{M}_{i,i+1}}{M_i} \quad (i=2,3,\ldots,s-2). \tag{4}$$

Abundance and recruitment were estimated as follows:

$$\hat{N}_i = \frac{C_i \hat{M}_{i-1,i}}{R_{i-1,i}} \quad (i=2,3,\ldots,s-1);\ \text{and,} \tag{5}$$

$$\hat{A}_{i-1,i} = \hat{N}_i - \hat{N}_{i-1}\hat{S}_{i-1,i} \quad (i=2,3,\ldots,s-2) \tag{6}$$

where:

$N_t$ = abundance just prior to sampling event "t";

$C_t$ = number of burbot captured during sampling event "t"; and,

$A_{s,t}$ = number of recruits added to the population between sampling events "s" and "t" that are still living just prior to event "t".

Equations 4 through 6 (and variances) were calculated with the program JOLLY as described in Pollock et al. (1985, 1990).

For those populations that have been in the stock assessment program since 1986 and earlier, a combination of estimation methods (Jolly-Seber and Chapman) was used to extend the range of the estimates according to the approach suggested in Pollock (1982). Gilbert (1973) has demonstrated that statistics using the Jolly-Seber models are unbiased when there are large sample sizes and large numbers of recaptured animals. To maximize sample sizes and numbers of recaptured burbot, sampling events separated by less than 4 weeks were pooled into one event. For those mark-recapture experiments that began in previous years with two sampling events during the first year, the abundance estimated from the Petersen model for that first year was used along with Equation 6 to estimate surviving recruitment between the first 2 years of the experiment. In this case, the variance of the first estimate of recruitment was calculated as follows (Goodman 1960):

$$V[\hat{A}_{o,1}] = V[\hat{N}_1] + V[\hat{N}_o]\hat{S}_{o,1}^2 + \hat{N}_o^2V[\hat{S}_{o,1}] - V[\hat{N}_o]V[\hat{S}_{o,1}]. \tag{7}$$

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:

$$\overline{CPUE} = \frac{1}{n}\sum_{i=1}^{n}\frac{1}{m_i}\sum_{i=1}^{m_i}\omega_i\, c_{ij} \tag{8}$$

where:

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

$n$ = number of transects;

$m_i$ = number of sets sampled on the ith transect;

$\omega_i$ = $M_i/\bar{M}$; 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 M and m are directly related to the length of transects. Thus $\hat{\omega}_i = m_i/\bar{m}$ was inserted for $\omega_i$. 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, Bernard et al. *In prep*), 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 $\hat{\omega}$ were estimated (see Appendix D). 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).

Catchability coefficients from nine mark-recapture experiments were calculated as the ratio of mean CPUE to density of fully recruited burbot as:

$$q_{ij} = \frac{A_i \overline{CPUE}_{ij}}{\hat{N}_{ij}} \qquad (9)$$

where:

$q_{ij}$ = catchability coefficient for the jth survey of the ith population,

$A_i$ = surface area (hectare) of the lake containing the ith population, and

$\overline{CPUE}_{ij}$ = mean CPUE for the jth survey of the ith population.

The $q_{ij}$ represents the fraction of a hectare fished with one unit of effort (a set). Because catchability is about twice as high just after the spring thaw than later during the summer (Bernard et al. *In prep*), catchability coefficients were stratified according to season of sampling. Those events less than 30 days after ice out and 30 days before ice cover were considered the spring stratum, the summer stratum were all others. Calculation of point estimates of abundance (≥ 450 mm TL) by direct expansion are obtained by multiplying mean CPUE by the surface area of the lake by one over the catchability coefficient.

# RESULTS

## Length Distributions

Three of the six populations sampled twice during 1991 (Moose, Tolsona, and Upper Tangle lakes) had length distributions that were significantly different between sampling events (Kolmogorov-Smirnov two-sample test, $P < 0.05$; Figure 5). The remaining three populations in Fielding, Landlock Tangle, and Round Tangle lakes had length distributions that were similar after a 30 to 47 day hiatus between sampling events. The increment of growth in mean length of fully recruited burbot in Moose and Tolsona lakes increased from 18 mm to 29 mm, between the two sampling events (Table 2). The difference between the two length distributions from burbot of Upper Tangle Lake is the smaller catch of burbot greater than 350 mm TL during the second event.

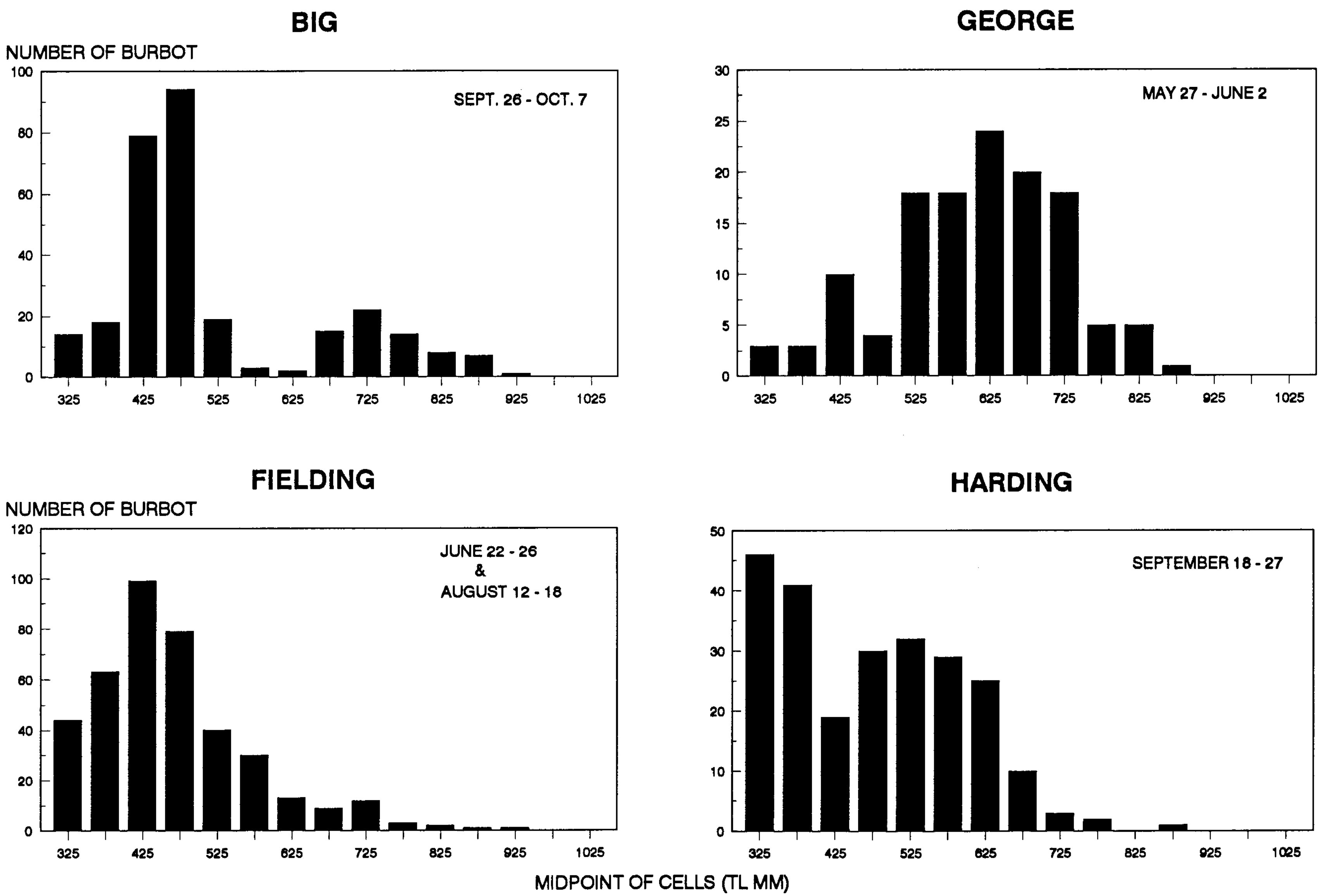
All of the length distributions have modes between 325 mm and 625 mm TL (Figure 5). Many of these length distributions have ascending left limbs with right limbs declining steeply with few burbot greater than 850 mm TL. Many of the lakes which are in close geographical proximity to one another display similar length distributions.

## Mean CPUE

Estimates of bootstrapped mean CPUE of fully recruited burbot ranged from 0.03 burbot per set in Nancy Lake to 3.62 burbot per set in Tolsona Lake (Table 3). Mean CPUE of partially recruited burbot in the same 12 populations ranged from 0.06 burbot per set in Lake Louise to 2.41 burbot per set in Tolsona Lake (Table 4). Estimates of bootstrapped mean CPUE of all burbot (larger or equal to 300 mm TL) for the remaining four populations (Tangle lakes and Sevenmile Lake) ranged from 0.34 burbot per set in Landlocked Tangle Lake to 1.32 burbot per set in Round Tangle Lake (Table 5). Estimated bias in mean CPUE as calculated through bootstrapping was less than 2%, except for partially recruited burbot in Nancy Lake (3.8%).

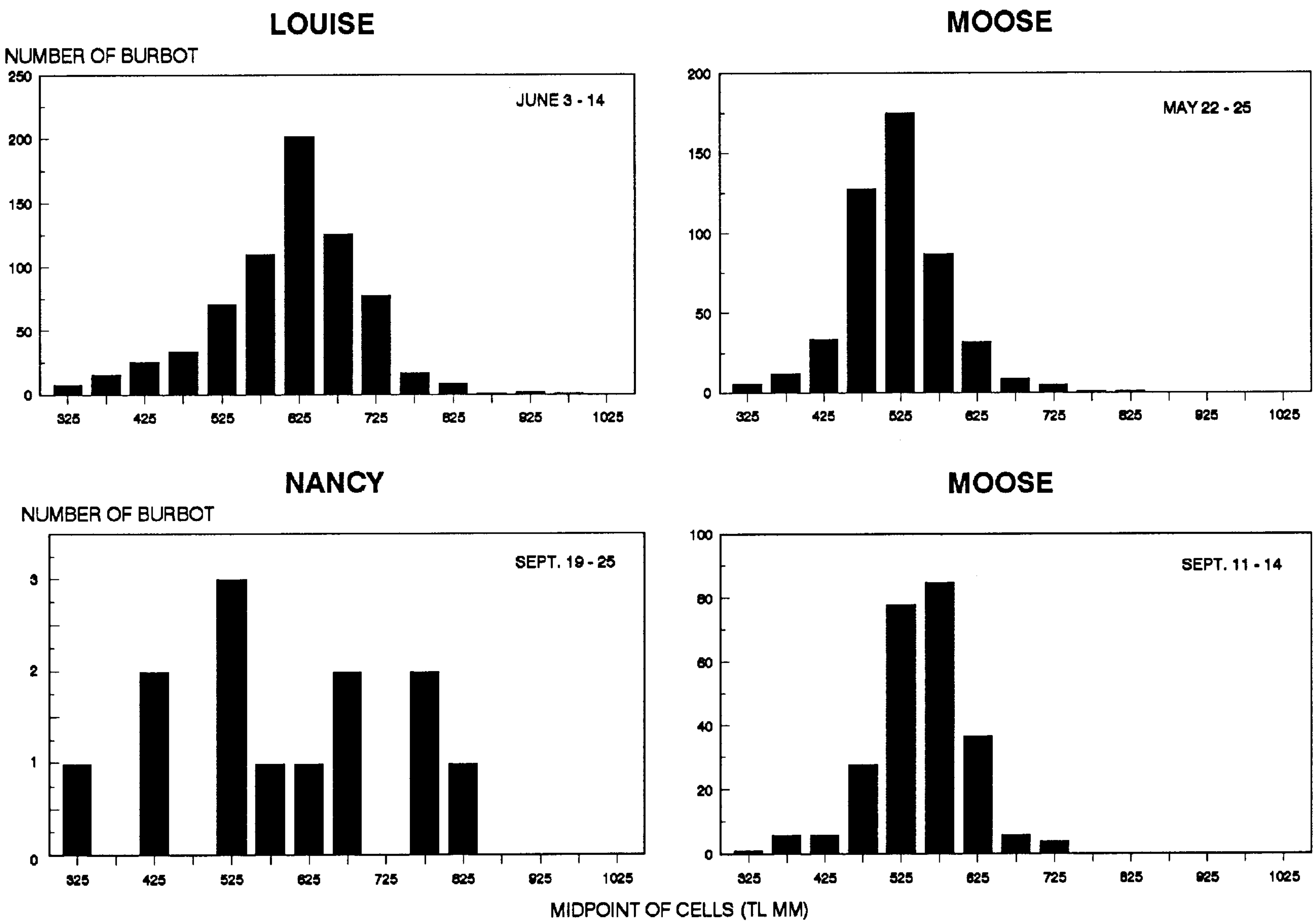
## Mark-Recapture Experiments

Occurrences of recaptured burbot from previous mark-recapture experiments in interconnected lakes other than the lake they were released into were negligible in Lake Louise (5 out 337 recaptures) and remains non-existent between Summit and Paxson lakes. The exception to this condition is the upstream movement of previously tagged burbot in the Tangle lakes complex (i.e., Shallow to Round to Upper Tangle lakes). Round Tangle Lake is separated from Upper Tangle Lake and Shallow Tangle Lake by 1,700 and 800 meters of river, respectively. Eleven percent of the 157 recaptured burbot in the Tangle lakes complex were recovered in lakes other than the lake in which they were released. Sixteen of the 17 "strays" were caught in Upper Tangle Lake. Of the 17 "strays", 9 were released into Round Tangle Lake and 7 were released into Shallow Tangle Lake. The remaining "stray" was released into Upper Tangle Lake and was recaptured downstream in Round Tangle Lake. None of these "strays" were recovered in different lakes in the same year. During 1991, three of the 10 recaptured burbot in Upper Tangle Lake were from Round Tangle Lake. Two of these 3 "strays" were tagged during 1989 and the other during 1990.



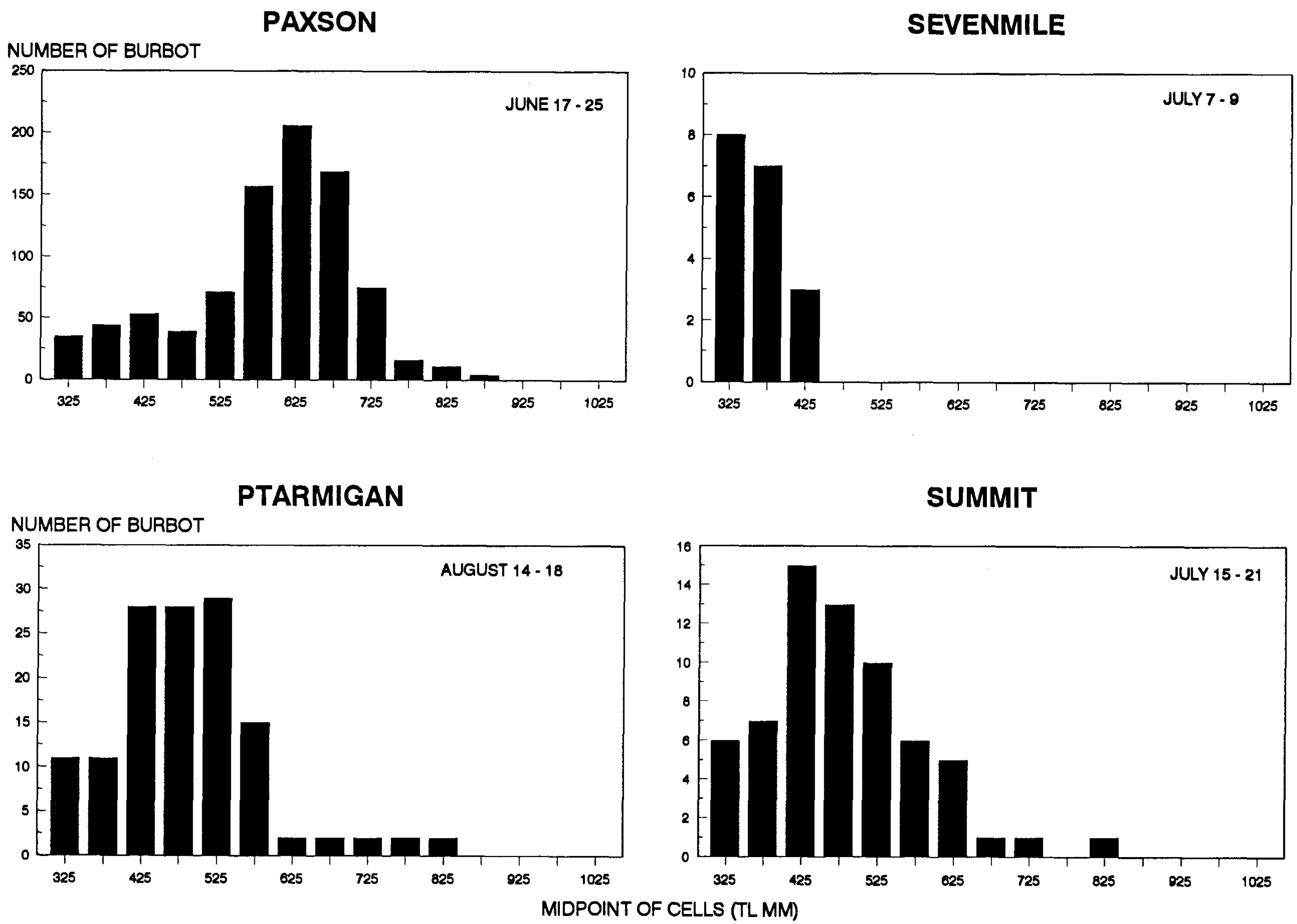

-continued-

Figure 5. Length-frequency histograms of burbot captured in interior Alaska lakes in 1991.



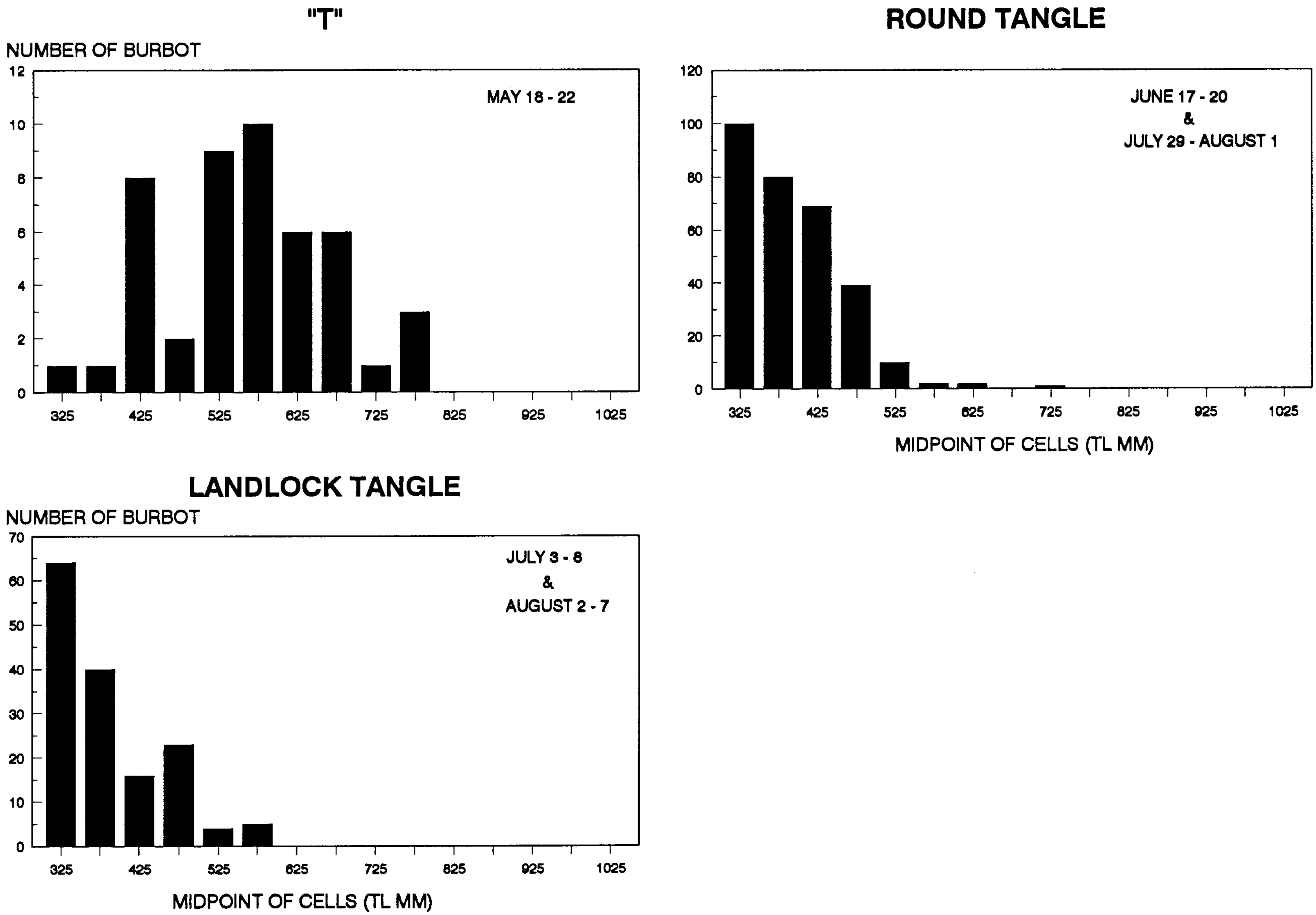

-continued-

Figure 5. (Page 2 of 5).




-continued-

Figure 5. (Page 3 of 5).




-continued-

Figure 5. (Page 4 of 5).

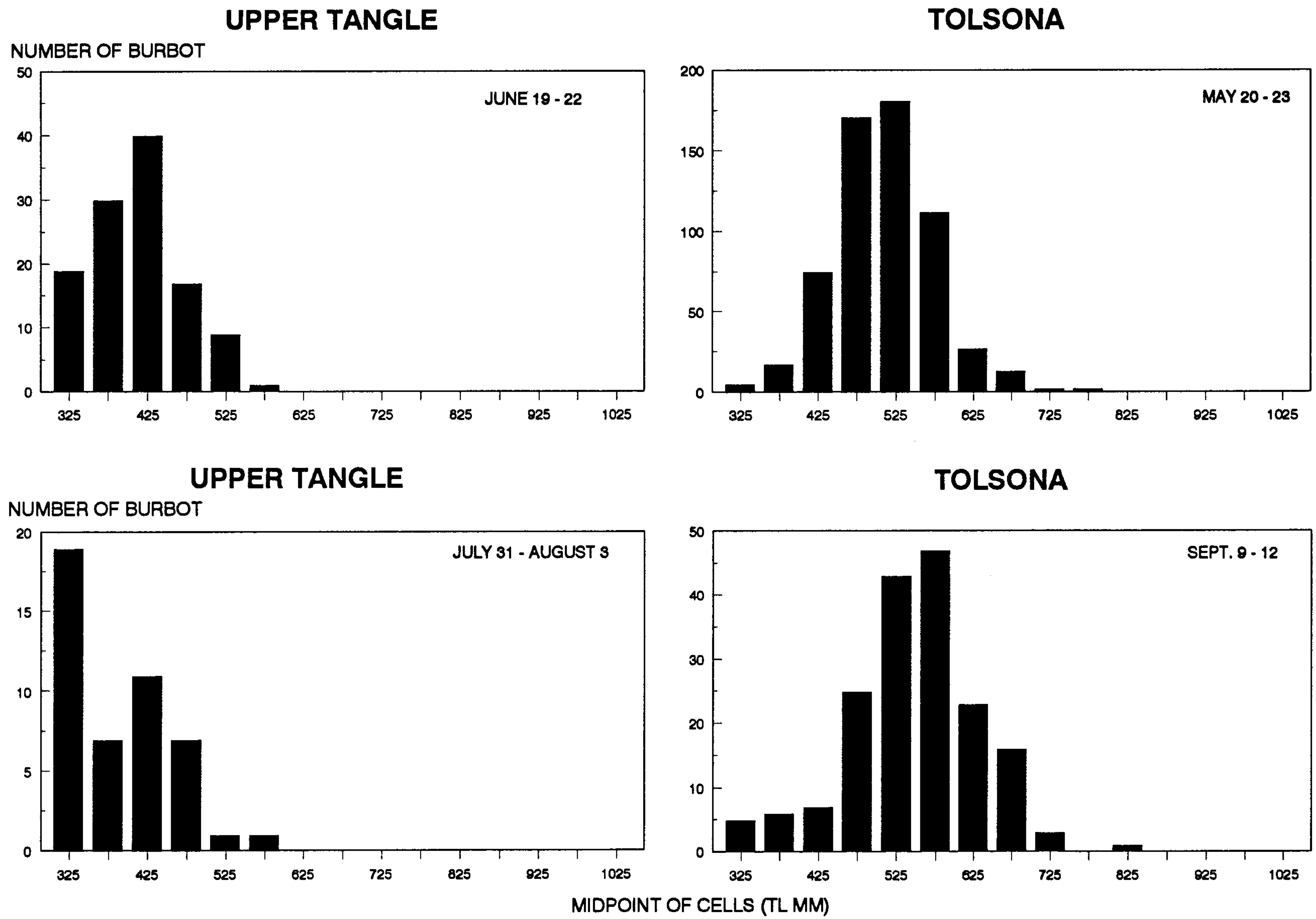



Figure 5. (Page 5 of 5).

Table 2. Mean lengths (mm TL) of burbot measured during sampling events in 16 lakes in interior Alaska in 1991.

| | | First Event Recruitment[a] to the gear | | | Second Event Recruitment[a] to the gear | | | All Events Fully Recruited[a] to the gear |
|---|---|---|---|---|---|---|---|---|
| Lake | Statistic | Part. | Fully | All | Part. | Fully | All | |
| Big | Mean | 385 | 631 | 468 | | | | 631 |
| | SE | 3 | 12 | 8 | | | | 12 |
| | Samples | 198 | 100 | 298 | | | | 100 |
| Fielding | Mean | 391 | 536 | 465 | 382 | 559 | 466 | 544 |
| | SE | 4 | 8 | 6 | 5 | 13 | 10 | 7 |
| | Samples | 124 | 127 | 251 | 76 | 69 | 145 | 196 |
| George | Mean | 395 | 638 | 608 | | | | 638 |
| | SE | 11 | 8 | 10 | | | | 8 |
| | Samples | 16 | 113 | 129 | | | | 113 |
| Harding | Mean | 363 | 563 | 474 | | | | 563 |
| | SE | 4 | 7 | 8 | | | | 7 |
| | Samples | 106 | 132 | 238 | | | | 132 |
| Louise | Mean | 354 | 586 | 541 | | | | 586 |
| | SE | 4 | 3 | 4 | | | | 3 |
| | Samples | 170 | 712 | 882 | | | | 712 |
| Moose | Mean | 405 | 504 | 473 | 395 | 522 | 503 | 511 |
| | SE | 3 | 3 | 3 | 8 | 3 | 4 | 2 |
| | Samples | 154 | 336 | 490 | 41 | 231 | 272 | 567 |
| Nancy | Mean | 390 | 650 | 590 | | | | 650 |
| | SE | 33 | 36 | 42 | | | | 36 |
| | Samples | 3 | 10 | 13 | | | | 10 |
| Paxson | Mean | 354 | 586 | 542 | | | | 586 |
| | SE | 4 | 3 | 4 | | | | 3 |
| | Samples | 170 | 712 | 882 | | | | 712 |
| Ptarmigan | Mean | 391 | 535 | 484 | | | | 535 |
| | SE | 6 | 8 | 8 | | | | 8 |
| | Samples | 46 | 86 | 132 | | | | 132 |
| Sevenmile | Mean | 361 | --- | 361 | | | | --- |
| | SE | 9 | --- | 9 | | | | --- |
| | Samples | 18 | 0 | 18 | | | | 0 |

-continued-

Table 2. (Page 2 of 2).

| Lake | Statistic | First Event Recruitment[a] to the gear Part. | Fully | All | Second Event Recruitment[a] to the gear Part. | Fully | All | All Events Fully Recruited[a] to the gear |
|---|---|---|---|---|---|---|---|---|
| Summit | Mean | 391 | 541 | 483 | | | | 541 |
| | SE | 9 | 12 | 12 | | | | 12 |
| | Samples | 25 | 40 | 65 | | | | 40 |
| T | Mean | 413 | 600 | 560 | | | | 600 |
| | SE | 10 | 13 | 15 | | | | 13 |
| | Samples | 10 | 37 | 47 | | | | 37 |
| Landlock Tangle | Mean | 354 | 507 | 392 | 349 | 479 | 371 | 495 |
| | SE | 6 | 10 | 9 | 5 | 9 | 7 | 7 |
| | Samples | 56 | 19 | 75 | 64 | 13 | 77 | 32 |
| Round Tangle | Mean | 370 | 491 | 395 | 362 | 492 | 382 | 491 |
| | SE | 3 | 8 | 5 | 5 | 13 | 6 | 7 |
| | Samples | 159 | 41 | 200 | 87 | 16 | 103 | 57 |
| Upper Tangle | Mean | 384 | 492 | 410 | 356 | 492 | 383 | 492 |
| | SE | 5 | 6 | 6 | 8 | 13 | 10 | 6 |
| | Samples | 88 | 28 | 116 | 37 | 9 | 46 | 37 |
| Tolsona | Mean | 403 | 505 | 465 | 383 | 534 | 501 | 513 |
| | SE | 2 | 2 | 3 | 10 | 5 | 6 | 2 |
| | Samples | 242 | 365 | 607 | 39 | 137 | 176 | 502 |

[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.

Table 3. Estimated mean CPUE of fully recruited burbot from systematic sampling of populations studied in 1991.

| Lakes and Dates | Strata | Number of Sets and Transects[a] | | Mean CPUE Bootstrapped | Arithmetic | %Δ | SE | CV |
|---|---|---|---|---|---|---|---|---|
| Big | | | | | | | | |
| 9/26-10/7 | <15 meters | 671 | 64 | 0.23 | 0.24 | -1.7% | 0.13 | 55.3% |
| Fielding | | | | | | | | |
| 6/22-26 | All depths | 179 | 32 | 0.71 | 0.71 | 0.6% | 0.11 | 16.0% |
| 7/12-18 | All depths | 237 | 42 | 0.29 | 0.29 | 0.0% | 0.06 | 20.3% |
| George | | | | | | | | |
| 5/27-6/2 | All depths | 298 | 37 | 0.38 | 0.38 | -0.4% | 0.06 | 15.2% |
| Harding | | | | | | | | |
| 9/18-27 | All depths | 480 | 26 | 0.27 | 0.28 | -1.0% | 0.04 | 14.0% |
| Louise | | | | | | | | |
| 6/3-14 | <15 meters | 1,409 | 83 | 0.44 | 0.44 | 0.0% | 0.03 | 7.6% |
| Moose | | | | | | | | |
| 5/22-25 | All depths | 100 | 15 | 3.27 | 3.27 | -0.1% | 0.32 | 9.9% |
| 9/11-14 | All depths | 120 | 16 | 1.78 | 1.77 | 0.2% | 0.22 | 12.5% |
| Nancy | | | | | | | | |
| 9/19-25 | <15 meters | 296 | 39 | 0.03 | 0.03 | 0.5% | 0.02 | 46.0% |
| Paxson | | | | | | | | |
| 6/17-25 | <15 meters | 1,032 | 148 | 0.69 | 0.69 | -0.2% | 0.05 | 7.1% |
| Ptarmigan | | | | | | | | |
| 8/14-18 | All depths | 77 | 15 | 1.08 | 1.10 | -1.5% | 0.18 | 16.7% |
| Summit | | | | | | | | |
| 7/15-21 | All depths | 294 | 31 | 0.13 | 0.13 | 0.4% | 0.03 | 23.5% |
| T | | | | | | | | |
| 5/18-22 | All depths | 98 | 10 | 0.37 | 0.37 | -1.6% | 0.09 | 24.9% |
| Tolsona | | | | | | | | |
| 5/20-23 | All depths | 100 | 13 | 3.62 | 3.63 | -0.2% | 0.42 | 11.7% |
| 9/9-12 | All depths | 118 | 14 | 1.14 | 1.16 | -1.5% | 0.17 | 14.7% |

[a] Single set transects were deleted from the calculation of mean CPUE.

Table 4. Estimated mean CPUE of partially recruited burbot from systematic sampling of populations studied in 1991.

| Lakes and Dates | Strata | Number of Sets and | Transects[a] | Mean CPUE Bootstrapped | Arithmetic | %Δ | SE | CV |
|---|---|---|---|---|---|---|---|---|
| Big | | | | | | | | |
| 9/26-10/7 | <15 meters | 671 | 64 | 0.39 | 0.39 | 0.3% | 0.13 | 34.2% |
| Fielding | | | | | | | | |
| 6/22-26 | All depths | 179 | 32 | 0.68 | 0.69 | -1.3% | 0.12 | 17.0% |
| 8/12-18 | All depths | 237 | 42 | 0.32 | 0.32 | 0.6% | 0.06 | 17.9% |
| George | | | | | | | | |
| 5/27-6/2 | All depths | 298 | 37 | 0.53 | 0.54 | -2.0% | 0.02 | 36.5% |
| Harding | | | | | | | | |
| 9/18-27 | All depths | 480 | 26 | 0.22 | 0.22 | -0.5% | 0.03 | 12.9% |
| Louise | | | | | | | | |
| 6/3-14 | <15 meters | 1,409 | 83 | 0.06 | 0.06 | 0.4% | 0.01 | 19.4% |
| Moose | | | | | | | | |
| 5/22-25 | All depths | 100 | 15 | 1.53 | 1.54 | -0.6% | 0.21 | 13.7% |
| 9/11-14 | All depths | 120 | 16 | 0.31 | 0.31 | 0.0% | 0.06 | 21.1% |
| Nancy | | | | | | | | |
| 9/19-25 | <15 meters | 296 | 39 | 0.10 | 0.10 | 3.8% | 0.01 | 73.9% |
| Paxson | | | | | | | | |
| 6/17-25 | <15 meters | 1,032 | 148 | 0.16 | 0.16 | -0.2% | 0.02 | 10.6% |
| Ptarmigan | | | | | | | | |
| 8/14-18 | All depths | 77 | 15 | 0.56 | 0.56 | 0.6% | 0.12 | 21.5% |
| Summit | | | | | | | | |
| 7/15-21 | All depths | 294 | 65 | 0.08 | 0.08 | -1.8% | 0.02 | 32.5% |
| T | | | | | | | | |
| 5/18-22 | All depths | 98 | 10 | 0.10 | 0.10 | -1.7% | 0.04 | 40.6% |
| Tolsona | | | | | | | | |
| 5/20-23 | All depths | 100 | 13 | 2.41 | 2.41 | 0.2% | 0.34 | 14.0% |
| 9/9-12 | All depths | 118 | 14 | 0.32 | 0.32 | 0.5% | 0.07 | 22.2% |

[a] Single set transects were deleted from the calculation of mean CPUE.

Table 5. Estimated mean CPUE of both partially and fully recruited burbot from systematic sampling of populations in lakes along the Denali Highway during 1991.

| Lakes and Dates | Strata | Number of Sets and Transects[a] | | Mean CPUE Bootstrapped | Arithmetic | %Δ | SE | CV |
|---|---|---|---|---|---|---|---|---|
| Landlock Tangle | | | | | | | | |
| 7/3-8 | < 15 m | 220 | 32 | 0.34 | 0.34 | 0.5% | 0.07 | 20.6% |
| 8/2-7 | < 15 m | 220 | 32 | 0.35 | 0.35 | -0.5% | 0.07 | 19.4% |
| Round Tangle | | | | | | | | |
| 6/17-20 | All depths | 120 | 16 | 1.32 | 1.32 | 0.1% | 0.19 | 14.5% |
| 7/29-8/1 | All depths | 120 | 16 | 0.85 | 0.85 | -0.4% | 0.12 | 13.9% |
| Sevenmile | | | | | | | | |
| 7/7-9 | All depths | 40 | 7 | 0.46 | 0.45 | 1.8% | 0.13 | 27.5% |
| Upper Tangle | | | | | | | | |
| 6/19-22 | All depths | 117 | 26 | 0.98 | 0.99 | -1.1% | 0.29 | 29.9% |
| 7/31-8/3 | All depths | 116 | 33 | 0.40 | 0.40 | 0.2% | 0.09 | 23.9% |

[a] Single set transects were deleted from the calculation of mean CPUE.

Estimated rates of tag loss for each experiment were not significantly different ($t$ test, $P > 0.05$) than reported estimates in Lafferty et al. (1990). Rates of tag loss between summer sampling events averaged 3.5%. Average rates of tag loss ranged from 5.3% for overwinter to 2.2% for 3 years. 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 TL) burbot in Fielding, George, Harding, Louise, Moose, Paxson, Summit, T, and Tolsona lakes ranged from 133 fish in Summit Lake in 1990 to 7,435 fish in Paxson Lake for the same year (Table 6). The only significant difference between abundance of fully recruited burbot during the last two annual sampling events occurred in Harding Lake ($t$ test, $\alpha = 0.05$). Abundance estimates of burbot 300 mm and larger in Landlock, Round, and Upper Tangle lakes ranged from 406 burbot in Landlock to 3,115 burbot in Upper Tangle Lake (Table 7). Comparing the last two previous abundance estimates, there is a significant ($t$ test, $\alpha = 0.05$) decrease in abundance of burbot in Landlock Tangle Lake. Unfortunately, insufficient burbot were recaptured in Sevenmile Lake in 1991 to calculate abundance. Ten or fewer burbot were recaptured in the mark-recapture experiments in George, Summit, and Upper Tangle lakes.

Densities of fully recruited burbot ranged from 0.08 fish per hectare in Summit Lake to 9.11 fish per hectare in Moose Lake (Table 8). Density of burbot 300 mm and larger in the lakes along the Denali Highway ranged from 1.85 fish per hectare in Landlock Tangle Lake to 21.94 fish per hectare in Upper Tangle Lake (Table 8). In general, deeper and larger lakes contained less dense populations of burbot.

The average catchability coefficient from summer surveys is 0.428 (Table 9). Using the summer catch coefficient to estimate abundance of fully recruited burbot in Big, Nancy, and Ptarmigan lakes resulted in estimates of 696, 23, and 645 burbot, respectively.

Survival Rates and Recruitment

Survival rates of fully recruited burbot (≥ 450 mm TL) between 1989 and 1990 ranged from 50.2% (SE = 10.2%) in Tolsona Lake to 146.5% (SE = 50.1%) in Harding Lake (Table 6). Disregarding fishing mortality from the sport fisheries, the annual survival rates of fully recruited burbot averaged 71% over the duration of the mark-recapture experiments. Estimates of burbot (≥ 450 mm TL) recruiting into the populations listed in Table 6 during 1989 to 1990 ranged from 23 in Summit Lake to 3,535 in Paxson Lake.

Annual survival rates of burbot greater than 300 mm TL in Tangle lakes ranged between 23.0 to 70.8% during 1989 and 1990 (Table 7). Disregarding fishing mortality from the sport fisheries, the average annual survival rate for all burbot in the Tangle lakes is 47%. Recruitment of burbot greater than 300 mm TL in the Tangle lakes ranged from 20 to 2,322 between 1989 to 1990.

Several additional appendices (B3 and C) provide continuity among previous annual reports or summarize information that could be useful to reader. Appendix B3 is a listing of the data for each specific study lake and the custodian. A graphic presentation of the catch by depth for partially and fully recruited burbot is located in Appendix C.

Table 6. Estimates of abundance, survival rates, and recruitment for fully recruited (≥ 450 mm TL) burbot residing in Fielding, George, Harding, Louise, Moose, Paxson, Summit, T, and Tolsona lakes.

| Lake | Date | Days between events | Abundance Est. | Abundance (SE) | Abundance CV % | Survival Rate % Est. | Survival Rate % (SE) | Recruitment Est. | Recruitment (SE) |
|---|---|---|---|---|---|---|---|---|---|
| Fielding | 7/14/84 | | N/A | | | | | | |
| | | 403 | | | | 69.8 | (15.6) | N/A | |
| | 8/21/85 | | 350 | (96) | 27.4 | | | | |
| | | 355 | | | | 48.2 | (6.7) | 142 | (66) |
| | 8/11/86 | | 299 | (49) | 16.3 | | | | |
| | | 360 | | | | 63.5 | (7.2) | 73 | (32) |
| | 8/06/87 | | 236 | (24) | 10.1 | | | | |
| | | 343 | | | | 94.0 | (9.8) | 243 | (49) |
| | 7/15/88 | | 445 | (58) | 13.0 | | | | |
| | | 365 | | | | 67.8 | (8.7) | 193 | (52) |
| | 7/15/89 | | 477 | (64) | 13.4 | | | | |
| | | 367 | | | | 68.5 | (10.1) | 261 | (63) |
| | 7/17/90 | | 584 | (87) | 14.9 | | | | |
| George | 6/15/87 | | 1,773[a] | (599) | 31.0 | | | | |
| | | 346 | | | | 45.4 | (18.5) | N/A | |
| | 5/27/88 | | 3,166 | (1,754) | 55.4 | | | | |
| | | 375 | | | | 66.4 | (28.0) | 1,349 | (1,454) |
| | 6/06/89 | | 3,450 | (1,587) | 46.0 | | | | |
| | | 354 | | | | 62.7 | (54.2) | 1,328 | (1,509) |
| | 5/26/90 | | 3,492 | (3,055) | 87.5 | | | | |
| Harding | 9/11/86 | | N/A | | | | | | |
| | | 324 | | | | 66.4 | (17.6) | N/A | |
| | 6/18/87 | | 259 | (82) | 21.6 | | | | |
| | | 468 | | | | 76.2 | (23.4) | 368 | (178) |
| | 9/28/88 | | 549 | (207) | 37.7 | | | | |
| | | 357 | | | | 39.1 | (11.4) | -4 | (73) |
| | 9/20/89 | | 206 | (62) | 30.0 | | | | |
| | | 349 | | | | 146.5 | (50.1) | 679 | (306) |
| | 9/04/90 | | 980 | (374) | 38.2 | | | | |

-continued-

Table 6. (Page 2 of 3).

| Lake | Date | Days between events | Abundance Est. | (SE) | CV % | Survival Rate % Est. | (SE) | Recruitment Est. | (SE) |
|---|---|---|---|---|---|---|---|---|---|
| Louise | 6/22/86 | | 6,990[b] | (2,131) | 30.5 | | | | |
| | | 381 | | | | 29.2 | (5.9) | 1,864 | (2,032) |
| | 7/13/87 | | 3,569 | (1,002) | 28.1 | | | | |
| | | 330 | | | | 92.5 | (16.6) | 2,884 | (1,406) |
| | 6/16/88 | | 5,922 | (1,417) | 23.9 | | | | |
| | | 357 | | | | 51.5 | (7.8) | 1,176 | (809) |
| | 6/08/89 | | 4,175 | (730) | 17.5 | | | | |
| | | 360 | | | | 63.5 | (9.7) | 1,250 | (546) |
| | 6/08/90 | | 3,899 | (634) | 16.3 | | | | |
| Moose | 9/01/88 | | 1,625 | (276) | 17.0 | | | | |
| | | 247 | | | | 59.6 | (6.6) | 243 | (160) |
| | 5/21/89 | | 1,212 | (135) | 11.1 | | | | |
| | | 61 | | | | 85.9 | (12.6) | 295 | (158) |
| | 7/10/89 | | 1,335 | (223) | 16.7 | | | | |
| | | 67 | | | | 68.1 | (12.7) | 77 | (115) |
| | 9/09/89 | | 986 | (160) | 16.2 | | | | |
| | | 19 | | | | 42.4 | (6.9) | 177 | (68) |
| | 10/08/89 | | 594 | (83) | 14.0 | | | | |
| | | 231 | | | | 98.2 | (15.3) | 352 | (107) |
| | 5/24/90 | | 935 | (150) | 16.0 | | | | |
| | | 124 | | | | 50.5 | (9.1) | 300 | (112) |
| | 9/05/90 | | 772 | (147) | 19.0 | | | | |
| | | 259 | | | | 73.6 | (14.1) | 616 | (163) |
| | 5/23/91 | | 1,184 | (214) | 18.1 | | | | |
| Paxson | 7/10/86 | | 7,426[c] | (733) | 9.9 | | | | |
| | | 365 | | | | 57.3 | (5.8) | N/A | |
| | 7/10/87 | | 4,015 | (563) | 14.0 | | | | |
| | | 339 | | | | 78.8 | (10.8) | -162 | (431) |
| | 6/10/88 | | 2,887 | (431) | 14.9 | | | | |
| | | 439 | | | | 99.9 | (22.6) | 3,123 | (994) |
| | 9/20/89 | | 5,964 | (1,420) | 23.8 | | | | |
| | | 355 | | | | 65.5 | (16.5) | 3,535 | (1,275) |
| | 9/18/90 | | 7,435 | (1,685) | 22.6 | | | | |

-continued-

Table 6. (Page 3 of 3).

| Lake | Date | Days between events | Abundance Est. | (SE) | CV % | Survival Rate % Est. | (SE) | Recruitment Est. | (SE) |
|---|---|---|---|---|---|---|---|---|---|
| Summit | 8/08/86 | | N/A | | | | | | |
| | | 368 | | | | 62.4 | (26.4) | N/A | |
| | 8/11/87 | | 385 | (181) | 47.0 | | | | |
| | | 332 | | | | 49.0 | (21.5) | 150 | (138) |
| | 7/09/88 | | 337 | (170) | 50.3 | | | | |
| | | 372 | | | | 40.5 | (20.5) | 29 | (64) |
| | 7/16/89 | | 164 | (81) | 49.4 | | | | |
| | | 367 | | | | 67.4 | (42.6) | 23 | (47) |
| | 7/18/90 | | 133 | (80) | 60.2 | | | | |
| T | 6/15/86 | | N/A | | | | | | |
| | | 406 | | | | 101.5 | (26.7) | N/A | |
| | 7/26/87 | | 94 | (34) | 36.2 | | | | |
| | | 346 | | | | 56.8 | (13.6) | 16 | (24) |
| | 5/19/88 | | 69 | (21) | 30.6 | | | | |
| | | 411 | | | | 66.9 | (14.4) | 34 | (13) |
| | 7/04/89 | | 79 | (11) | 14.1 | | | | |
| | | 320 | | | | 92.2 | (24.9) | 62 | (25) |
| | 5/20/90 | | 134 | (39) | 29.2 | | | | |
| Tolsona | 10/26/86 | | 1,901[a] | (120) | 21.6 | | | | |
| | | 237 | | | | 60.0 | (4.6) | 138 | (209) |
| | 6/03/87 | | 1,291 | (120) | 9.3 | | | | |
| | | 336 | | | | 74.3 | (6.5) | 616 | (136) |
| | 5/26/88 | | 1,571 | (165) | 10.5 | | | | |
| | | 96 | | | | 77.1 | (8.8) | 68 | (123) |
| | 9/01/88 | | 1,280 | (155) | 12.1 | | | | |
| | | 267 | | | | 74.2 | (9.3) | 611 | (135) |
| | 5/24/89 | | 1,562 | (178) | 11.3 | | | | |
| | | 112 | | | | 95.8 | (15.6) | 152 | (156) |
| | 9/14/89 | | 1,648 | (270) | 16.4 | | | | |
| | | 241 | | | | 50.2 | (10.2) | 583 | (170) |
| | 5/25/90 | | 1,409 | (258) | 18.3 | | | | |
| | | 124 | | | | 41.0 | (7.9) | 97 | (86) |
| | 9/06/90 | | 675 | (115) | 17.0 | | | | |
| | | 256 | | | | 57.1 | (13.3) | 729 | (184) |
| | 5/22/91 | | 1,114 | (250) | 22.4 | | | | |

[a] Estimate obtained from Parker et al. (1989).

[b] Estimate obtained from Parker et al. (1987).

[c] Estimate obtained from Bernard et al. (*In prep*).

Table 7. Estimates of abundance, survival rates, and recruitment for all burbot greater than 300 mm TL residing in Landlock Tangle, Round Tangle, and Upper Tangle lakes.

| Lake | Date | Days between events | Abundance Est. | Abundance (SE) | Abundance CV % | Survival Rate % Est. | Survival Rate % (SE) | Recruitment Est. | Recruitment (SE) |
|---|---|---|---|---|---|---|---|---|---|
| Landlock Tangle | 7/19/87 | | 294[a] | (132) | 45.0 | | | | |
| | | 735 | | | | 23.9 | (9.8) | 920 | (487) |
| | 7/25/89 | | 970 | (499) | 51.4 | | | | |
| | | 360 | | | | 41.1 | (18.1) | 20 | (203) |
| | 7/20/90 | | 406 | (185) | 45.6 | | | | |
| Round Tangle | 8/07/86 | | 1,240[b] | (379) | 30.6 | | | | |
| | | 369 | | | | 36.1 | (12.1) | N/A | |
| | 8/11/87 | | 744 | (295) | 39.7 | | | | |
| | | 310 | | | | 34.5 | (11.5) | 364 | (171) |
| | 6/17/88 | | 619 | (211) | 34.1 | | | | |
| | | 389 | | | | 38.1 | (14.0) | 660 | (283) |
| | 7/11/89 | | 893 | (343) | 38.4 | | | | |
| | | 349 | | | | 51.6 | (20.8) | 1,188 | (628) |
| | 6/25/90 | | 1,644 | (752) | 45.7 | | | | |
| Upper Tangle | 8/04/86 | | N/A | | | | | | |
| | | 375 | | | | 23.0 | (10.8) | N/A | |
| | 8/14/87 | | 238 | (130) | 54.6 | | | | |
| | | 311 | | | | 70.4 | (31.0) | 324 | (204) |
| | 6/21/88 | | 491 | (236) | 48.1 | | | | |
| | | 397 | | | | 78.7 | (56.8) | 738 | (619) |
| | 7/23/89 | | 1,124 | (848) | 75.4 | | | | |
| | | 350 | | | | 70.8 | (86.9) | 2,322 | (3,194) |
| | 7/08/90 | | 3,115 | (3,974) | 127.6 | | | | |

[a] Estimate obtained from Parker et al. (1988).

[b] Estimate obtained from Parker et al. (1987).

Table 8. Estimated density of burbot in 13 lakes in interior Alaska.

| Year | Lake | Size of Burbot | Estimated Abundance | SE | Area of Lake (hectare) | Estimated Density (burbot/hectare) | SE |
|---|---|---|---|---|---|---|---|
| 1989 | | | | | | | |
| | Sevenmile | ≥ 300 | 150[a] | 100 | 34 | 4.41 | 2.94 |
| 1990 | | | | | | | |
| | Fielding | ≥ 450 | 584 | 87 | 538 | 1.09 | 0.16 |
| | George | ≥ 450 | 3,492 | 3,055 | 1,863 | 1.87 | 1.64 |
| | Harding | ≥ 450 | 980 | 374 | 1,000 | 0.98 | 0.33 |
| | Louise | ≥ 450 | 3,899 | 634 | 6,519 | 0.60 | 0.09 |
| | Paxson | ≥ 450 | 7,435 | 1,685 | 1,575 | 4.72 | 1.07 |
| | Summit | ≥ 450 | 133 | 80 | 1,651 | 0.08 | 0.05 |
| | T | ≥ 450 | 134 | 39 | 162 | 0.83 | 0.24 |
| | Landlocked Tangle | ≥ 300 | 406 | 185 | 219 | 1.85 | 0.84 |
| | Round Tangle | ≥ 300 | 1,644 | 752 | 155 | 10.61 | 4.85 |
| | Upper Tangle | ≥ 300 | 3,115 | 3,974 | 142 | 21.94 | 27.99 |
| 1991 | | | | | | | |
| | Moose | ≥ 450 | 1,184 | 214 | 130 | 9.11 | 1.65 |
| | Tolsona | ≥ 450 | 1,114 | 250 | 130 | 8.57 | 1.92 |

[a] From Lafferty et al. 1991.

Table 9. Summer and spring catchability coefficients of fully recruited burbot (≥ 450 mm TL) in nine populations during 1986-1991.

<u>Summer</u>

| Population | Date | Surface Area (hectare) | Estimated CPUE | Estimated Abundance | Estimated Density | Catchability Coefficient |
|---|---|---|---|---|---|---|
| Fielding | 28-Jul-86 | 538 | 0.267 | 299 | 0.556 | 0.480 |
| Paxson | 04-Aug-86 | 1575 | 1.220 | 7,426 | 4.715 | 0.259 |
| Louise | 19-Aug-86 | 6519 | 0.584 | 6,990 | 1.072 | 0.545 |
| Fielding | 21-Aug-86 | 538 | 0.380 | 299 | 0.556 | 0.684 |
| Tolsona | 23-Sep-86 | 130 | 4.072 | 1,901 | 14.623 | 0.278 |
| George | 22-Jun-87 | 1836 | 0.203 | 1,773 | 0.966 | 0.210 |
| Tolsona | 23-Jun-87 | 130 | 2.881 | 1,291 | 9.931 | 0.290 |
| Hudson | 06-Jul-87 | 259 | 2.839 | 3,671 | 14.174 | 0.200 |
| Summit | 13-Jul-87 | 1651 | 0.196 | 599 | 0.363 | 0.540 |
| Fielding | 21-Jul-87 | 538 | 0.490 | 236 | 0.439 | 1.117 |
| Louise | 02-Aug-87 | 6519 | 0.414 | 3,569 | 0.547 | 0.756 |
| Paxson | 06-Aug-87 | 1575 | 0.865 | 4,015 | 2.549 | 0.339 |
| Fielding | 17-Aug-87 | 538 | 0.365 | 236 | 0.439 | 0.832 |
| Summit | 02-Sep-87 | 1651 | 0.169 | 599 | 0.363 | 0.466 |
| T | 21-Sep-87 | 162 | 0.278 | 94 | 0.580 | 0.479 |
| T | 19-May-88 | 162 | 0.230 | 69 | 0.426 | 0.540 |
| Paxson | 19-Jul-88 | 1575 | 0.475 | 2,887 | 1.833 | 0.259 |
| Fielding | 27-Jul-88 | 538 | 0.317 | 445 | 0.827 | 0.383 |
| Tolsona | 01-Sep-88 | 130 | 3.483 | 1,280 | 9.846 | 0.354 |
| Moose | 16-Sep-88 | 130 | 4.407 | 1,625 | 12.500 | 0.353 |
| Moose | 10-Jul-89 | 130 | 2.831 | 1,335 | 10.269 | 0.276 |
| Fielding | 30-Jul-89 | 538 | 0.264 | 477 | 0.887 | 0.298 |
| T | 17-Aug-89 | 162 | 0.125 | 79 | 0.488 | 0.256 |
| Tolsona | 12-Sep-89 | 130 | 4.186 | 1,648 | 12.677 | 0.330 |
| Paxson | 15-Sep-89 | 1575 | 0.474 | 5,964 | 3.787 | 0.125 |
| Moose | 15-Sep-89 | 130 | 2.817 | 986 | 7.585 | 0.371 |
| Moose | 04-Oct-89 | 130 | 2.424 | 594 | 4.569 | 0.531 |
| T | 20-May-90 | 162 | 0.730 | 134 | 0.827 | 0.883 |
| Fielding | 19-Jul-90 | 538 | 0.234 | 584 | 1.086 | 0.216 |
| Moose | 05-Sep-90 | 130 | 2.260 | 772 | 5.938 | 0.381 |
| Tolsona | 06-Sep-90 | 130 | 2.950 | 675 | 5.192 | 0.568 |
| Paxson | 18-Sep-90 | 1575 | 0.500 | 7,435 | 4.721 | 0.106 |
| Average | | | | | | 0.428 |

-continued-

Table 9. (Page 2 of 2).

Spring

| Population | Date | Surface Area (hectare) | Estimated CPUE | Estimated Abundance | Estimated Density | Catchability Coefficient |
|---|---|---|---|---|---|---|
| Louise | 25-Jun-86 | 6519 | 0.980 | 6,990 | 1.072 | 0.914 |
| Paxson | 07-Jul-86 | 1575 | 2.242 | 7,426 | 4.715 | 0.476 |
| Tolsona | 08-Oct-86 | 130 | 5.593 | 1,901 | 14.623 | 0.382 |
| T | 26-May-87 | 162 | 0.367 | 94 | 0.580 | 0.632 |
| George | 01-Jun-87 | 1836 | 0.391 | 1,773 | 0.966 | 0.405 |
| Tolsona | 02-Jun-87 | 130 | 6.155 | 1,291 | 9.931 | 0.620 |
| Hudson | 15-Jun-87 | 259 | 3.606 | 3,671 | 14.174 | 0.254 |
| Louise | 06-Jul-87 | 6519 | 0.586 | 3,569 | 0.547 | 1.070 |
| Paxson | 06-Jul-87 | 1575 | 1.721 | 4,015 | 2.549 | 0.675 |
| Tolsona | 25-May-88 | 130 | 5.966 | 1,571 | 12.085 | 0.494 |
| Louise | 11-Jun-88 | 6519 | 0.587 | 5,922 | 0.908 | 0.646 |
| Paxson | 22-Jun-88 | 1575 | 1.095 | 2,887 | 1.833 | 0.597 |
| Fielding | 29-Jun-88 | 538 | 0.815 | 445 | 0.827 | 0.985 |
| T | 17-May-89 | 162 | 0.712 | 79 | 0.488 | 1.460 |
| Moose | 21-May-89 | 130 | 7.097 | 1,212 | 9.323 | 0.761 |
| Tolsona | 23-May-89 | 130 | 6.000 | 1,562 | 12.015 | 0.499 |
| George | 01-Jun-89 | 1836 | 0.990 | 3,450 | 1.879 | 0.527 |
| Louise | 01-Jun-89 | 6519 | 0.392 | 4,175 | 0.640 | 0.612 |
| Fielding | 26-Jun-89 | 538 | 0.806 | 477 | 0.887 | 0.909 |
| Tolsona | 22-May-90 | 130 | 3.580 | 1,409 | 10.838 | 0.330 |
| Moose | 24-May-90 | 130 | 3.830 | 935 | 7.192 | 0.533 |
| George | 26-May-90 | 1836 | 0.610 | 3,492 | 1.902 | 0.321 |
| Louise | 06-Jun-90 | 6519 | 0.500 | 3,899 | 0.598 | 0.836 |
| Fielding | 16-Jun-90 | 538 | 0.877 | 584 | 1.086 | 0.808 |
| Tolsona | 22-May-91 | 130 | 3.620 | 1,114 | 8.569 | 0.422 |
| Moose | 23-May-91 | 130 | 3.270 | 1,184 | 9.108 | 0.359 |
| Average | | | | | | 0.636 |

## DISCUSSION

Capture histories used in the mark-recapture experiments described in this report have been adjusted for delayed mortality from decompression reported in Bernard et al. (*In prep*). Logistic regressions were used to relate depth of first capture of fully recruited burbot to their recapture rates. Burbot first captured at depths > 15 m during sampling events in 1986 and 1987 at Paxson Lake and in 1987 and 1988 at Lake Louise were recaptured at significantly lower rates than were those fish first captured in shallower waters. Capture histories were corrected by removing fish captured > 15 m from experiments as marked fish for these sampling events. Some changes resulted in statistics from the multiple-year, open experiments as reported in previous years (see Lafferty et al. 1991 to compare). Since depth was not related to rates of recapture in any other population for any other sampling event than those specified above, no other adjustments were needed. Because sampling was restricted to waters ≤ 15 m in Paxson Lake and Lake Louise beginning in 1989, difficulties with decompression are not anticipated for these experiments.

Poor survival of burbot during summer 1990 in Tolsona Lake and during September 1989 in Moose Lake may be the consequence of warm water and low dissolved oxygen. The low survival rates during the times in question (42% in Moose Lake over 30 days and 41% in Tolsona Lake over 103 days) are considerably lower than annual survival rates in other years. Inspection of their SE's shows that these low survival rates are not an artifact of the mark-recapture experiment. Since little if any fishing occurs during the summer, legal exploitation can be excluded as a cause of this poor survival. Moose and Tolsona lakes are shallow (maximum depths of 4 and 6 m, respectively) with considerable littoral area. Combinations of sunny, windy days could drive water temperatures above the 12° C that burbot prefer (Ferguson 1958) and oxygen below their tolerance. These same conditions have been speculated as the cause of burbot dying in the deeper sets in Hudson Lake, another shallow lake, during sunny, windy days (Bernard et al. *In prep*). Information on water temperature and dissolved oxygen in Moose and Tolsona lakes was not gathered during or between the surveys.

Abundance of fully recruited burbot in Harding Lake showed a significant increase, while burbot populations 300 mm and larger in the Tangle lakes showed no change, or a significant decrease. It is believed that the burbot populations in Harding Lake and the Tangle lakes responded differently to the same restrictive regulations in part because of the nature and extent of their fisheries prior to regulation changes. While the status of these populations prior to the initiation of research in the mid 1980s is unknown, it is hypothesized that the open water fishery in the Tangle lakes reduced those burbot of spawning size to a greater extent than the burbot population targeted by ice fisherman in Harding Lake. Thus, sufficient numbers of spawning size burbot were still available in Harding Lake to effect a change in the population abundance upon reduction of fishing mortality. Burbot of larger size are found in Harding Lake, as compared to burbot populations in the Tangle lakes. The lack of large burbot in the Tangle lakes could be either the result of exploitation, or burbot in Tangle lakes have historically matured and spawned at a smaller size. At the present time, data for burbot in the Tangle lakes and other Interior lakes are insufficient to accurately estimate the age and length at maturity.

Our final observation concerns a simple way to increase the number of sets in a survey without hampering the calculation of mean CPUE as an index of abundance. The rule of "one set per hectare" is used to limit competition among sets; competition would bias mean CPUE as an index of abundance. When many sets are needed to obtain the necessary sample sizes for mark-recapture experiments, this rule often limits the number of sets and precision of abundance estimates. Our solution is to conduct not one, but several surveys across the lake in succession. The first survey would provide an unbiased estimate of mean CPUE while the others would increase the number of fish marked for the experiment. Although there is no demonstrable trap shyness between surveys separated by 2 weeks (Bernard et al. 1991), trap shyness might be a factor if surveys were only separated by a few days. Fish captured during all surveys would be combined into a single sampling event for the mark-recapture experiment. Any fish captured during more than one survey would be considered captured once for the sampling event. This is the same procedure suggested by Pollock (1982) for preparing data collected for two-event experiments on closed populations for use as a single event in multiple-event experiments on open populations.

## ACKNOWLEDGEMENTS

We are grateful to the field crews: Rich Conklin, Doug Dawson, Don Demuth, Doug Edwards, Damion Haley, Audra Janiak, Mark Jurgens, Larry Livington, Tracy Nelson, Ed Peck, Derek Sawyer, Steffan Scribner and Tim Sine. A word of appreciation goes to Gary Pearse, Dinty Bush Services, and Urban Rahoi for their logistical help throughout the research program. The National Park Service is thanked for the assistance of Andrea Blakesley and Mary Beth Cook during the sampling of Ptarmigan Lake. We thank the many lodge owners for their assistance in collecting angler tag returns and informing the public of the continuing burbot research. We are especially grateful to Doug Vincent-Lang, John H. Clark, Doug McBride, and Peggy Merritt for their editorial comments.

## LITERATURE CITED

Arvey, W. D. 1989. Annual management report for sport fisheries in the Arctic-Yukon-Kuskokwim region. Alaska Department of Fish and Game Fishery Management Report No. 91-3.

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, editors. The Age and Growth of Fish. Iowa State University Press, Ames, Iowa.

Bernard, D. R., J. F. Parker, and R. Lafferty. *In prep*. Stock assessment of burbot populations in small and moderately sized lakes. North American Journal of Fisheries Management.

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.

Chapman, D. G. 1951. Some properties of the hypergeometric distribution with applications to zoological censuses. University of California Publications in Statistics 1:131-160.

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.

Cochran, W. G. 1977. Sampling techniques, third edition. John Wiley and Sons, Inc. New York.

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.

Ferguson, R. C. 1958. The preferred temperature of fish and their midsummer distribution in temperate lakes and streams. Journal of the Fisheries Research Board of Canada 15:607-624.

Gilbert, R. O. 1973. Approximations of the bias in the Jolly-Seber estimates. Biometrics 28:337-343.

Goodman, L. A. 1960. On the exact variance of products. J. American Statistical Association 55:708-13.

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. and Doug Vincent-Lang. 1991. Status of lake burbot stocks in the upper Copper/upper Susitna management area. Report to the Alaska Board of Fisheries. Alaska Department of Fish and Game, Anchorage.

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.

______. 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.

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

______. 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.

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, Juneau.

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.

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.

Robson, D. and H. A. Regier. 1964. Sample size in Petersen mark-recapture experiments. Trans. Amer. Fish. Soc. 93:215-226.

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

______. 1982. The estimation of animal abundance and related parameters, second edition. 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.

Whitmore, D. C. and Doug Vincent-Lang. 1991. Annual management report for the upper Copper/upper Susitna management area. Report to the Board of Fisheries. Alaska Department of Fish and Game, Anchorage.

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

# APPENDIX A

## DESCRIPTION OF LAKES WITH BURBOT POPULATIONS SAMPLED IN 1991

Appendix A. Description of lakes with burbot populations sampled in 1991.

BIG LAKE (61°33′ N, 149°52′ W) is a road accessible lake located 13 miles WSW of the town of Wasilla. The surface area of Big Lake is 1,296 hectares with a maximum depth of 30 meters. Most of the land is privately owned with many cabins and homes. There are several commercial marinas and lodges along the shores of Big Lake. Alaska State Parks does maintain a boat launch facility at one of the two small campgrounds. Fish species residing in Big Lake include: rainbow trout *Oncorhynchus mykiss*, arctic char *Salvelinus alpinus*, coho salmon *Oncorhynchus kisutch*, sockeye salmon *Oncorhynchus nerka*, humpback whitefish *Coregonus pidschian*, round whitefish *Prosopium cylindraceum*, longnose suckers *Catostomus catostomus*, slimy sculpin *Cottus cognatus*, prickly sculpin *Cottus asper*, three-spine stickleback *Gasterosteus aculeatus*, nine-spine stickleback *Pungitius pungitius*, and arctic lamprey *Lampetra japonica*.

FIELDING LAKE (63°10′ N, 145°42′ W) is accessible by road 3 km southwest of the Richardson Highway. Fielding Lake is 538 hectare with a maximum depth of 24 m and an elevation of 906 m. Campground facilities and a lodge operated during the summer 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*, lake trout *Salvelinus namaycush*, and round whitefish.

GEORGE LAKE (63°47′N, 144°31′ W) is located approximately 72 km southeast of Delta Junction across the Tanana River. George Lake is accessible by plane or boat in the summer months and by snowmachine during a limited time when the Tanana River is frozen (February 1-April 15). The lake is 1,863 hectare with a maximum depth of 11 m and an elevation of 389 m. There are only two private recreational cabins on George Lake. The Dot Lake Native Corporation (Dot Lake, Alaska) owns most of the shoreline, and permission is required for access for recreational purposes. Sport fishing for northern pike *Esox lucius* is popular just as the ice leaves the lake in the spring when these fish congregate at the shallow west end of the lake to spawn. George Lake also contains Arctic grayling, humpback whitefish, least cisco *Coregonus sardinella*, longnose suckers, and round whitefish.

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 hectare with a maximum depth of 47 m and an elevation of 218 m. Campground facilities and a boat launch are located on the west shore of the lake; recreational cabins and houses are located along the shoreline. Indigenous species in Harding Lake are burbot, least cisco, northern pike, and slimy sculpin. Transplanted species include Arctic char, Arctic grayling, coho salmon, lake trout, rainbow trout, sheefish *Stenodus leucicthys*, and sockeye salmon.

LAKE LOUISE (62°20′ N, 146°30′ W) is the largest lake in a three-lake system that is accessible by the Glenn Highway on a 25 km gravel road. Lake Louise is 6,519 hectare with maximum depth of 51 m and an elevation of 720 m. A state campground with boat launch is available. Four lodges are found along the south end of the lake, and numerous cabins are located around the shore. Lake Louise has supported year-round fishing for Arctic grayling, lake trout, and round whitefish.

-continued-

MOOSE LAKE (62°07′ N, 146°05′ W) is accessible from Tolsona Lake by a 1 km trail from the north end of Tolsona Lake. Moose Lake is 130 hectare with a maximum depth of 6 m and an elevation of 625 m. There are four cabins located along the lake shore and no public recreational facilities. Moose Lake receives fishing pressure largely during the winter months for burbot. Moose Lake contains Arctic grayling, longnose suckers, and rainbow trout.

NANCY LAKE (61°41′ N, 149°59′ W) is one of largest lakes of an aggregate of lakes located south of the Parks Highway at mile 67. Surface area of Nancy Lake is 327 hectares with a maximum depth of 22 meters. During 1966 a law was enacted to encircle this collection of lakes into the Nancy Lake Recreation Area. Recreational amenities are diverse between the private and public sector in this area. Alaska State Parks maintains two large campgrounds, picnic areas, a boat launch and an extensive canoe trail system with rental cabins. The sport fish species present in Nancy Lake include rainbow trout, Dolly Varden *Salvelinus malma*, sockeye salmon, chinook salmon *Oncorhynchus tshawytscha*, and coho salmon.

PAXSON LAKE (62°50′ N, 145°35′ W) is directly accessible from the Richardson Highway 8 km south of Paxson. Paxson Lake is 1,575 hectare with a maximum depth of 29 m and an elevation of 778 m. There are numerous cabins along the shore and the Bureau of Land Management maintains a public campground and boat launch. Paxson Lake is the start of a popular float trip on the Gulkana River to Sourdough. This lake is popular for its wide variety of fishing as well as hunting opportunities. Paxson Lake contains Arctic grayling, lake trout, sockeye salmon, whitefish, and other species.

PTARMIGAN LAKE (61°51′ N, 141°10′ W) is 48 kilometers by air southeast of the village of Chisana, approximately a 1 hour flight from Tok. Elevation of this lake is 1,077 meters with a surface area of 206 hectare and a maximum depth of 12 meters. This lake is located in the Nutzotin Mountains within the Wrangell-St. Elias National Preserve. Ptarmigan Lake Lodge is the sole development on this lake; recreational opportunities include fishing and hunting. Fisherman target lake trout, grayling and burbot, however, round whitefish and longnose suckers also inhabit the lake.

SEVENMILE LAKE (63°06′ N, 145°38′ W) is located 1 km by road from the Denali Highway. Sevenmile Lake is 34 hectare with a maximum depth of 12 m and an elevation of 991 m. A public boat launch and campsites are available at the south end of the lake. Sevenmile Lake contains burbot and lake trout populations. No other species are known to exist in the lake.

SUMMIT LAKE (63°12′ N, 145°33′ W) is directly accessible from the Richardson Highway just 6 km north of Paxson. Summit Lake is 1,651 hectare with a maximum depth of 72 m and an elevation of 979 m. Public facilities are available for launching boats. There is one lodge and a private recreational campground along the lake. Summit Lake contains Arctic grayling, lake trout, round whitefish, and sockeye salmon.

-continued-

T LAKE (63°48′ N, 143°53′ W) is a remote fly-in lake, located approximately 18 km from the village of Dot Lake along the Alaska Highway. T Lake is 162 hectare with a maximum depth of 18 m and an elevation of 434 m. Only one permanent recreational structure exists on the lake. T Lake contains humpback whitefish, least cisco, and northern pike.

LANDLOCK TANGLE LAKE (63°00′ N, 146°03′ W) is located south of Upper Tangle Lake and is accessible by foot over a 1 km portage. Landlock Tangle Lake is 219 hectare with maximum depth of 36 m and an elevation of 875 m. Landlock Tangle Lake has Arctic grayling, lake trout, longnose suckers, and round whitefish.

ROUND TANGLE LAKE (63°02′ N, 145°48′ W) is located north of the Denali Highway. Round Tangle Lake is 155 hectare 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, lake trout, longnose suckers, 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 hectare 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, and longnose suckers.

TOLSONA LAKE (62°06′ N, 146°04′ W) is accessible from the Glenn Highway. Tolsona Lake is 130 hectare with a maximum depth of 4 m and an elevation of 625 m. Tolsona Lake has numerous cabins and one lodge. No public recreational facilities are available. This lake has had a popular burbot fishery in the winter in recent years. Tolsona Lake has Arctic grayling, longnose suckers, stocked rainbow trout, and other species.

# 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 1991) for the populations in Fielding, George, Harding, Louise, Paxson, Summit, T, Moose, and Tolsona lakes.

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

| GEORGE LAKE | | | | | | |
|---|---|---|---|---|---|---|
| DATE: | Year | 1987 | 1988 | 1989 | 1990 | 1991 |
| | Beginning | 6/01 | 5/24 | 6/01 | 5/21 | 5/27 |
| | Ending | 6/30 | 5/31 | 6/11 | 5/31 | 6/02 |
| NUMBER OF FULLY RECRUITED BURBOT: | | | | | | |
| Recaptured from Event | 1 | 0 | 6 | 5 | 2 | 0 |
| Recaptured from Event | 2 | | 0 | 13 | 4 | 3 |
| Recaptured from Event | 3 | | | 0 | 10 | 2 |
| Recaptured from Event | 4 | | | | 0 | 2 |
| Recaptured from Event | 5 | | | | | 0 |
| Captured with Tags | | 0 | 6 | 18 | 16 | 7 |
| Captured without Tags | | 200 | 242 | 276 | 167 | 106 |
| Captured | | 200 | 248 | 294 | 183 | 113 |
| Released with Tags | | 196 | 248 | 294 | 183 | 104 |

-continued-

Appendix B1. (Page 2 of 5).

| | | | | | | |
|---|---|---|---|---|---|---|
| HARDING LAKE | | | | | | |
| DATE: Year | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
| Beginning | 9/08 | 6/16 | 9/26 | 9/18 | 8/18 | 9/18 |
| Ending | 9/14 | 6/20 | 9/30 | 9/22 | 9/22 | 9/22 |
| NUMBER OF FULLY RECRUITED BURBOT: | | | | | | |
| Recaptured from Event 1 | 0 | 14 | 3 | 2 | 0 | 1 |
| Recaptured from Event 2 | | 0 | 9 | 4 | 4 | 3 |
| Recaptured from Event 3 | | | 0 | 8 | 5 | 2 |
| Recaptured from Event 4 | | | | 0 | 8 | 9 |
| Recaptured from Event 5 | | | | | 0 | 13 |
| Recaptured from Event 6 | | | | | | 0 |
| Captured with Tags | 0 | 14 | 12 | 14 | 17 | 28 |
| Captured without Tags | 55 | 87 | 76 | 38 | 98 | 104 |
| Captured | 55 | 103 | 88 | 52 | 115 | 132 |
| Released with Tags | 54 | 81 | 77 | 52 | 110 | 132 |
| LAKE LOUISE | | | | | | |
| DATE: Year | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
| Beginning | 6/25 | 7/06 | 6/11 | 6/01 | 6/04 | 6/03 |
| Ending | 9/02 | 8/19 | 6/24 | 6/16 | 6/19 | 6/14 |
| NUMBER OF FULLY RECRUITED BURBOT: | | | | | | |
| Recaptured from Event 1 | 0 | 19 | 9 | 12 | 2 | 2 |
| Recaptured from Event 2 | | 0 | 19 | 12 | 15 | 3 |
| Recaptured from Event 3 | | | 0 | 32 | 21 | 12 |
| Recaptured from Event 4 | | | | 0 | 72 | 34 |
| Recaptured from Event 5 | | | | | 0 | 73 |
| Recaptured from Event 6 | | | | | | 0 |
| Captured with Tags | 0 | 19 | 28 | 56 | 110 | 124 |
| Captured without Tags | 523 | 501 | 494 | 573 | 607 | 497 |
| Captured | 523 | 520 | 522 | 629 | 717 | 621 |
| Released with Tags | 470 | 235 | 430 | 625 | 714 | 618 |

-continued-

| PAXSON LAKE | | | | | | |
|---|---|---|---|---|---|---|
| DATE: Year | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
| Beginning | 7/07 | 7/06 | 6/22 | 9/15 | 9/10 | 6/17 |
| Ending | 9/20 | 8/14 | 7/27 | 9/25 | 9/26 | 6/25 |
| NUMBER OF FULLY RECRUITED BURBOT: | | | | | | |
| Recaptured from Event 1 | 0 | 80 | 31 | 11 | 7 | 11 |
| Recaptured from Event 2 | | 0 | 97 | 18 | 16 | 33 |
| Recaptured from Event 3 | | | 0 | 22 | 11 | 23 |
| Recaptured from Event 4 | | | | 0 | 14 | 11 |
| Recaptured from Event 5 | | | | | 0 | 35 |
| Recaptured from Event 6 | | | | | | 0 |
| Captured with Tags | 0 | 80 | 128 | 51 | 48 | 113 |
| Captured without Tags | 759 | 829 | 325 | 227 | 357 | 602 |
| Captured | 759 | 909 | 453 | 278 | 405 | 715 |
| Released with Tags | 660 | 762 | 410 | 272 | 391 | 693 |

| SUMMIT LAKE | | | | | | |
|---|---|---|---|---|---|---|
| DATE: Year | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
| Beginning | 7/12 | 7/13 | 7/06 | 7/14 | 7/16 | 7/15 |
| Ending | 9/04 | 9/20 | 7/11 | 7/17 | 7/20 | 7/21 |
| NUMBER OF FULLY RECRUITED BURBOT: | | | | | | |
| Recaptured from Event 1 | 0 | 10 | 1 | 2 | 0 | 0 |
| Recaptured from Event 2 | | 0 | 8 | 3 | 6 | 0 |
| Recaptured from Event 3 | | | 0 | 2 | 3 | 1 |
| Recaptured from Event 4 | | | | 0 | 2 | 4 |
| Recaptured from Event 5 | | | | | 0 | 3 |
| Recaptured from Event 6 | | | | | | 0 |
| Captured with Tags | 0 | 10 | 9 | 7 | 11 | 8 |
| Captured without Tags | 111 | 122 | 35 | 20 | 21 | 32 |
| Captured | 111 | 132 | 44 | 27 | 32 | 40 |
| Released with Tags | 51 | 130 | 41 | 27 | 29 | 39 |

-continued-

Appendix B1. (Page 4 of 5).

| T LAKE | | | | | | |
|---|---|---|---|---|---|---|
| DATE: Year | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
| Beginning | 6/11 | 5/26 | 5/17 | 5/17 | 5/18 | 5/18 |
| Ending | 6/19 | 9/25 | 5/21 | 5/22 | 5/23 | 5/22 |
| NUMBER OF FULLY RECRUITED BURBOT: | | | | | | |
| Recaptured from Event 1 | 0 | 6 | 0 | 2 | 0 | 0 |
| Recaptured from Event 2 | | 0 | 1 | 11 | 1 | 0 |
| Recaptured from Event 3 | | | 0 | 8 | 2 | 0 |
| Recaptured from Event 4 | | | | 0 | 20 | 9 |
| Recaptured from Event 5 | | | | | 0 | 10 |
| Recaptured from Event 6 | | | | | | 0 |
| Captured with Tags | 0 | 6 | 1 | 21 | 23 | 19 |
| Captured without Tags | 13 | 43 | 18 | 42 | 27 | 18 |
| Captured | 13 | 49 | 19 | 63 | 50 | 37 |
| Released with Tags | 13 | 47 | 17 | 62 | 48 | 36 |

-continued-

Appendix B1. (Page 5 of 5).

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| MOOSE LAKE | | | | | | | | | | |
| DATE: Year | 1988 | 1988 | 1989 | 1989 | 1989 | 1989 | 1990 | 1990 | 1991 | 1991 |
| Beginning | 5/24 | 9/16 | 5/24 | 7/07 | 9/07 | 10/6 | 5/21 | 9/04 | 5/22 | 9/11 |
| Ending | 5/26 | 9/18 | 5/26 | 7/09 | 9/09 | 10/8 | 5/23 | 9/06 | 5/25 | 9/14 |
| NUMBER OF FULLY RECRUITED BURBOT: | | | | | | | | | | |
| Recaptured from Event 1 | 0 | 42 | 39 | 13 | 6 | 2 | 11 | 1 | 2 | 1 |
| Recaptured from Event 2 | | 0 | 66 | 6 | 7 | 2 | 3 | 0 | 1 | 0 |
| Recaptured from Event 3 | | | 0 | 45 | 34 | 16 | 23 | 4 | 4 | 4 |
| Recaptured from Event 3 | | | | 0 | 28 | 8 | 0 | 2 | 2 | 0 |
| Recaptured from Event 4 | | | | | 0 | 29 | 6 | 1 | 3 | 0 |
| Recaptured from Event 5 | | | | | | 0 | 33 | 12 | 10 | 4 |
| Recaptured from Event 6 | | | | | | | 0 | 20 | 15 | 12 |
| Recaptured from Event 7 | | | | | | | | 0 | 30 | 8 |
| Recaptured from Event 8 | | | | | | | | | 0 | 52 |
| Recaptured from Event 9 | | | | | | | | | | 0 |
| Captured with Tags | 0 | 42 | 105 | 64 | 75 | 57 | 76 | 40 | 67 | 81 |
| Captured without Tags | 429 | 217 | 336 | 96 | 95 | 93 | 150 | 92 | 260 | 132 |
| Captured | 429 | 259 | 441 | 160 | 170 | 150 | 226 | 132 | 327 | 213 |
| Released with Tags | 426 | 259 | 441 | 160 | 168 | 150 | 226 | 132 | 325 | 213 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| TOLSONA LAKE | | | | | | | | | | |
| DATE: Year | 1986 | 1987 | 1988 | 1988 | 1989 | 1989 | 1990 | 1990 | 1991 | 1991 |
| Beginning | 9/23 | 6/02 | 5/25 | 8/30 | 5/23 | 9/12 | 5/22 | 9/05 | 5/20 | 9/09 |
| Ending | 10/10 | 6/04 | 5/27 | 9/01 | 5/25 | 9/14 | 5/24 | 9/07 | 5/23 | 9/12 |
| NUMBER OF FULLY RECRUITED BURBOT: | | | | | | | | | | |
| Recaptured from Event 1 | 0 | 123 | 35 | 14 | 5 | 3 | 5 | 9 | 0 | 0 |
| Recaptured from Event 2 | | 0 | 79 | 32 | 33 | 18 | 11 | 5 | 1 | 1 |
| Recaptured from Event 3 | | | 0 | 51 | 36 | 13 | 11 | 8 | 0 | 0 |
| Recaptured from Event 4 | | | | 0 | 45 | 13 | 4 | 5 | 3 | 0 |
| Recaptured from Event 5 | | | | | 0 | 63 | 14 | 8 | 10 | 2 |
| Recaptured from Event 6 | | | | | | 0 | 22 | 9 | 5 | 2 |
| Recaptured from Event 7 | | | | | | | 0 | 21 | 15 | 2 |
| Recaptured from Event 8 | | | | | | | | 0 | 33 | 7 |
| Recaptured from Event 9 | | | | | | | | | 0 | 35 |
| Recaptured from Event 10 | | | | | | | | | | 0 |
| Captured with Tags | 0 | 123 | 114 | 97 | 119 | 110 | 67 | 65 | 67 | 49 |
| Captured without Tags | 531 | 379 | 236 | 118 | 239 | 139 | 148 | 115 | 296 | 88 |
| Captured | 531 | 502 | 350 | 215 | 358 | 249 | 215 | 180 | 363 | 137 |
| Released with Tags | 531 | 497 | 350 | 215 | 358 | 249 | 215 | 180 | 362 | 136 |

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

Appendix B2. Mark-recapture histories of burbot of all sizes[a] by year for the populations in Landlock Tangle, Round Tangle, Sevenmile, and Upper Tangle lakes.

LANDLOCK TANGLE LAKE

| DATE: | 1987 | 1989 | 1990 | 1991 |
|---|---|---|---|---|
| Year | 1987 | 1989 | 1990 | 1991 |
| Beginning | 6/30 | 7/21 | 7/03 | 7/03 |
| Ending | 8/07 | 8/11 | 8/05 | 8/07 |
| NUMBER OF BURBOT OF ALL SIZES: | | | | |
| Recaptured from Event 1 | 0 | 7 | 5 | 1 |
| Recaptured from Event 2 | | 0 | 12 | 4 |
| Recaptured from Event 3 | | | 0 | 9 |
| Recaptured from Event 4 | | | | 0 |
| Captured with Tags | 0 | 7 | 17 | 14 |
| Captured without Tags | 222 | 146 | 88 | 138 |
| Captured | 222 | 153 | 105 | 152 |
| Released with Tags | 211 | 122 | 105 | 151 |

ROUND TANGLE LAKE

| DATE: | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|
| Year | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
| Beginning | 7/21 | 7/27 | 6/15 | 6/24 | 6/23 | 6/17 |
| Ending | 8/25 | 8/25 | 6/19 | 7/28 | 6/26 | 8/01 |
| NUMBER OF BURBOT OF ALL SIZES: | | | | | | |
| Recaptured from Event 1 | 0 | 13 | 7 | 1 | 0 | 0 |
| Recaptured from Event 2 | | 0 | 15 | 5 | 0 | 0 |
| Recaptured from Event 3 | | | 0 | 17 | 5 | 1 |
| Recaptured from Event 4 | | | | 0 | 8 | 10 |
| Recaptured from Event 5 | | | | | 0 | 11 |
| Recaptured from Event 6 | | | | | | 0 |
| Recaptured from Event 7 | | | | | | |
| Captured with Tags | 0 | 13 | 22 | 23 | 13 | 22 |
| Captured without Tags | 221 | 137 | 179 | 207 | 138 | 278 |
| Captured | 221 | 150 | 201 | 230 | 151 | 300 |
| Released with Tags | 191 | 146 | 193 | 220 | 150 | 284 |

-continued-

Appendix B2. (Page 2 of 2).

SEVENMILE LAKE

| DATE: Year | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|
| Beginning | 7/22 | 6/16 | 6/19 | 6/29 | 6/23 | 7/07 |
| Ending | 9/21 | 8/06 | 7/19 | 8/05 | 8/09 | 7/09 |
| NUMBER OF BURBOT OF ALL SIZES: | | | | | | |
| Recaptured from Event 1 | 0 | 51 | 5 | 2 | 0 | 0 |
| Recaptured from Event 2 | | 0 | 9 | 2 | 0 | 0 |
| Recaptured from Event 3 | | | 0 | 9 | 2 | 0 |
| Recaptured from Event 4 | | | | 0 | 3 | 1 |
| Recaptured from Event 5 | | | | | 0 | 0 |
| Recaptured from Event 6 | | | | | | 0 |
| Captured with Tags | 0 | 51 | 14 | 13 | 5 | 1 |
| Captured without Tags | 198 | 158 | 41 | 39 | 33 | 17 |
| Captured | 198 | 209 | 55 | 52 | 38 | 18 |
| Released with Tags | 94 | 156 | 55 | 52 | 38 | 18 |

UPPER TANGLE LAKE

| DATE: Year | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 |
|---|---|---|---|---|---|---|
| Beginning | 7/21 | 7/31 | 6/18 | 7/07 | 7/07 | 6/19 |
| Ending | 8/20 | 8/29 | 6/22 | 8/08 | 7/10 | 8/03 |
| NUMBER OF BURBOT OF ALL SIZES: | | | | | | |
| Recaptured from Event 1 | 0 | 5 | 2 | 1 | 0 | 0 |
| Recaptured from Event 2 | | 0 | 11 | 4 | 0 | 0 |
| Recaptured from Event 3 | | | 0 | 5 | 2 | 3 |
| Recaptured from Event 4 | | | | 0 | 1 | 2 |
| Recaptured from Event 5 | | | | | 0 | 1 |
| Recaptured from Event 6 | | | | | | 0 |
| Captured with Tags | 0 | 5 | 13 | 10 | 3 | 6 |
| Captured without Tags | 101 | 69 | 97 | 86 | 67 | 155 |
| Captured | 101 | 74 | 109 | 96 | 70 | 161 |
| Released with Tags | 83 | 74 | 108 | 93 | 68 | 148 |

[a] Burbot are ≥300 mm TL.

Appendix B3. Summary of data archives.

| Location | Project Leader | Storage Softwear and version |
|---|---|---|
| Region II<br>Anchorage | R. Lafferty<br>267-2225 | Comma delimited ASCII files<br>Standard RTS Archive format[a] |

| Lake | Data Map<br>File Name | Data Format | Softwear |
|---|---|---|---|
| Big | K0120HA1.dta | Hoopnet | RTS-ASCII |
| Fielding | U0130HA1.dta | Hoopnet | RTS-ASCII |
| | U0130HB1.dta | Hoopnet | RTS-ASCII |
| | FIEL91TD.dbf | Tag History | DBASE |
| George | U0110HA1.dta | Hoopnet | RTS-ASCII |
| | GEOR91TD.dbf | Tag History | DBASE |
| Harding | U1890HA1.dta | Hoopnet | RTS-ASCII |
| | HARD91TD.dbf | Tag History | DBASE |
| Louise | I0100H-1.dta | Hoopnet | RTS-ASCII |
| | Lou91TH .dbf | Tag History | Dbase |
| Moose | I2270H-1.dta | Hoopnet | RTS-ASCII |
| | MOO91THB.dbf | Tag History | Dbase |
| Nancy | K0130HA1.dta | Hoopnet | RTS-ASCII |
| Paxson | I0130H-1.dta | Hoopnet | RTS-ASCII |
| | PAX91TH .dbf | Tag History | Dbase |
| Ptarmigan | U2540HA1.DTA | Hoopnet | RTS-ASCII |

-continued-

Appendix B3. (Page 2 of 3).

| Location | Project Leader | Storage Softwear and version |
|---|---|---|
| Region III<br>Delta Jct. | F. Parker<br>895-4632 | Comma delimited ASCII files<br>Standard RTS Archive format[a] |

| | Data Map | | |
|---|---|---|---|
| Lake | File Name | Data Format | Softwear |
| Sevenmile | U3060HA1.dta | Hoopnet | RTS-ASCII |
| | SEVE91TH.dbf | Tag History | Dbase |
| Summit | I0140HA1.dta | Hoopnet | RTS-ASCII |
| | SUMM91TD.dbf | Tag History | Dbase |
| T | U3370HA1.dta | Hoopnet | RTS-ASCII |
| | TEE91TD.dbf | Tag History | Dbase |
| Landlock Tangle | U015EHA1.dta | Hoopnet | RTS-ASCII |
| | U015EHB1.dta | Hoopnet | RTS-ASCII |
| | LLTA91TD.dbf | Tag History | Dbase |
| Round Tangle | U015CHA1.dta | Hoopnet | RTS-ASCII |
| | U015CHB1.dta | Hoopnet | RTS-ASCII |
| | RDTA91TD.dbf | Tag History | Dbase |
| Upper Tangle | U015DHA1.dta | Hoopnet | RTS-ASCII |
| | U015DHB1.dta | Hoopnet | RTS-ASCII |
| | UPTA91TD.dbf | Tag History | Dbase |
| Tolsona | I2860h-1.dta | Hoopnet | RTS-ASCII |
| | TOL91THB.dbf | Tag History | Dbase |

-continued-

Appendix B3. (Page 3 of 3).

---

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.

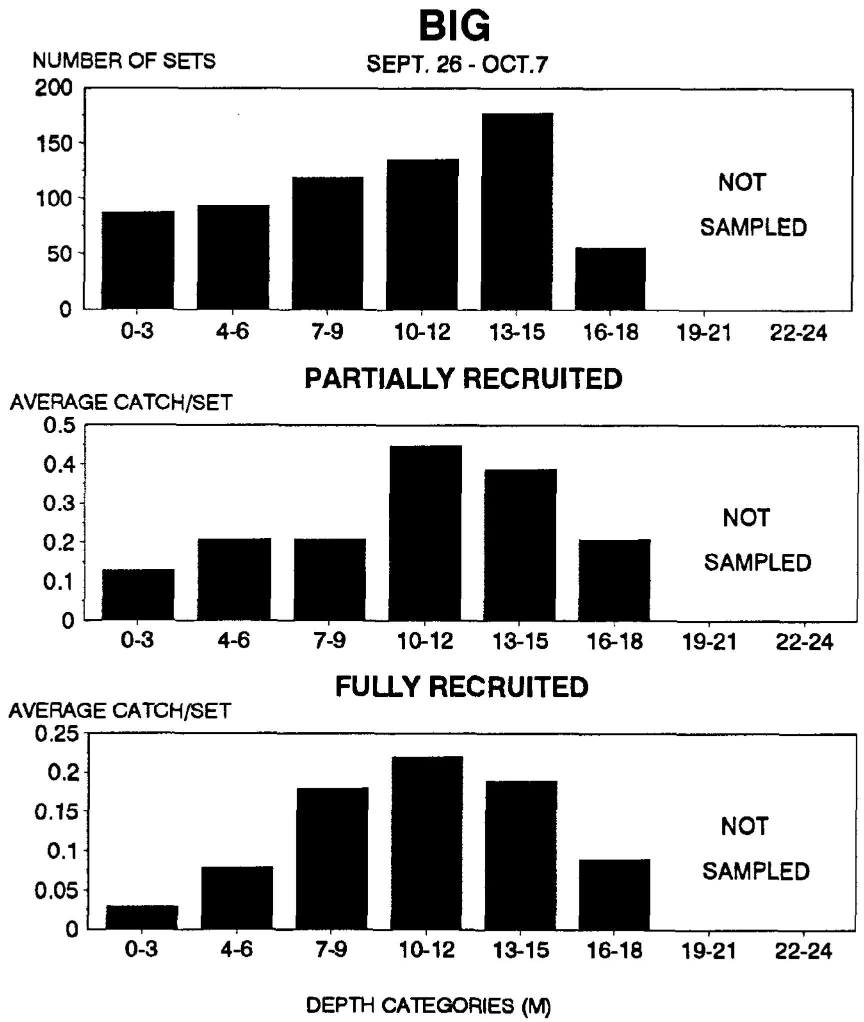
Specific codes and organization of columns for each data format are available on request from RTS.

---

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

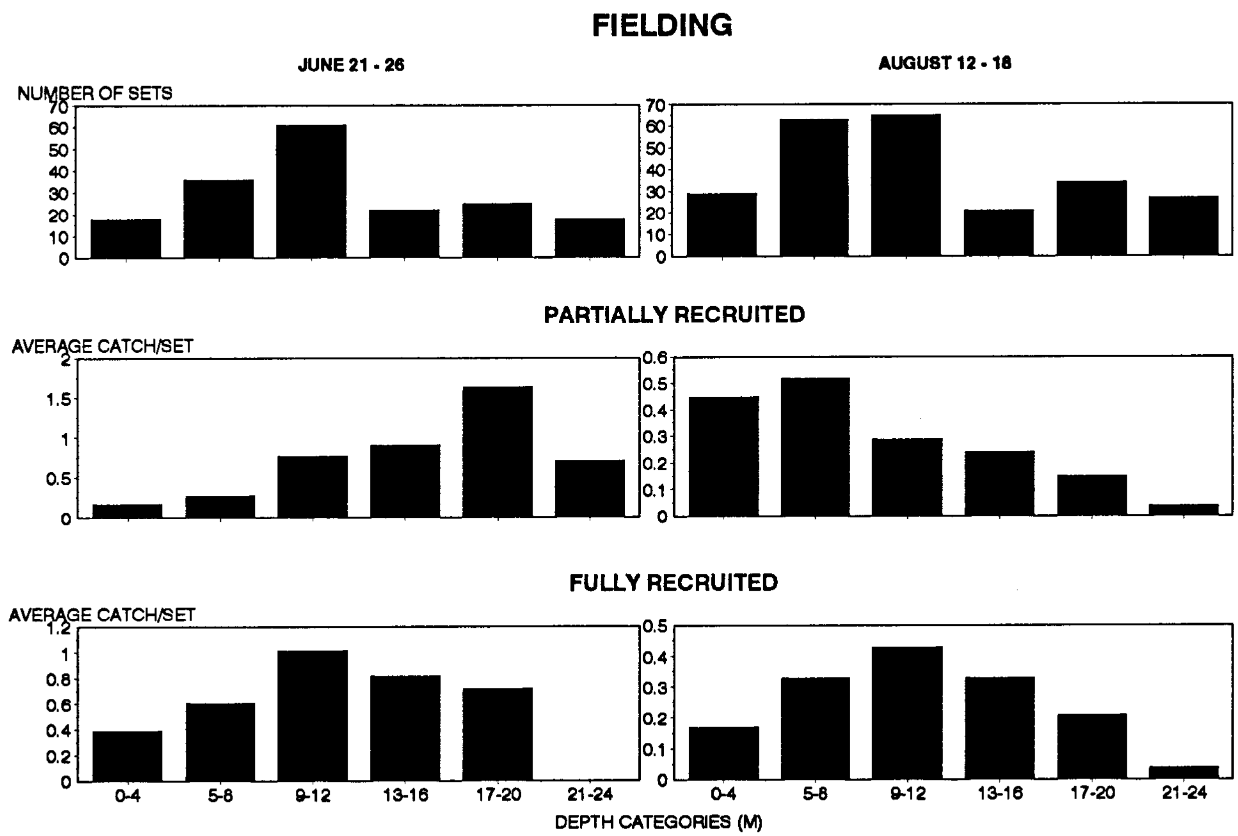
APPENDIX C

FREQUENCY OF SETS BY DEPTH AND AVERAGE CATCH



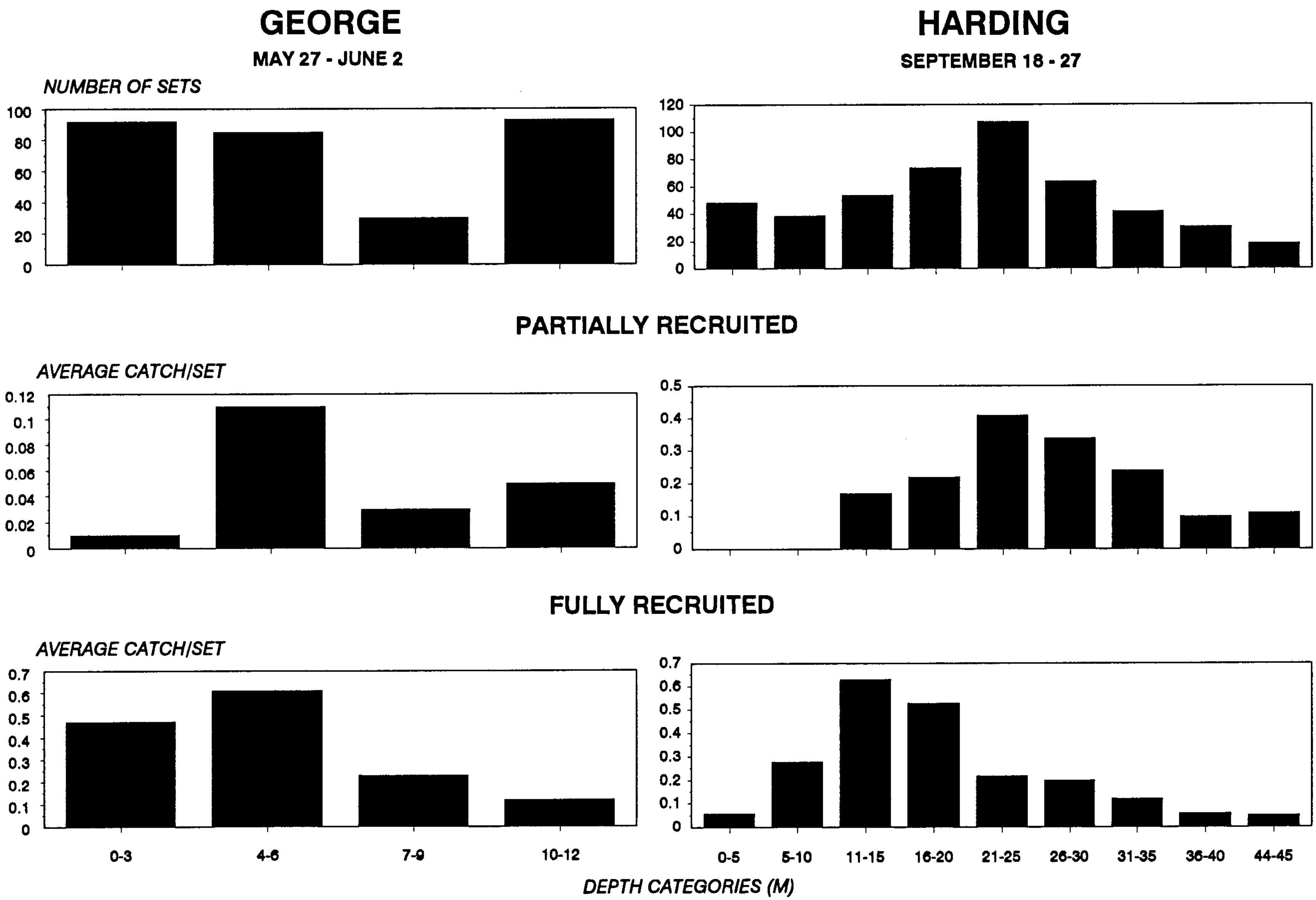

-continued-

Appendix C. Frequency of sets by depth and average catch of burbot by depth for interior Alaska lakes sampled in 1991.



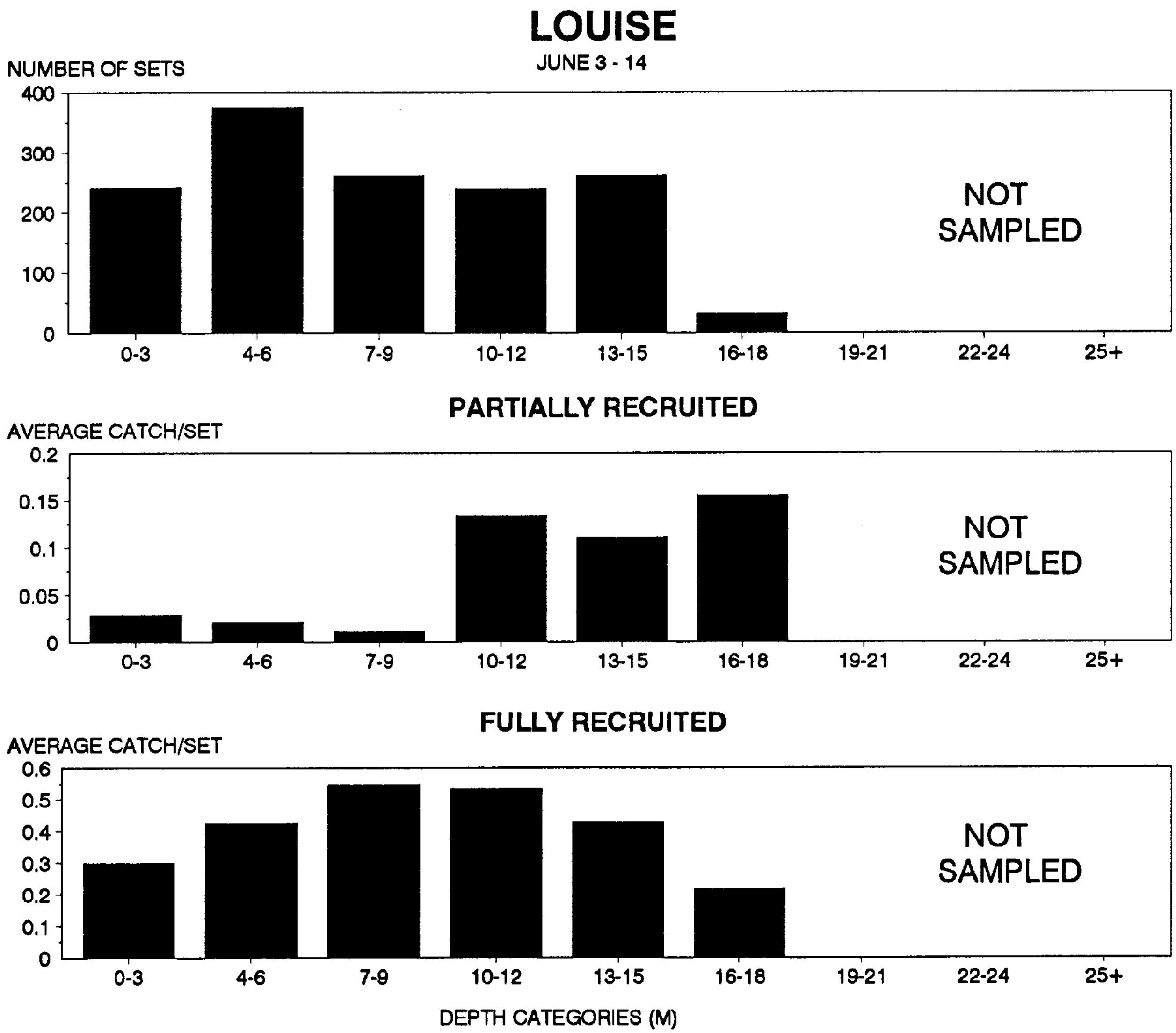

-continued-

Appendix C. (Page 2 of 12).



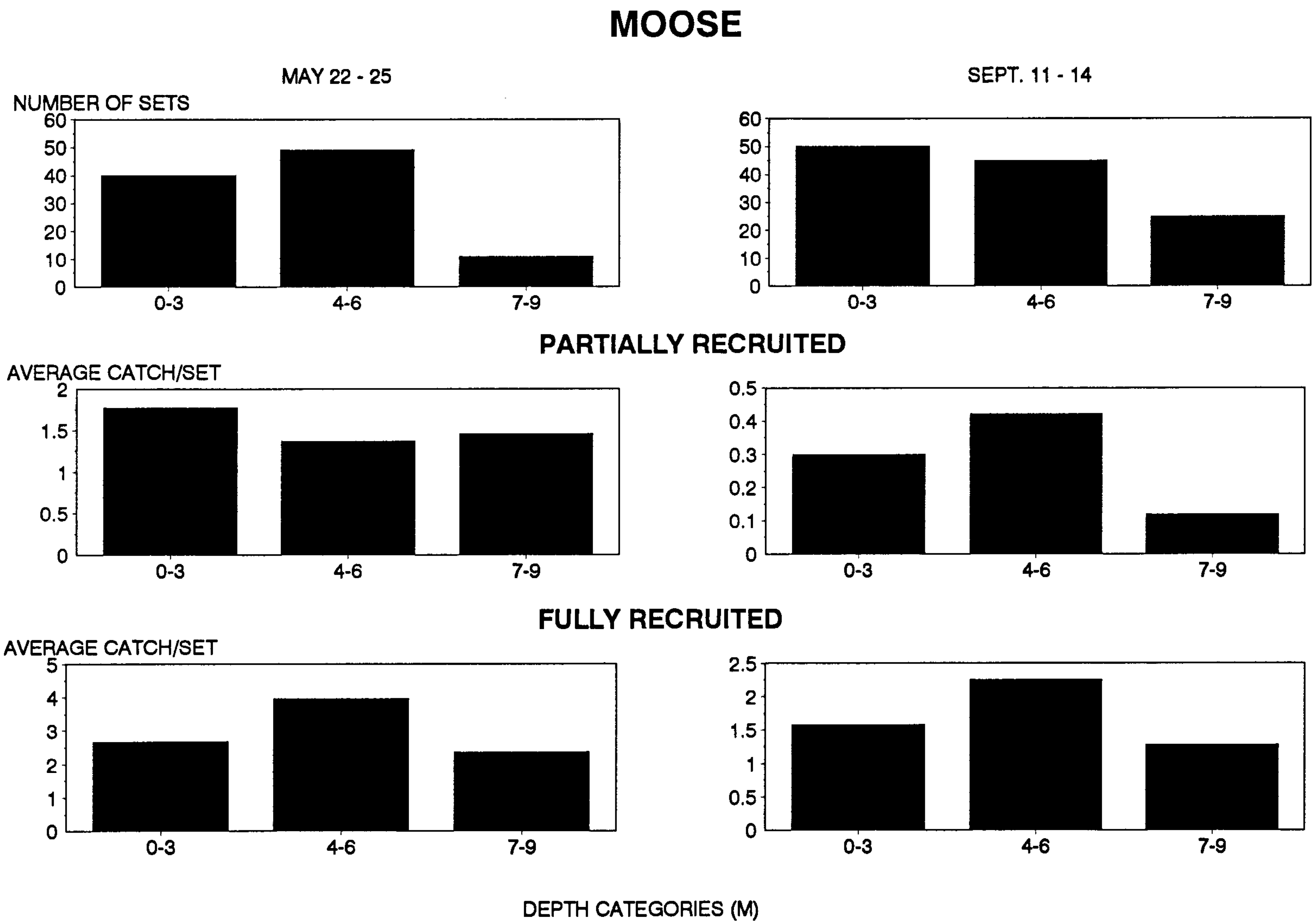

-continued-

Appendix C. (Page 3 of 12).



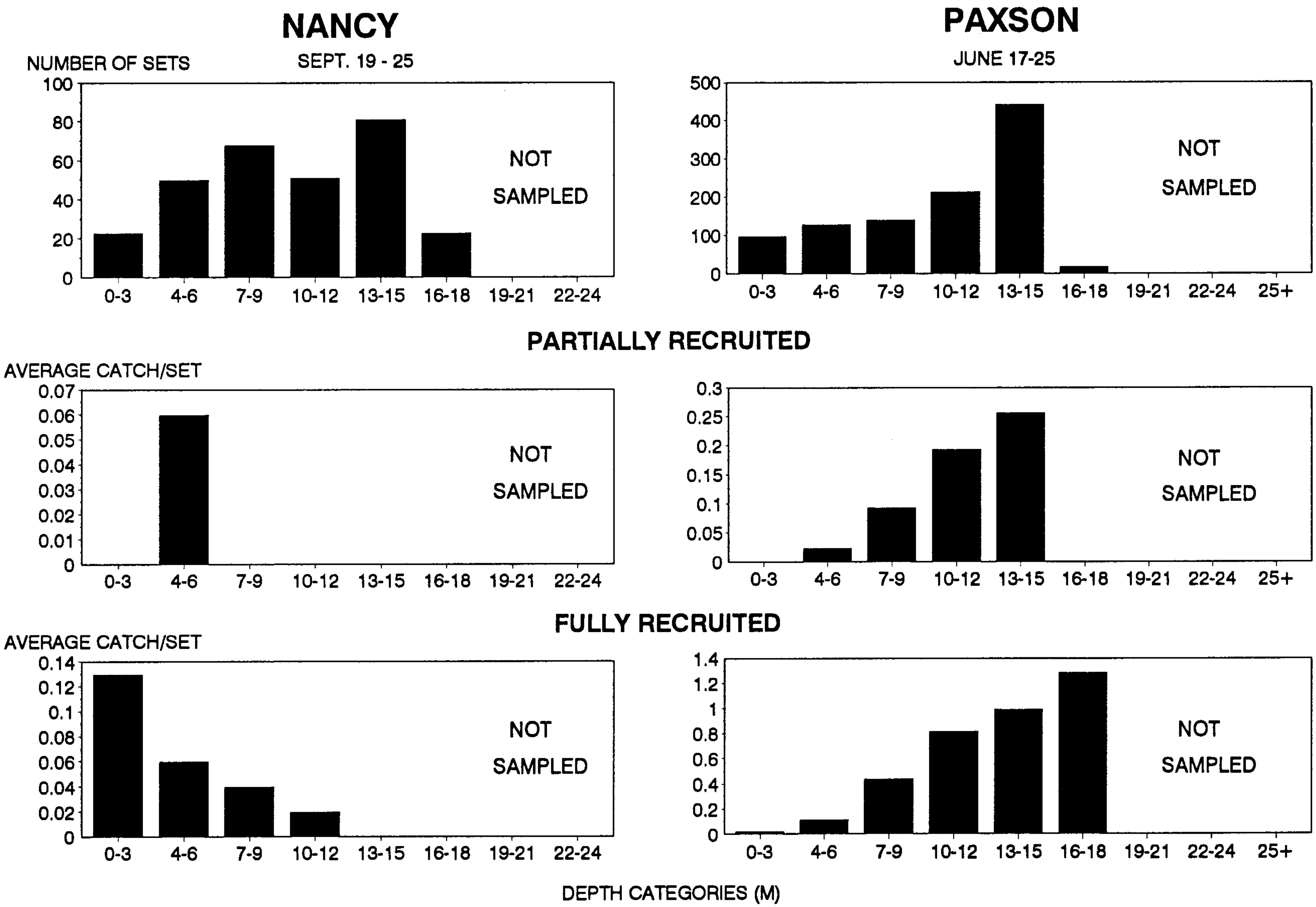

-continued-

Appendix C. (Page 4 of 12).



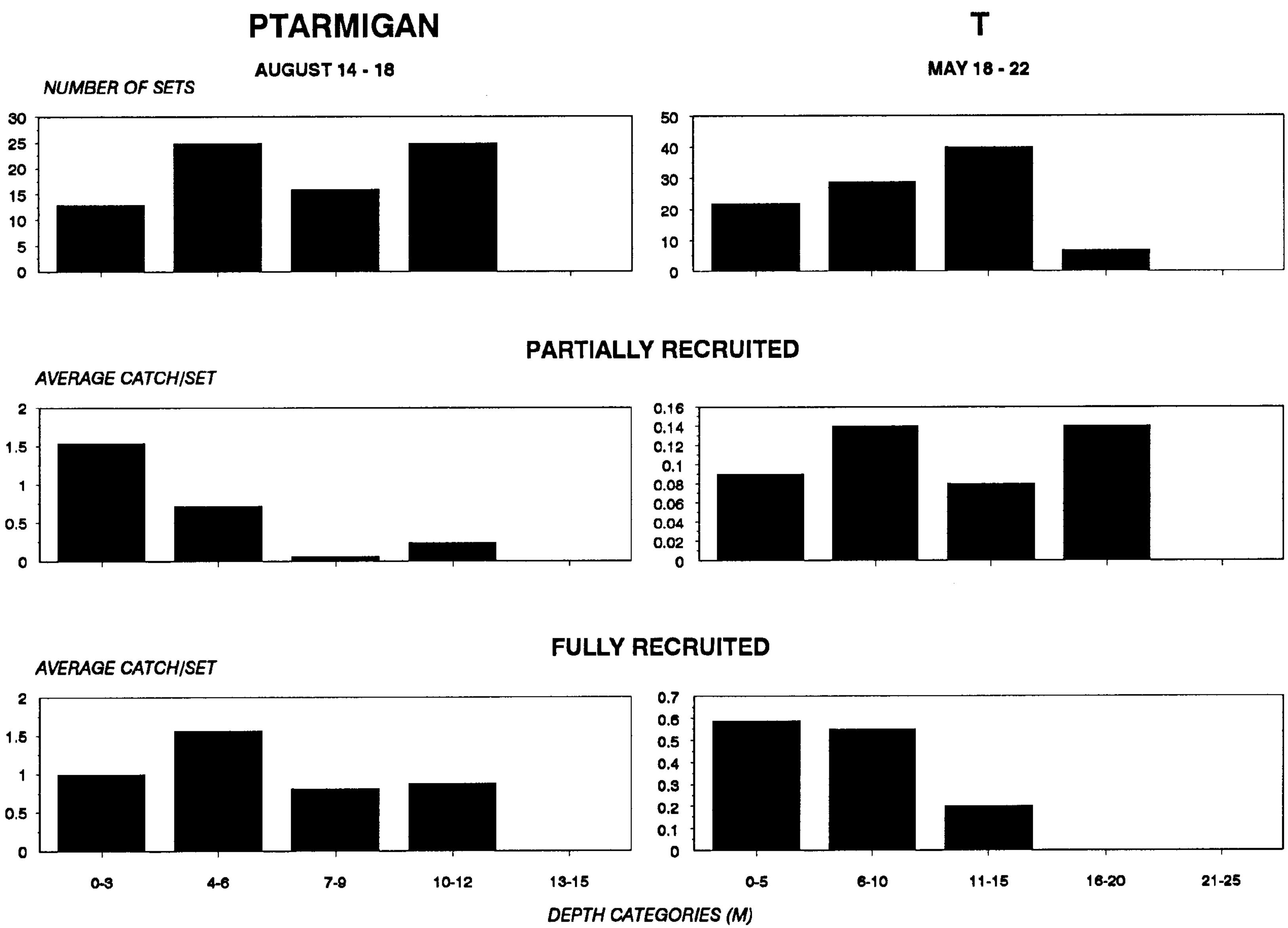

-continued-

Appendix C. (Page 5 of 12).



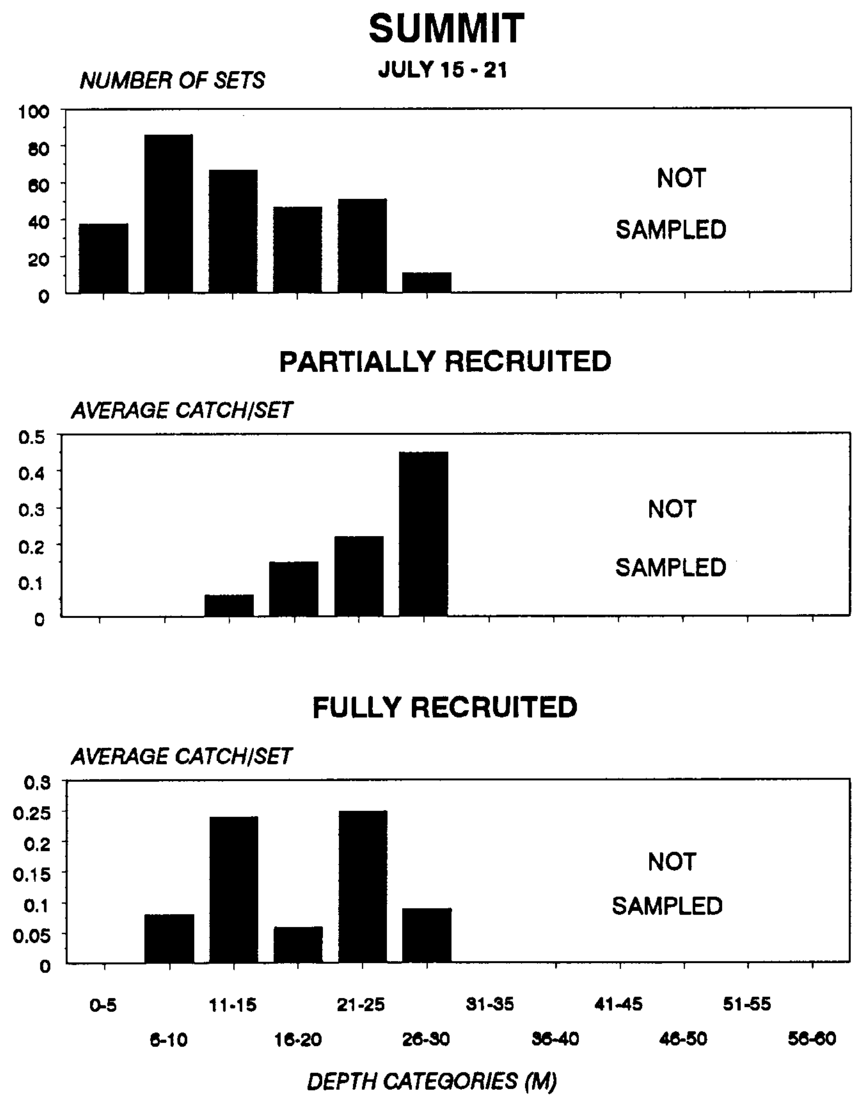

-continued-

Appendix C. (Page 6 of 12).



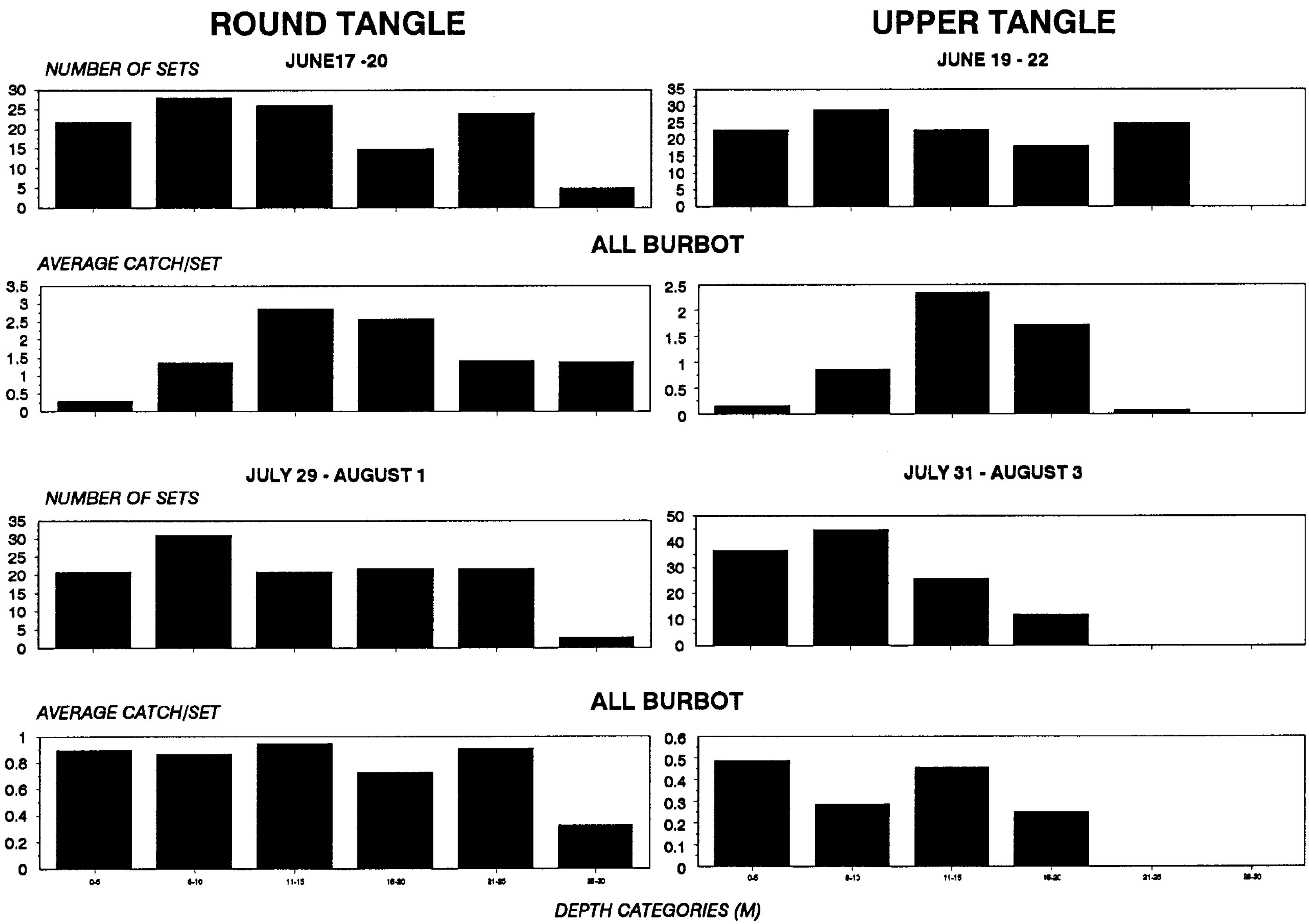

-continued-

Appendix C. (Page 7 of 12).



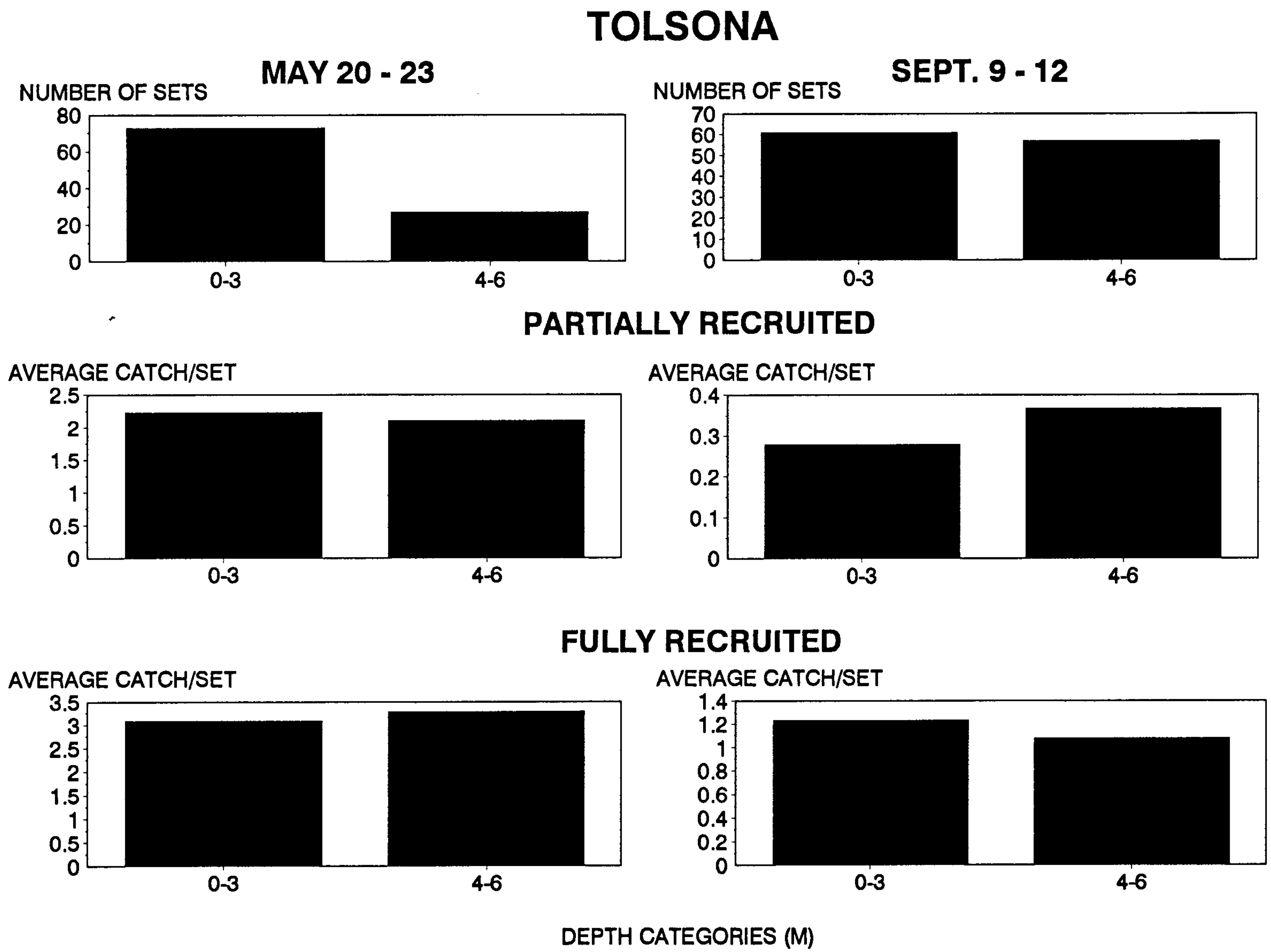

-continued-

Appendix C. (Page 8 of 12).




-continued-

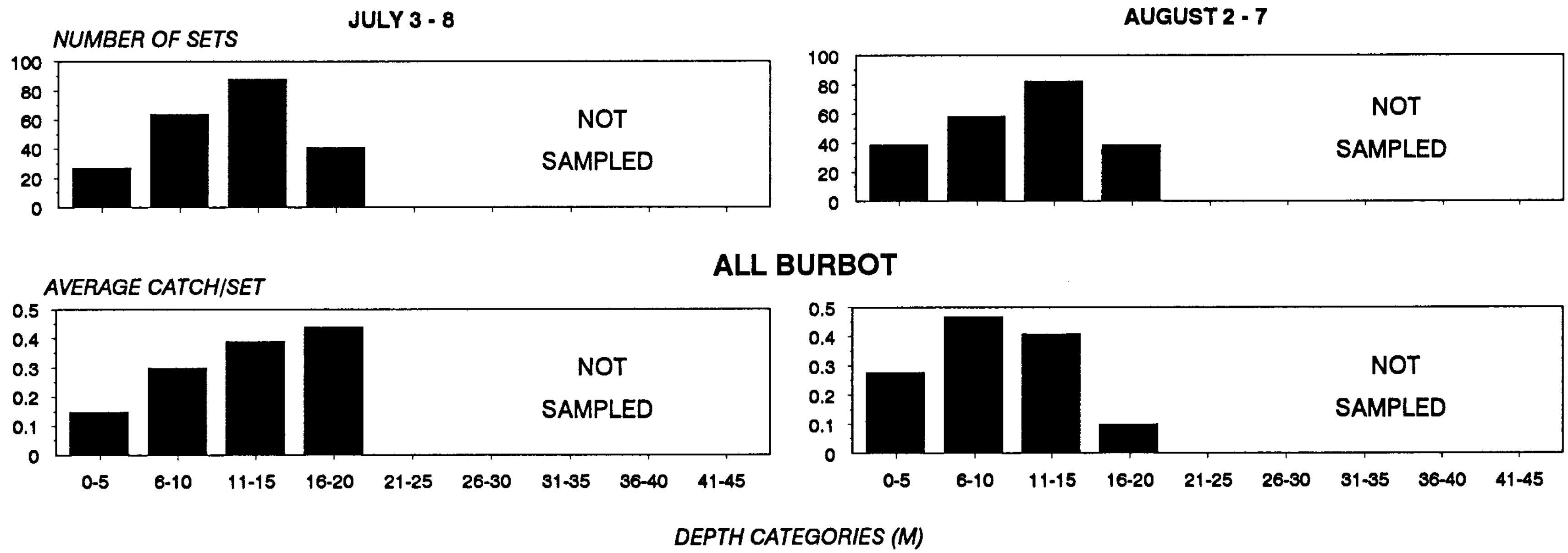
Appendix C. (Page 9 of 12).




-continued-

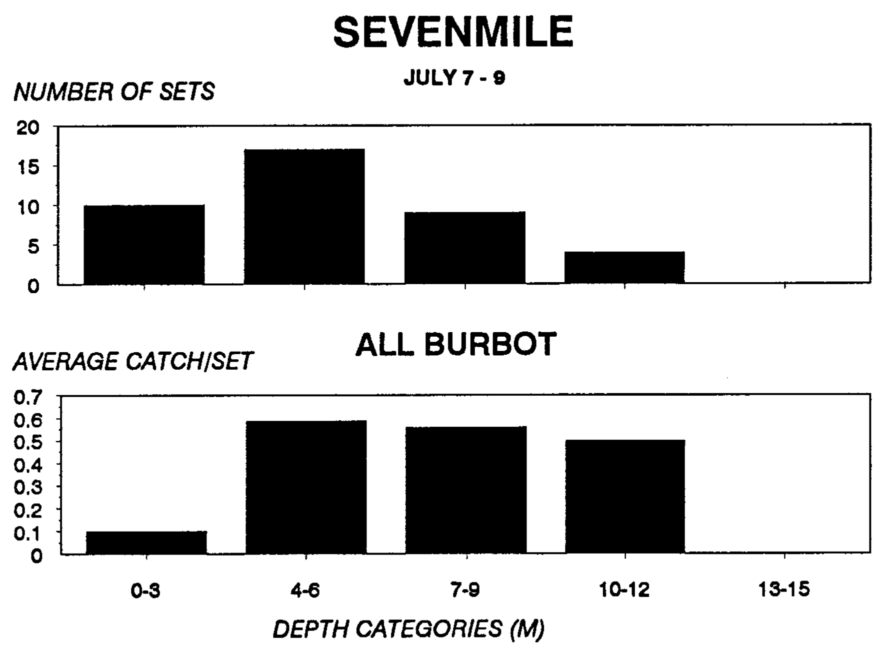
Appendix C. (Page 10 of 12).

# LANDLOCK TANGLE




-continued-

Appendix C. (Page 11 of 12).




Appendix C. (Page 12 of 12).

# APPENDIX D

# BIAS AND VARIANCE OF MEAN CPUE

Appendix D. 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):

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

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:

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

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:

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

-continued-

where:

$$\overline{\overline{CPUE}}^{*} = \frac{\sum_{b=1}^{B} \overline{CPUE}_{b}^{*}}{B} \tag{D.4}$$

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.