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STOCK ASSESSMENT AND BIOLOGICAL CHARACTERISTICS OF BURBOT IN LAKES OF INTERIOR ALASKA DURING 1987[1]

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ABSTRACT

Abundance and/or indices of abundance of burbot *Lota lota* were estimated for populations in 24 lakes in interior Alaska. Sampling occurred from June through September, 1987. Although burbot 300 millimeters (total length) and longer were captured, burbot were not fully recruited to the gear (hoop traps) until they reached 450 millimeters. Abundance of fully recruited burbot estimated with mark-recapture experiments was greatest in Lake Louise (5,251), Hudson (3,761), Crosswind (3,651), and Paxson (3,246) Lakes. Survival rates between years ranged from 46 to 62 percent per year for populations in Paxson, Fielding, Louise, and Tolsona Lakes. Annual recruitment of juveniles was estimated for populations in Tolsona and Fielding Lakes. Average tag loss among all populations was 5.4 percent within a year and 16.3 percent between years.

Mean catch per unit of effort of fully recruited burbot was above 1.00 burbot per 48-hour set for populations in Tolsona (6.15), Moose (5.75), Hudson (3.69), and Paxson Lakes (1.79). In June, large burbot tended to be in the shallows and small burbot in deeper water; by summer, both large and small burbot were at all depths. Mean catch per unit of effort for fully recruited burbot declined an average 49 percent from June and July to August and September.

Size and age composition of burbot populations varied widely among lakes with some having no large burbot at all. Recognizing the sex of mature burbot through inspection of gonads proved difficult. Parameters in the allometric length-weight relationships for populations in Crosswind and Fielding Lakes were estimated. Growth coefficients for the von Bertalanffy model of growth were calculated from growth of individual fish for populations in Moose and Paxson Lakes.

KEY WORDS: Burbot, *Lota lota*, lakes, abundance, hoop traps, systematic design, random design, stratified design, otolith, selectivity, mean length, length-weight, age, catch per unit of effort, survival rates, recruitment.

INTRODUCTION

Since 1977, 80% of the estimated harvest of burbot *Lota lota* in Alaska has come from lakes in the Tanana River drainage and in the vicinity of Glennallen (Mills 1987). Set lines and jigs fished through the ice are the most popular gear in these sport fisheries. Harvest of burbot has increased annually an average 30% with the greatest harvests occurring in recent years. These statistics, along with stock assessment of the burbot population in Fielding Lake since 1981 (Peckham 1985), prompted a closure of Fielding Lake to the taking of burbot from 17 May through 31 December 1984. During the winter of 1987, new regulations were promulgated in response to recruitment overfishing in several important fisheries. The new regulations reduced daily bag limits and restricted the number of set lines.

The purpose of this project is the stock assessment of burbot populations in lakes in interior Alaska and the gathering of biological information germane to the productivity of these populations. Information from this project will be used to estimate the range over which sustained harvests from these stocks can be maintained. The objectives for work in 1987 are the estimation of:

1) mean Catch Per Unit of Effort (CPUE) of burbot in 24 lakes as an index of abundance;

2) abundance of burbot in 22 lakes;

3) mean total length (TL) of captured burbot in 24 lakes;

4) mean length at age for burbot in 24 lakes;

5) parameters in the length-weight relationships of burbot populations in 24 lakes; and

6) annual survival rates and growth rates in the 20 populations sampled in 1986 and in 1987.

The study lakes in the Tanana River drainage were Fielding, Harding, T, George, Sevenmile, Round Tangle, Shallow Tangle, Upper Tangle, and Landlock Tangle Lakes (Figure 1). The study lakes near Glennallen were Susitna, Lost Cabin, Minnesota, Crosswind, Hudson, Sucker, Deep, Tyone, Forgotten, Burnt, Moose, Tolsona, Summit, and Paxson Lakes and Lake Louise (Figure 1). Each lake chosen for this study has (or had) a popular sport fishery for burbot (according to statistics reported in Mills 1987) or is reasonably accessible to anglers. More detailed descriptions of each study lake are in the Appendix.

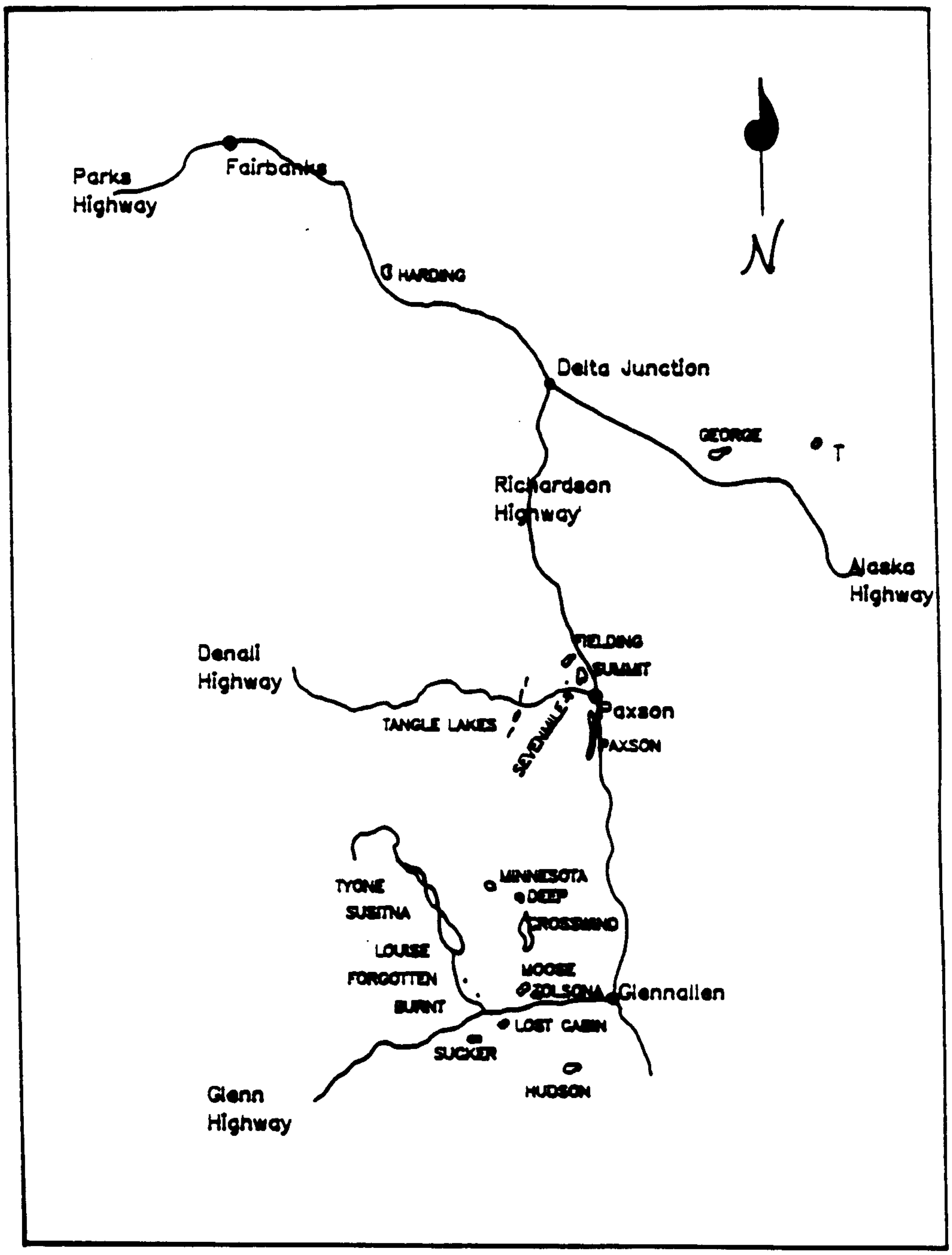

Figure 1. Location of the lakes in the Tanana River drainage and near Glennallen that were included in studies of burbot populations in interior Alaska in 1987.

METHODS

Gear Description

Burbot were captured in hoop traps 3.05 m long with seven 6.35-mm steel hoops (Figure 2). Hoop diameters taper from 0.61 m at the entrance to 0.46 m at the cod end. Each trap has a double throat (tied to the first and third hoop) which narrows to 0.31 m (flattened). All netting is knotted nylon woven into 25 mm bar mesh, held together with No. 15 cotton twine, and treated with an asphaltic compound. Each trap was kept stretched with two sections of 12 mm galvanized steel conduit attached by snap clips to the end hoops. A numbered buoy was attached to the cod end of the trap with 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.

Study Design

Mean CPUE was estimated with either a stratified-random or a stratified-systematic survey design (Table 1). For three smaller lakes, locations for sets were randomly selected from a grid overlay representing 125 m squares[1] placed over a map of the lake. Random placement of sets proved too time consuming to implement on larger lakes because of the difficulty in navigation to a set location. Therefore, the locations of sets on 21 larger lakes were chosen systematically. First, an overlay with parallel lines was placed across a map of the 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 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 with every subsequent set along that transect at 125 m. The desired number of sets for each lake and each survey design was chosen according to the rules in Pearse and Conrad (1986) for the first sampling event. The number of sets for the second

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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 in burbot caught per 48-hour set in 1985 in Fielding Lake by the density of burbot per ha from the mark-recapture experiment (Pearse and Conrad 1986). This estimated fishing area was arbitrarily increased to 1.25 ha to ensure elimination of gear competition; this area corresponds to traps set at a distance of 125 m.

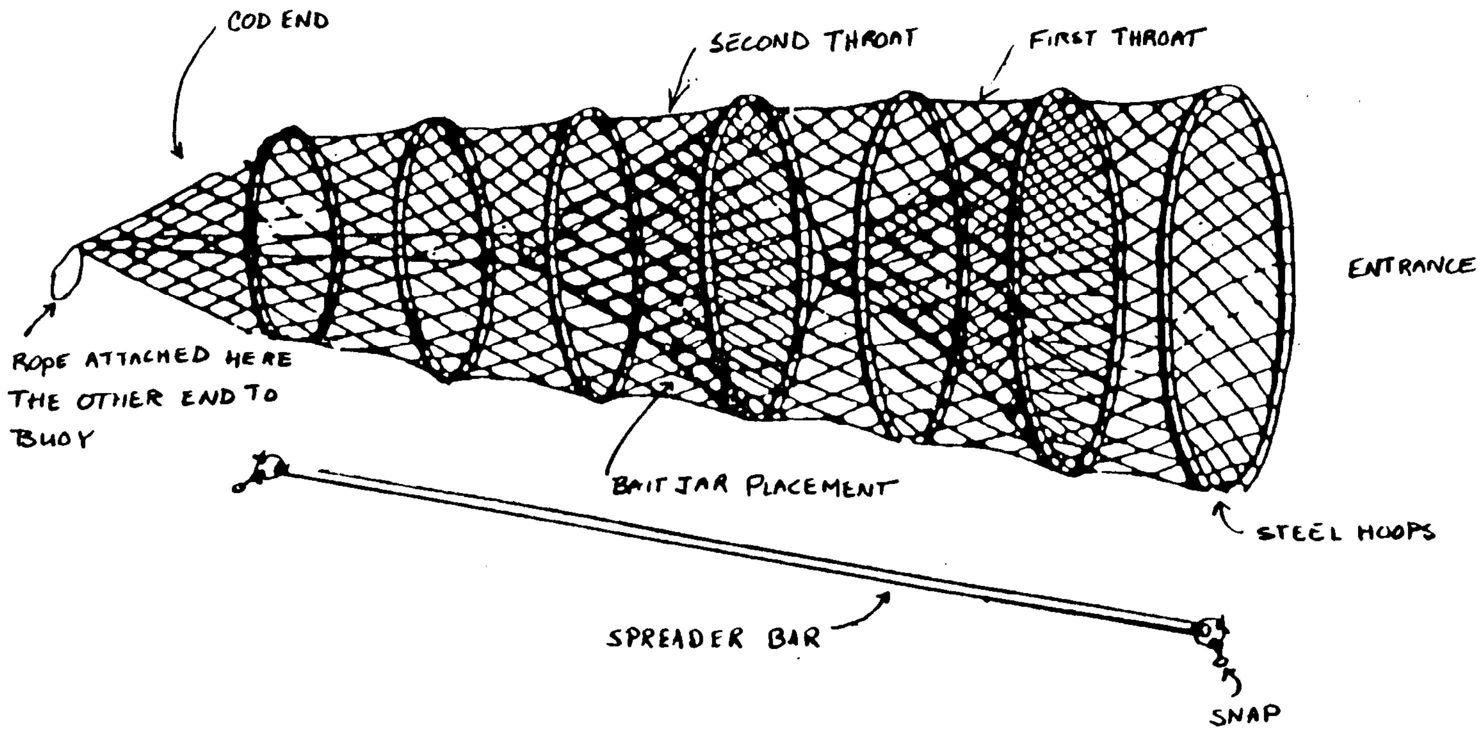

Figure 2. Schematic drawing of hoop traps used to catch burbot in interior Alaska in 1987.

Table 1. Numbers of sets, dates of sampling events, and sampling designs for the stock assessment of burbot populations in 24 lakes in interior Alaska in 1987.

Lake	Area (ha)	Sampling: Event	Dates	Design[1]	Number of Sets
Fielding	538	1	7/21-27	systematic	240
		2	8/17-22	systematic	234
George	1,863	1	6/01-11	systematic	422
		2	6/22-30	systematic	418
Harding	1,000	1	6/16-20	systematic	239
Landlock Tangle	219	1	6/30-7/06	random	208
		2	8/02-07	systematic	219
Paxson	1,575	1	7/06-13	systematic	358
		2	8/06-14	systematic	414
Round Tangle	155	1	7/27-30	systematic	99
		2	8/22-25	systematic	118
Sevenmile	34	1	6/16-20	systematic	30
		2	7/31-8/06	systematic	40
Shallow Tangle	130	1	7/29-8/01	systematic	100
		2	8/24-30	systematic	83
Summit	1,651	1	7/13-21	systematic	400
		2	9/02-10	systematic	398
T	162	1	5/26-6/01	systematic	60
		2	9/21-25	systematic	90
Upper Tangle	142	1	7/31-8/03	systematic	100
		2	8/25-29	systematic	120
SUBTOTALS	7,469		5/26-9/25		4,390

-Continued-

Table 1. Numbers of sets, dates of sampling events, and sampling designs for the stock assessment of burbot populations in 24 lakes in interior Alaska in 1987 (continued).

Lake	Area (ha)	Sampling: Event	Dates	Design	Number of Sets
Burnt	24	1	8/08-10	random	20
		2	9/12-14	random	19
Crosswind	3,238	1	7/23-8/06	systematic	337
		2	8/13-27	systematic	384
Deep	304	1	7/18-22	systematic	98
		2	8/07-11	systematic	96
Forgotten	7	1	8/08-10	random	10
		2	9/12-14	random	10
Hudson	259	1	6/15-19	systematic	100
		2	7/06-10	systematic	88
Lost Cabin	34	1	6/09-11	systematic	30
		2	6/30-7/02	systematic	30
Louise	6,519	1	7/06-20	systematic	547
		2	8/02-19	systematic	545
Minnesota	325	1	7/13-17	systematic	98
Moose	130	1	6/01-05	systematic	120
		2	6/22-26	systematic	120
Sucker	283	1	6/10-14	systematic	105
		2	6/29-7/01	systematic	70
Susitna	3,816	1	7/18-31	systematic	542
		2	8/17-30	systematic	540
Tolsona	130	1	6/02-04	systematic	60
		2	6/23-25	systematic	60
Tyone	389	1	7/29-8/04	systematic	198
		2	8/28-9/01	systematic	194
TOTALS	22,927		6/01-9/14		8,811

[1] Systematic and random designs are described in the text.

sampling event was chosen according to rules in Robson and Regier (1964) for sample size in mark-recapture experiments and with estimates of CPUE from the first sampling event.

Traps were set and retrieved beginning on one end of the lake in progression to the other end. In the larger lakes, crews (three members per crew: one person piloted the boat and recorded data while the other two handled traps and took biological information from the burbot caught) set and retrieved traps simultaneously. In smaller lakes, crews worked alone. Each crew set and/or retrieved from 50 to 80 traps per 8-hour day. The time of setting and retrieving each set was recorded to the minute. The depth of each set was measured with a fathometer. Each hoop trap was soaked for approximately 48 hours (a set) to optimize catch (Pearse and Conrad 1986). Each new set started with fresh bait, and old bait was discarded on shore.

Burbot were placed in a plastic tank during sampling. Each burbot was measured and those longer than 300 mm TL were finclipped (pelvic fin) and tagged with an anchor-type, individually numbered Floy tag inserted at the base of the dorsal fin. Burbot that exhibited stress associated from deep-water removal (usually an expanded gas bladder) or trap-inflicted injury were weighed and dissected. Otoliths were removed from these burbot and their sex and maturity were recorded.[2] Ages of burbot were estimated from whole, polished otoliths by counting annuli.

Abundance

For those 22 populations with two sampling events, abundance of burbot was estimated with a mark-recapture experiment with the Chapman modification of methods developed by Petersen (see Seber 1970):

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

$$2)\quad V[\hat{N}] = \frac{\hat{N}(M - R)(C - R)}{(R + 1)(R + 2)}$$

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[2] During the second sampling event, burbot were separated into 50 mm length groups and five burbot were randomly selected from each group for dissection from populations in Tolsona and Paxson Lakes. Those burbot in a length group that had died during sampling were counted towards the quota.

where:

N = abundance;
M = number of marked burbot released alive into the populations 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.

A 2 to 17-week hiatus occurred between sampling events in the same lake to permit tagged fish to mingle with untagged fish. The longer waits occurred on the larger lakes. Recovery rates of tagged fish by size were used to detect size selectivity of the sampling gear, and the nonparametric technique of Robson and Flick (1964) was used to detect any growth recruitment to populations between sampling events.

Survival Rates and Recruitment

Survival rates and recruitment were estimated with the techniques of Jolly (1965) and Seber (1965):

3) $$\hat{M}_{i,i+1} = \frac{R_{i,i+2}M_{i+1}}{R_{i+1,i+2}} + R_{i,i+1} + D_{i,i+1}$$

where:

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).

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

4) $$\hat{S}_{i,i+1} = \frac{\hat{M}_{i,i+1}}{M_i}$$

Abundance and recruitment were estimated as follows:

5) $$\hat{N}_i = \frac{C_i\hat{M}_{i-1,i}}{R_{i-1,i}}$$

6) $$\hat{A}_{i-1,i} = \hat{N}_i - \hat{N}_{i-1}\hat{S}_{i-1,i}$$

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".

These procedures are based on the same assumptions as is the Petersen method, except that mortality and recruitment are permitted between sampling events. The statistics in Equations 4-6 (and their variances) were calculated with the program JOLLY as described in Pollock et al. (1985) and Brownie et al. (1986). Because the Jolly-Seber method requires at least four sampling events and is unbiased only for situations with large sample sizes and with large numbers of recaptured fish (Gilbert 1973), this method could be used for two populations only (those in Tolsona and in Fielding Lakes). In one of these cases (the experiment in Fielding Lake), data were pooled within a year to boost sample sizes.

For populations in Paxson Lake and Lake Louise, the approach suggested by Pollock (1982) was used. Survival rates were estimated with techniques listed above while abundance was estimated with techniques based on closed populations such as Equations 1 and 2. The equation to estimate survival rates is very robust to small sample sizes (Ricker 1975; Seber 1982) with the following modification:

7) $$\hat{M}_{i,i+1} = \frac{R_{i,i+2}(M_{i+1} + 1)}{(R_{i,i+1} + 1)} + R_{i,i+1} + D_{i,i+1}$$

The data from sampling events in 1986 were pooled for application of this approach. Mark-recapture histories were developed for each fish handled during all three events (one in 1986 and two in 1987). For each population there would be K ($= M_1 + C_2 - R_{1,2} + C_3 - R_{1,3} - R_{2,3}$) individual fish in each history. One thousand bootstrap samples of size K were generated from histories of each population according to procedures in Efron (1982). A survival rate was calculated with Equation 7 from each bootstrap; these individual survival rates were averaged over the thousand bootstrap samples and a variance was calculated as the sums of the deviations squared divided by 1,000. The estimates of S_b (the average from the bootstrap samples) and of abundance from the Petersen method (N_{86} and N_{87}) were placed in Equation 6 to estimate recruitment; the variance of estimated recruitment was calculated as follows (see Goodman 1960):

$$8)\qquad V[\hat{R}_{86,87}] = V[\hat{N}_{87}] + V[\hat{N}_{86}]\hat{\bar{S}}_b^{\,2} + \hat{N}_{86}^{\,2}V[\hat{\bar{S}}_b] - V[\hat{N}_{86}]V[\hat{\bar{S}}_b]$$

This approach was also used to extend the estimates of survival and recruitment for populations in Fielding and Tolsona Lakes 1 extra year beyond those obtained from the Jolly-Seber method. Data collected in 1986 from Fielding were pooled to create a single sampling event, and a bootstrap estimate of the survival rate was calculated. Application of Equations 6 and 8 along with the Petersen estimate of abundance for 1987 produced estimates of recruitment for this population over the winter of 1986-7. For the population in Tolsona Lake, the abundance estimate for 1986 along with the survival rate estimated through the Jolly-Seber method were placed into Equations 6 and 8 to estimate recruitment between the sampling events in 1986.

Mean CPUE

Mean CPUE was calculated for 24 populations during 46 sampling events. Means from the random designs were calculated according to procedures described in Sukhatme et al. (1984):

$$9)\qquad \overline{CPUE} = \bar{x} = \frac{1}{m}\sum_{j=1}^{m} x_j \quad \text{where} \quad x_j = \frac{C_j}{E_j}$$

$$10)\qquad V[\overline{CPUE}] = \sum_{j=1}^{m} \frac{(x_j - \bar{x})^2}{m\,(m-1)}$$

where:

- C = catch;
- E = effort in units of 48 hours; and
- m = number of sets.

Because the exact "area" that the average trap fished is unknown, the maximum possible number of sets is also unknown, therefore, finite population correction factors were excluded from Equation 10 and the following formulae for calculating variances.

The sampling design listed above is a two-stage sampling design with transects as primary units and sets along transects as secondary units (Sukhatme et al. 1984). Although all transects had an equal probability of being chosen for a survey, they were of different sizes depending upon the shape of the lake. Under these conditions, the following equation was used to calculate unbiased estimates of mean CPUE:

$$11)\quad \overline{CPUE} = \frac{\sum_{i=1}^{n} \sum_{j=1}^{m_i} x_{ij}}{\sum_{i=1}^{n} m_i} \qquad \text{where } x_{ij} = \frac{C_{ij}}{E_{ij}}$$

where:

n = number of transects; and
m = number of sets on a specific transect.

However, the formula for calculating the variance to estimates from Equation 11 requires knowledge of the maximum number of sets (secondary units) in each lake (Cochran 1977; Sukhatme et al. 1984). For reasons stated above, the maximum possible number of sets is not known. Since the variances for estimates from Equation 11 could not be calculated, estimates of mean CPUE based on arithmetic means and their variances were also calculated even though they are slightly biased:

$$12)\quad \overline{CPUE} = \bar{\bar{x}} = \frac{1}{n} \sum_{i=1}^{n} \frac{1}{m_i} \sum_{j=1}^{m_i} x_{ij}$$

$$13)\quad V[\overline{CPUE}] = \sum_{i=1}^{n} \frac{(\bar{x}_1 - \bar{\bar{x}})^2}{n\,(n - 1)} + \sum_{i=1}^{n} \sum_{j=2}^{m_i} \frac{(x_{ij} - x_{i,j-1})^2}{2\, n^2\, m_i\, (m_i - 1)}$$

Equation 13 was composed of elements taken from Sukhatme et al. (1984) for two-stage sampling with primary units of equal size (variance among transects) and from Wolter (1984) for unbiased estimation of variance from systematically drawn samples (variance within transects). The x_{ij} were arranged in serial order along transects for these calculations. In the instance where data from a set are missing, the transect was decomposed into smaller transects with contiguous sets.

Estimates of mean CPUE were post-stratified by depth according to procedures described in Sukhatme et al. (1984) and Pearse and Conrad (1986):

$$14)\quad \overline{CPUE}_{st} = \sum_{h=1}^{L} W_h\, \overline{CPUE}_h$$

$$15)\quad V[\overline{CPUE_{st}}] = \sum_{h=1}^{L} W_h\, V[\overline{CPUE_h}] + \sum_{h=1}^{L} \frac{(1-W_h)V[\overline{CPUE_h}]}{n}$$

where:

- L = the number of strata;
- n = the number of sets (random design) or transects (systematic design); and
- W_h = ratio of the area covered by stratum h to the area of the lake.

Average catch by depth was plotted for each sampling event in which 20 or more burbot were captured. Depths at which average catch by depth changed dramatically in these plots were chosen as the boundaries between strata. The weights (W_h) were calculated as averages over the years of the fractions of sets that had been within each depth stratum.

When a boundary between strata cut across a transect in the systematic design, each part of the dissected transect was considered a new transect, each within its separate stratum. In those cases where such a new transect consisted of only one set, that datum was excluded from the analysis.

Stratified estimates of mean CPUE were calculated in all instances where average catch by depth changed dramatically. In these instances, unstratified estimates were calculated as well. If the two estimates (stratified and unstratified) were dissimilar by an amount greater than the arbitrary standard of half the standard error of the larger estimate, the stratified estimate was reported as the more accurate estimate. Otherwise, the unstratified estimate was given.

Age and Length

Parameters of allometric length-weight relationships for burbot were estimated with a computer program that iteratively "fits" nonlinear models to bivariate data. The algorithm of the program follows the Marquardt compromise (Marquardt 1963). Fifty-five separate sets of estimates of the parameters were calculated with each calculation beginning with a new set of initial values. The initial values of the allometric constant ranged from 2.0 to 4.0 by increments of 0.2; the initial values of the linear constant ranged from 4.0 to 12.0 by increments of 2.0. The output from all 44 operations was an isopleth diagram of the sums of squares of the residuals arising from each operation and the set of estimates which corresponded to the lowest sums of squares.

The measurements of recaptured burbot were used to estimate the parameters of the von Bertalanffy model of growth. The differential form of this model is:

$$16)\qquad \frac{dl}{dt} = k(L_{\infty} - l_t)$$

where:

- k = the coefficient of growth;
- L_{∞} = the asymptotic length; and
- l_t = the length of a burbot at time t.

Equation 16 was approximated with a difference equation as per Jain (1984):

$$17)\qquad l_{t+\Delta t} - l_t \approx \exp[\Delta t\{k(L_{\infty} - l_t)\}]$$

where Δt is the change in time in years. In turn, Equation 17 was transformed, rearranged, and defined for individual fish:

$$18)\qquad \frac{\mathrm{Log}_e \Delta l_j}{\Delta t} \approx kL_{\infty} - kl_{t,j} + \epsilon_j$$

where ϵ_j is the deviation of the jth burbot from the norm. Under the model in Equation 18, the parameters k and L_{∞} were estimated through least-squares regression on all instances where $\Delta l_j > 0$. Bootstrap methods of Efron (1982) were used to estimate the variances and covariances of the parameters. Data from burbot that had been at large more than 200 days were used in the analysis. When several sampling events followed in rapid succession (within 100 days), the recapture histories were combined to create a record of capture; in this case, time of capture was set at the midpoint between sampling events.

RESULTS

Recruitment to the Gear

Contingency table analysis of rates of recapture of tagged burbot indicates that larger burbot were captured at a higher rate than were smaller burbot in hoop traps (Table 2). In the six populations with enough tagged and recaptured fish to meet the assumptions of the test, significantly high χ^2 statistics occurred for four. Further testing of data from Tolsona and Fielding Lakes showed that significant differences in the recovery rates of tagged fish occurred only when 450 mm TL was a boundary between groups. Further testing also revealed that this singular break came at 500 mm TL for burbot in Moose Lake and 550 mm TL in Paxson Lake. The rate of capture of small burbot was 34% of that for

Table 2. Results of contingency table analysis of the recapture rates of tagged burbot by length for data collected in 1987.

```
                       Test Breaks¹(mm TL)                 Significant
Lakes          450    500    550    600    650    700       Tests²

Paxson     ----><----><----><----><----><---------        P<0.005
               <----><----><----><----><---------      0.03<P<0.05
                     <----><----><----><---------      0.05<P<0.10
                           <----><----><---------
           ---------><---->

Moose      ----><----><-------------------------       0.01<P<0.03
           ----><---->

Tolsona    ----><----><-------------------------         P<0.005
               <----><-------------------------

Fielding   ----><----><---><-------------------          P<0.005
               <----><---><-------------------

Hudson     ---------><----><-------------------

T          -------------------------------><---
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[1] Each group of lines corresponds to a battery of tests (there are four groups). The symbols "><" correspond to boundaries between adjacent categories in a test.

[2] Tests are RxC contingency tables and χ^2 statistics for $H_o:p_i = p$ where p_i = probability of catching a burbot in the ith length group. The numbers of marked fish caught and not caught were used in the contingency table. The first test in a battery had length groups of 50 mm TL except where data were grouped into larger categories to meet the requirements of the test. If the null hypothesis was rejected, further tests in a battery were done (if possible) to estimate at what length the probability of capture changed.

large burbot in Tolsona Lake, 51% in Moose Lake, 33% in Paxson Lake, and 38% in Fielding Lake.

Of the 22 populations sampled twice, there was no shift in recruitment to the gear of burbot by size between sampling events in 15 (Figure 3). Populations in Harding and Minnesota Lakes[3] were sampled but once. Differences between length distributions from different sampling events were tested with the Kolmogorov-Smirnov Two-sample Test with $\alpha = 0.05$. Of the 15 populations with no differences, the length distributions were pooled over sampling events. All but three of these pooled distributions had the ascending left limb characteristic of pre-recruits with modes between 400 to 550 mm TL. Distributions for populations in Landlock Tangle, Shallow Tangle, and Round Tangle Lakes were the three exceptions with no ascending left limb at all.

In the eight populations in which the length distributions differed between sampling events, the catchability of large fish relative to small fish decreased between sampling events in four cases (Paxson, Crosswind, Susitna, and Upper Tangle Lakes) and increased in four (George, Moose, Tolsona, and Tyone) (Figure 4). Decreases in the catchability of large burbot between sampling events occurred in deep lakes (maximum depths 29 m or more); decreases in the catchability of small burbot occurred in shallow lakes (maximum depths 11 m or less). All of these length distributions have ascending left limbs except for the set from Upper Tangle Lake.

As was done in Parker et al. (1987), 450 mm TL was used as the size of full recruitment to the gear for burbot in all populations. Although there was some variance from this value in the contingency table analysis (populations in Paxson and Moose Lake), there were some mitigating evidence as well. Contingency table analysis on data from Moose Lake collected in 1986 showed that 450 mm TL was the appropriate size of recruitment (Parker et al. 1987). Also, comparison of the length distributions of both sampling events in 1987 from Moose Lake showed a significant shift towards higher catchability for larger fish between events (Figure 4) which could have moved the threshold of recruitment upward from 450 mm TL just for that event. Comparison of abundance estimates from Moose Lake supported this contention in that there was little difference in the estimates whether the data were stratified at 500 mm TL or not (Appendix Table 5). A similar comparison for the population in Paxson Lake also showed little difference whether or not the data were stratified at 550 mm TL or at 450 mm TL.

<u>Abundance</u>

Burbot were recaptured in all 22 lakes in which two sampling events occurred. Lake Louise had the highest estimated abundance of fully recruited burbot (5,251) (Table 3). Populations in Hudson, Crosswind,

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[3] Although two sampling events were planned for Minnesota Lake, only one burbot was caught during the first event. For this reason, this population was not further analyzed.

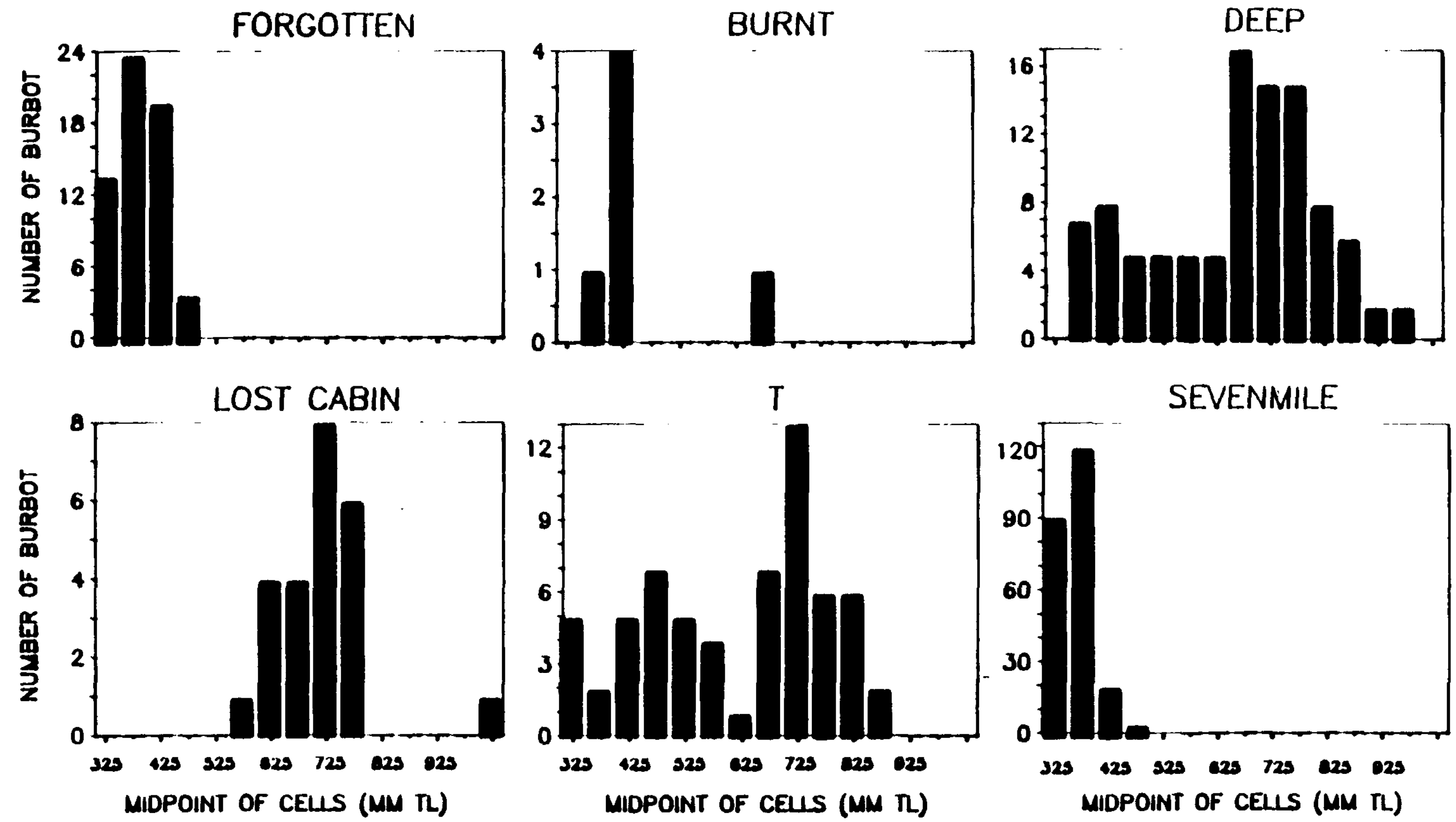

Figure 3. Length-frequency histograms of burbot captured during all sampling events in 1987 in which size distributions were not significantly different (see text)(continued).

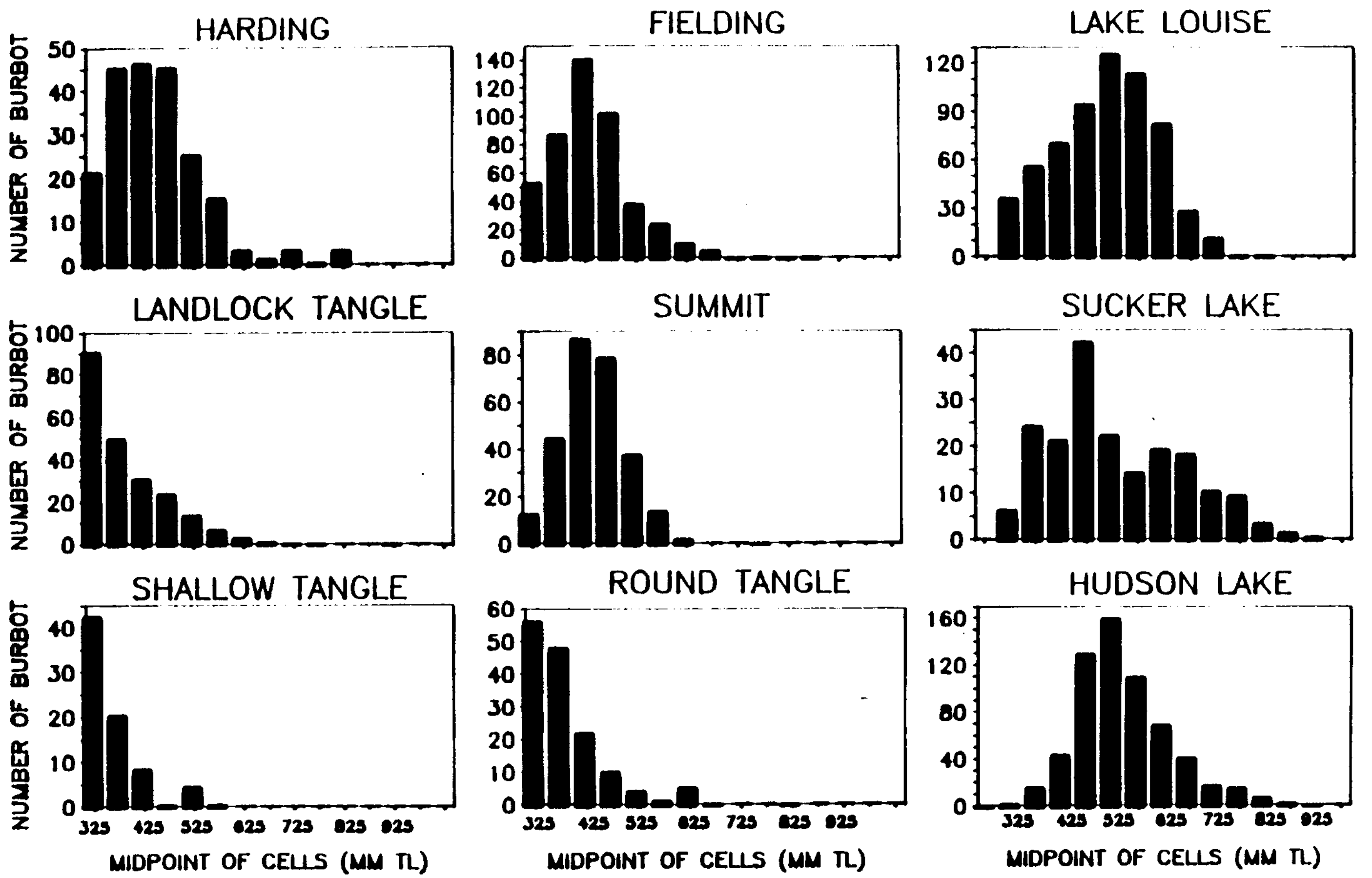

Figure 3. Length-frequency histograms of burbot captured during all sampling events in 1987 in which size distributions were not significantly different (see text).

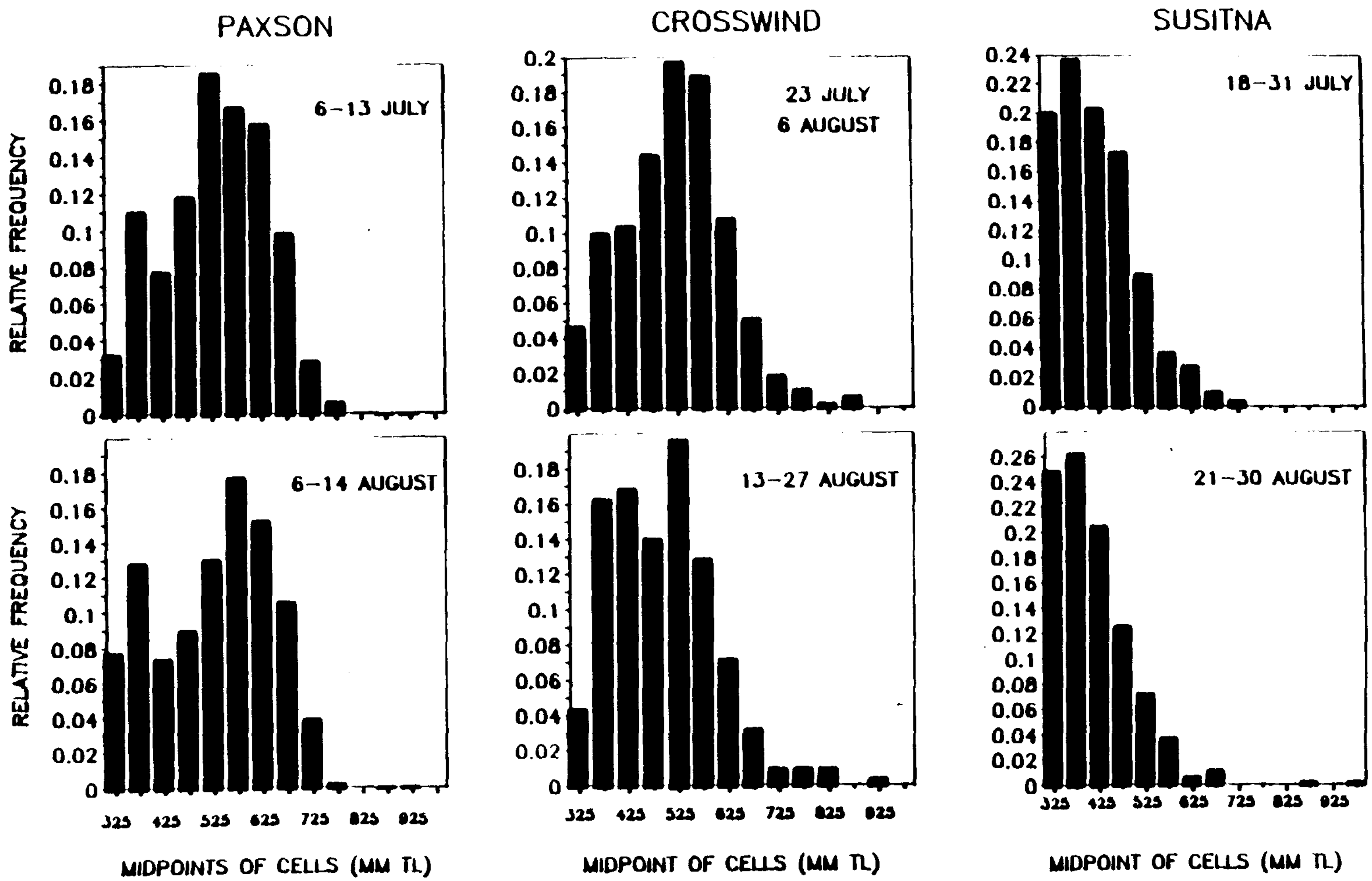

Figure 4. Length-frequency histograms of burbot captured during all sampling events in 1987 in which size distributions were significantly different (see text).

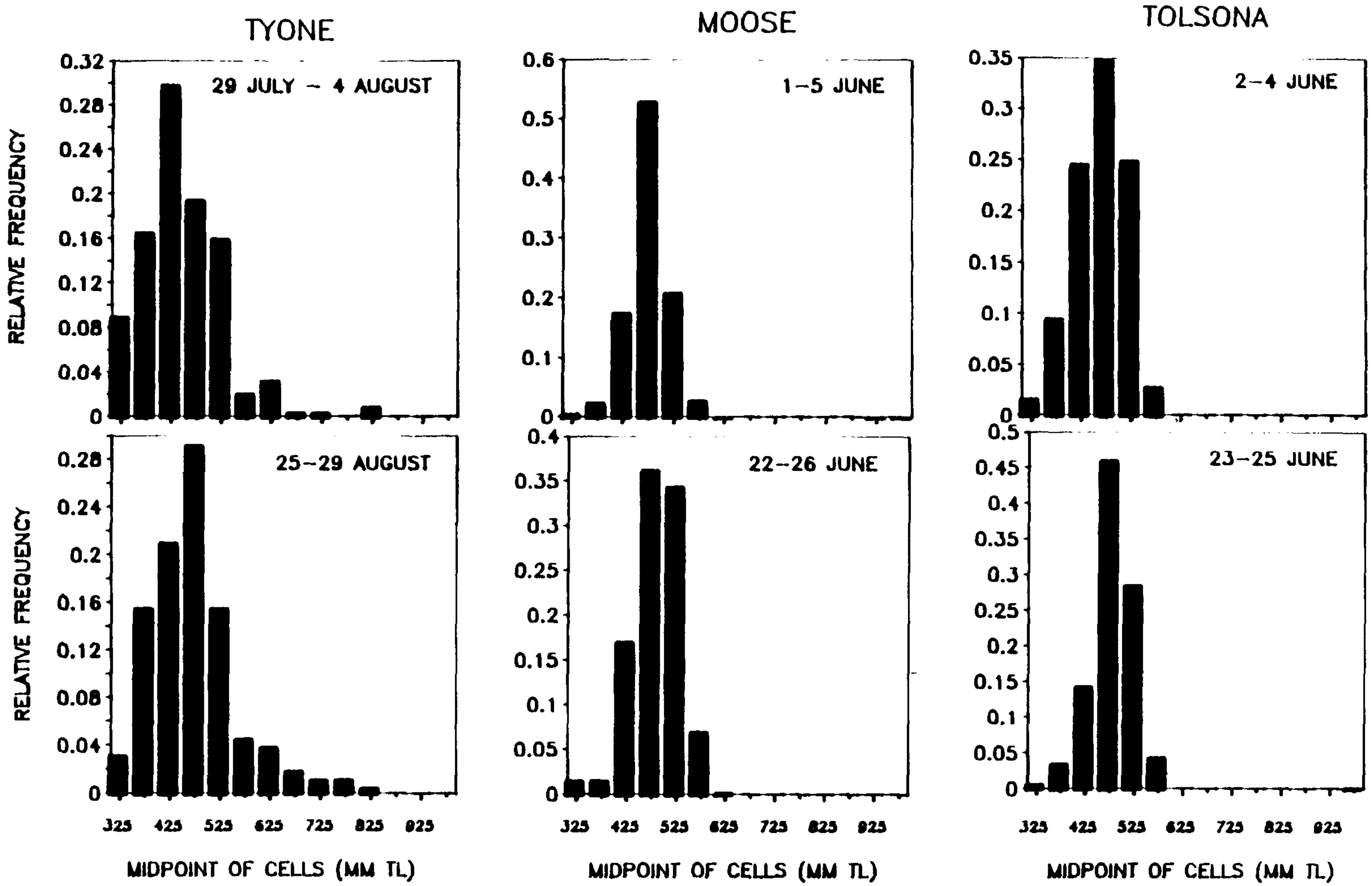

Figure 4. Length-frequency histograms of burbot captured during all sampling events in 1987 in which size distributions were significantly different (see text) (continued).

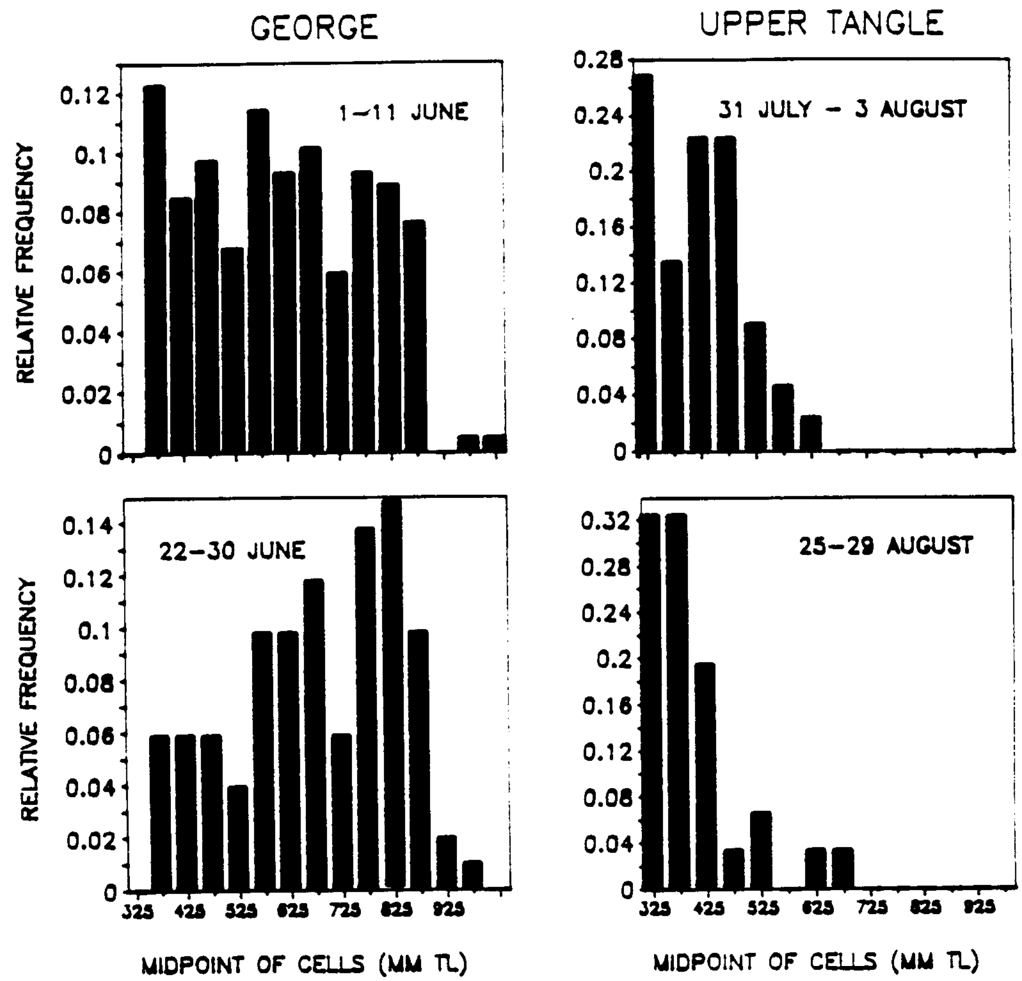

Figure 4. Length-frequency histograms of burbot captured during all sampling events in 1987 in which size distributions were significantly different (see text) (continued).

Table 3. Estimated abundance (N) of burbot partially and fully recruited to sampling gear from 22 lakes in interior Alaska in 1987.

Lake	Size[1]	Number of Marked Burbot Released	Number Caught Second Event	Number Recaptured	$\hat{N}$	SE[$\hat{N}$]	CV[$\hat{N}$][2]
Burnt	fully	1	2	0			
	partially	3	0	0			
Crosswind	fully	165	109	4	3,651	1,434	39.3%
	partially	47	67	0			
Deep	fully	53	27	2	503	231	46.0%
	partially	13	7	0			
Forgotten	fully	2	2	2	2	0	0.0%
	partially	33	25	6	125	34	27.0%
Hudson	fully	337	238	21	3,671	705	19.2%
	partially	39	26	0			
Lost Cabin	fully	20	4	2	34	10	29.7%
	partially	0	0	0			
Louise	fully	264	217	10	5,251	1,446	27.5%
	partially	72	59	1	2,189	1,226	56.0%
Moose	fully	653	173	50	2,230	249	11.1%
	partially	183	46	10	785	192	24.5%
Paxson	fully	571	351	61	3,246	351	10.8%
	partially	157	140	4	4,455	1,758	39.5%
Sucker	fully	100	48	5	824	283	34.4%
	partially	42	12	0			
Summit	fully	74	63	7	599	177	29.5%
	partially	64	75	3	1,234	521	42.2%
Susitna	fully	111	61	1	3,471	1,954	56.3%
	partially	200	165	0			
Tolsona	fully	393	170	64	1,036	92	8.9%
	partially	228	41	11	801	183	22.8%

- Continued -

Table 3. Estimated abundance (N) of burbot partially and fully recruited to sampling gear from 22 lakes in interior Alaska in 1987 (continued).

Lake	Size[1]	Number of Marked Burbot Released	Number Caught Second Event	Number Recaptured	$\hat{N}$	SE[$\hat{N}$]	CV[$\hat{N}$]
Tyone	fully	75	87	3	1,671	711	42.5%
	partially	97	59	0			
Fielding	fully	105	81	34	247	26	10.5%
	partially	131	150	12	1,532	372	24.3%
George	fully	166	84	7	1,773	549	31.0%
	partially	72	18	1	693	373	53.9%
Landlock Tangle	fully	33	25	2	294	132	45.0%
	partially	76	79	2	2,052	987	48.1%
Round Tangle	fully	17	9	3	44	14	30.9%
	partially	78	48	2	1,289	613	47.5%
Sevenmile	fully	0	0	0			
	partially	59	140	8	939	265	28.2%
Shallow Tangle	fully	2	4	0			
	partially	44	27	1	629	342	54.4%
T	fully	23	24	14	39	4	10.1%
	partially	8	4	1	22	9	40.3%
Upper Tangle	fully	17	5	1	53	24	44.9%
	partially	28	26	1	391	210	53.7%

[1] For most populations, burbot ≥ 450 mm TL were considered fully recruited to the gear while smaller fish were considered to be partially recruited.

[2] Coefficient of variation.

and Paxson Lake followed with 3,671, 3,651, and 3,246 burbot, respectively. The population in Sevenmile Lake had no "fully recruited" burbot at all. Paxson Lake contained the largest number of partially recruited burbot (4,455) with Lake Louise and Landlock Tangle next (2,189 and 2,052, respectively). Populations of fully recruited burbot in Moose, Tolsona, and Hudson Lakes were the most dense (Table 4) with the population in Sevenmile and Forgotten Lakes having that distinction for partially recruited burbot. Generally, the deeper lakes contained the less dense populations of burbot of all sizes.

All of the populations studied in 1987 are geographically closed or separated by lengthy rivers except for populations in Louise, Susitna, and Tyone Lakes; those in Upper, Round, and Shallow Tangle Lakes; and those in Summit and Paxson Lakes. These three sets of lakes are joined directly or by a short river. Three burbot first released in Tyone Lake in 1986 were recaptured in Susitna Lake in 1987. All three were recaptured near the strait that connects the two lakes. These fish were excluded from data from the population in Lake Louise. There is no other instance of migration between lakes within 1986 or within 1987.

No growth recruitment between sampling events was found for populations in Fielding, T, or Paxson Lake ($\alpha = 0.10$). The hiatus between sampling events in these three lakes were 27, 87, and 31 days, respectively. Burbot of all sizes were used in the tests. No other populations were checked for growth recruitment because the hiatus between sampling events was shorter or there were few recaptured fish.

Even though 43 burbot of all sizes lost their tags, they were identified as recaptured fish by their clipped fins. The loss rate was 5.4% between sampling events in the same year pooled over all populations (Table 5). The loss rate was higher between sampling events separated by a winter (16.3%). The loss rate for fish free for two winters in Fielding Lake was 11.0% with a SE of 3.3% (10 tags lost out of 91 recaptured fish). There was no evidence of regenerated fins on any of the recaptured burbot with tags.

The overwinter and annual survival rates of fully recruited burbot ranged from 46.3% in Lake Louise to 61.2% in Paxson Lake (Table 6, Figure 5). The SEs for all of the estimates were approximately 10% except for the rate in Lake Louise which was near 20%. The bootstrap samples for the population in Lake Louise were highly skewed leftward. Because of this imprecision in the survival rate, the estimate of growth recruitment to the population in Lake Louise has a coefficient of variation (CV) greater than 100% (2,015 estimated recruits with a SE of 2,739). Although the precision of the survival rate was much better for the population in Paxson Lake, the estimated recruitment was negative (-2,330 with a SE of 1,572). This impossible situation is most likely the result of the imprecision in the estimate of abundance for 1986. Analysis of data from Moose Lake was not included in this report pending a review of those data collected in 1986. Mark-recapture histories for all populations are in Appendix Tables 1-4.

Table 4. Estimated density of burbot in 22 lakes in interior Alaska during 1987.

Fully Recruited[1]			Partially Recruited		
Lake	Number per ha	SE	Lake	Number per ha	SE
Moose	17.2	1.9	Sevenmile	27.6	8.2
Hudson	14.2	2.8	Forgotten	17.9	5.1
Tolsona	8.0	0.7	Landlock Tangle	9.4	5.2
Tyone	4.3	2.0	Round Tangle	8.3	4.6
Sucker	2.9	1.1	Tolsona	6.2	1.5
Paxson	2.1	0.2	Moose	6.0	1.5
Landlock Tangle	1.9	0.7	Shallow Tangle	4.8	3.2
Deep	1.7	0.9	Paxson	2.8	1.1
Crosswind	1.1	0.5	Upper Tangle	2.8	1.8
Lost Cabin	1.0	0.3	Fielding	2.8	0.7
George	1.0	0.3	Summit	0.7	0.4
Susitna	0.9	0.6	George	0.4	0.3
Louise	0.8	0.2	Louise	0.3	0.2
Fielding	0.5	0.0	T	0.1	0.1
Upper Tangle	0.4	0.2			
Summit	0.4	0.1	Burnt	0	
Round Tangle	0.3	0.1	Crosswind	0	
Forgotten	0.3	0.0	Deep Lake	0	
T	0.2	0.0	Lost Cabin	0	
			Hudson	0	
Burnt	0		Sucker	0	
Shallow Tangle	0		Susitna	0	
Seven Mile	0		Tyone	0	

[1] For most populations, burbot $\geq$ 450 mm TL were considered fully recruited to the gear while smaller fish were considered to be partially recruited.

Table 5. Rates of tag loss for burbot in interior Alaska.

Lakes	During Summer Recaptured w/o Tags	All	Fraction w/o Tags	SE	Overwinter Recaptured w/o Tags	All	Fraction w/o Tags	SE
Burnt	0	9	0.000	0.000	1	2	0.500	0.500
Crosswind	0	4	0.000	0.000				
Deep	0	2	0.000	0.000				
Fielding	0	124	0.000	0.000	15	145	0.103	0.025
Forgotten	0	43	0.000	0.000	5	23	0.217	0.088
George	0	8	0.000	0.000				
Harding					2	17	0.118	0.081
Hudson	2	23	0.087	0.060				
Landlock Tangle	0	5	0.000	0.000	3	5	0.600	0.245
Lost Cabin	0	4	0.000	0.000				
Louise	1	19	0.053	0.053	4	17	0.235	0.106
Moose	32	166	0.193	0.031	43	117	0.368	0.045
Paxson	1	101	0.010	0.010	6	109	0.055	0.022
Round Tangle	0	11	0.000	0.000	3	12	0.250	0.131
Sevenmile	2	18	0.111	0.076	15	46	0.326	0.070
Shallow Tangle	0	2	0.000	0.000	0	0		
Sucker	2	5	0.400	0.245				
Summit	1	23	0.043	0.043	2	12	0.167	0.112
Susitna	0	1	0.000		1	3	0.333	0.333
T	0	15	0.000	0.000	1	1	1.000	
Tolsona	0	213	0.000	0.000	1	113	0.009	0.009
Tyone	1	5	0.200	0.200	0	4	0.000	0.000
Upper Tangle	1	2	0.500	0.500	1	5	0.200	0.200
TOTAL	43	803	0.054	0.008	103	631	0.163	0.015

Table 6. Estimates of survival rates, recruitment, and abundance from Jolly-Seber and other methods for four populations of burbot (longer than 449 mm TL) from Interior Alaska.

	First Event Abundance N	R	Survival Rate Period	Survival Rate Daily	Second Event Abundance N	R	Survival Rate Period	Survival Rate Daily	Third Event Abundance N	R	Survival Rate Period	Survival Rate Daily	Fourt Event Abundance N
FIELDING	10/5/84[1]		355[2]		9/25/85		332		9/2/86		325		7/24/88
Estimate	N/A		55.5%	99.8%	279	209	61.1%	99.9%	365	45[3]	55.3%[4]	99.8%	247[5]
SE			10.6%	0.1%	71	79	9.9%	0.1%	72	61	10.5%		27
TOLSONA	9/25/86		14		10/9/86		237		6/3/87				
Estimate	1,901[6]	6[3]	98.4%	99.9%	1,877	481	55.4%	99.8%	1,336				
SE	120	398	13.4%	1.0%	282	144	10.8%	0.1%	212				
PAXSON	7/10/86		365		7/10/87								
Estimate	9,111[6]	(2,330)[3]	61.2%[4]	99.7%	3,246								
SE	1,996	1,572	10.4%		351								
LOUISE	6/27/86		381		7/13/87								
Estimate	6,990[6]	2,015[3]	46.3%[4]	99.8%	5,251								
SE	2,131	2,739	19.8%		2,189								

1 Date of the middle of each sampling event or group of sampling events.
2 Number of days between sampling events.
3 Estimated through Equation 8.
4 Estimated through bootstrap on Equation 7.
5 Estimated with Equation 1 on sampling events wholly within 1987.
6 Statistics from Parker et al. (1987).

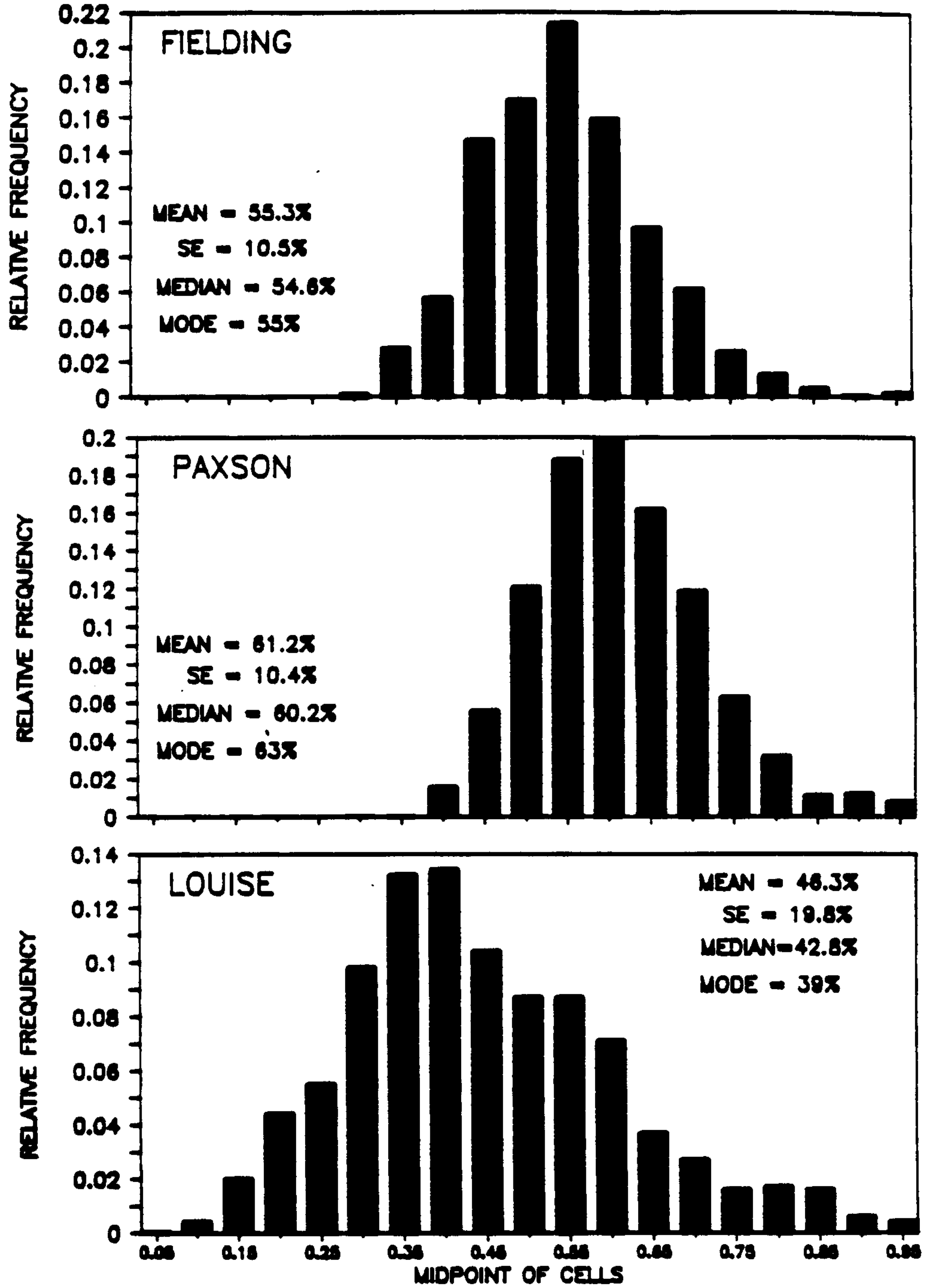

Figure 5. Distribution of bootstrap samples used to estimate overwinter survival rates of fully recruited burbot in Louise, Fielding, and Paxson Lakes from 1986 to 1987.

Mean CPUE

Because abundance estimates were split into partially and fully recruited burbot, so too were estimates of mean CPUE. Mean CPUE ranged from 5.75 fully recruited burbot per set in Moose Lake for the sampling event in early June to 0.03 in Shallow Tangle Lake in late July (Table 7). No fully recruited burbot were caught in Sevenmile Lake. Mean CPUE for partially recruited burbot ranged from 3.55 and 3.47 in Tolsona and Forgotten Lakes, respectively, to 0.04 in T and George Lakes (Table 8). No burbot <450 mm TL were captured in Lost Cabin or Burnt Lakes. Post-stratification of CPUE by depth was tried for fully recruited burbot in Deep Lake (second sampling event) and in Shallow Tangle Lake (second event). Post-stratification by depth was tried for partially recruited burbot captured during the first sampling events in Crosswind, Landlock Tangle, Harding, and Paxson Lakes and both events in Deep and George Lakes. Since post-stratification did not significantly change estimates of mean CPUE in any of these cases, the unstratified estimates are listed in Tables 7 and 8. Frequency of sets by depth and of average catch by depth of fully and partially recruited burbot are in Appendix Figures 1-9 for most lakes.

Burbot in most deep lakes were concentrated shortly after the spring thaw then dispersed for the summer. For instance, average catches of fully recruited burbot were higher in the shallows of Paxson Lake in early to mid July while average catches of smaller burbot during the same sampling event were greater in the depths of the lake (Figure 6); yet by mid-August all burbot had dispersed and mixed through all depths. A similar situation occurred in Lake Louise (see Appendix Figure 7). All burbot were concentrated in the depths of Harding Lake in mid June (see Appendix Figure 2). Burbot were distributed in the shallower George Lake like those of the deeper Paxson Lake during sampling events in early and in late June (see Appendix Figure 5). During sampling in Landlock Tangle Lake in early July, fully recruited burbot were caught in the shallows while smaller burbot were caught in deeper water (see Appendix Figure 6); 1 month later, burbot of all sizes were concentrated in shallow water. Other lakes were either sampled only in July and August and have populations dispersed through all depths, or are too shallow for comparisons of average catch by depth.

Mean CPUE also changed seasonally among sampling events by declining in summer (Table 9). Of the 22 populations with estimates of mean CPUE for each sampling event, there was a drop in mean CPUE in 18 populations between sampling events for fully recruited burbot. Of those 18, eight had drops that were at least twice the CV of the estimates of mean CPUE with an average decline of 48.7%. Sampling began on 2 June on these eight populations and had concluded by 27 August. Mean CPUE of fully recruited burbot declined the most (74%) between early and late June in Moose Lake. A similar situation occurred for partially recruited burbot. Of the 20 populations with estimates for each sampling event, there were declines of mean CPUE of partially recruited burbot in 17 populations.

Table 7. Estimated mean CPUE of burbot fully recruited to the sampling gear (≥450 mm TL) from stratified and unstratified random and systematic sampling events in all populations studied in 1987.

Lakes and Dates	Strata	Number of Sets and	Transects	Mean CPUE Unbiased	Biased	%Δ	Biased Mean CPUE SE	CV
BURNT[1]								
8/08-10	All depths	20		0.05			0.05	100.0%
9/12-14	All depths	19		0.11			0.07	63.6%
CROSSWIND								
7/23-8/06	All depths	337	33	0.59	0.57	-3.4%	0.07	12.3%
8/13-27	All depths	381	38	0.30	0.31	3.3%	0.05	16.1%
DEEP								
7/18-22	All depths	97	15	0.58	0.64	10.3%	0.16	25.0%
8/07-11	All depths	96	15	*0.29*[2]	*0.27*	*-6.9%*	*0.09*	*33.3%*
FIELDING								
7/21-27	All depths	239	40	0.49	0.45	-8.2%	0.08	17.8%
8/17-22	All depths	233	39	0.36	0.30	-16.7%	0.06	20.0%
FORGOTTEN[1]								
8/08-10	All depths	10		0.32			0.16	50.0%
9/12-24	All depths	10		0.19			0.19	100.0%
GEORGE								
6/01-11	All depths	422	35	0.39	0.33	-15.4%	0.06	18.2%
6/22-30	All depths	418	28	0.21	0.18	-14.3%	0.05	27.8%
HARDING								
6/16-20	All depths	234	16	0.45	0.41	-8.9%	0.07	17.1%
HUDSON								
6/15-19	All depths	99	16	3.69	3.90	5.7%	0.41	10.5%
7/06-10	All depths	87	15	2.96	2.81	-5.1%	0.29	10.3%
LANDLOCK TANGLE[1,3]								
6/30-7/06	All depths	208		0.12			0.03	25.0%
8/02-07	All depths	216	31	0.13	0.12	-7.7%	0.05	41.7%
LOST CABIN								
6/09-11	All depths	28	11	0.70	0.68	-2.9%	0.18	26.5%
6/30-7/02	All depths	26	9	0.15	0.15	0.0%	0.11	73.3%

-Continued-

Table 7. Estimated mean CPUE of burbot fully recruited to the sampling gear (≥450 mm TL) from stratified and unstratified random and systematic sampling events in all populations studied in 1987 (continued).

Lakes and Dates	Strata	Number of Sets and	Transects	Mean CPUE Unbiased	Biased	%Δ	Biased Mean CPUE SE	CV
LOUISE								
7/06-20	All depths	543	38	0.61	0.57	-6.6%	0.07	12.3%
8/02-19	All depths	543	38	0.42	0.41	-2.4%	0.06	14.6%
MOOSE								
6/01-05	All depths	117	18	5.75	5.76	0.2%	0.64	11.1%
6/22-26	All depths	118	18	1.50	1.57	4.7%	0.25	15.9%
PAXSON								
7/06-13	All depths	358	47	1.79	1.77	-1.1%	0.15	8.5%
8/06-14	All depths	414	56	0.89	0.87	-2.2%	0.09	10.3%
ROUND TANGLE								
7/27-30	All depths	97	18	0.16	0.15	-6.3%	0.06	40.0%
8/22-25	All depths	118	15	0.08	0.08	0.0%	0.04	50.0%
SHALLOW TANGLE								
7/29-8/01	All depths	96	31	0.03	0.02	-33.3%	0.02	100.0%
8/24-30	All depths	83	20	0.04	0.04	0.0%	0.03	75.0%
SUCKER								
6/10-14	All depths	103	19	0.98	0.86	-12.2%	0.15	17.4%
6/29-7/01	All depths	64	16	0.60	0.56	-6.7%	0.12	21.4%
SUMMIT								
7/13-21	All depths	393	67	0.20	0.19	-5.0%	0.04	21.1%
9/02-10	All depths	391	66	0.18	0.18	0.0%	0.04	22.2%
SUSITNA								
7/18-31	All depths	541	68	0.22	0.24	9.1%	0.04	16.7%
8/21-30	All depths	539	68	0.12	0.13	8.3%	0.03	23.1%
T								
5/26-6/01	All depths	60	7	0.39	0.35	-10.3%	0.15	42.9%
9/21-25	All depths	90	11	0.30	0.30	0.0%	0.12	40.0%
TOLSONA								
6/02-04	All depths	58	12	6.15	5.71	-7.2%	0.75	13.1%
6/23-25	All depths	59	12	2.79	2.62	-6.1%	0.47	17.9%

-Continued-

Table 7. Estimated mean CPUE of burbot fully recruited to the sampling gear (≥450 mm TL) from stratified and unstratified random and systematic sampling events in all populations studied in 1987 (continued).

Lakes and Dates	Strata	Number of Sets and Transects		Mean CPUE Unbiased	Mean CPUE Biased	%Δ	Biased Mean CPUE SE	Biased Mean CPUE CV
TYONE								
7/29-8/04	All depths	196	37	0.39	0.41	5.1%	0.08	19.5%
8/28-9/01	All depths	194	41	0.49	0.51	4.1%	0.13	25.5%
UPPER TANGLE								
7/31-8/03	All depths	90	28	0.14	0.15	7.1%	0.06	40.0%
8/25-29	All depths	117	31	0.04	0.02	-50.0%	0.02	100.0%

[1] All sampling events were systematic except for those on Burnt and Forgotten Lakes and the first sampling event on Landlock Tangle Lake.

[2] Those instances when stratified estimates were tried but not used (see text) are designated with unstratified estimates written in italics.

[3] The numbers of burbot handled during the mark-recapture experiments in Landlock Tangle Lake are larger than those used to estimate mean CPUE. Burbot that were incidentally captured in gear set for lake trout in these lakes were included in the mark-recapture experiment because they were caught at the same time as were those from the survey design.

Table 8. Estimated mean CPUE of burbot partially recruited to the sampling gear (<450 mm TL) from stratified and unstratified random and systematic sampling events in all populations studied in 1987.

Lakes and Dates	Strata	Number of Sets and Transects		Mean CPUE Unbiased	Mean CPUE Biased	%Δ	Biased Mean CPUE SE	Biased Mean CPUE CV
BURNT[1]								
8/08-10	All depths	20		0.16			0.09	56.3%
9/12-14	All depths	19		0				
CROSSWIND								
7/23-8/06	All depths	337	33	0.22[2]	0.18	-18.2%	0.04	22.2%
8/13-27	All depths	381	38	0.19	0.15	-21.1%	0.04	26.7%
DEEP								
7/18-22	All depths	97	15	0.12	0.14	16.7%	0.07	50.0%
8/07-11	All depths	96	15	0.07	0.05	-28.6%	0.04	80.0%
FIELDING								
7/21-27	All depths	239	40	0.56	0.52	-7.1%	0.07	13.5%
8/17-22	All depths	233	39	0.65	0.60	-7.7%	0.09	15.0%
FORGOTTEN[1]								
8/08-10	All depths	10		3.47			0.39	11.2%
9/12-24	All depths	10		2.40			0.47	19.6%
GEORGE								
6/01-11	All depths	422	35	0.17	0.14	-17.6%	0.04	28.6%
6/22-30	All depths	418	28	0.04	0.04	0.0%	0.02	50.0%
HARDING								
6/16-20	All depths	234	16	0.49	0.47	-4.1%	0.10	21.3%
HUDSON								
6/15-19	All depths	99	16	0.42	0.41	-2.4%	0.10	24.4%
7/06-10	All depths	87	15	0.31	0.42	35.5%	0.14	33.3%
LANDLOCK TANGLE[1,3]								
6/30-7/06	All depths	208		0.44			0.05	11.4%
8/02-07	All depths	216	31	0.41	0.42	2.4%	0.09	21.4%
LOST CABIN								
6/09-11	All depths	28	11	0				
6/30-7/02	All depths	26	9	0				

-Continued-

Table 8. Estimated mean CPUE of burbot partially recruited to the sampling gear (<450 mm TL) from stratified and unstratified random and systematic sampling events in all populations studied in 1987 (continued).

Lakes and Dates	Strata	Number of Sets and	Transects	Mean CPUE Unbiased	Biased	%Δ	Biased Mean CPUE SE	CV
LOUISE								
7/06-20	All depths	543	38	0.20	0.22	10.0%	0.07	31.8%
8/02-19	All depths	543	38	0.15	0.20	33.3%	0.06	30.0%
MOOSE								
6/01-05	All depths	117	18	1.63	1.65	1.2%	0.28	17.0%
6/22-26	All depths	118	18	0.36	0.42	16.7%	0.12	28.6%
PAXSON								
7/06-13	All depths	358	47	0.52	0.53	1.9%	0.09	17.0%
8/06-14	All depths	414	56	0.36	0.38	5.6%	0.05	13.2%
ROUND TANGLE								
7/27-30	All depths	97	18	0.82	0.76	-7.3%	0.12	15.8%
8/22-25	All depths	118	15	0.43	0.47	9.3%	0.13	27.7%
SEVENMILE[3]								
6/16-20	All depths	30	8	1.66	1.60	-3.6%	0.54	33.8%
7/31-8/06	All depths	40	11	1.67	1.59	-4.8%	0.41	25.8%
SHALLOW TANGLE								
7/29-8/01	All depths	96	31	0.53	0.33	-37.7%	0.14	42.4%
8/24-30	All depths	83	20	0.35	0.33	-5.7%	0.09	27.3%
SUCKER								
6/10-14	All depths	103	19	0.44	0.39	-11.4%	0.11	28.2%
6/29-7/01	All depths	64	16	0.14	0.16	14.3%	0.08	50.0%
SUMMIT								
7/13-21	All depths	393	67	0.18	0.20	11.1%	0.05	25.0%
9/02-10	All depths	391	66	0.18	0.19	5.6%	0.04	21.1%
SUSITNA								
7/18-31	All depths	541	68	0.41	0.46	12.2%	0.07	15.2%
8/21-30	All depths	539	68	0.31	0.35	12.9%	0.06	17.1%
T								
5/26-6/01	All depths	60	7	0.17	0.17	0.0%	0.07	41.2%
9/21-25	All depths	90	11	0.04	0.04	0.0%	0.04	100.0%

-Continued-

Table 8. Estimated mean CPUE of burbot partially recruited to the sampling gear (<450 mm TL) from stratified and unstratified random and systematic sampling events in all populations studied in 1987 (continued).

Lakes and Dates	Strata	Number of Sets and	Transects	Mean CPUE Unbiased	Biased	%Δ	Biased Mean CPUE SE	CV
TOLSONA								
6/02-04	All depths	58	12	3.55	3.56	0.3%	0.61	17.1%
6/23-25	All depths	59	12	0.64	0.65	1.6%	0.15	23.1%
TYONE								
7/29-8/04	All depths	196	37	0.51	0.55	7.8%	0.12	21.8%
8/28-9/01	All depths	194	41	0.31	0.29	-6.5%	0.07	24.1%
UPPER TANGLE								
7/31-8/03	All depths	90	28	0.29	0.23	-20.7%	0.09	39.1%
8/25-29	All depths	117	31	0.23	0.20	-13.0%	0.07	35.0%

[1] All sampling events were systematic except for those on Burnt and Forgotten Lakes and the first sampling event on Landlock Tangle Lake.

[2] Those instances when stratified estimates were tried but not used (see text) are designated with unstratified estimates written in italics.

[3] The numbers of burbot handled during the mark-recapture experiments in Landlock Tangle and Sevenmile Lakes are larger than those used to estimate mean CPUE. Burbot that were incidentally captured in gear set for lake trout in these lakes were included in the mark-recapture experiment because they were caught at the same time as were those from the survey design.

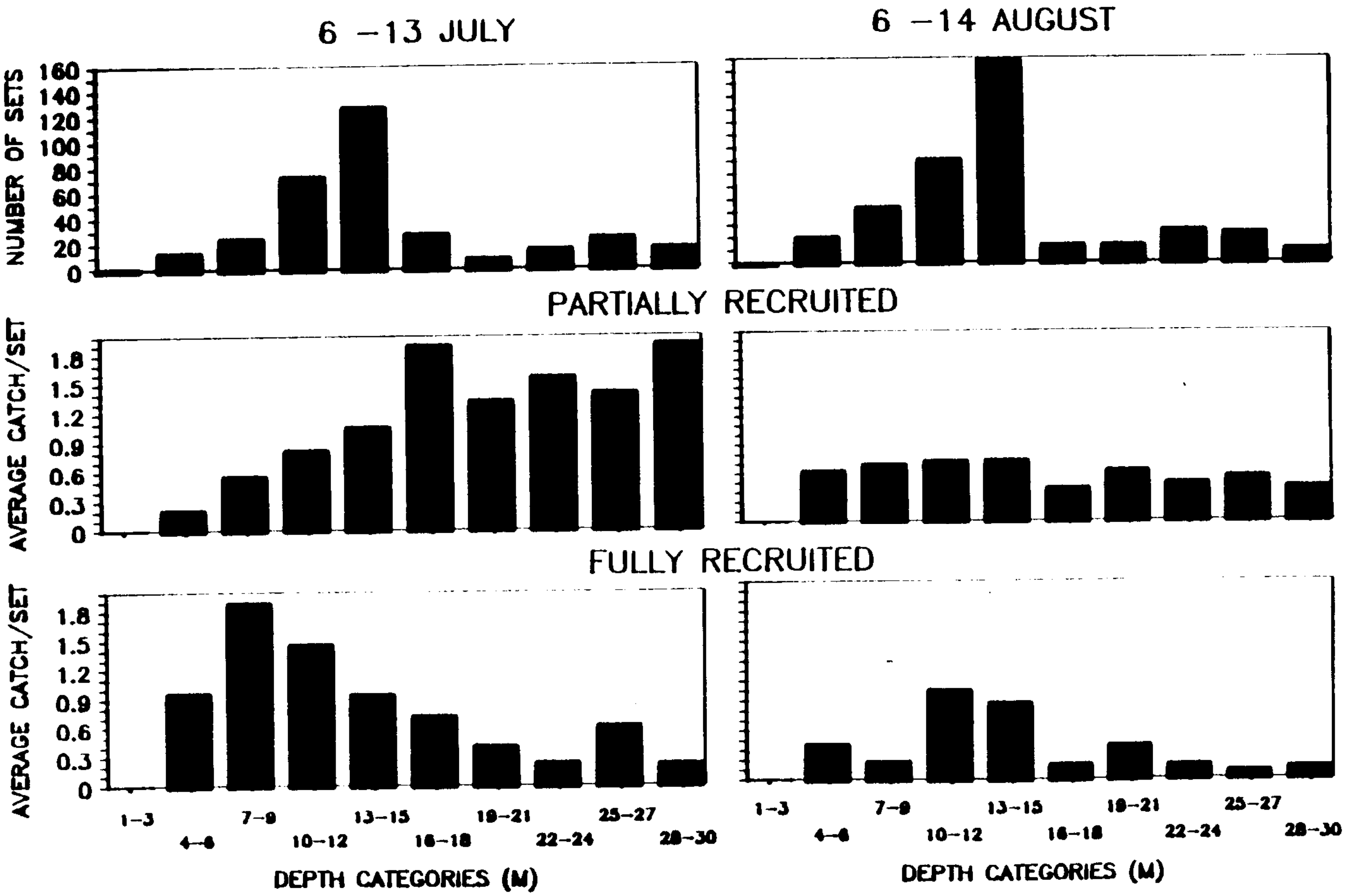

Figure 6. Frequency of sets by depth and average catch by depth of partially (<450 mm TL) and fully recruited (≥450 mm TL) burbot for the sampling events in Paxson Lake in 1987.

Table 9. Change in mean CPUE of fully (<450 mm TL) and partially recruited (≥450 mm TL) burbot between sampling events in 22 lakes sampled in 1987.

	Fully Recruited				Partially Recruited			
Lake and Dates	Unbiased Mean CPUE	%Δ	Average[1] CV	%Δ/CV	Unbiased Mean CPUE	%Δ	Average[1] CV	%Δ/CV
PAXSON								
7/06-13	1.79				0.52			
8/06-14	0.89	-50.3%	9.2%	5.4	0.36	-30.8%	15.1%	2.0
MOOSE								
6/01-05	5.75				1.63			
6/22-26	1.50	-73.9%	13.9%	5.3	0.36	-77.9%	22.8%	3.4
TOLSONA								
6/02-04	6.15				3.55			
6/23-25	2.79	-54.6%	14.5%	3.8	0.64	-82.0%	20.1%	4.1
CROSSWIND								
7/23-8/06	0.59				0.22			
8/13-27	0.30	-49.2%	14.3%	3.4	0.19	-13.6%	24.4%	<1
LOUISE								
7/06-20	0.61				0.20			
8/02-19	0.42	-31.1%	12.9%	2.4	0.15	-25.0%	30.9%	<1
GEORGE								
6/01-11	0.39				0.17			
6/22-30	0.21	-46.2%	19.6%	2.4	0.04	-76.5%	39.3%	1.9
SUCKER								
6/10-14	0.98				0.44			
6/29-7/01	0.60	-38.8%	17.7%	2.2	0.14	-68.2%	39.1%	1.7
SUSITNA								
7/18-31	0.22				0.41			
8/21-30	0.12	-45.5%	21.6%	2.1	0.31	-24.4%	16.2%	1.5
HUDSON								
6/15-19	3.69				0.42			
7/06-10	2.96	-19.8%	10.5%	1.9	0.31	-26.2%	28.9%	<1
DEEP								
7/18-22	0.58				0.12			
8/07-11	0.29	-50.0%	29.3%	1.7	0.07	-41.7%	65.0%	<1
FIELDING								
7/21-27	0.49				0.56			
8/17-22	0.36	-26.5%	16.5%	1.6	0.65	16.1%	14.2%	1.1
LOST CABIN								
6/09-11	0.70							
6/30-7/02	0.15	-78.6%	49.5%	1.6				
UPPER TANGLE								
7/31-8/03	0.14				0.29			
8/25-29	0.04	-71.4%	46.4%	1.5	0.23	-20.7%	37.1%	<1

–Continued–

Table 9. Change in mean CPUE of fully (<450 mm TL) and partially recruited (≥450 mm TL) burbot between sampling events in 22 lakes sampled in 1987 (continued).

Lake and Dates	Fully Recruited				Partially Recruited			
	Unbiased Mean CPUE	%Δ	Average CV	%Δ/CV	Unbiased Mean CPUE	%Δ	Average CV	%Δ/CV
BURNT								
8/08-10	0.05							
9/12-14	0.11	120.0%	81.8%	1.5				
ROUND TANGLE								
7/27-30	0.16				0.82			
8/22-25	0.08	-50.0%	43.8%	1.1	0.43	-47.6%	21.7%	2.2
TYONE								
7/29-8/04	0.39				0.51			
8/28-9/01	0.49	25.6%	23.5%	1.1	0.31	-39.2%	23.0%	1.7
FORGOTTEN								
8/08-10	0.32				3.47			
9/12-24	0.19	-40.6%	75.0%	<1	2.40	-30.8%	15.4%	2.0
LANDLOCK TANGLE								
6/30-7/06	0.12				0.44			
8/02-07	0.13	8.3%	33.3%	<1	0.41	-6.8%	16.4%	<1
SHALLOW TANGLE								
7/29-8/01	0.03				0.53			
8/24-30	0.04	33.3%	87.5%	<1	0.35	-34.0%	34.8%	1.0
T								
5/26-6/01	0.39				0.17			
9/21-25	0.30	-23.1%	41.4%	<1	0.04	-76.5%	70.6%	1.1
SUMMIT								
7/13-21	0.20				0.18			
9/02-10	0.18	-10.0%	21.6%	<1	0.18	0.0%	23.0%	<1
SEVENMILE								
6/16-20					1.66			
7/31-8/06					1.67	0.6%	29.8%	<1

[1] The coefficients of variation are based on the SE of the biased estimates in Tables 5 and 6.

Six of these 17 had declines that were at least twice their CV; these populations had an average decline of 51.4%. Sampling on these six populations began 2 June and ended 14 September. Mean CPUE of partially recruited burbot declined the most (82%) between early and late June in Tolsona Lake.

Mean CPUE has a monotonically increasing relationship with the density in burbot per ha for both fully and partially recruited burbot (Figure 7). Only the estimates of mean CPUE for the first sampling events were used in this comparison because the abundance estimates corresponded to these events. Estimates for fully recruited burbot from Lake Louise, from all the Tangle Lakes, and from T, George, Forgotten, Fielding, Summit, Crosswind, Deep, Lost Cabin, and Susitna Lakes were grouped below two burbot per ha and one burbot per set. Estimates for partially recruited burbot from Shallow and Upper Tangle, Paxson, Fielding, Summit, George, and T Lakes and from Lake Louise were grouped below four burbot per ha and one burbot per set.

Age and Length

Mean length of large and small burbot varied among lakes and among sampling events in lakes (Table 10). T, Deep, and Lost Cabin Lakes contained on average the largest burbot fully recruited to the gear over both events (696, 714, and 695 mm TL, respectively) with populations in Paxson and George Lakes the next largest (627 and 678 mm TL, respectively). Forgotten Lake contained the smallest of the fully recruited burbot (467 mm TL). All the estimates of mean lengths of fully recruited burbot based on large sample sizes were similar between sampling events in the same lake except for populations in George, Landlock Tangle, T, Crosswind, and Moose Lakes. The mean length decreased between events in Landlock Tangle and Crosswind Lakes; it increased in George, T, and Moose Lakes.

Information on age and sex composition and mean length at age were reported for populations for which data from at least 20 fish were available (Table 11). Standard errors for estimates of length at age are in Appendix Table 6. Recognition of the sex of burbot by inspection of their gonads proved quite difficult. Differences between gonads of different "sexes" were subtle. Since these data were collected long after the spawning season had ended (February - April), there was no chance to verify the accuracy of our determinations.

Only enough information was collected to estimate the parameters in the allometric length-weight relationships for populations in Crosswind and in Fielding Lakes (Figure 8). Data from other populations were too few or were of too short a range to provide dependable estimates (see Appendix Figures 17-18). Under these circumstances, the algorithm used to estimate parameters could converge only to a broad range of estimates of near equal predictive qualities or could not converge at all. Data from Crosswind Lake were collected in 1987; data from Fielding Lake were collected from 1982-1987. Data were collected in 1987 on burbot in

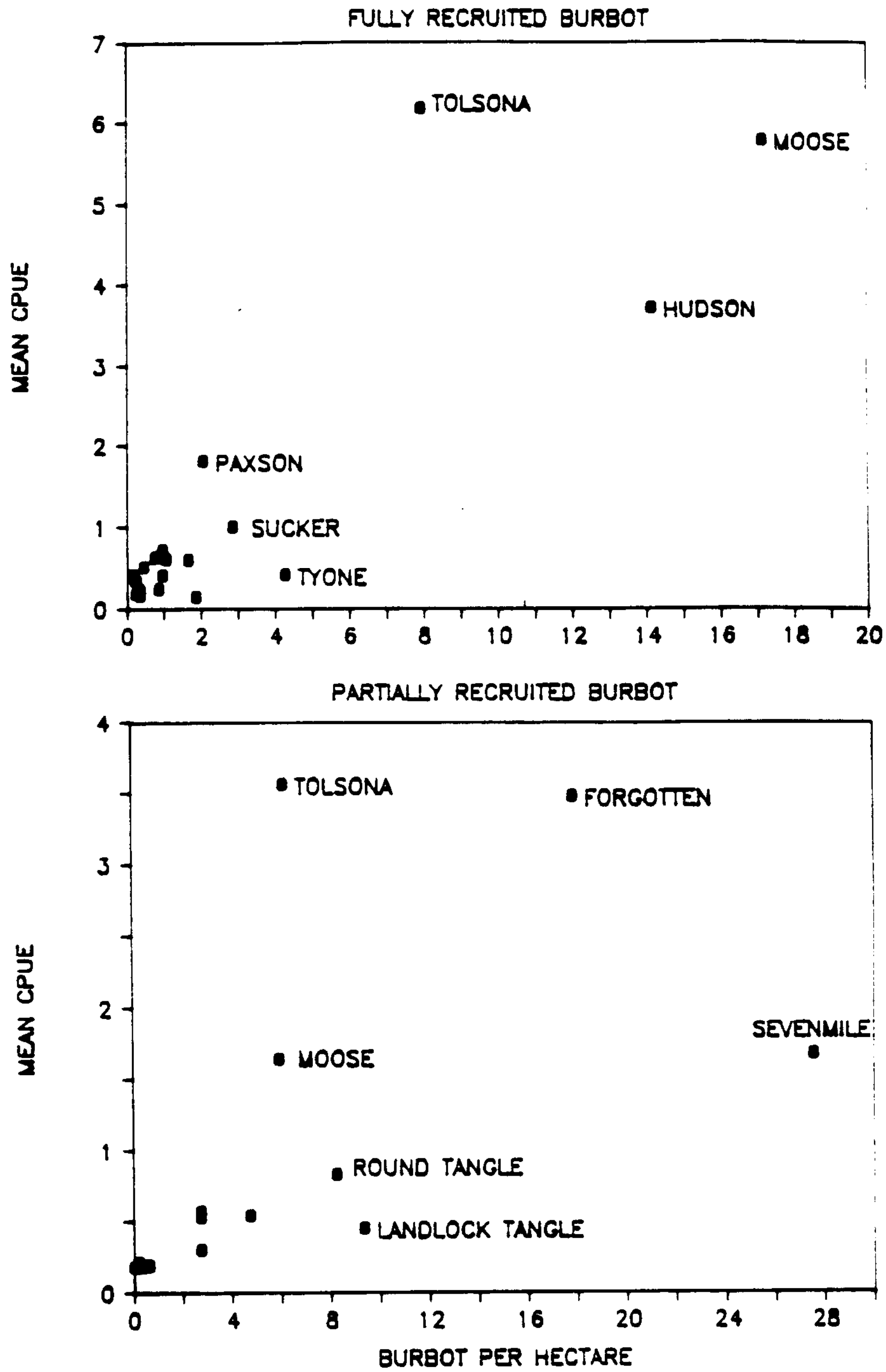

Figure 7. Mean CPUE and estimated density of partially (<450 mm TL) and fully recruited (≥450 mm TL) burbot in 22 lakes in interior Alaska in 1986.

Table 10. Mean lengths (mm TL) of burbot measured during sampling events in 22 lakes in interior Alaska in 1987.

Lake	Statistic	First Event Partially	First Event Fully[1]	First Event All	Second Event Partially	Second Event Fully	Second Event All	Both Events Fully
Fielding	Mean	396	521	452	386	526	435	523
	SE	3	7	6	3	9	6	6
	Samples	132	107	239	150	81	231	189
George	Mean	371	649	565	374	678	624	659
	SE	5	9	11	10	12	15	7
	Samples	72	166	238	18	84	102	250
Harding	Mean	385	535	456				
	SE	4	9	7				
	Samples	114	103	217				
Landlock Tangle	Mean	325	545	370	354	515	392	532
	SE	5	17	9	5	11	8	11
	Samples	129	33	162	81	25	106	58
Paxson	Mean	454	625	534	430	627	527	626
	SE	3	3	4	5	4	5	2
	Samples	404	356	760	250	241	491	597
Sevenmile	Mean	311		311	304		304	
	SE	4		4	3		3	
	Samples	77		77	140		140	
Shallow Tangle	Mean	357	546	369	337	498	358	518
	SE	5	8	8	6	16	11	13
	Samples	46	3	49	27	4	31	4
Summit	Mean	402	501	454	395	500	443	501
	SE	3	5	5	4	6	6	6
	Samples	69	76	145	75	63	138	139
T	Mean	332	651	567	391	696	652	673
	SE	24	26	31	25	24	29	18
	Samples	9	25	34	4	24	28	49

- Continued -

Table 10. Mean lengths (mm TL) of burbot measured during sampling events in 22 lakes in interior Alaska in 1987 (continued).

		First Event			Second Event			Both Events
Lake	Statistic	Partially	Fully	All	Partially	Fully	All	Fully
Upper Tangle	Mean	370	500	419	364	567	396	515
	SE	9	11	12	8	34	16	13
	Samples	28	17	45	26	5	31	22
Burnt	Mean	367	621	431		489	489	533
	SE	24		66		17	17	45
	Samples	3	1	4	0	2	2	3
Crosswind	Mean	389	568	523	353	523	497	533
	SE	5	6	7	4	8	8	5
	Samples	62	184	246	27	149	176	360
Deep	Mean	427	703	618	399	714	621	680
	SE	16	12	19	22	16	28	11
	Samples	20	46	66	10	24	34	80
Forgotten	Mean	365	464	371	385	467	391	379
	SE	7	6	6	5	4	6	3
	Samples	33	2	35	25	2	27	4
Hudson	Mean	414	573	556	389	562	545	568
	SE	4	5	5	16	5	6	4
	Samples	39	339	378	26	242	268	581
Louise	Mean	391	563	519	395	565	522	563
	SE	4	4	5	4	5	6	3
	Samples	108	314	422	72	212	284	526
Lost Cabin	Mean		668	668		695	695	672
	SE		21	21		20	20	18
	Samples	0	19	19	0	4	4	24
Moose	Mean	419	491	475	420	504	487	493
	SE	2	1	2	5	3	3	1
	Samples	191	678	869	46	173	219	851

- Continued -

Table 10. Mean lengths (mm TL) of burbot measured during sampling events in 22 lakes in interior Alaska in 1987 (continued).

		First Event			Second Event			Both Events
Lake	Statistic	Partially	Fully	All	Partially	Fully	All	Fully
Sucker	Mean	394	599	539	380	581	541	593
	SE	5	11	11	10	17	17	9
	Samples	43	103	146	12	48	60	151
Susitna	Mean	375	522	427	371	532	415	525
	SE	3	6	5	3	12	6	5
	Samples	217	119	336	164	62	226	181
Tolsona	Mean	408	496	464	416	500	484	497
	SE	2	1	2	5	4	4	2
	Samples	230	393	623	40	170	210	563
Tyone	Mean	395	519	449	396	527	474	523
	SE	4	8	6	4	9	8	6
	Samples	97	76	173	59	87	146	163

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

Table 11. Estimated mean length at age for burbot sampled from several lakes in interior Alaska in 1987.

	Harding				George				Paxson				Landlock Tangle			
Age	n[1]	M[2]	F[3]	Both	n	M	F	Both	n	M	F	Both	n	M	F	Both
0	0				0				0				0			
1	6	227	217	229	1			156	0				0			
2	3	200	312	307	2	258	255	256	1	355		355	3		232	241
3	20	376	353	369	6	410	329	343	5	278	330	319	6	365	316	324
4	16	424	439	432	3	487	390	422	8	386	382	385	9	358	329	338
5	7	493	486	491	1	437		437	2	425	446	436	1	420		420
6	5	480	528	508	1	494		494	3		495	494	1	490		490
7	1	740		740	0				10	532	519	535	1		483	483
8	2		548	548	0				5	592	594	589	0			
9	0				1	625		625	8	566	582	604	1		423	423
10	0				0				8	619	626	621	0			
11	0				0				4	622	662	652	0			
12	1		806	806	0				3		680	674	0			
13	0				1	805		805	3	700		697	0			
14	0				0				0				0			
15	0				0				0				0			
16	0				1	877		877	1			860	0			
All	61	397	447	413	17	549	315	425	61	519	519	542	22	392	328	342

- Continued -

Table 11. Estimated mean length at age for burbot sampled from several lakes in interior Alaska in 1987 (continued).

	Lake Louise				Crosswind				Deep				Susitna			
Age	n	M	F	Both	n	M	F	Both	n	M	F	Both	n	M	F	Both
0	0				0				0				0			
1	0				0				0				0			
2	0				0				0				0			
3	3		390	390	2			364	0				0			
4	9	406	332	366	16	370	393	359	1		334	334	4		352	352
5	15	403	414	404	11	440	426	423	2	369	321	345	12	363	407	370
6	33	460	476	469	6	503	511	509	3	412	378	400	5		376	376
7	14	552	516	517	4	520	545	539	1	418		418	4	496	423	441
8	22	439	538	487	13	531	528	528	0				2		405	405
9	13	417	476	445	3	471	550	497	3	589	578	582	3		511	511
10	12	529	572	565	1		644	644	1	696		696	2		502	502
11	6	643	612	618	2	604		604	2	697	678	688	2		572	572
12	0				0				3	664	699	681	0			
13	1		658	658	0				3	838	707	750	0			
14	1		602	602	2	719	853	786	1		799	799	0			
15	0				0				3	735		735	0			
16	0				0				0				0			
All	129	460	504	477	62	485	504	467	24	608	587	593	34	382	427	411

[1] Sample size.
[2] Males.
[3] Females.

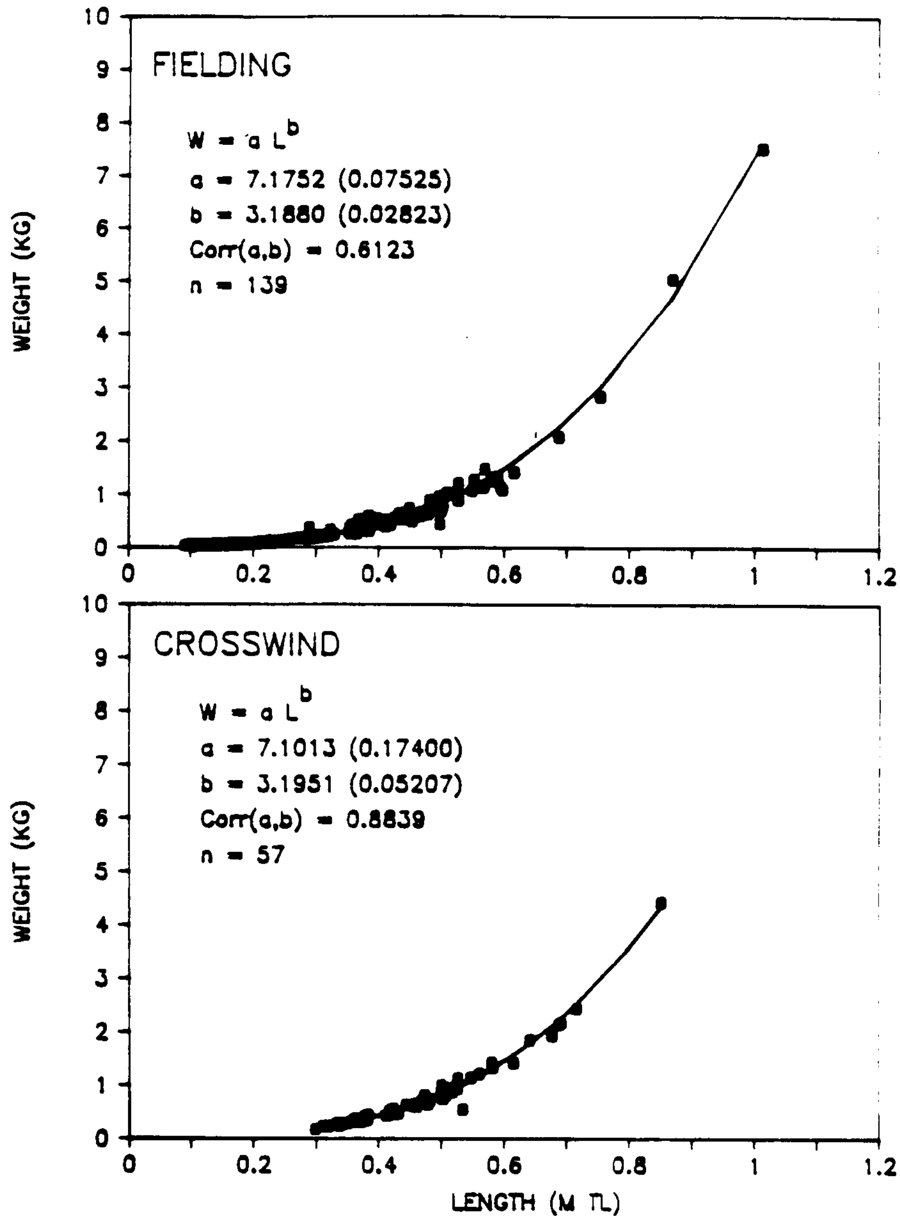

Figure 8. Estimates of parameters in the length-weight relationships for burbot in Crosswind and Fielding Lakes in 1987. Values in parentheses are standard errors of estimates.

Paxson and Harding Lakes; the length-weight relationships for these populations were described in Parker et al. (1987).

Enough fish were recaptured to estimate growth parameters in Moose, Paxson, Tolsona, Fielding, and Sevenmile Lakes (Figure 9). All records where fish had decreased in length were discarded for this analysis. The estimated asymptotic lengths for populations in Moose and Paxson Lakes are 1,009 and 972 mm TL, respectively. The estimated coefficients of growth for these populations are 0.0083 and 0.0079, respectively. Sixteen records from Paxson Lake and three from Moose Lake with "negative" growth were discarded. Procedures failed to provide meaningful estimates of growth parameters from populations in Fielding, Sevenmile, and Tolsona Lakes. In Fielding Lake, 107 burbot at large for 2 years grew on average 55 mm TL (SD = 33 mm, median = 44, mode = 44); one other record with negative growth was discarded. Those 84 burbot at large for 1 year in Fielding Lake grew on average 27 mm TL (SD = 20 mm, median = 23 mm, mode = 17 mm); another six records with negative growth were discarded. One hundred twenty-nine burbot at large for less than a year (237 days) in Tolsona Lake grew on average 11 mm TL (SD = 10 mm, median = 10 mm, mode = 12 mm); another 15 records with negative growth were discarded. Twenty-one burbot were recaptured in Sevenmile Lake after 321 days (on average) of freedom; these burbot grew on average 8 mm TL (SD = 6 mm, median = 8 mm, mode = 3 mm); 14 records were discarded.

DISCUSSION

The accuracy of abundance estimates from the mark-recapture experiments are predicated on certain conditions (Ricker 1975): 1) equal probability of capture for all burbot during at least one sampling event or complete dispersal of tagged burbot throughout the population; 2) ability to identify marked fish; 3) no recruitment between sampling events; and 4) equal probability of survival and capture of marked and unmarked fish. In all our sampling events, sampling effort and subsequently tagged fish were spread throughout each lake. Therefore, the first condition need hold only for local areas, not for the whole lake, for our estimates to be unbiased. Also, the dispersal of burbot throughout all depths in the summer would promote the dispersal of fish tagged in early summer. And calculation of separate estimates for large and small burbot negated problems with different gear selectivity for burbot of different sizes. As for the second condition, there was no evidence of fin regeneration even though there was some loss of tags. As for the third condition, sampling events were often a few weeks apart so there was little time for recruitment through growth. When we looked for growth recruitment between sampling events, no such recruitment was found. Comparison of the fractions of marked burbot in the population in Tolsona Lake during different sampling events can be used to evaluate our meeting the fourth condition in a somewhat less than rigorous fashion. From Parker et al. (1987), 28% (131 of the 473) of the fully recruited burbot captured in October, 1986 in Tolsona Lake carried marks; from this report, 88 of the 395 (22%) fully recruited burbot caught in early June 1987 were from the

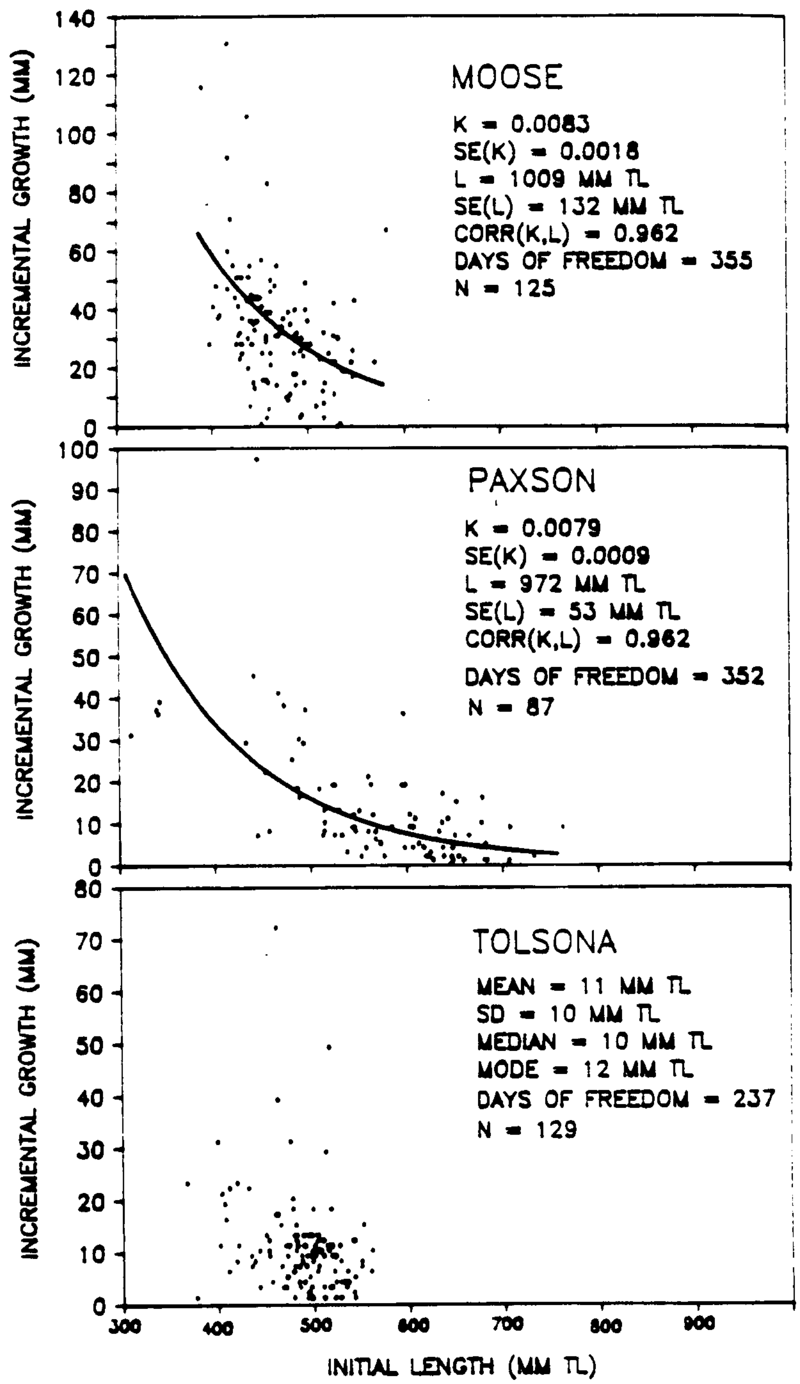

Figure 9. Growth statistics for burbot from Paxson, Moose, and Tolsona Lakes that were released in 1986 and recaptured in 1987.

same marked population. However, burbot in this lake grew over the winter, and there was no doubt some growth recruitment to the population. If recruits were 20% of the population in June 1987, then the 88 marked fish were 28% of the portion of the fully recruited population in October 1986 that was still alive in June 1987. The estimated recruitment over the winter in this report was 26% of the abundance in October 1986. Although this situation is not definitive proof of no differences in survival rates and behavior between marked and unmarked fish, it is at least consistent with there being no change in differences between sampling events separated by 14 and by 237 days.

Estimates of abundance from the Chapman modification of the Petersen estimator and from the Jolly-Seber method were at variance in two cases. The "Petersen" estimate for the population of fully recruited burbot in Fielding Lake in 1986 was 213 (SE=41) (Parker et al. 1987); the "Jolly-Seber" estimate for the same period was 365 (SE=72). The Petersen estimate for fully recruited burbot in Tolsona Lake in 1986 was 1,901 (SE=120) and in 1987 the estimate is 1,036 (SE=92); the Jolly-Seber estimates for similar periods were 1,877 (SE=282) and 1,336 (SE=212), respectively. This discrepancy arose because abundance is calculated in the Petersen method through estimating the fraction "p" of the population that is marked while in the Jolly-Seber method abundance is calculated through estimating the probability of capture "ρ". In the Petersen method, p is estimated as the fraction of marked burbot in the catch from the last sampling event; in the Jolly-Seber method, ρ is the fraction of marked burbot extant just prior to the penultimate sampling event that were caught in that event. Both estimates of p and ρ are subject to sampling error and will thus likely differ, but not significantly so, unless sample sizes for both are large. This is the case here. The estimate of ρ has the advantage of being immune to recruitment between the last and penultimate sampling events. However, if no recruitment occurs between these events (which is also the case here), the estimate with the lowest CV is most likely the most desirable.

Estimates of recruitment for the Jolly-Seber methods are only as strong as are estimates of abundance (Gilbert 1973). Where CVs for abundance estimates were small, such as in populations from Fielding and Tolsona Lakes, estimates of recruitment were positive and significantly different from zero. Where CVs were large, such as for populations in Paxson Lake and Lake Louise, estimates of recruitment were either nonsensical or nonsignificant. The estimated abundance declined from 9,111 (CV=21.9%) fully recruited burbot in Paxson Lake in 1986 (Parker et al. 1987) to 3,246 (CV=10.8%) 1 year later. The mean CPUE that corresponds to the former estimate is 2.28 burbot per set (SE=0.17) (Parker et al. 1987) and to the latter 1.79 (SE=0.15) in 1987. This information is consistent with a drop in abundance of fully recruited burbot between years, but not with a drop of almost six thousand fish. The imprecision in the estimate from 1986 is a clue that that estimate was too high.

Precision of estimates of mean CPUE suffered somewhat when systematic designs were stratified. In those cases when a transect was "stranded" with only one set after post-stratification, no estimate of "within" transect variance existed for that transect, and it was excluded from the analysis. Enough of these instances during a sampling event would drop the degrees of freedom in stratified designs to the point that stratified estimates might no longer be more precise than unstratified estimates. This is one possible reason why stratified estimates were not selected over their unstratified "competitors" in this analysis.

Adjusting CPUE by soak times introduced some small bias into estimates of mean CPUE. When a set is not soaked for exactly 48 hours, division of its catch by the time of set will not adjust "zero" catches. Pearse and Conrad (1986) found that catches are asymptotic which means that "zero" catches would most likely remain "zero" catches for some time after a 48-hour soak. However, linearly increasing the raw CPUE of larger catches by the hours soaked would add some small bias to the estimates. Since most soak times were within a few hours of 2 days, this bias should be insignificant.

The decline of CPUE between spring and summer observed in 1987 and in previous years (Parker et al. 1987) presents some sampling problems in the stock assessment of burbot populations. Experience over the past 2 years is that there is a "spring" (and a "fall") of high CPUE for burbot and a "summer" of low CPUE. Some populations have shorter, earlier "springs" with protracted "summers"; lakes for these populations tend to be small, shallow, and at lower elevations, such as Moose and Tolsona Lakes. Some populations have longer, later "springs" with short "summers"; lakes for these populations tend to be large, deep, and at higher elevations, such as Lake Louise and Paxson Lake. Obviously, estimates of mean CPUE from populations with no history of study are suspect until the relevant "spring" and "summer" are defined. Since the summer period appears longer than the spring, sampling well within this period should be attainable and provide estimates that are at least comparable among years. However, the low CPUE during this period also means fewer fish will be captured. Any mark-recapture experiment that is prosecuted during the "summer" will have lower sample sizes unless fishing effort is about doubled. This situation could make "summer" mark-recapture experiments prohibitively expensive on the larger lakes with less dense populations. Obviously, mark-recapture experiments on the larger lakes should be prosecuted in the "spring" when CPUE is higher.

Although the threshold of recruitment to the gear was set at 450 mm TL, this threshold is not universal and is somewhat dynamic. Those situations where the threshold was higher (populations in Moose and Paxson Lake) have been discussed above. However, there were some situations when the threshold was obviously lower than 450 mm. For instance, there were no burbot larger that 450 mm caught in Sevenmile Lake at all. Also, there were no descending left limbs in the distributions of any of the populations in the Tangle Lakes. This is a repeat of the situation found for these populations a year earlier (Parker et al. 1987). The few numbers of recaptured fish precluded any test of where that threshold for these populations could be. There is also some evidence that changes in CPUE and changes in the distribution of burbot between sampling events affects their catchability. Of the eight populations where the length distributions differed between sampling events, six (Paxson, Tyone, Crosswind, Susitna, Moose, and Tolsona) had significant declines in CPUE between events and a seventh (Upper Tangle) had a large, though insignificant, drop in CPUE. The eighth (George) had a large shift in the distribution of large and small burbot between events.

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APPENDICES

APPENDICES

Description of Lakes

BURNT LAKE (62°07′ W, 146°6′ W) is located 1 km east of the road to Lake Louise 4 km from the Glenn Highway. Burnt Lake is 24 ha with a maximum depth of 10 m and an elevation of 854 m. There are no cabins or public recreational facilities, and this lake has relatively little fishing pressure. Burnt Lake contains Arctic grayling *Thymallus arcticus* and burbot.

CROSSWIND LAKE (62°20′ N, 146°00′ W), also known as Charley Lake, is 32 km northwest of Glennallen. Crosswind Lake is 3,232 ha with a maximum depth of 37 m and an elevation of 640 m. There are no public recreational facilities at the lake, although there are numerous private and commercial cabins. For its size and location, this lake receives very light fishing pressure. Crosswind Lake contains lake trout *Salvelinus namaycush*, Arctic grayling, round whitefish *Prosopium cylindraceum*, burbot, and longnose suckers *Catostomus catostomus*.

DEEP LAKE (62°29′ N, 146°00′ W) is 8 km north of Crosswind Lake. Deep Lake is 303 ha with a maximum depth of 12 m and an elevation of 670 m. One private cabin and no public facilities are at the lake; there is very little fishing pressure. Deep Lake contains lake trout, round whitefish, burbot, and longnose suckers.

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. Campground facilities and a lodge operated during the summer are located at the mouth of the outlet, also 15 to 20 recreational cabins are located along the south shore. Fielding Lake contains Arctic grayling, lake trout, round whitefish, and burbot.

FORGOTTEN LAKE (62°08′ W, 146°27′ W) is directly accessible from the road to Lake Louise 12 km from the Glenn Highway. Forgotten Lake is 6 ha with a maximum depth of 6 m and an elevation of 915 m. No cabins or public recreational facilities are at the lake, and there is relatively little fishing pressure. Forgotten Lake has Arctic grayling and burbot.

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 ha with a maximum depth of 11 m and a 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 longnose suckers, round whitefish, humpback whitefish *Coregonus pidschian*, least cisco *Coregonus sardinella*, burbot, and Arctic grayling.

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. Campground facilities and a boat launch are located on the west shore of the lake; recreational cabins and houses are located along the shoreline. Harding Lake contains indigenous species of northern pike, least cisco, slimy sculpin *Cottus cognatus*, and burbot. Transplanted species include lake trout, rainbow trout *Salmo gairdneri*, Arctic grayling, sheefish *Stenodus leucicthys*, and coho salmon *Oncorhynchus kisutch*.

HUDSON LAKE (61°53' N, 145°40' W) is a remote lake 19 km southwest of Copper Center. Hudson Lake is 259 ha with a maximum depth of 16 m and an elevation of 655 m. Although there are no cabins or public recreational facilities at the lake, there is a large winter ice fishery for burbot. Hudson Lake contains Arctic grayling, round whitefish, longnose suckers, burbot, and rainbow trout.

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 ha 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 supports year round fishing for lake trout, burbot, Arctic grayling, and round whitefish.

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 ha with a maximum depth of 36 m and an elevation of 875 m. Landlock Tangle Lake has Arctic grayling, lake trout, round whitefish, and burbot.

LOST CABIN LAKE (62°04' N, 146°11' W) is 2 km south of Milepost 165.5 on the Glenn Highway. Lost Cabin Lake is 34 ha with a maximum depth of 4 m and an elevation of 617 m. No cabins or public recreational facilities are at the lake; there is relatively little fishing pressure. Lost Cabin Lake contains Arctic grayling, longnose suckers, and burbot.

MINNESOTA LAKE (62°35' N, 146°10' W) is a remote lake 19 km north-northwest of Crosswind Lake. Minnesota Lake is 323 ha with a maximum depth of 20 m and an elevation of 800 m. One cabin and no public recreational facilities are at the lake, and there is relatively little fishing pressure. Minnesota Lake contains lake trout, round whitefish, burbot, and Arctic grayling.

MOOSE LAKE (62°07' N, 146°05' W) is accessible from Tolsona Lake by all-terrain vehicle on a 1 km trail from the north end of Tolsona Lake. Moose Lake is 130 ha 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 burbot, Arctic grayling, longnose suckers, and rainbow trout.

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 ha 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 lake trout, burbot, sockeye salmon *O. nerka*, Arctic grayling, round whitefish, and other species.

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

SEVENMILE Lake (63°06′ N, 145°38′ W) is located 1 km by road from the Denali Highway. Sevenmile Lake is 34 ha 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 lake trout and burbot populations. No other species are known to exist in the lake.

SHALLOW TANGLE LAKE (63°02′ N, 145°48′ W) is located north of Round Tangle Lake. Shallow Tangle Lake is accessible by boat through Round Tangle Lake and a 500 m river between the two lakes. Shallow Tangle Lake is 130 ha with a maximum depth of 24 m and an elevation of 849 m. Shallow Tangle Lake has Arctic grayling, lake trout, round whitefish, burbot, and longnose suckers.

SUCKER LAKE (62°01′ N, 146°20′ W) is 6.5 km south of Milepost 158 on the Glenn Highway. Sucker Lake has 283 surface ha with a maximum depth of 7 m and an elevation of 616 m. There are no private or public facilities at the lake, but it does support a large winter ice fishery for burbot. Sucker Lake contains burbot, Arctic grayling, round whitefish, and longnose suckers.

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 ha with a maximum depth of 72 m and an elevation of 979 m. Public facilities are available for launching boats only. There is one lodge and a private recreational vehicle campground along the lake. Summit Lake contains lake trout, sockeye salmon, burbot, and round whitefish.

SUSITNA LAKE (62°25′ N, 146°38′ W) is the second lake in a three-lake system and is accessible by a connecting channel of 100 m to Lake Louise. Susitna Lake is 3,816 ha with a maximum depth of 37 m and an elevation of

720 m. There are many private recreational cabins scattered along the shores of Susitna Lake, however, no commercial accommodations are present. Susitna Lake has lake trout, burbot, longnose suckers, and round whitefish.

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 ha 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 northern pike, humpback whitefish, least cisco, and burbot.

TOLSONA LAKE (62°06′ N, 146°04′ W) is accessible from the Glenn Highway. Tolsona Lake is 130 ha 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 burbot, Arctic grayling, stocked rainbow trout, longnose suckers, and other species.

TYONE LAKE (62°30′ N, 146°45′ W) is the first lake in a three-lake system and is accessible by a connecting channel of 100 m to Susitna Lake. Tyone Lake is 389 ha with a maximum depth of 9 m and an elevation of 720 m. There is the abandoned remains of an Indian settlement (Tyone Village) and only a handful of private cabins located on this lake. Tyone Lake has Arctic grayling, lake trout, burbot, 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 ha with a maximum depth of 30 m and an elevation of 868 m. There is a boat launch and campground facilities available at the mouth of this lake. Upper Tangle Lake has Arctic grayling, lake trout, round whitefish, burbot, and longnose suckers.

Appendix Table 1. Mark and recapture histories of burbot by sampling event for 17 populations studied from 1982 through 1987.

	TYONE				TOLSONA				FORGOTTEN				LOUISE				SUSITNA			
DATE:																				
Year	1986	1986	1987	1987	1986	1986	1987	1987	1986	1986	1987	1987	1986	1986	1987	1987	1986	1986	1987	1987
Beginning	6/26	8/11	7/29	8/28	9/23	10/8	6/02	6/23	6/03	6/16	8/08	9/12	6/25	8/19	7/06	8/02	6/27	8/13	7/18	8/21
Ending	6/28	8/13	8/04	9/01	9/27	10/10	6/04	6/25	6/07	6/20	8/10	9/14	6/28	9/02	7/20	8/19	6/29	8/19	7/31	8/30
NUMBER OF FULLY RECRUITED BURBOT:[1]																				
Recaptured from Event 1	0	2	1	4	0	131	68	23	0	3	0	0	0	8	5	4	0	0	0	2
Recaptured from Event 2	0	0	2	0	0	0	20	12	0	0	0	0	0	0	5	5	0	0	1	0
Recaptured from Event 3	0	0	0	3	0	0	0	64	0	0	0	2	0	0	0	10	0	0	0	1
Captured with Tags	0	2	3	7	0	131	88	99	0	3	0	2	0	8	10	19	0	0	1	3
Captured without tags	111	79	73	80	531	342	307	71	2	0	2	0	243	280	303	198	37	47	117	58
Captured	111	81	76	87	531	473	395	170	2	3	2	2	243	288	313	217	37	47	118	61
Released with Tags	111	71	75	86	531	141	393	167	2	2	2	2	220	258	264	186	34	43	111	58
NUMBER OF PARTIALLY RECRUITED BURBOT:																				
Recaptured from Event 1	0	0	0	0	0	7	11	3	0	32	5	3	0	0	1	0	0	0	0	0
Recaptured from Event 2	0	0	1	0	0	0	2	0	0	0	11	7	0	0	1	0	0	0	2	0
Recaptured from Event 3	0	0	0	0	0	0	0	11	0	0	0	6	0	0	0	1	0	0	0	0
Captured with Tags	0	0	1	0	0	7	13	14	0	32	16	16	0	0	2	1	0	0	2	0
Captured without tags	20	83	96	59	163	106	215	27	65	30	17	9	79	82	107	58	43	94	216	165
Captured	20	83	97	59	163	113	228	41	65	62	33	25	79	82	109	59	43	94	218	165
Released with Tags	19	70	97	59	152	8	228	40	65	46	33	25	38	62	72	54	36	75	200	157

- Continued -

Appendix Table 1. Mark and recapture histories of burbot by sampling event for 17 populations studied from 1982 through 1987 (continued).

	MOOSE				SUMMIT				UPPER TANGLE				ROUND TANGLE				SHALLOW TANGLE			
DATE:																				
Year	1986	1986	1987	1987	1986	1986	1987	1987	1986	1986	1987	1987	1986	1986	1987	1987	1986	1986	1987	1987
Beginning	6/02	8/04	6/01	6/22	7/12	8/26	7/13	9/02	7/21	8/18	7/31	8/25	7/21	8/16	7/27	8/22	7/21	8/16	7/29	8/24
Ending	6/14	8/08	6/05	6/26	7/17	9/04	7/21	9/20	7/25	8/20	8/03	8/29	7/25	8/18	7/30	8/25	7/25	8/18	8/01	8/30
NUMBER OF FULLY RECRUITED BURBOT:																				
Recaptured from Event 1	0	86	63	16	0	3	6	2	0	0	0	0	0	1	1	0	0	1	0	0
Recaptured from Event 2	0	0	30	12	0	0	2	0	0	0	3	0	0	0	1	0	0	0	0	0
Recaptured from Event 3	0	0	0	50	0	0	0	7	0	0	0	1	0	0	0	3	0	0	0	0
Captured with Tags	0	86	93	78	0	3	8	9	0	0	3	1	0	1	2	3	0	1	0	0
Captured without tags	862	95	563	95	52	59	68	57	7	9	14	4	21	10	15	6	3	0	3	4
Captured	862	181	656	173	52	62	76	63	7	9	17	5	21	11	17	9	3	1	3	4
Released with Tags	846	180	653	172	51	3	74	63	7	9	17	5	20	11	17	9	2	1	2	1
NUMBER OF PARTIALLY RECRUITED BURBOT:																				
Recaptured from Event 1	0	22	5	1	0	10	3	2	0	0	0	0	0	5	3	1	0	0	0	0
Recaptured from Event 2	0	0	7	0	0	0	1	0	0	0	1	1	0	0	7	0	0	0	0	0
Recaptured from Event 3	0	0	0	8	0	0	0	3	0	0	0	1	0	0	0	2	0	0	0	1
Captured with Tags	0	22	12	9	0	10	4	5	0	0	1	2	0	5	10	3	0	0	0	1
Captured without tags	739	96	171	37	182	166	65	70	46	39	27	24	134	56	71	45	81	31	46	26
Captured	739	118	183	46	182	176	69	75	46	39	28	26	134	61	81	48	81	31	46	27
Released with Tags	691	116	183	45	152	10	64	70	41	26	28	26	114	52	78	47	50	0	44	19

- Continued -

Appendix Table 1. Mark and recapture histories of burbot by sampling event for 17 populations studied from 1982 through 1987 (continued).

	LANDLOCK TANGLE			HARDING			TEE			BURNT				PAXSON					SEVENMILE			
DATE:																						
Year	1986	1987	1987	1985	1986	1987	1986	1987	1987	1986	1986	1987	1987	1986	1986	1986	1987	1987	1986	1986	1987	1987
Beginning	7/20	6/30	8/02	7/22	9/08	6/16	6/11	5/26	9/21	6/04	6/16	8/08	9/12	7/07	8/04	9/16	7/06	8/06	7/22	9/17	6/16	7/31
Ending	7/24	7/06	8/07	7/26	9/14	6/20	6/19	6/01	9/25	6/08	6/20	8/10	9/14	7/12	8/14	9/20	7/13	8/14	8/09	9/21	6/20	8/06
NUMBER OF FULLY RECRUITED BURBOT:																						
Recaptured from Event 1	0	1	1	0	0	2	0	2	4	0	1	0	0	0	16	13	32	23				
Recaptured from Event 2	0	0	2	0	0	14	0	0	14	0	0	1	0	0	0	7	10	9				
Recaptured from Event 3										0	0	0	0	0	0	0	17	10				
Recaptured from Event 4														0	0	0	0	60				
Captured with Tags	0	1	3	0	0	16	0	2	18	0	1	1	0	0	16	20	59	102				
Captured without tags	12	32	22	25	55	71	0	23	16	4	0	0	2	537	338	168	530	249				
Captured	12	33	25	25	55	103	13	25	24	4	1	1	2	537	354	188	589	351				
Released with Tags	12	33	24	18	54	81	13	23	24	4	1	1	2	463	111	184	571	335				
NUMBER OF PARTIALLY RECRUITED BURBOT:																						
Recaptured from Event 1	0	1	2	0	0	0	0	0	0	0	8	1	0	0	1	0	1	0	0	10	5	5
Recaptured from Event 2	0	0	2	0	0	3	0	0	1	0	0	0	0	0	0	0	1	0	0	0	16	25
Recaptured from Event 3										0	0	0	0	0	0	0	2	0	0	0	0	8
Recaptured from Event 4														0	0	0	0	4				
Captured with Tags	0	1	4	0	0	3	0	0	1	0	8	1	0	0	1	0	4	4	0	10	21	38
Captured without tags	38	89	75	35	59	108	8	7	3	20	7	2	0	85	81	35	167	136	116	82	56	102
Captured	38	90	79	35	59	114	8	7	4	20	15	3	0	85	82	35	171	140	116	92	77	140
Released with Tags	42	76	78	22	47	80	4	8	4	20	14	3	0	50	17	33	157	108	36	68	59	105

- Continued -

Appendix Table 1. Mark and recapture histories of burbot by sampling event for 17 populations studied from 1982 to 1987 (continued).

	FIELDING LAKE									
DATE:										
Year	1982	1984	1984	1985	1985	1985	1986	1986	1987	1987
Beginning	9/29	7/20	10/1	7/16	8/19	9/23	7/28	8/21	7/21	8/17
Ending	10/1	7/20	10/8	7/20	8/26	9/27	8/01	8/25	7/27	8/22
NUMBER OF FULLY RECRUITED BURBOT:										
Recaptured from Event 1	0	0	0	0	0	0	0	0	0	0
Recaptured from Event 2	0	0	0	0	0	0	1	0	1	0
Recaptured from Event 3	0	0	0	1	10	2	1	0	1	0
Recaptured from Event 4	0	0	0	0	9	4	4	2	1	6
Recaptured from Event 5	0	0	0	0	0	11	11	4	9	1
Recaptured from Event 6	0	0	0	0	0	0	4	2	6	0
Recaptured from Event 7	0	0	0	0	0	0	0	13	13	4
Recaptured from Event 8	0	0	0	0	0	0	0	0	9	4
Recaptured from Event 9	0	0	0	0	0	0	0	0	0	34
Captured with Tags	0	0	0	1	19	17	17	21	40	48
Captured without tags	2	2	41	45	78	26	45	28	67	33
Captured	2	2	41	46	97	43	62	49	107	81
Released with Tags	1	2	41	47	96	20	59	30	105	55
NUMBER OF PARTIALLY RECRUITED BURBOT:										
Recaptured from Event 1	0	0	0	0	0	0	0	0	0	0
Recaptured from Event 2	0	0	0	1	0	0	2	0	0	0
Recaptured from Event 3	0	0	0	7	10	1	1	3	0	0
Recaptured from Event 4	0	0	0	0	12	3	5	1	1	3
Recaptured from Event 5	0	0	0	0	0	16	25	13	7	8
Recaptured from Event 6	0	0	0	0	0	0	3	3	4	0
Recaptured from Event 7	0	0	0	0	0	0	0	20	11	9
Recaptured from Event 8	0	0	0	0	0	0	0	0	8	1
Recaptured from Event 9	0	0	0	0	0	0	0	0	0	12
Captured with Tags	0	0	0	8	22	20	36	40	31	33
Captured without tags	5	3	62	104	250	47	176	90	101	117
Captured	5	3	62	112	272	67	204	129	132	150
Released with Tags	5	3	62	111	272	21	189	44	131	32

[1] Burbot fully recruited to the gear are burbot longer than 449 mm TL.

Appendix Table 2. Mark and recapture history on burbot by year for the population in Fielding Lake.

DATE:				
Year	1984	1985	1986	1987
Beginning	7/20	7/16	7/28	7/21
Ending	10/8	9/27	8/25	8/22
NUMBER OF FULLY RECRUITED BURBOT:[1]				
Recaptured from Event 1	0	13	2	2
Recaptured from Event 2		0	27	23
Recaptured from Event 3			0	30
Captured with Tags	0	13	29	55
Captured without tags	43	149	90	93
Captured	43	162	119	148
Released with Tags	43	138	76	126

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

Appendix Table 3. Number of fully (≥450 mm TL) and partially (<450 mm TL) recruited burbot caught (C), number tagged (M), and number recaptured (R) in populations during two sampling events on six lakes in interior Alaska in 1987.

	Fully Recruited				Partially Recruited			
Lake	M_1	C_2	R_2	M_2	M_1	C_2	R_2	M_2
Crosswind	165	109	4	94	47	67	0	54
Deep	53	27	2	9	13	7	0	1
George	166	84	7	80	72	18	1	10
Hudson	337	238	21	234	39	26	0	17
Lost Cabin	20	4	2	4	0	0	0	0
Sucker	100	48	5	42	42	12	0	5

Appendix Table 4. Mark-recapture histories for populations of burbot in Lake Louise, Paxson, Sevenmile, and Fielding Lakes that were used to draw bootstrap samples to estimate survival rates.

Sampling Events[1]			Paxson	Louise	Fielding	Sevenmile
First			7/7-9/20/86	6/25-9/2/86	7/28-8/25/86	7/24-9/21/86
	Second		7/6-13/87	7/06-20/87	7/21-27/87	6/16-20/87
		Third	8/6/87	8/02-19/87	8/17-22/87	7/31-8/06/87
1	0	0	620	460	50	44
1	1	0	48	8	8	18
1	Dead	0	0	2	0	1
1	1	1	11	2	15	2
1	0	1	42	9	7	31
0	1	1	49	10	21	6
0	1	0	463	254	62	32

[1] A one denotes capture during this event, a zero nocapture.

Appendix Table 5. Estimates of abundance (N) for burbot populations in Paxson and Moose Lakes by size groups (mm TL) in 1987.

	Paxson			Moose		
	< 450	450-549	≥550	<450	450-449	≥500
NUMBER OF BURBOT:						
Marked	157	227	344	183	445	208
Caught	140	110	241	46	80	93
Recaptured	4	14	47	10	25	25
ESTIMATES:						
N	4,455	1,686	1,738	785	1,388	755
SE[N]	1,758	379	206	192	214	116
CV[N]	39.5%	22.5%	11.9%	24.5%	15.4%	15.3%
SUM OF ESTIMATES:						
N		3,425			2,143	
SE[N]		432			243	
CV[N]		12.6%			11.3%	
ESTIMATES FROM SUMMED DATA:						
N		3,246			2,230	
SE[N]		351			250	
CV[N]		10.8%			11.2%	
PERCENT DIFFERENCE		5.5%			-3.9%	

Appendix Table 6. Standard errors for estimated mean length at age for burbot sampled in eight lakes in interior Alaska in 1987.

Age	George				Harding				Paxson				Landlock Tangle			
	n[1]	M[2]	F[3]	Both	n	M	F	Both	n	M	F	Both	n	M	F	Both
0	0				0				0				0			
1	1				6	7		7	0				0			
2	2			2	3		13	9	1				3		39	24
3	6		17	22	20	13	10	9	5		27	24	6		7	10
4	3		49	34	16	10	8	6	8	15	4	9	9	14	5	7
5	1				7	18	4	12	2			11	1			
6	1				5	0	35	22	3			24	1			
7	0				1				10	12	41	15	1			
8	0				2		17	17	5	24		3	0			
9	1				0				8	9		17	1			
10	0				0				8	13	12	8	0			
11	0				0				4		8	11	0			
12	0				1				3		30	18	0			
13	1				0				3	40		23	0			
14	0				0				0				0			
15	0				0				0				0			
16	1				0				1				0			
All	17	73	26	46	61	19	22	14	61	23	28	16	22	23	16	14

-Continued-

Appendix Table 6. Standard errors for estimated mean length at age for burbot sampled in eight lakes in interior Alaska in 1987 (continued).

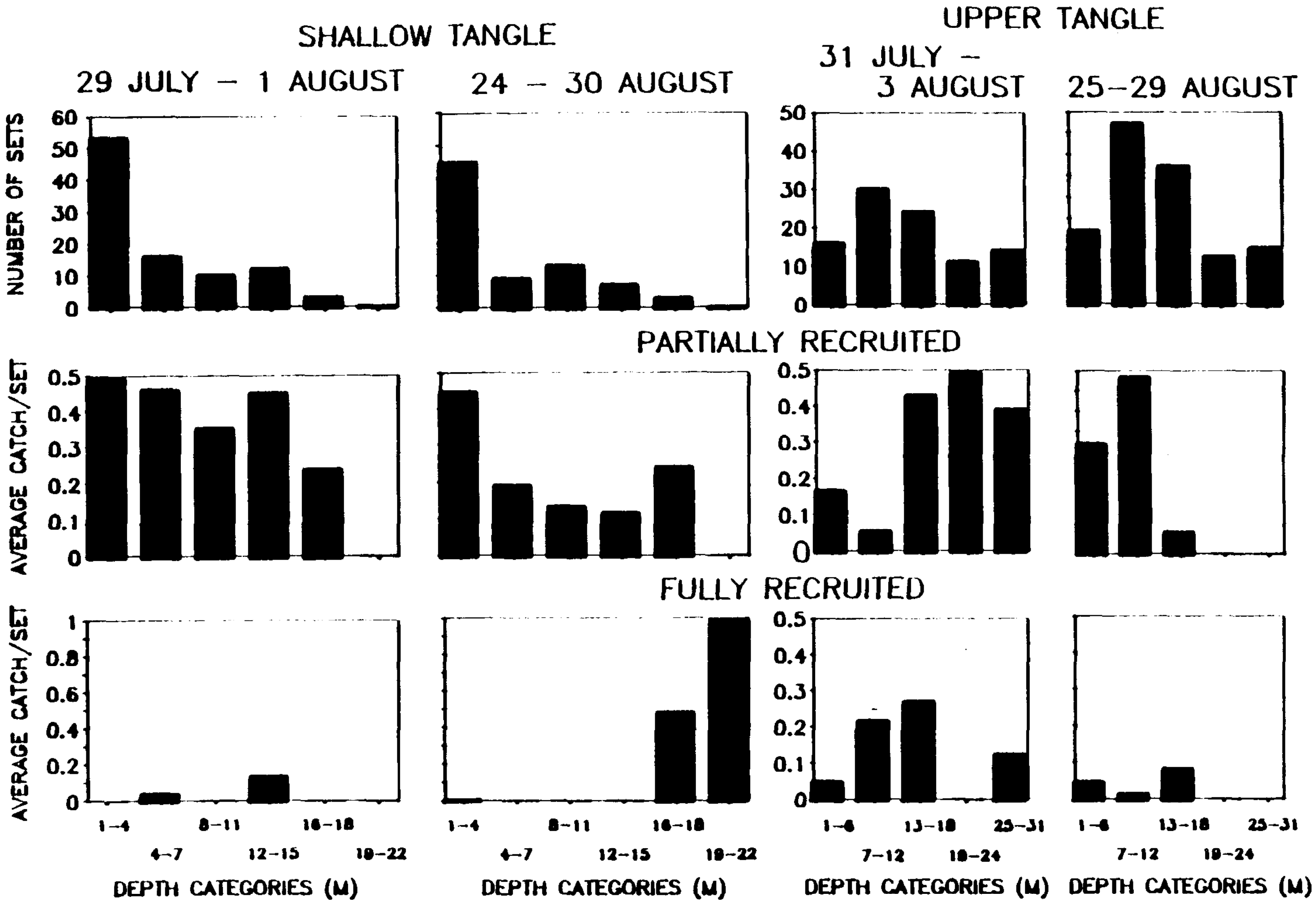
	Crosswind				Deep				Louise				Susitna			
Age	n	M	F	Both	n	M	F	Both	n	M	F	Both	n	M	F	Both
0	0				0				0				0			
1	0				0				0				0			
2	0				0				0				0			
3	2			2	0				1				0			
4	16	6	19	8	1				9	15	13	14	0			
5	11	20	22	16	2			24	15	13	24	11	4		8	8
6	6		21	17	3	45		28	33	11	11	7	12	13	15	12
7	4		39	28	1				14	9	8	6	5		25	25
8	13	16	29	22	0				22	41	23	22	4		7	19
9	3	37		33	3		59	34	13	21	30	17	2		48	48
10	1				1				12	68	17	17	2		23	23
11	2	76		76	2			9	6		17	15	2		7	7
12	0				3			33	0				2		16	16
13	0				3		86	66	1				0			
14	1			67	1				1				0			
15	0				3	13		13	0				0			
All	62				24				129				34			

[1] Sample size.
[2] Males.
[3] Females.

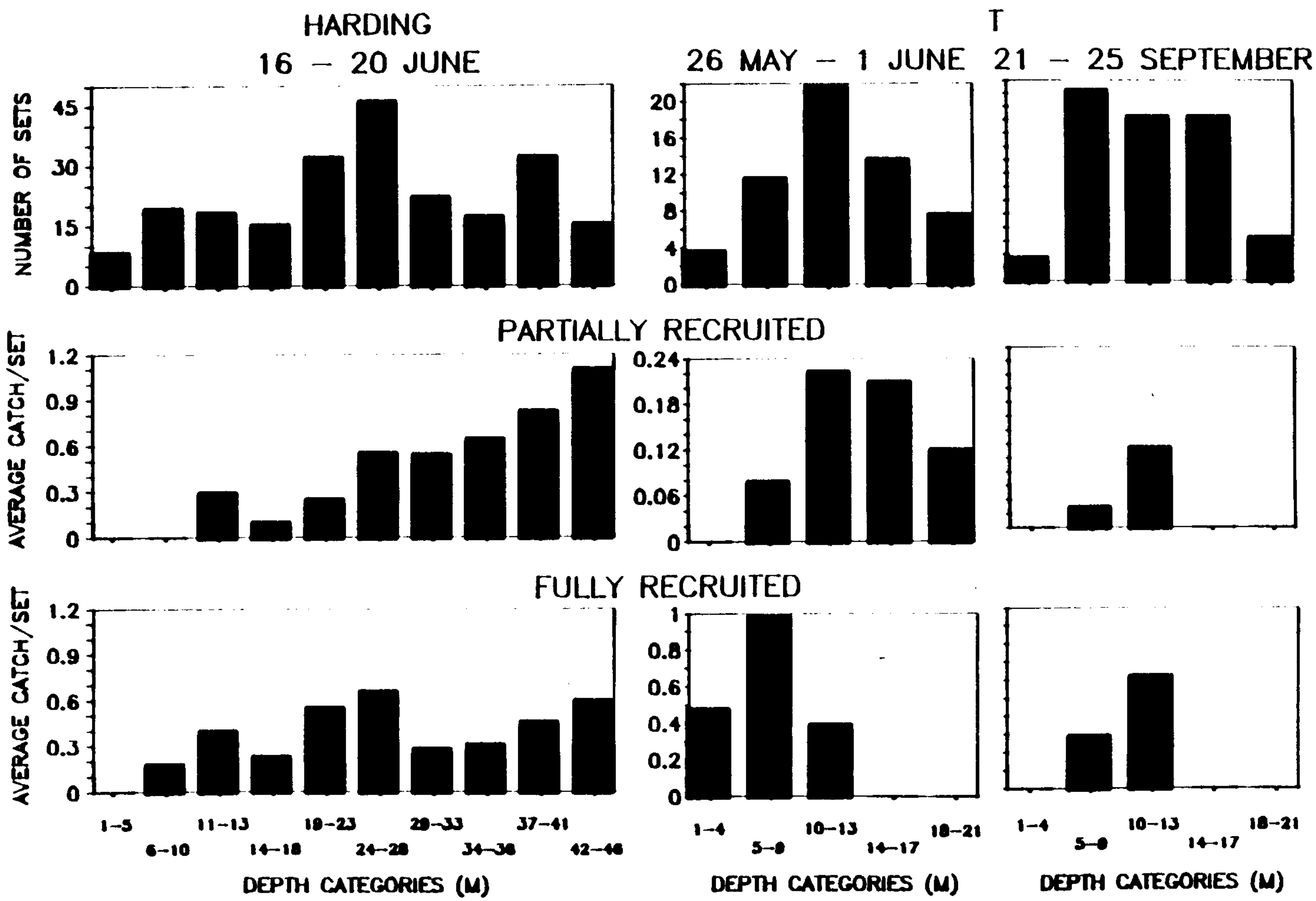
Appendix Table 7. Numbers of burbot killed during sampling in 23 lakes in interior Alaska in 1987[1]

Lake	Fully Recruited	Partially Recruited	Lake	Fully Recruited	Partially Recruited
Landlock			Moose	1	1
Tangle	2	20	Tolsona	4	0
Summit	3	9	Hudson	3	7
Fielding	4	5	Crosswind	35	27
Sevenmile		5	Lost Cabin	0	0
T	0	1	Sucker	6	7
Shallow			Deep	18	6
Tangle	1	0	Louise	77	52
Upper			Susitna	11	34
Tangle	0	1	Tyone	2	0
Round			George	5	12
Tangle	0	4	Harding	30	42
Paxson	45	15			
TOTAL	90	116		192	188

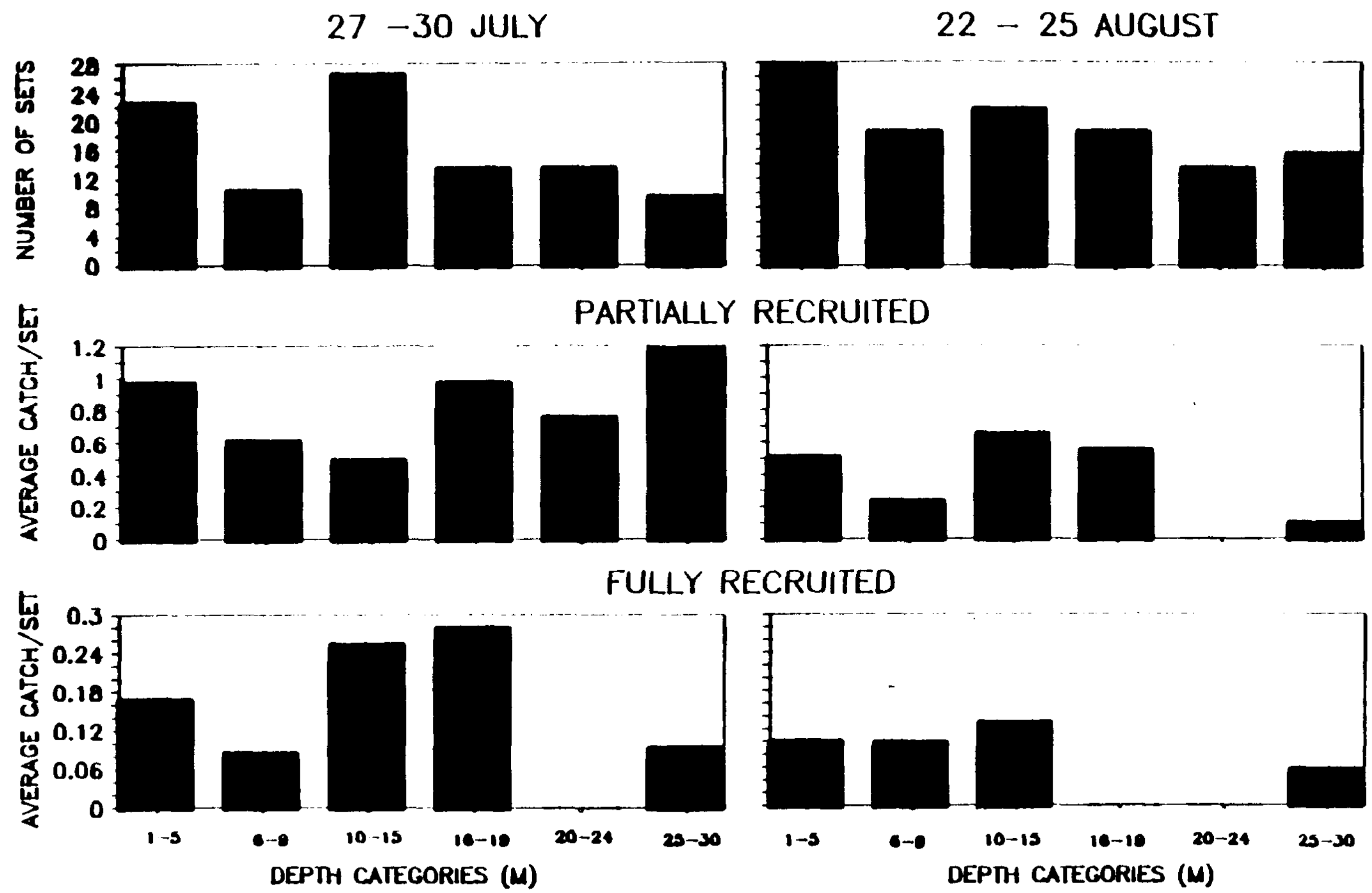
[1] Fully recruited burbot are ≥450 mm TL while partially recruited burbot are smaller.



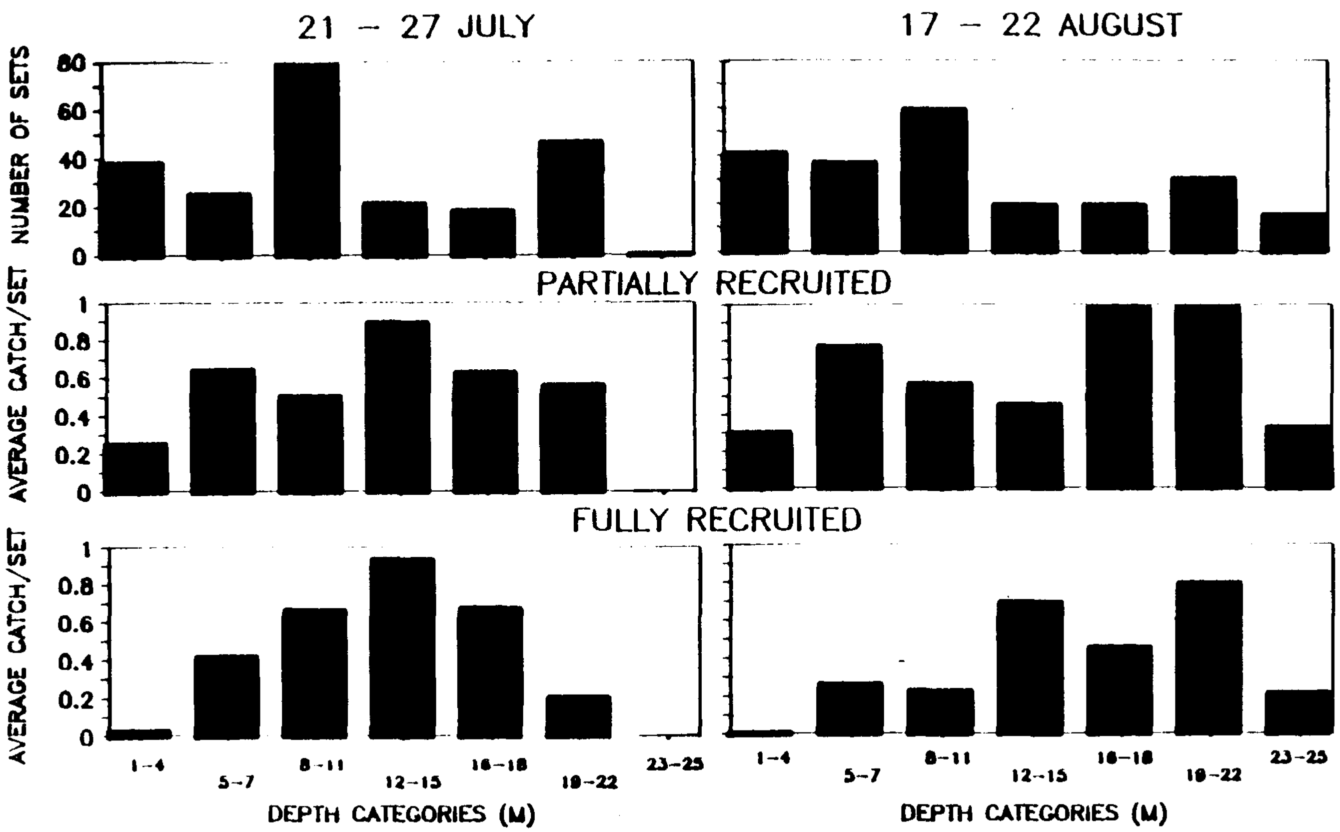
Appendix Figure 1. Frequency of sets by depth and average catch by depth of fully ($\geq$450 mm TL) and partially recruited (<450 mm TL) burbot for the sampling events in Shallow and Upper Tangle Lakes in 1987.



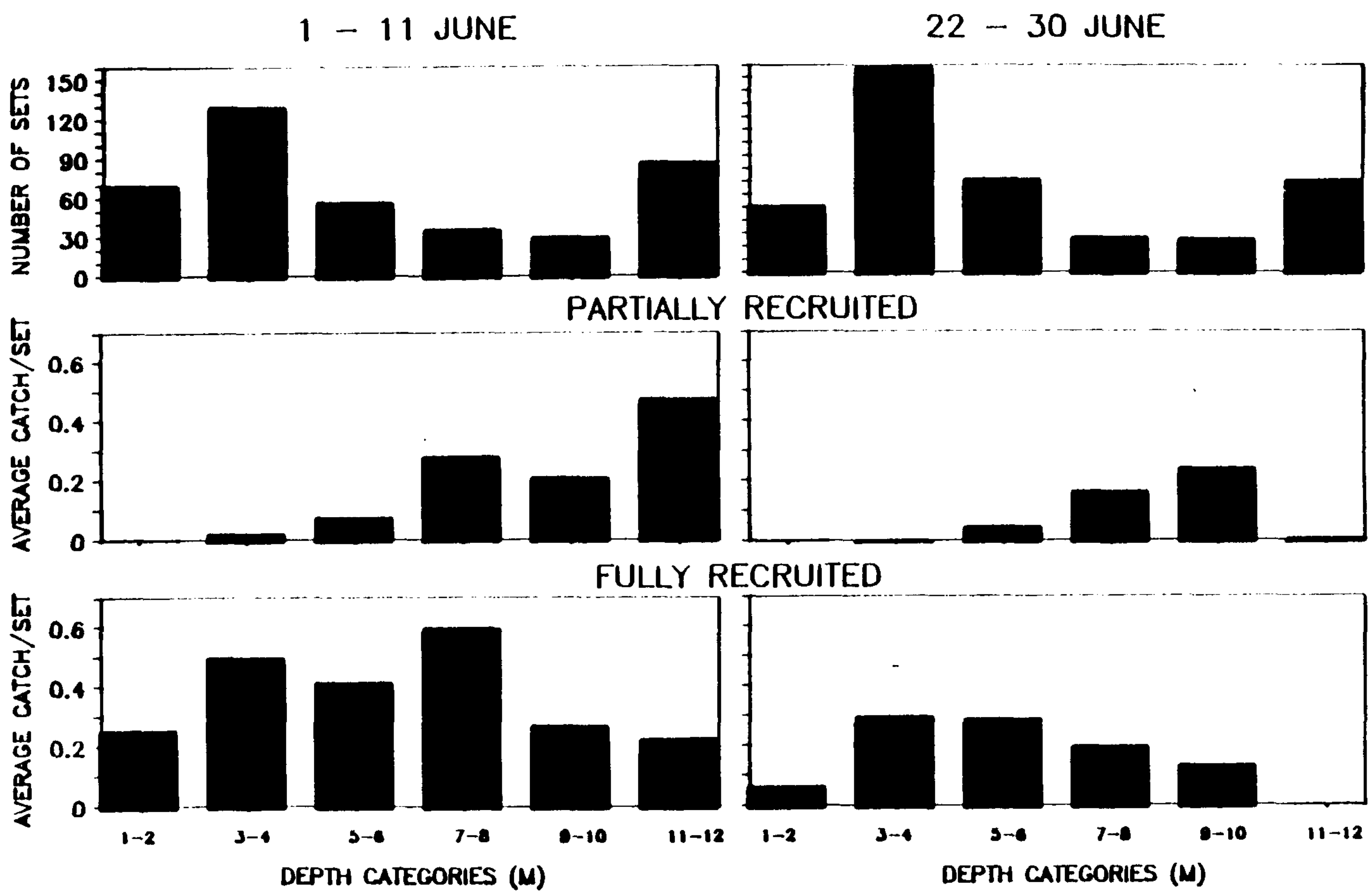
Appendix Figure 2. Frequency of sets by depth and average catch by depth of fully (≥450 mm TL) and partially recruited (<450 mm TL) burbot for the sampling events in T and Harding Lakes in 1987.



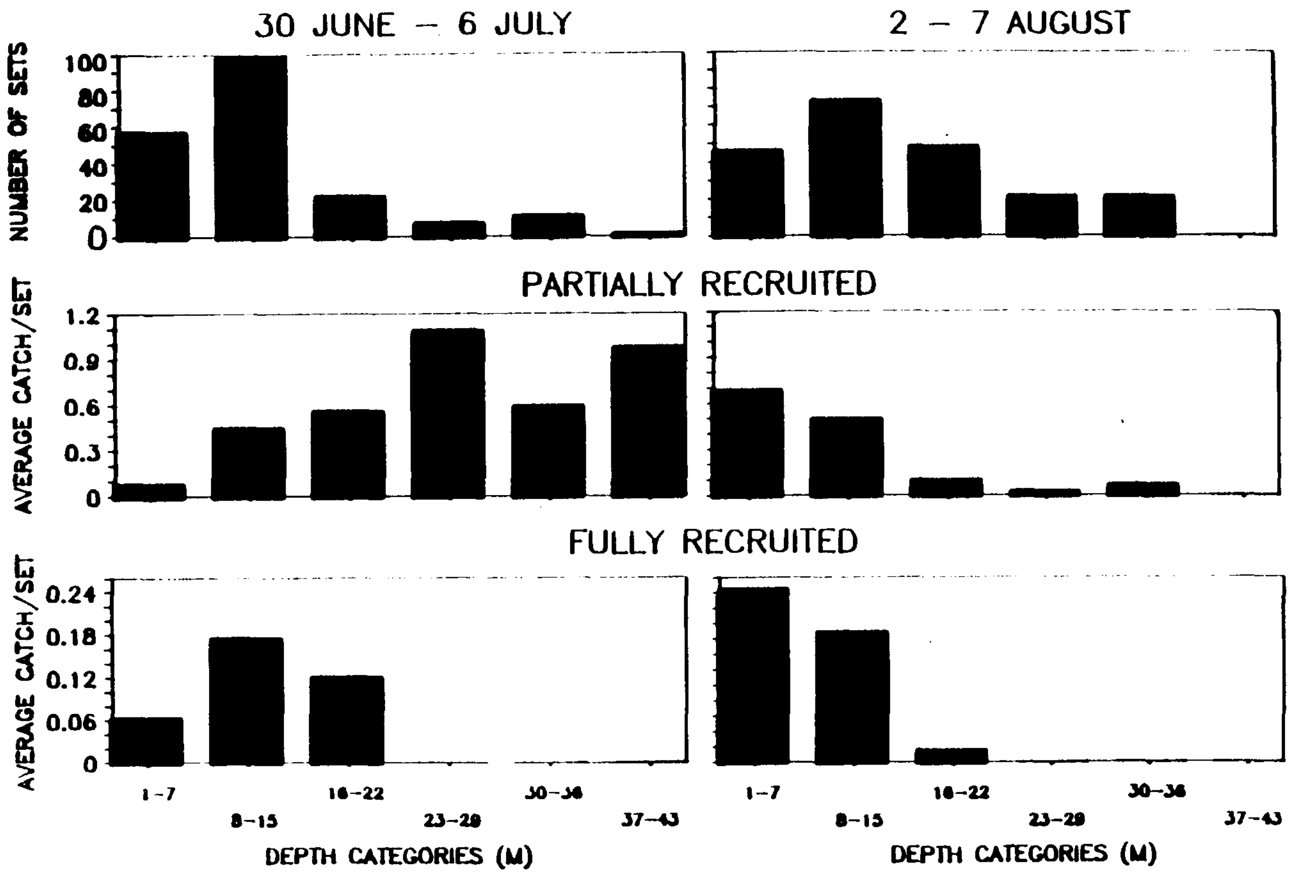
Appendix Figure 3. Frequency of sets by depth and average catch by depth of fully (≥450 mm TL) and partially recruited (<450 mm TL) burbot for the sampling events in Round Tangle Lake in 1987.



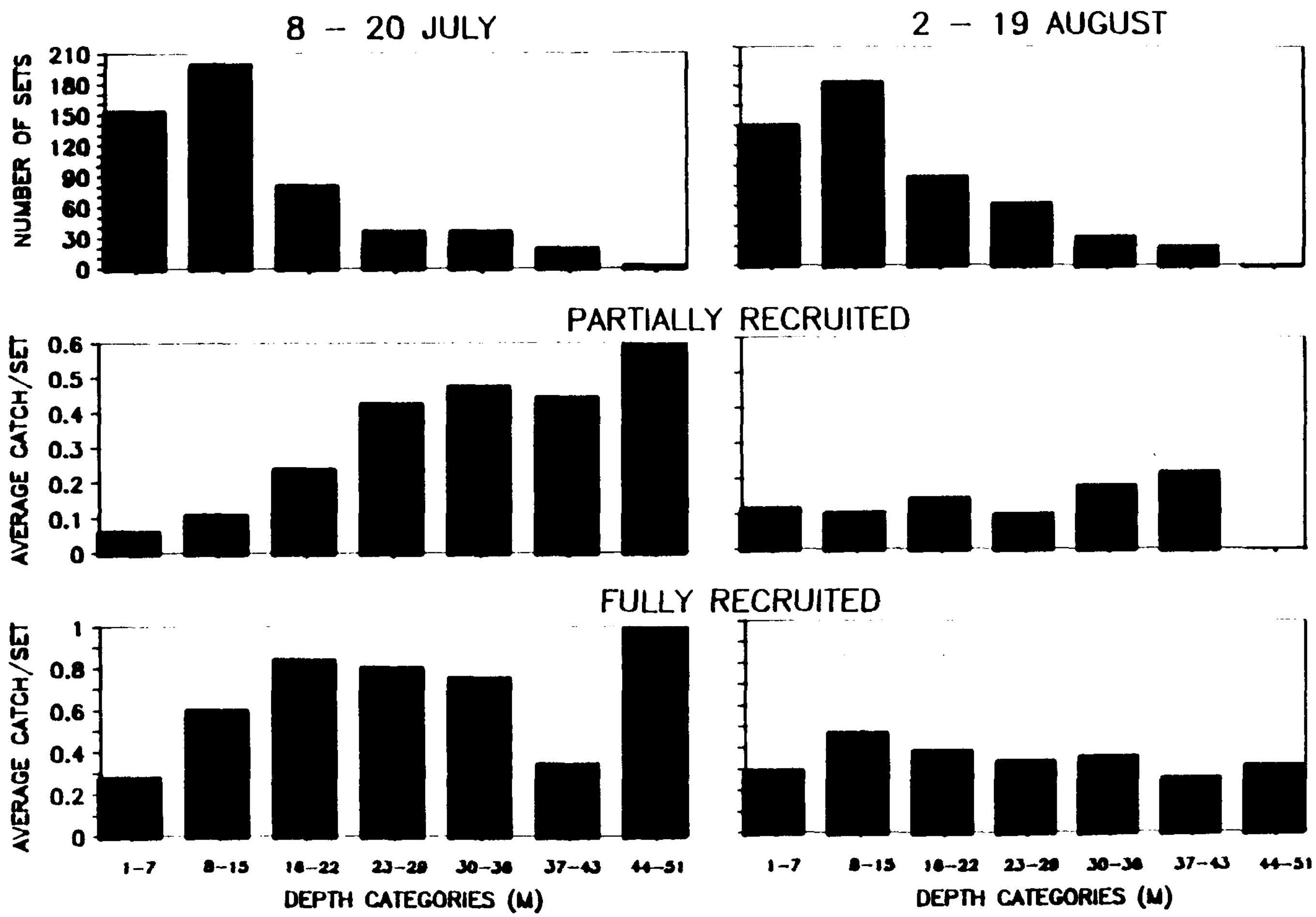
Appendix Figure 4. Frequency of sets by depth and average catch by depth of fully (≥450 mm TL) and partially recruited (<450 mm TL) burbot for the sampling events in Fielding Lake in 1987.



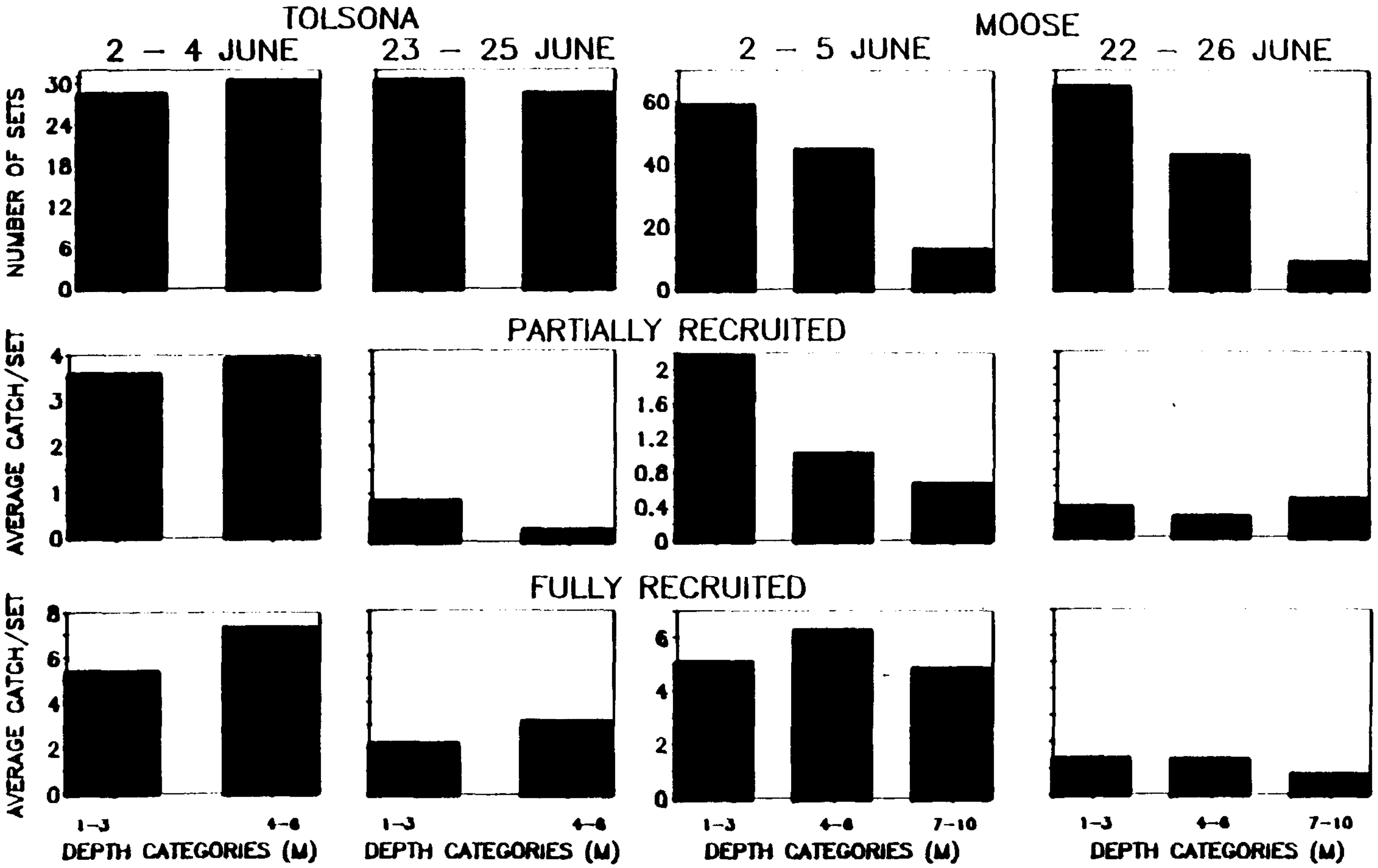
Appendix Figure 5. Frequency of sets by depth and average catch by depth of fully (≥450 mm TL) and partially recruited (<450 mm TL) burbot for the sampling events in George Lake in 1987.



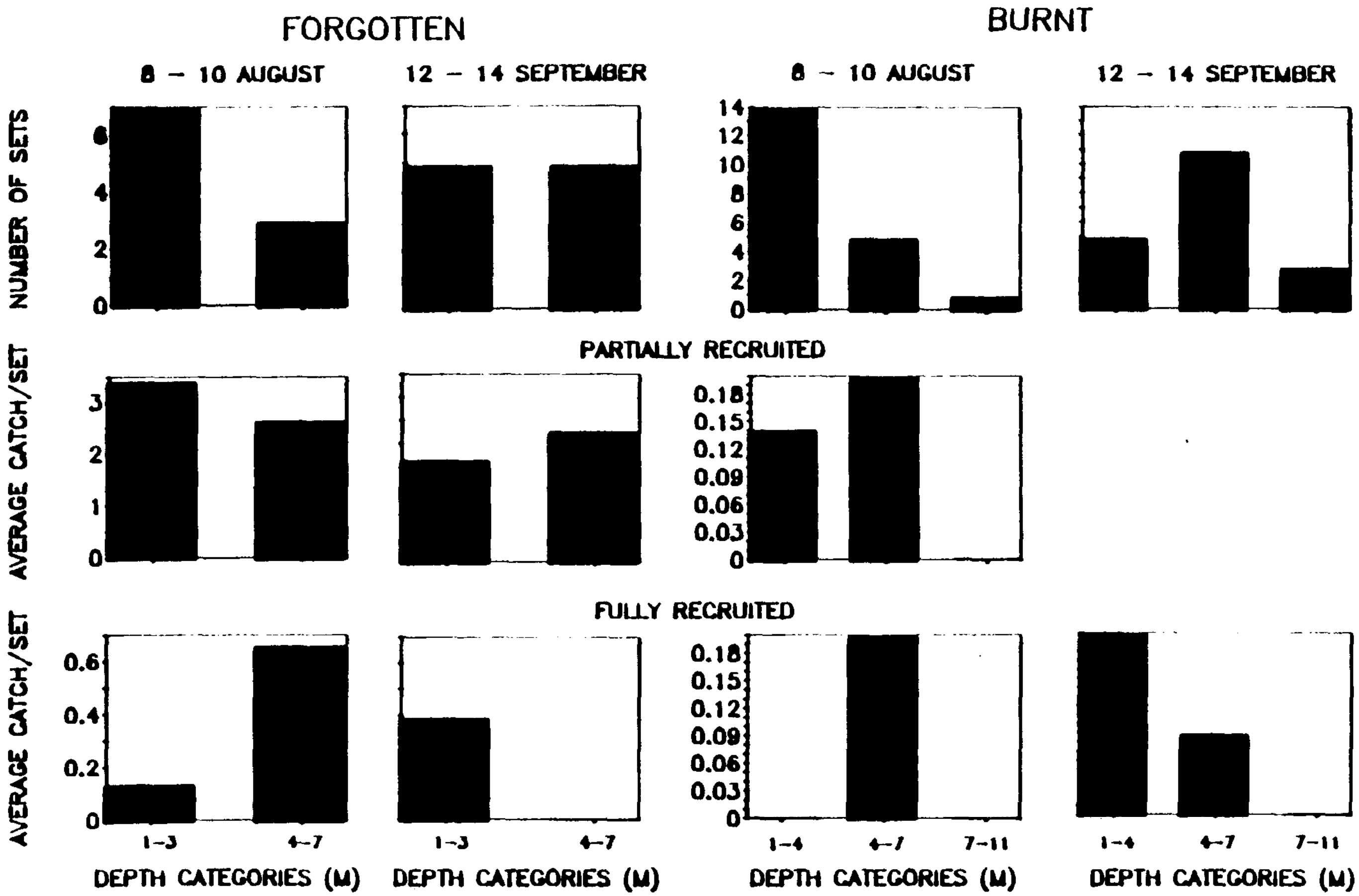
Appendix Figure 6. Frequency of sets by depth and average catch by depth of fully (≥450 mm TL) and partially recruited (<450 mm TL) burbot for the sampling events in Landlock Tangle Lake in 1987.



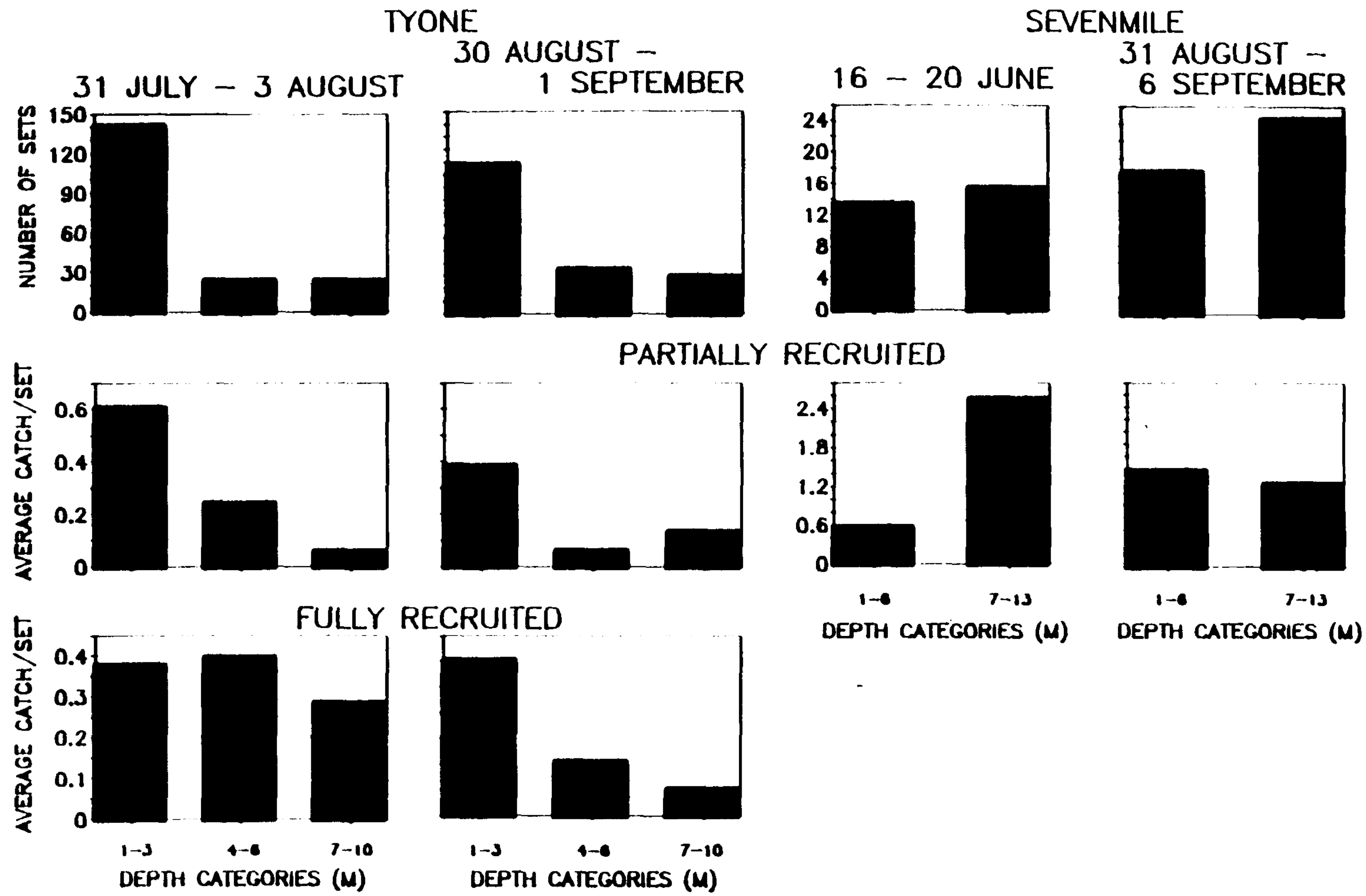
Appendix Figure 7. Frequency of sets by depth and average catch by depth of fully (≥450 mm TL) and partially recruited (<450 mm TL) burbot for the sampling events in Lake Louise in 1987.



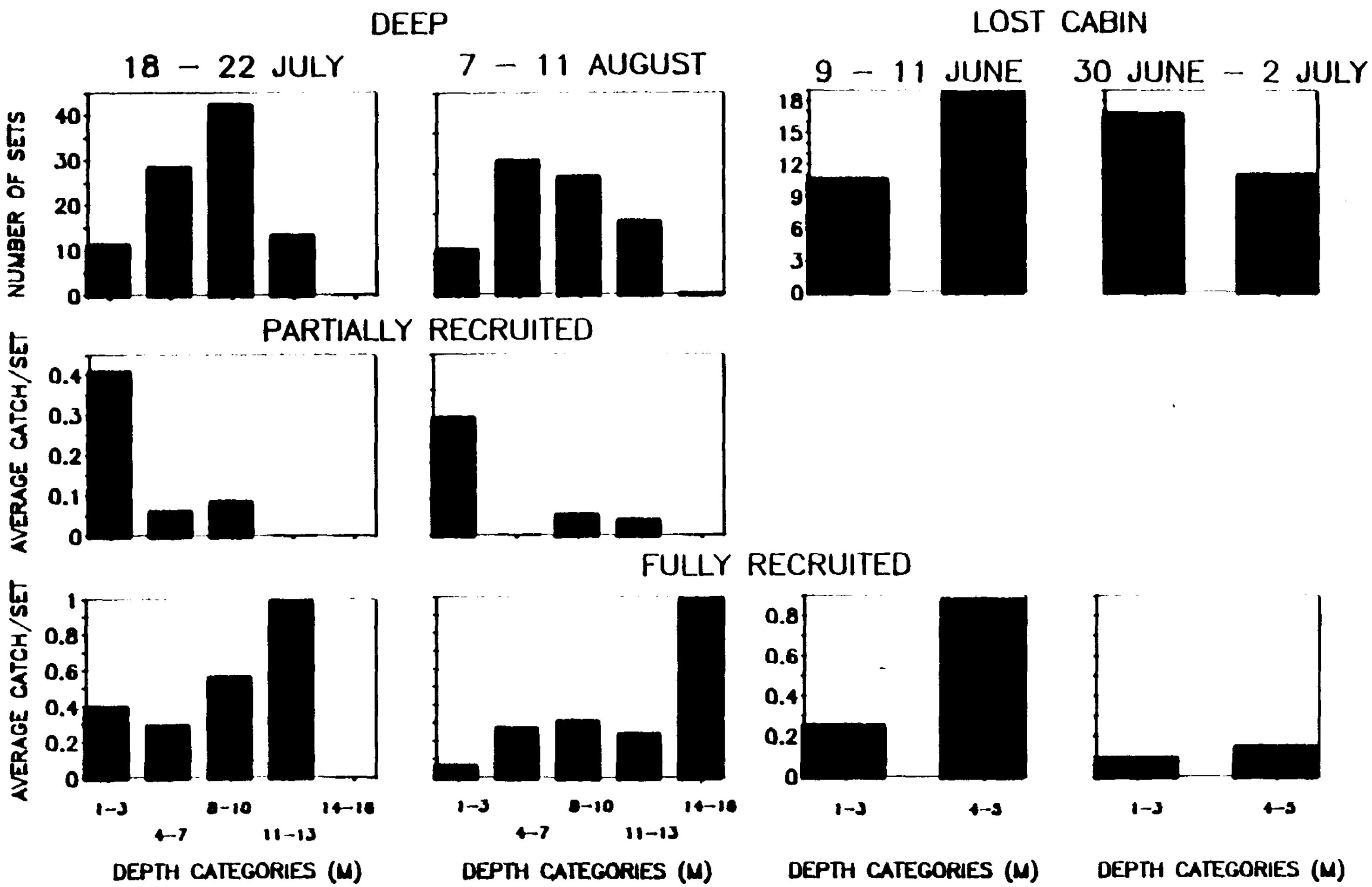
Appendix Figure 8. Frequency of sets by depth and average catch by depth of fully (≥450 mm TL) and partially recruited (<450 mm TL) burbot for the sampling events in Tolsona and Moose Lakes in 1987.



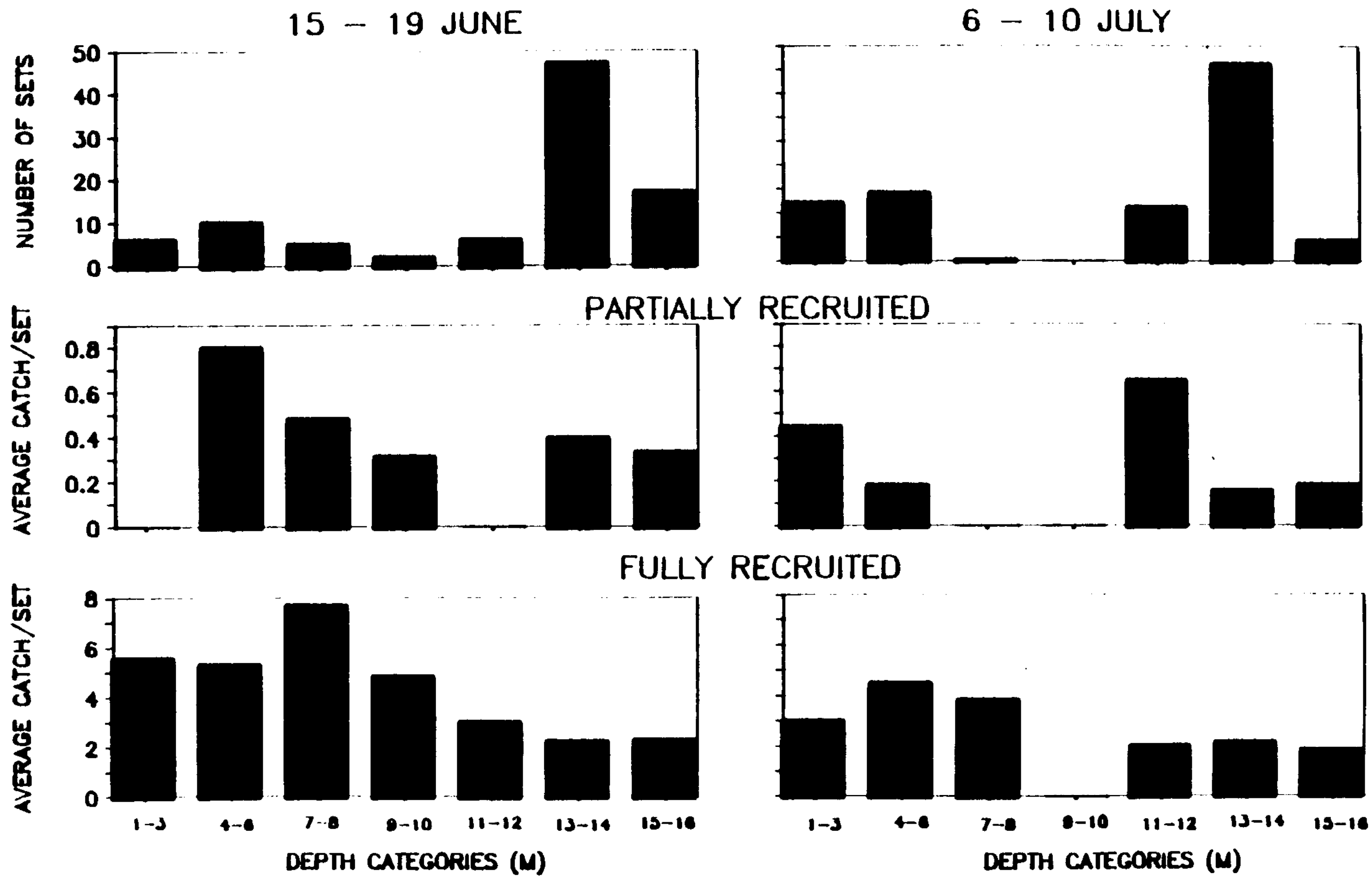
Appendix Figure 9. Frequency of sets by depth and average catch by depth of fully (≥450 mm TL) and partially recruited (<450 mm TL) burbot for the sampling events in Burnt and Forgotten Lakes in 1987.



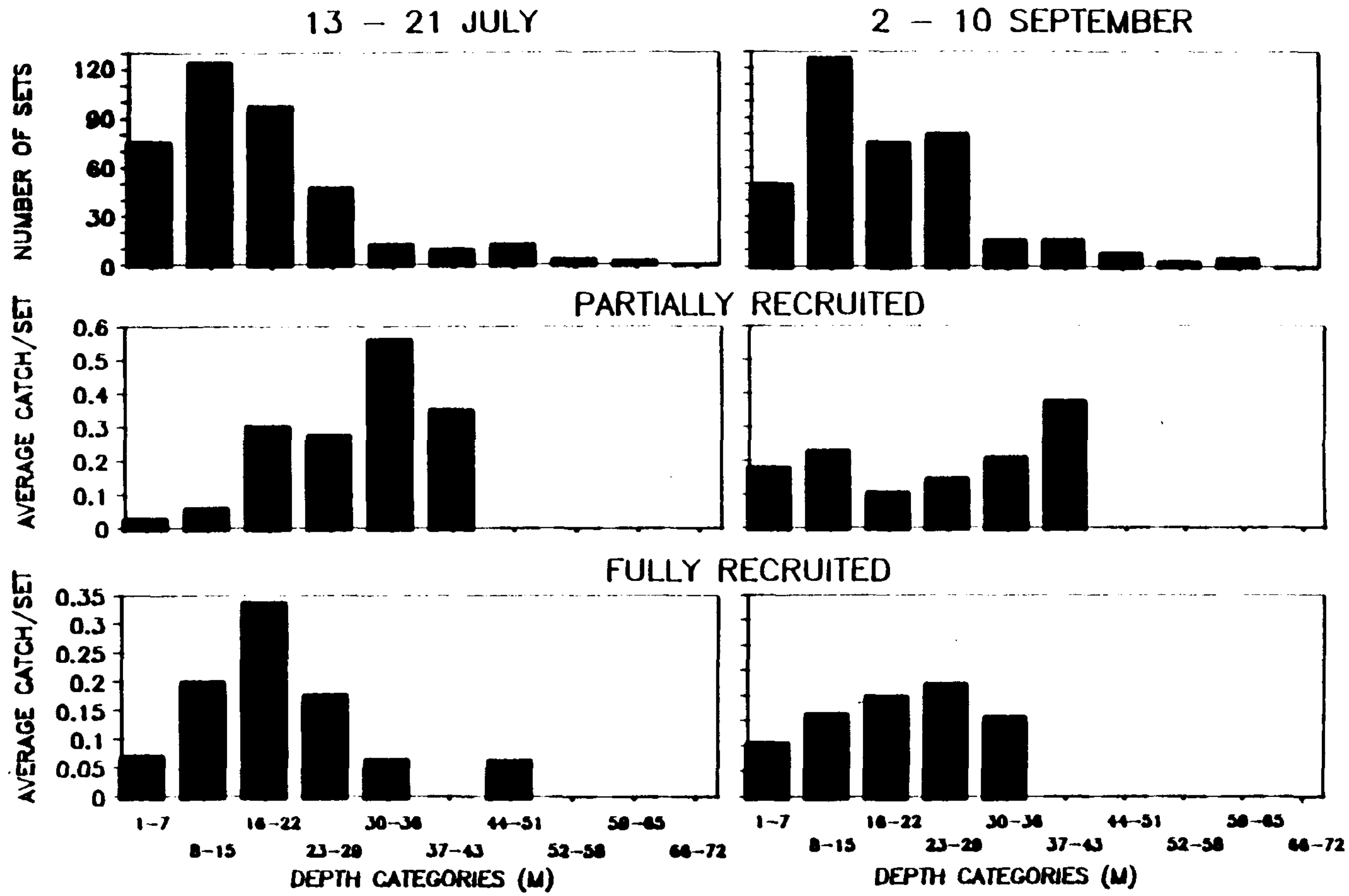
Appendix Figure 10. Frequency of sets by depth and average catch by depth of fully (≥450 mm TL) and partially recruited (<450 mm TL) burbot for the sampling events in Tyone and Sevenmile Lakes in 1987.



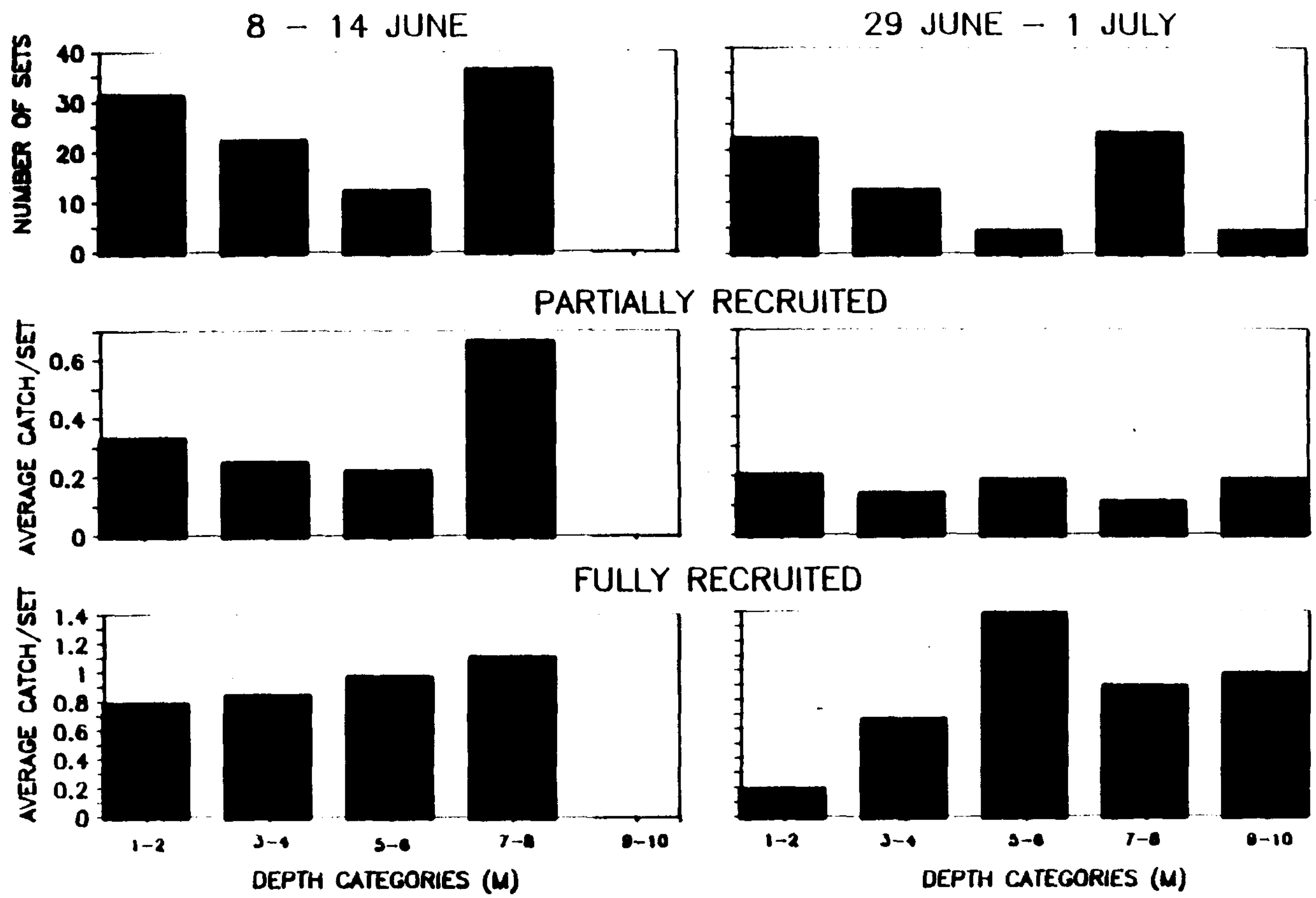
Appendix Figure 11. Frequency of sets by depth and average catch by depth of fully (≥450 mm TL) and partially recruited (<450 mm TL) burbot for the sampling events in Deep and Lost Cabin Lakes in 1987.



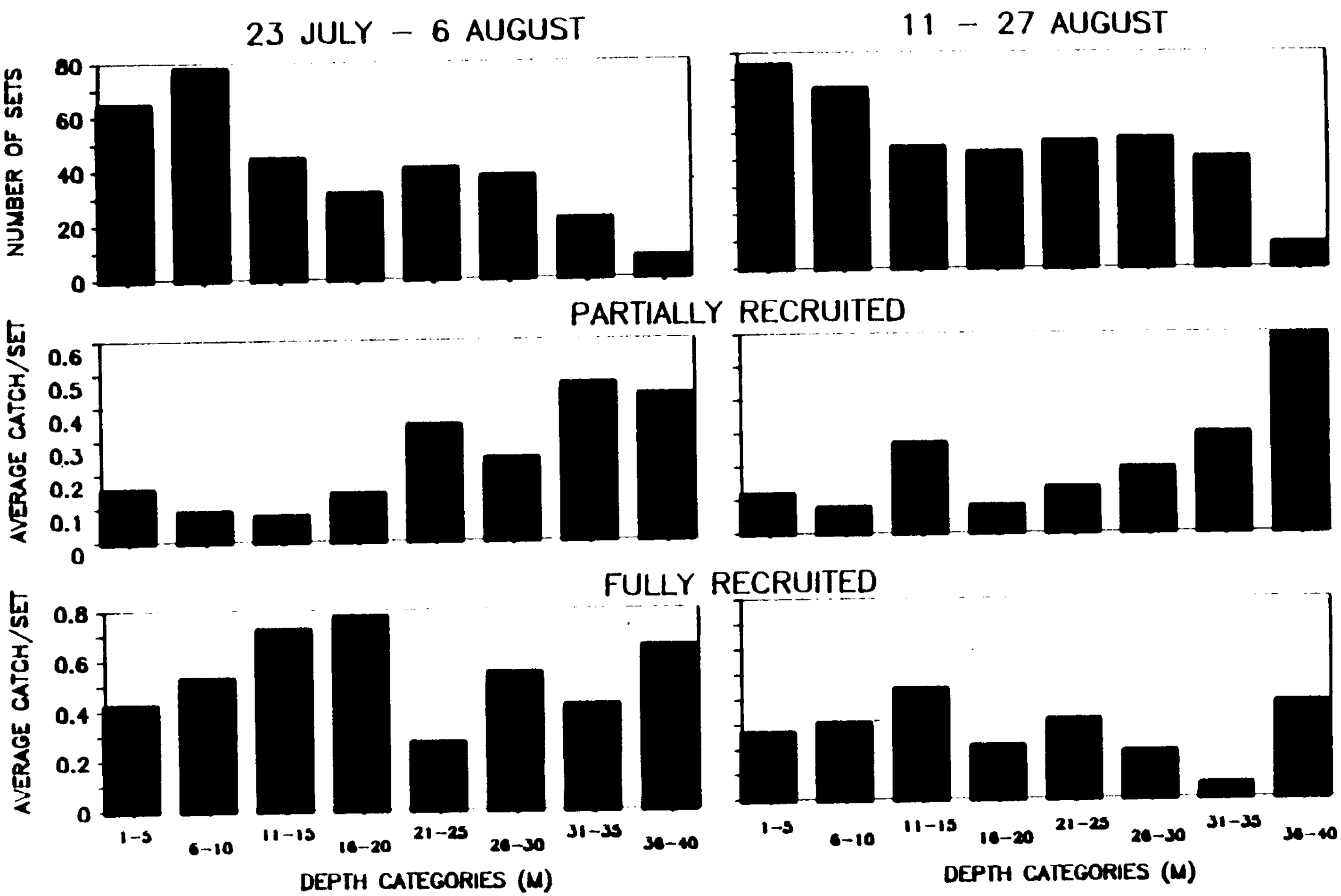
Appendix Figure 12. Frequency of sets by depth and average catch by depth of fully (≥450 mm TL) and partially recruited (<450 mm TL) burbot for the sampling events in Hudson Lake in 1987.



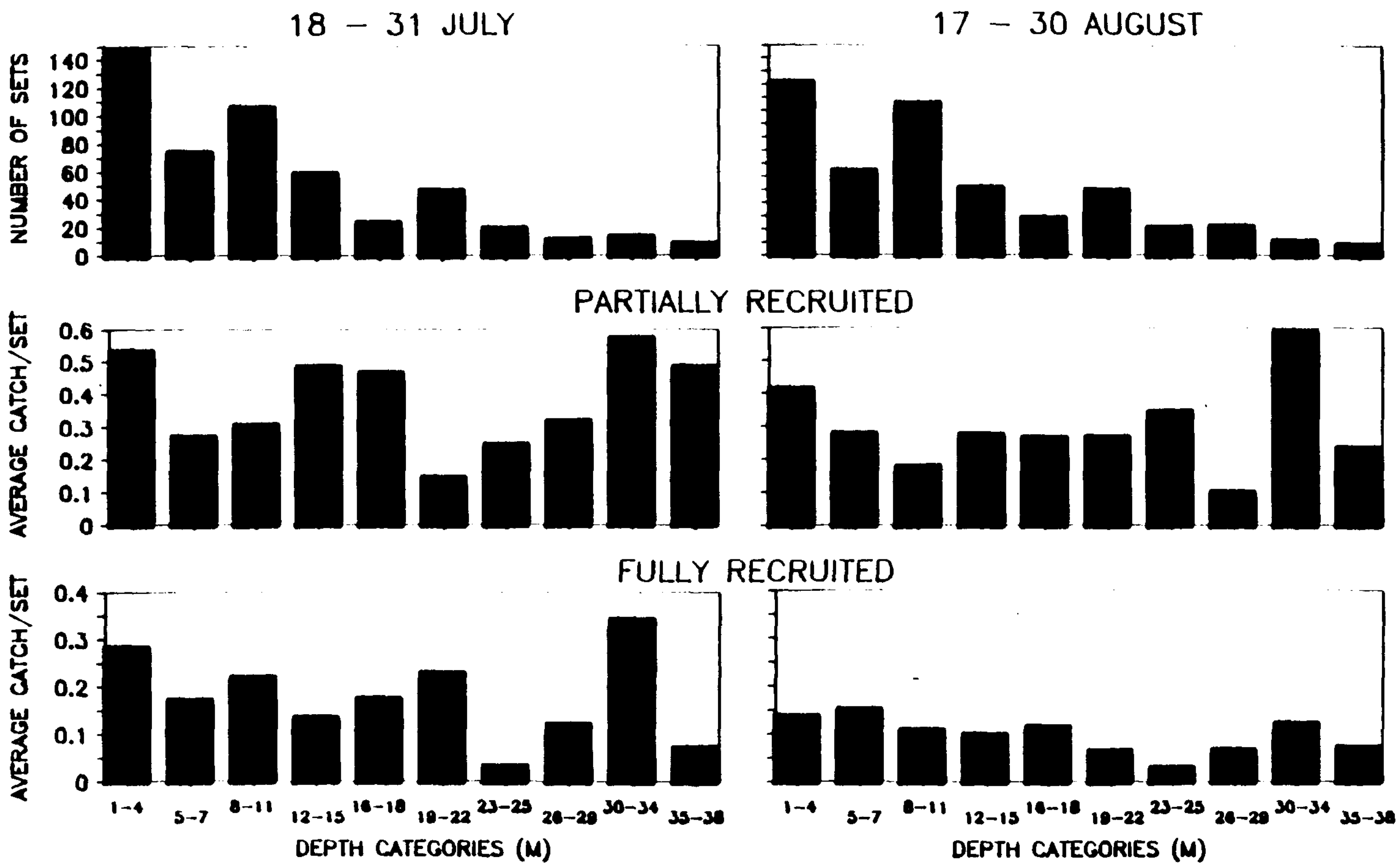
Appendix Figure 13. Frequency of sets by depth and average catch by depth of fully (≥450 mm TL) and partially recruited (<450 mm TL) burbot for the sampling events in Summit Lake in 1987.



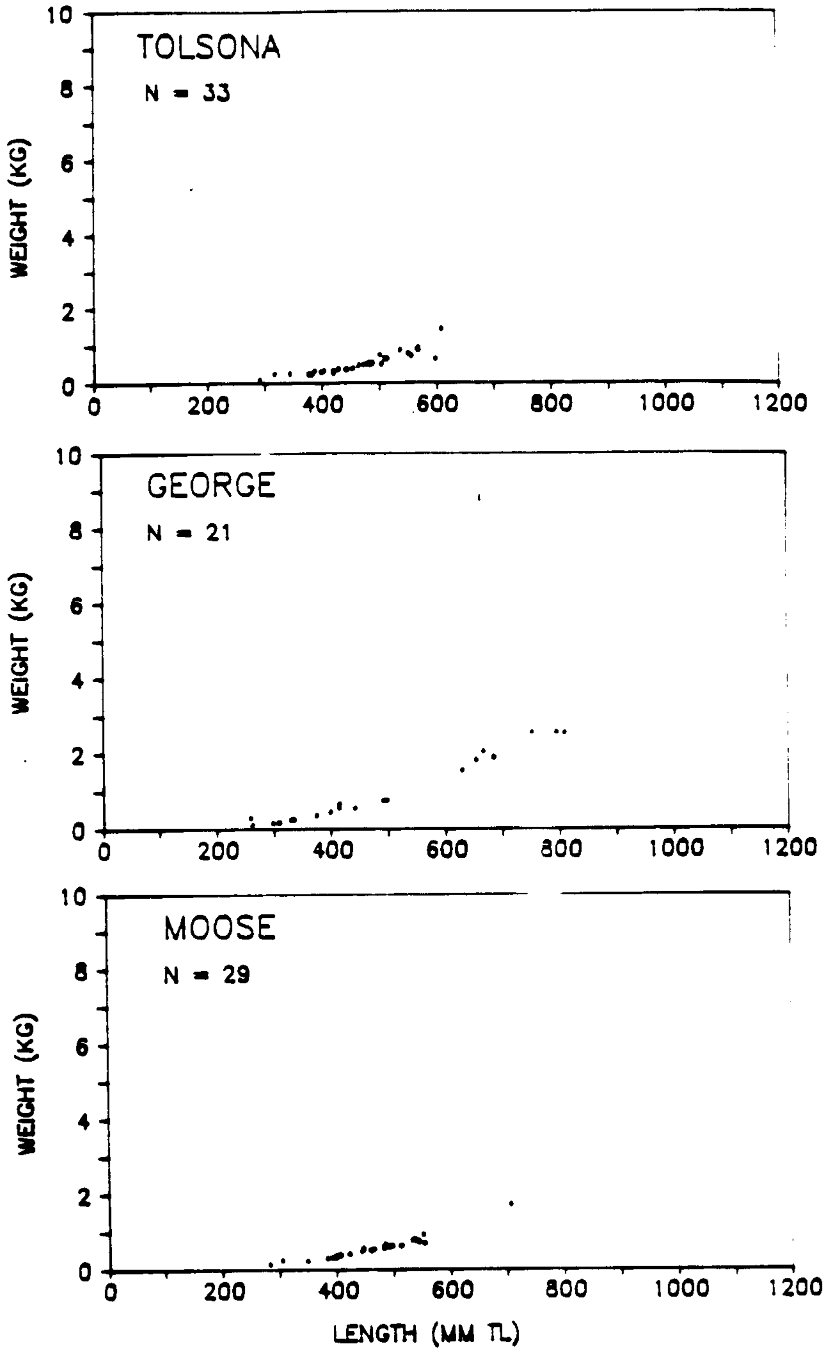
Appendix Figure 14. Frequency of sets by depth and average catch by depth of fully (≥450 mm TL) and partially recruited (<450 mm TL) burbot for the sampling events in Susitna Lake in 1987.



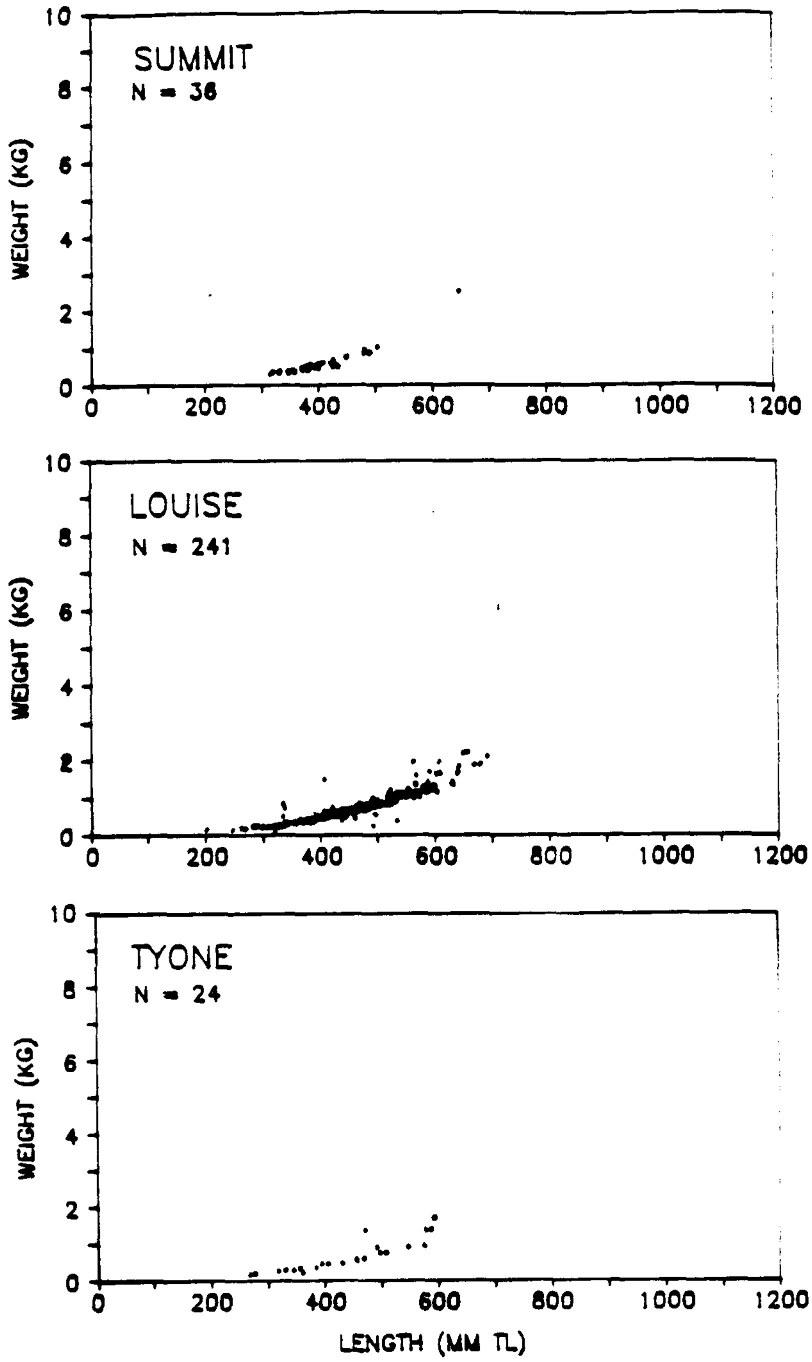
Appendix Figure 15. Frequency of sets by depth and average catch by depth of fully (≥450 mm TL) and partially recruited (<450 mm TL) burbot for the sampling events in Crosswind Lake in 1987.



Appendix Figure 16. Frequency of sets by depth and average catch by depth of fully (≥450 mm TL) and partially recruited (<450 mm TL) burbot for the sampling events in Sucker Lake in 1987.



Appendix Figure 17. Length and weight data for burbot in Tolsona, Moose, and George Lakes. Data were collected in 1986 and 1987 from the former two populations and from 1987 from George Lake.



Appendix Figure 18. Length and weight data for burbot in Lake Louise and in Summit and Tyone Lakes. Data were collected in 1986 and 1987.