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Interannual Intrastream Movements of Arctic Grayling in the Chena, Salcha, and Goodpaster Rivers

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ABSTRACT

The interannual intrastream movements of Arctic grayling *Thymallus arcticus* were estimated in the Chena (1987 through 1992), Salcha (1989 through 1992), and Goodpaster rivers (1988 through 1992) during 1987 through 1992. Releases of marked fish in three (Salcha and Goodpaster rivers) or six (Chena River) areas of each river during June through August of 1987 through 1992 were used to estimate the probability of moving between areas after a hiatus of 1 through 5 years. After a hiatus of 1 year, 74% to 93% of releases in the Chena River had not moved. Of fish that did move, a majority were in a downstream direction. Sixty-four percent to 86% of releases in the Salcha River had not moved after a hiatus of 1 year. Movement was observed both upstream and downstream. After 1 year, 85% to 95% of releases in the Goodpaster River had not moved, with the majority of movement in an upstream direction. After a hiatus of 2 years, 74% to 97% of releases in the Chena River had not moved, with most of the movements downstream. In the Salcha River, 47% to 73% of releases did not move after 2 years; movement occurred both upstream and downstream. Eighty-four percent to 91% of releases in the Goodpaster River had not moved after 2 years; movement occurred both upstream and downstream. After a hiatus of 3 years, 55% to 91% of releases in the Chena River had not moved; movement occurred both upstream and downstream. Between 0% and 83% of releases in the Salcha River had not moved; movement was primarily upstream. In the Goodpaster River, 81% to 100% of releases had not moved; movement was primarily upstream. After a hiatus of 4 years, 36% to 100% of releases in the Chena River had not moved; movement was both upstream and downstream. Sixty-seven percent to 100% of releases in the Goodpaster River had not moved; movement was observed upstream and downstream. After a hiatus of 5 years 64% to 100% of releases in the Chena River had not moved; movement occurred in both directions. There appeared to be a net influx of marked fish into the midstream and upstream areas of the Chena River, while net influx into the upstream area was observed in the Salcha River. A net influx of marked fish into the upstream area was observed in the Goodpaster River. Maximum movement occurred after a hiatus of 3 to 4 years in all rivers. Potential bias in estimates of mortality appears to be highest in the Salcha River, uncertain in the Chena River, and intermediate in the Goodpaster River. The inability to discern seasonal changes from interannual changes in distribution of fish appears to be the greatest potential source of bias in estimates of movement. In the future, attempts to segregate movements by size, age, or sexual maturity at the time of release or recovery will be made. Modeling of interannual movements may allow predictions of changes in fish distribution that come from changes in recruitment or changes in the distribution in fishing effort.

KEY WORDS: Arctic grayling, *Thymallus arcticus*, Chena River, Salcha River, Goodpaster River, interannual movement.

INTRODUCTION

Background

Past research in the Tanana River drainage has shown that fluvial Arctic grayling make extensive migrations from overwintering areas to spawning areas, spawning areas to summer feeding areas, and summer feeding areas back to overwintering areas (Reed 1964, Tack 1980, Ridder 1991). For an individual stock of Arctic grayling, each of these areas can be contained in a single river system (e.g., the stock or stocks of the Chena River; Tack 1980) or each of these areas can be contained in separate river systems (e.g., stocks using Shaw Creek, the Richardson Clearwater River, and the Tanana River; Ridder 1984, 1991). As a result, stock assessments of fluvial Arctic grayling in the Tanana River drainage are performed when Arctic grayling are thought to have reached their summer feeding area and have ceased migrating (Clark and Ridder 1988). In general, migration to summer feeding areas ceases in mid-June and migration from summer feeding areas to overwintering areas begins as early as mid-August (Tack 1980). Assuming that Arctic grayling return to the same summer feeding area annually (Tack 1980), the assessed stock in a particular section of river can be thought of as closed to immigration and emigration (geographic closure), but open to the processes of recruitment and mortality (demographically open). If the assumption of geographic closure is valid, annual stock assessments could be performed on a sufficiently large section of river and the resultant estimates of recruitment and mortality would be unbiased for the stock or portion of the stock residing in that particular section of river.

Alternatively, research on the distribution of Arctic graying during summer has shown that larger fish inhabit upstream areas of rivers of the Tanana drainage. Tack (1980) found that while smaller fish were present in usptream areas of the Goodpaster River during spawning, they were subsequently displaced into headwater tributaries or downstream in the mainstem during summer. Smaller fish may be displaced by competition with larger fish for food and space (Tack 1980, Hughes 1991). Larger fish may prefer upstream areas because of cooler summer temperatures and a higher concentration of invertebrate drift than found in downstream area (Hughes, Simon Fraser University, Burnaby, British Columbia, Canada, personal communication).

Differences in size distribution of Arctic grayling in summer feeding areas do influence how stock assessments are performed. If Arctic grayling were randomly distributed with respect to size along the length of a river, choice of a particular study section for stock assessment would simply entail choosing a sufficiently large section of river so that precise estimates of abundance and age and size composition could be estimated. The question of where along the length of the river should stock assessment be performed would be irrelevant. Because there is a gradient in size of Arctic grayling along a river, the length of study section chosen for stock assessment must be long enough to contain a sufficient number of adult Arctic grayling. If the section began in a lower reach of river, was long enough to contain both small and large Arctic grayling, and fish returned annually to summer feeding areas, estimates of recruitment (generally smaller fish) would likely be unbiased.

Estimates of mortality would likely be biased if there were differences in mortality rate among sizes of fish.

If the hypothesis that Arctic grayling move upstream as they grow older caused the size gradient observed in rivers of the Tanana River drainage, there would be additional bias in estimates of mortality. Emigration of large Arctic grayling out of a particular study section would cause a negative bias in mortality rates. Immigration of smaller fish into a study section would have the opposite effect on estimates of mortality. However, the size gradient observed on these rivers could be caused by factors other than fish moving upstream as they grew older. If the interannual movements of Arctic grayling could be quantitatively estimated, the confusion surrounding these competing hypotheses would be reduced and stock assessment programs could be tailored to alleviate bias in estimates of mortality and recruitment.

This research project was initiated to quantitatively estimate rates of movement of Arctic grayling in three rivers and to determine if movements are of a magnitude that might seriously bias estimates of mortality in a stock assessment program. The Chena, Salcha, and Goodpaster rivers were chosen because there are ongoing stock assessment projects on each and the scope of each project differs in the length of study section and timing of the stock assessment (see Clark 1993 and Ridder et al. 1993). Arctic grayling in the Chena River have been investigated intensively since 1987, with estimates of mortality and recruitment for a study section that encompasses the lower 152 km of the mainstem. Stock assessment occurs during the month of July in the Chena River. Similarly, a 36.8 km section of the lower Salcha River has been studied annually since 1989 (assessment during June). Annually since 1988, a 50 km section of the lower Goodpaster River has been assessed during August.

To estimate movements, the study section in each river was divided into three or more areas ranging in length from 12.8 km to 40 km. As part of the annual stock assessment, abundance of Arctic grayling was estimated in each area by means of mark-recapture experiments. Tagged Arctic grayling, released and recovered during these mark-recapture experiments provided the raw data needed to estimate rates of movement between areas.

Objectives

The objective of this research project was to estimate mixing rates (contributions) of Arctic grayling initially marked in their summer feeding areas in year t and recovered in summer feeding areas in years t+1 through t+5 in the Chena River, years t+1 through t+3 in the Salcha River, and years t+1 through t+4 in the Goodpaster River. In addition, estimates were calculated for the proportion of marked fish in summer feeding areas in year t, surviving to year $t+h$ and not leaving the study section, that were residing in summer feeding areas in year $t+h$.

METHODS

Study Design

Questions concerning the effect of movements of Arctic grayling on the accuracy of stock assessment programs in rivers were not quantitatively addressed in a separate study of fish movement. Data collected during annual stock assessments on the Chena, Salcha, and Goodpaster rivers were used to evaluate movement and estimate the rate of movement over time. Estimates of abundance and variance of the abundance estimate, number of fish marked and released, and number of fish examined for marks were gleaned from the Fishery Data Series reports for each river system. Methods of capture and marking, collection of biological data, analysis of capture-recapture data, and methods of estimation are also addressed in each report. All captures were made with a pulsed-DC electrofishing boat described by Clark and Ridder (1987).

Chena River:

Beginning in 1987, a program of stock assessment on the Chena River was designed so that abundance could be estimated for the lower 152 km of the mainstem for fish ≥ 150 mm fork length (Clark and Ridder 1988; Figure 1). During the month of July abundance was estimated for the entire 152 km of river, but estimates of abundance or density (per km) were also calculated in six discrete areas. These areas are (see Figure 1):

1) river kilometer 0 through 40 (from the mouth upstream to the Nordale Road crossing);

2) river kilometer 41 through 72 (from the Nordale Road crossing upstream to the Moose Creek Dam complex);

3) river kilometer 73 through 88 (from the Moose Creek Dam complex upstream to the second bluff);

4) river kilometer 89 through 104 (from the second bluff upstream to Theis' cabin);

5) river kilometer 105 through 117 (from Theis' cabin to 28 Mile access on the Chena Hot Springs Road); and,

6) river kilometer 118 through 152 (from 28 Mile access upstream to the first bridge crossing at mile 38 on the Chena Hot Springs Road).

The proportion of fish marked and released in each of the six areas was estimated from the number of marks released during abundance estimation and the estimate of abundance. As the stock assessment program progressed through time, each year of marking and abundance estimation represented a release of new fish and a recovery sample for marks released during previous years (Figure 2). From each recovery sample, the proportion of fish that were previously marked and released into one of the six areas was estimated from the number of marked fish and the total number of fish examined for marks. Movement was defined to occur when a marked fish was released into one of the

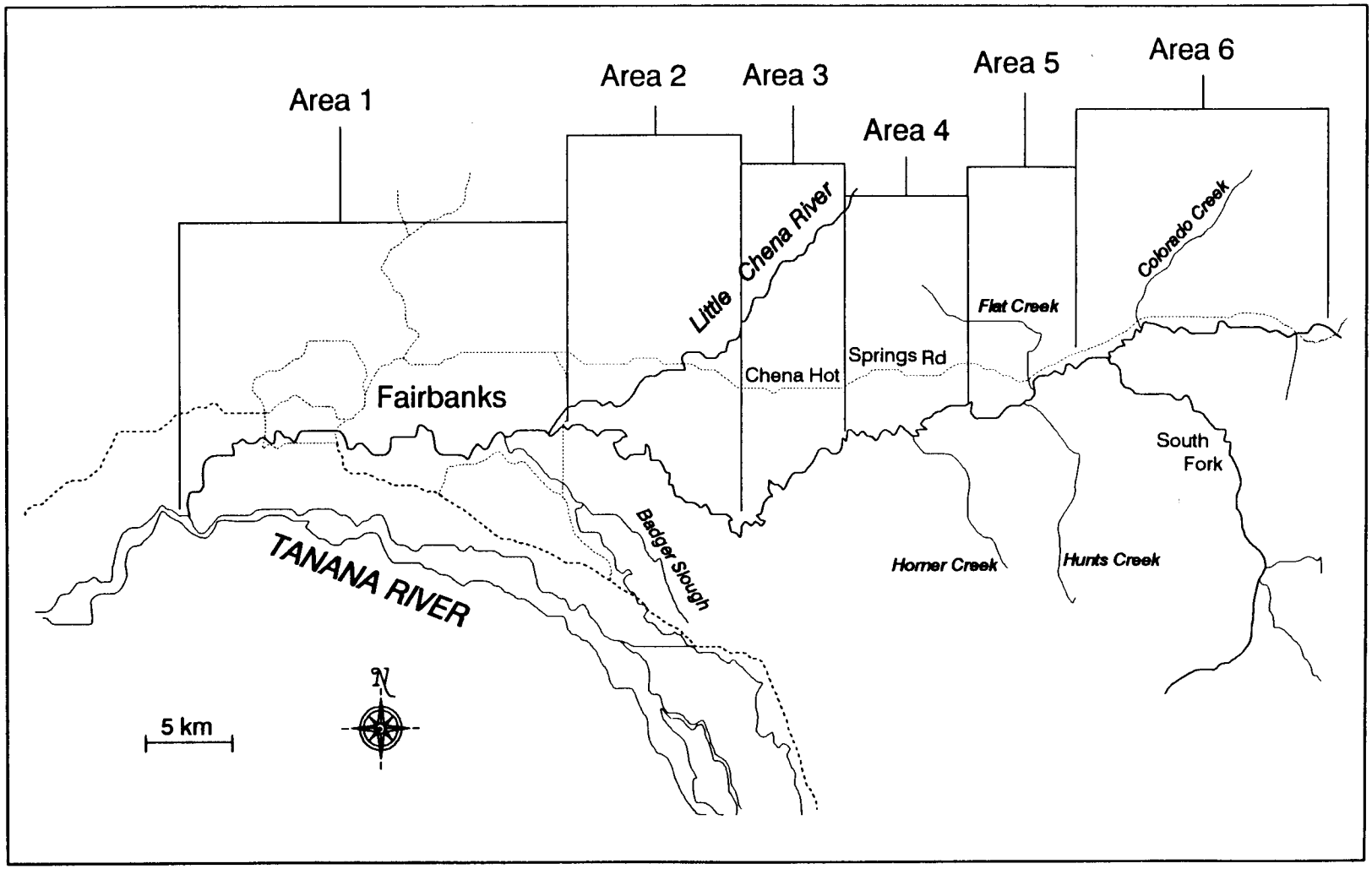

Figure 1. Study section and six areas used for estimation of movements of Arctic grayling in the Chena River, 1987 through 1992.

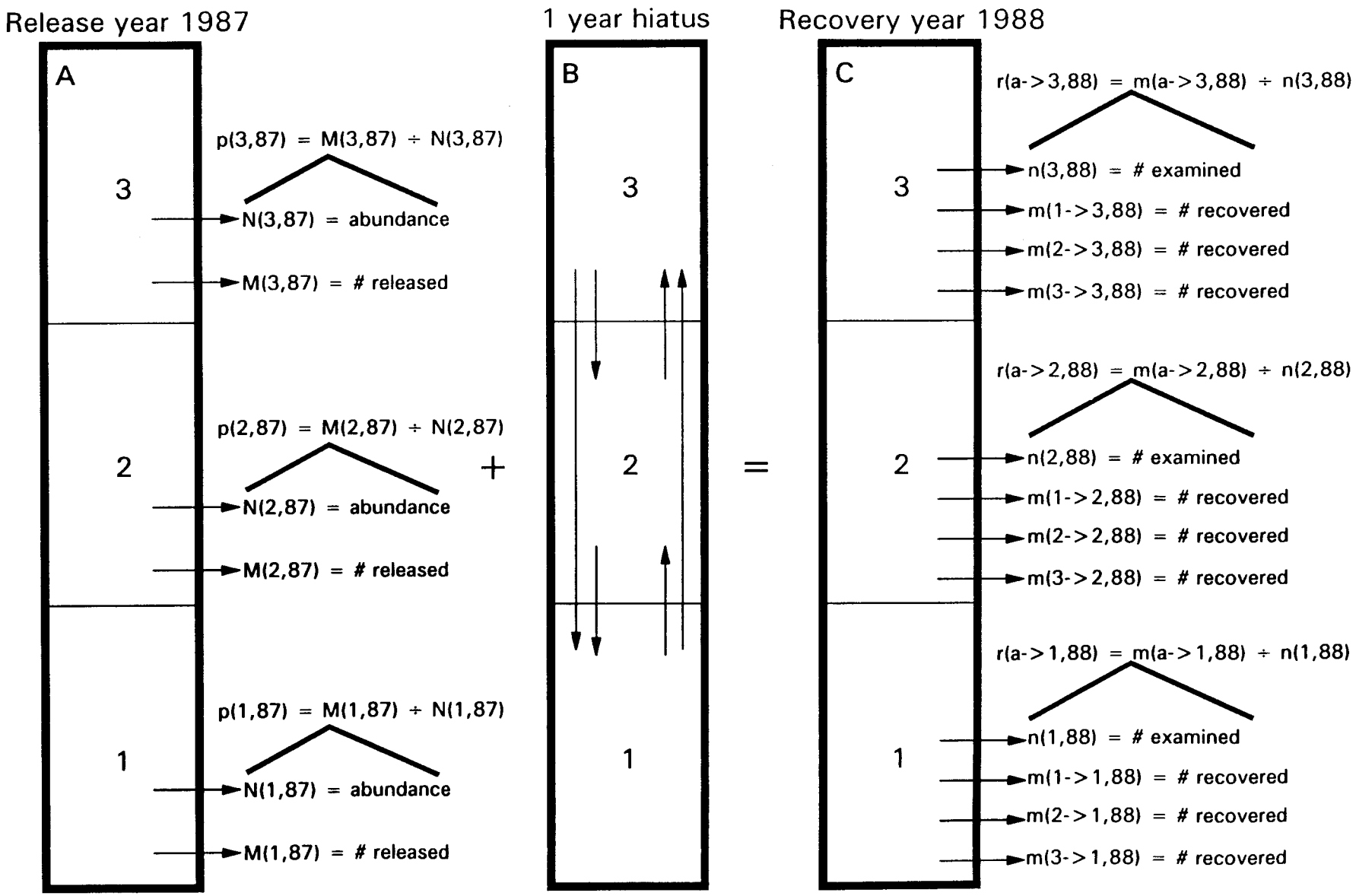

Figure 2. Diagrammatic representation of the estimation process used in release and recovery areas of the Chena, Salcha, and Goodpaster rivers.

six areas and recovered in a different area at least one stock assessment cycle (approximately one year) later. Contributions of marked fish to each of the six areas was estimated using the ratio of the proportion recovered to the proportion marked.

Salcha River:

Stock assessment of Arctic grayling in the lower 36.8 km of the Salcha River began in 1989 (Figure 3). During 1985 through 1988, estimates of age and size composition and/or abundance were calculated for a subset of this river section (Ridder et al. 1993). Similar to the Chena River, estimates of movement were calculated from capture-recapture data collected during stock assessment. The Salcha River was divided into three approximately equal areas of river. These areas are (see Figure 3):

1) river kilometer 0 through 12.8;

2) river kilometer 13.0 through 25.6; and,

3) river kilometer 26.0 through 38.4.

Proportions of fish marked, fish recovered, and contributions to the three areas were estimated identically to the Chena River study.

Goodpaster River:

Stock assessment of Arctic grayling in the lower 53 km of the Goodpaster River began in 1988 (Figure 4). During 1976 through 1987, estimates of age and size composition and/or abundance were calculated for a subset of this river section (Ridder et al. 1993). Similar to the Chena River, estimates of movement were calculated from capture-recapture data collected during stock assessment. The Goodpaster River was divided into three approximately equal areas of river. These areas are (see Figure 4):

1) river kilometer 0 through 19.2;

2) river kilometer 20.0 through 33.6; and,

3) river kilometer 34 through 52.3.

Proportions of fish marked, fish recovered, and contributions to the three areas were estimated identically to the Chena River study.

Data Collection and Reduction

Fish were marked with individually numbered Floy internal anchor tags. Fork length of each marked fish was recorded and scales were taken from a sample of marked fish for determination of age. Numbers of fish marked, numbers examined for recoveries, estimates of abundance, and estimates of variance of abundance in each area were gleaned from Fishery Data Series reports for each river (see Table 1).

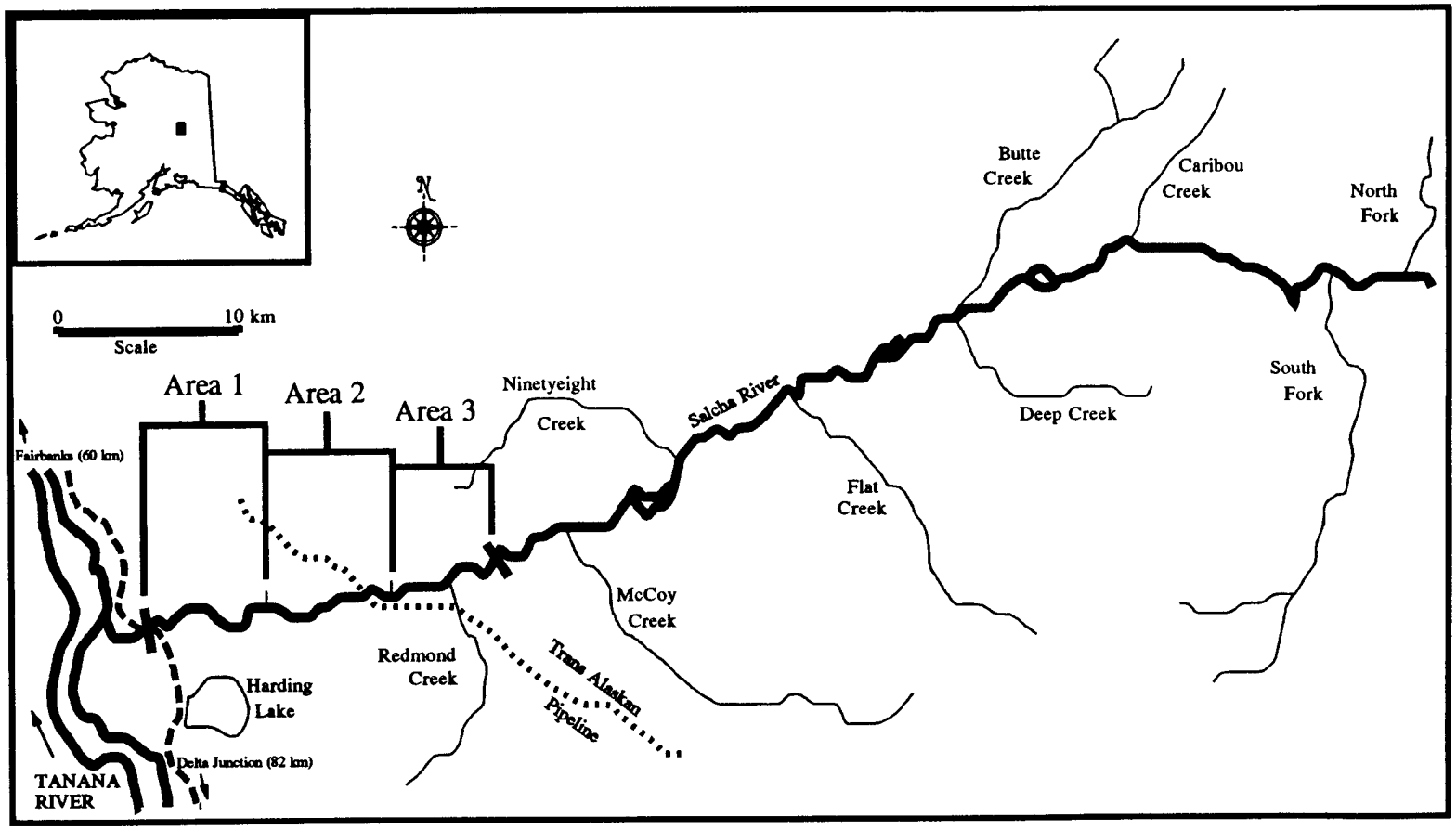

Figure 3. Study section and three areas used for estimation of movements of Arctic grayling in the Salcha River, 1989 through 1992.

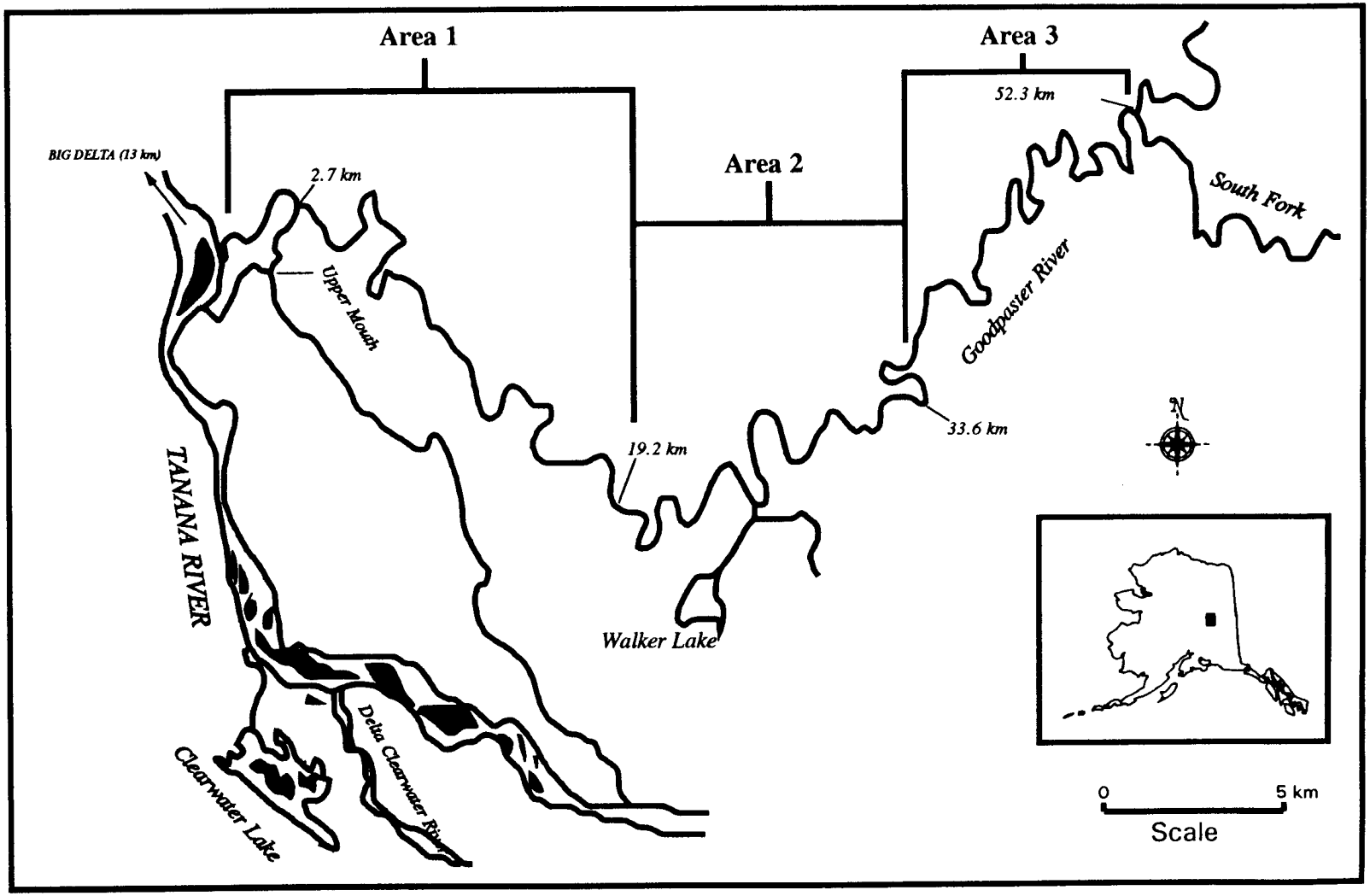

Figure 4. Study section and three areas used for estimation of movements of Arctic grayling in the Goodpaster River, 1988 through 1992.

Table 1. Sources of stock assessment data concerning numbers of Arctic grayling released, numbers examined for recoveries, abundance estimates, and estimates of variance of abundance for the Chena, Salcha, and Goodpaster rivers, 1987 through 1992.

Year	System	Source
1987	Chena	Clark and Ridder 1988
1988	Chena	Clark 1989
1989	Chena	Clark 1990
1990	Chena	Clark 1991
1991	Chena	Clark 1993
1992	Chena	Clark 1993
1989	Salcha	Clark and Ridder 1990
1990	Salcha	Clark et al. 1991
1991	Salcha	Fleming et al. 1992
1992	Salcha	Ridder et al. 1993
1988	Goodpaster	Ridder 1989
1989	Goodpaster	Clark and Ridder 1990
1990	Goodpaster	Clark et al. 1991
1991	Goodpaster	Fleming et al. 1992
1992	Goodpaster	Ridder et al. 1993

Numbers of fish recovered that were originally marked and released in each area were counted from a data base containing every marked fish released into each river during 1987 through 1992. During stock assessment the approximate river mile of release was recorded on data forms along with biological and tagging information for each fish. Using data base software, programs were written to extract recovery information, by area (ranges of river miles), for each river system. First recoveries occurring during the same year as release were removed from the data base. Next, only capture histories of individual fish that had been ultimately recovered were extracted from the data base. The extracted records were then segregated by year of release and the resultant data bases exported to a spreadsheet program. Using the field containing river mile of release, numbers of recoveries were counted by area of recovery for each area of release. These data were arranged in a matrix (6 x 6 for the Chena and 3 x 3 for the Salcha and Goodpaster rivers) of recoveries for each year of release. The rows of the matrix corresponded to release areas and the columns of the matrix corresponded to the recovery areas.

In addition, age and size information from each fish were extracted along with marking data. These data were used to generate graphs of age and size compositions by area of release for each year of the movement study.

Data Analysis

First, the proportion of fish in each area *a* that was marked and released was estimated for each year of release *t*. Using the number of fish marked and released and the abundance estimate in each area, the proportion marked was (see Table 2 for definitions of notation):

$$\hat{p}_{a,t} = \frac{M_{a,t}}{\hat{N}_{a,t}} \tag{1}$$

The estimate of variance of $p_{a,t}$ was approximated with the delta method (Seber 1982):

$$\hat{V}\left[\hat{p}_{a,t}\right] \approx \frac{M_{a,t}^2 \hat{V}\left[\hat{N}_{a,t}\right]}{\hat{N}_{a,t}^4} \tag{2}$$

On recovery in year $t+h$, the proportion of fish originally released in area *a* and recovered in area *b* was estimated from the sample of fish examined for marks in each area and the matrix of recoveries for year of release *t*:

$$\hat{r}_{a\rightarrow b,t+h} = \frac{m_{a\rightarrow b,t+h}}{n_{b,t+h}} \tag{3}$$

The variance of this proportion was estimated as the variance of a binomial:

$$\hat{V}\left[\hat{r}_{a\rightarrow b,t+h}\right] = \frac{\hat{r}_{a\rightarrow b,t+h}\left(1 - \hat{r}_{a\rightarrow b,t+h}\right)}{\left(n_{b,t+h} - 1\right)} \tag{4}$$

Table 2. Definitions for notation used in equations for estimating proportion of marked fish in the release area, proportion of marked fish in the recovery sample, contribution of marked fish to the recovery area, the number of marked fish in the recovery area, and the proportion of marked fish in the recovery area.

Notation	Definition
s	number of release or recovery areas.
a	area of release (1, ..., s).
b	area of recovery (1, ..., s).
t	year of release.
h	hiatus between release and recovery (years).
$M_{a,t}$	number of marked fish released in area *a* during year *t*.
$m_{a\to b,t+h}$	number of marked fish (from release area *a*) in the recovery sample in area *b* during year *t+h*.
$n_{b,t+h}$	number of fish examined for marks in the recovery sample in area *b* during year *t+h*.
$\hat{N}_{a,t}$	abundance of fish in release area *a* during year *t*.
$\hat{N}_{b,t+h}$	abundance of fish in recovery area *b* during year *t+h*.
$\hat{p}_{a,t}$	proportion of marked fish in release area *a* during year *t*.
$\hat{r}_{a\to b,t+h}$	proportion of marked fish (from release area *a*) in the recovery sample in area *b* during year *t+h*.
$\hat{c}_{a\to b,t+h}$	contribution of marked fish (from release area *a*) to recovery area *b* during year *t+h*.
$\hat{M}_{a\to b,t+h}$	number of marked fish (from release area *a*) in recovery area *b* during year *t+h*.
$\hat{M}_{b,t+h}$	number of marked fish (from all release areas) in recovery area *b* during year *t+h*.
$\hat{P}_{a\to b,t+h}$	proportion of marked fish (from release *a*), surviving to year *t+h* and not leaving the study section, that were in recovery area *b* during year *t+h*.

The contribution of fish originally released into area *a* and recovered in area *b* during year *t+h* was estimated as the ratio of the proportions from equations 1 and 3:

$$\hat{c}_{a\to b,t+h} = \frac{\hat{r}_{a\to b,t+h}}{\hat{p}_{a,t}} \tag{5}$$

The estimate of variance of $c_{a\to b,t+h}$ was approximated with the delta method (Seber 1982):

$$\hat{V}\left[\hat{c}_{a\to b,t+h}\right] \approx \hat{c}^2_{a\to b,t+h}\left(\frac{\hat{V}\left[\hat{r}_{a\to b,t+h}\right]}{\hat{r}^2_{a\to b,t+h}} + \frac{\hat{V}\left[\hat{p}_{a,t}\right]}{\hat{p}^2_{a,t}}\right) \tag{6}$$

Contributions are essentially a combination of probabilities resulting from the probability of moving or not moving to another area, the probability of surviving to year *t+h*, and the probability of not leaving the study section under investigation. Using the estimate of abundance in recovery area *b* during year t+h, an estimate of the number of marked fish originally released into area *a* that were residing in recovery area *b* during year *t+h* was calculated as:

$$\hat{M}_{a\to b,t+h} = \hat{r}_{a\to b,t+h}\hat{N}_{b,t+h} \tag{7}$$

Variance of $M_{a\to b,t+h}$ was estimated with the formula for the variance of the product of two independent estimates (Goodman 1960):

$$\hat{V}\left[\hat{M}_{a\to b,t+h}\right] = \hat{r}^2_{a\to b,t+h}\hat{V}\left[\hat{N}_{b,t+h}\right] + \hat{N}^2_{b,t+h}\hat{V}\left[\hat{r}_{a\to b,t+h}\right] - \hat{V}\left[\hat{N}_{b,t+h}\right]\hat{V}\left[\hat{r}_{a\to b,t+h}\right] \tag{8}$$

To estimate the number of marked fish residing in area *b* during year *t+h*, the numbers of marked fish residing in area *b* were summed for all areas of release (*a*):

$$\hat{M}_{b,t+h} = \sum_{a=1}^{s} \hat{M}_{a\to b,t+h} \tag{9}$$

Variance of $M_{b,t+h}$ was estimated by summing the individual variances for all areas of release (*a*):

$$\hat{V}\left[\hat{M}_{b,t+h}\right] = \sum_{a=1}^{s} \hat{V}\left[\hat{M}_{a\to b,t+h}\right] \tag{10}$$

Although estimates of the number of marked fish residing in each area provided useful information, differing levels of marking by year and in each area could confound the investigation of movement. To alleviate this problem, estimates of the proportion of marked fish, surviving to year *t+h* and not leaving the study section, that moved from area *a* to area *b* during hiatus *h* were calculated by:

$$\hat{P}_{a\to b,t+h} = \frac{\hat{M}_{a\to b,t+h}}{\hat{M}_{b,t+h}} \tag{11}$$

Variance of $P_{a\to b,t+h}$ was approximated with the formula for variance of the quotient of two dependent estimates (Bernard 1983):

$$\hat{V}\left[\hat{P}_{a\to b,t+h}\right] \approx \hat{P}^2_{a\to b,t+h}\left(\frac{\hat{V}\left[\hat{M}_{a\to b,t+h}\right]}{\hat{M}^2_{a\to b,t+h}} + \frac{\hat{V}\left[\hat{M}_{b,t+h}\right]}{\hat{M}^2_{b,t+h}} - \frac{2\hat{V}\left[\hat{M}_{a\to b,t+h}\right]}{\hat{M}_{a\to b,t+h}\hat{M}_{b,t+h}}\right) \qquad (12)$$

With a series of releases, each with hiatus *h*, the average proportion of marked fish, surviving through hiatus *h* and not leaving the study section, that moved from area *a* to area *b* during hiatus *h* was calculated by:

$$\hat{\bar{P}}_{a\to b,t+h} = \frac{\sum_t \hat{P}_{a\to b,t+h}}{R_h} \qquad (13)$$

Variance of this average was calculated with the standard formula for the mean of replicate estimates:

$$\hat{V}\left[\hat{\bar{P}}_{a\to b,t+h}\right] = \frac{\sum\left(\hat{P}_{a\to b,t+h} - \hat{\bar{P}}_{a\to b,t+h}\right)^2}{R_h(R_h - 1)} + \frac{\sum \hat{V}\left[\hat{P}_{a\to b,t+h}\right]}{R_h^2} \qquad (14)$$

where: R_h = the number of replicates of hiatus h.

Plots were also used to summarize and illustrate movements of fish over time. Individual plots of averages for each hiatus ($\hat{\bar{P}}_{a\to b,t+h}$ from equation 13) were created for each area within a study section to illustrate movements of fish out of a specific area. These plots were used to emphasize movement of fish out of areas. To emphasize movements of fish into areas, net movement of fish across areas (by length of hiatus) was plotted by first summing the average proportion of marked fish ($\hat{\bar{P}}_{a\to b,t+h}$ from equation 13) for a particular recovery area:

$$\hat{\bar{P}}_{b,t+h} = \sum_{a=1}^{s} \hat{\bar{P}}_{a\to b,t+h} \qquad (15)$$

If $\hat{\bar{P}}_{b,t+h} = 1$ for a particular area, there was no net movement of marked fish into that area. If $\hat{\bar{P}}_{b,t+h} > 1$ or $\hat{\bar{P}}_{b,t+h} < 1$, there was a net increase or decrease into the area, respectively. Graphing $\hat{\bar{P}}_{b,t+h} - 1$ for each area during a particular hiatus gives the net movement of fish across particular areas for the given hiatus.

RESULTS

Chena River

Estimates of proportions marked, proportions of marked fish in recovery samples, and contributions of marked fish to each area are summarized for release years 1987 through 1991 in Appendices A1 through A36. There were five replicate releases of fish that were recovered after a hiatus of 1 year. Arctic grayling tended to move from all six areas to all other areas of the Chena River during a 1 year hiatus. More specifically, releases in areas 1 and 2 were recovered in all six areas, whereas fish released in areas 4 through 6 were recovered in all areas except area 1 (Table 3). Fish released in area 3 were recovered in all areas except areas 1 and 5 (Table 3). Between 74% and 93% of all releases that survived a 1 year hiatus and did not leave the study section were recovered in the same area as they were released in. Of fish that moved, the greatest percentages (>10%) occurred from area 4 to area 3 (downstream) and from area 5 to area 4 (downstream; Table 3).

There were four replicate releases of fish that were recovered after a hiatus of 2 years. Movement of Arctic grayling tended to be more restricted than that seen after a 1 year hiatus. More specifically, releases in area 4 were the only fish recovered in all six areas (Table 4). Fish released in area 1 were only recovered in areas 1 and 2 (Table 4). Between 74% and 97% of all releases that survived a 2 year hiatus and did not leave the study section were recovered in the same area as they were released in. Of fish that moved, the greatest percentages (>10%) occurred from: area 2 to area 3 (upstream); area 4 to area 3 (downstream); and, from area 5 to area 4 (downstream; Table 4). Nine percent of fish released in area 6 moved downstream to area 5.

There were three replicate releases of fish that were recovered after a hiatus of 3 years. Again, movement of Arctic grayling tended to occur in upstream and downstream directions, but to a greater extent than after a 2 year hiatus. More specifically, releases in area 4 were recovered in all six areas (Table 5). Fish released in areas 2, 3, and 5 were recovered in three areas other than the area of release (Table 5). Between 55% and 91% of all releases that survived a 3 year hiatus and did not leave the study section were recovered in the same area as they were released in. Of fish that moved, the greatest percentages (>10%) occurred from: area 1 to area 3 (upstream); area 1 to area 4 (upstream); area 4 to area 3 (downstream); area 5 to area 4 (downstream); and, from area 6 to area 5 (downstream; Table 5).

There were two replicate releases of fish that were recovered after a hiatus of 4 years. Again, movement of Arctic grayling tended to occur in upstream and downstream directions, but to a lesser extent than after a 3 year hiatus. More specifically, releases in area 1 were not recovered any in area except area 1 (Table 6). Fish released in all other areas were found in one to three other areas, but not in all six areas (Table 6). Between 36% and 100% of all releases that survived a 4 year hiatus and did not leave the study section were recovered in the same area as they were released in. Of fish that moved, the greatest percentages (>10%) occurred from: area 2 to areas 3 and 4

Table 3. Estimates of average proportion of marks ($P_{a \to b, t+1}$) and standard error of Arctic grayling marked and released in year t and recovered in year $(t+1)$[a] in six areas of the Chena River.

	Area of recapture					
Area of release[b]	1	2	3	4	5	6
1	0.83	0.02	0.02	0.01	0.06	0.06
SE	0.08	0.02	0.02	0.02	0.05	0.04
2	0.01	0.83	0.08	0.02	0.04	0.01
SE	0.01	0.06	0.04	0.02	0.03	0.01
3	0	0.05	0.93	0.01	0	<0.01
SE	0	0.02	0.02	0.01	0	0.01
4	0	0.02	0.15	0.74	0.06	0.03
SE	0	0.02	0.07	0.06	0.03	0.02
5	0	0.01	0.02	0.12	0.77	0.07
SE	0	0.01	0.02	0.07	0.09	0.05
6	0	0.01	0.05	0.04	0.03	0.87
SE	0	0.01	0.03	0.02	0.02	0.05
Sum	0.84	0.94	1.26	0.94	0.97	1.04
SE	0.08	0.08	0.10	0.11	0.13	0.09

[a] Average from a sample of 5 replicates (releases from 1987 through 1991).
[b] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Table 4. Estimates of average proportion of marks ($P_{a \to b, t+2}$) and standard error of Arctic grayling marked and released in year t and recovered in year (t+2)[a] in six areas of the Chena River.

	Area of recapture					
Area of release[b]	1	2	3	4	5	6
1	0.97	0.03	0	0	0	0
SE	0.03	0.03	0	0	0	0
2	0.02	0.78	0.12	0	0.06	0.02
SE	0.03	0.08	0.05	0	0.03	0.01
3	0	0.04	0.88	0.04	0.02	0.02
SE	0	0.03	0.05	0.03	0.02	0.02
4	0.01	0.02	0.17	0.74	0.04	0.02
SE	0.01	0.01	0.10	0.10	0.03	0.01
5	0	0.02	0	0.15	0.81	0.02
SE	0	0.02	0	0.13	0.13	0.02
6	0	0.01	0.03	0.06	0.09	0.81
SE	0	0.01	0.02	0.03	0.05	0.07
Sum	1.00	0.89	1.20	0.98	1.02	0.89
SE	0.05	0.14	0.10	0.19	0.13	0.08

[a] Average from a sample of 4 replicates (releases from 1987 through 1990).

[b] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Table 5. Estimates of average proportion of marks ($P_{a \to b, t+3}$) and standard error of Arctic grayling marked and released in year t and recovered in year $(t+3)$[a] in six areas of the Chena River.

	Area of recapture					
Area of release[b]	1	2	3	4	5	6
1	0.55	0.08	0.24	0.13	0	0
SE	0.17	0.08	0.18	0.11	0	0
2	0.02	0.80	0.08	0.06	0.04	0
SE	0.03	0.12	0.07	0.07	0.05	0
3	0	0.02	0.91	0.04	0.02	0.01
SE	0	0.02	0.06	0.04	0.02	0.01
4	0.01	0.05	0.11	0.74	0.03	0.06
SE	0.01	0.04	0.08	0.07	0.04	0.03
5	0	0.01	0.03	0.22	0.68	0.05
SE	0	0.02	0.04	0.17	0.14	0.04
6	0	0.01	0	0.02	0.12	0.84
SE	0	0.02	0	0.03	0.05	0.05
Sum	0.58	0.97	1.36	1.22	0.91	0.96
SE	0.16	0.14	0.22	0.23	0.18	0.08

[a] Average from a sample of 3 replicates (releases from 1987 through 1989).

[b] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Table 6. Estimates of average proportion of marks ($P_{a \to b, t+4}$) and standard error of Arctic grayling marked and released in year t and recovered in year (t+4)[a] in six areas of the Chena River.

Area of release[b]	Area of recapture					
	1	2	3	4	5	6
1	1.00	0	0	0	0	0
SE	0	0	0	0	0	0
2	0	0.65	0.20	0.15	0	0
SE	0	0.35	0.22	0.17	0	0
3	0	0.04	0.96	0	0	0
SE	0	0.04	0.04	0	0	0
4	0	0	0.26	0.68	0.04	0.02
SE	0	0	0.09	0.09	0.05	0.03
5	0	0.02	0	0.07	0.36	0.54
SE	0	0.03	0	0.10	0.36	0.46
6	0	0	0.04	0	0.08	0.88
SE	0	0	0.06	0	0.08	0.06
Sum	1.00	0.72	1.45	0.91	0.47	1.45
SE	0	0.37	0.22	0.15	0.33	0.45

[a] Average from a sample of 2 replicates (releases from 1987 and 1988).

[b] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

(upstream); area 4 to area 3 (downstream); and, from area 5 to area 6 (upstream; Table 6).

There was one release of fish that were recovered after a hiatus of 5 years. There was much less movement of fish during the 5 year hiatus than all other lengths of hiatus. More specifically, releases in areas 1, 2, 5, and 6 were not recovered any area except the area of release (Table 7). Fish released in area 4 moved to three other areas during the hiatus (Table 7). Between 64% and 100% of all releases that survived a 5 year hiatus and did not leave the study section were recovered in the same area as they were released in. Of fish that moved, the greatest percentages (>10%) occurred from: area 4 to area 3 (downstream) and from area 4 to area 6 (upstream; Table 7).

A graph of the proportions of fish released in area 1 that were alive and in the study section after 1 to 5 years indicated that the period of greatest movement was detected after 3 years (Figure 5). After three years an average of 45% of fish released in area 1 had moved upstream. The least movement was detected after 4 and 5 years. In area 2 movement was detected after 1 through 4 years, but not after 5 years (Figure 6). Movement was detected primarily in the upstream direction, with a maximum of 35% of fish released moving upstream. Very little movement, either upstream or downstream, was detected out of area 3 (Figure 7). Maximum movement was detected after 2 years. Movement was detected out of area 4 after a hiatus of 1 through 5 years, with maximum movement detected after 5 years (Figure 8). Detected movement occurred in the downstream direction to a greater extent than upstream movement. In area 5 movement was detected out of the area after 1 through 4 years (Figure 9). After 4 years an average of 74% of fish released in area 5 had moved out of the area, primarily upstream to area 6. Movement out of area 6 was detected after all years except after 5 years (Figure 10). Maximum movement out of area 6 was detected after 2 years.

When movements of marked fish were tracked between areas and the net changes in the distribution of marked fish graphed, there was a net increase in the proportion of marked fish in areas 3 and 6 after a 1 year hiatus (Figure 11). After 2 years there was a net influx of marked fish into areas 3 and 5, while after 3 years there was a net influx of marked fish into area 3 and 5. After 4 years there was a net influx of marked fish into areas 3 and 6. Areas 2, 3, and 6 had a net influx of marked fish after 5 years.

Salcha River

Estimates of proportions marked, proportions of marked fish in recovery samples, and contributions of marked fish to each area are summarized for release years 1989 through 1991 in Appendices B1 through B16. There were three replicate releases of fish that were recovered after a hiatus of 1 year. Arctic grayling moved from all three areas to all other areas of the Salcha River during a 1 year hiatus (Table 8). Between 64% and 86% of all releases that survived a 1 year hiatus and did not leave the study section were recovered in the same area as they were released in. Of fish that moved, the greatest percentages (>10%) occurred from: area 1 to area 2 (upstream); area

Table 7. Estimates of average proportion of marks ($P_{a \to b, t+5}$) and standard error of Arctic grayling marked and released in year t and recovered in year (t+5)[a] in six areas of the Chena River.

	Area of recapture					
Area of release[b]	1	2	3	4	5	6
1	1.00	0	0	0	0	0
SE	0	0	0	0	0	0
2	0	1.00	0	0	0	0
SE	0	0	0	0	0	0
3	0	0.06	0.94	0	0	0
SE	0	0.07	0.07	0	0	0
4	0	0.03	0.20	0.64	0	0.12
SE	0	0.04	0.13	0.16	0	0.09
5	0	0	0	0	1.00	0
SE	0	0	0	0	0	0
6	0	0	0	0	0	1.00
SE	0	0	0	0	0	0
Sum	1.00	1.10	1.14	0.64	1.00	1.12
SE	0	0.08	0.15	0.16	0	0.09

[a] Average from a sample of 1 replicate (release from 1987).

[b] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

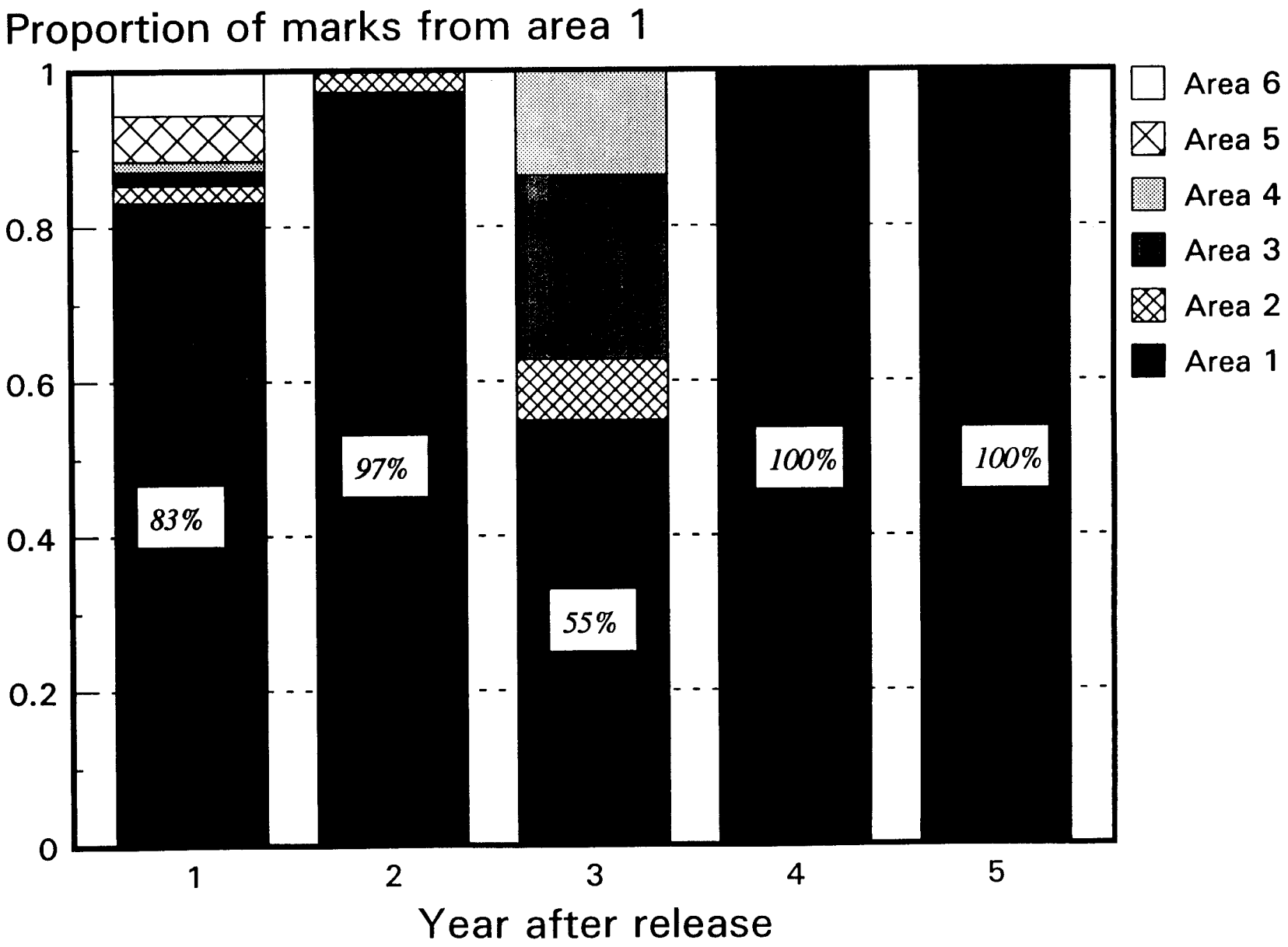

Figure 5. Average proportion of Arctic grayling released in area 1 (rkm 0-40) in year t, survived and did not leave the study section, that were recovered in years t+1 through t+5 in one of six areas of the Chena River, 1987 through 1992.

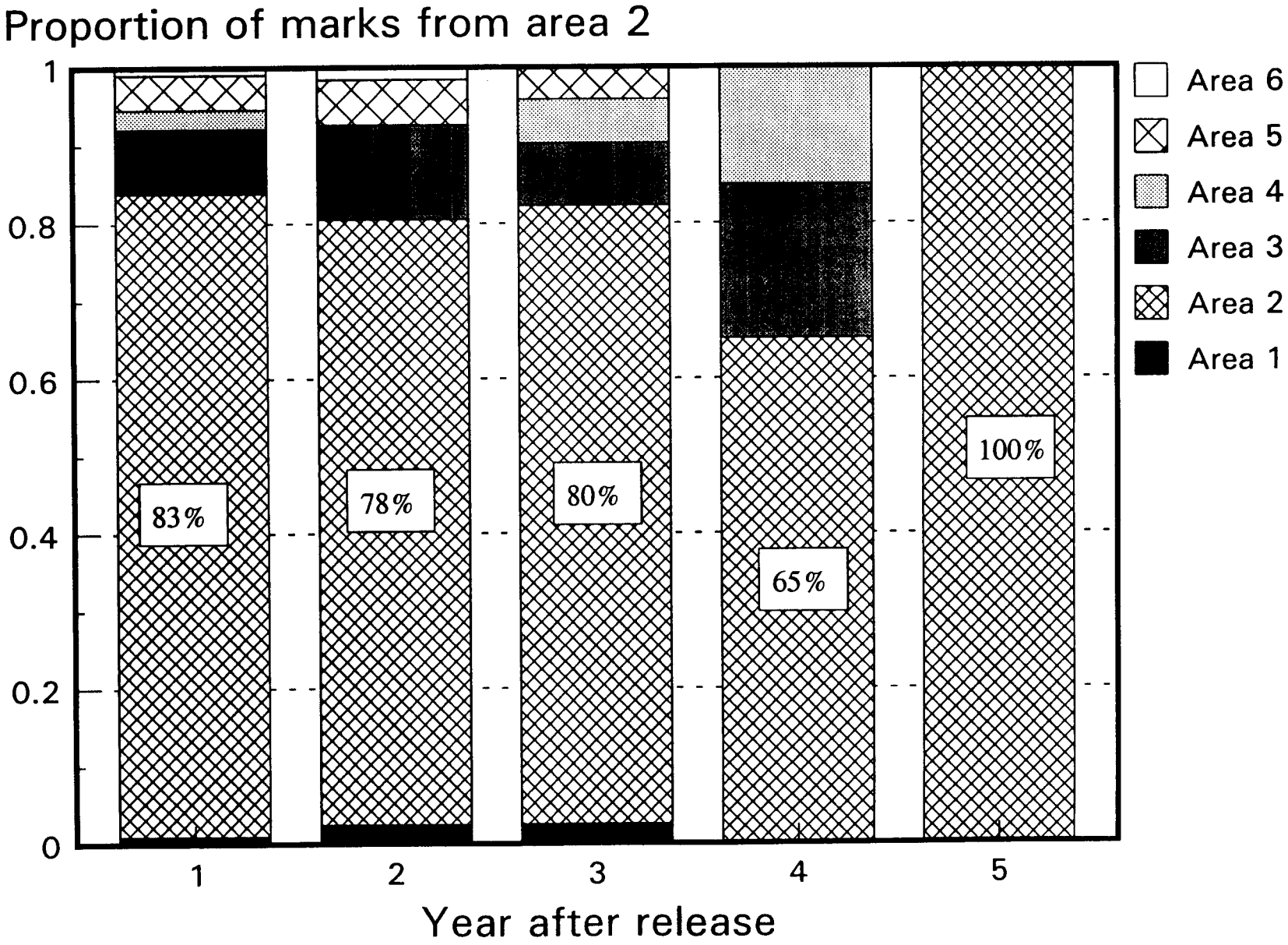

Figure 6. Average proportion of Arctic grayling released in area 2 (rkm 41-72) in year t, survived and did not leave the study section, that were recovered in years t+1 through t+5 in one of six areas of the Chena River, 1987 through 1992.

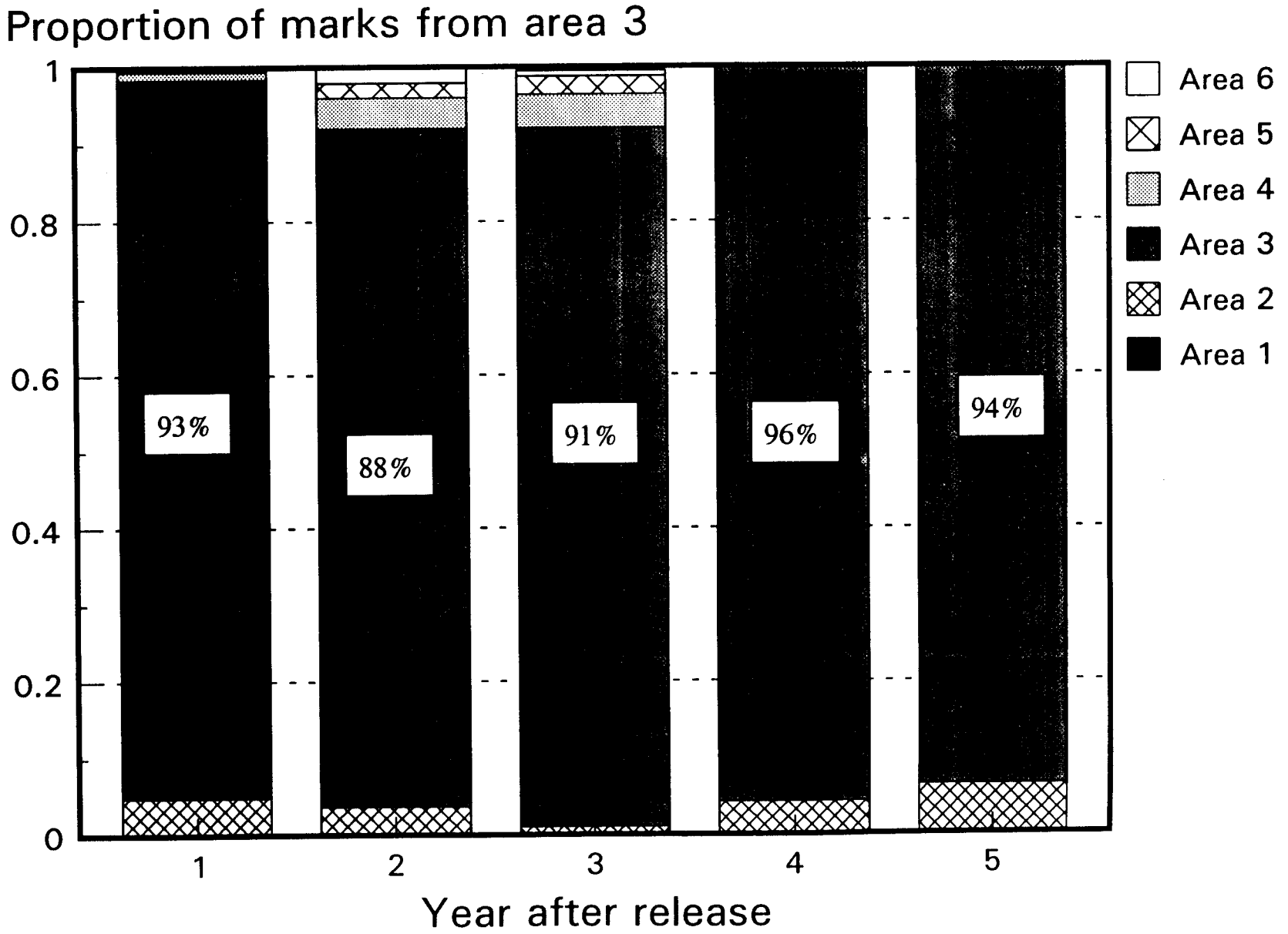

Figure 7. Average proportion of Arctic grayling released in area 3 (rkm 73-88) in year t, survived and did not leave the study section, that were recovered in years t+1 through t+5 in one of six areas of the Chena River, 1987 through 1992.

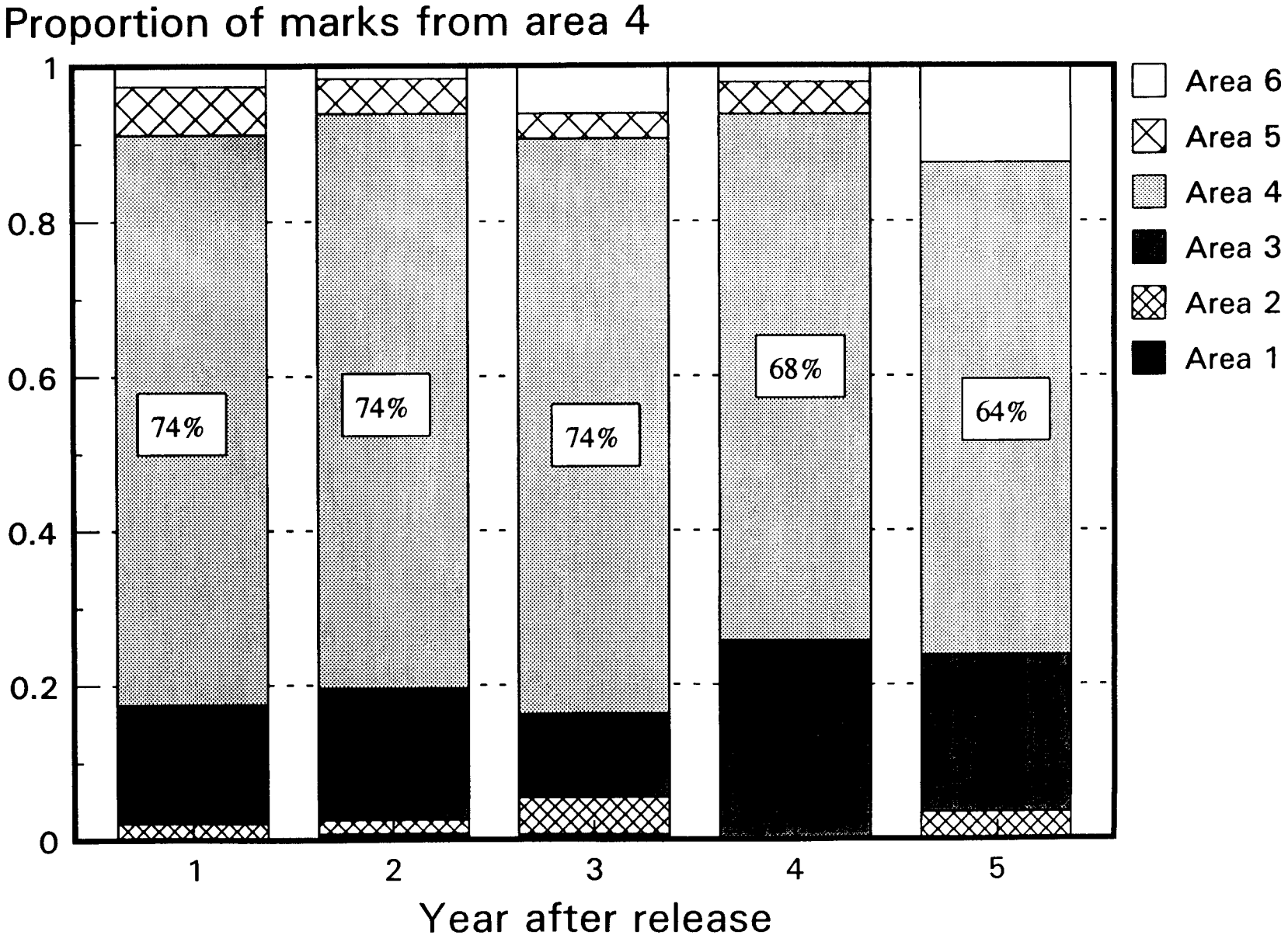

Figure 8. Average proportion of Arctic grayling released in area 4 (rkm 89-104) in year t, survived and did not leave the study section, that were recovered in years t+1 through t+5 in one of six areas of the Chena River, 1987 through 1992.

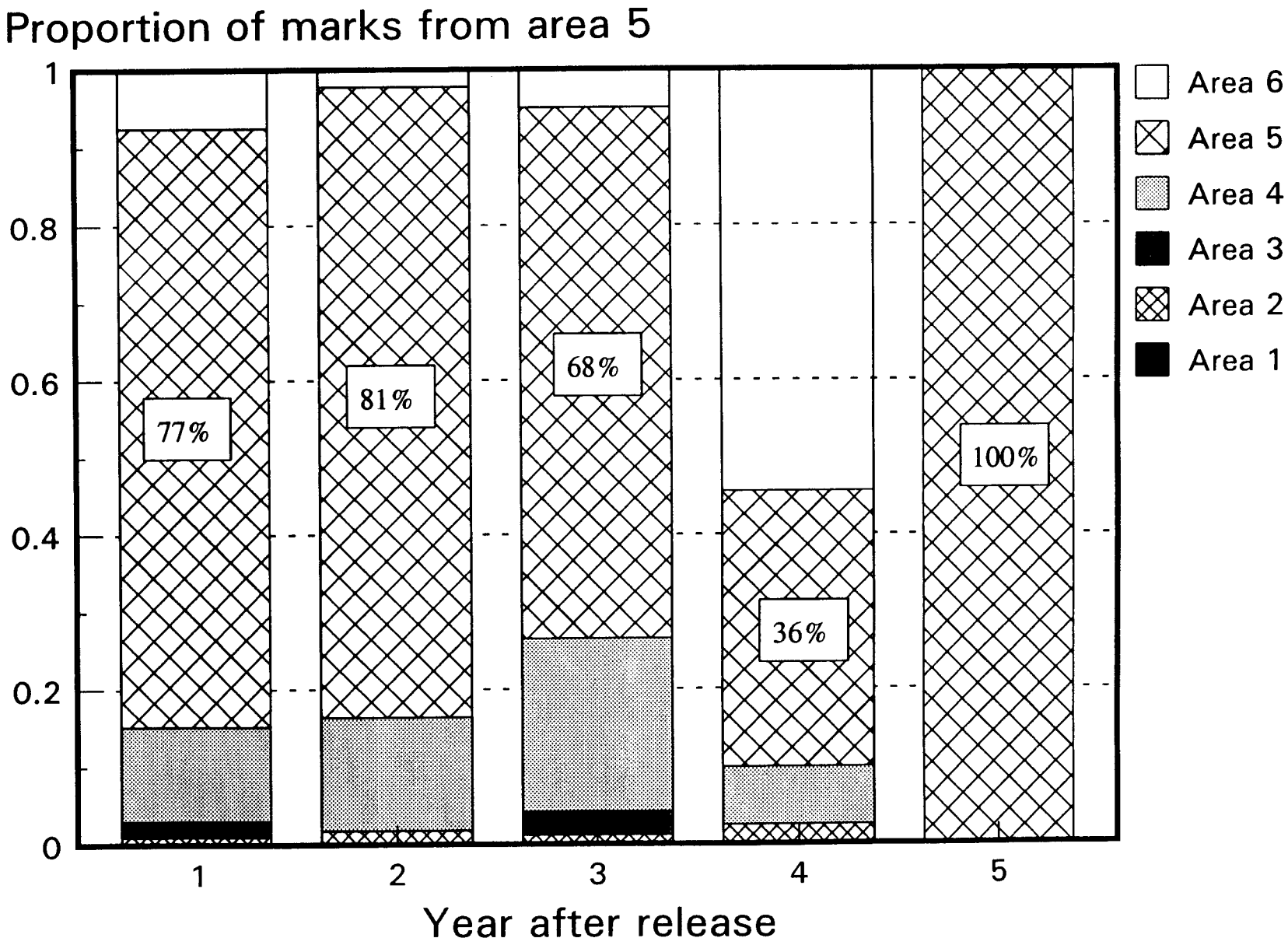

Figure 9. Average proportion of Arctic grayling released in area 5 (rkm 105-117) in year *t*, survived and did not leave the study section, that were recovered in years *t*+1 through *t*+5 in one of six areas of the Chena River, 1987 through 1992.

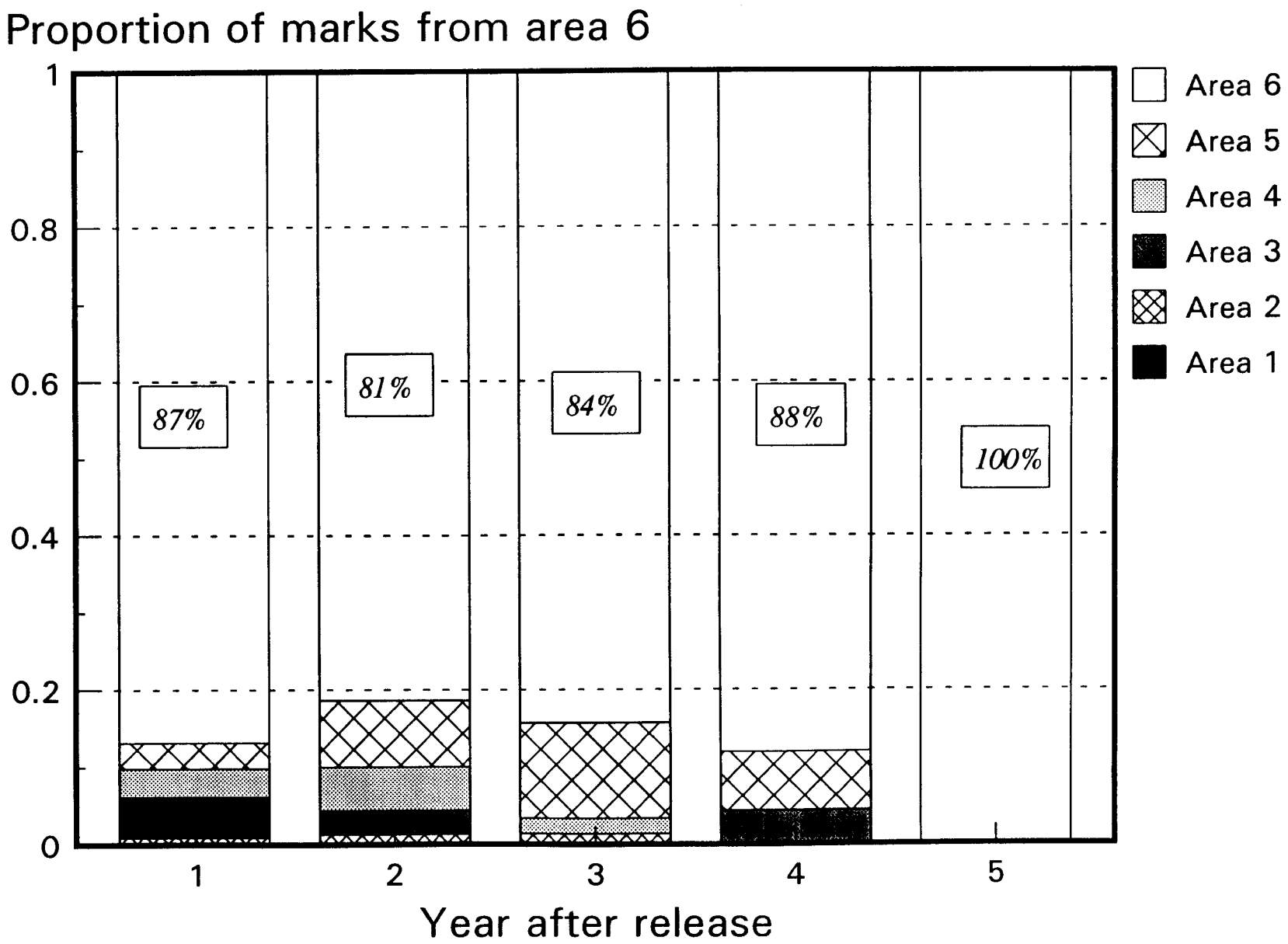

Figure 10. Average proportion of Arctic grayling released in area 6 (rkm 118-152) in year t, survived and did not leave the study section, that were recovered in years t+1 through t+5 in one of six areas of the Chena River, 1987 through 1992.

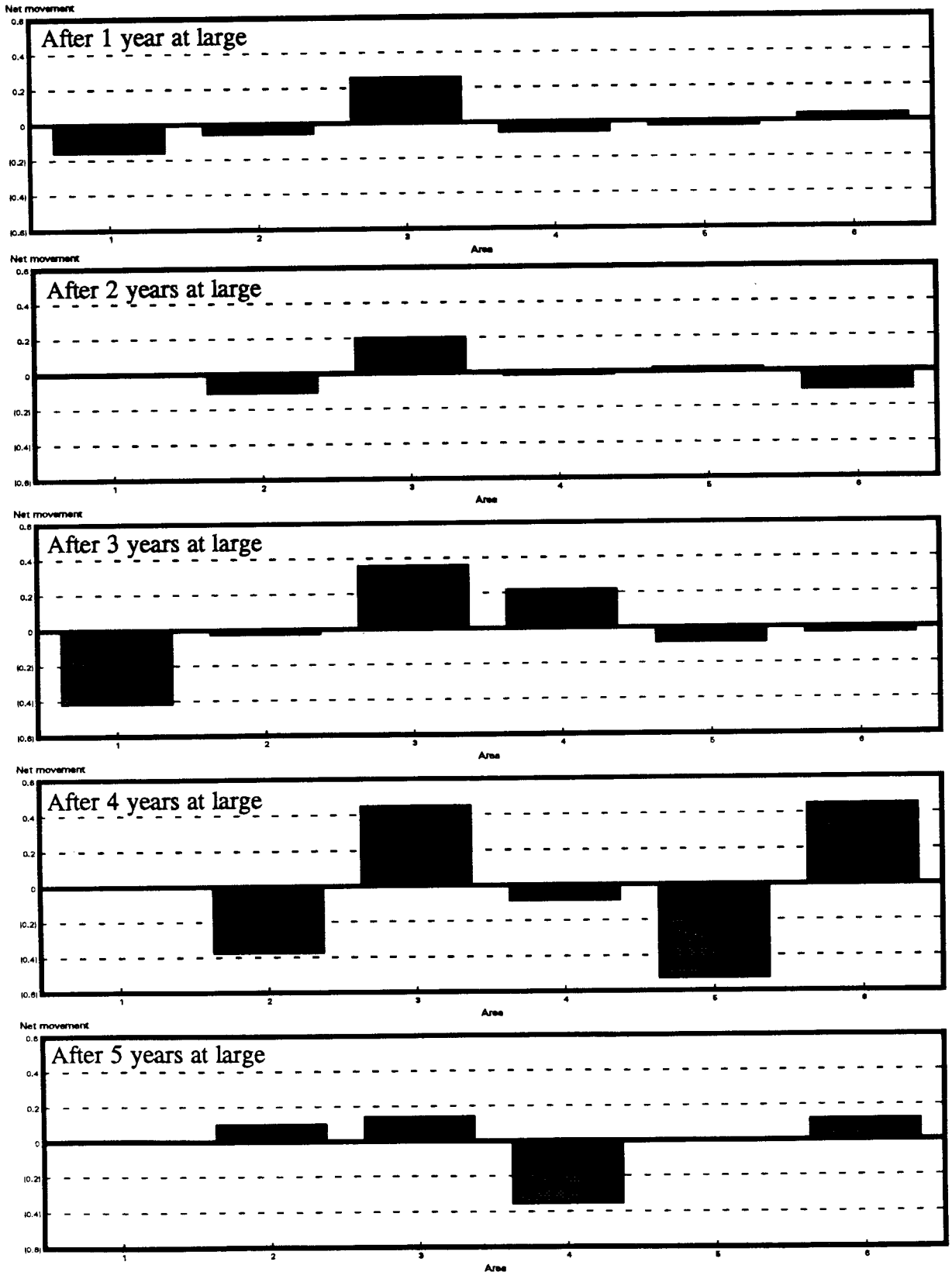

Figure 11. Average net movement (proportional loss or gain of marked fish) of Arctic grayling by years at large in six areas of the Chena River, 1987 through 1992.

Table 8. Estimates of average proportion of marks ($P_{a \to b, t+1}$) and standard error of Arctic grayling marked and released in year t and recovered in year (t+1)[a] in three areas of the Salcha River.

	Area of recapture					
Area of release[b]	1	SE	2	SE	3	SE
1	0.86	0.09	0.10	0.07	0.03	0.04
2	0.18	0.09	0.64	0.12	0.18	0.11
3	0.10	0.11	0.24	0.17	0.66	0.17
Sum	1.14	0.17	0.98	0.22	0.88	0.20

[a] Average from a sample of 3 replicates (releases from 1989 through 1991).
[b] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.

2 to areas 1 and 3 (both directions); and from area 3 to areas 1 and 2 (downstream; Table 8).

There were two replicate releases of fish that were recovered after a hiatus of 2 years. Arctic grayling moved from all three areas to all other areas of the Salcha River during a 2 year hiatus (Table 9). Between 47% and 73% of all releases that survived a 2 year hiatus and did not leave the study section were recovered in the same area as they were released in. Of fish that moved, the greatest percentages (>10%) occurred from: area 1 to areas 2 and 3 (upstream); area 2 to area 3 (upstream); and from area 3 to areas 1 and 2 (downstream; Table 9).

There was one release of fish that were recovered after a hiatus of 3 years. There was less detected movement of Arctic grayling in the Salcha River during a three year hiatus. Between 0% and 83% of all releases that survived a 3 year hiatus and did not leave the study section were recovered in the same area as they were released in. Movement was primarily in the upstream direction, with the greatest movement (100%) from area 2 to area 3 (Table 10). Movement was also detected (>10%) from area 1 to areas 2 and 3 (upstream) and from area 3 to area 2 (downstream).

A graph of the proportions of fish released in area 1 that were alive and in the study section after 1 to 3 years indicated that the period of greatest movement was detected after 2 years (Figure 12). After 2 years an average of 52% of fish released in area 1 had moved upstream. Upstream movement out of area 2 increased as the hiatus was increased, with 0% of fish released in area 2 remaining there after 3 years (Figure 13). Maximum movement out of area 3 was detected after 2 years, with 53% of releases detected downstream of area 3 (Figure 14).

When movements of marked fish were tracked between areas and the net changes in the distribution of marked fish graphed, there was a net increase in the proportion of marked fish in area 1 after a 1 year hiatus (Figure 15). After 2 years there was a net influx of marked fish into area 2. After 3 years there was a net influx of marked fish into area 3.

Goodpaster River

Estimates of proportions marked, proportions of marked fish in recovery samples, and contributions of marked fish to each area are summarized for release years 1988 through 1991 in Appendices C1 through C25. There were four replicate releases of fish that were recovered after a hiatus of 1 year. Arctic grayling moved from all three areas to all other areas of the Goodpaster River during a 1 year hiatus (Table 11). Between 85% and 95% of all releases that survived a 1 year hiatus and did not leave the study section were recovered in the same area as they were released in. Of fish that moved, the greatest percentage (9%) occurred from area 2 to area 3 (upstream; Table 11).

There were three replicate releases of fish that were recovered after a hiatus of 2 years. Arctic grayling moved from all three areas to all other areas of

Table 9. Estimates of average proportion of marks ($P_{a \to b, t+2}$) and standard error of Arctic grayling marked and released in year t and recovered in year $(t+2)$[a] in three areas of the Salcha River.

	Area of recapture					
Area of release[b]	1	SE	2	SE	3	SE
1	0.48	0.26	0.26	0.16	0.26	0.21
2	0.05	0.07	0.73	0.16	0.22	0.14
3	0.21	0.20	0.32	0.16	0.47	0.20
Sum	0.74	0.33	1.31	0.28	0.95	0.32

[a] Average from a sample of 2 replicates (releases from 1989 and 1990).
[b] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.

Table 10. Estimates of average proportion of marks ($P_{a \to b, t+3}$) and standard error of Arctic grayling marked and released in year t and recovered in year (t+3)[a] in three areas of the Salcha River.

	Area of recapture					
Area of release[b]	1	SE	2	SE	3	SE
1	0.51	0.27	0.29	0.24	0.20	0.19
2	0	0	0	0	1.00	0
3	0	0	0.17	0.17	0.83	0.17
Sum	0.51	0.27	0.46	0.30	2.03	0.25

[a] Average from a sample of 1 replicate (release from 1989).
[b] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.

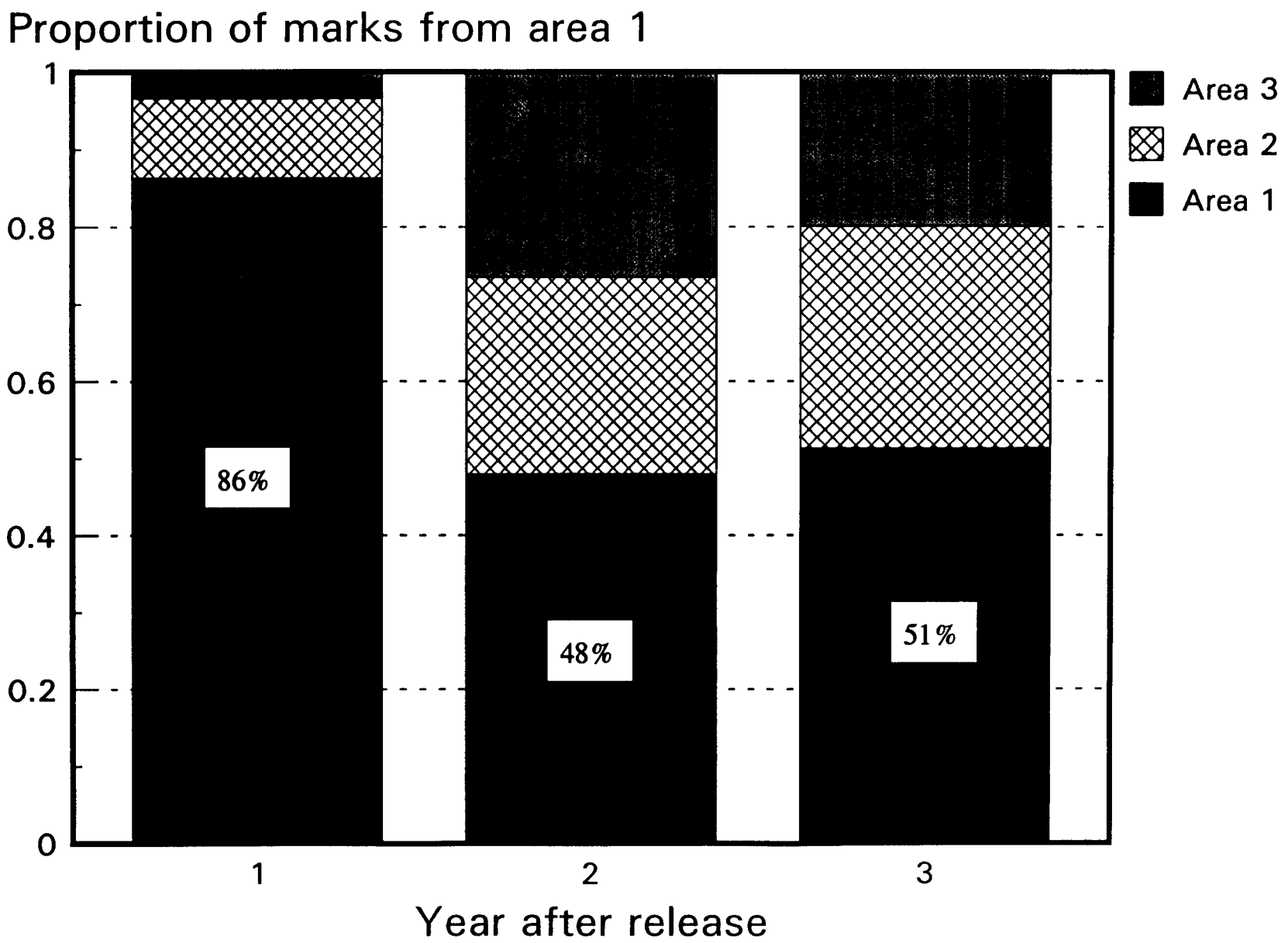

Figure 12. Average proportion of Arctic grayling released in area 1 (rkm 0-12.8) in year t, survived and did not leave the study section, that were recovered in years t+1 through t+3 in one of three areas of the Salcha River, 1989 through 1992.

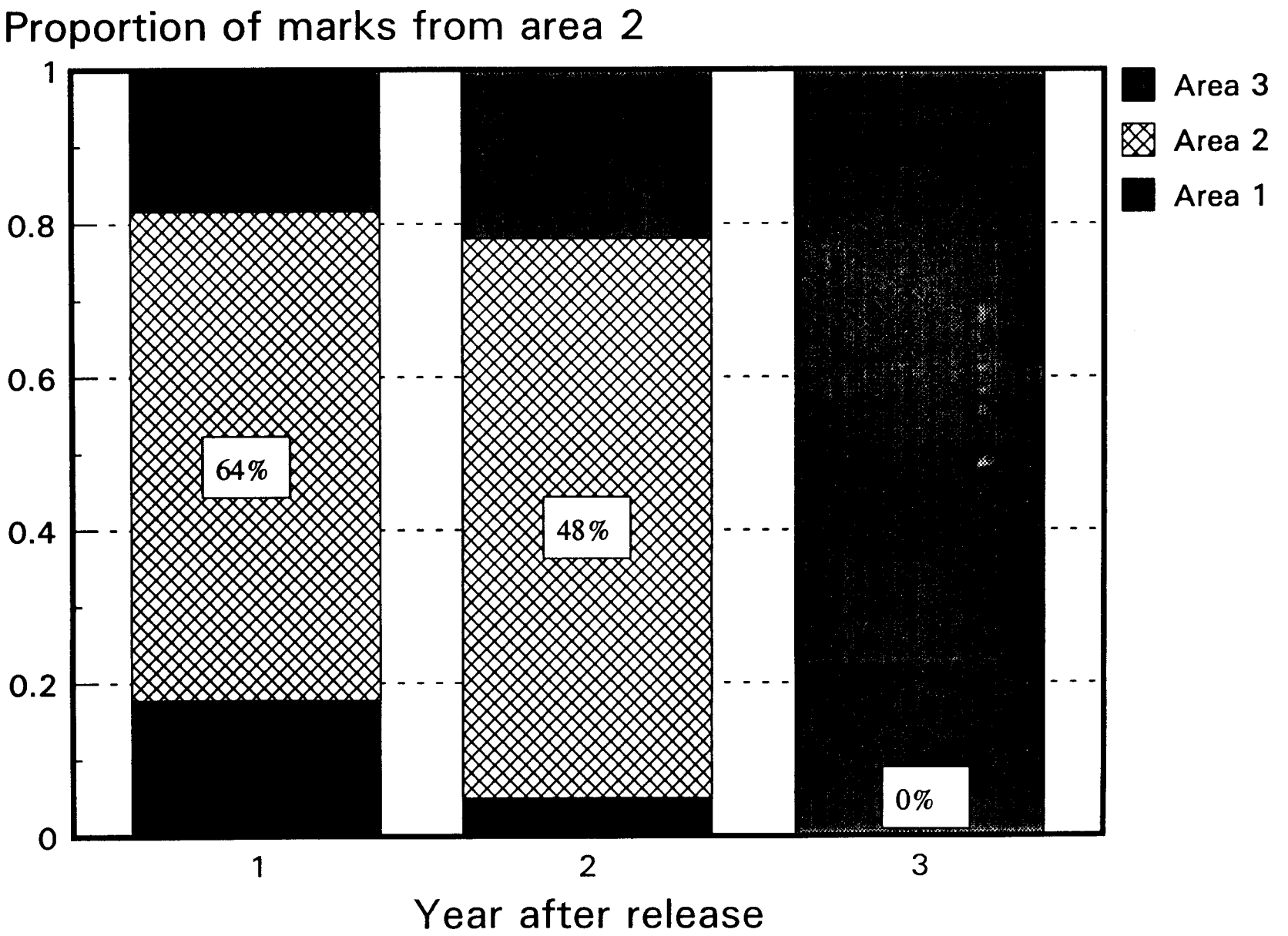

Figure 13. Average proportion of Arctic grayling released in area 2 (rkm 13-25.6) in year t, survived and did not leave the study section, that were recovered in years t+1 through t+3 in one of three areas of the Salcha River, 1989 through 1992.

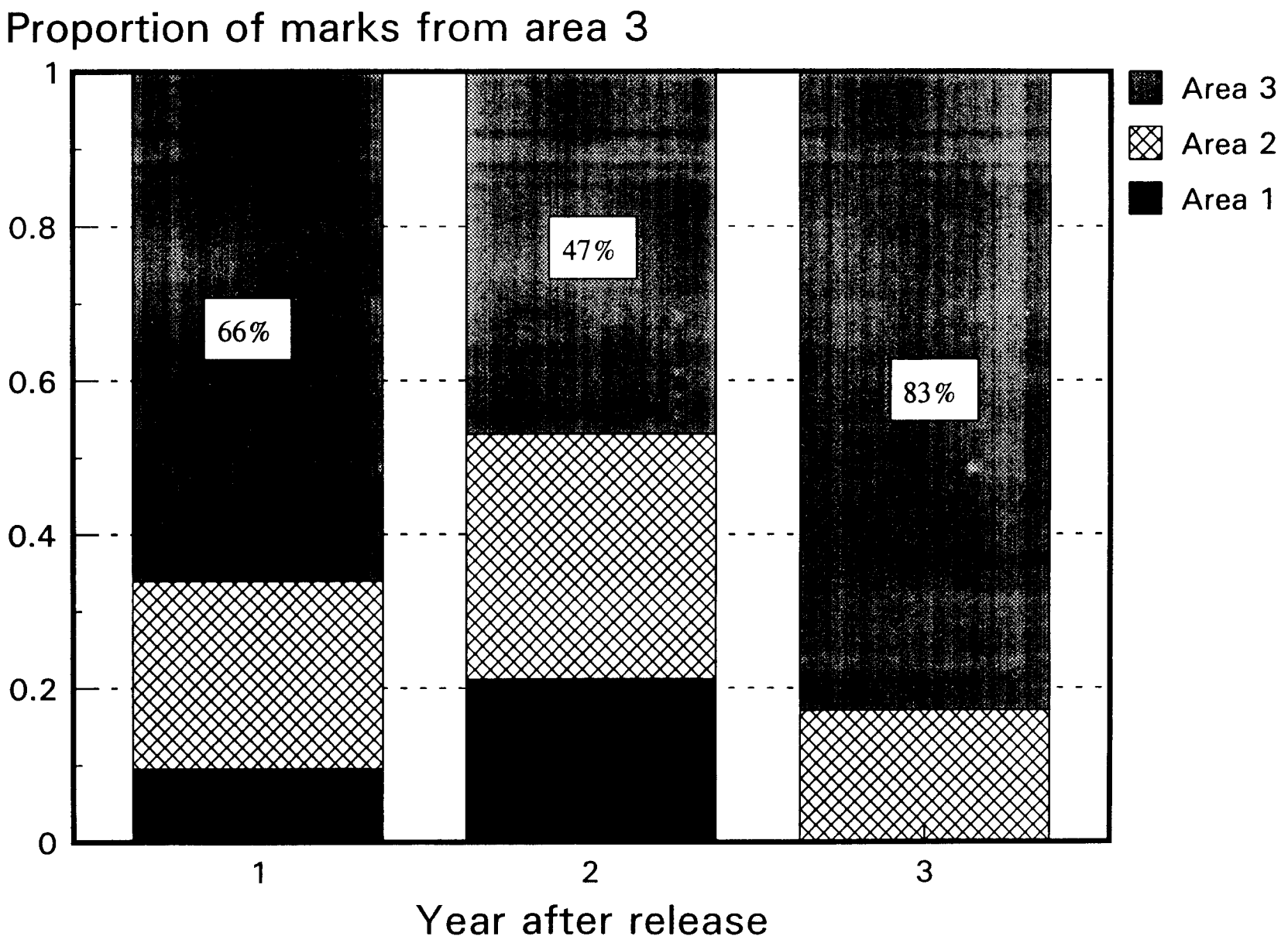

Figure 14. Average proportion of Arctic grayling released in area 3 (rkm 26-38.4) in year t, survived and did not leave the study section, that were recovered in years t+1 through t+3 in one of three areas of the Salcha River, 1989 through 1992.

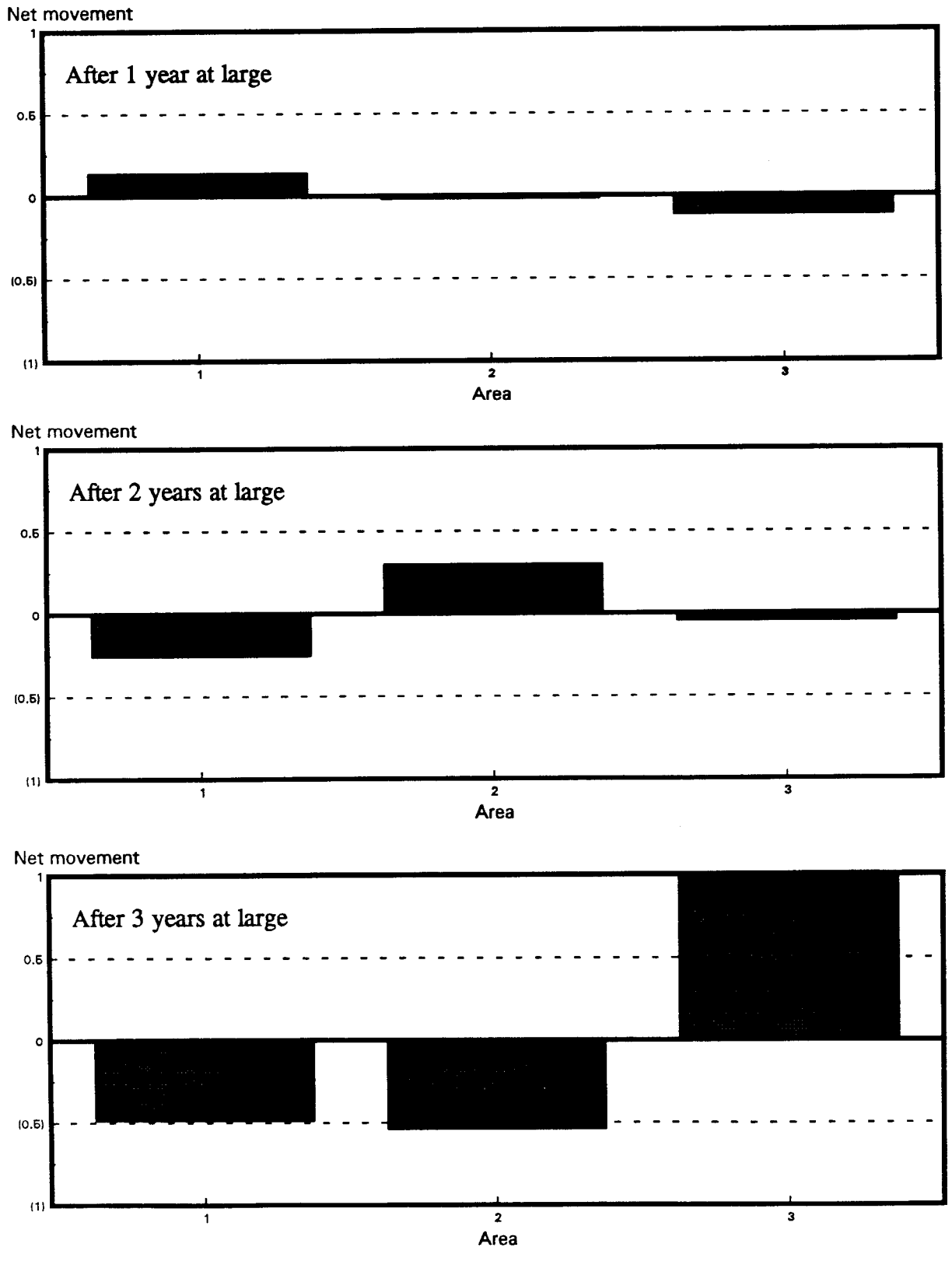

Figure 15. Average net movement (proportional loss or gain of marked fish) of Arctic grayling by years at large in three areas of the Salcha River, 1989 through 1992.

Table 11. Estimates of average proportion of marks ($P_{a \to b, t+1}$) and standard error of Arctic grayling marked and released in year t and recovered in year (t+1)[a] in three areas of the Goodpaster River.

	Area of recapture					
Area of release[b]	1	SE	2	SE	3	SE
1	0.92	0.04	0.07	0.04	0.01	0.01
2	0.06	0.02	0.85	0.05	0.09	0.05
3	0.02	0.01	0.03	0.02	0.95	0.02
Sum	1.00	0.05	0.95	0.05	1.05	0.06

[a] Average from a sample of 4 replicates (releases from 1988 through 1991).
[b] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

the Goodpaster River during a 2 year hiatus (Table 12). Between 84% and 91% of all releases that survived a 2 year hiatus and did not leave the study section were recovered in the same area as they were released in. Of fish that moved, the greatest percentages occurred from: area 1 to area 2 (8% upstream); area 2 to area 3 (9% upstream); and, from area 3 to area 1 (8% downstream; Table 12).

There were two replicate releases of fish that were recovered after a hiatus of 3 years. There was less detected movement of Arctic grayling in the Goodpaster River during a three year hiatus. Between 81% and 100% of all releases that survived a 3 year hiatus and did not leave the study section were recovered in the same area as they were released in. Movement was primarily in the upstream direction, with the greatest movement (>10%) from area 1 to area 3 (Table 13). Movement was also detected from area 3 to area 1 (9% downstream; Table 13).

There was one release of fish that were recovered after a hiatus of 4 years. Only upstream movement was detected after a hiatus of 4 years. Between 67% and 100% of all releases that survived a 4 year hiatus and did not leave the study section were recovered in the same area as they were released in. Of fish that moved, the greatest movements (>10%) were from area 1 to area 3 (upstream) and from area 2 to area 3 (upstream; Table 14).

A graph of the proportions of fish released in area 1 that were alive and in the study section after 1 to 4 years indicated that the period of greatest movement was detected after 4 years (Figure 16). After 4 years an average of 33% of fish released in area 1 had moved upstream. Movement out of area 2 was variable, with approximately equal proportions of fish upstream and downstream of the area after 2 years (Figure 17). Maximum movement out of area 3 was detected after 2 and 3 years, with 9% of releases detected downstream of area 3 (Figure 18).

When movements of marked fish were tracked between areas and the net changes in the distribution of marked fish graphed, there was a net decrease in the proportion of marked fish in area 2 and a net increase in the proportion of marked fish in area 3 after a 1 year hiatus (Figure 19). After 2 years there appeared to be little net change in the proportion of marked fish in each area. After 3 years there was a net influx of marked fish into areas 2 and 3. After a 4 year hiatus, there was a net influx of marked fish into area 3.

DISCUSSION

Implications of Interannual Movements

Based on release-recovery data collected on all three study sections, there appeared to be interannual movement of Arctic grayling in the upstream and downstream direction. However, with few exceptions, the majority of releases in all study sections did not move after up to 5 years. On average, 75% to 93% of fish that survived and did not leave the Chena River and Goodpaster River study sections, did not move from the release area during the

Table 12. Estimates of average proportion of marks ($P_{a \to b, t+2}$) and standard error of Arctic grayling marked and released in year t and recovered in year (t+2)[a] in three areas of the Goodpaster River.

	Area of recapture					
Area of release[b]	1	SE	2	SE	3	SE
1	0.89	0.08	0.08	0.06	0.03	0.04
2	0.07	0.08	0.84	0.09	0.09	0.10
3	0.01	0.02	0.08	0.09	0.91	0.08
Sum	0.97	0.14	1.00	0.13	1.03	0.17

[a] Average from a sample of 3 replicates (releases from 1988 through 1990).
[b] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Table 13. Estimates of average proportion of marks ($P_{a \to b, t+3}$) and standard error of Arctic grayling marked and released in year t and recovered in year (t+3)[a] in three areas of the Goodpaster River.

	Area of recapture					
Area of release[b]	1	SE	2	SE	3	SE
1	0.81	0.21	0.05	0.08	0.13	0.17
2	0	0	1.00	0	0	0
3	0	0	0.09	0.11	0.91	0.11
Sum	0.81	0.21	1.14	0.16	1.04	0.13

[a] Average from a sample of 2 replicates (releases from 1988 and 1989).
[b] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Table 14. Estimates of average proportion of marks ($P_{a \to b, t+4}$) and standard error of Arctic grayling marked and released in year t and recovered in year (t+4)[a] in three areas of the Goodpaster River.

	Area of recapture					
Area of release[b]	1	SE	2	SE	3	SE
1	0.67	0.24	0	0	0.33	0.24
2	0	0	0.75	0.20	0.25	0.20
3	0	0	0	0	1.00	0
Sum	0.67	0.24	0.75	0.20	1.58	0.31

[a] Average from a sample of 1 replicate (release from 1988).
[b] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

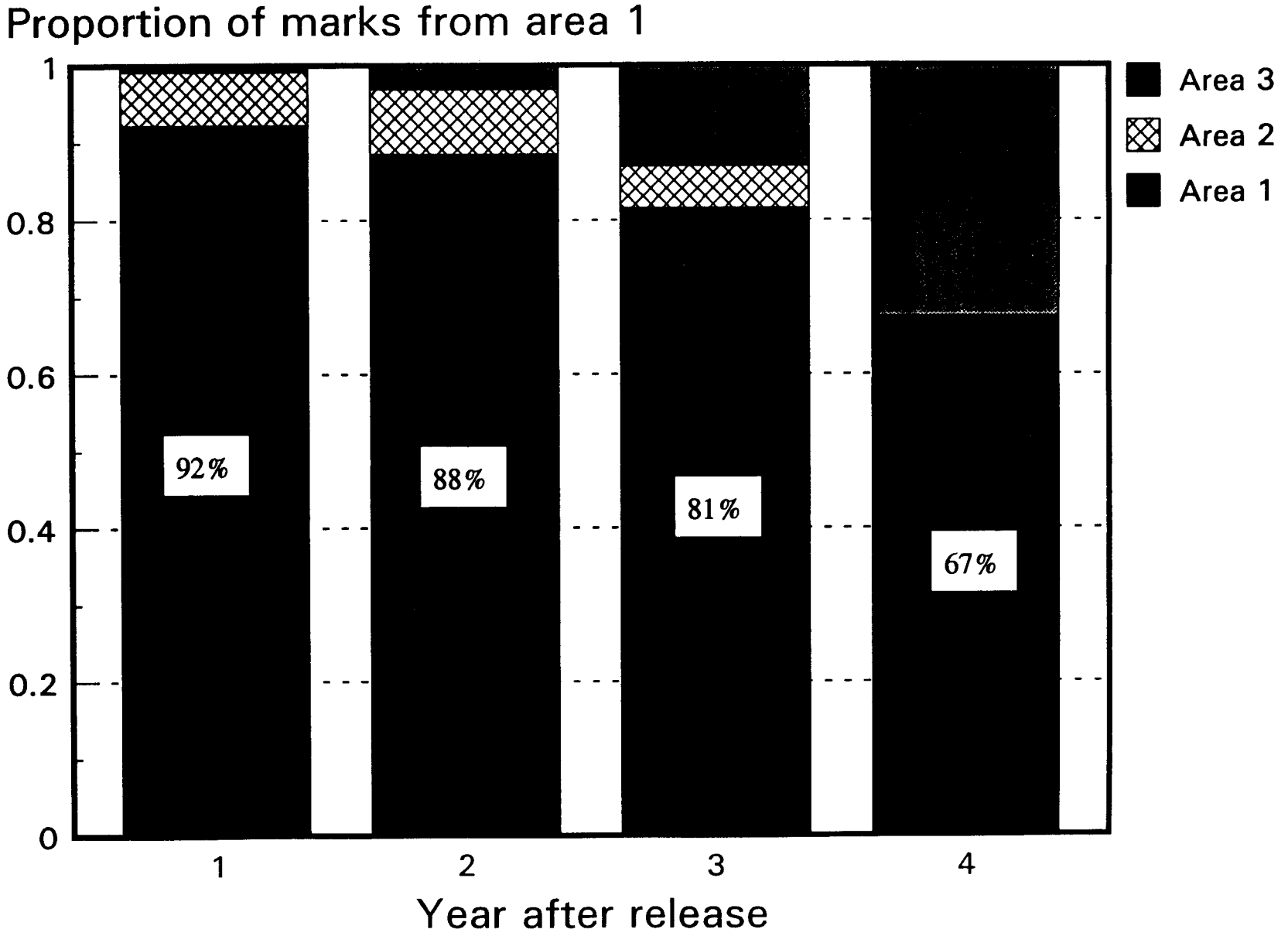

Figure 16. Average proportion of Arctic grayling released in area 1 (rkm 0-19.2) in year t, survived and did not leave the study section, that were recovered in years t+1 through t+4 in one of three areas of the Goodpaster River, 1988 through 1992.

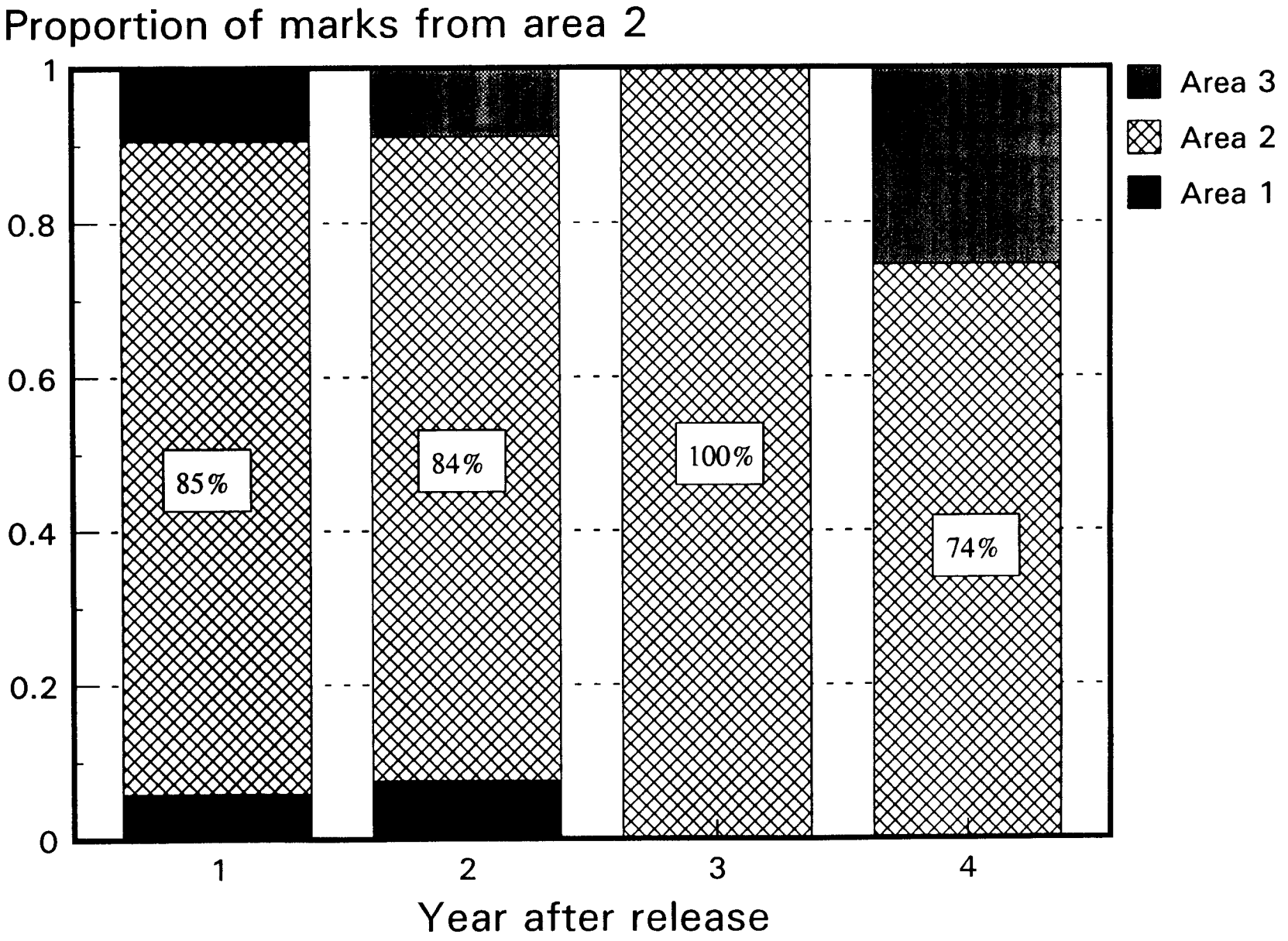

Figure 17. Average proportion of Arctic grayling released in area 2 (rkm 20-33.6) in year t, survived and did not leave the study section, that were recovered in years t+1 through t+4 in one of three areas of the Goodpaster River, 1988 through 1992.

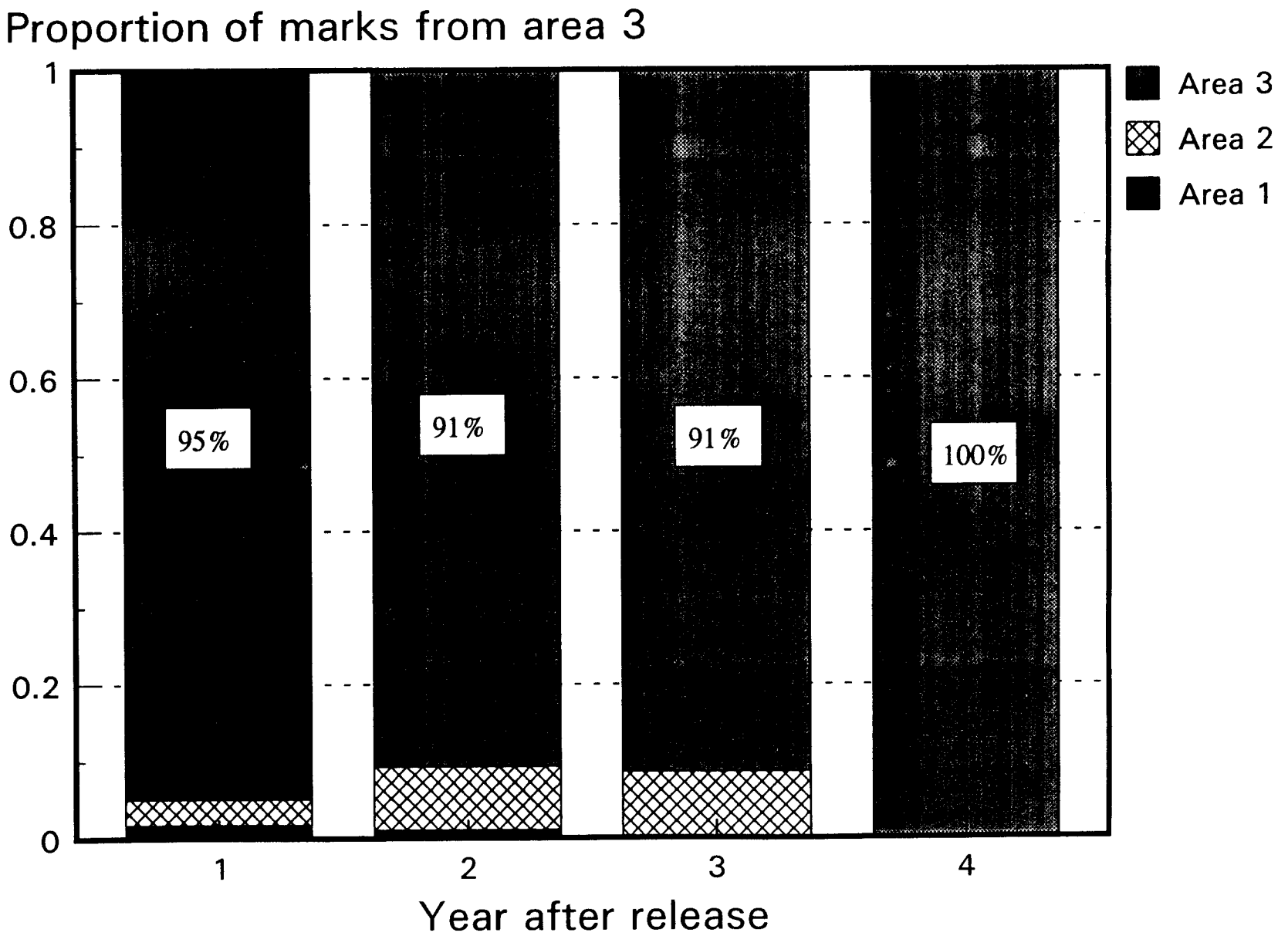

Figure 18. Average proportion of Arctic grayling released in area 3 (rkm 34-52.3) in year t, survived and did not leave the study section, that were recovered in years t+1 through t+4 in one of three areas of the Goodpaster River, 1988 through 1992.

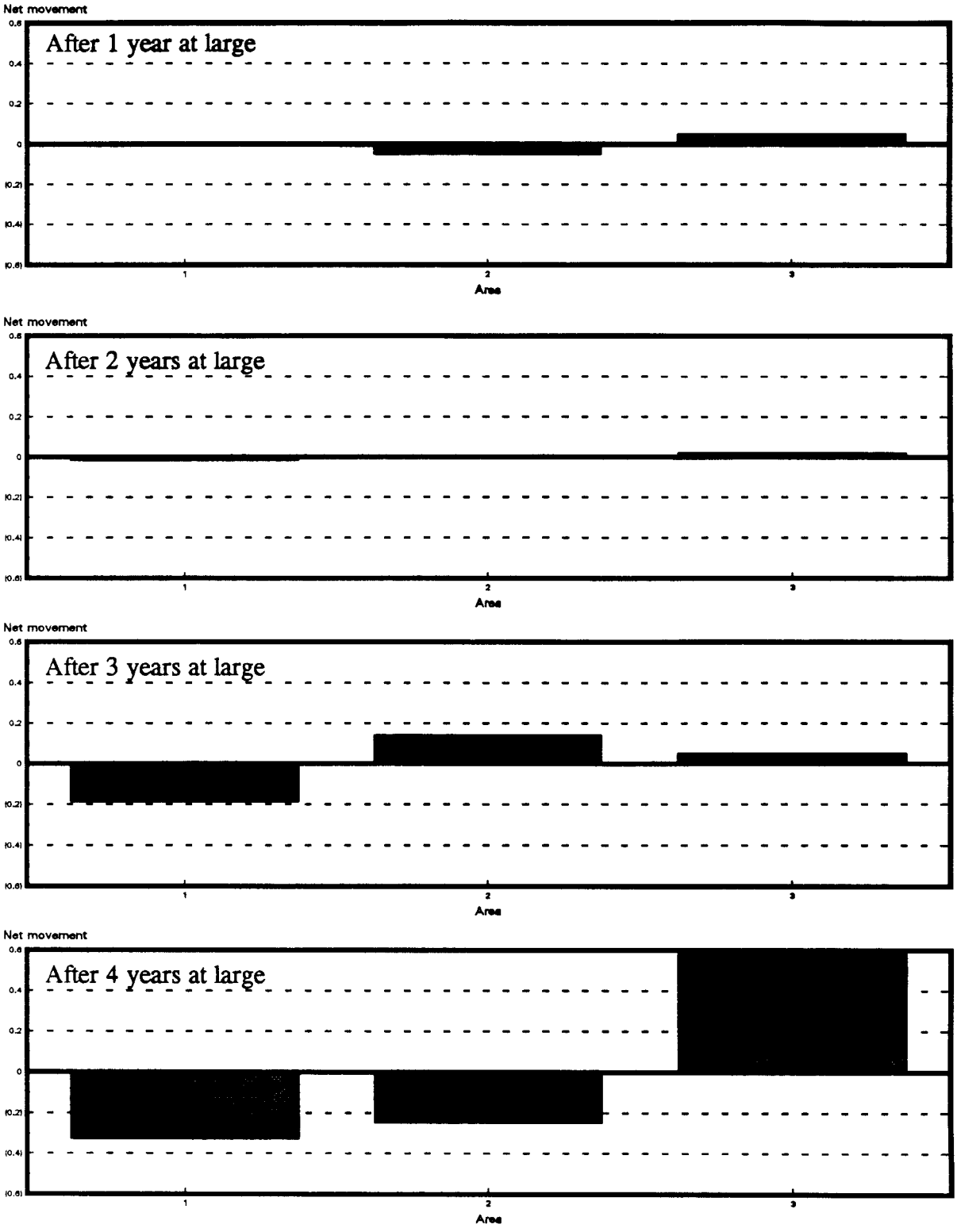

Figure 19. Average net movement (proportional loss or gain of marked fish) of Arctic grayling by years at large in three areas of the Goodpaster River, 1988 through 1992.

investigation. In the Salcha River, 45% to 72% of releases did not move. Fish movement in the Chena River attained a maximum of 25% in years 3 and 4, with more than 50% of these movements in an upstream direction. Fifty-five percent of releases in the Salcha River had moved in year 3, with 90% of these movements in an upstream direction. Maximum movement between areas of the Goodpaster River was observed in year 4, with 19% of releases moving exclusively upstream. Assuming that the magnitude of upstream movement observed within study sections occurs along the entire length of these rivers, movement of Arctic grayling out of the study section for stock assessment appears likely.

The net effect of movements in the Chena River study section was an accumulation of marked fish in area 3 and area 6. Assuming unmarked fish also undertook similar movements and movement was not influenced by size or age of fish, larger and older fish should have accumulated in areas 3 and 6 over time. However, larger and older fish do also occur in areas 4 and 5 (see Appendices D1 through D12). Net movement out of areas 4 and 5 did occur, suggesting that smaller fish may leave these areas. Net movement out of areas 1 and 2 and a lack of older and larger fish suggest that larger fish move upstream out of these areas. If smaller fish are migrating downstream, while larger fish are migrating upstream, estimates of mortality for this particular section of the Chena River may be unbiased, biased low, or biased high, depending on year-class strength and differential mortality by size.

The net effect of movements in the Salcha River study section was an accumulation of marked fish in area 3. Age and size composition of fish in the three areas did not differ markedly (Appendices E1 through E8), suggesting that fish of all sizes moved upstream over time. Net movements of fish in the Salcha River study section were the highest of the three rivers, resulting in a net loss of 50% of marked fish in areas 1 and 2 after 3 years. Based on these observations, estimates of mortality calculated for this particular section of the Salcha River may be biased low, while estimates of age and size composition may be unbiased.

The net effect of movements in the Goodpaster River study section was an accumulation of marked fish in area 3. Very little net movement was observed during the first 2 years at large. After year 3, there was net movement into areas 2 and 3, and after 4 years a net movement into area 3. There are larger and older fish in area 3, suggesting movement of fish upstream as they grow older and larger (Appendices F1-F10). Based on these observations, estimates of mortality calculated for this particular section of the Goodpaster River may be biased low, while estimates of age and size composition may be biased towards younger, smaller fish.

Most of the recovery data indicate that no interannual movement occurred. Based on this result, one might question the significance of observed movements in relation to the implications of emigration of the stock. Observed movement could have been the consequence of marking during the annual migration back to summer feeding areas from a spawning or overwintering area. For example a fish caught in area 2 during early July could have been migrating from a spawning area in area 2 to its actual summer feeding area in area 4. During the year of recovery, the same fish may have already migrated

to area 4 for summer feeding by late July and be recovered in area 4. This example results in movement from area 2 to area 4, but movement in the sense of the entire stock did not occur. If this type of "release while in transit" did occur, estimates of movement could be biased. Additionally, year-to-year variation in the timing of annual movements may have increased estimates of variance of average proportion of fish that moved.

Another possible bias in estimates of movement is unequal length of areas in the Chena River. The six areas of the Chena River were chosen because of previously established boundaries for abundance estimation (see Clark and Ridder 1987). Areas 1 and 2 were the longest (32 and 40 river kilometers, respectively), while area 5 was only 12 river kilometers long. On the basis of area length alone, movement of fish from area 5 would be much more likely than movements from areas 1 and 2. However, there were no large differences in the proportion of fish that survived and had not moved from areas 1 and 2 versus fish that had not moved from area 5 (Tables 3 through 7). Therefore differences in length between areas did not appear to affect estimates of movement in the Chena River.

Future Research

Tack (1980) observed that smaller fish present in upstream areas of the Goodpaster River during June were nearly absent or absent in July and August. Sampling in downstream areas of the Goodpaster River confirmed that smaller fish had migrated downstream during summer. If smaller fish move downstream during summer, possibly tagged and captured while in transit, then interannual downstream movement might be observed in the two rivers where marking occurs in June (Salcha) and July (Chena). There was insufficient time to fully analyze the effect of size at marking on subsequent movement, but this aspect will be investigated in the future. If the observed downstream movement is exclusively by smaller fish, one could assume that Tack's (1980) observations are accurate and restrict the analysis of movement to larger fish exclusively. Moreover, data on sexual maturity have been collected on all three rivers (see Clark 1992), allowing an analysis of movements by maturity status at release or recovery.

If the observed movements in this study accurately reflect interannual changes in the distribution of fish during summer, then the probabilities of movement could be used in a model of fish distribution. The model could be validated by using actual age or size compositions as the starting conditions for the model and comparing the age or size compositions of the output with actual compositions estimated several years later. If the model gave satisfactory results it could be used to predict changes in fish distribution with changes in recruitment and possibly to predict age and size compositions for areas upstream (or downstream) outside of the study section. The model could also be used to predict the consequences of local depeletions of fish (usually near popular access sites) on the overall stability of the population. This type of model could also be used to assess bias in estimates of mortality in recruitment when interannual movement occurs.

Conclusions

In general, more than 50% of Arctic grayling released into the three study sections did not move within the study section for up to five years after release. However, movements downstream and upstream did occur, with net movement in the upstream direction in all three rivers. The highest proportion of movement was observed in the Salcha River, which also had the shortest study section. Net movement in the Chena River was into the midstream areas, although there was net movement into the furthest upstream area. The least proportion of movement was observed in the Goodpaster River. Maximum movement in all study sections occurred either in year 3 or 4 of the observations. Based on these observations, potential bias in estimates of mortality would be highest in the Salcha River, uncertain in the Chena River, and intermediate in the Goodpaster River. The inability to discern seasonal changes from interannual changes in distribution of fish appears to be the greatest potential source of bias in estimates of movement. In the future, attempts to segregate movements by size, age, or sexual maturity at the time of release or recovery will be made. Modeling of interannual movements may allow predictions of changes in fish distribution that come from changes in recruitment or changes in the distribution in fishing effort.

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APPENDIX A
Data Summaries - Chena River

Appendix A1. Estimates of the proportion of Arctic grayling marked in six areas of the Chena River in July and August of 1987.

Area of release[a]	M_a[b]	N_a[c]	SE[d]	p_a[e]	SE[f]
1	209	4,931	933	0.04	0.01
2	261	2,125	247	0.12	0.01
3	307	1,965	482	0.16	0.04
4	430	4,088	1,072	0.10	0.03
5	488	5,198	1,372	0.09	0.02
6	642	10,573	3,089	0.06	0.02

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.
[b] M_a is the number of Arctic grayling released with marked in area *a*.
[c] N_a is the estimated abundance of Arctic grayling in area *a*.
[d] SE is the standard error of estimated abundance for area *a*.
[e] p_a is the proportion of Arctic grayling with marks in area *a*.
[f] SE is the standard error of p_a.

Appendix A2. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1987 and recovered in 1988 in six areas of the Chena River.

		Area of recapture					
Area of release[a]		1	2	3	4	5	6
1	m	8	0	0	0	1	1
	r	0.02	0	0	0	<0.01	<0.01
	SE[r]	0.01	0	0	0	<0.01	<0.01
2	m	1	15	2	0	2	0
	r	<0.01	0.07	<0.01	0	<0.01	0
	SE[r]	<0.01	0.02	<0.01	0	<0.01	0
3	m	0	1	34	0	0	0
	r	0	<0.01	0.08	0	0	0
	SE[r]	0	<0.01	0.01	0	0	0
4	m	0	0	6	30	1	0
	r	0	0	0.01	0.05	<0.01	0
	SE[r]	0	0	0.01	0.01	<0.01	0
5	m	0	0	0	3	29	2
	r	0	0	0	<0.01	0.05	<0.01
	SE[r]	0	0	0	<0.01	0.01	<0.01
6	m	0	0	1	1	0	51
	r	0	0	<0.01	<0.01	0	0.06
	SE[r]	0	0	<0.01	<0.01	0	0.01
	n	398	228	438	657	543	845

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A3. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1987 and recovered in 1988 in six areas of the Chena River.

	Area of recapture					
Area of release[a]	1	2	3	4	5	6
1	0.47	0	0	0	0.04	0.03
SE	0.19	0	0	0	0.04	0.03
2	0.02	0.54	0.04	0	0.03	0
SE	0.02	0.15	0.03	0	0.02	0
3	0	0.03	0.50	0	0	0
SE	0	0.03	0.15	0	0	0
4	0	0	0.13	0.43	0.02	0
SE	0	0	0.06	0.14	0.02	0
5	0	0	0	0.05	0.57	0.02
SE	0	0	0	0.03	0.18	0.02
6	0	0	0.04	0.02	0	0.99
SE	0	0	0.04	0.03	0	0.32

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A4. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1987 and recovered in 1989 in six areas of the Chena River.

		Area of recapture					
Area of release[a]		1	2	3	4	5	6
1	m	1	0	0	0	0	0
	r	<0.01	0	0	0	0	0
	SE[r]	<0.01	0	0	0	0	0
2	m	1	7	3	0	2	1
	r	<0.01	0.02	0.01	0	<0.01	<0.01
	SE[r]	<0.01	0.01	<0.01	0	<0.01	<0.01
3	m	0	0	14	0	0	1
	r	0	0	0.03	0	0	<0.01
	SE[r]	0	0	0.01	0	0	<0.01
4	m	0	0	0	20	2	1
	r	0	0	0	0.04	<0.01	<0.01
	SE[r]	0	0	0	0.01	<0.01	<0.01
5	m	0	0	0	1	17	0
	r	0	0	0	<0.01	0.03	0
	SE[r]	0	0	0	<0.01	0.01	0
6	m	0	0	0	0	1	23
	r	0	0	0	0	<0.01	0.03
	SE[r]	0	0	0	0	<0.01	0.01
	n	252	293	409	529	491	694

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A5. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1987 and recovered in 1989 in six areas of the Chena River.

Area of release[a]	Area of recapture					
	1	2	3	4	5	6
1	0.09	0	0	0	0	0
SE	0.09	0	0	0	0	0
2	0.03	0.19	0.06	0	0.03	0.01
SE	0.03	0.08	0.03	0	0.02	0.01
3	0	0	0.22	0	0	0.01
SE	0	0	0.08	0	0	0.01
4	0	0	0	0.36	0.04	0.01
SE	0	0	0	0.12	0.03	0.01
5	0	0	0	0.02	0.37	0
SE	0	0	0	0.02	0.13	0
6	0	0	0	0	0.03	0.55
SE	0	0	0	0	0.03	0.19

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A6. Numbers recovered ($m_{a\to b,t+h}$), sample size during recovery ($n_{b,t+h}$), estimates of the proportion marked in the recovery sample ($r_{a\to b,t+h}$), and standard error of Arctic grayling marked and released in 1987 and recovered in 1990 in six areas of the Chena River.

Area of release[a]		Area of recapture 1	2	3	4	5	6
1	m	3	0	0	1	0	0
	r	<0.01	0	0	<0.01	0	0
	SE[r]	<0.01	0	0	<0.01	0	0
2	m	0	4	1	2	0	0
	r	0	0.01	<0.01	<0.01	0	0
	SE[r]	0	0.01	<0.01	<0.01	0	0
3	m	0	0	16	0	0	1
	r	0	0	0.04	0	0	<0.01
	SE[r]	0	0	0.01	0	0	<0.01
4	m	0	1	0	16	2	2
	r	0	<0.01	0	0.02	<0.01	<0.01
	SE[r]	0	<0.01	0	0.01	<0.01	<0.01
5	m	0	0	0	2	11	1
	r	0	0	0	<0.01	0.02	<0.01
	SE[r]	0	0	0	<0.01	<0.01	<0.01
6	m	0	0	0	0	2	21
	r	0	0	0	0	<0.01	0.02
	SE[r]	0	0	0	0	<0.01	<0.01
	n	592	304	422	634	617	1,240

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A7. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1987 and recovered in 1990 in six areas of the Chena River.

	Area of recapture					
Area of release[a]	1	2	3	4	5	6
1	0.12	0	0	0.04	0	0
SE	0.07	0	0	0.04	0	0
2	0	0.11	0.02	0.03	0	0
SE	0	0.05	0.02	0.02	0	0
3	0	0	0.24	0	0	<0.01
SE	0	0	0.08	0	0	<0.01
4	0	0.03	0	0.24	0.03	0.01
SE	0	0.03	0	0.09	0.02	0.01
5	0	0	0	0.03	0.19	0.01
SE	0	0	0	0.02	0.08	0.01
6	0	0	0	0	0.05	0.28
SE	0	0	0	0	0.04	0.10

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A8. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1987 and recovered in 1991 in six areas of the Chena River.

		Area of recapture					
Area of release[a]		1	2	3	4	5	6
1	m	2	0	0	0	0	0
	r	<0.01	0	0	0	0	0
	SE[r]	<0.01	0	0	0	0	0
2	m	0	5	2	2	0	0
	r	0	0.01	0.01	0.01	0	0
	SE[r]	0	<0.01	0.01	<0.01	0	0
3	m	0	1	5	0	0	0
	r	0	<0.01	0.02	0	0	0
	SE[r]	0	<0.01	0.01	0	0	0
4	m	0	0	2	6	0	1
	r	0	0	0.01	0.02	0	<0.01
	SE[r]	0	0	0.01	0.01	0	<0.01
5	m	0	0	0	0	0	1
	r	0	0	0	0	0	<0.01
	SE[r]	0	0	0	0	0	<0.01
6	m	0	0	0	0	1	8
	r	0	0	0	0	<0.01	0.01
	SE[r]	0	0	0	0	<0.01	<0.01
	n	1,058	783	240	315	566	808

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A9. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1987 and recovered in 1991 in six areas of the Chena River.

Area of release[a]	Area of recapture					
	1	2	3	4	5	6
1	0.04	0	0	0	0	0
SE	0.03	0	0	0	0	0
2	0	0.05	0.07	0.05	0	0
SE	0	0.02	0.05	0.04	0	0
3	0	0.01	0.13	0	0	0
SE	0	0.01	0.07	0	0	0
4	0	0	0.08	0.18	0	0.01
SE	0	0	0.06)	0.09	0	0.01
5	0	0	0	0	0	0.01
SE	0	0	0	0	0	0.01
6	0	0	0	0	0.03	0.16
SE	0	0	0	0	0.03	0.07

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A10. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1987 and recovered in 1992 in six areas of the Chena River.

		Area of recapture					
Area of release[a]		1	2	3	4	5	6
1	m	1	0	0	0	0	0
	r	<0.01	0	0	0	0	0
	SE[r]	<0.01	0	0	0	0	0
2	m	0	4	0	0	0	0
	r	0	<0.01	0	0	0	0
	SE[r]	0	<0.01	0	0	0	0
3	m	0	1	5	0	0	0
	r	0	<0.01	0.01	0	0	0
	SE[r]	0	<0.01	<0.01	0	0	0
4	m	0	1	2	6	0	2
	r	0	<0.01	<0.01	0.01	0	<0.01
	SE[r]	0	<0.01	<0.01	<0.01	0	<0.01
5	m	0	0	0	0	4	0
	r	0	0	0	0	<0.01	0
	SE[r]	0	0	0	0	<0.01	)
6	m	0	0	0	0	0	6
	r	0	0	0	0	0	0.01
	SE[r]	0	0	0	0	0	<0.01
	n	1,423	1,417	487	467	877	792

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A11. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1987 and recovered in 1992 in six areas of the Chena River.

Area of release[a]	Area of recapture					
	1	2	3	4	5	6
1	0.02	0	0	0	0	0
SE	0.02	0	0	0	0	0
2	0	0.02	0	0	0	0
SE	0	0.01	0	0	0	0
3	0	<0.01	0.07	0	0	0
SE	0	<0.01	0.03	0	0	0
4	0	0.01	0.04	0.12	0	0.02
SE	0	0.01	0.03	0.06	0	0.02
5	0	0	0	0	0.05	0
SE	0	0	0	0	0.03	0
6	0	0	0	0	0	0.12
SE	0	0	0	0	0	0.06

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A12. Estimates of the proportion of Arctic grayling marked in six areas of the Chena River in July and August of 1988.

Area of release[a]	M_a[b]	N_a[c]	SE[d]	p_a[e]	SE[f]
1	398	5,525	1,397	0.07	0.02
2	228	2,235	979	0.10	0.04
3	438	1,907	311	0.23	0.04
4	657	3,916	652	0.17	0.03
5	543	3,762	742	0.14	0.03
6	844	4,683	646	0.18	0.02

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.
[b] M_a is the number of Arctic grayling released with marks in area *a*.
[c] N_a is the estimated abundance of Arctic grayling in area *a*.
[d] SE is the standard error of estimated abundance for area *a*.
[e] p_a is the proportion of Arctic grayling with marks in area *a*.
[f] SE is the standard error of p_a.

Appendix A13. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1988 and recovered in 1989 in six areas of the Chena River.

		Area of recapture					
Area of release[a]		1	2	3	4	5	6
1	m	2	0	0	0	1	1
	r	0.01	0	0	0	<0.01	<0.01
	SE[r]	0.01	0	0	0	<0.01	<0.01
2	m	0	7	3	1	1	0
	r	0	0.02	0.01	<0.01	<0.01	0
	SE[r]	0	0.01	<0.01	<0.01	<0.01	0
3	m	0	1	36	0	0	0
	r	0	<0.01	0.09	0	0	0
	SE[r]	0	<0.01	0.01	0	0	0
4	m	0	2	2	26	4	3
	r	0	0.01	<0.01	0.05	0.01	<0.01
	SE[r]	0	<0.01	<0.01	0.01	<0.01	<0.01
5	m	0	0	0	1	36	1
	r	0	0	0	<0.01	0.07	<0.01
	SE[r]	0	0	0	<0.01	0.01	<0.01
6	m	0	0	2	0	1	52
	r	0	0	<0.01	0	<0.01	0.07
	SE[r]	0	0	<0.01	0	<0.01	0.01
	n	252	293	409	529	491	694

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A14. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1988 and recovered in 1989 in six areas of the Chena River.

Area of release[a]	Area of recapture					
	1	2	3	4	5	6
1	0.11	0	0	0	0.03	0.02
SE	0.08	0	0	0	0.03	0.02
2	0	0.23	0.07	0.02	0.02	0
SE	0	0.13	0.05	0.02	0.02	0
3	0	0.01	0.38	0	0	0
SE	0	0.01	0.09	0	0	0
4	0.02	0.04	0.03	0.29	0.05	0.03
SE	0.02	0.03	0.02	0.07	0.02	0.01
5	0	0	0	0.01	0.51	0.01
SE	0	0	0	0.01	0.13	0.01
6	0.02	0	0.03	0	0.01	0.42
SE	0.02	0	0.02	0	0.01	0.08

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A15. Numbers recovered ($m_{a\to b,t+h}$), sample size during recovery ($n_{b,t+h}$), estimates of the proportion marked in the recovery sample ($r_{a\to b,t+h}$), and standard error of Arctic grayling marked and released in 1988 and recovered in 1990 in six areas of the Chena River.

		Area of recapture					
Area of release[a]		1	2	3	4	5	6
1	m	10	0	0	0	0	0
	r	0.02	0	0	0	0	0
	SE[r]	<0.01	0	0	0	0	0
2	m	0	10	2	0	2	0
	r	0	0.03	<0.01	0	<0.01	0
	SE[r]	0	0.01	<0.01	0	<0.01	0
3	m	0	1	15	2	1	0
	r	0	<0.01	0.04	<0.01	<0.01	0
	SE[r]	0	<0.01	0.01	<0.01	<0.01	0
4	m	0	0	1	27	1	1
	r	0	0	<0.01	0.04	<0.01	<0.01
	SE[r]	0	0	<0.01	0.01	<0.01	<0.01
5	m	0	0	0	0	20	1
	r	0	0	0	0	0.03	<0.01
	SE[r]	0	0	0	0	0.01	<0.01
6	m	0	0	1	2	0	40
	r	0	0	<0.01	<0.01	0	0.03
	SE[r]	0	0	<0.01	<0.01	0	<0.01
	n	592	304	422	634	617	1,240

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A16. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1988 and recovered in 1990 in six areas of the Chena River.

Area of release[a]	Area of recapture					
	1	2	3	4	5	6
1	0.23	0	0	0	0	0
SE	0.09	0	0	0	0	0
2	0	0.32	0.05	0	0.03	0
SE	0	0.17	0.04	0	0.03	0
3	0	0.01	0.15	0.01	0.01	0
SE	0	0.01	0.05	0.01	0.01	0
4	0	0	0.01	0.25	0.01	<0.01
SE	0	0	0.01	0.06	0.01	<0.01
5	0	0	0	0	0.22	0.01
SE	0	0	0	0	0.07	0.01
6	0	0	0.01	0.02	0	0.18
SE	0	0	0.01	0.01	0	0.04

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A17. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1988 and recovered in 1991 in six areas of the Chena River.

		Area of recapture					
Area of release[a]		1	2	3	4	5	6
1	m	11	1	1	1	0	0
	r	0.01	<0.01	<0.01	<0.01	0	0
	SE[r]	<0.01	<0.01	<0.01	<0.01	0	0
2	m	0	6	0	0	0	0
	r	0	0.01	0	0	0	0
	SE[r]	0	<0.01	0	0	0	0
3	m	0	0	12	1	1	0
	r	0	0	0.05	<0.01	<0.01	0
	SE[r]	0	0	0.01	<0.01	<0.01	0
4	m	0	0	2	10	0	2
	r	0	0	0.01	0.03	0	<0.01
	SE[r]	0	0	0.01	0.01	0	<0.01
5	m	0	1	0	6	9	0
	r	0	<0.01	0	0.02	0.02	0
	SE[r]	0	<0.01	0	0.01	<0.01	0
6	m	0	1	0	0	2	21
	r	0	<0.01	0	0	<0.01	0.03
	SE[r]	0	<0.01	0	0	<0.01	0.01
	n	1,058	783	240	315	566	808

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A18. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1988 and recovered in 1991 in six areas of the Chena River.

Area of release[a]	Area of recapture					
	1	2	3	4	5	6
1	0.14	0.02	0.06	0.04	0	0
SE	0.06	0.02	0.06	0.04	0	0
2	0	0.07	0	0	0	0
SE	0	0.04	0	0	0	0
3	0	0	0.22	0.01	0.01	0
SE	0	0	0.07	0.01	0.01	0
4	0	0	0.05	0.19	0	0.01
SE	0	0	0.04	0.07	0	0.01
5	0	0.01	0	0.13	0.11	0
SE	0	0.01	0	0.06	0.04	0
6	0	0.01	0	0	0.02	0.14
SE	0	0.01	0	0	0.01	0.04

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A19. Numbers recovered ($m_{a\to b,t+h}$), sample size during recovery ($n_{b,t+h}$), estimates of the proportion marked in the recovery sample ($r_{a\to b,t+h}$), and standard error of Arctic grayling marked and released in 1988 and recovered in 1992 in six areas of the Chena River.

		Area of recapture					
Area of release[a]		1	2	3	4	5	6
1	m	7	0	0	0	0	0
	r	<0.01	0	0	0	0	0
	SE[r]	<0.01	0	0	0	0	0
2	m	0	14	0	0	0	0
	r	0	0.01	0	0	0	0
	SE[r]	0	<0.01	0	0	0	0
3	m	0	1	12	0	0	0
	r	0	<0.01	0.02	0	0	0
	SE[r]	0	<0.01	0.01	0	0	0
4	m	0	0	3	9	2	0
	r	0	0	0.01	0.02	<0.01	0
	SE[r]	0	0	<0.01	0.01	<0.01	0
5	m	0	1	0	1	9	1
	r	0	<0.01	0	<0.01	0.01	<0.01
	SE[r]	0	<0.01	0	<0.01	<0.01	<0.01
6	m	0	0	1	0	0	17
	r	0	0	<0.01	0	0	0.02
	SE[r]	0	0	<0.01	0	0	<0.01
	n	1,423	1,417	487	467	877	792

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A20. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1988 and recovered in 1992 in six areas of the Chena River.

Area of release[a]	Area of recapture					
	1	2	3	4	5	6
1	0.07	0	0	0	0	0
SE	0.03	0	0	0	0	0
2	0	0.10	0	0	0	0
SE	0	0.05	0	0	0	0
3	0	<0.01	0.11	0	0	0
SE	0	<0.01	0.03	0	0	0
4	0	0	0.04	0.11	0.01	0
SE	0	0	0.02	0.04	0.01	0
5	0	<0.01	0	0.01	0.07	0.01
SE	0	<0.01	0	0.01	0.03	0.01
6	0	0	0.01	0	0	0.12
SE	0	0	0.01	0	0	0.03

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A21. Estimates of the proportion of Arctic grayling marked in six areas of the Chena River in July and August of 1989.

Area of release[a]	M_a[b]	N_a[c]	SE[d]	p_a[e]	SE[f]
1	252	2,450	439	0.10	0.02
2	293	1,715	241	0.17	0.02
3	409	2,287	452	0.18	0.03
4	529	3,613	711	0.15	0.03
5	491	2,642	497	0.19	0.03
6	694	4,860	882	0.14	0.02

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.
[b] M_a is the number of Arctic grayling released with marks in area *a*.
[c] N_a is the estimated abundance of Arctic grayling in area *a*.
[d] SE is the standard error of estimated abundance for area *a*.
[e] p_a is the proportion of Arctic grayling with marks in area *a*.
[f] SE is the standard error of p_a.

Appendix A22. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1989 and recovered in 1990 in six areas of the Chena River.

		Area of recapture					
Area of release[a]		1	2	3	4	5	6
1	m	4	0	0	0	0	1
	r	0.01	0	0	0	0	<0.01
	SE[r]	<0.01	0	0	0	0	<0.01
2	m	0	7	1	1	2	0
	r	0	0.02	<0.01	<0.01	<0.01	0
	SE[r]	0	0.01	<0.01	<0.01	<0.01	0
3	m	0	1	35	3	0	0
	r	0	<0.01	0.08	<0.01	0	0
	SE[r]	0	<0.01	0.01	<0.01	0	0
4	m	0	0	1	47	2	1
	r	0	0	<0.01	0.07	<0.01	<0.01
	SE[r]	0	0	<0.01	0.01	<0.01	<0.01
5	m	0	0	0	3	35	3
	r	0	0	0	<0.01	0.06	<0.01
	SE[r]	0	0	0	<0.01	0.01	<0.01
6	m	0	0	0	3	0	55
	r	0	0	0	<0.01	0	0.04
	SE[r]	0	0	0	<0.01	0	0.01
	n	592	304	422	634	617	1,240

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A23. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1989 and recovered in 1990 in six areas of the Chena River.

Area of release[a]	Area of recapture					
	1	2	3	4	5	6
1	0.07	0	0	0	0	0.01
SE	0.03	0	0	0	0	0.01
2	0	0.13	0.01	0.01	0.02	0
SE	0	0.05	0.01	0.01	0.01	0
3	0	0.02	0.46	0.03	0	0
SE	0	0.02	0.12	0.02	0	0
4	0	0	0.02	0.51	0.02	<0.01
SE	0	0	0.02	0.12	0.02	0.01
5	0	0	0	0.02	0.30	0.01
SE	0	0	0	0.01	0.08	0.01
6	0	0	0	0.03	0	0.31
SE	0	0	0	0.02	0	0.07

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A24. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1989 and recovered in 1991 in six areas of the Chena River.

Area of release[a]		Area of recapture 1	2	3	4	5	6
1	m	11	0	0	0	0	0
	r	0.01	0	0	0	0	0
	SE[r]	<0.01	0	0	0	0	0
2	m	0	31	1	0	0	1
	r	0	0.04	<0.01	0	0	<0.01
	SE[r]	0	0.01	<0.01	0	0	<0.01
3	m	0	0	8	1	0	0
	r	0	0	0.03	<0.01	0	0
	SE[r]	0	0	0.01	<0.01	0	0
4	m	0	1	5	16	1	1
	r	0	<0.01	0.02	0.05	<0.01	<0.01
	SE[r]	0	<0.01	0.01	0.01	<0.01	<0.01
5	m	0	0	0	7	11	0
	r	0	0	0	0.02	0.02	0
	SE[r]	0	0	0	0.01	0.01	0
6	m	0	1	0	2	6	31
	r	0	<0.01	0	0.01	0.01	0.04
	SE[r]	0	<0.01	0	<0.01	<0.01	0.01
	n	1,058	783	240	315	566	808

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A25. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1989 and recovered in 1991 in six areas of the Chena River.

Area of release[a]	Area of recapture					
	1	2	3	4	5	6
1	0.10	0	0	0	0	0
SE	0.03	0	0	0	0	0
2	0	0.23	0.02	0	0	0.01
SE	0	0.05	0.02	0	0	0.01
3	0	0	0.19	0.02	0	0
SE	0	0	0.07	0.02	0	0
4	0	0.01	0.14	0.35	0.01	0.01
SE	0	0.01	0.07	0.11	0.01	0.01
5	0	0	0	0.12	0.10	0
SE	0	0	0	0.05	0.04	0
6	0	0.01	0	0.04	0.07	0.27
SE	0	0.01	0	0.03	0.03	0.07

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A26. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1989 and recovered in 1992 in six areas of the Chena River.

		Area of recapture					
Area of release[a]		1	2	3	4	5	6
1	m	2	1	1	0	0	0
	r	<0.01	<0.01	<0.01	0	0	0
	SE[r]	<0.01	<0.01	<0.01	0	0	0
2	m	2	18	1	0	2	0
	r	<0.01	0.01	<0.01	0	<0.01	0
	SE[r]	<0.01	<0.01	<0.01	0	<0.01	0
3	m	0	2	12	1	1	0
	r	0	<0.01	0.02	<0.01	<0.01	0
	SE[r]	0	<0.01	0.01	<0.01	<0.01	0
4	m	1	2	2	11	0	2
	r	<0.01	<0.01	<0.01	0.02	0	<0.01
	SE[r]	<0.01	<0.01	<0.01	0.01	0	<0.01
5	m	0	0	1	0	16	2
	r	0	0	<0.01	0	0.02	<0.01
	SE[r]	0	0	<0.01	0	<0.01	<0.01
6	m	0	0	0	1	3	24
	r	0	0	0	<0.01	<0.01	0.03
	SE[r]	0	0	0	<0.01	<0.01	0.01
	n	1,423	1,417	487	467	877	792

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A27. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1989 and recovered in 1992 in six areas of the Chena River.

Area of release[a]	Area of recapture					
	1	2	3	4	5	6
1	0.01	0.01	0.02	0	0	0
SE	0.01	0.01	0.02	0	0	0
2	0.01	0.07	0.01	0	0.01	0
SE	0.01	0.02	0.01	0	0.01	0
3	0	0.01	0.14	0.01	0.01	0
SE	0	0.01	0.05	0.01	0.01	0
4	<0.01	0.01	0.03	0.16	0	0.02
SE	<0.01	0.01	0.02	0.06	0	0.01
5	0	0	0.01	0	0.10	0.01
SE	0	0	0.01	0	0.03	0.01
6	0	0	0	0.01	0.02	0.21
SE	0	0	0	0.01	0.01	0.06

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A28. Estimates of the proportion of Arctic grayling marked in six areas of the Chena River in July and August of 1990.

Area of release[a]	M_a[b]	N_a[c]	SE[d]	p_a[e]	SE[f]
1	592	10,444	5,190	0.06	0.03
2	304	2,310	262	0.13	0.01
3	422	1,749	297	0.24	0.04
4	634	3,560	598	0.18	0.03
5	617	3,688	657	0.17	0.03
6	1,240	8,162	1,085	0.15	0.02

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.
[b] M_a is the number of Arctic grayling released with marks in area *a*.
[c] N_a is the estimated abundance of Arctic grayling in area *a*.
[d] SE is the standard error of estimated abundance for area *a*.
[e] p_a is the proportion of Arctic grayling with marks in area *a*.
[f] SE is the standard error of p_a.

Appendix A29. Numbers recovered ($m_{a\to b,t+h}$), sample size during recovery ($n_{b,t+h}$), estimates of the proportion marked in the recovery sample ($r_{a\to b,t+h}$), and standard error of Arctic grayling marked and released in 1990 and recovered in 1991 in six areas of the Chena River.

Area of release[a]		Area of recapture 1	2	3	4	5	6
1	m	37	3	1	1	1	0
	r	0.03	<0.01	<0.01	<0.01	<0.01	0
	SE[r]	0.01	<0.01	<0.01	<0.01	<0.01	0
2	m	0	26	0	0	0	1
	r	0	0.03	0	0	0	<0.01
	SE[r]	0	0.01	0	0	0	<0.01
3	m	0	2	10	0	0	1
	r	0	<0.01	0.04	0	0	<0.01
	SE[r]	0	<0.01	0.01	0	0	<0.01
4	m	0	0	7	18	0	1
	r	0	0	0.03	0.06	0	<0.01
	SE[r]	0	0	0.01	0.01	0	<0.01
5	m	0	0	1	7	19	1
	r	0	0	<0.01	0.02	0.03	<0.01
	SE[r]	0	0	<0.01	0.01	0.01	<0.01
6	m	0	2	3	2	5	54
	r	0	<0.01	0.01	0.01	0.01	0.07
	SE[r]	0	<0.01	0.01	<0.01	<0.01	0.01
	n	1,058	783	240	315	566	808

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A30. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1990 and recovered in 1991 in six areas of the Chena River.

Area of release[a]	Area of recapture					
	1	2	3	4	5	6
1	0.62	0.07	0.07	0.06	0.03	0
SE	0.32	0.05	0.08	0.06	0.03	0
2	0	0.25	0	0	0	0.01
SE	0	0.06	0	0	0	0.01
3	0	0.01	0.17	0	0	<0.01
SE	0	0.01	0.06	0	0	<0.01
4	0	0	0.16	0.32	0	0.01
SE	0	0	0.07	0.09	0	0.01
5	0	0	0.02	0.13	0.20	0.01
SE	0	0	0.02	0.05	0.06	0.01
6	0	0.02	0.08	0.04	0.06	0.44
SE	0	0.01	0.05	0.03	0.03	0.08

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A31. Numbers recovered ($m_{a\to b,t+h}$), sample size during recovery ($n_{b,t+h}$), estimates of the proportion marked in the recovery sample ($r_{a\to b,t+h}$), and standard error of Arctic grayling marked and released in 1990 and recovered in 1992 in six areas of the Chena River.

		Area of recapture					
Area of release[a]		1	2	3	4	5	6
1	m	32	4	0	0	0	0
	r	0.02	<0.01	0	0	0	0
	SE[r]	<0.01	<0.01	0	0	0	0
2	m	0	26	1	0	1	0
	r	0	0.02	<0.01	0	<0.01	0
	SE[r]	0	<0.01	<0.01	0	<0.01	0
3	m	0	3	12	0	1	1
	r	0	<0.01	0.02	0	<0.01	<0.01
	SE[r]	0	<0.01	0.01	0	<0.01	<0.01
4	m	2	3	7	10	1	0
	r	<0.01	<0.01	0.01	0.02	<0.01	0
	SE[r]	<0.01	<0.01	<0.01	0.01	<0.01	0
5	m	0	2	0	0	15	1
	r	0	<0.01	0	0	0.02	<0.01
	SE[r]	0	<0.01	0	0	<0.01	<0.01
6	m	0	3	2	1	6	43
	r	0	<0.01	<0.01	<0.01	0.01	0.05
	SE[r]	0	<0.01	<0.01	<0.01	<0.01	0.01
	n	1,423	1,417	487	467	877	792

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A32. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1990 and recovered in 1992 in six areas of the Chena River.

Area of release[a]	Area of recapture					
	1	2	3	4	5	6
1	0.40	0.05	0	0	0	0
SE	0.21	0.03	0	0	0	0
2	0	0.14	0.02	0	0.01	0
SE	0	0.03	0.02	0	0.01	0
3	0	0.01	0.10	0	<0.01	0.01
SE	0	0.01	0.03	0	<0.01	0.01
4	0.01	0.01	0.08	0.12	0.01	0
SE	0.01	0.01	0.03	0.04	0.01	0
5	0	0.01	0	0	0.10	0.01
SE	0	0.01	0	0	0.03	0.01
6	0	0.01	0.03	0.01	0.04	0.36
	0	0.01	0.02	0.01	0.02	0.07

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A33. Estimates of the proportion of Arctic grayling marked in six areas of the Chena River in July and August of 1991.

Area of release[a]	M_a[b]	N_a[c]	SE[d]	p_a[e]	SE[f]
1	1,054	4,648	683	0.23	0.03
2	779	1,878	161	0.41	0.03
3	240	1,844	589	0.13	0.04
4	315	2,639	771	0.12	0.03
5	566	5,136	1,204	0.11	0.03
6	808	5,822	1,004	0.14	0.02

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.
[b] M_a is the number of Arctic grayling released with marks in area *a*.
[c] N_a is the estimated abundance of Arctic grayling in area *a*.
[d] SE is the standard error of estimated abundance for area *a*.
[e] p_a is the proportion of Arctic grayling with marks in area *a*.
[f] SE is the standard error of p_a.

Appendix A34. Numbers recovered ($m_{a\to b,t+h}$), sample size during recovery ($n_{b,t+h}$), estimates of the proportion marks in the recovery sample ($r_{a\to b,t+h}$), and standard error of Arctic grayling marked and released in 1991 and recovered in 1992 in six areas of the Chena River.

Area of release[a]		Area of recapture 1	2	3	4	5	6
1	m	161	5	0	0	0	0
	r	0.11	<0.01	0	0	0	0
	SE[r]	0.01	<0.01	0	0	0	0
2	m	3	153	4	1	1	1
	r	<0.01	0.11	0.01	<0.01	<0.01	<0.01
	SE[r]	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
3	m	0	4	21	0	0	0
	r	0	<0.01	0.04	0	0	0
	SE[r]	0	<0.01	0.01	0	0	0
4	m	0	1	3	17	6	2
	r	0	<0.01	0.01	0.04	0.01	<0.01
	SE[r]	0	<0.01	<0.01	0.01	<0.01	<0.01
5	m	0	4	1	2	30	12
	r	0	<0.01	<0.01	<0.01	0.03	0.01
	SE[r]	0	<0.01	<0.01	<0.01	0.01	<0.01
6	m	0	3	2	0	5	79
	r	0	<0.01	<0.01	0	0.01	0.10
	SE[r]	0	<0.01	<0.01	0	<0.01	0.01
	n	1,423	1,417	487	467	877	792

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A35. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1991 and recovered in 1992 in six areas of the Chena River.

Area of release[a]	Area of recapture					
	1	2	3	4	5	6
1	0.50	0.02	0	0	0	0
SE	0.08	0.01	0	0	0	0
2	<0.01	0.26	0.02	<0.01	<0.01	<0.01
SE	<0.01	0.03	0.01	<0.01	<0.01	<0.01
3	0	0.02	0.33	0	0	0
SE	0	0.01	0.13	0	0	0
4	0	0.01	0.05	0.30	0.06	0.02
SE	0	0.01	0.03	0.11	0.03	0.02
5	0	0.03	0.02	0.04	0.31	0.14
SE	0	0.01	0.02	0.03	0.09	0.05
6	0	0.01	0.03	0	0.04	0.72
SE	0	0.01	0.02	0	0.02	0.15

[a] Areas of release and recapture are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.

Appendix A36. Estimates of abundance of Arctic grayling in six areas of the Chena River in July and August of 1992.

Area[a]	N_a[b]	SE[c]
1	5,456	931
2	5,860	898
3	3,633	875
4	3,475	856
5	4,864	1,013
6	6,061	1,131

[a] Areas are: 1) river kilometer 0 through 40; 2) river kilometer 41 through 72; 3) river kilometer 73 through 88; 4) river kilometer 89 through 104; 5) river kilometer 105 through 117; and, 6) river kilometer 118 through 152.
[b] N_a is the estimated abundance of Arctic grayling in area *a*.
[c] SE is the standard error of estimated abundance for area *a*.

APPENDIX B
Data Summaries - Salcha River

Appendix B1. Estimates of the proportion of Arctic grayling marked in three areas of the Salcha River in June of 1989.

Area of release[a]	M_a[b]	N_a[c]	SE[d]	p_a[e]	SE[f]
1	380	2,302	446	0.16	0.02
2	436	2,641	478	0.16	0.02
3	326	1,975	413	0.16	0.03

[a] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.
[b] M_a is the number of Arctic grayling released with marks in area *a*.
[c] N_a is the estimated abundance of Arctic grayling in area *a*.
[d] SE is the standard error of estimated abundance for area *a*.
[e] p_a is the proportion of Arctic grayling with marks in area *a*.
[f] SE is the standard error of p_a.

Appendix B2. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1989 and recovered in 1990 in three areas of the Salcha River.

		Area of recapture					
Area of release[a]		1	SE	2	SE	3	SE
1	m	23		6		4	
	r	0.09	0.02	0.02	0.01	0.01	0.01
2	m	2		12		8	
	r	0.01	0.01	0.03	0.01	0.02	0.01
3	m	0		1		10	
	r	0	0	<0.01	<0.01	0.03	0.01
	n	257		359		329	

[a] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.

Appendix B3. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1989 and recovered in 1990 in three areas of the Salcha River.

	Area of recapture					
Area of release[a]	1	SE	2	SE	3	SE
1	0.54	0.12	0.10	0.04	0.07	0.04
2	0.05	0.03	0.20	0.06	0.15	0.05
3	0	0	0.02	0.02	0.18	0.06

[a] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.

Appendix B4. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1989 and recovered in 1991 in three areas of the Salcha River.

		Area of recapture					
Area of release[a]		1	SE	2	SE	3	SE
1	m	6		2		2	
	r	0.02	0.01	0.01	<0.01	<0.01	<0.01
2	m	0		2		1	
	r	0	0	0.01	<0.01	<0.01	<0.01
3	m	1		1		2	
	r	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
	n	272		303		580	

[a] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.

Appendix B5. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1989 and recovered in 1991 in three areas of the Salcha River.

	Area of recapture					
Area of release[a]	1	SE	2	SE	3	SE
1	0.13	0.06	0.04	0.03	0.02	0.01
2	0	0	0.04	0.03	0.01	0.01
3	0.02	0.02	0.02	0.02	0.02	0.01

[a] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.

Appendix B6. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1989 and recovered in 1992 in three areas of the Salcha River.

Area of release[a]		Area of recapture					
		1	SE	2	SE	3	SE
1	m	2		1		1	
	r	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2	m	0		0		2	
	r	0	0	0	0	<0.01	<0.01
3	m	0		1		7	
	r	0	0	<0.01	<0.01	0.01	<0.01
	n	430		383		554	

[a] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.

Appendix B7. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1989 and recovered in 1992 in three areas of the Salcha River.

	Area of recapture					
Area of release[a]	1	SE	2	SE	3	SE
1	0.03	0.02	0.02	0.02	0.01	0.01
2	0	0	0	0	0.02	0.02
3	0	0	0.02	0.02	0.08	0.03

[a] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.

Appendix B8. Estimates of the proportion of Arctic grayling marked in three areas of the Salcha River in June of 1990.

Area of release[a]	M_a[b]	N_a[c]	SE[d]	p_a[e]	SE[f]
1	257	1,571	346	0.16	0.02
2	359	2,195	408	0.16	0.02
3	329	2,012	391	0.16	0.02

[a] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.
[b] M_a is the number of Arctic grayling released with marks in area *a*.
[c] N_a is the estimated abundance of Arctic grayling in area *a*.
[d] SE is the standard error of estimated abundance for area *a*.
[e] p_a is the proportion of Arctic grayling with marks in area *a*.
[f] SE is the standard error of p_a.

Appendix B9. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1990 and recovered in 1991 in three areas of the Salcha River.

Area of release[a]		Area of recapture					
		1	SE	2	SE	3	SE
1	m	9		2		0	
	r	0.03	0.01	0.01	<0.01	0	0
2	m	2		13		3	
	r	0.01	<0.01	0.04	0.01	<0.01	<0.01
3	m	0		6		9	
	r	0	0	0.02	0.01	0.02	<0.01
	n	272		303		580	

[a] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.

Appendix B10. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1990 and recovered in 1991 in three areas of the Salcha River.

Area of release[a]	Area of recapture					
	1	SE	2	SE	3	SE
1	0.20	0.07	0.04	0.03	0	0
2	0.04	0.03	0.26	0.08	0.03	0.02
3	0	0	0.12	0.05	0.09	0.03

[a] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.

Appendix B11. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1990 and recovered in 1992 in three areas of the Salcha River.

		Area of recapture					
Area of release[a]		1	SE	2	SE	3	SE
1	m	1		1		2	
	r	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2	m	1		6		3	
	r	<0.01	<0.01	0.02	0.01	<0.01	<0.01
3	m	1		4		11	
	r	<0.01	<0.01	0.01	<0.01	0.02	0.01
	n	430		383		554	

[a] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.

Appendix B12. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1990 and recovered in 1992 in three areas of the Salcha River.

	Area of recapture					
Area of release[a]	1	SE	2	SE	3	SE
1	0.01	0.01	0.02	0.02	0.02	0.02
2	0.01	0.01	0.10	0.04	0.03	0.02
3	0.01	0.01	0.06	0.03	0.12	0.04

[a] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.

Appendix B13. Estimates of the proportion of Arctic grayling marked in three areas of the Salcha River in June of 1991.

Area of release[a]	M_a[b]	N_a[c]	SE[d]	p_a[e]	SE[f]
1	272	1,367	811	0.20	0.06
2	303	1,523	856	0.20	0.06
3	580	2,916	1,185	0.20	0.06

[a] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.
[b] M_a is the number of Arctic grayling released with marks in area *a*.
[c] N_a is the estimated abundance of Arctic grayling in area *a*.
[d] SE is the standard error of estimated abundance for area *a*.
[e] p_a is the proportion of Arctic grayling with marks in area *a*.
[f] SE is the standard error of p_a.

Appendix B14. Numbers recovered ($m_{a\to b,t+h}$), sample size during recovery ($n_{b,t+h}$), estimates of the proportion marked in the recovery sample ($r_{a\to b,t+h}$), and standard error of Arctic grayling marked and released in 1991 and recovered in 1992 in three areas of the Salcha River.

Area of release[a]		Area of recapture					
		1	SE	2	SE	3	SE
1	m	5		0		0	
	r	0.02	0.01	0	0	0	0
2	m	6		15		4	
	r	0.02	0.01	0.05	0.01	0.01	<0.01
3	m	3		1		14	
	r	0.01	0.01	<0.01	<0.01	0.02	0.01
	n	430		383		554	

[a] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.

Appendix B15. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1991 and recovered in 1992 in three areas of the Salcha River.

	Area of recapture					
Area of release[a]	1	SE	2	SE	3	SE
1	0.09	0.05	0	0	0	0
2	0.11	0.05	0.25	0.09	0.03	0.02
3	0.05	0.04	0.02	0.02	0.12	0.05

[a] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.

Appendix B16. Estimates of abundance of Arctic grayling in three areas of the Salcha River in June of 1992.

Area[a]	N_a[b]	SE[c]
1	2,424	1,433
2	2,159	1,352
3	3,123	1,626

[a] Areas are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.
[b] N_a is the estimated abundance of Arctic grayling in area *a*.
[c] SE is the standard error of estimated abundance for area *a*.

APPENDIX C
Data Summaries - Goodpaster River

Appendix C1. Estimates of the proportion of Arctic grayling marked in three areas of the Goodpaster River in August of 1988.

Area of release[a]	M_a[b]	N_a[c]	SE[d]	p_a[e]	SE[f]
1	773	3,143	394	0.25	0.02
2	863	3,505	416	0.25	0.02
3	356	1,448	267	0.25	0.02

[a] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.
[b] M_a is the number of Arctic grayling released with marks in area *a*.
[c] N_a is the estimated abundance of Arctic grayling in area *a*.
[d] SE is the standard error of estimated abundance for area *a*.
[e] p_a is the proportion of Arctic grayling with marks in area *a*.
[f] SE is the standard error of p_a.

Appendix C2. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1988 and recovered in 1989 in three areas of the Goodpaster River.

Area of release[a]		Area of recapture					
		1	SE	2	SE	3	SE
1	m	53		5		1	
	r	0.07	0.01	0.01	<0.01	<0.01	<0.01
2	m	4		58		5	
	r	<0.01	<0.01	0.10	0.01	0.01	<0.01
3	m	0		1		31	
	r	0	0	<0.01	<0.01	0.07	0.01
	n	788		606		412	

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C3. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1988 and recovered in 1989 in three areas of the Goodpaster River.

	Area of recapture					
Area of release[a]	1	SE	2	SE	3	SE
1	0.27	0.04	0.03	0.01	0.01	0.01
2	0.02	0.01	0.39	0.06	0.05	0.02
3	0	0	0.01	0.01	0.31	0.06

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C4. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1988 and recovered in 1990 in three areas of the Goodpaster River.

Area of release[a]		Area of recapture 1	SE	2	SE	3	SE
1	m	21		2		1	
	r	0.03	0.01	<0.01	<0.01	<0.01	<0.01
2	m	0		26		5	
	r	0	0	0.05	0.01	0.02	0.01
3	m	1		0		12	
	r	<0.01	<0.01	0	0	0.04	0.01
	n	693		544		289	

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C5. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1988 and recovered in 1990 in three areas of the Goodpaster River.

Area of release[a]	Area of recapture					
	1	SE	2	SE	3	SE
1	0.12	0.03	0.01	0.01	0.01	0.01
2	0	0	0.19	0.04	0.07	0.03
3	0.01	0.01	0	0	0.17	0.05

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C6. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1988 and recovered in 1991 in three areas of the Goodpaster River.

		Area of recapture					
Area of release[a]		1	SE	2	SE	3	SE
1	m	9		0		0	
	r	0.02	0.01	0	0	0	0
2	m	0		23		0	
	r	0	0	0.04	0.01	0	0
3	m	0		0		2	
	r	0	0	0	0	0.01	0.01
	n	462		507		194	

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C7. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1988 and recovered in 1991 in three areas of the Goodpaster River.

Area of release[a]	Area of recapture					
	1	SE	2	SE	3	SE
1	0.08	0.03	0	0	0	0
2	0	0	0.18	0.04	0	0
3	0	0	0	0	0.04	0.03

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C8. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1988 and recovered in 1992 in three areas of the Goodpaster River.

Area of release[a]		Area of recapture					
		1	SE	2	SE	3	SE
1	m	6		0		1	
	r	0.01	<0.01	0	0	<0.01	<0.01
2	m	0		7		1	
	r	0	0	0.01	<0.01	<0.01	<0.01
3	m	0		0		3	
	r	0	0	0	0	0.01	0.01
	n	645		533		223	

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C9. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1988 and recovered in 1992 in three areas of the Goodpaster River.

Area of release[a]	Area of recapture					
	1	SE	2	SE	3	SE
1	0.04	0.02	0	0	0.02	0.02
2	0	0	0.05	0.02	0.02	0.02
3	0	0	0	0	0.05	0.03

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C10. Estimates of the proportion of Arctic grayling marked in three areas of the Goodpaster River in August of 1989.

Area of release[a]	M_a[b]	N_a[c]	SE[d]	p_a[e]	SE[f]
1	788	3,505	488	0.22	0.02
2	606	2,695	428	0.22	0.02
3	412	1,833	353	0.22	0.02

[a] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.
[b] M_a is the number of Arctic grayling released with marks in area *a*.
[c] N_a is the estimated abundance of Arctic grayling in area *a*.
[d] SE is the standard error of estimated abundance for area *a*.
[e] p_a is the proportion of Arctic grayling with marks in area *a*.
[f] SE is the standard error of p_a.

Appendix C11. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1989 and recovered in 1990 in three areas of the Goodpaster River.

		Area of recapture					
Area of release[a]		1	SE	2	SE	3	SE
1	m	45		5		0	
	r	0.06	0.01	0.01	<0.01	0	0
2	m	2		34		5	
	r	<0.01	<0.01	0.06	0.01	0.02	0.01
3	m	2		1		21	
	r	<0.01	<0.01	<0.01	<0.01	0.07	0.01
	n	693		544		289	

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C12. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1989 and recovered in 1990 in three areas of the Goodpaster River.

	Area of recapture					
Area of release[a]	1	SE	2	SE	3	SE
1	0.29	0.05	0.04	0.02	0	0
2	0.01	0.01	0.28	0.05	0.08	0.03
3	0.01	0.01	0.01	0.01	0.32	0.07

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C13. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1989 and recovered in 1991 in three areas of the Goodpaster River.

Area of release[a]		Area of recapture					
		1	SE	2	SE	3	SE
1	m	10		2		0	
	r	0.02	0.01	<0.01	<0.01	0	0
2	m	0		15		0	
	r	0	0	0.03	0.01	0	0
3	m	0		1		13	
	r	0	0	<0.01	<0.01	0.07	0.02
	n	462		507		194	

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C14. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1989 and recovered in 1991 in three areas of the Goodpaster River.

	Area of recapture					
Area of release[a]	1	SE	2	SE	3	SE
1	0.10	0.03	0.02	0.01	0	0
2	0	0	0.13	0.04	0	0
3	0	0	0.01	0.01	0.30	0.08

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C15. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1989 and recovered in 1992 in three areas of the Goodpaster River.

Area of release[a]		Area of recapture					
		1	SE	2	SE	3	SE
1	m	7		1		1	
	r	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
2	m	0		12		0	
	r	0	0	0.02	0.01	0	0
3	m	0		2		4	
	r	0	0	<0.01	<0.01	0.02	0.01
	n	645		533		223	

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C16. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1989 and recovered in 1992 in three areas of the Goodpaster River.

	Area of recapture					
Area of release[a]	1	SE	2	SE	3	SE
1	0.05	0.02	0.01	0.01	0.02	0.02
2	0	0	0.10	0.03	0	0
3	0	0	0.02	0.01	0.08	0.04

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C17. Estimates of the proportion of Arctic grayling marked in three areas of the Goodpaster River in August of 1990.

Area of release[a]	M_a[b]	N_a[c]	SE[d]	p_a[e]	SE[f]
1	693	3,296	519	0.21	0.02
2	544	2,587	460	0.21	0.02
3	289	1,375	335	0.21	0.02

[a] Areas of release and recapture are: 1) river kilometer 0 through 12.8; 2) river kilometer 13.0 through 25.6; and, 3) river kilometer 26.0 through 38.4.
[b] M_a is the number of Arctic grayling released with marks in area *a*.
[c] N_a is the estimated abundance of Arctic grayling in area *a*.
[d] SE is the standard error of estimated abundance for area *a*.
[e] p_a is the proportion of Arctic grayling with marks in area *a*.
[f] SE is the standard error of p_a.

Appendix C18. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1990 and recovered in 1991 in three areas of the Goodpaster River.

Area of release[a]		Area of recapture 1	SE	2	SE	3	SE
1	m	18		1		0	
	r	0.04	0.01	<0.01	<0.01	0	0
2	m	3		38		1	
	r	0.01	<0.01	0.07	0.01	<0.01	<0.01
3	m	0		1		7	
	r	0	0	<0.01	<0.01	0.04	0.01
	n	462		507		194	

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C19. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1990 and recovered in 1991 in three areas of the Goodpaster River.

	Area of recapture					
Area of release[a]	1	SE	2	SE	3	SE
1	0.18	0.05	0.01	0.01	0	0
2	0.03	0.02	0.36	0.07	0.02	0.02
3	0	0	0.01	0.01	0.17	0.07

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C20. Numbers recovered ($m_{a\to b,t+h}$), sample size during recovery ($n_{b,t+h}$), estimates of the proportion marked in the recovery sample ($r_{a\to b,t+h}$), and standard error of Arctic grayling marked and released in 1990 and recovered in 1992 in three areas of the Goodpaster River.

Area of release[a]		Area of recapture 1	SE	2	SE	3	SE
1	m	17		0		0	
	r	0.03	0.01	0	0	0	0
2	m	6		17		0	
	r	0.01	<0.01	0.03	0.01	0	0
3	m	0		2		3	
	r	0	0	<0.01	<0.01	0.01	0.01
	n	645		533		223	

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C21. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1990 and recovered in 1992 in three areas of the Goodpaster River.

	Area of recapture					
Area of release[a]	1	SE	2	SE	3	SE
1	0.12	0.03	0	0	0	0
2	0.04	0.02	0.15	0.04	0	0
3	0	0	0.02	0.01	0.06	0.04

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C22. Estimates of the proportion of Arctic grayling marked in three areas of the Goodpaster River in August of 1991.

Area of release[a]	M_a[b]	N_a[c]	SE[d]	p_a[e]	SE[f]
1	462	3,227	706	0.14	0.02
2	507	3,541	739	0.14	0.02
3	194	1,355	457	0.14	0.02

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.
[b] M_a is the number of Arctic grayling released with marks in area *a*.
[c] N_a is the estimated abundance of Arctic grayling in area *a*.
[d] SE is the standard error of estimated abundance for area *a*.
[e] p_a is the proportion of Arctic grayling with marks in area *a*.
[f] SE is the standard error of p_a.

Appendix C23. Numbers recovered ($m_{a \to b, t+h}$), sample size during recovery ($n_{b, t+h}$), estimates of the proportion marked in the recovery sample ($r_{a \to b, t+h}$), and standard error of Arctic grayling marked and released in 1991 and recovered in 1992 in three areas of the Goodpaster River.

Area of release[a]		Area of recapture 1	SE	2	SE	3	SE
1	m	43		0		0	
	r	0.07	0.01	0	0	0	0
2	m	5		47		0	
	r	0.01	<0.01	0.09	0.01	0	0
3	m	1		1		10	
	r	<0.01	<0.01	<0.01	<0.01	0.04	0.01
	n	645		533		223	

[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C24. Estimates of contribution (c_a) and standard error of Arctic grayling marked and released in 1991 and recovered in 1992 in three areas of the Goodpaster River.

Area of release[a]	Area of recapture					
	1	SE	2	SE	3	SE
1	0.47	0.09	0	0	0	0
2	0.05	0.02	0.62	0.12	0	0
3	0.01	0.01	0.01	0.01	0.31	0.11

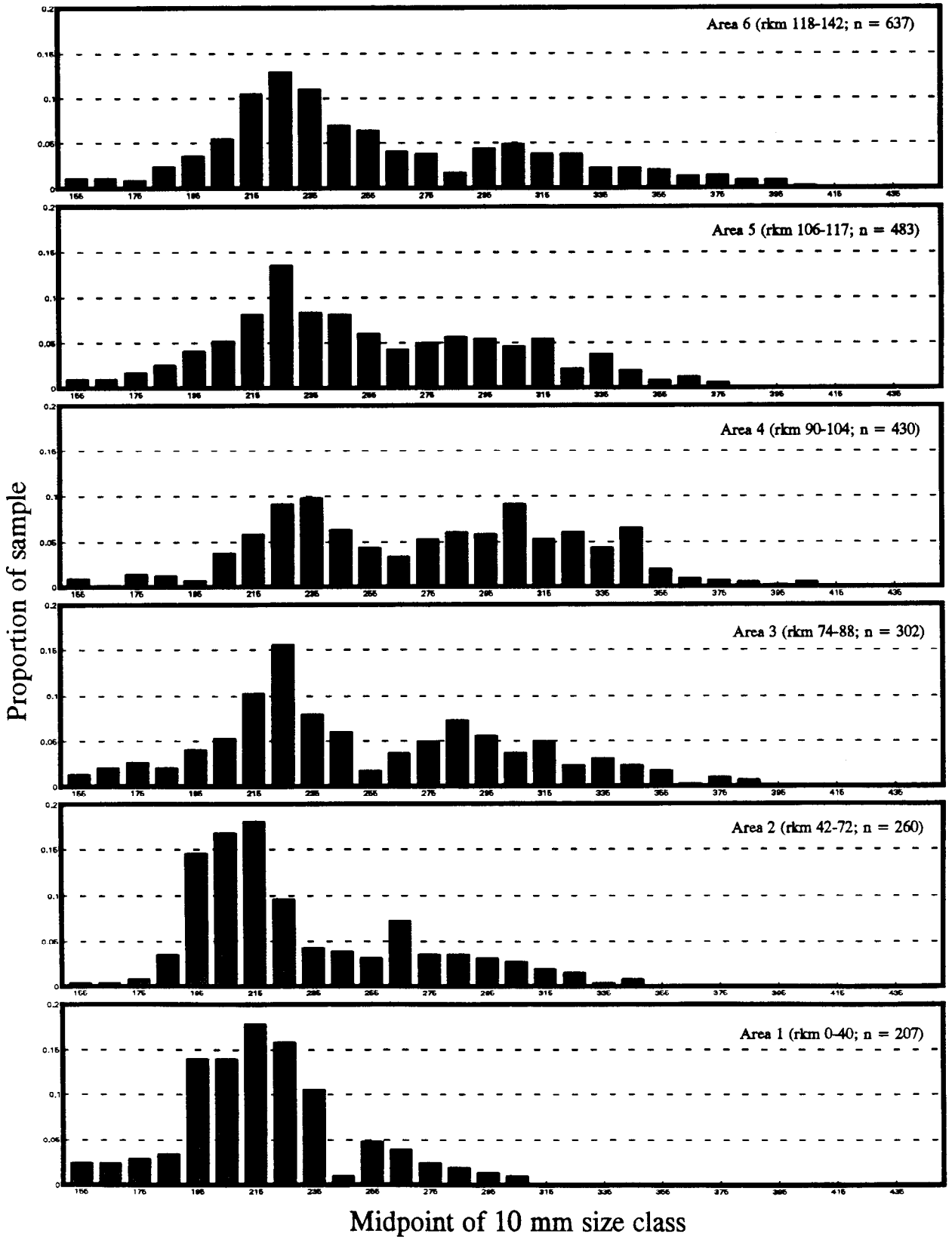
[a] Areas of release and recapture are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.

Appendix C25. Estimates of abundance of Arctic grayling in three areas of the Goodpaster River in August of 1992.

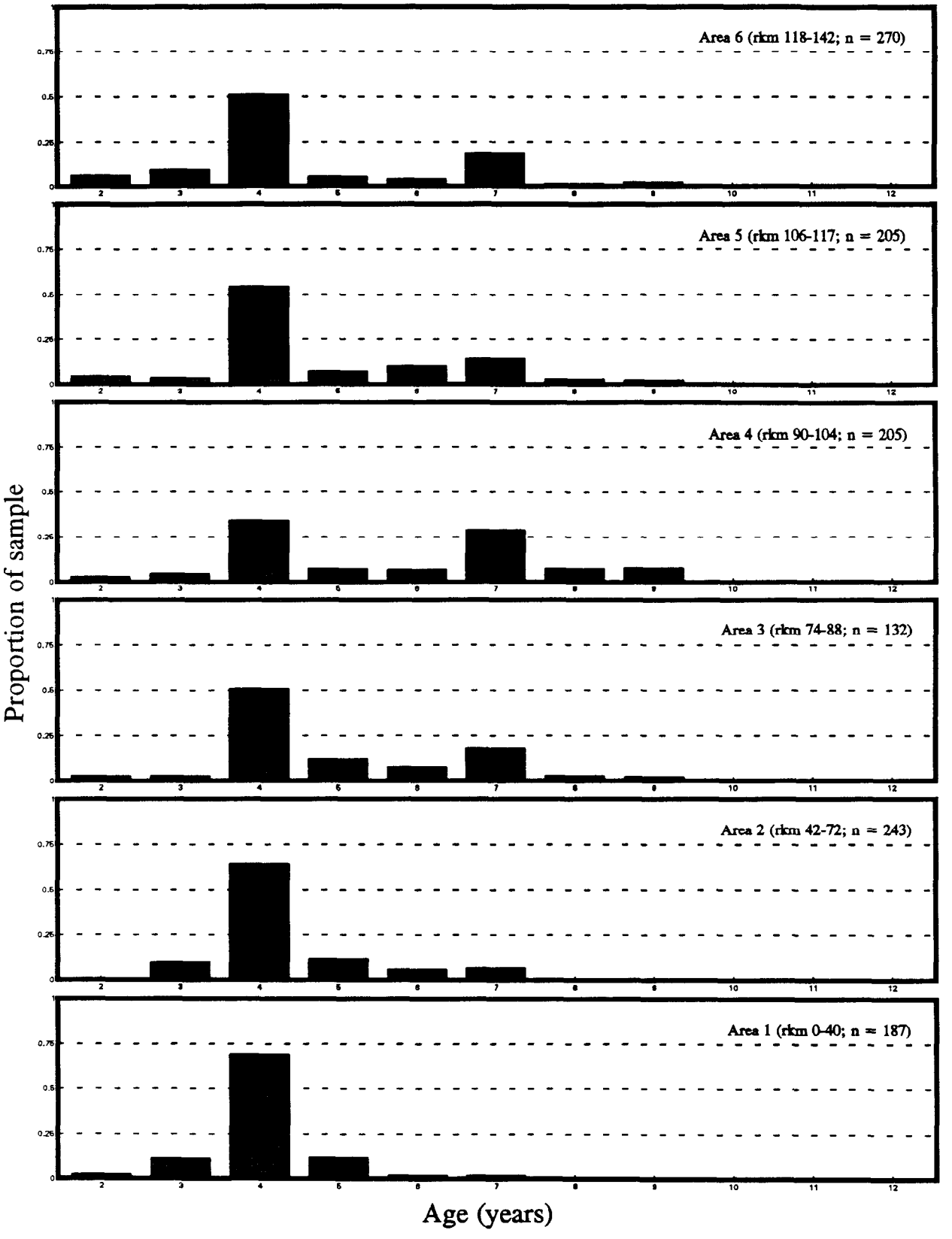
Area[a]	N_a[b]	SE[c]
1	3,077	603
2	2,299	287
3	1,510	457

[a] Areas are: 1) river kilometer 0 through 19.2; 2) river kilometer 20.0 through 33.6; and, 3) river kilometer 34.0 through 52.3.
[b] N_a is the estimated abundance of Arctic grayling in area *a*.
[c] SE is the standard error of estimated abundance for area *a*.

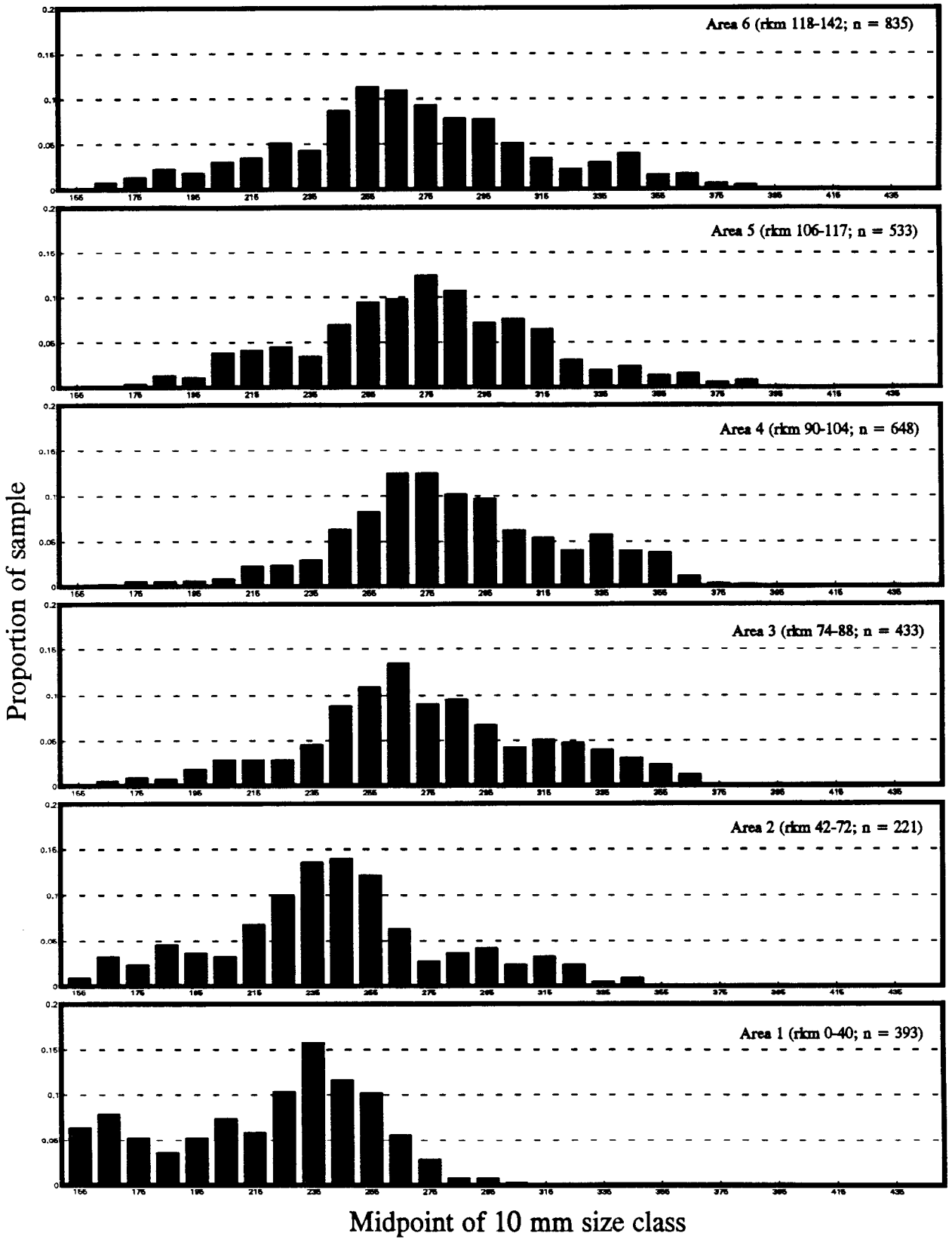
APPENDIX D
Age and Size Composition - Chena River



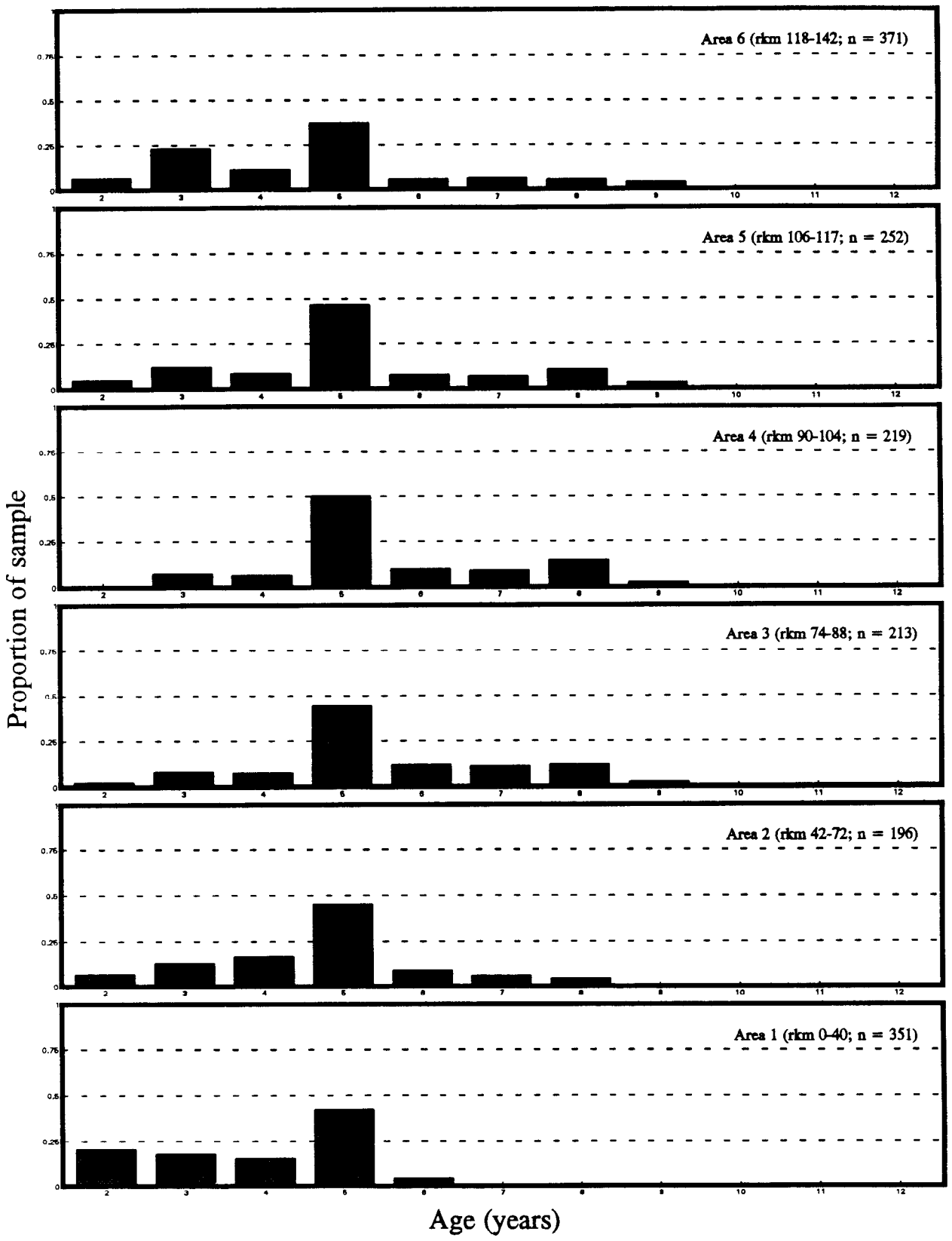
Appendix D1. Size composition (mm fork length) of Arctic grayling marked and released in six areas of the Chena River during 1987.



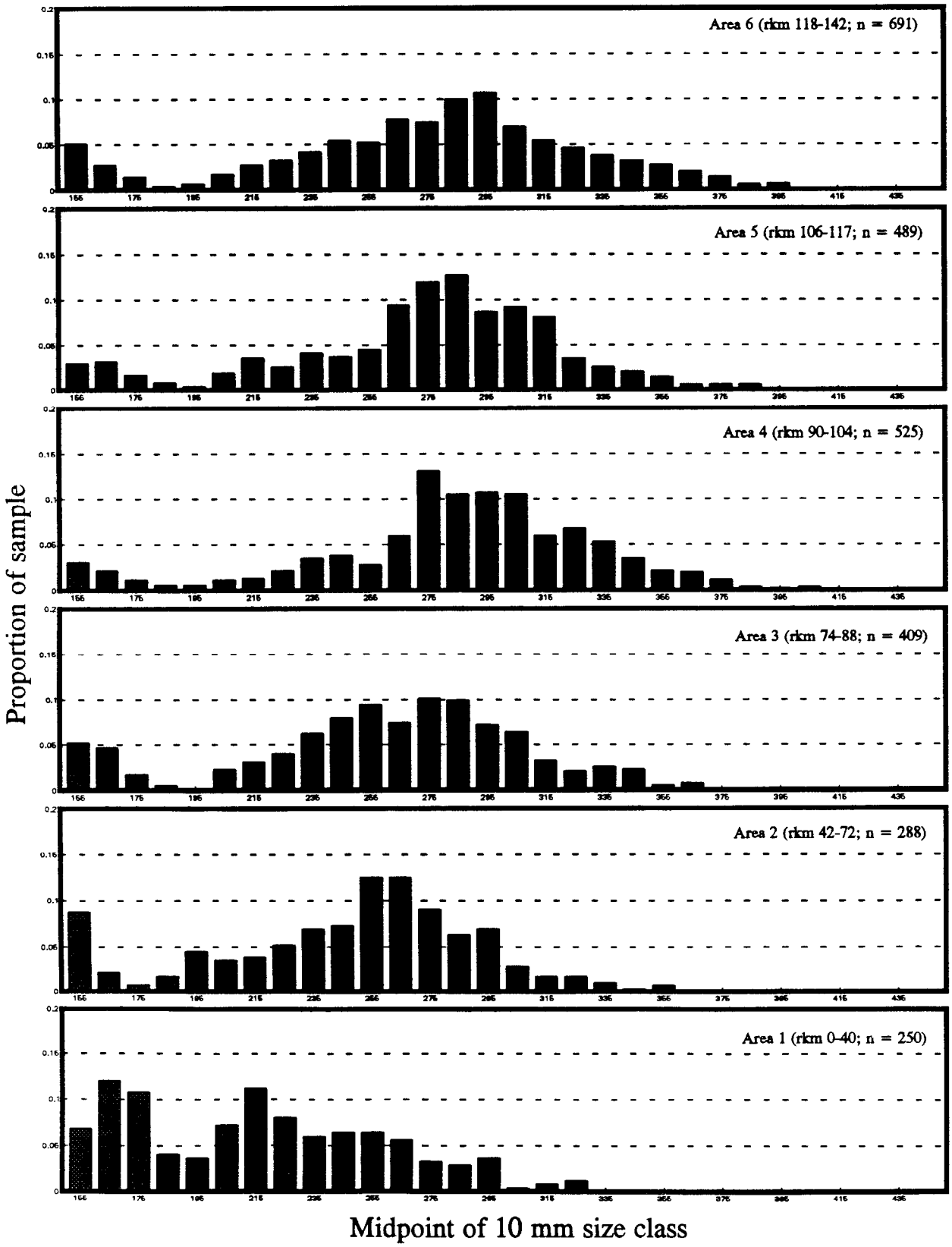
Appendix D2. Age composition (years) of Arctic grayling marked and released in six areas of the Chena River during 1987.



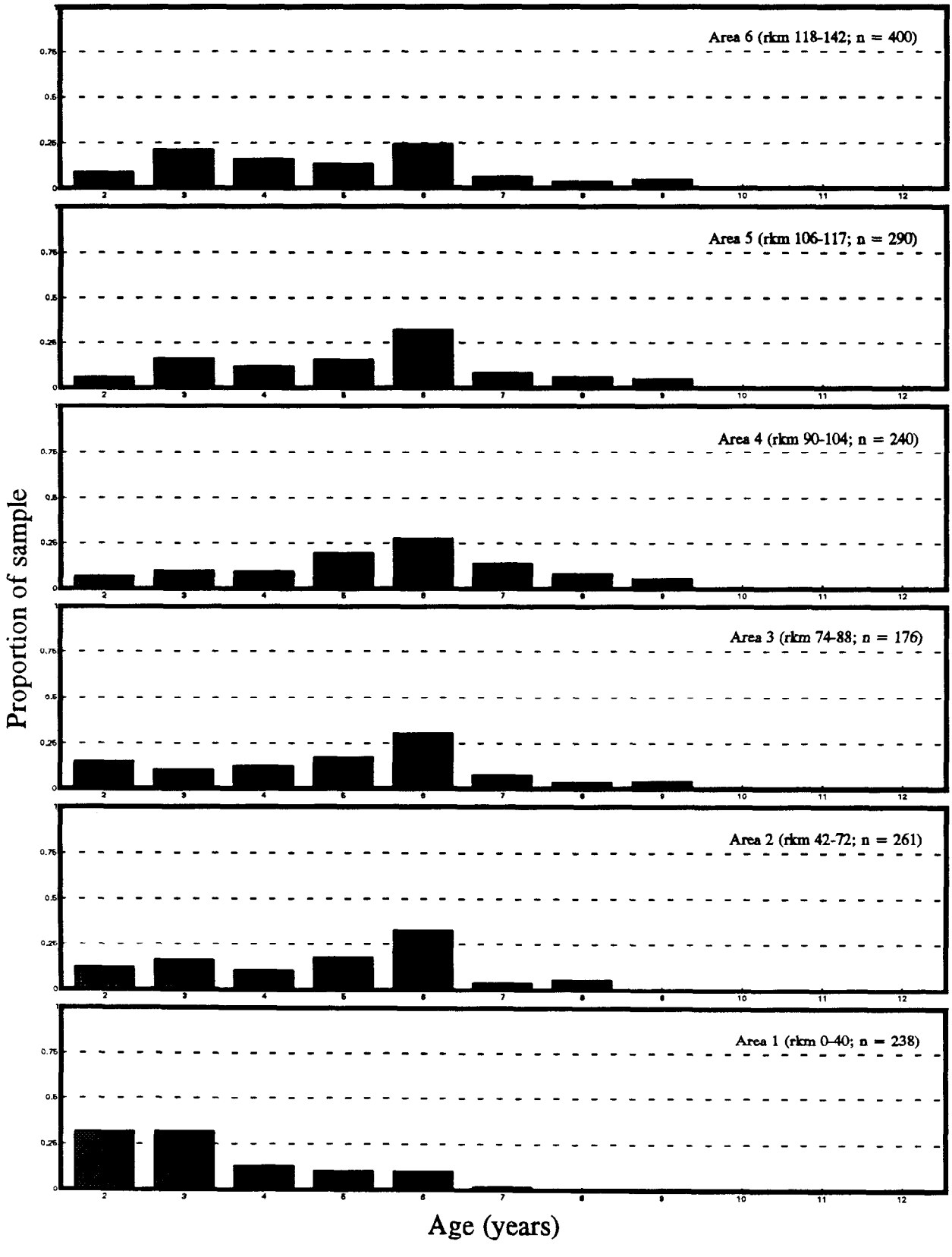
Appendix D3. Size composition (mm fork length) of Arctic grayling marked and released in six areas of the Chena River during 1988.



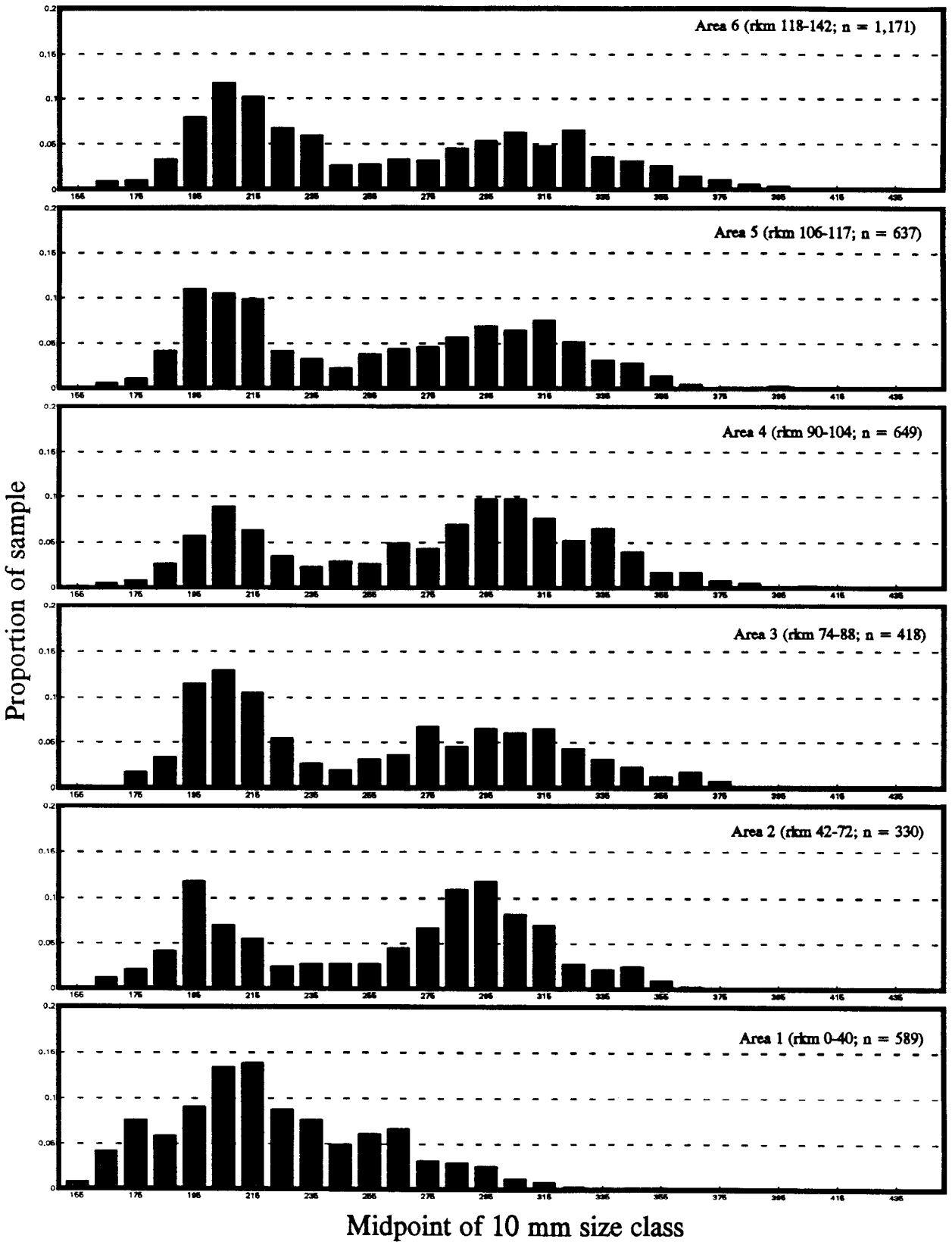
Appendix D4. Age composition (years) of Arctic grayling marked and released in six areas of the Chena River during 1988.



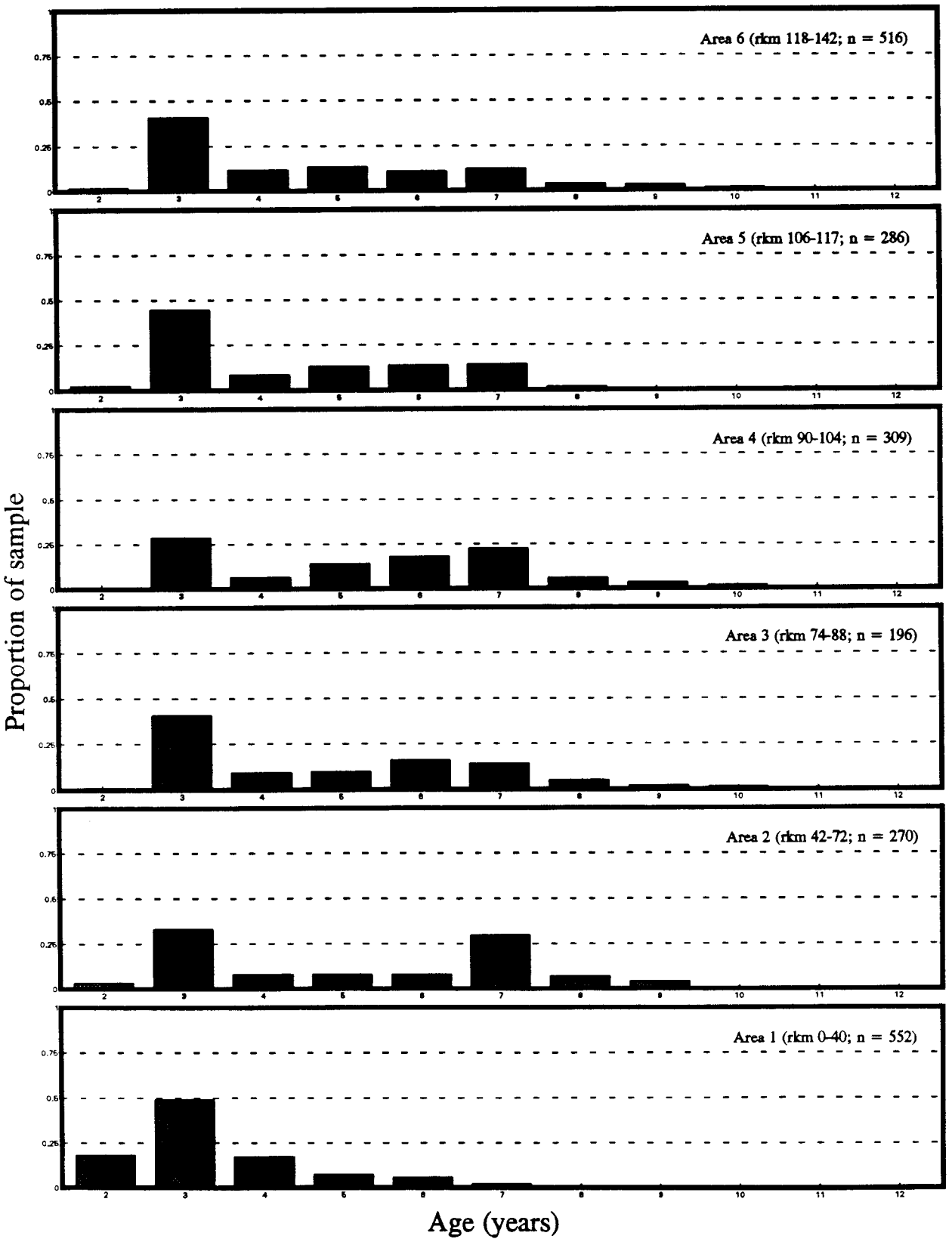
Appendix D5. Size composition (mm fork length) of Arctic grayling marked and released in six areas of the Chena River during 1989.



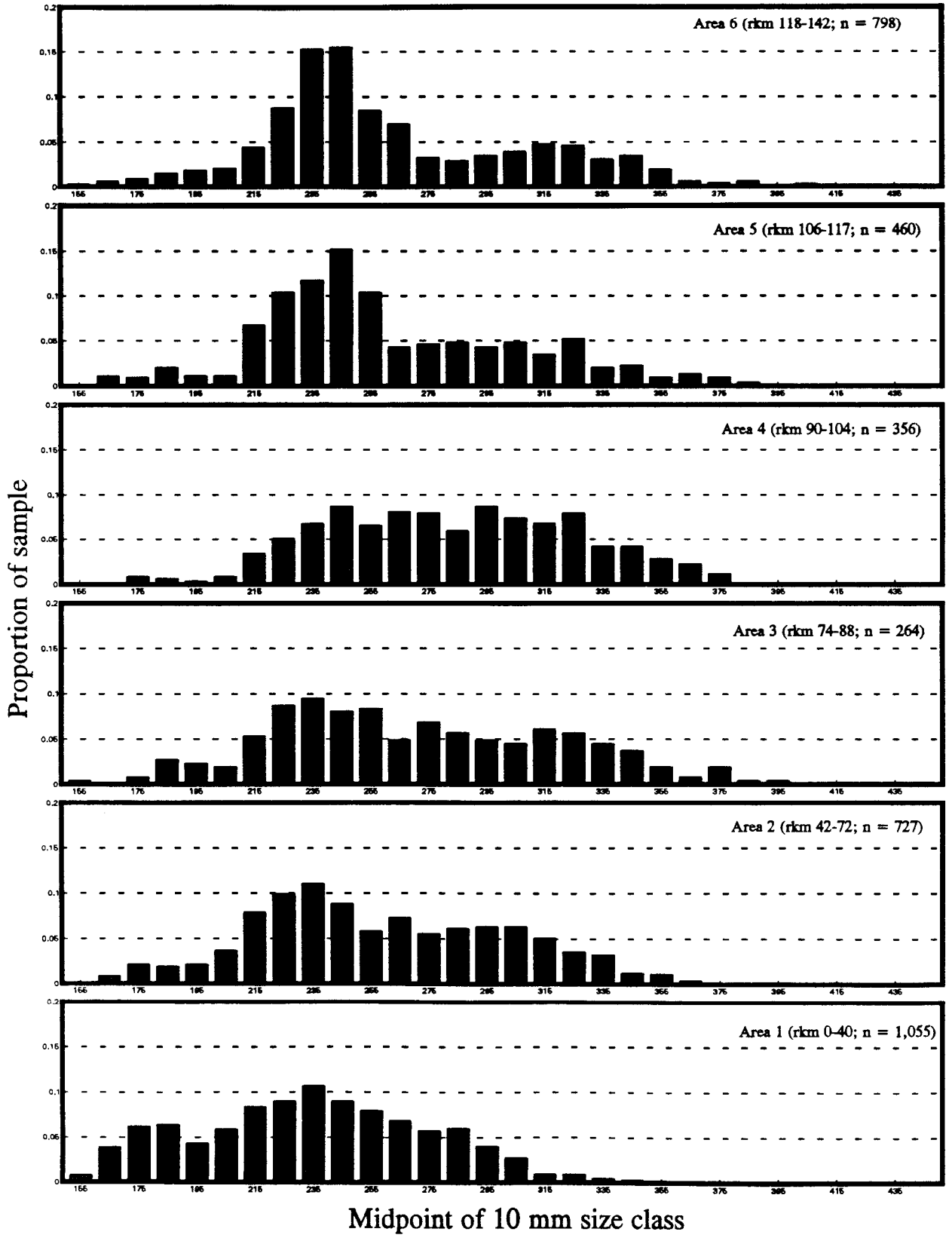
Appendix D6. Age composition (years) of Arctic grayling marked and released in six areas of the Chena River during 1989.



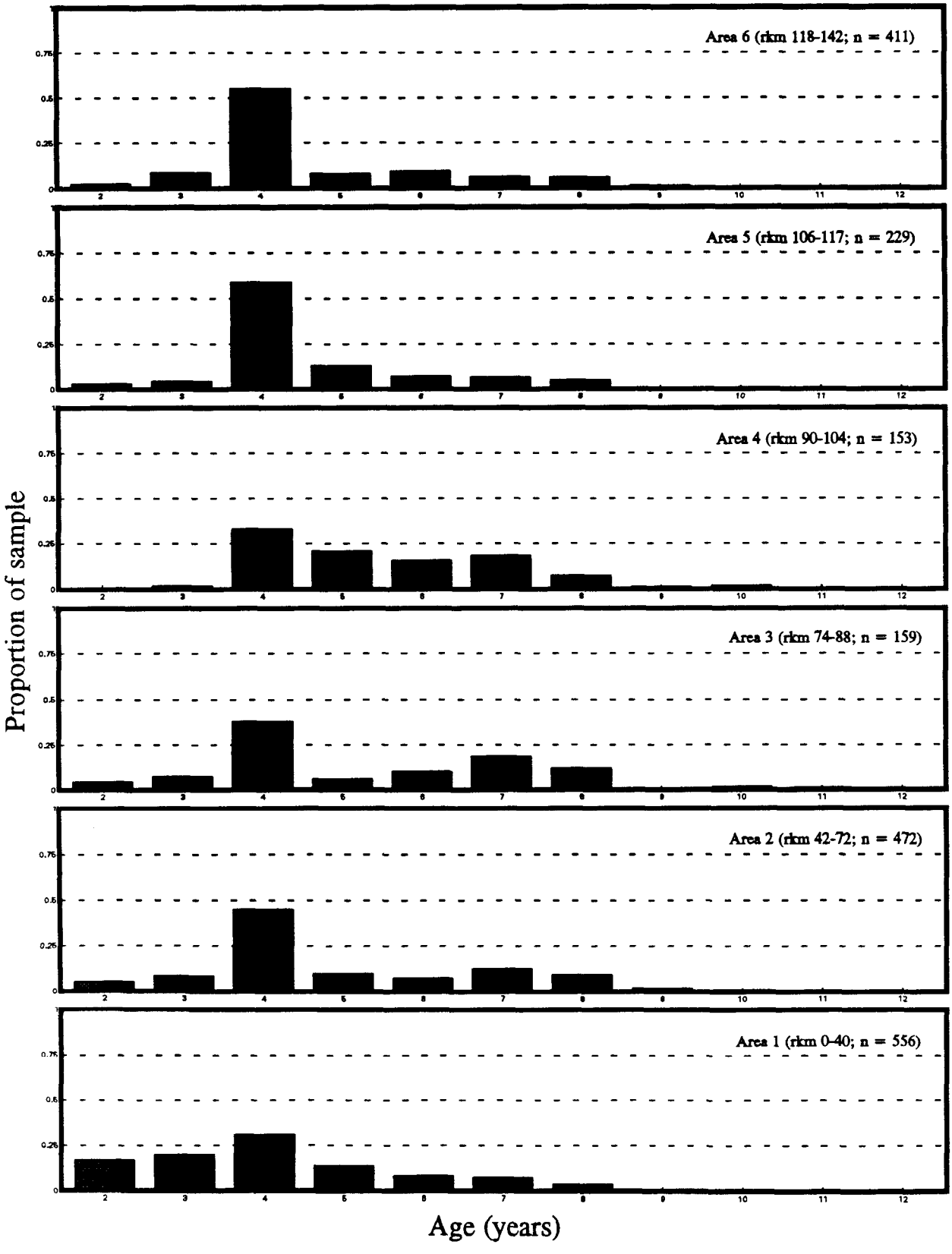
Appendix D7. Size composition (mm fork length) of Arctic grayling marked and released in six areas of the Chena River during 1990.



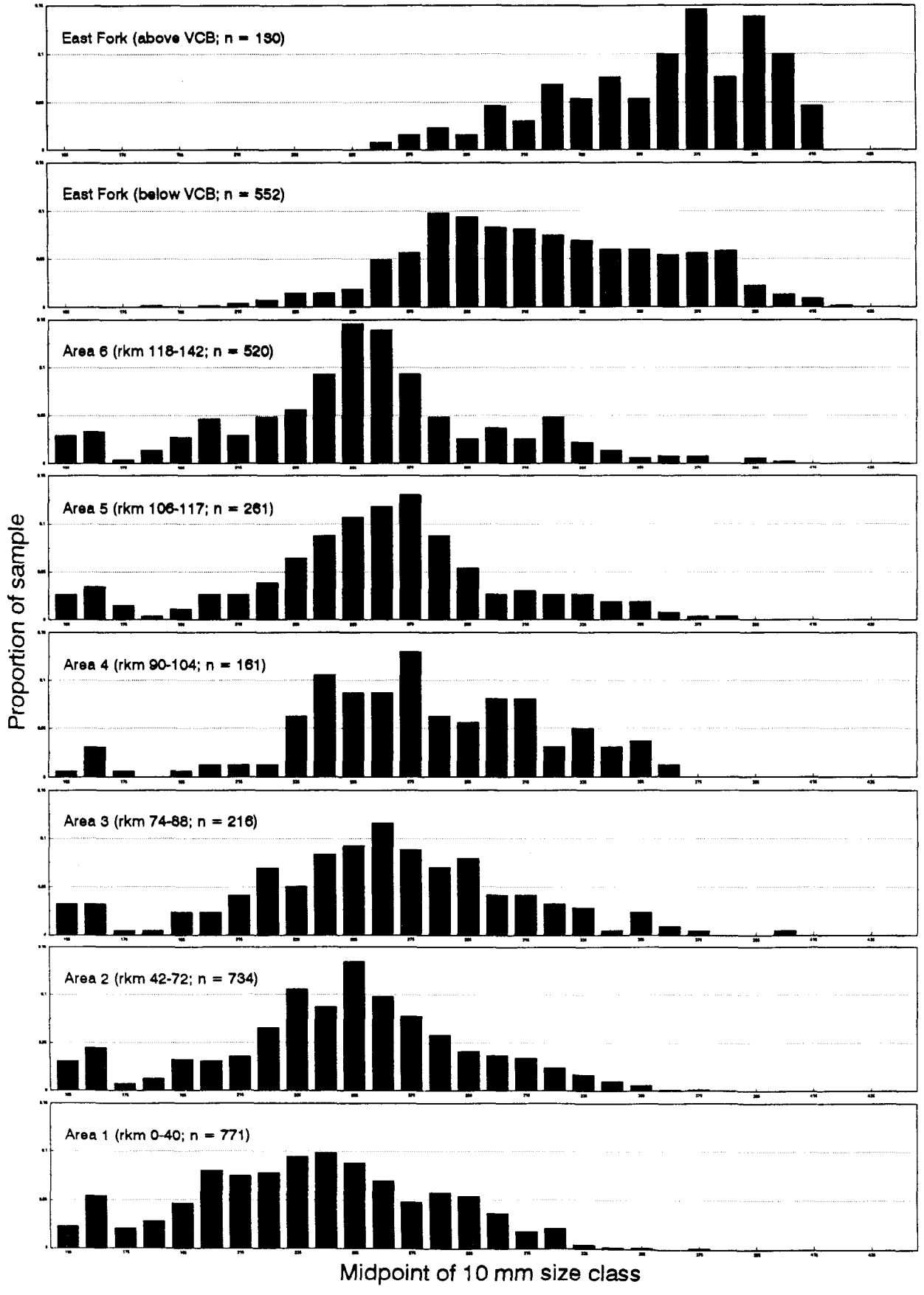
Appendix D8. Age composition (years) of Arctic grayling marked and released in six areas of the Chena River during 1990.



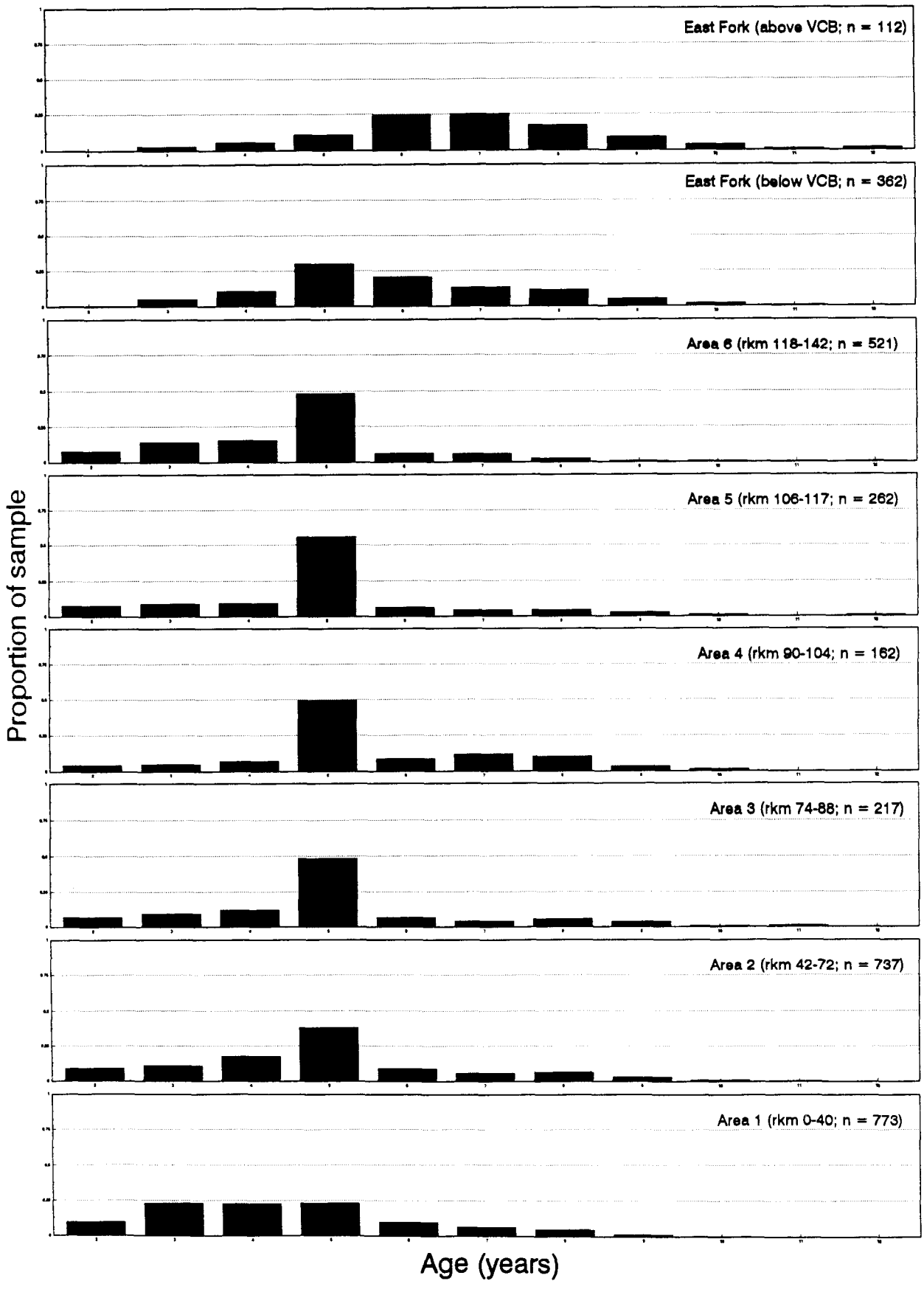
Appendix D9. Size composition (mm fork length) of Arctic grayling marked and released in six areas of the Chena River during 1991.



Appendix D10. Age composition (years) of Arctic grayling marked and released in six areas of the Chena River during 1991.

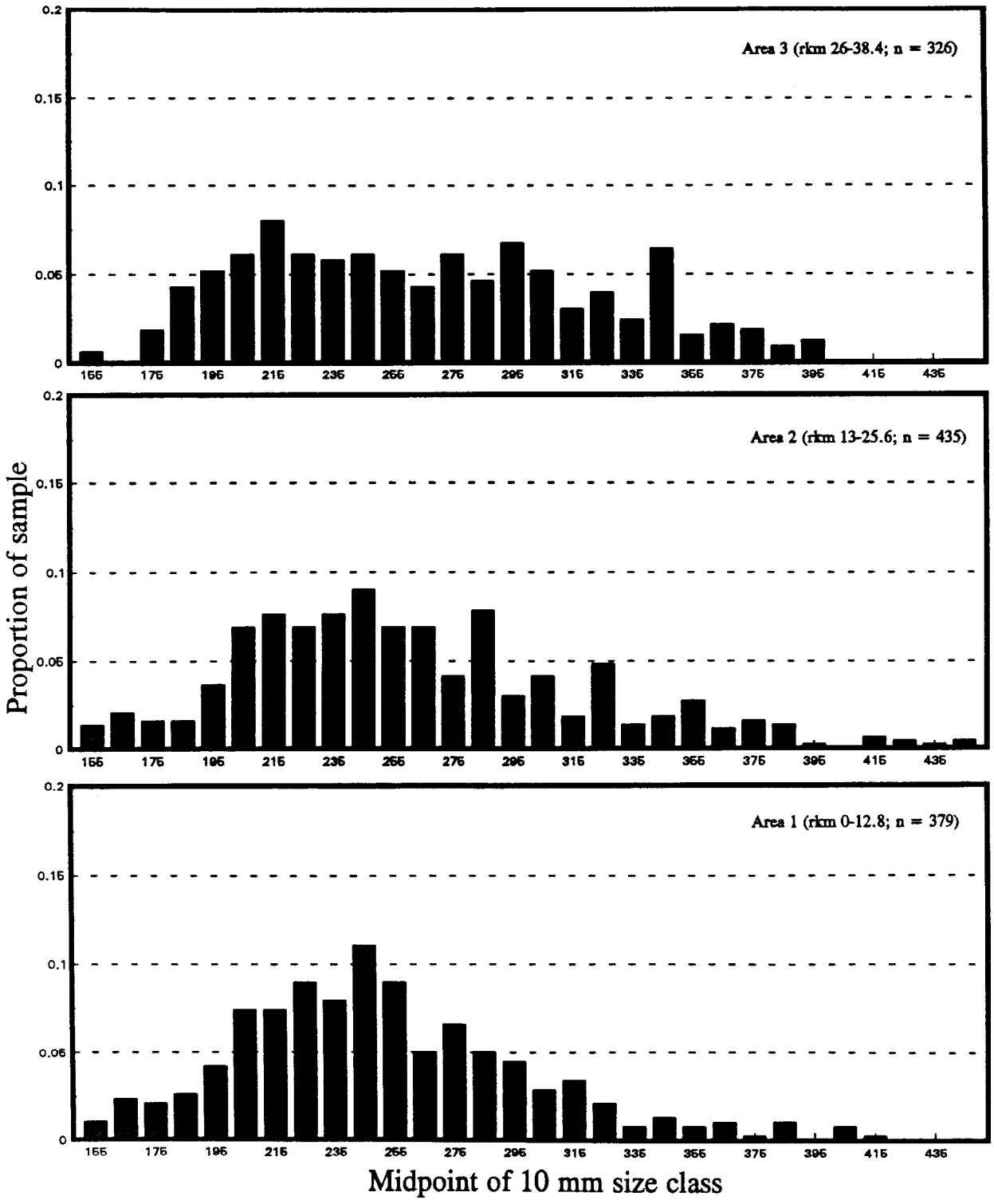


Appendix D11. Size composition (mm fork length) of Arctic grayling examined for marks in six areas of the Chena River and two areas of the East Fork of the Chena River during 1992.

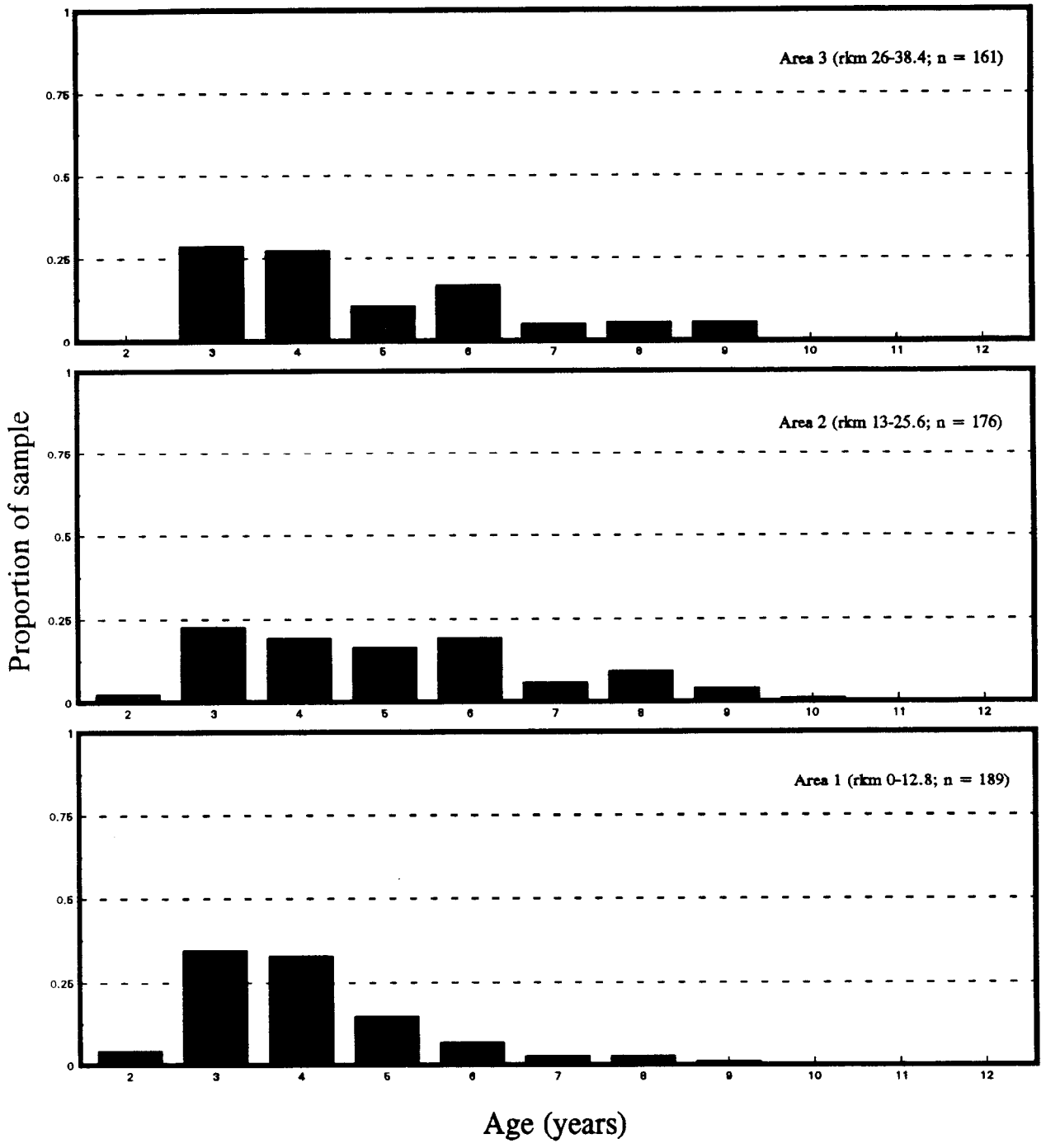


Appendix D12. Age composition (years) of Arctic grayling examined for marks in six areas of the Chena River and two areas of the East Fork of the Chena River during 1992.

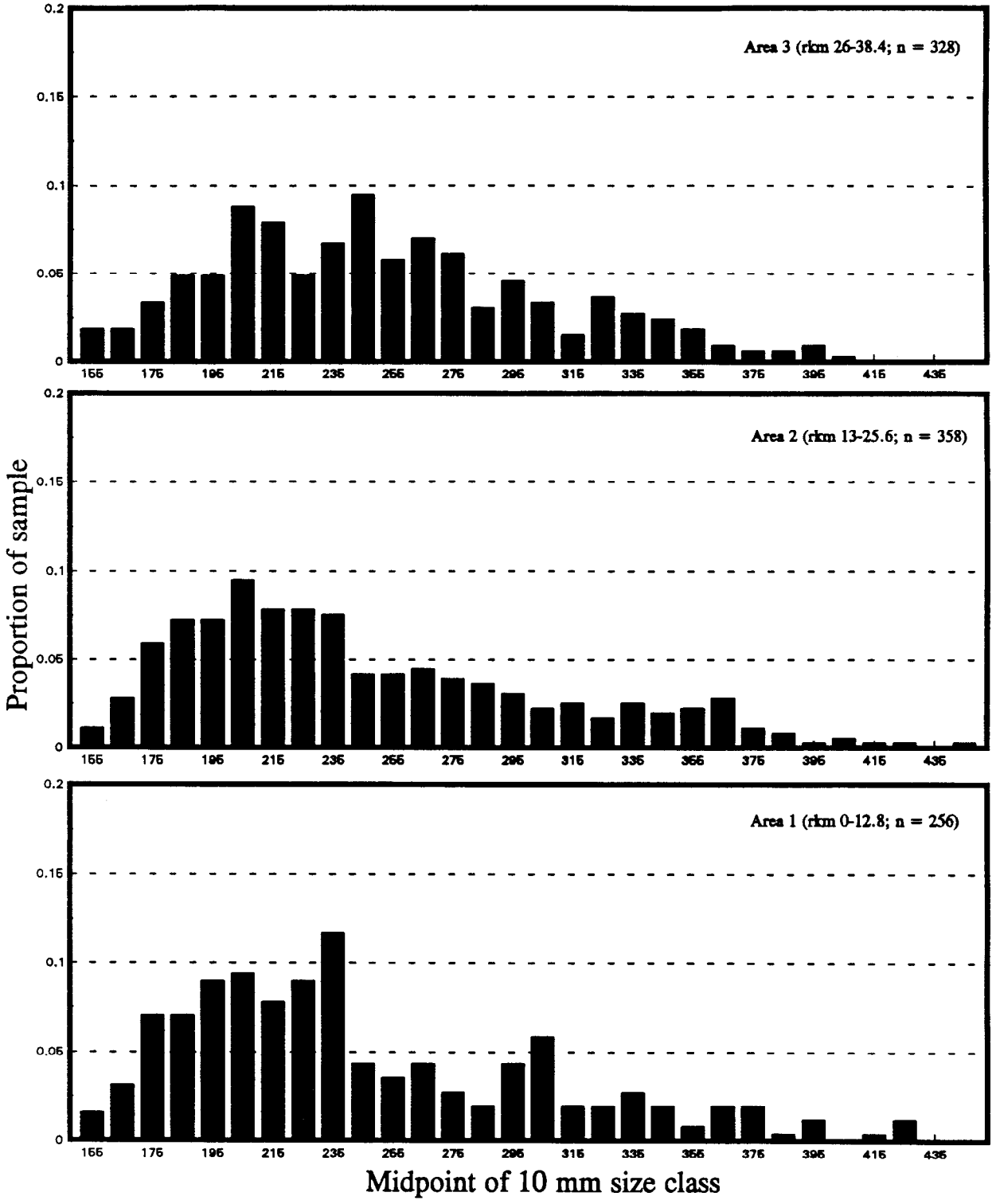
APPENDIX E
Age and Size Composition - Salcha River



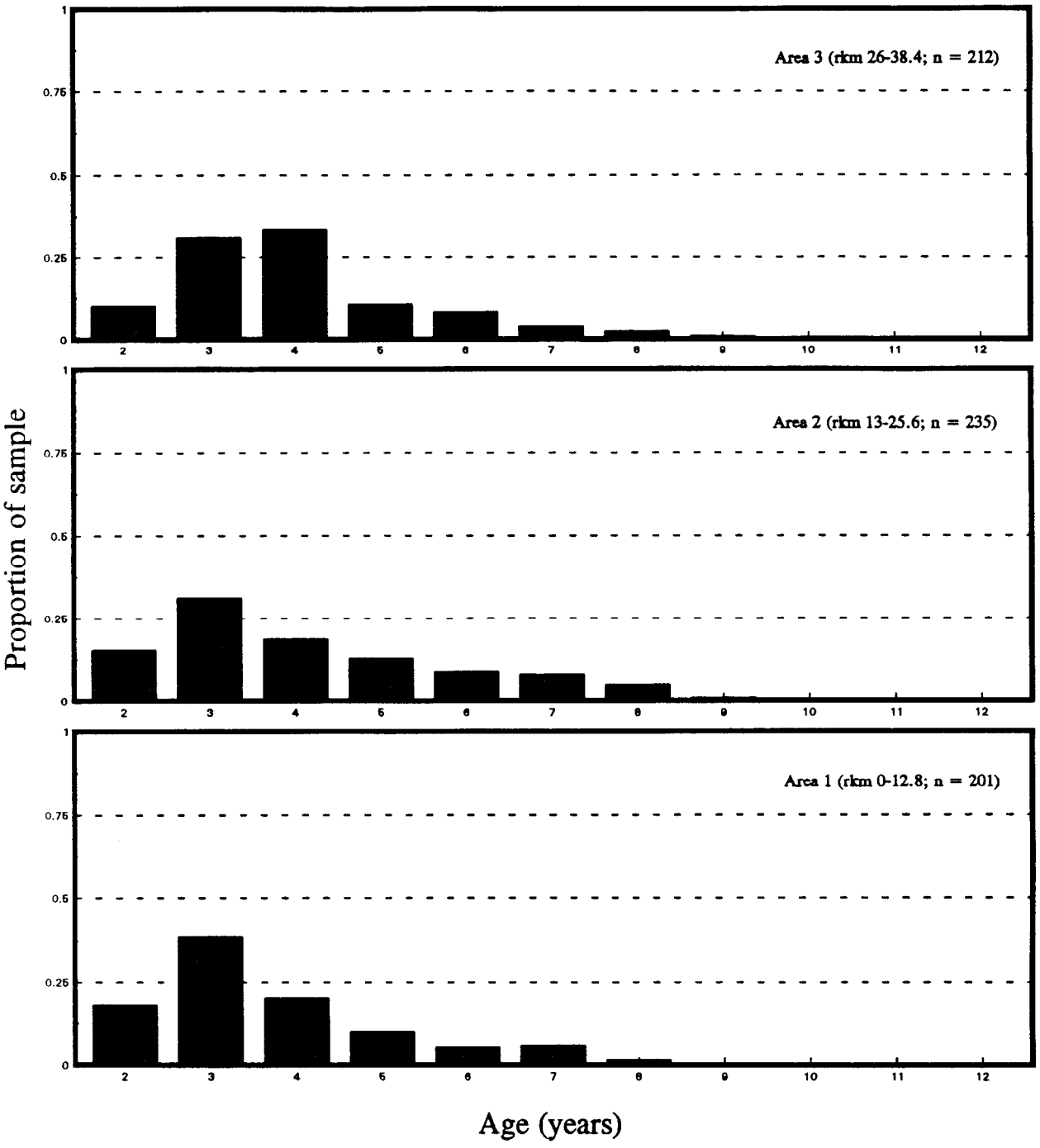
Appendix E1. Size composition (mm fork length) of Arctic grayling marked and released in three areas of the Salcha River during 1989.



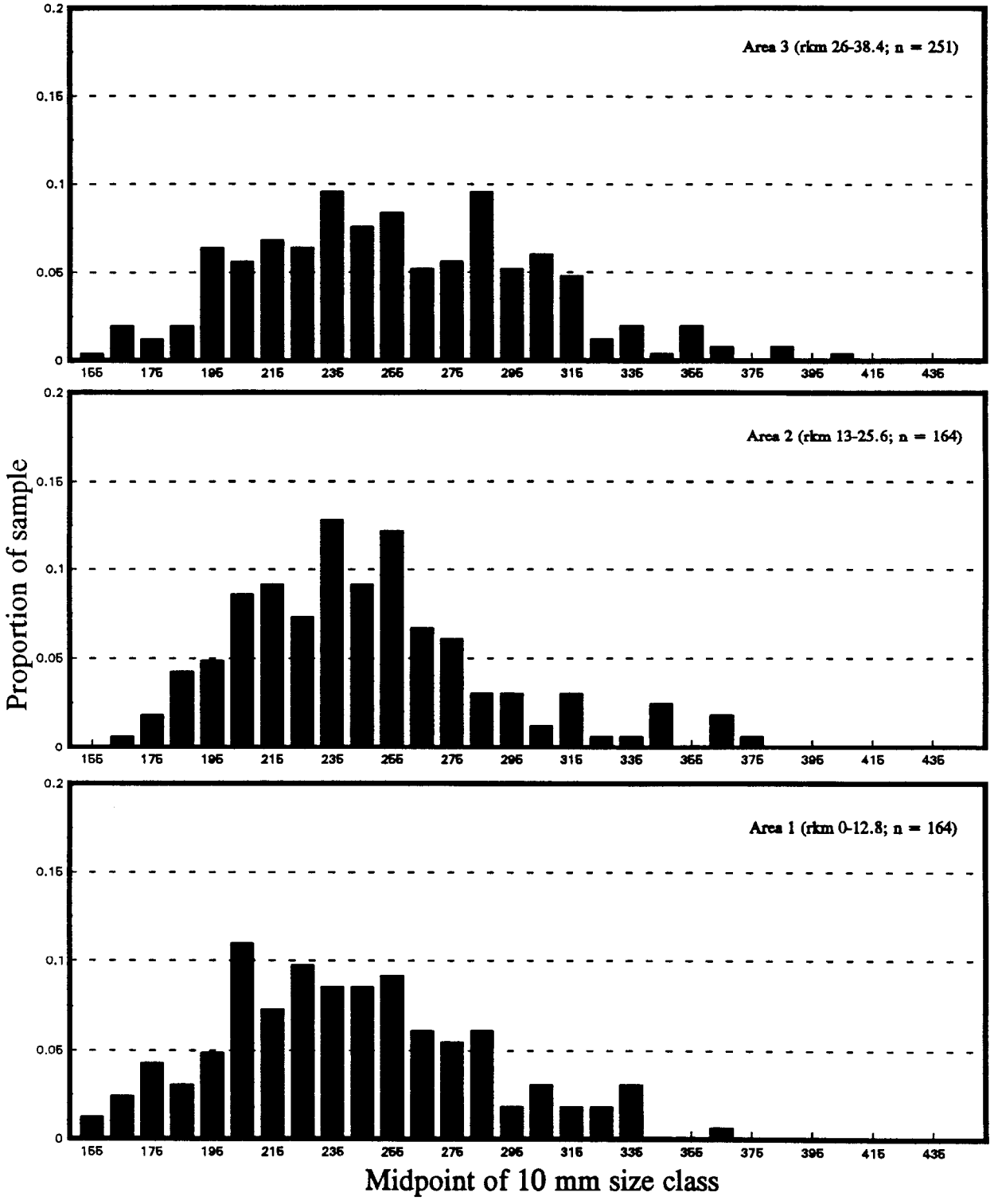
Appendix E2. Age composition (years) of Arctic grayling marked and released in three areas of the Salcha River during 1989.



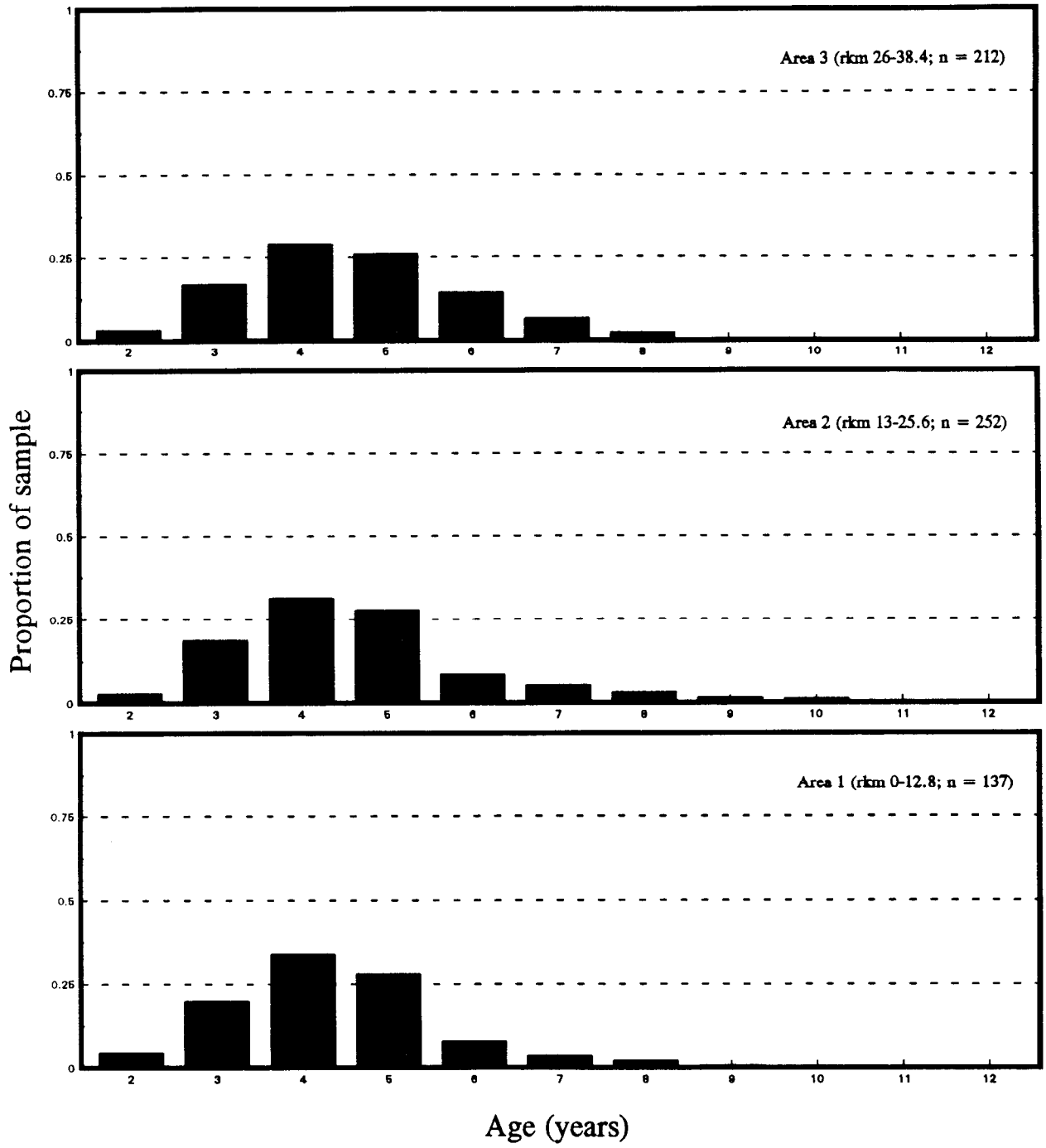
Appendix E3. Size composition (mm fork length) of Arctic grayling marked and released in three areas of the Salcha River during 1990.



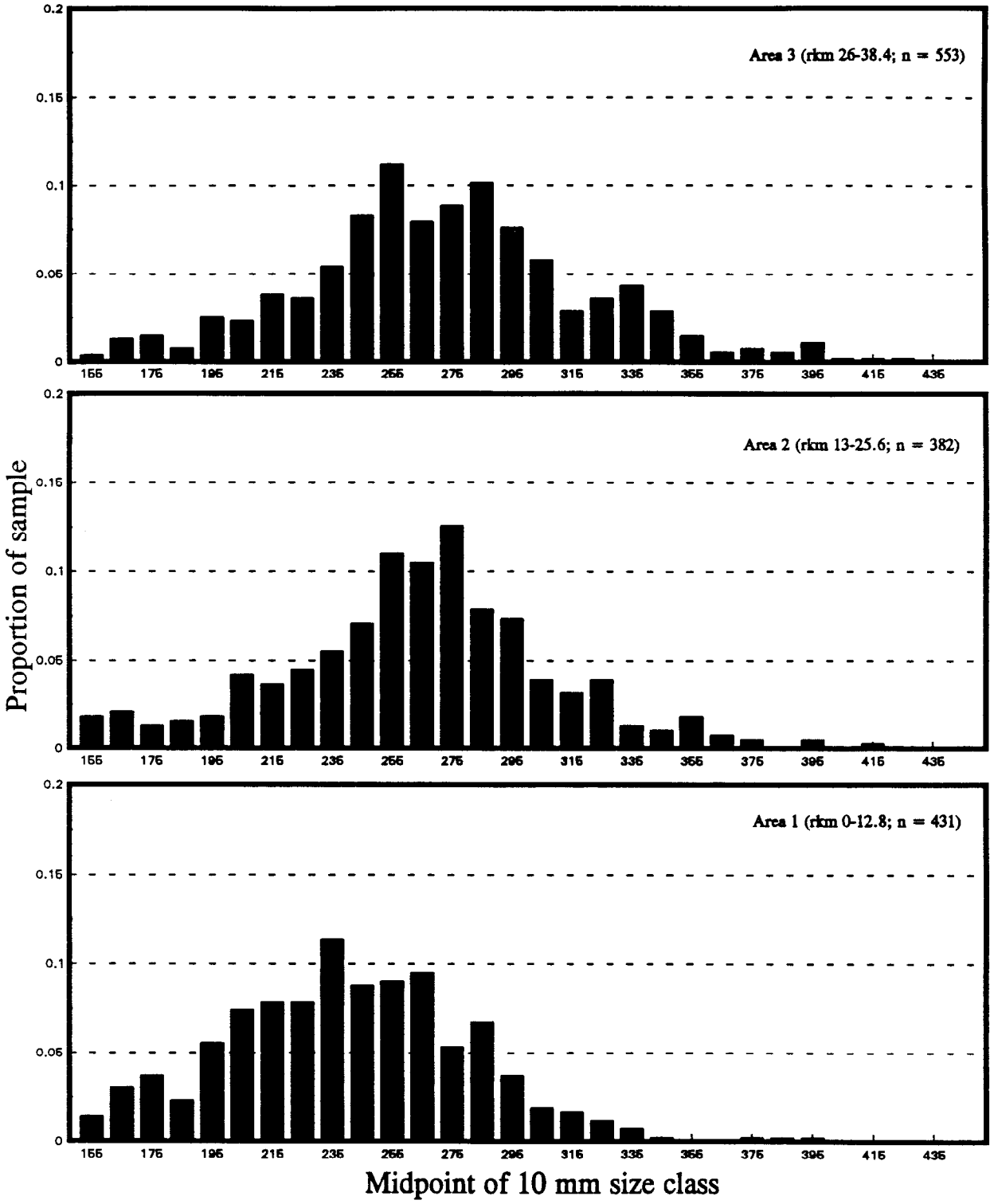
Appendix E4. Age composition (years) of Arctic grayling marked and released in three areas of the Salcha River during 1990.



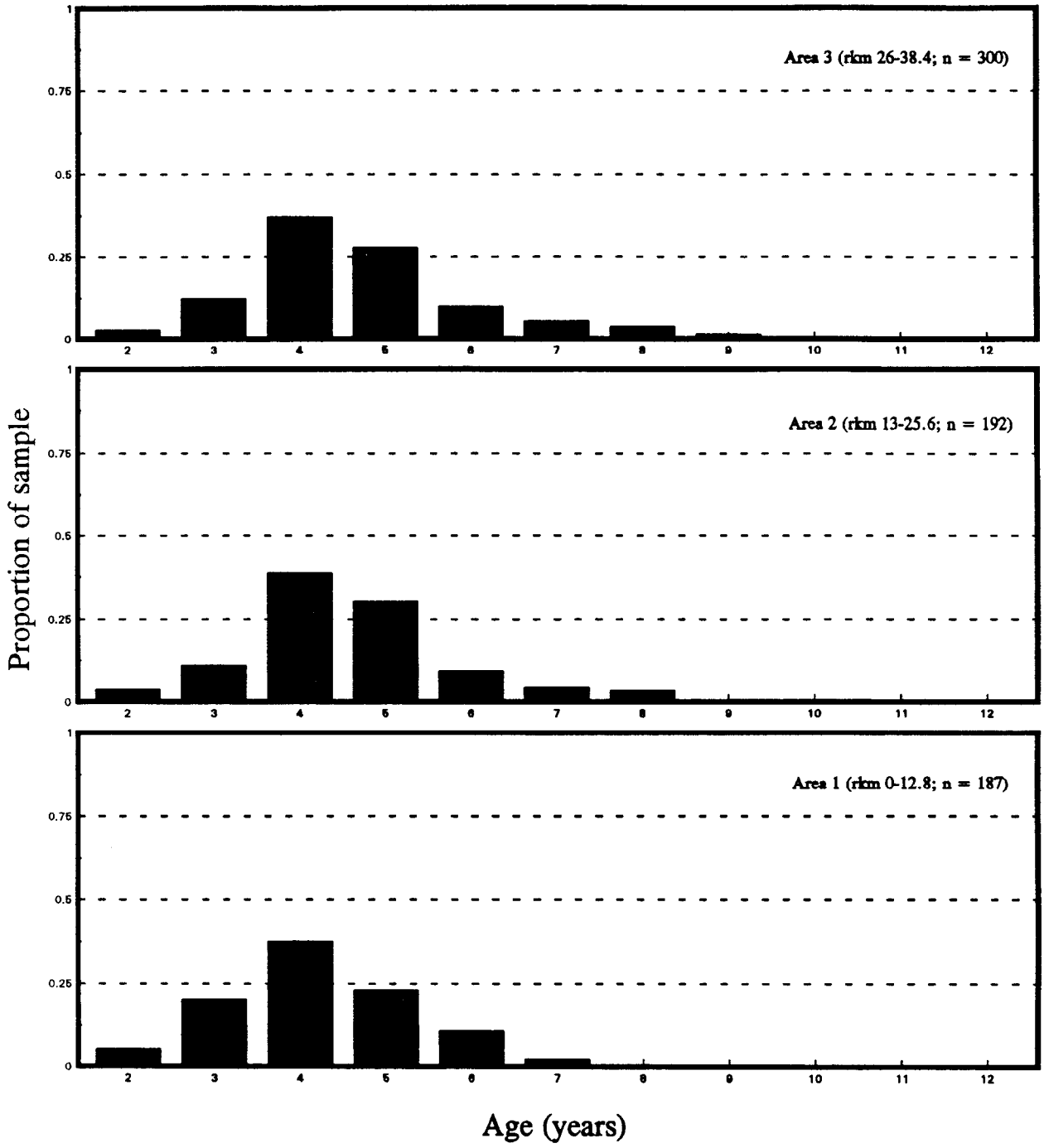
Appendix E5. Size composition (mm fork length) of Arctic grayling marked and released in three areas of the Salcha River during 1991.



Appendix E6. Age composition (years) of Arctic grayling marked and released in three areas of the Salcha River during 1991.

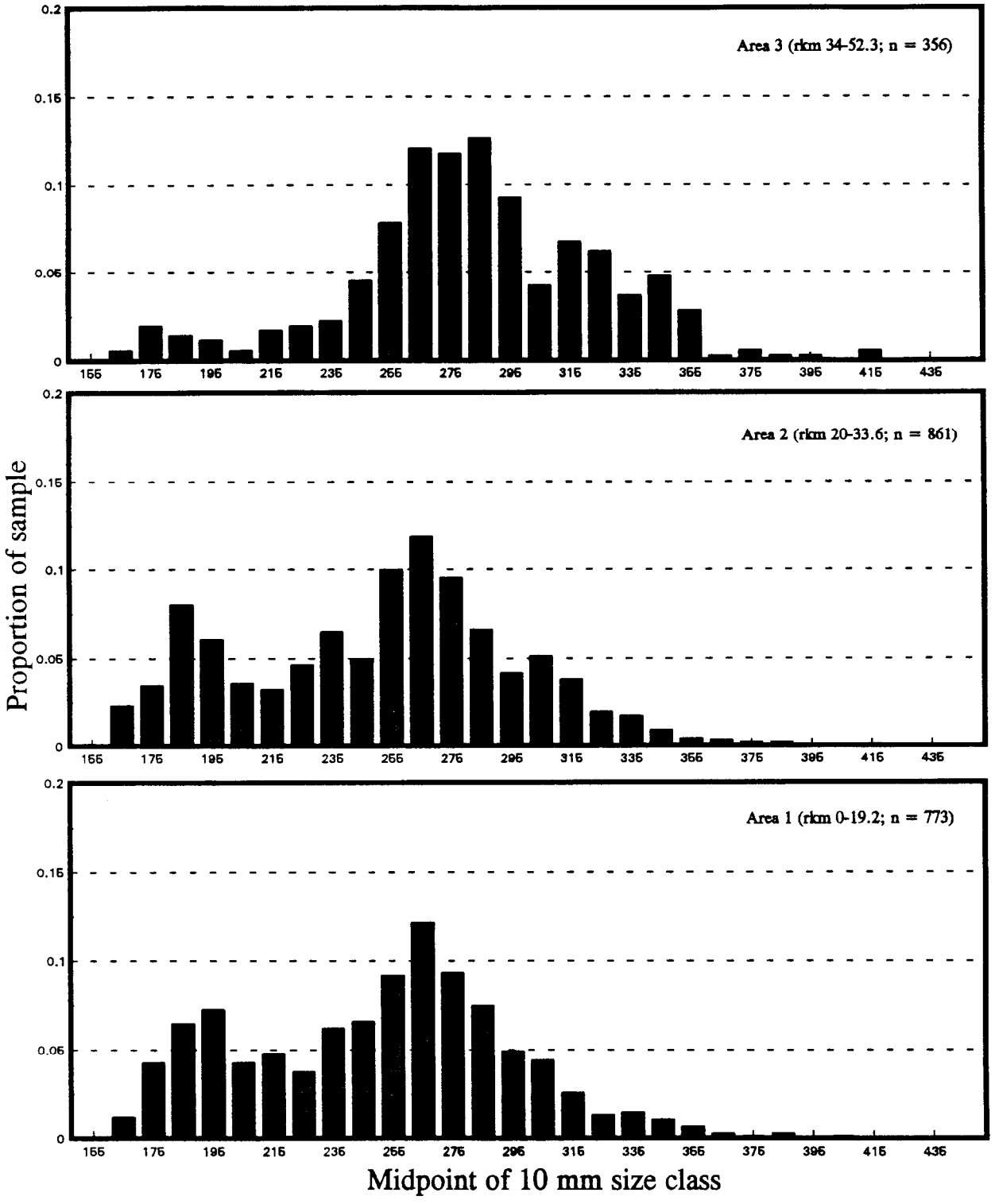


Appendix E7. Size composition (mm fork length) of Arctic grayling examined for marks in three areas of the Salcha River during 1992.

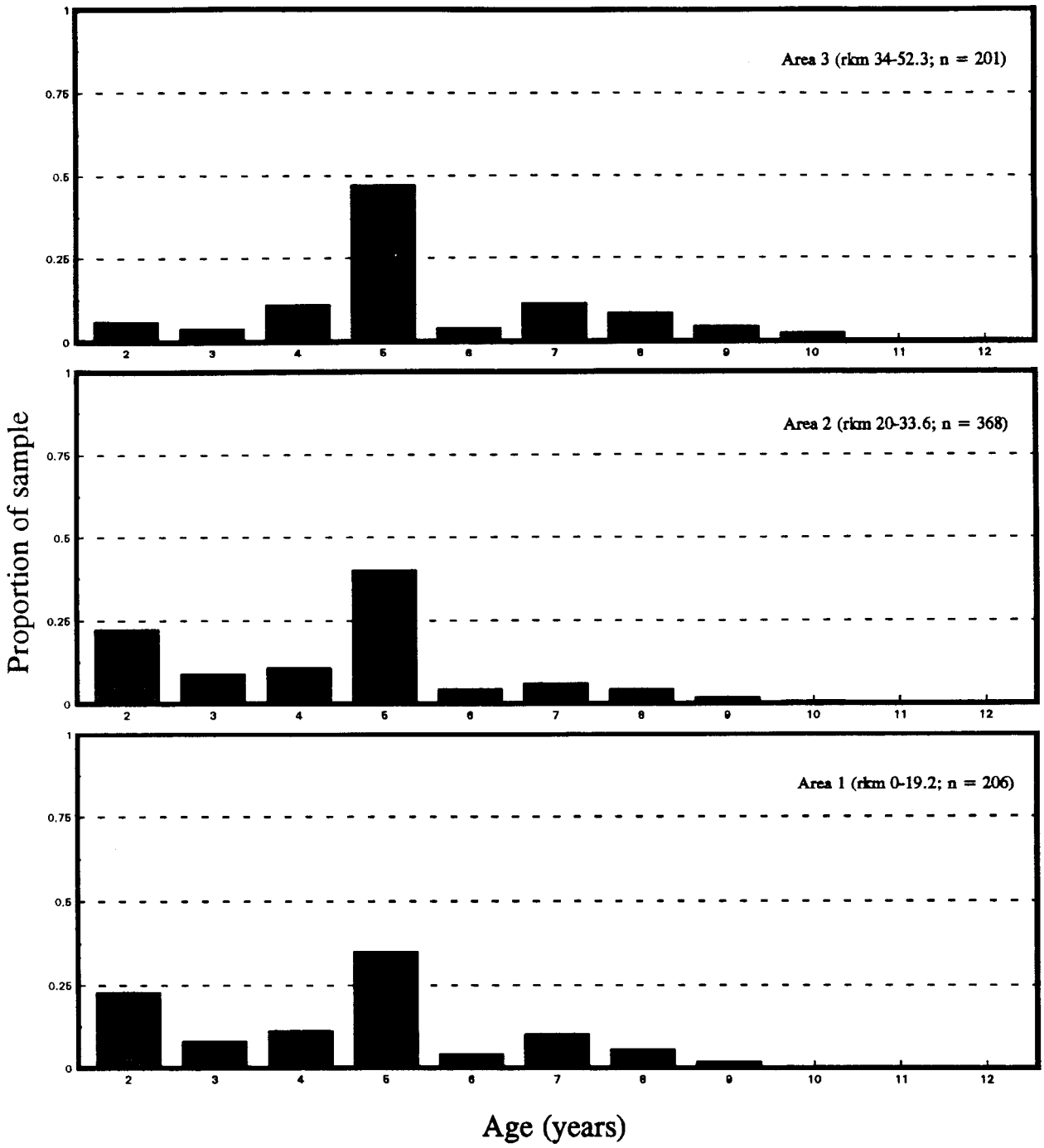


Appendix E8. Age composition (years) of Arctic grayling examined for marks in three areas of the Salcha River during 1992.

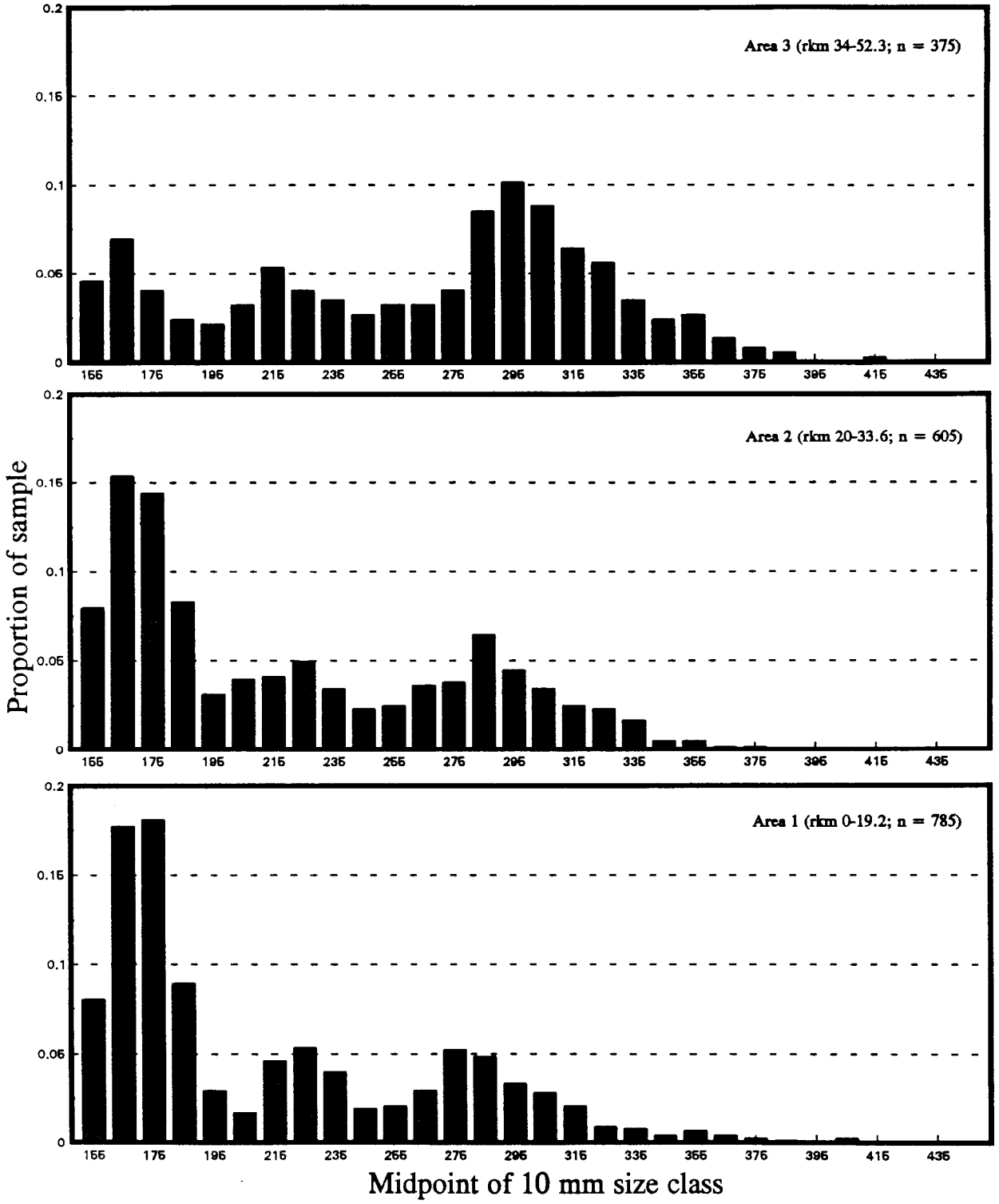
APPENDIX F
Age and Size Composition - Goodpaster River



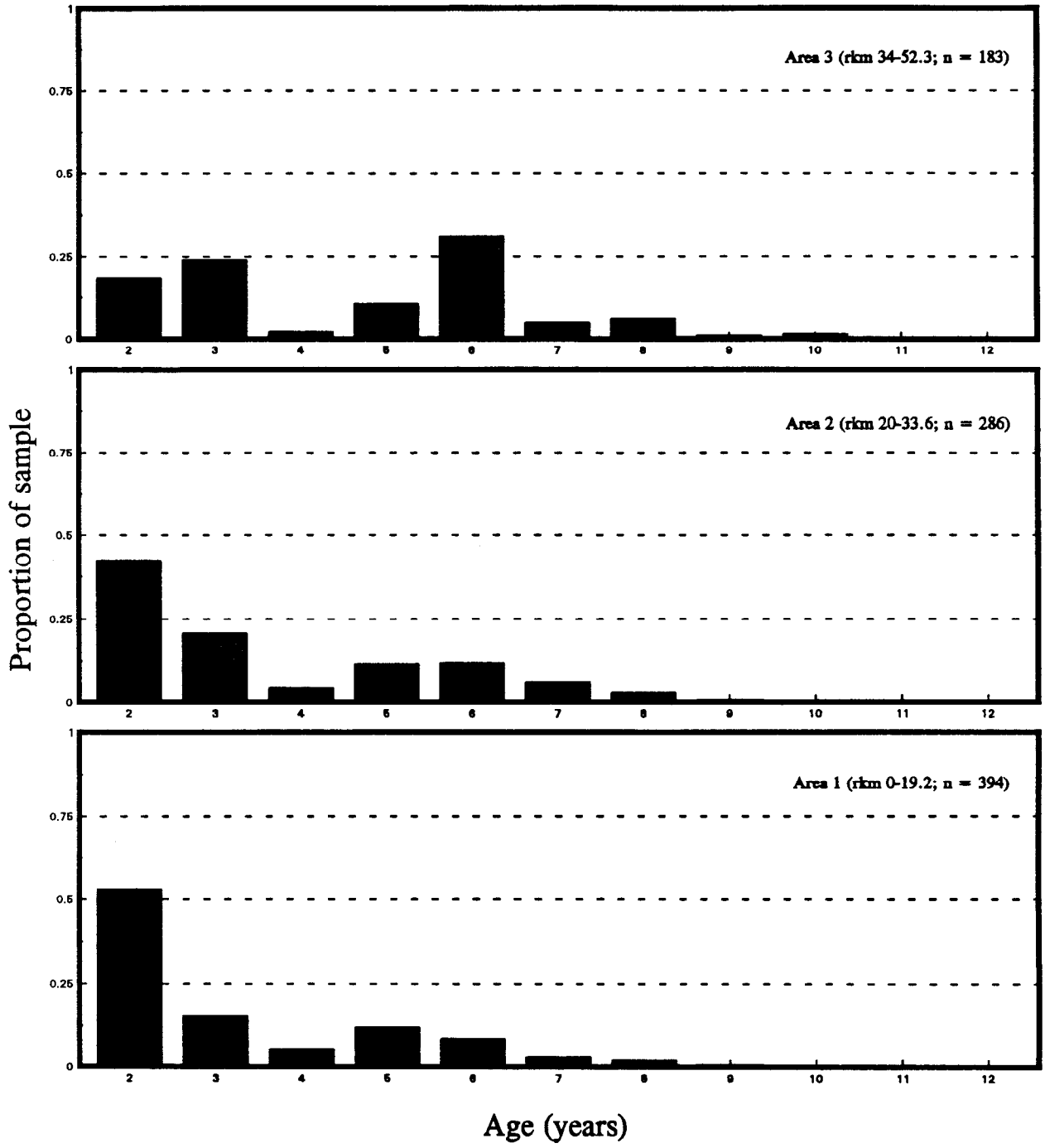
Appendix F1. Size composition (mm fork length) of Arctic grayling marked and released in three areas of the Goodpaster River during 1988.



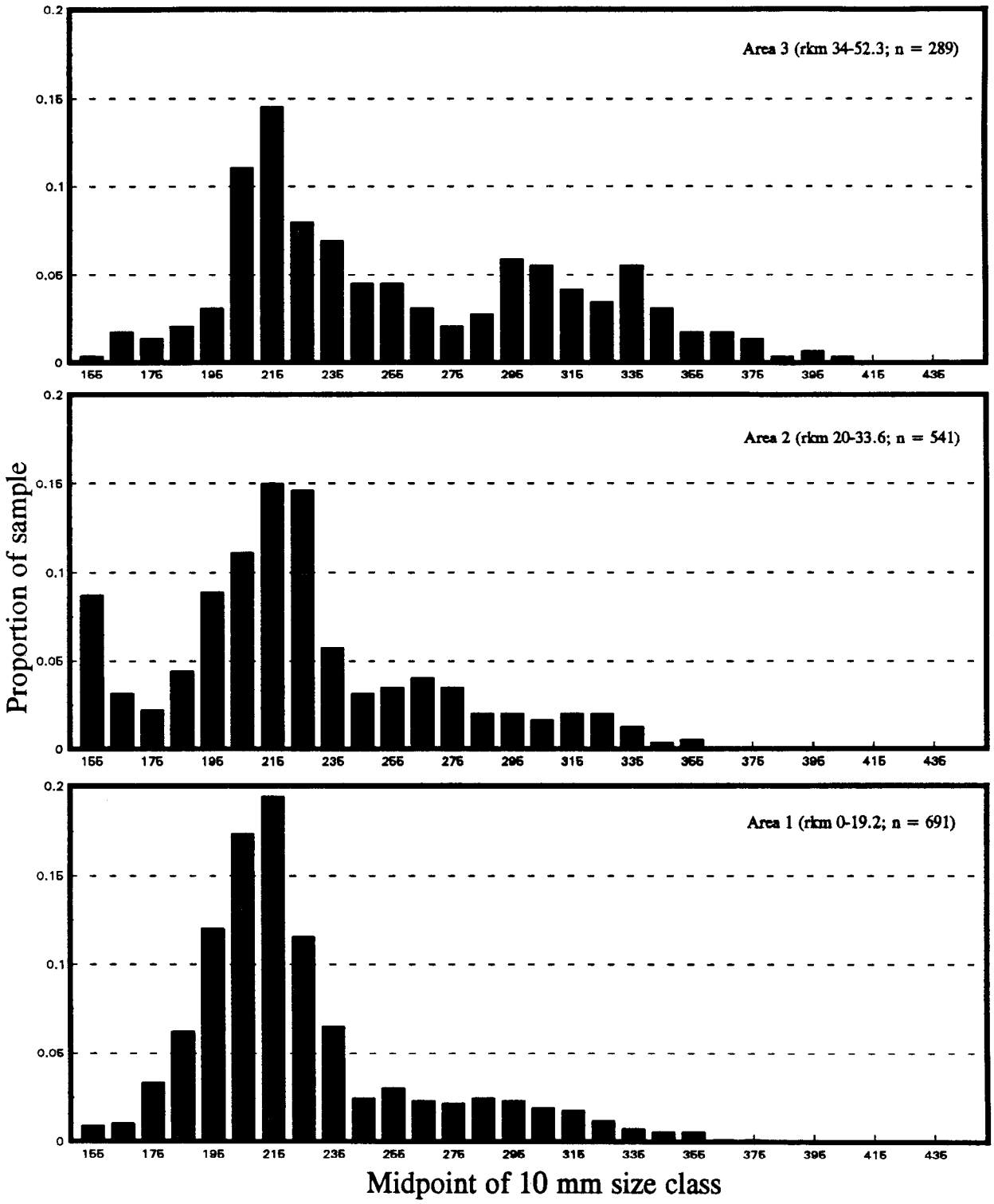
Appendix F2. Age composition (years) of Arctic grayling marked and released in three areas of the Goodpaster River during 1988.



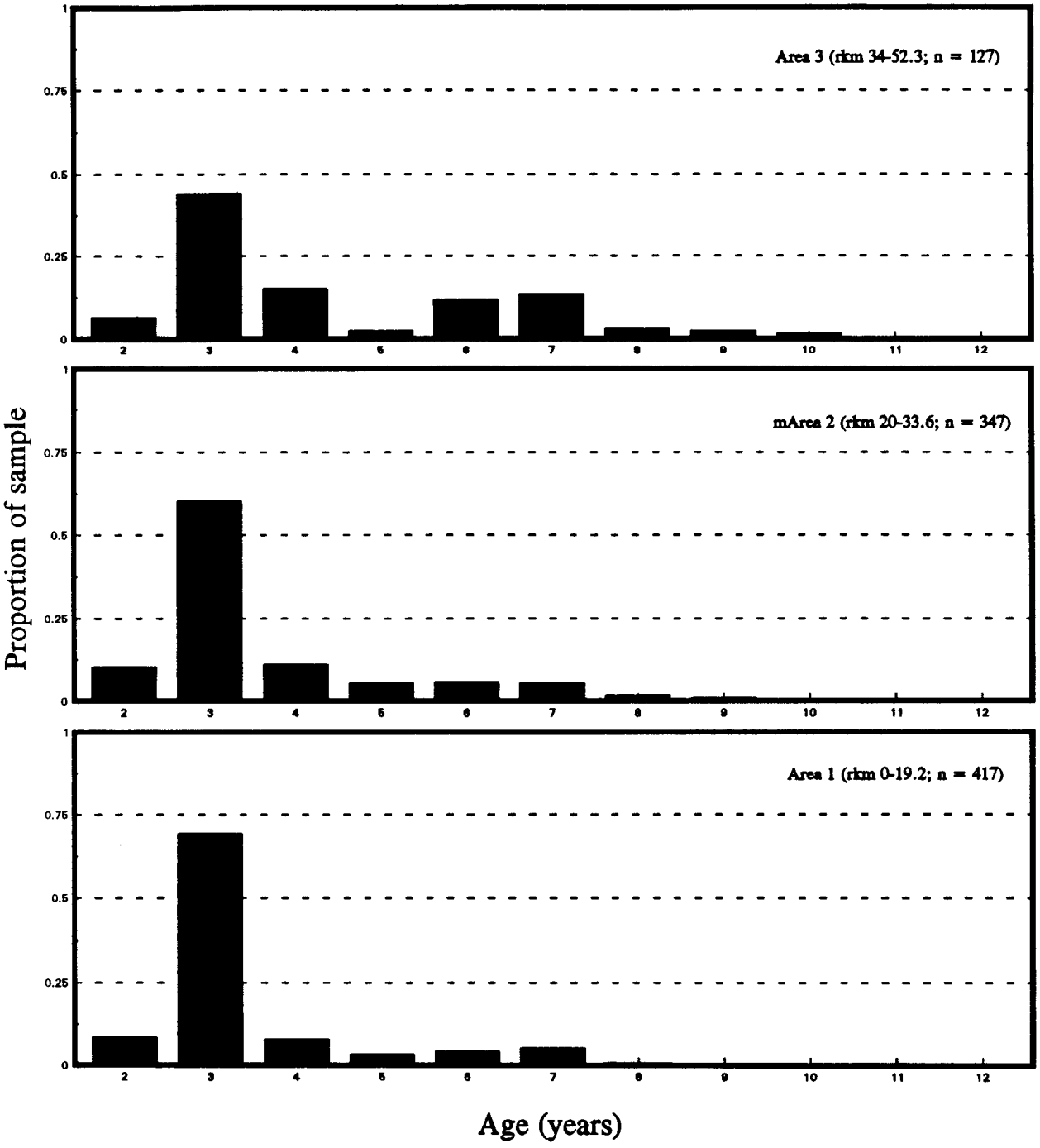
Appendix F3. Size composition (mm fork length) of Arctic grayling marked and released in three areas of the Goodpaster River during 1989.



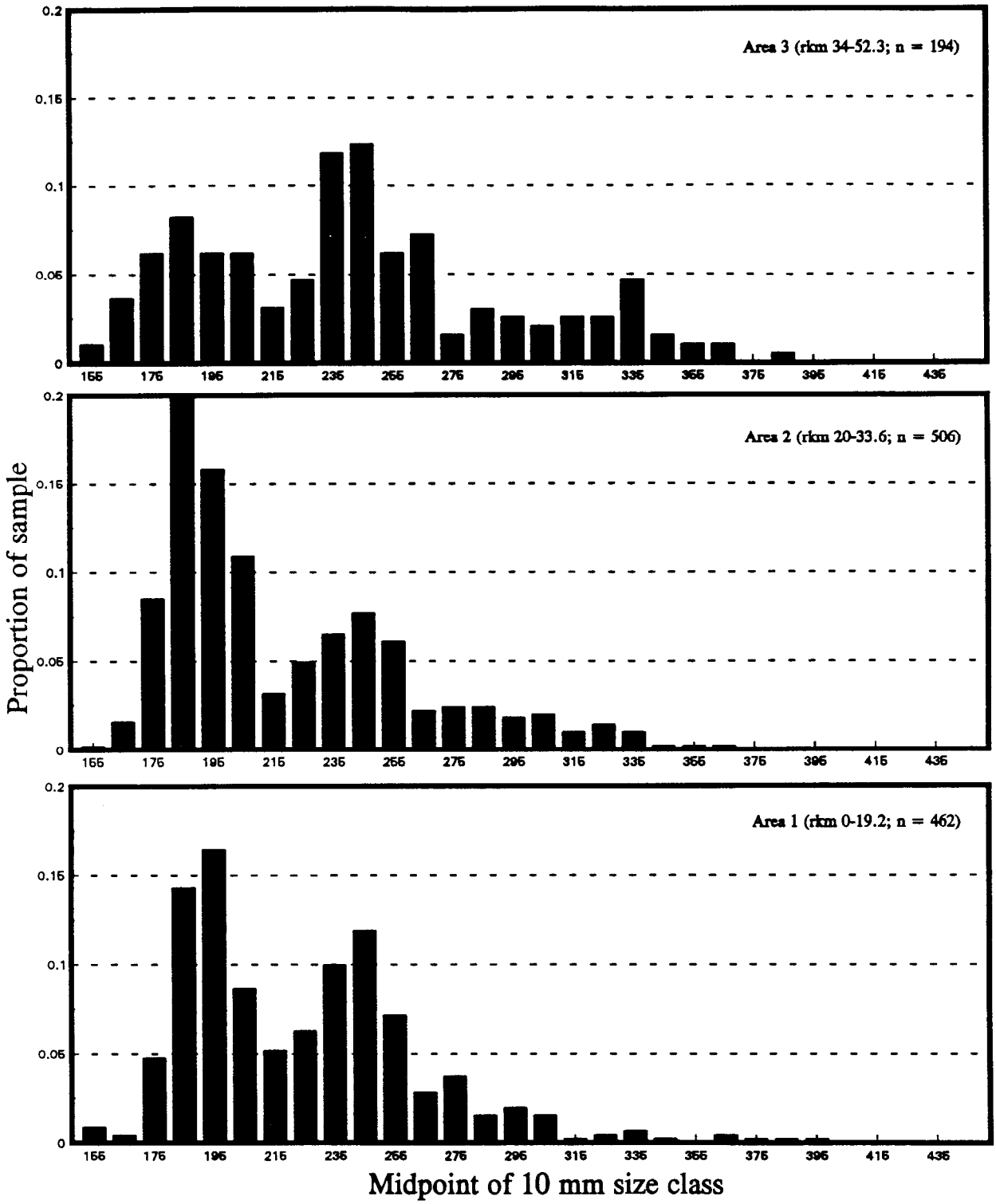
Appendix F4. Age composition (years) of Arctic grayling marked and released in three areas of the Goodpaster River during 1989.



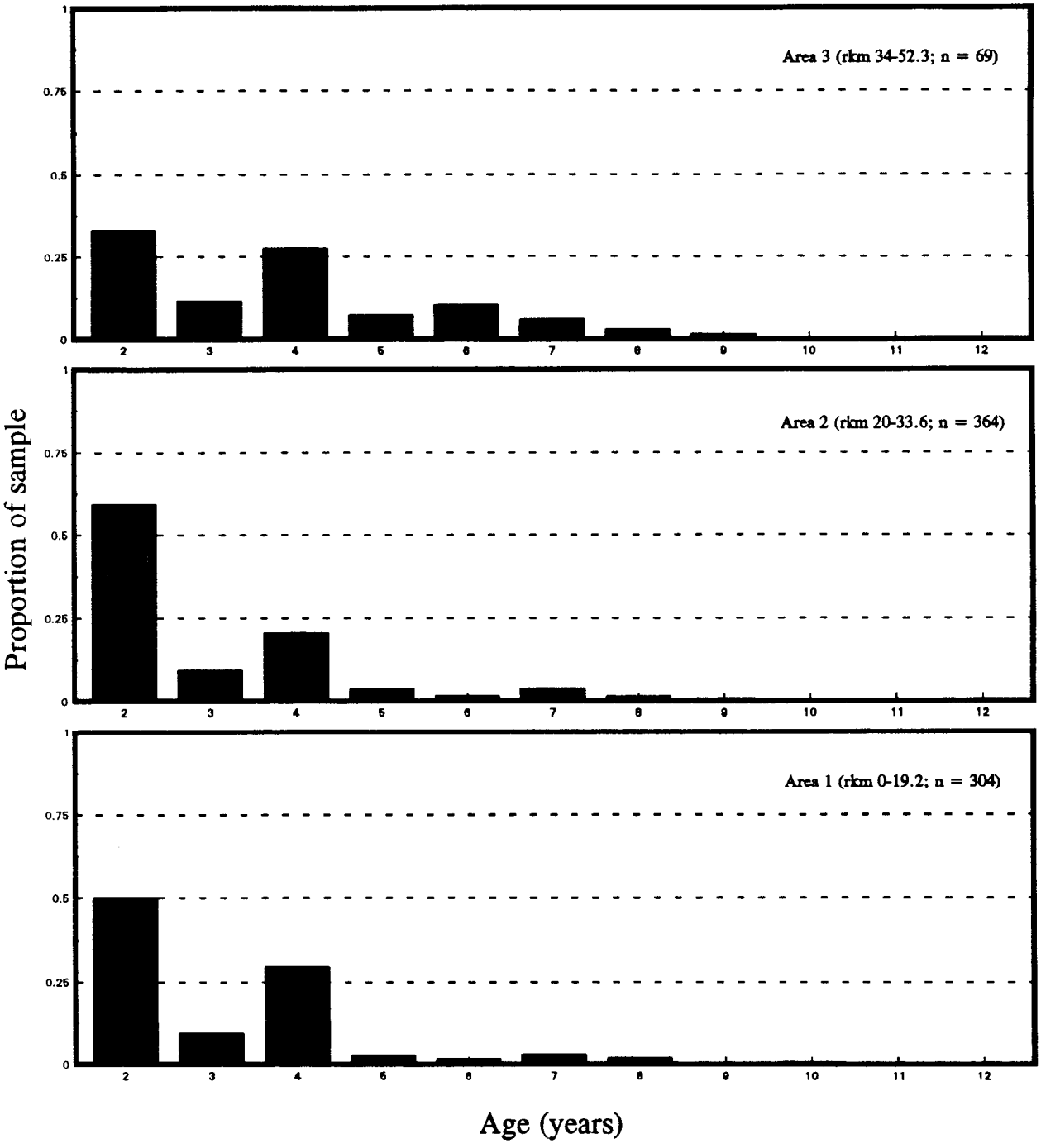
Appendix F5. Size composition (mm fork length) of Arctic grayling marked and released in three areas of the Goodpaster River during 1990.



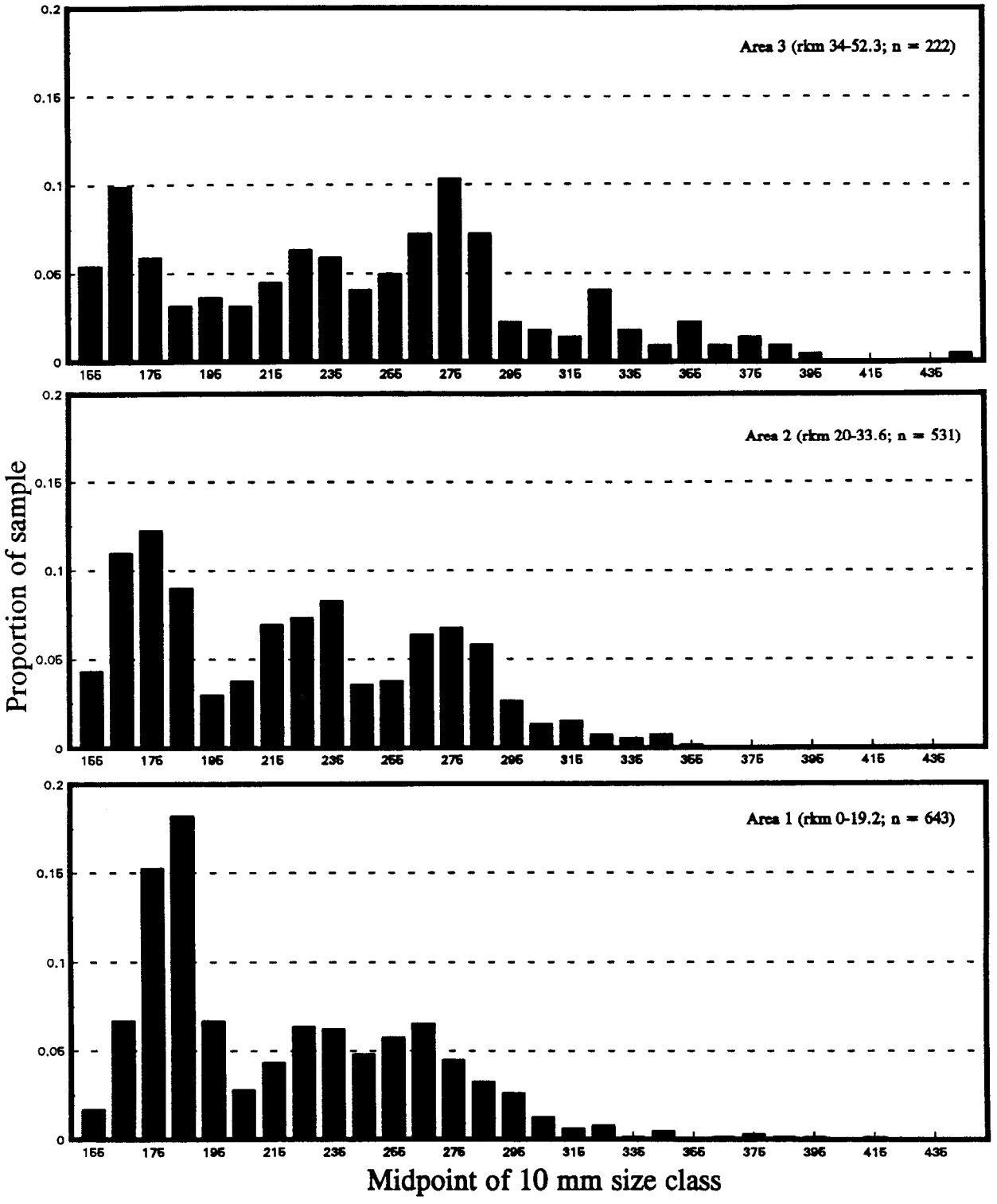
Appendix F6. Age composition (years) of Arctic grayling marked and released in three areas of the Goodpaster River during 1990.



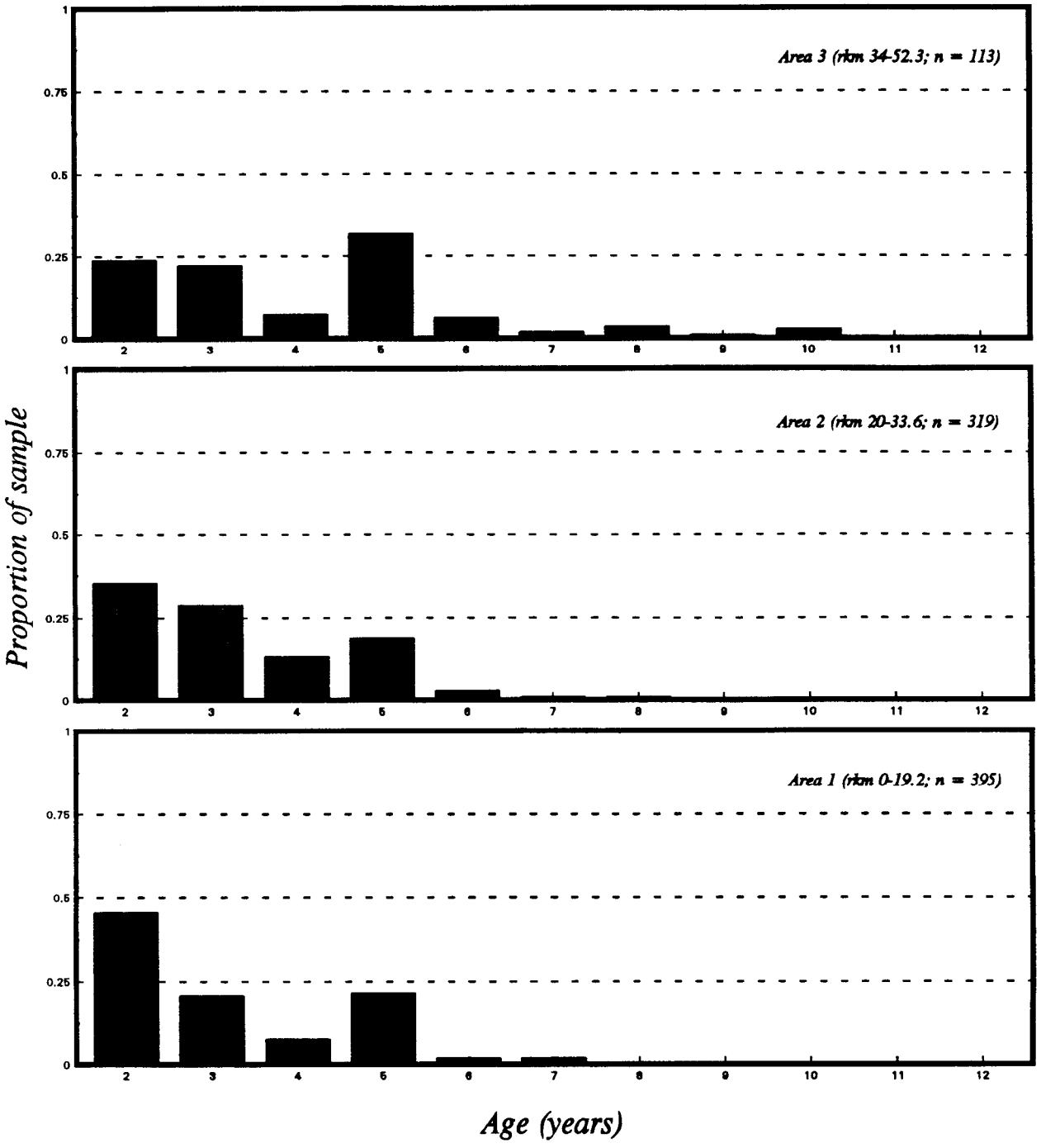
Appendix F7. Size composition (mm fork length) of Arctic grayling marked and released in three areas of the Goodpaster River during 1991.



Appendix F8. Age composition (years) of Arctic grayling marked and released in three areas of the Goodpaster River during 1991.



Appendix F9. Size composition (mm fork length) of Arctic grayling examined for marks in three areas of the Goodpaster River during 1992.



Appendix F10. Age composition (years) of Arctic grayling examined for marks in three areas of the Goodpaster River during 1992.