Dynamics of a Super-Population of Dolly Varden in the Chiniak Bay System, Kodiak Island, Alaska

A

Thesis

for the Degree of

Master of Science

By

Mary E. Whalen, B.S., A.A.

Fairbanks, Alaska

May 1993

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Presented to the Faculty
of the University of Alaska Fairbanks
in Partial Fulfillment of the Requirements
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31 March 1993

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ABSTRACT

A weir was operated at Buskin Lake, Kodiak Island, Alaska in the spring of 1990, 1991 and 1992 to study the stock structure of a super-population of Dolly Varden (*Salvelinus malma*) in Chiniak Bay. In 1991, Jolly-Seber estimates of abundance (60,585) and survival (29.3%) were higher than the weir estimates of 30,725 and 6.3%. Growth parameter estimates were 0.23 for the Brody coefficient and 522 mm as the largest fish in the population. Age 4-7 fish dominated the spring emigration from Buskin Lake. Dolly Varden found in the fall at the American and Olds rivers and Buskin Lake constitute the main spawning stocks for the Chiniak Bay super-population at 3,375, 2,669 and 3,711 fish respectively in 1991. A dynamic pool model used in conjunction with Relative Stock Density was effective in detecting increases in length-specific exploitation of larger fish, but not for detecting increasing fishing mortality in the mature stock.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

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INTRODUCTION

Chiniak Bay is located at the northeast corner of Kodiak Island (Figure 1). The Kodiak road system follows the entire coastline of Chiniak Bay. The city of Kodiak and the United States Coast Guard Base, with a combined population of approximately 15,000, also lie on the shores of the bay.

Dolly Varden char *Salvelinus malma* in the Chiniak Bay system have a complex life history. These fish form a "super-population" because mixed stocks (different reproductive units) overwinter in Buskin Lake (101 ha), approximately 8 km from the city of Kodiak. The super-population of Dolly Varden emigrate from Buskin Lake in the spring to feed in marine waters during the summer (Sonnichsen 1990). Some enter other streams in the Chiniak Bay area to spawn in the fall before returning to the lake to overwinter. This is consistent with the model of the southeastern Alaska Dolly Varden stock structure developed by Armstrong (1965) and Armstrong and Morrow (1980). Historically, the Buskin River was not thought a significant spawning stream, with as few as 500 Dolly Varden observed spawning in all Buskin tributaries (Marriott 1965).

The Buskin River is the most intensively sport-fished river on Kodiak Island. In 1990, approximately 42% of the freshwater sport fishing effort on Kodiak Island occurred on the Buskin River (Mills 1991). Dolly Varden contribute to sport fisheries throughout the Chiniak Bay area. Depletion of the Dolly Varden population in the Buskin River could result in a reduction in the abundance of spawning stocks in other Chiniak Bay tributaries. Also, reduction of Dolly Varden in the spawning streams could affect abundance of the super-population.

The Alaska Department of Fish and Game (ADF&G) initiated a long-term study in 1985 on the Buskin River, and in 1988 on the American and Olds

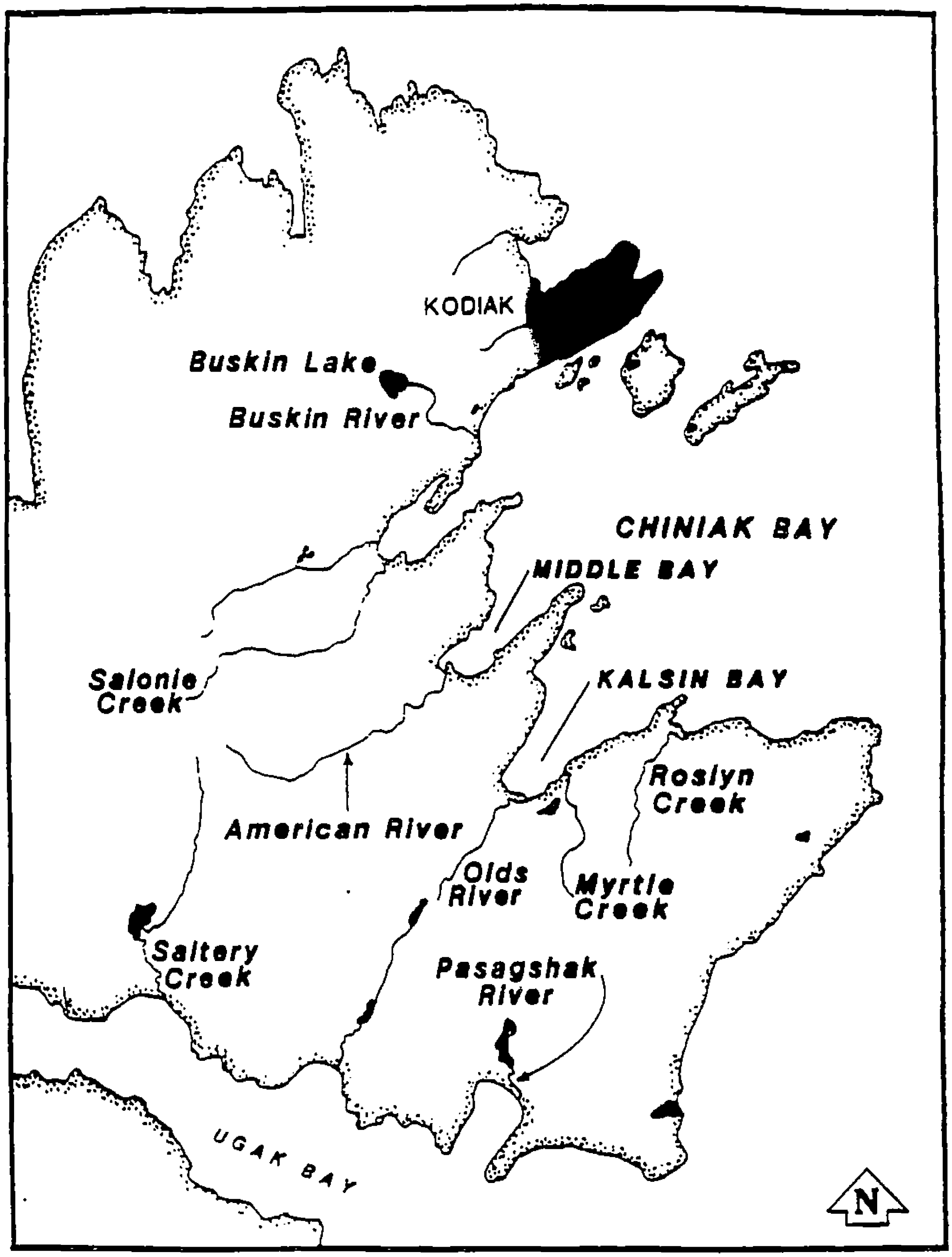

Figure 1. The Chiniak Bay area, Kodiak Island, Alaska.

rivers to develop a model of stock structure of Dolly Varden in the Chiniak Bay area. Prior to 1990, a weir was operated on the Buskin River approximately 1.4 km upstream from tidewater to assess the Dolly Varden emigration and immigration (Murray 1987 - 1989; Sonnichsen 1990). This weir did not effectively stop fish less than 350 mm long and therefore did not adequately sample the population of Dolly Varden in the Buskin River. In 1990, the weir was moved to the outlet of Buskin Lake and a 1-inch plastic mesh was placed over the weir (Figure 2). This enabled ADF&G to more effectively survey the spring emigration of Dolly Varden from Buskin Lake.

The goal of this study was to use the weir at the lake, and fall spawning ground surveys on the American and Olds rivers, and Buskin Lake, to estimate parameters of the super-population: survival, growth, and abundance. Fishing mortality was estimated from ADF&G Statewide Harvest Surveys (Mills 1979-1992) in conjunction with a roving creel survey performed on the 1990 Buskin River sport fishery during spring emigration. Because this super-population received extensive fishing effort, monitoring sport fishing mortality was a definable management objective. A dynamic pool model assisted in understanding the relationship between fishing mortality and the super-population parameters. The model could be a useful tool in managing the Dolly Varden resource in Chiniak Bay.

Specific objectives for this study were to:

1. census the emigration of Dolly Varden 210 mm or longer (fork length) through the weir at Buskin Lake from mid-April through mid-June;
2. estimate abundance and survival of emigrating Dolly Varden 210 mm and over in 1990 and 1991 using the Jolly-Seber method and data from 1990, 1991 and 1992;
3. estimate length composition of Dolly Varden during the entire spring emigration;
4. census the emigration of Dolly Varden through the weir on the

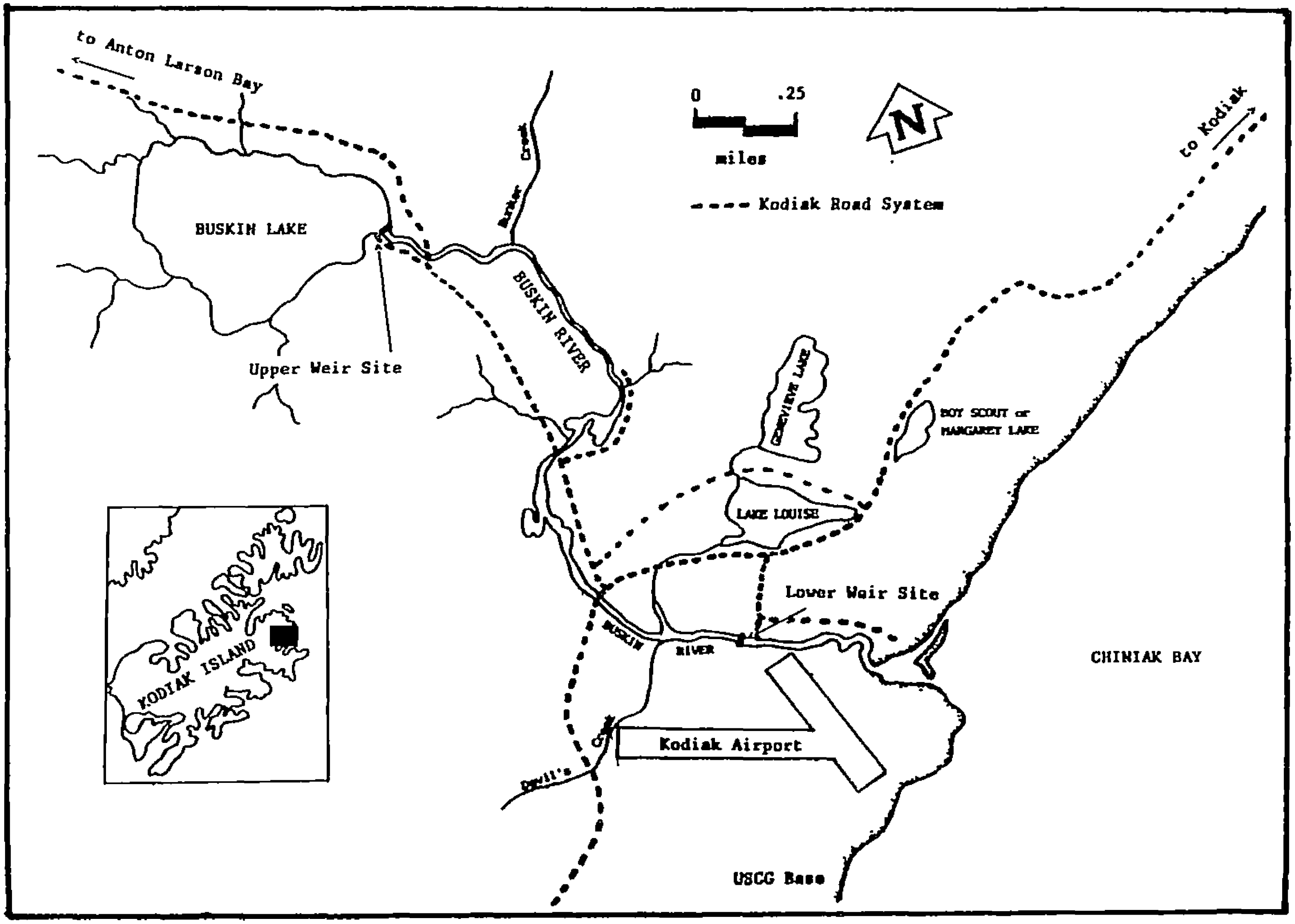

Figure 2. Buskin River, Kodiak Island, Alaska.

stream leaving Lake Louise and entering the Buskin River from mid-April through mid-June;

5. estimate length compositions of Dolly Varden during the emigration from Lake Louise;
6. estimate age composition of an emigration sample taken during the 1992 Buskin Lake weir operation;
7. develop a growth model from mark-recapture data;
8. estimate survival from recaptures at the Buskin River weir;
9. estimate relative maturity of samples taken during the immigration in 1990 and 1991;
10. estimate age composition using the maturity samples taken during the immigration in 1990 and 1991;
11. estimate abundance of spawning Dolly Varden in the American and Olds rivers and Buskin Lake during October 1990 and 1991 using the Petersen estimation method; and
12. estimate survival at the spawning areas using recaptures from the October surveys.

METHODS

Spring Emigration

Weir Operations:

The Buskin River Dolly Varden emigration was assessed with an aluminum picket weir overlaid with 2.5 cm (1 inch) Vexar© plastic mesh. A trap was incorporated into the weir to capture Dolly Varden. The weir was installed at the outlet of Buskin Lake in mid-April and was operated until mid-June. Although the emigration may begin before mid-April, I believe the initial portion of the emigration was not missed in 1991 and 1992 because the weir was installed as close to ice breakup as possible. In 1990 sport anglers reported catching Dolly Varden in the Buskin River before the weir was installed on 23 April. The number of fish missed was probably low because few fish were leaving the lake at the beginning of weir operation. On 5 June 1990, the Vexar was mistakenly removed from the weir before the emigration was complete, therefore the 1990 total weir count is a minimum number because the weir did not stop small fish in the last two weeks of operation. There were two instances of missed counts during the 1991 spring weir operation. On 6 May, water levels rose above the pickets of the weir over a 3 m (10 ft.) section for approximately 9 hours. An estimated count for this time period was made by multiplying an observed rate of 25 fish passing over the top of the weir during 0.5 hour by 18 to account for the 9 hours. The second instance was on June 3 when the weir was vandalized during the early morning hours. The back gate of the trap was removed and fish were allowed to pass through the weir unobserved. An estimated count for this instance was made by averaging counts from the first trap of the morning for three days before and after that date.

Dolly Varden were counted and at least 100 per week were measured for fork length. A goal of at least 10% of the Dolly Varden passing through the weir were to be tagged with numbered green Floy FD 68D anchor tags. Another 20% of the Dolly Varden were to be examined for the presence of a tag. Due to high water during the emigration in 1990 and 1992, these goals were not met (Table 1). In 1991, all tagged Dolly Varden were also clipped (left ventral fin) for a tag loss study.

Water temperatures and levels were recorded daily at the weir. The water level indicator at the river's edge reflected only relative changes in water level, not actual levels. Water temperatures were taken inside the trap of the weir.

To determine if a significant population of Dolly Varden was residing in a connecting lake system to the Buskin River, a weir was installed on the stream that flows between Lake Louise and the Buskin River on 24 April 1991 and again on 25 April 1992. Lake Louise and Genevieve Lake are part of this separate lake system. The weir consisted of a wood frame structure overlaid with 2.5 cm (1 inch) Vexar plastic mesh. A trap was incorporated into the center of the weir to capture and retain Dolly Varden. At least 125 fish were measured for fork length each week. No tagging was performed at this site. All Dolly Varden measured were examined for the presence of a tag and any fin clips. On numerous occasions, this weir was vandalized. No estimates of counts lost due to the vandalism were made because of insufficient information about fish passing at the time. The Lake Louise weir was dismantled in mid-June of each year.

Length Composition:

During the emigration all Dolly Varden tagged were measured for fork length. Kolmogorov-Smirnov two-sample goodness of fit tests were used to test the null hypothesis that the length distributions did not differ between weeks in 1991 and 1992. Chi-square tests were used in 1990.

Anderson-Darling k-sample tests were used to determine significant differences between weekly length distributions at the Lake Louise weir.

Table 1. Total weir counts, number of Dolly Varden tagged and examined during the emigration on the Buskin River, 1990 - 92.

	Year		
	1990	1991	1992
Date Weir Installed	23 April	19 April	13 April
Date Vexar Removed[a]	5 June	17 June	19 June
Total Count	90,600	30,725	74,451
Number Tagged	7,492	4,500	7,202
Percent Tagged	8.27%	14.65%	9.67%
Number Examined	22,815	11,565	15,978
Percent Examined	25.18%	37.64%	21.46%

[a] Total weir counts represent a minimum number because small fish were not stopped by the weir after the Vexar was removed.

Age Composition:

A sample of at least 150 fish were sacrificed during each two week time period in 1992 to collect sagittal otoliths for age composition analysis. Otoliths were stored dry, then soaked in a 50% glycerine and 50% water solution for about 24 hours. The otolith was placed on a black background and viewed with reflected light through a binocular microscope (10X). Age was determined by counting the number of hyaline zones on the otolith. The age composition of each sample of Dolly Varden was estimated assuming a multinomial distribution by:

$$\hat{p}_h = \frac{n_h}{n_t}, \qquad [1]$$

and variance was estimated as (Cochran, 1977: 52):

$$V[\hat{p}_h] = \frac{\hat{p}_h(1 - \hat{p}_h)}{(n_t - 1)}, \qquad [2]$$

where:

p_h = proportion of Dolly Varden at age h,
n_h = number of otoliths of age h, and
n_t = total number of otoliths read.

Kolmogorov-Smirnov two-sample tests were used to determine significant differences between the lengths in the age sample and the length sample from the weir by three 2-week time periods. If the length distributions were the same between samples, the age composition could have been directly applied to weir length samples. Because the distributions differed in the second and third 2-week periods, the total age composition was weighted using the weir length compositions. This weighting procedure involved multiplying the value estimated in equation 1 (by each length category (10 mm groups) by age) with the actual number in each length category measured from the weir length sample. These values were summed across length category. Age composition frequencies were calculated as in equation 1 and then pooled by 2-week periods for the total weighted age composition.

Anderson-Darling k-sample tests were used to test the null hypothesis that length distributions did not differ between sexes of Dolly Varden.

Growth Model:

Non-linear least squares estimation procedures were done for all four cases of the Schnute size-age growth model (Schnute 1981, Baker et al. 1991) using mark-recapture data collected each spring from 1989 to 1992. I also added a fifth case representing the von Bertalanffy model:

$$Y_r = [Y_m^b \exp[-a(t_r - t_m)] + \frac{y_1^b - y_2^b \exp[-a(T_2 - T_1)]}{1 - \exp[-a(T_2 - T_1)]} \{1 - \exp[-a(t_r - t_m)]\}]^{1/a}, \quad [3]$$

where:

Y_r	=	size at recapture (input from data),
Y_m	=	size at marking (input from data),
$t_r - t_m$	=	time (in years) between recapture and marking (input, from data),
y_1	=	length of smallest fish found in mark-recapture sample (set at 198 mm),
y_2	=	length of largest fish in population (parameter to be estimated),
T_1	=	youngest age at marking (determined from random age-length sample from 1989 to 1992 emigration, set at four),
T_2	=	age at recapture (determined the same as T_1, set at 12),
a	=	Brody growth parameter, determining the shape of the growth curve (parameter to be estimated),
b	=	relative location of the inflection point (in this case, set at one).

The most parsimonious model for each year was chosen using a general linear model F-test (Baker et al. 1991):

$$F = \frac{RSS_y - RSS_x}{df_y - df_x} / \hat{\sigma}_x^2 \qquad [4]$$

where:

RSS_y = residual sum of square of case y.
RSS_x = residual sum of square of case x.
df = degrees of freedom of the respective cases, and
$\hat{\sigma}_x^2$ = residual mean square error of case x
= (RSS_x/df_x).

Case x was simply the case with more parameters than case y. The null hypothesis that both cases adequately fit the data was rejected at $\alpha = 0.05$ if the F value was greater than the $F_\alpha(df_y-df_x, df_x)$. If more than one case was accepted and had the same number of parameters, the case with the lowest RSS was chosen.

Jolly-Seber Estimation:

In addition to the weir counts, abundance and survival were estimated with a Jolly-Seber model (Jolly 1965, Seber 1965) using 1990-92 mark-recapture data collected at the weir. The Jolly-Seber method gave an abundance estimate for 1991 and a survival estimate for 1990. I also performed a Jolly-Seber estimate on the American River spawning population data collected from 1988 to 1991. Estimates for the American River were for: 1988 and 1989 (survival), 1989 and 1990 (abundance), and 1989 (recruitment).

The following assumptions must be met to achieve unbiased estimates from this open population model (Seber 1982):

1. marked fish have the same probability of being caught in the *i*th sample as unmarked fish.
2. marked fish have the same probability of survival as unmarked fish.
3. marked fish do not lose their marks.
4. all samples are instantaneous.
5. all marks are recognized and reported on recovery.

The computer program JOLLY (Pollock et al. 1990) was used to estimate abundance and survival (Seber 1982: 196-205). The capture history data set used in this program is given in Table 2.

To test the assumption that marked fish do not lose their marks, tagged fish were examined for adipose and left ventral fin clips. Dolly Varden were tagged and adipose fin clipped during the spring and fall sampling events in 1989 (Sonnichsen 1990). No fin clips were used in 1990. A left ventral fin clip was used on fish tagged during the 1991 spring emigration. Percent tag loss was estimated using a simple proportion:

$$\hat{p}_{ri} = \frac{n_{ri}}{n_r}, \qquad [5]$$

where:

n_{ri} = number of fish recaptured in year r that were missing a tag and fin clipped in year i, and

n_r = total number of fish recaptured in year r that were marked in year i.

Variance of the tag loss point estimate is approximated using the following equation (Lindgren 1962):

$$\hat{V}[\hat{p}_{ri}] = \frac{\hat{p}_{ri}(1-\hat{p}_{ri})}{n_r - 1}. \qquad [6]$$

Table 2. Capture histories for emigrating Buskin River Dolly Varden for 1990 to 1992 for the JOLLY computer program. Captured in the event = 1, not captured in the event = 0.

1990	1991	1992	Frequency
0	0	1	7,307
0	1	0	4,640
0	1	1	102
1	0	0	8,172
1	0	1	49
1	1	0	196
1	1	1	4
		Total	20,470

To distinguish naturally missing or disfigured adipose fins in fish too small to be tagged during the 1989 season, I used the growth model described above to calculate what size the smallest fish tagged in 1989 would be during the 1992 season. I then removed all fish smaller than that size and used the remaining fish to estimate tag loss.

Survival Estimation:

In addition to the Jolly-Seber survival estimates, I estimated survival rates for the Buskin River and American River using recapture data one year after marking. The procedure involved using the proportion examined for marks from the weir operation the year after marking:

$$\hat{S}_i = \frac{m_{i+1}}{M_i \; e_{i+1}} \qquad [7]$$

$$e_{i+1} = \frac{n_{i+1}}{N_{i+1}} \qquad [8]$$

where:

- $\hat{S}_i$ = estimated survival from the ith year to the (ith + 1) year,
- M_i = number of fish marked and released in the ith year,
- m_{i+1} = recaptures found in (ith + 1) year marked in the ith year,
- e_{i+1} = proportion of emigrants examined for marks in the (ith + 1) year,
- n_{i+1} = number of fish examined for marks in the (ith + 1) year,
- N_{i+1} = weir count in the (ith + 1) year.

Variance of survival was estimated as (Lindgren 1962):

$$V[\hat{S}_i] = (e_{i+1})^{-2} \frac{p_m(1-p_m)}{M_i - 1} \qquad [9]$$

where:

p_m = proportion marked in examined sample = m_{i+1}/M_i

Sport Fishery

Estimates of harvest, effort and length composition of fish caught in the sport fishery were obtained through the Buskin River creel survey using a stratified systematic sample design during the spring emigration from 1985 to 1990 (Murray 1987 - 89, Sonnichsen 1990, and Whalen 1991). The creel survey was a program conducted by the Alaska Department of Fish and Game. Even though this survey was not part of the thesis project, creel length distributions and exploitation were used in the dynamic pool model.

Harvest estimates were also obtained from an annual statewide postal survey (Mills 1990, 1991, 1992). This survey provided estimates of harvest of Dolly Varden in the Buskin River for the entire year. The on-site creel survey estimates harvest only for the spring sport fishery. Therefore estimates of total fishing mortality for the Buskin River were calculated using the statewide postal survey harvest estimates by:

$$F_i = \frac{\hat{H}_i}{\hat{N}_i}, \qquad [10]$$

where:

$\hat{H}_i$ = statewide postal survey harvest estimate in year i,

$\hat{N}_i$ = Jolly-Seber abundance estimate in year i.

Variance of fishing mortality is estimated by (Lindgren 1962):

$$V[\hat{F}_i] = \frac{1}{\hat{N}^2_i} V[\hat{H}_i] + \frac{\hat{H}^2_i}{\hat{N}^4_i} V[\hat{N}_i]. \qquad [11]$$

Summer Immigration

Relative Maturity:

To determine if there was a major spawning population in the Buskin River, the percent of mature females was estimated during the immigration of 1990 and 1991. In 1990, the weir was moved to 1.4 km above tidewater on 16 July to assess the pink salmon (*Oncorhynchus gorbusha*) and coho salmon (*O. kisutch*) runs. Because of the possibility of washout, the Vexar was not in place when the weir was at its lower site. During the 1991 immigration, the weir remained at the lake outlet site, also without Vexar. Only one sample of Dolly Varden was taken during each year's immigration. The weir washed out on 1 August in 1990 and was dismantled at the lake on 25 July in 1991. Enumeration of Dolly Varden during the immigration was incomplete due to weir washouts and the absence of the Vexar. Otoliths of all fish sampled, male and female, were taken to ascertain age at relative maturity. Maturity estimation was accomplished through the examination of the ovaries using criteria described by Blackett (1968):

State I. Immature female: completely undeveloped ovary, eggs minute (usually less than 0.90 mm in diameter) and yolkless.

State II. Maturing female: maturing ovary will develop by spawning period, eggs usually larger than 1.75 mm in diameter and appear to be approaching an advanced stage of maturity. Oil droplets are present in the eggs and vessel structure is well developed in the ovarian tissue.

State III. Completely mature female: ovaries have reached a degree of maturity allowing the eggs to be easily stripped from the fish with only slight pressure.

State IV. Completely spawned female: only vestiges of recently spawned eggs in the ovary; i.e., ovary appears as a string with many minute recruitment eggs embedded in the tissue.

State V. Immature female but shows a degree of development: ovaries do not appear as if they would mature this year but development is definitely more advanced than State I. Egg diameters are usually greater than 0.90 mm but less than 1.75 mm. Ovary size is large enough to indicate spawning next year.

Age determination and composition was accomplished as described in the spring emigration methods above.

Fall Spawning Ground Surveys

To determine relative proportion of spawning stocks of the super-population, fall spawning ground surveys were performed. The Alaska Department of Fish and Game initiated these surveys on the American and Olds rivers in 1988. For the purposes of this study, only methods for the 1990 and 1991 surveys will be presented here. Methods for the 1989 season are detailed in Sonnichsen (1990).

American River:

A single year Petersen mark-recapture experiment was used to determine the population of spawning Dolly Varden in the American River. The following assumptions must be met in order to achieve unbiased estimates of a closed population (Ricker 1975):

1. marked and unmarked fish suffer negligible mortality.
2. marked and unmarked fish are equally vulnerable to the gear.
3. marked fish do not lose their mark.

4. marked fish become randomly mixed with the unmarked fish.
5. all marks are recognized and reported on recovery.
6. there is negligible recruitment to the catchable population.

Two samples were taken in each of the two years in early October. The American River was divided into two sublocations to test for equal mixing of marked and unmarked fish between sampling events. One day in 1990 and two days in 1991 were allowed for mixing of marked and unmarked fish. A 50-foot beach seine was used to capture Dolly Varden. All fish were tagged with numbered green Floy anchor tags, measured for fork length, and examined for fin clips.

Statistical tests were used to assess the validity of the assumptions of the Petersen estimation procedure. We have no evidence that marking Dolly Varden with anchor tags caused changes in mortality or behavior to affect assumptions 1 and 2. Recruitment into the American River population in October is considered negligible and emigration, if any is assumed to be equal between marked and unmarked fish (assumption 6).

To test for equal mixing between marked and unmarked fish for the American River, a contingency table analysis was used. The test compared the ratio of marked to unmarked fish at each sublocation in event 2. A chi-square test was performed to determine statistical significance.

A Kolmogorov-Smirnov (K-S) two-sample test was used in 1990 and a K-sample Anderson-Darling test was used in 1991 to determine if the different sizes of fish had equal probability of capture at the American River. The lengths of fish from event 1 were compared to the lengths of fish recaptured in event 2. Likewise, the fish in event 1 were compared to all the fish in event 2.

Concerning assumption 3, tag loss estimates were not calculated for the fall sampling events because crews did not consistently look for missing fins. The fall spawning survey tag loss was assumed to be the same as tag loss calculated for the spring emigration for the 1992 ventral fin clip study. The fall survey tag loss could also have been lower than the spring emigration tag loss because of the shorter time period between spring to fall than from spring to spring events.

The abundance of the American River population could be estimated, if the above conditions were met, using the Chapman modification of the Petersen estimate (Ricker 1975):

$$\hat{N} = \frac{(M+1)(C+1)}{(R+1)} - 1 \qquad [12]$$

where:

N = estimated population size,

M = marked fish at large,

C = number of fish caught during the second event, and

R = number of recaptures in catch.

With estimated variance (Ricker 1975):

$$\hat{V}(\hat{N}) = \frac{\hat{N}^2(C-R)}{(C+1)(R+2)} \qquad [13]$$

Olds River:

A fall spawning ground survey at the Olds River was not conducted in 1990 due to high water levels. In 1991, three samples were taken on 7, 8, and 12 October. The first two events were pooled because they were only one day apart. The Olds River was also divided into two sublocations to test for equal mixing between marked and unmarked fish. Sampling methods and tests for the assumptions of the Petersen estimate were the same as with the American River described above. At the Olds River, there was no size selectivity between the first and second event releases but there was a significant difference between lengths of the first event's releases and the second event's recaptures (Table A-1). Therefore, stratification by size group was necessary. I determined the length at stratification as 365 mm from a comparison of the plot of the cumulative length frequencies of both events.

The ratio of marked to unmarked fish was significantly different between sublocations at the Olds River at $\alpha = 0.05$ (Table A-2). Therefore, to achieve an unbiased estimate of population abundance, the Olds River population estimate should be stratified geographically by sublocation. The appropriate estimator was a stratified Petersen (Seber 1982, section 11.1.1). The stratified estimator ($\underline{W}$) is:

$$\underline{W} = D_u \, M^{-1}\underline{a} \qquad [14]$$

where:

$\underline{W}$	=	a vector with the estimates of the number of <u>untagged</u> Dolly Varden in each sublocation <u>just after the release of the tagged fish</u>.
D_u	=	a diagonal matrix of the number of untagged fish observed in each recovery sublocation j.
M	=	a matrix of m_{ij}, the number of tagged fish in each recovery sublocation, j , which were released in tagging sublocation i, and
$\underline{a}$	=	a vector of the number of tagged fish released in tagging sublocation i.

The number of Dolly Varden in each sublocation at the time of tagging is the sum of the estimated number of untagged fish present and the number of tagged fish released in the sublocation.

The variance-covariance matrix of $\underline{W}$ was estimated with (Seber 1982):

$$E[(W^{\wedge}-W)(W^{\wedge}-W)'] = D_W B^{-1} D_u D^{-1}{}_a B'^{-1} D_W + D_W(D_p - I) \qquad [15]$$

where:

D_w = diagonal matrix of estimated abundance in each sublocation,

D_p = diagonal matrix of reciprocals of p_i, which is the estimated probability of an animal surviving and being caught,

B = matrix of b_{ij}, the probability that a member of a_i is in sublocation j at sampling and that it is alive,

I = the identity matrix,

and;

$$B = D^{-1}{}_{a}MD_{q}. \qquad [16]$$

The variance of the point estimate for the total number of Dolly Varden present is the sum of the variance and covariance estimates for the individual strata.

Assumptions necessary for the stratified Petersen are the same as for the unstratified Petersen except that capture probabilities for fish in different sublocations need not be the same but tagged fish are assumed to behave independently of one another with regard to moving among sublocations (Seber 1982).

Buskin Lake:

I suspected that a substantial number of Dolly Varden were spawning in the Buskin River system itself, despite historical accounts of few spawners observed. Therefore, in 1990, the entire Buskin River system was surveyed to locate the spawning population. High numbers of mature Dolly Varden were discovered at the northwest end of Buskin Lake, so population estimates were attempted only for this site. Three other Buskin River sites, the mainstem of the Buskin River, the headwaters of the Buskin River near the lake outlet, and Buskin Lake near the outlet, were surveyed and length distributions were compared to the northwest end of Buskin Lake.

Dolly Varden were captured and tagged at Pillar Creek to investigate the potential contribution of these fish to the Buskin Lake overwintering population. One hundred forty-three fish were tagged and released.

Three samples were taken at Buskin Lake, on 9, 10, and 11 October 1990. Tests for the assumptions were the same as with the American River described above, except the northwest end of Buskin Lake was not divided into sublocations in 1990, therefore, a test for equal mixing was not done.

The abundance estimate for the northwest end of Buskin Lake was obtained using the Chapman modification of the Schnabel estimate (Ricker 1975):

$$\hat{N} = \frac{\mathrm{sum}(C_t M_t)}{R+1} \qquad [17]$$

where:

N = estimated population size,

M_t = marked fish at large at time t,

C_t = number of fish caught at time t, and

R = number of recaptures in catch.

Confidence intervals (95%) were calculated using R as a Poisson variable (Ricker 1975, Appendix II).

In 1991, the only Buskin River system survey was conducted at the northwest end of Buskin Lake and a single year Petersen estimator was used. Tests for the assumptions and methods of the estimator are the same as described above for the American River. To test for equal mixing of marked and unmarked fish, the northwest end of Buskin Lake was divided into two sublocations during the 1991 survey.

Dynamic Pool Model

A length-based dynamic pool model was used to examine effects of the sport fishery on the Chiniak Bay Dolly Varden super-population. Modeling was meant to show trends in stock structure by using various scenarios of fishing mortality and length-specific harvest. The goal of this model was to address additional data needs and to aid in management decisions. Two questions were raised concerning the present stock structure of the super-population:

1. At what levels of harvest would there be an effect on the super-population?
2. If anglers caught larger fish than they are presently, what effect would occur?

In order to use a dynamic pool model, an age structured length frequency was needed. An age sample was taken during the 1992 spring emigration, but was not representative of the super-population as evidenced by the rejection of the null hypothesis that the length distribution of the age sample was not significantly different from the weir length sample. An age structured length frequency was created using results from the Jolly-Seber abundance estimate for 1991. Each length frequency at age was calculated using the normal distribution equation (Zar 1984):

$$f_{ia} = N_a \frac{1}{\sigma \sqrt{2 \pi}} \exp[-(X_i - \mu)^2/2 \sigma^2] \qquad [18]$$

where:

f_{ia} = frequency at age a of the length group i,

$\hat{N}_a$ = number of Dolly Varden at age a,

σ = standard deviation of the mean length at age (from von Bertalanffy growth model),

X_i = length interval,

μ = mean length at age (from von Bertalanffy growth model).

The number of Dolly Varden at age was calculated iteratively using the total abundance for 1991 from the Jolly-Seber estimation and using a survival rate that decreased by age but averaged to the Jolly-Seber estimate for survival for ages 4 through 12.

This "true" representation of the 1991 Buskin River Dolly Varden super-population was then subjected to a harvest using the catch equation (Ricker 1975):

$$C_{ia} = p_i \; q \; N_{ia}, \qquad [19]$$

where:

C_{ia}	=	number of fish in length group i of age a remaining after harvest
p_i	=	probability of capture at length group i,
q	=	catchability,
N_{ia}	=	number of fish in length group i at age a in "true" population.

Six scenarios were modeled on the "true" population. Three levels of catchability, or q, (the 1991 level of 0.12 , 0.25, and 0.50) and two levels of length-specific exploitation (1990 creel and a larger length objective) were used. The resulting length distribution after harvest was then subtracted from the "true" population. This new population was subjected to survival, depicting the population at the start of the second year of modeling.

Relative Stock Density (RSD) was used to evaluate changes in stock structure. RSD is the proportion of a specific size group in a stock (Gablehouse 1984):

$$RSD_x = \frac{N_x}{N_s} * 100, \qquad [20]$$

where:

N_x = number of fish $\geq$ X mm

N_s = number of fish $\geq$ stock size (set here at 210 mm).

Confidence intervals were calculated using (Weithman et al. 1979):

$$R \pm t \sqrt{\left(\frac{R\,(1 - R)}{n - 1}\right)\left(\frac{N - n}{N}\right)}, \qquad [21]$$

where:

R = decimal fraction of RSD at size group,

n = number of fish in sample (i.e. creel),

N = number of fish in "true" population,

t = t_α (n-1).

Only two years were modeled because the stock-recruit relationship was unknown and modeling beyond two years would have been unrealistic. Two size groups were chosen for the RSD calculation to effectively monitor the super-population. From maturity and fall spawning ground length frequency data, $\geq$ 350 mm was chosen as the first size group to represent the health of the spawning stock. Then, $\geq$ 400 mm was selected as an early warning indicator to observe if very large fish were disappearing from the stock before the health of the stock was affected.

RESULTS

Spring Emigration

Census:

During the 1990 emigration, 77 tagged Dolly Varden were confirmed to have passed through the weir twice. The weir count, adjusted for these duplicate captures, was 90,600. A total of 30,725 Dolly Varden emigrated through the Buskin Lake weir in 1991, and a total of 74,451 fish passed the weir in 1992 (Table A-3).

The estimated count for 6 May 1991 when water topped the weir was 450 Dolly Varden; for 3 June 1991 when the weir was vandalized, 150 fish. Peak weir counts coincided with water temperatures of 6^{o}C (Figure 3). During the 1991 emigration high weir counts lagged behind high water levels because of difficulty in sampling fish from the trap. In 1992, the peak weir count was directly related to the peak water level (Figure 3). Water level remained low for an extended period of time due to a lack of rainstorm events followed by a storm on 25 May. The storm increased water levels, flushing out Dolly Varden holding at the weir. A total of 33,128 fish (44.5% of the emigration) passed through the weir in the six days following the storm. These fish could not be measured, tagged or examined for tags, so a length distribution or a recapture percentage were not available for this portion of the population.

The Lake Louise weir count totalled 4,669 Dolly Varden in 1991 and 3,422 fish in 1992 (Table A-4).

Length Composition:

In 1990, larger Dolly Varden emigrated through the weir in the early weeks, smaller fish passed through in higher numbers later (Figure 4). Weeks 7 and 8 reflect the size of Dolly Varden after the Vexar was removed from the weir, therefore, these data were not included in the

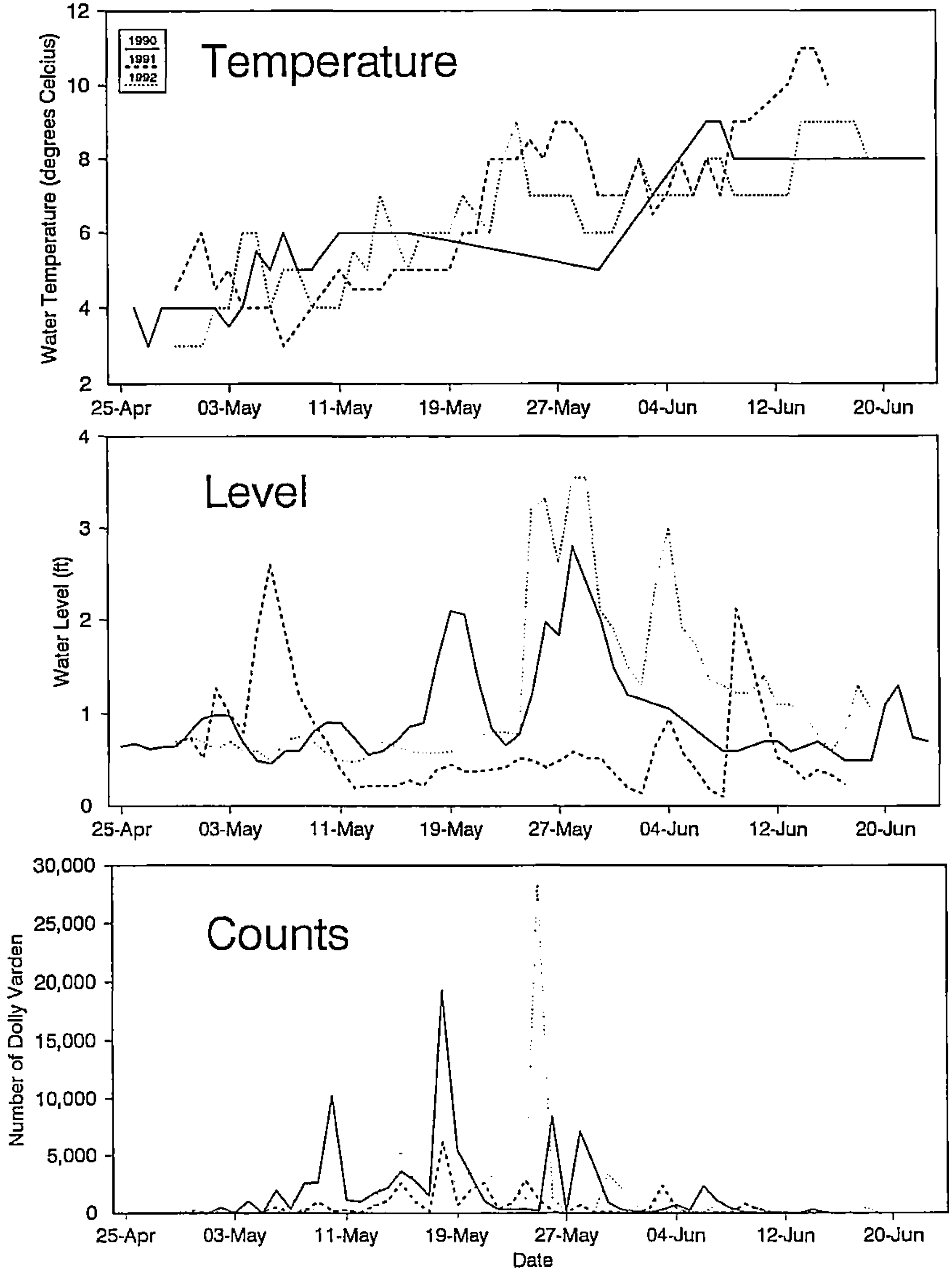

Figure 3. Water temperature, level and weir counts for the Buskin River weir, 1990 to 1992.

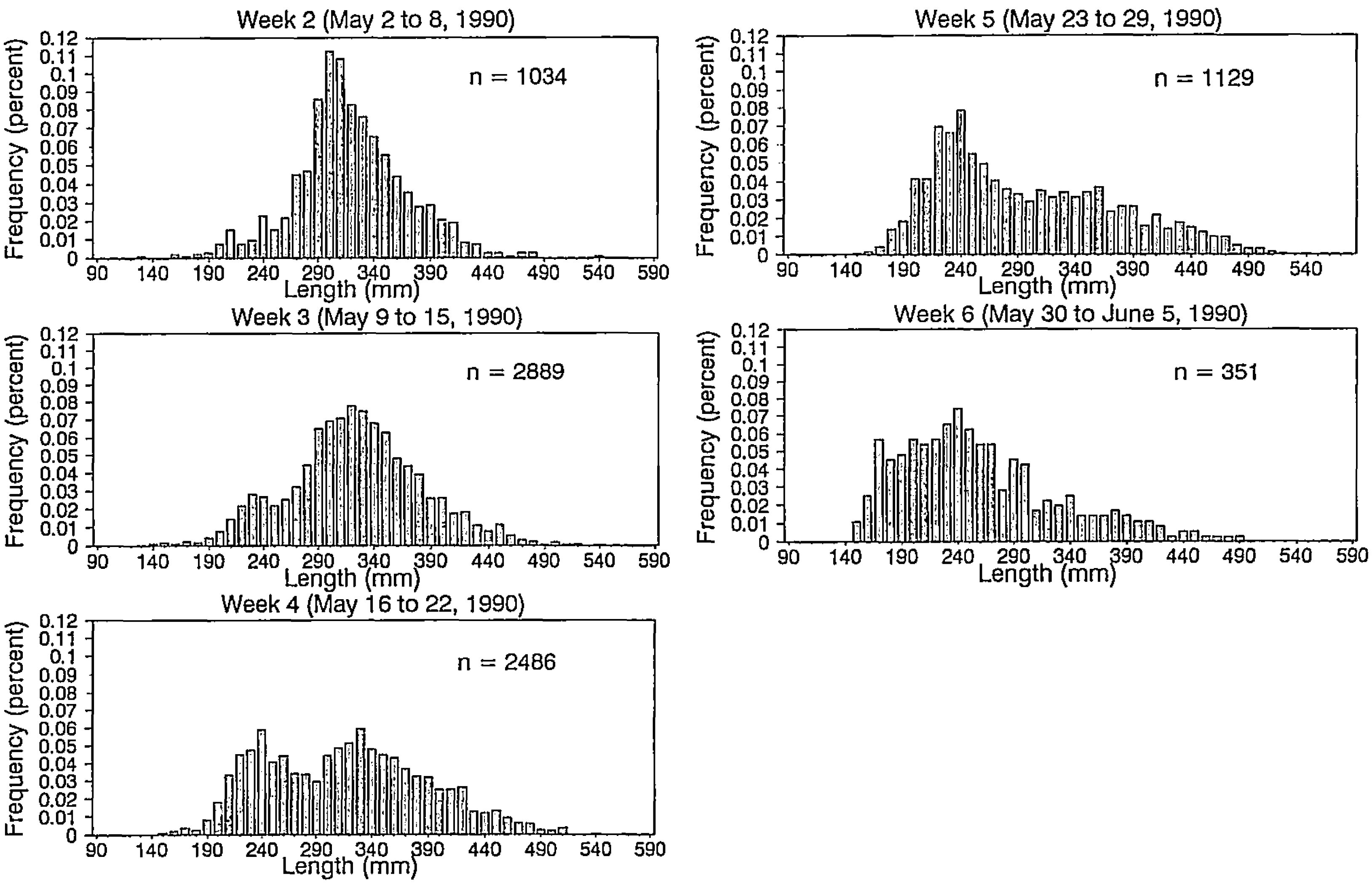

Figure 4. Length frequencies for emigrating Buskin River Dolly Varden for weeks 2 through 6, 1990.

length frequency discussion. Week 1 was not included because the sample size was only 14. A significant difference was found in the distribution of length classes among weeks 2 through 6 ($X^2 = 824.813$, df = 16, and $P < 0.001$, Table 3).

In 1991 and 1992, the first four weeks of the emigration exhibited a marked shift in length composition from large Dolly Varden in the beginning to smaller fish over time. The last four weeks of the emigration were not as distinct, but appear to shift back to larger fish (Figures 5 - 8). According to Kolmogorov-Smirnov tests, significant differences were found among all combinations of weeks in 1991 except between weeks 5 and 6 and then between weeks 7 and 8 (Table 4). Cumulative length distribution frequencies agree with the above conclusions, though weeks 5 and 6 show slight differences as the fish get larger (Figure 9). Also, weeks 7 and 8 show larger differences, especially from 350 to 410 mm than the P-values indicate. Kolmogorov-Smirnov tests indicated significant differences in length distribution among all paired combinations of weeks in 1992 (Table 5). Cumulative length distribution frequencies agreed with the above conclusions, though a number of the weeks did not show differences in the 240-330 mm length range (Figure 10). Weighted overall length frequencies for all three years were calculated using the weir counts and number of fish measured in each length category (Figure 11). Length at full recruitment to the weir appeared to be the same in all years: 210 mm. A visual comparison of weighted length frequencies among 1990, 1991 and 1992 showed a higher portion of recruit size fish in 1992.

The weighted length composition of Dolly Varden sampled at Lake Louise indicated these fish were smaller than those at the Buskin River (Figure 12). The cumulative length distributions of fish > 200 mm (Figure 13) were significantly different ($D_{MAX} = 0.1434$, $P = 0.0001$) between the two systems. Average size of fish from Lake Louise and Buskin River in 1991 was 284 and 322 mm, respectively. The average size of Dolly Varden from Lake Louise in 1992 (270 mm) was closer to the average size of fish from

Table 3. Counts of emigrating Dolly Varden by length group and week at the Buskin River Weir in spring of 1990.

	Length (mm)				
Week	0-250	251-300	301-350	351-400	401-600
2	84	263	442	182	62
3	368	622	1035	588	277
4	604	460	631	452	339
5	413	229	189	154	143
6	184	85	40	25	17

chi-square value = 824.813 df = 16 $P < .001$

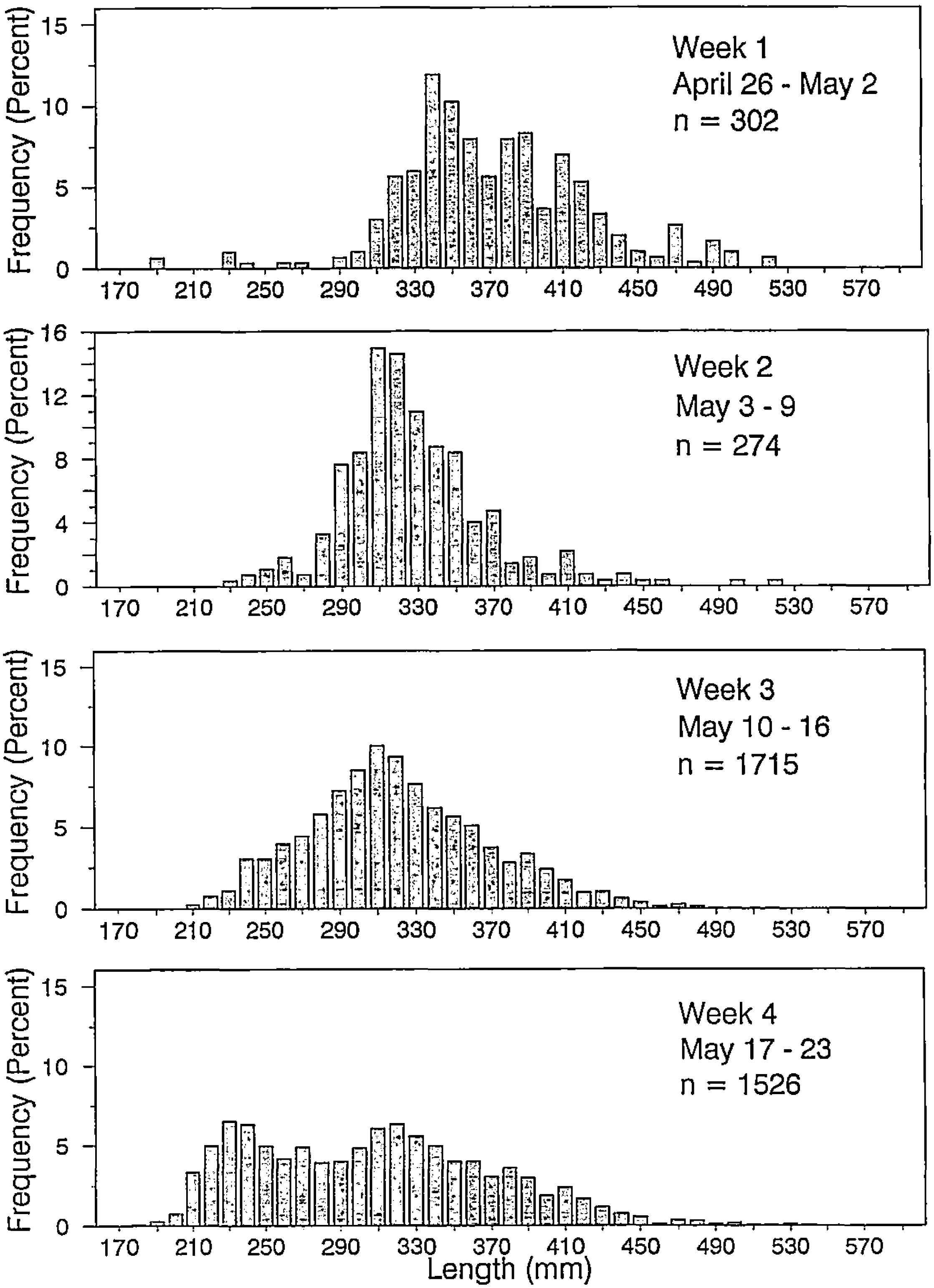

Figure 5. Length frequencies for emigrating Buskin River Dolly Varden for weeks 1 through 4, 1991.

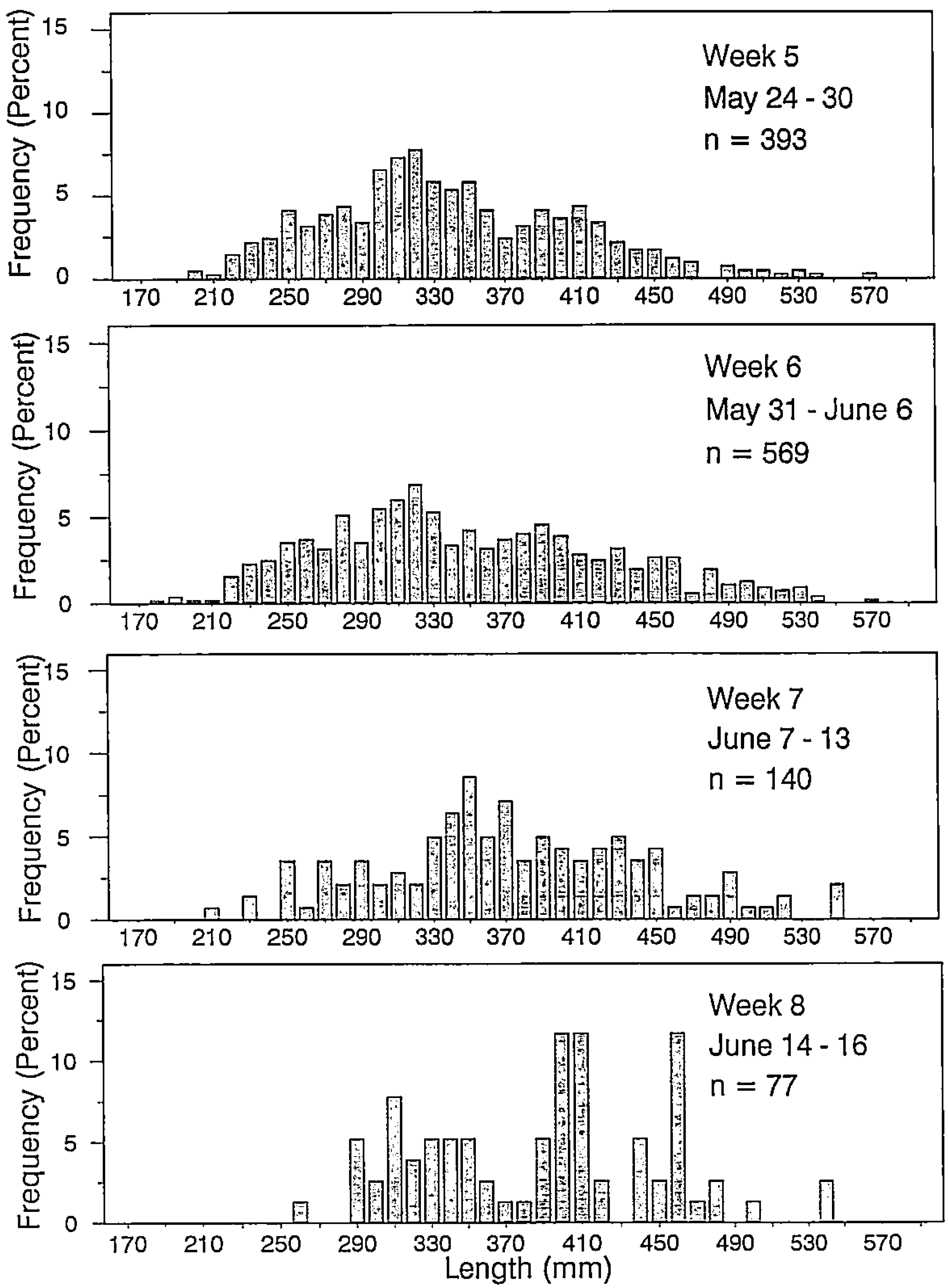

Figure 6. Length frequencies for emigrating Buskin River Dolly Varden for weeks 5 through 8, 1991.

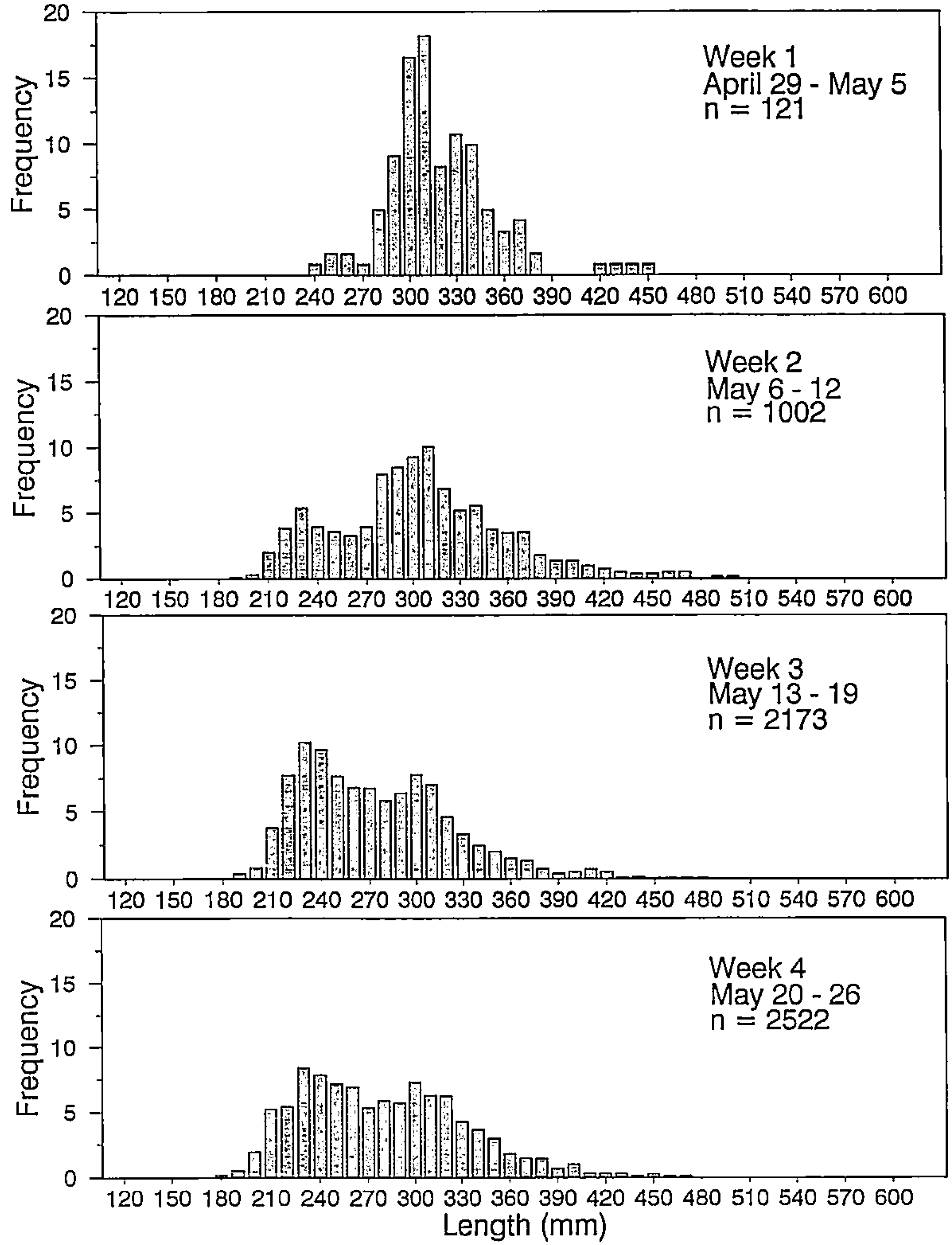

Figure 7. Length frequencies for emigrating Buskin River Dolly Varden for weeks 1 through 4, 1992.

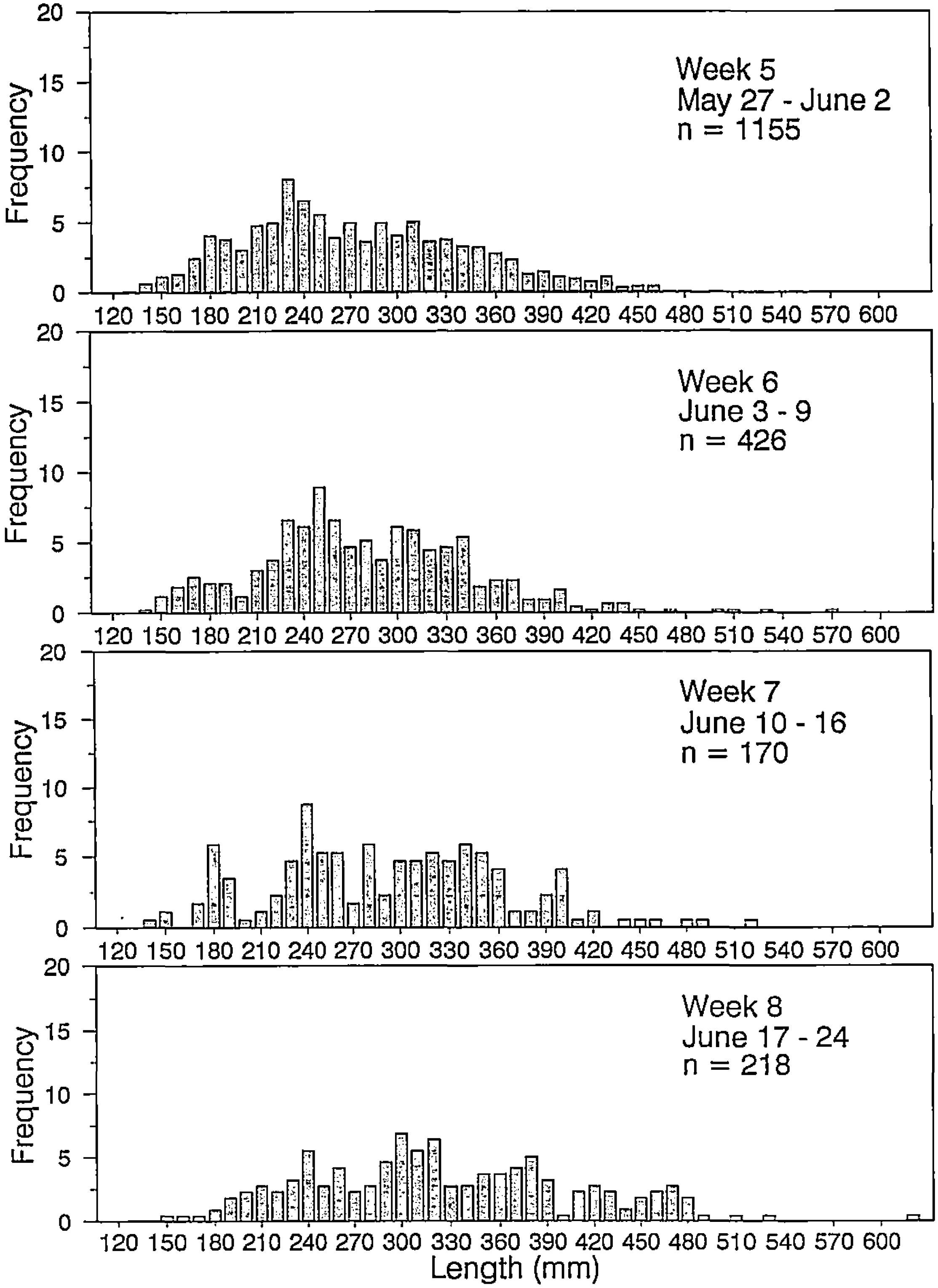

Figure 8. Length frequencies for emigrating Buskin River Dolly Varden for weeks 5 through 8, 1992.

Table 4. Results of Kolmogorov-Smirnov tests on length distributions for Buskin River Dolly Varden emigration, spring 1991.

			Week						
			2	3	4	5	6	7	8
Week	n		n = 274	n = 1715	n = 1528	n = 406	n = 567	n = 140	n = 77
1	302	D_{MAX}	.0129	.0066	.0034	.0131	.0587	.1252	.2444
		P	.0000[a]	.0000[a]	.0000[a]	.0000[a]	.0000[a]	.0393[a]	.0011[a]
2	274	D_{MAX}		.0516	.0720	.2043	.2669	.4018	.5098
		P		.0000[a]	.0000[a]	.0000[a]	.0000[a]	.0000[a]	.0000[a]
3	1715	D_{MAX}			.0280	.1574	.2230	.3829	.4695
		P			.0000[a]	.0000[a]	.0000[a]	.0000[a]	.0000[a]
4	1528	D_{MAX}				.2049	.2019	.3992	.4535
		P				.0000[a]	.0000[a]	.0000[a]	.0000[a]
5	406	D_{MAX}					.0795	.2436	.3269
		P					.0909	.0000[a]	.0000[a]
6	567	D_{MAX}						.2170	.2745
		P						.0000[a]	.0001[a]
7	140	D_{MAX}							.1701
		P							.0917

[a] - significantly different at $\alpha = 0.05$.

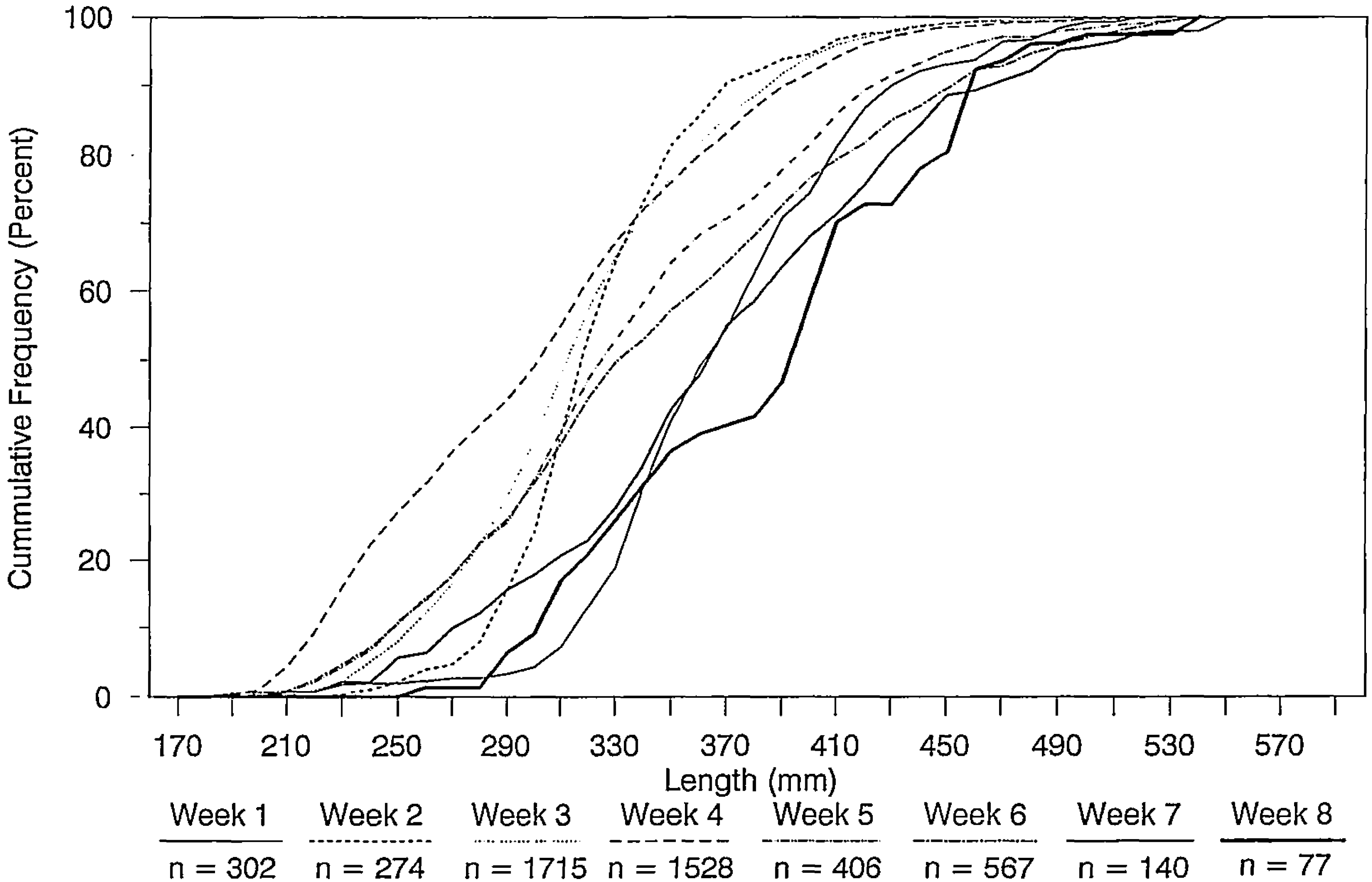

Figure 9. Cumulative length distributions in percent frequency for Dolly Varden emigration, spring 1991.

Table 5. Results of Kolmogorov-Smirnov tests on length distributions for Buskin River Dolly Varden emigration, spring 1992.

			Week[a]						
			2	3	4	5	6	7	8
Week	n		n = 1002	n = 2173	n = 2522	n = 1155	n = 426	n = 170	n = 218
1	121	D_{MAX}	0.0542	0.0046	0.0117	0.0449	0.0303	0.0964	0.2449
		P	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0001
2	1002	D_{MAX}		0.0005	0.0008	0.0022	0.0094	0.0458	0.2087
		P		<0.0000	<0.0001	<0.0001	<0.0001	0.0001	<0.0001
3	2173	D_{MAX}			0.0666	0.0961	0.0921	0.2036	0.3247
		P			0.0001	<0.0001	0.0004	<0.0001	<0.0001
4	2522	D_{MAX}				0.0555	0.0432	0.1568	0.2822
		P				<0.0001	0.0033	0.0007	<0.0001
5	1155	D_{MAX}					0.1033	0.1329	0.2751
		P					0.0024	0.0097	<0.0001
6	426	D_{MAX}						0.1229	0.2586
		P						0.0447	<0.0001
7	170	D_{MAX}							0.1924
		P							0.0013

a - Weeks significantly different if $P < 0.05$.

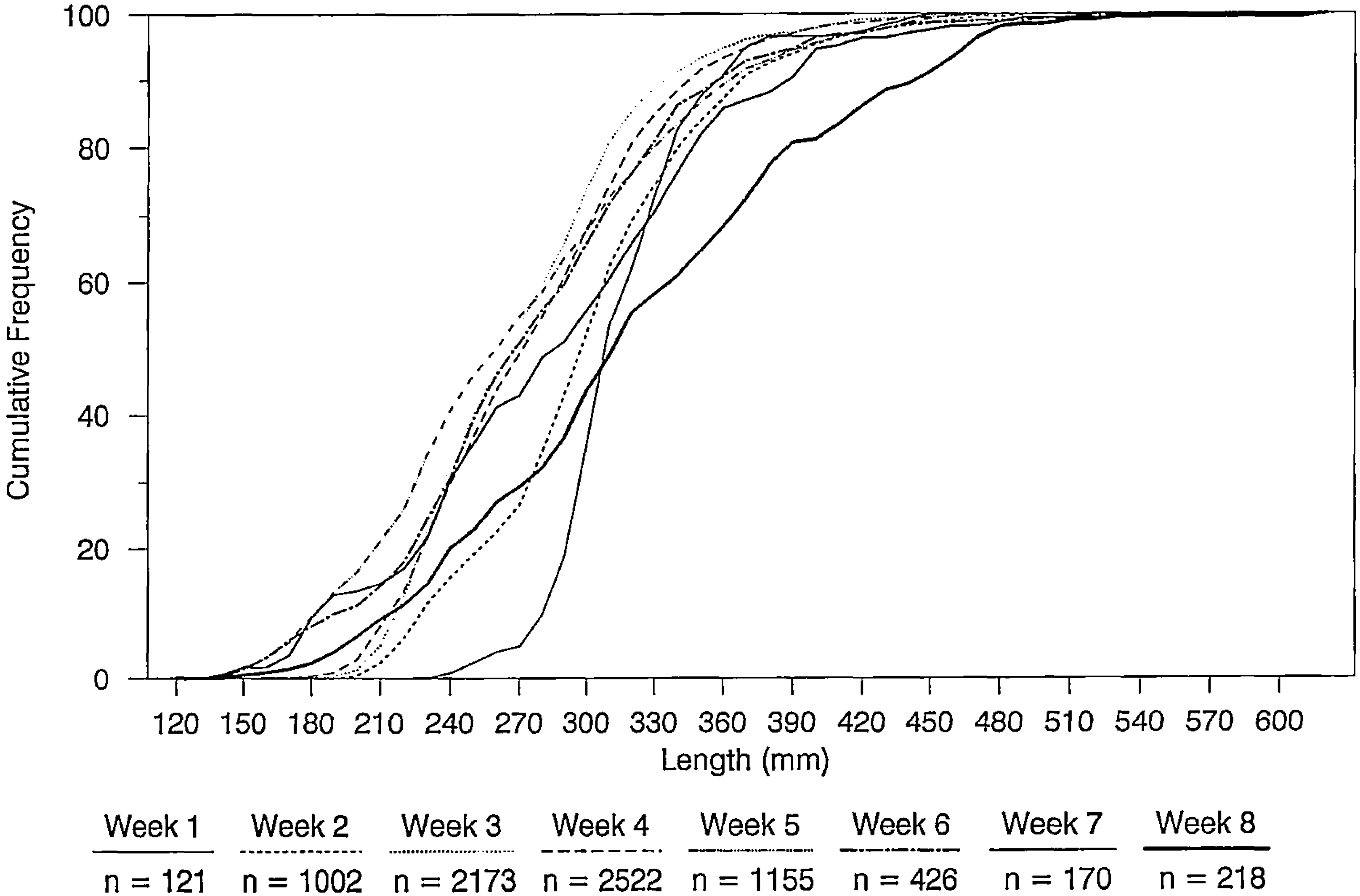

Figure 10. Cumulative length frequencies for emigrating Buskin River Dolly Varden, spring 1992.

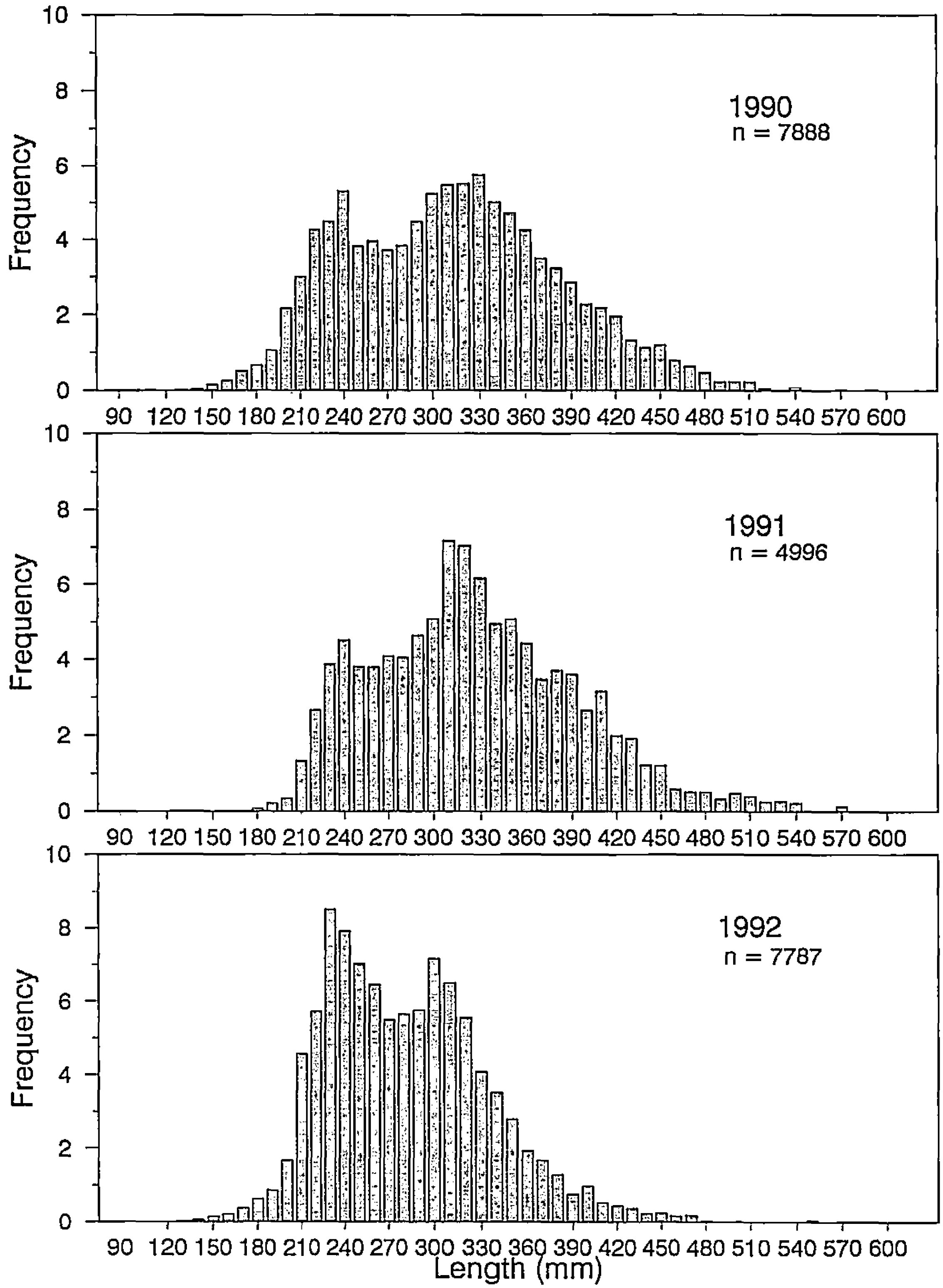

Figure 11. Weighted length frequency comparisons for emigrating Buskin River Dolly Varden for 1990 to 1992.

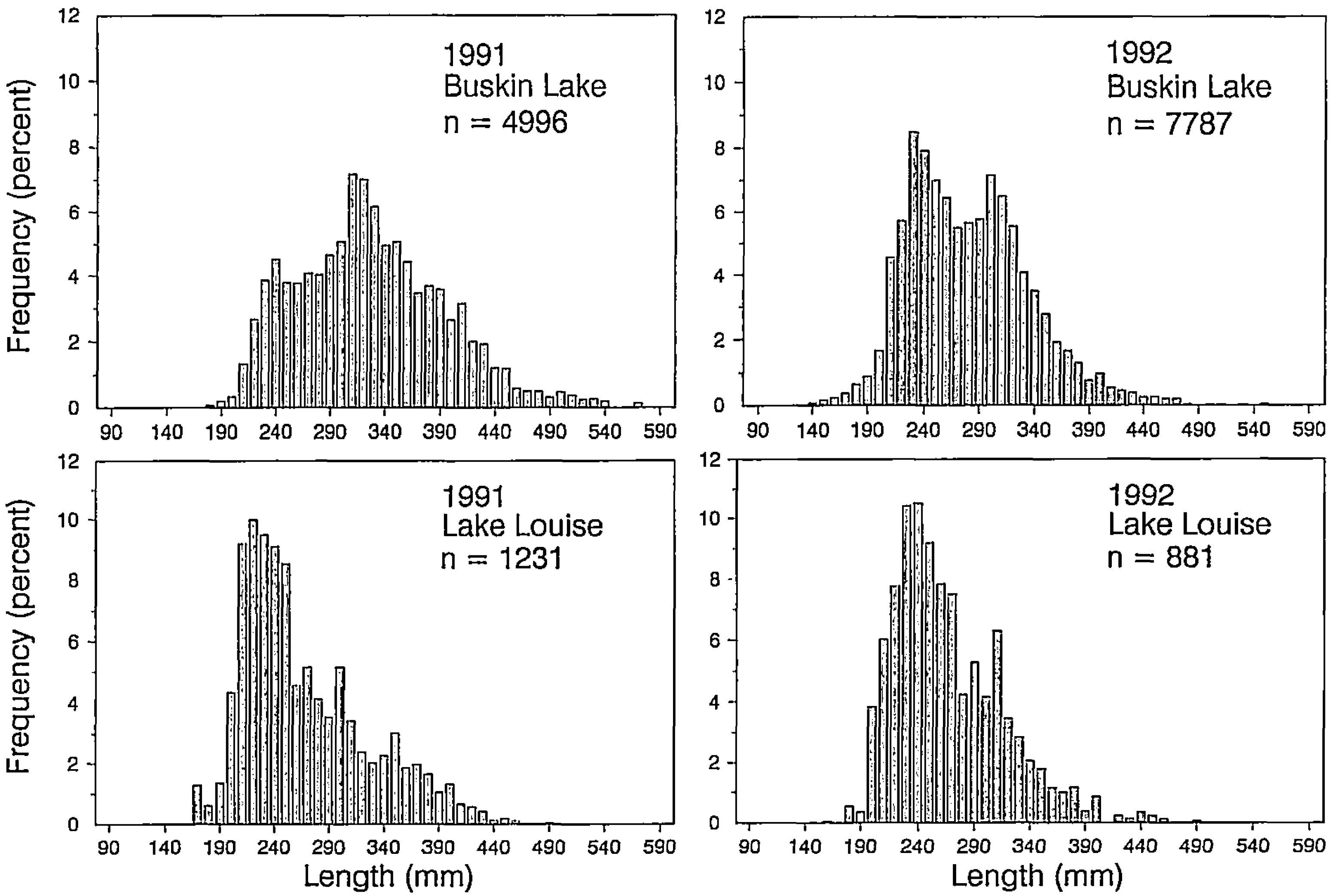

Figure 12. Weighted length frequencies for emigrating Dolly Varden from Buskin Lake and Lake Louise weirs, spring 1991 and 1992.

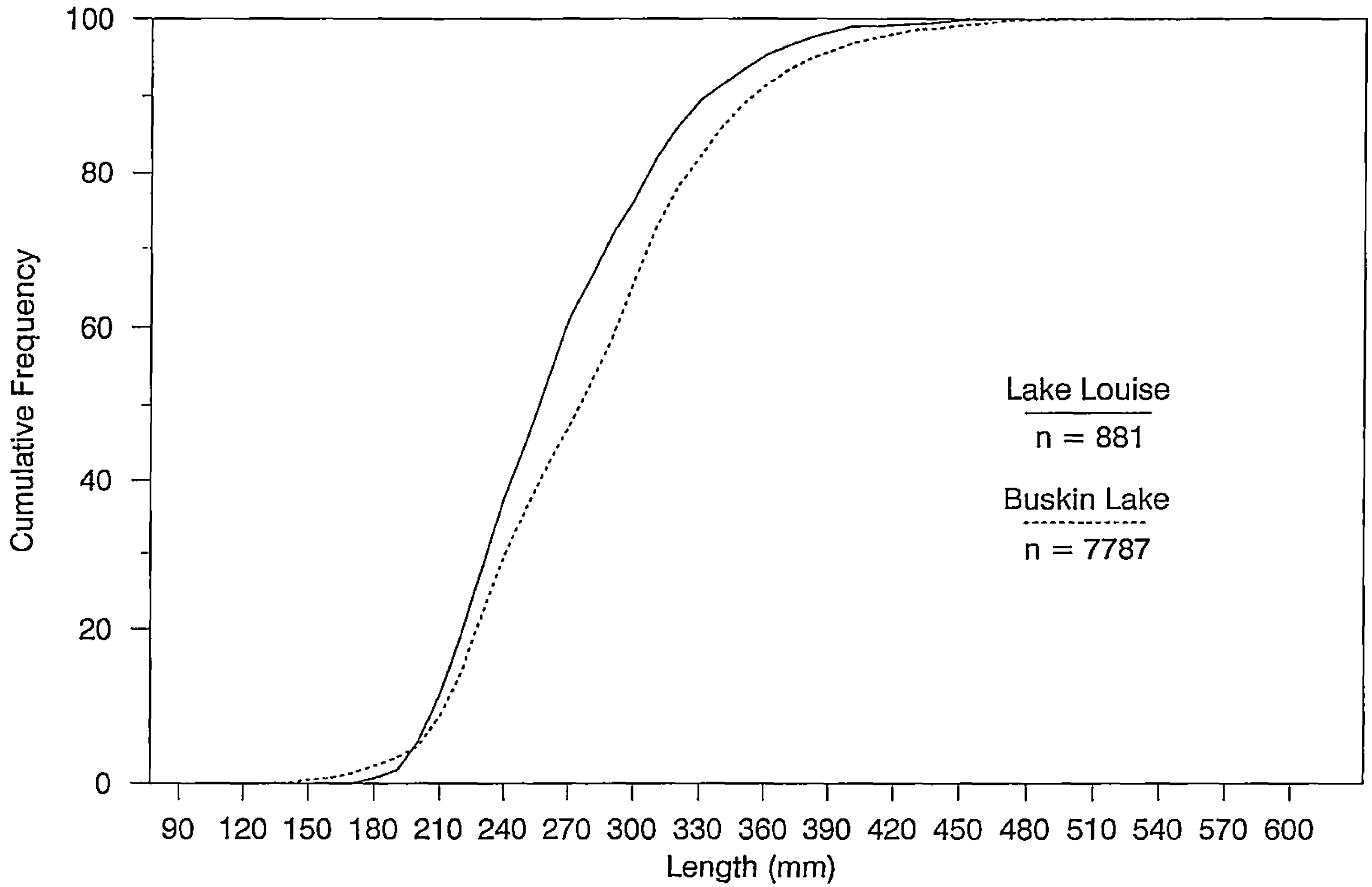

Figure 13. Cumulative length frequencies of emigrating Dolly Varden from Lake Louise and Buskin Lake weirs, spring 1992.

the Buskin River weir (284 mm) than in 1991. Weighted length distributions of fish leaving Lake Louise were similar during 1991 and 1992 except that in 1992 there were fewer large (> 330 mm) fish (Figure 14). As in the Buskin River, larger fish tended to emigrate from Lake Louise earlier than smaller fish. The length distribution shifted toward smaller fish over time, but a pulse of larger fish left the lake during the fourth week (Figures 15 and 16). Length compositions were not significantly different between weeks one and four and among weeks two, three and five (Table 6).

Tag Returns:

During 1984 - 92, a total of 60,367 Dolly Varden were tagged from the Chiniak Bay, Ugak Bay and Afognak Island areas combined (Table 7). The number of Dolly Varden tagged for 1990, 1991, and 1992 was 7,492, 4,500 and 7,202, respectively. A total of 22,815, 11,565 and 15,978 fish were examined for tags in 1990 - 92, respectively. Generally, fish tagged at the weir from 1990 to 1992 were tagged in proportion to abundance (Figure 17). Recaptures totaled 1,527, 480 and 284 in the three years. Thirty-seven percent (106 fish) of the recaptures in 1992 were from 1991 spring Buskin Lake tagging (Table 8). Similarly, 42% of the recaptures in 1991 were from the 1990 spring Buskin Lake tagging.

Age Composition:

Age classes 3 through 9 were present in the 1992 Dolly Varden emigration sample (Table 9). The weighted age sample was dominated by age 5 (34.3%, SE = 0.55) and age 6 (31.4%, SE = 0.54). The mean length for age 5 Dolly Varden was 245 mm (SE = 2.46) and for age 6 was 283 mm (SE = 3.30) (Table 10). The Kolmogorov-Smirnov test showed a significant difference between the length distributions from the age sample and the length sample at the weir for the second and third 2-week time periods, but not the first period (Time period 1: D_{MAX} = 0.0636, P = 0.5891; Time period 2: D_{MAX} = 0.2254, P = 0.0001; Time period 3: D_{MAX} = .2930, P =

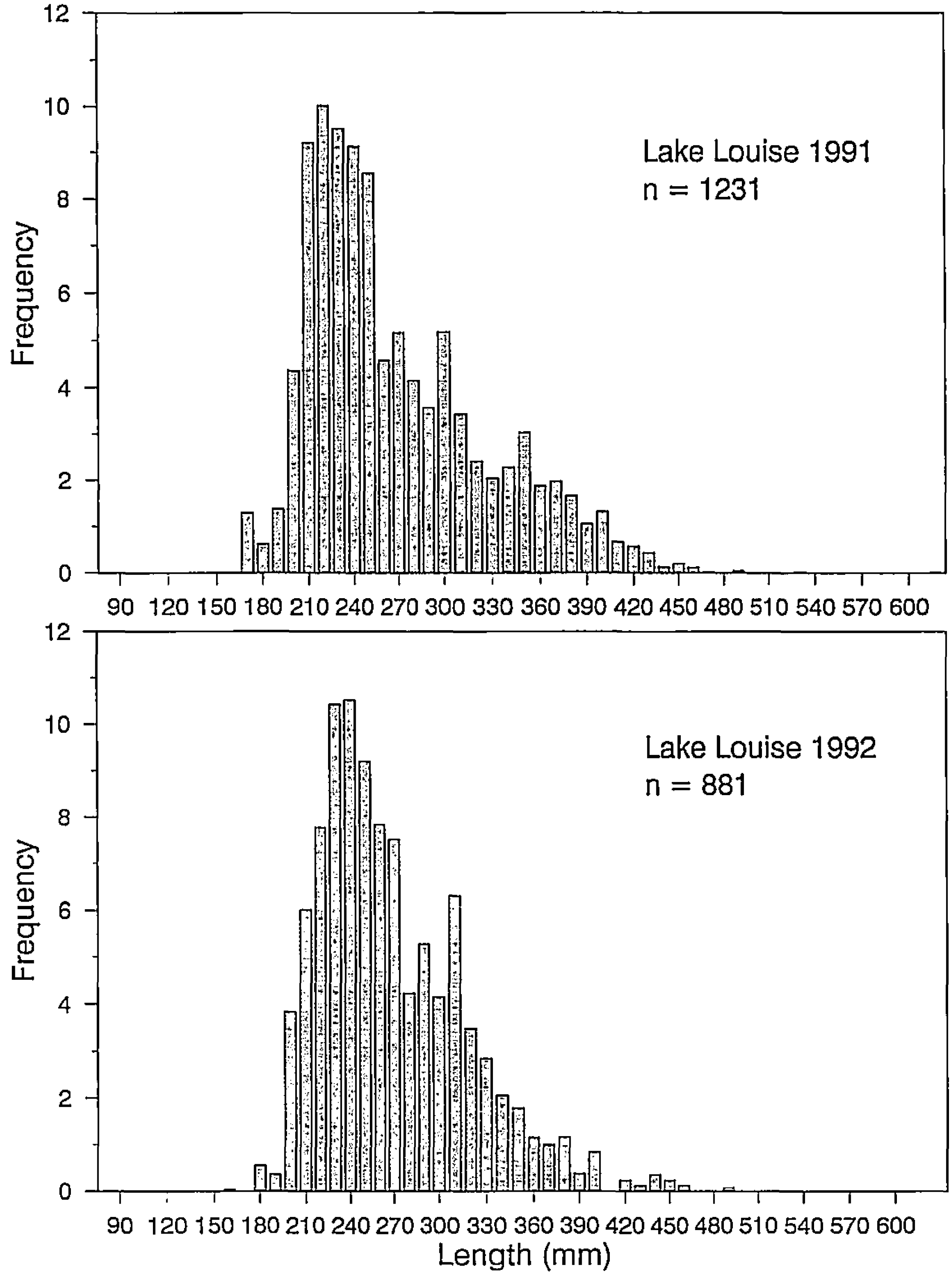

Figure 14. Weighted length frequencies for emigrating Dolly Varden from Lake Louise, spring 1991 and 1992.

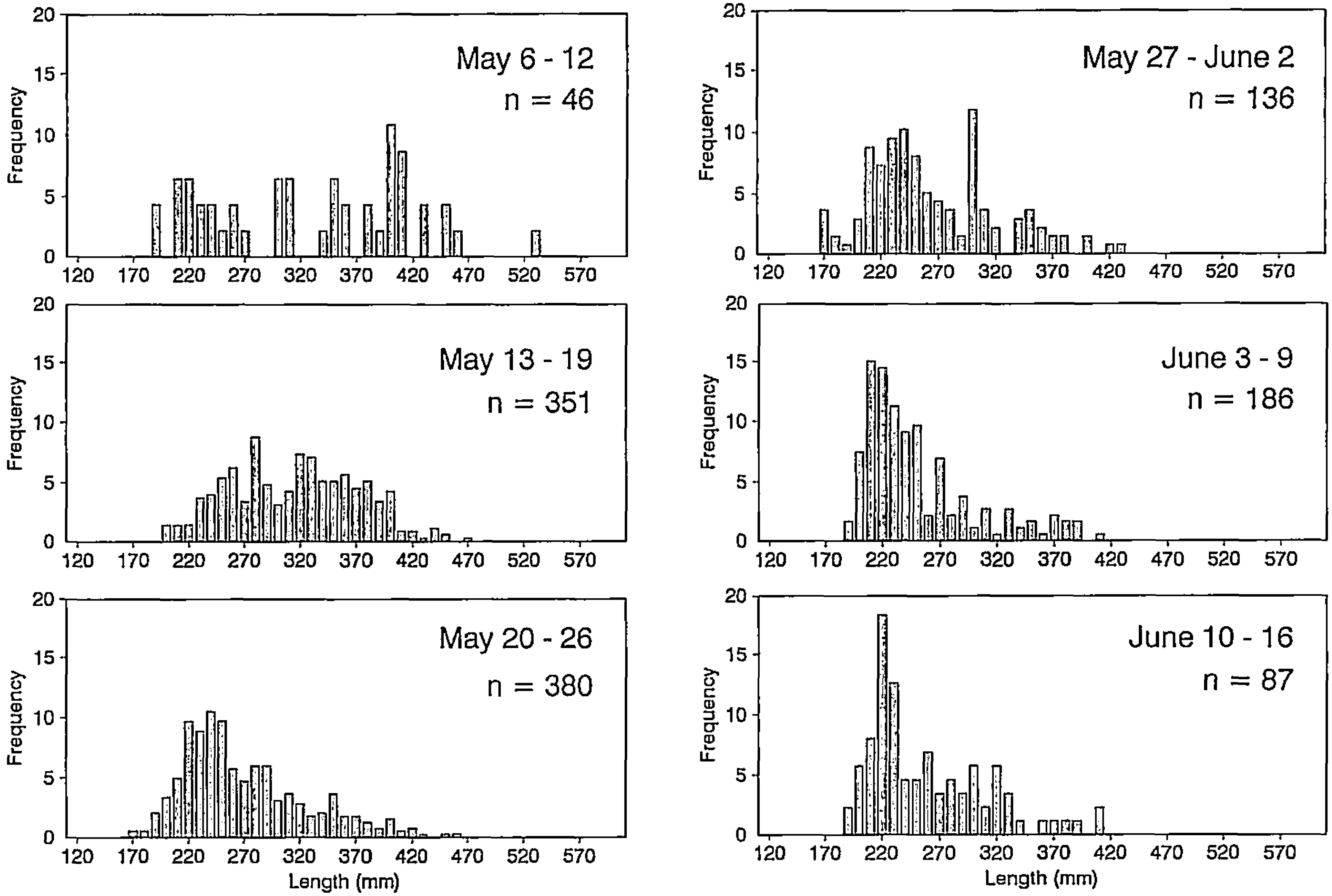

Figure 15. Length frequencies for emigrating Dolly Varden from Lake Louise for spring 1991.

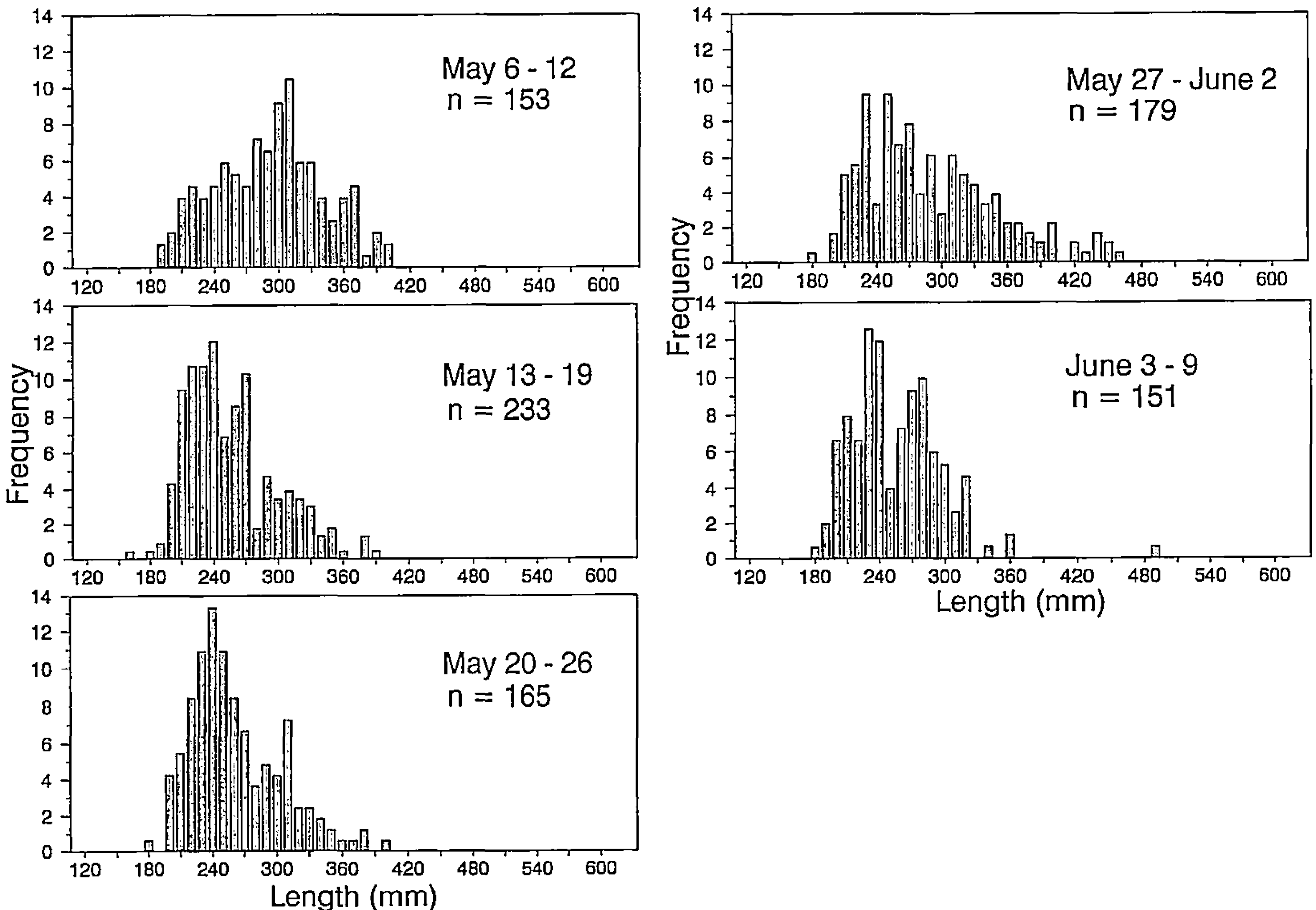

Figure 16. Length frequencies for emigrating Dolly Varden from Lake Louise for spring 1992.

Table 6. Results of the K-sample Anderson-Darling tests showing differences in the length distributions for Lake Louise Dolly Varden emigration, spring 1992.

			Week			
			2	3	4	5
Week	n		n = 233	n = 165	n = 179	n = 151
1	153	A^2_{akN}	23.779	16.147	1.959	22.687
		r2	0.574	0.573	0.573	0.573
		TakN	30.174a	20.042a	1.261	28.822a
2	233	A^2_{akN}		0.944	16.890	0.762
		r2		0.574	0.574	0.574
		TakN		-0.064	21.024a	-0.330
3	165	A^2_{akN}			10.494	1.500
		r2			0.573	0.573
		TakN			12.534a	0.710
4	179	A^2_{akN}				15.220
		r2				0.573
		TakN				18.880a

a - significant difference at α = 0.05.

Table 7. Tagging summary, Kodiak Dolly Varden 1984 - June 1992.

Year	Site	Dates	Tag Color	Tag Numbers	Number Tagged
1984	Buskin River	17 May-17 Jun	Yellow	1 - 474	472
1985	Buskin River	27 Apr-17 Jun	Yellow	475 - 1800	1318
			Green	651 - 743	
1986	Buskin River	24 Apr-16 May	Pink	2001 - 6000	3986
	Buskin River	29-30 Oct	Red	1 - 575	461
	Salonie Creek	14 Aug	Orange	2501 - 2550	97
		14 Sept	Orange	2851 - 2897	
	American River	7-12 Aug	Orange	1403 - 1962	560
	Olds River	5-6 Aug	Orange	1 - 1402	1402
	Roslyn River	13 Aug	Orange	2001 - 2030	30
	Pasagshak River	15 & 19 Aug	White	1 - 1000	1596
		11-12 Sept	White	18235 - 19993[a]	
	Afognak River	4-5 Sept	Blue	1 - 1000	1476
			Blue	20325 - 20803	
1987	Buskin River	20-30 May	Yellow	1801 - 4000	4051
			Orange	1963 - 3000[a]	
			Pink	4001 - 5000	
	Buskin River	26-27 Aug	Pink	6001 - 7000	1000
	American River	20 & 22 Aug	Orange	4501 - 6000	1500
	Olds River	11-12 Aug	Orange	3001 - 4500	1498
	Pasagshak River	24-25 Aug	White	1001 - 2000	1000
	Saltery Creek	14-15 May	Green	3001 - 5000	2000
	Afognak River	4-5 Sept	Blue	1001 - 2000	1000
1988	Buskin River	20-25 Oct	Red	1001 - 2000	2998
			Pink	7001 - 8000	
			Green	124001 - 125000	
	American River	18-22 Oct	Pink w/ Black	5001 - 6000[a]	650
	Olds River	26-31 Oct	Green	125001 - 125267	267
1989	Buskin River	3 May-1 Jun	Green	125268 - 129308[a]	4012
	Buskin River	Oct	Green	155737 - 156500	4433
			Green	156550 - 157000	
			Green	157347 - 157999	
			Green	162457 - 164280[a]	
			Green	164801 - 165375	
			Green	165501 - 165725[a]	
	American River	Oct	Green	157001 - 157346	801
			Green	162001 - 162456	
	Olds River	Oct	Green	155001 - 155736	784
			Green	156501 - 156550	

- continued -

Table 7. Tagging summary, Kodiak Dolly Varden 1984 - June 1992 (continued).

Year	Site	Dates	Tag Color	Tag Numbers	Number Tagged
1990	Buskin Lake	30 Apr-14 Jun	Green	190001 - 195000	7492
			Green	211001 - 213499	
	American River	6 Oct-8 Oct	Green	213500 - 214045	546
			Green	214610 - 214821	212
	Olds River	7 Oct	Green	214046	1
			Green	214601 - 214609	9
	Buskin Lake-NW	9 Oct-11 Oct	Green	215085 - 215731	646
	Buskin Lake-Out	9 Oct	Green	214826 - 215084	259
	Buskin River	9 Oct	Green	214047 - 214125	79
	Pillar Creek	10 Oct	Green	214126 - 214268	143
1991	Buskin Lake	26 Apr-16 Jun	Green	216000 - 217000	4500
			Green	218001 - 220000	
			Green	250001 - 251501	
	Olds River	7 Oct-12 Oct	Green	255001 - 255589	589
			Green	255601 - 255767	167
			Green	256001 - 256186	187
			Green	256965 - 257000	36
	American River	9 Oct-11 Oct	Green	255590 - 255599	10
			Green	256201 - 256467	267
			Green	256630 - 256964	334
	Buskin Lake	10 Oct-13 Oct	Green	255768 - 255891	124
			Green	256468 - 256629	162
1992	Buskin Lake	29 Apr-19 Jun	Green	252001 - 255000	
			Green	368001 - 371000	
			Green	372001 - 373216	7212
				Total Tagged	60,367

a - Missing blocks of tags in this sequence.

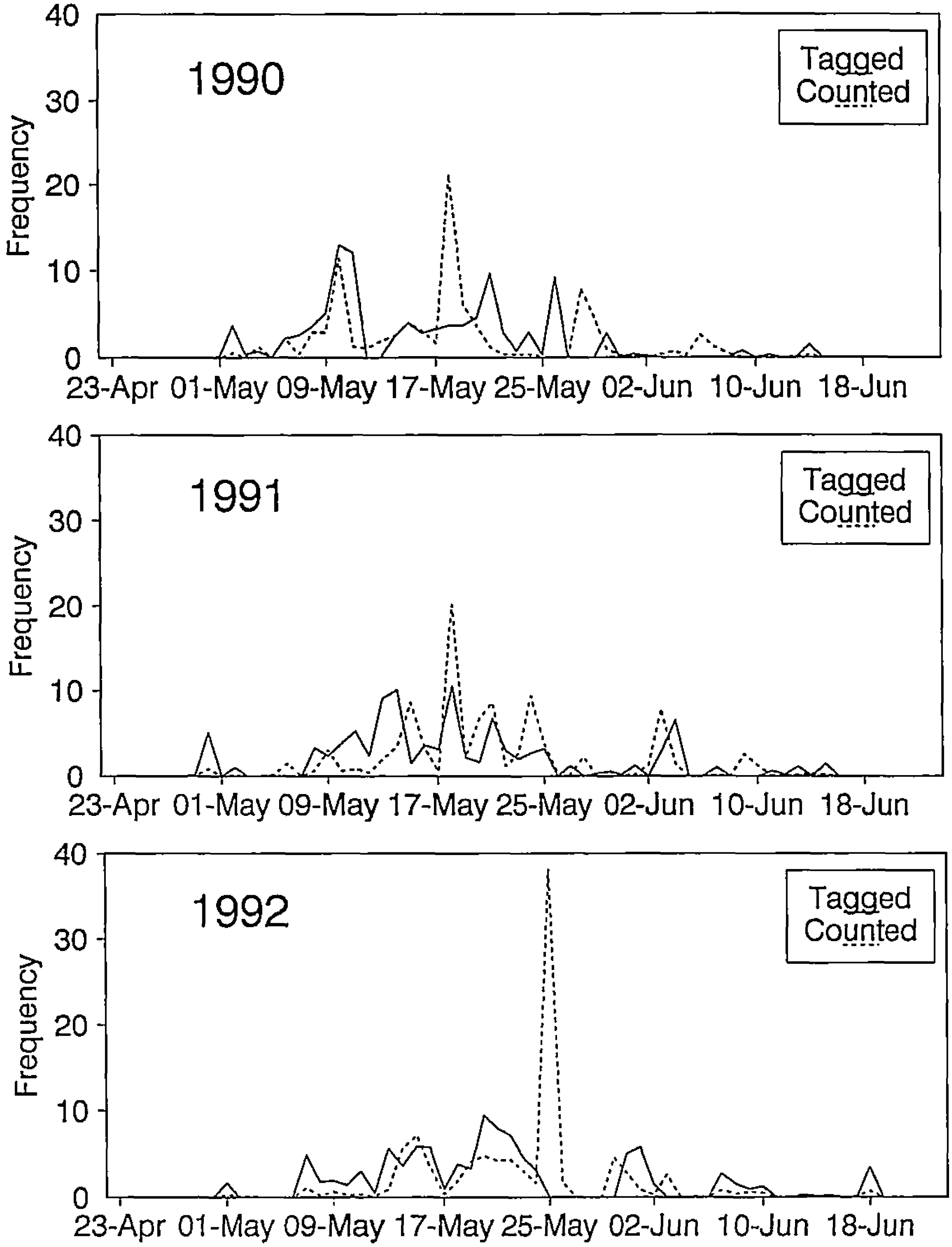

Figure 17. Percent of total emigrating Dolly Varden weir count and daily tag count, spring 1990 to 1992.

Table 8. Dolly Varden tag recoveries by release location for all tagging sites for 1988 - 1992.

Recaptures (# unique examined)	Releases (# unique releases with tags): 1988 Fall American (709)	1988 Fall Olds (283)	1988 Fall Buskin R (3,006)	1989 Spring Buskin R (4,476)	1989 Fall American (893)	1989 Fall Olds (833)	1989 Fall Buskin R (4,484)	1990 Spring Buskin L (8,450)	1990 Summer Buskin (21)	1990 Fall American (897)	1990 Fall NW Busk L (725)	1990 Fall Busk Main (87)	1990 Fall Busk R Out (4)	1990 Fall Busk L Out (295)	1990 Fall Olds (11)	1990 Fall Pillar Cr (143)	1991 Spring Buskin L (4,956)	1991 Spring L Louise (32)	1991 Fall American (715)	1991 Fall Olds (1,163)	1991 Fall NW Busk L (340)	1992 Spring Buskin L (7,479)
1989 Spring Buskin R (10,126)	50	21	105																			
1989 Fall American (896)	38	0	3	50		0	0															
1989 Fall Olds (836)	1	5	9	21	0		0															
1989 Fall Buskin R (4,503)	0	0	30	12	0	0																
1990 Spring Buskin L (22,815)	16	10	161	221	57	69	378															
1990 Spring Busk Creel (372)	0	0	4	4	0	0	4	19														
1990 Summer Buskin R (403)	0	0	2	3	0	0	4	11														
1990 Fall American (897)	2	0	6	8	34	0	7	33	0			0	0	0								
1990 Fall Olds (12)	0	0	0	0	0	1	0	0	0			0	0	0								
1990 Fall NW Busk L (725)	0	0	4	14	2	0	4	52	2	0		0	0	1	0	0						
1990 Fall Busk R Main (87)	0	0	2	0	0	1	1	5	0	0	0		0	0	0	0						
1990 Fall Busk R Out (276)	0	0	0	0	0	0	3	1	0	0	0	0		0	0	0						
1990 Fall Busk L Out (391)	0	0	0	0	1	0	20	16	0	0	0	0	0		0	0						
1991 Spring Buskin L (11,549)	1	0	22	27	5	15	95	201	1	23	56	3	0	14	0	0						
1991 Spring L Louise (1232)	0	0	0	0	0	3	3	13	0	11	0	0	0	0	0	0						
1991 Summer Busk Matur (288)	0	0	0	0	0	0	2	2	0	0	1	0	0	0	0	0	5	0				
1991 Fall American (715)	2	0	0	4	13	0	17	17	0	19	1	0	0	0	0	0	18	0		0	0	
1991 Fall Olds (1,164)	3	0	0	3	0	18	12	19	0	0	3	0	0	1	0	0	18	0	0		0	
1991 Fall NW Busk L (340)	0	0	3	2	0	2	3	17	0	0	11	1	0	1	0	0	16	0	0	0		
1992 Spring Buskin L (15,938)	2	0	8	5	2	5	28	53	0	4	0	0	0	9	0	0	106	1	14	34	9	
1992 Spring L Louise (959)	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	8	0	3	8	0	0

Table 9. Age distribution of Dolly Varden sampled at the Buskin Lake weir during emigration, spring 1992.

	Age								
	Age Not Available	3	4	5	6	7	8	9	Total
Females									
Sample Size	3	4	37	105	42	16	5		212
% of sexed sample	0.8	1.1	9.9	28.1	11.2	4.3	1.3		56.7
SE	0.46	0.53	1.55	2.33	1.63	1.05	0.59		2.57
Males									
Sample Size		1	37	61	47	12	2	2	162
% of sexed sample		0.3	9.9	16.3	12.6	3.2	0.5	0.5	43.3
SE		0.27	1.55	1.91	1.72	0.91	0.38	0.38	2.57
Sex Not Recorded									
Sample Size	1		5	25	37	30	7	1	106
All									
Sample Size	4	5	79	191	126	58	14	3	480
% of sample	0.8	1.0	16.5	39.8	26.3	12.1	2.9	0.6	100.0
SE	0.42	0.46	1.69	2.24	2.01	1.49	0.77	0.36	
Weighted All[a]									
Sample Size		34	697	2608	2588	1183	234	52	7396
% of sample		0.6	11.4	34.3	31.4	17.8	3.9	0.7	100.0
SE		0.09	0.37	0.55	0.54	0.44	0.23	0.10	

a - Weighted by total weir length distribution.

Table 10. Mean fork length at age (mm) of Dolly Varden sampled at the Buskin Lake weir during the emigration, spring 1992.

	Age								
	Age Not Available	3	4	5	6	7	8	9	Total
<u>Females</u>									
Average Length	219.33	183.50	195.92	240.45	278.60	322.50	361.40		247.91
SE	8.67	17.13	4.93	2.83	5.90	5.65	11.87		3.38
Sample Size	3	4	37	105	42	16	5		212
Minimum	204	145	142	191	218	285	330		142
Maximum	234	228	261	326	362	372	397		397
<u>Males</u>									
Average Length		163.00	199.41	234.08	271.94	349.08	400.50	386.50	249.16
SE			4.46	2.88	4.97	10.39	19.50	33.50	4.24
Sample Size		1	37	61	47	12	2	2	162
Minimum		163	155	196	207	295	381	353	155
Maximum		163	249	290	344	426	420	420	426
<u>Sex Not Recorded</u>									
Mean Length	285.00		239.60	294.87	301.42	339.50	360.29	383.00	312.68
SE			12.14	7.73	5.42	6.24	7.76		4.23
Sample Size	1		5	23	36	30	7	1	103
Minimum	285		216	196	217	257	320	383	196
Maximum	285		285	373	350	406	381	383	406
<u>All</u>									
Mean Length	235.75	179.40	200.32	245.02	282.66	336.79	366.43	385.33	262.32
SE	17.52	13.89	3.38	2.46	3.30	4.30	6.96	19.38	2.57
Sample Size	4	5	79	189	125	58	14	3	477
Minimum	204	145	142	191	207	257	320	353	142
Maximum	285	228	285	373	362	426	420	420	426

0.0001). Anderson-Darling tests indicated no significant difference between the length distributions of the two sexes (T_{aKN} = -0.888, A^2_{aKN} = 0.3275, σ^2 = 0.5738).

Growth Model:

For 1989 to 1990 and 1990 to 1991, the case five (von Bertalanffy) model was the most parsimonious model fitting the data, while case three was selected for 1991 to 1992 (Table 11). I wanted to use the same procedure to model growth for all three years, and because results of the von Bertalanffy model were similar to the case three model (i.e. similar F-value and RSS) for 1991 to 1992, I used the von Bertalanffy model for all three years. The Schnute mark-recapture version of the von Bertalanffy model was used to estimate parameters y_2 and a (Table 12). These estimates were then used in equation (3) to model growth during each year (Figure 18).

Jolly-Seber Estimates:

During the 1990-92 spring emigrations, 8.8%, 14.6% and 9.7% of the Dolly Varden passing through the weir were examined for missing fins, respectively. In 1990, 15 fish were discovered with no tag and no adipose fin. The smallest fish tagged in 1989 was 151 mm during the fall sampling events. That fish would have negligible growth to spring 1990. All fish found missing adipose fins and a tag in 1990 were longer than 242 mm, therefore, all of these fish were used in the calculation of tag loss. A total of 282 Dolly Varden were recaptured from the 1989 season in which adipose fins were clipped. This results in a tag loss estimate for 1989 to 1990 of 5.32% (SE < 0.01).

In 1991, 14 fish were found with no tag and no adipose fin. From the growth model, a 151 mm Dolly Varden tagged in the fall of 1989 would grow to approximately 234 mm in the spring of 1991. All fourteen fish found in the spring 1991 sample were longer than 234 mm. A total of 83

Table 11. F-test results for comparison of growth models on Buskin River Dolly Varden for mark-recapture data from 1989 to 1992.

	Data Sets		
	1989 to 1990	1990 to 1991	1991 to 1992
Comparisons[a]:			
Case 1[b] = Case 2	4.51	1.86	3.58
Case 1 = Case 3	1.30	3.26	0.45
Case 1 = Case 5	0.49	0.00	0.69
$F_{critical}$	3.88	3.89	3.94
RSS (3 parameter models):			
Case 2	104,838.9	72,144.9	33,288.0
Case 3	103,352.6	72,655.6	32,298.7
Case 5	102,981.4	71,469.4	32,377.2

a - Case 4 would not run since one parameter had to be set, leaving only one parameter left for this model.

b - Case descriptions are given in Baker et al. 1991.

Table 12. Parameter estimates for selected growth models for Buskin River Dolly Varden, 1989 to 1992.

		Selected Model and Year			
		1989 to 1990	1990 to 1991	1991 to 1992	
Parameter[a]		Case 5	Case 5	Case 3[b]	Case 5[c]
y_2	Estimate	530.50	522.51	522.94	491.58
	SE	9.99	12.00	13.20	13.00
a	Estimate	0.1999	0.2276		0.2107
	SE	0.0259	0.0271		0.0352
b	Estimate			2.4951	
	SE			0.2660	

[a] y2 = the largest fish in the population.

a = the Brody growth parameter.

b = the location of inflection point.

[b] Case 3 was the most parsimonious model.

[c] Case 5 was chosen as explained in text.

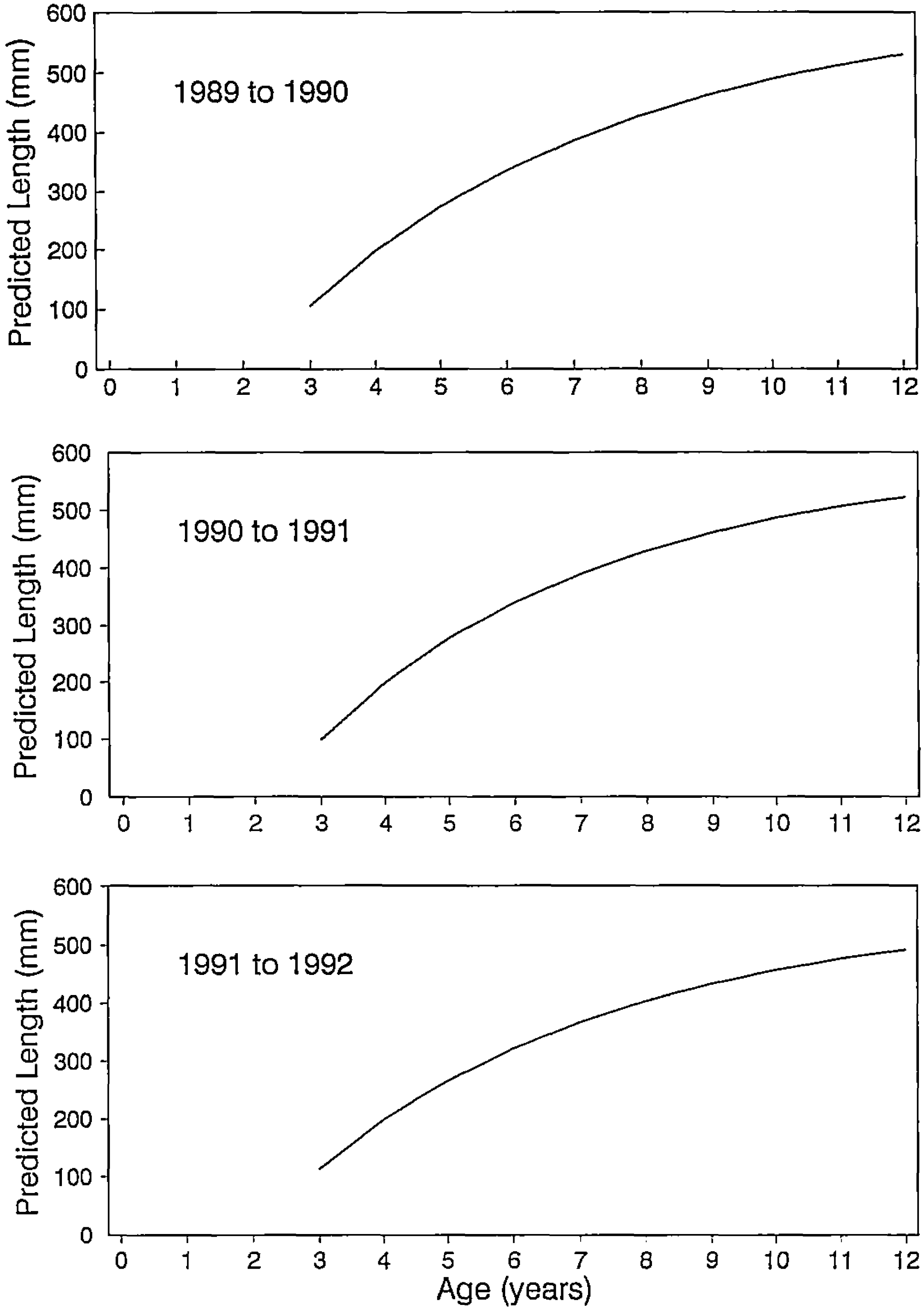

Figure 18. Von Bertalanffy growth curves for Buskin River Dolly Varden, 1989 to 1992.

fish were recaptured from the 1989 season. The resulting tag loss estimate is 16.87% (SE < 0.01) for 1989 to 1991.

During the 1992 emigration, seven Dolly Varden were discovered with no tag and no adipose fin. Of these seven fish, four were deleted because they were < 304 mm, the length the growth models predicted that a 151 mm fish from 1989 would be in 1992. A total of 15 recaptures from the 1989 season were found in the 1992 sample. Therefore, a tag loss estimate in 1992 for the 1989 adipose clipped fish is 20.00% (SE = 0.01). Of fish marked in spring 1991 (in which the left ventral fin of all tagged Dolly Varden was clipped) and recaptured in 1992, only one of 55 fish found with a left ventral fin clip was missing the tag, resulting in a 1.82% (SE = 0.15) tag loss estimate.

The Jolly-Seber estimate of Dolly Varden emigrating from the Buskin River in 1991 was considerably higher than the weir count. The weir count in 1991 was 30,725 and the Jolly-Seber estimate was 60,585 (SE = 10,354). The weir count did not fall within the 95% confidence intervals of 40,291 to 80,879. The Jolly-Seber estimate of survival 29.26% (SE = 4.63%) was significantly higher than the estimated survival from recaptures of 6.29% (SE = 0.44). The 95% confidence intervals for the two estimates of survival did not overlap.

The Jolly-Seber estimate of abundance was 3,790 (SE = 1,267) for the American River in 1989 (Table 13). A Petersen estimate for 1989 of 4,125 (SE = 805.22) (Sonnichsen 1990) was within the 95% confidence intervals (1,308 to 6,273) of the Jolly-Seber estimate. The 1990 Jolly-Seber estimate was 12,423 (SE = 4,574). The Petersen estimate for 1990 of 3,947 (SE = 540) (refer to Fall Spawning Population Estimates) was also within the 95% confidence intervals (3,458 to 21,389) of the Jolly-Seber estimate.

Table 13. Results of the Jolly-Seber run made on Dolly Varden mark-recapture data from the American River, 1988 to 1991.

Parameter		Year 1988	1989	1990
Abundance	Estimate		3,790	12,424
	SE		1,267	4,574
Survival	Estimate.	0.2481	0.5777	
	SE	0.0778	0.1976	
Recruitment	Estimate		10,234	
	SE		3,963	

<u>Sport Fishery</u>

The total estimated effort from 23 April through 25 May, 1990 from the Buskin River creel survey was 4,268 angler hours while the total catch was 6,355 and total harvest was 2,362 Dolly Varden. Total harvest estimated from the Statewide Harvest Survey for 1990 in the Buskin River was 4,209. The Statewide Harvest Survey comprises the whole calendar year while the Buskin River creel survey was during the spring emigration only. Therefore the total harvest during the spring emigration was 56% of the entire year's harvest.

As in past years, the majority of the Dolly Varden sampled during the creel survey were less than 350 mm (Figure 19). When the length frequency of the sport caught fish was compared to the frequencies of Dolly Varden passing through the weir at the same time period, chi-square tests showed there were significant differences between them ($X^2 = 38.372$, df = 4, $P < 0.001$, Figure 20). The large sample sizes of weir-caught fish may cause statistically significant differences between the two comparisons even though the differences may have no practical significance.

Fishing mortality estimated from the Statewide Harvest Survey for 1991 was 0.116 (SE < 0.001). All Chiniak Bay sites were pooled. These included Chiniak Bay saltwater (boat and shoreline), Buskin River, American River, Olds River, Chiniak Creek, Russian Creek, and Roslyn Creek. The total harvest was 7,031 Dolly Varden, catch was 16,688 fish and estimated effort was 56,728 angler days.

<u>Summer Immigration</u>

Relative Maturity:

Results from the summer maturity samples indicated that 48.2% of the females were mature (State II) in 1990 compared to 8.3% mature females in 1991. The difference between years resulted from maturity samples being taken while the weir was at the lake in 1991 and in 1990 they were

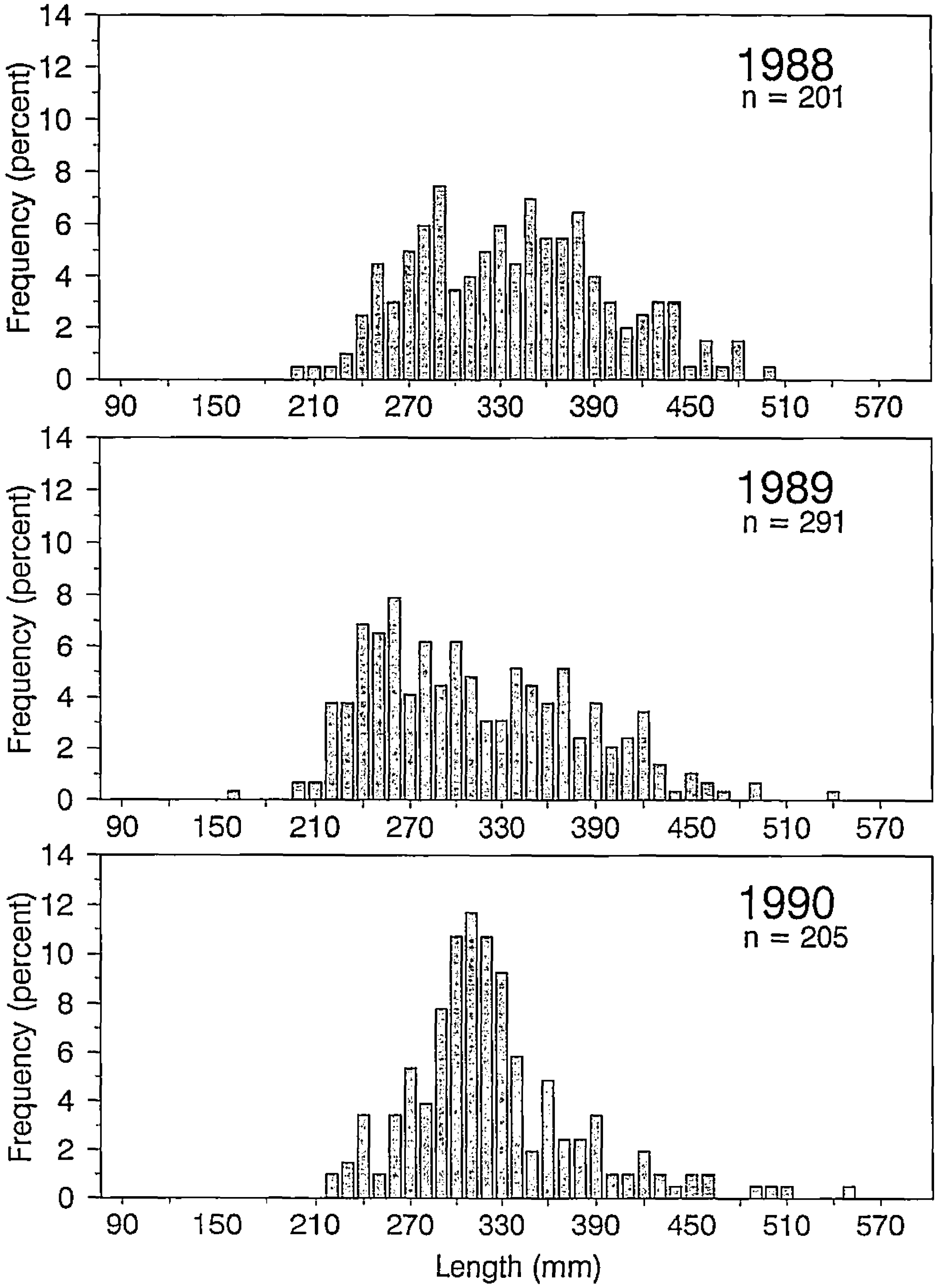

Figure 19. Comparison of three years of length frequencies of Buskin River creel caught Dolly Varden, 1988 to 1990.

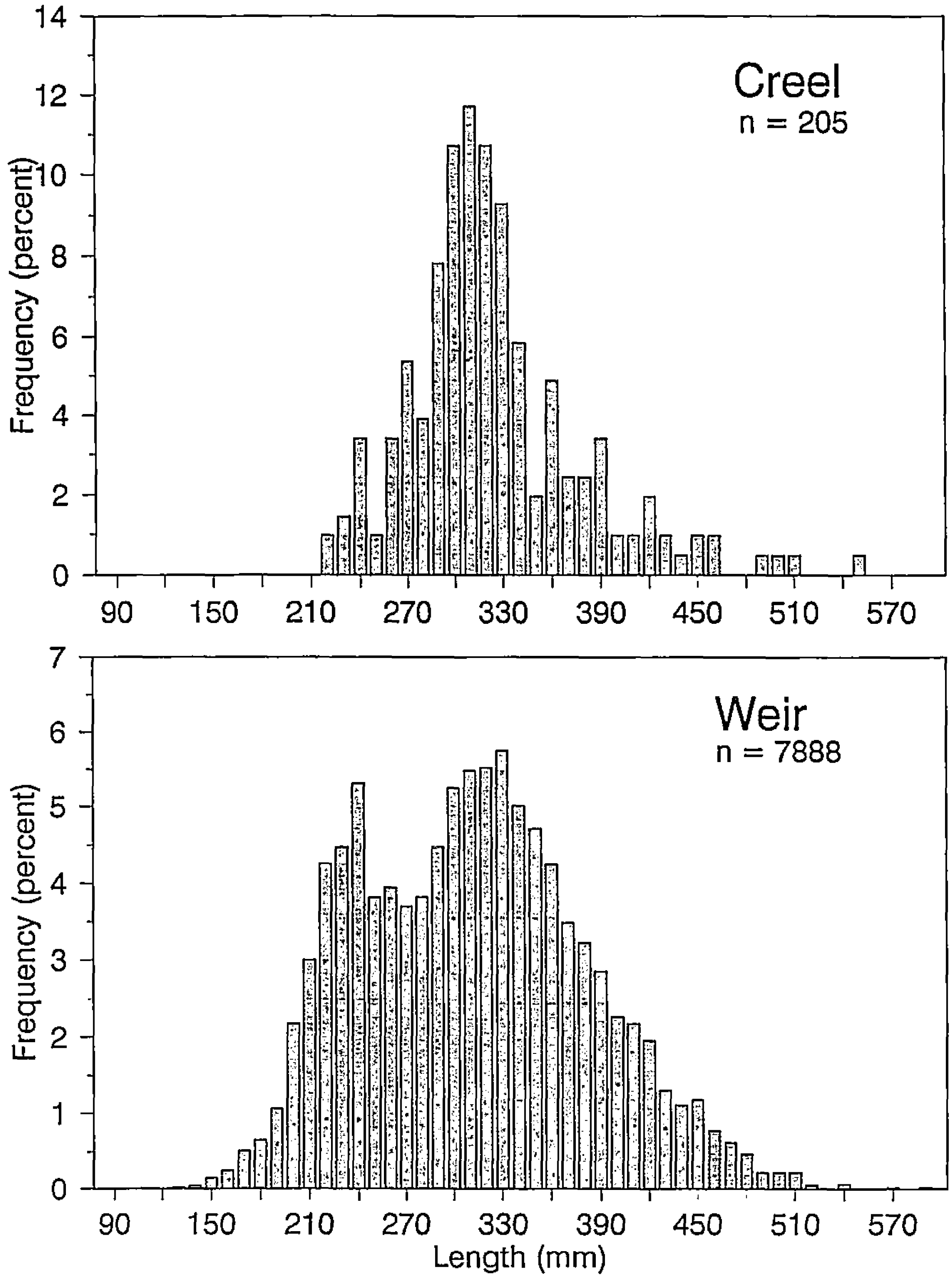

Figure 20. Comparison of length frequencies from 1990 creel and 1990 weir, Buskin River Dolly Varden.

taken at the lower site. When comparing length and maturity state, the two years were very different from each other. There were larger fish in 1990, and there was a higher percentage of mature fish in the larger size categories (> 350 mm) than in 1991 (Table 14). The smaller size categories contained more State I females as expected. Comparing average lengths and ranges by location and maturity states in 1990, State II fish from the July sample in the Buskin River are in the same size class as the State III fish found on the spawning grounds at the northwest end of Buskin Lake (Table 15). From sampling in past years, it is apparent that tens of thousands of Dolly Varden enter the Buskin River in late summer. A high percentage of these fish are sexually mature, indicating that the Buskin River system has a significant spawning population.

During the fall spawning ground survey in 1990, a large number of Dolly Varden were present in Buskin Lake near the outlet. A maturity sample of these fish indicated that 71% of the females were in State V, possibly preparing to spawn in 1991.

Age Composition:

Age classes 3 through 12 were present in the 1990 Dolly Varden immigration maturity sample (Table 16). This sample was dominated by age 7 (28.65%, SE = 3.33) and age 6 (24.86%, SE = 3.19). The mean length for age 7 Dolly Varden was 413 mm (SE = 41) and for age 6 was 363 mm (SE = 46) (Table 17). The 1991 Dolly Varden immigration maturity sample contained age classes 3 through 15 (Table 18). Age 6 was the dominant age class (41.40%, SE = 2.92) and age 5 was the second most prevalent age class (22.81%, SE = 2.49). The mean length for age 6 was 312 mm (SE = 32) and age 5 was 295 mm (SE = 20) (Table 19). When the age distribution was broken into maturity states for females, 1990 (53) had more spawners than 1991 (12) (Table 20). The average size of spawners in 1990 (434.17 mm, SE = 34.77) was larger than in 1991 (389.00 mm, SE = 51.76). The Kolmogorov-Smirnov tests showed significant

Table 14. Percent of immigrating female Dolly Varden in each length class by maturity state at the Buskin River weir for 18 - 19 July 1990 and 11 - 20 July 1991.

		Maturity State				
Length	n	I	II	III	IV	V
1990						
n		26	53	0	0	31
< 350	41	58.5%	2.4%	0.0%	0.0%	39.0%
350 - 400	16	12.5%	25.0%	0.0%	0.0%	62.5%
> 400	53	0.0%	90.6%	0.0%	0.0%	9.4%
1991						
n		67	12	0	0	65
< 300	56	78.6%	0.0%	0.0%	0.0%	21.4%
300 - 350	64	35.9%	4.7%	0.0%	0.0%	59.4%
> 350	24	0.0%	37.5%	0.0%	0.0%	62.5%

Table 15. Comparison of average lengths and ranges by maturity state of Dolly Varden from the Buskin River system and the American River, 1990.

Location	Date	Maturity State	Average Length (mm)	Length Range (mm)	Sample Size
Buskin River	7/18 to 7/19	I	306	277 - 391	26
		V	350	258 - 431	31
		II	434	330 - 545	53
Buskin Lake outlet	10/9	I	273	239 - 304	16
		V	305	259 - 366	43
		III	355	349 - 361	2
Buskin Lake northwest end	10/9 to 10/11	III[a]	428	275 - 593	723
American River	10/6 and 10/8	III[a]	405	232 - 648	897

[a] - fish on spawning grounds assumed to be state III.

Table 16. Age distribution of Dolly Varden sampled at the Buskin River weir during immigration, 18 - 19 July, 1990.

	Age										
	03	04	05	06	07	08	09	10	11	12	Total
Females											
Sample size		5	23	22	29	19	6	2	2	1	109
% of sample		2.70	12.43	11.89	15.68	10.27	3.24	1.08	1.08	0.54	58.91
SE		1.20	2.43	2.39	2.68	2.24	1.31	0.76	0.76	0.54	3.63
Males											
Sample size	1		13	24	24	10	3	1			76
% of sample	0.54		7.03	12.97	12.97	5.41	1.62	0.54			41.09
SE	0.54		1.88	2.48	2.48	1.67	0.93	0.54			3.63
All											
Sample size	1	5	36	46	53	29	9	3	2	1	185
% of sample	0.54	2.70	19.46	24.86	28.65	15.68	4.86	1.62	1.08	0.54	100.00
SE	0.54	1.20	2.92	3.19	3.33	2.68	1.59	0.93	0.76	0.54	

Table 17. Mean fork length (mm) at age of Dolly Varden sampled at the Buskin River weir during immigration, 18 - 19 July, 1990.

	Age										
	03	04	05	06	07	08	09	10	11	12	Total
<u>Females</u>											
Mean Length		293.20	315.78	359.68	411.79	419.00	421.33	494.50	479.00	512.00	381.03
SE		13.79	35.96	49.44	51.02	32.65	6.80	71.42	12.73		64.34
Sample Size		5	23	22	29	19	6	2	2	1	109
Minimum		277	258	284	283	360	411	444	470	512	258
Maximum		311	415	432	484	475	430	545	488	512	545
<u>Males</u>											
Mean Length	277.00		351.62	365.25	413.42	432.80	431.33	400.00			388.92
SE			51.67	44.36	26.39	43.81	3.21				50.84
Sample Size	1		13	24	24	10	3	1			76
Minimum	277		286	282	370	344	429	400			277
Maximum	277		414	443	480	510	435	400			510
<u>All</u>											
Mean Length	277.00	293.20	328.72	362.59	412.53	423.76	424.67	463.00	479.00	512.00	384.27
SE		13.79	45.09	46.41	41.36	36.70	7.52	74.34	12.73		59.34
Sample Size	1	5	36	46	53	29	9	3	2	1	185
Minimum	277	277	258	282	283	344	411	400	470	512	258
Maximum	277	311	415	443	484	510	435	545	488	512	545

Table 18. Age distribution of Dolly Varden sampled at the Buskin River weir during immigration, 11 - 20 July, 1991

	Age									
	04	05	06	07	08	09	10	11	 15	Total
Females										
Sample size	9	34	59	26	8	6		1		143
% of sample	3.16	11.93	20.70	9.12	2.81	2.11		0.35		50.18
SE	1.04	1.92	2.40	1.71	0.98	0.85		0.35		2.97
Males										
Sample size	10	31	58	28	7	5	1		1	141
% of sample	3.51	10.88	20.35	9.82	2.46	1.75	0.35		0.35	49.47
SE	1.09	1.85	2.39	1.77	0.92	0.78	0.35		0.35	2.97
All										
Sample size	19	65	118	54	15	11	1	1	1	285
% of sample	6.67	22.81	41.40	18.95	5.26	3.86	0.35	0.35	0.35	100.00
SE	1.48	2.49	2.92	2.33	1.33	1.14	0.35	0.35	0.35	

Table 19. Mean fork length (mm) at age of Dolly Varden sampled at the Buskin River weir during immigration, 11 - 20 July, 1991

	Age									
	04	05	06	07	08	09	10	11	 15	Total
Females										
Mean Length	288.00	287.82	307.49	345.23	363.13	389.50		505.00		316.38
SE	24.42	19.00	29.51	35.06	49.50	40.70				43.49
Sample Size	9	34	59	26	8	6		1		143
Minimum	239	262	246	305	322	349		505		239
Maximum	311	340	399	445	450	442		505		505
Males										
Mean Length	276.00	302.35	316.28	358.00	381.86	427.60	393.00		524.00	327.87
SE	28.76	17.44	33.87	35.14	38.78	32.37				47.93
Sample Size	10	31	58	28	7	5	1	1		141
Minimum	223	270	203	300	333	398	393		524	203
Maximum	310	333	385	429	425	477	393		524	524
All										
Mean Length	281.68	294.75	311.68	351.85	371.87	406.82	393.00	505.00	524.00	321.98
SE	26.77	19.55	31.83	35.36	44.31	40.54				46.03
Sample Size	19	65	118	54	15	11	1	1	1	285
Minimum	223	262	203	300	322	349	393	505	524	203
Maximum	311	340	399	445	450	477	393	505	524	524

Table 20. Mean length by age group and sexual maturity of female immigrating Dolly Varden at the Buskin River weir, July 1990 and July 1991.

	Age Group									
Component	4	5	6	7	8	9	10	11	12	Total
1990										
Nonspawner[a]										
Mean Length	293.20	311.57	339.38	350.11	386.20					330.73
SE	13.79	33.45	40.77	36.13	31.25					42.02
Sample Size	5	21	16	9	5					56
Spawner[b]										
Mean Length		360.00	413.83	439.55	430.71	421.33	494.50	479.00	512.00	434.17
SE		42.43	20.99	25.96	24.78	6.80	71.42	12.73		34.77
Sample Size		2	6	20	14	6	2	2	1	53
1991										
Nonspawner[a]										
Mean Length	288.00	287.82	305.91	339.36	339.25	407.75				309.73
SE	24.42	19.00	27.14	34.60	13.25	37.65				36.29
Sample Size	9	34	58	22	4	4				131
Spawner[b]										
Mean Length			399.00	377.50	387.00	353.00		505.00		389.00
SE				15.02	63.42	5.66				51.76
Sample Size			1	4	4	2		1		12

[a] State I or V maturity state.

[b] State II maturity state.

differences between the length distribution of all spawners in 1990 and 1991 (D_{MAX} = 0.0456, P = 0.0001). For 1990, K-S tests showed significant differences between the sexes (D_{MAX} = 0.1983, P = .0493) and between spawners and nonspawners (D_{MAX} = 0.8373, P < 0.0001). For 1991, K-S tests showed no significant difference at 95% confidence between the sexes (D_{MAX} = 0.1479, P = 0.0725), and significant differences between spawners and nonspawners (D_{MAX} = 0.7793, P < 0.0001).

Fall Spawning Population Estimates

Chi-square test indicated no evidence of unequal mixing of marked and unmarked fish between sublocations at the American River in both 1990 and 1991 (Table A-5). At the American River there was no size selectivity between events from Kolmogorov-Smirnov and Anderson-Darling test results (Table A-6). The Petersen estimate for the American River in 1990 was 3,947 Dolly Varden (SE = 540.33). In 1991, the Petersen estimate for the American River was 3,375 Dolly Varden (SE = 469). These are consistent with the 1989 estimate of 4,125 fish (SE = 805, Sonnichsen 1990) and with the 1988 estimate of 3,048 fish (SE = 419, Sonnichsen et al. in press).

I attempted to do a stratified Petersen estimate at the Olds River in 1991 that was separated by two length groups, but could not because there were negative capture probabilities (p_j) in sublocation 1 for both length groups. The non-stratified Petersen estimate was 2,669 Dolly Varden (SE = 197), however this is a biased estimate due to significant differences in capture probabilities and size selectivity. This estimate is less than the estimate obtained in 1989 of 3,856 (SE = 545) (Sonnichsen 1990). The population estimate was not performed in 1990 for the Olds River due to high water conditions.

There was size selectivity between events one and two in 1990 at the northwest end of Buskin Lake but no selectivity between the events one and three or between events two and three. During the 1991 survey, there was size selectivity between events one and two releases only, but since the two samples were random with respect to size it was not necessary to stratify the Buskin Lake population estimate by size (Table A-7). Chi-square results indicated no evidence of unequal mixing in 1991 (Table A-8). The estimate for spawning adults in 1990 in Buskin Lake was 19,289 fish (SE = 5,824) and in 1991, was 3,711 Dolly Varden (SE = 1,179). Variance estimates from both years were high due to the low number of recaptures from previous events (Table 21). These surveys showed that a large number of spawning adults were present in the Buskin River system that have not been documented previously.

In 1990, only 87 fish were found in the mainstem of the Buskin River. These consisted of adults with an average size of 385 mm. High numbers of small (average size = 260 mm) Dolly Varden were present in the upper section of the Buskin River near the lake outlet as was documented in 1989 (Sonnichsen 1990). A large number of Dolly Varden, averaging 299 mm, were also present in the lake near the outlet. Length frequencies among all four Buskin River system survey sites were significantly different (Figure 21, Table A-9).

Of the 143 fish tagged at Pillar Creek in 1990, no fish were recovered in any location in Chiniak Bay in 1991 or 1992. No recovery survey in Pillar Creek was performed in 1991 to discern if Chiniak Bay fish were migrating to this site.

In a comparison of length frequencies of all three spawning ground survey sites (American and Olds rivers, and Buskin Lake) in 1991, it is apparent the lengths differ (Figure 22). The Olds River had the smallest fish and Buskin Lake had the largest fish. This is reflected in the Kolmogorov-Smirnov tests as they were all significantly different from each other. For comparison of the Olds River and American River, $D_{MAX} = 0.4448$, $P < 0.0001$. For the Olds River and Buskin Lake, $D_{MAX} = 0.5142$, $P < 0.0000$. For the comparison between the American River and Buskin Lake, $D_{MAX} = 0.1324$, $P = 0.0004$.

Table 21. Release and recapture data for Petersen estimates on Dolly Varden in the Chiniak Bay area, October 1990 and 1991.

Location Sampled	Date	Number Tagged	Number Recaptures[a]	Number Unique Examined[b]
<u>1990</u>				
American River	10/6	546	69	617
	10/8	212	27	280
Olds River	10/7	10	1	12
Northwest end of Buskin Lake	10/9	51	2	53
	10/10	534	69	603
	10/11	62	7	69
Outlet of Buskin Lake	10/9	259	37	296
Buskin River mainstem	10/9	79	8	87
Buskin River near lake outlet	10/10	0	4	276
Pillar Creek	10/10	143	0	255
<u>1991</u>				
Olds River	10/7	508	-	508
	10/8	366	38	367
	10/12	325	106	325
American River	10/9	319	-	319
	10/11	421	39	421
Buskin Lake - northwest end	10/10	201	-	201
	10/13	146	7	146

[a] Number of recaptures from previous events in 1991.

[b] Including fish measured only.

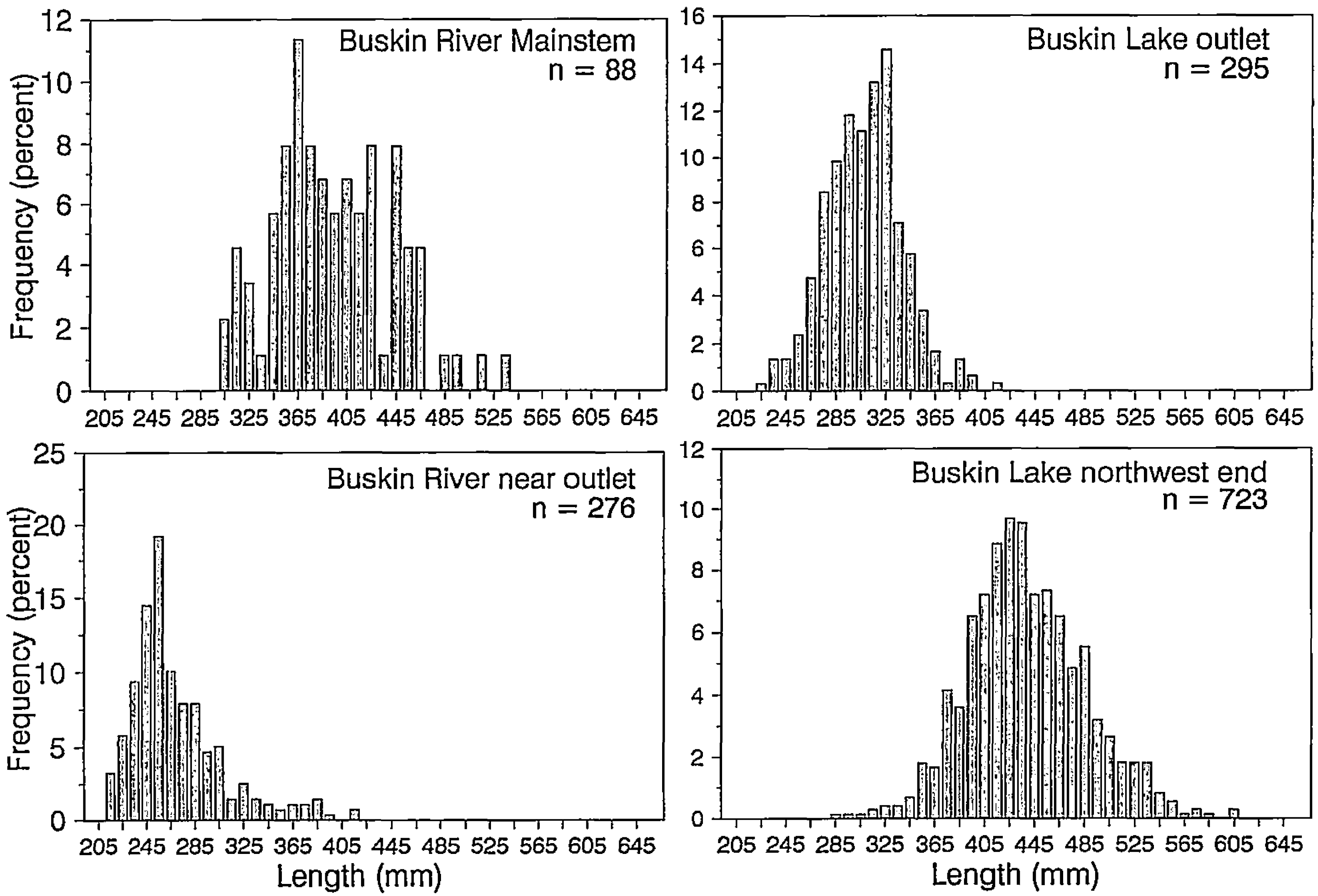

Figure 21. Length frequencies of Buskin River system Dolly Varden at four locations, October, 1990.

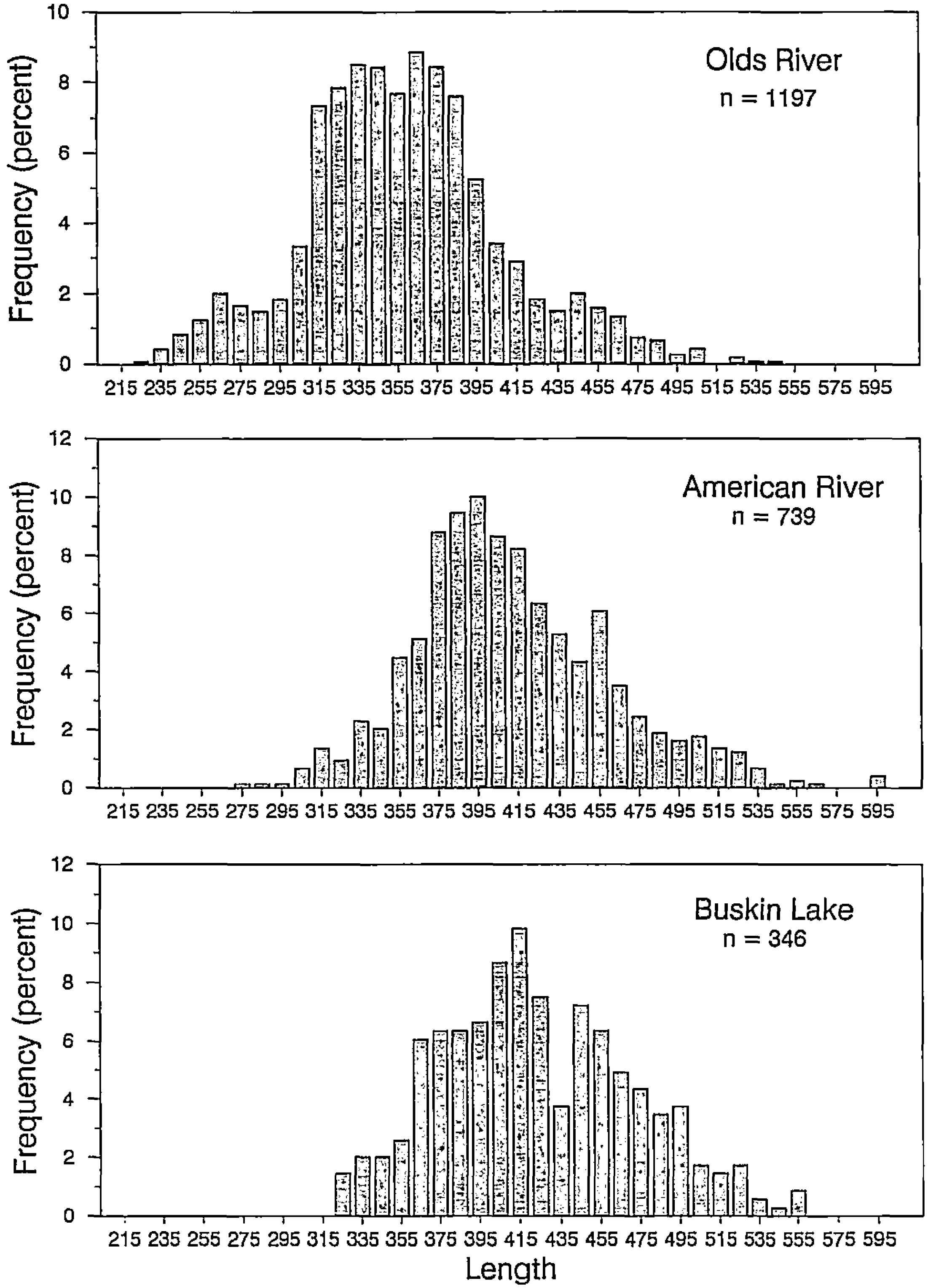

Figure 22. Comparison of length frequencies for spawning ground surveys. October 1991.

Dynamic Pool Model Simulation

Using a length-specific exploitation similar to the 1990 creel length frequency data in the simulations with the dynamic pool model showed that increasing levels of fishing mortality of the entire stock had little effect on Relative Stock Density (Figure 23). RSD-350 for the sport harvest only increased sharply from 25% to a 50% fishing mortality. The RSD-400 remained constant with increased fishing at the lower, base level of length-specific exploitation. In contrast, when simulated harvest targeted larger fish, RSD-350 for the creel decreased by as much as 40% with increased fishing mortality in the second year (Figure 24). The RSD-350 for the "true" population decreased in the same manner, by as much as 50%. Since the proportion of fish over 350 mm in the "true" population was smaller (20%) than in the creel (55%), the change over time was greater in comparison. This was especially evident in the early warning representation in both the "true" population and the sport harvest.

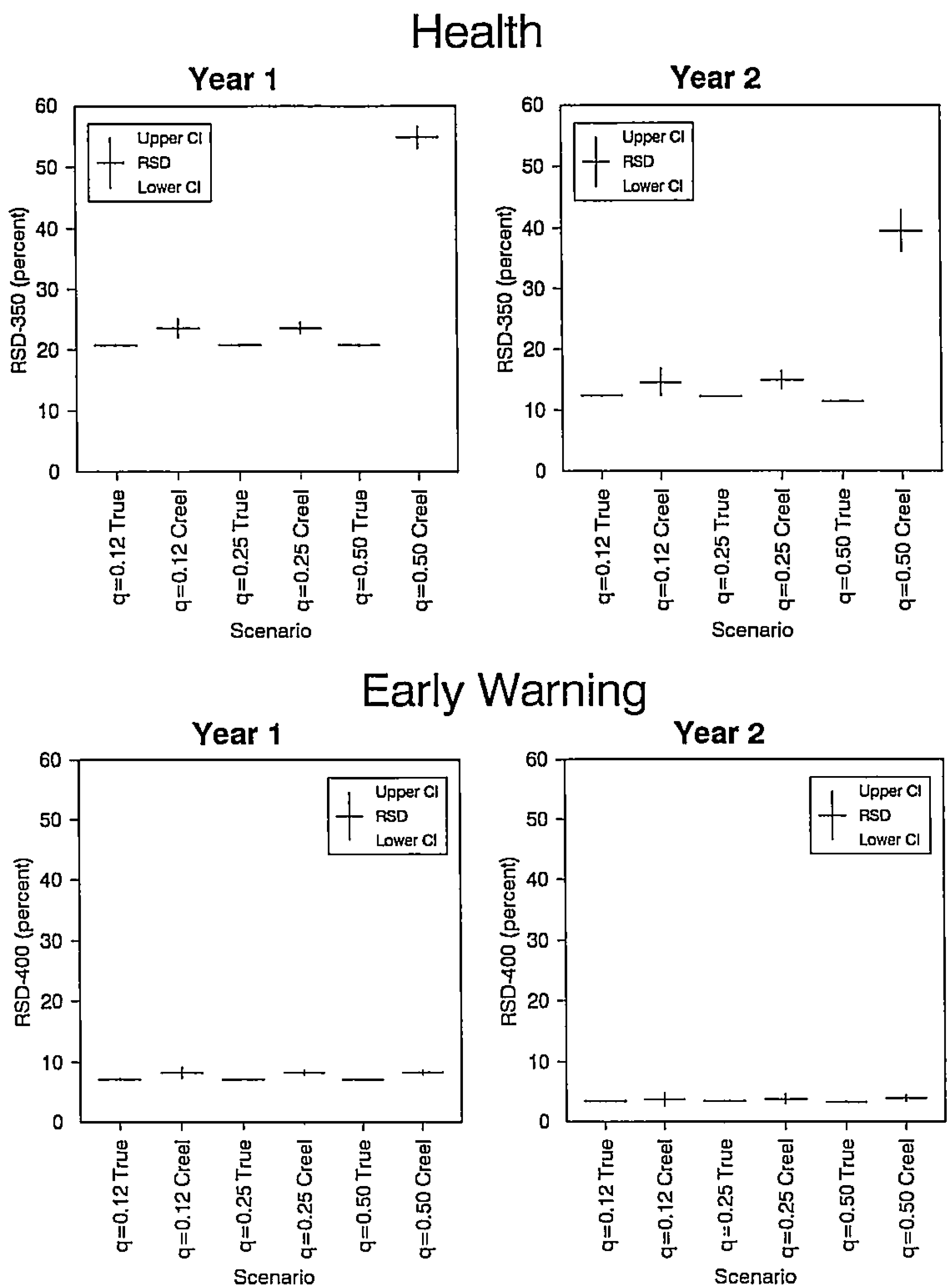

Figure 23. Results from simulation of various scenarios of catchability on Buskin River Dolly Varden using Relative Stock Density (RSD) as an index. Length specific harvest is 1990 base level.

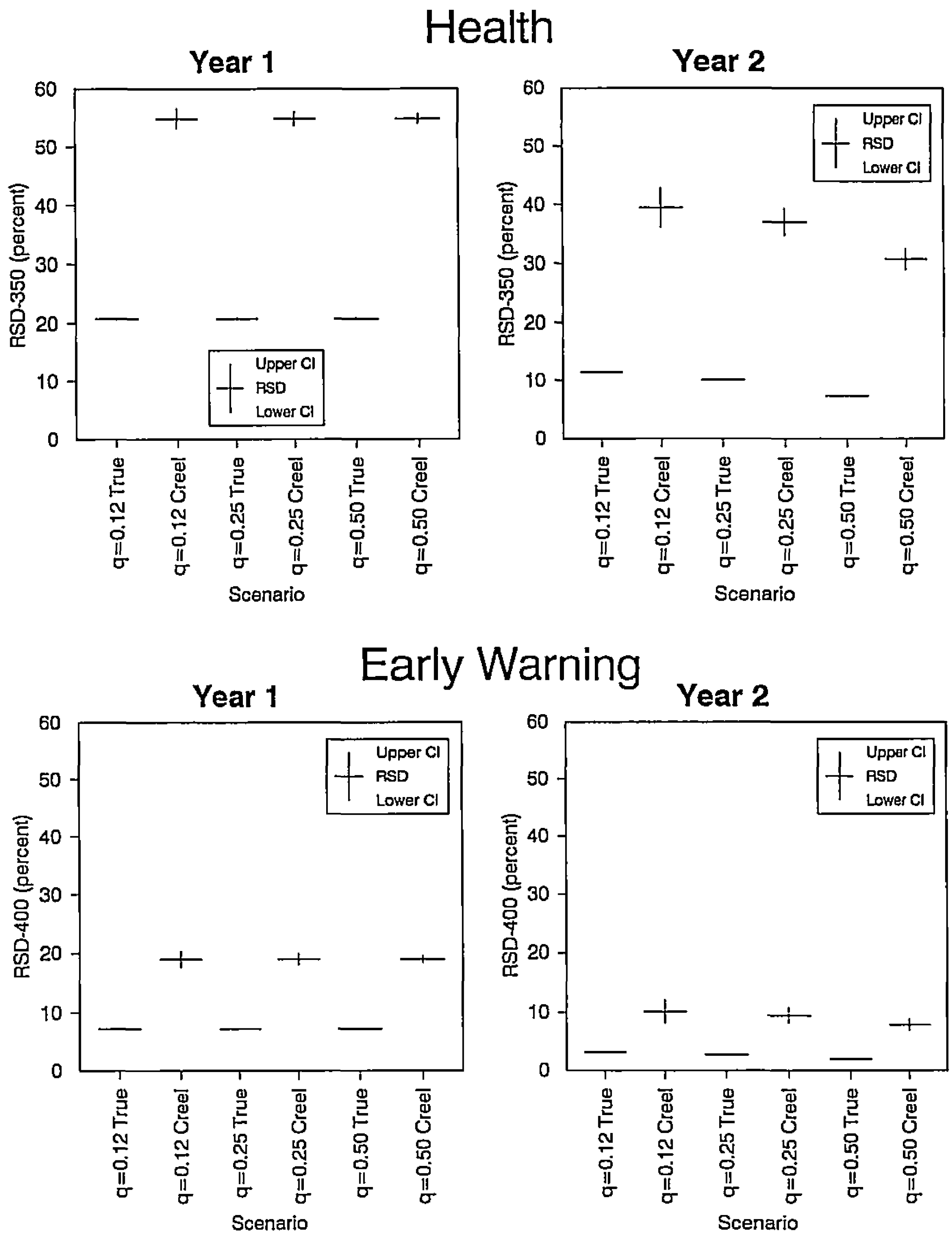

Figure 24. Results from simulation of various scenarios of catchability on Buskin River Dolly Varden using Relative Stock Density (RSD) as an index. Length specific harvest is larger than 1990 base level.

DISCUSSION

Interpretation of Results

The Buskin River spring emigration varied considerably over the three years of this study. From weir counts, abundance dropped by over 65% from 1990 to 1991, but improved by over 40% from 1991 to 1992. It was obvious there was a larger recruit class of Dolly Varden in 1992 than in previous years as evidenced by the weighted length distribution comparisons. These length distribution comparisons for the 1992 spring emigration are questionable though because of the high percentage (44.5%) of Dolly Varden that were not measured on 25 May due to high water.

Temporal length composition changes were similar in all three years in that the large fish emigrated first, followed by smaller size fish. In 1992, a pulse of larger fish appeared with the high concentrations of smaller fish near the end of the emigration, flattening out the length distribution.

The emigration from Lake Louise dropped in 1992 from 1991 by over 25%. It is possible that a portion of the Lake Louise overwintering population had moved to Buskin Lake, especially because the Buskin Lake emigration increased in 1992. Lake Louise Dolly Varden exhibited similar temporal length composition changes as Buskin Lake with a pulse of large fish near the end of the emigration. The narrower length interval of fish at that time could be due to the smaller sample size at Lake Louise versus Buskin Lake. In general, Dolly Varden from Lake Louise were smaller than Buskin Lake, but the difference between the two was smaller in 1992 than in 1991.

The dominant age groups from the emigration sample were age 5 and 6. Maturity samples taken in 1990 and 1991 indicated that most of these fish were preparing to spawn the next year. This is further evidence for a higher number of recruit age fish this year compared to previous years.

Sport caught Dolly Varden were mainly below 350 mm from the 1990 creel survey. This suggests that anglers retained fish in similar concentrations by length as the Dolly Varden passing through the weir at the same time instead of targeting larger fish as expected from sport anglers.

The percentage of State II females in 1991 (8.3%) was significantly lower than 1990 (48.2%), perhaps because in 1991 the weir was at the lake when the maturity sample was taken. Also, the major portion of mature adults could have entered the Buskin River at a different time and may have been missed with the 1991 sample, especially considering the number of mature adults returning was considerably lower in 1991 than in 1990.

The modal age of Dolly Varden in the maturity sample changed from 1990 to 1991 by a year class. In 1990, the dominant age class was age 7 and in 1991, it was age 6. Also, the mean length of spawners was smaller in 1991 than in 1990.

The tag loss estimates for adipose clipped fish increased over the years as expected. It is logical to assume Dolly Varden tag loss would increase over time. Several recommendations concerning clipping adipose fins for a tag loss study have surfaced. First, a comprehensive baseline estimate of naturally missing adipose fins for the population in question must be acquired for all size groups. Second, great care must be given to the clipping procedure and in the observation of clips in subsequent years. Buskin River Dolly Varden seem to exhibit adipose fin regeneration or naturally possess a disfigured fin as evidenced by at least 4 fish with missing fins found in 1992 in length groups extremely unlikely to have been part of the 1989 adipose fin clip sample. Ventral clips, on the other hand, apparently do not need as much attention to detail as the adipose clip. The fin is clipped at the bone and does not regenerate. Therefore, the tag loss estimate of 1.82% from the left ventral clip was used in all analyses. This level of tag loss was considered fairly insignificant and I would conclude the Jolly-Seber assumption that fish do not lose their marks is sufficiently met.

Given the age structure observed in the 1992 spring sample and a survival rate of 6% (from the weir calculations), the population size required to sustain Dolly Varden from age 4 to age 9 would be far greater than the weir counts from any of the three years.

The Jolly-Seber abundance estimate for 1991 of 60,585 was significantly higher than the weir count of 30,725 in 1991. Also, differences between survival rates calculated from recaptures at the weir and the Jolly-Seber estimates imply that there is a portion of the recaptures that may be alive but are not seen at the weir. This leads me to believe we are missing a portion of the super-population through the weir. Six possible explanations are evident. First, Dolly Varden may remain in Buskin Lake during the time of weir operation. Second and third, Dolly Varden may leave Buskin Lake before or after weir operation. Fourth, these fish may overwinter in another freshwater system other than Buskin Lake. Fifth, the Dolly Varden may overwinter in marine waters. Finally, it is possible the Jolly-Seber estimate is biased and the conclusions made above would be in error.

Ericksen and Marshall (1991) discovered Dolly Varden of all sizes staying in Chilkat Lake, Haines after the emigration. No surveys in Buskin Lake during the summer months were performed. It seems unlikely that Dolly Varden leave Buskin Lake before or after weir operation because weir counts at the beginning and end of weir operation were very low. Sonnichsen et al. (In prep) concluded these fish were not overwintering in freshwater systems outside of Chiniak Bay. Over 31,000 Dolly Varden were tagged during this study within and outside the

Chiniak Bay area and no Dolly Varden were recaptured in nearby Pasagshak, Saltery or Afognak rivers during extensive tagging efforts. Bias of the Jolly-Seber estimates is possible, but the survival estimate of 29% is closer to the survival estimate of 23.5% reported by Armstrong and Morrow (1980) than the weir estimates of survival of 6% for 1991.

I would conclude Dolly Varden are either remaining in the Buskin Lake through the summer or staying in the marine waters throughout the winter. Further investigation is needed to fully assess where these fish are located.

From comparison of the Jolly-Seber estimates and the Petersen estimates for the American River spawning population, there is no evidence that this stock of Dolly Varden does not return to the spawning grounds in the American River every year.

From the results of the fall spawning population surveys, I have updated the previous model of stock structure to include Buskin Lake as a significant spawning area for the Chiniak Bay Dolly Varden super-population. This Buskin Lake spawning population is difficult to quantify due to the fish moving on and offshore during the surveys, but it is apparent large numbers of spawning size Dolly Varden occupy this area.

Simulation of the dynamic pool model produced fairly predictable results except that the RSD-400 was not as sensitive an indicator at lower length-specific exploitation as expected. The RSD-350 and RSD-400 were greatly affected by the larger fish exploitation, suggesting that RSD from creel survey data can be used as an effective index when the management concern is for a change in the target size of Dolly Varden from the anglers. However, the RSD from creel survey data is fairly insensitive to all but high rates of fishing mortality.

Comparisons to Other Char Populations

The Chiniak Bay Dolly Varden super-population exhibits marked similarities with the Dolly Varden surveyed by Robert Armstrong in Southeast Alaska from 1962-1972, in particular the Eva Lake-Hood Bay population. Eva Lake and Buskin Lake are at similar latitudes (57°36' and 57°47') and are comparable in size (105 ha and 101 ha respectively). The overwintering population sizes were similar for 1962 Eva Lake and 1990 Buskin Lake of approximately 90,000 fish (Armstrong 1963). Emigration timing and temporal length distributions were alike between the two populations (Armstrong 1965).

Comparison of age samples showed Eva Lake Dolly Varden were larger at age than Buskin Lake fish during the spring emigration, but the two sites were similar during the summer immigration especially in the 1990 Buskin River sample (Heiser 1966).

Armstrong (1974) stated homing to the natal spawning streams was strong and there was no indication of straying between adjacent spawning streams. Only 4 fish tagged in the American River in 1988 had been recaptured in the Olds River in any subsequent event (Table 8).

Blackett (1968) cited no Dolly Varden were observed spawning in Eva Lake, but over 2,000 fish migrating up Eva Creek in 1964 were preparing to spawn that fall. Blackett stated that it was possible the lake may have been too extensive an area to enable location of spawning by observation surveys alone. Lake spawning by Dolly Varden is not well documented in the literature.

Dolly Varden from northwestern Alaska migrate to sea in the spring from overwintering sites in the Noatak, Wulik and Kivalina River systems (DeCicco 1989). These stocks also homed to spawn but there was a component of Dolly Varden that spawned in the summer months instead of the fall. The summer spawners did not migrate to sea the year of spawning. The average size of the Dolly Varden from these three northwest Alaska rivers was much larger and matured at an older age than the Chiniak Bay Dolly Varden (Fred DeCicco, ADF&G Fairbanks, Alaska personal communication).

The Chiniak Bay Dolly Varden super-population also share similarities with some anadromous arctic char populations. Arctic char overwintered in Nauyuk Lake, Northwest Territories, Canada and migrated to sea in the spring (Gyselman 1984). Growth rates from Arctic char in the Vardnes River in northern Norway were up to 80 mm during the summer (Berg and Berg 1989), similar to Chiniak Bay Dolly Varden. Grainger (1953) found the temporal length distribution changes from larger to smaller char in Frobisher Bay, Baffin Island, Canada. Lake spawning is common in anadromous Arctic char in the central Canadian Arctic and in the Arctic islands because the rivers freeze completely in the winter (Johnson 1980).

Management Implications

With discrepancies between the weir count and survival data and the Jolly-Seber estimates, the previous model of stock structure has changed. It was assumed that the entire super-population could be accessed through the weir as the Dolly Varden emigrated Buskin Lake. It was also assumed that all of the Dolly Varden in the Chiniak Bay overwintered in Buskin Lake. There is insufficient data at this time to conclude where the missing portion of fish reside. For the Jolly-Seber estimates to be valid, an assumption must be made that all fish in the Chiniak Bay super-population must pass the weir at least once during the term of the Jolly-Seber estimation. Therefore, parameters estimated using the weir data may be biased and decisions based on these values should be made with caution.

An alternative management approach would be to monitor the fall spawning populations only for fluctuations in population size and length distribution of the spawners. Changes in these stocks would be a clear indicator that the super-population may be affected also.

The modeling exercise revealed Relative Stock Density as an effective management tool for monitoring the harvest to detect changes in length-specific exploitation but not for detecting increasing harvest rates.

Recommendations

Because the Jolly-Seber estimation indicated that a significant portion of the super-population may not pass through the weir each year, the weir operations should continue only as a tool to capture fish for use in the Jolly-Seber method. Abundance and survival estimates from the Jolly-Seber can be utilized in the dynamic pool model. Marking fish will also provide additional data for growth modeling thus increasing precision. I recommend a survey in Buskin Lake during the summer months to ascertain whether Dolly Varden are remaining in the lake instead of emigrating to sea. To reduce bias in the dynamic pool model, I would recommend an extensive age structured length sample be acquired each year the Jolly-Seber is used. This would greatly facilitate a manager's ability to model the super-population with higher confidence.

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Table A-1. Results of the K-sample Anderson-Darling tests on assumptions of size selectivity in Petersen estimates for the Olds River, October 1991. Number of observations in parenthesis. Critical value for T_{akN} = 1.96 at 95% confidence.

First Sample	Second Sample	A^2_{akN}	σ^2	T_{akN}
Event #1[a] Releases (872)	Event #2[a] Releases (326)	0.9344	0.5780	-0.086
Event #1[a] Releases (872)	Event #2[a] Recaptures (106)	6.4618	0.5782	7.183[b]

[a] event #1 is pooled from 10/7/91 and 10/8/91, and event #2 is from 10/12/91.

[b] significantly different at $\alpha = 0.05$

Table A-2. Comparison of number of marked fish in event 2 to number of unmarked fish in event 2 at sublocations within the Olds River, October 1991.

Site	Sublocation 1	Sublocation 2
Marked	19	19
Unmarked	228	101

Chi-square = 5.767, df = 1, P = 0.016.

Table A-3. Weir counts for the Buskin River Dolly Varden emigration, 1985-1992.

Date	1985	1986	1987	1988	1989	1990	1991	1992
21-Apr	2	0	0	0	0	0	0	0
22-Apr	0	0	69	0	0	0	0	0
23-Apr	0	0	49	0	0	0	0	0
24-Apr	0	0	113	0	0	0	0	0
25-Apr	0	0	81	0	0	1	0	0
26-Apr	0	0	33	0	0	0	4	0
27-Apr	0	0	40	0	123	10	0	0
28-Apr	241	0	20	0	0	0	0	0
29-Apr	0	6	62	0	0	7	8	104
30-Apr	0	17	221	0	738	2	249	0
01-May	0	1	14	0	1081	12	0	226
02-May	0	3	27	0	0	492	50	83
03-May	0	3	8	0	17	41	0	108
04-May	0	0	6	0	75	1099	9	0
05-May	158	0	2482	453	98	0	69	0
06-May	0	17	3660	0	2	1999	460	0
07-May	0	16	659	330	298	394	0	814
08-May	0	0	939	408	1215	2663	204	139
09-May	0	1	50	4059	3054	2663	918	461
10-May	0	0	1081	1012	780	10385	185	174
11-May	0	0	3721	6420	3	1152	245	221
12-May	1849	0	35	44	58	976	115	66
13-May	0	0	30	0	2065	1735	619	714
14-May	0	0	109	255	5825	2235	1075	4219
15-May	0	0	1014	340	2307	3656	2635	5355
16-May	0	684	4803	349	1485	2829	1003	2638
17-May	0	161	71	4167	541	1508	151	293
18-May	0	264	3050	29	0	19317	6198	1421
19-May	7584	15099	1318	1920	742	5490	691	3092
20-May	0	1995	2046	1327	10737	3330	2060	3573
21-May	0	3713	541	7041	1791	1043	2636	3127
22-May	0	76	292	421	540	329	365	3220
23-May	0	3215	391	179	720	334	830	2246
24-May	0	14507	130	106	0	315	2883	1259
25-May	0	3	409	1245	30	212	1169	28358
26-May	6456	523	658	40	50	8468	142	1301
27-May	0	1355	25	38	747	40	53	21
28-May	0	0	19	49	6	7140	675	28
29-May	0	0	641	3	66	4162	69	0
30-May	0	0	628	12	10	914	177	3420
31-May	0	0	69	0	289	269	31	2108
01-Jun	0	0	30	1	43	200	60	623
02-Jun	5505	0	15	0	0	20	375	198

(continued)

Table A-3. Weir counts for the Buskin River Dolly Varden emigration, 1985-1992. (continued)

Date	1985	1986	1987	1988	1989	1990	1991	1992
03-Jun	0	0	12	85	0	271	2411	1930
04-Jun	0	0	5	2	0	687	411	0
05-Jun	0	0	10	1	5	248	0	72
06-Jun	0	0	213	0	13	2330	-2	24
07-Jun	0	0	3	0	3	1075	51	623
08-Jun	0	0	7	0	15	420	0	283
09-Jun	0	0	0	0	1	69	791	488
10-Jun	0	0	10	0	1	11	347	382
11-Jun	0	0	0	0	7	32	31	0
12-Jun	0	0	0	0	1	1	17	89
13-Jun	0	0	0	0	2	54	68	31
14-Jun	0	0	0	0	6	325	105	18
15-Jun	0	0	0	0	0	106	79	80
16-Jun	2	0	0	0	2	2	3	12
17-Jun	0	0	0	0	3	0	0	80
18-Jun	0	0	0	0	2	0	0	519
19-Jun	0	0	0	0	1	0	0	0
20-Jun	0	0	0	0	2	0	0	21
21-Jun	0	0	0	0	2	1	0	0
22-Jun	0	0	0	0	1	0	0	0
23-Jun	0	0	0	0	0	0	0	22
24-Jun	0	0	0	0	0	0	0	0
25-Jun	0	0	0	0	0	0	0	0
26-Jun	0	0	0	0	0	0	0	0
27-Jun	0	0	0	0	0	0	0	3
28-Jun	0	0	0	0	0	0	0	158
29-Jun	0	0	0	0	0	0	0	1
30-Jun	0	0	0	0	0	0	0	1
01-Jul	0	0	0	0	0	0	0	0
02-Jul	0	0	0	0	0	0	0	1
03-Jul	0	0	0	0	0	0	0	0
04-Jul	0	0	0	0	0	0	0	2
05-Jul	0	0	0	0	0	0	0	0
06-Jul	0	0	0	0	0	0	0	0
07-Jul	0	0	0	0	0	0	0	0
08-Jul	0	0	0	0	0	0	0	1
09-Jul	0	0	0	0	0	4	0	0
10-Jul	0	0	0	0	0	0	0	0
11-Jul	0	0	0	0	0	0	0	0
12-Jul	0	0	0	0	0	0	0	0
13-Jul	0	0	0	0	0	0	0	0
14-Jul	0	0	0	0	0	0	0	0
15-Jul	0	0	0	0	0	4	0	0
16-Jul	0	0	0	0	0	25	0	0
Total	21797	41659	29919	30336	35603	91107	30725	74451

Table A-4. Daily weir counts for the Lake Louise Dolly Varden emigration, 1991 and 1992.

Date	1991		1992	
	Daily Count	Cumulative	Daily Count	Cumulative
24-Apr	3	3	0	0
25-Apr	0	3	0	0
26-Apr	2	5	0	0
27-Apr	1	6	0	0
28-Apr	2	8	0	0
29-Apr	2	10	0	0
30-Apr	9	19	0	0
01-May	5	24	0	0
02-May	5	29	0	0
03-May	5	34	0	0
04-May	3	37	0	0
05-May	3	40	0	0
06-May	4	44	30	30
07-May	17	61	18	48
08-May	6	67	26	74
09-May	9	76	0	74
10-May	6	82	1	75
11-May	2	84	13	88
12-May	2	86	65	153
13-May	4	90	115	268
14-May	13	103	63	331
15-May	11	114	64	395
16-May	11	125	17	412
17-May	11	136	11	423
18-May	251	387	12	435
19-May	50	437	130	565
20-May	33	470	109	674
21-May	13	483	119	793
22-May	64	547	293	1086
23-May	223	770	210	1296
24-May	103	873	40	1336
25-May	167	1040	197	1533
26-May	175	1215	778	2311
27-May	274	1489	173	2484
28-May	56	1545	136	2620
29-May	130	1675	169	2789
30-May	152	1827	64	2853

(continued)

Table A-4. Daily weir counts for the Lake Louise Dolly Varden emigration, 1991 and 1992. (continued)

Date	1991		1992	
	Daily Count	Cumulative	Daily Count	Cumulative
31-May	61	1888	67	2920
01-Jun	70	1958	21	2941
02-Jun	268	2226	80	3021
03-Jun	517	2743	66	3087
04-Jun	247	2990	179	3266
05-Jun	150	3140	15	3281
06-Jun	177	3317	6	3287
07-Jun	44	3361	21	3308
08-Jun	74	3435	8	3316
09-Jun	582	4017	36	3352
10-Jun	311	4328	12	3364
11-Jun	129	4457	12	3376
12-Jun	121	4578	3	3379
13-Jun	28	4606	7	3386
14-Jun	26	4632	8	3394
15-Jun	28	4660	4	3398
16-Jun	3	4663	6	3404
17-Jun	6	4669	13	3417
18-Jun	0	4669	5	3422
19-Jun	0	4669	0	3422

Table A-5. Comparison of number of marked fish in event 2 to number of unmarked fish in event 2 at sublocations within the American River, October 1990 - 91.

Site	Sublocation 1	Sublocation 2
1990		
Marked	26	17
Unmarked	152	91
Chi-square = 0.068, df = 1, P = 0.794.		
1991		
Marked	22	17
Unmarked	236	160
Chi-square = 0.149, df = 1, P = 0.700.		

Table A-6. Results of the Kolmogorov-Smirnov two-sample and K-sample Anderson-Darling tests on assumptions of size selectivity in Petersen estimates for the American River, October 1990-91. Number of observations in parenthesis. Critical value for T_{akN} = 1.96 at 95% confidence.

First Sample	Second Sample	Test Statistics		
1990		D_{MAX}	P	
Event #1 Releases (617)	Event #2 Releases (280)	0.0461	0.7762	
Event #1 Releases (617)	Event #2 Recaptures (43)	0.0772	0.9634	
1991		A^2_{akN}	σ^2	T_{akN}
Event #1 Releases (318)	Event #2 Releases (419)	0.4722	0.5767	-0.695
Event #1 Releases (318)	Event #2 Recaptures (39)	0.6073	0.5755	-0.518

Table A-7. Results of the Kolmogorov-Smirnov two-sample and K-sample Anderson-Darling tests on assumptions of size selectivity in Petersen estimates for Buskin Lake, October 1990 - 91. Number of observations in parenthesis. Critical value for T_{akN} = 1.96 at 95% confidence.

First Sample	Second Sample	Test Statistics		
1990		D_{MAX}	P	
Event #1 Releases (53)	Event #2 Releases (603)	0.2789	0.0006[a]	
Event #2 Releases (603)	Event #3 Recaptures (68)	0.1586	0.0835	
Event #1 Releases (53)	Event #3 Recaptures (68)	0.1859	0.2156	
1991		A^2_{akN}	σ^2	T_{akN}
Event #1 Releases (200)	Event #2 Releases (146)	5.9354	0.5734	6.518[a]
Event #1 Releases (200)	Event #2 Recaptures (7)	0.8317	0.5822	-0.221

[a] Significantly different at α = 0.05.

Table A-8. Comparison of number of marked fish in event 2 to number of unmarked fish in event 2 at sublocations within the northwest end of Buskin Lake, October 1991.

Site	Sublocation 1	Sublocation 2
Marked	6	1
Unmarked	123	16

Chi-square = 0.050, df = 1, P = 0.823.

Table A-9. Results of Kolmogorov-Smirnov tests on length distributions for Buskin River system fall spawning ground surveys. Number of observations in parenthesis.

Location #1	Location #2	D_{MAX}	P
Buskin Lake - northwest end (723)	Buskin River - mainstem (88)	.3499	.0000[a]
Buskin River - mainstem (88)	Buskin River - near lake outlet (276)	.8878	.0000[a]
Buskin River - near lake outlet (276)	Buskin Lake - outlet (295)	.5229	.0000[a]
Buskin Lake - northwest end (723)	Buskin River - near lake outlet (276)	.8990	.0000[a]
Buskin Lake - northwest end (723)	Buskin Lake - outlet (295)	.8352	.0000[a]
Buskin River - mainstem (88)	Buskin Lake - outlet (295)	.7095	.0000[a]

[a] - Significantly different at $\alpha = 0.05$.