Fishery Data Series No. 92-29

Stock Assessment of Dolly Varden in the Buskin River, Kodiak Island, Alaska, 1991

by

Mary E. Whalen

September 1992

Alaska Department of Fish and Game

Division of Sport Fish

FISHERY DATA SERIES NO. 92-29

STOCK ASSESSMENT OF DOLLY VARDEN IN THE BUSKIN RIVER, KODIAK ISLAND, ALASKA, 1991[1]

By

Mary E. Whalen

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

September 1992

[1] This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-7, Job No. S-2-3.

The Fishery Data Series was established in 1987 for the publication of technically oriented results for a single project or group of closely related projects. Fishery Data Series reports are intended for fishery and other technical professionals. Distribution is to state and local publication distribution centers, libraries and individuals and, on request, to other libraries, agencies, and individuals. This publication has undergone editorial and peer review.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABSTRACT

During April 19-June 17, 1991, a weir was operated at the outlet of Buskin Lake to estimate abundance, growth, length distribution, maturity state, and run timing of Dolly Varden *Salvelinus malma*. Of a total of 30,725 Dolly Varden that emigrated through the weir, 4,500 were tagged and 480 were recaptured from previous tagging. A total of 4,669 Dolly Varden were counted emigrating through the Lake Louise weir. The weir was reinstalled at the Buskin Lake site on June 22 and operated through July 27 to enumerate sockeye salmon. Dolly Varden immigration into the lake was minimal during this time. The weir was moved to the lower Buskin River on August 19. Of the Dolly Varden entering the Buskin River between July 11 and 20, only 8.3% were mature. Age composition analysis on the 1990 and 1991 maturity samples indicated a shift in the dominant year class from age 7 to age 6. Total immigration of Dolly Varden could not be estimated because the weir was not in operation from July 25 to August 19 and because fish continued to enter the river into the fall. Spawning ground surveys on the American and Olds rivers found 3,376 and 2,669 Dolly Varden, respectively. A survey at the northwest end of Buskin Lake found 3,712 Dolly Varden.

KEY WORDS: Buskin River, Dolly Varden, *Salvelinus malma*, abundance, growth, length, maturity, age composition, American River, Olds River.

INTRODUCTION

The Buskin River (Figure 1), near the city of Kodiak, is the most intensively fished river on Kodiak Island. In 1990, approximately 40% of the freshwater sport fishing effort on Kodiak Island occurred on the Buskin River (Mills 1991). Angler effort on the Buskin River is directed toward Dolly Varden *Salvelinus malma*, coho salmon *Oncorhynchus kisutch*, sockeye salmon *O. nerka*, and pink salmon *O. gorbuscha*. The Dolly Varden sport harvest ranged from 5,293 to 15,150 fish annually during the period 1977 through 1990 (Mills 1979-1991).

Buskin Lake (Figure 2) is the major overwintering area for Dolly Varden from tributaries throughout Chiniak Bay. This "super-population" of Dolly Varden that overwinter in Buskin Lake emigrate from Buskin River in the spring to feed in marine waters during summer. Some enter other streams to spawn before returning to the lake to overwinter again in the fall (Sonnichsen 1990). Historically, the Buskin River was not thought a significant spawning stream, with as few as 500 Dolly Varden observed spawning in all Buskin River tributaries (Marriott 1965). In 1990, a substantial number of Dolly Varden were discovered spawning in Buskin Lake. Also, 48.2% of the females entering the Buskin River in July were mature (Whalen 1991). A more intensive fall survey on Buskin Lake was performed in 1991 to determine the spawning population size. Dolly Varden found in the Buskin River 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 number available for sport harvest in all of the Chiniak Bay streams.

This is the seventh year of a long-term study of the Dolly Varden fishery in the Buskin River. Since inception, work on this project has concentrated on developing a model of stock structure for this resource. The ultimate goal is to estimate key parameters of the superpopulation of Dolly Varden that overwinter in Buskin Lake. Eventually, data from many years will be used to estimate the population parameters in question, namely abundance, recruitment, survival, fishing mortality and sustained yield. This document is an interim working report to account for methods and results of the 1991 season.

Specific objectives for the 1991 study were to:

1. census the emigration of Dolly Varden 210 mm or longer (fork length) through the weir on the Buskin River from mid-April through mid-June;

2. estimate abundance, recruitment, and survival of emigrating Dolly Varden 300 mm and over for the 1989 season with the Jolly-Seber method using 1989, 1990, and 1991 data;

3. estimate length compositions of Dolly Varden during the entire spring emigration;

4. census the emigration of Dolly Varden 210 mm or longer (fork length) through the weir on the stream leaving Lake Louise and entering the Buskin River from mid-April through mid-June;

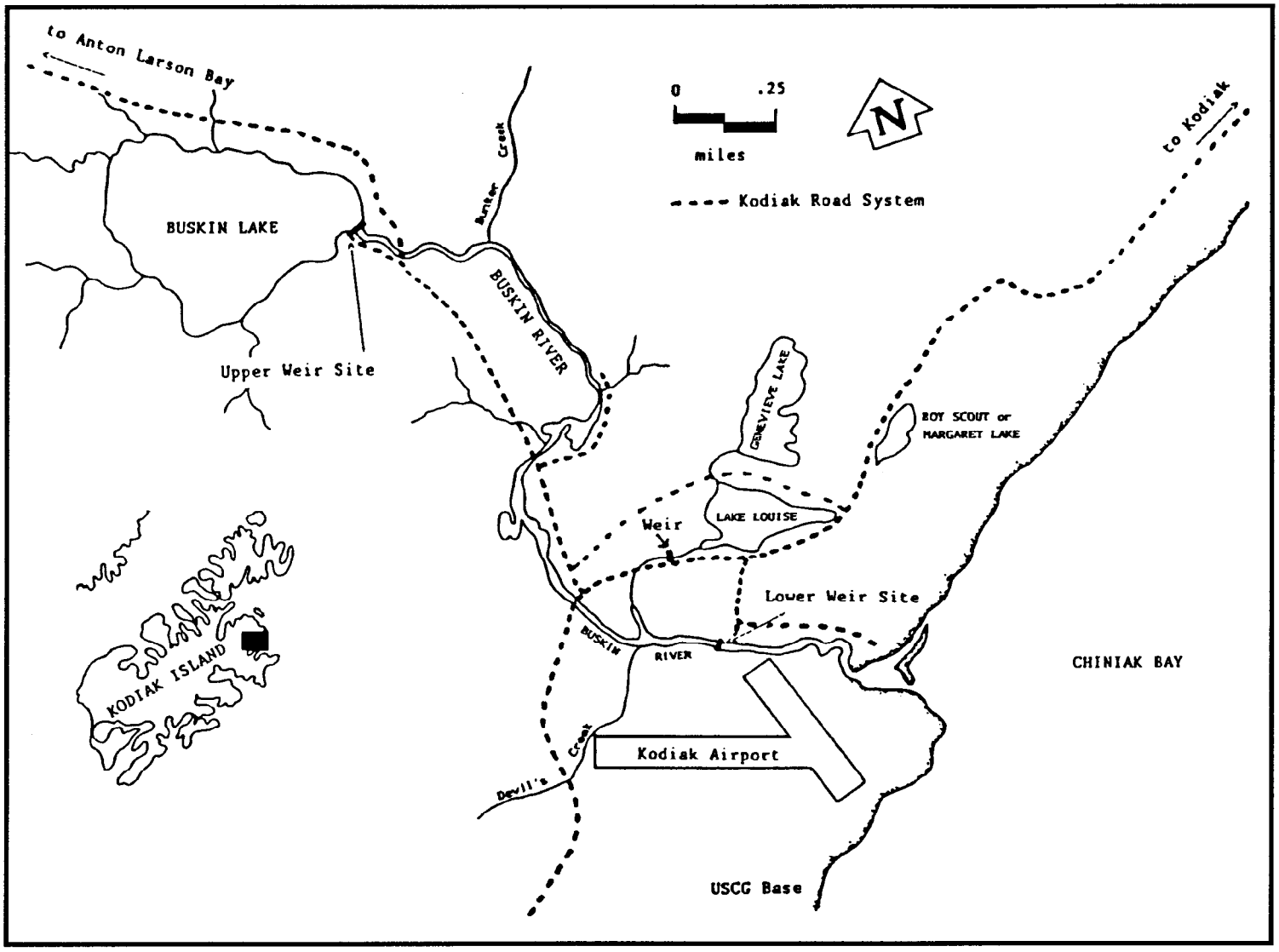

Figure 1. Buskin River, Kodiak Island, Alaska.

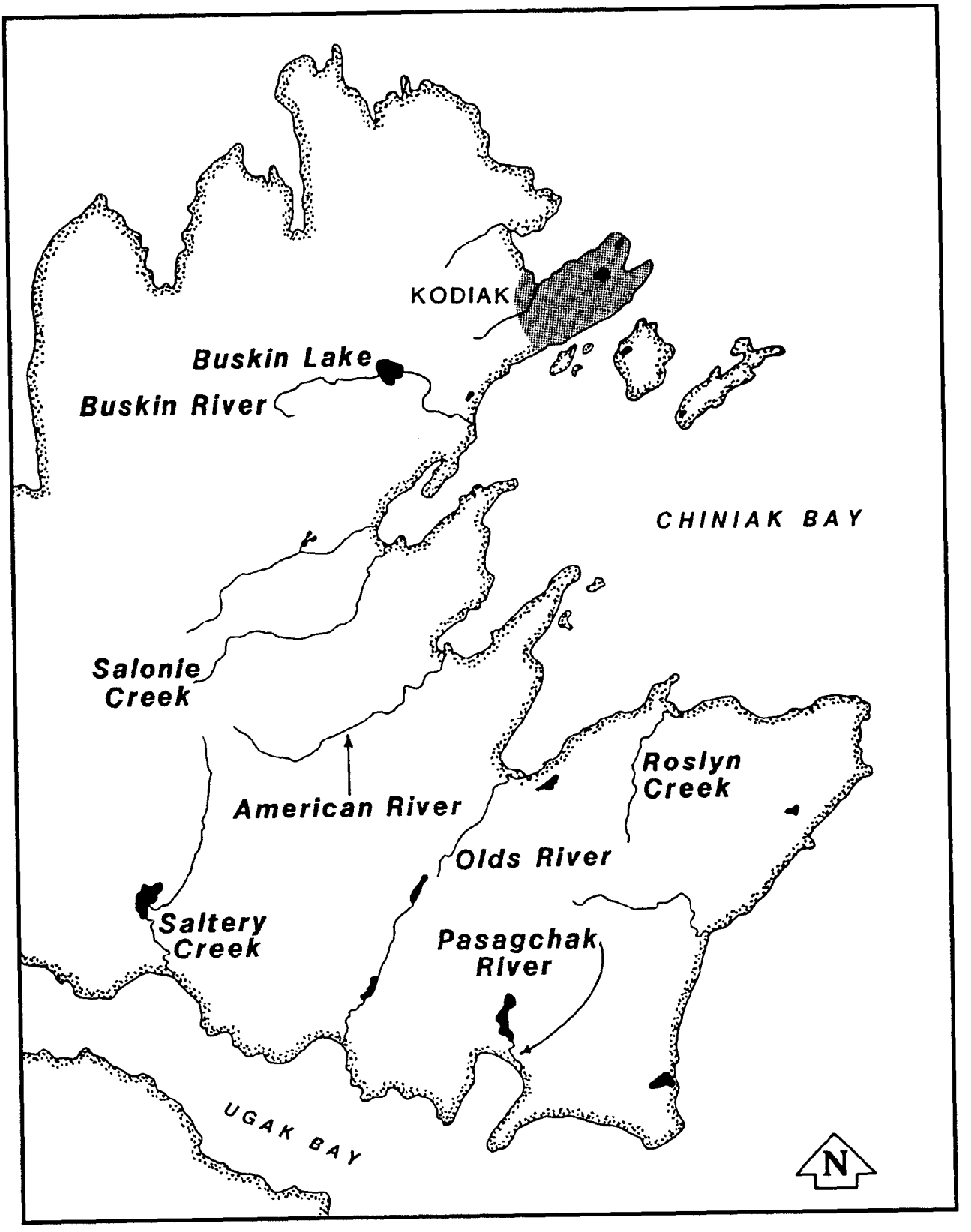

Figure 2. The Chiniak Bay area, Kodiak Island, Alaska.

5. estimate length compositions of Dolly Varden during the emigration from Lake Louise;

6. estimate relative maturity of immigrating female Dolly Varden with instantaneous samples taken every 2 weeks from July to late September when the weir is in operation;

7. estimate age composition of maturity samples taken in 1990 and 1991; and

8. estimate the spawning abundance of Dolly Varden in the Olds and American rivers and Buskin Lake during early October.

METHODS

Dolly Varden Census

To achieve these objectives, the following activities were undertaken: a weir was constructed at the outlet of Buskin Lake and on the stream leaving Lake Louise through which Dolly Varden were counted, maturity and otolith samples were taken from immigrating fish during summer weir operation, and fall spawning ground surveys were conducted in October on the Olds and American rivers and Buskin Lake.

Buskin River Weir:

Dolly Varden emigration was assessed with the use of an aluminum picket weir overlaid with 1 inch Vexar plastic mesh. A trap was incorporated into the weir to facilitate the capture and retention of Dolly Varden. The weir was installed at the outlet of Buskin Lake on April 19 and continued until June 17. I believe the initial portion of the emigration was not missed because the weir was installed as close to ice breakup as possible. There were two instances of missed counts during the spring weir operation. On May 6, water levels rose above the pickets of the weir over a 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 in a half hour time period 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 using counts from the first trap of the morning for 3 days on either side of that date and averaging.

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

The weir was reinstalled at the lake site on June 22 to continue the sockeye salmon immigration census. Dolly Varden immigrating into Buskin Lake were also enumerated at that time, though numbers were minimal. The weir was dismantled on July 25 and was not in operation again until August 21 when the weir was moved to 1.4 km upstream of tidewater to census coho salmon immigration.

Lake Louise Weir:

To determine if a significant population of Dolly Varden was residing in a connecting lake system of the Buskin River, a weir was installed on the stream that runs between Lake Louise and the Buskin River on April 24, 1991. Lake Louise and Genevieve Lake are part of this alternate lake system. The Dolly Varden from these lakes were assessed with the use of a wood frame weir overlaid with 1 inch Vexar plastic mesh. A trap was incorporated into the center of the weir to facilitate capture and retention of Dolly Varden. All fish emigrating this system were measured for fork length only. No tagging was performed at this site. All Dolly Varden were examined for the presence of a tag and an adipose finclip. On numerous occasions, this weir was vandalized. Holes were discovered in the Vexar in the back of the trap and the door to the trap was pried off. No estimates of counts lost due to vandalism were made because of insufficient information about fish passing at the time. The Lake Louise weir was dismantled on June 17.

Biological Data

Length Composition:

During the emigration, 4,996 Dolly Varden were tagged and/or measured. Kolmogorov-Smirnov (K-S) two-sample tests were used to test the null hypothesis that the length distributions did not differ among weeks. A test to see what size Dolly Varden would pass through the pickets without Vexar was performed. Length, head, and girth measurements were taken on 76 fish and an attempt was made to gently push the fish through the pickets. Head measurements were made at the thickest part of the head. Girth consisted of a measurement around the thickest portion of the body anterior to the dorsal fin.

To assess reasons why the abundance of the Dolly Varden emigration was so dramatically different from the 1990 emigration, comparisons of fish recaptured in 1991 that were released in 1990 (sample size = 161) were made (Whalen 1991). The length frequency of these fish in 1990 was plotted against the total length frequency of fish released with tags in 1990. Also, the length distribution of these 161 Dolly Varden in 1991 was compared to the total length distribution of all fish examined and measured.

Relative Maturity:

In an attempt to investigate reasons for the decreased size of the emigration from the 1990 level, maturity samples were to be taken every 2 weeks during summer weir operation. Due to a lack of fish immigrating later in the summer, only two samples were taken. A sample of 148 fish was taken from July 11 to 15 and another sample of 140 fish was taken from July 16 to 20. Since these two samples were so close together in time, they were treated as one sample. 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 Composition:

Sagittal otoliths were collected from the random maturity samples taken from immigrating Dolly Varden in both 1990 and 1991. Otoliths were stored dry, then soaked in a 50% glycerine and 50% water solution for about 24 hours. Age was determined by counting the number of hyaline zones on the otolith placed on a black background and viewed with reflected light. A binocular microscope (10X) was used for examinations. Age composition was estimated as a simple proportion. The variance of the estimated proportion of age class h ($\hat{p}_h$) was estimated as (Scheaffer et al. 1979):

$$V[\hat{p}_h] = \hat{p}_h(1 - \hat{p}_h)/(n_t - 1) \quad (1)$$

where n_t is the number of otoliths read.

The K-S tests were used to determine if significant differences existed between lengths by sex between and within years. K-S tests were also used to determine if maturity states between and within years were significantly different.

Abundance Estimates

Emigration:

During the emigration, approximately 10% of the Dolly Varden passing through the weir were tagged with numbered green Floy FD 68D anchor tags as was done in 1989 and 1990. Another 20% of the Dolly Varden were examined for the presence of a tag.

As a supplement to the weir counts, a Jolly-Seber estimate was calculated using mark-recapture data collected from 1989, 1990, and 1991 emigration weir operations (Jolly 1965, Seber 1965). The 1989 weir reliably stopped fish only to 300 mm, therefore, a stratified estimate of fish over 300 mm was calculated. The Jolly-Seber method provides an abundance estimate for the 1989 season only.

The following assumptions must be met in order to achieve unbiased estimates in an open population (Seber 1982):

1. marked fish have the same probability of being caught in the *i*th sample as an unmarked fish.

2. marked fish suffer the same mortality 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.

Formulas used are provided by Seber 1982 (pages 196 to 205). The computer program JOLLY was used to calculate abundance, recruitment, and survival estimates (Pollock et al. 1990). The capture history for the 1989-1991 emigrations used in this program is given in Table 1.

To test the assumption that marked fish do not lose their marks, the fish tagged were also examined for adipose finclips. Dolly Varden were tagged and adipose finclipped during the spring and fall sampling events in 1989 to initiate a tag loss study (Sonnichsen 1990). Tag loss estimates were calculated using the following equation:

$$\text{tag loss} = \frac{\text{\# of fish missing a tag and adipose fin from this sample}}{\text{\# of fish recaptured from the 1989 season in this sample}} \cdot \qquad (2)$$

A separate tag loss study was started this year with a left ventral finclip to differentiate from the 1989 study.

Spawning Ground Surveys:

Spawning ground surveys were conducted at the Olds and American rivers and Buskin Lake. Single year Petersen mark-recapture methods were used at all sites to determine the populations of spawning Dolly Varden.

Three samples were taken in the Olds River on October 7, 8, and 12. The first two events were pooled because they were only 1 day apart. Two samples were taken at the American River and Buskin Lake on October 9 and 11 and October 10 and 13, respectively (Table 2). All three sites were divided into two sublocations to test for equal mixing of marked and unmarked fish between sampling events. At least 2 days were allowed at any of the sites for mixing of marked and unmarked fish. A beach seine 15.2 m (50 ft) in length was used at the American and Olds rivers. A beach seine 30.5 m (100 ft) in length was

Table 1. Capture history of emigrating Buskin River Dolly Varden for the JOLLY computer program, 1989-1991[a].

Event 1 1989	Event 2 1990	Event 3 1991		Frequency
0	0	1		3,263
0	1	0		5,003
0	1	1		101
1	0	0		3,174
1	0	1		14
1	1	0		149
			Total	11,704

[a] 0 signifies not captured in that event and 1 was captured in that event.

Table 2. Release and recapture data for Petersen estimates for the Olds and American rivers and Buskin Lake, October 1991.

Site	Date	Number Tagged	Number Recaptures[a]	Number Unique Examined
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.

used at Buskin Lake. All fish were tagged with numbered green Floy anchor tags, measured for fork length, and examined for adipose and left ventral finclips.

To achieve unbiased estimates of a closed population (Seber 1982):

1. all Dolly Varden must have the same probability of capture during the first sample or in the second sample or marked and unmarked fish must mix randomly between the first and second samples.

2. marked fish do not lose their mark.

3. all marks are recognized and reported on recovery.

4. there is negligible recruitment to the catchable population.

The abundance of the American and Olds rivers and Buskin Lake populations can be estimated if the above conditions are met using the Chapman modification of the Petersen estimate (Ricker 1975):

$$\hat{N} = \frac{(M+1)(C+1)}{(R+1)} - 1 \qquad (3)$$

where $\hat{N}$ = estimated population size, M = marked fish at large, C = number of fish caught, R = number of recaptures in catch. The variance of the estimate was calculated as:

$$\widehat{var}(N) = \frac{N^2\,(C-R)}{(C+1)(R+2)} \quad . \qquad (4)$$

Statistical tests on the assumptions established validity of the Petersen estimation procedure. There was no evidence that marking Dolly Varden with anchor tags caused changes in mortality or behavior. Recruitment into the American and Olds rivers' populations in October is considered negligible and emigration, if any, is assumed to be equal between marked and unmarked fish.

Tag loss estimates were not calculated for the fall sampling events because crews did not consistently look for missing adipose or left ventral fins and counts obtained of finclips were unreliable. Tag loss was assumed to be similar to the tag loss estimate calculated for the spring emigration Dolly Varden.

A K-sample Anderson-Darling test was used to determine if different sizes of fish had equal probability of capture at the American and Olds rivers and Buskin Lake (assumption 2). 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.

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 3). Therefore, stratification by size group was necessary. I determined the

Table 3. Results of the K-sample Anderson-Darling tests on assumptions of size selectivity in Petersen estimates for the Olds and American rivers and Buskin Lake, October 1991. Number of observations in parentheses. Critical value for T_{akN} = 1.96 at 95% confidence.

First Sample	Second Sample	A^2_{akN}	σ^2	T_{akN}
Olds River				
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]
American River				
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
Buskin Lake - northwest end				
Event #1 Releases (200)	Event #2 Releases (146)	5.9354	0.5734	6.518[b]
Event #1 Releases (200)	Event #2 Recaptures (7)	0.8317	0.5822	-0.221

[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 α = 0.05.

length at which I would separate the data was 365 mm from a comparison of the plot of the cumulative length frequencies of both events.

At the American River, I found no size selectivity in any comparison (Table 3). At Buskin Lake, 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.

To test for equal mixing between marked and unmarked fish for the American and Olds rivers and Buskin Lake, a contingency table was used (assumption 4). 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 (Table 4). For the Olds River, the ratio was significantly different at $\alpha = 0.05$. Therefore, to achieve an unbiased estimate of population abundance, the Olds River population estimate should be divided into sublocation one and two. The American River and Buskin Lake ratios were not significantly different at $\alpha = 0.05$ and did not require geographical stratification.

For the Olds River, the appropriate estimator is a Darroch (Seber 1982 section 11.1.1). The stratified estimator ($\underline{W}$) is:

$$\underline{W} = D_u M^{-1} \underline{a} \qquad (5)$$

where:

$\underline{W}$ = a vector with the estimates of the number of untagged Dolly Varden in each sublocation just after the release of the tagged fish,

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):

$$E[(W\hat{}-W)(W\hat{}-W)'] = D_w B^{-1} D_u D^{-1}{}_a B'^{-1} D_w + D_w(D_p - I) \qquad (6)$$

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,

Table 4. Comparison of number of marked fish in event 2 to number of unmarked fish in event 2 at sublocations within the Olds and American rivers and Buskin Lake, October 1991.

Site	Sublocation 1	Sublocation 2
Olds River		
Marked	19	19
Unmarked	228	101
Chi-square = 5.767, df = 1, 0.025<P<0.01		
American River		
Marked	22	17
Unmarked	236	160
Chi-square = 0.149, df = 1, 0.50<P<0.75		
Buskin Lake - northwest end		
Marked	6	1
Unmarked	123	16
Chi-square = 0.050, df = 1, 0.75<P<0.90		

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:

$$B = D^{-1}{}_{a}MD_{q}. \quad (7)$$

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. However, tagged fish are assumed to behave independently of one another with regard to movement between sublocations (Seber 1982).

RESULTS

Dolly Varden Census

A total of 30,725 Dolly Varden emigrated through the Buskin River weir (Appendix A1). Appendix A2 lists weir counts at the Buskin River weir for 1985-1990. The estimated count for May 6 when water flowed over the top of the weir was 450 Dolly Varden and the estimate for June 3 when the weir was vandalized was 150 fish. Peak weir counts seemed to coincide with water temperatures of 6°C. High counts were offset from high water levels because of difficulty in sampling fish from the trap (Figure 3).

The Lake Louise weir count totalled 4,669 Dolly Varden and 186 rainbow trout (Appendix A3).

The length at which Dolly Varden cannot pass through the weir pickets was highly variable (Appendix B). Whether a fish passed through the pickets was more dependent on head or girth measurements which were highly variable to the condition of the fish and not as much to the length of the fish. The sample size of this test was also not sufficient to establish a size at which the weir reliably stopped Dolly Varden.

Biological Data

Length Composition:

The first 4 weeks of the emigration exhibited a marked shift in length composition from large Dolly Varden in the beginning to smaller fish over time (Figure 4). The last 4 weeks of the emigration were not as distinct, but larger fish again appeared to be predominant in the samples (Figure 5). According to K-S tests, significant differences were found among all combinations of weeks except between weeks 5 and 6 and then between weeks 7 and 8 (Table 5). Cumulative length distribution frequencies agreed with the above conclusions, although weeks 5 and 6 showed slight differences as the fish got larger (Figure 6). Also, weeks 7 and 8 showed further differences

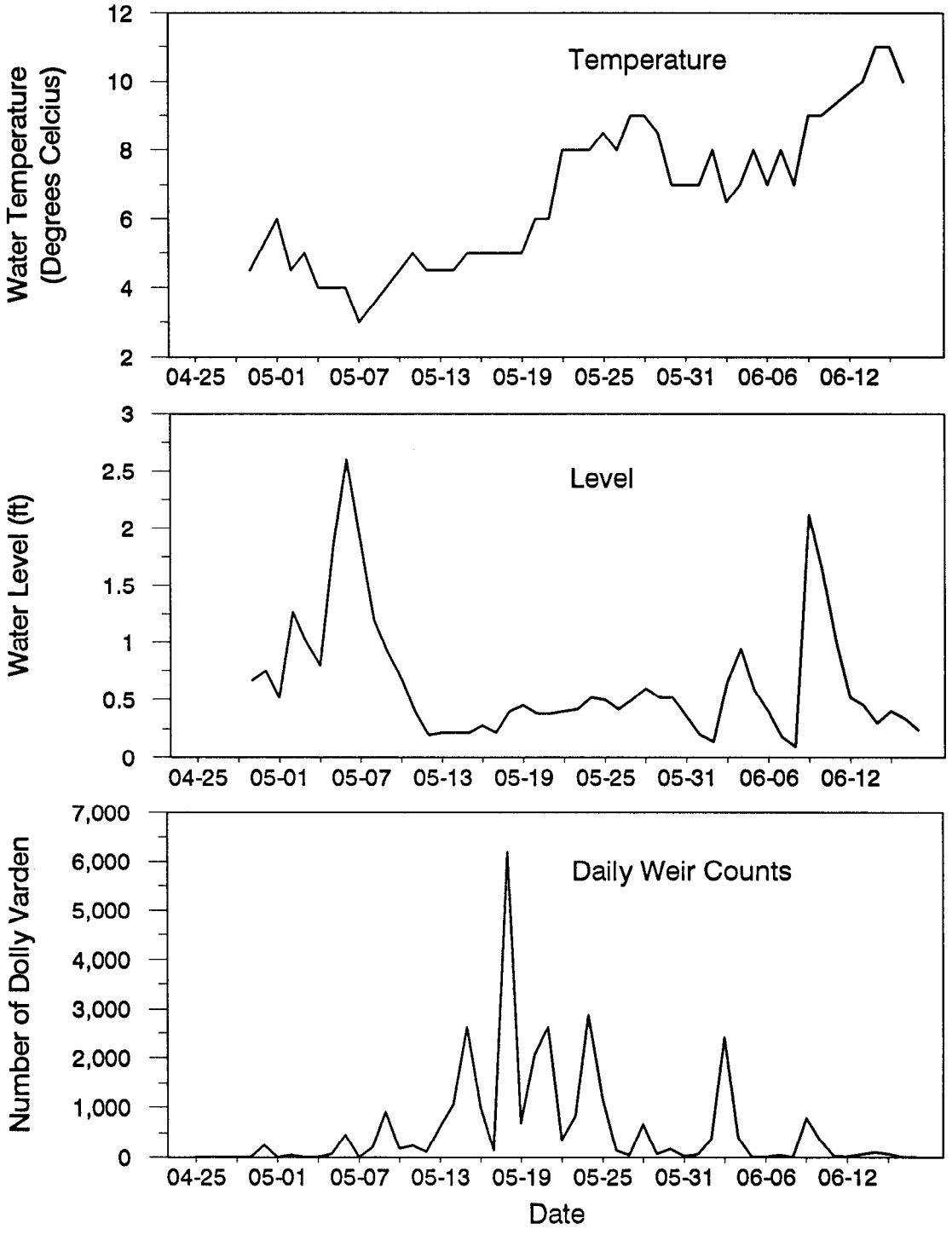

Figure 3. Water temperatures, levels and daily weir counts for the Buskin River Dolly Varden emigration, spring 1991.

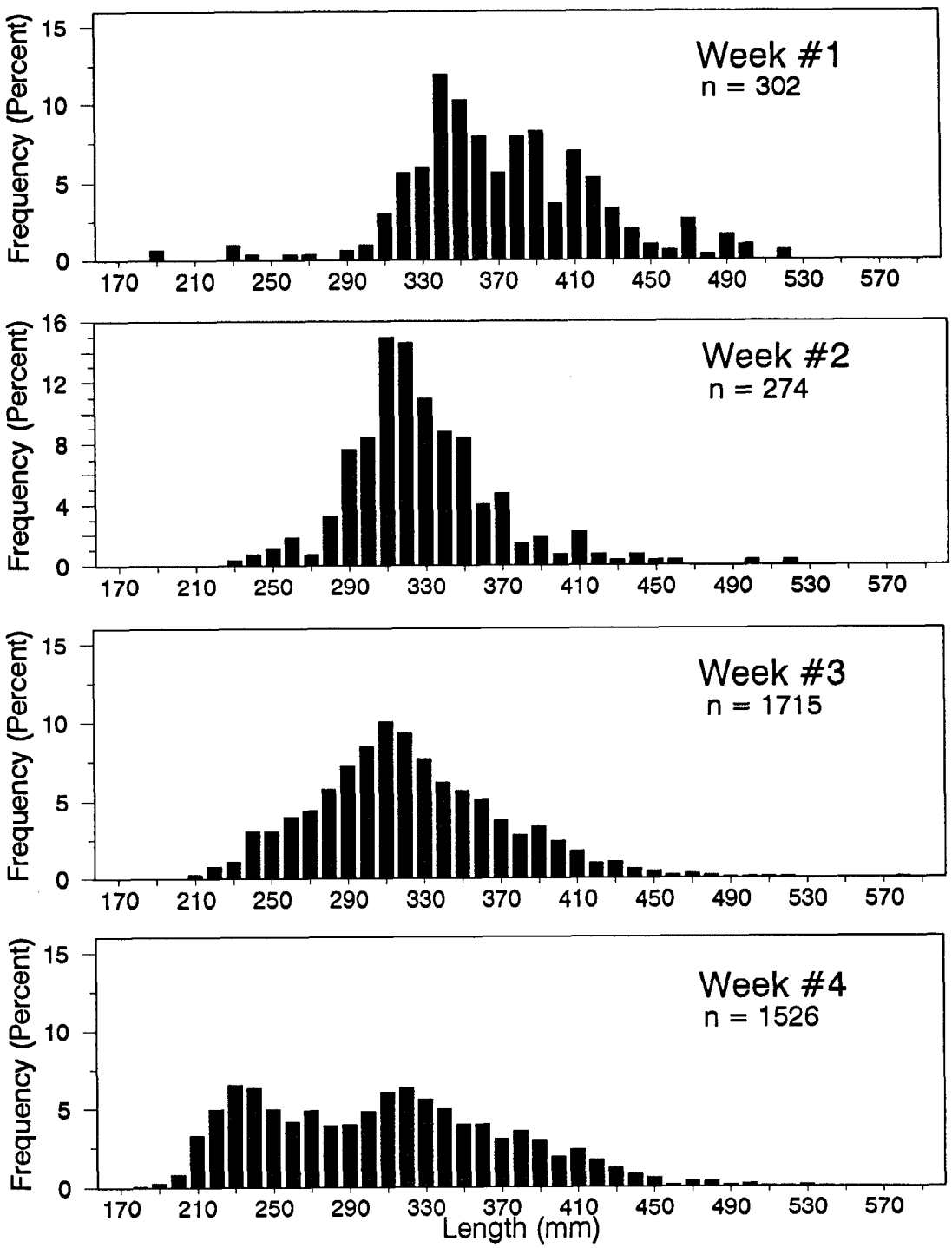

Figure 4. Length frequencies for emigrating Buskin River Dolly Varden for weeks 1 through 4, 1991.

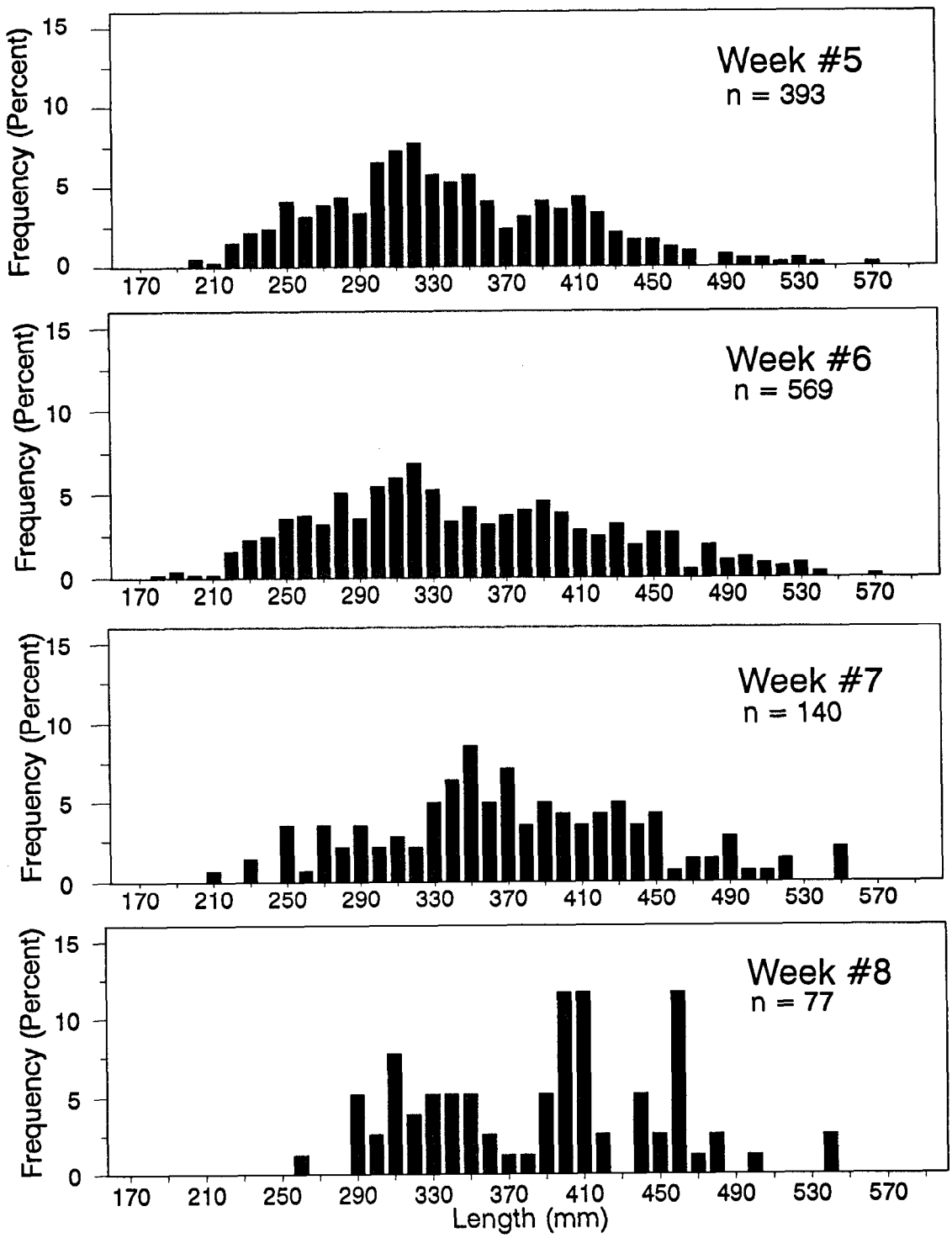

Figure 5. Length frequencies for emigrating Buskin River Dolly Varden for weeks 5 through 8, 1991.

Table 5. Results of Kolmogorov-Smirnov tests on length distributions for Buskin River Dolly Varden emigration, spring 1991.

			Comparison 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 95% confidence interval.

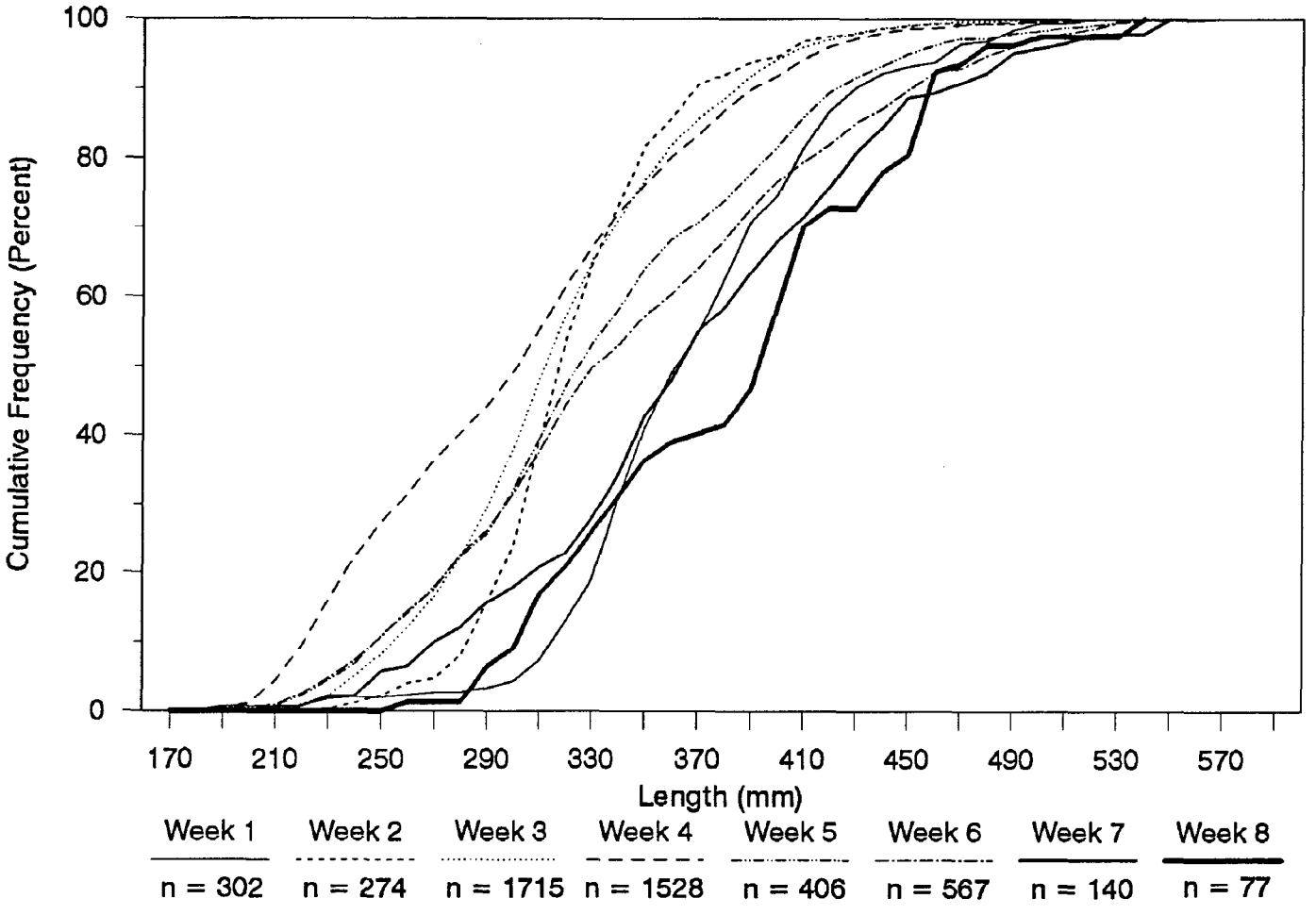

Figure 6. Cumulative length distributions in percent frequency for Dolly Varden emigration, spring 1991.

than the P-values indicated. A weighted overall length frequency was calculated taking into consideration the weir counts and number of fish measured in each length category (Figure 7). Length at full recruitment to the weir appears to be the same as in 1990, 210 mm. A comparison of weighted length frequencies between 1990 and 1991 showed similar modes and general shape of the curve (Figure 8). Also, frequency of small length groups (under 240 mm) was smaller in 1991 than 1990 indicating less recruit size fish.

According to the Lake Louise weighted length composition (Figure 9), these fish were smaller than the Buskin River Dolly Varden. Average size for Lake Louise was 284 mm, and for the Buskin River weir the average size was 322 mm.

Tag Returns:

During 1984-1991, a total of 53,155 Dolly Varden were tagged from the Chiniak Bay, Ugak Bay, and Afognak Island areas combined (Table 6). Between April 26 and June 16, 1991, 4,500 Dolly Varden were tagged. A total of 11,565 Dolly Varden were examined for tags. Generally, fish were tagged in proportion to abundance (Figure 10) and in relation to length distribution. Recaptures totalled 480 fish. Recaptured Dolly Varden from sampling events in 1989-1991 were compared to previous years' releases (Table 7). This information will be valuable in the years ahead in determining key population parameters for this fishery.

When the Dolly Varden recaptured in 1991 that were released in 1990 were compared to their overall length frequencies, a few points were evident (Figure 11). When broken into length classes, these fish exhibited differential tag return ratios. The Dolly Varden under 300 mm had a 6.1% return, fish between 300 and 349 mm had 2.0% return, and the fish 350 mm and over only had a .76% return.

Relative Maturity:

Results from the summer maturity sample indicated that only 8.3% of the females were mature (State II) compared to 48.2% mature in 1990 (Whalen 1991). When comparing length and maturity state, small fish (under 300 mm) were mainly State I, medium sized fish (300 to 350 mm) were mostly State IV, but with some State I (35.9%) and a few State II fish (4.7%), as expected. Large fish (over 350 mm) were mainly State V with more State II and no State I fish (Table 8). These large fish were expected to have a higher percentage of State II females as in 1990. The difference this year was that these maturity samples were taken while the weir was at the lake and last year they were taken at the lower site.

Age Composition:

Age classes 3 through 12 were present in the 1990 Dolly Varden immigration maturity sample (Table 9). 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 10). The 1991 Dolly Varden immigration maturity sample contained age classes 3 through 15 (Table 11). 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

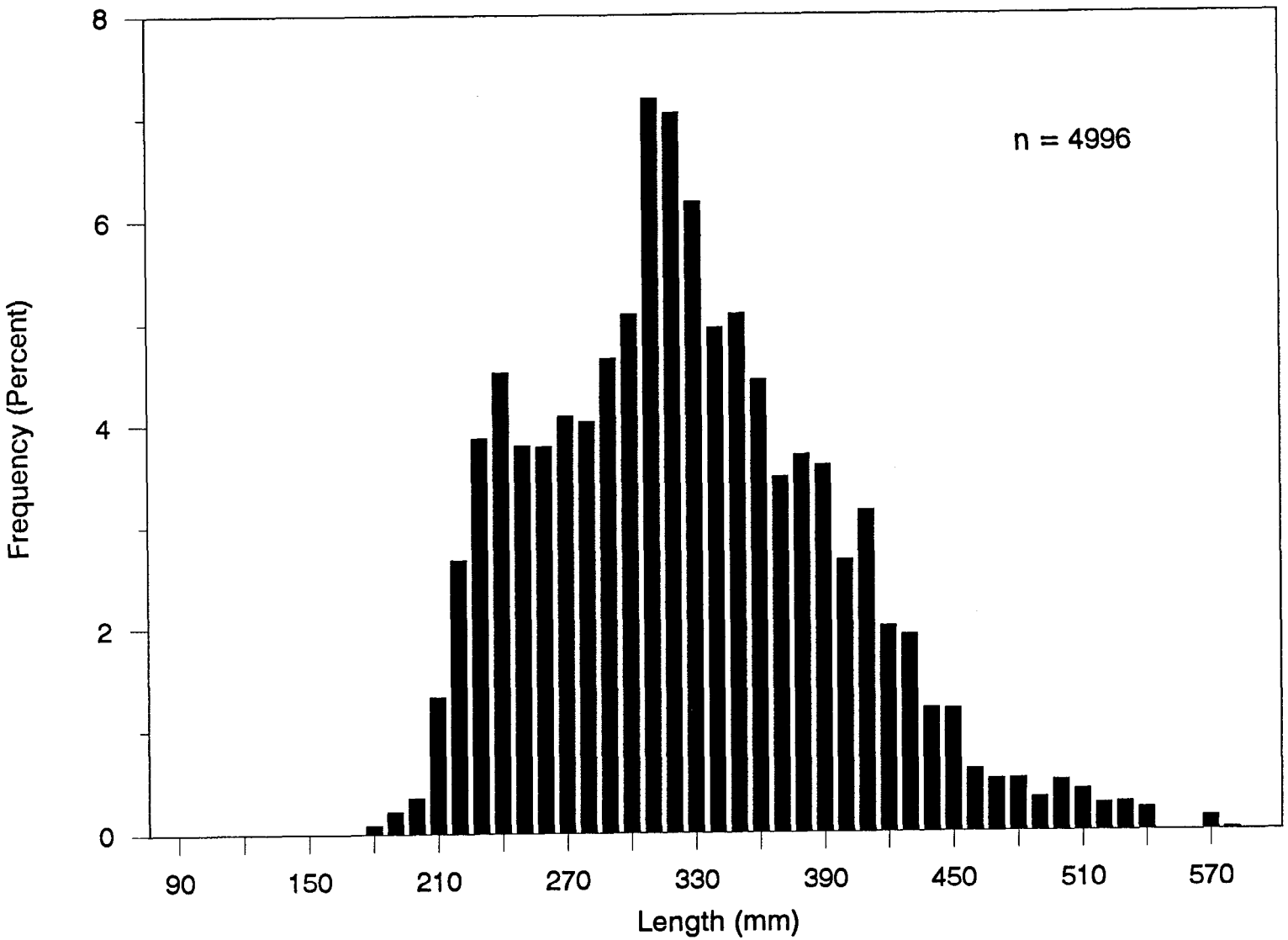

Figure 7. Weighted length frequency for emigrating Buskin River Dolly Varden, spring 1991.

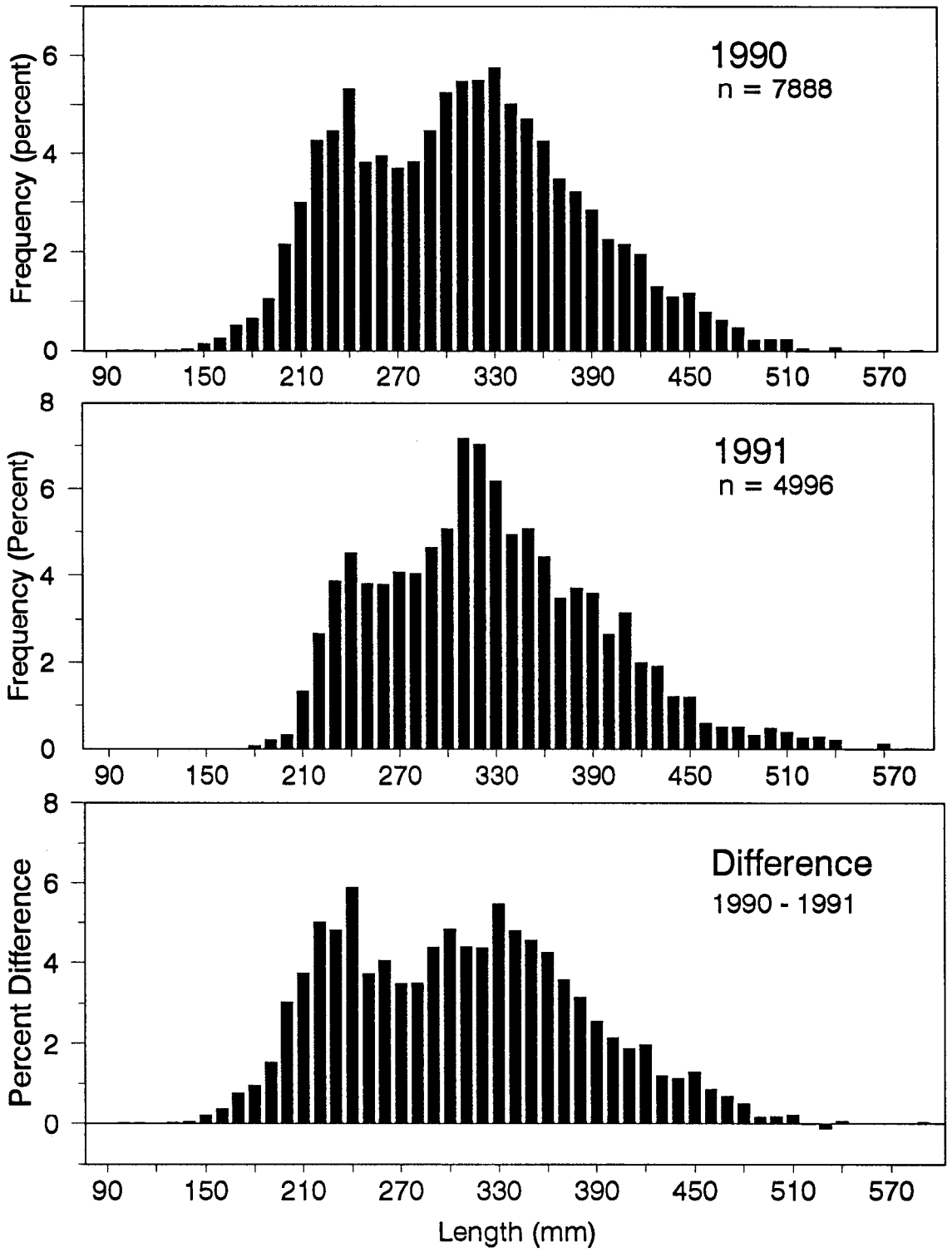

Figure 8. Weighted length frequency comparison for emigrating Buskin River Dolly Varden for 1990 and 1991 and the difference between the two.

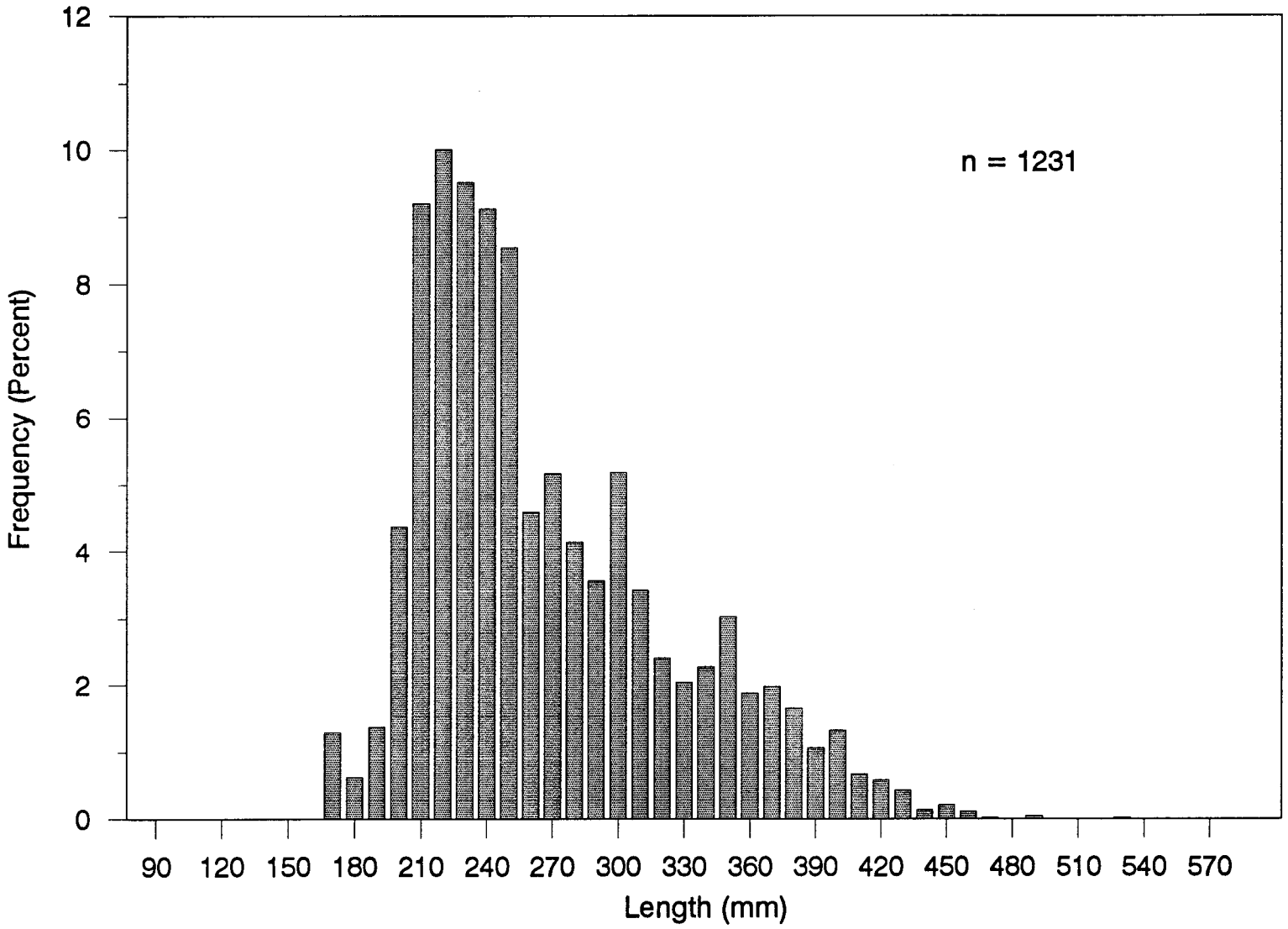

Figure 9. Weighted length frequency for Dolly Varden from Lake Louise, spring 1991.

Table 6. Tagging summary, Kodiak Dolly Varden 1984-1991.

Year	Site	Dates	Tag Color	Tag Numbers	Number Tagged
1984	Buskin River	May 17-Jun 17	Yellow	1 - 474	472
1985	Buskin River	Apr 27-Jun 17	Yellow	475 - 1,800	1,318
			Green	651 - 743	
1986	Buskin River	Apr 24-May 16	Pink	2,001 - 6,000	3,986
	Buskin River	Oct 29-30	Red	1 - 575	461
	Salonie Creek	Aug 14	Orange	2,501 - 2,550	97
		Sept 14	Orange	2,851 - 2,897	
	American River	Aug 7-12	Orange	1,403 - 1,962	560
	Olds River	Aug 5-6	Orange	1 - 1,402	1,402
	Roslyn River	Aug 13	Orange	2,001 - 2,030	30
	Pasagshak River	Aug 15 & 19	White	1 - 1,000	1,596
		Sept 11-12	White	18,235 - 19,993[a]	
	Afognak River	Sept 4-5	Blue	1 - 1,000	1,476
			Blue	20,325 - 20,803	
1987	Buskin River	May 20-30	Yellow	1,801 - 4,000	4,051
			Orange	1,963 - 3,000[a]	
			Pink	4,001 - 5,000	
	Buskin River	Aug 26-27	Pink	6,001 - 7,000	1,000
	American River	Aug 20 & 22	Orange	4,501 - 6,000	1,500
	Olds River	Aug 11-12	Orange	3,001 - 4,500	1,498
	Pasagshak River	Aug 24-25	White	1,001 - 2,000	1,000
	Saltery Creek	May 14-15	Green	3,001 - 5,000	2,000
	Afognak River	Sept 4-5	Blue	1,001 - 2,000	1,000

-continued-

Table 6. (Page 2 of 3).

Year	Site	Dates	Tag Color	Tag Numbers	Number Tagged
1988	Buskin River	Oct 20-25	Red	1,001 - 2,000	2,998
			Pink	7,001 - 8,000	
			Green	124,001 - 125,000	
	American River	Oct 18-22	Pink w/ Black	5,001 - 6,000[a]	650
	Olds River	Oct 26-31	Green	125,001 - 125,267	267
1989	Buskin River	May 3-Jun 1	Green	125,268 - 129,308[a]	4,012
	Buskin River	Oct	Green	155,737 - 156,500	4,433
			Green	156,550 - 157,000	
			Green	157,347 - 157,999	
			Green	162,457 - 164,280[a]	
			Green	164,801 - 165,375	
			Green	165,501 - 165,725[a]	
	American River	Oct	Green	157,001 - 157,346	801
			Green	162,001 - 162,456	
	Olds River	Oct	Green	155,001 - 155,736	784
			Green	156,501 - 156,550	
1990	Buskin Lake	Apr 30-Jun 14	Green	190,001 - 195,000	7,492
			Green	211,001 - 213,499	
	American River	Oct 6-Oct 8	Green	213,500 - 214,045	546
			Green	214,610 - 214,821	212
	Olds River	Oct 7	Green	214,046	1
			Green	214,601 - 214,609	9
	Buskin Lake-NW	Oct 9-Oct 11	Green	215,085 - 215,731	646
	Buskin Lake-Out	Oct 9	Green	214,826 - 215,084	259
	Buskin River	Oct 9	Green	214,047 - 214,125	79
	Pillar Creek	Oct 10	Green	214,126 - 214,268	143

-continued-

Table 6. (Page 3 of 3).

Year	Site	Dates	Tag Color	Tag Numbers	Number Tagged
1991	Buskin Lake	Apr 26-Jun 16	Green	216,000 - 217,000	4,500
			Green	218,001 - 220,000	
			Green	250,001 - 251,501	
	Olds River	Oct 7-Oct 12	Green	255,001 - 255,589	589
			Green	255,601 - 255,767	167
			Green	256,001 - 256,186	187
			Green	256,965 - 257,000	36
	American River	Oct 9-Oct 11	Green	255,590 - 255,599	10
			Green	256,201 - 256,467	267
			Green	256,630 - 256,964	334
	Buskin Lake	Oct 10-Oct 13	Green	255,768 - 255,891	124
			Green	256,468 - 256,629	162
				Total Tagged	53,155

[a] Missing blocks of tags in this sequence.

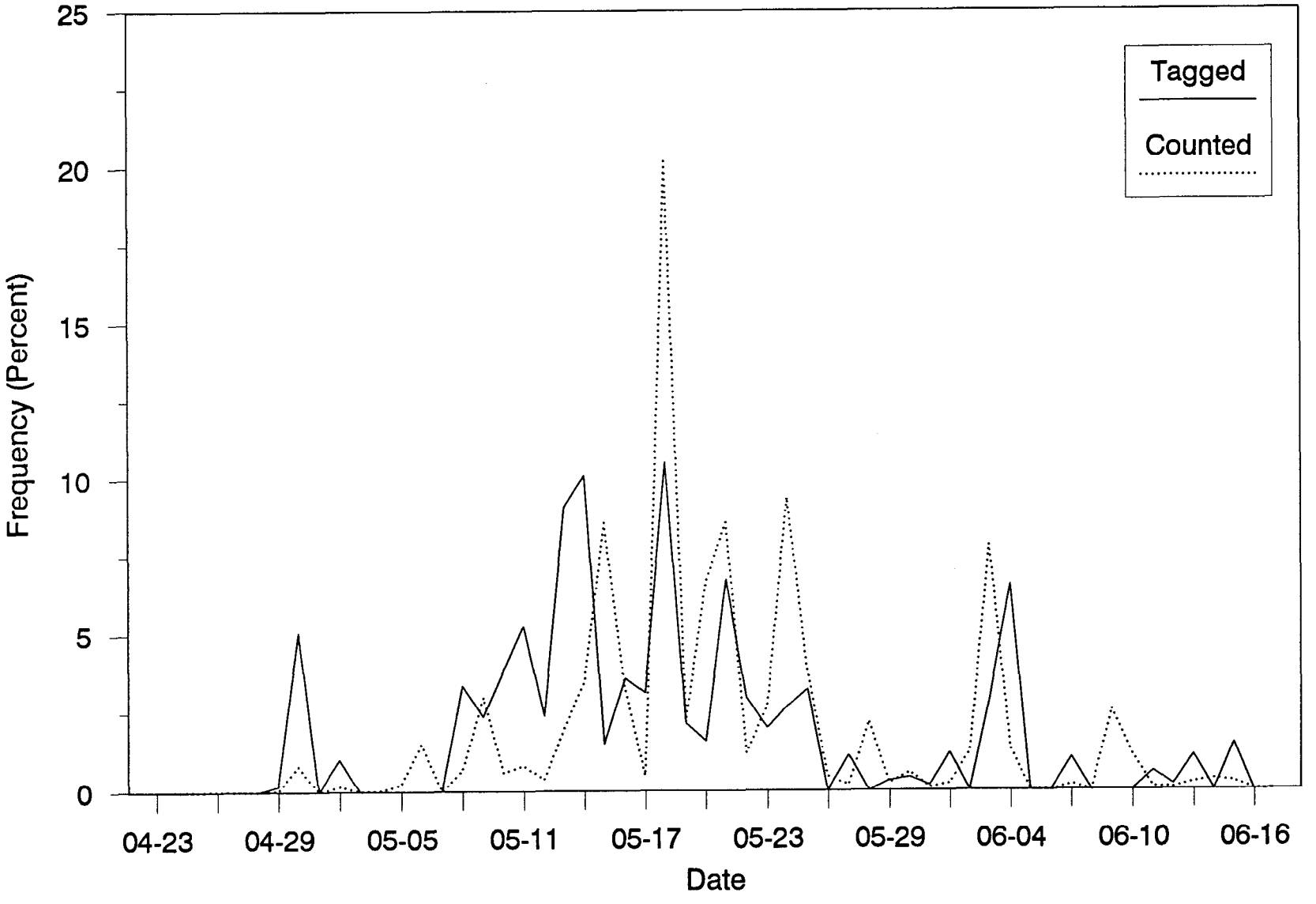

Figure 10. Percent of total emigrating Buskin River Dolly Varden weir count and daily tag count, spring 1991.

Table 7. Dolly Varden tag recoveries by release location for all tagging sites for 1988-1991.

Recaptures (# unique examined)	Releases (# unique releases with tags)								
	1988 Fall American (709)	1988 Fall Olds (283)	1988 Fall Buskin (3,006)	1989 Spring Buskin (4,476)	1989 Fall American (893)	1989 Fall Olds (833)	1989 Fall Buskin (4,484)	1990 Spring Buskin Weir (8,450)	1990 Summer Buskin Weir (21)
1989 Spring Buskin Weir (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 (4,503)	0	0	30	12	0	0	-	-	-
1990 Spring Buskin Weir (22,815)	16	10	161	221	57	69	378	-	-
1990 Spring Buskin Creel (372)	0	0	4	4	0	0	4	19	-
1990 Summer Buskin Weir (403)	0	0	2	3	0	0	4	11	-
1990 Fall American (897)	2	0	6	8	34	0	7	33	0
1990 Fall Olds (12)	0	0	0	0	0	1	0	0	0

-continued-

Table 7. (Page 2 of 4).

Recaptures (# unique examined)	Releases (# unique releases with tags)								
	1988 Fall American (709)	1988 Fall Olds (283)	1988 Fall Buskin (3,006)	1989 Spring Buskin (4,476)	1989 Fall American (893)	1989 Fall Olds (833)	1989 Fall Buskin (4,484)	1990 Spring Buskin Weir (8,450)	1990 Summer Buskin Weir (21)
1990 Fall Buskin Lake northwest end (725)	0	0	4	14	2	0	4	52	2
1990 Fall Buskin River mainstem (87)	0	0	2	0	0	1	1	5	0
1990 Fall Buskin River nr lk outlet (276)	0	0	0	0	0	0	3	1	0
1990 Fall Buskin Lake near outlet (391)	0	0	0	0	1	0	20	16	0
1991 Spring Buskin Weir (11,549)	1	0	22	27	5	15	95	201	1
1991 Summer Buskin Weir maturity (288)	0	0	0	0	0	0	2	2	0
1989 Spring Buskin Weir (10,126)	-	-	-	-	-	-	-	-	-
1989 Fall American (896)	-	-	-	-	-	-	-	-	-

-continued-

Table 7. (Page 3 of 4).

Recaptures (# unique examined)	Releases (# unique releases with tags)								
	1988 Fall American (709)	1988 Fall Olds (283)	1988 Fall Buskin (3,006)	1989 Spring Buskin (4,476)	1989 Fall American (893)	1989 Fall Olds (833)	1989 Fall Buskin (4,484)	1990 Spring Buskin Weir (8,450)	1990 Summer Buskin Weir (21)
1989 Fall Olds (836)	-	-	-	-	-	-	-	-	-
1989 Fall Buskin (4,503)	-	-	-	-	-	-	-	-	-
1990 Spring Buskin Weir (22,815)	-	-	-	-	-	-	-	-	-
1990 Spring Buskin Creel (372)	-	-	-	-	-	-	-	-	-
1990 Summer Buskin Weir (403)	-	-	-	-	-	-	-	-	-
1990 Fall American (897)	-	-	0	0	0	-	-	-	-
1990 Fall Olds (12)	-	-	0	0	0	-	-	-	-
1990 Fall Buskin Lake northwest end (725)	0	-	0	0	1	0	0	-	-
1990 Fall Buskin River mainstem (87)	0	0	-	0	0	0	0	-	-

-continued-

Table 7. (Page 4 of 4).

Recaptures (# unique examined)	Releases (# unique releases with tags)								
	1988 Fall American (709)	1988 Fall Olds (283)	1988 Fall Buskin (3,006)	1989 Spring Buskin (4,476)	1989 Fall American (893)	1989 Fall Olds (833)	1989 Fall Buskin (4,484)	1990 Spring Buskin Weir (8,450)	1990 Summer Buskin Weir (21)
1990 Fall Buskin River nr lk outlet (276)	0	0	0	-	0	0	0	-	
1990 Fall Buskin Lake near outlet (391)	0	0	0	0	-	0	0	-	
1991 Spring Buskin Weir (11,549)	23	56	3	0	13	0	0	-	
1991 Summer Buskin Weir maturity (288)	0	1	0	0	0	0	0	5	

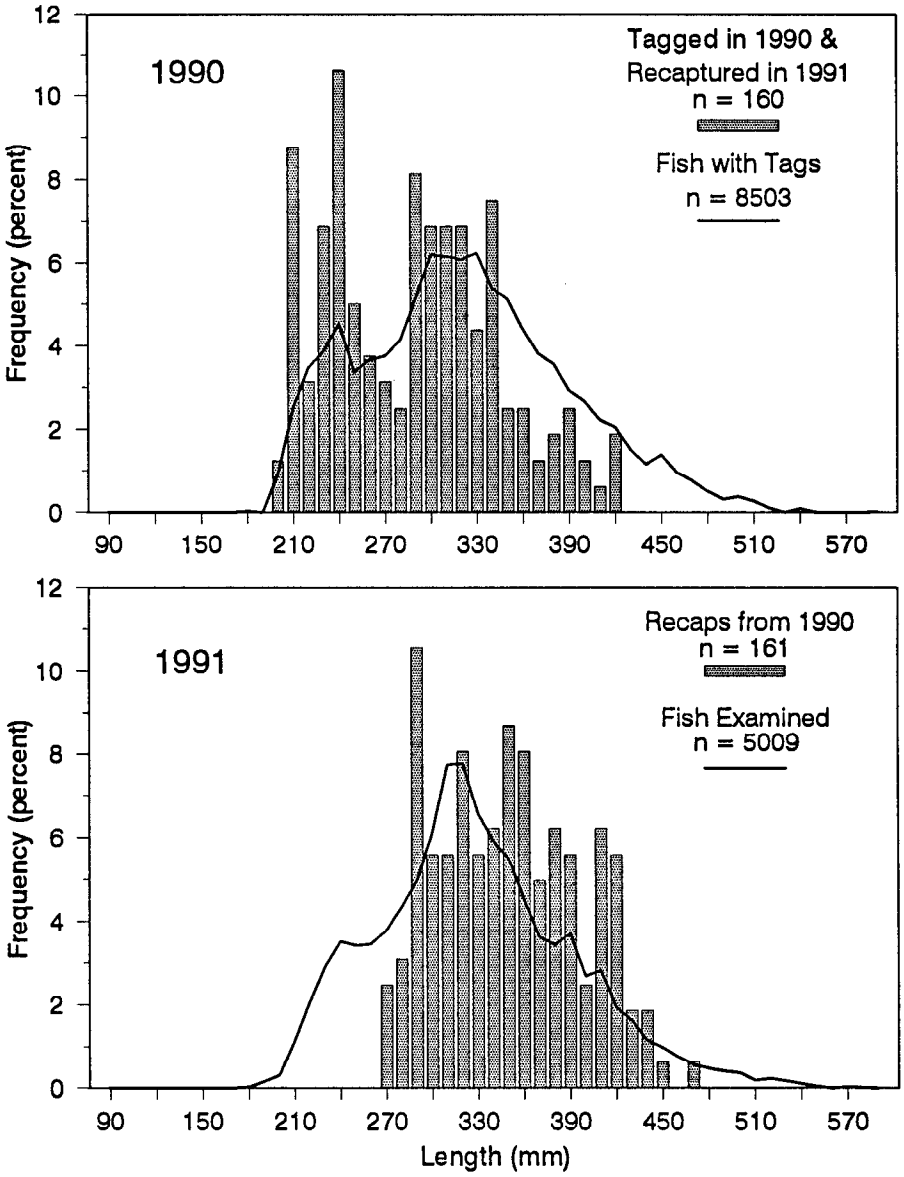

Figure 11. Length frequencies of Dolly Varden recaptured in spring 1991 from the spring 1990 release.

Table 8. Percent of immigrating female Dolly Varden in each length class by maturity state at the Buskin River weir for July 11-20, 1991. Sample size for females = 144.

Maturity State	n	Length (mm) < 300 n = 56	300 - 350 n = 64	> 350 n = 24
I	67	78.6%	35.9%	0.0%
II	12	0.0%	4.7%	37.5%
III	0	0.0%	0.0%	0.0%
IV	0	0.0%	0.0%	0.0%
V	65	21.4%	59.4%	62.5%

Table 9. Age distribution of Dolly Varden sampled at the Buskin River weir during immigration, July 18-19, 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 10. Mean fork length at age (millimeter) of Dolly Varden sampled at the Buskin River weir during immigration, July 18-19, 1990.

	Age										
	03	04	05	06	07	08	09	10	11	12	Total
Females											
Mean Length		293	316	360	412	419	421	494	479	512	381
SE		14	36	49	51	32	70	71	13		64
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
Males											
Mean Length	277.00		352	365	413	433	431	400			389
SE			52	44	26	44	3				51
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
All											
Mean Length	277	293	329	363	413	424	425	463	479	512	384
SE		14	45	46	41	37	8	74	13		59
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 11. Age distribution of Dolly Varden sampled at the Buskin River weir during immigration, July 11-20, 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	

mean length for age 6 was 312 mm (SE = 32) and age 5 was 295 mm (SE = 20) (Table 12). When age distribution was broken into maturity states for females, more spawners were present in 1990 (53) than in 1991 (12) (Table 13). Also, the average size of spawners in 1990 (434 mm, SE = 35) was larger than in 1991 (389 mm, SE = 52). The Kolgomorov-Smirnov tests showed significant differences between 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 = 0.0000). 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 = 0.0000).

Abundance Estimates

Emigration:

During the 1991 spring emigration, 14.6% of the Dolly Varden passing through the weir were examined for a missing adipose fin. Fourteen fish were missing their adipose fin and had no tag. A total of 142 Dolly Varden from the 1989 season were recaptured this spring; the result is a 9.9% (±5%) tag loss for a 2-year time span (Table 6).

The abundance estimate of emigrating Dolly Varden for 1989 from the computer run of JOLLY was 30,478 fish (SE = 7,502). The survival estimate was 26.08% (SE = 6.18%). The probability of capture was 17.12% (SE = 4.21%). Since there were no fish that were captured in all three events, a recruitment estimate could not be calculated. From weighted length distributions in the 1989 emigration, an estimate of fish 300 mm and over was calculated to be 23,785. This estimate falls within the confidence limits of the Jolly-Seber estimate from the program JOLLY.

Spawning Ground Surveys:

The Petersen estimate for the American River was 3,375 Dolly Varden (SE = 469). This is consistent with the 1990 estimate of 3,947 fish (SE = 540, Whalen 1991), the 1989 estimate of 4,125 fish (SE = 805, Sonnichsen 1990) and with the 1988 estimate of 3,048 fish (SE = 419, S. Sonnichsen, Alaska Department of Fish and Game, Anchorage, personal communication).

I attempted to do a stratified Petersen estimate for the Olds River spawning population 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). The population estimate was not accomplished in 1990 for the Olds River due to high water conditions.

The estimate for spawning adults in Buskin Lake was 3,711 Dolly Varden (SE = 1,179). The variance estimate is high due to a low number of recaptures from previous events. The population estimate for Buskin Lake is quite different from the 1990 estimate of 19,289 fish (SE = 5,824), though both years had low numbers of recaptures.

Table 12. Mean fork length at age (millimeter) of Dolly Varden sampled at the Buskin River weir during immigration, July 11-20, 1991.

	Age									
	04	05	06	07	08	09	10	11	 15	Total
Females										
Mean Length	288	288	307	345	363	390		505		316
SE	24.42	19.00	29.51	35.06	49.50	40.70				43
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	302	316	358	382	428	393		524	328
SE	28.76	17.44	33.87	35.14	38.78	32.37				48
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	282	295	312	352	372	407	393	505	524	322
SE	26.77	19.55	31.83	35.36	44.31	40.54				46
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 13. 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	312	339	350	386					331
SE	13.79	33.45	40.77	36.13	31.25					42
Sample Size	5	21	16	9	5					56
Spawner[b]										
Mean Length		360	414	440	431	421	495	479	512	434
SE		42.43	20.99	25.96	24.78	6.80	71.42	12.73		35
Sample Size		2	6	20	14	6	2	2	1	53
1991										
Nonspawner[a]										
Mean Length	288	288	306	339	339	408				310
SE	24.42	19.00	27.14	34.60	13.25	37.65				36
Sample Size	9	34	58	22	4	4				131
Spawner[b]										
Mean Length			399	378	387	353		505		389
SE				15.02	63.42	5.66				52
Sample Size			1	4	4	2		1		12

[a] State I or V maturity state.

[b] State II maturity state.

In a comparison of length frequencies of all three spawning ground survey sites, it is apparent the lengths differed from each other (Figure 12). The Olds River had the smallest fish and Buskin Lake had the largest fish. This is reflected in the K-S tests as they were all significantly different from each other. For comparison of the Olds River and American River, D_{MAX} = 0.4448, P = 0.0000. 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.

DISCUSSION

The 1991 spring Dolly Varden emigration was significantly reduced from the 1990 emigration. Reasons for this decline could stem from the fact that the larger fish were not returning in the same percentages as the smaller fish, presumably from high mortality due to spawning. This was evidenced by comparisons of length frequencies of the two years and from mean length at age and sexual maturity. Also, comparisons of the two years' weighted length frequencies showed a smaller recruit class in 1991 than 1990. The combination of the two could be an explanation for this decline in abundance.

Tag loss estimates for the 1991 emigration were twice that of the estimate in 1990 (Whalen 1991). It is important to point out that this estimate is over a 2-year time span since they are based on the 1989 finclipping events.

The Jolly-Seber estimates for abundance and survival had higher variances than expected even though we had high sample sizes. It is possible that there were violations to the assumptions of this method. A tag loss of almost 10% violated the assumption that no tags are shed or overlooked. When this assumption is violated, estimates of survival and recruitment are biased and the precision of all estimates is reduced (Arnason and Mills 1981). If tag retention rate is known or estimated, Arnason and Mills (1981) give equations for corrected estimates of survival and its standard error. But, the use of these equations requires that tag loss be independent with time. Since the tag loss estimates have changed from 1990, these equations could not be used. It is recommended that a more thorough examination of violations of the Jolly-Seber method assumptions be made so that more precise and unbiased estimates can be obtained.

Temporal length composition changes were similar to 1990 in that the large fish entered first and shifted progressively to the smaller sizes, but this year, the large amounts of small fish were not as evident in the end of the run.

The Lake Louise weir operation verified there was a segment of Dolly Varden overwintering in a location other than Buskin Lake. Since these fish were of considerably smaller size, I assume these do not constitute a spawning population.

The percentage of State II females in 1991 (8.3%) was significantly lower than 1990 (48.2%). This could be due to the fact that 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 we may have missed

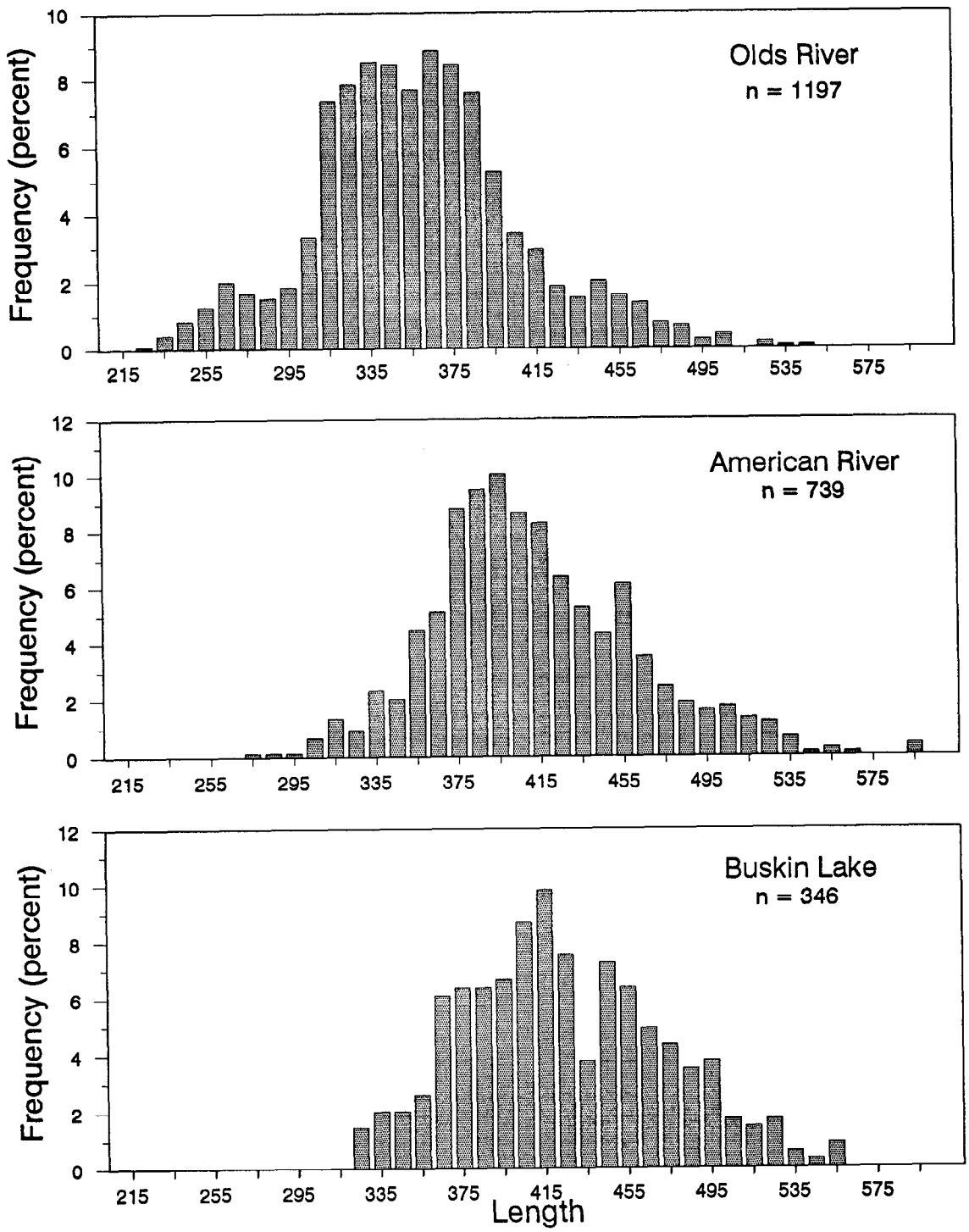

Figure 12. Comparison of length frequencies for spawning ground surveys, October 1991.

it with this sample, especially considering that the number of mature adults returning was considerably lower than in 1990.

The age composition 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.

Future goals of this project are to obtain at least 3 years of tagging information at the present weir site to attain an estimate of population abundance for Dolly Varden 210 mm and over using the Jolly-Seber method. Data from previous years will not be used in this Jolly-Seber estimate due to the weir not stopping fish under 300 mm. To get a valid survival estimate, there should be no gear type differences and size bias. This also addresses the concerns raised about violations to the assumptions of the Jolly-Seber. Tag return data will also be useful in determining growth of Dolly Varden which will be analyzed at a future date.

ACKNOWLEDGEMENTS

I thank Len Schwarz, Doug McBride, and Marianna Alexandersdottir for their supervision and guidance. Technicians Robert Lynch, Gail Smith, and Glen Eaton helped conduct weir operations. The fall spawning ground survey crew was Doug McBride, Len Schwarz, Sandy Sonnichsen, Glen Eaton, Dave Rutz, Wolfgang Kurtz, and Rocky Holmes. Doris Mensch provided secretarial support. The U.S. Coast Guard allowed us access to their land and facilities. I would like to thank Jeff Wadle for an extensive amount of volunteer time.

LITERATURE CITED

Arnason, A. N. and K. H. Mills. 1981. Bias and loss of precision due to tag loss in Jolly-Seber estimates for mark-recapture experiments. Can. J. Fish. Aquat. Sci. 38:1077-1095.

Blackett, R. H. 1968. Spawning behavior, fecundity, and early life history of anadromous Dolly Varden *Salvelinus malma* (Walbaum) in Southeastern Alaska. Alaska Department of Fish and Game. Research Report No. 6.

Jolly, G. M. 1965. Explicit estimates from capture-recapture data with both death and immigration-stochastic model. Biometrika 52:225-247.

Marriott, R. A. 1965. Inventory and cataloging of the sport fish and sport fish waters of Southwest Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1964-1965, Project F-5-R-6, 6(6-A):97-110.

Mills, M. J. 1979. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1978-1979, Project F-9-11, 20 (SW-I-A), Juneau.

_____. 1980. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980, Project F-9-12, 21 (SW-I-A), Juneau.

_____. 1981a. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A), Juneau.

_____. 1981b. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A), Juneau.

_____. 1982. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1981-1982, Project F-9-14, 23 (SW-I-A), Juneau.

_____. 1983. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, Project F-9-15, 24 (SW-I-A), Juneau.

_____. 1984. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984, Project F-9-16, 25 (SW-I-A), Juneau.

_____. 1985. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1984-1985, Project F-9-17, 26 (SW-I-A), Juneau.

_____. 1986. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1985-1986, Project F-9-18, 27 (RT-2), Juneau.

_____. 1987. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Fishery Data Series No. 2, Juneau.

_____. 1988. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Fishery Data Series No. 52, Juneau.

_____. 1989. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Fishery Data Series No. 122, Juneau.

_____. 1990. Harvest and participation in Alaska sport fisheries during 1989. Alaska Department of Fish and Game. Fishery Data Series No. 90-44, Anchorage.

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

Pollock, K. H., J. D. Nichols, C. B. Brownie, and J. E. Hines. 1990. Statistical inference for capture-recapture experiments. Wildl. Monogr. 107.

LITERATURE CITED (Continued)

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada 191.

Scheaffer, R. L., W. Mendenhall, and L. Ott. 1979. Elementary survey sampling. Duxbury Press, North Scituate, Massachusetts.

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

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, second edition. MacMillan, New York.

Sonnichsen, S. 1990. Stock assessment of Dolly Varden in the Buskin River, Kodiak, Alaska 1989. Alaska Department of Fish and Game. Fishery Data Series No. 90-41, Anchorage.

Whalen, M. E. 1991. Stock assessment of Dolly Varden in the Buskin River, Kodiak, 1990. Alaska Department of Fish and Game. Fishery Data Series No. 91-68, Anchorage.

APPENDIX A

Appendix A1. Weir counts for the Buskin River Dolly Varden emigration, 1991.

Date	Daily Weir Count	Cumulative Weir Count
Apr 26	4	4
Apr 27	0	4
Apr 28	0	4
Apr 29	8	12
Apr 30	249	261
May 01	0	261
May 02	50	311
May 03	0	311
May 04	9	320
May 05	69	389
May 06	460	849
May 07	0	849
May 08	204	1,053
May 09	918	1,971
May 10	185	2,156
May 11	245	2,401
May 12	115	2,516
May 13	619	3,135
May 14	1,075	4,210
May 15	2,635	6,845
May 16	1,003	7,848
May 17	151	7,999
May 18	6,198	14,197
May 19	691	14,888
May 20	2,060	16,948
May 21	2,636	19,584
May 22	365	19,949
May 23	830	20,779
May 24	2,883	23,662
May 25	1,169	24,831
May 26	142	24,973
May 27	53	25,026
May 28	675	25,701
May 29	69	25,770
May 30	177	25,947
May 31	31	25,978
Jun 01	60	26,038
Jun 02	375	26,413
Jun 03	2,411	28,824
Jun 04	411	29,235
Jun 05	0	29,235
Jun 06	-2	29,233
Jun 07	51	29,284
Jun 08	0	29,284
Jun 09	791	30,075
Jun 10	347	30,422
Jun 11	31	30,453
Jun 12	17	30,470
Jun 13	68	30,538
Jun 14	105	30,643
Jun 15	79	30,722
Jun 16	3	30,725
Jun 17	0	30,725

Appendix A2. Weir counts for the Buskin River Dolly Varden emigration, 1985 through 1990.

Date	1985	1986	1987	1988	1989	1990
Apr 21	2	0	0	0	0	0
Apr 22	0	0	69	0	0	0
Apr 23	0	0	49	0	0	0
Apr 24	0	0	113	0	0	0
Apr 25	0	0	81	0	0	1
Apr 26	0	0	33	0	0	0
Apr 27	0	0	40	0	123	10
Apr 28	241	0	20	0	0	0
Apr 29	0	6	62	0	0	7
Apr 30	0	17	221	0	738	2
May 01	0	1	14	0	1,081	12
May 02	0	3	27	0	0	492
May 03	0	3	8	0	17	41
May 04	0	0	6	0	75	1,099
May 05	158	0	2,482	453	98	0
May 06	0	17	3,660	0	2	1,999
May 07	0	16	659	330	298	394
May 08	0	0	939	408	1,215	2,663
May 09	0	1	50	4,059	3,054	2,663
May 10	0	0	1,081	1,012	780	10,385
May 11	0	0	3,721	6,420	3	1,152
May 12	1,849	0	35	44	58	976
May 13	0	0	30	0	2,065	1,735
May 14	0	0	109	255	5,825	2,235
May 15	0	0	1,014	340	2,307	3,656
May 16	0	684	4,803	349	1,485	2,829
May 17	0	161	71	4,167	541	1,508
May 18	0	264	3,050	29	0	19,317
May 19	7,584	15,099	1,318	1,920	742	5,490
May 20	0	1,995	2,046	1,327	10,737	3,330
May 21	0	3,713	541	7,041	1,791	1,043
May 22	0	76	292	421	540	329
May 23	0	3,215	391	179	720	334
May 24	0	14,507	130	106	0	315
May 25	0	3	409	1,245	30	212
May 26	6,456	523	658	40	50	8,468
May 27	0	1,355	25	38	747	40
May 28	0	0	19	49	6	7,140
May 29	0	0	641	3	66	4,162
May 30	0	0	628	12	10	914
May 31	0	0	69	0	289	269
Jun 01	0	0	30	1	43	200
Jun 02	5,505	0	15	0	0	20

-continued-

Appendix A2. (Page 2 of 2).

Date	1985	1986	1987	1988	1989	1990
Jun 03	0	0	12	85	0	271
Jun 04	0	0	5	2	0	687
Jun 05	0	0	10	1	5	248
Jun 06	0	0	213	0	13	2,330
Jun 07	0	0	3	0	3	1,075
Jun 08	0	0	7	0	15	420
Jun 09	0	0	0	0	1	69
Jun 10	0	0	10	0	1	11
Jun 11	0	0	0	0	7	32
Jun 12	0	0	0	0	1	1
Jun 13	0	0	0	0	2	54
Jun 14	0	0	0	0	6	325
Jun 15	0	0	0	0	0	106
Jun 16	2	0	0	0	2	2
Jun 17	0	0	0	0	3	0
Jun 18	0	0	0	0	2	0
Jun 19	0	0	0	0	1	0
Jun 20	0	0	0	0	2	0
Jun 21	0	0	0	0	2	1
Jun 22	0	0	0	0	1	0
Jun 23	0	0	0	0	0	0
Jun 24	0	0	0	0	0	0
Jun 25	0	0	0	0	0	0
Jun 26	0	0	0	0	0	0
Jun 27	0	0	0	0	0	0
Jun 28	0	0	0	0	0	0
Jun 29	0	0	0	0	0	0
Jun 30	0	0	0	0	0	0
Jul 01	0	0	0	0	0	0
Jul 02	0	0	0	0	0	0
Jul 03	0	0	0	0	0	0
Jul 04	0	0	0	0	0	0
Jul 05	0	0	0	0	0	0
Jul 06	0	0	0	0	0	0
Jul 07	0	0	0	0	0	0
Jul 08	0	0	0	0	0	0
Jul 09	0	0	0	0	0	4
Jul 10	0	0	0	0	0	0
Jul 11	0	0	0	0	0	0
Jul 12	0	0	0	0	0	0
Jul 13	0	0	0	0	0	0
Jul 14	0	0	0	0	0	0
Jul 15	0	0	0	0	0	4
Jul 16	0	0	0	0	0	25
Total	21,797	41,659	29,919	30,336	35,603	91,107

Appendix A3. Weir counts for the Lake Louise Dolly Varden and rainbow trout emigration, 1991.

Date	Dolly Varden Daily Count	DV Cum	Rainbow Trout Daily Count	RT Cum
Apr 24	3	3	11	11
Apr 25	0	3	0	11
Apr 26	2	5	2	13
Apr 27	1	6	6	19
Apr 28	2	8	8	27
Apr 29	2	10	3	30
Apr 30	9	19	8	38
May 01	5	24	9	47
May 02	5	29	2	49
May 03	5	34	4	53
May 04	3	37	4	57
May 05	3	40	0	57
May 06	4	44	2	59
May 07	17	61	3	62
May 08	6	67	0	62
May 09	9	76	3	65
May 10	6	82	0	65
May 11	2	84	3	68
May 12	2	86	1	69
May 13	4	90	2	71
May 14	13	103	2	73
May 15	11	114	0	73
May 16	11	125	1	74
May 17	11	136	4	78
May 18	251	387	3	81
May 19	50	437	3	84
May 20	33	470	3	87
May 21	13	483	0	87
May 22	64	547	1	88
May 23	223	770	2	90
May 24	103	873	2	92
May 25	167	1,040	2	94
May 26	175	1,215	3	97
May 27	274	1,489	5	102
May 28	56	1,545	0	102
May 29	130	1,675	2	104
May 30	152	1,827	5	109
May 31	61	1,888	2	111
Jun 01	70	1,958	0	111
Jun 02	268	2,226	10	121
Jun 03	517	2,743	6	127
Jun 04	247	2,990	3	130
Jun 05	150	3,140	1	131
Jun 06	177	3,317	11	142
Jun 07	44	3,361	4	146
Jun 08	74	3,435	9	155
Jun 09	582	4,017	6	161
Jun 10	311	4,328	0	161
Jun 11	129	4,457	0	161
Jun 12	121	4,578	1	162
Jun 13	28	4,606	10	172
Jun 14	26	4,632	11	183
Jun 15	28	4,660	1	184
Jun 16	3	4,663	1	185
Jun 17	6	4,669	1	186

APPENDIX B

Appendix B. Length, head, and girth measurements for a test if emigrating Dolly Varden pass through weir pickets, 1991.

Length	Head	Girth	Pass[a]	Length	Head	Girth	Pass[a]
209			1	303	110	121	1
213	70	82	1	312	110	121	1
215	71	80	1	309	110	122	1
210	72	81	1	290	111	115	1
222	75	88	1	299	112	126	1
213	75	81	1	328	112	133	1
226	75	80	1	327	112	134	1
246	80	91	1	281	112	121	1
218	81	90	1	306	113	117	1
295	87	120	1	305	113	118	1
235	88	90	1	221	113	130	1
282	89	112	1	300	114	121	1
283	92	108	1	315	115	125	1
284	92	112	1	211	108	109	0
301	97	109	1	327	108	128	0
289	97	111	1	328	109	124	0
270	99	108	1	331	109	129	0
313	100	121	1	336	110	118	0
275	100	105	1	318	110	126	0
282	101	110	1	318	110	113	0
292	102	118	1	324	112	122	0
316	102	129	1	330	112	113	0
293	103	115	1	312	112	119	0
298	104	114	1	335	112	133	0
296	104	118	1	327	114	120	0
310	104	124	1	315	114	130	0
281	105	111	1	318	118	122	0
296	105	114	1	329	118	140	0
305	105	113	1	324	118	126	0
322	106	128	1	221	118	120	0
320	107	125	1	305	119	125	0
322	108	126	1	343	120	133	0
291	108	121	1	340	120	128	0
301	109	120	1	307	120	121	0
317	109	119	1	340	122	130	0
301	109	110	1	334	122	136	0
321	109	120	1	340	122	123	0
292	110	121	1	339	130	151	0

[a] 1 = yes, 0 = no.