Fishery Data Series No. 94-51

Lower Kenai Peninsula Dolly Varden Studies During 1993

by

L. L. Larsen

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Alaska Department of Fish and Game

Division of Sport Fish

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LOWER KENAI PENINSULA DOLLY VARDEN STUDIES DURING 1993[1]

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ABSTRACT

During the period 3 July to 16 August 1993, abundance, composition, and selected fishery statistics were estimated for Dolly Varden *Salvelinus malma* (Walbaum) on the Anchor River. A total of 8,262 Dolly Varden were counted through a weir located 1.5 km upstream from salt water on the Anchor River. This Dolly Varden immigration is the lowest total adult return documented since this study was begun in 1987, however, the spawner component of this return increased slightly from the previous year.

Dolly Varden behavior in the intertidal waters downstream of the weir structure appeared to have changed from previous years. Dolly Varden were not observed in traditional holding areas prior to migrating upstream through the weir structure. This behavioral change coincided with unseasonably warm stream water conditions and is suspected of having a negative influence on Dolly Varden catch rates by anglers in the intertidal area.

KEY WORDS: Anchor River, Kenai Peninsula, anadromous, Dolly Varden, weir, age composition, sex composition, maturity index, *Salvelinus malma*, population dynamics, mortality, survival.

INTRODUCTION

This is the seventh year of a long-term study of lower Kenai Peninsula Dolly Varden *Salvelinus malma* (Walbaum) populations. This study provides information necessary to manage the Dolly Varden spawning stocks. The acquisition of basic Anchor River and non-Anchor River population data such as a total census, length and age composition, relative maturity, and exploitation and contribution rates to the fishery provides the means to estimate key population parameters necessary for estimating maximum sustained yield (MSY). Since this fishery is complicated by concurrent fisheries for other species, it is also necessary to acquire specific fisheries information on all species so that additional regulatory measures (if necessary) can be effectively implemented.

The Anchor River on the lower Kenai Peninsula (Figure 1) supports recreational fishing for chinook salmon *Oncorhynchus tshawytscha*, coho salmon *O. kisutch*, pink salmon *O. gorbuscha*, Dolly Varden, and anadromous (steelhead) and resident rainbow trout *O. mykiss*. The downstream section of this stream is crossed by the Sterling Highway making it easily accessible to the fishing public. Much of the river frontage along the lower 3 km of this stream is publicly owned, providing ample camping and parking areas. Due to the relatively small size of this stream, all fishing is conducted from the bank. The Anchor River has provided an average of 30,668 recreational fishing days (angler-days) annually from 1977 through 1992 (Mills 1979-1993). The fisheries targeting chinook salmon, coho salmon, steelhead, and Dolly Varden are of major importance to recreational anglers on the Anchor River, whereas the fisheries targeting resident rainbow trout and pink salmon are of lesser importance.

The recreational fishery for Dolly Varden in the Anchor River is one of the largest in Alaska and is of particular concern to resource managers. The recreational harvest has decreased in recent years, in part through more restrictive regulations and as the result of a declining Dolly Varden population. During the period 1977 to 1983, the harvest from this fishery averaged nearly 15,000 fish annually (Mills 1979-1984). In 1984, regulations for this fishery became more restrictive, bag and possession limits were reduced from ten to five fish, and the use of bait was prohibited after 16 September. While these regulations were in effect, the harvest of Dolly Varden averaged approximately 3,700 fish (Table 1). Although a marked decline was observed in the harvest of Dolly Varden after initiation of the new regulations, concerns were expressed that the decline may reflect a depressed population (Larson 1990). During 1990, the use of bait was prohibited during the period 15 August through 31 December (ADF&G 1990). In 1991, regulations further restricted the daily bag limit from five to two fish and the use of bait was prohibited during the period 1 September through 31 December (ADF&G 1991). The reduction in bag limit from five to two Dolly Varden was implemented on the Anchor River, Deep Creek, Stariski Creek, and the Ninilchik River to protect the Dolly Varden spawning stocks of the lower Kenai Peninsula. These same regulations remained in effect during 1993.

The Anchor River Dolly Varden population seems to follow a life history model similar to those described for Kodiak and Southeast Alaskan Dolly Varden (Sonnichsen 1990; Armstrong 1965, 1984). In this hypothetical model, the Anchor River is a spawning stream inhabited by juveniles (presmolt) and

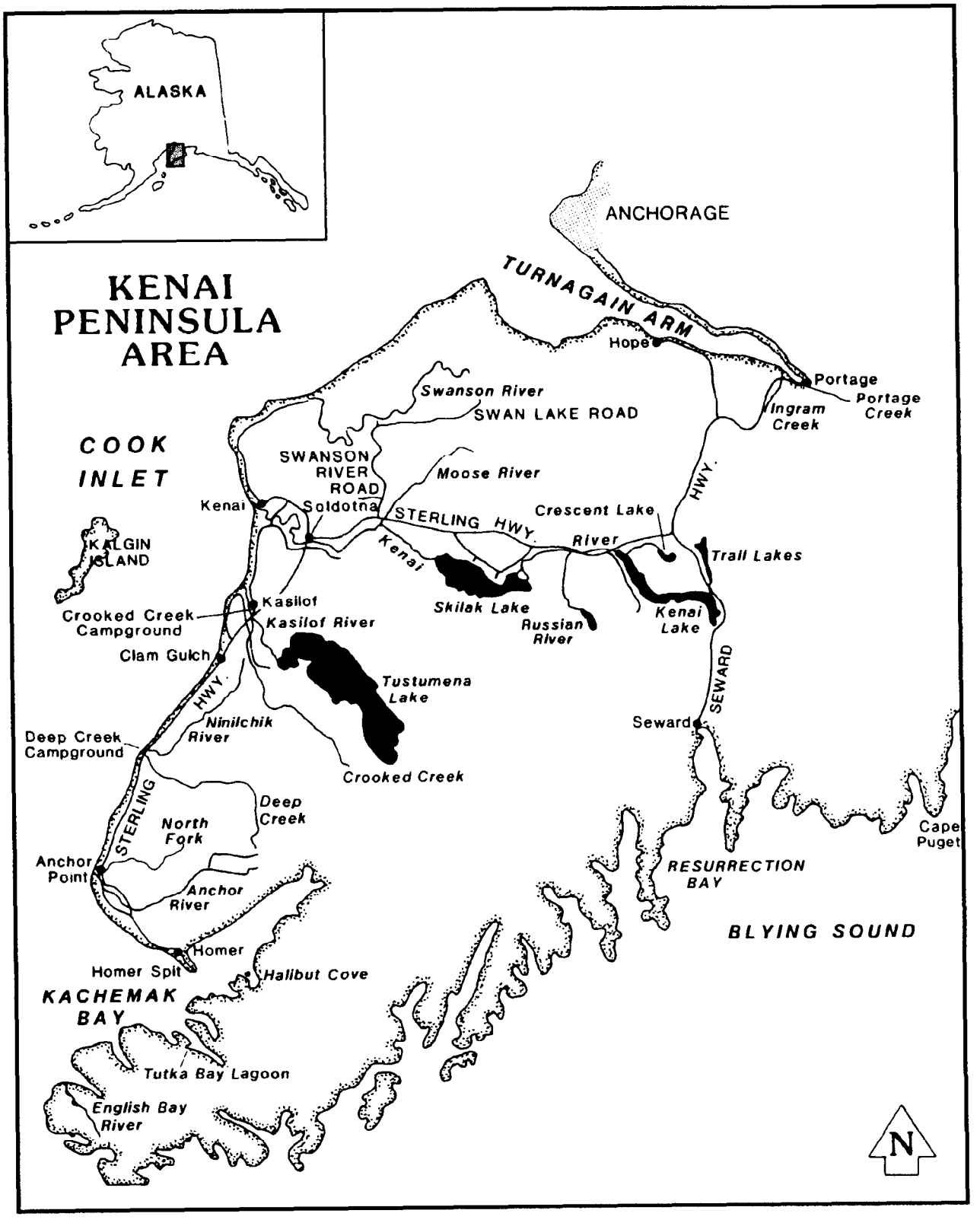

Figure 1. Map of Kenai Peninsula.

adults. The adults that spawn in the Anchor River remain there over winter and those that survive return to salt water the following spring (Larson 1990). Subadults forage in Cook Inlet and migrate to an overwintering area possibly other than the Anchor River for 1 or 2 years after smolting. Major coastal overwintering areas that have been described for Dolly Varden are lakes (Armstrong 1965 and 1984); thus, likely areas for the Anchor River population might be English Bay Lakes or Packers Lake, among others. Upon maturing, these fish return to the Anchor River as spawners. Results from 1989 (Larson 1990) indicate that (1) the immigration of mature females peaks earlier in the season and (2) the size range at which 100% of Dolly Varden are mature is narrow, but changes over time. Postspawners have been documented entering the Anchor River during September (Larson 1993) and may overwinter in the Anchor River as well. Although the postspawner origins are unknown, nearby Stariski Creek is one likely stream for this behavior.

This study provides information to test this model by censusing immigrating and emigrating Dolly Varden through the Anchor River weir.

The specific research objectives for 1993 were to:

1. census the immigration of Dolly Varden through a weir on the Anchor River during the period 1 July to 15 August;

2. estimate the length frequency of immigrating Dolly Varden at the weir by weekly intervals during the period 1 July to 15 August;

3. estimate the sex ratio, relative maturity, percent spawners, and age composition of immigrant Dolly Varden at the weir by biweekly periods during 1 July through 15 August; and

4. estimate the sex ratio, relative maturity, percent spawners, and age composition of Dolly Varden harvested downstream of the weir in the Anchor River sport fishery by biweekly periods during 1 July through 15 August.

This report includes historical data pertaining to Dolly Varden of the Anchor River that have been compiled and analyzed from the following sources: Allin (1954, 1957), Balland (1985, 1986), Nelson et al. (1987), Larson et al. (1988), Larson and Balland (1989), Larson (1990-1993), Wallis and Balland (1981-1984) and Wallis and Hammarstrom (1979-1982). Harvest and effort estimates have been reported by Mills (1979-1994).

METHODS

Study Design

A floating weir was installed in the Anchor River at the upstream limit of tidal influence to assess the immigration and emigration of all Dolly Varden over 200 mm in fork length between 3 July and 16 August. A random sample of immigrant Dolly Varden was collected at the weir and assessed for length, sex, age, and maturity during biweekly periods. Gonad development as described by Blackett (1968) was used to determine the relative maturity of female Dolly Varden collected at the weir. A random sample of harvested Dolly Varden was

examined from the sport fishery and sampled for length, age, sex, and relative maturity during biweekly periods from 1 July through 1 September. Males and females were assumed to have the same proportions in the different maturity categories for both weir and sport harvest samples.

Anchor River Weir

A weir was installed approximately 1.5 km upstream from the saltwater terminus of the Anchor River (Figure 2). The weir structure was constructed nearly entirely of floating weir panels, with rigid panels connecting the floating panels to the embankments. The rigid panel pickets were 1.25 cm diameter solid aluminum rods placed in an aluminum channel framework having a 1.25 cm gap between pickets. Channel frames were 3.6 m long by 1.05 m high. The aluminum frames rested against 1.05 m high vertical weir panels at the outer extremities of the floating weir panels and sandbag abutments along the shoreline. The floating panel pickets were 2.5 cm diameter hollow PVC tubing, capped at each end to provide buoyancy, having a 1.5 cm gap between pickets. Each panel, 4.5 m long, was anchored at one end to a cable and railroad track hinge system laid perpendicular to the stream flow and along the stream bottom. A resistance board fastened to the downstream end of each panel provided the necessary lift to the panels as river water depth varied. Traps were installed to capture both upstream and downstream migrating fish. The weir prevented passage of fish approximately 200 mm and larger.

Basic stream depth and temperature characteristics were obtained on a daily basis at the weir site. Depth readings were recorded daily at 2200 hours from 3 July through 15 August and temperature readings were recorded continually with a thermograph from 6 July through 15 August.

All fish passing through the upstream and downstream traps were counted by species and examined for tags and evidence of angler hook wounds. Dolly Varden were tagged over a 4-year period from 1986-1989. Tagging occurred on the Anchor River (1986-1989), Deep Creek (1987), and the Ninilchik River (1987-1988). Dolly Varden that were difficult to handle were anesthetized in a CO_2 water bath prior to being measured, otherwise a tagging cradle was used (Hammarstrom and Larson 1985). Fish sampled from the upstream trap were chosen by randomly selecting a trap load and sampling all fish from that trap load, whereas as many fish as possible were sampled in the downstream trap.

To achieve the desired precision for estimates, approximately 11% of the immigrating Dolly Varden were sampled for length (nearest millimeter fork length). Approximately 5% of the Dolly Varden immigration were sampled for age, sex, and weight; all female Dolly Varden from this sample were examined for relative maturity. These fish were sacrificed, weighed, and measured to the nearest millimeter fork length; and otoliths were removed for age determination (Williams and Bedford 1973). Each female Dolly Varden sampled for relative maturity was given a maturity index code of 1 to 5 according to the following criteria (Blackett 1968): (1) immature female with egg diameter less than 0.90 mm; (2) mature female with egg diameter greater than 1.75 mm; (3) completely mature female, eggs easily stripped; (4) completely spawned female; and (5) immature female but showing development, egg diameter greater than 0.90 mm and less than 1.75 mm. Dolly Varden given maturity index codes of 2, 3, or 4 were categorized as spawners, those with index code 1 were categorized as nonspawners, and those with index code 5 were potential spawners.

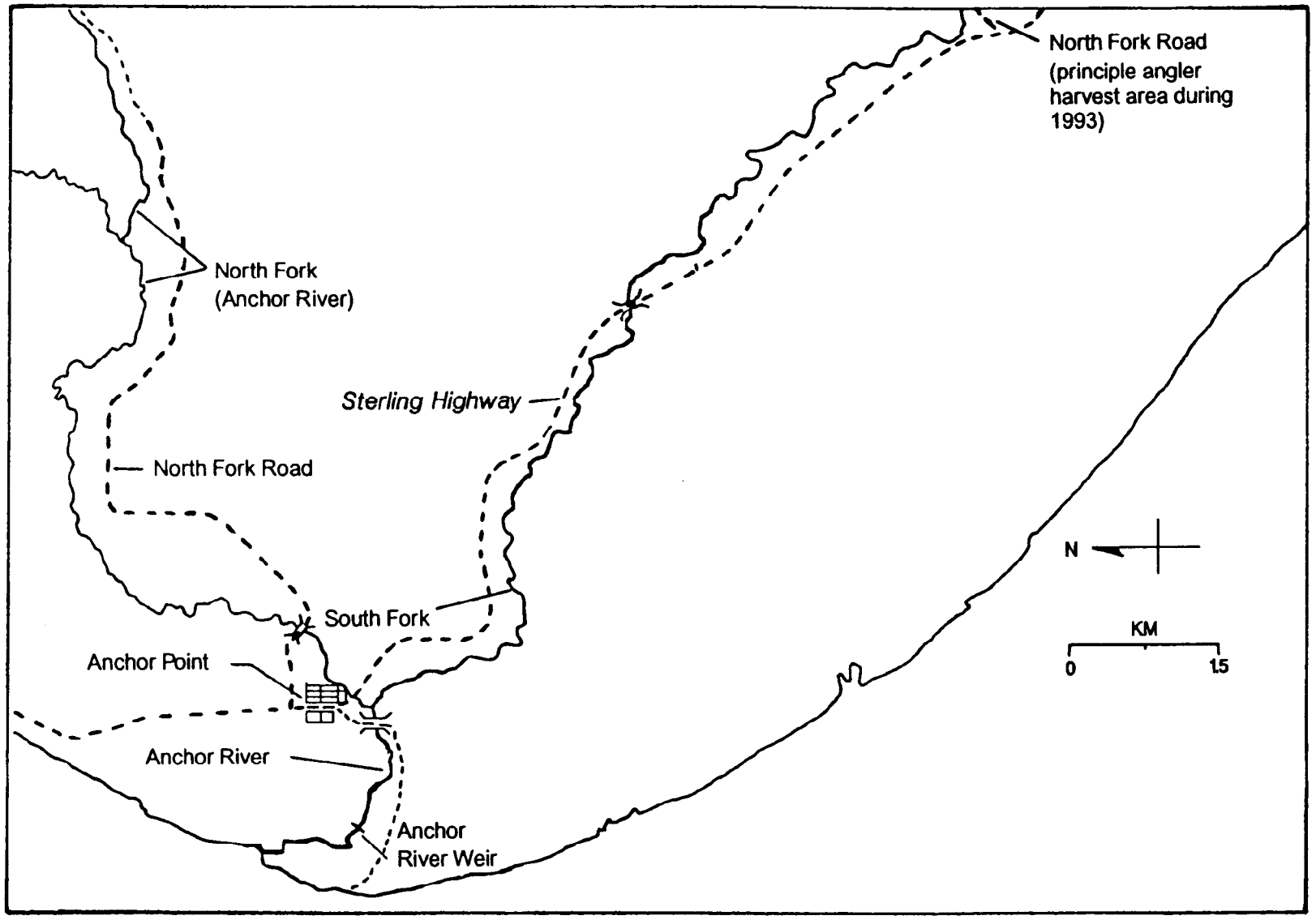

Figure 2. Map of the Anchor River.

Males and females were assumed to have the same proportions in the different maturity categories.

Mortalities deposited on the upstream side of the weir face and in the downstream trap were sampled for age (by removal and examination of otoliths), sex, relative maturity, and length (nearest millimeter fork length). Mortalities were also examined for injuries. The purpose of sampling mortalities was to assess the different types of injuries which may be affecting Dolly Varden of various age, length and sexual maturity, in particular hook wounds. These observations are subjective in nature and do not necessarily constitute the cause of death but could have management implications depending on frequency.

Sport Fishery

Estimates of recreational harvest of Anchor River Dolly Varden and effort were provided through the postseason statewide harvest survey (Mills 1994); inseason creel survey interviews of the Anchor River recreational fishery have not been conducted since 1991. Prior to 1992, these two independent estimates of harvest did not vary substantially (Table 1) and an inseason estimate was not considered necessary to manage the sport fishery. Estimates of catch from the creel survey were always substantially lower than those from the statewide harvest survey.

To obtain a maturity index of the harvest, biological samples were collected from the sport fishery from 1 July through 15 August by a part-time creel clerk and weir personnel. The creel clerk worked a random schedule and weir personnel assisted on a time available basis.

During 1993, a change in Dolly Varden behavior prevented anglers from harvesting many fish downstream of the weir (Objective 4) and the majority of the sport harvest occurred upstream of the weir. Therefore, biological sampling was altered to the upstream harvest areas. Fork length to the nearest millimeter was recorded, otoliths were removed for age determination, and sex and relative maturity were recorded for ungutted fish. Dolly Varden were also examined for injuries.

Stock Structure and Dynamic Rates

The proportions of fish in each age and sexual maturity component from 1989-1993, and their respective variances, were estimated as simple proportions (Cochran 1977: 50-52). Sexual maturity was categorized three ways by maturity index codes 1-5: by spawners (codes 2-4 combined), nonspawners (code 1), and potential spawners (code 5). The inclusion of 1987 and 1988 data was based on 1989 maturity index and length frequency data (Larson 1990). Based on 1989 length frequency data, Dolly Varden less than 300 mm fork length were considered nonspawners; fish 300-349 mm, potential spawners; and fish greater than 349 mm, spawners. Males and females were assumed to have the same proportions in the different maturity categories.

The number of Dolly Varden (sexes combined) by sexual maturity or age component was estimated for biweekly time periods by:

$$\hat{N}_{il} = \hat{P}_{il} N_i \qquad (1)$$

Table 1. Historical catch and harvest data from the Anchor River Dolly Varden sport fishery, 1977-1993.

Year	Creel Survey[a]		Statewide Harvest Survey[b]	
	Catch	Harvest	Catch	Harvest
1977				9,222
1978				17,357
1979				21,364
1980				10,948
1981				15,271
1982				10,375
1983				17,277
1984				5,560
1985				7,720
1986				3,910
1987	9,414	2,653		2,735
1988	11,992	2,915		2,746
1989	5,605	1,615		1,476
1990	5,391	2,124[c]	11,441	2,821
1991	5,995	1,520[d]	14,433	1,409
1992			18,303	2,532
1993			9,719	1,031

[a] Larson et al. 1988; Larson and Balland 1989; Larson 1990-1992.

[b] Mills 1979-1994.

[c] Fishing for Dolly Varden was closed by emergency order after 7 August 1990.

[d] The daily Dolly Varden bag limit was reduced from five to two beginning in 1991.

where:

$\hat{N}_{il}$ = estimated number of fish in length range or age class l during period i;

$\hat{P}_{il}$ = proportion of fish in length range or age l during period i; and

N_i = weir count during period i.

The variance was estimated as:

$$V(\hat{N}_{il}) = N_i^2 V(\hat{P}_{il}) \tag{2}$$

where:

$$V(\hat{P}_{il}) = \frac{\hat{P}_{il}(1 - \hat{P}_{il})}{n_i - 1} . \tag{3}$$

The length frequency of immigrating Dolly Varden changes over time (Larson et al. 1988), therefore the estimated population of each sexual maturity component was stratified temporally in three, 2-week periods from July through mid-August. The time frame, July through mid-August, encompasses most of the Dolly Varden immigration and was common to all 7 years of weir operation.

Annual survival to the weir and instantaneous dynamic rates were computed from estimates of numbers by age of the immigration through the weir in 1991 (Larson 1992), 1992 (Larson 1993) and 1993. These data were used to compute estimates of annual survival ($\hat{S}$) by age (Ricker 1975):

$$\hat{S} = \frac{\hat{N}_{[t+1,l+1]}}{\hat{N}_{[t,l]}} \tag{4}$$

where:

$\hat{N}$ = immigration through the weir,
t = year, and
l = age.

Annual mortality ($\hat{A}$) was computed for each age class by subtraction:

$$\hat{A} = 1 - \hat{S} . \tag{5}$$

Annual fishing mortality or exploitation ($\hat{E}$) was defined as mortality due to fishing which occurs in the Anchor River. Nearly all of the harvest from 1988 through 1992 occurred downstream of the weir. However, during 1993 the harvest occurred primarily upstream of the weir. Exploitation was computed from estimates of harvest ($\hat{H}$) and immigration ($\hat{N}$) by age:

$$\hat{E} = \frac{\hat{H}_{[t,1]}}{(\hat{H}_{[t,1]} + \hat{N}_{[t,1]}} . \tag{6}$$

The instantaneous rate of total mortality ($\hat{Z}$) was computed as (Ricker 1975):

$$\hat{Z} = -\ln(\hat{S}) . \tag{7}$$

Instantaneous annual fishing mortality was computed from the Baranof catch equations:

$$\hat{H} = \hat{N} * \left(\frac{\hat{F}}{\hat{Z}}\right) * (1 - e^{-\hat{Z}}) \tag{8}$$

$$\hat{F} = \left(\frac{\hat{H}}{1 - e^{-\hat{Z}}}\right) * \left(\frac{\hat{Z}}{\hat{N}}\right) .$$

Instantaneous natural mortality was computed by subtraction:

$$\hat{M} = \hat{Z} - \hat{F} . \tag{9}$$

RESULTS

Anchor River Weir

The Anchor River weir was in continuous operation from 3 July to 16 August 1993. The weir was removed from the river on 16 August. River water levels remained low throughout most of the duration of the weir operation and the weir was considered "fish tight" during its entire operation.

Water depth and temperature recorded at the upstream trap location varied from 27.5 cm to 40.0 cm and 10.3°C to 21.2°C, respectively (Appendix A1). Daily water temperature readings varied from 1.5°C to 8.3°C within a 24-hour period. In comparison, the water depth was less and water temperature higher than previous years (Nelson et al. 1987; Larson et al. 1988; Larson and Balland 1989; Larson 1990-1993).

A total of 8,262 Dolly Varden 200 mm or greater in length were counted passing upstream of the Anchor River weir from 3 July to 16 August (Appendix A2). The peak of the immigration occurred on 18 July (Figure 3), with 50% of the run having passed the weir by this date (Figure 4).

Dolly Varden immigrating through the weir and sampled in the sport fishery ranged in age from 2 to 9 years (Table 2 and Appendix A3). The age composition between weir and sport fishery samples was not significantly different (χ^2 = 6.72, df = 4, P = 0.15) (Table 2 and Figure 5). This is similar to the 1989 findings but contrary to findings from 1990-1992.

The age distribution of immigrating Dolly Varden sampled at the weir changed significantly (χ^2 = 59.34, df = 10, P < 0.005) (Table 3) over biweekly

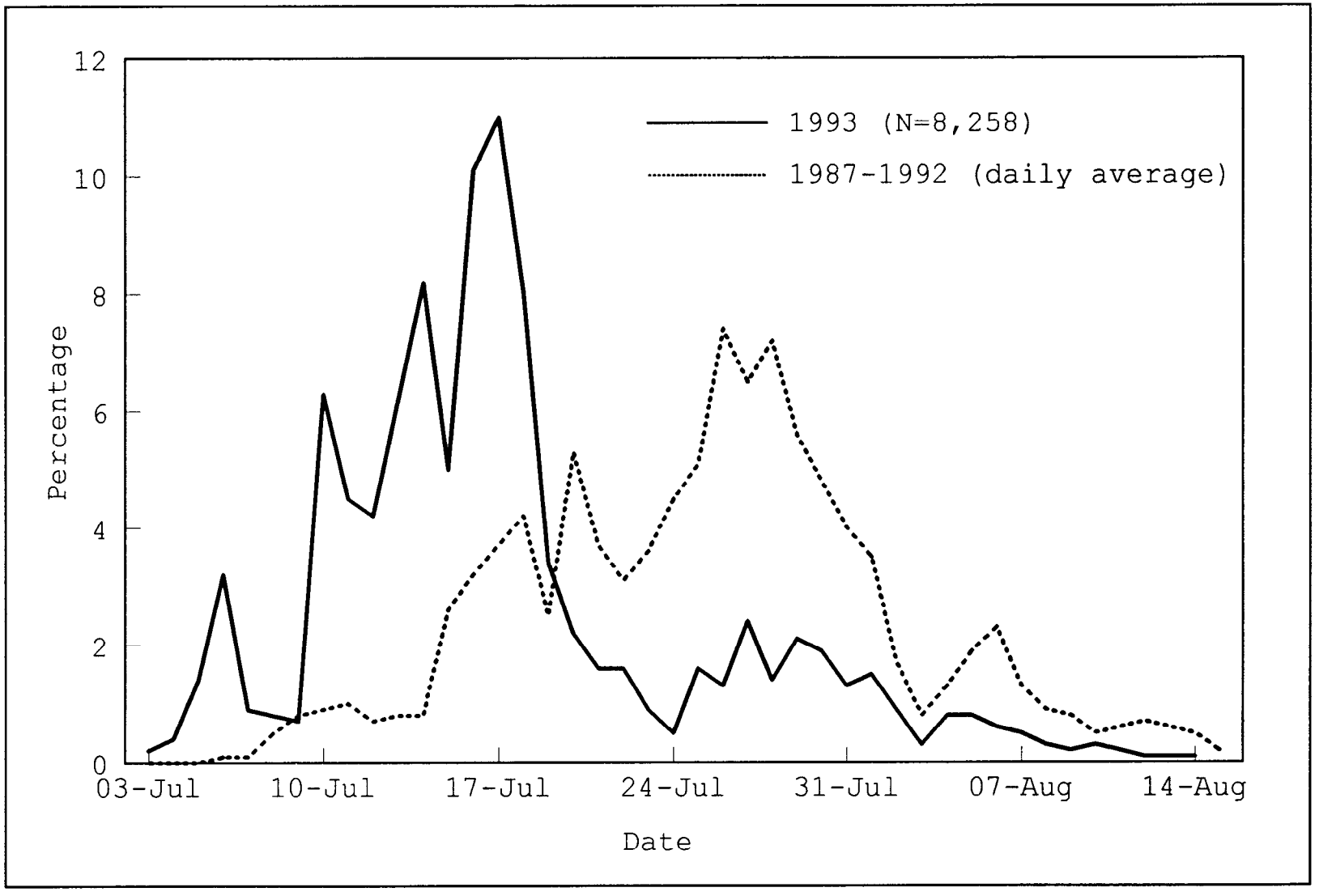

Figure 3. Daily run timing of Dolly Varden entering the Anchor River, 3 July-15 August. Fish were counted while passing upstream through the Anchor River weir, 1987-1993.

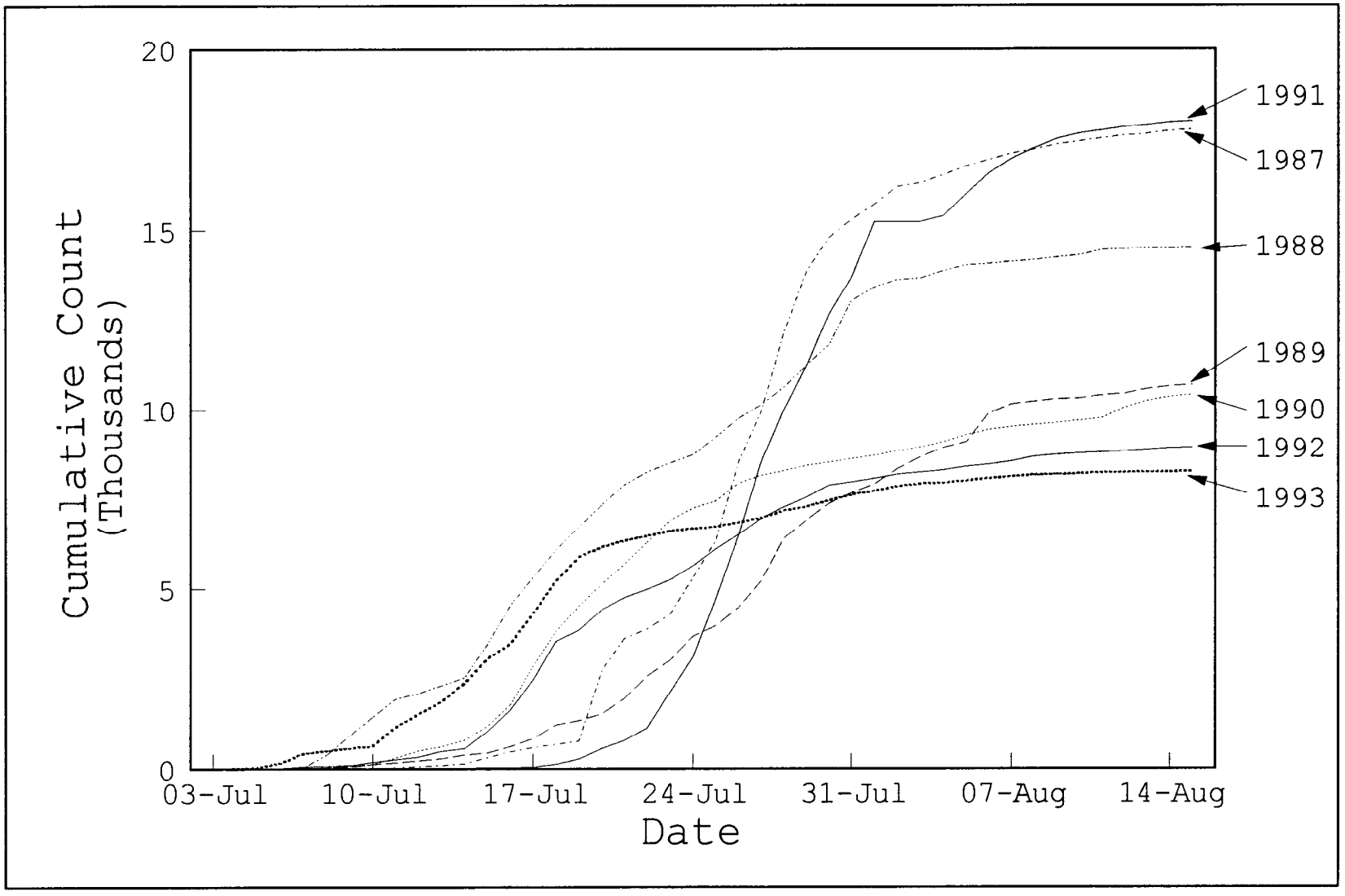

Figure 4. Cumulative run timing of Dolly Varden entering the Anchor River weir site, 1 July-15 August. Fish were counted while passing upstream through the Anchor River weir, 1987-1993.

Table 2. Age and sex compositions of Dolly Varden collected at the weir site and in the sport harvest on the Anchor River during 1993.

	Age Group								
Component	2	3	4	5	6	7	8	9	Total
Weir Samples (Upstream Trap)									
Male									
Percent	0.0	23.0	20.9	38.8	15.1	1.4	0.7	0.0	100.0
SE		0.04	0.03	0.04	0.03	0.01	0.01	0.00	
Sample Size		32	29	54	21	2	1		139
Female									
Percent	0.7	16.0	21.8	30.7	21.8	7.0	1.9	0.4	100.0
SE		0.02	0.03	0.03	0.03	0.02	0.01	0.00	
Sample Size	1	41	56	79	56	18	5	1	257
Sexes Combined[a]									
Percent	0.3	18.3	21.6	33.6	19.3	5.3	1.5	0.3	100.0
SE	0.00	0.02	0.02	0.02	0.02	0.01	0.01	0.00	
Sample Size	1	73	86	134	77	21	6	1	399
Sport Harvest									
Male									
Percent	0.0	5.3	26.3	47.4	15.8	5.3	0.0	0.0	100.0
SE		0.05	0.10	0.12	0.09	0.05	0.00	0.00	
Sample Size	0	1	5	9	3	1			19
Female									
Percent	0.0	4.2	20.8	29.2	33.3	12.5	0.0	0.0	100.0
SE		0.04	0.08	0.09	0.10	0.07	0.00	0.00	
Sample Size	0	1	5	7	8	3	0	0	24
Sexes Combined[a]									
Percent	0.0	4.3	21.3	40.4	23.4	10.6	0.0	0.0	100.0
SE		0.03	0.06	0.07	0.06	0.05	0.00	0.00	
Sample Size	0	2	10	19	11	5			47

[a] The combined sex category contains additional samples than the sum of the individual male and female categories. This is due to age but not sex being determined on some biological samples.

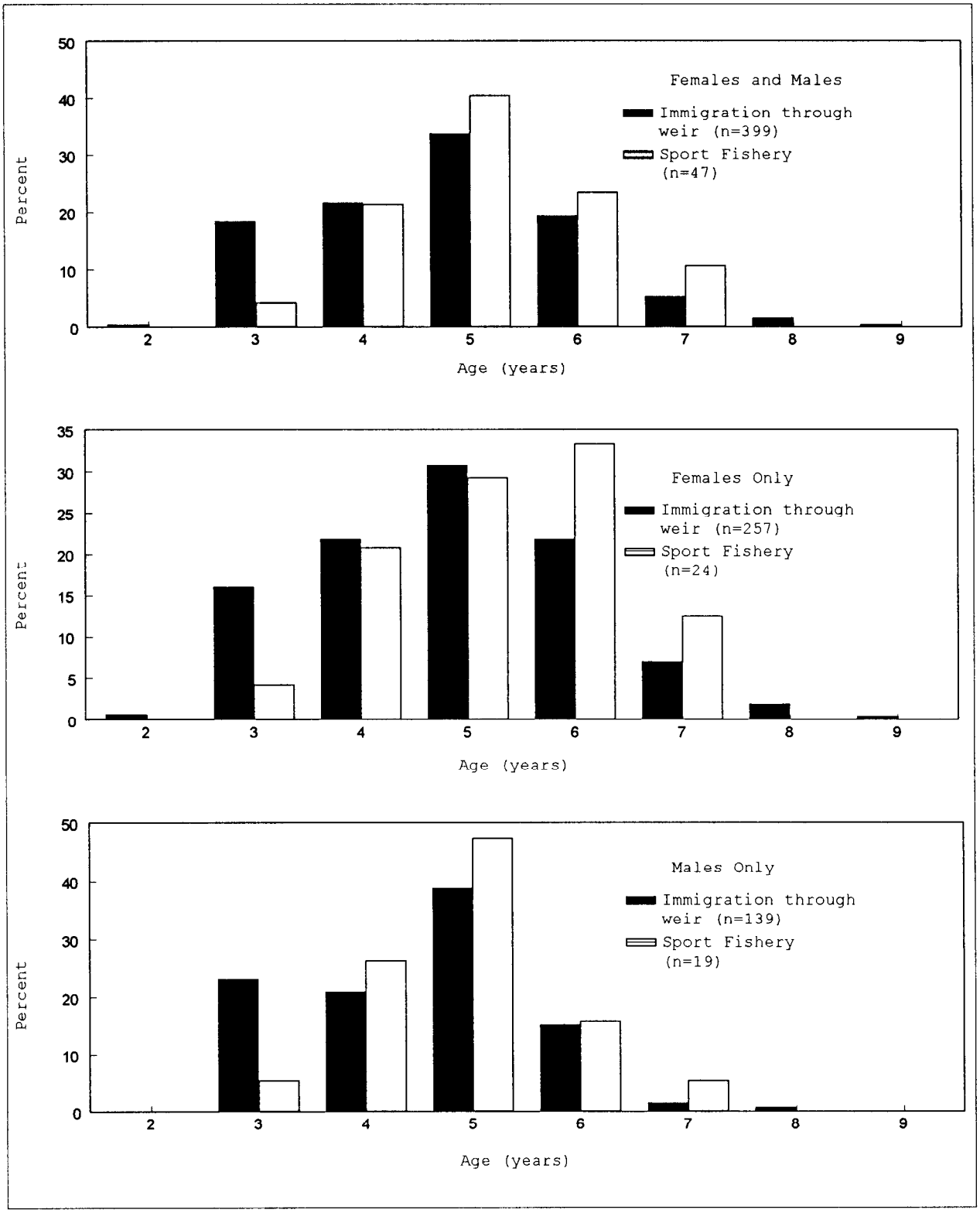

Figure 5. Age and sex composition of Dolly Varden sampled at the Anchor River weir site and in the sport fishery, 1993.

Table 3. Estimated age composition of Anchor River Dolly Varden sampled biweekly from the weir site, 1993.

	Age Group[a]								
	2	3	4	5	6	7	8	9	Total
7/3 - 7/18									
Percent	0.0	4.3	17.4	40.6	30.4	4.3	2.9	0.0	100.0
SE	0.00	0.02	0.03	0.04	0.04	0.02	0.01	0.00	
Sample Size	0	6	24	56	42	6	4	0	138
7/19 - 7/31									
Percent	0.0	17.3	21.3	33.9	17.3	7.9	1.6	0.8	100.0
SE	0.00	0.03	0.04	0.04	0.03	0.02	0.01	0.01	
Sample Size	0	22	27	43	22	10	2	1	127
8/1 - 8/15									
Percent	0.7	33.3	25.9	25.9	9.6	3.7	0.7	0.0	100.0
SE	0.01	0.04	0.04	0.04	0.03	0.02	0.01	0.00	
Sample Size	1	45	35	35	13	5	1	0	135
Total									
Percent	0.3	18.3	21.5	33.5	19.3	5.3	1.8	0.3	100.0
SE	0.00	0.02	0.02	0.02	0.02	0.01	0.01	0.00	
Sample Size	1	73	86	134	77	21	7	1	400

[a] Age groups 2 and 3, and 8 and 9, were combined for Chi-square analysis.

periods. The proportion of younger fish increased from 3 July through 15 August (Appendix A3). Because of small sample sizes the age composition by biweekly periods was not examined for the sport fishery.

Immigrating male and female Dolly Varden were both predominantly age 5 (Figure 5). Few fish were older than age 6 and the combined year-classes from 7 through 9 accounted for less than 10% of the run. These results are consistent with those observed from 1990-1992 (Larson 1991-1993) and suggest a low frequency of repeat spawning due to high natural or fishing mortality.

Of the 402 fish sampled at the weir, 65% were females; of the 44 fish sampled in the sport harvest, 57% were females (Table 4). These ratios did not change significantly (weir: $\chi^2 = 0.17$, df = 2, P = 0.92; sport harvest: $\chi^2 = 0.24$, df = 2, P = 0.89) over time when compared in biweekly periods. These results are contradictory to 1990 (Larson 1991) but similar to 1991 and 1992 (Larson 1992-1993) findings.

One-way analysis of variance (Snedecor and Cochran 1967) was used to test the null hypothesis that there was no change in mean length of fish by age class across three biweekly periods at the weir. The mean length changed significantly for age-4 ($F = 7.7$, df = 2, 83, $P < 0.001$), age-6 ($F = 11.8$, df = 2, 74, $P < 0.001$) and age-7 ($F = 5.8$, df = 2, 18, $P < 0.02$) fish. Age-4 fish decreased in size over biweekly periods, with a significant difference in mean length occurring between the first and third and second and third periods, but not between the first and second periods. Age-6 fish increased in size over biweekly periods, with a significant difference in mean length between the first and second and first and third periods, but not between the second and third periods. Age-7 fish varied in mean length between biweekly periods, with a significant difference between the first and third and second and third periods, but not between the first and second periods. This level of variability in mean length between biweekly periods is unique to 1993 and not reflective of previous years when mean length generally decreased within each age class from 1 July through 15 August.

The overall change in mean length of fish across weeks at the weir (Figure 6) increased slightly between the first and second week and then decreased each week from the second through the sixth week. These results are consistent with those observed from 1989 through 1992 (Larson 1990-1993) when mean length generally decreased over the same 6-week period (1 July through 15 August).

The Dolly Varden sport fishery during 1993 changed radically from previous years. Harvest of Dolly Varden downstream of the weir, which had been estimated as high as 96% in previous years (Larson 1991), was practically nonexistent. Most of the harvest during 1993 occurred approximately 10 miles upstream of the weir, on the South Fork of the Anchor River and in the vicinity of the North Fork Road (Figure 2). Dolly Varden were observed entering the Anchor River from salt water in the evening hours, passing through the upstream trap during the hours of darkness, and upstream of the North and South fork confluence (approximately 2 miles upstream from salt water) before sunrise.

Dolly Varden harvested in the sport fishery had a tendency to be slightly larger than those sampled at the weir (Table 5), especially in the younger age classes (ages 3 and 4), thus indicating a tendency by anglers to harvest

Table 4. Estimated sex ratios of Anchor River Dolly Varden sampled biweekly from the weir site and in the sport fishery, 1993.

	7/3 - 7/18			7/19 - 7/31			8/1 - 8/15						
Sex	Count	%	SE	Count	%	SE	Count	%	SE	Total Count	%	$\hat{N}$	SE
Weir													
Male	50	36	0.04	43	34	0.04	47	35	0.04	140	35	2,876	803
Female	89	64	0.04	85	66	0.04	88	65	0.04	262	65	5,382	803
Total	139	100		128	100		135	100		402	100	8,258	
Sport Fishery													
Male	4	40	0.16	6	40	0.13	9	47	0.12	19	43	4,179	
Female	6	60	0.16	9	60	0.13	10	53	0.12	25	57	5,540	
Total	10	100		15	100		19	100		44	100	9,719	

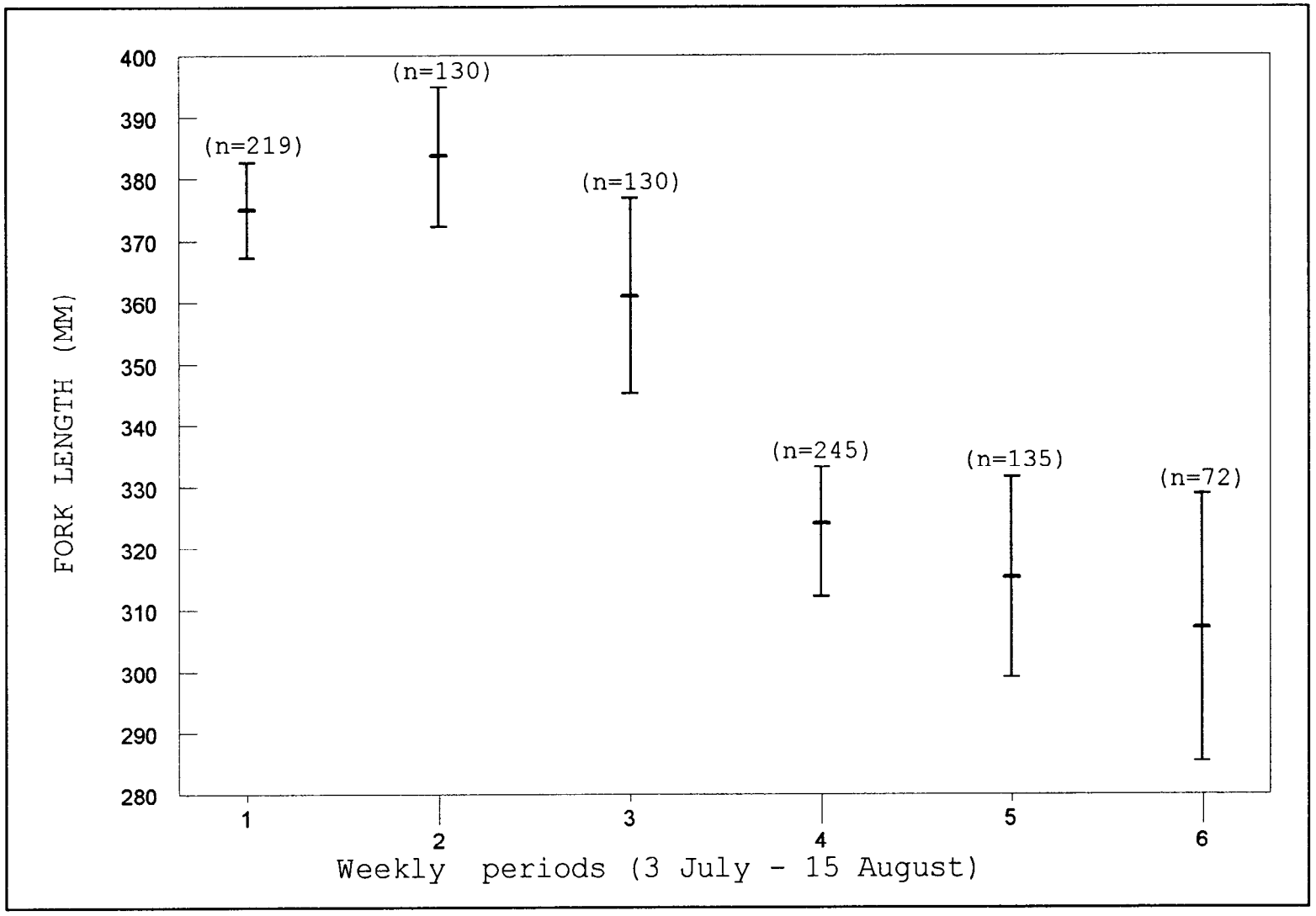

Figure 6. Mean length by weekly period with 95% confidence intervals from Dolly Varden sampled moving upstream through the Anchor River weir, 1993.

Table 5. Mean length (millimeters) by age group and female sexual maturity of Dolly Varden collected at the Anchor River weir site and in the sport fishery, 1993.

Component		Age Group 2	3	4	5	6	7	8	9
Weir Samples (Upstream Trap)									
Nonspawners[a]									
	Mean Length	213	232	258	293				
	Standard Error		3.8	8.2	14.5				
	Sample Size	1	36	16	5				
Potential Spawners[b]									
	Mean Length		279	320	324	328			
	Standard Error		14.8	2.9	8.0	11.8			
	Sample Size		5	29	19	7			
Spawners[c]									
	Mean Length			356	419	418	461	449	427
	Standard Error			18.0	6.3	6.3	12.5	31.2	
	Sample Size			11	55	49	18	5	1
Sport Harvest									
Nonspawner[a]									
	Mean Length		264	286	241				
	Standard Error			28.0					
	Sample Size		1	2	1				
Potential Spawners[b]									
	Mean Length				375				
	Standard Error								
	Sample Size				1				
Spawners[c]									
	Mean Length			386	403	444	424		
	Standard Error			0.5	26.3	23.4	8.0		
	Sample Size			2	5	8	2		

[a] Immature females with egg diameter less than 0.90 mm (maturity index code 1).

[b] Immature females showing development, egg diameter greater than 0.90 mm and less than 1.75 mm (maturity index code 5).

[c] Mature females with egg diameter greater than 1.75 mm, or completely mature females (eggs easily stripped), or completely spawned females (maturity index codes 2-4).

larger fish. The sample size of sport harvested spawners and nonspawners was insufficient for statistical length comparisons between sport harvested fish and those sampled at the weir.

Estimates, based on female maturity index codes, of the Dolly Varden immigration through the weir from 3 July through 15 August indicate that about 59% were spawners, 26% potential spawners, and 14% nonspawners (Table 6, Figure 7, and Appendix A4). The proportion of immigrating Dolly Varden nonspawners (female maturity index code 1) and spawners (female maturity index code 2) changed significantly (χ^2 = 24.7, df = 2, P < 0.005) over time (Table 6). Nonspawners increased in abundance while spawners decreased biweekly through 15 August. These results are consistent with those observed in 1989, 1990, and 1992 (Larson 1990-91 and 1993). The sample sizes from the sport fishery were not sufficient to examine female maturity index codes on a biweekly basis.

The cumulative length distribution between immigrating spawners and nonspawners differed significantly at age group 4 (D_{max} = 0.78; n = 16, 11; P < 0.001) and age group 5 (D_{max} = 0.95; n = 55, 5; P < 0.001), spawners being larger than nonspawners (Table 5). These results are consistent with those observed from 1989 through 1992 (Larson 1990-1993).

A total of 128 Dolly Varden was found dead in the downstream trap or along the upstream side of the weir face (Table 7). A subjective examination for possible causes of death revealed 43 fish (33.6%) with apparent hook wounds, 11 (8.6%) fish with net injuries, 32 (25.0%) fish with unknown injuries, 13 (10.2%) fish with predator injuries, and 29 (22.7%) fish with no apparent injuries (Table 8). Injuries which resulted in lesions to the skin generally had topical evidence of a bacterial infection resembling furunculosis (a necrotic lesion which ulcerates to release lightly infectious reddish fluid).

A total of 67 live Dolly Varden passed through the downstream trap from 3 July to 16 August (Table 7). The majority (55%) of these fish were less than 300 mm in fork length. When examined for injuries, 67.2% had no apparent injuries while 29.9% had apparent hook wounds (Table 8).

Stock Structure and Dynamic Rates

The estimated spawner component of immigrating Dolly Varden sampled at the Anchor River weir from 3 July through 15 August decreased each year from 1987 through 1990, increased to the second highest level during 1991, then decreased to near 1990 levels during 1992 and 1993 (Table 9 and Figure 7). The combined potential spawner and nonspawner components have ranged from approximately 3,300 to 10,300 fish annually during the period 1987-1993 (Figure 7). The nonspawners are considered to be of mixed origin (Armstrong 1965), and therefore, variations in nonspawner abundance are not necessarily reflective of the Anchor River stock status.

Estimates of annual survival through age 5 were generally greater than one (Table 10). Fish younger than age 5 were incompletely recruited to the spawning population (Table 3 and Larson 1992). Fourteen of the 15 estimates of annual survival for ages 6-8 were all less than one and show a strong decreasing trend as fish age from age 6 to age 8. Based on maturity sampling, these age classes are comprised virtually entirely of spawners and should annually

Table 6. Relative maturity of Dolly Varden sampled at the Anchor River weir and in the sport fishery by period, 1993.

			Female Maturity Index[a]																
			1					2					3	4	5				
Period	N	n_i	n	%	Mean Length	$\hat{N}$	SE	n	%	Mean Length	$\hat{N}$	SE	n	n	n	%	Mean Length	$\hat{N}$	SE
Weir Samples																			
7/3-18	5,217	89	7	8	266	410	151	54	61	411	3,167	271	0	0	28	32	326	1,642	259
7/19-31	2,390	85	17	20	247	478	228	53	62	430	1,490	276	0	0	15	18	314	422	219
8/1-15	651	88	35	40	238	259	34	35	40	421	259	34	0	0	18	21	310	133	28
Total	8,258	262	59	14	244	1,147	177	142	59	421	4,915	251	0	0	61	26	319	2,196	224
Sport Harvest																			
7/1-18		6	1	17	314			5	83	449			0	0	0	0			
7/19-31		10	2	20	264			8	80	428			0	0	0	0			
8/1-15		9	2	22	250			5	56	398			0	0	2	22	334		
Total	1,031	25	5	20	269	206		18	72	425	742		0	0	2	8	334	83	

[a] Maturity index: 1 = immature female with egg diameter less than 0.90 mm; 2 = mature female with egg diameter greater than 1.75 mm; 3 = completely mature female (eggs easily stripped); 4 = completely spawned female; and 5 = immature female but shows development, egg diameter greater than 0.90 mm and less than 1.75 mm.

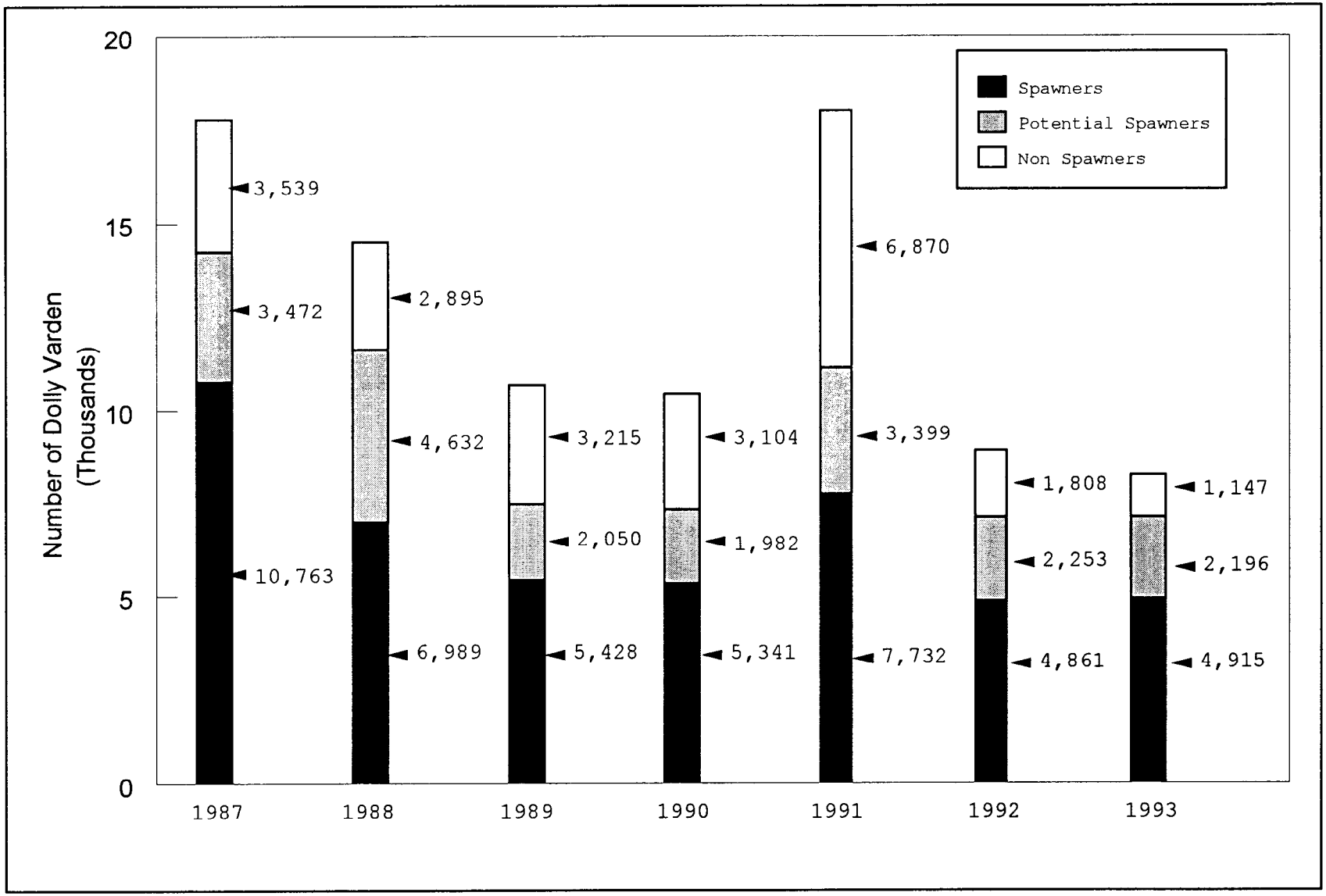

Figure 7. Estimated sexual maturity component of immigrating Dolly Varden sampled at the Anchor River weir from 1 July through 15 August, 1987-1993.

Table 7. Number of Dolly Varden sampled from the upstream trap, sport harvest, mortalities recovered at the weir site, and downstream trap, by length range, Anchor River, 3 July-15 August 1993.

	Upstream Trap		Sport Harvest		Mortalities		Downstream Trap	
Length Range	Count	%	Count	%	Count	%	Count	%
<200	14	2	0	0	3	2	2	3
200-249	186	20	1	2	20	16	17	25
250-299	95	10	6	13	16	13	18	27
300-349	171	18	6	13	25	20	12	18
350-399	153	16	9	19	37	29	7	10
400-449	193	21	17	35	19	15	9	13
450-499	83	9	7	15	5	4	0	0
500>	36	4	2	4	3	2	2	3
Total	931	100	48	100	128	100	67	100

Table 8. Injuries observed by length range from Dolly Varden sampled in the emigration through the Anchor River weir and from mortalities collected at the weir site, 1993.

Length Range	No Injuries	%	Angler Wound	%	Net Wound	%	Unknown Injuries	%	Predator Injuries	%	Total
Live Emigration											
<200	2	3.0		0.0		0		0		0.0	2
200-249	7	10.4	10	14.9		0		0		0.0	17
250-299	13	19.4	4	6.0		0		0		0.0	18
300-349	8	11.9	4	6.0		0		0	1	1.5	12
350-399	7	10.4		0.0		0		0		0.0	7
400-449	6	9.0	2	3.0		0		0		0.0	9
450-499		0.0				0		0	1	1.5	0
500>	2	3.0		0.0		0		0		0.0	2
Total	45	67.2	20	29.9		0		0	2	3.0	67
Downstream Mortalities											
<200	1	0.8	2	1.6		0.0		0.0		0.0	3
200-249	7	5.5	8	6.3		0.0	4	3.1	1	0.8	20
250-299		0.0	10	7.8	1	0.8	3	2.3	2	1.6	16
300-349	4	3.1	10	7.8	7	5.5	3	2.3	1	0.8	25
350-399	7	5.5	7	5.5	2	1.6	15	11.7	6	4.7	37
400-449	9	7.0	4	3.1		0.0	5	3.9	1	0.8	19
450-499	1	0.8	2	1.6	1	0.8		0.0	1	0.8	5
500>		0.0		0.0		0.0	2	1.6	1	0.8	3
Total	29	22.7	43	33.6	11	8.6	32	25.0	13	10.2	128

Table 9. Estimated sexual maturity of Dolly Varden sampled at the Anchor River weir from July through 15 August, 1987-1993.

			Nonspawners				Potential Spawners				Spawners			
Year	Period	Weir Cnt	n	%	$\hat{N}$	SE	n	%	$\hat{N}$	SE	n	%	$\hat{N}$	SE
1987[a]	July 4-17	596	17	3.8	23	5	57	12.9	77	8	369	83.3	496	9
	July 18-31	14,688	215	17.3	2,534	46	237	19.0	2,794	48	794	63.7	9,360	58
	Aug 1-15	2,490	431	39.4	982	24	264	24.2	601	21	398	36.4	907	24
	Total	17,774	663	23.8	3,539	57	558	20.1	3,472	53	1,561	56.1	10,763	66
1988[a]	July 4-17	5,323	105	7.8	417	20	431	32.2	1,712	34	804	60.0	3,194	36
	July 18-31	7,713	337	29.3	2,258	40	403	35.0	2,701	42	411	35.7	2,754	42
	Aug 1-15	1,480	8	14.8	219	14	8	14.8	219	14	38	70.4	1,041	18
	Total	14,516	450	17.7	2,895	46	842	33.1	4,632	57	1,253	49.2	6,989	60
1989	July 5-18	1,229	3	4.5	56	7	21	31.8	391	16	42	63.6	782	17
	July 19-31	6,429	50	32.9	2,115	38	22	14.5	931	28	80	52.6	3,384	40
	Aug 1-15	3,034	43	34.4	1,044	26	30	24.0	728	24	52	41.6	1,262	27
	Total	10,692	96	28.0	3,215	46	73	21.3	2,050	42	174	50.7	5,428	52
1990	July 2-15	1,201	12	15.8	190	13	15	19.7	237	14	49	64.5	774	17
	July 16-31	7,418	16	23.9	1,771	37	12	17.9	1,329	33	39	58.2	4,318	42
	Aug 1-15	1,808	55	63.2	1,143	21	20	23.0	416	18	12	13.8	249	15
	Total	10,427	83	36.1	3,104	49	47	20.4	1,982	41	100	43.5	5,341	51
1991	July 2-18	141	3	37.5	53	6	1	12.5	18	4	4	50.0	71	6
	July 19-31	13,531	24	40.0	5,412	57	12	20.0	2,706	47	24	40.0	5,412	57
	Aug 1-15	4,330	25	32.5	1,406	31	12	15.6	675	24	40	51.9	2,249	33
	Total	18,002	52	35.9	6,871	64	25	17.2	3,399	51	68	46.9	7,732	67

-continued-

Table 9. (Page 2 of 2).

			Nonspawners				Potential Spawners				Spawners			
Year	Period	Weir Cnt	n	%	$\hat{N}$	SE	n	%	$\hat{N}$	SE	n	%	$\hat{N}$	SE
1992	July 4-18	3,547	5	6.9	246	15	22	30.6	1,084	27	45	62.5	2,217	29
	July 19-31	4,423	14	21.2	938	27	15	22.7	1,005	28	37	56.1	2,480	33
	Aug 1-15	953	38	65.5	624	15	10	17.2	164	12	10	17.2	164	12
	Total	8,923	57	29.1	1,808	43	47	24.0	2,253	40	92	46.9	4,861	47
1993	July 4-18	5,217	7	7.9	410	19	28	31.5	1,641	34	54	60.7	3,166	35
	July 19-31	2,390	17	20.0	478	20	15	17.6	422	19	53	62.4	1,490	24
	Aug 1-15	651	35	39.8	259	12	18	20.5	133	10	35	39.8	259	12
	Total	8,258	59	22.5	1,147	38	61	23.3	2,196	38	142	54.2	4,915	45

[a] Sexual maturity based on female length frequency and maturity index data collected during 1989 (nonspawners: <300 mm; potential spawners: 300-349 mm; spawners: >349 mm).

Table 10. Anchor River Dolly Varden estimates by age of percent composition, weir counts, annual survival and annual mortality from 1 July through 15 August, 1988-1993.[a]

		Age									
Year	n	2	3	4	5	6	7	8	9	10+	Total
Weir Count											
1988	622	58	842	3,353	7,040	2,366	682	73	102	0	14,516
1989	557	71	750	2,492	2,681	3,520	933	231	14	0	10,692
1990	366	38	1,961	2,580	3,409	1,595	769	25	25	21	10,427
1991	240	164	1,663	6,262	6,229	2,185	1,040	423	36	0	18,002
1992	380	8	1,387	2,474	2,751	1,882	552	182	57	0	9,293
1993	400	5	858	1,585	3,097	2,065	439	194	19	0	8,262
Percent											
1988	622	0.4	5.8	23.1	48.5	16.3	4.7	0.5	0.7	0.0	100.0
1989	557	0.7	7.0	23.3	25.1	32.9	8.7	2.2	0.1	0.0	100.0
1990	366	0.4	18.8	24.7	32.7	15.3	7.4	0.2	0.2	0.2	100.0
1991	240	0.9	9.2	34.8	34.6	12.1	5.8	2.3	0.2	0.0	100.0
1992	380	0.1	14.9	26.6	29.6	20.3	5.9	2.0	0.6	0.0	100.0
1993	400	0.1	10.4	19.2	37.5	25.0	5.3	2.3	0.2	0.0	100.0

	Age							
	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Annual Survival								
1988-1989	12.93	2.960	0.800	0.500	0.394	0.339	0.192	0.000
1989-1990	27.62	3.440	1.368	0.595	0.218	0.027	0.108	1.500
1990-1991	43.76	3.193	2.414	0.641	0.652	0.550	1.440	0.000
1991-1992	8.46	1.488	0.439	0.302	0.253	0.175	0.135	0.000
1992-1993	107.25	1.143	1.252	0.751	0.233	0.351	0.104	0.000
Annual Mortality								
1988-1989	-11.93	-1.960	0.200	0.500	0.606	0.661	0.808	1.000
1989-1990	-26.62	-2.440	-0.368	0.405	0.782	0.973	0.892	-0.500
1990-1991	-42.76	-2.193	-1.414	0.359	0.348	0.450	-0.440	1.000
1991-1992	-7.46	-0.488	0.561	0.698	0.747	0.825	0.865	1.000
1992-1993	-106.25	-0.143	-0.252	0.249	0.767	0.649	0.896	1.000

[a] Age composition based on fish mortalities collected on the weir face (1988) and random sampling schedules (1989-1993).

return to spawn. These estimates seem a realistic expression of that phenomenon. While age 9 and older fish should fit the same pattern as that described for age 6-8 fish, annual survival for these age classes varies widely from 0 to 1.5 and is likely attributable to rare event sampling; these age classes are found in only trace levels (less than 1%) (Table 10).

Exploitation by the sport fishery ($\hat{E}$) (Table 11) indicates that anglers harvest fish of spawning age, primarily age 4 and older.

Since the only values of annual survival by age ($\hat{S}$) that were within realistic estimates were those for ages 5-9, these are the only instantaneous rates that have meaning. The instantaneous rates of total mortality (Z) were generally positive and increasing after age 5 (Table 12) during 1993. This indicates a decrease in Dolly Varden recruitment after age 4 during 1993, although in some years (1989 and 1992) Dolly Varden recruitment decreased after age 3.

No trends were evident in instantaneous annual fishing mortality ($\hat{F}$) (Table 12) and the values are variable across years and ages. The year 1993 stands out as a year with some of the lowest values of annual fishing mortality, especially in the younger age groups (2-3, 3-4, and 4-5), which corresponds to a lack of nonspawners (Tables 9 and 11).

Instantaneous natural mortality ($\hat{M}$) (Table 12) was approximately an order of magnitude higher than the values of F for ages 5 through 9. This indicates that the number of deaths due to harvest in the sport fishery was much lower than from natural causes. These results are consistent with previous years and support the literature which indicates mortality due to spawning is high.

DISCUSSION

Dolly Varden

The 1993 immigration of Anchor River Dolly Varden decreased from the 1992 weir count by several hundred fish and represents the smallest total return since a weir was established in 1987. The maturity components of the 1993 immigration indicate that the number of nonspawners dropped approximately 37% from 1992, however, spawners actually increased slightly from 4,861 to 4,915 (Table 9).

This study provides information necessary to manage the Dolly Varden spawning stock. The spawning population has not varied appreciably in 4 out of the last 5 years (Figure 7). This relatively stable spawning population level is believed lower than historical levels and further restrictions to the sport fishery may be necessary should the spawning population continue to drop. If additional conservative management of the sport fishery becomes necessary, restricting the sport fishery during the beginning of the Dolly Varden immigration would offer the greatest protection to the spawning segment (fish of Anchor River origin) of the immigration (Larson 1993). Because Dolly Varden nonspawners are believed to consist of mixed stocks, liberalization of the Dolly Varden fishery later in the immigration would have the least impact on fish of Anchor River origin.

Table 11. Anchor River sport harvest estimates of percent composition, harvest and annual fishing mortality by age downstream of the fish weir, 1988-1993.

		Age									
Year	n	2	3	4	5	6	7	8	9	10+	Total
Percent by Age											
1988	224	0	2.7	26.3	47.7	17.8	3.6	1.4	0.5		100.0
1989	60	0	6.7	30.0	25.0	31.6	5.0	1.7		100.0	
1990	87	0	9.2	27.6	41.3	9.2	9.2	2.3	1.2		100.0
1991	188	0	3.7	23.4	36.2	24.5	9.6	1.6	0.5	0.5	100.0
1992	143	0	4.9	34.3	35.0	21.0	1.4	1.4	2.1		100.1
1993	47	0	4.3	21.3	40.4	23.4	10.6				100.0
Estimated Harvest by Age											
1988	224	0	58	567	1,028	384	78	30	11	0	2,156
1989	60	0	71	316	263	333	53	18	0	0	1,053
1990	87	0	195	586	877	195	195	49	25	0	2,124
1991	188	0	56	356	550	372	146	24	8	0	1,520
1992	143	0	124	868	885	532	35	35	53	0	2,532
1993	47	0	44	220	417	241	109	0	0	0	1,031
Annual Fishing Mortality (E) or Exploitation											
1988			0.065	0.145	0.127	0.140	0.102	0.293	0.096	-	
1989			0.086	0.113	0.089	0.086	0.053	0.072	0.000	-	
1990			0.091	0.185	0.205	0.109	0.203	0.661	0.505	0.000	
1991			0.033	0.054	0.081	0.146	0.123	0.054	0.174	1.000	
1992			0.082	0.260	0.244	0.220	0.060	0.163	0.483	-	
1993			0.049	0.122	0.119	0.105	0.199	0.000	0.000	-	

Table 12. Anchor River Dolly Varden instantaneous estimates of annual, fishing and natural mortality, 1988-1993.

	Age							
Year	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10
Instantaneous Annual Mortality (Z)								
1988-1989	-2.560	-1.085	0.224	0.693	0.931	1.083	1.651	-
1989-1990	-3.319	-1.235	-0.313	0.519	1.521	3.620	2.224	-0.405
1990-1991	-3.779	-1.161	-0.881	0.445	0.428	0.598	-0.365	-
1991-1992	-2.135	-0.397	0.823	1.197	1.376	1.743	2.004	-
1992-1993	-4.675	-0.133	-0.225	0.287	1.456	1.046	2.260	-
Instantaneous Annual Fishing Mortality (F)								
1988-1989	0.261	0.208	0.088	0.066	0.034	0.043	0.000	-
1989-1990	0.343	0.396	0.300	0.093	0.108	0.195	0.275	0.000
1990-1991	0.131	0.096	0.133	0.135	0.112	0.042	0.252	-
1991-1992	0.217	0.425	0.208	0.146	0.030	0.072	0.291	-
1992-1993	0.244	0.148	0.150	0.101	0.110	0.000	0.000	-
Instantaneous Annual Natural Mortality (M)								
1988-1989	-2.821	-1.293	0.136	0.628	0.896	1.040	1.651	-
1989-1990	-3.662	-1.631	-0.613	0.426	1.413	3.425	1.948	-0.405
1990-1991	-3.910	-1.257	-1.014	0.309	0.315	0.556	-0.617	-
1991-1992	-2.352	-0.823	0.615	1.050	1.346	1.671	1.713	-
1992-1993	-4.919	-0.281	-0.375	0.186	1.345	1.046	2.260	-

Observations of the sport fishery indicate anglers are self-imposing a hook-and-release attitude when fishing for Dolly Varden. It seems that a growing number of Dolly Varden anglers are fishing for recreation rather than for food. Finding harvested fish from which to collect biological samples has been increasingly difficult, even when large numbers of fish are being caught. This could be a product of public awareness of the conservation issue relating to current Dolly Varden stocks or the two-fish bag limit restriction may be deterring harvest oriented anglers from participating. If an angler creel survey is conducted in the future, soliciting why anglers fish for Dolly Varden would be a question that may aide in developing effective management strategies.

While the reason(s) for the overall population decline since 1987 is not completely understood, the 1993 return may have been influenced by climatic conditions. During 1993, weather conditions were unusually warm with little rainfall. As a result, the Anchor River water remained low, clear and relatively warm throughout most of the weir operation. Water temperatures reached a high of 21.2°C (Appendix A1). The average daily water temperature through 15 August, based on available thermograph data, was 26% higher during 1993 (Appendix A1) than 1992 (Larson 1993). Although speculative, there were some differences in fish behavior that accompanied these warm water conditions that were unique to 1993.

Dolly Varden were not holding in traditional intertidal river areas prior to migrating upstream through the weir. Dolly Varden appeared to acclimate to fresh water as close to the saltwater interface as possible. Prior to the hours of darkness, anglers reported seeing and catching few Dolly Varden downstream of the weir, even on nights of large weir counts. The sport fishery downstream of the weir structure, which accounted for over 99% of the estimated harvest in 1991 (the last year of an inseason angler creel survey) (Larson 1992), was practically nonexistent during 1993. Apparently, the rapid movement of immigrating Dolly Varden from salt water through the weir was not conducive to angler interception. Most of the biological samples collected from angler harvest occurred at the North Fork Road bridge (Figure 2) on the south fork of the Anchor River, approximately 10 river miles upstream from salt water.

It is possible that these elevated water temperatures may have also inhibited the immigration of the nonspawner component more so than the spawner or potential spawner components. The estimated numbers of spawners and potential spawners were similar between 1992 and 1993, varying from 1% to 3%; however the nonspawner component dropped by 37% during this same period (Table 9). Based on the life history model used to describe Dolly Varden behavior, this could be a reflection of how nonspawners respond to unusually warm river water conditions. The life history model used to describe Dolly Varden (Armstrong 1965 and 1984) indicates that spawners, upon reaching sexual maturity, return to their natal streams to spawn; nonspawners are of mixed origin and enter various drainages to forage and to look for a suitable overwintering location. Therefore, nonspawners may be less likely to enter a stream where the water temperatures were elevated beyond some threshold, especially when there are alternative river systems nearby to satisfy their foraging and overwintering needs, like the Kasilof and Kenai rivers. Spawners and potential spawners, on the other hand, driven by homing instincts to spawn in their natal stream, may be more likely to return to them even under warm water conditions.

Two alternative hypotheses to explain the reduction of nonspawners during 1993 would be the loss of recruitment or a random foraging event. No estimate of smolt production is conducted and a complete understanding of the migratory movements of nonspawners remains preliminary. Future weir operations are necessary to determine recruitment levels.

These explanations for the difference between 1992 and 1993 maturity components are arguable. Certainly one must be cautious in predicting recruitment from nonspawner weir counts as they have been shown to not be reliable (Larson 1993). The warm river water conditions did not exclude all nonspawners, therefore, the affect of warm water on Dolly Varden nonspawner immigration is likely variable. Whether the unique phenomenon observed during 1993 is repeatable, under similar conditions, is yet to be seen.

There is currently no standard for determining the sexual maturity of male Dolly Varden. This study has assumed the proportion of female spawners also represents the male component. Intuitively, this is likely a false assumption. Males have been known to mature earlier than females and are less likely to survive multiple spawning events than females (Armstrong 1974). It is recommended that male gonad development be examined when biological samples are collected and, if possible, a maturity standard be developed.

Stock Structure and Abundance:

Examination of dynamic rates pertaining to Dolly Varden were first presented in 1991 (Larson 1992) and further examination of the historical data during 1992 (Larson 1993) and 1993 (Tables 10-12) reinforced the basic premises deduced during 1991. They indicate that the Anchor River Dolly Varden stock has a high rate of turnover. To some extent, a high degree of fluctuation should be expected. These fish are fairly productive and the number of deaths due to fishing is much lower than from "natural" causes. The annual rates of fishing mortality reflect changes in availability of Dolly Varden to the fishery and changes in regulations. The number of fish available for harvest varies from year to year, depending on run timing, as well as abundance.

Run timing, during the first 6 of the past 7 years, has followed an alternating pattern of an early return one year followed by a later run the next (Larson 1993). In 1988, 1990, and 1992, the Dolly Varden run was early, and fish were available for harvest over a longer time period. These years also reflected higher fishing mortality, probably due to the availability of Dolly Varden to anglers for a longer period of time. This pattern was broken during 1993 with a consecutive early return. The reason for this anecdotal behavior remains unknown.

The effects from varying spawning escapements, documented since 1987, on recruitment will become evident over the next several years. The 1987 escapement provided age-5 Dolly Varden to the fishery during 1993. This age group consisted largely of spawners and was reflective of Anchor River recruitment from the 1987 spawning escapement, the second largest escapement to date (Figure 4). Until we can compare the 1987 recruitment with subsequent escapements, we are still premature in modeling relationships between spawning escapement and recruitment. By continuing this project, the necessary data will be provided to further model the dynamic rates (survival, recruitment, mortality) of Anchor River Dolly Varden and determine if there is a

relationship between the size of the spawning population and subsequent production. If estimating production is possible, this may assist in developing appropriate regulatory measures if necessary.

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APPENDIX A

SUPPORTING STATISTICS

Appendix A1. Daily river water depth and temperature readings recorded at the Anchor River weir upstream trap, 1993.[a]

Date	Water Depth (cm)	Water Temp (2200 hours)	Thermograph Reading HIGHS (Celsius)	LOWS (Celsius)	Difference (Celsius)
03-Jul	32.5	12.0			
04-Jul	32.5	11.5			
05-Jul	32.5	14.0			
06-Jul	31.3	15.5	17.2	10.3	6.9
07-Jul	30.6	16.5	17.7	10.6	7.1
08-Jul	30.6	17.0	18.2	10.3	7.9
09-Jul	30.6	17.5	19.0	11.0	8.0
10-Jul	28.8	19.0	19.9	11.6	8.3
11-Jul	28.8	19.5	20.7	12.4	8.3
12-Jul	27.5	20.0	21.2	13.0	8.2
13-Jul	27.5	17.0	18.3	13.4	4.9
14-Jul	28.8	17.5	20.2	12.8	7.4
15-Jul	27.5	18.5	20.3	13.3	7.0
16-Jul	28.8	19.0	20.6	13.8	6.8
17-Jul	29.4	21.0	20.6	13.8	6.8
18-Jul	28.8	15.5	17.3	13.9	3.4
19-Jul	28.8	16.5	16.8	13.0	3.8
20-Jul	29.4	17.0	17.7	13.2	4.5
21-Jul	29.4	17.0	17.1	13.2	3.9
22-Jul	29.4	17.5	18.5	11.3	7.2
23-Jul	29.4	15.0	15.7	12.3	3.4
24-Jul	29.4	16.0	16.2	11.9	4.3
25-Jul	30.0	14.5	14.5	12.7	1.8
26-Jul	36.3	14.0	14.0	12.0	2.0
27-Jul	32.5	17.5	17.9	10.5	7.4
28-Jul	34.4	14.5	15.9	13.6	2.3
29-Jul	40.0	15.0	15.7	12.4	3.3
30-Jul	36.3	16.5	17.0	10.8	6.2
31-Jul	33.8	17.5	18.2	12.5	5.7
01-Aug	32.5	18.0	19.3	14.0	5.3
02-Aug	31.3	17.0	18.5	12.3	6.2
03-Aug	30.0	16.0	16.7	11.8	4.9
04-Aug	30.0	15.0	15.0	11.7	3.3
05-Aug	30.0	15.0	14.9	11.1	3.8

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Appendix A1. (Page 2 of 2).

Date	Water Depth (cm)	Water Temp (2200 hours)	Thermograph Reading HIGHS (Celsius)	LOWS (Celsius)	Difference (Celsius)
06-Aug	30.0	15.0	14.4	12.0	2.4
07-Aug	30.0	18.0	19.0	12.2	6.8
08-Aug	28.8	19.0	19.7	12.6	7.1
09-Aug	28.8	19.0	20.0	13.6	6.4
10-Aug	30.0	15.0	17.0	13.3	3.7
11-Aug	31.9	17.0	17.7	12.8	4.9
12-Aug	30.6	18.0	17.3	12.7	4.6
13-Aug	31.3	14.5	15.0	13.2	1.8
14-Aug	38.8	13.0	13.0	11.5	1.5
15-Aug	36.3	14.0	13.8	10.3	3.5

[a] Water temperature (Celsius) was recorded both continually by thermograph and instantaneously by thermometer at 2200 hours, while river depth was instantaneously recorded at 2200 hours daily. River water depth was relative to a selected location on the upstream trap.

Appendix A2. The daily and cumulative number of fish, by species, passed downstream through the Anchor River weir during 1993.

	Dolly Varden		Chinook Salmon		Pink Salmon		Coho Salmon		Steelhead		Sockeye Salmon		Chum Salmon	
Date	Daily Count	Cum.[a] Count	Daily Count	Cum. Count	Daily Count	Cum. Count	Daily Count	Cum. Count	Daily Count	Cum. Count	Daily Count	Cum. Count	Daily Count	Cum. Count
03-Jul	0	0	5	5				0		0		0		0
04-Jul	18	18	10	15	4	4		0		0		0		0
05-Jul	36	54	9	24	11	15		0		0	1	1		0
06-Jul	119	173	1	25	4	19		0		0		1		0
07-Jul	261	434	7	32	11	30		0		0		1		0
08-Jul	72	506	1	33	5	35		0		0		1		0
09-Jul	67	573	5	38	5	40		0		0		1		0
10-Jul	59	632	3	41	4	44		0		0		1		0
11-Jul	518	1,150	3	44	6	50		0		0		1		0
12-Jul	368	1,518	1	45	6	56		0		0		1		0
13-Jul	343	1,861	1	46	6	62		0		0		1		0
14-Jul	515	2,376	2	48	5	67		0		0		1		0
15-Jul	678	3,054	6	54	6	73		0		0		1		0
16-Jul	415	3,469	2	56	1	74		0		0		1		0
17-Jul	838	4,307	2	58	4	78		0		0		1		0
18-Jul	912	5,219	2	60	2	80		0		0		1		0
19-Jul	661	5,880	0	60	8	88		0		0		1		0
20-Jul	280	6,160		60	8	96		0		0	1	2		0
21-Jul	178	6,338	2	62	4	100		0		0		2		0
22-Jul	129	6,467	6	68	4	104		0		0		2		0
23-Jul	133	6,600	1	69	14	118		0		0		2	1	1
24-Jul	72	6,672	1	70	20	138		0		0	1	3		1
25-Jul	40	6,712	1	71	10	148		0		0		3		1

-continued-

Appendix A2. (Page 2 of 2).

	Dolly Varden		Chinook Salmon		Pink Salmon		Coho Salmon		Steelhead		Sockeye Salmon		Chum Salmon	
Date	Daily Count	Cum.[a] Count	Daily Count	Cum. Count	Daily Count	Cum. Count	Daily Count	Cum. Count	Daily Count	Cum. Count	Daily Count	Cum. Count	Daily Count	Cum. Count
26-Jul	135	6,847	2	73	36	184		0		0	1	4		1
27-Jul	111	6,958		73	39	223		0		0	1	5		1
28-Jul	200	7,158		73	34	257	1	1		0	5	10		1
29-Jul	119	7,277		73	28	285	1	2		0	5	15		1
30-Jul	171	7,448	1	74	36	321	1	3		0	6	21		1
31-Jul	160	7,608	2	76	22	343	1	4		0	5	26		1
01-Aug	105	7,713	0	76	44	387	1	5		0	5	31		1
02-Aug	124	7,837	0	76	51	438	1	6		0	6	37		1
03-Aug	77	7,914	1	77	23	461	1	7		0		37		1
04-Aug	24	7,938		77	27	488	6	13		0	7	44	2	3
05-Aug	65	8,003		77	14	502	1	14		0	2	46		3
06-Aug	63	8,066	3	80	42	544	3	17		0		46	2	5
07-Aug	52	8,118	2	82	22	566	3	20		0	1	47	4	9
08-Aug	39	8,157		82	18	584	4	24		0	1	48	1	10
09-Aug	24	8,181	1	83	16	600	1	25		0	2	50	1	11
10-Aug	14	8,195		83	47	647	13	38		0		50		11
11-Aug	22	8,217	1	84	35	682	11	49		0	2	52		11
12-Aug	17	8,234	1	85	24	706	19	68		0	2	54		11
13-Aug	7	8,241		85	34	740	15	83		0	1	55		11
14-Aug	8	8,249	5	90	187	927	178	261		0	9	64	1	12
15-Aug	9	8,258		90	71	998	29	290	1	1	6	70		12
16-Aug	4	8,262		90	21	1,019	9	299		1	1	71		12

[a] Cumulative count.

Appendix A3. Daily summary of Dolly Varden age compositions from fish sampled at random from the upstream trap of the Anchor River weir, 1993.

Date	Age Group 2	3	4	5	6	7	8	9	Daily Total
7-Jul	0	1	8	15	10	2	0	0	36
8-Jul	0	3	12	30	23	2	2	0	72
9-Jul	0	2	4	11	9	2	2	0	30
21-Jul	0	16	23	29	16	6	2	1	93
22-Jul	0	6	4	14	6	4	0	0	34
3-Aug	1	28	20	18	8	2	0	0	77
4-Aug	0	5	6	7	2	3	0	0	23
5-Aug	0	12	9	10	3	0	1	0	35
Total	1	73	86	134	77	21	7	1	400

Appendix A4. Dolly Varden samples collected at random from the upstream trap of the Anchor River fish weir showing daily summaries of female gonad maturity and sex ratios, 1993.

	Female Maturity Index[a]					Sex Totals		Sample
Date	1	2	3	4	5	Females	Males	Size
7-Jul		10			9	19	17	36
8-Jul	4	32			16	52	19	71
9-Jul	3	12			3	18	14	32
21-Jul	13	36			11	60	34	94
22-Jul	4	17			4	25	9	34
3-Aug	21	16			12	49	28	77
4-Aug	6	9			3	18	5	23
5-Aug	8	10			3	21	14	35
Total	59	142			61	262	140	402

[a] Maturity Index Codes:
1 = immature female with egg diameter less than 0.90 mm,
2 = mature female with egg diameter greater than 1.75 mm,
3 = completely mature female (eggs easily stripped),
4 = completely spawned female,
5 = immature female but shows development, egg diameter greater than 0.90 mm and less than 1.75 mm.