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Stock Assessment of Humpback Whitefish and Least Cisco in the Chatanika River in 1990 and 1991

by

L. Saree Timmons

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Alaska Department of Fish and Game

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ABSTRACT

In 1991, abundance of humpback whitefish *Coregonus pidschian* larger than 359 millimeters in the Chatanika River was estimated to be 15,313 fish (SE = 2,078). Abundance of least cisco *Coregonus sardinella* larger than 289 millimeters was estimated to be 135,065 (SE = 24,513) in 1991. In 1990 and 1991, most humpback whitefish were ages 5, 6, or 7. Two- and three- year-olds comprised a large portion of the least cisco population. All humpback whitefish passing a weir in 1990 were between ages 4 and 8; most least cisco were between ages 2 and 6. The length and age distributions of least cisco passing the weir in 1990 were significantly different from the length and age distributions of least cisco above Olnes Pond. Mean lengths at age of least cisco ages 2 through 7 passing the weir were significantly different from mean lengths at age of least cisco captured above Olnes Pond, except for least cisco age 3 and age 7. In 1991, an estimated 95 and 28 percent of the least cisco and humpback whitefish, respectively, that were tagged in Goldstream Creek moved into the Chatanika River by September, 1991.

KEY WORDS: humpback whitefish, *Coregonus pidschian*, least cisco, *Coregonus sardinella*, Chatanika River, abundance estimate, length composition, age composition, sex composition, mean length at age, Goldstream Creek.

INTRODUCTION

During summer and fall, humpback whitefish *Coregonus pidschian* and least cisco *Coregonus sardinella* migrate up the Chatanika River (Figure 1). A fall spear fishery, targeting the runs of whitefish during spawning, developed in the upper Chatanika River (areas 1-4) during the early 1970's (Figures 2 and 3). Initially, the fishery was of little consequence, with annual harvests of only a few thousand fish. During the 1980's, the popularity of the fishery increased: harvest of whitefish rose from 1,635 fish in 1977 to a high of 25,074 fish in 1987 (Table 1; Figure 4). In 1987, prompted by concern over the increasing harvests, the Alaska Board of Fisheries implemented a daily bag and possession limit of 15 fish. Subsequently, harvest in the Chatanika River dropped to 7,983 whitefish in 1988, the first year the bag limit was in effect (Mills 1989). However, by 1989, the harvest of 15,542 whitefish was about double that in 1988 (Mills 1990), probably because anglers compensated for the bag limit by fishing more often. In 1990, the fishery was closed on October 11 by Emergency Order, and harvest of whitefish fell to 5,216 in 1990, about one-third the 1989 harvest. On September 8, 1991, the whitefish fishery was again closed by Emergency Order.

In response to the rapidly increasing harvest of whitefish in the Chatanika River in the early 1980's, stock assessment research of whitefish was expanded in 1986. Several methods of estimating abundance of whitefish, including side-scan sonar, counting towers, and mark-recapture experiments, were evaluated in 1986 and 1987 (Hallberg and Holmes 1987; Hallberg 1988). Counts by the sonar proved unreliable, most likely because of the milling behavior of whitefish along the edge of the beam. While all estimating techniques had shortcomings, abundance estimates from the tower counts and mark-recapture experiments were within 5% of each other. Because of the higher cost of operating the counting tower and the inability of that method to distinguish between species, only the mark-recapture experiments were continued in 1988 and 1989 (Hallberg 1989; Timmons 1990).

Mark-recapture experiments in 1986-1988 were conducted by tagging humpback whitefish and least cisco prior to the spear fishery (Hallberg and Holmes 1987; Hallberg 1988, 1989). For the mark event, humpback whitefish and least cisco were captured with boat-mounted electrofishing gear, generally in areas 2-5, but in 1988, humpback whitefish and least cisco were tagged downstream of area 5 (Figures 2 and 3). The spear fishery was used as the recapture event: during creel surveys, humpback whitefish and least cisco were examined for tags, and the marked to unmarked ratio in the harvest was used to estimate abundance. Because the whitefish spear fishery takes place primarily in areas 3-4 (Figure 3, the 1986-1988 abundance estimates relied on the assumption that humpback whitefish and least cisco tagged upstream or downstream of area 4 would migrate through the spear fishery.

Sampling during 1988 revealed that assumptions for the mark-recapture experiment were not being met, when least cisco tagged downstream of area 4 did not move into areas 2-4 during the spear fishery (Hallberg 1989). In 1989, sampling efforts were concentrated in areas 3 and 4 (the area of the spear fishery), with the result that assumptions for the mark-recapture experiment were met (Timmons 1990). However, research in the Chatanika River

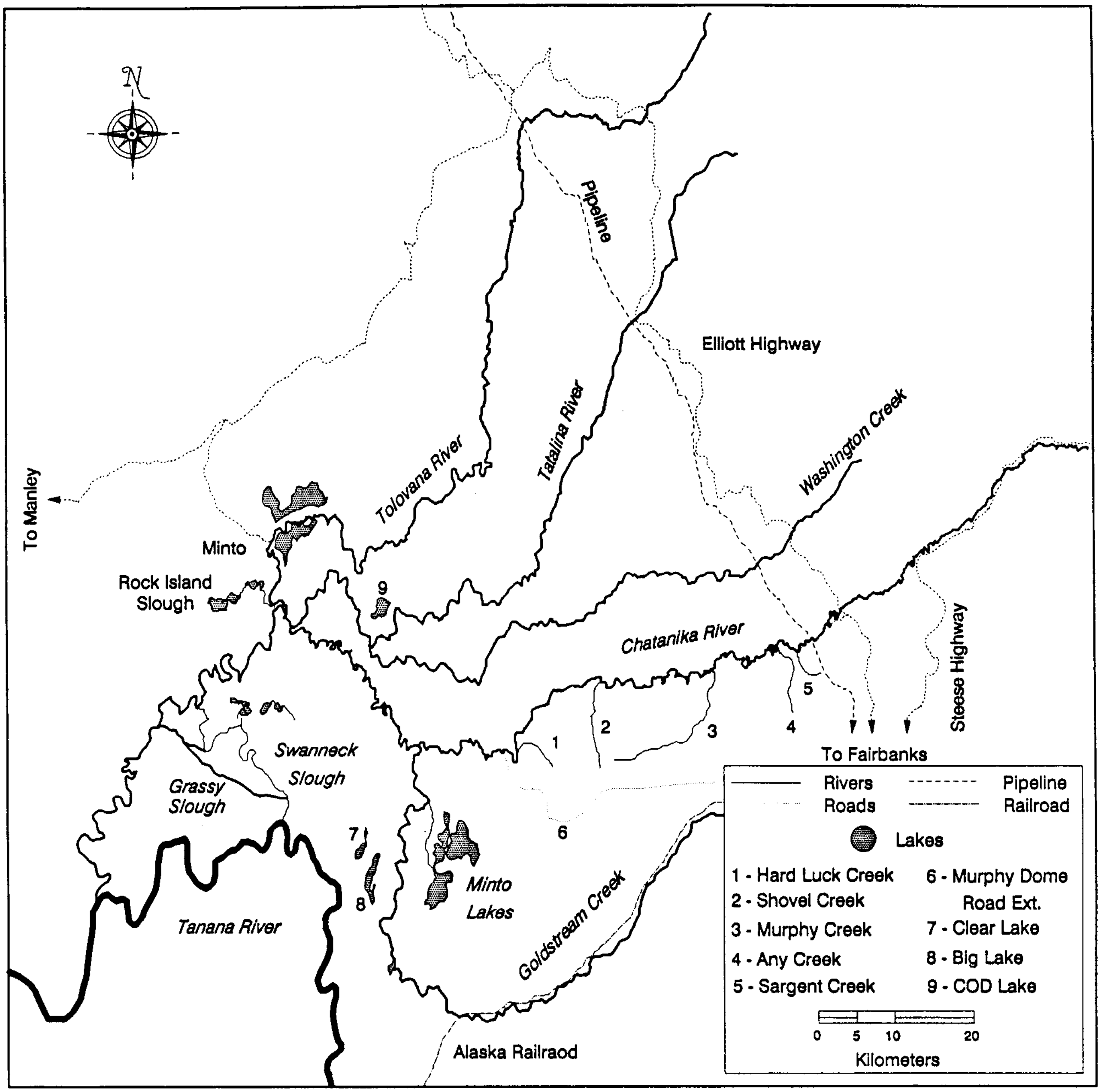


Figure 1. Map of Minto Flats drainage.

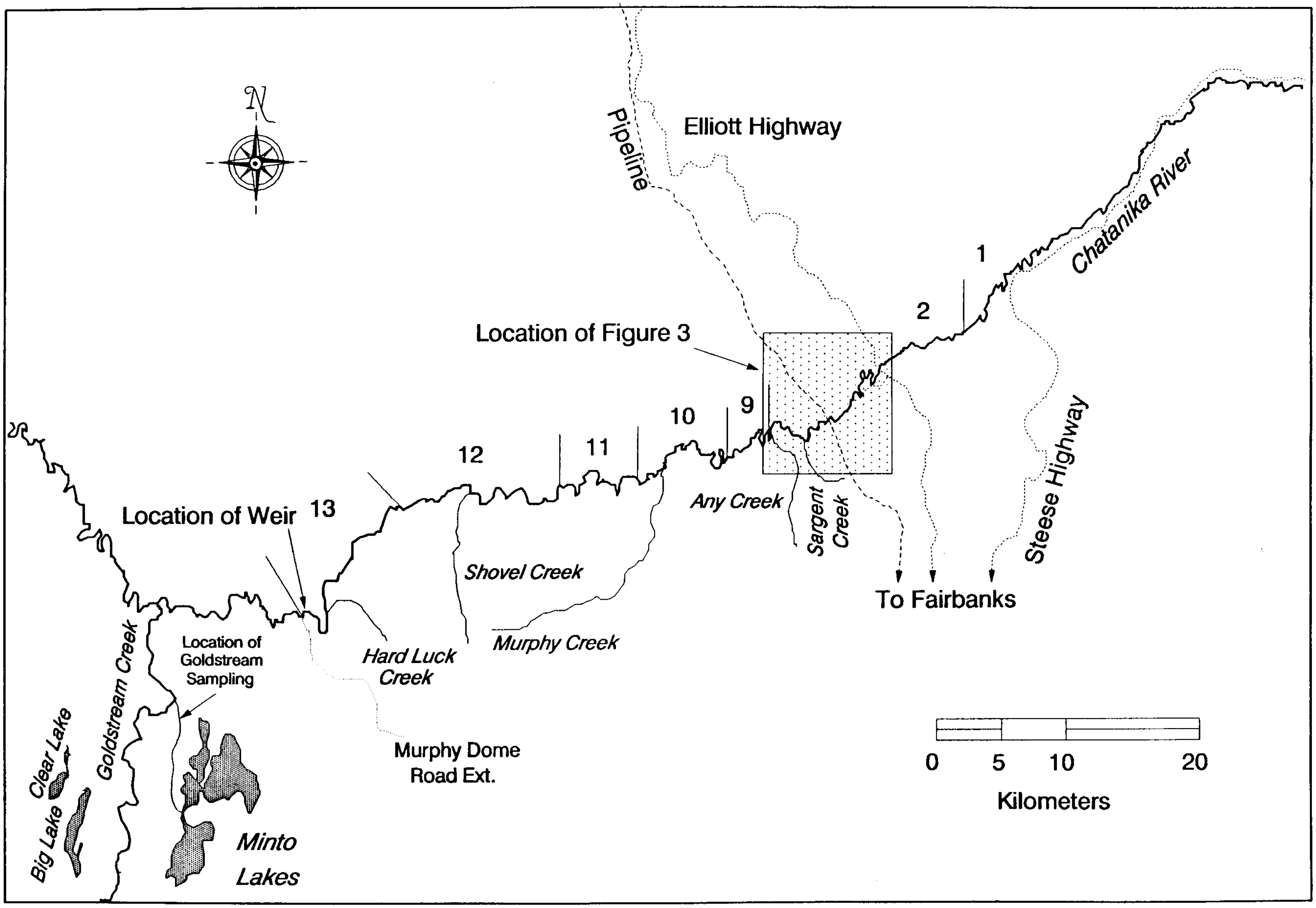


Figure 2. Map of the Chatanika River.

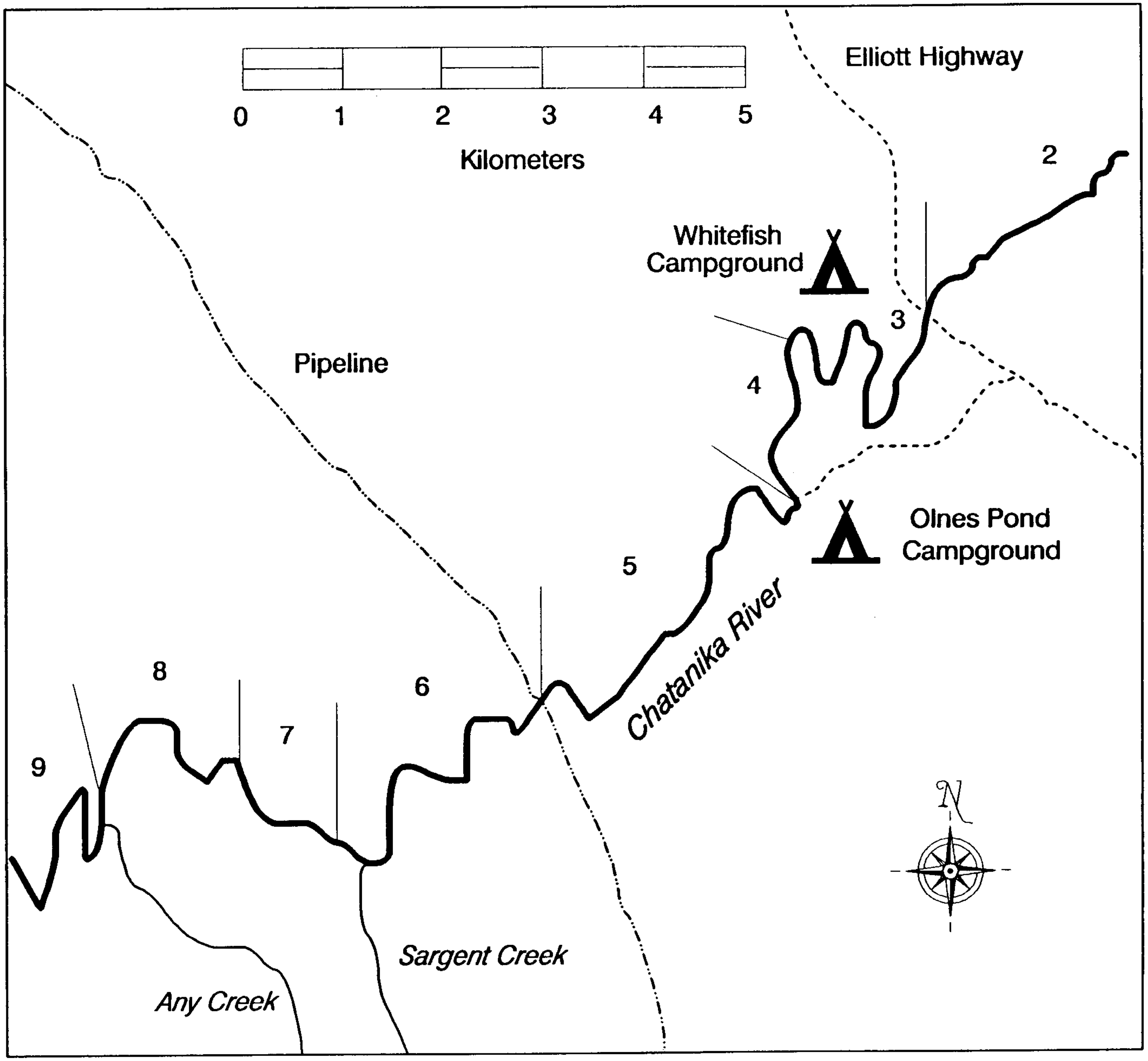


Figure 3. Map of the Chatanika River, from the Elliott Highway Bridge to Any Creek.

Table 1. Harvests of whitefish from the Chatanika River, the Tanana River drainage, and Alaska from 1977 through 1990[a].

Year	Harvest			Percent of Tanana Dr. Total	Percent of Alaska Total
	Chatanika	Tanana Drainage	Alaska		
1977	1,635	3,378	6,748	48	24
1978	6,013	6,573	11,731	91	51
1979	3,021	5,159	9,666	59	31
1980	3,340	5,958	11,464	56	29
1981	3,185	4,873	9,251	65	34
1982	6,640	8,643	15,433	77	43
1983	5,895	8,311	16,872	71	35
1984	9,268	11,658	16,719	79	55
1985	14,350	20,230	30,337	71	47
1986	22,038	26,810	39,718	82	55
1987	25,074	27,159	32,602	92	77
1988	7,983	11,775	20,312	68	39
1989	15,542	16,935	24,337	92	64
1990	5,216	6,891	15,595	76	33

[a] From Mills (1979-1991).

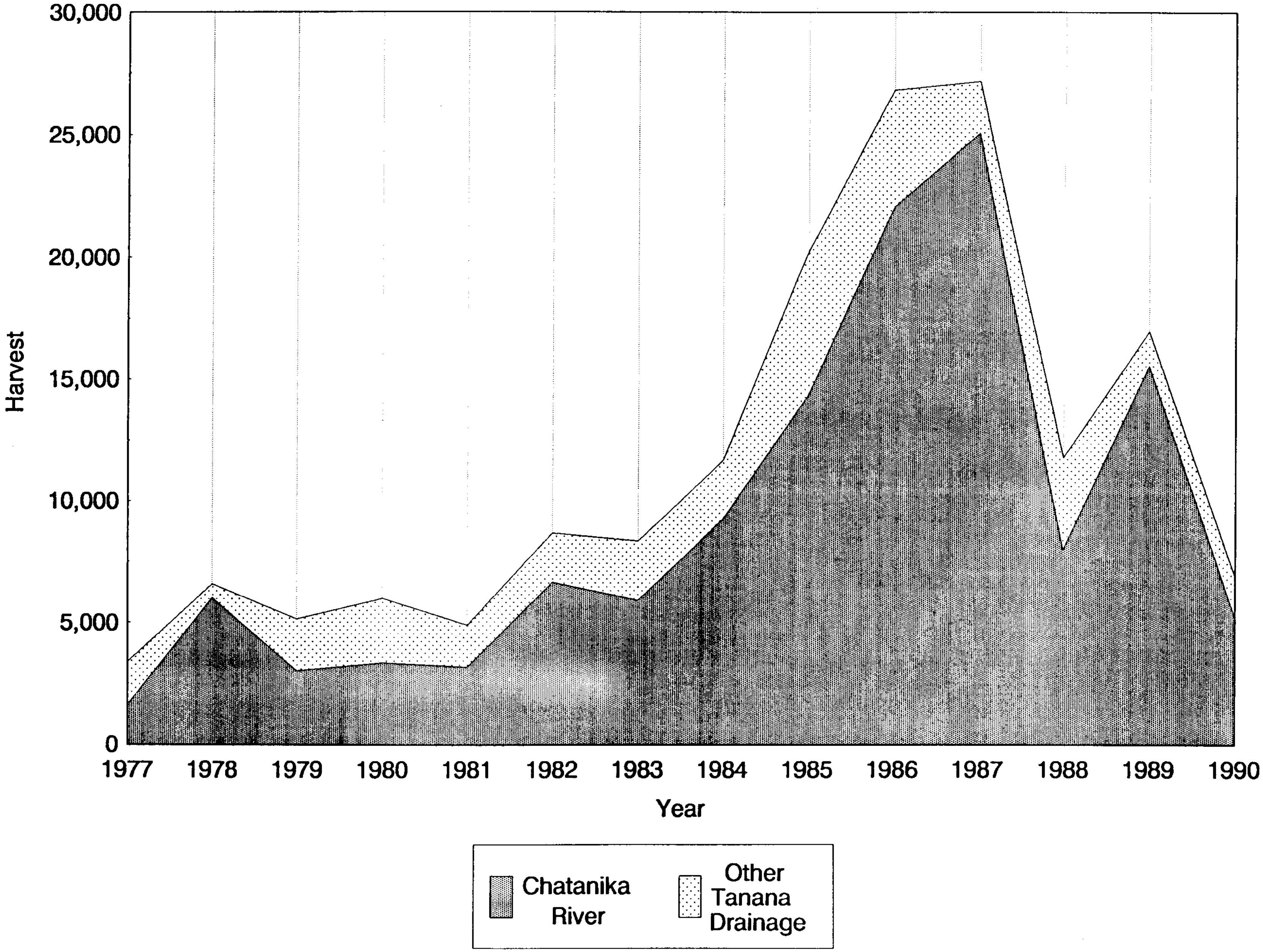


Figure 4. Harvest of whitefish from the Chatanika River and from the Tanana River drainage from 1977 through 1990.

in late fall of 1989, unrelated to the whitefish studies, revealed large numbers of humpback whitefish and least cisco far downstream of area 4, indicating that the mark-recapture experiments were estimating abundance of only a portion of the whitefish populations. Therefore, major changes to the whitefish project were initiated in 1990 and 1991. In 1990, a weir was placed at the lower end of the Chatanika River and counting of the migrating whitefish was attempted. In 1991, mark-recapture experiments to obtain abundance estimates of humpback whitefish and least cisco for the entire river (areas 2-13) were conducted. Electrofishing was used to capture fish for both the mark and recapture events in 1991, rather than using the sport fishery for the recapture event. In 1991, humpback whitefish and least cisco were also captured and tagged in Goldstream Creek (Figure 2).

The goal of this ongoing study is to monitor the status of the humpback whitefish and least cisco populations of the Chatanika River. Estimates of total annual mortality, recruitment, and sustainable yields are needed for managing the Chatanika River fishery to provide long-term, quality fishing opportunities to the public.

Specific objectives for the 1990 study (F-10-6, Job No. R-3-2f) of the Chatanika River whitefish were to:

1. estimate the abundance of humpback whitefish and least cisco upstream of Olnes Pond;

2. estimate length, age, and sex compositions of humpback whitefish and least cisco upstream of Olnes Pond;

3. estimate the mean length at age of 6, 7, and 8 year old humpback whitefish and mean length at age of 3 through 7 year old least cisco;

4. test the hypothesis that the exploitation rate of least cisco tagged between the pipeline crossing and Olnes Pond was at least 25% less than the exploitation rate of least cisco tagged between Olnes Pond and the Elliott Highway Bridge;

5. count the number of humpback whitefish and least cisco passing a weir near the Murphy Dome Road Extension on their upstream migration;

6. estimate the length, age, and sex compositions of humpback whitefish and least cisco passing a weir near the Murphy Dome Road Extension on their upstream migration;

7. estimate the mean length at age of humpback whitefish (ages 6, 7, and 8) and least cisco (ages 3 through 7) passing a weir near the Murphy Dome Road Extension on their upstream migration;

8. test the hypothesis that the exploitation rate of fish tagged at the weir from July 1 through August 15 was the same as the exploitation rate of fish tagged at the weir after August 15; and,

9. determine if the length, age, and sex compositions, mean lengths-at-age, and number of humpback whitefish and least cisco passing a weir near the Murphy Dome Road were significantly different from those of the humpback whitefish and least cisco captured above Olnes Pond.

Specific objectives for the 1991 study (F-10-7, Job No. R-3-2e) of the Chatanika River whitefish were to estimate:

1. the abundance of humpback whitefish and least cisco in the Chatanika River, from the Murphy Dome Road Extension to the Steese Highway Bridge;

2. length, age, and sex compositions of humpback whitefish and least cisco in the Chatanika River;

3. the mean length at age of humpback whitefish that were of ages 6, 7, and 8, and of least cisco that were of ages 3 through 7; and,

4. the proportion of least cisco tagged in Goldstream Creek in May 1991 that moved and survived to be in the Chatanika River by September 1991.

METHODS

1990 Study Design and Data Collection

The 1990 study consisted of two phases: a weir placed in the lower Chatanika River in July, and a mark-recapture experiment in the upper Chatanika River in August and September.

Chatanika River Weir:

A weir spanning the Chatanika River was constructed near the end of the Murphy Dome Road Extension in early July, 1990 (Figure 2). The picket weir was constructed of 0.76 m (2.5 ft) panels made of T-bar. Each panel held 17 conduits (0.22 mm diameter and 2.03 m length) which served as pickets. Panels rested against wood tripods crossed with steel pipes. Pickets could be removed to allow fish to pass the weir or to capture fish in a live box for sampling. The weir was in operation from July 8, 1990 through July 11, 1990. High water compromised the weir from July 12 through July 18, 1990. On July 19, 1990, the weir was again operable, although it had been moved a short distance downstream to a more stable location. The weir was in operation from July 19 through August 2, 1990, when high water again compromised the weir and other difficulties arose. The weir was dismantled on August 2.

Fish were allowed to pass the weir twice daily, or more often if necessary. Fish were counted as they passed over a white flash panel. Humpback whitefish and least cisco were difficult to distinguish from each other as they passed the weir. Hence, they were pooled into a single "whitefish" count. Humpback whitefish and least cisco captured in the live box were identified by species, tagged with an individually numbered Floy anchor tag, measured to the nearest mm fork length (FL), and given an adipose fin clip. Tagged humpback whitefish and least cisco were released downstream of the weir to allow them to recover from sampling. Scale samples, taken from the left side of the fish from an area above the lateral line and below the dorsal fin (Van Oosten 1923), were collected from all humpback whitefish and least cisco sampled at the weir. In the field, scales were wiped clean of mucus and mounted on gum cards. Later, the mounted scales were impressed on acetate cards with a Carver hydraulic press at a temperature of 93°C and pressure of 137,895 kPa for 30 seconds. Scale impressions were viewed with a microfiche reader at about 40x to count annuli and determine ages.

Abundance Estimates:

The Petersen single-season, mark-recapture method (Seber 1982) was to be used to estimate abundance of humpback whitefish and least cisco in areas 3-4 (the area of the spear fishery). From August 20 to September 12, 1990, humpback whitefish and least cisco were captured with an electrofishing boat, from the Elliott Highway Bridge downstream to the Olnes Pond Campground (Figure 3). Several excursions below area 4 were also made to meet objective 4 (1990) and to attempt to recover data lost when the weir was inoperable. The recapture event consisted of fish sampled in a creel survey which was conducted at the Whitefish Campground located at the Elliott Highway Bridge and at the Olnes Pond Campground (Figure 3), from September 15 to October 11, 1990. Only humpback whitefish and least cisco caught in areas 3-4 were considered in the 1990 mark-recapture experiment.

A 6.2 m aluminum river boat with a pulsed DC electrofishing unit was used to capture whitefish. A gas generator provided 240 volts AC input to a Coffelt model 3E variable voltage pulsator. Output to the four anodes, which were attached to a boom on the front of the boat and were constructed of twisted steel cable approximately 1.5 m long, varied from 200 to 300 volts DC. The aluminum hull of the boat served as the cathode. Amperage was generally 4.0 A, duty cycle was 50%, and pulse rate was 40 Hz. Conductivity was not measured, but water temperatures ranged from 4°C to 10°C (Appendix A).

Stunned whitefish were collected from the water with hand-held dip nets and were placed in a large tub with circulating water. During the mark event, humpback whitefish and least cisco were measured, tagged with an individually numbered blue Floy anchor tag, and given an adipose fin clip. When possible, sex was determined by presence of sex products. Scale samples were taken for all humpback whitefish and least cisco captured during the mark event. The section of the river in which each fish was captured was recorded.

From September 14 through October 10, 1990, creel sampling of spear fishermen near the Elliott Highway Bridge and Olnes Pond Campground (Figure 3) served as the recapture event. All humpback whitefish and least cisco sampled from the creel were counted and examined for tags and fin clips. Because there were some reports that anglers were targeting larger fish during the spear fishery (due to the bag limit), whitefish examined for tags in the creel survey were measured in 1990. A scale sample was taken from fish with tags from prior years, and tag numbers from all recaptured fish were recorded, regardless of the year in which they were tagged.

During the electrofishing and creel survey, humpback whitefish and least cisco with adipose clips but no tag were categorized as tag loss from a prior year ("old" tag loss) or tag loss from the current year ("new" tag loss). Humpback whitefish and least cisco with an open wound from a missing tag were considered to have been tagged that year; whitefish with a small or no scar were considered to have been tagged in a previous year.

<u>1991 Study Design and Data Collection</u>

During 1991, movement of humpback whitefish and least cisco from Goldstream Creek to the Chatanika River was studied. The abundance of humpback whitefish and least cisco was estimated, and length, age, and sex compositions and mean length at age were estimated.

Movement from Goldstream Creek to the Chatanika River:

To estimate the proportion of humpback whitefish and least cisco tagged in Goldstream Creek in May 1991 that moved to the Chatanika River by September 1991, humpback whitefish and least cisco were captured from April 30 through May 14, 1991, with gill nets and fyke traps in Goldstream Creek, just above its confluence with the Chatanika River (Figure 2). Captured humpback whitefish and least cisco were tagged with an individually numbered, blue, Floy anchor tag, measured, and given an upper caudal fin clip.

Abundance Estimates:

In 1991, abundance of humpback whitefish and least cisco was estimated by the Petersen single-season mark-recapture method (Seber 1982) for areas 2-13. Low water conditions prevented sampling above area 2 with the electrofishing boat. Humpback whitefish and least cisco were captured during three events: a pre-mark event (July 11 - July 16), a mark event (August 23 - August 26), and a recapture event (September 9 - September 14). One pass of the Chatanika River (areas 2-13) was made during each sampling event using a boat electroshocker. Two, three-person crews conducted the sampling. One crew captured fish while the other crew sampled fish. On September 26, 1991, one three-person crew electrofished areas 4-5 to determine if whitefish had moved into that area.

Captured humpback whitefish and least cisco were tagged and sampled as in the 1990 mark-recapture experiment. Scales were collected from all humpback whitefish and least cisco captured in July, but due to the large numbers of fish handled during August and September, only the first 60 humpback whitefish and least cisco from each area were sampled for scales in August and September. Humpback whitefish with adipose clips but no tag were categorized as a new or an old tag loss as in 1990, except that humpback whitefish and least cisco with an upper caudal fin clip but no tags were categorized as tag loss from Goldstream Creek. Section of the river in which each fish was captured was also recorded.

Data Analysis

After whitefish were tagged and sampled at the Chatanika River and Goldstream Creek, data were analyzed to estimate abundance, length, age, and sex compositions, mean length at age, and the proportion of humpback whitefish and least cisco tagged in Goldstream Creek that moved into the Chatanika River.

Abundance Estimates and Movement from Goldstream Creek to the Chatanika River:

In 1990, the Petersen single-mark method was to be used to estimate the abundance of each species in areas 2-4 (Seber 1982). Knowledge gained in 1990 and 1991, however, made it obvious that abundance estimates in areas 2-4 in 1990 would be biased. First, the primary purpose of the 1990 abundance estimate was to compare the abundance estimated in areas 2-4 with the total number of whitefish migrating into the Chatanika River, but a total whitefish count was not obtained at the weir. Second, other research activities in late fall of 1990 revealed relatively large numbers of humpback whitefish and least cisco well downstream of area 4, indicating that estimates of abundance for areas 2-4 would be applicable for an unknown proportion of the total population. Finally, abundance in areas 2-4 probably fluctuates from year to year, independent of total abundance, because the river bed of the Chatanika River changes with each high water event and spawning locations probably change somewhat from year to year. Therefore, abundance could not be reasonably estimated for humpback whitefish and least cisco in 1990.

In 1991, the Bailey modification of the Petersen single-mark method was used to estimate the abundance of humpback whitefish and least cisco in the Chatanika River from area 2 through area 13 (Seber 1982):

$$\hat{N} = \frac{M(C+1)}{(R+1)}; \text{ and,} \qquad (1)$$

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

where:

C = number of fish captured during the recapture event;

M = number of fish marked during the marking event; and,

R = number of fish recaptured during the recapture event.

In prior years (1986 - 1989), estimates of abundance of least cisco were limited to fish larger than 289 mm (Hallberg and Holmes 1987; Hallberg 1988, 1989; Timmons 1990). Therefore, abundance of least cisco larger than 289 mm was also estimated by multiplying the estimated proportion of least cisco larger than 289 mm by the estimate of total abundance. The variance of the estimate was calculated according to Goodman's (1960) formula:

$$\hat{V}[\hat{N}_i) = \hat{N}^2 V(\hat{p}_i) + \hat{p}_i^2 V(\hat{N}) + V(\hat{p}_i) V(\hat{N}) \qquad (3)$$

where:

$\hat{N}$ = the estimated abundance of least cisco;

$V[\hat{N}]$ = the variance of the estimated abundance of least cisco;

$\hat{p}_i$ = the estimated proportion of least cisco larger than 289 mm; and,

$V[\hat{p}_i]$ = the variance of the estimated proportion of least cisco larger than 290 mm.

Conditions for the accurate use of the Petersen single-mark method are:

1. marking does not affect the catchability of whitefish;

2. marked whitefish do not lose their marks between sampling events;

3. recruitment *and* death of whitefish do not occur between sampling events;

4. every whitefish has an equal probability of being marked and released alive during the first sampling event; *or* every fish has an equal probability of being captured during the second sampling event; *or* marked fish mix completely with unmarked fish between sampling events (Seber 1982).

In 1991, marking was not expected to affect the catchability of humpback whitefish and least cisco because mortality from electrofishing these species has been low (Holmes et al. 1990). Double marking with the fin clip was intended to permit correction of abundance estimates for any tag loss that may have occurred. Recruitment was expected as humpback whitefish and least cisco moved into the Chatanika River during the hiatus, therefore, the estimate of abundance is relevant to the recapture event. Death and emigration between events was expected to be negligible because the hiatus was short, sampling occurred prior to spawning, and there was no fishery in 1991. Two contingency table analyses (Seber 1982) were used to determine if condition 4 had been met. A chi-square test, which compared the recapture to catch ratios (by area strata), tested for complete mixing of fish or that every fish had the same probability of being tagged during the marking event. The second contingency table, which compared numbers (by area strata) of fish released, recaptured, and not recaptured, was employed to detect mixing of marked whitefish with unmarked whitefish. Area strata were defined as areas 1-5, areas 6-8, areas 9-10, and areas 11-13. To detect size-selectivity during the mark and recapture events, two Kolmogorov-Smirnov tests were conducted (Conover 1980). Outcome of the tests determined whether the estimates of abundance were stratified by size and from which event age and length data were to be used (Appendix B).

The proportion of least cisco and humpback whitefish that were tagged in Goldstream Creek in 1991 and moved into the Chatanika River was estimated by the equations:

$$\hat{p} = \hat{N} \cdot \frac{G_{recaps}}{G_{tags} \cdot C}; \text{ and,} \tag{4}$$

$$V[\hat{p}] = G_{tags}^{-2}(V[\hat{N}]\hat{q}^2 + V[\hat{q}]\hat{N}^2 - V[\hat{N}]V[\hat{q}]) \tag{5}$$

where:

$\hat{p}$ = proportion of tagged least cisco or humpback whitefish that moved from Goldstream Creek to the Chatanika River;

$\hat{N}$ = estimate of abundance of least cisco or humpback whitefish in the Chatanika River;

$V[\hat{N}]$ = variance of the estimate of abundance of least cisco or humpback whitefish in the Chatanika River;

G_{recaps} = number of whitefish marked in Goldstream and recaptured in the Chatanika River;

G_{tags} = number of least cisco or humpback whitefish tagged in Goldstream Creek;

C = number of least cisco examined for tags in the Chatanika River;

$\hat{q}$ = G_{recaps}/C; and, (6)

$[\hat{q}]$ = $\hat{q}(1-\hat{q})/(C-1)$. (7)

Length, Age, and Sex Compositions and Mean Length at Age:

To estimate length compositions, humpback whitefish and least cisco were grouped by 10 mm length categories. Length compositions were considered to be a series of proportions, one for each length group, whose sum was one. Length compositions were calculated according to the equations:

$$\hat{p}_i = \frac{y_i}{n}; \text{ and,} \tag{8}$$

$$V[\hat{p}_i] = \frac{\hat{p}_i(1-\hat{p}_i)}{n-1}; \tag{9}$$

where:

$\hat{p}_i$ = the estimated proportion of fish of length group i in the population;

y_i = the number of fish of length group i in the sample;

n = the number of fish in the sample; and,

$V[\hat{p}_i]$ = the variance of the estimated proportion of fish of length group i in the population.

Age and sex compositions were also considered as a series of proportions and were estimated with Equations 8 and 9, with age or sex substituted for length group. Simple averages and squared deviations from the mean were used to calculate mean lengths at age and standard errors. Only fish captured in areas 2-4 were used to calculate mean length at age in 1990. All fish sampled in August and September (excluding the September 26, 1991 sample) were used to calculate mean length at age in 1991.

Recapture Rate by Area and Time in 1990:

To determine if exploitation rates of humpback whitefish and least cisco differed by area in 1990, proportions of recaptures in the spear fishery to number of fish tagged were compared by area. Chi-square tests were used to determine if proportions were significantly different overall. If they were significantly different, multiple comparison tests were then conducted to determine which proportions were different (Zar 1984; pp 401-402). To test the hypothesis that the exploitation rate of least cisco tagged between the pipeline crossing and Olnes Pond (area 5) was at least 25% less than the exploitation rate of least cisco tagged between Olnes Pond and the Elliott Highway Bridge (areas 3-4), the proportions exploited in these two areas were compared using a normal approximation (Zar 1984, pp. 395-396). The hypothesis described in objective 8 of the 1990 study design could not be tested because the weir was not operable after August 2, 1990.

RESULTS

Length, Age, and Sex Compositions and Mean Length at Age - 1990

In 1990, 995 whitefish (humpback whitefish and least cisco combined) were counted passing the weir (Table 2), 776 during the first week of operation. By late July, 1990, whitefish counts fell to only a few fish per day. Of the whitefish captured in the live box, 21 were humpback whitefish and 479 were least cisco. Between August 20 and September 12, 1990, 612 humpback whitefish and 1,748 least cisco were released with tags in areas 2-4. Lengths of 116 humpback whitefish and 224 least cisco in area 2 were obtained, and lengths of 475 humpback whitefish and 1,505 least cisco in areas 3-4 were obtained. Of the 531 humpback whitefish examined in the creel survey between September 15 and October 11, 1990, 47 humpback whitefish were recaptures. Of the 1,321

Table 2. Daily counts of fish passing the Chatanika River weir during 1990.

	Whitefish[a]		Chum Salmon[b]		Chinook Salmon[b]		Northern Pike[b]		Arctic Grayling[b]	
Date	Count	Cumm. Total	Count	Cumm. Total	Count	Cumm. Total	Count	Cumm. Total	Count	Cumm. Total
7/8	43	43	1	1	0	0	8	8	0	0
7/9	333	376	2	3	0	0	4	12	0	0
7/10	379	755	1	4	0	0	1	13	0	0
7/11	21	776	2	6	0	0	0	13	0	0
Subtotal	776		6		0		0		0	
7/20	40	40	36	36	1	1	0	0	0	0
7/21	14	54	50	86	4	5	0	0	1	1
7/22	70	124	127	213	14	19	0	0	1	2
7/23	77	201	24	237	5	24	0	0	1	3
7/24	1	202	11	248	32	56	0	0	0	3
7/25	0	202	0	248	0	56	0	0	0	3
7/26	[c]	202	[c]	248	[c]	56	[c]	0	[c]	3
7/27	9	211	7	255	0	56	3	3	0	3
7/28	6	217	1	256	0	56	0	3	0	3
7/29	1	218	3	259	1	57	1	4	0	3
7/30	1	219	0	259	0	57	0	4	0	3
7/31	0	219	0	259	0	57	0	4	0	3
Subtotal	219		259		57		4		3	
Total	995		265		57		4		3	

[a] Humpback whitefish and least cisco could not be distinguished from one another. Therefore, counts are for species combined.

[b] Chum salmon = *Oncorhynchus keta*; chinook salmon = *Oncorhynchus ishawytscha*; northern pike = *Esox lucius*; Arctic grayling = *Thymallus arcticus*.

[c] Counts could not be made on 7/26/90 due to water conditions.

least cisco examined in the creel survey, 158 were recaptures. Numbers of humpback whitefish and least cisco marked and recaptured by area and time in 1990 are presented in Appendices C and D, respectively. Lengths were obtained from 769 humpback whitefish and 3,164 least cisco in areas 5-6, as well as from 183 humpback whitefish and 784 least cisco in areas 7-8. In all areas, ages could not be determined for a few fish sampled, and no ages were obtained for humpback whitefish and least cisco sampled in areas 7-8.

Mean length of humpback whitefish captured at the weir was 420 mm and lengths varied from 330 mm to 469 mm (Table 3, Figure 5). Mean length of least cisco was 342 mm and most least cisco were between 330 mm and 379 mm (Table 4, Figure 6). All humpback whitefish captured at the weir were between ages 4 and 8 (Figure 7; Table 5), and most least cisco were between ages 2 and 6 (Figure 8; Table 6). Mean lengths at age were not calculated for humpback whitefish because of the small sample size. Mean length of age 3 least cisco was 332 mm (SE = 5); mean length at age 7 was 361 mm (SE = 9) (Table 7). Because no sex products were obvious, sex was determined for only three of the 21 humpback whitefish sampled at the weir. All three were autopsied. Two of the three were males; one was female. Of 62 least cisco for which sex could be determined (47 mortalities and 15 live), 26 were male (41.9%, SE = 6.3) and 36 were female (58.1%, SE = 6.3). Seven least cisco that had been tagged at the weir in July 1990, were recaptured during electrofishing or in the spear fishery in August, September, or October, 1990 (Table 8). No humpback whitefish tagged at the weir were recaptured during electrofishing or in the spear fishery.

Mean length of humpback whitefish captured in areas 5-6 was 419 mm; mean length in areas 7-8 was 430 mm (Table 3, Figure 5). Mean length of least cisco captured in areas 5-6 was 337 mm; mean length in areas 7-8 was 342 mm (Table 4, Figure 6). In all areas, most humpback whitefish were ages 5, 6, or 7 (Table 5, Figure 7). Least cisco ranged from age 1 to age 7 in areas 2 through 6 (Table 6, Figure 8).

Size-selective sampling was detected for neither humpback whitefish nor least cisco during the mark and recapture events, so data from both events were pooled to estimate compositions in areas 2-4. Lengths of whitefish marked during electrofishing were not significantly different from lengths of whitefish recaptured in the creel survey (DN = 0.13, $P = 0.49$ for humpback whitefish; DN = 0.06, $P = 0.72$ for least cisco), and lengths of humpback whitefish marked were not significantly different from lengths of humpback whitefish captured in the fishery (DN = 0.07, $P = 0.09$). Lengths of least cisco were significantly different (DN = 0.12, $P < 0.01$), but the difference was so small as to imply that size-selective sampling during the electrofishing was insignificant (Figure 9).

Most humpback whitefish (sexes combined) in areas 2-4 were between 380 mm and 449 mm in length (Figure 10; Table 9) and were age 5, 6, or 7 (Table 10; Figure 11). The mean length of humpback whitefish was 412 mm (SE = 1) for sexes combined, 416 mm (SE = 1) for females, and 407 mm (SE = 4) for males. The length distributions of male and female humpback whitefish were significantly different (Kolmogorov-Smirnov Test; DN = 0.20, $P < 0.01$). Mean length at age of humpback whitefish in areas 2-4 ranged from 406 mm for age 5

Table 3. Length (mm) distributions by area for humpback whitefish captured in the Chatanika River, 1990.

Length Group	Areas 2			Areas 3-4			Areas 5-6			Areas 7-8			Weir		
	n	%	SE	n	%	SE	n	%	SE	n	%	SE	n	%	SE
< 330	0	0.0	0.0	0	0.0	0.0	7	0.9	0.3	4	2.2	1.1	0	0.0	0.0
330-339	0	0.0	0.0	1	0.2	0.2	4	0.5	0.3	0	0.0	0.0	1	4.8	3.3
340-349	1	0.9	0.9	1	0.2	0.2	6	0.8	0.3	3	1.6	0.9	0	0.0	0.0
350-359	1	0.9	0.9	4	0.8	0.4	8	1.0	0.4	0	0.0	0.0	0	0.0	0.0
360-369	0	0.0	0.0	7	1.5	0.6	8	1.0	0.4	1	0.6	0.6	1	4.8	3.3
370-379	8	6.9	2.4	19	4.0	0.9	23	3.0	0.6	5	2.7	1.2	1	4.8	3.3
380-389	8	6.9	2.4	28	5.9	1.1	31	4.0	0.7	3	1.6	0.9	1	4.8	3.3
390-399	20	17.2	3.5	60	12.6	1.5	67	8.7	1.0	10	5.5	1.7	1	4.8	3.3
400-409	22	19.0	3.7	91	19.2	1.8	109	14.2	1.3	12	6.6	1.8	1	4.8	3.3
410-419	19	16.4	3.5	100	21.1	1.9	123	16.0	1.3	27	14.8	2.6	4	19.1	4.6
420-429	16	13.8	3.2	65	13.7	1.6	137	17.8	1.4	28	15.3	2.7	2	9.5	3.9
430-439	9	7.8	2.5	51	10.7	1.4	79	10.3	1.1	23	12.6	2.5	4	19.0	4.6
440-449	8	6.9	2.4	26	5.5	1.0	60	7.8	1.0	19	10.4	2.3	1	4.7	3.3
450-459	2	1.7	1.2	15	3.2	0.8	45	5.9	0.9	13	7.1	1.9	0	0.0	0.0
460-469	2	1.7	1.2	2	0.4	0.3	28	3.6	0.7	12	6.6	1.8	1	4.7	3.3
470-479	0	0.0	0.0	2	0.4	0.3	16	2.1	0.5	11	6.0	1.8	3	14.2	4.3
480-489	0	0.0	0.0	1	0.2	0.2	7	0.9	0.3	2	1.1	0.8	0	0.0	0.0
490-499	0	0.0	0.0	1	0.2	0.2	6	0.8	0.3	4	2.2	1.1	0	0.0	0.0
500-509	0	0.0	0.0	0	0.0	0.0	2	0.3	0.2	2	1.1	0.8	0	0.0	0.0
> 509	0	0.0	0.0	1	0.2	0.2	3	0.4	0.2	4	2.2	1.1	0	0.0	0.0
Total	116	100.0		475	100.0		769	100.0		183	100.0		21	100.0	
Mean Length	409			412			419			430			420		
SE	2			1			1			3			8		

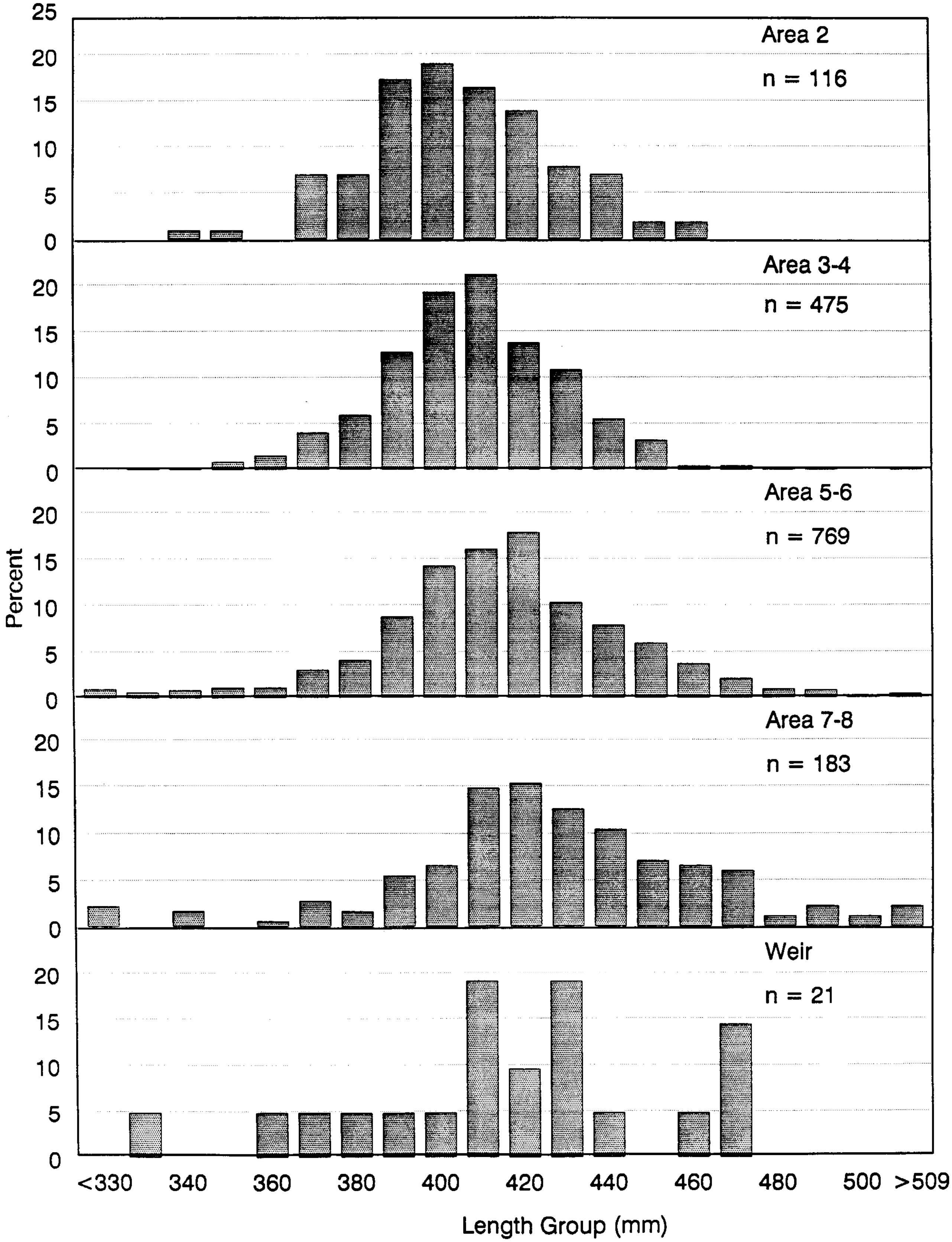


Figure 5. Length distribution of humpback whitefish captured in five areas of the Chatanika River in 1990.

Table 4. Length (mm) distributions by area for least cisco captured in the Chatanika River, 1990.

Length Group	Area 2			Areas 3-4			Areas 5-6			Areas 7-8			Weir		
	n	%	SE	n	%	SE	n	%	SE	n	%	SE	n	%	SE
< 290	6	2.7	1.1	49	3.3	0.5	54	1.7	0.2	8	1.0	0.4	27	5.6	1.1
290-299	7	3.1	1.2	75	5.0	0.6	131	4.1	0.4	24	3.1	0.6	23	4.8	1.0
300-309	25	11.2	2.1	119	7.9	0.7	183	5.8	0.4	29	3.7	0.7	25	5.2	1.0
310-319	16	7.1	1.7	141	9.4	0.8	258	8.2	0.5	52	6.6	0.9	26	5.4	1.0
320-329	29	13.0	2.3	205	13.6	0.9	438	13.8	0.6	93	11.9	1.2	33	6.9	1.2
330-339	59	26.3	3.0	304	20.2	1.0	633	20.0	0.7	143	18.2	1.4	58	12.1	1.5
340-349	37	16.5	2.5	255	16.9	1.0	503	15.9	0.7	123	15.7	1.3	77	16.1	1.7
350-359	24	10.7	2.1	175	11.6	0.8	416	13.2	0.6	125	15.9	1.3	76	15.9	1.7
360-369	15	6.7	1.7	99	6.6	0.6	290	9.2	0.5	92	11.7	1.2	58	12.1	1.5
370-379	4	1.7	0.9	52	3.5	0.5	171	5.4	0.4	57	7.3	0.9	46	9.6	1.4
380-389	1	0.5	0.5	18	1.2	0.3	53	1.7	0.2	30	3.8	0.7	18	3.8	0.9
390-399	1	0.5	0.5	9	0.6	0.2	26	0.8	0.2	6	0.8	0.3	8	1.7	0.6
> 399	0	0.0	0.0	4	0.2	0.1	8	0.2	0.1	2	0.3	0.2	4	0.8	0.4
Total	224	100.0		1,505	100.0		3,164	100.0		784	100.0		479	100.0	
Mean Length	332			333			337			342			342		
SE	1			1			<1			1			1		

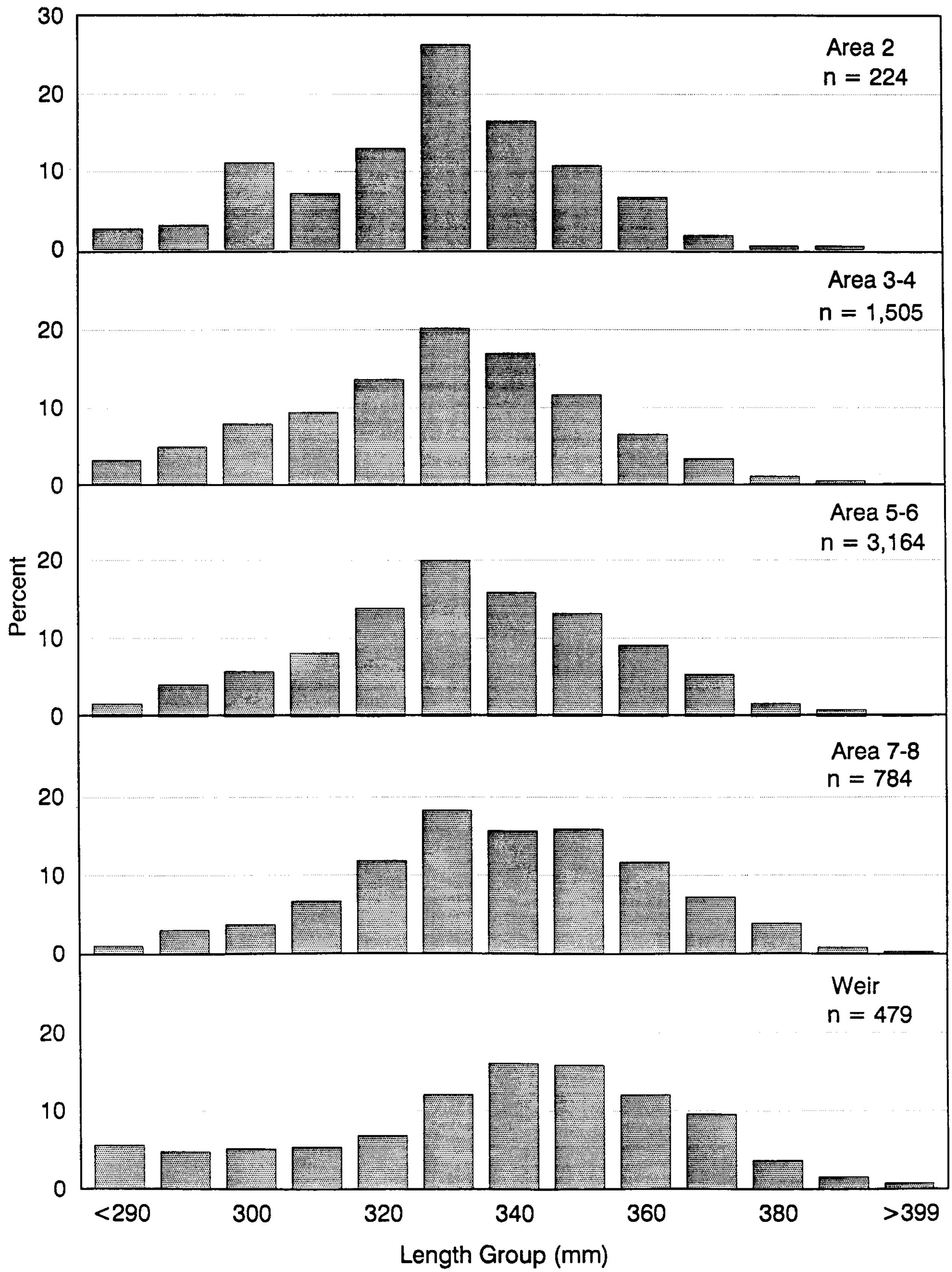


Figure 6. Length distribution of least cisco captured in five areas of the Chatanika River in 1990.

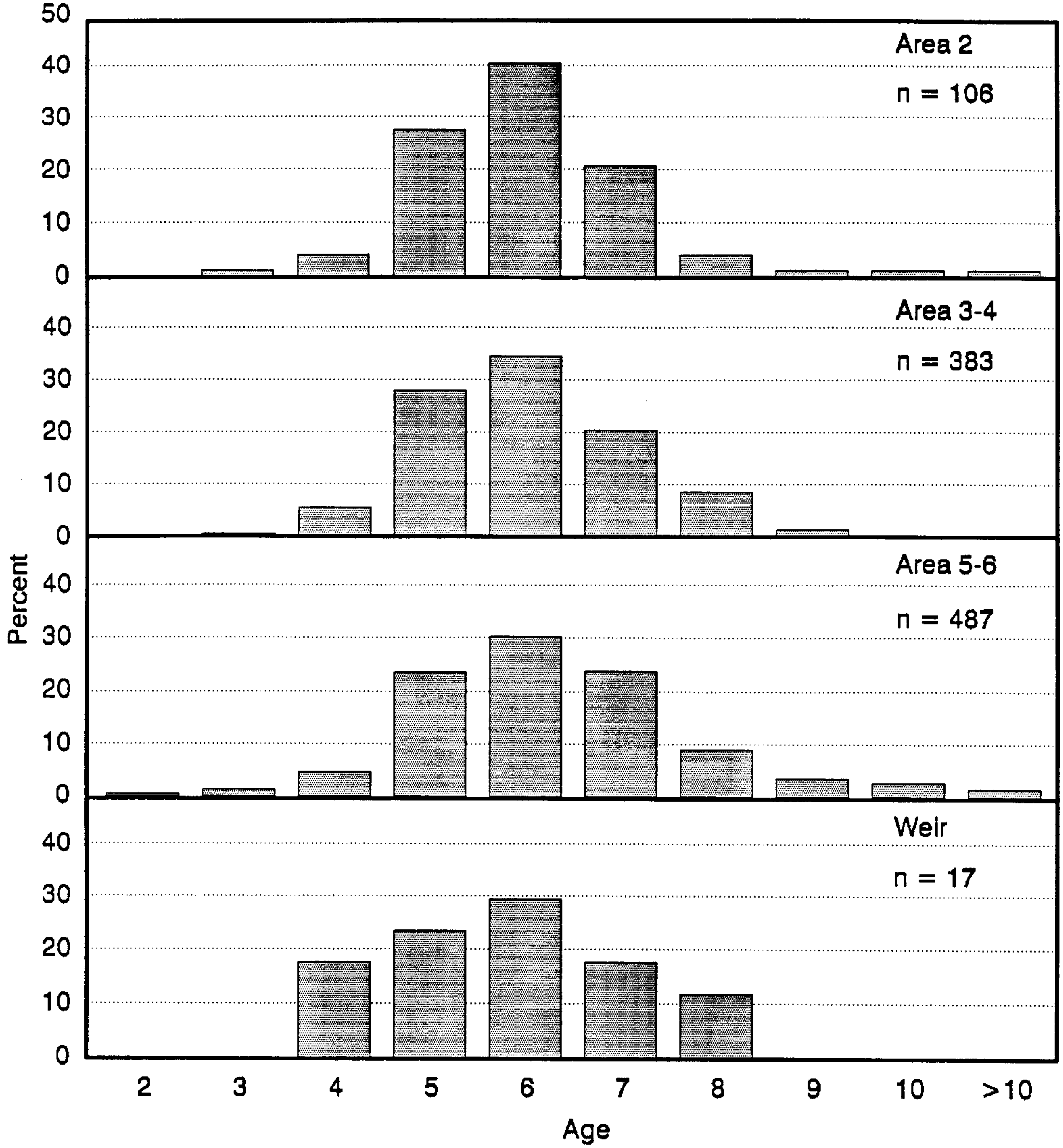


Figure 7. Age distribution of humpback whitefish captured in four areas of the Chatanika River in 1990.

Table 5. Age composition of humpback whitefish captured in four areas of the Chatanika River, 1990.

Age Group	Area 2			Areas 3-4			Areas 5-6			Weir		
	n	%	SE	n	%	SE	n	%	SE	n	%	SE
2	0	0.0	0.0	0	0.0	0.0	2	0.0	0.0	0	0.0	0.0
3	1	0.9	0.9	3	0.8	0.5	6	10.7	0.9	0	0.0	0.0
4	4	3.8	1.9	21	5.5	1.2	22	30.8	1.4	3	17.7	9.5
5	29	27.4	4.4	107	27.9	2.3	115	43.8	1.5	4	23.5	10.6
6	43	40.6	4.8	132	34.5	2.4	147	13.0	1.0	5	29.4	11.4
7	22	20.8	4.0	78	20.4	2.1	116	1.5	0.4	3	17.7	9.5
8	4	3.8	1.9	33	8.6	1.4	43	0.2	0.2	2	11.7	8.1
9	1	0.9	0.9	6	1.6	0.6	16	0.0	0.6	0	0.0	0.0
10	1	0.9	0.9	2	0.5	0.4	13	0.0	0.6	0	0.0	0.0
>10	1	0.9	0.9	1	0.2	0.3	7	0.0	0.6	0	0.0	0.0
Total	106	100.0		383	100.0		487	100.0		17	100.0	

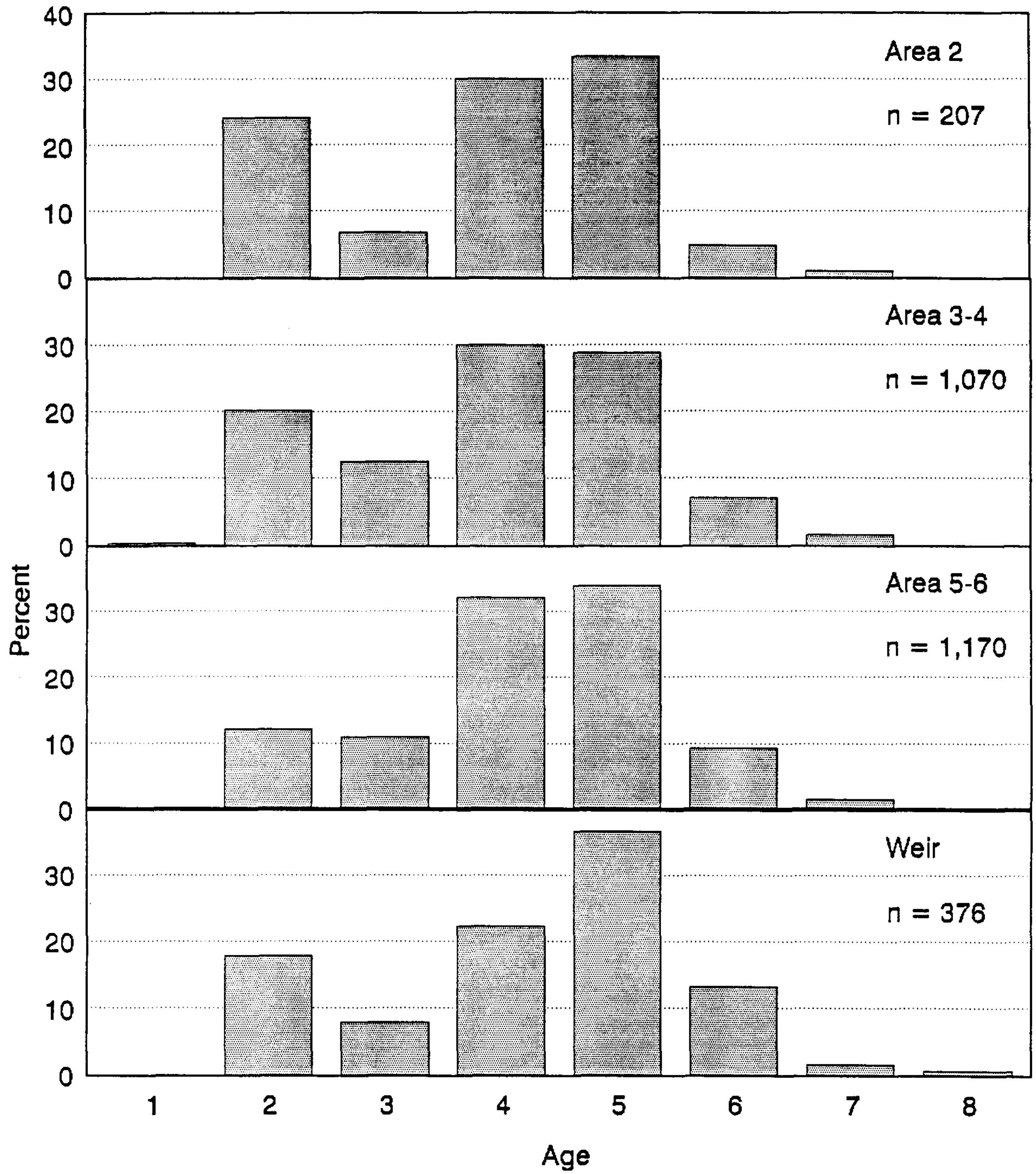


Figure 8. Age distribution of least cisco captured in four areas of the Chatanika River in 1990.

Table 6. Age composition of least cisco captured in four areas of the Chatanika River, 1990.

Age Group	Area 2			Areas 3-4			Areas 5-6			Weir		
	n	%	SE	n	%	SE	n	%	SE	n	%	SE
1	0	0.0	-	2	0.2	4.3	0	0.0	-	0	0.0	-
2	50	24.2	6.1	215	20.1	2.7	141	12.1	2.8	67	17.8	4.7
3	14	6.8	7.0	133	12.4	2.9	128	10.9	2.8	30	8.0	5.0
4	62	30.0	5.9	320	30.0	2.6	376	32.1	2.4	84	22.3	4.6
5	69	33.3	5.7	308	28.8	2.6	397	33.9	2.4	137	36.4	4.1
6	10	4.7	7.2	76	7.0	3.0	109	9.3	2.8	50	13.3	4.9
7	2	1.0	9.8	16	1.5	3.1	19	1.7	3.0	6	1.7	5.6
8	0	0.0	-	0	0.0	-	0	0.0	-	2	0.5	7.3
Total	207	100.0		1,070	100.0		1,170	100.0		376	100.0	

Table 7. Mean length at age of least cisco captured at the weir in 1990.

Age	n	Mean (mm)	SE
2	66	299	2
3	30	332	5
4	84	344	2
5	137	350	2
6	50	363	3
7	6	361	9

Table 8. Least cisco tagged at the weir in 1990 and recaptured during electrofishing or through the recreational spear fishery in 1990.

Tag Number	Date Tagged	Date Recaptured	Area Recaptured
84110	July 8	September 29	4
84117	July 8	September 12	7
84290	July 9	October 5	4
84297	July 9	August 23	6
84386	July 10	September 12	7
84442	July 24	August 23	6
84454	July 24	September 11	5

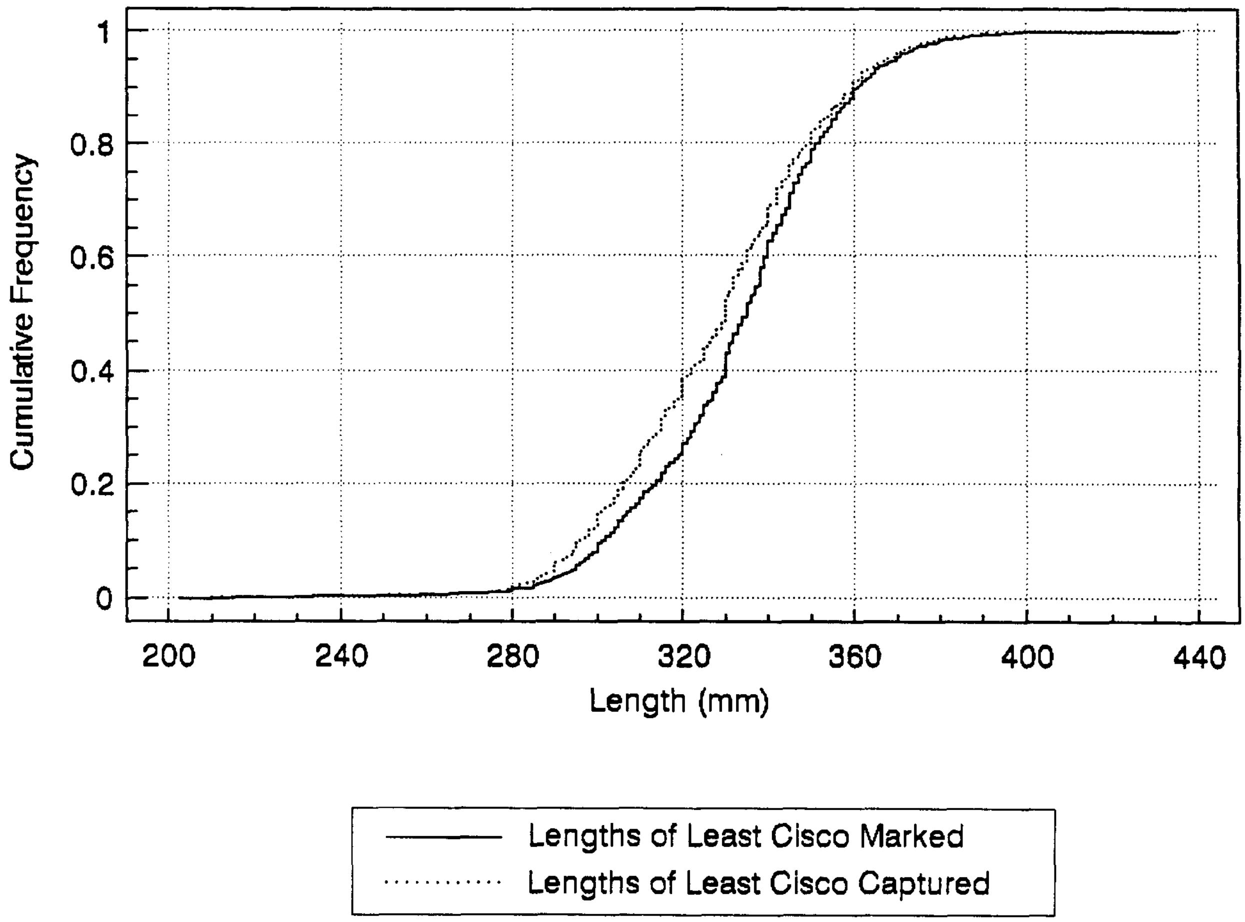


Figure 9. Cumulative frequency distributions of lengths of least cisco marked versus lengths of least cisco captured.

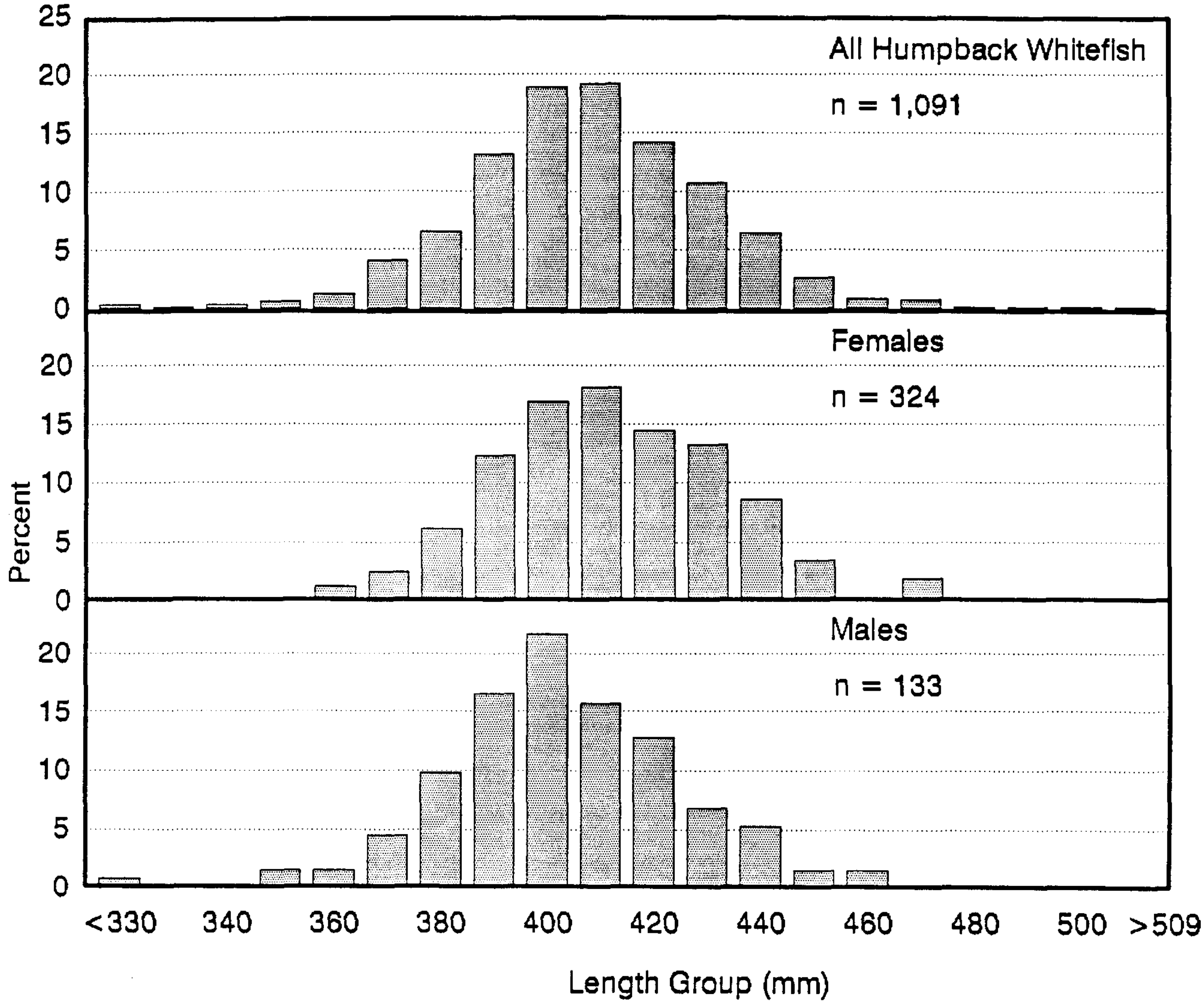


Figure 10. Length distribution of humpback whitefish in areas 2-4 in 1990 (sexes combined, females, and males).

Table 9. Length compositions of male, female, and sexes combined, humpback whitefish captured in the Chatanika River in 1990 (areas 2-4 only).

Length Group (mm)	n	All Percent	SE	n	Female Percent	SE	n	Male Percent	SE
<330	3	0.3	0.2	0	0.0	0.0	1	0.8	0.8
330-339	1	0.1	0.1	0	0.0	0.0	0	0.0	0.0
340-349	3	0.3	0.2	0	0.0	0.0	0	0.0	0.0
350-359	7	0.6	0.2	1	0.3	0.3	2	1.5	1.1
360-369	13	1.2	0.3	4	1.2	0.6	2	1.5	1.1
370-379	44	4.0	0.6	8	2.5	0.9	6	4.5	1.8
380-389	71	6.5	0.8	20	6.2	1.3	13	9.8	2.6
390-399	143	13.1	1.0	40	12.4	1.8	22	16.5	3.2
400-409	206	18.9	1.2	55	17.0	2.1	29	21.8	3.6
410-419	209	19.2	1.2	59	18.2	2.2	21	15.8	3.2
420-429	154	14.1	1.1	47	14.5	2.0	17	12.8	2.9
430-439	117	10.7	0.9	43	13.3	1.9	9	6.8	2.2
440-449	70	6.4	0.7	28	8.6	1.6	7	5.3	1.9
450-459	29	2.7	0.5	11	3.4	1.0	2	1.5	1.1
460-469	9	0.8	0.3	1	0.3	0.3	2	1.5	1.1
470-479	8	0.7	0.3	6	1.9	0.8	0	0.0	0.0
480-489	1	0.1	0.1	0	0.0	0.0	0	0.0	0.0
490-499	1	0.1	0.1	0	0.0	0.0	0	0.0	0.0
500-509	1	0.1	0.1	1	0.3	0.3	0	0.0	0.0
>509	1	0.1	0.1	0	0.0	0.0	0	0.0	0.0
Total	1,091	100.0		324	100.0		133	100.0	
Mean Length	412			416			407		
SE	1			1			4		

Table 10. Age composition and mean length at age of humpback whitefish captured in 1990 (areas 2-4 only).

Age	Age Composition n	Percent	SE	Mean Length at Age n	Mean (mm)	SE
3	4	0.8	0.4	4	378	12
4	25	5.0	1.0	25	403	4
5	136	27.4	2.0	136	406	2
6	179	36.0	2.2	179	409	1
7	103	20.7	1.8	103	423	2
8	37	7.4	1.2	37	421	4
9	8	1.6	0.6	8	438	6
10	3	0.6	0.4	3	430	3
>10	2	0.4	0.3	2	459	7
Total	497	100.0				

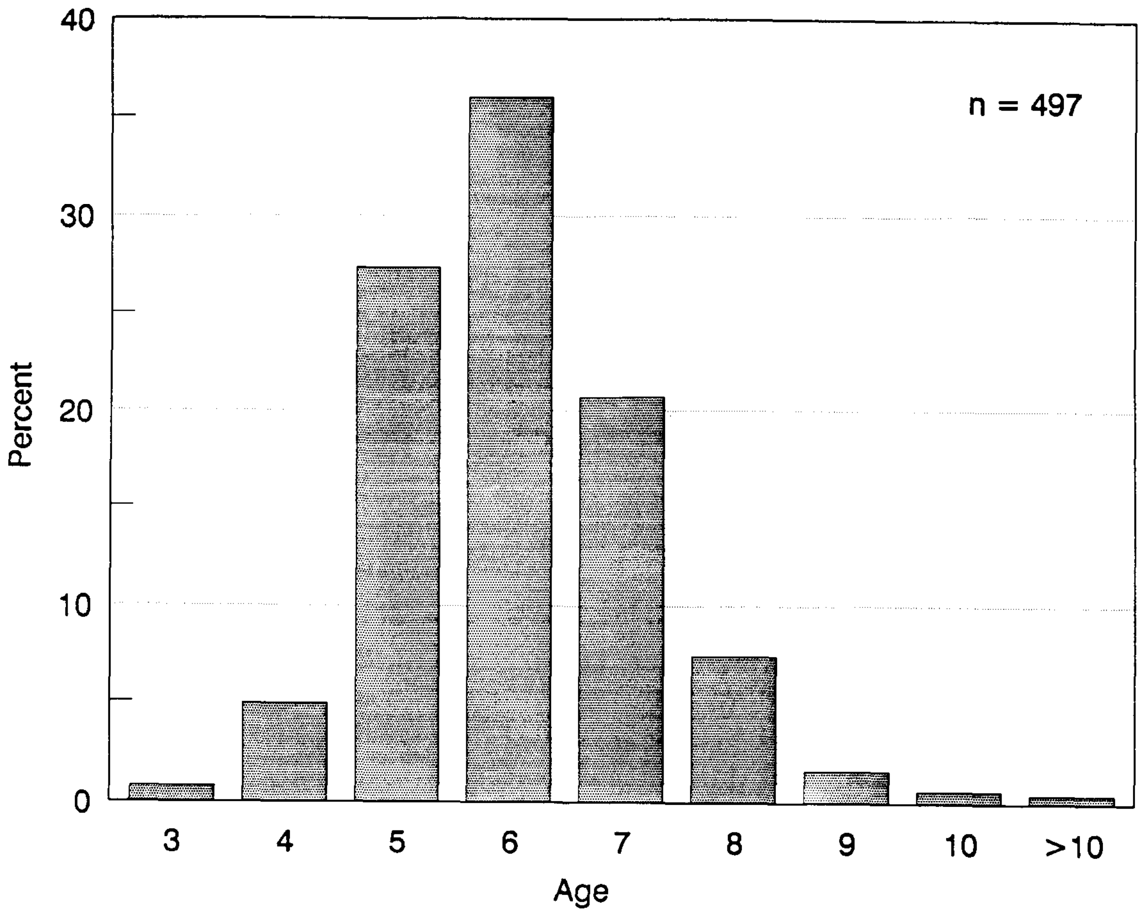


Figure 11. Age distribution of humpback whitefish in areas 2-4 in 1990 (sexes combined, females, and males).

to 423 mm for age 7 (Table 10). Mean length at age by sex was not calculated for humpback whitefish because of the small number for which both age and sex were known. Using all data collected during the mark and recapture events, sex composition of humpback whitefish was 64% females and 36% males (Table 11). However, sex of a large portion of humpback whitefish could not be determined externally before the end of the mark event (Figure 12). The hypotheses in objective 9 (1990) could not be tested for humpback whitefish because of the small sample size at the weir.

Mean length of female least cisco in areas 2-4 was 339 mm; mean length of males was 321 mm (Table 12). Length distributions of male and female least cisco were significantly different (Kolmogorov-Smirnov Test; DN = 0.39, $P < 0.01$). The lengths of female least cisco were distributed from about 300 mm to 379 mm. The length distribution of male least cisco was truncated at larger length groups, with few male least cisco over 349 mm (Figure 13). Most least cisco were ages 2-5 (Table 13; Figure 14). Mean length at age ranged from 306 mm for age 2 to 357 mm for age 7 (Table 13). Of the least cisco for which sex was determined, 35% were females and 65% were males (Table 14). However, sex could not be determined for a large portion of the least cisco during the mark event (Figure 12).

Lengths of least cisco captured in areas 2-4 were significantly different from lengths of least cisco captured at the weir in 1990 (Kolmogorov-Smirnov Test; DN = 0.26, $P < 0.01$; Figure 6). Age compositions of least cisco captured at the weir and least cisco in areas 2-4 were also significantly different ($\chi^2 = 30.34$, $P < 0.01$; Figure 8). Mean length at age was significantly different for ages 2 through 7 (t-test, all P's < 0.01), except for least cisco age 3 ($P = 0.74$) and age 7 ($P = 0.68$) (Tables 6 and 7). Differences in sex composition of least cisco at the weir and in areas 2-4 were not compared because the sex of a large portion of the least cisco captured in areas 2-4 could not be determined at the time of sampling.

Recapture Rate in Fishery by Area in 1990

Recapture rates of humpback whitefish in the spear fishery were significantly different among areas ($\chi^2 = 10.45$, df = 3, $P = 0.02$). Recapture rates of humpback whitefish released in areas 1-2, areas 3-4, and areas 5-6 were not significantly different, but the recapture rate of humpback whitefish released below area 6 was significantly lower than the other three groups (overall $\alpha = 0.05$; multiple comparison test, Zar 1984; Table 15).

Recapture rates of least cisco in the fishery were significantly different for fish released in different areas ($\chi^2 = 136.49$, df = 3, $P < 0.01$); no two rates were alike ($\alpha = 0.05$; multiple comparison test, Zar 1984; Table 16). The rate of recapture of least cisco tagged in areas 5-6 was at least 25% less than the rate of recapture of least cisco tagged in areas 3-4 (Z = 3.47, $P < 0.01$; Zar 1984, pp. 395-396; Table 16).

Abundance Estimates in 1991

In 1991, least cisco were captured from area 4 through area 13. No least cisco were captured upriver of area 4. Humpback whitefish were captured in

Table 11. Sex composition of humpback whitefish, 1990 (areas 2-4 only).

Sex	n	Percent	SE
Females	423	64.4	1.9
Males	234	35.6	1.9
Total	657	100.0	

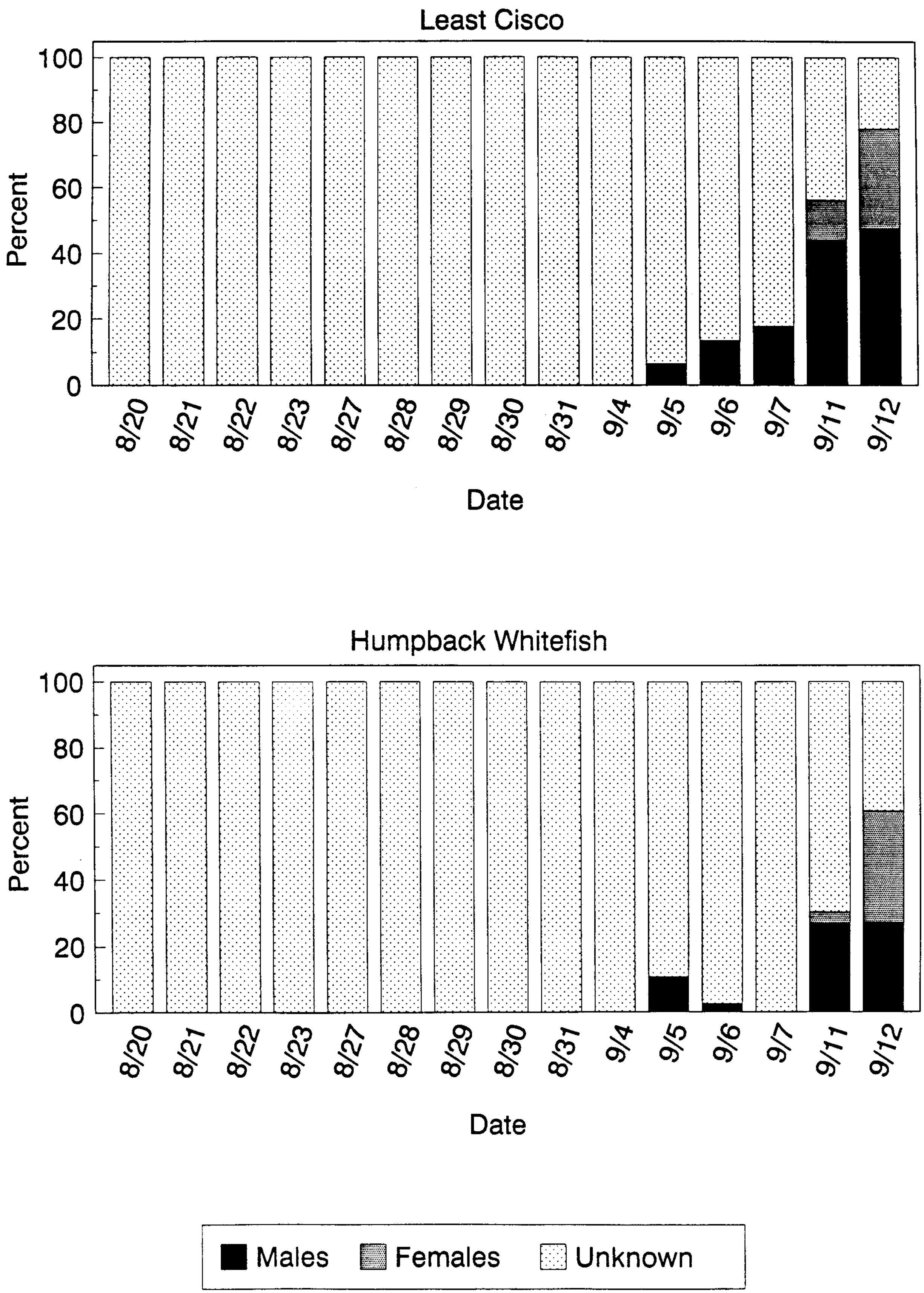


Figure 12. Sex composition of humpback whitefish and least cisco sampled in the Chatanika River in 1990, by date.

Table 12. Length compositions (male, female, and sexes combined) of least cisco captured in the Chatanika River in 1990 (areas 2-4 only).

Length Group (mm)	All			Female			Male		
	n	Percent	SE	n	Percent	SE	n	Percent	SE
<290	108	3.7	0.4	5	1.2	0.5	46	5.9	0.9
290-299	178	6.1	0.5	17	4.1	1.0	78	10.0	1.1
300-309	267	9.2	0.5	27	6.4	1.2	92	11.8	1.2
310-319	308	10.6	0.6	55	13.2	1.7	104	13.4	1.2
320-329	390	13.5	0.6	37	8.9	1.4	129	16.6	1.3
330-339	561	19.3	0.7	46	11.1	1.5	173	22.3	1.5
340-349	456	15.7	0.7	59	14.2	1.7	115	14.8	1.3
350-359	302	10.4	0.6	71	17.1	1.9	29	3.7	0.7
360-369	185	6.4	0.5	55	13.2	1.7	8	1.0	0.4
370-379	95	3.3	0.3	33	7.9	1.3	2	0.3	0.2
380-389	31	1.1	0.2	9	2.2	0.7	0	0.0	0.0
390-399	15	0.5	0.1	2	0.5	0.3	1	0.1	0.1
>399	4	0.1	0.1	0	0.0	0.0	0	0.0	0.0
Total	2,900	100.0		416	100.0		777	100.0	
Mean Length	331			339			321		
SE	<1			1			1		

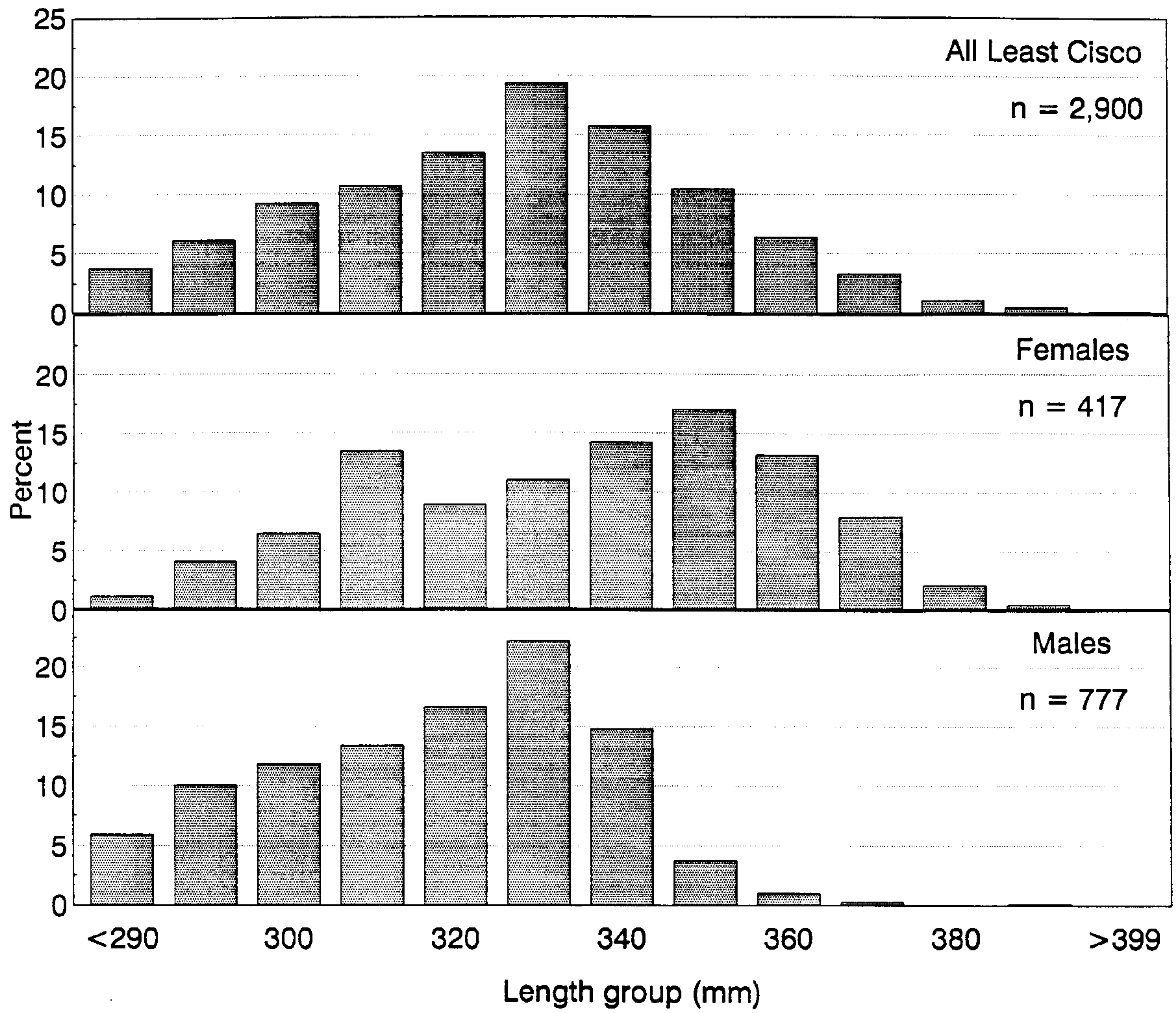


Figure 13. Length distribution of least cisco in areas 2-4 in 1990.

Table 13. Age composition and mean length at age of least cisco captured in 1990 (areas 2-4 only).

	Age Composition			Mean Length at Age		
Age	n	Percent	SE	n	Mean (mm)	SE
1	2	0.2	4.0	2	298	0
2	265	20.7	2.5	265	306	1
3	148	11.5	2.6	146	330	2
4	383	29.9	2.3	381	338	<1
5	379	29.6	2.4	376	343	1
6	87	6.8	2.7	86	345	3
7	18	1.4	2.9	18	357	5
8	0	0.0	0.0	0	-	-
Total	1,282	100.0				

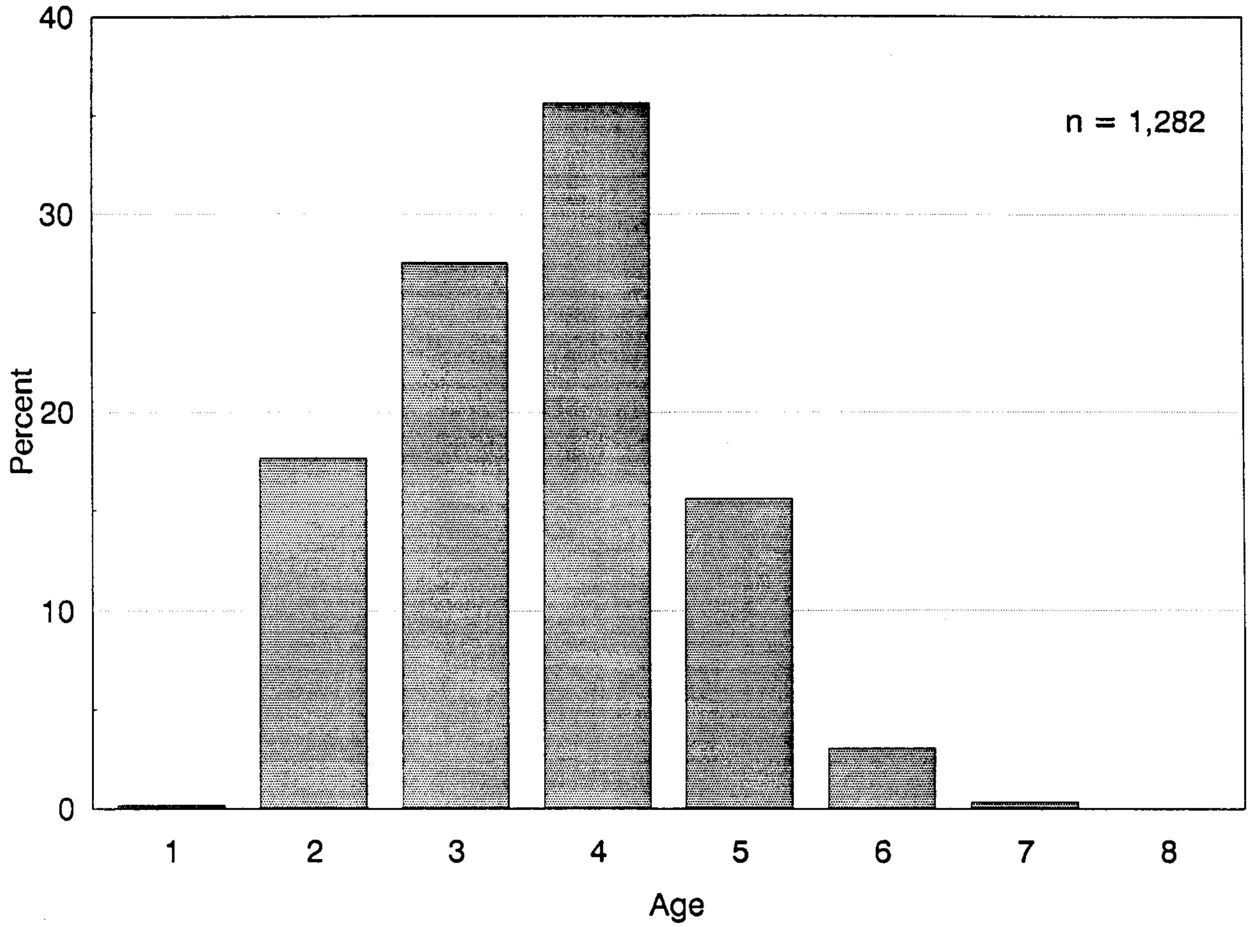


Figure 14. Age distribution of least cisco in areas 2-4 in 1990.

Table 14. Sex composition of least cisco, 1990 (areas 2-4 only).

Sex	n	Percent	SE
Females	416	34.8	1.4
Males	778	65.2	1.4
Total	1,194	100.0	

Table 15. Proportions of humpback whitefish marked and recaptured by area, 1990.

Area Released	Number Released with Tags	Number Recaptured in the Spear Fishery	Proportion Recaptured[a]
1 - 2	116	9	0.078 |
3 - 4	477	37	0.078 |
5 - 6	769	39	0.051 |
Below 6, including weir	202	4	0.020
Total	1,564	89	

[a] Proportions were significantly different overall ($\chi^2 = 10.45$; df = 3; $P = 0.02$). Proportions connected by line are not significantly different at $\alpha = 0.05$ (multiple comparison test; Zar pp. 401-402).

Table 16. Proportions of least cisco marked and recaptured by area, 1990.

Area Released	Number Released with Tags	Number Recaptured in the Spear Fishery	Proportion Recaptured[a]
1 - 2	225	32	0.142
3 - 4	1,507	125	0.083
5 - 6	3,173	122	0.038
Below 6, including weir	1,214	9	0.007
Total	6,119	288	

[a] Proportions were significantly different overall ($\chi^2 = 136.49$; df = 3; $P < 0.01$). All proportions were significantly different from each other at overall $\alpha = 0.05$ (multiple comparison test, Zar pp. 401-402).

all areas. On September 21, 1991, the day after the conclusion of the recapture event, electrofishing in the Chatanika River between the Murphy Dome Extension and the confluence with Goldstream Creek produced no humpback whitefish or least cisco (Figure 2).

The pre-mark event and the mark event were combined into a single mark event for purposes of the mark-recapture experiment for least cisco, because lengths of least cisco from the pre-mark event were not significantly different from lengths of least cisco from the original mark event (Kolmogorov-Smirnov Test; DN = 0.05, $P = 0.36$). In July and August of 1991, 2,156 least cisco were released with tags in the Chatanika River (Table 17). During the recapture event, 2,084 least cisco were captured and examined for tags, of which 27 had tags from the mark event and one was judged to have had lost a tag from the mark event, for a total of 28 recaptures for the mark-recapture experiment. Recorded old tag losses totaled 3.0% in July (13 fish) and 2.0% in September (42 fish).

The 1991 abundance of least cisco was estimated to be 155,009 (SE = 28,103) fish larger than 199 mm, and 135,065 (SE = 24,513) fish larger than 289 mm. The proportion of least cisco sampled in September that were larger than 289 mm was 0.87 (SE = 0.007). Results of the two Kolmogorov-Smirnov tests indicated that there was no size-selectivity during the recapture event, but there was size-selectivity during the mark event. Lengths of least cisco marked in July or August were not significantly different from lengths of least cisco recaptured in September (DN = 0.11, $P = 0.91$), but lengths of least cisco marked in July or August were significantly different from lengths of least cisco captured in September (DN = 0.09, $P < 0.01$). The contingency table analyses indicated that least cisco had the same probability of being marked during July or August, regardless of area. Recapture to catch ratios of least cisco in the recapture event were not significantly different by area ($\chi^2 = 6.28$, df = 3, $P = 0.10$; Table 18), and mixing of marked and unmarked least cisco consisted of a general upstream movement (Table 19). Fish with missing adipose fins, no tag, and no tag scar were not considered recaptures.

The pre-mark event was excluded from estimates of abundance of humpback whitefish in 1991, because lengths of humpback whitefish from the pre-mark event were significantly different from lengths of humpback whitefish from the mark event (Kolmogorov-Smirnov test, DN = 0.08, P = 0.02). Abundance was calculated for humpback whitefish larger than 359 mm only, because no humpback whitefish smaller than 360 mm were recaptured in September although humpback whitefish smaller than 360 mm were marked in August. In August, 653 humpback whitefish larger than 359 mm were released with tags, 1,195 humpback whitefish larger than 359 mm were examined for tags in September, of which 50 (43 with tags and seven which were judged to have lost tags) were recaptures from August. Recorded old tag losses totaled 4.8% (22 fish) in July and 4.3% (54 fish) in September.

Abundance of humpback whitefish larger than 359 mm in September was estimated to be 15,313 (SE = 2,078). Results of the two Kolmogorov-Smirnov tests indicated that there was no size-selectivity during the second sampling event, but there was during the first. Lengths of humpback whitefish marked in August were not significantly different from lengths of humpback whitefish

Table 17. Numbers of least cisco and humpback whitefish marked and examined for marks during three events in 1991.

	Least Cisco			Humpback Whitefish		
	July	August	September	July	August	September
Number Released Alive with Marks	432	1,717	-	460	730	-
Number Examined for Marks	-	1,720	2,084	-	730	1,268
Percent with New Tag Loss[a]	-	0.2 (4)	0.1 (1)	-	0.8 (6)	0.6 (7)
Percent with Old Tag Loss[a]	3.0 (13)	1.5 (26)	2.0 (42)	4.8 (22)	3.6 (26)	4.3 (54)
Number Recaptured from July	-	13	4	-	10	14
Number Recaptured from August	-	-	23	-	-	44

[a] Numbers in parentheses.

recaptured in September (DN = 0.16, $P = 0.26$), but lengths of humpback whitefish marked in August were significantly different from lengths of humpback whitefish examined for tags in September (DN = 0.08, $P < 0.01$). Recapture to catch ratios by area were not significantly different ($\chi^2 = 0.99$, df = 3, $P = 0.80$; Table 20), indicating that either marked humpback whitefish mixed completely with unmarked humpback whitefish between sampling events, or that every humpback whitefish had the same probability of being tagged during the mark event. Mixing of humpback whitefish was generally upstream (Table 21).

Length, Age, and Sex Compositions, and Mean Length at Age - 1991

Least cisco in the Chatanika River in 1991 were primarily between 330 and 359 mm, and ages 2, 3, 5, and 6 (Tables 22 and 23, Figure 15). Mean length at age ranged from 293 mm for age 2 to 365 mm for age 7 (Table 23). In 1991, most humpback whitefish were between 410 and 459 mm (Table 24, Figure 16), and ages 6 through 9. Mean length at age was 414 mm for age 6 humpback whitefish, 425 mm for age 7, and 432 mm for age 8 (Table 25). Sex compositions for humpback whitefish and least cisco were not calculated because sex could be determined for only a small proportion of the samples.

Movement of Least Cisco and Humpback Whitefish from Goldstream Creek to the Chatanika River in 1991

An estimated 95% (SE = 24%) of the least cisco tagged in Goldstream Creek in May moved into the Chatanika River by September. In May of 1991, 1,189 least cisco larger than 289 mm were tagged in Goldstream Creek. During July, August, and September, 1991, 3,815 least cisco larger than 289 mm were examined for tags in the Chatanika River from area 2 through area 13, of which 32 had been tagged in Goldstream Creek. Most least cisco captured in Goldstream Creek were between 320 mm and 369 mm (Figure 17).

An estimated 28% (SE = 8%) of the humpback whitefish tagged in Goldstream Creek moved into the Chatanika River by September. In May of 1991, 343 humpback whitefish larger than 360 mm were tagged in Goldstream Creek. In July, August, and September, 14 humpback whitefish which had been tagged in Goldstream Creek, out of 2,222 examined for tags, were recaptured in the Chatanika River from area 2 through area 13. Most humpback whitefish were between 400 mm and 489 mm (Figure 17).

DISCUSSION

The 1990 study confirmed that two of the assumptions for earlier mark-recapture experiments were not met. First, the mark-recapture experiments prior to 1990 relied on marked whitefish mixing completely with unmarked whitefish during the hiatus, but statistically different recapture rates by area of tagging showed definitively that tagged and untagged whitefish do not mix completely between events. Second, the assumption that the pipeline was the downstream boundary of the humpback whitefish and least cisco populations in the fall was shown to be false by the large numbers of humpback whitefish and least cisco found below area 5 in 1990 and 1991. The 1991 study design

Table 20. Numbers of humpback whitefish larger than 359 mm, by area of capture, that were examined in September, 1991 and recaptured from August, 1991, and number that were untagged in September.[a]

	Area of Capture				Total
	1 - 5	6 - 8	9 - 10	11 - 13	
Marked	6	23[b]	16[c]	5	50
Unmarked	172	446	398	129	1,145
Total	178	469	414	134	1,195
Proportion Marked	0.034	0.049	0.040	0.039	

[a] $\chi^2 = 0.99$, df = 3, $P = 0.80$
[b] Includes two fish judged to have lost their tags.
[c] Includes five fish judged to have lost their tags.

Table 21. Numbers of humpback whitefish larger than 359 mm marked and recaptured by area in August (mark event) and September (recapture event), 1991.

Area Released	Area Recaptured				Total Recaptured	Number Not Recaptured	Total Released
	1-5	6-8	9-10	11-13			
1 - 5	1	0	0	0	1	33	34
6 - 8	3	6	1	0	10	114	124
9 - 10	2	12	7	0	21	204	225
11 - 13	0	3	3	5	11	259	270
Total	6	21	11	5	43[a]	610	653

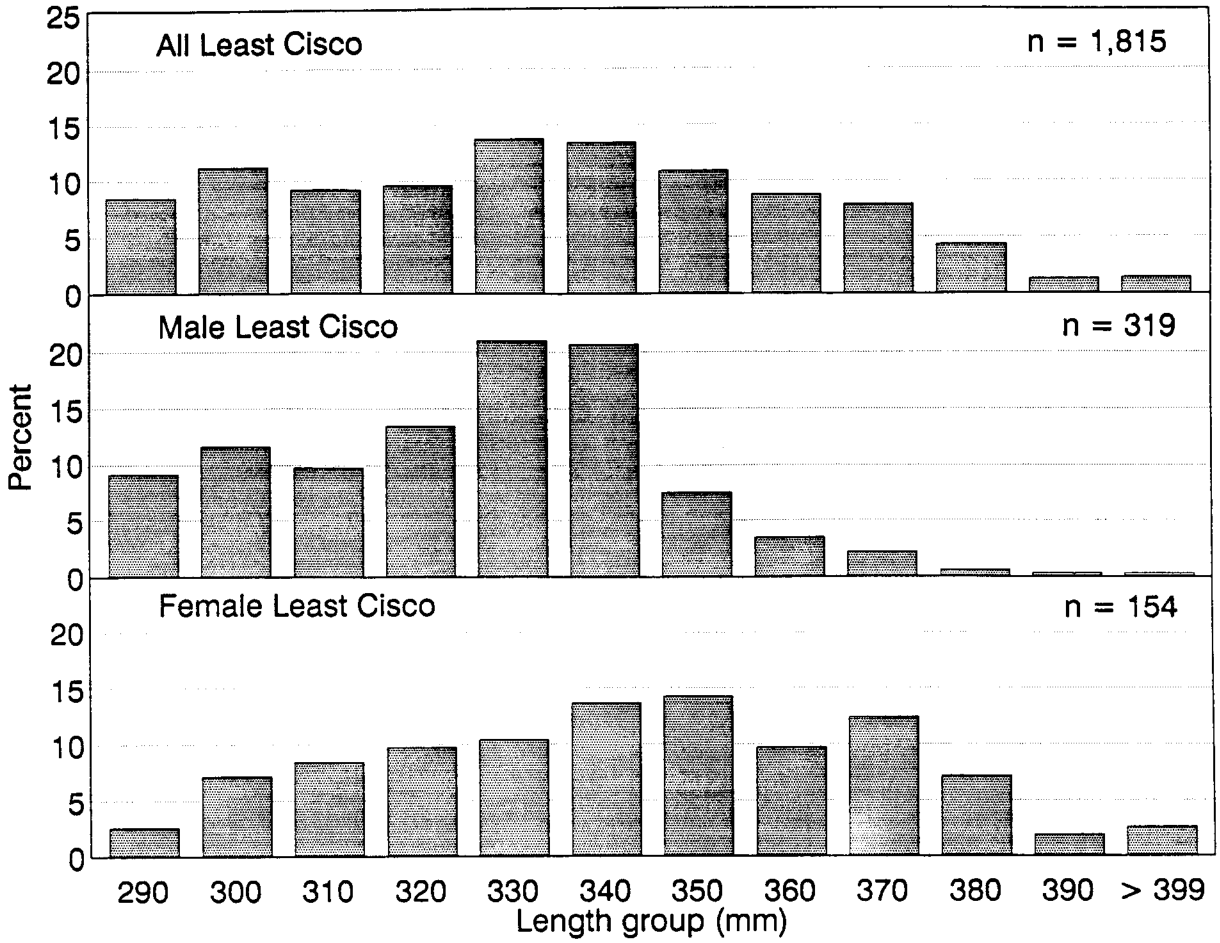
[a] Does not include fish judged to have lost their tags.

Table 22. Length composition of least cisco in the Chatanika River in 1991.

Length Group (mm)	All			Female			Male		
	n	Percent	SE	n	Percent	SE	n	Percent	SE
290-299	154	8.5	0.7	4	2.6	1.3	29	9.1	1.6
300-309	204	11.2	0.7	11	7.1	2.1	37	11.6	1.8
310-319	167	9.2	0.7	13	8.4	2.3	31	9.7	1.7
320-329	174	9.6	0.7	15	9.7	2.4	43	13.5	1.9
330-339	249	13.7	0.8	16	10.4	2.5	67	21.0	2.3
340-349	243	13.4	0.8	21	13.6	2.8	66	20.7	2.3
350-359	197	10.9	0.7	22	14.3	2.8	24	7.5	1.5
360-369	158	8.7	0.7	15	9.7	2.4	11	3.5	1.0
370-379	143	7.9	0.6	19	12.3	2.7	7	2.2	0.8
380-389	78	4.3	0.5	11	7.1	2.1	2	0.6	0.4
390-399	23	1.3	0.3	3	2.0	1.1	1	0.3	0.3
>399	25	1.4	0.3	4	2.6	1.3	1	0.3	0.3
Total	1,815	100.0		154	100.0		319	100.0	
Mean Length	338			347			330		
SE	1			2			1		

Table 23. Age composition and mean length at age of least cisco in the Chatanika River in 1991.

	Age Composition			Mean Length at Age		
Age	n	Percent	SE	n	Mean (mm)	SE
2	63	17.4	2.0	151	293	1.9
3	86	23.7	2.2	210	317	1.8
4	45	12.4	1.7	84	336	1.7
5	75	20.7	2.1	165	348	2.7
6	73	20.1	2.1	154	355	1.7
7	17	4.7	1.1	41	365	1.9
8	4	1.1	0.6	5	389	4.1
Total	363	100.0				



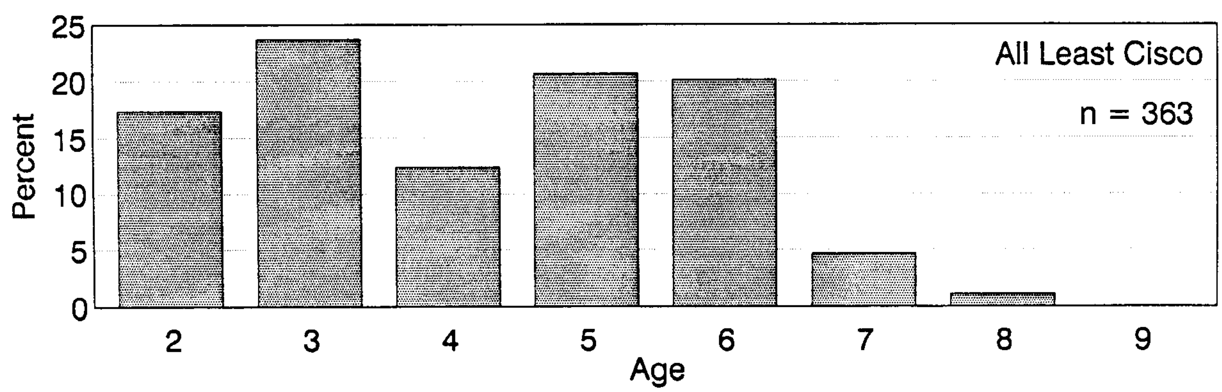
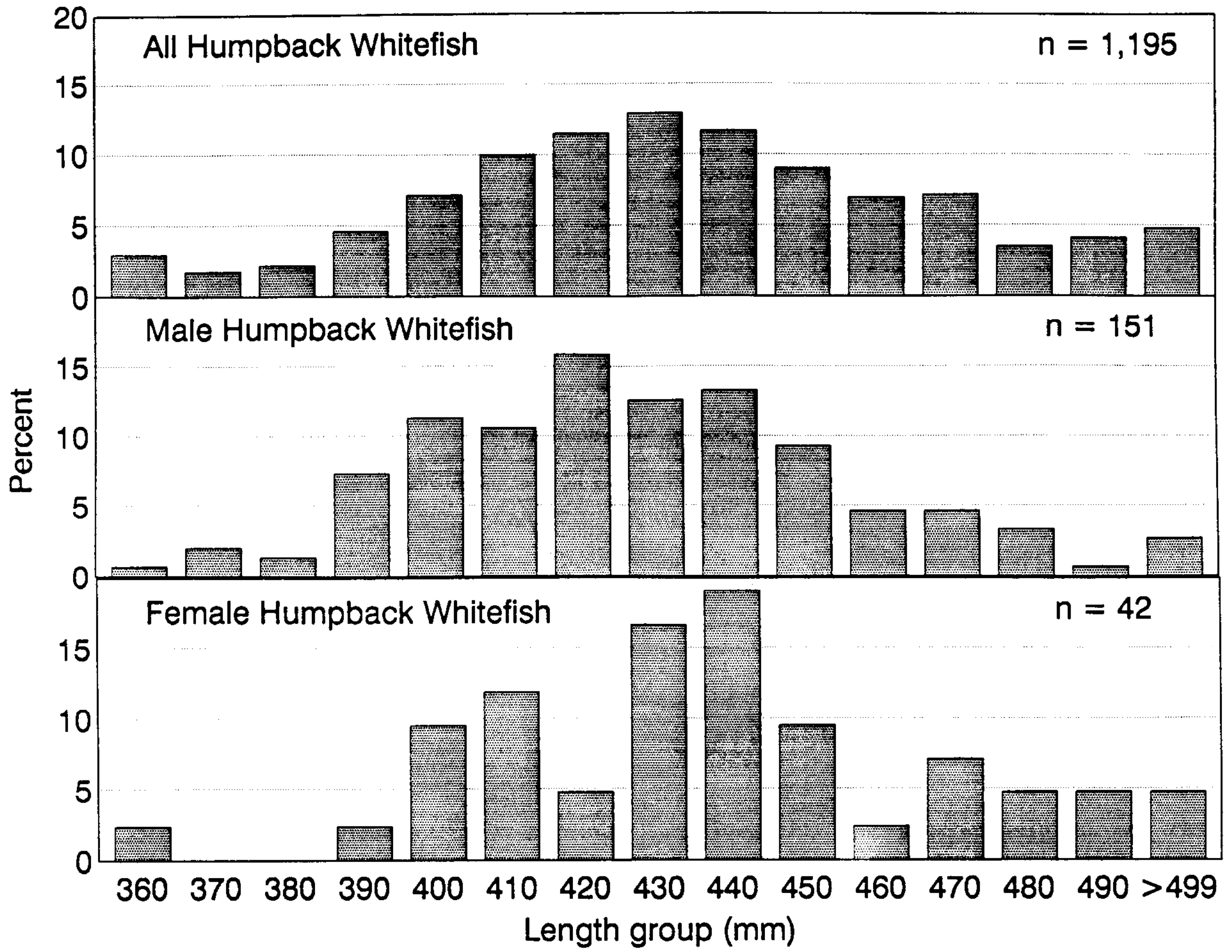


Figure 15. Length and age distribution of least cisco in the Chatanika River in 1991.

Table 24. Length composition of humpback whitefish in the Chatanika River in 1991.

Length Group (mm)	All			Female			Male		
	n	Percent	SE	n	Percent	SE	n	Percent	SE
360-369	35	2.9	0.5	1	2.4	2.4	1	0.7	0.7
370-379	21	1.8	0.4	0	0.0	0.0	3	2.0	1.1
380-389	26	2.2	0.4	0	0.0	0.0	2	1.3	0.9
390-399	55	4.6	0.6	1	2.4	2.4	11	7.3	2.1
400-409	85	7.1	0.7	4	9.5	4.6	17	11.3	2.6
410-419	119	10.0	0.9	5	11.9	5.1	16	10.6	2.5
420-429	137	11.5	0.9	2	4.8	3.3	24	15.9	3.0
430-439	154	12.9	1.0	7	16.7	5.8	19	12.6	2.7
440-449	139	11.6	0.9	8	19.1	6.1	20	13.3	2.8
450-459	108	9.0	0.8	4	9.5	4.6	14	9.3	2.4
460-469	83	7.0	0.7	1	2.4	2.4	7	4.6	1.7
470-479	85	7.1	0.7	3	7.1	4.0	7	4.6	1.7
480-489	42	3.5	0.5	2	4.8	3.3	5	3.3	1.5
490-499	49	4.1	0.6	2	4.8	3.3	1	0.7	0.7
>499	57	4.8	0.6	2	4.8	3.3	4	2.7	1.3
Total	1,195	100.0		42	100.0		151	100.0	
Mean Length	439			444			433		
SE	1			5			2		



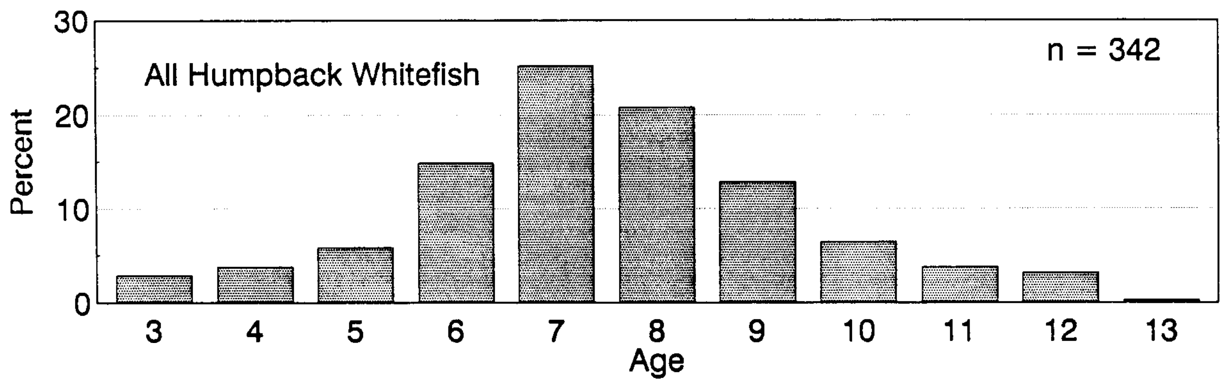
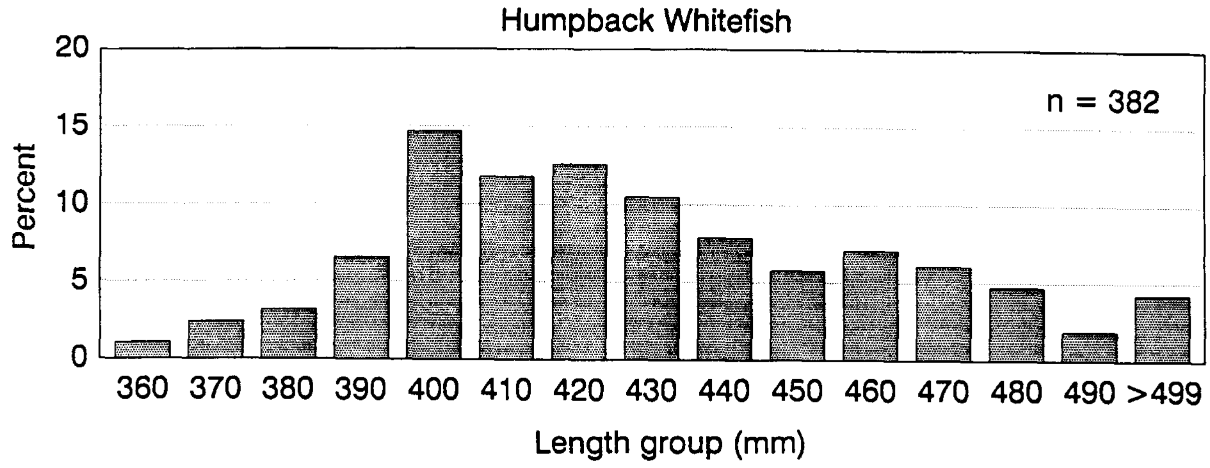


Figure 16. Length and age distribution of humpback whitefish in the Chatanika River in 1991.

Table 25. Age composition and mean length at age of humpback whitefish in the Chatanika River in 1991.

	Age Composition			Mean Length at Age		
Age	n	Percent	SE	n	Mean (mm)	SE
3	10	2.9	0.9	49	358	5
4	13	3.8	1.0	36	355	4
5	20	5.9	1.3	38	398	4
6	51	14.9	1.9	96	414	3
7	86	25.2	2.4	154	425	2
8	71	20.8	2.2	134	432	2
9	44	12.9	1.8	70	443	3
10	22	6.4	1.3	32	464	5
11	13	3.8	1.0	23	463	10
12	11	3.2	1.0	15	481	4
13	1	0.3	0.3	2	481	9
Total	342	100.0				



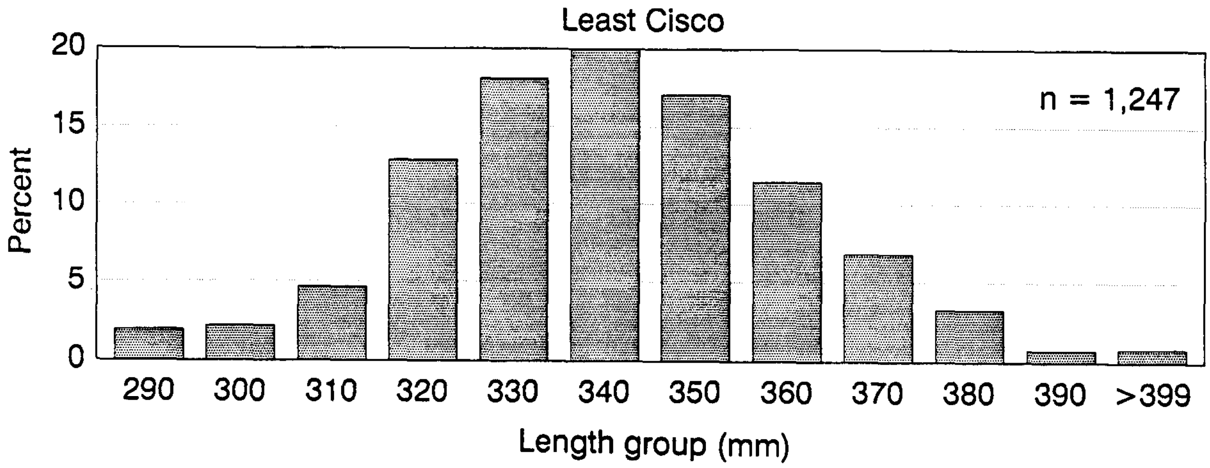


Figure 17. Length distributions of humpback whitefish and least cisco captured in Goldstream Creek in 1991.

addressed these short-comings by conducting the entire mark-recapture experiment with electrofishing and sampling the same areas for the mark and recapture events, and by redefining the boundaries of the abundance estimates to be areas 2-13.

By increasing the number of whitefish examined during the recapture event, precision of abundance estimates could be improved in the future with little additional effort. Two passes of the river could be made for the recapture event, rather than just one, and rather than tagging whitefish during the recapture event, as has been the practice, whitefish could be examined for tags and fin clips, measured, and scales taken from a sub-sample. Processing time is greatly reduced when fish are not tagged and when scale samples are not required. For example, by only examining fish for tags and measuring them, one three-person crew was able to sample over 1,100 whitefish in areas 4-5 on September 26, 1991.

Abundance estimates in 1991 could have been biased by misidentification of new tag loss as old, and the lack of recognition of new tag loss, resulting in a fish being misclassified as a new capture. If wounds from lost tags healed between events, then fish found with missing adipose fins and no tagging wound during the recapture event would have been misidentified as old tag loss, resulting in too few recaptures and an over-estimate of abundance. Since 1986, only adipose fin clips have been used as a secondary mark, but as tags are shed across years, the population of untagged whitefish with adipose clips has grown. If tag loss from the current year was being mistakenly identified as old tag loss, the percent of old tag loss should have been much higher in August and September than in July, but old tag loss in August and September was not higher than in July. Old tag loss for the three events was slightly higher for humpback whitefish, but old tag loss in August and September was not higher than in July. If adipose fins were partially clipped during the mark event (instead of completely severed from the body), and no tag scar was evident, then it is likely that crew could not distinguish a recaptured fish with a missing tag (either old or new tag loss) from a new fish. This possibility would have resulted in too few recaptures and an over-estimate of abundance. To completely eliminate the problem of misidentifying tag loss, a different secondary mark, such as a fin punch, could be used. Fin punches are generally recognizable throughout one summer, but should be grown over by the next field season. If fin punches are used, data should be collected carefully during the first season to insure that fin punches provide an acceptable solution to the problem.

The upper boundary of the humpback whitefish population in the Chatanika River in September must be determined for mark-recapture experiments to be unbiased in future years. Captures of humpback whitefish at the upper boundary of area 2 in September, 1991 indicate that humpback whitefish may have moved upriver of area 2 between the mark and recapture events. If untagged humpback whitefish moved simultaneously into the lower study area between the mark and recapture events, the abundance estimate (15,313) is a maximum estimate. If the upper boundary cannot be defined because of gear constraints, it must be determined that humpback whitefish do not move into the lower area between the mark and recapture events. The upstream boundary of area 2 was satisfactory for least cisco, as indicated by the lack of least cisco above area 4 during all three events in 1991. The downstream boundary of area 13 (the Murphy Dome Extension) appears to be satisfactory for both humpback whitefish and least cisco in September, because no humpback whitefish or least cisco were found below area 13 just after the conclusion of the mark-recapture experiment in 1991.

Smaller and younger humpback whitefish are not entering the fishery, despite the reduced bag limit implemented in 1988 and the emergency closures in 1990 and 1991 (Figures 18 and 19). With a maximum age of about 10, few fish under age 7, and a maximum abundance of only 15,313, great care must be taken to protect the spawning humpback whitefish over the next few years. The status of the least cisco population may be improving, as smaller and younger least cisco, which had been nearly absent in 1989, were present in all areas sampled in the Chatanika River in 1990 and 1991 (Figures 20 and 21).

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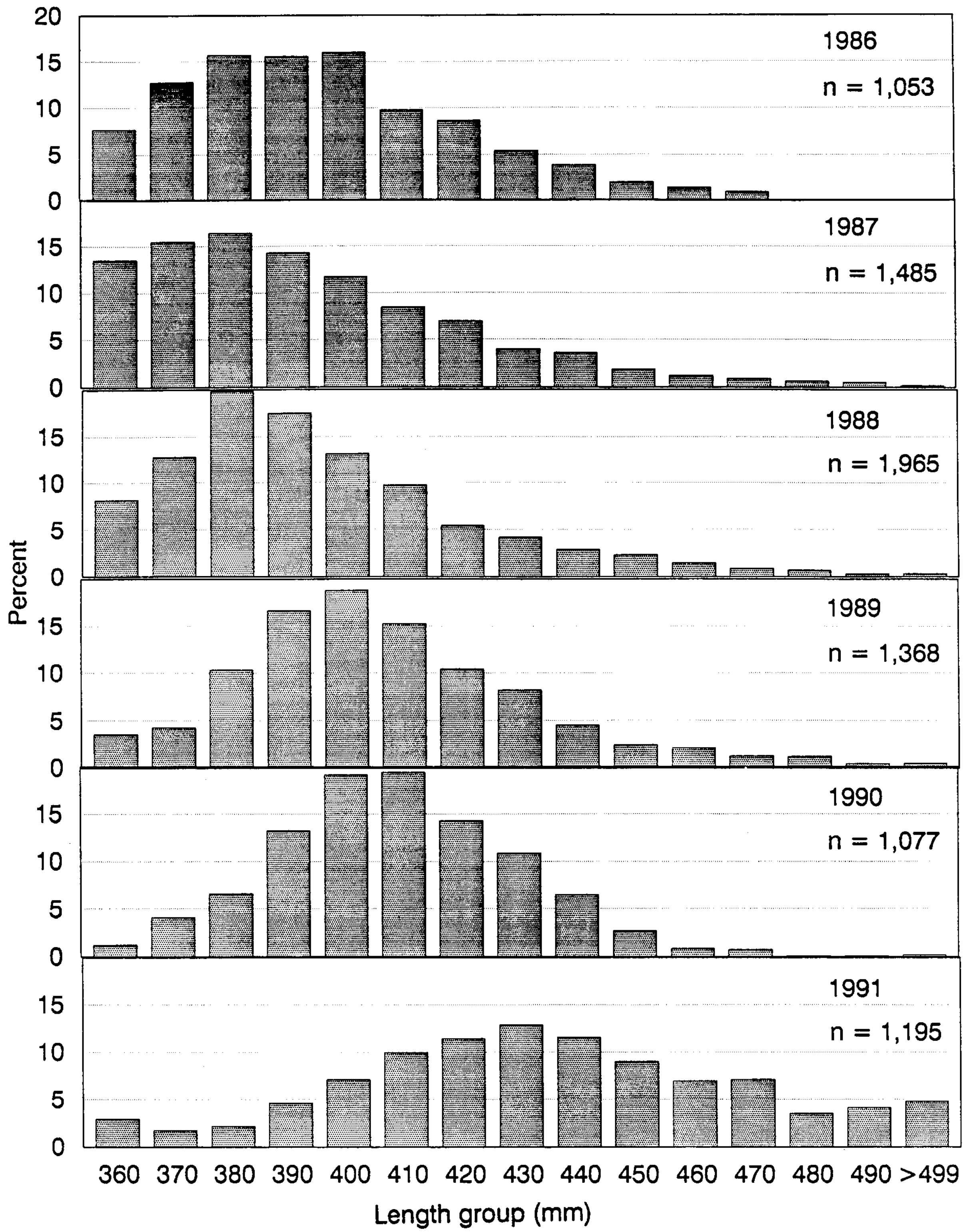

Figure 18. Length distributions of humpback whitefish in the Chatanika River, 1986-1991.

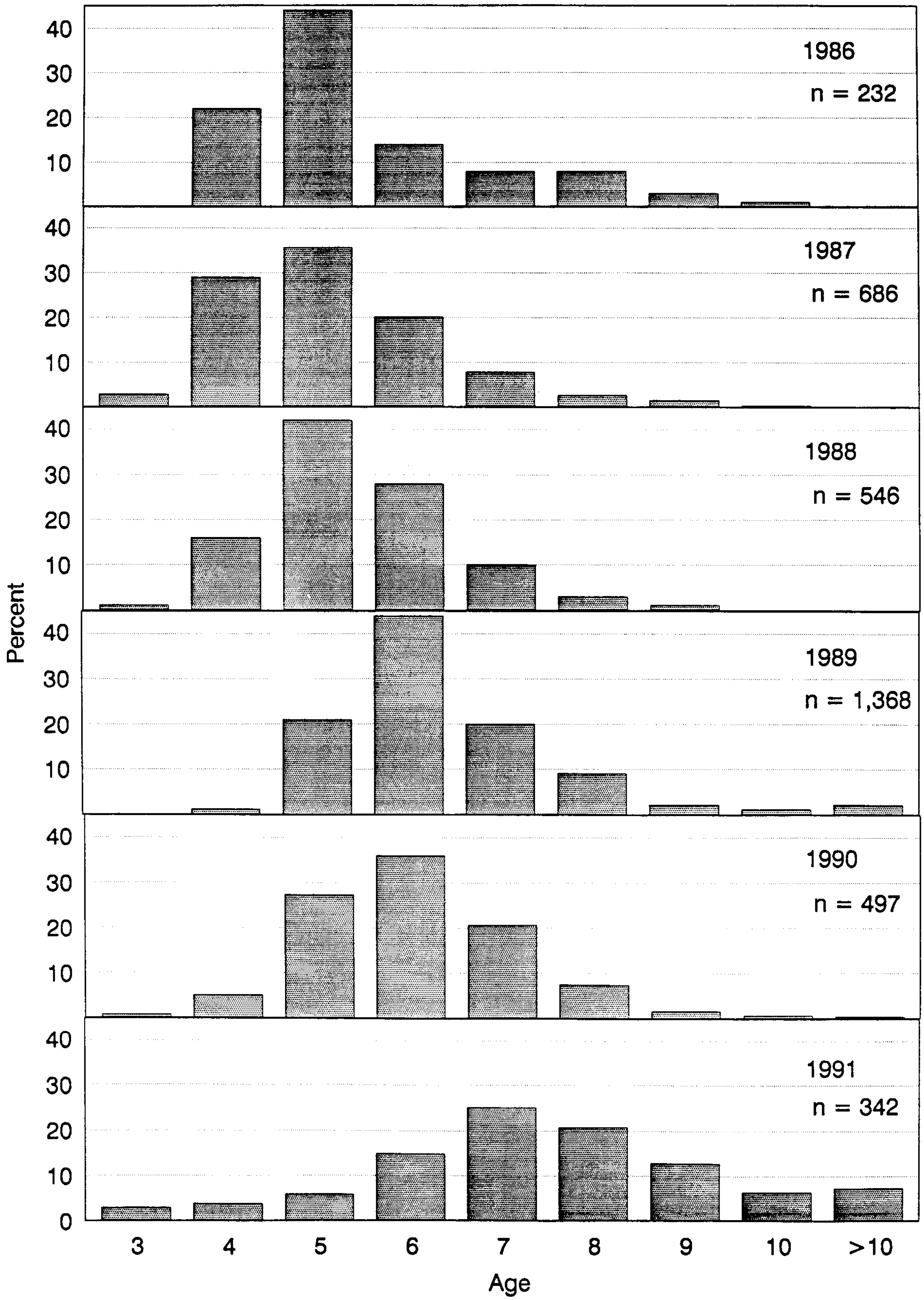

Figure 19. Age distributions of humpback whitefish in the Chatanika River, 1986-1991.

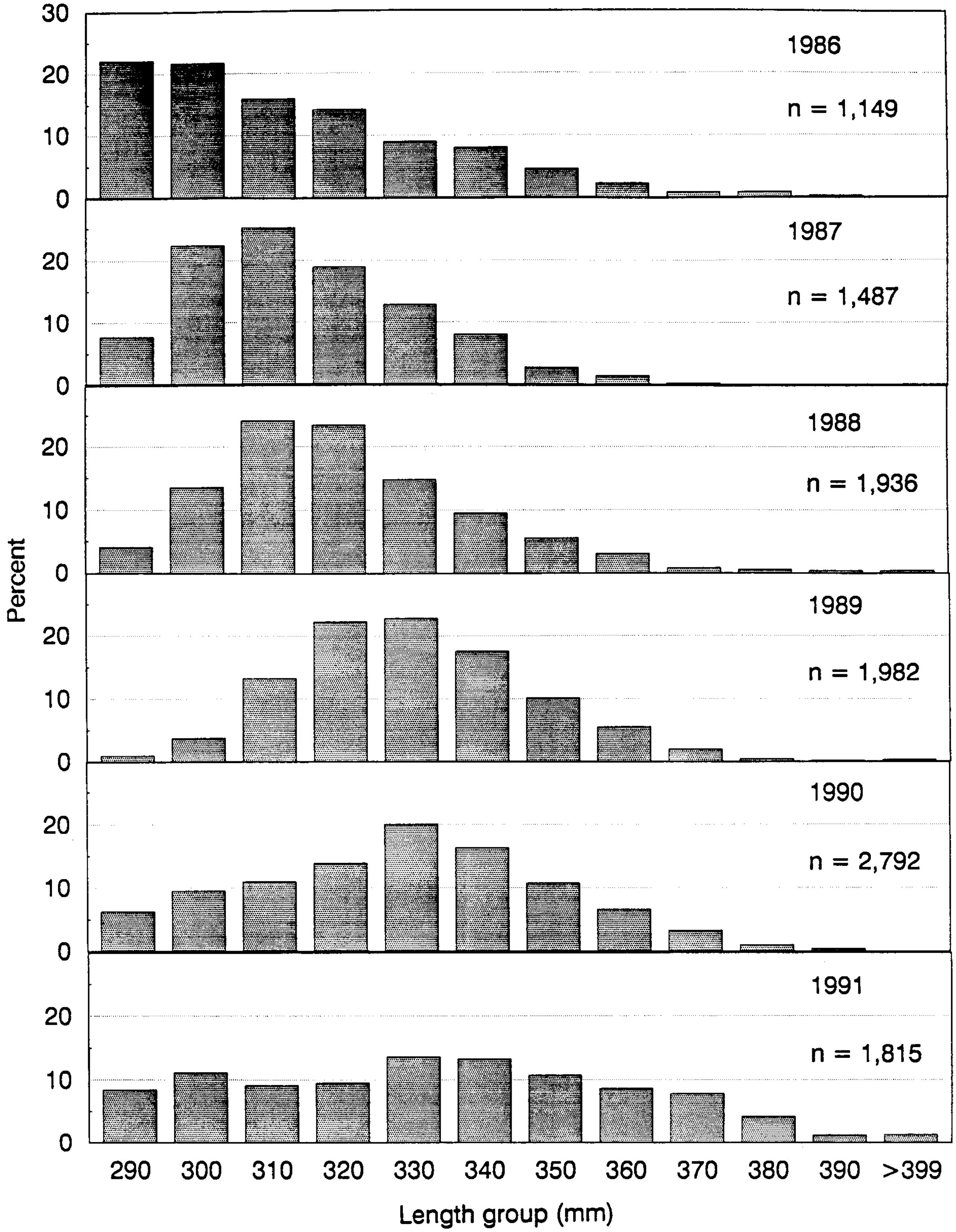

Figure 20. Length distributions of least cisco in the Chatanika River, 1986-1991.

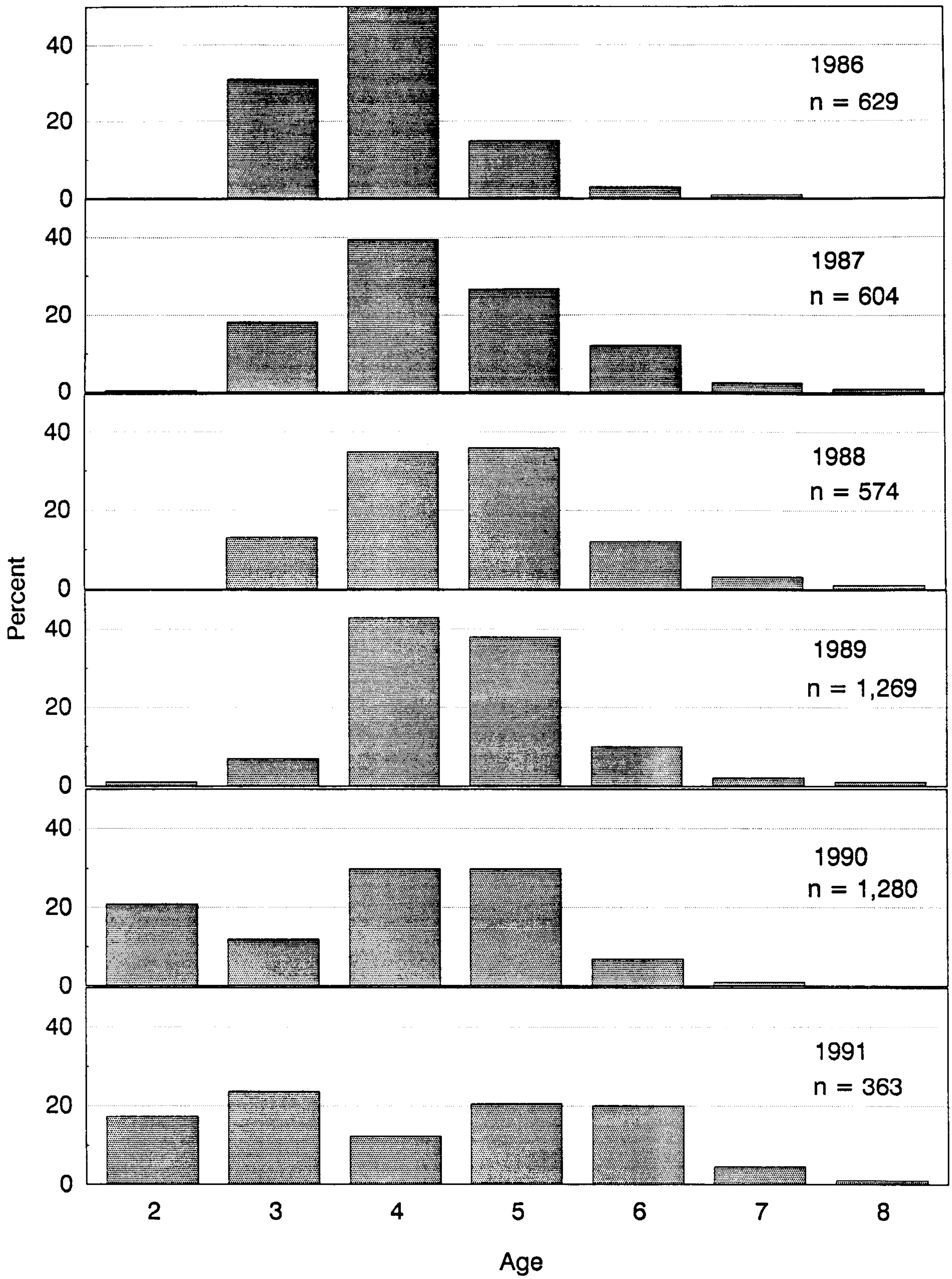

Figure 21. Age distributions of least cisco in the Chatanika River, 1986-1991.

LITERATURE CITED

Conover, W. J. 1980. Practical nonparametric statistics. John Wiley and Sons. N.Y. 493 pp.

Goodman, L. A. 1960. On the exact variance of products. Journal of the American Statistical Association. 66:708-713.

Hallberg, J. E. and R. A. Holmes. 1987. Abundance and size composition of Chatanika River least cisco and humpback whitefish with estimates of exploitation by recreational spear fishermen. Alaska Department of Fish and Game, Fishery Data Series No. 25. 26 pp.

Hallberg, J. E. 1988. Abundance and size composition of Chatanika River least cisco and humpback whitefish with estimates of exploitation by recreational spear fishermen. Alaska Department of Fish and Game, Fishery Data Series No. 61. 33 pp.

Hallberg, J. E. 1989. Abundance and size composition of Chatanika River least cisco and humpback whitefish with estimates of exploitation by recreational anglers. Alaska Department of Fish and Game, Fishery Data Series No. 108. 22 pp.

Holmes, R., D. McBride, T. Viavant, and J. Reynolds. 1990. Electrofishing induced mortality and injury to rainbow trout, Arctic grayling, humpback whitefish, least cisco, and northern pike. Alaska Department of Fish and Game, Fishery Data Series No. 90-3. 95 pp.

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). 122 pp.

______. 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). 65 pp.

______. 1981a. Alaska statewide sport fish harvest studies (1979). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A). 77 pp.

______. 1981b. Alaska statewide sport fish harvest studies (1980). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1980-1981, Project F-9-13, 22 (SW-I-A). 107 pp.

______. 1982. Alaska statewide sport fish harvest studies (1981). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1981-1982, Project F-9-14, 23 (SW-I-A). 115 pp.

______. 1983. Alaska statewide sport fish harvest studies (1982). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1982-1983, Project F-9-15, 24 (SW-I-A). 118 pp.

_____. 1984. Alaska statewide sport fish harvest studies (1983). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1983-1984, Project F-9-16, 25 (SW-I-A). 123 pp.

_____. 1985. Alaska statewide sport fish harvest studies (1984). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1984-1985, Project F-9-17, 26 (SW-I-A). 137 pp.

_____. 1986. Alaska statewide sport fish harvest studies (1985). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1985-1986, Project F-10-1, 27 (RT). 137 pp.

_____. 1987. Alaska statewide sport fisheries harvest report. Alaska Department of Fish and Game, Fishery Data Series No. 2. 140 pp.

_____. 1988. Alaska statewide sport fisheries harvest report. Alaska Department of Fish and Game, Fishery Data Series No. 52. 142 pp.

_____. 1989. Alaska statewide sport fisheries harvest report. Alaska Department of Fish and Game, Fishery Data Series No. 122. 140 pp.

_____. 1990. Harvest and participation in Alaska sport fisheries during 1989 (1990). Alaska Department of Fish and Game, Fishery Data Series No. 90-44. 152 pp.

_____. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska statewide sport fisheries harvest report. Alaska Department of Fish and Game, Fishery Data Series No. 91-58. 184 pp.

Seber, G. A. 1982. The estimation of animal abundance and related parameters. 2nd ed. Charles Griffin and Company Limited, Charles Griffin House, Crendon Street, High Wycombe Bucks, HP13 6LE, England. 654 pp.

Timmons, L. S. 1990. Abundance and length, age, and sex composition of Chatanika River humpback whitefish and least cisco. Alaska Department of Fish and Game, Fishery Data Series No. 90-2. 40 ppt.

Van Oosten, J. 1923. The whitefishes (Coregonus clupeaformis). A study of the scales of whitefishes of known ages. Zoologica (N.Y) 2:381-412.

Zar, J. H. 1984. Biostatistical analysis. Printice-Hall, Inc. Englewood Cliffs, N.J. 718 pp.

APPENDIX A

Appendix A. Daily water temperatures at the Chatanika River in 1990.

Date	Water Temperature
Weir	
7/9	18°C
7/10	16°C
7/11	15°C
7/21	18°C
7/22	15°C
7/24	17°C
7/25	15°C
7/27	12°C
7/28	14°C
7/29	15°C
7/30	14°C
7/31	14°C
Upper Chatanika	
8/22	10°C
8/23	10°C
8/27	8°C
8/28	7°C
8/29	7°C
8/30	7°C
8/31	7°C
9/4	7°C
9/5	7°C
9/6	5°C
9/7	4°C
9/11	4°C
9/12	4°C

APPENDIX B

Appendix B. Detection of size-selectivity in sampling and its effects on estimation of size composition

Results of Hypothesis Tests (K-S and χ^2) on Lengths of Fish Marked during the First Event and Recaptured during the Second Event	Results of Hypothesis Tests (K-S) on Lengths of Fish Captured during the First Event and Captured during the Second Event
Case I:	
"Accept" H_o	"Accept" H_o
There is no size-selectivity during either sampling event.	
Case II:	
"Accept" H_o	Reject H_o
There is no size-selectivity during the second sampling event but there is during the first.	
Case III:	
Reject H_o	"Accept" H_o
There is size-selectivity during both sampling events.	
Case IV:	
Reject H_o	Reject H_o
There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.	

-continued-

Case I: Calculate one unstratified abundance estimate, and pool lengths, sexes, and ages from both sampling events to improve precision of proportions in estimates of composition.

Case II: Calculate one unstratified abundance estimate, and only use lengths, sexes, and ages from the second sampling event to estimate proportions in compositions.

Case III: Completely stratify both sampling events, and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Pool lengths, ages, and sexes from both sampling events to improve precision of proportions in estimates of composition, and apply formulae to correct for size bias to the pooled data.

Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata to get a single estimate for the population. Also, calculate a single estimate of abundance without stratification.

Case IVa: If the stratified and unstratified abundance estimates for the entire population are dissimilar, discard the unstratified estimate. Only use the lengths, ages, and sexes from the second sampling event to estimate proportions in composition, and apply formulae to correct for size bias to data from the second event.

Case IVb: If the stratified and unstratified abundance estimates for the entire population are similar, discard the estimate with the larger variance. Only use the lengths, ages, and sexes from the first sampling event to estimate proportions in compositions, and do not apply formulae to correct for size bias.

APPENDIX C

Appendix C1. Numbers of humpback whitefish marked and recaptured in areas 2, 3, and 4 in 1990.

Area Released	Area Recaptured 3	Area Recaptured 4	Total Recaptured	Number Not Recaptured	Total Released
2	5	4	9	109	118
3	3	8	11	145	156
4	6	21	27	311	338
Total	14	33	47	565	612

Appendix C2. Numbers of marked and unmarked humpback whitefish (by area) examined during the recapture event in 1990.[a]

	Area of Capture		Total
	3	4	
Marked	14	33	47
Unmarked	126	358	484
Total	140	391	531

[a] $\chi^2 = 0.31$, df = 1, $P = 0.58$

Appendix C3. Numbers of marked and unmarked humpback whitefish (by time period) examined during the recapture event in 1990.[a]

	Time of Capture		
	Early[b]	Late[c]	Total
Marked	11	36	47
Unmarked	96	388	484
Total	107	424	531

[a] $\chi^2 = 0.34$, df = 1, $P = 0.56$
[b] Early = September 19 - September 30, 1990
[c] Late = October 1 - October 11, 1990

Appendix C4. Numbers of humpback whitefish marked and recaptured by time period in 1990.

Time Released	Time Recaptured Early[c]	Late[d]	Total Recaptured	Number Not Recaptured	Total Released
Early[a]	6	21	27	433	460
Late[b]	5	15	20	132	152
Total	11	36	47	565	612

[a] Early = August 20 - August 31, 1990
[b] Late = September 1 - September 12, 1990
[c] Early = September 19 - September 30, 1990
[d] Late = October 1 - October 11, 1990

APPENDIX D

Appendix D1. Numbers of least cisco marked and recaptured by area in 1990.

Area Released	Area Recaptured 3	Area Recaptured 4	Total Recaptured	Number Not Recaptured	Total Released
2	10	22	32	194	226
3	19	54	73	677	750
4	16	37	53	719	772
Total	45	113	158	1,590	1,748

Appendix D2. Numbers of marked and unmarked least cisco (by area) examined during the recapture event in 1990.[a]

	Area of Capture 3	4	Total
Marked	45	113	158
Unmarked	489	674	1,163
Total	534	787	1,321

[a] $\chi^2 = 10.63$, df = 1, $P < 0.01$

Appendix D3. Numbers of marked and unmarked least cisco (by time period) examined during the recapture event in 1990.[a]

	Time of Capture		
	Early[b]	Late[c]	Total
Marked	68	90	158
Unmarked	679	484	1,161
Total	747	574	1,321

[a] $\chi^2 = 13.33$, df = 1, $P < 0.01$
[b] Early = September 15 - September 30, 1990
[c] Late = October 1 - October 11, 1990

Appendix D4. Numbers of least cisco marked and recaptured by time period in 1990.

Time Released	Time Recaptured Early[c]	Time Recaptured Late[d]	Total Recaptured	Number Not Recaptured	Total Released
Early[a]	30	29	59	562	621
Late[b]	38	61	99	1,028	1,127
Total	68	90	158	1,590	1,748

[a] Early = August 20 - August 31, 1990
[b] Late = September 1 - September 12, 1990
[c] Early = September 15 - September 30, 1990
[d] Late = October 1 - October 11, 1990