FISHERY DATA SERIES 90-2

ABUNDANCE AND LENGTH, AGE, AND SEX COMPOSITION OF CHATANIKA RIVER HUMPBACK WHITEFISH AND LEAST CISCO[1]

By

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May 1990

[1] This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777K) under Project F-10-5, Job No. W-8-1.

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ABSTRACT

Abundance of humpback whitefish and least cisco was estimated in a section of the Chatanika River between the Elliott Highway Bridge and Olnes Pond Campground with a Petersen mark-recapture experiment. Totals of 17,322 (standard error = 1,655) humpback whitefish and 53,409 least cisco (standard error = 5,110) were estimated for the river section examined. Most humpback whitefish sampled were age five, six, or seven; most least cisco sampled were age four or five. Females of both species out-numbered males. The mean length of humpback whitefish captured was 410 millimeters, while least cisco had a mean length of 334 millimeters. Shifts in age and length compositions were apparent from 1986 through 1989.

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

INTRODUCTION

During late summer and early fall, humpback whitefish *Coregonus pidschian* and least cisco *Coregonus sardinella* migrate up the Chatanika River to spawn (Figure 1). Because of its proximity to Fairbanks and the large size of these spawning runs, whitefish harvests on the Chatanika River increased from 1,635 fish in 1977 to 25,074 fish in 1987 (Mills 1979-1989; Table 1). Prompted by concern over increasing harvests, in 1987 the Board of Fisheries restricted the harvest of whitefish in the Tanana River drainage to a bag limit of 15 fish per day. Although the harvest of whitefish in the Chatanika River dropped to 7,983 fish in 1988, that harvest still represented almost 70% of the whitefish harvest in the Tanana River drainage and almost 40% of the total whitefish harvest in Alaska (Mills 1989). In fact, throughout the 12 years for which statewide harvest data are available, the Chatanika River has contributed the majority of the whitefish harvest for the Tanana River drainage, and has consistently contributed a large portion to the statewide harvest (Figure 2).

Most of the harvest from the Chatanika River occurs between the Elliott Highway Bridge and the Olnes Pond Campground during a popular fall spear fishery (Figure 3), with a limited harvest taken along the Steese Highway. In prior years, the area of the Olnes Pond Campground has been referred to as the "ditch area", but because a developed State campground is now situated in that area, it will be referred to as the Olnes Pond Campground hereafter.

In response to the rapidly increasing harvest of whitefish in the early 1980's, stock assessment of the Chatanika River whitefish was initiated in 1986. Several methods of estimating abundance of whitefish, including sidescan sonar, counting towers, and mark-recapture experiments, were evaluated in 1986. Counts by the sonar proved unreliable, most likely because of the milling behavior of whitefish along the edge of the beam and the inability of the unit to distinguish upstream from downstream targets. While all estimating techniques had shortcomings, results of the 1986 tower counts and mark-recapture experiments were encouraging in that both methods provided abundance estimates that were within 5% of each other. In 1987, further evaluation of the counting tower and the mark-recapture experiment confirmed that both methods can provide relatively precise abundance estimates, but 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 conducted in 1988 (Hallberg and Holmes 1987; Hallberg 1988, 1989). Fecundity of whitefish was also estimated during 1988 (Clark and Bernard 1988).

The goal of this ongoing study is to monitor the status (including abundance, length, age, and sex composition) of the humpback whitefish and least cisco populations in the section of the Chatanika River which encompasses the spear fishery. Ultimately, estimates of total annual mortality, recruitment, and sustainable yields can be calculated. All these parameters are necessary for managing the Chatanika River fishery to provide long-term, quality fishing opportunities to the public.

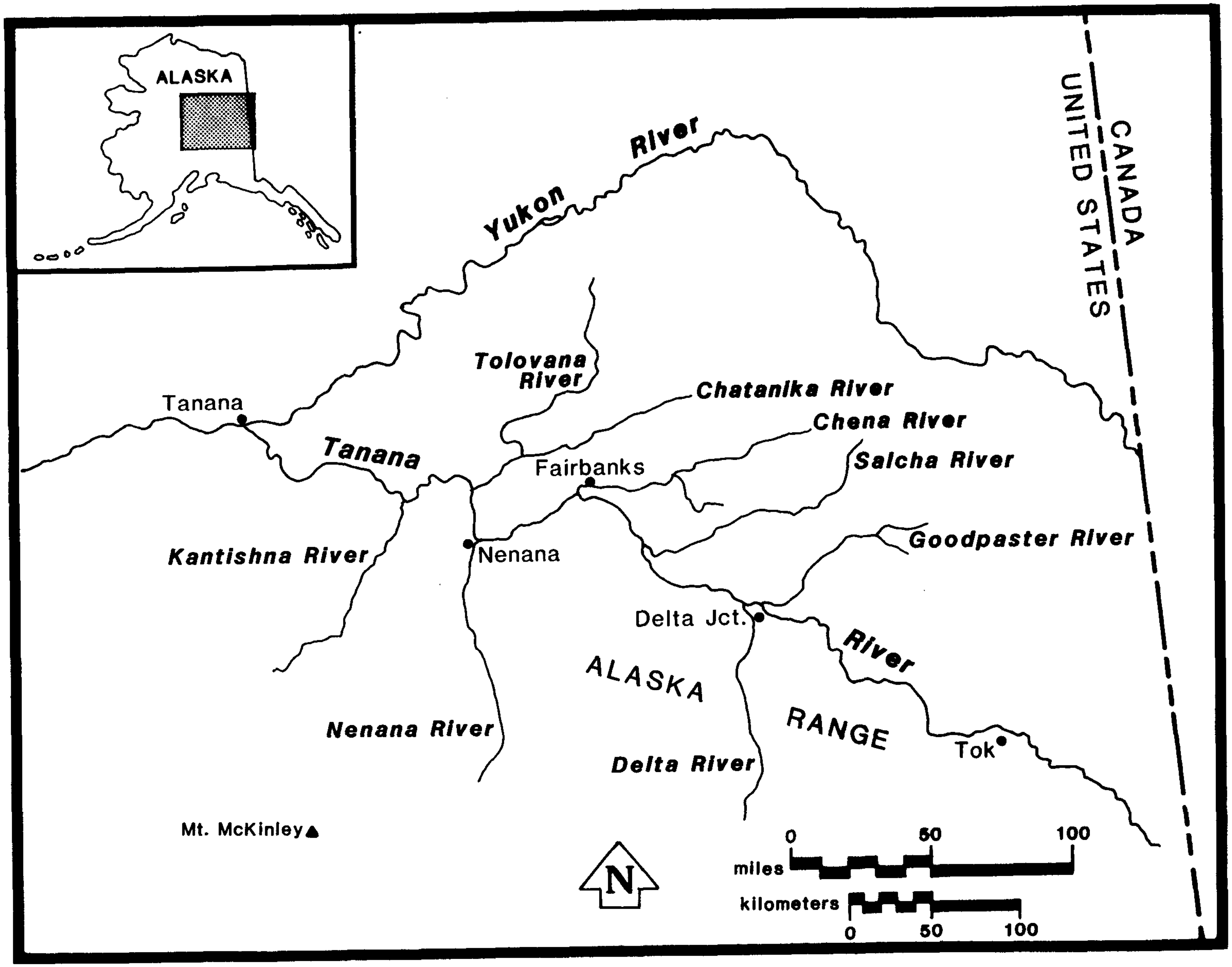

Figure 1. Location of the Chatanika River in relation to Alaska and Fairbanks.

Table 1. Harvests of whitefish from the Chatanika River, the Tanana River drainage, and Alaska from 1977 through 1988[a].

Year	Harvest: Chatanika	Harvest: Tanana Drainage	Harvest: Alaska	Percent of Tanana Dr. Total	Percent of Alaska Total
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

[a] From Mills (1979-1989).

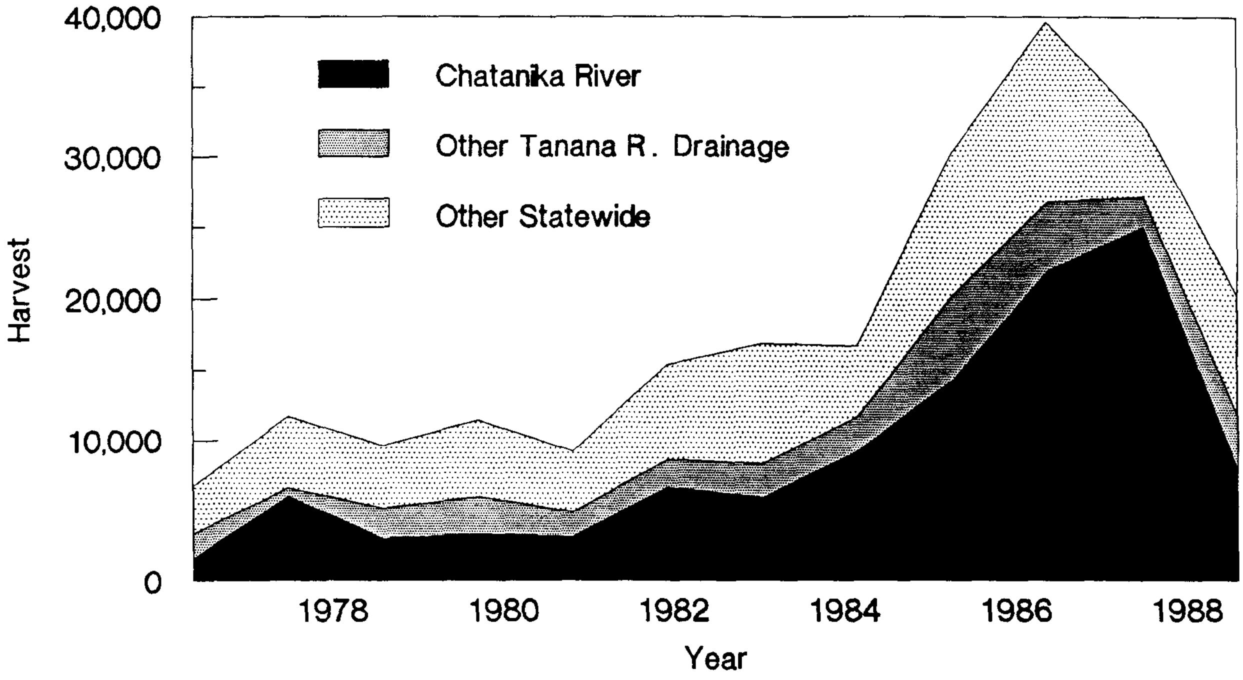

Figure 2. Harvest of whitefish from the Chatanika River, other rivers of the Tanana River drainage, and Alaska, from 1977 through 1988.

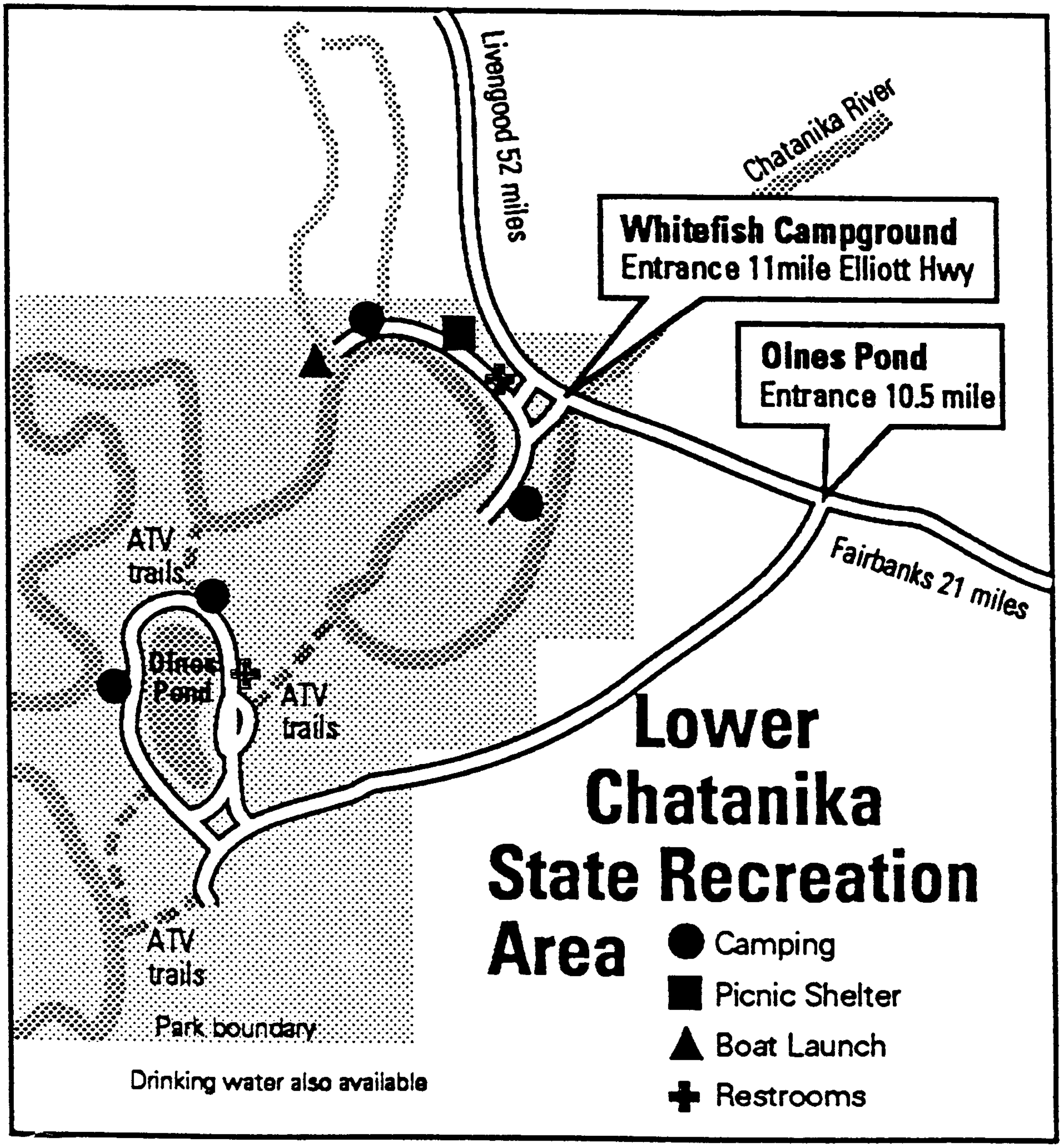

Figure 3. Map of Chatanika River study area.

Specific objectives for the 1989 study of Chatanika River whitefish were to:

1. estimate abundance of humpback whitefish and least cisco during 1989 using single-season, mark-recapture estimators;

2. estimate age and sex compositions of spawning populations of humpback whitefish and least cisco;

3. estimate the mean length of humpback whitefish and least cisco in the Chatanika River spawning population; and,

4. estimate the potential productivity of spawning female humpback whitefish and least cisco during 1989 in the Chatanika River.

In addition to these objectives, length compositions of the whitefish populations were calculated, growth of humpback whitefish and least cisco was estimated from recaptured fish which were tagged in prior years, and survival and recruitment were estimated for humpback whitefish. Abundance estimates obtained from this study will be used in the creel census study to calculate exploitation rates for the whitefish populations of the Chatanika River.

METHODS

Study Design and Data Collection

Whitefish were captured from the Chatanika River during the late summer and early fall of 1989 to estimate abundance, length, age, and sex compositions, and mean length.

Abundance Estimates:

The Petersen single-season mark-recapture method (Ricker 1975) was chosen to estimate abundance of humpback whitefish because abundance can be estimated in one season with the Petersen method and this method has worked well in the past for humpback whitefish of the Chatanika River (Hallberg and Holmes 1987; Hallberg 1988, 1989). From 16 August to 27 September 1989, humpback whitefish were captured with an electrofishing boat, from the Elliott Highway Bridge downstream to the Olnes Pond Campground (Figure 3). The recapture event consisted of fish sampled in creel censuses conducted at the Whitefish Campground located at the Elliott Highway Bridge and at the Olnes Pond Campground, from 27 September to 21 October 1989. Since only whitefish caught in the area of the spear fishery were considered in the mark-recapture experiment, the population estimate is relevant to the area of the river from the Olnes Pond Campground and above.

The 1989 operational plan called for a series of Petersen and Jolly-Seber estimates of population abundance to be calculated for least cisco, using each sweep with the electrofishing gear as the mark for the Petersen experiment and as the mark-recapture for the Jolly-Seber estimates, and catches from the spear fishery on succeeding nights as the recapture for the Petersen estimates (Ricker 1975; Seber 1982). This approach was planned because it was assumed that arrival of least cisco on the spawning grounds would span both the mark and recapture periods, violating the assumption of no recruitment for the Petersen method. The Jolly-Seber method allows for recruitment, which was expected to be large between the beginning and end of the entire experiment, but was expected to be minimal between the individual mark and recapture events. However, since tagging the large number of least cisco required for Jolly-Seber estimates proved impossible, a single Petersen estimate was attempted for least cisco, with one marking event (the electrofishing from 16 August to 27 September) and one recapture event (the creel census from 27 September to 21 October). This sampling scheme was identical to that used for the humpback whitefish estimates. The operational plan also called for areas of the Chatanika River below the Olnes Pond Campground to be sampled as time permitted, but only two runs were made below Olnes Pond, due to the difficulty in obtaining the required samples for the mark-recapture experiment and due to extremely low water levels that made navigating the river very difficult. Those whitefish sampled below the ditch were not included in the population estimate. Only two runs were made above the Elliott Highway Bridge in 1989, also because of the low level of the river.

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 23°C to 11°C. Capturing whitefish in August proved to be difficult, probably because of the very clear water conditions, which apparently allowed whitefish to see and evade the boat before they could be stunned by the electricity. Floating a short distance with the electrical current off, then turning it on for a short time, solved the problem, and thereafter electrofishing was highly successful.

Stunned whitefish were collected from the water with hand-held dip nets and were placed in a large tub with circulating water. During the marking effort, fish were tagged with an individually numbered green Floy anchor tag and were given an adipose fin clip. Tag numbers of all fish recaptured from prior years were recorded, and section of the river in which fish were captured was also recorded.

During September and October, creel sampling of spear fishermen near the Elliott Highway Bridge, Olnes Pond area, and along the Steese Highway (Figure 3) served as the recapture event. All fish sampled from the creel were counted and examined for tags and fin clips. Since the results of chi-square contingency table analyses for 1986, 1987, and 1988 showed no significant difference between the size of fish caught by the electrofishing gear and the size of fish caught by spear fishermen (Hallberg and Holmes 1987; Hallberg 1988, 1989), only recaptured fish from prior years were measured during the creel census. A scale sample was also 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. The total number of each species tagged, the number examined for marks, and the number of marked fish recovered in the spear fishery provided the necessary components for the abundance estimates.

Target sample sizes for the mark and recapture events were calculated according to methods described in Robson and Regier (1964). Based on 1987 abundance estimates of 28,165 humpback whitefish and 55,620 least cisco, 1,350 humpback whitefish and 1,900 least cisco were to be tagged during the marking event, and 1,350 humpback whitefish and 1,900 least cisco were to be examined for tags during the recapture event to meet the 1989 objectives. Abundance estimates from 1987 were used to calculate the sample sizes because 1988 abundance estimates were not available.

Length, Age, and Sex Composition and Mean Length:

A random subsample of 600 fish per species was required to provide a sufficient sample size to attain the desired accuracy and precision for the multinomial proportions of length, age, and sex compositions (Thompson 1987). However, all fish were measured to the nearest millimeter of fork length (FL), including fish with tags from prior years, so that growth rates could be estimated for recaptured fish in future years. Scale samples, taken from the left side of the fish from an area above the lateral line and below the dorsal fin, to be used for age analysis and age validation, were also collected from all fish captured during the marking event. In the field, scales were wiped clean of mucus and mounted on gum cards. Mounted scales were impressed on acetate cards and scale impressions were magnified with a micro-fiche reader to count annuli. When possible, sex was determined by expressing sex products, and was recorded as male, female, or undetermined. All length, age, sex, and tag information from both events was recorded on Tagging-Length mark-sense forms.

Since all fish encountered during the marking event were measured, it was expected that the desired precision and accuracy would be met for estimates of mean length. Based on Cochran's (1977) methods for determining sample size, the smallest sample size for a species during the marking event (1,350 fish) would be sufficient to meet objective criteria for a population with a standard deviation of 190 mm FL. The standard deviations for both species were well below this level in the past (Hallberg and Holmes 1987; Hallberg 1988, 1989).

Data Analysis

After whitefish were tagged and sampled at the Chatanika River, data were analyzed to estimate abundance, length, age, and sex compositions, mean length, and potential productivity.

Abundance Estimates:

The Chapman modification of the Petersen single-mark method was used to estimate the abundance of each species (Ricker 1975). Abundance estimates are germane to the time immediately after the marked fish are released. Conditions for the accurate use of the Petersen single-mark method for each species are:

1. the marked whitefish suffer the same natural mortality as the unmarked;

2. the marked whitefish are as vulnerable to the fishing being carried out as are the unmarked ones;

3. the marked fish do not lose their mark;

4. the marked fish become randomly mixed with the unmarked; or the distribution of fishing effort (in subsequent sampling) is proportional to the number of fish present in different parts of the body of water; and,

5. recruitment to the catchable population during the time the recoveries are being made is negligible.

The live box and frequent processing of captured fish ensured that there was little difference in natural mortality between marked and unmarked fish, and electrofishing has been shown to have minimal effect on whitefish (Holmes et al. 1989). Most spear fishermen were unaware of tagged whitefish in their catches, indicating that the Floy tags were probably not visible to most spear fishermen, so the requirement that marked and unmarked fish are equally vulnerable to the fishery was met. Double marking with the fin clip permitted correction of abundance estimates for any tag loss that may have occurred.

Two contingency table analyses (Seber 1982) were used to test that marked fish mixed randomly with unmarked fish and that recruitment during the recapture event was negligible. The first chi-square test, which compared the recapture to catch ratios (by time or 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 chi-square test, which compared numbers (by time or area strata) of fish released, recaptured, and not recaptured, was employed to detect mixing of marked fish with unmarked fish.

When all conditions are met, abundance and variance of abundance for the Petersen estimate can be calculated according to the following equations:

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

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

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.

Length, Age, and Sex Composition and Mean Length:

Length compositions of sampled whitefish were analyzed graphically with percent-frequency histograms. Humpback whitefish and least cisco were grouped by 10 mm length categories, with males and females separated to determine if length compositions differed between sexes.

Age composition was considered a series of proportions, one for each age group, whose sum was one. The maximum likelihood estimate of a marginal proportion and associated variance in such a multinomial distribution of ages is:

$$\hat{p}_i = \frac{y_i}{n}; \text{ and,} \tag{3}$$

$$\hat{V}[\hat{p}_i] = \frac{\hat{p}_i(1-\hat{p}_i)}{n - 1}. \tag{4}$$

where:

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

y_i = the number of fish of age i in the sample;

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

$\hat{V}[p_i]$ = the variance of the estimated proportion of fish of age i in the population.

Sex composition was also considered a series of proportions (male, female, and unknown) and was estimated with Equations 3 and 4 with sex substituted for age. Simple averages and squared deviations from the mean were used to calculate mean lengths and standard errors.

Survival and Recruitment:

Survival and recruitment were estimated using abundance estimates and age compositions from 1986 through 1989. Survival (S) was calculated by dividing the abundance of a fully recruited cohort in one year by the abundance of that cohort in the previous year:

$$S_t = \frac{N_{t+1}}{N_t} . \tag{5}$$

where N_t = abundance of a cohort in year t. The standard error of the estimated survival was the square root of the variance of survival ($V[S_t]$), where:

$$V[S_t] = S^2 \left[\frac{V[N_{t+1}]}{N_{t+1}^2} + \frac{V[N_t]}{N_t^2} \right] . \tag{6}$$

The average survival between each of the four years was then calculated using survival between age 7 and 8 and between age 8 and 9. Recruitment, which was calculated for each year for each cohort that was not fully recruited the year before, was defined as:

$$A_{t+1} = N_{t+1} - (N_t \cdot S_t); \text{ and,} \tag{7}$$

$$V[A_{t+1}] = V[N_{t+1}] + V[N_t] \cdot S_t^2 + N_t^2 \cdot V[S_t] - V[N_t] \cdot V[S_t] . \tag{8}$$

where S_t is the average survival from year t to year t+1, and $A_{(t+1)}$ is the recruitment from year t to year t+1.

Potential Productivity:

The potential productivities of female humpback whitefish and least cisco were estimated using length-dependent fecundities (Clark and Bernard 1988). Cochran (1977) gives the equations for making such estimations as:

$$\hat{F} = \frac{\hat{N} \sum^{m} \hat{F}_j}{m} . \tag{9}$$

$$V[\hat{F}] = \frac{\hat{N}^2 \sum^{m} (\hat{F}_j - \bar{F})^2}{m(m - 1)} + \frac{\hat{N}^2 \sum^{m} V[\hat{F}_j]}{m^2} . \tag{10}$$

where:

$\hat{F}$ = egg production by the spawning population;

$\hat{N}$ = estimated abundance of females;

$\hat{F}_j$ = estimated fecundity of fish j predicted from its length;

m = the number of fish in the sample;

$V[\hat{F}]$ = the variance of the egg production of the spawning population;

$\bar{F}$ = the mean fecundity of the sampled fish; and,

$V[\hat{F}_j]$ = the variance of the estimated fecundity of fish j predicted from its length.

RESULTS

Abundance Estimates

Between 16 August and 27 September 1989, 1,337 humpback whitefish were tagged. Of the 1,216 humpback whitefish examined in the creel census between 27 September and 23 October 1989, 93 were legitimate recaptures for the abundance estimate. Marked to unmarked ratios, by area, of humpback whitefish examined in the creel census were not significantly different (χ^2 = 1.06, df = 1, $P > 0.05$), indicating that either marked humpback whitefish mixed completely with unmarked humpback whitefish or that all humpback whitefish had the same probability of being tagged. No significant difference was found between the numbers of recaptures and non-recaptures by area of release and recapture (χ^2 = 0.13, df = 2, $P > 0.05$), indicating that mixing of humpback whitefish between areas was complete. Marked to unmarked ratios, by time, of humpback whitefish examined in the creel census were not significantly different (χ^2 = 0.07, df = 1, $P > 0.05$), but a significant difference was found between the number of recaptures and non-recaptures by time of release and recapture (χ^2 = 26.66, df = 2, $P < 0.05$), indicating that although marked humpback whitefish did not mix completely with unmarked humpback whitefish across time, all humpback whitefish did have the same probability of being tagged. Results of the chi-square analyses by time also indicated that recruitment was negligible during the time the recoveries were being made.

Since all conditions were met, the Chapman modification of the Petersen single-mark method was used to estimate the abundance of humpback whitefish at 17,322 (SE = 1,655).

Least cisco were also tagged between 16 August and 27 September 1989 and examined for tags in the creel census between 27 September and 23 October 1989. A total of 1,917 least cisco were tagged, and of the 2,728 examined in the creel census, 97 were legitimate recaptures for the abundance estimate. Marked to unmarked ratios, by area, of least cisco examined in the creel census were not significantly different (χ^2 = 3.07, df = 1, $P > 0.05$), indicating that either marked least cisco mixed completely with unmarked least cisco or that all least cisco had the same probability of being tagged. No significant difference was found between the numbers of recaptures and non-recaptures by area of release and recapture (χ^2 = 0.07, df = 2, $P > 0.05$), indicating that mixing of least cisco between areas was complete. Marked to unmarked ratios, by time, of least cisco examined in the creel census were not significantly different (χ^2 = 2.66, df = 1, $P > 0.05$), and no significant difference was found between the number of recaptures and non-recaptures by time of release and recapture (χ^2 = 2.81, df = 2, $P > 0.05$), indicating that marked least cisco mixed completely with unmarked least cisco across time, and that all least cisco had the same probability of being tagged. Results of the chi-square analyses by time also indicated that negligible recruitment occurred during the time the recoveries were being made.

Since all conditions were met, the abundance of least cisco was estimated by the Chapman modification of the Petersen method to be 53,409 (SE = 5,110).

A total of 49 humpback whitefish which were tagged in prior years were recovered during the marking event, during the creel census, or by spear fishermen who notified the Department of Fish and Game of the recovery. Of those recaptures from prior years, 30 (61%) fish were originally tagged in 1988, 13 (27%) in 1987, and 6 (12%) in 1986. Seventeen least cisco with tags from prior years were captured during 1989 during the tagging effort, during the creel census, or by spear fishermen. Of those recaptures of least cisco from prior years, 14 (82%) were tagged in 1988, 2 (12%) were tagged in 1987, and 1 (6%) was tagged in 1986.

Length, Age, and Sex Composition and Mean Length

Most humpback whitefish of both sexes were between 370 mm and 449 mm in length (Figure 4) and were age 5, 6, or 7 (Table 2; Figure 5). During the early part of the tagging effort, determination of the sex of humpback whitefish was very difficult, but became increasingly easier toward the end of September (Figure 6). Therefore, the sex ratio of humpback whitefish was determined using only data collected between 16 September and 27 September 1989, when sex of most fish was easily determined. Of the 548 humpback whitefish tagged during that period, 292 (53%, SE = 3) were males, 244 (45%, SE = 3) were females, and 12 (2%, SE = 4) were of unknown sex. The mean length of humpback whitefish was 410 mm (SE = 0.73) for sexes combined, 412 mm (SE = 1.25) for females, and 411 mm (SE = 1.36) for males. Mean length by age was similar between males and females (Figure 7).

Most least cisco were between 310 mm and 379 mm (Figure 8), and were primarily age 4 or 5 (Figure 9). Determination of sex was also difficult for least cisco between 16 August and 15 September so only data collected after September 15 were used to determine sex ratios (Figure 10). The population of least cisco in the Chatanika River, as determined from a sample 1,333 least cisco, was composed of 65% males (SE = 2), 32% females (SE = 2), and 3% undetermined sex (SE < 1). Least cisco averaged 334 mm (SE = 0.41) in length for sexes combined, 347 mm for females (SE = 0.69), and 328 mm for males (SE = 0.48). Length at age was generally greater for females than for males (Figure 11; Table 3).

Growth of humpback whitefish tagged in 1986, 1987, or 1988 and recaptured after one year was regressed against length at tagging. Two sets of data were used, one that included all data, and one that included only growth that was positive or zero. Based on 53 recaptures, growth of fish was inversely related to length: smaller fish grew more over one year than larger fish (Figure 12). Regressions were not attempted for least cisco, because data were available for only eight recaptures, and because no direct relationship between growth and length was apparent when data were plotted (Figure 13).

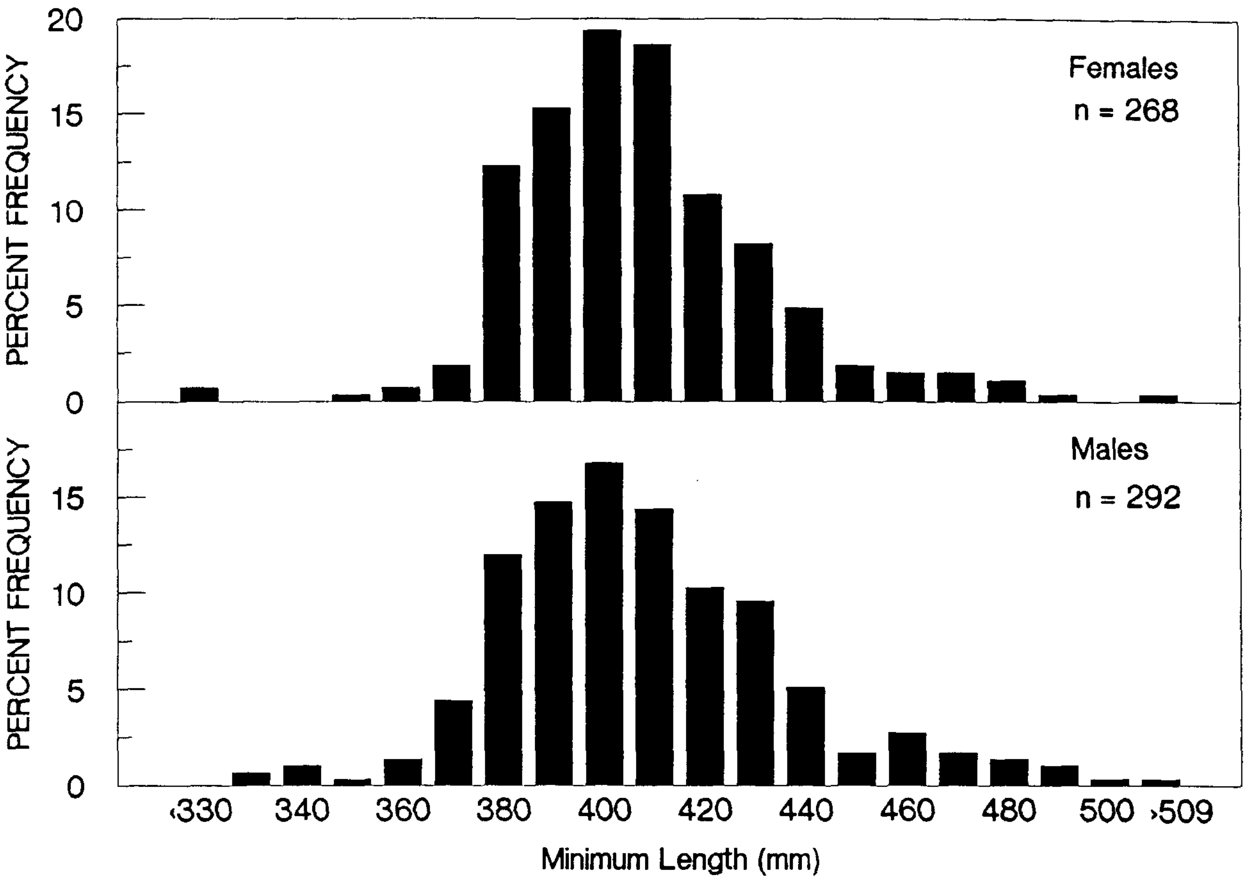

Figure 4. Length compositions of female and male humpback whitefish from the Chatanika River in 1989.

Table 2. Mean length by age and proportion of ages of humpback whitefish of the Chatanika River in 1989.

Age	Mean Length	SE	n	Proportion of Population	SE
Sexes Combined					
4	400	5	13	0.01	<0.01
5	403	2	211	0.21	0.01
6	407	1	433	0.44	0.01
7	415	2	198	0.20	0.01
8	419	3	84	0.09	0.01
9	441	7	23	0.02	<0.01
10	450	9	9	0.01	<0.01
11	474	19	8	0.01	<0.01
12	468	--	1	<0.01	<0.01
13	489	5	2	<0.01	<0.01
All Ages[a]	410	1	1,368[b]		
Females					
4	391	--	1	--	--
5	408	3	52	0.19	0.06
6	408	2	126	0.47	0.04
7	414	3	52	0.19	0.06
8	413	4	24	0.09	0.06
9	441	9	10	0.04	0.06
10	466	--	1	<0.01	<0.01
11	475	--	1	<0.01	<0.01
12	--	--	0	--	--
13	493	--	1	<0.01	<0.01
All Ages[a]	412	1	415		
Males					
4	390	12	4	0.01	0.07
5	401	3	65	0.22	0.05
6	409	2	124	0.42	0.04
7	418	3	63	0.22	0.05
8	423	9	23	0.08	0.06
9	444	26	3	0.01	0.07
10	431	7	4	0.01	0.07
11	478	13	4	0.01	0.07
12	468	--	1	<0.01	<0.01
13	484	--	1	<0.01	<0.01
All Ages[a]	411	1	431		

[a] The "All Ages" category does not equal the sum of individual age categories because the "All Ages" category includes fish of unknown age.

[b] The total for the "Sexes Combined" category is greater than the sum of the female and male categories because the "Sexes Combined" category includes fish of unknown sex.

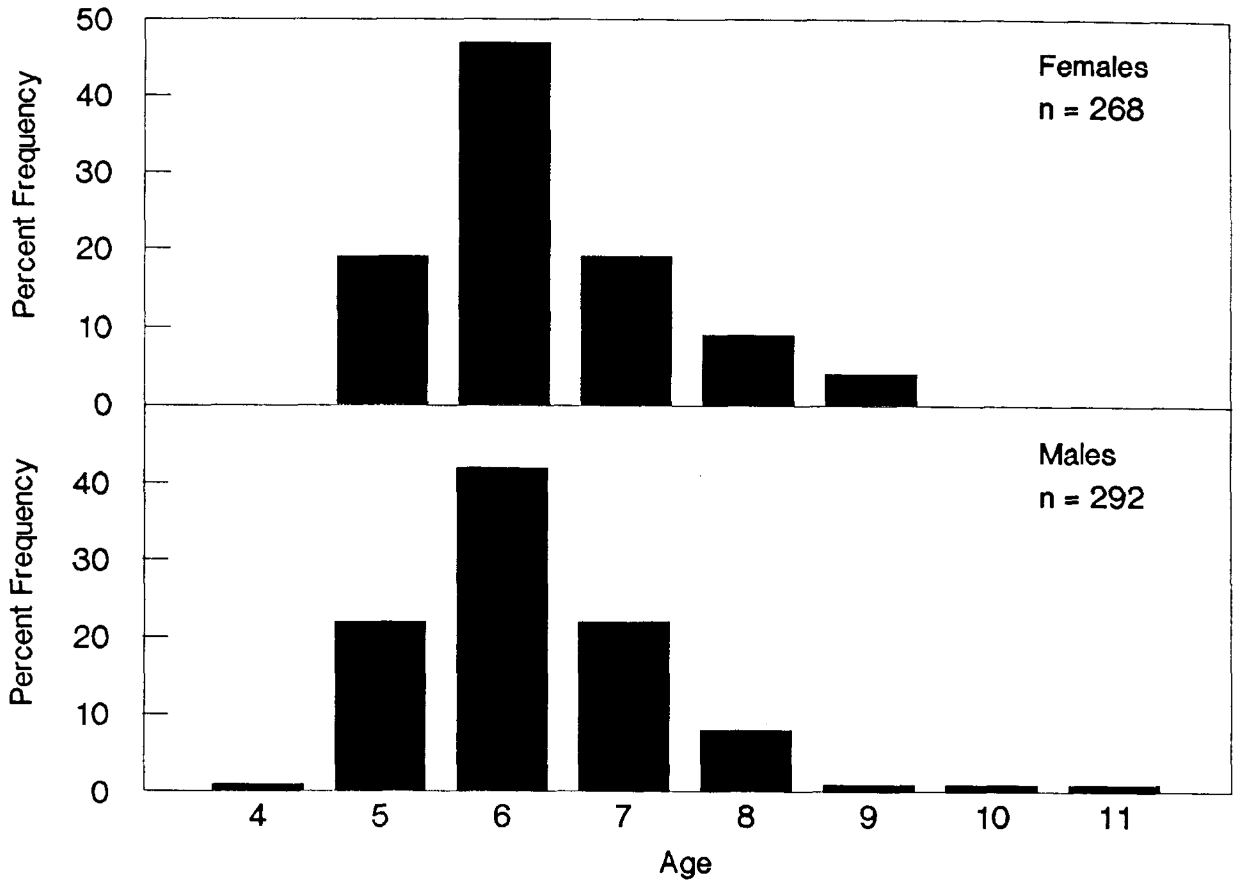

Figure 5. Age compositions of female and male humpback whitefish from the Chatanika River in 1989.

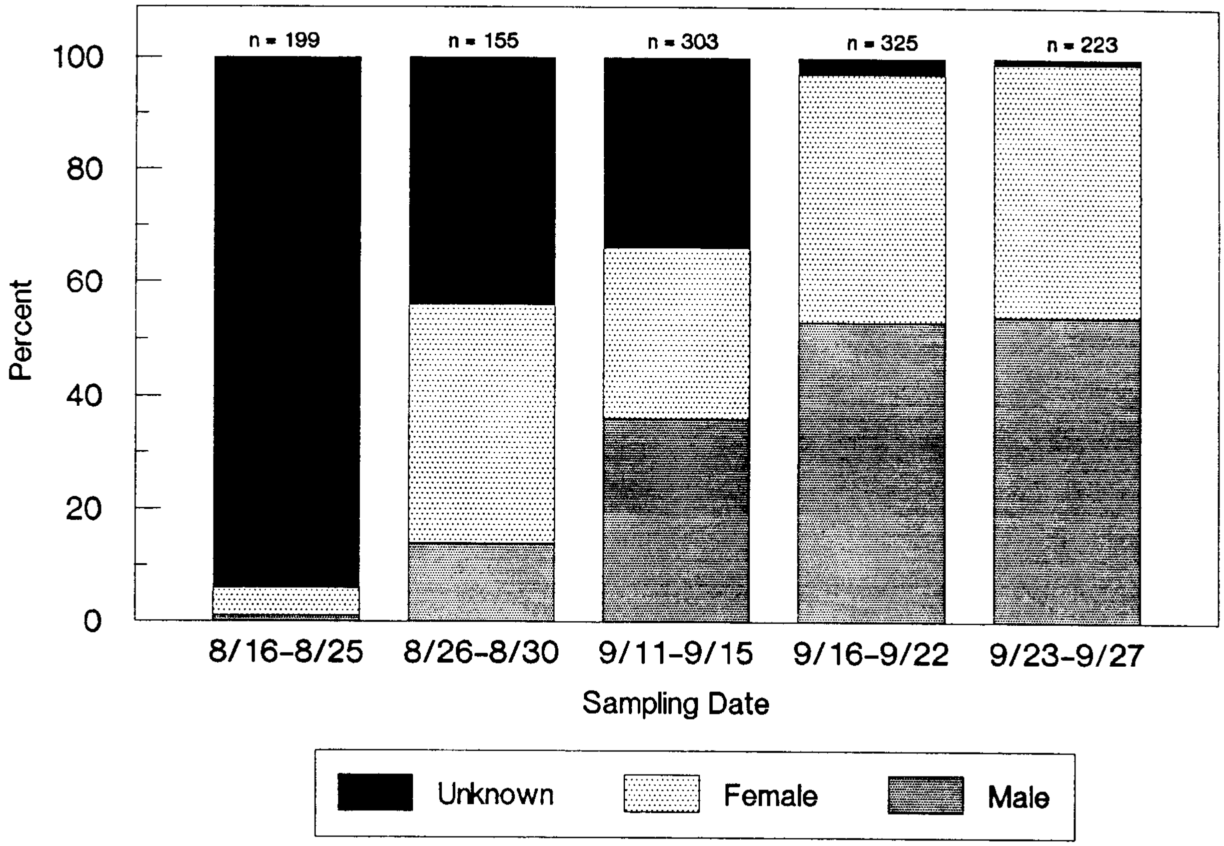

Figure 6. Sex composition of the humpback whitefish population of the Chatanika River during five weeks in 1989.

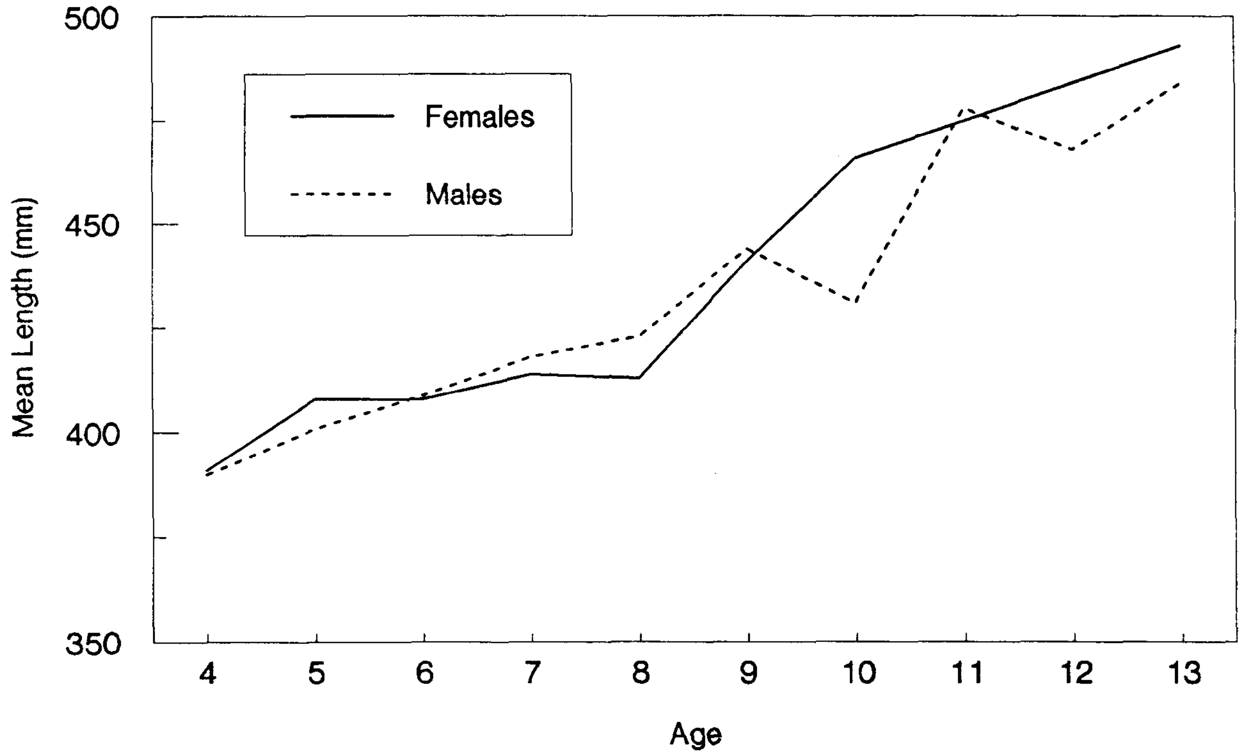

Figure 7. Mean length-at-age of female and male humpback whitefish of the Chatanika River in 1989.

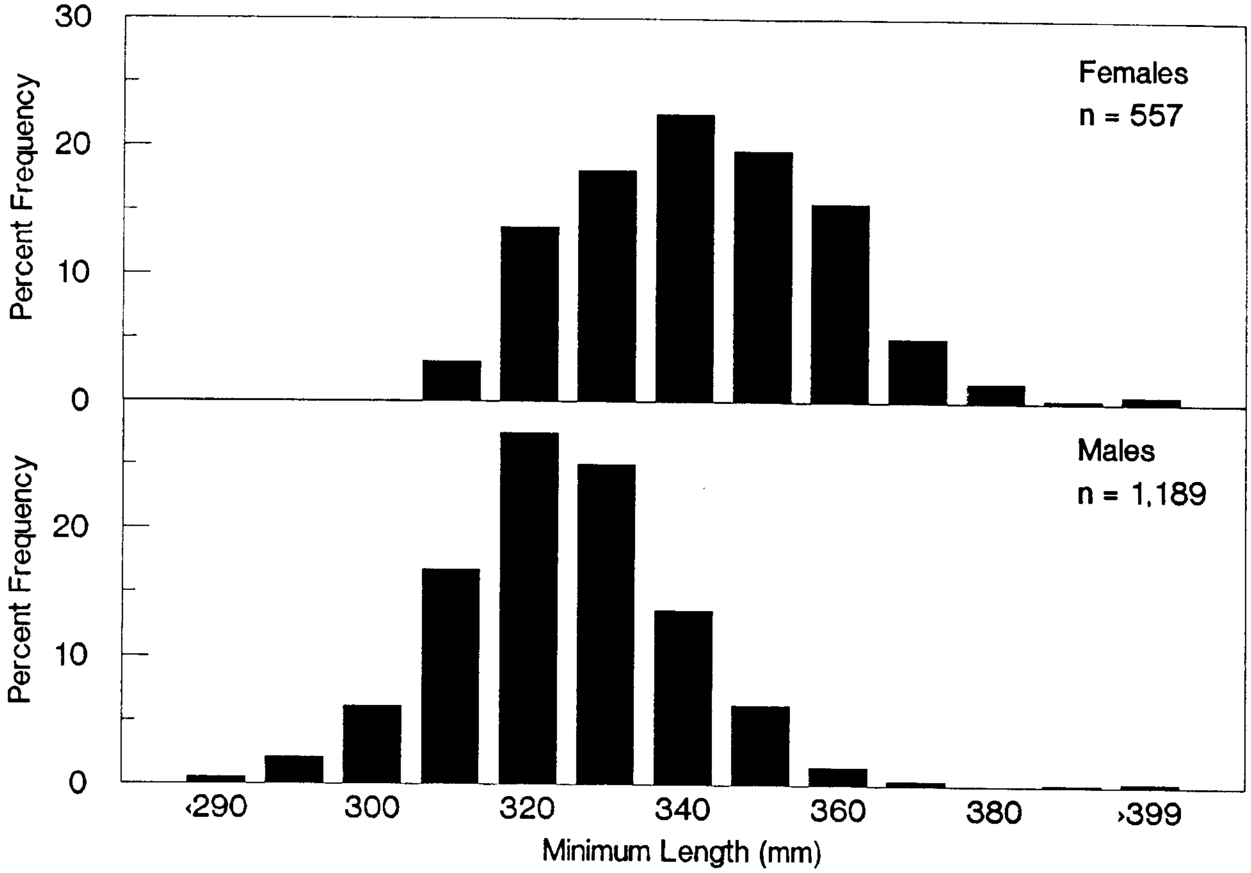

Figure 8. Length compositions of female and male least cisco from the Chatanika River in 1989.

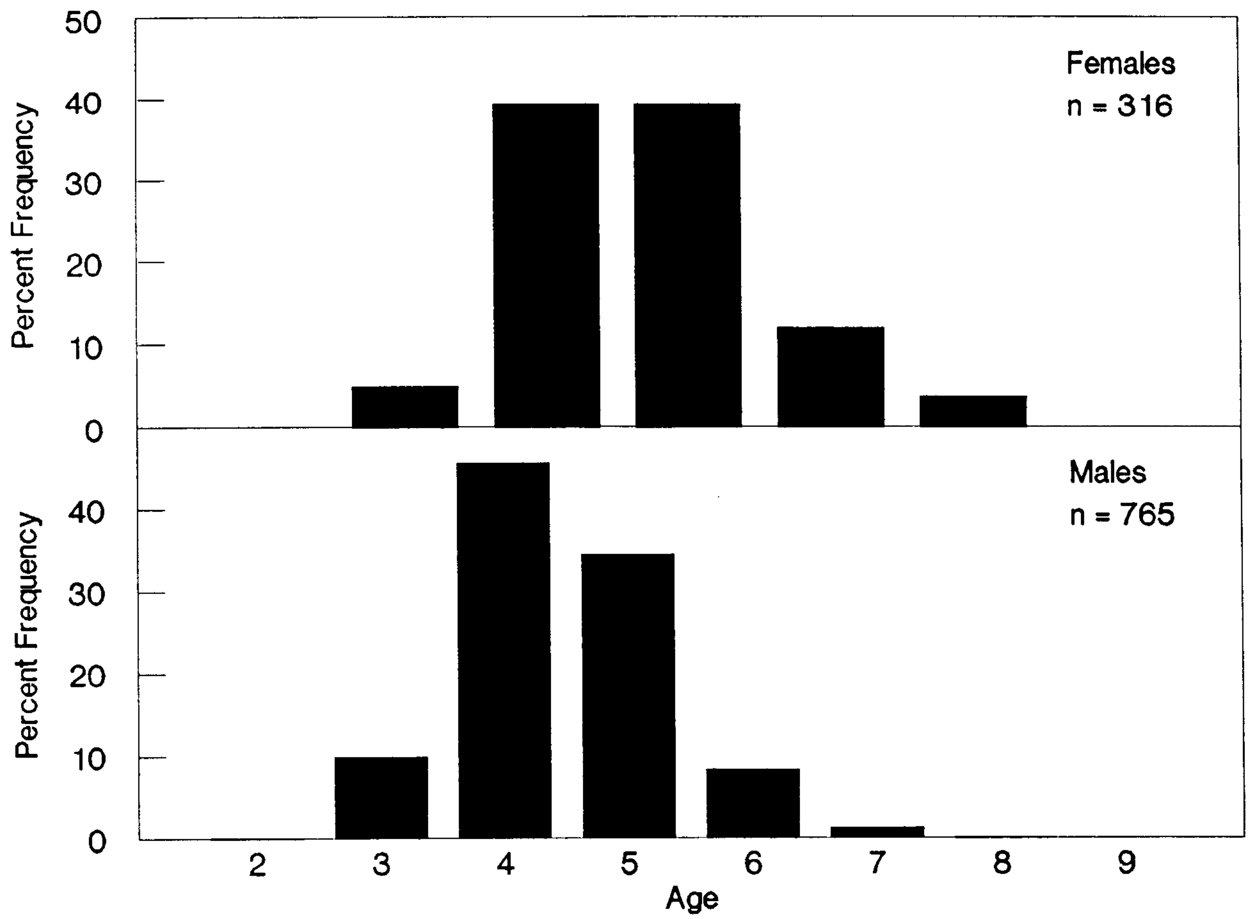

Figure 9. Age compositions of female and male least cisco from the Chatanika River in 1989.

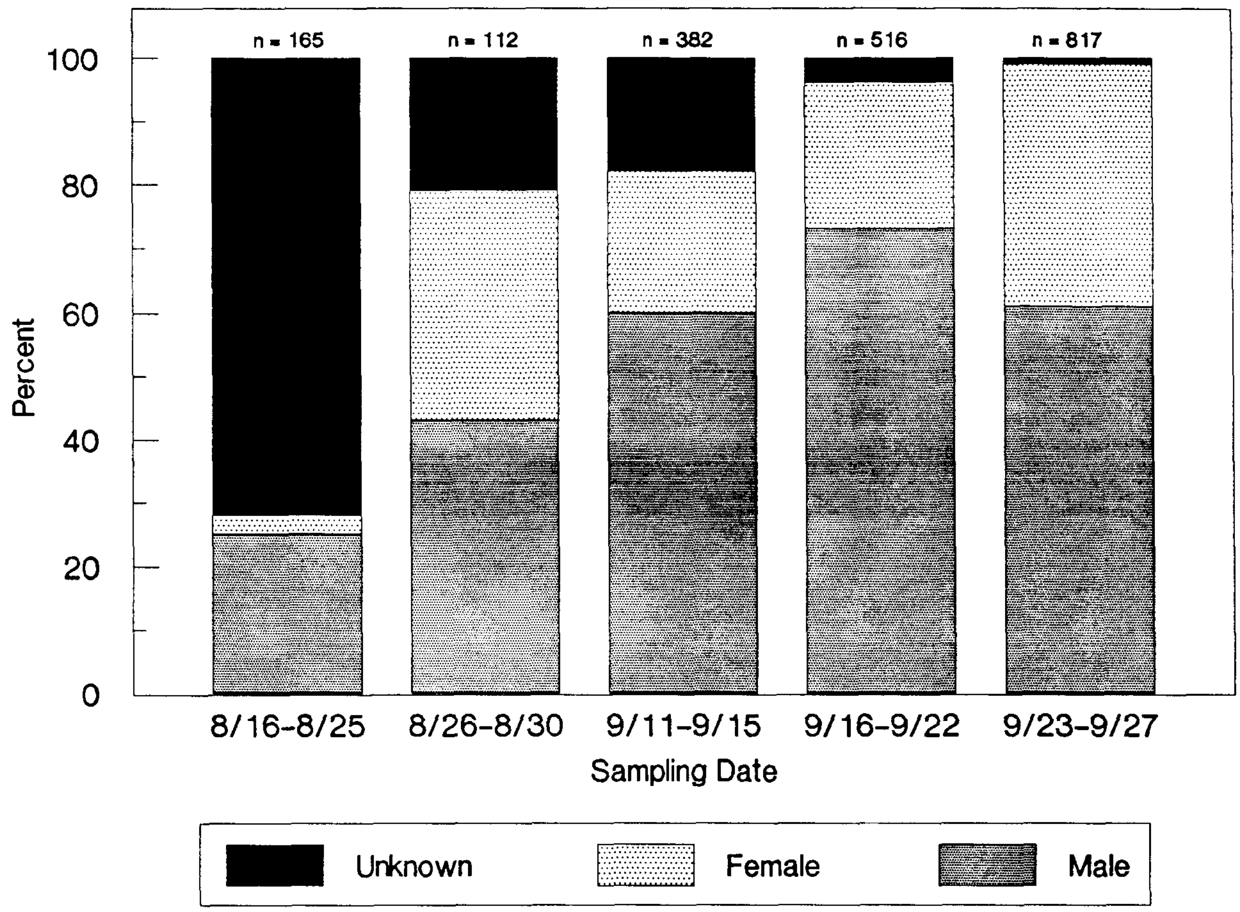

Figure 10. Sex composition of the least cisco population of the Chatanika River during five weeks in 1989.

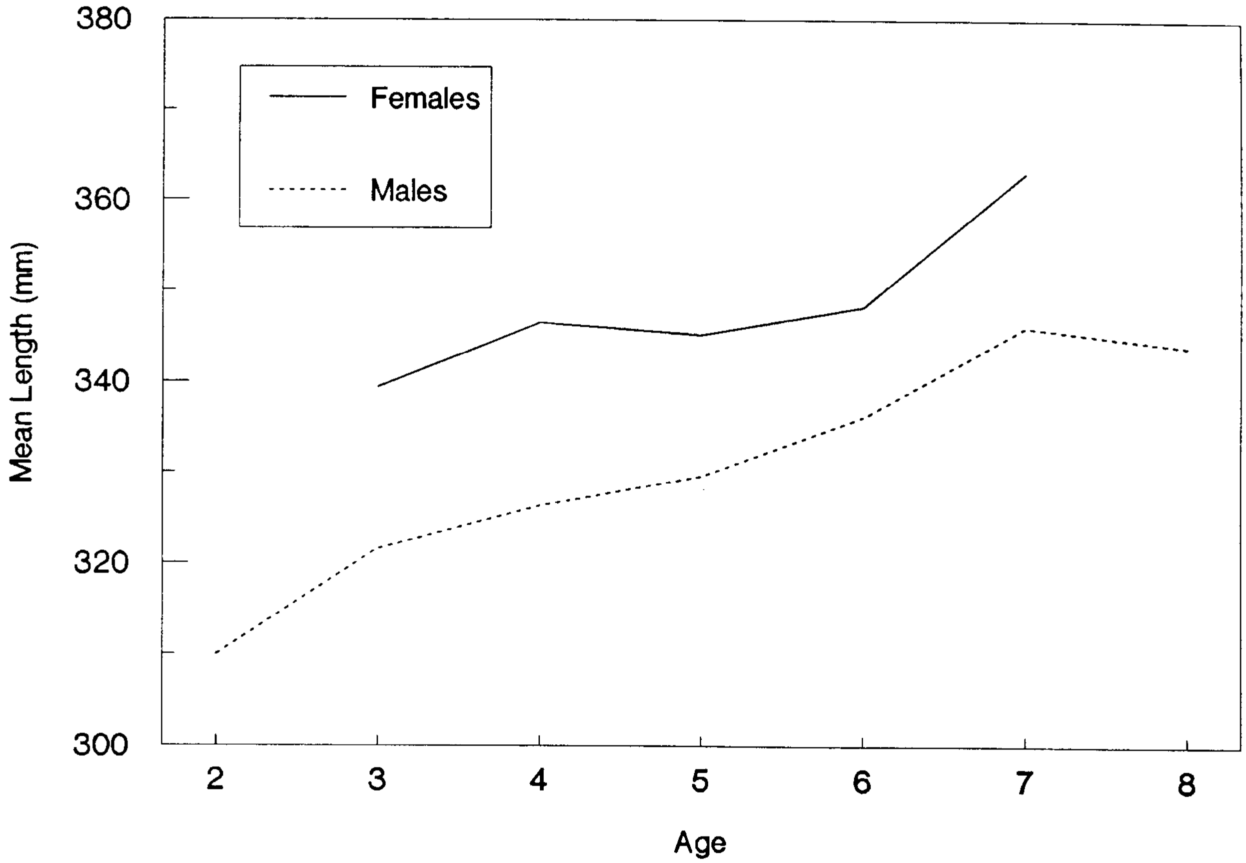

Figure 11. Mean length-at-age of female and male least cisco of the Chatanika River in 1989.

Table 3. Mean length by age and proportion of ages of least cisco of the Chatanika River in 1989.

Age	Mean Length	SE	n	Proportion of Population	SE
Sexes Combined					
2	310	--	1	0.01	<0.01
3	325	2	95	0.07	0.01
4	331	1	543	0.43	0.01
5	335	1	478	0.38	0.01
6	340	2	125	0.10	0.01
7	353	4	26	0.02	<0.01
8	344	--	1	0.01	<0.01
All Ages[a]	334	<1	1,269[b]		
Females					
2	--	--	0	--	--
3	339	3	16	0.05	0.02
4	347	1	125	0.40	0.08
5	345	2	125	0.40	0.08
6	348	3	38	0.12	0.03
7	363	5	12	0.04	0.01
8	--	--	0	--	--
All Ages[a]	347	1	557		
Males					
2	310	--	1	<0.01	<0.01
3	322	2	76	0.10	0.01
4	326	1	349	0.46	0.03
5	330	1	264	0.35	0.03
6	336	2	64	0.08	0.01
7	346	7	10	0.01	0.01
8	344	--	1	<0.01	<0.01
All Ages[a]	328	<1	1,189		

[a] The "All Ages" category does not equal the sum of individual age categories because the "All Ages" category includes fish of unknown age.
[b] The total for the "Sexes Combined" category is greater than the sum of the female and male categories because the "Sexes Combined" category includes fish of unknown sex.

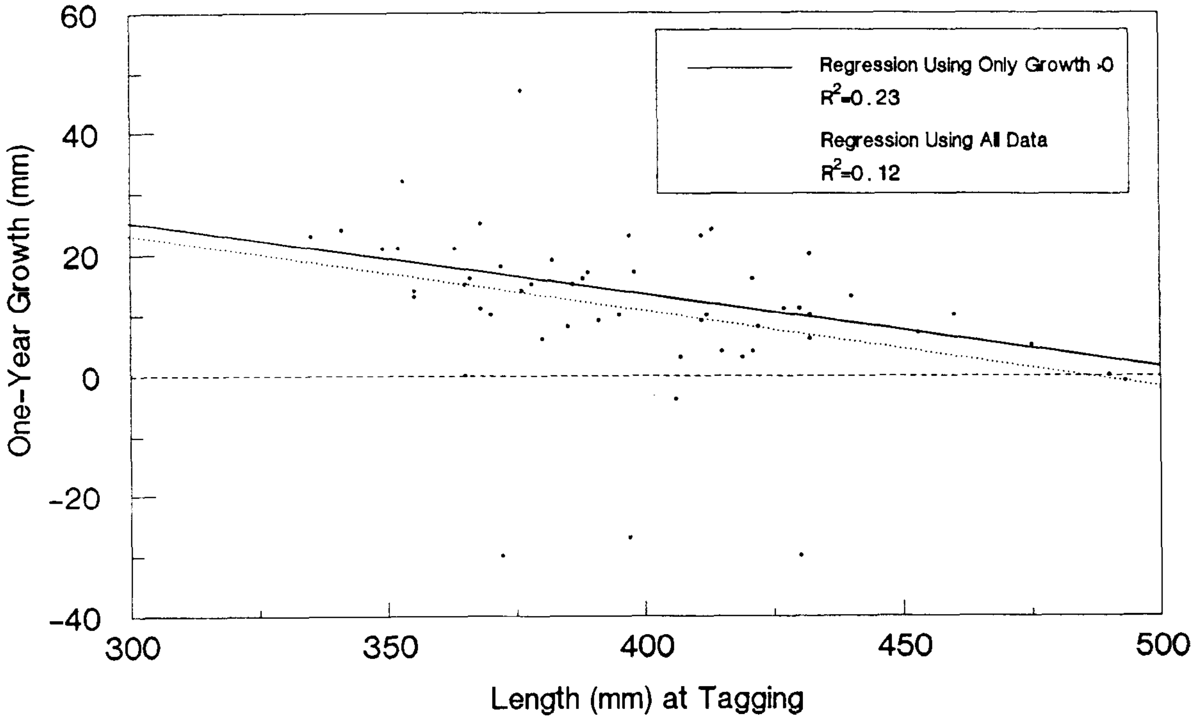

Figure 12. Regression of one-year growth against length-at-tagging of humpback whitefish tagged in 1986, 1987, or 1988 and recaptured one year later.

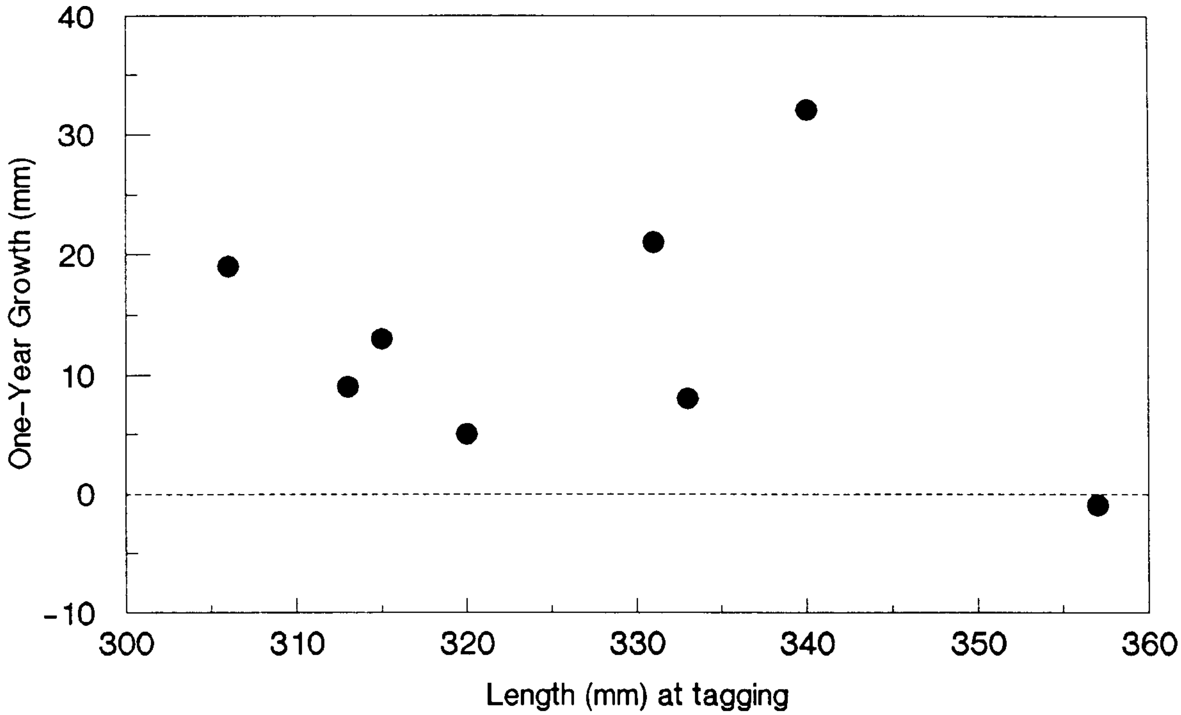

Figure 13. Plot of one-year growth against length-at-tagging of least cisco tagged in 1986, 1987, or 1988 and recaptured one year later.

Survival and Recruitment

Estimates of survival and recruitment were made using estimates of cohort abundance from 1986 through 1989 (Table 4). Average annual survival of humpback whitefish ranged from 0.37 between 1988 and 1989 to 0.49 between 1987 and 1988 (Table 5). Most cohorts were fully recruited by age 7. Total recruitment of humpback whitefish age 6 and younger was 20,485 for 1986 to 1987, 27,371 for 1987 to 1988, and 2,619 for 1988 to 1989 (Table 5).

Potential Productivity

Potential productivity of whitefish in the study area was estimated to be 206,284,488 eggs for humpback whitefish (SE = 3,614,375) and 856,209,364 eggs for least cisco (SE = 3,936,626).

DISCUSSION

All objectives were met for the 1989 study. Standard errors for the abundance estimates and composition estimates for both species were generally low. Composition estimates, which were divided by sex, had greater standard errors because sexed samples were difficult to obtain until late September and were therefore fewer.

A late fall in 1989 resulted in unique circumstances for the sampling of whitefish on the Chatanika River. The very low water levels and warm water temperatures of the river, which persisted to 13 September 1989, may have resulted in a late run of humpback whitefish. Humpback whitefish were not captured in large numbers until mid-September, in contrast to prior years when tagging of humpback whitefish was nearly completed by 1 September. In addition, only two humpback whitefish were captured above the bridge, in contrast to previous years when humpback whitefish were found in abundance for several kilometers above the bridge. The least cisco run was similar to other years, and appeared to be unaffected by the unusual river conditions, probably because least cisco do not normally arrive in the Chatanika River until late September, when the 1989 water temperature had dropped and the river level had risen. Data are not available at this time to predict the possible effects the 1989 river conditions may have on recruitment in coming years.

In 1988, non-mixing of least cisco tagged downstream of the fishery with those tagged in the fishery area precluded an abundance estimate. In an attempt to alleviate that problem, least cisco and humpback whitefish were tagged only between the Elliott Highway Bridge and the Olnes Pond Campground in 1989. Although this approach eliminated problems of mixing, resulting in successful tagging experiments, only abundance of least cisco between the Elliott Highway Bridge and the Olnes Pond Campground could be estimated; abundance of least cisco for the entire river could not be estimated with the 1989 method. Since estimates of abundance in the past encompassed the river as far down as the pipeline crossing, the 1989 abundance estimates for least cisco cannot be compared to past years.

Table 4. Abundance[a] and standard errors of humpback whitefish from the Chatanika River, 1986 through 1989.

	Abundance							
	1986[b]		1987[c]		1988[d]		1989	
Cohort	$\hat{N}$	SE	$\hat{N}$	SE	$\hat{N}$	SE	$\hat{N}$	SE
1975	129	93	0		0		35	25
1976	386	173	123	72	0		18	18
1977	1,221	369	411	137	0		141	49
1978	1,221	369	739	193	377	173	159	52
1979	2,120	562	2,217	395	1,057	307	406	83
1980	6,554	1,473	5,666	813	4,076	730	1,482	154
1981	3,213	789	10,059	1,329	11,699	1,663	3,493	221
1982	64	64	8,170	1,107	17,360	2,337	7,638	273
1983			780	199	6,416	1,023	3,722	226
1984					226	133	229	63
1985							0	
Total[e]	14,906	3,172	28,165	3,434	41,211	5,155	17,322	1,655

[a] Abundance = $\hat{N}$.
[b] From Hallberg and Holmes (1987).
[c] From Hallberg (1988).
[d] From Hallberg (1989).
[e] Sums of individual cohorts may not equal total abundance because of rounding to whole numbers.

Table 5. Survival[a], recruitment[b], and standard errors of humpback whitefish from the Chatanika River, 1986 through 1989.

	Survival						Recruitment					
	1986 - 1987		1987 - 1988		1988 - 1989		1986 - 1987		1987 - 1988		1988 - 1989	
Cohort	$\hat{S}$	SE	$\hat{S}$	SE	$\hat{S}$	SE	$\hat{A}$	SE	$\hat{A}$	SE	$\hat{A}$	SE
1977	0.34	0.15	---	---	---	---	---	---	---	---	---	---
1978	0.61	0.24	0.51	0.27	---	---						
1979	---	---	0.48	0.16	0.38	0.11	1,219	558	---	---	---	---
1980	---	---	---	---	0.36	0.08	2,580	1,404	1,279	1,078	---	---
1981	---	---	---	---	---	---	8,546	1,450	6,734	2,197	0	---
1982	---	---	---	---	---	---	8,140	1,107	13,327	2,609	1,150	1,468
1983	---	---	---	---	---	---	---	---	6,031	1,026	1,324	576
1984	---	---	---	---	---	---	---	---	---	---	145	51
Average	0.47	0.02	0.49	0.02	0.37	<0.01						
Total							20,485	2,369	27,371	3,721	2,619	1,886

[a] Survival = $\hat{S}$.

[b] Recruitment = $\hat{A}$.

Lake whitefish *Coregonus clupeaformis*, on which the vast majority of whitefish research has centered, spawn annually in southern areas of their range, but may spawn only every two to three years in more northern regions (Morrow 1980). Based on recaptures of tagged fish, some humpback whitefish of the Chatanika River spawn in successive years, but the data are still too scanty to estimate the percentage of the population that returns in any one year, and what portion of the population returns to spawn more than twice. Recaptures of tagged least cisco were too few to determine if least cisco generally spawn more than once.

The proportions of male and female whitefish remained relatively constant over the four years of the study, and in all years, males out-numbered females in the populations of both species (Table 6). The whitefish populations of the Chatanika River differ from studies of lake whitefish in this respect. For example, the sex ratio of lake whitefish from Saskatchewan was approximately 1:1 (Qadri 1968).

Although 1989 abundance estimates of least cisco in the Chatanika River cannot be compared with prior years, percent compositions for both whitefish species can be compared across years. The age compositions of humpback whitefish from 1986 through 1989 were significantly different (χ^2 = 542, df = 21, $P < 0.05$). From 1986 through 1988, age 5 fish made up about 40% of the humpback whitefish population, but the 1989 population was composed of only 21% age 5 fish. In 1986 and 1987, age 4 fish made up 22% and 29% of the spawning population, respectively, but that portion of the population fell to only 16% in 1988 and to just 1% in 1989 (Figure 14). Length compositions for the years 1986 through 1989, which were also significantly different (χ^2 = 634, df = 63, $P < 0.05$), did not show such a dramatic change, but a shift to greater lengths was evident (Figure 14). Mean length at age of young fish, as well as overall mean length, increased between 1986 and 1989 (Table 6; Figure 15).

Recruitment plunged to a low of only 2,619 humpback whitefish in 1989, compared to 20,485 in 1987 and 27,371 in 1988. In 1987 and 1988, the bulk of the recruitment was made up of age 4 and 5 fish. For example, in 1987, 8,140 age 4 fish (1982 cohort) recruited to the fishery, and in 1988, 6,031 age 4 fish (1983 cohort) recruited to the fishery; but in 1989, recruitment of age 4 fish (1984 cohort) was only 145 (Table 5).

Between 1986 and 1989, age compositions of least cisco, which were significantly different (χ^2 = 332, df = 18, $P < 0.05$), also shifted to older fish. The 1986 population was primarily composed of age 3 and 4 least cisco, whereas the 1988 population was made up of primarily age 4 and 5 fish. The percentage of age 3 fish dropped from about 30% in 1986 to about 10% in 1989 (Figure 16). Length frequencies, which were also significantly different (χ^2 = 1,679, df = 28, $P < 0.05$), shifted toward larger fish between 1986 and 1989 (Figure 16). Mean length at age, as well as overall mean length, also increased from 1986 to 1989 (Figure 15; Table 6).

Shifts in age and length compositions and recruitment could result from a number of causes. Differences in sampling methods could account for changes in age and length frequencies between years. Although fish sampled for length and age data were collected with electrofishing gear in all four years, the

Table 6. Sex ratios and mean length of humpback whitefish and least cisco of the Chatanika River from 1986 through 1989.

Year	Percent of Population		Mean Length (mm)	SE
	Males	Females		
Humpback Whitefish				
1986	63	37	395	Not Available
1987	62	38	392	0.70
1988	Not Available		396	0.60
1989[a]	53	45	410	0.70
Least Cisco				
1986	60	40	313	Not Available
1987	66	34	319	0.40
1988	Not Available		319	0.40
1989[a]	65	32	334	0.40

[a] Percentages do not equal 100 because total included fish of undetermined sex.

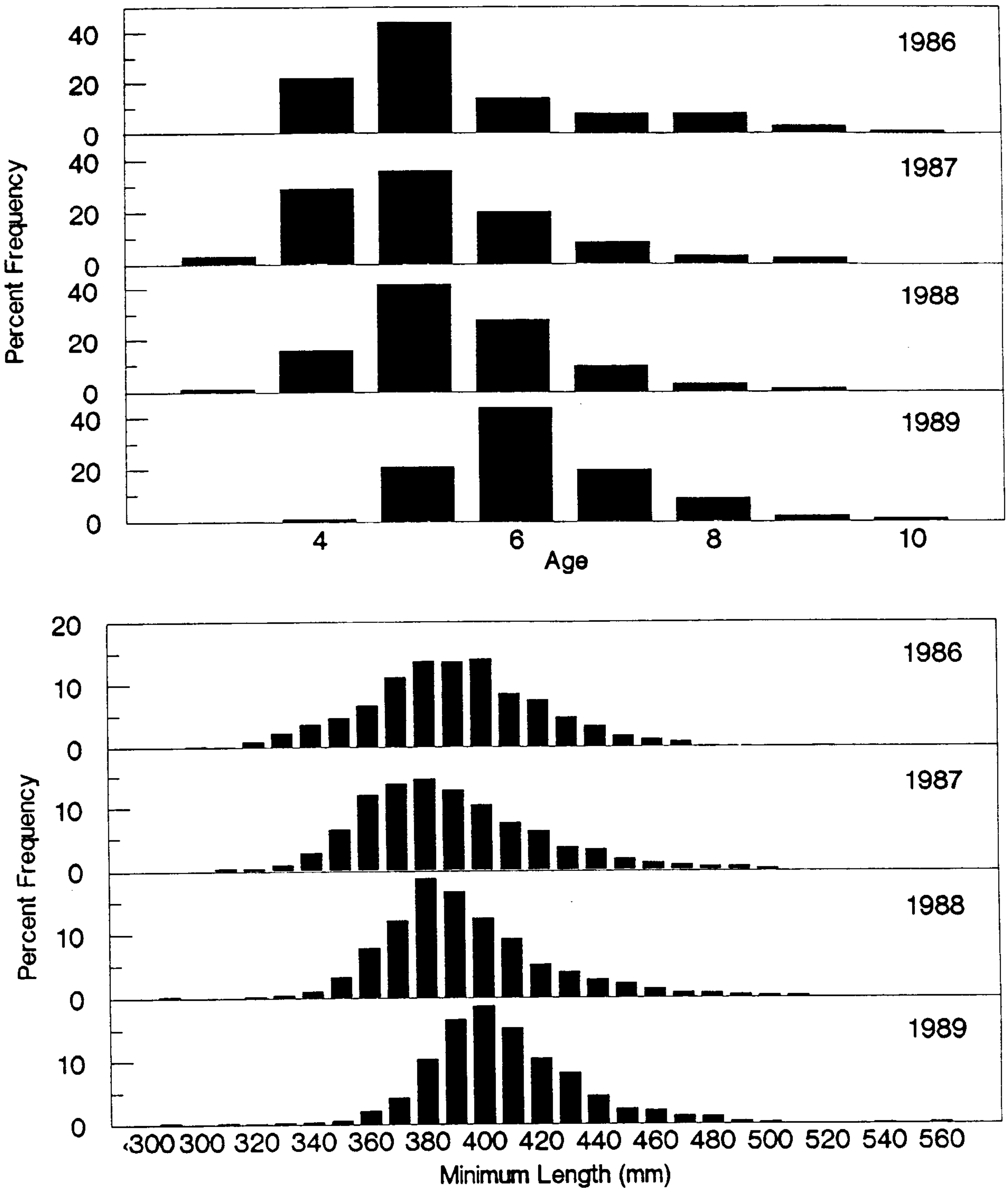

Figure 14. Length and age compositions of humpback whitefish from the Chatanika River from 1986 through 1989.

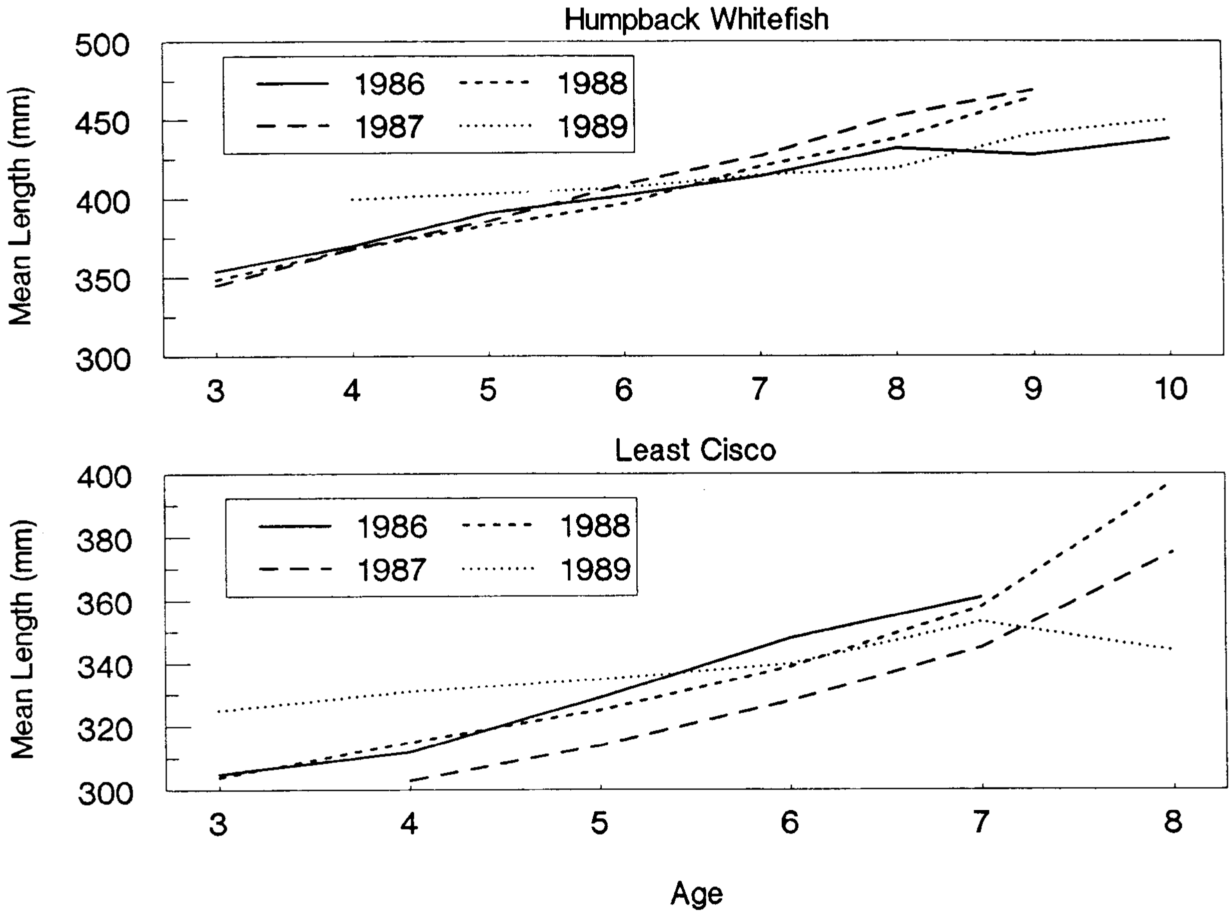

Figure 15. Mean length-at-age of humpback whitefish and least cisco of the Chatanika River from 1986 through 1989.

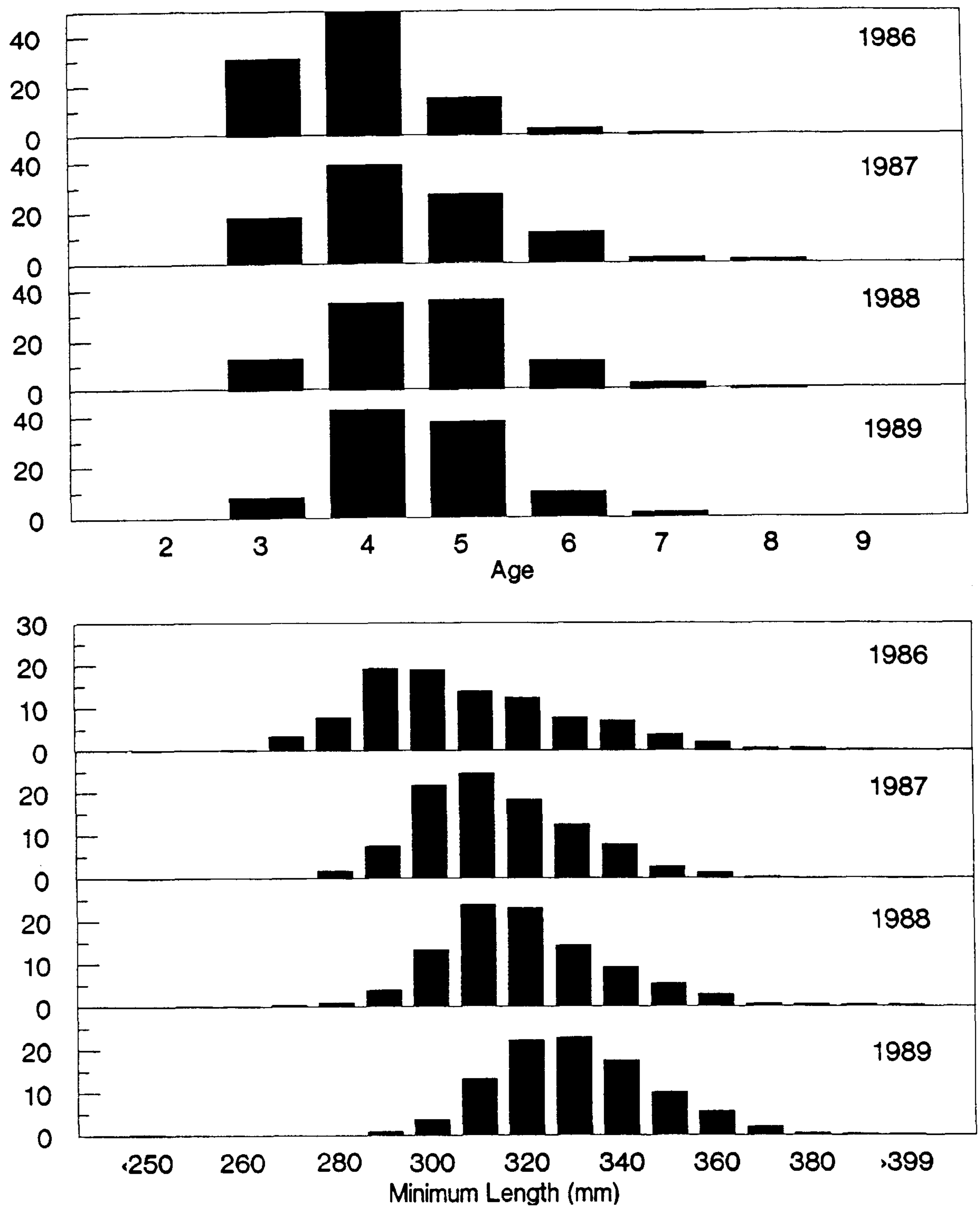

Figure 16. Length and age compositions of least cisco from the Chatanika River from 1986 through 1989.

area sampled was much smaller in 1989 than in the other years. If whitefish are distributed in the Chatanika River according to length or age factors, sampling a smaller or different area could affect both the age and length frequencies. That explanation seems unlikely since, rather than being an anomaly, the 1989 data continue a trend seen in the other three years.

Since an age validation study for whitefish of the Chatanika River has not been completed, the low occurrence of age 4 and 5 humpback whitefish, and age 3 least cisco, may be due to errors in estimating age. A change in personnel responsible for reading scales occurred between 1988 and 1989, and differences in criteria for estimating whitefish ages from scales could be reflected in the age frequencies. However, a study of precision of several methods for determining ages of whitefish revealed only small differences in ages determined from scales by the two readers (L. S. Timmons 1989[1]). Moreover, if errors in age estimation did produce the changes in age composition across years, the 1989 reader would have overestimated age, or the 1986 - 1988 reader would have underestimated age. In either case, age 5 fish in 1989, for example, would be expected to be smaller than age 5 fish in other years. But the opposite was true: length at most ages was greater in 1989 than in the other years. Finally, the 1989 age composition continues an existing trend, and is supported by the changes in the length frequencies and increasing overall mean length by year, which would not be affected by errors in age estimation.

Assuming that the 1989 data is truly representative of the population, increasing harvest in the early 1980's may have had some effect on recruitment three, four, and five years later. According to Healy (1975, 1980), increased exploitation of lake whitefish results in increased growth rate, shifts of the age structure to younger ages, and maturation at earlier ages. The growth rate of Chatanika River whitefish does appear to be increasing, which might be indicative of the increased fishing pressure in the early 1980's, but the shift to older fish is opposite of Healy's prediction. Only spawning whitefish were sampled in this study, but if we assume that the fish in the Chatanika River are representative of the entire population, it would appear that age at maturation is increasing, rather than decreasing as Healy's study indicated it would.

The paucity of age 4 and 5 humpback whitefish, and age 3 least cisco, in the 1989 population may be due to environmental factors, rather than fishing pressure. Age 4 and 5 Arctic grayling *Thymallus arcticus*, which usually make up a large portion of the Arctic grayling population of the Chatanika River, were also found in very low numbers in 1989 (Clark 1990). Discharge data for the Chatanika River are unavailable, but data from the nearby Chena River may be indicative of discharge of the Chatanika River. Also necessary for an evaluation of the effects of environment on whitefish abundance, but missing for least cisco, are total numbers of whitefish in age categories for 1989. An inverse correlation does appear between mean discharge of the Chena River in May and recruitment of age 4 humpback whitefish (Figure 17). Young whitefish are thought to hatch in early spring (Morrow 1980) and would

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[1] L. S. Timmons. 1989. Unpublished Data. ADFG, 1300 College Rd., Fairbanks, AK 99701.

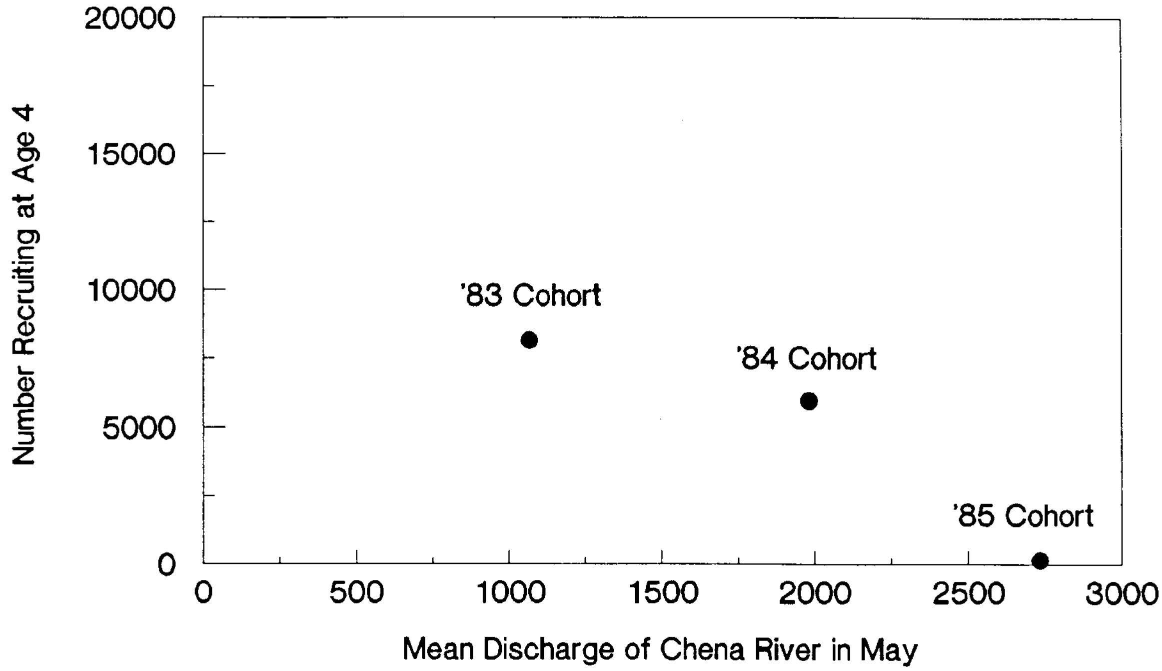

Figure 17. Number of humpback whitefish recruiting at age 4 plotted against mean discharge of the Chena River in the May following their natal year.

probably be very vulnerable to large fluctuations in discharge. It is interesting to note that the low recruitment of the 1985 cohort corresponds to a very high discharge the spring those fish were emerging as young of the year. Perhaps with discharge data from the Chatanika River itself, an accurate relationship between discharge and recruitment could be elucidated.

Reckahn (1986) found that growth of lake whitefish followed long-term cyclical trends that were related to air temperature, and water temperature and level, and recruitment has been correlated with air temperatures at the times of spawning and hatching (Christie 1963). Those studies were based on long-term data bases of 39 and 85 years, respectively, whereas the Chatanika River study spans only four years. A longer series of age and length composition data, total numbers of least cisco in the age and length categories, discharge, and temperature of the river in the fall and spring, are needed before the relationships between stock and recruitment, and between environment and recruitment, can be established.

Studies of whitefish have focused almost exclusively on lake-dwelling lake whitefish in the Great Lakes region and in some northern areas of Canada. In many of those lakes, particularly the Great Lakes where they were one of the most important commercial species, whitefish have been exploited so heavily that many species have all but disappeared. The Chatanika River provides an excellent chance to study several species of whitefish about which little is known. The river is readily accessible, and whitefish are relatively easy to capture and are found in great abundance. At this point, knowledge of the Chatanika River whitefish is limited to some basic information on abundance, age, growth, and fecundity of humpback whitefish and least cisco only. Humpback whitefish and least cisco are found in the Chatanika River primarily August through October, but little is known about where they spend the other nine months of the year, their migratory habits, or the impact of fisheries in other areas, such as Minto Flats, on Chatanika River stocks. Whether the whitefish population is made up of one or many stocks is also unanswered, and with only four years of data, the relationship between recruitment and environmental factors or fishing pressure is also unknown. Knowledge of the early life history of Chatanika River humpback whitefish and least cisco, such as movement and habitat use, is limited to a few qualitative studies in the 1970's. Almost nothing is known about the sheefish *Stenodus leucichthys* and round whitefish *Prosopium cylindraceum* that also inhabit the river.

Reckahn (1986) strongly recommended the continued collection of base-line data for long-term studies of cyclic trends of whitefish and other species, and emphasized the need for strict adherence to comparable sampling methods from year to year to insure the validity of across-year comparisons. The 15-fish bag limit, which was implemented in 1988, appears to be controlling the harvest of whitefish to about 10,000 fish per year, but the changes in age and length compositions and recruitment over just four years indicate that the Chatanika River whitefish are not in a static state. Data are insufficient at this time to understand the population dynamics of the Chatanika River whitefish and the effects of exploitation and environment on recruitment. Continued study of the biology, movements, and population dynamics of Chatanika River whitefish will produce significant contributions to general whitefish knowledge, and will provide the necessary information to manage the whitefish fishery of the Chatanika River.

ACKNOWLEDGEMENTS

Thanks to Tom Kerns, Erik Adey, Pat Houghton, Tim Viavant, and Tim McKinley who assisted with the tagging, creel census, and laboratory work. Dave Bernard and Jerry Hallberg provided statistical and technical assistance, and Peggy Merritt reviewed the manuscript.

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