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ABUNDANCE AND SIZE COMPOSITION OF CHATANIKA RIVER LEAST CISCO AND HUMPBACK WHITEFISH WITH ESTIMATES OF EXPLOITATION BY RECREATIONAL FISHERMEN[1]

By

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ABSTRACT

Mark-recapture experiments and visual counts of passing fish were conducted to estimate abundance of least cisco *Coregonus sardinella* and humpback whitefish *Coregonus pidschian* during the fall 1987 spawning migration in the Chatanika River. Total estimated run strength was 83,785 and 90,165 whitefish from the mark-recapture experiments and from expansions of tower counts, respectively. Approximately two-thirds of the run was composed of least cisco with the other one-third being humpback whitefish. The estimated rate of exploitation of least cisco by the recreational spear fishery in 1987 was 0.427 using mark-recapture abundance estimates and 0.376 using expanded tower count estimates of abundance. In 1986, least cisco exploitation was estimated at 0.227. The estimated rate of exploitation of humpback whitefish by the sport fishery in 1987 was 0.163 using mark-recapture abundance estimates and 0.170 using expanded tower count estimates of abundance. Exploitation estimates for humpback whitefish in 1986 were similar to those estimated in 1987. Dominant age classes (age 4 for least cisco and age 5 for humpback whitefish) remained the same in both 1986 and 1987. For both species, males were more common than females in both years.

KEY WORDS: humpback whitefish, *Coregonus pidschian*, least cisco, *Coregonus sardinella*, Chatanika River, mark-recapture experiment, counting tower, harvest, exploitation.

INTRODUCTION

The Chatanika River originates in the foothills of the White Mountains near the confluences of McManus, Faith, and Smith Creeks, approximately 80 km northeast of Fairbanks. From this point, the river flows southwesterly for 210 km before emptying into the Tolovana River.

The Chatanika River is home to a large spawning population of humpback whitefish *Coregonus pidschian* and least cisco *Coregonus sardinella*. During late summer and fall, these fish migrate upstream to the spawning grounds located in the upper reaches of the Chatanika River. Because of the proximity to Fairbanks and the large size of these spawning runs, the Chatanika River fishery accounts for more than 75% of the total harvest of all whitefish species in the Tanana River drainage (Mills 1986). Most of this harvest occurs during the popular fall spear fishery on spawning whitefish around the Elliott Highway Bridge and along the Steese Highway (Figure 1).

In recent years, human population growth and increasing angler awareness of the unique spear fishery have led to increases in fishing effort and whitefish harvest. Since 1977, harvest of whitefish from the Chatanika River has increased at an average annual rate of 34% (Table 1), making it the fastest growing fishery in the Tanana River drainage.

Concern about possible overharvest in this rapidly expanding fishery prompted the initiation of this study; the goal being to estimate sustainable yields for the humpback whitefish and least cisco stocks of the Chatanika River. To estimate sustainable yields for these whitefish species, accurate and timely estimates of population abundance, age composition, growth rates, harvest, exploitation rates, mortality rates, and recruitment rates are needed.

A creel census of the spear fishery began in 1984. Stock assessment of the Chatanika River whitefish began in 1986. Side-scan SONAR, counting towers, and mark-recapture experiments were evaluated as estimators of population abundance. Mark-recapture experiments and the tower counts produced abundance estimates that were within 5% of each other. Total estimated run strength in 1986 was 87,912 and 92,038 whitefish from the mark-recapture experiments and from expansions of the tower counts, respectively. No abundance estimate was obtained using SONAR because of difficulties distinguishing upstream versus downstream targets of migrating whitefish. The combined harvest of humpback whitefish and least cisco in the recreational spear fishery in 1986 was an estimated 19,105 fish (Clark and Ridder 1987). Using estimates from the mark-recapture experiment and from the creel census, exploitation rates for least cisco and humpback whitefish were 0.227 and 0.170, respectively. Exploitation rates estimated from tower counts and creel census were 0.218 and 0.159 for least cisco and humpback whitefish, respectively.

In 1987, the counting tower and the mark-recapture experiment were once again used to estimate population abundance. While both methods were suitable for estimating whitefish abundance in the Chatanika River in 1986, both methods presented some problems that required further research. Results of the mark-recapture experiment were suspect because few humpback whitefish were sampled in the fishery. A flood in the late fall coupled with a tardy start-up date

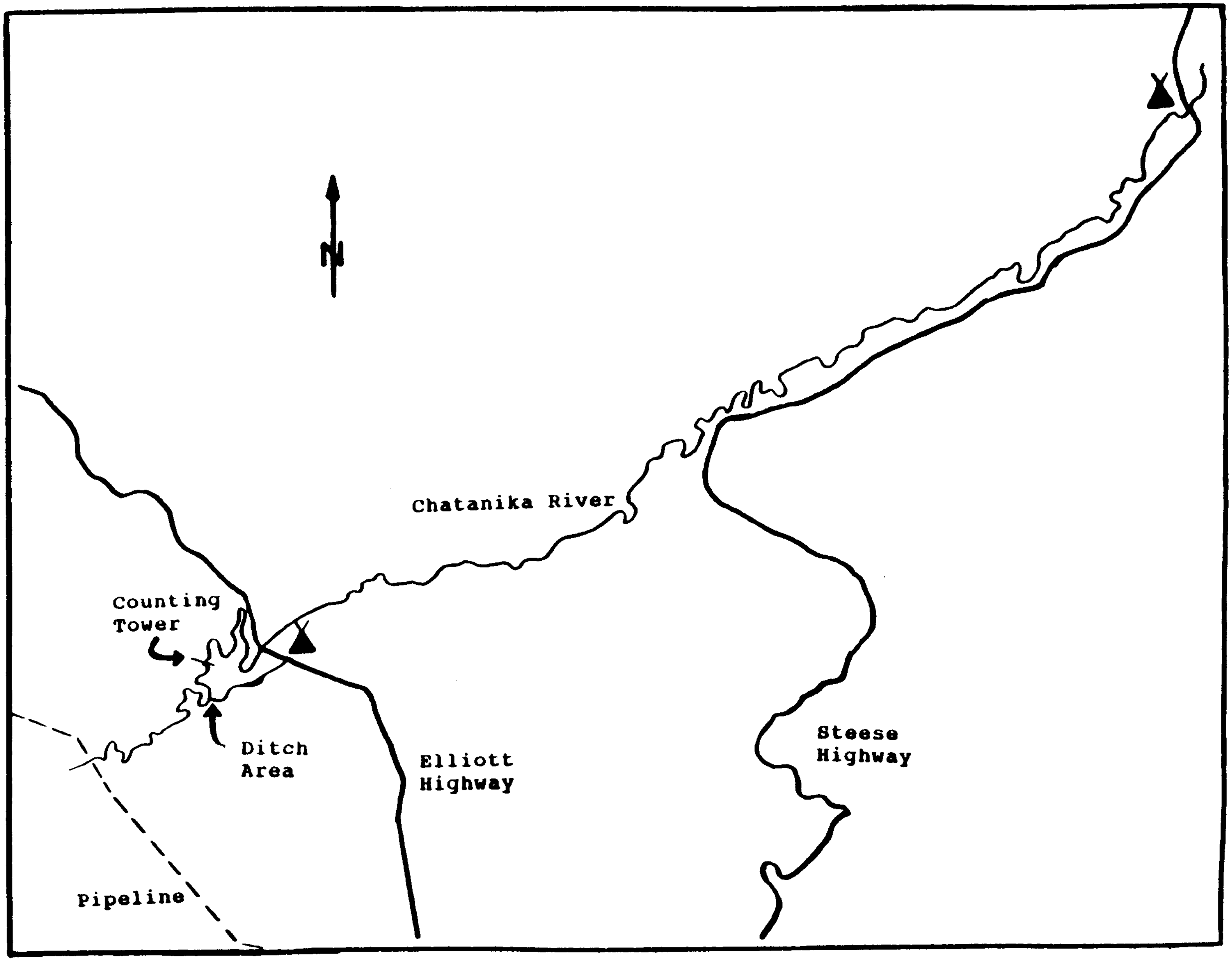

Figure 1. The Chatanika River showing its proximity to the Steese and Elliott Highways.

Table 1. Estimated annual harvest of whitefish from the Chatanika River, Tanana River Drainage, and all of Alaska obtained from the statewide harvest Postal surveys, and estimated whitefish harvest obtained from the Chatanika River on-site creel census, 1977-1987.

	Whitefish Harvest			
	Chatanika River			
Year	Postal Survey[1]	On-Site Creel Census	Tanana R. Drainage[1]	Statewide[1]
1977	1,635	986[2]	3,378	6,748
1978	6,013	5,517[2]	6,573	11,731
1979	3,021	2,183[2]	5,159	9,666
1980	3,340	1,587[2]	5,958	11,464
1981	3,185	No CC	4,873	9,251
1982	6,640	No CC	8,643	15,433
1983	5,895	No CC	8,311	16,872
1984	9,268	5,758[2]	11,658	16,719
1985	14,350	4,561[2]	20,230	30,337
1986	22,038	19,105[2]	26,810	39,718
1987		28,312[3]		

[1] From Mills (1979-1987).
[2] Harvest estimate is for the Elliott Highway area only.
[3] Harvest estimate includes the Elliott High area (19,003 fish) as well as the "ditch area" (9,309 fish).

made evaluation of the tower counts inconclusive. These shortcomings were addressed by changes reflected in the 1987 operational plan.

In 1987, the specific objectives of this project were:

1. to estimate, using a mark-recapture experiment, humpback whitefish and least cisco population abundance prior to the start of the spear fishery in 1987;

2. to estimate, using a counting tower, the abundance of whitefish entering and leaving the spawning grounds in 1987;

3. to estimate the age composition of humpback whitefish and least cisco;

4. to estimate the mean length of humpback whitefish and least cisco; and,

5. to estimate the exploitation rate of humpback whitefish and least cisco in the Chatanika River spear fishery during fall, 1987.

METHODS

Tower Counts

Counts of migrating whitefish were made on the Chatanika River approximately 4 km downstream from the Elliott Highway Bridge (Figure 1). A section of standard construction scaffolding (2 m high) was erected on the south bank of the river to serve as a counting platform. A 25-meter long light string with flood lamps located at 3 m intervals was suspended across the river approximately 5 m above the water surface to provide illumination for counts conducted during the night. The light string was powered by a portable gasoline generator. A flash panel (approximately 1.3 m wide; made of aluminum roofing material) was anchored to the river bottom beneath the light string. This substrate served as a bright area to improve visibility of migrating whitefish.

Counting of upstream and downstream migrating whitefish commenced on 19 September and continued through 17 October, a total of 29 days. Each 24 hour day was divided into two 12-hour strata: night (1801-0600) and day (0601-1800). Each "night" counting event began at 1800 or 1815 (chosen at random). Whitefish were counted for a 15 minute period and for every other 1/4 hour thereafter, for the duration of the 12 hour period. A similar counting schedule was developed for the "day" stratum, with counts starting at 0600 or 0615 and continuing at 15 minute intervals for the following 12 hours. Counts were conducted every other day during the night stratum and every fourth day during the day stratum. Tower personnel used two tally whackers to enumerate upstream and downstream fish passage. Whitefish species could not be determined (Hallberg and Holmes 1987), so counts reflected total numbers of migrating fish.

The equations to expand the 1/4-hour counts of both upstream and downstream migrating fish to estimate total movement within a stratum were:

$$(1)\quad \hat{A} = 48\, N\, \bar{\bar{x}} \qquad \text{and} \qquad (2)\quad \bar{\bar{x}} = \frac{\sum_{i=1}^{n} \sum_{j=2}^{m} x_{ij}}{n\, m}$$

where:

$\bar{\bar{x}}$ = mean count per 15 minute time period per stratum;

x_{ij} = whitefish counted during the i^{th} period of day j;

$\hat{A}$ = stratum abundance;

48 = number of quarter hours in a 12-hour stratum;

N = the number of days within a stratum;

n = the number of days sampled within a stratum; and,

m = the number of quarter hours sampled within a stratum.

The variance for the estimated migration within each stratum was taken from Cochran (1977) and Wolter (1984):

$$(3)\quad V[\hat{A}] = (48\, N)^2\, V[\bar{\bar{x}}]$$

where:

$$(4)\quad V[\bar{\bar{x}}] = (1 - n/N) \sum_{i=1}^{n} \frac{(\bar{x}i - \bar{\bar{x}})^2}{n\,(n - 1)} + \frac{(1 - m/48)}{m\, N} \sum_{i=1}^{n} \sum_{j=2}^{m} \frac{(x_{ij} - x_{i,j-1})^2}{2\, n\, m\, (m - 1)} \quad ; \text{and,}$$

$$(5)\quad \bar{x}_i = \frac{\sum_{j=1}^{m} x_{ij}}{m} \quad .$$

Total upstream and downstream movement and their associated variances were the sum of the estimates from all strata.

Mark-Recapture Experiment

Humpback whitefish and least cisco were captured within 15 km of the Elliott Highway Bridge using a pulsed-DC electrofishing boat from 10 August to 23 September. Since marking took place before the majority of the fishery occurred, the abundance estimates are germane to the time prior to the fishery. Captured fish were held in a live box with circulating water. All humpback whitefish and least cisco captured were measured to the nearest millimeter of fork length (FL), tagged with an individually numbered Floy anchor tag, and the adipose fin was clipped prior to release.

Creel census catch sampling of the spear fishery served as the recapture event to provide marked and unmarked ratios. This second sampling event occurred near the Elliott Highway Bridge and near the Steese Highway from mid-September to mid-October. All fish sampled from the creel were measured (FL) and examined for tags and fins clips. The creel census sampling design and methodology is described by Baker (1988).

Potential bias in the abundance estimator due to length selectivity of capture gear used in the first event was tested using the Kolomogorov-Smirnov two-sample test. Potential sampling bias related to run timing was evaluated using chi-square contingency table analysis. The appropriate abundance estimator (Chapman's modification of the Petersen estimator) was chosen based on the result of these tests.

Species, Length, Age, and Sex Composition

Species composition of the run was estimated by two methods. First, the mark-recapture experiment provided an estimate of abundance for each species. Second, the numbers of fish tagged and the numbers of fish recaptured in the creel census were used to apportion the tower estimates of downstream migration by species with the following formulas:

(6) $\hat{A}_2 = \dfrac{\hat{A}}{1 + B}$ (7) $\hat{A}_1 = \dfrac{\hat{A}\hat{B}}{B + 1}$ and, (8) $B = \dfrac{n_1 r_2 m_1}{n_2 r_1 m_2}$

where:

$\hat{A}$ = the total estimated downstream count;

$\hat{A}_i$ = the estimated abundance of species i;

n_i = the number of species i in the creel samples;

r_i = the number of tagged fish of species i in the creel samples; and,

m_i = the number of species i that were tagged.

Since the tower was located downstream from the area of most recreational fishing effort, the estimated harvest of each species that occurred upstream of the counting tower was added to the estimated downstream migration for each species to obtain a total run estimate.

The variance of each tower count apportionment was estimated by bootstrapping the creel census catch sample 500 times (Efron 1982). The sum of this variance (for each species) and the associated harvest variance estimate provided an estimate of total run variance.

During creel census activities (see Baker 1988), all fish of each species were measured to the nearest millimeter (FL) and examined for tags. The first 600 fish of each species were sampled for scales.

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

(9)
$$\hat{p}_i = \frac{y_i}{n}$$

where:

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

n = the number in the sample.

The unbiased variance for each proportion is:

(10)
$$V[\hat{p}_i] = \frac{\hat{p}_i(1 - \hat{p}_i)}{n - 1} .$$

Because all means are distributed normally (according to the Central Limit Theorem), simple averages and squared deviations from the mean were used to calculate mean length for each age class and its variance.

Abundance of whitefish by age class was estimated by multiplying the estimated proportion within each age class by the total abundance estimate. The variance of this product was estimated as suggested by Goodman (1960).

Sex of harvested fish (determined by presence of sex products) was noted by creel clerks whenever possible. Estimated proportions of males and females and associated standard errors were calculated using the binomial distribution. Again, abundance by sex for each species was estimated as the product of the estimated abundance of that species and the estimated proportion of each sex. The variance of this product was estimated as outlined by Goodman (1960).

Exploitation Rate Estimates

Exploitation rates by species were estimated by dividing harvest (obtained from the creel census study; Baker 1988) by abundance estimates from the mark-recapture experiment. The approximate variance of the exploitation rate was calculated according to the Delta method (Seber 1973):

$$(11) \qquad V[\hat{E}] = \frac{\hat{H}2}{\hat{A}^2} \left(\frac{V[\hat{H}]}{\hat{H}^2} + \frac{V[\hat{A}]}{\hat{A}^2} \right)$$

where:

H = the estimated harvest, and

A = the estimated abundance.

To estimate the exploitation rate by species using data from the counting tower, the estimated harvest was added to the estimated number of whitefish moving downstream. This was necessary because the harvest takes place before the downstream migration occurs. The formula for estimating the exploitation rate using tower counts was as follows:

$$(12) \qquad \hat{E} = \hat{H} / \hat{N}$$

where:

H = estimated harvest by species;

D = estimated downstream migrating whitefish by species (using equations 6, 7, and 8); and,

$\hat{N} = \hat{D} + \hat{H}$.

The approximate variance of this estimate is:

$$(13) \qquad V[\hat{E}] = \hat{E}^2 \left\{ \frac{V[\hat{H}]}{\hat{H}^2} + \frac{V[\hat{N}]}{\hat{N}^2} - \frac{2V[\hat{H}]}{V[\hat{N}]} \right\}$$

where:

$V[\hat{N}] = V[\hat{D}] + V[\hat{H}]$.

RESULTS

Tower Counts

In 1987, the counting towers were placed into operation on 19 September, 7 days earlier than the 26 September 1986 start-up date. Counts of migrating whitefish during this 7-day period accounted for 20% of all the downstream migrants and 48% of the whitefish moving upstream past the tower (Figure 2).

Upstream counts were highest in late September and declined drastically around 1 October (Figure 2). The large number of fish moving upstream in late September corresponds to an apparent pulse of upstream migrating least cisco in route to spawning locations as evidenced by the large number of least cisco tagged in late September (Table 2). Downstream movements peaked on 25 September and 9 October. These two events were nearly the same in 1986, when peak downstream movements occurred on 28 September and 8 October (Hallberg and Holmes 1987).

Tower operation was continued until 17 October, when counts decreased to near zero and the river began to freeze. It is assumed that the decline in counts at the end of the season, coupled with a concurrent decline in the CPUE and harvest of whitefish from the fishery (Baker 1988), indicate that the majority of the downstream migration of both species had been counted.

Daily whitefish movements in 1987 were similar to those identified in 1986 (Hallberg and Holmes 1987) in that the majority of fish passed the counting tower during the night. Ninety-four percent of all downstream moving whitefish passed the counting towers during the night stratum, with peak movement occurring around 2200 hours. The upstream migration tended to be more dispersed (74% of all movement occurring at night) with peak counts occurring from 1800 to 2400 hours (Figure 3). A relatively constant, low rate of downstream movement occurred during the daylight hours. However, there was some increased upstream movement around 0800 hours over what can otherwise be described as a slow rate of upstream migration during this daylight period (Figure 3).

An estimated 65,688 upstream (SE = 28,416) and 71,162 (SE = 10,400) downstream migrating whitefish passed the counting tower from 19 September through 17 October (Table 2). Variability of the estimates was greatest for upstream daytime counts (CV = 95.5%) and lowest for downstream night counts (CV = 16.1%). Coefficient of variation was similar between upstream night and downstream day counts, 20.5% and 25.9%, respectively.

Baker (1988) estimated the combined harvest of least cisco and humpback whitefish in the recreational spear fishery on the Chatanika river between 11 September and 17 October at 28,312 fish (SE = 5,204). The estimated harvest occurring below the counting tower (at the "ditch area") was 9,309 fish (SE = 3,454). The estimated harvest occurring above the counting tower (near the Elliott Highway) was 19,003 whitefish (SE = 3,892). The harvest occurring above the counting tower, when added to the estimated number of fish moving downstream past the counting tower, put the pre-fishery abundance of whitefish at 90,165, SE = 11,104 (Table 3). The species apportionment of the

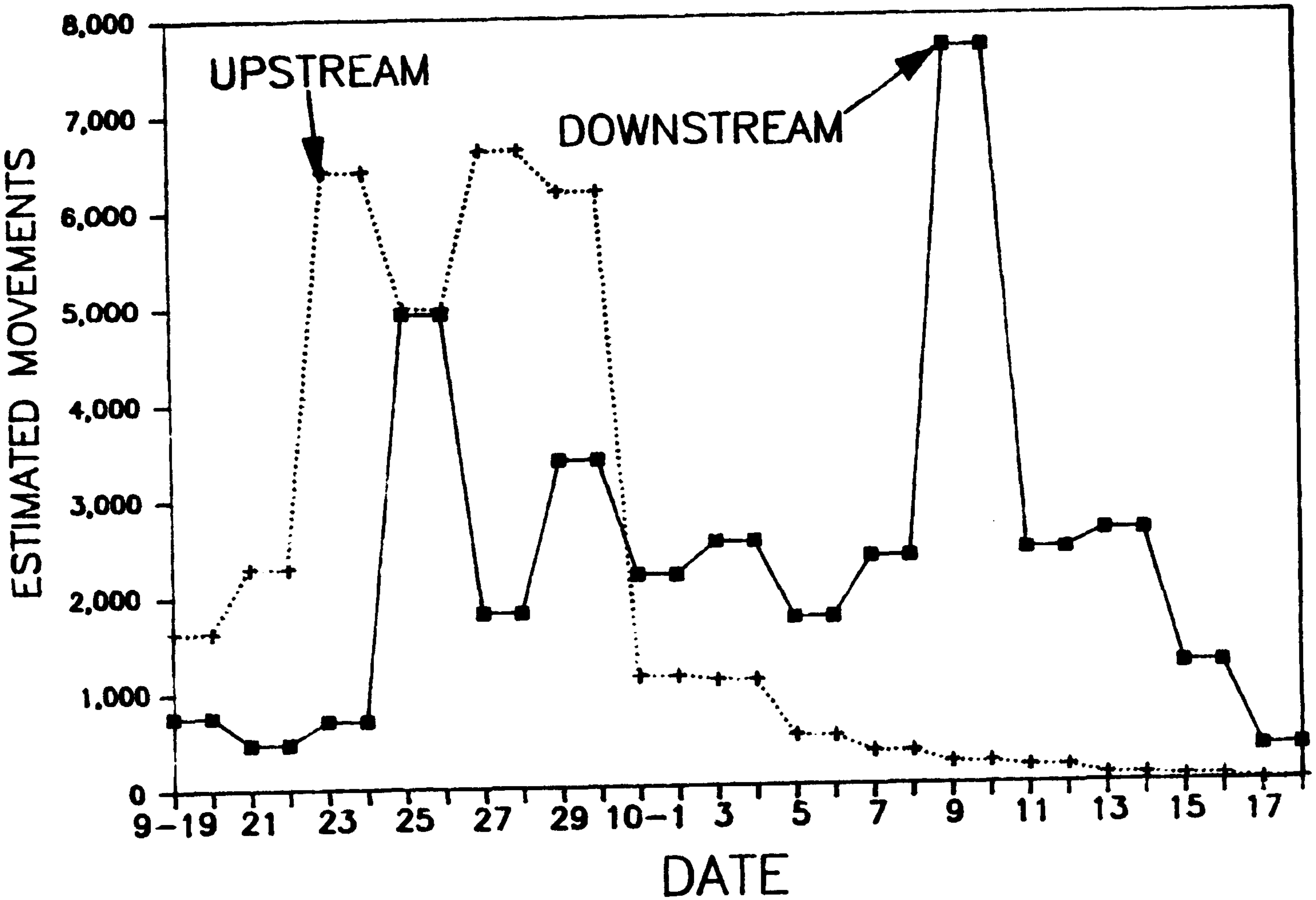

Figure 2. Daily estimates of upstream and downstream migrating whitefish at the counting tower site on the Chatanika River, 1987.

Table 2. Number of least cisco and humpback whitefish tagged per day using a boat mounted DC electrofishing unit, 10 August through 23 September 1987.

Date	Number Tagged	
	Least Cisco	Humpback Whitefish
10 August	1	124
11 August	0	73
12 August	3	102
13 August	0	97
14 August	11	208
17 August	64	350
26 August	4	51
28 August	1	195
31 August	34	153
01 September	71	175
02 September	84	136
14 September	16	0[1]
22 September	453	0
23 September	775	0
Total	1,517	1,664

[1] Although humpback whitefish were captured after 2 September, none were tagged because the sampling goal of 1,500 humpback whitefish had already been reached.

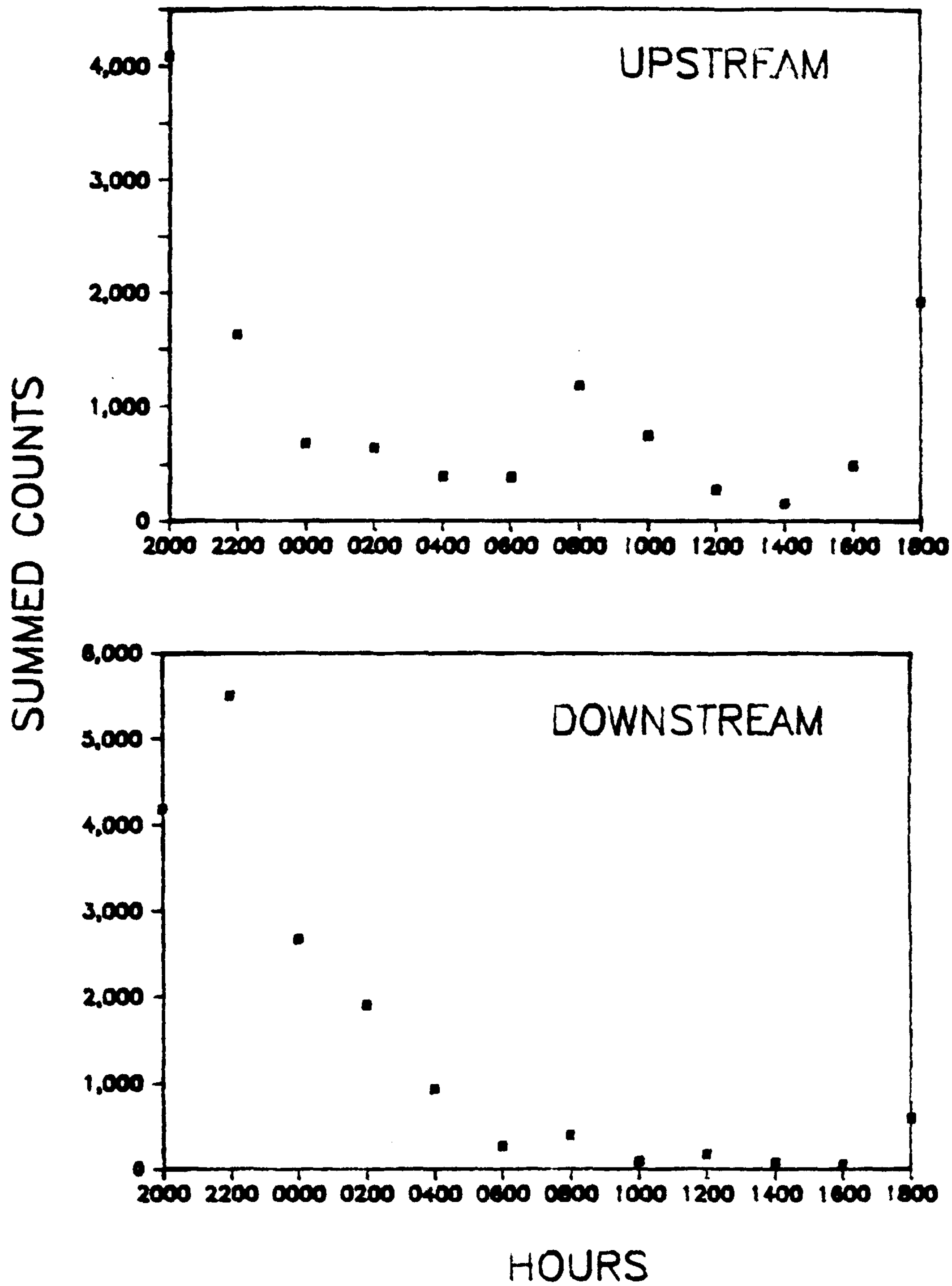

Figure 3. Counts of whitefish at the counting tower site on the Chatanika River in 1987 summed over days for each hour of the day.

Table 3. Estimated harvest of whitefish from the Elliott Highway area (Baker 1988) and total upstream and downstream movements of whitefish obtained from tower counts on the Chatanika River, 26 September through 11 October. Total run strength was estimated as the sum of downstream movements and harvest.

Stratum	Average Count Per Period	Estimated Movement	Standard Error	Coefficient of Variation
Upstream				
Night (2100-0659)	25	36,700	7,521	20.5%
Day (0700-2059)	19	28,988	27,402	94.5%
Total	22	65,688	28,416	43.3%
Downstream				
Night (2100-0659)	44	63,320	10,200	16.1%
Day (0700-2059)	5	7,842	2,031	25.9%
Total	24.5	71,162	10,400	14.6%
Harvest[1]				
Humpback		3,072	670	21.8%
Least Cisco		15,931	3,834	24.1%
Total		19,003	3,892	20.5%
Run Total (Downstream + Harvest)		90,165	11,104	12.3%

[1] Harvest estimates are only for the Elliott Highway area because most fishing at the "ditch area" occurred below the counting tower (Baker 1988).

estimated whitefish abundance from the tower counts were 63,173 (SE = 8,447) least cisco (70%), and 26,992 (SE = 3,434) humpback whitefish (30%).

Population Abundance Estimates

As in 1986, the length composition of least cisco tagged was not significantly different from that of fish recaptured (DN = 0.104; P = 0.999). Nor was there any length sampling bias for humpback whitefish (DN = 0.110; P = 0.511). This indicates that all sizes of whitefish had equal opportunity of being speared in the fishery.

Time bias in both the marking and recapture events was evaluated using chi-square analyses. The probability of capture during three time periods through the course of the fishery was not significantly different for marked and unmarked humpback whitefish ($\chi^2 = 0.23$; df = 2; P > 0.75), or for marked and unmarked least cisco ($\chi^2 = 3.29$; df = 2; P > 0.20). The rate of recapture of least cisco marked early during the run (10 August through 14 September) was not significantly different from those marked after 14 September ($\chi^2 = 2.51$; df = 1; P > 0.10). Significant differences in the probability of recapture of humpback whitefish marked during three time periods did occur ($\chi^2 = 7.75$; df = 2; P < 0.03). However, because sampling during at least one of the marking or recapture events was not biased, the population estimates were not stratified by time for either species. Thus, abundance was estimated using Chapman's modification of the Petersen estimator (Seber 1982).

A total of 1,664 humpback whitefish were tagged between 10 August and 2 September. One thousand five hundred seventeen least cisco were tagged from 10 August to 23 September, with more than 80% (1,228) of these being tagged on 22 and 23 September (Table 2). During creel census catch sampling, 1,014 humpback whitefish and 2,234 least cisco were sampled. Of these, 59 humpback whitefish and 60 least cisco were recaptured (Tables 4 and 5). Using these statistics, the estimated abundance of humpback whitefish was 28,165 (Table 4). The estimated abundance of least cisco was 55,620 (Table 5). The least cisco abundance estimate represents a 24% decline from the 1986 estimate, while the humpback whitefish estimate was nearly double the 1986 estimate.

Species, Length, Age, and Sex Composition

Because the whitefish spear fishery was not size selective, samples taken from creel census harvest sampling provide unbiased estimates of length, age, and sex composition.

Species Composition:

Of the 90,165 whitefish (Table 3) estimated to have been in the spawning run (the expanded number of whitefish migrating downstream past the tower plus the estimated harvest from the Elliott Highway fishery), 63,173 (70%) were least cisco and 26,992 (30%) were humpback whitefish. Estimates of abundance by species from the mark-recapture experiment are 55,620 (66%) least cisco and 28,165 (34%) humpback whitefish (Tables 4 and 5).

Table 4. Summary of number of humpback whitefish examined for presence of marks (C) during creel census sampling of the Chatanika River spear fishery, number recaptured (R), and estimated population abundance, 11 September to 18 October 1987.

	Daily		Cumulative		Modified Petersen		
Date	C	R	C	R	Abundance Estimate	SE	CV
09/11	4	1	4	1	4,162	1,860	44.7%
09/13	4	0	8	1	7,492	3,812	50.9%
09/14	3	0	11	1	9,989	5,262	52.7%
09/18	28	2	39	3	16,649	7,055	42.4%
09/20	3	0	42	3	17,898	7,614	42.5%
09/22	27	2	69	5	19,424	7,007	36.1%
09/24	16	2	85	7	17,898	5,668	31.7%
09/25	35	1	120	8	22,384	6,792	30.3%
09/26	42	1	162	9	27,139	7,904	29.1%
09/28	18	1	180	10	27,396	7,639	27.9%
09/29	17	0	197	10	29,969	8,380	28.0%
09/30	25	1	222	11	30,940	8,317	26.8%
10/02	48	5	270	16	26,541	6,020	22.7%
10/03	68	4	338	20	26,877	5,515	20.5%
10/04	9	0	347	20	27,590	5,666	20.5%
10/05	14	0	361	20	28,700	5,901	20.6%
10/06	48	3	408	23	28,443	5,480	19.3%
10/08	199	11	608	34	28,970	4,638	16.0%
10/09	216	10	823	44	30,524	4,317	14.1%
10/10	77	3	901	47	31,287	4,286	13.7%
10/11	11	0	912	47	31,669	4,340	13.7%
10/12	35	6	947	53	29,229	3,765	12.9%
10/13	20	1	967	54	29,303	3,740	12.8%
10/14	2	0	969	54	29,364	3,748	12.8%
10/17	43	5	1,012	59	28,110	3,427	12.2%
10/18	2	0	1,014	59	28,165	3,434	12.2%

Table 5. Summary of number of least cisco examined for presence of marks (C) during creel census sampling of the Chatanika River spear fishery, number recaptured (R), and estimated population abundance, 11 September to 18 October 1987.

	Daily		Cumulative[1]		Modified Petersen Abundance Estimate		
Date	C	R	C	R		SE	CV
09/14	3	0					
09/18	4	0					
09/20	48	1					
09/22	56	0					
09/24	103	0					
09/25	279	11	279	11	35,421	9,573	27.0%
09/26	399	10	618	21	42,712	8,683	20.3%
09/28	110	2	278	23	46,110	8,997	19.5%
09/29	308	10	1,036	33	46,300	7,610	16.4%
09/30	215	1	1,251	34	54,302	8,819	16.2%
10/02	86	3	1,337	37	54,451	8,330	15.6%
10/03	212	5	1,549	42	54,720	8,018	14.7%
10/04	30	2	1,579	44	53,300	7,630	14.3%
10/05	193	4	1,772	48	54,928	7,535	13.7%
10/06	58	1	1,830	49	55,590	7,550	13.6%
10/08	95	1	1,925	50	57,328	7,711	13.5%
10/09	154	4	2,079	54	57,409	7,431	12.9%
10/10	130	5	2,209	59	55,914	6,920	12.4%
10/11	4	0	2,213	59	56,051	6,933	12.4%
10/12	10	1	2,223	60	55,346	6,791	12.3%
10/13	3	0	2,226	60	55,420	6,800	12.3%
10/17	8	0	2,234	60	55,620	6,825	12.3%

[1] Catches prior to 25 September are not included in the estimate because marking had not been completed at that time.

Length and Age Composition:

The mean length of 2,551 humpback whitefish sampled during the electrofishing, creel census, and catch sampling was 392 mm (range 290 - 504 mm; SE = 0.7). The modal length group, 380 to 389 (Figure 4), corresponds to approximately the average size of a 5 year old fish (Table 6). As in 1986, ages of humpback whitefish in the spawning run ranged from 3 to 10 (Table 7). In both 1986 and 1987, age 5 was the dominant age class. However, age composition in 1987 was significantly different from that of 1986 ($\chi^2 = 27.21$, df = 4, $P < 0.001$). The age compositions of males and females were also significantly different, with a larger proportion of females in the older age classes ($\chi^2 = 16.89$, df = 5, $P < 0.01$).

Average length of 2,600 least cisco sampled from electrofishing, creel census, and catch sampling was 319 mm (range 200 - 450, SE = 0.4). The modal length group, 310 to 320 mm (Figure 4), corresponds to the size of a 4 year old fish (Table 6). Ages of least cisco in the spawning run ranged from 2 to 8 (Table 7). Since these fish were sampled from the spawning run, their length and age compositions can be assumed to be representative of mature fish. In both 1986 and 1987, age 4 was the dominate year class. However, the overall age composition in 1987 was significantly different from that of 1986 ($\chi^2 = 91.37$, df = 4, $P < 0.001$). The age compositions of males and females were also significantly different with a larger proportion of females in the older age classes ($\chi^2 = 72.62$, df = 4, $P < 0.001$).

Age specific abundance estimates were calculated as the product of the estimated age class proportions and the abundance estimates. Strong year classes were apparent, but a relatively constant decline in year class strength (after the age of full recruitment) occurred for both species in both 1986 and 1987 (Table 8).

Growth of individual whitefish prior to maturity is quite rapid but slows after maturity. Age 3 humpback whitefish (the youngest age class represented in the spawning run) averaged 345 mm in length, while 10 year old fish (the oldest age class) were only 152 mm longer on average (Table 6). This represents an average growth of 22 mm annually from age 4 through 10. Lengths obtained from fish tagged in 1986 and recaptured in 1987 documented an average annual growth of 9.3 mm (SE = 0.9) (Table 9).

Age 2 least cisco (the youngest age class represented in the spawning run) averaged 254 mm in length, while 8 year old fish (the oldest age class represented in the sample) were only 142 mm longer on average (Table 6). This represents an average annual growth of 24 mm for adult least cisco. Lengths obtained from seven least cisco that were tagged in 1986 and recaptured in 1987 documented average annual growth of 11.1 mm (SE = 1.1) (Table 10).

The average length of male whitefish in the spawning run was slightly less than that of females. Male humpback whitefish averaged 387 mm FL (SE = 1.6) while females averaged 397 mm (SE = 2.1). Male least cisco averaged 316 mm (SE = 1.0) and females averaged 329 mm (SE = 1.4). These differences are due

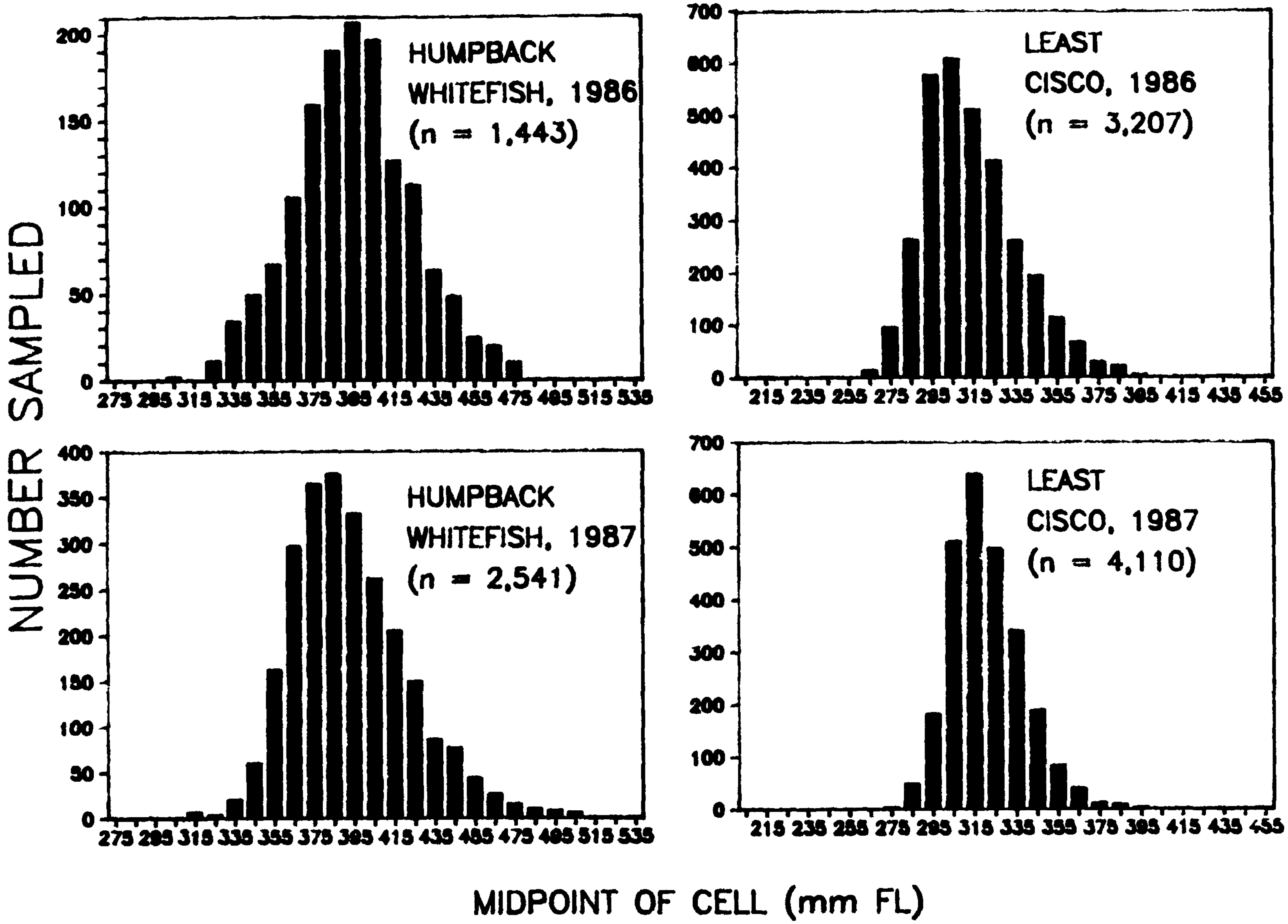

Figure 4. Length frequency distribution for least cisco and humpback whitefish sampled from the Chatanika River in 1986 and 1987.

Table 6. Mean length-at-age of humpback whitefish and least cisco sampled from the Chatanika River in 1987.

	Males				Females				All			
Age	Sample Size	Mean Length (mm)	SE (mm)	Length Change (mm)	Sample Size	Mean Length (mm)	SE (mm)	Length Change (mm)	Sample Size	Mean Length (mm)	SE (mm)	Length Change (mm)
Least Cisco												
2	2	254	12.0						2	254	12.0	
3	86	302	1.1	48	20	310	2.5		110	303	1.1	49
4	156	313	0.7	11	64	315	1.9	5	238	314	0.7	11
5	70	326	0.9	13	71	330	1.1	15	162	328	0.7	14
6	19	349	2.8	23	49	344	1.4	14	73	345	1.4	17
7	6	370	5.1	21	8	379	4.1	35	14	375	3.3	30
8	2	415	5.0	45	3	390	5.8	11	5	400	7.1	25
Average Annual Growth				26.8				16.0				24.3
Humpback Whitefish												
3	10	348	4.3		6	350	9.2		19	345	4.7	
4	95	365	1.5	17	49	371	2.2	21	199	368	0.9	23
5	118	386	1.4	21	64	387	1.7	16	245	386	0.9	18
6	56	410	1.7	14	54	410	2.0	23	138	409	1.1	23
7	20	428	4.4	18	17	425	3.2	15	54	427	2.5	18
8	2	445	5.5	17	9	456	5.5	31	18	452	4.0	25
9	3	473	8.6	28	4	465	13.1	9	10	469	5.6	17
10					1	492	---	27	3	497	2.7	28
Average Annual Growth				19.2				20.3				21.7

Table 7. Estimated age composition by sex of least and humpback whitefish in the harvest from the Chatanika River/Elliott Highway spear fishery, 11 September to 17 October 1987.

	Males			Females			All		
Age	n	p	SE	n	p	SE	n	p	SE
Least Cisco									
2	2	0.006	0.004				2	0.003	0.002
3	86	0.252	0.023	20	0.092	0.019	110	0.182	0.016
4	156	0.457	0.027	64	0.294	0.030	238	0.394	0.020
5	70	0.205	0.021	71	0.326	0.031	162	0.268	0.018
6	19	0.056	0.012	49	0.225	0.028	73	0.121	0.013
7	6	0.018	0.007	8	0.037	0.012	14	0.023	0.006
8	2	0.006	0.004	6	0.028	0.011	5	0.008	0.004
	341			218			604[1]		
Humpback Whitefish									
3	10	0.033	0.010	6	0.029	0.011	19	0.028	0.006
4	95	0.311	0.026	49	0.239	0.029	199	0.290	0.017
5	118	0.387	0.027	64	0.312	0.032	245	0.357	0.018
6	56	0.184	0.022	54	0.263	0.030	138	0.201	0.015
7	20	0.066	0.014	17	0.083	0.019	54	0.079	0.010
8	2	0.007	0.004	9	0.044	0.014	18	0.026	0.006
9	3	0.010	0.005	4	0.020	0.009	10	0.015	0.004
10	1	0.003	0.003	2	0.010	0.006	3	0.004	0.002
	305			205			686[1]		

[1] The sum of the male and female samples is less than the sample of all fish because sex was not noted for all fish samples.

Table 8. Estimated age specific abundance of humpback whitefish and least cisco in the spawning population of the Chatanika River, 1986 and 1987.

Age	1986		1987	
	Estimated Abundance	SE	Estimated Abundance	SE
Least Cisco				
2	232	166	185	131
3	22,633	3,971	10,129	1,516
4	36,445	6,194	21,916	2,905
5	10,794	2,055	14,919	2,084
6	1,973	569	6,722	1,103
7	929	357	1,289	373
8			460	211
Total	73,006		55,620	
Humpback Whitefish				
3	64	64	780	199
4	3,213	789	8,170	1,107
5	6,554	1,473	10,059	1,329
6	2,120	562	5,666	813
7	1,221	369	2,217	395
8	1,221	369	739	193
9	386	173	411	137
10	129	93	123	72
Total	14,908		28,165	

Table 9. Annual growth increments of individual humpback whitefish tagged during population sampling in 1986 and recaptured during population sampling in 1987.

Tag Number	Length in 1987 (mm FL)	Length in 1986 (mm FL)	Annual Increment of Growth (mm FL)
10100	409	404	5
10110	397	385	12
10124	402	392	10
10280	402	400	2
10294	414	409	5
10967	414	400	14
29016	385	368	17
29080	...	406	...
29092	411	394	17
29109	423	420	3
29127	403	393	10
29172	415	410	5
29288	...	358	...
29336	414	401	13
29429	...	394	...
29769	420	419	1
29771	368	353	15
29777	...	341	...
29785	350	336	14
29790	...	335	...
29833	410	400	10
29849	412	402	10
29851	388	377	11
29867	415	408	7
29872	415	405	10
29882	500	493	7
29899	409	401	8
29932	400	393	7
33013	...	397	...
33048	...	413	...
33056	...	365	...
33061	393	380	13
33162	...	419	...
33203	...	384	...
33215	430	415	15
33289	397	395	2
33306	...	445	...
33326	...	427	...
Average Growth (SE)			9.3 (0.9)

Table 10. Annual growth increments of individual least cisco tagged during population sampling in 1986 and recaptured during population sampling in 1987.

Tag Number	Length in 1987 (mm FL)	Length in 1986 (mm FL)	Annual Increment of Growth (mm FL)
33405	318	310	8
33523	309	297	12
33526	308	296	12
34115	...	292	...
34162	302	286	16
34255	...	285	...
34362	311	302	9
34433	...	317	...
34566	314	302	12
34599	354	348	9
Average Growth (SE)			11.1 (1.1)

to the larger proportion of females in older age classes. Length at age of male and females for both least cisco and humpback whitefish were virtually identical (Figure 5)

Sex Composition:

Of a sample of 902 least cisco that were examined for sex, 592 ($p = 0.66$; SE = 0.02) were males and 310 ($p = 0.34$; SE = 0.02) were females. The estimated number of male least cisco in the spawning population was 36,504 (SE = 4,563). The estimated number of females was 19,115 (SE = 2,503). The age composition of males and females (Table 7) was significantly different ($\chi^2 = 69.67$, df = 4, $P < 0.001$) with females more common in the older age classes.

The proportion of males in the spawning population was also greater for humpback whitefish where a sample of 665 fish contained 415 males ($p = 0.62$; SE = 0.02) and 250 females ($p = 0.38$; SE = 0.02). The estimated abundance of males and females was 17,577 (SE = 2,207) and 10,588 (SE 1,394), respectively. The age composition of males and females (Table 7) was significantly different ($\chi^2 = 16.89$, df = 5, $P < 0.005$) with females more common in the older age classes.

Exploitation Rates

Using estimates from the mark-recapture experiment and the creel census of the spear fishery, the estimated rate of exploitation was 0.427 (SE = 0.106) for least cisco and 0.163 (SE = 0.038) for humpback whitefish (Table 11). Based on abundance estimates obtained from counting towers, the estimated exploitation rates were 0.376 (SE = 0.0650) and 0.170 (SE = 0.035) for least cisco and humpback whitefish, respectively (Table 11).

The rate of tag recovery during creel sampling was similar for both species; 4.0% for least cisco and 3.6% for humpback whitefish. A chi-square comparison of the number of tags recovered from the creel sampling versus tags not recovered showed no significant difference between the two species ($\chi^2 = 0.49$; df = 1; $P > 0.5$). The rate of voluntary tag returns were also similar for humpback whitefish and least cisco($\chi^2 = 0.22$; df = 1; $P > 0.50$).

DISCUSSION

In 1987, combined estimates of humpback whitefish and least cisco abundance provided by counting towers and mark recapture population experiments were relatively close to each other (within 10%). Total whitefish abundance estimates between 1986 and 1987 were within 5% of each other. However, the estimated abundance of humpback whitefish in 1987 was almost twice that of 1986. On the other hand, estimated least cisco abundance dropped between 20% and 30% from 1986 to 1987, depending on the estimator. The tower count and mark-recapture estimates obtained in 1986 (particularly the humpback whitefish estimate) were thought to be low due to a late start of the counting tower, flooding which caused an early close to counting tower operations and the fishery, and insufficient coverage in the creel census causing biased

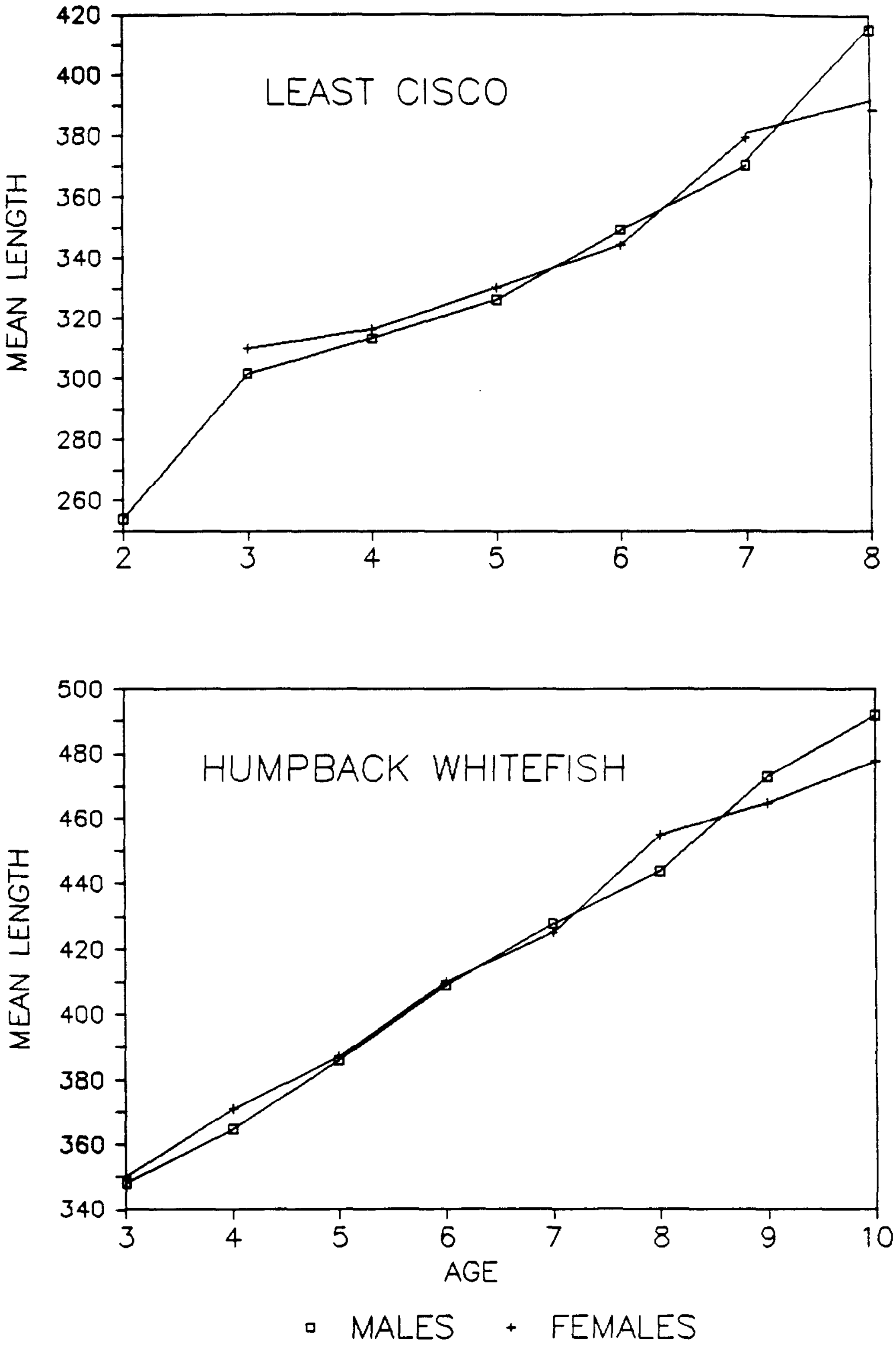

Figure 5. Mean length (FL) at age by sex for least cisco and humpback whitefish sampled from the Chatanika River spear fishery, 1987.

Table 11. Abundance and exploitation rate estimates of least cisco and humpback whitefish obtained from tower counts and mark/recapture experiments, 1987.

	Least Cisco		Humpback Whitefish	
	Tower counts[1]	Mark/recapture experiment	Tower counts	Mark/recapture experiment
Estimated abundance	63,173	55,620	26,992	28,165
SE	8,447	6,825	3,414	3,434
CV	13.4%	12.3%	12.7%	12.2%
Exploitation Rate	0.376	0.427	0.170	0.163
SE	0.065	0.105	0.035	0.038
CV	17.3%	24.6%	20.6%	23.3%

1 Sum of the total estimated number of downstream migrating whitefish and the estimated whitefish harvest from the Elliott Highway fishery.

recapture sampling and low harvest estimates (Holmes and Hallberg 1987). The large increase in humpback whitefish abundance in 1987 therefore, is likely due not to any significant increase in run size, but to the underestimate in 1987. The decline in least cisco abundance between the 2 years is more likely due to an actual population decline resulting from overexploitation in prior years.

To improve the accuracy of estimates, several sample design adjustments were included in 1987. Tower counts were begun on 15 September; 7 days earlier than the 1986 start up date of 26 September. During this 7-day period, approximately 20% of all whitefish passed the tower on their downstream migration and 48% of all whitefish moved upstream. Because of the large number of fish moving upstream at the start of counting, it is obvious that a complete count of upstream migrating fish was not made. It also appears that downstream counts are biased low because as many as 760 whitefish passed the tower daily on their downstream migration at the start of operations. From data collected while electrofishing, it appears that whitefish, especially humpback whitefish, enter the river too early and over too long a period to make upstream counts feasible. However, an earlier start date (10 to 15 September) would probably allow a complete count of downstream migrating whitefish.

Downstream migration counts peaked on 25 September and 9 October in both 1986 and 1987. The peak in late September for both years apparently resulted from boat traffic herding large numbers of whitefish downstream past the counting tower. In both years, these concentrations became so great that counting tower personnel could only estimate the numbers of whitefish passing downstream. In 1986, it was thought that the second peak of downstream movement that occurred on 8 October was associated with the rising water levels and the flood event on 10 October. However, in 1987 a similar peak occurred at nearly the same date and without any threat of flooding. This indicates that spawning is normally completed by early October and that the downstream migration is probably peaking at this time.

In 1986, we concluded that flooding, which caused a premature end to counting on 11 October, had also been a factor in underestimating total run abundance. In 1987, counting was continued until freeze-up (17 October), when total daily downstream counts had dropped to only a few hundred a day. However, almost 20% of the downstream migration occurred during the period 11 to 17 October, again supporting the conclusion that the 1986 estimate was low. Thus it is clear that for tower counts of downstream migrating whitefish to be accurate, counting must begin early and continue until mid to late October.

Run timing and segregation of the species on the spawning grounds provided potential biases to accurate whitefish abundance estimation using mark-recapture experiments. Tagging data indicated that humpback whitefish had a protracted upstream run with fish reaching the Elliott Highway area as early as 10 August. The upstream migration appears to last until early September. Least cisco, on the other hand, arrive in a large pulse in mid-September. Thus, tagging of the least cisco population can occur in a relatively short time span, whereas humpback whitefish must be tagged over the course of a month or more. Tag returns from the Steese Highway area in both 1986 and 1987 indicated that humpback whitefish migrated farther upstream than least cisco. In the 1987 creel census catch sample, nearly 60% of humpback whitefish, both tagged and untagged, were sampled during the last 10 days of the fishery, 8 to 17 October (Table 4). This would indicate that a majority of humpback whitefish were once again available to the spearfishermen at the Elliott Highway area only during their outmigration which occurs just before freeze-up. Voluntarily supplied information from fisherman spearing both inside and outside the traditional fishing area (Elliott Highway Bridge area) revealed that 10 out of a total of 45 (22%) tagged humpback whitefish were taken from the area along the Steese Highway. No least cisco recaptures were obtained from the Steese Highway area. Since least cisco spawn in the vicinity of the Elliott Highway, they are available to fishermen throughout the fishery. This is probably the major reason that least cisco undergo a much higher exploitation rate than humpback whitefish. In 1987, the ability to conduct the creel census until freeze-up increased the sample of humpback whitefish harvested near the Elliott Highway during their downstream migration. A more extensive catch sampling program in all areas of the river should minimize potential biases in the future.

The 1987 mark-recapture population estimates of least cisco and humpback whitefish abundance appear to be relatively free of bias. First, for the second year, no size selectivity occurred between marked (electrofishing) and recaptured (spear fishery harvest) fish. Second, there was no difference in probability of recapture through the course of the fishery. However, for humpback whitefish there was sampling bias associated with the time of tagging. Chi-square tests demonstrated that humpback whitefish tagged during the early, middle, and late time periods underwent significantly different rates of exploitation, with fish tagged during the middle time period being recaptured more frequently than fish tagged at other times. However, because recapture efforts were not time biased, at least one of two conditions (random tagging or recapture) existed, and therefore, the Petersen abundance estimate was valid.

The accuracy of exploitation rate estimates necessarily depend on the accuracy of population abundance estimates and fishery harvest estimates. The Department has conducted a creel census of the Chatanika River spear fishery seven times since 1977. In every year, the estimated harvest from the on-site creel census has been less than that obtained from the statewide postal harvest survey. The creel census estimates have averaged only 65% of the postal survey estimates. The most likely cause of this bias is that the on-site creel censuses did not cover all areas where, or times when, fishing occurred. The spear fishery in the Chatanika River was thought to occur mainly near the Elliott Highway, within 4 km above and below the bridge. Some fishing has also traditionally occurred near the Steese Highway. In previous years some spearfishing was documented near what is called the "ditch area", located approximately 6 km below the bridge, but the harvest here was thought to be minimal. In 1987, heavy spearfishing activity was observed at the "ditch area." The creel census and catch sampling was modified to include this area on 1 October, when heavy fishing effort was first observed. If this area had not been included in the creel census, the total estimated harvest would have been reduced by one third, and thus, exploitation would have also been underestimated. The fact that creel census efforts in prior years did not include areas away from the Elliott Highway Bridge indicates that harvest and exploitation were probably underestimated in those years as well. Again, a more complete creel census, covering all areas of the fishery, will be the best method of improving harvest, population abundance, and exploitation rate estimates. It should be noted that the additional harvest in the "ditch area" was not added to the downstream abundance tower counts because this harvest occurs below the counting tower, and therefore these fish would have already been counted as downstream migrants.

A superficial evaluation of estimates would lead to the conclusion that both harvest and abundance of humpback whitefish doubled between 1986 and 1987, and exploitation remained relatively constant at about 17%. Unfortunately, it is clear that both abundance and harvest were underestimated in 1986 (due to the reasons listed above), and so, estimates of exploitation were also biased. However, it does appear that exploitation of humpback whitefish is below the maximum (about 20%) that the Department believes is sustainable given the life history features of the species. However, the situation is much different with the least cisco population. Exploitation increased from 0.23 in 1986 to 0.43 in 1987. Harvest of least cisco increased by 35% and abundance levels dropped by 27% between 1986 and 1987. Concern over apparent overexploitation of the least cisco population prompted Sport Fish Division to propose a new fishing regulation. The proposed regulation that was subsequently adopted by the Alaska Board of Fisheries is a bag and possession limit of 15 whitefish in the Tanana River Drainage. If such a limit had been in effect prior to the 1987 spear season, the harvest would have been reduced by an estimated 11,000 whitefish and the exploitation rate would have decreased to 18%. Creel census information collected in 1987 indicated that 82% of the spearfishermen took less than 15 whitefish per trip. Thus, harvest would have been reduced to sustainable levels while affecting only a small proportion of the fishermen.

Age composition in 1987 for both species was significantly different from 1986. This indicates that either variable recruitment occurred or that harvest in recent years has affected age class composition. However, the dominant age class was age 4 for least cisco and 5 for humpback whitefish in both years. This indicates that these are the ages at which 100% of all fish become sexually mature. Sex composition of the spawning populations of both species was highly skewed. In both 1985 and 1986, approximately two thirds of the populations were composed of males. Little data on sex composition of other spawning populations of whitefish in Alaska exist. Bendock (1984) reported the male to female ratio of 121 least cisco sampled from six coastal streams in northern Alaska to be 1.0:0.36. The male to female ratio of a small sample (n = 17) of mature humpback whitefish from the same area was 1.0:0.7.

RECOMMENDATIONS

1. Whitefish abundance and harvest estimates should be continued to enable the evaluation of how the new bag limit is affecting whitefish harvest and least cisco and humpback whitefish population structure.

2. Tower counts should be discontinued in favor of the less labor intensive mark recapture experiments.

3. The creel census should be expanded to include a statistically based sample of all areas of the fishery.

4. Marking should be conducted continuously during the upstream migration to insure a random mark.

5. To improve efficiency of creel sampling, all aging samples will be obtained during marking efforts.

6. Sex of whitefish should be determined during marking and creel sampling to determine if the spear fishery is selective by sex.

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