Fishery Data Series No. 96-19

Stock Assessment and Life History Studies of Whitefish in the Chatanika River During 1994 and 1995

by

Douglas F. Fleming

July 1996

Alaska Department of Fish and Game

Division of Sport Fish

Symbols and Abbreviations

The following symbols and abbreviations, and others approved for the Système International d'Unités (SI), are used in Division of Sport Fish Fishery Manuscripts, Fishery Data Series Reports, Fishery Management Reports, and Special Publications without definition. All others must be defined in the text at first mention, as well as in the titles or footnotes of tables and in figures or figure captions.

Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
metric ton	mt
milliliter	ml
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
ounce	oz
pound	lb
quart	qt
yard	yd
Spell out acre and ton.	

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
hour (spell out for 24-hour clock)	h
minute	min
second	s
Spell out year, month, and week.	

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

All commonly accepted abbreviations.	e.g., Mr., Mrs., a.m., p.m., etc.
All commonly accepted professional titles.	e.g., Dr., Ph.D., R.N., etc.
and	&
at	@
Compass directions:	
east	E
north	N
south	S
west	W
Copyright	©
Corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
et alii (and other people)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.,
id est (that is)	i.e.,
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
number (before a number)	# (e.g., #10)
pounds (after a number)	# (e.g., 10#)
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S. state and District of Columbia abbreviations	use two-letter abbreviations (e.g., AK, DC)

Mathematics, statistics, fisheries

alternate hypothesis	H_A
base of natural logarithm	e
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	F, t, χ^2, etc.
confidence interval	C.I.
correlation coefficient	R (multiple)
correlation coefficient	r (simple)
covariance	cov
degree (angular or temperature)	°
degrees of freedom	df
divided by	÷ or / (in equations)
equals	=
expected value	E
fork length	FL
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	$\log_2$, etc.
mideye-to-fork	MEF
minute (angular)	'
multiplied by	x
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
standard length	SL
total length	TL
variance	Var

FISHERY DATA SERIES NO. 96-19

STOCK ASSESSMENT AND LIFE HISTORY STUDIES OF WHITEFISH IN THE CHATANIKA RIVER DURING 1994 AND 1995

by

Douglas F. Fleming
Division of Sport Fish, Fairbanks

Alaska Department of Fish and Game
Division of Sport Fish, Research and Technical Services
333 Raspberry Road, Anchorage, Alaska, 99518-1599

July 1996

Development and publication of this manuscript were partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-11, Job No. R-3-5(a).

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

Douglas F. Fleming
Alaska Department of Fish and Game, Division of Sport Fish, Region III,
1300 College Road, Fairbanks, AK 99701-1599, USA

This document should be cited as:
Fleming, D. F. 1996. Stock assessment and life history studies of whitefish in the Chatanika River during 1994 and 1995. Alaska Department of Fish and Game, Fishery Data Series No. 96-19, Anchorage.

TABLE OF CONTENTS

Page

ABSTRACT 1

INTRODUCTION 1

Historical Perspective 1
Fishing Mortality 3
Natural Mortality 3
Stock Assessment and Basic Life History 4

METHODS 6

Stock Assessment Study area 6
Field Sampling 6
Abundance Estimation 7
Age and Size Composition 8
Survival, Mortality, and Exploitation 9
Minimal Migration Investigation 12
Maturity Investigation 12
Radio Telemetry of Humpback Whitefish 13

RESULTS 16

Sampling 16
Abundance Estimation 17
Age and Size Composition 17
Survival, Mortality, and Exploitation 22
Minimal Migration Investigation 22
Maturity Investigation 25
Radio Telemetry of Humpback Whitefish 26

DISCUSSION 30

CONCLUSION 35

ACKNOWLEDGMENTS 35

LITERATURE CITED 35

APPENDIX A 41

APPENDIX B 43

LIST OF TABLES

Table **Page**

1. Estimates of sampled contributions by each age class and 10 mm FL incremental size groupings for humpback whitefish (≥360 mm FL) captured in the Chatanika River, 22 through 26 August 1994 18
2. Estimates of sampled contributions by each age class and 10 mm FL incremental size groupings for least cisco (≥290 mm FL) captured in the Chatanika River, 22 through 26 August 1994 20

LIST OF FIGURES

Figure **Page**

1. Map of 1992-1994 study areas encompassing Minto Flats and Chatanika River 2
2. Estimated proportions of humpback whitefish by length (≥360 mm FL) in the Chatanika River, 1992 through 1994 19
3. Estimated proportions of least cisco by length (≥290 mm FL) in the Chatanika River, 1992 through 1994 21
4. Apportionment of estimated abundance across age classes for humpback whitefish (≥360 mm FL) present in a 78.2 km section of the Chatanika River during August 1993 and 1994. 23
5. Apportionment of estimated abundance across age classes for least cisco (≥290 mm FL) present in the Chatanika River 1991 to 1994. 24
6. Map of locations within Minto Flats and Chatanika River where radio-tagged humpback whitefish were located between April and September 1995 28
7. Locations of reported subsistence harvest of coregonid species by Minto villagers in 1984 (from Andrews 1988). 29
8. Systematic marking and recapture sampling event catches of least cisco (≥290 mm FL) during august 1992, 1993, and 1994 stock assessments along the Chatanika River 33

LIST OF APPENDICES

Appendix **Page**

A1. Methodologies for alleviating bias due to gear selectivity by means of statistical inference 42
B1. Tabulated radio telemetry data 44

ABSTRACT

Stock assessment and three life history studies were conducted on humpback whitefish *Coregonus pidschian* and least cisco *Coregonus sardinella* in the Chatanika River and adjoining waters, near Fairbanks, Alaska during 1994 and 1995. The stock assessment occurred in a 102 km (64 mile) section of the Chatanika River during August 1994. Mark-recapture experiments were utilized to estimate abundance and stock composition of both species. The investigation was timed to correspond to the upstream spawning migration of both species, and to provide in-season estimates of abundance prior to the onset of a recreational spear fishery. An estimated 14,292 (SE = 1,215) humpback whitefish (≥360 mm FL) were present in the study area. The assessed stock was characterized by a high proportion of large humpback whitefish (≥430 mm FL) with ages 8, 9, and 10 predominating. An estimated 29,557 (SE = 3,410) least cisco (≥290 mm FL) were present in the study area. The assessed stock was predominated by ages 3 and 5 least cisco. Survival estimates from August 1993 to August 1994 were 41.8 and 84.6 percent for least cisco and humpback whitefish, respectively. These survival estimates assume that least cisco and humpback whitefish are consecutive year spawners.

Three supplemental investigations attempted to gather life history data to examine geographic closure of the Chatanika River whitefish stocks. A migration study found that at least 10 percent of least cisco present in the lower Chatanika River during early September eventually travel upstream to areas where a fishery occurs. A second study attempted to estimate maturity among adult-sized fish in an effort to detect non-consecutive spawning. In the course of this study, fish could not be categorized using external examinations because many fish failed to reach spawning condition. A radio telemetry study on humpback whitefish sought to characterize the geographic range with respect to time, areas of overwintering, availability to traditional subsistence fisheries, and the annual stock assessment program. High levels of mortality among radio-tagged fish precluded objective estimates.

KEY WORDS: humpback whitefish, *Coregonus pidschian*, least cisco, *Coregonus sardinella*, abundance estimation, age composition, length composition, spawning stock, survival, migratory movements, radio telemetry, maturity, scales.

INTRODUCTION

HISTORICAL PERSPECTIVE

During summer and early fall, humpback whitefish *Coregonus pidschian* and least cisco *Coregonus sardinella* migrate from areas within Minto Flats up the Chatanika River to spawn (Figure 1). A significant fall spear fishery for these species developed during the 1980's, primarily between the Elliott Highway Bridge and the Ones Pond Campground, with a limited harvest taken along the Steese Highway. Estimates of whitefish harvests from the Chatanika River increased from 1,635 in 1977 to a high of 25,074 whitefish in 1987 (Mills 1979-1988). In response to increasing harvests in the whitefish spear fishery, stock assessments were initiated in 1986 for humpback whitefish and least cisco (Hallberg and Holmes 1987). Since then, stock assessments have evolved into large area mark-recapture studies (Timmons 1991, Fleming 1993, 1994).

Prompted by concern over increasing harvests of whitefish, 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. Further management actions have led to emergency closures during the 1990 season, and a complete closure in 1991 as a preliminary assessment indicated the need for conservation of the spawning stocks. In 1992 the Board of Fisheries shortened the season and reduced the geographic area of the fishery so that a low level fishery might continue.

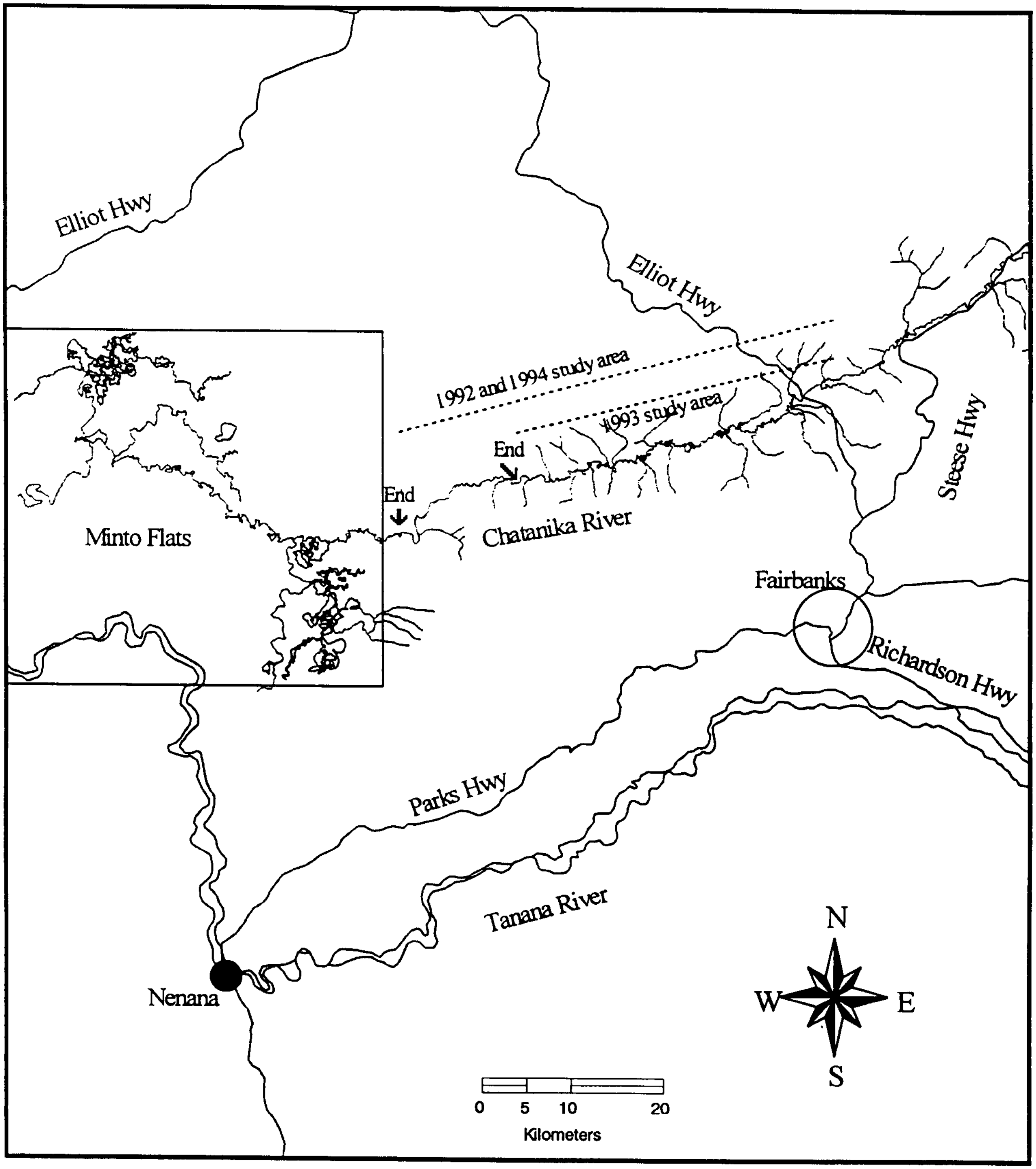

Figure 1.-The overall study area including parts of the Chatanika River and Minto Flats where 1992-1994 stock assessments and life history studies were conducted.

Results from 1992 and 1993 mark-recapture experiments have indicated that abundances of the whitefish stocks have declined despite the conservative regulatory action. Abundance estimates for the last two years of stock assessment in a 78.2 km section[1] of the Chatanika River were:

Assessment year:	Humpback whitefish	Least cisco
1992	19,187 fish (SE = 1,617)	75,035 fish (SE = 8,555)
1993	13,112 fish (SE = 1,096)	46,562 fish (SE = 5,971)

The apparent decrease in whitefish abundance between 1992 and 1993 was likely caused by a combination of factors, including: 1) fishing mortality (sport and/or subsistence); 2) increased natural mortality and decreased recruitment; and 3) stock assessment and life history.

FISHING MORTALITY

Recent declines in whitefish abundance may have resulted in part from high harvest levels of spawners in past years, but it is unlikely that the most recent harvests have contributed substantially to the declines. Creel survey estimates of harvest beginning in 1986 were as follows (Clark and Ridder 1987; Baker 1988, 1989; Merritt et al. 1990; and, Hallberg and Bingham 1991, 1992, 1993, 1994, 1995):

Year	Humpback whitefish	SE	Least cisco	SE
1986	2,528	914	16,575	2,513
1987	4,577	926	23,735	5,121
1988	3,571	293	4,456	314
1989	3,835	491	9,784	1,443
1990	957	34	5,396	175
1991[a]	0	---	0	---
1992	392	9	1,898	49
1993	87	18	609	62
1994[a]	0	---	0	---
1995[a]	0	---	0	---

[a] The spear fishery was closed by emergency order in these years.

The estimated subsistence harvest in Minto Flats for 1994 was 415 humpback whitefish and 115 least cisco (J. E. Hallberg, Alaska Department of Fish and Game, Fairbanks, personal communication). These recent subsistence harvests are less than reported by Andrews in 1988 (6,477 coregonids, all species). It is likely that subsistence harvests of whitefish in Minto Flats in 1992 and 1993 were of the same order of magnitude as those in 1994.

NATURAL MORTALITY

Natural mortality appears to have changed and is likely to be the primary factor influencing abundances of humpback whitefish and least cisco. Merritt (1995) estimated instantaneous

[1] Stock assessment in 1993 was conducted over a 78.2 km section of the Chatanika River , and a 102 km section in 1994. In order to make comparisons between the two years, 1994 abundances were reestimated using data collected in the shorter section.

natural mortality of humpback whitefish in the Chatanika River for 1990, 1991, and 1992 as 0.47, 0.36, and 0.54, respectively (an average of 0.46). These estimates are comparable to others estimated for coregonids (Healy 1975). In 1993 estimates of natural mortality for humpback whitefish and least cisco were 0.60 and 0.70, respectively (Fleming 1994). The annual rates of natural mortality between 1992 and 1993 were 43.4% for humpback whitefish and 47.8% for least cisco in 1993 (Fleming 1994).

Increased numbers of northern pike have been observed and captured during the Chatanika River mark-recapture experiments (Fleming- *Unpublished data*). Sport fishery statistics from 1992 through 1994 (Mills 1993, 1994, and Howe et. al 1995) indicate catch rates of northern pike in Minto Flats may have tripled and increased ten-fold in the Chatanika River. Increased catches of northern pike *Esox lucius* in the Chatanika River and in Minto Flats since 1992 have suggested that increased predation is occurring on whitefish. While predation may be a primary factor controlling recent stock abundance and recruitment in the assessed stocks of whitefish, other investigators have found the effects of predation difficult to discern through investigations (He and Kitchell 1990).

STOCK ASSESSMENT AND BASIC LIFE HISTORY

Stock assessment of whitefish in the Chatanika River has focused on the migratory portion of the population that returns to the upper Chatanika River. Assessment and management of this resource assumes that once a fish is recruited to the migratory stock, it returns each year at a similar time making it vulnerable to assessment sampling.

Vulnerability of whitefish to sampling may vary due to: 1) variation in migration timing to the assessed portion of the Chatanika River; 2) differing levels of fidelity to spawning or overwintering locations which are part of the assessed area; and, 3) substantial portions of the population that do not spawn each year (non-consecutive spawners).

The life history of humpback whitefish and least cisco appears to include a migration to feeding areas in Minto Flats during the spring break-up, and shortly thereafter a migration to the Chatanika River during summer. The upstream migration may begin in early June (D. Fleming *Unpublished data*) and continue until the end of September. Because the migration can be protracted over three months, timing of stock assessments may affect abundance estimates. Catch variability by river section and recorded movements by tagged whitefish in 1992 and 1993 indicated differences in migratory timing between years (Fleming 1994). During 1991, several whitefish sampled in the lower Chatanika River during mid-September were recaptured September 26 in the area of the spearfishery, which was as much as 100 km upstream from the release site. The varied extent of migrations (with respect to time and area) and subsequent biases, if any, remains unquantified.

Although some individual humpback whitefish and least cisco have been captured in consecutive years on the Chatanika River, no information currently exists to conclude annual fidelity or annual spawning. Information from consecutive returns suggest that at least *some* individual whitefish return annually to the Chatanika River. High rates of tag shedding have interfered with analyses which might conclude annual fidelity for all members of the assessed stock. Similarly, a non-returning fraction of the stock, which may continue feeding or migrate to other locations at the time of stock assessment, has not been detected or quantified.

Various species of whitefish may or may not spawn annually after reaching sexual maturity. When spawning is non-consecutive, it is thought to be an adaptation for survival in harsh northern climates (Morin et al. 1982). This non-consecutive or skip-spawning pattern has been documented in northern Alaska (Craig 1989) for the same species of whitefish as these studies. In a study by Lambert and Dodson (1990), on cisco *Coregonus artedii*, and lake whitefish *Coregonus clupeaformis* in the Eastmain River (James Bay, Canada), it was demonstrated by seasonal tissue energy content that neither species could spawn in two successive years. In the same study they found that non-reproducing fish (skip-spawners and immature fish) entered the river several months later than pre-spawners. Bernatchez and Dodson (1987) concluded that early migration of pre-spawning cisco and lake whitefish was an adaptation to conserve energy during migration. It is not known whether the protracted summer migration of whitefish in the Chatanika River is due to early entry by pre-spawners, and/or late entry by non-spawners.

In 1994, whitefish research included stock assessment and several life history investigations to characterize geographic closure of the Chatanika River stocks of whitefish. One experiment was designed to determine whether whitefish present during mid-September in the lower 15 km of the Chatanika River assessment area are more upstream into the area of the fishery, during the fishery. The second investigation was to ascertain whether non-consecutive spawning fish were part of the assessed stock. Several experiments used time and area information collected by radio-tracking mature humpback whitefish to determine seasonal geographic ranges. One experiment sought to determine whether Chatanika River humpback whitefish frequented areas of traditional subsistence fisheries. The other experiment sought to estimate levels of fidelity to the Chatanika River during subsequent year stock assessment and spawning events. To date no other large spawning aggregates of whitefish have been described for the Minto Flats area other than a small (unquantified) run to the upper Tolovana River (A. Townsend, Alaska Department of Fish and Game, Fairbanks, personal communication).

Specific objectives for the 1994 non-federally funded study on humpback whitefish and least cisco in the Chatanika River were to:

1. estimate abundance of humpback whitefish greater than 359 mm FL and least cisco greater than 289 mm in a 102 km section of the Chatanika River, beginning 5 km above the Elliott Highway Bridge downstream to the Murphy Dome Road Extension, such that each estimate is within 25% of the true abundance 95% of the time;

2. estimate age and size compositions of humpback whitefish and least cisco inhabiting the 102 km section of the Chatanika River such that the estimated proportions are within 5 percentage points of the true proportions 95% of the time;

3. test the hypothesis that humpback whitefish and least cisco tagged and released in the lower 45 km of the study area during early September, do not immigrate to the area of the fishery at a level greater than 10%, with $\alpha = 0.10$ and $\beta = 0.10$;

4. test the hypothesis that 100% of least cisco greater than 349 mm FL and humpback whitefish greater than 449 mm FL are mature in the area of the fishery and the lower 45 km of the study area, such that a 5% deviation from 100% maturity can be detected with $\alpha = 0.05$ and $\beta = 0.05$;

5. estimate the proportion of humpback whitefish that enter traditional subsistence fishing areas of Minto Flats, such that the estimated proportion is within 15 percentage points of the true proportion 90% of the time; and,
6. estimate the proportion of humpback whitefish that return to the study area of the Chatanika River, following the year of tagging, such that the estimated proportion is within 15 percentage points of the true proportion 90% of the time.

For 1955, the following tasks in the Federal Aid project F-10-11, R-3-5 (a) were addressed in this report:

1. estimate instantaneous natural mortality from the historical data base for humpback whitefish and least cisco; and,
2. continue tracking radio-tagged humpback whitefish.

METHODS

Stock Assessment Study Area

Past stock assessments for both species of whitefish occurred over limited areas of the Chatanika River accessed by the Elliott Highway, but recent assessments have extended sampling significantly downstream (Figure 1). The assessments prior to 1990 were within an area 15 km above and below the Elliott Highway bridge. This section of the Chatanika River is characterized by moderate gradient, with short meandering stretches interspersed with gravel riffles, and has been thought to provide spawning habitat for the whitefish as well as being affected by the recreational spear fishery. In 1991, the study area was extended downstream an additional 83.7 km after detecting exploitation of whitefish tagged well below the spearfishing area (Timmons 1991). In 1991 the assessed sizes for least cisco included fish greater than 289 mm and humpback whitefish greater than 359 mm fork length (FL). Fish of these sizes were found to be recruited to the gear (electrofishing). Assessments since 1991 have used the same size thresholds for stock assessment. The addition to the study area included several different types of river habitat. Immediately downstream, moderate gradient habitat (described above) continues for 5 km before changing to a low gradient section of slow flows, with silt and sand bottom and high cutbanks. This middle low gradient stream type extends downstream 51.4 km, beginning with continuous meanders and oxbows which changes to long straight reaches. Then the river changes to a higher gradient, and continues 28.2 km to the end of the study area as a series of wide shallow runs and riffles, with coarse cobble and bedrock substrate.

Field Sampling

The mark-recapture experiment on the Chatanika River in 1994 began on 15 August, and was completed on 26 August with near identical timing to 1992 and 1993 assessments. There were two distinct sampling events. Sampling was performed by three crews, each with three persons. Two of the crews used pulsed DC electrofishing boats to capture fish, while the third crew performed mark-recapture sampling of captured fish in a separate boat. Each sampling event lasted five days and consisted of a single downstream pass by the three crews working together. The upstream limit of the 1994 study section was approximately 4 km upstream of the Elliott Highway bridge. The 1994 lower sampling boundary was downstream 98.1 km at the terminus of the Murphy Dome Road Extension.

Highway bridge. The 1994 lower sampling boundary was downstream 98.1 km at the terminus of the Murphy Dome Road Extension.

To limit holding time and stress of captured fish and to ensure an even distribution of marked fish in the study area, sampling was conducted as a series of 48 discrete "runs". A run consisted of 20 min of electrofishing in the downstream direction. In the upper and lowermost portions of the river, where the stream channel was confined, electrofishing boats were often fished in a staggered formation. In the middle portion, where the river was more typically wide and slow, boats were fished side-by-side along each bank. Variable voltage pulsator (VVP) settings were 60 Hz pulse DC ranging from 190 to 250 volts and 2 to 7 A. Water conditions were low and clear with the exception of the last two days of the second sampling event, in which reduced water clarity coincided with a rising hydrograph. Water temperatures ranged between 8.0°C and 11.0°C. Stunned fish were dipped and placed into large aerated live wells to await sampling. At the completion of each run, labeled flagging was staked and left at the downstream sampling end-point for later reference. At each flagged location, a global positioning system (GPS) unit determined near-exact location for later referencing of release-recapture information. All captured fish in the first sampling event were measured to the nearest millimeter FL, fin clipped (upper caudal clip), and tagged with an individually numbered gray Floy FD-67 internal anchor tag at the base of the dorsal fin. During the second (recapture) sampling event, all fish were examined for marks, measured, and fin clipped (lower caudal clip). Additionally, scales were systematically collected, gently cleaned, and mounted directly onto gum cards for later pressing and aging. Fish with tag losses were given new tags, and previous fin clips were noted. Data collection procedures from previously marked humpback whitefish and least cisco were similar, but previous fin clips, tag losses, tag numbers, and colors were also recorded. All data was recorded on Alaska Department of Fish and Game Tagging Length Form, Version 1.0.

ABUNDANCE ESTIMATION

A closed-model mark-recapture experiment was used to estimate the abundance of whitefish in 1994, similar to the approach used in 1992 and 1993. The use of a closed-model abundance estimator using mark-recapture experiments assumes the following (Seber 1982):

1. the population in the study area must be closed, i.e. the effects of migration, mortality, and recruitment are negligible;
2. all whitefish have the same probability of capture during the first sample or in the second sample or marked and unmarked whitefish mix completely between the first and second samples;
3. marking of whitefish does not affect their probability of capture in the second sample; and,
4. whitefish do not lose their mark between sampling events.

Sampling was designed to lessen risks associated with closure (assumption 1) by shortening the duration of the mark-recapture experiment considerably and sampling as much of the river as practically feasible. It was improbable that substantial migration, mortality, or recruitment occurred during the seven day hiatus given the large size of the sampling area. This assumption could be partially examined through comparison of the marked-to-unmarked ratios in the lowermost section (subject to immigration from fish downstream). Assumptions 2 and 3 were examined for size and geographic differences in capture probability. Size selectivity was tested with two Kolmogorov-Smirnov two-sample tests (KS tests). The first test examined the cumulative length frequency distributions of marked fish with those recaptured. The second test compared cumulative length frequency distributions of fish from the first (mark event) and second (recapture event) samples. The results of these tests suggested methods to alleviate size bias (Appendix A1). Spatial differences in capture probability were evaluated through comparisons of area specific recapture-to-catch ratios. When statistically significant differences were detected, an iterative series of chi-square tests using recapture and catch locations detected the location in the sampling area where differences in capture probability were maximized. If the chi-square statistic (1 df) was statistically significant at this location, the mark-recapture experiment could be stratified. The last testable assumption was met by double marking each fish, with a tag and a fin-clip specific to the 1993 mark-recapture experiment.

The two KS tests indicated that only first event sampling was size selective for each of the two species, not requiring further stratification of the data. Capture probabilities did not vary significantly among the sampled areas. Because the assumption of equal capture probability was not rejected, the modified Petersen estimator of Bailey (1951, 1952) was selected. Bailey's modification was used because of the systematic sampling approach and the level of mixing (localized, not complete; Seber 1982) of marked and unmarked fish over the length of the sampling area (Seber 1982). Unstratified point estimates of abundance were calculated as:

$$\hat{N} = \frac{M(C+1)}{(R+1)} \quad (1)$$

where:
- M = the number of fish marked and released during the marking event sample;
- C = the number of fish examined for marks during the recapture event;
- R = the number of fish recaptured during the second sampling event (recapture); and,
- $\hat{N}$ = estimated abundance of fish.

Variance of the abundance estimate was estimated by (Bailey 1951, 1952):

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

AGE AND SIZE COMPOSITION

Apportionment of the estimated abundance among age or size groupings depends on the extent of sampling biases. The outcome of tests for size selectivity, and chi-square tests to detect geographic differences in capture probabilities, determined the necessary adjustments. When no adjustments were required for length selectivity or geographic differences in capture probability, the proportion of fish at age *k* (or length class *k*) was estimated using the appropriate sample (Appendix A1: from the first event, second, or both events) by:

$$\hat{p}_k = \frac{y_k}{n} \quad (3)$$

where: $\hat{p}_k$ = the proportion of fish that are age or length class *k*;

y_k = the number of fish sampled that are age or length class *k*; and,

n = the total number of fish sampled.

The unbiased variance of this proportion was estimated as:

$$\hat{V}[p_k] = \left[\frac{\hat{p}_k(1-\hat{p}_k)}{(n-1)}\right]. \quad (4)$$

Other stock assessment categories utilized the same approach, where substitutions for class were: age classes and 10 mm FL incremental size groupings. Incremental size composition categories were 10 mm FL groupings with mid-points 295 to 395 mm FL for least cisco and 365 to 495 mm FL for humpback whitefish.

SURVIVAL, MORTALITY, AND EXPLOITATION

A second examination of survival, mortality, and exploitation was facilitated by consecutive annual stock assessments conducted in 1993 (Fleming 1994) and this assessment. Creel survey harvest estimates (Hallberg and Bingham 1994) provided point estimates of humpback whitefish and least cisco harvests for the 1993 spear fishery. Because sampling in 1993 did not cover the entire portion sampled in 1994, abundance estimates from 1994 (102.1 km) were re-estimated to the shorter (78.2 km) 1993 study area for survival estimation and comparison purposes. Care was taken to remove all records of fish downstream of the 1993 lower study area boundary that were handled (marked, examined, or recovered from) prior to the re-estimation. The re-estimated abundances were then apportioned by age class using 1994 composition estimates.

Survival was estimated as the proportion of the summed abundance from a portion of an age series at one time (year t), that are estimated to be present at a later time (Ricker 1975). Only ages that appear to be fully recruited were used as the portion of an age series. Abundance-at-age estimates beginning in 1992 (Fleming 1993) indicated humpback whitefish age 7 years and older and least cisco age 3 years and older were fully recruited at the time and location of the stock assessment. The ages at full recruitment for the present investigation were assumed to be the same, so that comparisons with previous estimates of survival, mortality, and exploitation (Fleming 1994) could be made. The annual survival rate *S*, was estimated as:

$$\hat{S} = \frac{\hat{N}_{t+1}}{\hat{N}_t} \quad (5)$$

where:

$\hat{S}$ = the estimated proportion of humpback whitefish age 7 and up (k = 7, 8, 9, 10,...15) in year t that survive to year t+1 as age 8 and up (k=8, 9, 10, 11,...16);

$\hat{N}_t$ = the summed estimated abundance of humpback whitefish age 7 years and up in year *t*; and,

$\hat{N}_t+1$ = the summed estimated abundance of humpback whitefish age 8 years and up in year *t+1*.

The variance of $\hat{S}$ was approximated with the delta method (Seber 1982; ignoring hat symbols) as:

$$V[\hat{S}] \approx \left[\frac{N_{t+1}}{N_t}\right]^2 \left[\frac{V[N_{t+1}]}{[N_{t+1}]^2} + \frac{V[N_t]}{N_t^{\,2}}\right] \tag{6}$$

where the variance for N_t and N_{t+1} were each estimated as a sum of the exact variance of a product from Goodman (1960):

$$V[\hat{N}_t] = \sum_{k=7}^{15} (V[\hat{p}_k]\hat{N}_{93}^{\,2} + V[\hat{N}_{93}]\hat{p}_k^{\,2} + V[\hat{p}_k]V[\hat{N}_{93}]) \tag{7}$$

and,

$$V[\hat{N}_{t+1}] = \sum_{k=8}^{16} (V[\hat{p}_k]\hat{N}_{94}^{\,2} + V[\hat{N}_{94}]\hat{p}_k^{\,2} + V[\hat{p}_k]V[\hat{N}_{94}]) \tag{8}$$

where:

$\hat{N}_{93}$ = the abundance estimate for humpback whitefish $\geq$ 360 mm FL in 1993; the variance of $\hat{N}_{93}$ was from the point estimated variance for the unstratified Petersen model (reported in Fleming 1994). The 1993 estimate was for a 78.2 km section of the Chatanika River;

$\hat{N}_{94}$ = the abundance estimate for humpback whitefish $\geq$ 360 mm FL in 1994; the variance of $\hat{N}_{94}$ was from the point estimated variance for the unstratified Petersen model. The 1994 estimate was only adjusted to reflect the same study area as the 1993 estimate for the purpose of estimating survival and other related parameters; and,

$\hat{p}_k$ = the unadjusted fraction of the fish in age class k from 1993 and the unadjusted fraction from the 1994 stock assessments.

Identical procedures were used with least cisco except that the age series used to estimate survival were 3 years and older in *year t*, and 4 years and older in *year t+1*. Additionally, the 1993 estimated abundance of least cisco was stratified by size, and adjusted fractions were used in the analysis. The annual survival rate was converted into annual and instantaneous rates of mortality with respect to the following relationships (from Ricker 1975):

Z = the instantaneous total mortality rate;

Z = -Ln (S);

F = the instantaneous rate of fishing mortality;

M = the instantaneous rate of natural mortality;

Z = F + M;

A = the annual mortality rate; and,

A = 1 - e^{-Z}, where e ≈ 2.71828; *and* A = 1 - S.

The survival rates estimated for humpback whitefish age 7 and older, and least cisco age 3 and older were assumed to be representative and applied only to the assessed stock. In order to apportion total instantaneous mortality (Z) among fishing (F) and natural (M) mortality components, Baranov's catch equation (Ricker 1975) was rearranged and solved for *F*:

$$F = \frac{Z}{A} * \frac{C}{N} \tag{9}$$

where:

C = the 1993 estimated harvest of humpback whitefish or least cisco (Hallberg and Bingham 1994) from the Chatanika River spear fishery;

N = the 1993 abundance estimate of humpback whitefish or least cisco in the Chatanika River ; and,

Z = the estimated total instantaneous mortality rate calculated for apparently recruited year classes (humpback whitefish: age 7 and older, least cisco: age 3 and older).

Recruited year classes were age classes whose representation (proportion or abundance) had reached a maxima.

Before estimating natural mortality and exploitation parameters, a classification of the whitefish fishery was needed to select estimator formulae. The two types proposed by Ricker (1975) are:

Type 1= where natural mortality occurs during a time of year other than the fishing season; the population decreases during the fishing season because of catch (harvest) removals only; or,

Type 2= where natural mortality occurs along with fishing; each occurs at a constant instantaneous rate, or the two rates vary in parallel fashion.

Based upon present insights into the basic life history for both species of whitefish, the Type 1 classification was selected. The rate of exploitation (u) estimated for a Type 1 fishery was (Ricker 1975):

$$u = 1 - e^{-F}.$$

The expectation of natural death was estimated (Ricker 1975):

$$v = n(1-u)$$

where:

v = expectation of natural death;

n = conditional rate of natural mortality, which is calculated as (from Ricker 1975); and,

n = $1-e^{-M}$.

MINIMAL MIGRATION INVESTIGATION

Previous investigators sought to understand the geographic range of the exploited stock by tag recoveries from fish released in the lower Chatanika River and Minto Flats (Timmons 1991). In these studies, contributions were estimated with regard to the area of release, but not with reference to time, which is a major factor for migratory fish within a river corridor. It is now known that some fish released in the lower river during 1991 entered the area of the fishery (Fleming; *Unpublished*). The current investigation tested to see if whitefish present in the lower Chatanika River, at a time after completion of the stock assessment, eventually migrated to the area of the fishery by the end of the spearfishing season. A mark-recapture experiment was designed to test if the level of migration is equal to or exceeds 10%, 90% of the time. Hypothesis testing of a minimal migration level was based on the following relationship (Pat Hansen; Alaska Department of Fish and Game- personal communication):

$$\alpha \cong \left[1-\frac{xy}{\hat{n}}\right]^{t} \qquad (12)$$

where:

- α = probability of a type I error;
- x = the number of whitefish to be examined;
- $\hat{n}$ = the estimated abundance of whitefish in the river;
- y = the minimal detectable migration rate; and,
- t = the number of marked whitefish available for potential capture.

The additional mark-recapture experiment was conducted in the Chatanika River in September 1994. On September 8-9, least cisco and humpback whitefish were sampled in an area 45 km upstream of the lower stock assessment boundary (Figure 1) and released bearing Floy anchor tags and adipose fin clips. On September 30, recovery sampling was conducted in a 5 km section downstream of the Elliott Highway bridge, which corresponded to the traditional area of the spearfishery. All sampling was performed by a single electrofishing crew of three persons. All capturing, sampling, and data collecting followed methods outlined earlier in this report.

The hypothesis testing was conducted with the recovery or non-recovery of a single fish released on September 8-9 in the lower portion of the river. The recovery of one tagged fish served to conclude that the migration rate from the lower river in September is at least 10%.

MATURITY INVESTIGATION

The life history of Chatanika River whitefish has been assumed to follow a pattern of annual spawning, but other than subsequent-year recapture of tagged fish in spawning areas, this assumption has never been rigorously examined. To date, investigators have found that fish sampled in the upper Chatanika River during late September are often visibly mature, based on the extrusion of sex products (Timmons 1990, 1991). Alt (1974, 1979) indicated that the onset of maturity for male and female humpback whitefish was 4 and 5 years, while least cisco were 2 and 3 years, respectively. Whitefish have been found to adapt to harsh northern climates by reductions to reproductive efforts, such as skip- or non-consecutive spawning (Morin et al. 1982). When this occurs, the sampled proportion of fish by age class that are mature may fail to reach

100% mature at any age. Along the Eastern shore of James and Hudson Bays, the maximum proportion mature in samples by age were approximately 80% for cisco and 75% for lake whitefish (Morin et al. 1982).

The presence of skip- or nonconsecutive spawning should be determined before size and age-at-maturity relationships can be accurately described for Chatanika least cisco and humpback whitefish. In an initial investigation, fish were visually examined for sexual maturity. Fish included in the study were screened to correspond to the mean lengths of age 5 least cisco and age 9 humpback whitefish. As a result, selected threshold sizes included least cisco greater than 349 mm FL and humpback whitefish greater than 449 mm FL (Fleming 1994; Appendices A3 and A4, respectively). These larger sizes were selected to lessen risks of including immature or first-time spawning fish by using onset ages and sizes of maturity reported by Alt (1974, 1979).

Fish were collected using electrofishing gear during early- and late September in the minimal migration study (September 8-9, and September 30, respectively) and while capturing fish for the radio telemetry project (September 20-27). Captured fish were sampled for size and examined for maturity. A fish was classified as mature if sex products were released when the fish was gently squeezed or "stripped".

The hypothesis testing included estimation of the binomial probability (in percentage) of immature non-virgin fish among fish above the selected threshold sizes.

RADIO TELEMETRY OF HUMPBACK WHITEFISH

Least cisco and humpback whitefish have been found inhabiting both river and lake areas within the Chatanika River and Minto Flats complex. To date, no information exists to define the level of geographic closure and geographic range of whitefish stocks assessed in the Chatanika River during August and September. If 100% of the fully recruited least cisco and humpback whitefish return each year to the Chatanika River at the same time, with no individuals present from other stocks, then closure exists at this time of year for these stocks. In recent years several tagged humpback whitefish from the Chatanika River were recovered as much as 415 river kilometers away (D. Fleming, *Unpublished*) during July and September in the year following release. Additionally, mature least cisco and humpback whitefish have been sampled in the upper Tolovana River during 1984 (A. Townsend, Alaska Department of Fish and Game, Habitat Division, personal communication). Although it is known that humpback whitefish and least cisco are harvested by subsistence fishers in Minto Flats (Andrews 1988), it is not known whether these traditional fisheries exploit whitefish that spawn in the Chatanika River.

The seasonal locations of radio-tagged humpback whitefish were sought for three purposes:

1. to determine if the Chatanika River stock of humpback whitefish is *closed* or *open*; to assess geographic range of humpback whitefish found in the Chatanika River; and,
2. to assess the level of annual fidelity to assessed areas of the Chatanika River over several years of study, to detect whether non-consecutive spawning occurs.

To date, there have been no other studies conducted using radio telemetry with either least cisco or humpback whitefish. Alt (1986) surgically implanted a radio tag into a humpback whitefish during a study on sheefish *Stenodus leucichthys*, but no tracking data was collected. Several other studies used radio telemetry with whitefish to locate spawning areas, including Arctic cisco

Coregonus autumnalis (Chan-Kue and Jessop 1991), and round whitefish *Prosopium cylindraceum* (King 1990).

Radio transmitters and their specifications were selected based on criteria that would allow:

1. Two years of tracking to establish spawning patterns (annual, alternate year) and geographic fidelity;
2. The ability to ascertain life-death status (to avoid extensive groundtruthing); and,
3. The collection of basic life history information related to migration, overwintering, and seasonal geographic ranges.

The radio tags selected were a modified Telonics™ CHP-4P transmitters designed for internal placement. Internal placement was desired due to the long duration of the investigation and to avoid potential fouling associated with externally mounted tags. The cylindrically shaped transmitters were 58 mm in length, and 20 mm in diameter. Transmitter output was conducted through a 260 mm multi-stranded stainless steel whip antenna (model TA-5LT; 1.02 mm diameter) which was shrink wrapped to prevent kinking and degradation of signal output. The weights of the transmitters (26 g) indicated that implanted fish would need to be 1,250 g or greater to follow the 2% in-air weight rule (Winter 1983). Using length-weight data collected by Townsend and Kepler (*Unpublished data*) humpback whitefish ≥ 450 mm FL weigh between 1,250 and 3,000 g. Recent assessment indicated that natural mortality for similarly sized humpback whitefish could be as high as 50%. A sample size of 52 radio transmitters was selected to allow estimation of the proportions with 15 percentage points 90% of the time with this level of natural mortality and a potential tag failure rate of 15%.

Frequencies selected for the transmitters ranged from 149.010 mhz to 149.594 mhz. The modified configuration of the transmitter included higher than standard signal output, hermetic sealing, and an integrated mortality sensor. Higher output was desired to assist locating fish while inhabiting the Minto Flats area or areas beyond. Hermetic sealing was selected for greater assurance against tag failure by water infiltration. The mortality sensor included a custom logic feature where inactivity of the fish beyond a threshold time limit would trigger a change in the transmitter output signal. If the fish remained active, the radio tag was designed to pulse signals at 30 beats per minute (BPM). If no more than 10 switch triggers occurred in a 9 h period, the pulse rate was doubled to 60 BPM, denoting that mortality was likely. If in the following 9 h activity increased (11 or more switch triggers) the transmitter resumed "live" status and pulse rate (30 BPM).

Tag performance for each tag was evaluated prior to implantation. Each tag was weighed to the nearest gram, and the functioning of the mortality switch was checked after 18 h storage, and again after tags were subjected to movement. The optimum frequency for each tag was determined at ambient (24° C) and freezing conditions (0° C) while immersed in an ice-bath.

Fish were captured by a pulsed DC electrofishing boat and three person crew. Handling, sampling, and data collection followed methods outlined earlier with exceptions related to the implanting of radio transmitters. Fish that were 450 mm FL and larger were retained in the aerated live tank until the surgical procedure. Fish were anesthetized with MS-222 at a concentration of 55 PPM in a 95 L plastic cooler. After losing equilibrium and reaching stage 3-4 anesthesia (Summerfelt and Smith 1990), fish were weighed to the nearest gram using a 5,000 g self-taring digital balance. Fish were then placed in a tagging cradle so that the ventral surface was upright. The fish's position was supported throughout the surgical procedure by water-soaked towels draped inside of the plastic trough-shaped cradle. Depending on the anesthesia stage and progress of the surgery, fish were irrigated with either additional anesthetic solution or fresh river water using a plastic "squirt" bottle.

All tools (scalpels, hemostats, and curved antenna threading needles) and radio transmitters were placed, cleaned, and temporarily stored in a cold sterilant (Novlasan™) prior to each surgery. At the incision site, scales were removed to allow the incision and suturing to be unimpaired by the heavy scales found on the ventral surface. The incision site was treated with 70% isopropyl alcohol, and a 20 mm incision was made with a scalpel. The end of the antenna was guided past the pelvic girdle and through an exit, created by a large suturing needle. Transmitters were inserted into the coelomic cavity, and rested immediately foreword of the pelvic girdle (Hart and Summerfelt 1975). Prior to suturing each fish, a topical antibiotic (Furacin powder) was spread in the coelomic cavity and on the incision wound. Fish were sutured with 3/0 Ethicon™ PDS monofilament sutures with an FS-1 curved cutting needle. Four to five sutures using surgeon's knots closed the incisions so that the skin and body wall were penetrated. The incision was then treated with 70% isopropyl alcohol before sealing the sutures and incision wound with Vetbond™ (Animal Care Products, 3M© Company), a cyanoacrylate tissue adhesive. After air-drying the adhesive for 30 s, fish were placed in the aerated livewell for recovery from the anesthesia. Upon regaining equilibrium, fish were released in quiet backwater areas of the Chatanika River and monitored as they swam away.

Radio tracking was primarily conducted using aircraft, but boats were used on several occasions for groundtruthing fish late in the study. Aerial tracking of the radio-tagged humpback whitefish was conducted using an Alaska Department of Fish and Game Cessna 185 aircraft. The aircraft was outfitted with a five-element Yagi antenna vertically mounted on the wing strut. The antenna wiring included a splitter and intercom isolating circuitry which allowed two tracking receivers to be operated independently by two biologists. Because the 52 tags had a 30 BPM pulse rate, the cycling time was too slow to use one radio without the risk of missing fish. The 52 frequencies were then split between the two receivers. One receiver was a Telonics™ TR-2 receiver coupled with a TS-1 scanner, and the other was a Lotek™ SRX_400 telemetry receiver. Trackings were conducted at altitudes ranging from 800 to 2,500 feet above ground level. When a fish's signal was heard, the scanning stopped and the airplane was maneuvered to pin-point the location of the fish. An onboard Global Positioning System (GPS) was used to determine and log the near exact location of the fish. Search paths for tracking primarily concentrated on the Chatanika River, Minto Flats, and its tributary rivers. On several occasions, the Tanana River from the mouth of the Kantishna River to Moose Creek, near North Pole, was included when some fish were not located in the primary study area. Aerial trackings were conducted during November 1994, January, March, April, May, June, early and late July, and September 1995.

Groundtruthing was conducted after late-Spring and summer trackings revealed that many fish remained in the Chatanika River during the summer. Primary groundtruth tracking was conducted from a 6.1 m aluminum riverboat, using a five element Yagi antenna which was mounted on a post on the bow of the boat to avoid interference from ignition circuitry in the outboard motor. One biologist listened to the scanning receiver through headphones while the other operated the boat. Using resistor type spark plugs, noise suppression was sufficient to operate the boat at speeds of approximately 30 km per hour. After initially hearing a signal, secondary tracking began. Secondary tracking included slow movement of the boat and tracking with the Lotek receiver set to a minimum gain and coupled to a short (0.25 m) whip antenna. This configuration was very sensitive (sudden changes in the signal strength and sound level) and allowed operating the boat to within 2 m of the transmitting radio tag (fish). On some occasions (such as shallow water or on-shore locations), an H-type antenna was used to locate transmitters. When water depths or clarity precluded physically locating transmitters or seeing fish, a pulsed DC backpack electrofishing unit was used to displace or stun tagged fish. Generally one person operated the electrofishing unit (the anode ring deep into the water, with the cathode trailing) while the boat operator moved the boat in a grid-like fashion to cover the area in which the transmitter was located. Immediately following this, the location of the transmitting tag was reestablished. The fish was concluded to be dead if the location had not changed.

Latitude and longitudes for each located fish were recorded for analysis and mapping purposes. Other tabulated information included the number of fish located and the mortality status of those located during each tracking. Locational data collected by radio-tracking provided information with which several estimates could be calculated. Each aerial tracking survey yielded an estimated binomial proportion of fish present or not present in the targeted areas. The first estimate was the proportion of radio-tagged whitefish present in traditional subsistence fishing areas of Minto Flats as described in 1988 by Andrews. Similarly, the proportion returning to the Chatanika River was to be estimated to assess annual fidelity to spawning areas with respect to stock assessment timing and study-area coverage on the Chatanika River.

The locations of active radio-tagged fish were plotted after latitudes and longitudes were interpolated onto 1:63360 scale USGS topographic maps. Distances were measured between locations by digitizing. As a quality control measure to ensure the locations of fish were accurate, the ability to repeatedly locate a non-moving fish from aerial tracking was examined. This was accomplished using fish that were groundtruthed and found to have died. Distance measurements were estimated between the groundtruth location of a particular transmitter and all prior locations from aerial tracking. Straight line distances were estimated using the great circle equation.

RESULTS

SAMPLING

A total of 2,582 humpback whitefish ($\geq$ 360 mm FL) and 2,873 least cisco ($\geq$ 290 mm FL) were captured over a 10-day period in the latter half of August. During the first sampling event, the water conditions were low and clear, with stream temperatures between 8.5 ^{O}C and 10.0 ^{O}C. Conditions during the second event were optimal until rainfall on August 24 caused higher water conditions on August 25-26. During the field investigation, 1,177 humpback whitefish ($\geq$ 360 mm FL) were marked and released alive over the 102 km study area in the first sampling event. In the second sampling event, 1,529 were examined for marks, yielding 125 recaptures. Concurrently, 1,218 least cisco ($\geq$ 290 mm FL) were marked and released alive in the first sampling event, and in the second sampling event 1,722 were examined for marks, yielding 70 recaptures.

The observed tag shedding rate from the marking to the recapture event was 2.4%, based on three of 125 humpback whitefish that were recaptured without tags, and 2.6% for least cisco based on two of 70 recaptures. The overall acute mortality rate from the experiment was one out of 2,582 individual humpback whitefish handled, or 0.03%. The overall acute mortality rate was 0.1% for least cisco, based on three mortalities from 2,873 fish.

ABUNDANCE ESTIMATION

A KS comparison of cumulative distribution functions (CDF's) from the humpback whitefish mark-recapture experiment failed to detect length selectivity in either sampling event (mark vs recaptures: D = 0.08, P = 0.44; and, mark vs catch: D = 0.04, P = 0.31). As a result, abundance was estimated using an unstratified approach with regards to size selectivity (Case I; Appendix A1). No significant differences were detected in capture probabilities (recapture-to-catch ratios) when examined by geographic area ($\chi 2$ = 2.57, df = 1, P = 0.277). Capture probabilities for the upstream (sampling runs 1-18), middle (sampling runs 19-35), and downstream (sampling runs 36-48) strata were 0.088, 0.083, and 0.058, respectively. Because of similar capture probabilities, the unstratified abundance was estimated using Bailey's modification to the Petersen estimator (Bailey 1951, 1952). The estimated abundance of humpback whitefish was 14,292 fish (SE = 1,215, CV = 8.5%) $\geq$ 360 mm FL. This estimate was based upon use of 125 recaptures (123 with complete capture histories, and 3 fish with shed tags).

A KS comparison of cumulative distribution functions (CDF's) from the least cisco mark-recapture experiment failed to detect length selectivity in either sampling event (mark vs recaptures: D = 0.06, P = 0.07; and, mark vs catch: D = 0.03, P = 0.79). As a result, least cisco abundance was estimated using an unstratified approach with regards to size selectivity (Case I; Appendix A1). No significant differences were detected in capture probabilities (recapture-to-catch ratios) when examined by geographic area ($\chi 2$ = 3.09, df = 1, P = 0.079). Capture probabilities for the upstream (sampling runs 1-18), middle (sampling runs 19-35), and downstream (sampling runs 19-39) strata were 0.043, 0.014, and 0.022, respectively. Because of similar capture probabilities, the unstratified abundance was estimated using Bailey's modification to the Petersen estimator (Bailey 1951, 1952). The estimated abundance of least cisco was 29,557 fish (SE = 3,410, CV = 11.5%) $\geq$ 290 mm FL. This estimate was based upon use of 70 recaptures (68 with complete capture histories, and 2 fish with shed tags).

AGE AND SIZE COMPOSITION

Scale samples were collected from 1,302 humpback whitefish, of which 906 were aged after an incidence of 28% regenerated or illegible scales. Ages observed for humpback whitefish in the Chatanika River ranged from 1 to 18 years for fish ranging between 360 and 560 mm FL. The predominant and median age class present among humpback whitefish sampled in the Chatanika River was age 9 (16% of the stock; Table 1) followed by age 10 (15%). The median-sized humpback whitefish was 439 mm FL, with a mode in relative abundance between 450 and 459 mm FL (Figure 2).

Scale samples were collected from 1,279 least cisco, of which 946 were aged after an incidence of 26% regenerated or illegible scales. Ages observed for least cisco in the Chatanika River ranged from 2 to 10 years for fish ranging between 290 and 450 mm FL, with 4 years as the median age. The predominant age class present among least cisco sampled in the Chatanika River was age 3 (29% of the stock; Table 2) followed by age 5 (27%). The median size least cisco was 335 mm FL, with the mode of abundance occurring between 330 to 339 mm FL (Figure 3).

Table 1.-Estimates of the sampled contributions by each age class and 10 mm FL incremental size groupings for humpback whitefish (≥360 mm FL) captured from the Chatanika River, August 22 through 26, 1994[a].

Age	Count[b]	P-hat[c]	SE[d]	Length	Count[b]	P-hat[c]	SE[d]
1	1	< 0.01	---	295	0	0.00	0.00
				305	0	0.00	0.00
2	1	< 0.01	< 0.01	315	0	0.00	0.00
				325	0	0.00	0.00
3	10	0.01	< 0.01	335	0	0.00	0.00
				345	0	0.00	0.00
4	81	0.09	0.01	355	0	0.00	0.00
				365	56	0.04	0.00
5	104	0.11	0.01	375	64	0.04	0.01
				385	75	0.05	0.01
6	52	0.06	0.01	395	83	0.05	0.01
				405	80	0.05	0.01
7	57	0.06	0.01	415	91	0.06	0.01
				425	122	0.08	0.01
8	96	0.11	0.01	435	161	0.11	0.01
				445	176	0.12	0.01
9	146	0.16	0.01	455	195	0.13	0.01
				465	144	0.10	0.01
10	142	0.15	0.01	475	107	0.07	0.01
				485	76	0.05	0.01
11	94	0.10	0.01	495	43	0.03	0.00
				505	21	0.01	0.00
12	64	0.07	0.01	515	7	< 0.01	0.00
				525	6	< 0.01	0.00
13	21	0.02	0.01	535	3	< 0.01	0.00
				545	1	< 0.01	0.00
14	17	0.02	< 0.01	555	1	< 0.01	0.00
				565	1	< 0.01	0.00
15	7	0.01	< 0.01	575	0	0.00	0.00
				585	0	0.00	0.00
16	11	0.01	< 0.01	595	0	0.00	0.00
				605	0	0.00	0.00
> 16	2	< 0.01	< 0.01				
Totals	904	1	---	Total	1,513	1.00	----

[a] Stock assessment was conducted between August 15 and 26, but age sampling occurred only during the second event, August 22 through 26.

[b] p = unadjusted proportion of humpback whitefish in the assessed stock at the time of the second sampling event, August 22 to 26, 1994.

[c] N= number of individuals sampled in each age class or 10 mm FL incremental size class.

[d] SE = standard error of the proportional contribution.

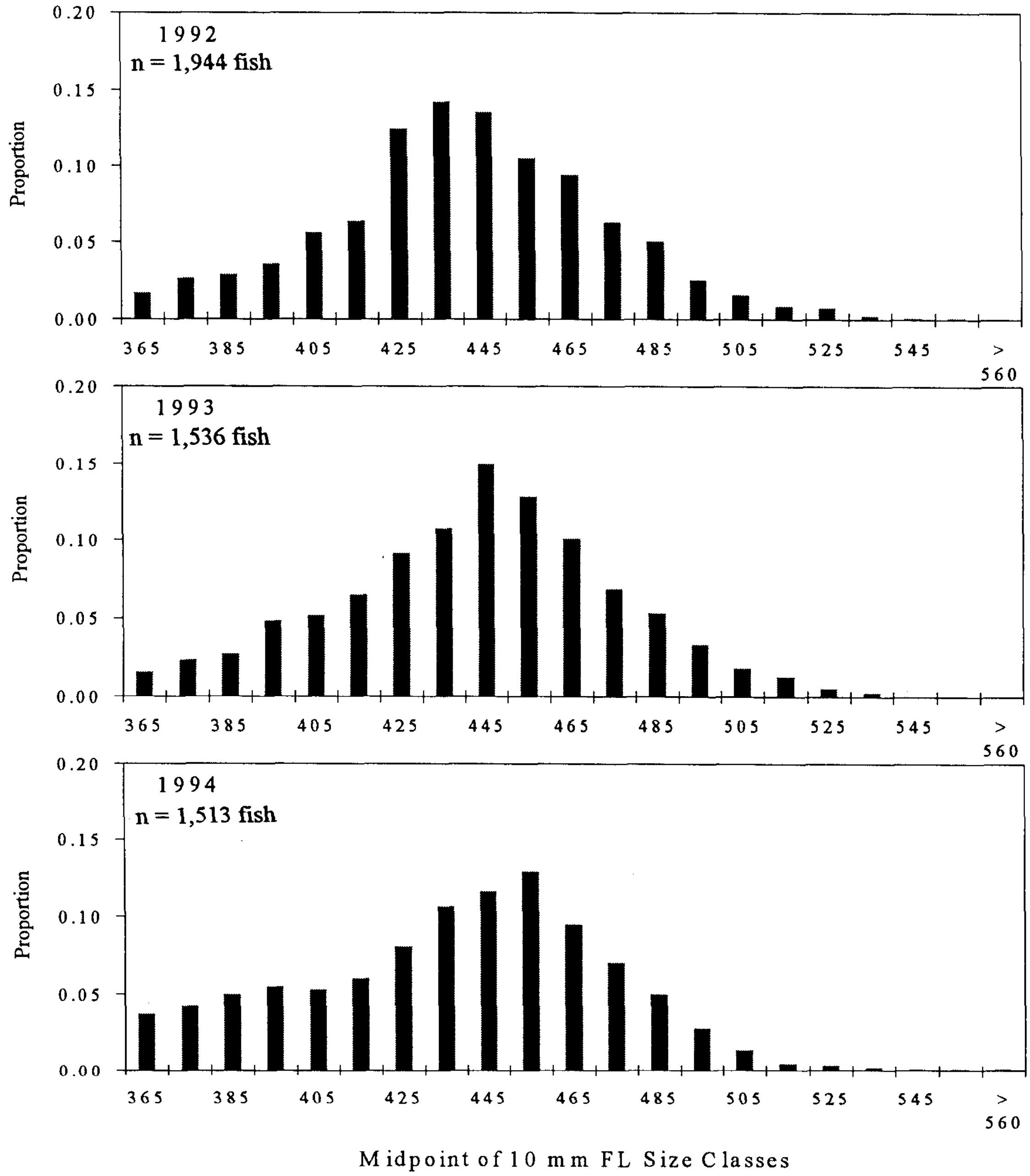

Figure 2.-Estimated proportion of humpback whitefish by length (≥ 360 mm FL) in the Chatanika River during 1992-1994.

Table 2.-Estimates of the sampled contributions by each age class and 10 mm FL incrementalsize groupings for least cisco (≥290 mm FL) captured along the Chatanika River, August 22 through 26 1994[a].

Age	Count[b]	P-hat[c]	SE[d]	Length	Count[b]	P-hat[c]	SE[d]
1	0	0.00	0	295	63	0.03	0.00
				305	92	0.05	0.00
2	16	0.02	< 0.01	315	191	0.10	0.01
				325	283	0.14	0.01
3	278	0.29	0.01	335	347	0.18	0.01
				345	331	0.17	0.01
4	222	0.23	0.01	355	256	0.13	0.01
				365	180	0.09	0.01
5	256	0.27	0.01	375	116	0.06	0.01
				385	72	0.04	0.00
6	79	0.08	< 0.01	395	30	0.02	0.00
				400+	15	0.01	0.00
7	34	0.04	< 0.01	----	0	0.00	0.00
				----	0	0.00	0.00
8	46	0.05	< 0.01	----	0	0.00	0.00
				----	0	0.00	0.00
9	19	0.02	< 0.01	----	0	0.00	0.00
				----	0	0.00	0.00
10	1	< 0.01	< 0.01	----	0	0.00	0.00
				----	0	0.00	0.00
11	0	0.00	0	----	0	0.00	0.00
Total	951	1.00	----	Total	1,976	1.00	----

[a] Stock assessment was conducted between August 15 and 26, but age sampling occurred only during the second event, August 22 through 26.

[b] p = unadjusted proportion of least cisco in the assessed stock at the time of the second sampling event, August 22 to 26, 1994.

[c] N= number of individuals sampled in each age or 10 mm FL incremental size class.

[d] SE = standard error of the proportional contribution.

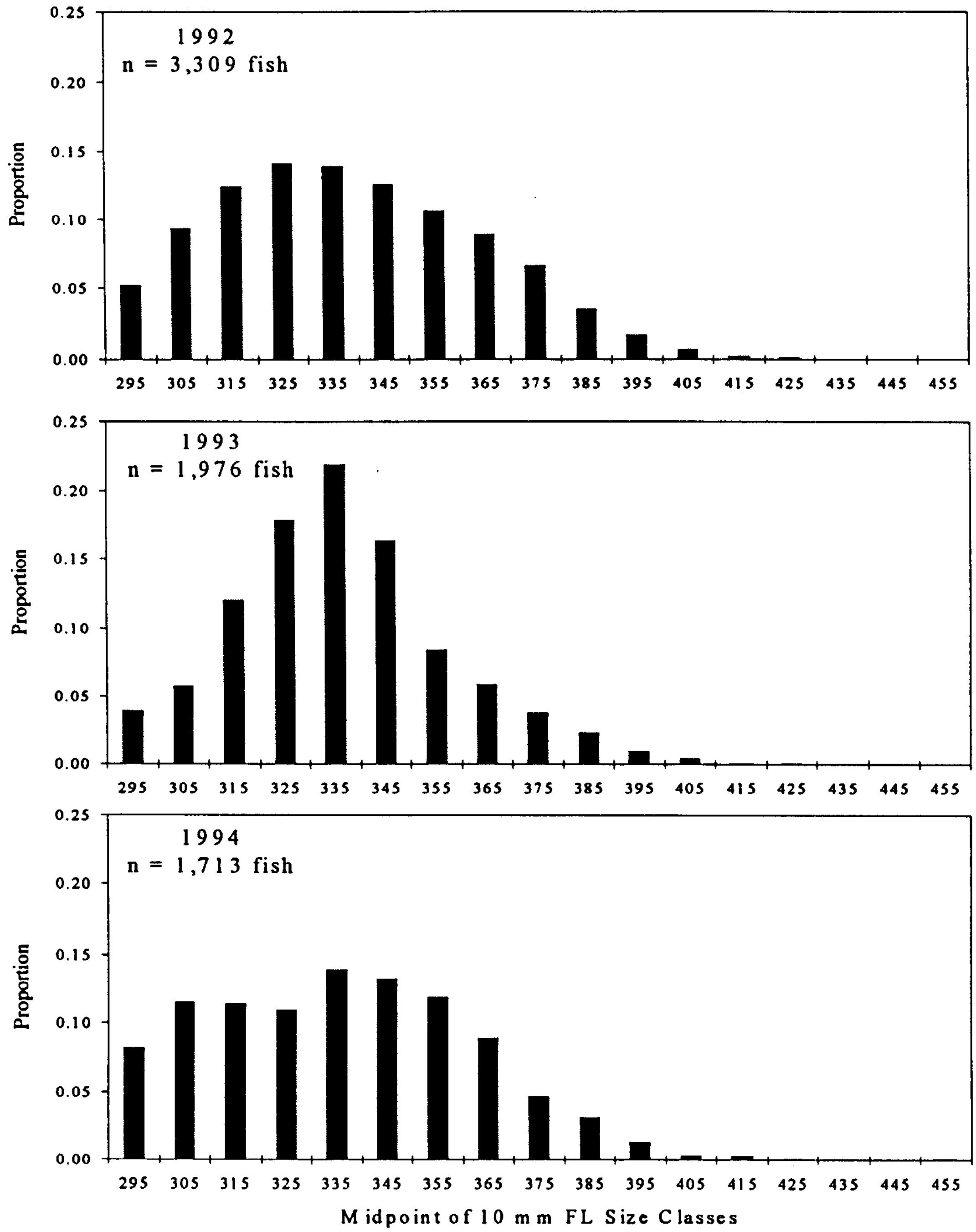

Figure 3.-Estimated proportion of least cisco by length (≥ 290 mm FL) in the Chatanika River during 1992-1994.

SURVIVAL, MORTALITY, AND EXPLOITATION

Survival was estimated for the portion of the Chatanika River whitefish that were defined as fully recruited to the assessed stock. Full recruitment was judged to be the condition when a group of fish (year class or size class) have become fully represented in catches. In the Chatanika River, humpback whitefish appear to be fully recruited to sampling gear at age 7, while least cisco are fully recruited by age 3. The 1994 estimated abundances of humpback whitefish and least cisco adjusted to the 1993 sampled area were estimated with Bailey's modification to the Petersen estimator. The estimated abundance of humpback whitefish in the 78.2 km section was 12,700 fish (SE = 1,138) $\geq$ 360 mm FL. The estimate for least cisco was 27,639 fish (SE = 3,211) $\geq$ 290 mm FL.

The fully recruited portion of the assessed humpback whitefish stock in 1993 was 9,972 fish age 7 years and older (Figure 4). Following the 1993 fishery, and overwintering, through 1994, it was estimated that 8,429 fish age 8 years and older, or 84.6% (SE = 6%), survived and were present. The 95% confidence range of the annual survival rate was 72 to 97%. The total instantaneous rate of mortality (*Z*) was 0.17. Recruitment of age 7 fish in the 78.2 km section during 1994 was 801 fish. Total recruitment (102 km) in 1994 was 901 fish.

The fully recruited portion of the assessed least cisco stock in 1993 was 45,680 fish age 3 years and older (Figure 5). Following the 1993 fishery, and overwintering, through 1993, it was estimated that 19,095 fish age 4 years and older, or 41.8% (SE = 4%), survived and were present. The 95% confidence range of the annual survival rate was 33% to 50%. The total instantaneous rate of mortality (*Z*) was 0.87. Recruitment of age 3 fish in the 78.2 km section during 1994 was 8,080 fish. Total recruitment (102 km) in 1994 was 8,630 fish.

Following the 1993 recreational spear fishing season, Hallberg (1994) estimated 87 humpback whitefish and 609 least cisco were harvested. The instantaneous rate of fishing mortality (F) was calculated by Baranov's catch equation. Instantaneous fishing mortality (F) was estimated at 0.007 for humpback whitefish and 0.03 for least cisco. Instantaneous natural mortality (M) was estimated at 0.16 for humpback whitefish and 0.84 for least cisco. The annual exploitation rates, or expectation of death attributable to the fishery (u), and the expectations of natural death (v) were estimated for both species. The estimated rates were as follows:

Source of Mortality:	Humpback Whitefish (1993 to 1994)	Least Cisco (1993 to 1994)
Fishery:	u = 0.7%	u = 3.2%
Natural:	v = 14.7%	v = 54.9%
Total:	A = 15.4%	A =58.1%

MINIMAL MIGRATION INVESTIGATION

On September 8-9, an electrofishing crew captured 433 least cisco and 85 humpback whitefish in the lower 45 km section of the Chatanika River. Fish were sampled and released bearing Floy anchor tags and an adipose fin clip. After a 22-day hiatus to allow for upstream migration, least

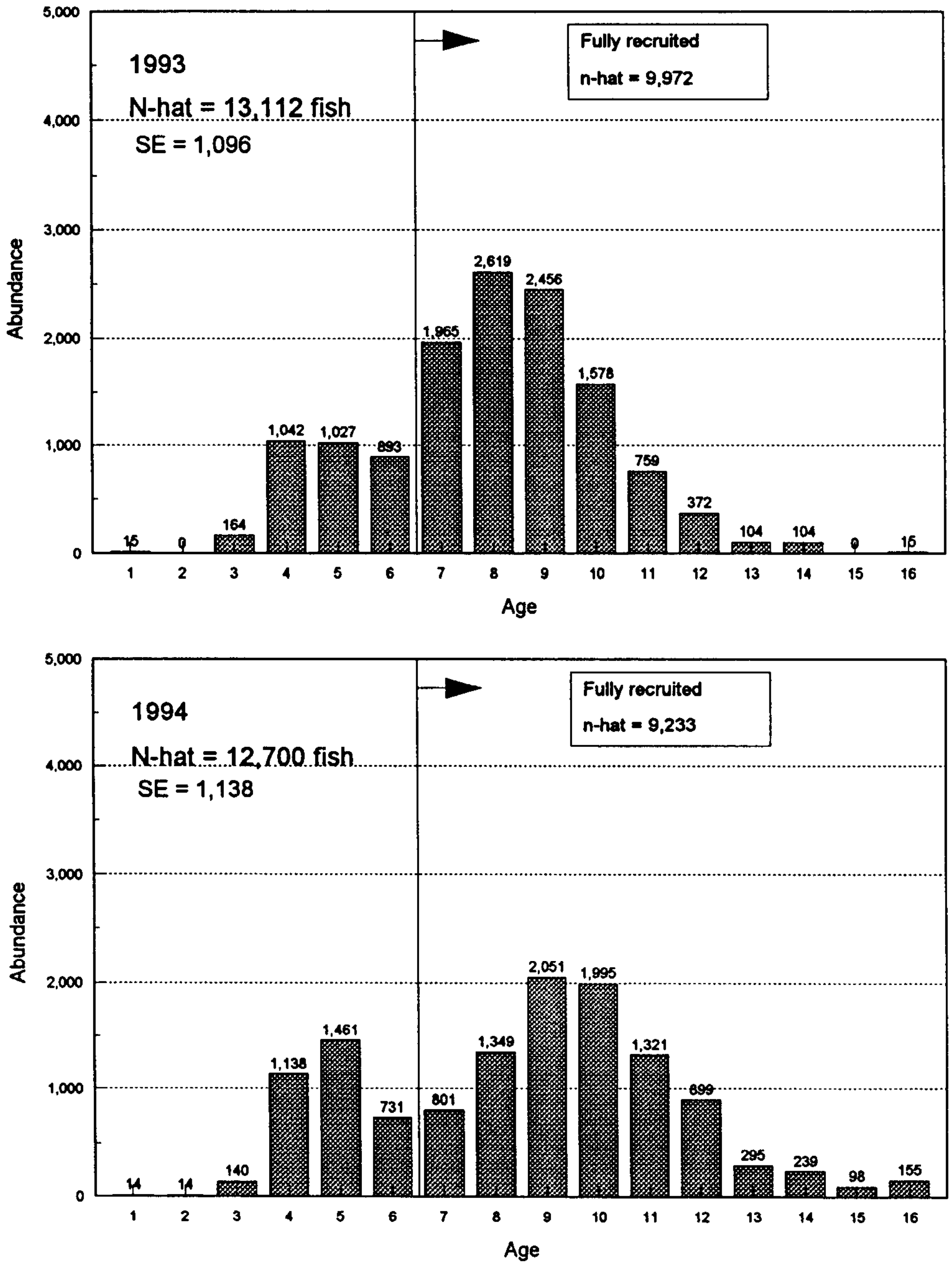

Figure 4.-Apportionment of estimated abundance by age class for humpback whitefish (≥360 mm FL) present in a 78.2 km section of theChatanika River during August 1993 and 1994.

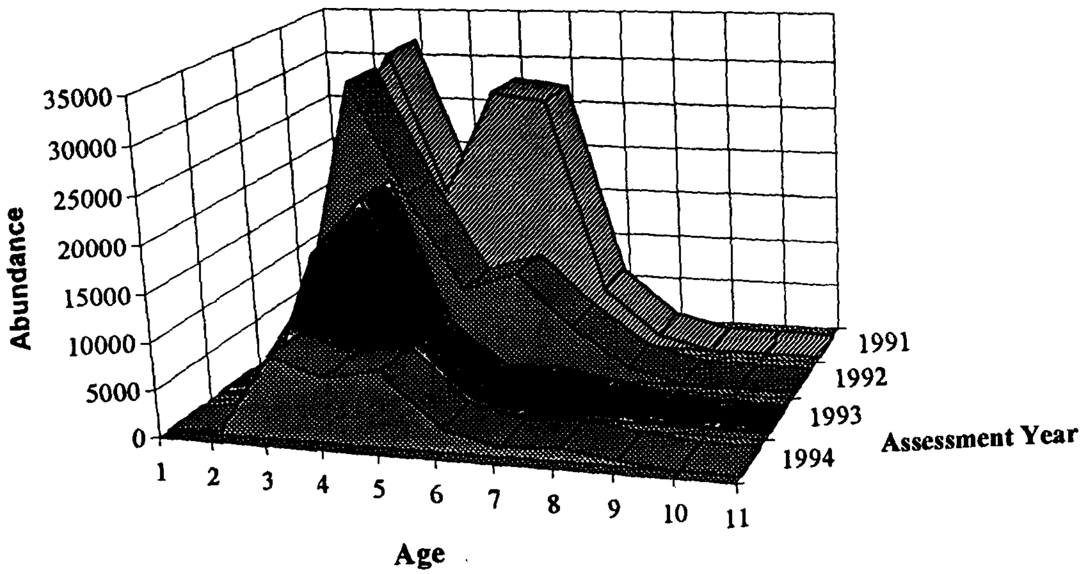

Figure 5.-Abundances of least cisco ≥290 mm FL apportioned by age classes, Chatanika River 1991-1994.

cisco and humpback whitefish were captured in the upper 5 km of the 102 km study area. On September 30, 229 least cisco and 75 humpback whitefish were captured in the area where the spearfishery has traditionally occurred. The catch included the recovery of two tagged least cisco but no tagged humpback whitefish from the downstream marking sample in early September. Additional sampling in late September conducted downstream of the fishery by as much as 15 river kilometers yielded only one additional tagged least cisco which was released in the lower river during the August stock assessment.

The upstream recovery of one or more tagged least cisco from the September release of 433 tagged fish served to reject the null hypothesis (Objective 4). This implies that at least 10% of the least cisco present in the lower river during early September migrate to the area of the fishery by the last scheduled day of the fishery, and our present estimates may likely be minimum estimates.

MATURITY INVESTIGATION

During all sampling conducted in September, each captured least cisco and humpback whitefish were visually examined for maturity. Each fish was classified as female, male, or unknown, based on the release of sex products when squeezed.

On September 8-9, 120 humpback whitefish and 491 least cisco were examined in the lower 45 km of the Chatanika River study area. All sizes of whitefish were examined. At this time, 20.8% of humpback whitefish and 21.7% of least cisco were identified as mature males or females. The sample of humpback whitefish was composed of 70.8% larger fish (≥360 mm FL) and 29.2% smaller fish (< 360 mm FL). The minimum size *mature* humpback whitefish detected in this sample was a 334 mm FL male. The sample of least cisco was composed of 88.4% larger fish (≥290 mm FL) and 11.6% smaller fish (< 290 mm FL). The minimum size *mature* least cisco detected in this sample was a 264 mm FL male.

Additional maturity data was collected on humpback whitefish and least cisco from September 20-30. During the surgical procedure to implant 52 radio transmitters into humpback whitefish, 45 of the fish were determined to be mature females. Only two of these large female humpback whitefish (0.04) gave eggs when squeezed prior to all surgical procedures. All seven males were identified as mature males prior to the surgical procedures.

During the recovery sampling in the migration study, a total of 347 humpback whitefish and 666 least cisco were examined between September 20-30, in the upper 15 km of the Chatanika River study area. Fifty percent of humpback whitefish and 80% of least cisco were identified as mature males or females. The sample of humpback whitefish was composed of 91.1% larger fish (≥360 mm FL) and 8.9% smaller fish (< 360 mm FL). The minimum size *mature* humpback whitefish detected in this sample was a 328 mm FL male. The sample of least cisco was composed of 97.0% larger fish (≥290 mm FL) and 3.0% smaller fish (< 290 mm FL). The minimum sized *mature* least cisco detected in this sample included a 263 mm FL male and a 283 mm FL female.

It was thought that sampling least cisco ≥ 350 mm FL and humpback whitefish ≥ 450 mm FL would represent non-virgin fish, that had spawned in other years. Information collected on maturity during September were grouped according to the date of sampling: early (September 8-9), middle (September 20-23), and, late (September 26-30). The sampled proportions for least cisco ≥ 350 mm and humpback whitefish ≥ 450 mm, blocked by early, middle, and late September sampling times expressed in percentages were:

	Least Cisco (≥ 350 mm FL)			Humpback Whitefish (≥ 450 mm FL)		
Sex / status	Early	Middle	Late	Early	Middle	Late
Female	10%	5%	45%	36%	3%	12%
Male	8%	36%	31%	18%	28%	24%
Unknown	82%	59%	24%	46%	69%	64%
Total	100%	100%	100%	100%	100%	100%
Sample size	51	63	90	11	39	41

While the incidence of unknown sex with least cisco declined over time, no clear changes were evident with humpback whitefish. The inclusion of smaller sizes of fish resulted in larger sample sizes, which appeared to clarify results for humpback whitefish:

	Least Cisco (≥ 290 mm FL)			Humpback Whitefish (≥ 360 mm FL)		
Sex / status	Early	Middle	Late	Early	Middle	Late
Female	3%	2%	25%	13%	2%	17%
Male	17%	67%	62%	13%	39%	42%
Unknown	80%	31%	13%	74%	59%	41%
Total	100%	100%	100%	100%	100%	100%
Sample size	432	251	395	85	181	135

Although fish were examined as late as September 30, substantial numbers of fish with unknown sex or maturity status were still present, particularly with humpback whitefish. Sampling beyond September 30 was precluded by freeze-up of the Chatanika River.

RADIO TELEMETRY OF HUMPBACK WHITEFISH

Weights of the radio transmitters ranged between 24 and 27 g and the median tag (measured in air) was 26 g. The measured frequency drift for the transmitters at 24° C and then 0° C ranged between +0.001 and +0.003 mhz; the median was +0.002 mhz. Tests determined that for all 52 transmitters, mortality circuitry functioned properly by switching pulse rates from 30 (active) to 60 BPM (inactive) after 18 h of stationary holding.

Fifty-two humpback whitefish ≥450 mm FL were selected from electrofishing catches of humpback whitefish and least cisco and surgically implanted with radio transmitters during the later half of September, 1994. The 52 fish were screened from a total catch of 347 humpback whitefish from a 15 km section of the Chatanika River downstream of the Elliott Highway. Specific statistics about the 45 female and 7 male implanted fish were:

Statistic:	Range	Median
Fish length	450 - 521 mm FL	468 mm FL
Fish weight	1,250 - 2,364 g	1,480 g
Fish age	9 - 14 years	9 years
Tag weight -to-fish weight	1.1 - 2.1 %	1.7%

Surgery times decreased from a high of 15 min total time, to an approximate average of 5 min per fish. None of the 52 humpback whitefish died during or shortly after the surgical procedures to implant radio transmitters. Following recovery from anesthesia, all fish swam off upstream.

Ten aerial trackings were conducted between November 1994 and September 1995. Statistics of these aerial trackings follow:

Tracking Dates	Transmitters Tracked	Transmitters Located	Percentage	Live (30 bpm) Status	Dead (60 bpm) Status
November 1	52	49	94%	10	39
January 10,12	52	50	96%	6	44
March 9	52	48	92%	6	42
April 18	52	49	94%	6	42
May 18	52	46	88%	5	39
June 15	5	3	60%	2	1
July 12	52	46	88%	2	44
July 24	15	10	67%	3	7
August 16	4	4	100%	0	4
September 14	28	18	64%	2	16

The overall success rate in locating fish by aerial tracking was 0.89 based on ten aerial trackings. Although some trackings did not seek to locate all fish, 44 of the 52 radio-tagged fish (85%) were located six or more times (median number locations per transmitter was seven). One fish was never located, and one fish was located ten times. Location error was estimated from 23 fish that were later found to be dead by groundtruthing. The estimated mean error in locating fish (precision) was 1.04 km and the median error was 0.61 km based on 139 measurements. Based on the location histories of the 52 fish, it is likely that four to five transmitters failed during the one year at large. These fish were located three-to-four times early in the study in near identical locations, and then were never located again. All tracking data is provided in Appendix B1.

During the winter months, 50 of the 51 located fish remained in the Chatanika River upstream of Goldstream Creek (Figures 1 and 6). In the January tracking, the remaining fish was relocated in the lower Tolovana River. Between the April and May trackings, six fish migrated down the Chatanika River to Minto Flats. Following the May tracking, no additional radio-tagged fish left the Chatanika River.

All seven migrating humpback whitefish either passed through, or were relocated in areas where traditional subsistence fisheries occur (Figure 7). The greatest detected movements were by two fish that migrated downstream to the Tolovana River drainage (150 km). One fish moved to the lower Tolovana River (163 km) between the September release and the January tracking. The other fish traveled to an area upstream of Minto Village, adjacent to Cooper Lake (170 km), between the April and May trackings. Both of these fish did not return to the Chatanika River and their transmitters remained in the mortality (60 BPM) mode through the September tracking. The remaining five fish entered Goldstream Creek and migrated to Big and Little Minto lakes between the April and May trackings, traveling at least 127 km from their release locations.

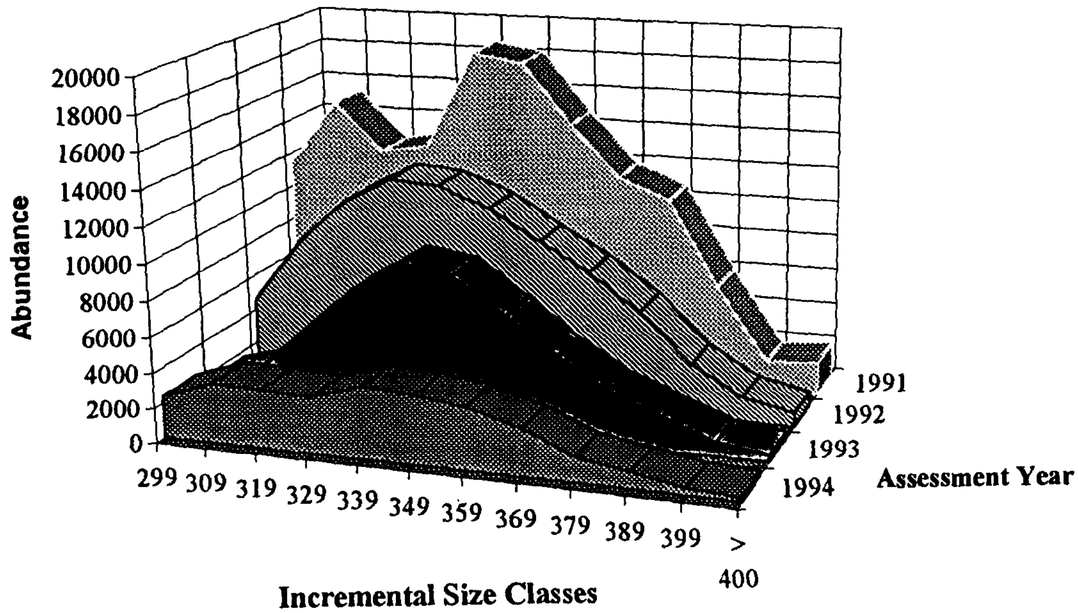

Figure 6.-Abundances of least cisco ≥290 mm FL apportioned by 10 mm FL incremental size groupings, Chatanika River 1991-1994.

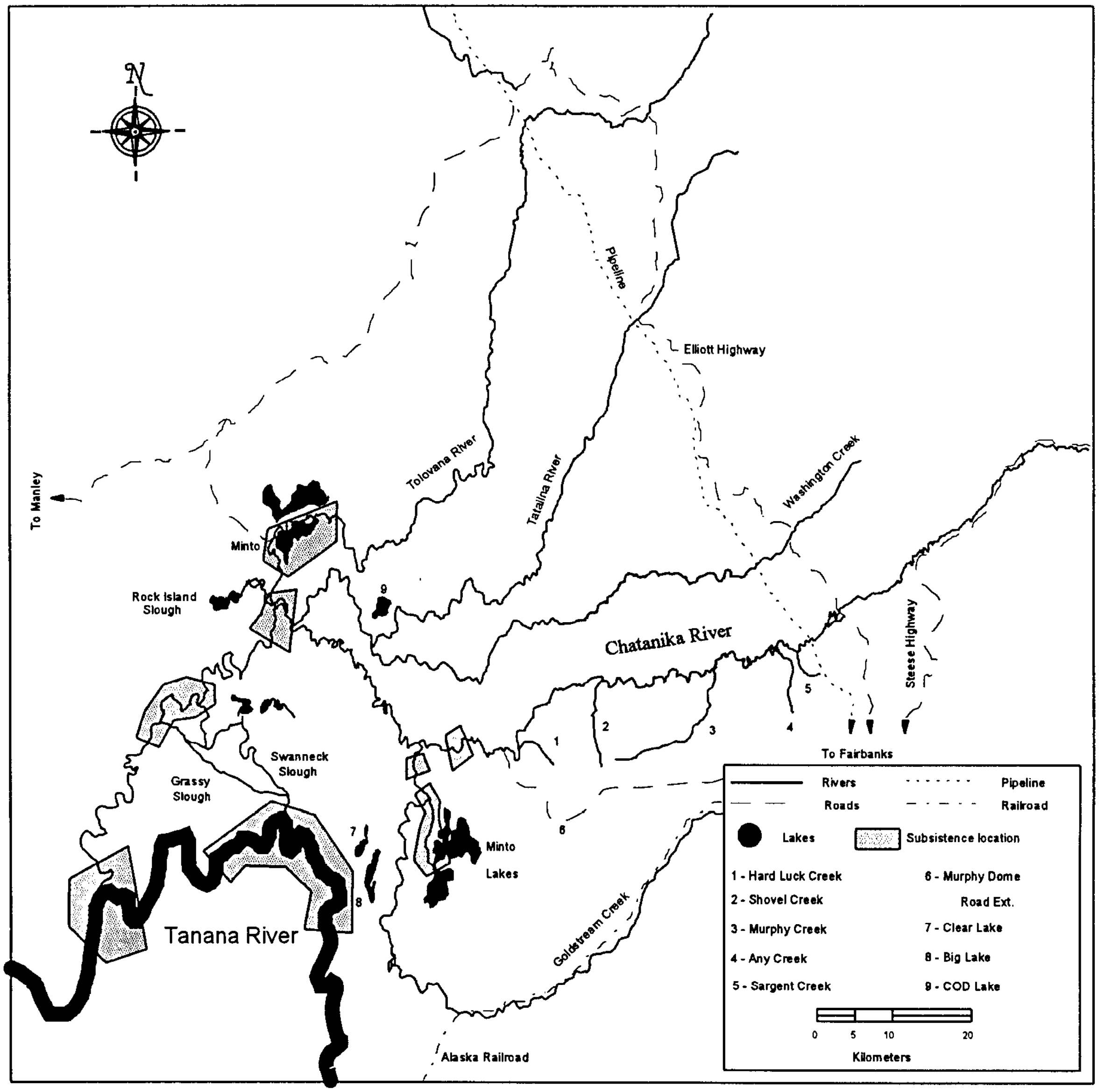

Figure 7.-Locations of reported subsistence harvest of whitefish (coregoninae family) by Minto villagers in 1984 (from Andrews 1988).

These five fish later returned to the Chatanika River sometime between the May and early July trackings. Of these, three fish remained between the Goldstream confluence and the lower boundary of the stock assessment sampling area through the September tracking. The transmitted mortality signal and lack of further movement indicated it was likely that these three fish died. Two surviving fish migrated back up the Chatanika River, into the stock assessment area on- or before July 12, 1995.

Large scale mortality was suspected when 39 fish remained in the Chatanika River following the May tracking, and again at the time of the early July tracking. On July 13-14 and July 23, the fates of 23 fish were determined by groundtruthing procedures. There were 41 fish in the river at that time. Between July and September, there were only five fish that indicated the "live" (30 BPM) status. The fates of these fish were as follows:

Fish Number:	Movement:	Fate:
21	Yes	**Live**: returned from Minto Flats, Live during ground truthing.
71	No	**Unknown**: was not located during groundtruthing.
181	No	**Dead**: tag found during groundtruthing.
462	No	**Unknown**: not located during groundtruthing.
511	Yes	**Live**: returned from Minto Flats, not groundtruthed.

Of the several fish transmitting live signals, two fish had returned from Minto Flats, and one other was confirmed dead by groundtruthing. The dead fish's tag was found on a shallow rock bar in turbulent flows which prolonged the "live" status signal. The two remaining fish were not located by groundtruthing, but were located by concurrent aerial radio-tracking. The suspected mortalities of 21 fish were confirmed using the groundtruthing procedures. A total of 22 fish were determined to have died from a total of 44 fish transmitting the mortality signal (60 BPM) during the late July tracking. Radio transmitters from dead fish were often in backwater areas where heavy silt deposits had buried the fish and or transmitters. In total, only two radio tags were physically recovered due to time constraints.

Because of the high level of mortality and resulting sample size of live or active fish (n = 7), the objective proportions were not estimated. Similarly, as a result of the high mortality, the project did not continue into a second year. Of the 52 fish released with implanted radio transmitters in September 1994, only two fish were known to have survived and returned to the Chatanika River in the following year.

DISCUSSION

In the past five years (1991-1995) management actions have reduced harvests of whitefish significantly (total harvest: 2,507 least cisco and 479 humpback whitefish), but recent composition and abundance estimates do not indicate recovery has occurred. Greater portions of the stocks continue to include older and larger fish, with correspondingly low levels of recruitment. The age structure of humpback whitefish has switched from primarily young (not fully recruited) fish to primarily older (recruited) fish. In 1986, fish 7 years and younger made up

80% of the stock (Hallberg and Holmes 1987). Approximately one generation later, these age groups represented only 27% of the stock in 1994. The age structure of the least cisco stock appears to have changed similarly. In 1991, 17% of the assessed population was fish 3 years and younger. By 1994, the same age groups represented only 1.7% of the assessed stock. In addition to changes in composition, abundance of least cisco stock may have declined by as much as 78% from 135,065 fish in 1991 (Timmons 1991). When compared to prior assessments, the 1994 recruitment levels for humpback whitefish and least cisco indicate that recruitment failures are occurring:

Year	Estimated Recruitment[a]	
	Humpback whitefish (age 7)	Least cisco (age 3)
1991	3,859	32,408
1992	3,521	26,944
1993	1,965	14,135
1994	901	8,630

[a] The recruitment estimates for 1991, 1992, and 1994 are based on the 102 km study area, whereas the 1993 estimate is from the 78.2 km section.

In four years time, recruitment levels of age 7 humpback whitefish and age 3 least cisco appear to have decreased by as much as 77% and 73%, respectively. The 901 humpback whitefish recruited in 1994 (age 7), resulted from those surviving from the 1987 spawning, when 4,577 humpback whitefish were harvested from an estimated abundance of 28,165 fish (Hallberg 1988). The 8,630 least cisco recruited in 1994 (age 3), resulted from those surviving from the 1991 spawning, when no spearfishery harvests occurred and the abundance was estimated at 135,065 fish (Timmons 1991). At this time there are no reasonable explanations to relate the lowest observed recruitments to the highest estimates of abundance of spawners other than changing natural mortality.

Estimates of natural mortality for fully recruited humpback whitefish have changed in recent years. Merritt (1995) estimated that the instantaneous natural mortality (M) of humpback whitefish for 1990-1992 was 0.47, 0.36, and 0.54, respectively. Subsequent estimates were 0.60 (1992 to 1993; Fleming 1994) and 0.16 (1993 to 1994; current assessment). Although the recent estimated *annual* survival was 85% for fully recruited fish, current recruitment levels may indicate lower survival of pre-recruited age classes of humpback whitefish to recruitment (at age 7). Recent estimates of instantaneous natural mortality for fully recruited least cisco were 0.70 (1992 to 1993; Fleming 1994) and 0.84 (1993 to 1994; current assessment). Natural mortality of least cisco is likely to be higher than humpback whitefish because of their shorter lifespan. It is unlikely that recent levels of mortality will sustain the least cisco population at past levels or provide for a harvestable surplus.

There may be several explanations for the increased survival of humpback whitefish and decreased survival for least cisco. One explanation involves predation of both species by northern pike. Although humpback whitefish may recruit to the Chatanika River four years later, the larger size at recruitment may offer future protection from predation. The mean length at recruitment (age 7) for humpback whitefish may range between 415 and 435 mm FL (Fleming 1994;

Appendix A3). It is likely that once a humpback whitefish reaches some threshold size it may outgrow the majority of its predators. Mean length at recruitment (age 3) for least cisco may range between 303 and 325 mm FL (Fleming 1994; Appendix A4). Because the maximum size of least cisco is less than humpback whitefish, very few may reach large enough sizes to avoid predation. Under a scenario with predation linked to size, a humpback whitefish may have a changing predation risk, while the predation risk of the least cisco may remain relatively constant through its life. Additionally, morphological differences between species may also confer competitive advantages of one species over another (Abrahams 1994). It is possible that the nuchal hump found on Humpback whitefish may afford further protection from ingestion by northern pike, or burbot *Lota lota* which are also present.

Another explanation for declining estimates of least cisco abundance and their depressed survival might be related to their vulnerability at the time of stock assessment. In stock assessments between 1986 and 1989 (Hallberg and Holmes 1987, Hallberg 1988, Hallberg 1989, Timmons 1990) humpback whitefish were consistently present from mid-August through September, but few least cisco were present in the 15 km sampling area before late September. Catch patterns in 1992 through 1994 in large sampling areas (≥ 78 km: Figure 8) and migratory movements (Fleming 1994) indicated variation in migration timing. While sampling a large area may act to lessen risks of run timing bias, risks remain particularly if an early- and late-run migration exists with least cisco. The catch pattern of least cisco in 1992 could have been the composite of early- and late-runs, while subsequent year catches may have been comprised of largely early-run fish. Additional evidence for a later least cisco run timing came from the minimal migration study in 1994. Least cisco catches in September were as much as twelve-fold higher than August catches in the same area, while September humpback whitefish catches were half as large as August catches. Hypothesis testing on migration concluded that at least 10% of least cisco in the lower area during early September could be exploited by the upstream fishery. The influence of this late migration on overall abundance cannot be ascertained from this study, but it can be concluded that August estimates of least cisco are minimum estimates. Since the migration of whitefish results in an accumulation, the most complete or maximal abundances would result from mid- to late September assessments. To determine magnitude of bias on abundance from late migration, stock assessment might use three sampling events.

The use of external examination as a tool to detect sex or maturity status in 1994 proved to be problematic. Throughout September, the status of many fish could not be determined. One problem with the visual approach was that fish may have spawned early and later been classified in the unknown sex category. Timmons (1990) visually classified the sex of nearly all sampled least cisco and humpback whitefish in late September 1989. In late September 1994, 87% of sampled least cisco and 59% of sampled humpback whitefish were classified by sex. The absence of fish in spawned-out condition may indicate that significant spawning had not occurred by 30 September 1994. There is a strong possibility that some, or all, of the fish with unknown status would eventually ripen and spawn later in 1994, but freeze-up of the river precluded later sampling.

While there is a possibility that some of the unknown sex humpback whitefish may not have spawned in 1994, internal examinations of 52 humpback whitefish did not support this idea. Bond (1982) indicated that a common problem in detecting skip-spawning fish has been that these fish are often widely dispersed and not present in spawning migrations and concentrations. In the course of sampling fish in the lower 45 km section, there were indications that additional smaller

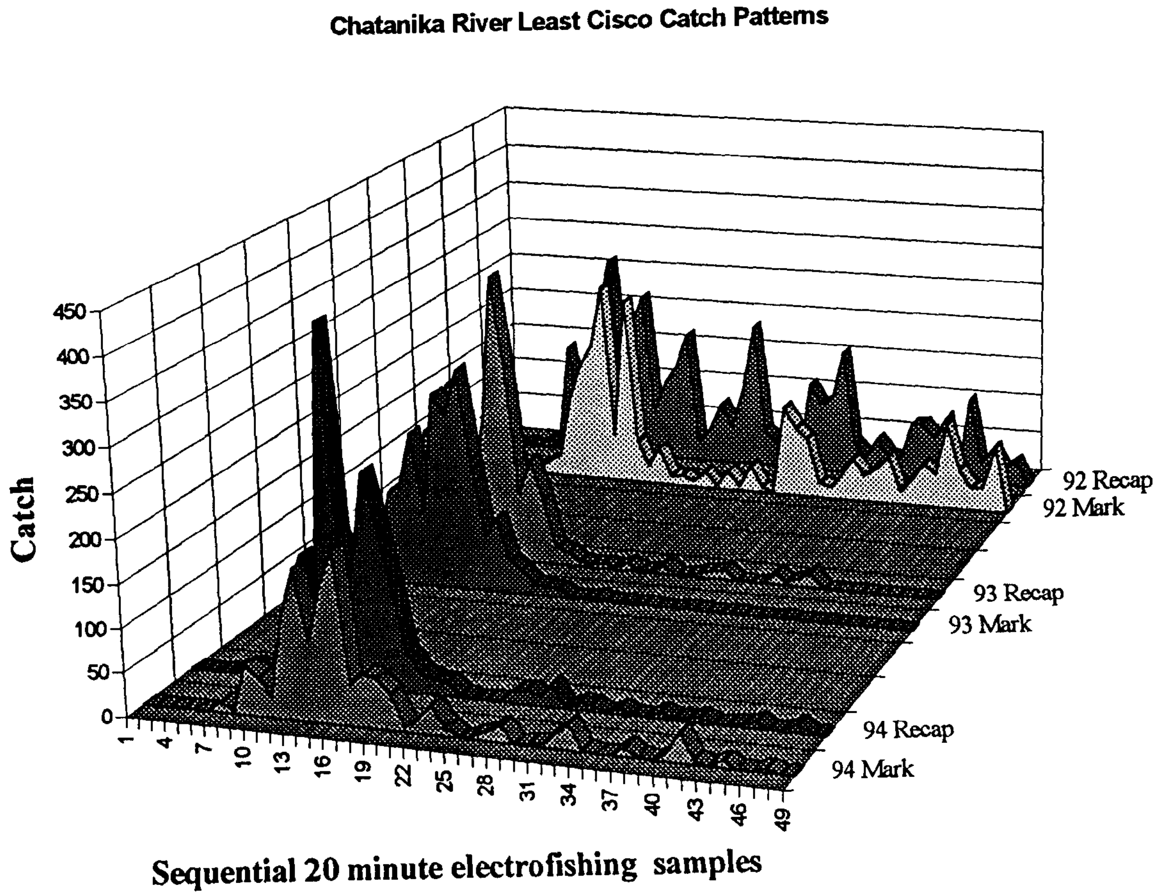

Figure 8.-Least cisco catch patterns along the Chatanika River during mark-recapture sampling conducted in 1992-1994. Samples are identified by year and sample event (Mark or Recap).

and younger fish were present in September. Two humpback whitefish killed during the migration study were dissected and found to be immature females with small undeveloped gonads; the lengths of these fish were 367 and 370 mm FL. Because the planned maturity sampling was not conducted in the downstream area in 1994, the composition of maturity statuses present in this area, i.e. immature, spawning, and skip- or nonconsecutive spawning fish remains unknown. Maturity sampling conducted in the upper Chatanika River revealed that it is unlikely that sex and maturity status of *live* whitefish can be determined. In 1995 maturity sampling utilized *post mortem* internal examination of fish captured in feeding areas so that sampling is representative of the population.

Objective proportions could not be estimated from the radio telemetry project due to a high level of mortality among radio-tagged humpback whitefish. In the initial year of a two year study only 7 of 52 fish implanted with radio transmitters survived Winter and migrated to areas within Minto Flats. All seven fish passed through or inhabited areas where traditional subsistence fisheries occur, and the known geographic range of Chatanika River humpback whitefish has now been expanded to include feeding areas near Minto Village. Radio tracking information on the mortality status indicated that most of the fish died during the 1994-5 winter. Later in the study, the mortality of 22 fish was confirmed by groundtruthing. The heavy losses could have resulted from a host of factors which might include (singly, or in combination): handling stresses, implantation prior to spawning, presence of an internal transmitter, transintestinal expulsion of radio transmitters, age, predation, and overwintering mortality.

Some factors that might have limited success of the current project have been associated in other radio telemetry studies. Brown and Mackay (1994) studied the spawning ecology of cutthroat trout *Oncorhyncus clarkii* using radio telemetry. Similar to the current study fish were collected by electrofishing, and 23 fish were implanted with radio tags as few as 10 days prior to observed spawning. Over the course of the study only three fish died (following spawning), and all but five fish spawned. Chang-Kue and Jessop (1991) evaluated use of external radio tags placed on Arctic cisco *Coregonus autumnalis* to study pre-spawning movements. Substantial movements by seven fish confirmed survival through the tagging procedure, but live status of four the remaining five fish were not confirmed due to limited tracking success in saline coastal waters where transmitter performance is poor, or unknown tag failures. Summerfelt and Mosier (1984) detailed how surgically implanted radio transmitters can be expelled from fish transintestinally. Humpback whitefish may have the ability to expel transmitters, but successful expulsion when the whitefish are overwintering seems less likely than during active feeding periods. It is possible that mortality of some or many fish in the current study could have been related to aspects of this phenomenon, such as through stresses upon energy stores used for overwintering.

While mortality sensors can be helpful in telemetry studies, several studies have indicated that their use can be problematic (Bendock and Alexandersdottir 1992, Johnson et al. 1992). Eiler (1990) found that mortality sensing transmitters were valuable in conjunction with aerial tracking of sockeye and coho salmon migrating in turbid glacial rivers. In the current study on humpback whitefish, mortality sensing transmitters were valuable only when substantial tracking histories existed. Because of low levels of activity by overwintering fish, errors in the assigned fates for several fish occurred. Several potential problems or concerns with motion sensitive transmitters were revealed in the course of this study. If implanted fish die and decompose in areas of high stream velocity or turbulence, radio transmitters can be agitated by flows and continue to transmit live status signals. One other consideration with motion sensing transmitters is dependence on a continued horizontal positioning within the fish to retain functionality of the sensor (Bill Burger, Telonics Inc.- Personal Communication). Positioning other than horizontal reduces sensitivity of the motion sensing circuitry and can bias results toward a higher incidence of deaths. Because no live humpback whitefish were recovered bearing radio transmitters, it is not known whether this problem occurred or influenced this study. Since many of the tags were located multiple times and later groundtruthed, it appears from this study that the patterns of mortality status may be a more accurate predictor than interpretation of an individual's status from a single tracking observation.

CONCLUSION

The whitefish populations of the Chatanika River continue to experience low recruitment and abundance. Given the poor condition of the stocks, stock assessments and the sport spearfishery were not conducted during 1995. Life history investigations conducted in 1994-1995 have begun to define the geographic range of fish assessed in the Chatanika River and indicated that portions of the exploited stock enter the Chatanika River after completion of the stock assessment. If a later run timing of least cisco substantially biases stock assessment estimates, future changes in research and or management approaches may be needed. If the bias is substantial and inseason management is desired (using the late August sampling design), estimates of stock abundance for least cisco might be considered as *indices* of abundance and parameter estimates of population dynamics may be greatly biased.

Because of the high levels of mortality, future telemetry studies might be conducted using small radio tags in short term studies. Fish could be fitted with externally-mounted radio tags during Spring or early Summer while in feeding areas and tracked through Fall, to estimate proportions returning to the Chatanika River, or elsewhere. Maturity investigations in 1996 will consist of internal examinations and gonadosomatic indices to avoid ambiguous results with visual classification. Additionally, maturity studies will include the sampling of fish at summer feeding areas for more representative sampling of the stock.

ACKNOWLEDGMENTS

The author wishes to thank Bob Clark, Don Roach, Pete Terzi, Klaus Wuttig, Dave Cox, Roy Perry, Doug Edwards, Charmi Weker, Bill Leslie, Renate Riffe, Tim Viavant, Jerry Hallberg, Toby Boudreau, and Pat Houghton for help in the field. Thanks also go to Gary Pearse for safe piloting, Renate Riffe for aging scales, Pat Hansen and Mike Wallendorf for statistical and editorial support, and to Bob Clark for miscellaneous assistance with the project. Fred Andersen and Peggy Merritt are also to be thanked for their administrative support for the project. Thanks also go to Sara Case for final preparation and publication of the report. This project and report were made possible by partial funding provided by the U.S. Fish and Wildlife Service through the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-11, Job No. 3-5(a).

LITERATURE CITED

Abrahams, M. V. 1994. Risk of predation and its influence on the relative abilities of two species of freshwater fishes. Canadian Journal of Fisheries and Aquatic Sciences. 51: 1629-1633.

LITERATURE CITED (Continued)

Alt, K. 1974. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1973-1974. Project F-9-6, 15 (R-II-G): pages 1-20.

Alt, K. 1979. Contributions to the life history of humpback whitefish in Alaska. Transactions of the American Fisheries Society 108:156-160.

Alt, K. 1986. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1983-1984. Special Segment L Project F-9-16, 25(SW-1-A): 122 pp.

Andrews, E. 1988. Use of fish and wildlife in Minto, Alaska. Alaska Department of Fish and Game Technical Paper No. 137, Juneau.

Bailey, N. T. J. 1951. On estimating the size of mobile populations from capture-recapture data. Biometrika 38:293-306.

Bailey, N. T. J. 1952. Improvements in the interpretation of recapture data. Journal of Animal Ecology 21:120-127.

Baker, T. T. 1988. Creel census in Interior Alaska in 1987. Alaska Department of Fish and Game, Fishery Data Series No. 64. Juneau 138 pp.

Baker, T. T. 1989. Creel censuses conducted in Interior Alaska during 1988. Alaska Department of Fish and Game, Fishery Data Series No. 95. Juneau 110 pp.

Bendock, T. and M. Alexandersdottir. 1992. Mortality and movement behavior of hooked-and-released chinook salmon in the Kenai River recreational fishery, 1989-1991. Alaska Department of Fish and Game, Fishery Manuscript Series No. 92-2. 66 pp.

Bernatchez, L., and J. J. Dodson. 1987. Extended freshwater residence prior to spawning: the influence of water velocity and temperature on swimming capacity and its role in controlling the upstream migration of anadromous *Coregonines* of James Bay, Quebec. *Pages 555-556 In* M. J. Dadswell et al., editors. Proceedings of an international symposium, Common strategies of anadromous and catadromous fishes. American Fisheries Society, Maryland.

Bond, W.A. 1982. A Study of the fishery resources of Tuktoyakuk Harbour, Southern Beaufort Sea Coast, with special references to life histories of anadromous Coregonids. Canadian Technical Report of Fisheries and Aquatic Sciences No. 1119. 90 pp.

Brown, R. S. and W. C. Mackay. 1995. Spawning ecology of cutthroat trout (*oncorhynchus clarki*) in the Ram River, Alberta. Canadian Journal of Fisheries and Aquatic Sciences. 52: 983-992.

Chang-Kue, K. T. G. and E. F. Jessop. 1991. An evaluation of the use of external radio tags to study the migrations of Arctic cisco in the Southeastern Beaufort Sea Region. Canadian Manuscript report of Fisheries and aquatic Sciences No. 2125. 27 pp.

Clark, R. A., and W. P. Ridder. 1987. Tanana Drainage creel census and harvest surveys, 1986. Alaska Department of Fish and Game, Fishery Data Series No. 12. 91 pp.

Craig, P. C. 1989. An introduction to Anadromous fishes in the Alaskan Arctic. Pages 27-54 *In* D. W. Norton, editor. Research advances on anadromous fish in arctic Alaska and Canada- nine papers contributing to an ecological synthesis. Institute of Arctic Biology, University of Alaska Fairbanks, Fairbanks, Alaska.

Eiler, J. H. 1990. Radio transmitters used to study salmon in glacial rivers. American Fisheries Society Symposium 7: 364-369

Fleming, D. F. 1993. Stock Assessment of humpback whitefish and least cisco in the Chatanika River during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-25. 26 pp.

Fleming, D. F. 1994. Stock Assessment and relative age validation of humpback whitefish and least cisco in the Chatanika River during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-41. 64 pp.

LITERATURE CITED (Continued)

Goodman, L. A. 1960. On the exact variance of a product. Journal of the American Statistical Association, Vol 55:708-713.

Hallberg, J. E. and A. E. Bingham. 1993. Creel surveys conducted in Interior Alaska during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-7, Anchorage.

Hallberg, J. E. and R. A. Holmes. 1987. Abundance and size composition of Chatanika River least cisco and humpback whitefish with estimates of by recreational spear fishermen. Alaska Department of Fish and Game, Fishery Data Series No. 87-25, Anchorage.

Hallberg, J. E. 1988. Abundance and size composition of Chatanika River least cisco and humpback whitefish with estimates of by recreational spear fishermen. Alaska Department of Fish and Game, Fishery Data Series No. 88-61, Anchorage.

Hallberg, J. E. 1989. Abundance and size composition of Chatanika River least cisco and humpback whitefish with estimates of by recreational spear fishermen. Alaska Department of Fish and Game, Fishery Data Series No. 88-61, Anchorage.

Hallberg, J., and A. E. Bingham. 1991. Creel surveys conducted in Interior Alaska during 1990. Alaska Department of Fish and Game, Fishery Data Series No. 91-56. Anchorage. 98 pp.

Hallberg, J., and A. E. Bingham. 1992. Creel surveys conducted in Interior Alaska during 1991. Alaska Department of Fish and Game, Fishery Data Series No. 92-7. Anchorage. 73 pp.

Hallberg, J., and A. E. Bingham. 1993. Creel surveys conducted in Interior Alaska during 1992. Alaska Department of Fish and Game, Fishery Data Series No. 93-7. Anchorage. 35 pp.

Hallberg, J., and A. E. Bingham. 1994. Creel surveys conducted in Interior Alaska during 1993. Alaska Department of Fish and Game, Fishery Data Series No. 94-27. Anchorage. 37 pp.

Hallberg, J., and A. E. Bingham. 1995. Creel surveys conducted in Interior Alaska during 1994. Alaska Department of Fish and Game, Fishery Data Series No. 95-21. Anchorage. 37 pp.

Hart, L. G., and R. C. Summerfelt. 1975. Surgical procedures for implanting ultrasonic transmitters into flathead catfish (*pylodicus olivaris*). Transactions of the American Fisheries Society 104:56-59.

He, X. and J. F. Kitchell. 1990. Direct and indirect effects of predation on a fish community: a whole lake experiment. Transactions of the American Fisheries Society 119: 825-835.

Healey, M. C. 1975. Dynamics of exploited whitefish populations and their management with special references to the Northwest Territories. Journal of the Fisheries Research Board of Canada. 32: 427-448.

Howe, A. L., G. Fidler, and M. J. Mills. 1995. Harvest, catch, and participation in Alaska sport fisheries during 1994. Alaska Department of Fish and Game, Fishery Data Series Number 94-24, Anchorage.

Johnson, R. E. , R. P. Marshall, and S. T. Elliott. 1992. Chilkat River chinook salmons Studies, 1991. Alaska Department of Fish and Game, Fisheries Data Series No. 92-49, Juneau.

King, L. P. 1990. Pickering NGS 'B' postoperational radio telemetry studies, 1986 and 1987. Ontario Hydro Research Division Report No. 90-81-K

Lambert, Y. and J. J. Dodson. 1990. Freshwater migration as a determinant factor in the somatic cost of reproduction of two anadromous coregonines of James Bay. Canadian Journal of Fishery and Aquatic Sciences., Vol. 47:318-334.

Merritt, M. F., A. E. Bingham, and Naomi Morton. 1990. Creel surveys conducted in Interior Alaska during 1989. Alaska Department of Fish and Game, Fishery Data Series No. 90-54. Anchorage 125 pp.

Merritt, M. F. 1995. Application of decision analysis in the evaluation of recreational fishery management problems. Doctoral dissertation, University of Alaska Fairbanks, Fairbanks. 183 pp.

LITERATURE CITED (Continued)

Mills, M. J. 1979. Alaska statewide sport fish harvest studies (1977). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1978-1979, Project F-9-11, 20 (SW-I-A).

Mills, M. J. 1980. Alaska statewide sport fish harvest studies (1978). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1979-1980, Project F-9-12, 21 (SW-I-A).

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

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

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

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

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

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

Mills, M. J. 1986. Alaska statewide sport fish harvest studies (1985). Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Performance Report, 1985-1986, Project F-10-1, 27 (RT-2).

Mills, M. J. 1987. Alaska statewide sport fisheries harvest report (1986). Alaska Department of Fish and Game, Fishery Data Series No. 2, Juneau.

Mills, M. J. 1988. Alaska statewide sport fisheries harvest report (1987). Alaska Department of Fish and Game, Fishery Data Series No. 52, Juneau.

Mills, M. J._ 1989. Alaska statewide sport fisheries harvest report (1988). Alaska Department of Fish and Game, Fisheries Data Series No. 122, Juneau.

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

Mills, M. J. 1991. Harvest, catch, and participation in Alaska sport fisheries during 1990. Alaska Department of Fish and Game, Fishery Data Series Number 91-58, Anchorage.

Mills, M. J. 1992. Harvest, catch, and participation in Alaska sport fisheries during 1991. Alaska Department of Fish and Game, Fishery Data Series Number 92-40, Anchorage.

Mills, M. J. 1993. Harvest, catch, and participation in Alaska sport fisheries during 1992. Alaska Department of Fish and Game, Fishery Data Series Number 93-42, Anchorage.

Mills, M. J. 1994. Harvest, catch, and participation in Alaska sport fisheries during 1993. Alaska Department of Fish and Game, Fishery Data Series Number 94-28, Anchorage.

Morin, R., J. J. Dodson, and G. Power. 1982. Life history variations of anadromous cisco (*Coregonus artedii*), lake whitefish (*Coregonus clupeaformis*), and round whitefish (*Prosopium cylindraceum*) populations of Eastern James-Hudson Bay. Canadian Journal of Fisheries and Aquatic Sciences. 39: 958-967.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada No. 191.

Seber, G. A. F. 1982. The estimation of animal abundance and related parameters, second edition. Charles Griffin and Company, Limited, London.

LITERATURE CITED (Continued)

Summerfelt, R. C., and D. Mosier. 1984. Transintestinal expulsion of surgically implanted dummy transmitters by channel catfish. Transactions of the American Fisheries Society 113: 760-766.

Summerfelt, R. C., and L. S. Smith. 1990. Anesthesia, Surgery, and related techniques. Pages 213-272 *in* C. B. Schreck and P. B. Moyle, editors. Methods for fish biology. American Fisheries Society, Bethesda, Maryland.

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

Timmons, L. S. 1991. Stock Assessment of humpback whitefish and least cisco in the Chatanika River in 1990 and 1991. Alaska Department of Fish and Game, Fishery Data Series No. 91-70. 79 pp.

Townsend, A. H., and P. P. Kepler. 1974. Population studies of northern pike and whitefish in the Minto Flats Complex with emphasis on the Chatanika River. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1973-1974. Project F-9-6, 15 (G-II): pages 59-79.

Winter, J. D. 1983. Underwater biotelemetry. Pages 371-396 *in* L. Nielsen and D. Johnson, editors. Fisheries techniques. American Fisheries Society. Southern Printing Company, Inc. Blacksburg, Virginia.

Appendix A

Appendix A1.-Methodologies for alleviating bias due to gear selectivity by means of statistical inference.

Result of first K-S test[a]	Result of second K-S test[b]
Case I[c]	
Fail to reject H_0	Fail to reject H_0
Inferred cause: There is no size-selectivity during either sampling event.	
Case II[d]	
Fail to reject H_0	Reject H_0
Inferred cause: There is no size-selectivity during the second sampling event, but there is during the first sampling event	
Case III[e]	
Reject H_0	Fail to reject H_0
Inferred cause: There is size-selectivity during both sampling events.	
Case IV[f]	
Reject H_0	Reject H_0
Inferred cause: There is size-selectivity during the second sampling event; the status of size-selectivity during the first event is unknown.	

a The first K-S (Kolmogorov-Smirnov) test is on the lengths of fish marked during the first event versus the lengths of fish recaptured during the second event. H_0 for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish recaptured during the second event.

b The second K-S test is on the lengths of fish marked during the first event versus the lengths of fish captured during the second event. H_0 for this test is: The distribution of lengths of fish sampled during the first event is the same as the distribution of lengths of fish sampled during the second event.

c Case I: Calculate one unstratified abundance estimate, and pool lengths and ages from both sampling event for size and age composition estimates.

d Case II: Calculate one unstratified abundance estimate, and only use lengths and ages from the second sampling event to estimate size and age composition.

e Case III: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Pool lengths and ages from both sampling events and adjust composition estimates for differential capture probabilities.

f Case IV: Completely stratify both sampling events and estimate abundance for each stratum. Add abundance estimates across strata. Also calculate a single abundance estimate without stratification.

If stratified and unstratified estimates are dissimilar, discard unstratified estimate and use lengths and ages from second event and adjust these estimates for differential capture probabilities.

If stratified and unstratified estimates are similar, discard estimate with largest variance. Use lengths and ages from first sampling event to directly estimate size and age compositions.

Appendix B
Tabulated Radio Telemetry Data

Appendix B1.-Tabulated Radio Telemetry Data.

Transmitter :		Implanted Fish:				Tracking Statistics:				GPS[d] Location	
Number	Freq[a]	Sex	Age	Length	Weight	Record	Tracking	Result[b]	BPM[c]	Latitude	Longitude
11	0.011	M	10	481	1467	1	Nov	0	nd	nd	nd
11	0.011					2	Jan	0	nd	nd	nd
11	0.011					3	March	0	nd	nd	nd
11	0.011					4	April	0	nd	nd	nd
11	0.011					5	May	0	nd	nd	nd
11	0.011					6	June	3	nd	nd	nd
11	0.011					7	July	0	nd	nd	nd
11	0.011					8	late July	0	nd	nd	nd
11	0.011					9	Groundtruth	3	nd	nd	nd
11	0.011					10	Sept	0	nd	nd	nd
21	0.021	F	13	470	1391	1	Nov	1	30	650342	1475353
21	0.021					2	Jan	1	30	650344	1475200
21	0.021					3	March	1	30	650349	1475319
21	0.021					4	April	1	30	650344	1475274
21	0.021					5	May	1	30	655353	1484696
21	0.021					6	June	1	30	645391	1484603
21	0.021					7	July	1	30	650215	1481056
21	0.021					8	late July	1	30	650228	1480854
21	0.021					9	Groundtruth	1	30	650196	1481071
21	0.021					10	Sept	1	30	650305	1480261
30	0.030	F	11	464	1483	1	Nov	1	60	650225	1480528
30	0.030					2	Jan	1	60	650258	1480575
30	0.030					3	March	1	60	650212	1480569
30	0.030					4	April	1	60	650234	1480660
30	0.030					5	May	1	60	650245	1480566
30	0.030					6	June	3	nd	nd	nd
30	0.030					7	July	1	60	650238	1480671
30	0.030					8	late July	3	nd	nd	nd
30	0.030					9	Groundtruth	3	nd	nd	nd
30	0.030					10	Sept	3	nd	nd	nd
51	0.051	F	14	464	1430	1	Nov	1	60	650136	1482300
51	0.051					2	Jan	0	nd	NA	
51	0.051					3	March	0	nd	nd	nd
51	0.051					4	April	0	nd	nd	nd
51	0.051					5	May	0	nd		
51	0.051					6	June	3	nd	nd	nd
51	0.051					7	July	1	60	650409	1474717
51	0.051					8	late July	0	nd	nd	nd
51	0.051					9	Groundtruth	0	nd	nd	nd
51	0.051					10	Sept	0	nd	nd	nd
62	0.062	F	12	488	1691	1	Nov	1	60	650136	1482300
62	0.062					2	Jan	1	60	650165	1482403
62	0.062					3	March	1	60	650125	1482374
62	0.062					4	April	1	60	650168	1482411
62	0.062					5	May	1	60	650158	1482332

-continued-

Transmitter :		Implanted Fish:				Tracking Statistics:				GPS[d] Location	
Number	Freq[a]	Sex	Age	Length	Weight	Record	Tracking	Result[b]	BPM[c]	Latitude	Longitude
62	0.062					6	June	3	nd	nd	nd
62	0.062					7	July	1	60	650189	1482465
62	0.062					8	late July	3	nd	nd	nd
62	0.062					9	Groundtruth	3	nd	nd	nd
62	0.062					10	Sept	3	nd	nd	nd
71	0.071	M	11	485	1480	1	Nov	1	60	650348	1475473
71	0.071					2	Jan	1	60	650357	1475392
71	0.071					3	March	1	60	650315	1475527
71	0.071					4	April	1	60	650357	1475263
71	0.071					5	May	1	nd	650300	1475763
71	0.071					6	June	3	nd	nd	nd
71	0.071					7	July	1	30	650333	1475249
71	0.071					8	late July	1	60	650362	1475408
71	0.071					9	Groundtruth	0	nd	nd	nd
71	0.071					10	Sept	0	nd	nd	nd
80	0.080	F	9	466	1381	1	Nov	1	60	650278	1480250
80	0.080					2	Jan	1	60	650272	1480247
80	0.080					3	March	1	60	650272	1480141
80	0.080					4	April	1	60	650299	1480189
80	0.080					5	May	1	60	650312	1480171
80	0.080					6	June	3	nd	nd	nd
80	0.080					7	July	1	60	nd	nd
80	0.080					8	late July	3	nd	nd	nd
80	0.080					9	Groundtruth	1	60	650303	1480178
80	0.080					10	Sept	3	nd	nd	nd
93	0.093	F	12	502	2364	1	Nov	1	60	650127	1481725
93	0.093					2	Jan	1	60	650158	1481686
93	0.093					3	March	1	60	650125	1481643
93	0.092					4	April	1	60	650157	1481687
93	0.092					5	May	1	60	650176	1482132
93	0.092					6	June	3	nd	nd	nd
93	0.092					7	July	1	60	650166	1481687
93	0.092					8	late July	3	nd	nd	nd
93	0.092					9	Groundtruth	1	60	650145	1481676
93	0.092					10	Sept	3	nd	nd	nd
102	0.102	F	R	468	1530	1	Nov	1	60	645885	1484627
102	0.102					2	Jan	1	60	645886	1484554
102	0.102					3	March	1	60	645884	1484610
102	0.102					4	April	1	60	645882	1484600
102	0.102					5	May	1	60	645889	1484634
102	0.102					6	June	3	nd	nd	nd
102	0.102					7	July	1	60	645879	1484610
102	0.102					8	late July	3	nd	nd	nd
102	0.102					9	Aug	1	60	645890	1484658
102	0.102					10	Groundtruth	3	nd	nd	nd

-continued-

Appendix B1.-Page 3 of 12.

Transmitter :		Implanted Fish:				Tracking Statistics:				GPS[d] Location	
Number	Freq[a]	Sex	Age	Length	Weight	Record	Tracking	Result[b]	BPM[c]	Latitude	Longitude
102	0.102					11	Sept	1	60	645899	1484806
111	0.111	F	10	458	1343	1	Nov	1	60	650197	1480799
111	0.111					2	Jan	1	60	650224	1480778
111	0.111					3	March	1	60	650227	1480797
111	0.111					4	April	1	60	650207	1480767
111	0.111					5	May	1	60	650212	1480994
111	0.111					6	June	3	nd	nd	nd
111	0.111					7	July	1	60	650225	1480550
111	0.111					8	late July	3	nd	nd	nd
111	0.111					9	Groundtruth	3	nd	nd	nd
111	0.111					10	Sept	1	60	650204	1480780
131	0.131	M	R	451	1250	1	Nov	1	30	650342	1475540
131	0.131					2	Jan	1	60	650246	1475931
131	0.131					3	March	1	60	650268	1480022
131	0.131					4	April	1	60	650254	1475936
131	0.131					5	May	1	60	650269	1475980
131	0.131					6	June	3	nd	nd	nd
131	0.131					7	July	0	nd	nd	nd
131	0.131					8	late July	0	nd	nd	nd
131	0.131					9	Groundtruth	3	nd	nd	nd
131	0.131					10	Sept	0	nd	nd	nd
142	0.142	F	R	452	1390	1	Nov	1	60	650139	1482168
142	0.142					2	Jan	1	60	650133	1482336
142	0.142					3	March	1	60	650171	1482404
142	0.143					4	April	1	60	650152	1482369
142	0.143					5	May	1	60	650175	1482476
142	0.143					6	June	3	nd	nd	nd
142	0.143					7	July	1	60	650129	1482360
142	0.143					8	late July	3	nd	nd	nd
142	0.143					9	Groundtruth	1	60	650138	1482347
142	0.143					10	Sept	3	nd	nd	nd
152	0.152	F	11	458	1489	1	Nov	1	60	650169	1481360
152	0.152					2	Jan	1	60	650159	1481360
152	0.152					3	March	1	60	650218	1481054
152	0.152					4	April	1	60	650187	1481410
152	0.152					5	May	1	60	650189	1481379
152	0.152					6	June	3	nd	nd	nd
152	0.152					7	July	1	60	650198	1481437
152	0.152					8	late July	3	nd	nd	nd
152	0.152					9	Groundtruth		60	650164	1481384
152	0.152					10	Sept	3	nd	nd	nd
162	0.162	F	12	454	1519	1	Nov	1	60	650136	1482811
162	0.162					2	Jan	1	60	650136	1482818
162	0.162					3	March	1	60	650131	1482889
162	0.161					4	April	1	60	650158	1482895
162	0.161					5	May	1	60	650151	1483077

-continued-

Transmitter :		Implanted Fish:					Tracking Statistics:			GPS[d] Location	
Number	Freq[a]	Sex	Age	Length	Weight	Record	Tracking	Result[b]	BPM[c]	Latitude	Longitude
162	0.161					6	June	3	nd	nd	nd
162	0.161					7	July	1	60	650179	1482496
162	0.161					8	late July	3	nd	nd	nd
162	0.161					9	Groundtruth	3	nd	nd	nd
162	0.161					10	Sept	1	60	650141	1482852
171	0.171	F	11	478	1482	1	Nov	1	60	650107	1483188
171	0.171					2	Jan	1	60	650077	1483196
171	0.171					3	March	1	60	650089	1483192
171	0.171					4	April	1	60	650080	1483197
171	0.171					5	May	1	60	650092	1483290
171	0.171					6	June	3	nd	nd	nd
171	0.171					7	July	1	60	650089	1483213
171	0.171					8	late July	3	nd	nd	nd
171	0.171					9	Groundtruth	1	60	650082	1483199
171	0.171					10	Sept	3	nd	nd	nd
181	0.181	F	11	461	1432	1	Nov	1	60	650137	1483003
181	0.181					2	Jan	1	60	650163	1482853
181	0.181					3	March	1	60	650158	1482864
181	0.181					4	April	1	60	650128	1482823
181	0.181					5	May	1	60	650071	1483429
181	0.181					6	June	3	nd	nd	nd
181	0.181					7	July	1	60	650165	1482989
181	0.181					8	late July	3	nd	nd	nd
181	0.181					9	Groundtruth		30	650155	1482959
181	0.181					10	Sept	3	nd	nd	nd
192	0.192	M	9	480	1435	1	Nov	1	60	650190	1480839
192	0.192					2	Jan	1	60	650155	1480960
192	0.192					3	March	1	60	650154	1480941
192	0.192					4	April	1	nd	650208	1481017
192	0.192					5	May	1	60		
192	0.192					6	June	3	nd	nd	nd
192	0.192					7	July	1	60	650168	1480946
192	0.192					8	late July	3	nd	nd	nd
192	0.192					9	Groundtruth		60	650164	1480952
192	0.192					10	Sept	3	nd	nd	nd
200	0.200	F	11	462	1590	1	Nov	1	60	650137	1482765
200	0.200					2	Jan	1	60	650141	1482733
200	0.200					3	March	1	60	650123	1482840
200	0.200					4	April	1	60	650170	1482720
200	0.200					5	May	1	60	650092	1483290
200	0.200					6	June	3	nd	nd	nd
200	0.200					7	July	1	60	650145	1482713
200	0.200					8	late July	3	nd	nd	nd
200	0.200					9	Groundtruth		60	650141	1482817
200	0.200					10	Sept	3	nd	nd	nd
210	0.210	F	12	491	1527	1	Nov	1	60	650280	1480423

-continued-

Appendix B1.-Page 5 of 12.

Transmitter:		Implanted Fish:					Tracking Statistics:			GPS[d] Location	
Number	Freq[a]	Sex	Age	Length	Weight	Record	Tracking	Result[b]	BPM[c]	Latitude	Longitude
210	0.210					2	Jan	1	60	650294	1480399
210	0.210					3	March	1	60	650281	1480434
210	0.210					4	April	1	60	650283	1480433
210	0.210					5	May	1	60	650274	1480493
210	0.210					6	June	3	nd	nd	nd
210	0.210					7	July	1	60	650279	1480339
210	0.210					8	late July	3	nd	nd	nd
210	0.210					9	Groundtruth		60	650287	1480390
210	0.210					10	Sept	3	nd	nd	nd
220	0.220	F	9	455	1490	1	Nov	1	60	650147	1481941
220	0.220					2	Jan	1	60	650139	1482082
220	0.220					3	March	1	60	650148	1482047
220	0.220					4	April	1	60	650131	1482273
220	0.220					5	May	1	60	650177	1482705
220	0.220					6	June	3	nd	nd	nd
220	0.220					7	July	1	60	650138	1482376
220	0.220					8	late July	3	nd	nd	nd
220	0.220					9	Groundtruth		60	650136	1482320
220	0.220					10	Sept	3	nd	nd	nd
230	0.230	F	R	455	1300	1	Nov	1	60	650154	1481863
230	0.230					2	Jan	1	60	650161	1482077
230	0.230					3	March	1	60	650180	1482062
230	0.230					4	April	1	60	650167	1482065
230	0.230					5	May	1	60	650173	1482067
230	0.230					6	June	3	nd	nd	nd
230	0.230					7	July	1	60	650169	1482010
230	0.230					8	late July	3	nd	nd	nd
230	0.230					9	Groundtruth		60	650167	1482041
230	0.230					10	Sept	3	nd	nd	nd
241	0.241	F	11	462	1455	1	Nov	1	60	650233	1481157
241	0.241					2	Jan	1	60	650193	1481263
241	0.241					3	March	1	60	650202	1481262
241	0.241					4	April	1	60	650170	1481359
241	0.241					5	May	1	60	650195	1481450
241	0.241					6	June	3	nd	nd	nd
241	0.241					7	July	1	60	650262	1480392
241	0.241					8	late July	3	nd	nd	nd
241	0.241					9	Groundtruth	3	nd	nd	nd
241	0.241					10	Sept	1	60	650224	1481203
252	0.252	F	9	453	1264	1	Nov	1	60	650164	1482546
252	0.252					2	Jan	1	60	650164	1482434
252	0.252					3	March	1	60	650164	1482434
252	0.252					4	April	1	60	650194	1482570
252	0.252					5	May	1	60	650175	1482525
252	0.252					6	June	3	nd	nd	nd
252	0.252					7	July	1	60	650158	1482518

-continued-

Transmitter:		Implanted Fish:				Tracking Statistics:				GPS[d] Location	
Number	Freq[a]	Sex	Age	Length	Weight	Record	Tracking	Result[b]	BPM[c]	Latitude	Longitude
252	0.252					8	late July	3	nd	nd	nd
252	0.252					9	Groundtruth	1	nd	nd	nd
252	0.252					10	Sept	0	nd	nd	nd
260	0.260	F	R	450	1900	1	Nov	1	60	650210	1480791
260	0.260					2	Jan	1	60	650204	1480785
260	0.260					3	March	1	60	650204	1480742
260	0.259					4	April	1	60	650202	1480747
260	0.259					5	May	1	nd	650255	1480525
260	0.259					6	June	3	nd	nd	nd
260	0.259					7	July	1	60	650202	1480839
260	0.259					8	late July	3	nd	nd	nd
260	0.259					9	Groundtruth	3	nd	nd	nd
260	0.259					10	Sept	0	nd	nd	nd
272	0.272	F	10	455	1329	1	Nov	1	60	650131	1483076
272	0.272					2	Jan	1	60	650089	1483192
272	0.272					3	March	1	60		
272	0.272					4	April	1	60	650147	1483162
272	0.272					5	May	1	60	650155	1483083
272	0.272					6	June	3	nd	nd	nd
272	0.272					7	July	1	60	650141	1483135
272	0.272					8	late July	3	nd	nd	nd
272	0.272					9	Groundtruth	1	nd	nd	nd
272	0.272					10	Sept	0	nd	nd	nd
279	0.279	F	14	500	1814	1	Nov	1	60	650138	1482874
279	0.279					2	Jan	1	60	650146	1482697
279	0.279					3	March	0	nd	nd	nd
279	0.278					4	April	1	60	650158	1483112
279	0.278					5	May	0	nd	nd	nd
279	0.278					6	June	3	nd	nd	nd
279	0.278					7	July	0	nd	nd	nd
279	0.278					8	late July	1	60		
279	0.278					9	Groundtruth	3	nd	nd	nd
279	0.278					10	Sept	0	nd	nd	nd
292	0.292	M	10	473	1360	1	Nov	1	30	650314	1475501
292	0.292					2	Jan	1	30	650320	1475519
292	0.292					3	March	1	30	650340	1475563
292	0.292					4	April	1	30	650333	1475575
292	0.292					5	May	1	60	650943	1491441
292	0.292					6	June	1	60	651031	1491798
292	0.292					7	July	1	60	650984	1491522
292	0.292					8	late July	1	60	650926	1491381
292	0.292					9	Groundtruth	3	nd	nd	nd
292	0.292					10	Sept	1	60		
301	0.301	F	12	472	1494	1	Nov	1	60	650197	1481159
301	0.301					2	Jan	1	60	650206	1481041
301	0.301					3	March	1	60	650184	1481039

-continued-

Transmitter :		Implanted Fish:					Tracking Statistics:			GPS[d] Location	
Number	Freq[a]	Sex	Age	Length	Weight	Record	Tracking	Result[b]	BPM[c]	Latitude	Longitude
301	0.300					4	April	1	60	650192	1481158
301	0.300					5	May	1	60	650164	1481907
301	0.300					6	June	3	nd	nd	nd
301	0.300					7	July	1	60	650211	1481028
301	0.300					8	late July	3	nd	nd	nd
301	0.300					9	Groundtruth		60	650232	1481234
301	0.300					10	Sept	3	nd	nd	nd
332	0.332	F	11	468	1566	1	Nov	1	60	650150	1482490
332	0.332					2	Jan	1	60	650188	1482489
332	0.332					3	March	1	60	650146	1482477
332	0.332					4	April	1	60	650156	1482583
332	0.332					5	May	1	60	650177	1482705
332	0.332					6	June	3	nd	nd	nd
332	0.332					7	July	1	60	650172	1482692
332	0.332					8	late July	3	nd	nd	nd
332	0.332					9	Groundtruth		60	650170	1482667
332	0.332					10	Sept	3	nd	nd	nd
343	0.343	F	13	471	1650	1	Nov	1	60	650124	1481705
343	0.343					2	Jan	1	60	650122	1481729
343	0.343					3	March	1	60	650124	1481694
343	0.343					4	April	1	60	650129	1481708
343	0.343					5	May	1	60	650180	1482430
343	0.343					6	June	3	nd	nd	nd
343	0.343					7	July	1	60	650157	1482050
343	0.343					8	late July	3	nd	nd	nd
343	0.343					9	Groundtruth		60	650151	1481706
343	0.343					10	Sept	3	nd	nd	nd
351	0.351	F	11	477	1443	1	Nov	1	30	650286	1475791
351	0.351					2	Jan	1	60	650300	1480385
351	0.351					3	March	1	60	650301	1480362
351	0.351					4	April	1	60	650290	1480439
351	0.351					5	May	1	60	650284	1480483
351	0.351					6	June	3	nd	nd	nd
351	0.351					7	July	1	60	650286	1480173
351	0.351					8	late July	3	nd	nd	nd
351	0.351					9	Groundtruth		60	650298	1480365
351	0.351					10	Sept	3	nd	nd	nd
362	0.362	M	9	463	1312	1	Nov	1	60	650164	1482861
362	0.362					2	Jan	1	60	650131	1482878
362	0.362					3	March	1	60	650127	1482964
362	0.363					4	April	1	60	650128	1482763
362	0.363					5	May	1	60	650102	1483262
362	0.363					6	June	3	nd	nd	nd
362	0.363					7	July	1	60	650141	1483017
362	0.363					8	late July	3	nd	nd	nd
362	0.363					9	Groundtruth		60	650149	1482932

-continued-

Appendix B1.-Page 8 of 12.

Transmitter:		Implanted Fish:					Tracking Statistics:			GPS[d] Location	
Number	Freq[a]	Sex	Age	Length	Weight	Record	Tracking	Result[b]	BPM[c]	Latitude	Longitude
362	0.363					10	Sept	3	nd	nd	nd
373	0.373	F	12	482	1792	1	Nov	1	60	650173	1480947
373	0.373					2	Jan	1	60	650180	1480987
373	0.373					3	March	1	60	650187	1480952
373	0.373					4	April	1	60	650165	1480976
373	0.373					5	May	1	60	650200	1480964
373	0.373					6	June	3	nd	nd	nd
373	0.373					7	July	1	60	650163	1480952
373	0.373					8	late July	3	nd	nd	nd
373	0.373					9	Groundtruth	3	nd	nd	nd
373	0.373					10	Sept	3	nd	nd	nd
383	0.383	F	14	521	1928	1	Nov	1	60	650217	1480856
383	0.383					2	Jan	1	60	650301	1475578
383	0.383					3	March	1	60	650205	1480711
383	0.383					4	April	1	60	650200	1480855
383	0.383					5	May	1	60	650194	1481503
383	0.383					6	June	3	nd	nd	nd
383	0.383					7	July	1	60	650225	1480570
383	0.383					8	late July	3	nd	nd	nd
383	0.383					9	Groundtruth	3	nd	nd	nd
383	0.383					10	Sept	1	60	650217	1480844
393	0.393	M	10	492	1450	1	Nov	1	30	650279	1480051
393	0.393					2	Jan	1	60	650222	1481323
393	0.393					3	March	1	60	650222	1481315
393	0.393					4	April	1	60	650207	1481330
393	0.393					5	May	1	60	650225	1481277
393	0.393					6	June	3	nd	nd	nd
393	0.393					7	July	1	60	650191	1481231
393	0.393					8	late July	3	nd	nd	nd
393	0.393					9	Groundtruth	3	nd	nd	nd
393	0.393					10	Sept	3	nd	nd	nd
413	0.413	F	I	469	1385	1	Nov	1	60	650199	1480703
413	0.413					2	Jan	1	60	650277	1480337
413	0.413					3	March	1	60	650251	1475973
413	0.412					4	April	1	60	650267	1475802
413	0.412					5	May	1	60	650158	1481764
413	0.412					6	June	3	nd	nd	nd
413	0.412					7	July	1	60	650210	1480787
413	0.412					8	late July	3	nd	nd	nd
413	0.412					9	Groundtruth	3	nd	nd	nd
413	0.412					10	Sept	1	60	650210	1480756
424	0.424	F	I	486	1441	1	Nov	1	60	650178	1481337
424	0.424					2	Jan	1	60	650168	1481462
424	0.424					3	March	1	60	650167	1481485
424	0.424					4	April	1	60	650192	1481158
424	0.424					5	May	1	60	650194	1481503

-continued-

Transmitter :		Implanted Fish:				Tracking Statistics:				GPS[d] Location	
Number	Freq[a]	Sex	Age	Length	Weight	Record	Tracking	Result[b]	BPM[c]	Latitude	Longitude
424	0.424					6	June	3	nd	nd	nd
424	0.424					7	July	1	60	650160	1481549
424	0.424					8	late July	3	nd	nd	nd
424	0.424					9	Groundtruth	1	60	650187	1481570
424	0.424					10	Sept	1	60	650154	1481538
432	0.432	F	R	457	1348	1	Nov	1	60	650363	1475388
432	0.432					2	Jan	1	30	650324	1475428
432	0.432					3	March	1	30	650364	1475397
432	0.431					4	April	1	30	650356	1475447
432	0.431					5	May	1	30	645394	1484816
432	0.431					6	June	0	nd	nd	nd
432	0.431					7	July	1	60	645890	1485189
432	0.431					8	late July	1	60	645911	1485179
432	0.431					9	Groundtruth	3	nd	nd	nd
432	0.431					10	Aug	1	60	645887	1485179
432	0.431					11	Sept	1	60	645897	1485162
453	0.453	F	11	457	1478	1	Nov	1	60	650138	1482874
453	0.453					2	Jan	1	60	650134	1482845
453	0.453					3	March	1	60	650170	1482893
453	0.453					4	April	1	60	650157	1482834
453	0.453					5	May	1	60	650128	1482868
453	0.453					6	June	3	nd	nd	nd
453	0.453					7	July	1	60	650145	1482836
453	0.453					8	late July	3	nd	nd	nd
453	0.453					9	Groundtruth		60	650136	1482868
453	0.453					10	Sept	1	60	650134	1482875
462	0.462	F	12	471	1506	1	Nov	1	60	650164	1482546
462	0.462					2	Jan	1	60	650170	1482357
462	0.462					3	March	1	60	650150	1482454
462	0.462					4	April	1	60	650194	1482483
462	0.462					5	May	0	nd	nd	nd
462	0.462					6	June	3	nd	nd	nd
462	0.462					7	July	0	nd	nd	nd
462	0.462					8	late July	1	30	650176	1482628
462	0.462					9	Groundtruth	0	nd	nd	nd
462	0.462					10	Sept	1	30	650166	1482618
473	0.473	F	10	458	1307	1	Nov	1	60	650147	1481941
473	0.473					2	Jan	1	60	650128	1481793
473	0.473					3	March	1	60	650122	1481849
473	0.473					4	April	1	60	650126	1481757
473	0.473					5	May	1	60	650176	1482132
473	0.473					6	June	3	nd	nd	nd
473	0.473					7	July	1	60	650152	1482089
473	0.473					8	late July	3	nd	nd	nd
473	0.473					9	Groundtruth		60	650163	1482019
473	0.473					10	Sept	3	nd	nd	nd

-continued-

Transmitter:		Implanted Fish:					Tracking Statistics:			GPS[d] Location	
Number	Freq[a]	Sex	Age	Length	Weight	Record	Tracking	Result[b]	BPM[c]	Latitude	Longitude
482	0.482	M	11	458	1401	1	Nov	0	nd	nd	nd
482	0.482					2	Jan	1	60	650165	1482099
482	0.482					3	March	0	nd	nd	nd
482	0.482					4	April	0	nd	nd	nd
482	0.482					5	May	0	nd	nd	nd
482	0.482					6	June	3	nd	nd	nd
482	0.482					7	July	0	nd	nd	nd
482	0.482					8	late July	0	nd	nd	nd
482	0.482					9	Groundtruth	3	nd	nd	nd
482	0.482					10	Sept	0	nd	nd	nd
491	0.491	F	13	487	1527	1	Nov	1	60	650170	1480903
491	0.491					2	Jan	1	60	650155	1480960
491	0.491					3	March	1	60	650170	1480955
491	0.491					4	April	1	60	650176	1481028
491	0.492					5	May	1	60	650175	1482496
491	0.492					6	June	3	nd	nd	nd
491	0.492					7	July	1	60	not pinpointed	
491	0.492					8	late July	3	nd	nd	nd
491	0.492					9	Groundtruth	3	nd	nd	nd
491	0.492					10	Sept	1	60	650174	1480949
503	0.503	F	R	468	1617	1	Nov	1	60	650369	1475013
503	0.503					2	Jan	1	60	650334	1475014
503	0.503					3	March	1	60	650317	1475050
503	0.503					4	April	1	60	650361	1475009
503	0.503					5	May	0	nd	nd	nd
503	0.503					6	June	3	nd	nd	nd
503	0.503					7	July	0	nd	nd	nd
503	0.503					8	late July	0	nd	nd	nd
503	0.503					9	Groundtruth	3	nd	nd	nd
503	0.503					10	Sept	0	nd	nd	nd
511	0.511	F	13	458	1500	1	Nov	1	60	650342	1475353
511	0.511					2	Jan	1	30	650366	1475432
511	0.511					3	March	1	30	650321	1475492
511	0.511					4	April	1	30	650324	1475448
511	0.511					5	May	1	30	645228	1485086
511	0.511					6	June	1	30	645499	1484683
511	0.511					7	July	1	60	650156	1482617
511	0.511					8	late July	1	30	650183	1481305
511	0.511					9	Groundtruth	3	nd	nd	nd
511	0.511					10	Sept	1	60	650308	1475546
522	0.522	F	14	474	1531	1	Nov	1	30	650340	1475335
522	0.522					2	Jan	1	30	650353	1475375
522	0.522					3	March	1	30	650378	1475351
522	0.522					4	April	1	30	650339	1475396
522	0.522					5	May	1	30	645195	1485142
522	0.522					6	June	3	nd	nd	nd

-continued-

Appendix B1.-Page 11 of 12.

Transmitter :		Implanted Fish:				Tracking Statistics:				GPS[d] Location	
Number	Freq[a]	Sex	Age	Length	Weight	Record	Tracking	Result[b]	BPM[c]	Latitude	Longitude
522	0.522					7	July	1	60	645929	1484376
522	0.522					8	late July	1	60	645932	1484371
522	0.522					9	Aug	1	60	6459041	1484351
522	0.522					10	Groundtruth	3	nd	nd	nd
522	0.522					11	Sept	1	60	645908	1484379
533	0.533	F	13	488	1587	1	Nov	1	30	650201	1481310
533	0.533					2	Jan	1	60	650154	1482032
533	0.533					3	March	1	60	650148	1482047
533	0.533					4	April	1	60	650324	1475448
533	0.533					5	May	1	60	650176	1482132
533	0.533					6	June	3	nd	nd	nd
533	0.533					7	July	1	60	650152	1482136
533	0.533					8	late July	3	nd	nd	nd
533	0.533					9	Groundtruth	1	60	650168	1482209
533	0.533					10	Sept	3	nd	nd	nd
544	0.544	F	11	450	1399	1	Nov	0	nd		
544	0.544					2	Jan	1	60	650232	1492658
544	0.544					3	March	1	60	650215	1492689
544	0.544					4	April	1	60	650219	1492592
544	0.544					5	May	1	60	650229	1492755
544	0.544					6	June	3	nd	nd	nd
544	0.544					7	July	1	60	not pinpointed	
544	0.544					8	late July	1	60	650214	1492731
544	0.544					9	Groundtruth	3	nd	nd	nd
544	0.544					10	Sept	1	60	same location	
553	0.553	F	12	487	1885	1	Nov	1	30	650218	1480572
553	0.553					2	Jan	1	30	650241	1480570
553	0.553					3	March	1	30	650204	1480711
553	0.553					4	April	1	30	650200	1480692
553	0.553					5	May	1	30	645440	1484611
553	0.553					6	June	0	nd	nd	nd
553	0.553					7	July	1	60	645852	1484195
553	0.553					8	late July	1	60	645855	1484171
553	0.553					9	Aug	1	60	645913	1484305
553	0.553					10	Groundtruth	3	nd	nd	nd
553	0.553					11	Sept	1	60	6458952	1484204
564	0.564	F	10	474	1417	1	Nov	1	30	650183	1481324
564	0.564					2	Jan	1	60	650144	1481551
564	0.564					3	March	1	60	650154	1481741
564	0.563					4	April	1	60	650156	1481734
564	0.563					5	May	1	60	650161	1482342
564	0.563					6	June	3	nd	nd	nd
564	0.563					7	July	1	60	650152	1481739
564	0.563					8	late July	3	nd	nd	nd
564	0.563					9	Groundtruth	1	60	650149	1481721
564	0.563					10	Sept	1	60	650163	1481600

-continued-

Appendix B1.-Page 12 of 12.

Transmitter :		Implanted Fish:				Tracking Statistics:				GPS[d] Location	
Number	Freq[a]	Sex	Age	Length	Weight	Record	Tracking	Result[b]	BPM[c]	Latitude	Longitude
584	0.584	F	11	485	1590	1	Nov	1	60	650352	1475234
584	0.584					2	Jan	1	60	650378	1475207
584	0.584					3	March	1	60	650326	1475138
584	0.584					4	April	1	60	650358	1475230
584	0.584					5	May	1	60	650349	1475264
584	0.584					6	June	3	nd	nd	nd
584	0.584					7	July	1	60	650347	1475224
584	0.584					8	late July	3	nd	nd	nd
584	0.584					9	Groundtruth	1	60	650359	1475244
584	0.584					10	Sept	3	nd	nd	nd
593	0.593	F	14	472	1570	1	Nov	1	30	650147	1481625
593	0.593					2	Jan	1	60	650161	1481377
593	0.593					3	March	1	60	650184	1481586
593	0.593					4	April	1	60	650163	1481481
593	0.593					5	May	1	60	650173	1482179
593	0.593					6	June	3	nd	nd	nd
593	0.593					7	July	1	60	650144	1481698
593	0.593					8	late July	3	nd	nd	nd
593	0.593					9	Groundtruth	1	60	650145	1481644
593	0.593					10	Sept	3	nd	nd	nd

a = Frequency of the radio transmitting tag in Megahertz (mhz).

b = Aerial tracking result. Fish were either not found (0), found (1), or not searched for (3).

c = Pulse rate of the radio transmitter in Beats Per Minute (BPM).

d = Global Positioning System used to determine near exact geographic location. Numbers represent location in degrees, minutes, seconds, such as: 65° 01' 63".