Fishery Data Series No. 99-18

Stock Monitoring of Whitefish in the Chatanika River During 1998

by
Douglas F. Fleming

August 1999

Alaska Department of Fish and Game Division of Sport Fish

Symbols and Abbreviations

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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

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by

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ABSTRACT

Stock assessment in 1997 indicated Chatanika River whitefish were not sufficient in number or composition to prosecute fisheries in 1997 or 1998. A monitoring project was used in 1998 to collect age and size data from the pre-spawning populations. In late August, 462 humpback whitefish *Coregonus pidschian* ≥ 360 mm FL and 216 least cisco *C. sardinella* ≥ 290 mm FL were sampled from a 30 km section of the Chatanika River. Sampling was conducted using electrofishing within the geographic bounds and timing of stock assessments from 1992-1994. Humpback whitefish that were ages 6 and 7 were most common, which indicated lower recruitment levels than in prior years. The most common size of humpback whitefish was between 430 and 440 mm FL. Ages 6 and 7 were the most common ages of least cisco, and the most common sizes fell between 350 and 360 mm FL. Again, a tendency toward older aged individuals has indicated lower recruitment levels in 1998. There were, however, a presence of younger and smaller fish which may suggest future improvement in recruitment.

Key Words: humpback whitefish, *Coregonus pidschian*, least cisco, *Coregonus sardinella*, age composition, length composition, recruitment, scales.

INTRODUCTION

Each year humpback whitefish *Coregonus pidschian* and least cisco *C. sardinella* migrate from Minto Flats into the Chatanika River to spawn and overwinter (Figure 1). Past investigations have indicated that whitefish migrate to spawning areas in the Chatanika River between June and September (Townsend and Kepler 1974, Fleming *Unpublished*). A significant fall spear fishery for these species developed during the 1980s, primarily between the Elliot Highway Bridge and the Olnes Pond Campground. In addition, a limited harvest was taken further upstream along the Steese Highway. Estimated whitefish harvest (species combined) from the Chatanika River increased from 1,635 fish in 1977 to 25,074 in 1987 (Mills 1979-1994). In response to increasing harvests, stock assessments were initiated in 1986 for humpback whitefish and least cisco.

Based on concerns of the increasing harvests of whitefish, the Board of Fisheries restricted the harvest of whitefish in the Tanana River drainage to a bag limit of 15 fish per day in 1987. Further management actions included an emergency closure during 1990 and a complete closure in 1991 because preliminary assessments indicated the need for conservation of the spawning stocks. Research efforts in 1991 confirmed preliminary information that the humpback whitefish stock was depressed (estimated abundance of humpback whitefish over a 125 km section of the river was 15,313 fish; Timmons 1991). For this reason, the Board of Fisheries shortened the season and reduced the geographic area of the fishery in 1992 to help rebuild the stock. A Chatanika River Fishery Management Plan was developed in 1992, which required abundance levels of 10,000 humpback whitefish and 40,000 least cisco before a fishery may be prosecuted. The spear fishery was closed by emergency order from 1994-1998 to allow for the unimpaired spawning of whitefish in the Chatanika River and to allow time for stock rebuilding.

Results of stock assessment investigations from 1992 through 1997 indicated that abundance of the whitefish stocks declined despite conservative regulatory action, fishery closures, and low levels of exploitation during this time (Fleming 1994, 1996, 1997). In 1995, the stocks of humpback whitefish and least cisco were not assessed. In 1996, age and size sampling of whitefish in the Chatanika River was conducted to detect stock rebuilding through recruitment of smaller and younger fish. Monitoring samples detected signs of stock rebuilding in the Humpback whitefish population (Fleming 1997). In 1997, a complete stock assessment, which

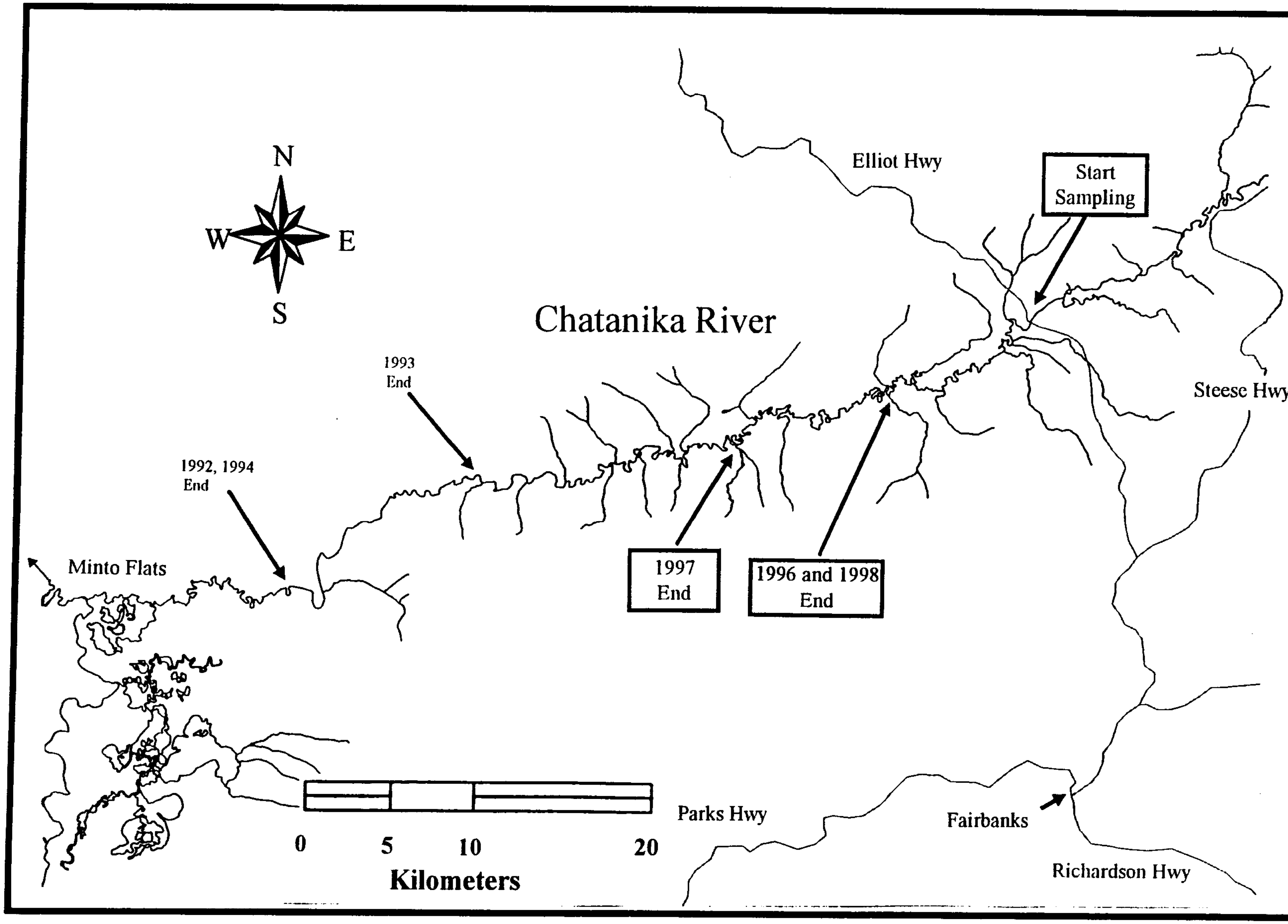

Figure 1.-Map of 1992-1998 study areas encompassing Minto Flats and the Chatanika River.

included estimating abundance of least cisco and humpback whitefish was carried out. The humpback whitefish population was found to have increased in number through recruitment, while the results indicated a stock collapse in the least cisco population. Estimated abundances of whitefish in a 78.2 km section of the Chatanika River in 1992, 1993, and 1994, and in a 53 km section in 1997 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)
1994	12,700 fish (SE = 1,138)	27,639 fish (SE = 3,211)
1997	16,107 fish (SE = 1,260)	22,811 fish (SE = 4,496)

Estimated harvest of Chatanika River whitefish from creel surveys document the change in harvest, which reflect changes in regulation and management: (Clark and Ridder 1987; Baker 1988, 1989; Merritt et al. 1990; Hallberg and Bingham 1991-1995; and, Howe et al. 1995-1998):

Year	Humpback Whitefish Harvest	SE	Least Cisco Harvest	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	---
1996[a]	0	---	0	---
1997[a]	0	---	0	---
1998[a]	0	---	0	---

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

The most recent estimate of subsistence harvest was in 1994, which included 415 humpback whitefish and 115 least cisco (J. E. Hallberg, Alaska Department of Fish and Game, Fairbanks, personal communication). This estimate of harvest was considerably less than the previous estimate reported by Andrews (1988; 6,477 *coregonids*, all species). It is believed that recent subsistence harvests of whitefish in Minto Flats are similar to those in 1994.

In 1998, a low level monitoring program was used to collect information on the whitefish stocks. Like 1996, age and size sampling was conducted to look for indications of stock rebuilding through recruitment. A sizeable shift in size and age composition toward smaller and younger fish in the limited sample could indicate a significant increase in recruitment, and trigger the resumption of full stock assessment.

The research objectives for 1998 were to estimate:

1. age composition of least cisco and humpback whitefish in a 30 km section of the Chatanika River during late-August, such that all proportions are within 10 percentage points of the true proportion 95% of the time; and,
2. length composition of least cisco and humpback whitefish in a 30 km section of the Chatanika River during late-August, such that all proportions are within 10 percentage points of the true proportion 95% of the time.

METHODS

STUDY AREA

Early whitefish stock assessments occurred over areas of the Chatanika River near the Elliot Highway, but after 1990 sampling was extended significantly downstream (Figure 1). Assessments prior to 1991 were within an area 15 km above and below the Elliot Highway bridge. This section of the Chatanika River is characterized by moderate gradient and short meanders interspersed with gravel riffles, is thought to provide spawning habitat for the whitefish, and is affected by the recreational spear fishery. In 1991, the study area was extended downstream an additional 83.7 km because exploitation of whitefish tagged well below the spear fishing area was detected (Timmons 1991). The extension of the study area included several additional habitat types. Immediately downstream of the earlier sampling area, moderate gradient habitat (described above) continues for an additional 5 km. At this location, the river transitions to a lower gradient section with a slow flow through numerous meanders. Here the channel is composed of silt and sand with adjacent cut banks rising 2-3 m to the surrounding taiga. The low gradient habitat extends downstream approximately 33 km before the river's course straightens with fewer bends and several shallow and rocky riffle areas. This varied habitat continues approximately 24 km. The river reverts to a higher gradient for the final 28 km to the end of the 1992 and 1994 study area. The river channel in this section is composed of a series of wide shallow runs and riffles, with coarse cobble and bedrock substrate. The 30 km study area in 1998 included low and moderate gradient portions of the Chatanika River upstream of Any Creek, which have been heavily utilized by pre-spawning whitefish in all past assessments.

STUDY DESIGN AND FIELD SAMPLING

Age and size sampling occurred in late August because a 1996 investigation into sample timing concluded that estimates of age and size composition taken during late August and the middle of September were functionally alike (Fleming 1997). A single crew of three persons used a pulsed

DC electrofishing boat to capture fish within a 30 km stretch of the Chatanika River. Sampling was conducted between the Elliot Highway bridge and Any Creek. The sampling period was August 25- 26, which corresponded to the timing of recent stock assessments (Timmons 1991, Fleming 1993, 1994, 1996, 1997).

To limit holding time and stress of captured fish, the electrofishing crew fished in a downstream direction for a maximum of 20 min. Twenty-minutes of electrofishing constituted each recorded sampling run. Variable voltage pulsator (VVP) settings were 60 Hz pulsed DC ranging from 220 to 260 volts and 1 to 5 A. Stunned fish were netted and placed into a large aerated live well to await sampling. During sampling, all fish were examined for tags, fork length measured, and the upper caudal fin partially clipped to avoid resampling. Three scales were systematically collected from each fish, gently cleaned, and mounted directly onto gum cards for later pressing and aging. Scales were taken from an area above the lateral line and below the dorsal fin on the left side of each sampled fish (Van Oosten 1923). Three scales per fish were collected and mounted to offset scale regeneration and to maintain precision levels in composition estimates. The scales from 10 fish were mounted on each gum card. Gum cards were later used to make triacetate impressions using a scale press (30 s at 137,895 kPa, at a temperature of 97°C). Ages were determined by counts of annuli from impressions of scales magnified to 40X with the aid of a microfiche reader. Criteria for determining the presence of an annulus were: 1) complete circuli cutting over incomplete circuli; 2) clear areas or irregularities in circuli along the anterior and posterior fields; and, 3) regions of closely spaced circuli followed by a region of widely spaced circuli (Van Oosten 1923).

Data collection procedures from previously marked humpback whitefish and least cisco were similar, but tag numbers, and tag colors were also recorded. All data were recorded on Alaska Department of Fish and Game Tagging Length Form, Version 1.0.

AGE AND SIZE COMPOSITIONS

Apportionment of the sample among age or size groupings depends on the extent of sampling biases, if known. Since 1991 there have been five stock assessments using mark-recapture, and among the 10 estimates (5 least cisco estimates, 5 humpback whitefish) there was only one estimate where adjustments led to meaningful differences in abundance, and to a lesser degree in composition estimates. In 1993, there was a 10% upward shift in the estimated abundance of least cisco after adjustments for size selectivity (Fleming 1994). In the same assessment, the estimated proportion of age-3 fish increased from 0.265 to 0.305 after adjustments for sampling bias, and the proportion of least cisco in the 330-339 mm FL size class increased from 0.175 to 0.219. Since size selectivity was either minimal or not detected in past mark-recapture experiments, unadjusted samples were considered comparable to those obtained with full mark-recapture procedures. The proportion of fish at age *k* (or length class *k*) in 1998 was estimated by:

$$\hat{p}_k = \frac{y_k}{n} \qquad (1)$$

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:

$$\hat{V}[p_k] = \left[\frac{\hat{p}_k(1-\hat{p}_k)}{(n-1)}\right]. \quad (2)$$

Stock assessment categories for the 1998 study used the same formulae, where substitutions for class were: age classes and 10 mm FL incremental size classes. Incremental 10 mm FL size classes had mid-points ranging from 295 to 425 mm FL for least cisco and 365 to 560 mm FL for humpback whitefish.

RESULTS

FIELD SAMPLING

On August 25 and 26, investigators captured and sampled 464 humpback whitefish and 222 least cisco between the Elliot Highway Bridge and Any Creek (Figure 1). Information from 462 humpback whitefish (≥ 360 mm FL) and 216 least cisco (≥ 290 mm FL) was used to generate composition estimates. During sampling, water conditions were moderately high and turbid with water temperatures ranging between 7.8°C and 10°C. The overall acute mortality rate from sampling was 0 out of 464 individual humpback whitefish handled, or 0.0%. The overall acute mortality rate was 0.4% for least cisco, based on 1 mortality out of 222 fish sampled.

AGE AND SIZE COMPOSITION

Humpback Whitefish

Scale samples were collected from 462 humpback whitefish during August, of which 417 were aged (9.7% of the samples were regenerated or illegible). Ages observed for humpback whitefish in the Chatanika River ranged from 3 to 14 years for fish ranging between 344 and 525 mm FL, with age 7 as the median age. The age class with the highest frequency was age 6 (27%; Table 1, Appendix A1) followed by age 7 fish (25%) in the August sample. The median size humpback whitefish was 428 mm FL, and the mode between 430 and 440 mm FL in the sample of 462 fish (Tables 1, Appendix A2).

Least Cisco

Scale samples were collected from 216 least cisco during August, of which 203 were aged (6% of the samples were regenerated or illegible). Ages observed for least cisco (≥ 290 mm FL) in the Chatanika River ranged from 2 to 11 years and lengths ranged between 240 and 416 mm FL. The age classes with the highest relative frequencies were age 6 and age 7 (each 24% of the stock: Table 2, Appendix B1), followed by age 4 (20%). The median size least cisco was 348 mm FL and the mode between 350 and 360 mm FL (Table 2, Appendix B2).

Table 1.- Sample sizes, estimated proportions, and standard errors of proportions by age and length classes (10 mm FL incremental size groupings) for humpback whitefish (> 360 mm FL) captured from the Chatanika River, August 25 through 26, 1998.

Age	Count	$\hat{p}$[a]	SE[b]	Length	Count	$\hat{p}$[a]	SE[b]
3	0	0.00	0.00	335	0	0.00	0.00
				345	0	0.00	0.00
4	15	0.04	0.01	355	0	0.00	0.00
				365	1	< 0.01	< 0.01
5	58	0.14	0.02	375	3	0.01	< 0.01
				385	15	0.03	0.01
6	111	0.27	0.02	395	26	0.05	0.01
				405	49	0.11	0.01
7	105	0.25	0.02	415	70	0.15	0.02
				425	78	0.17	0.02
8	31	0.07	0.01	435	58	0.12	0.01
				445	58	0.12	0.01
9	29	0.07	0.01	455	29	0.06	0.01
				465	26	0.05	0.01
10	28	0.07	0.01	475	13	0.03	0.01
				485	11	0.02	0.01
11	15	0.04	0.01	495	11	0.02	0.01
				505	9	0.02	0.01
12	13	0.03	0.01	515	4	0.01	< 0.01
				525	1	< 0.01	< 0.01
13	9	0.02	0.01	535	0	0.00	0.00
				545	0	0.00	0.00
14	3	< 0.01	< 0.01	555	0	0.00	0.00
15	0	0.00	0.00				
16	0	0.00	0.00				
> 16	0	0.00	0.00				
Totals	417	1	---	Total	462	1.00	----

[a] $\hat{p}$ = proportion of humpback whitefish in the assessed stock at the time of sampling.

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

Table 2.- Sample sizes, estimated proportions, and standard errors of proportions by age and length classes (10 mm FL incremental size groupings) for least cisco (≥290 mm FL) captured from the Chatanika River, August 25 through 26, 1998.

Age	Count	$\hat{p}$[a]	SE[b]		Length	Count	$\hat{p}$[a]	Se[b]
1	0	0.00	0.00		295	6	0.03	0.01
					305	8	0.04	0.01
2	2	0.01	< 0.01		315	9	0.04	0.01
					325	23	0.11	0.02
3	13	0.06	0.02		335	32	0.15	0.02
					345	35	0.16	0.02
4	41	0.20	0.03		355	43	0.20	0.03
					365	25	0.12	0.02
5	38	0.19	0.03		375	13	0.06	0.02
					385	12	0.05	0.02
6	48	0.24	0.03		395	5	0.02	0.01
					405	4	0.02	0.01
7	49	0.24	0.03		415	1	< 0.01	< 0.01
					425	0	0.00	0.00
8	8	0.04	0.01		435	0	0.00	0.00
					445	0	0.00	0.00
9	1	< 0.01	< 0.01		455	0	0.00	0.00
					465	0	0.00	0.00
10	1	< 0.01	< 0.01		475	0	0.00	0.00
					485	0	0.00	0.00
11	2	0.01	0.01		495	0	0.00	0.00
					505	0	0.00	0.00
12	0	0.00	0.00		515	0	0.00	0.00
					525	0	0.00	0.00
Totals	203	1	---		Total	216	1.00	----

[a] $\hat{p}$ = proportion of least cisco in the assessed stock at the time of sampling.
[b] **SE** = standard error of the proportional contribution.

DISCUSSION

In the past eight years (1991-1998) management actions have reduced sport harvests of Chatanika River whitefish (cumulative harvest: 2,507 least cisco and 479 humpback whitefish) to conserve stocks. After 1994 estimates indicated least cisco had declined to levels below the fishery threshold, abundance estimation was suspended in 1995. In 1996, size and age sampling was undertaken to monitor the populations for signs of stock rebuilding. An increased presence of small humpback whitefish recruiting to the population was detected in that year. Later, a mark-recapture abundance estimate conducted in 1997 reconfirmed the finding of humpback whitefish recruitment. However, findings from 1996 and 1997 indicated continued declines and recruitment failure in the least cisco stock. The composition of the least cisco stock had shifted toward older and larger fish.

The 1998 sampling program sought to detect changes in the size and age compositions of samples that would indicate rebuilding through recruitment. The 1998 size and age composition estimates indicated the growth of the humpback whitefish spawning stock through recruitment has slowed. Compared to 1996 and 1997, smaller proportions of the stock in 1998 were comprised of small humpback whitefish corresponding to ages 4 and 5 years (Appendices A1 and A2). On the other hand, sampling results from 1998 indicated slight improvements in recruitment to the least cisco spawning stock. Least cisco between 320 and 340 mm FL and age-4 fish were more strongly represented in the 1998 sample than in 1997 (Appendices B1 and B2). Moreover, increased catches in the smallest size grouping of assessed least cisco (290 to 300 mm FL) may suggest changes in levels of pre-recruitment survival. It is apparent that the stock collapse and associated recruitment failures reached a low point in 1997 (Appendix B3). Moreover, if recruitment events in the near future become significant, the CDF curve should shift left and return to a relative location similar to samples from 1989-1994.

It appears that the least cisco population fluctuates from high levels to low levels. One factor contributing to changes in least cisco abundance may be the latent effects of fishing mortality on parental stock during the 1980s, especially if a significant biological relationship exists between spawners and production of juvenile or recruiting whitefish. If this is true, we should see a significant increase of recruitment in the near future.

It is more likely that in recent years, abundance levels were related to changing levels of natural mortality prior to recruitment to the spawning stock. The Chatanika River drainage and Minto Flats complex contains several predatory fish stocks that use whitefish as a forage base. The northern pike *Esox lucius* population is also believed to have fluctuated between the middle 1980s and the present time. In 1994, an exceptionally greater number of northern pike were captured by anglers and a more widespread distribution was noted during whitefish assessment (D. Fleming, *Unpublished*). Likewise, sport angling reports and statewide harvest, catch and participation reports indicated a peak in northern pike catchability in Minto Flats during 1994 (Howe et al. 1995). Northern pike abundance may have increased recently in response to combinations of regulatory measures (Burkholder 1990) and favorable water conditions for reproduction and rearing.

Hydrologic fluctuations may influence the production of many fish species and subsequent levels of natural mortality in the Chatanika River and Minto Flats area. Varying water levels have been observed in the Minto Flats area between years or groups of years. It has been hypothesized that high water conditions may be favorable for the production of northern pike but the effect on whitefish is unknown. Low water conditions may reduce overwinter survival of northern pike and whitefish. These effects may have strong influences on whitefish recruitment, yet are uncontrollable, poorly understood, and not documented.

The hatch-out and post-hatch feeding of YOY river-spawning whitefish, however, are known to be influenced by hydrological effects. Research into the hatching and post-hatch drifting of larval whitefish have found that egg hatching is closely coupled to the mechanical agitation by increasing streamflows (Naesje et al. 1995). Moreover, Naesje et al. (1995) coupled this hatching strategy to the need of post-hatch larval whitefish to quickly reach feeding areas so that they can begin feeding, given the small metabolic reserves provided in the generally small egg sizes of *coregonids*. In Canada's MacKenzie River, most larval *coregonids* passively drift downstream and initiate feeding in areas ranging to the river's delta (Reist and Bond 1988) while larval Arctic cisco may be transported westward by wind-driven coastal currents to the Colville River in Alaska (Fechhelm and Griffiths 1990). It is likely that larval humpback whitefish and least cisco are similarly transported in the open river systems along the Yukon drainage, including the Tanana and its tributaries such as the Chatanika River. During breakup on the Chatanika River, water has been observed to backup from the river's channel into the surrounding lakes creating seasonal flooding. This has been seen during high flows of water resulting from snowmelt in the spring, ice jams following breakup, and from heavy summer rainfall (M. Evenson, Alaska Department of Fish and Game, Fairbanks, personal communication). It could be hypothesized that survival through the post-hatch drift period and eventual recruitment levels may be higher in years when the drifting larval whitefish are transported to adjacent lakes to start feeding. Moreover, if water levels in the Chatanika River are low during winter, overwintering habitat may become limiting. The prerecruit survival of whitefish could be reduced by increased predation following concentration of predators and prey, or inadequate supplies of oxygenated water may lead to winter-kill of all resident species.

The current state of the humpback whitefish stock indicates that the relatively large influx of recruiting fish first seen in 1996 is still present in the population. Unfortunately, the similarity between 1997 stock assessment estimates and the current composition estimates do not indicate another pulse of recruiting fish. It is poorly understood how the strong age-5 year class survived as a prey species during a period of increasing and peak numbers of northern pike in the Minto Flats area prior to recruitment to the spawning stock. One hypothesis is that those recruits reared in areas outside of the Minto Flats, such as from the mainstem or tributaries of the Tanana and Yukon Rivers, or from the Yukon River Delta. Other studies suggest a compound life history pattern for various *corregonids* inhabiting large Sub-Arctic and Arctic rivers such as the MacKenzie River, in Canada's Northwest Territory (Reist and Bond 1988). There, multiple life-history types may include lacustrine, riverine, and esturine-anadromous patterns within the populations.

Because relating hydrological conditions in Minto Flats to recruitment may be very difficult with the lack of appropriate data, I suggest that future whitefish studies should determine if Chatanika

River whitefish spawning stocks include fish from outside of the Minto Flats area. Otolith samples from Chatanika River and Minto Flats whitefish should be analyzed by strontium microprobe analysis to detect anadromy (see Secor et al. 1995, Babaluk et al. 1997 and Howland 1997). Tagging studies (radio transmitters or standard tagging) also could help to determine if production and recruitment are from freshwater areas outside of Minto Flats. If Chatanika River whitefish stocks do not range outside Minto Flats, then the scope of factors influencing recruitment can be localized and were easily studied. Cause and effect inferences about the recruitment process can then be focused on natural mortality processes within the Minto Flats area, especially since the recent fishing mortality level has been low.

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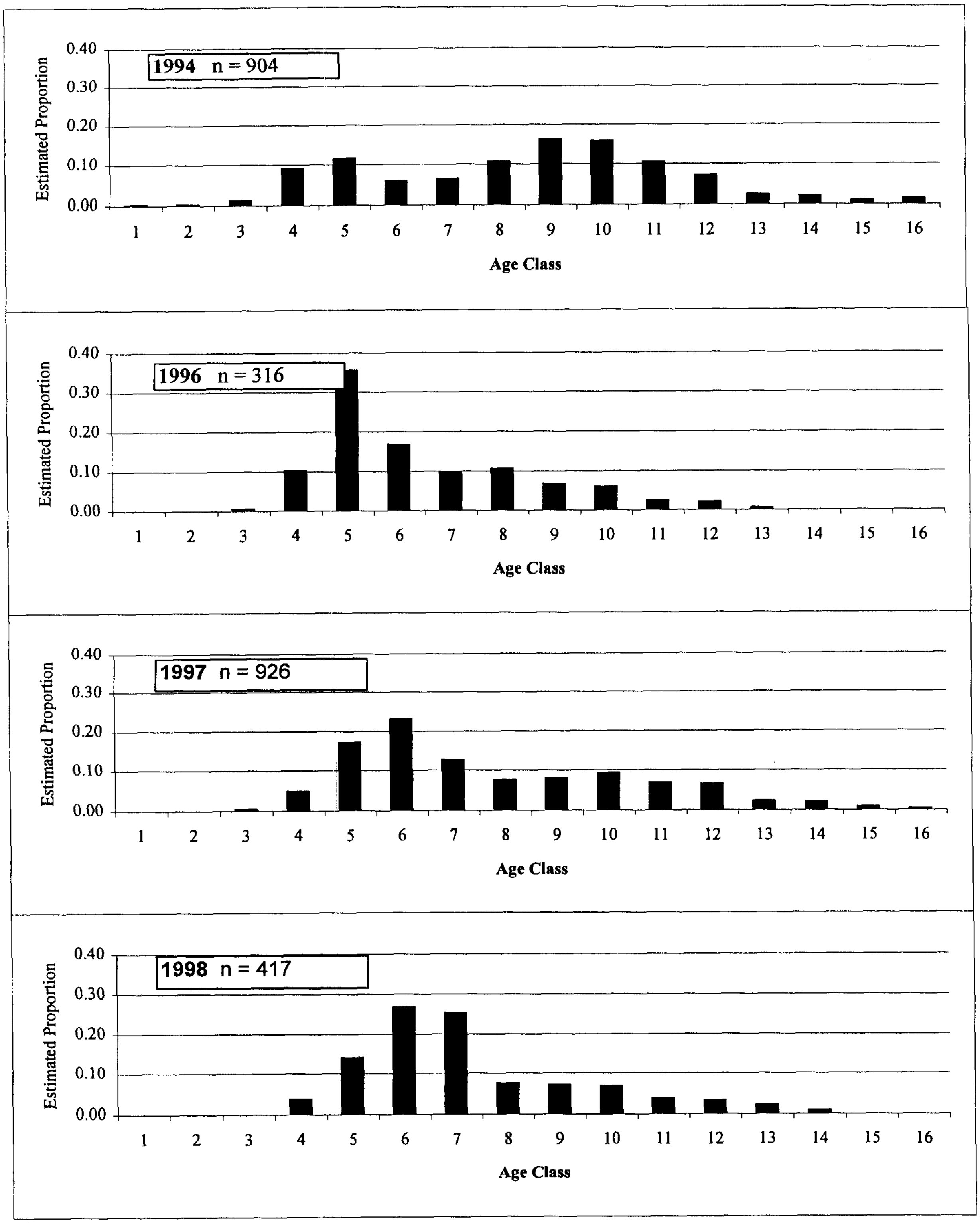
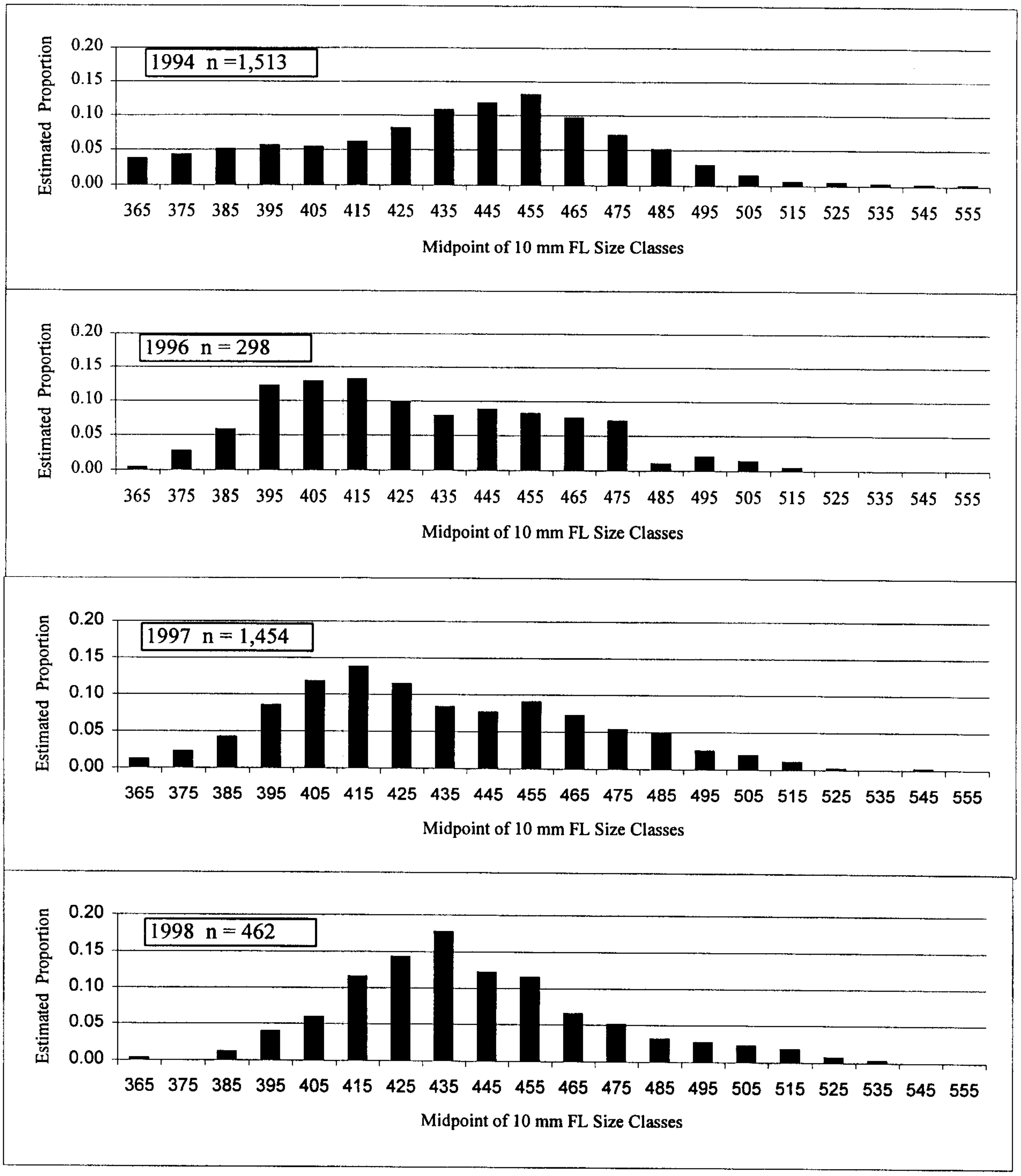
Appendix A
RECENT STOCK COMPOSITION OF HUMPBACK WHITEFISH

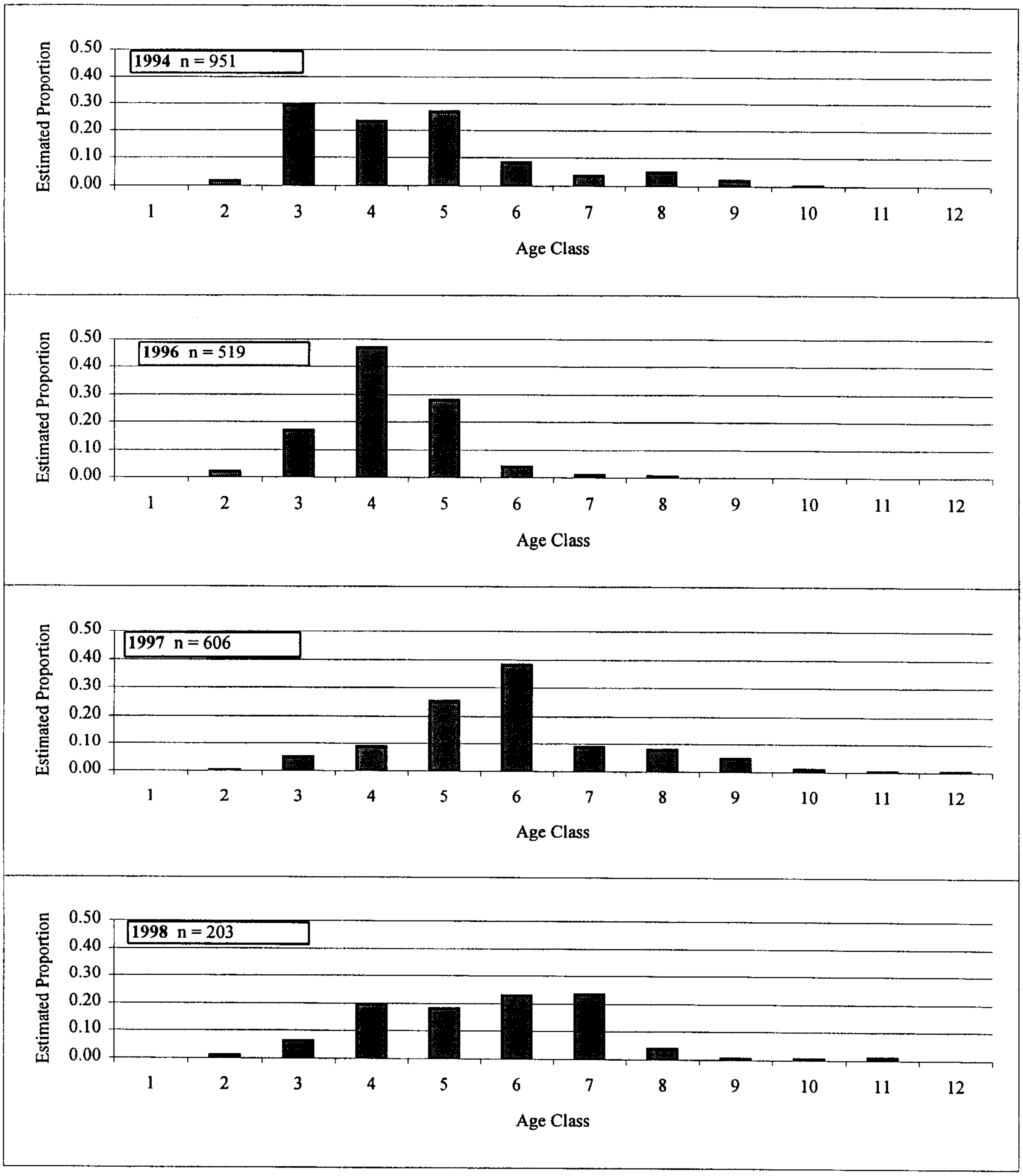


A1.-Estimated proportions of humpback whitefish (≥360 mm FL) by age class in the Chatanika River in 1994, 1996, 1997, and 1998

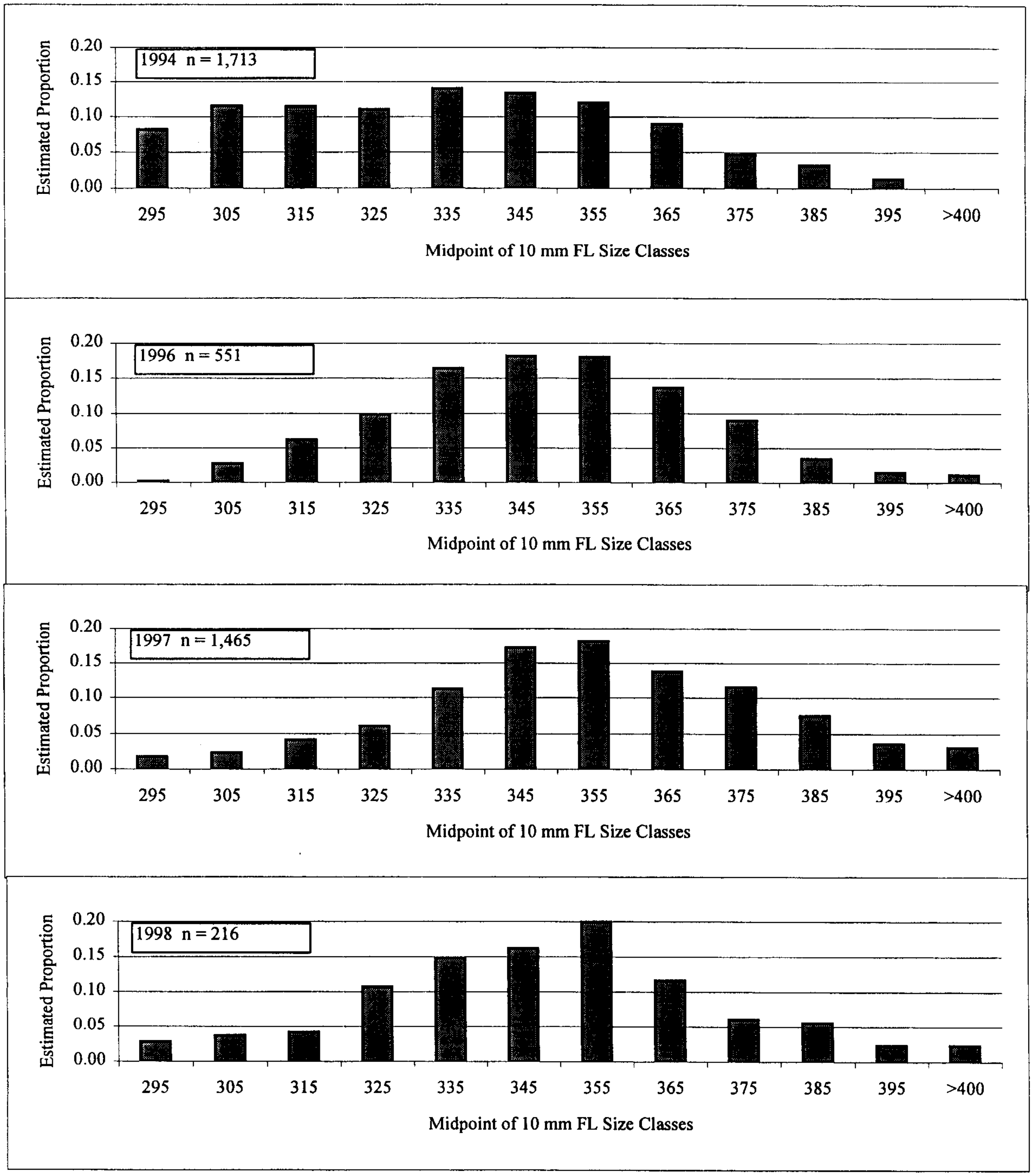


A2.-Estimated proportions of humpback whitefish (≥360 mm FL) by size in the Chatanika River in 1994, 1996, 1997, and 1998

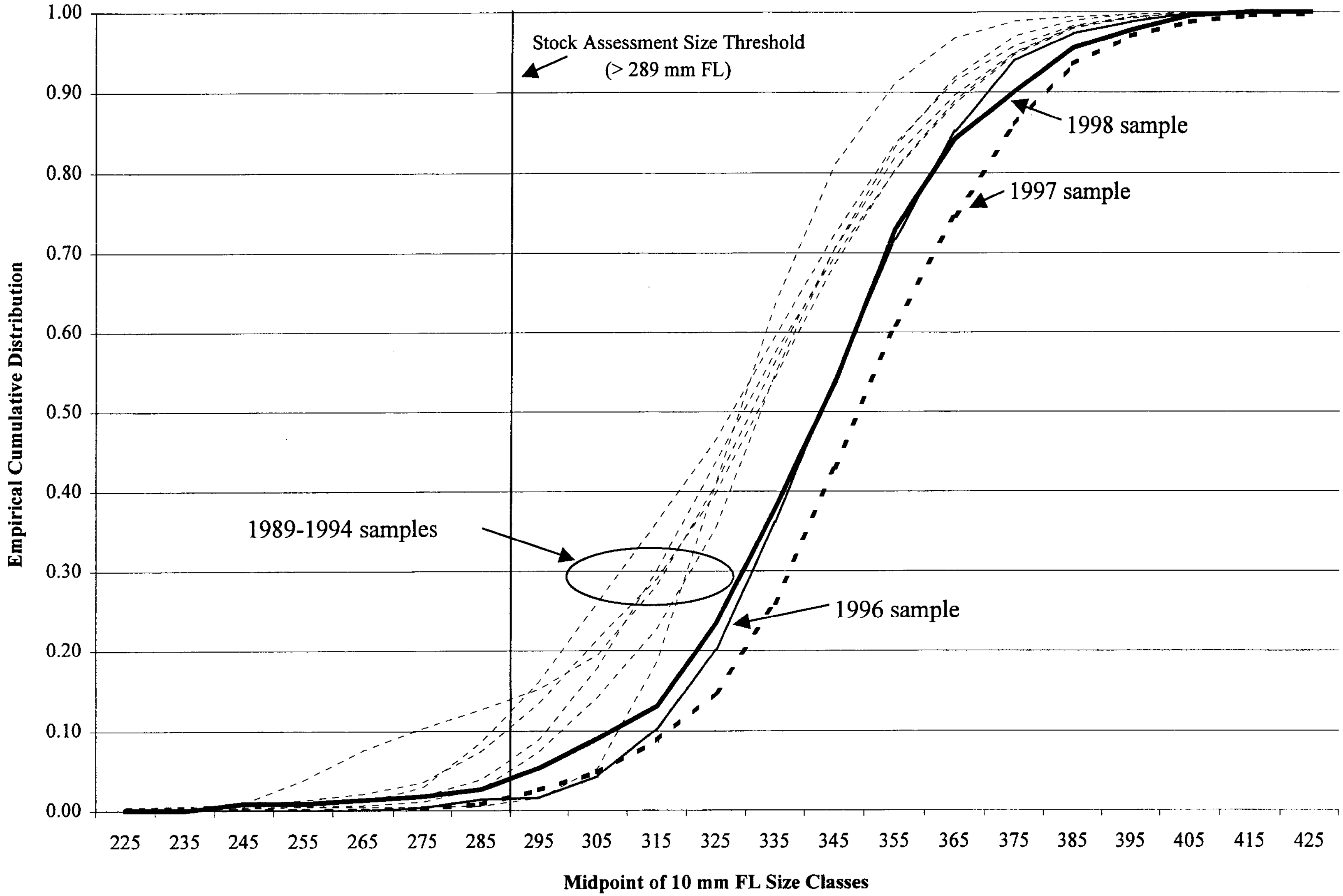
Appendix B
RECENT STOCK COMPOSITION OF LEAST CISCO



B1.-Estimated proportions of least cisco (≥290 mm FL) by age in the Chatanika River in 1994, 1996, 1997, and 1998



B2.-Estimated proportions of least cisco (≥290 mm FL) by size in the Chatanika River in 1994, 1996, 1997, and 1998



B3.-Empirical cumulative distribution of the sampled lengths of least cisco from Chatanika River stock assessments in 1986-1998.

Appendix C
DATA FILE LISTING

Appendix C.-Data file names and description of archived data files.

Data Files[a]	Description
U000400r011998	Humpback whitefish data file
U000400r021998	Least cisco data file

[a] Data files were archived at and are available from the Alaska Department of Fish and Game, Sport Fish Division, Research and Technical Services, 333 Raspberry Road, Anchorage, Alaska 99518-1599.