R. CLARK

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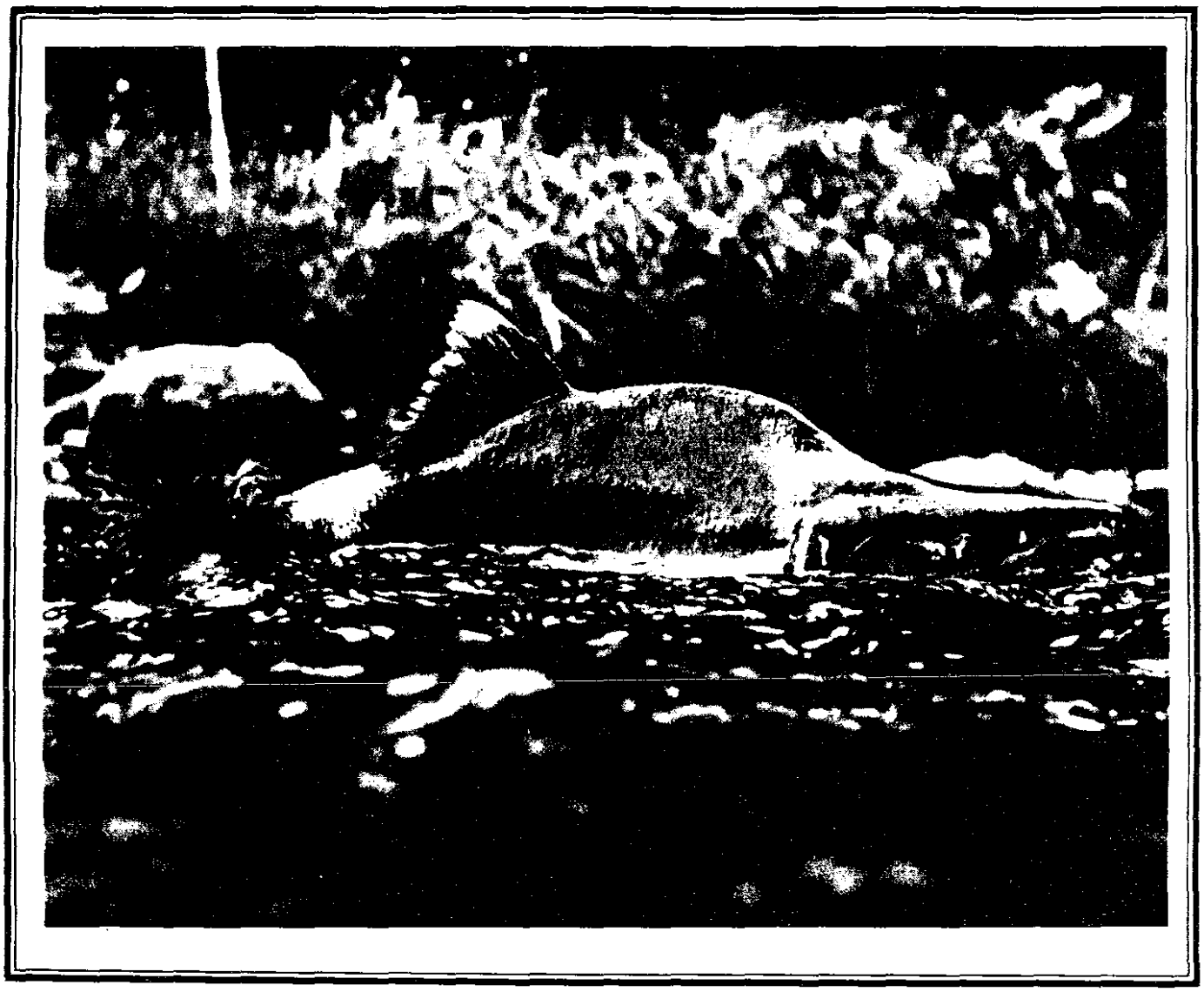

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ɔURCES OF VARIABILITY IN THREE AGING ..ɹuCTURES FOR YUKON RIVER FALL CHUM SALMON (Oncorhynchus keta Walbaum) ESCAPEMENT SAMPLES

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ABSTRACT

Fall chum salmon (Oncorhynchus keta Walbaum) are of increasing importance to commercial and subsistence fishermen of the Yukon River drainage. As demand for the fall chum salmon resource increases, the ability to make timely and accurate management decisions becomes increasingly important. To this end, a precise and accurate method of aging fall chum salmon from escapement samples must be developed. Scales, otoliths and vertebrae were taken from escapement samples in the Delta and Toklat Rivers in 1985 to quantify sources of variability for utility of age determination with these structures. Comparisons of age estimates from scales and vertebrae are more precise than estimates from otoliths, as determined with an index of average percent error (APE). Vertebrae tended to represent fall chum salmon ages as older than age determinations from scales. The presumed reason for the disparity in ages between the two structures is that scales tend to erode or be reabsorbed as migration to the spawning site proceeds while vertebrae do not.

INTRODUCTION

Fall chum salmon (Oncorhynchus keta Walbaum) are an increasingly important fishery resource in the Yukon River drainage, with annual commercial harvests averaging 337,450 fish in the four year period from 1979 to 1983 (Buklis and Barton 1984). In 1983, the ex-vessel value of the Yukon River fall chum harvest to commercial fishermen was $719,800. Fall chum salmon are also harvested by a growing subsistence fishery, with catch averaging 135,266 fish annually from 1974 to 1983. Although commercial and subsistence harvests have increased 30 and 36 percent respectively, for the recent four year period (1979 - 1983), total returns have increased only 10 percent. The escapement index in this same period has declined 42 and 58 percent for the Porcupine and Tanana River drainages, respectively.

Improvements in the accuracy and timeliness of management decisions are needed to accommodate increased demand for the fall chum salmon. Buklis and Barton (1984) made several recommendations concerning management of the fall chum salmon fishery. One of their recommendations was that a more accurate and precise method for determining the age of fall chum salmon in escapement samples be developed.

Age of fall chum salmon escapement samples has been determined from scales taken from carcasses. These samples have been difficult to age because of reabsorption and erosion of the scales. The last annulus is sometimes missing from the scale and extent of erosion or reabsorption is not consistent from fish to fish, making accurate aging difficult. Age composition of Yukon River fall

chum salmon, as determined from scales, generally has age 4 fish accounting for the bulk of fish sampled, while age 3 and age 5 fish make up the rest of the samples. Few age 6 fish are found in samples from the Yukon River drainage.

Although Buklis and Barton (1984) suggest aging chum salmon with otoliths or vertebrae, and ages from otoliths have been compared to those from scales (Barton, Division of Commercial Fisheries, ADF&G, Fairbanks, pers. comm.), the variability of ages from scales, otoliths, or vertebrae has not been rigorously analyzed for fall chum salmon. Knowledge of the reproducibility of ages from scales, otoliths, and vertebrae would allow managers of this important fishery to collect more accurate and precise estimates of age composition from the spawning grounds, thereby increasing the accuracy of forecasting future returns of fall chum salmon.

The hypothesis of this study is that either vertebrae or otoliths provide a more permanent record of the age of fall chum salmon than do scales because the former structures are immune to reabsorption or erosion.

METHODS

Preparation of structure samples

Scales, otoliths, and vertebrae were taken from 150 fall chum salmon in the escapement to the Delta and Toklat Rivers of the Tanana drainage (Figure 1). Four scales were taken from the preferred zone on the left side of each fish (INPFC 1963). Two to four vertebrae were taken from the tail section of each fish. Both otoliths (sagitta) were taken from each fish. Scales were immediately mounted on gummed scale cards and impressions made in acetate film at a later date (Clutter and Whitesel 1956). Vertebrae and otolith samples were placed in coin envelopes. Otoliths were subsequently cleaned and placed in plastic bottle caps with a mixture of water and glycerine. Vertebrae samples were cleaned by scraping away the muscle tissue and drying the centra in plastic ice-cube trays. The average time taken to prepare each of the three types of structures was calculated. Acetate impressions of scale samples were read with a Bruning Model 200 microfiche reader. Otoliths were read with a Nikon Model 90378 compound microscope (1x to 4x magnification). Vertebrae were read by either visual examination under incandescent light or with the aforementioned compound microscope.

Sources of reader variability

Of the 150 fall chum salmon sampled from the Delta River escapement, 60 samples were used in this analysis. Six readers were chosen to each age all of the 60 samples using all 3 structures (scales, otoliths, and vertebrae). Each reader aged each fall chum salmon sample nine times, three repetitions of each of the three structures (Table 1). In total, each fish was aged 54 times. The total amount of time expended to read each set of structures was recorded to the nearest 1 minute.

Average Percent Error (APE) was calculated for each structure-reader combination as an index of repeatability of age determinations. APE is calculated by first dividing the summed age determinations of fish j by the number of replicates for that fish, R:

$$Xj = \frac{1}{R} \sum_{i=1}^{R} Xij \qquad (1)$$

where,

R = the number of replicated readings of the jth fish,
Xij = the ith age determination of the jth fish,
Xj = the average age, rounded to the nearest integer, of the jth fish.

Next, the average error of the jth fish is calculated by:

$$\frac{1}{R} \sum_{i=1}^{R} \frac{| Xij - Xj |}{Xj} \qquad (2)$$

APE is then calculated by the average of the average errors of all fish sampled, N:

$$\frac{1}{N} \sum_{j=1}^{N} \left[\frac{1}{R} \sum_{i=1}^{R} \frac{| Xij - Xj |}{Xj} \right] \qquad (3)$$

where,

N = the total number of fish to be aged.

The APE calculations (Equation 3) as presented here are a variation of the APE index developed by Beamish and Fournier (1981). The only change from Beamish and Fournier's (1981) calculation is that average age is rounded to the whole year in these analyses, whereas they used average age without rounding. APE was calculated for each structure-reader combination and for each structure with all readers combined. From these two sets of APE values the within-reader and between-reader repeatability of ages from the three structures could be measured.

Additionally, the median ages, by structure, of the 60 fall chum salmon samples used in the analysis described above were compared for within-reader differences. A series of tests of significance were made to analyze the hypothesis that: the median age of fall chum salmon as determined from scale samples by one reader is not different from the median age as determined from vertebrae of otolith samples from the same fish and same reader.

Comparison of age composition

To estimate differences in age composition of fall chum salmon escapement samples using scales, otoliths (otoliths later dropped from analysis), or vertebrae, the whole sample of 150 fall chum salmon from the Delta River was read by one reader, making only one replicate reading for each structure. The difference in age composition, as determined by either scales, otoliths, or vertebrae, was tested for significance with contingency table analysis. The hypothesis of this analysis was: the age composition as determined from one reading of scale samples is not different from the age composition as determined from one reading of vertebrae of otolith samples from the same fish. An

additional set of 150 fall chum salmon taken from the escapement to the Toklat River in 1985 was also subjected to the aforementioned analysis.

RESULTS

Sampling error

APE indices ranged from 1.29 to 8.68 percent for scales; 2.89 to 15.87 percent for otoliths; and 1.18 to 4.32 percent for vertebrae (Table 2). The APE indices for vertebrae were either the lowest or near lowest indices among the three structures for all readers. Five of the six readers had APE indices for otoliths that were higher than from the other structures. Scales were ranked last by one reader out of six. The average ranking of APE indices of each structure was 1.50 for vertebrae, 1.67 for scales, and 2.83 for otoliths.

Between-reader variability, as measured from APE indices of all readers combined, was highest for otoliths (28.09 percent) and lowest for vertebrae (5.09 percent). The APE index for scales was intermediate (5.79 percent), but was closer to that of vertebrae (Table 2). Because of highest within and between-reader variability, otoliths were removed from further analyses.

Differences

Of all possible within replicate comparisons of age determinations made with vertebrae versus those made with scales, the trend was towards greater ages with vertebra samples (Figure 2). Five of the six readers aged vertebrae "older" than scales, three readers significantly so (Table 3). The remaining reader aged vertebrae "younger" than scales, but not significantly so. When the average age (rounded to the whole year) was calculated for each fish, 12 of the 58 chum salmon (two had unreadable scales) had vertebrae one year "older" than their scales. The remaining 46 fish had scales and vertebrae the "same age".

There were no apparent differences in the average time taken to read a set of 30 samples from each of the structures (Table 4). Vertebra samples tended to take longer to age than scales, but these differences were not significant. The greatest expenditure of time was made preparing vertebra samples for reading. From estimates of the average time to prepare a set of 30 samples by structure, scales took 7.5 minutes while vertebrae took 150.0 minutes to prepare. Based upon average time to prepare and read a set of 30 samples by structure, it would take a technician 8.8 hours for scales and 57.2 hours for vertebrae to prepare and read the suggested sample of 600 fall chum salmon for age composition estimates.

Age composition, as determined from matched sets of scales and vertebrae, was significantly different for both the Delta River and Toklat River escapement collections (chi-squared(Delta) = 21.14, chi-squared(Toklat) = 15.63, $P < 0.05$, df = 2). The greatest differences occurred in the proportion of age 5 fish in the sample (Figure 3). Vertebra readings tended to represent a higher proportion of fish in these samples as age 5 than did scale readings.

DISCUSSIONS AND CONCLUSIONS

Based on the fact that no age validation has been made on fall chum salmon with either scales or vertebrae, a single hypothesis can be made concerning the accuracy of these structures. It is presumed that fall chum salmon scales are prone to reabsorption and erosion, especially when samples are taken on the spawning grounds. It is also presumed that one of more annuli may be missing from some of the scale samples taken from fall chum salmon and that determination of the absence of additional annuli cannot be made with acceptable precision. The hypothesis I have come to is that readings of vertebrae tend to more accurately determine the actual age of fall chum salmon than readings of scales. The vertebral column of fall chum salmon is probably immune to the same forces of erosion that tend to make scale readings questionable in terms of accuracy. Additionally, if scale samples tended to have one or more annuli missing, one would expect a more accurate aging structure to consistently have readings that were one or more years greater than those from scales. Testing of my hypothesis would require a validation of aging techniques with scales and vertebrae.

One possible method of validating aging structures for fall chum salmon would be to conduct a coded-wire tagging study. Returns of coded-wire tagged chum salmon could be sampled for scales and vertebrae and the actual age (length of time after tagging) compared to "ages" read from the structures. Another method of validating (although somewhat imperfectly) scales and vertebrae would be to compare "ages" read from samples collected on the lower Yukon River; where the forces of erosion and reabsorption may not have begun to affect scales. If scale and vertebrae "ages" were not statistically different, one could surmise that vertebrae would be more accurate than scales when used in escapement samples. This comparison is imperfect because we do not know if scales record the actual age, even in the lower Yukon River.

If my hypothesis concerning the accuracy of vertebrae samples for determining the age of fall chum salmon is correct, then the time spent preparing the vertebrae samples for reading should be the only limiting factor influencing their use in the future. I think that the wide disparity in time spent to prepare scales versus time spent on vertebrae (up to 7 times longer to prepare) can be reduced with additional sampling in the future along with refinements in preparation techniques.

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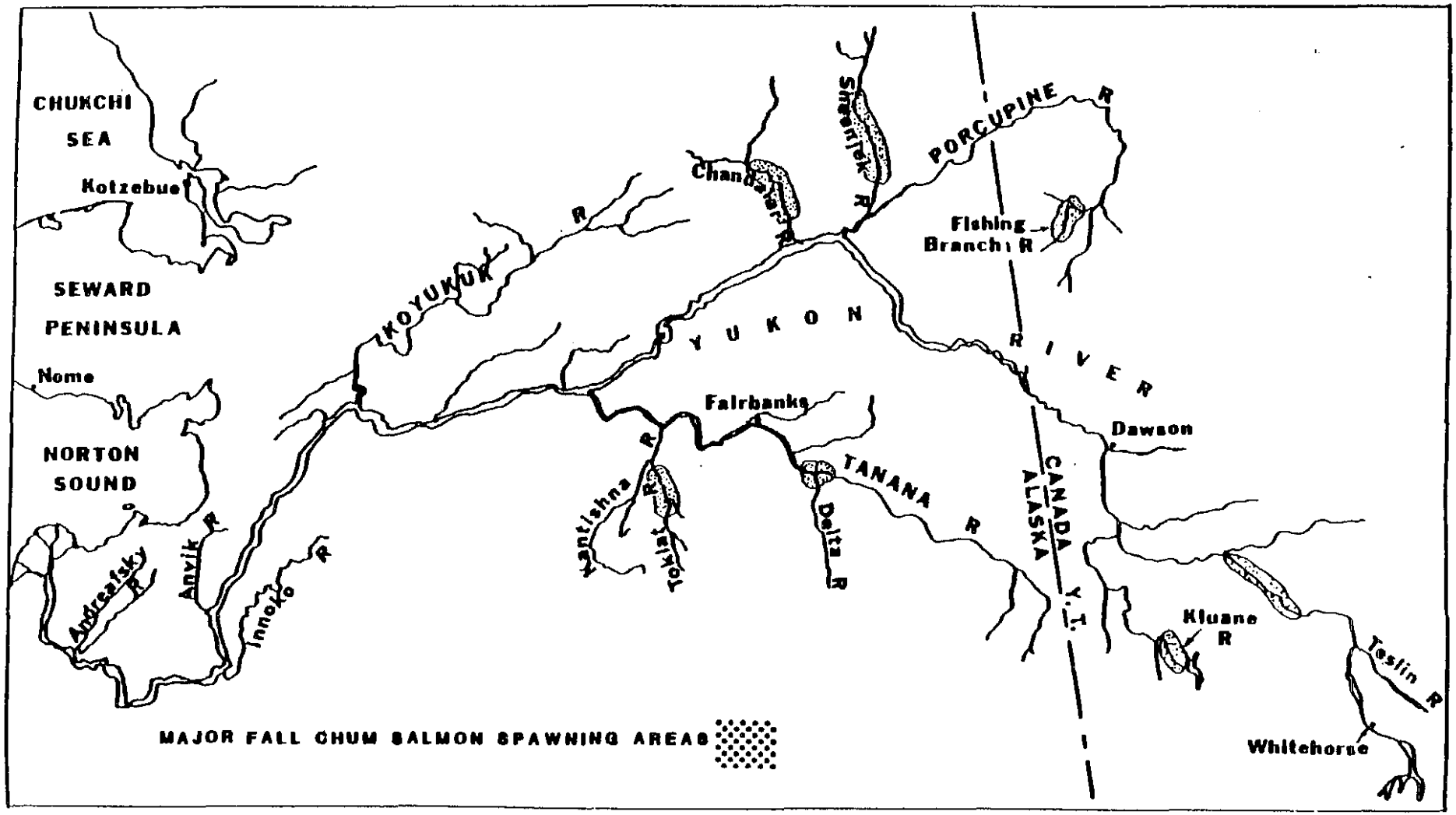

Figure 1. Major fall chum salmon spawning areas in the Yukon River drainage.

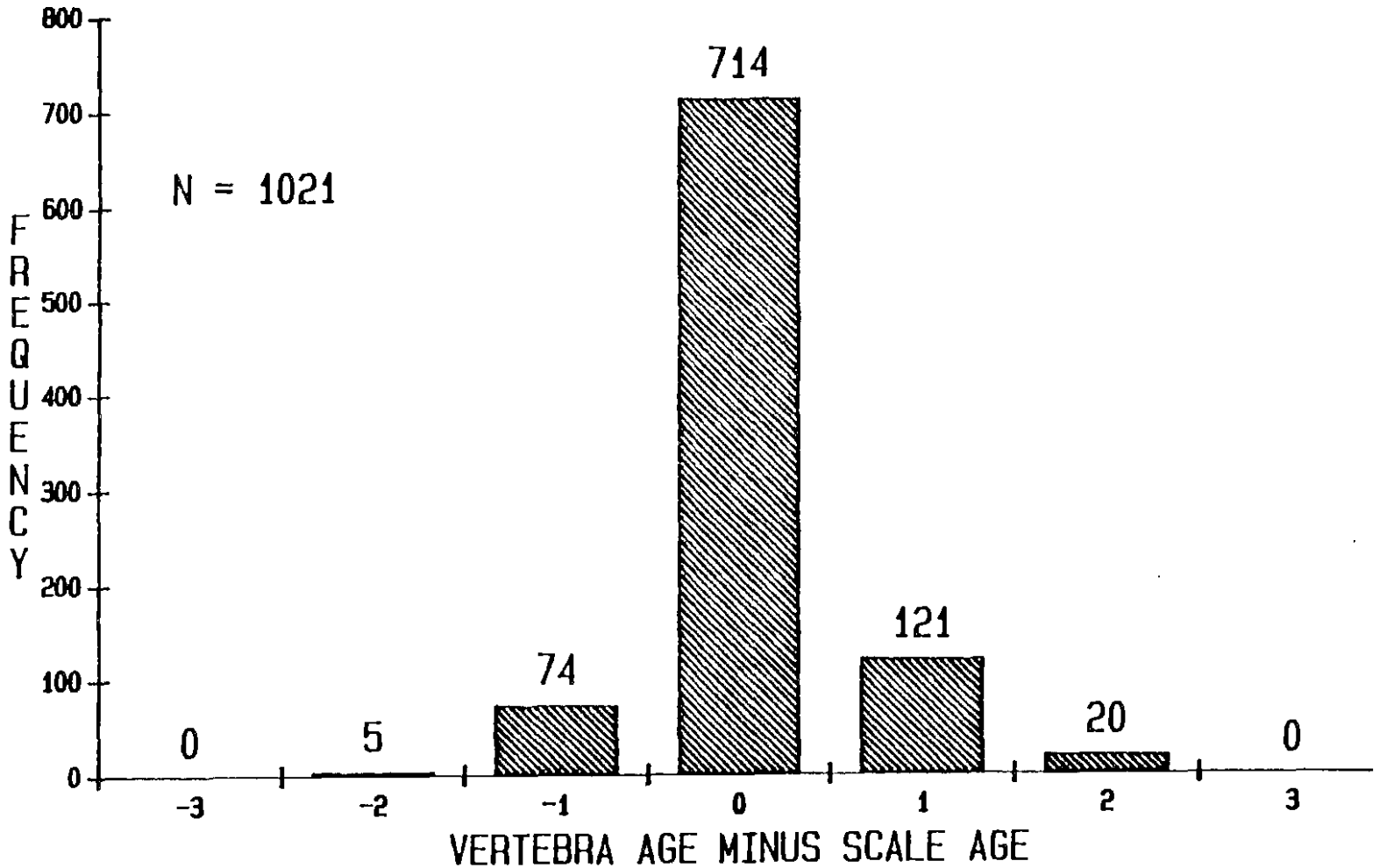

Figure 2. A comparison of age determinations from replicated readings of fall chum salmon scales and vertebrae combined across all readers. Samples are from the Delta River, 1985.

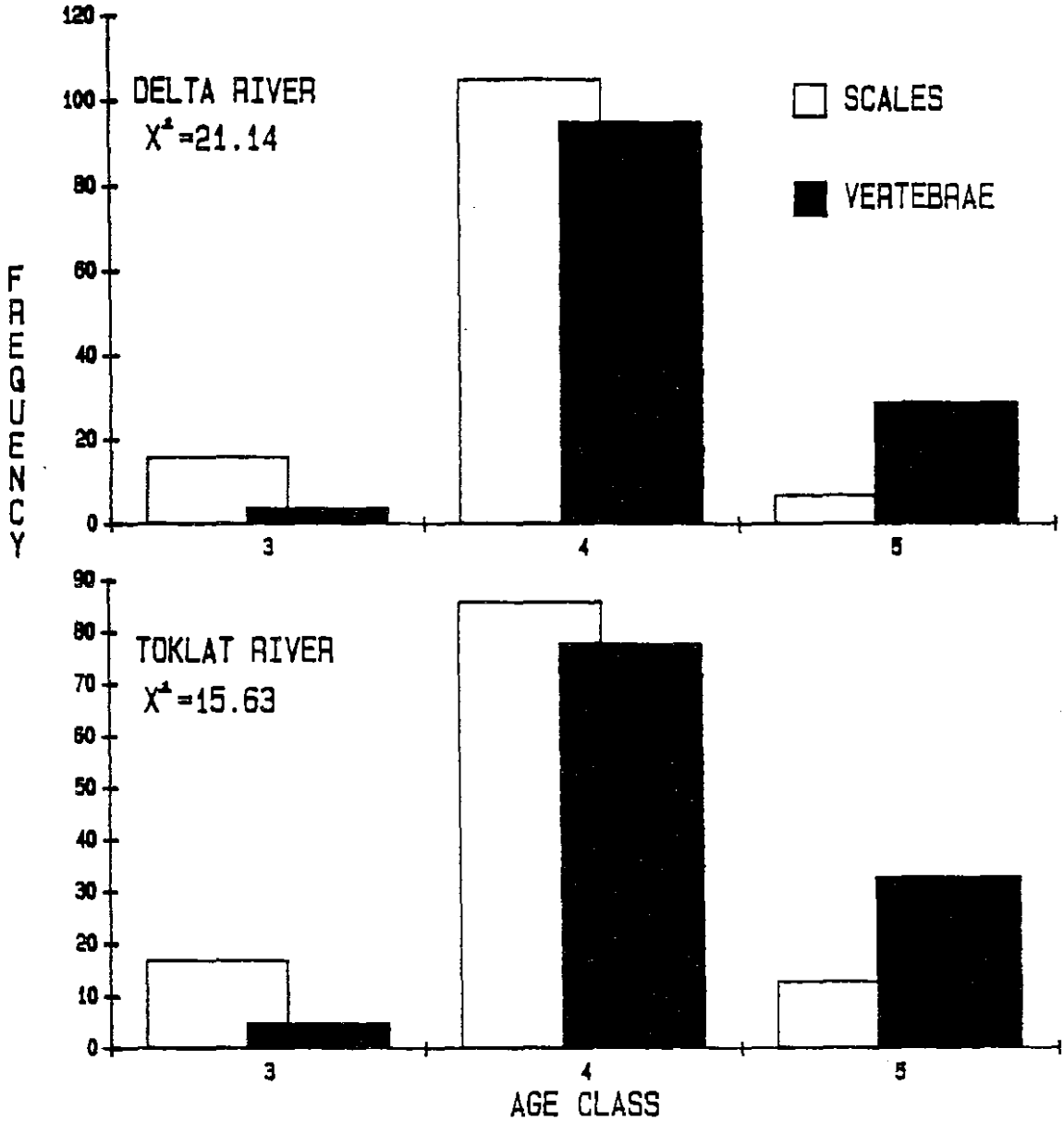

Figure 3. Comparisons of age composition estimates made from a single reading of scales and vertebrae from the Delta and Toklat Rivers, 1985.

Table 1. Sample design and sample sizes for the sources of reader variability study.

STRUCTURE	READERS	x	GROUPS	x	FISH PER GROUP	x	REPETITIONS PER GROUP	=	TOTAL
SCALE	6		2		30		3		1080
OTOLITH	6		2		30		3		1080
VERTEBRA	6		2		30		3		1080
TOTAL	6		6		30		3		3240

Table 2. Average percent error (APE) of replicate readings by structure-reader combination. Numbers in parentheses are ranking of variability within readers across structures. Combined APE index values represent the between-reader variability within a structure.

	AVERAGE PERCENT ERROR (APE)		
READER	SCALE	OTOLITH	VERTEBRA
1	2.08 (2)	2.89 (3)	1.18 (1)
2	1.87 (1)	4.14 (3)	2.03 (2)
3	1.29 (2)	2.43 (3)	1.06 (1)
4	2.19 (1)	6.53 (3)	4.06 (2)
5	3.76 (1)	15.87 (3)	4.32 (2)
6	8.68 (3)	2.28 (2)	1.31 (1)
AVG. RANK	1.67	2.83	1.50
ALL READERS COMBINED	5.79 (2)	28.09 (3)	5.09 (1)

Table 3. Mann-Whitney tests of significance for the hypothesis that median age determined from scale samples is not different from median age determined from vertebra samples from the same fish.

READER	RANK SUMS SCALE	RANK SUMS VERTEBRA	P	AGED GREATER?
1	174.2	180.7	0.5496	NS[a]
2	135.7	217.9	< 0.001	VERTEBRA
3	159.4	195.0	0.0011	VERTEBRA
4	160.4	194.0	0.0020	VERTEBRA
5	186.4	168.9	0.1092	NS
6	163.6	168.2	0.6652	NS

[a] Not significant at an alpha-level = 0.05

Table 4. Mean time to read structures from a sample of 30 fish (minutes per 30 fish). Ninety-five percent confidence interval (C.I.) is based on a Z-value of 1.96.

STRUCTURE	MEAN	STD. ERR	MIN	MAX	95% C.I.
SCALE	19.0	1.4	7.0	43.0	16.2 - 21.8
OTOLITH	18.0	1.6	5.0	51.0	14.8 - 21.2
VERTEBRA	21.5	1.3	10.0	39.0	19.0 - 24.0