JUVENILE LIFE HISTORY AND AGE COMPOSITION OF MATURE FALL CHINOOK SALMON RETURNING TO THE KLAMATH RIVER, 1984-1986

by

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ABSTRACT

The juvenile life history and age composition of Klamath River fall chinook salmon (Oncorhvnchus tshawvtscha) were determined for adult populations returning to major spawning tributaries from 1984 to 1986. Three juvenile life histories were identified from the analysis of adult scales. Most adults exhibited scale patterns indicative of typical summer emigration but a significant portion of some tributary populations had extended juvenile rearing. Measurements of scale radius and circuli counts were used to determine indices of early freshwater growth and size at ocean entry. Comparisons between tributary populations showed differences in proportions of life history type and in freshwater growth rates. Age at maturity was inversely related to the rate of growth during the first year. Older age-at-return groups showed higher incidence of extended juvenile freshwater rearing.

Age composition analysis showed that very few older aged adults returned to spawn on major Klamath River tributaries during 1986. Comparisons between the age composition of recent runs with those of historic runs suggests a reduction in the average age of returning wild Klamath River fall chinook salmon.

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INTRODUCTION

Among all Pacific Coast salmon species, the chinook salmon Oncorhvnchus tshawvtscha has been shown to exhibit the greatest variability in life history strategies. Juvenile life history varies widely both in terms of the duration and location of freshwater rearing and in the timing of juvenile emigration to the ocean. Juvenile growth characteristics can also vary widely within a given river system. Much of what is known about juvenile life history has come from sampling juvenile populations. Juvenile sampling studies unfortunately do not produce a full understanding of the relative importance of different juvenile life history strategies as they relate to survival through to maturity and successful reproduction. This relationship can only be understood by determining the juvenile life history of returning adults using adult scale analysis. By matching the first year growth patterns observed on adult scales to a specific juvenile life history type, the contribution of different early life history strategies to the reproductive population of a given stock on a given river system can be determined. This can be accomplished through the analysis of the first year patterns of adult scales. An understanding of the first year nuclear region of scales is also important for correct determination of age (Koo 1967).

Gilbert (1914) was the first to identify different life history patterns from scales of adult chinook salmon. He coined the terms "ocean type" and "stream type" to distinguish two basic types of nuclear scale patterns. The ocean type nucleus represents fish which migrate to the ocean early in their first year possessing mostly ocean growth in the first year growth zone. The stream type nucleus is composed entirely of freshwater growth and the first annulus is formed at about the same time these fish migrate to the ocean during the early months of the second year. Snyder (1931) used Gilbert's classification system to determine proportions of these two life history types for Klamath River fall chinook salmon for return years 1919, 1920, 1923, and 1930. Snyder discovered many individuals with scale patterns which were intermediate in nature between the ocean type and stream type patterns. He assumed these intermediate patterns represented extended freshwater or estuarine rearing during the first year of growth but he could not clearly separate these types from the more classic ocean type life history pattern.

Rich and Holmes (1928) introduced the term "composite nucleus" to describe the dominant juvenile life history pattern for Columbia River fall chinook salmon. Columbia chinook were found to migrate to the ocean throughout the year (Rich 1920) and most exhibited a composite nucleus of part freshwater growth and part ocean growth. Some had small amounts of freshwater growth and large amounts of ocean growth and others had large amounts of stream growth and small amounts of ocean growth. Between these two types were intergradations so complete as to make finer distinctions impossible.

Recently, finer distinctions have been made for juvenile life history types in several river systems. Reimers (1973) identified five life history patterns for fall chinook salmon from Sixes River, Oregon. Reimers collected juvenile scales from locations throughout the basin at various times of the year. He then interpreted the juvenile life history patterns of returning adults using the juvenile scale collections as reference material. Schluchter and Lichatowich (1977) identified seven life history patterns for spring chinook salmon from the Rogue River, Oregon.

Little is currently known about the juvenile life history of wild Klamath River fall chinook salmon. Snyder (1931) observed a pronounced emigration of juveniles during the summer and early fall near the mouth of the river. Juvenile sampling on the upper Trinity River near Lewiston has shown that local downstream migration peaks in May and June, continues until July, and practically ceases by the first of August (Moffett and Smith 1950). A second smaller pulse in downstream movement was observed in October or

The specific objectives of this study were to:

1. Document juvenile life history strategies of returning Klamath River wild fall chinook salmon populations.
2. Compare life history strategies of tributary populations by comparing juvenile life history type proportions, indices of freshwater growth, and age composition of returning adults.
3. Document any change which has occurred over time in the juvenile life history strategies or age composition of the Klamath River fall chinook salmon population by comparing scale samples collected from recent runs with scale samples collected from historic runs.

MATERIALS AND METHODS

Scale Analysis of 1984-86 Return Years

Scale samples were collected from adult chinook salmon captured at counting weirs operated by the California Department of Fish and Game (CDFG) on the lower portions of the South Fork Trinity, Salmon River, Scott River, Shasta River, and Bogus Creek during the fall of 1986 (Figure 1). A few samples were collected during carcass surveys on the South Fork Trinity in 1986 and were included in the South Fork Trinity collections. Scale samples were also collected at the South Fork Trinity weir in 1984 and 1985. Scales were removed from the left side of each fish three or four scale rows above the lateral line and slightly posterior to the posterior insertion of the dorsal fin. Collection date and fish length were recorded with each scale sample.

From each scale sample four to eight scales were mounted between two glass microscope slides and magnified at 140x using a Realist Vantage I microfiche projector. The selection of mounted scales from the total available scale sample was guided using two rules. First, regenerated scales were not mounted. Second, only scales with the least reabsorption were considered. If all scales from the total sample exhibited extensive reabsorption, making correct age

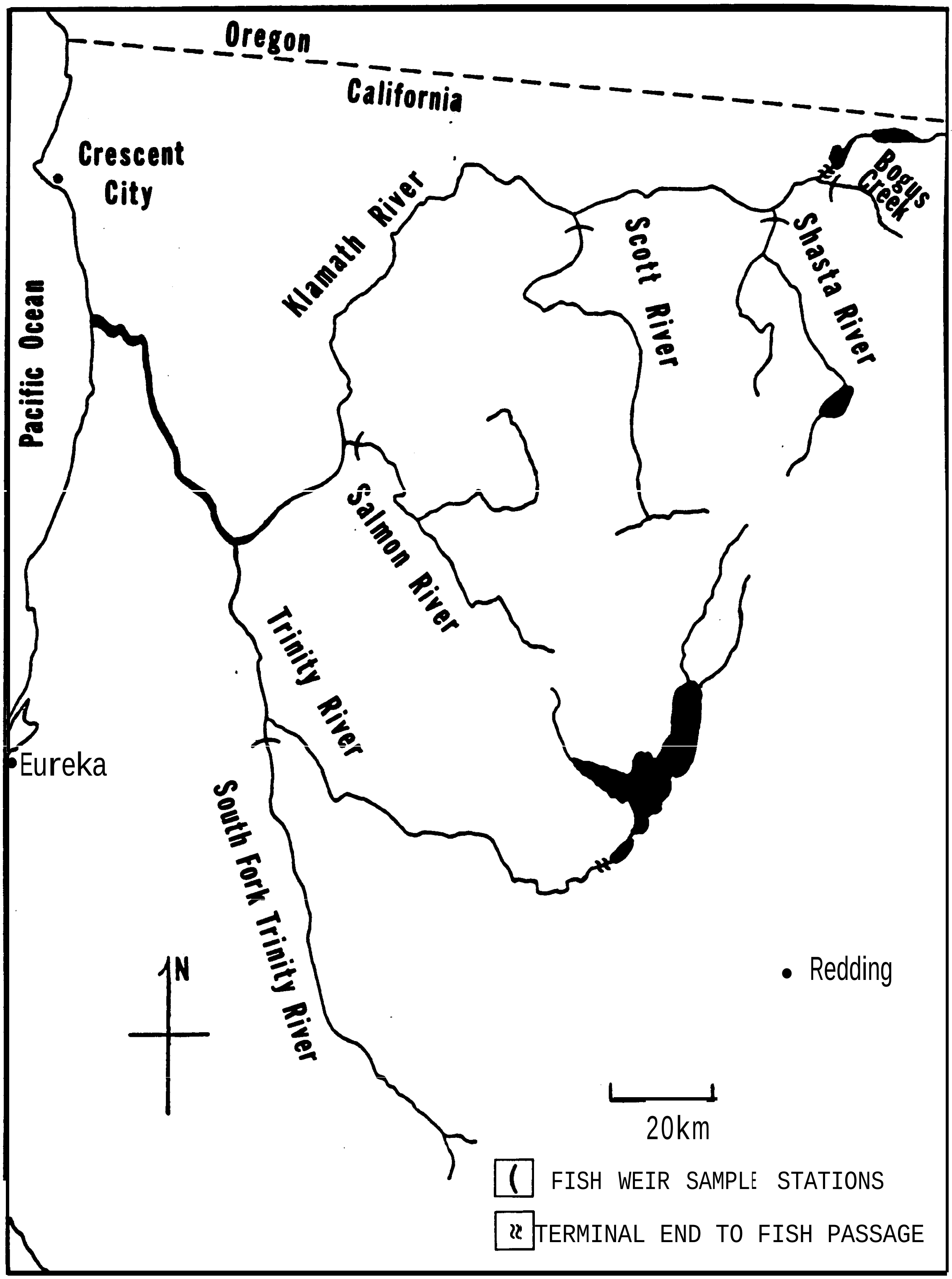

Figure 1. Klamath River Sampling Stations Located on Major Chinook Salmon Spawning Tributaries.

determination doubtful, the sample was excluded from the analysis. A single scale was then selected from each mounted sample for analysis. An attempt was made to select the largest and most symmetrical scale from each mounted sample. All scale measurements were taken on the single scale. The additional mounted scales were used as additional reference samples when life history patterns were particularly difficult to interpret.

For each representative scale a paper strip was placed against the face of the microfiche projector along a radial line 20 degrees dorsal to the anterior-posterior scale axis. The center and outer edge of the scale focus and the outer edge of each succeeding circulus encountered along the line out to the first annulus were marked. The point of ocean entry and the outer edge of the first annulus were also marked. The point on the scale representing ocean entrance was determined by identifying an abrupt change from narrowly spaced circuli near the scale focus or center (indicative of freshwater growth) to wider spaced circuli formed during growth in the ocean. The outer edge of the first annulus was determined by identifying that point on the scale where circuli spacing started to significantly widen from the narrow spacing of slower winter ocean growth to the relatively explosive spring and summer ocean growth pattern exhibited by chinook salmon.

All circuli counts and scale measurements were taken from the marked paper strips. Measurements were made to the nearest mm. All circuli counts began at the first circulus outside the scale focus. Scale radius to the point of ocean entry was measured from the center of the scale focus to the outside edge of the last apparent freshwater circulus. The age of spawners was determined by counting scale annuli.

Scale radius measurements to ocean entry were used to compare size at ocean entry between age at return groups from different tributaries (Mottley 1942). Scale circuli spacing reflects growth rates of fishes (Koo 1967) and have been previously used as an indicator of chinook salmon freshwater growth rates (McPherson and Cramer 1983; Cramer and McPherson 1983). The term "band width" has been used to describe the measured width of bands of scale circuli. Reimers (1973) used successive widths of bands of five circuli to study the first year growth of juvenile and adult fall chinook. Band widths represent circuli spacing over a given portion of life history and can be used to compare freshwater growth rates of chinook salmon (McPherson and Cramer 1983). In this study band widths were measured from the outside edge of the scale focus to the 10th and 30th circulus. Measurements to circulus 10 were used to compare early freshwater growth rates between different age-at-return groups from the different tributaries sampled. Klamath River fall chinook almost always possess at least 10 freshwater scale circuli.

Juvenile life history type classification was determined by subjectively interpreting the first year scale pattern. Visual interpretation was based primarily on the relative proportions of circuli formed during growth in freshwater (closely spaced) versus circuli formed in the ocean (widely spaced) during the first year. Measurements to circulus 30 were used as a more objective method to help validate subjective juvenile life history type classification for return groups which were particularly difficult to visually interpret.

Back-calculated lengths at ocean entry for various life history groups were determined using the length-scale relationship developed by Mills (1987). This relationship was developed using fish lengths and scale measurements from juveniles collected within the Klamath basin in 1984 and 1985. Adult scales could not be used to develop a length-scale relationship due to extensive and varying degrees of scale reabsorption and erosion. The regression equation used was: $L = 34.5 + 3.48X$ where L = length in mm and X = anterior scale radius. ($DF = 171$, $r = 0.79$). Prior to back calculation, a correction factor of $48/140 = 0.342857$ was used to adjust freshwater scale radius measurements to compensate for the difference between the magnifications used by Mills and in this study. All statistical comparisons were performed using simple two sample t-tests.

Subsampling and Analysis of the 1921 Return Year

In addition to the investigations of 1984-86 returns, a sample of fall chinook salmon scales collected from the Klamath River in 1921 was examined to compare life history characteristics and age composition of historic runs with the current population. These collections were made by J.O. Snyder, California Department of Fish and Game, during his early investigations of Klamath River fall chinook salmon. Scale samples collected by Snyder and his co-workers were from the gillnet fishery operating in the Klamath estuary. Between 50 and 100 fish were sampled each day during the 1921 gillnet season resulting in scale collections from 3,949 fish.

The 1921 collection was systematically subsampled to produce a smaller representative sample of 173 fish. The total available sample was first stratified by harvest week to eliminate potential sampling bias favoring any particular portion of the season (in those days larger older fish were known to enter the estuary at the end of the fishing season (Snyder 1930)). Each weekly sample was then sequentially ordered by fish length and a representative 1 in 23 subsample was systematically selected. Age and juvenile life history classification for the 1921 samples were determined using the same methods employed for the 1984-1986 scale samples.

RESULTS

Ase Composition

1986 Return Year

Major differences were observed in the age composition of Klamath River tributary populations (Table 1). Jack (precocious male salmon) returns during 1986 were strong on the Shasta and Scott rivers while Bogus Creek and the Salmon River had relatively weak jack returns. In general, age 3 fish dominated the 1986 returns. Age 4 fish were poorly represented on all tributaries except the Salmon River where they composed 24% of the run.

Age composition results obtained through scale analysis only approximate the actual age composition of each returning tributary population. This is evident when comparing the length frequency distributions of fish included in the scale analysis with California Department of Fish and Game (CDFG) length data collected from all fish observed at the various weir sampling sites (Figure 2). A strong sampling bias appears to have occurred in the scale samples collected at the Shasta River weir and the Salmon River weir sites. Figure 2 shows that jacks and smaller age 3 fish were over-represented in the scale samples collected from the Shasta River and that Salmon River scale samples appear to be biased towards larger older individuals. Of

Table 1. Age Composition of Fall Chinook Salmon Returning to Klamath River Tributaries During 1986.

	Age at Return							
	2		3		4		5	
Tributary	%	n	%	n	%	n	%	n
So. Fk. Trinity	33	(69)	65	(137)	2	(5)	0	(1)
Salmon River	9	(5)	64	(37)	24	(14)	3	(2)
Scott River	41	(33)	46	(37)	13	(11)	0	(0)
Shasta River	57	(27)	34	(16)	9	(4)	0	(0)
Bogus Creek	19	(13)	79	(54)	2	(1)	0	(0)
Klamath River[a]	23	(52,391)	64	(147,333)	12	(26,996)	1	(3,098)

[a]Age composition and estimated number by age of Klamath River fall chinook salmon entering the estuary during 1986 (USFWS 1987).

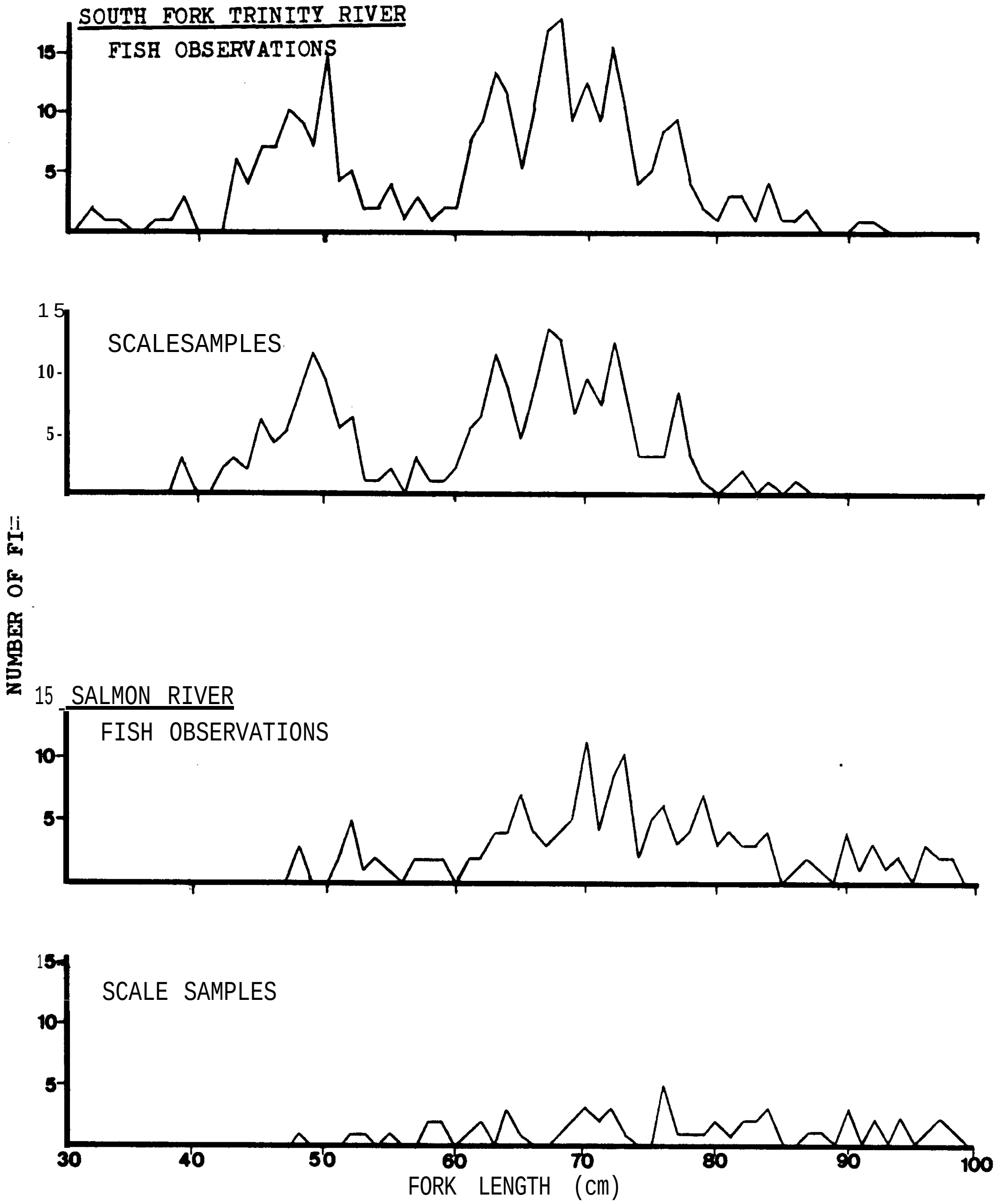

Figure 2. Length Frequencies of Fish Observations Compared to Lengths of Fish Included in the Scale Analysis for Each Weir Site Sampled During 1986.

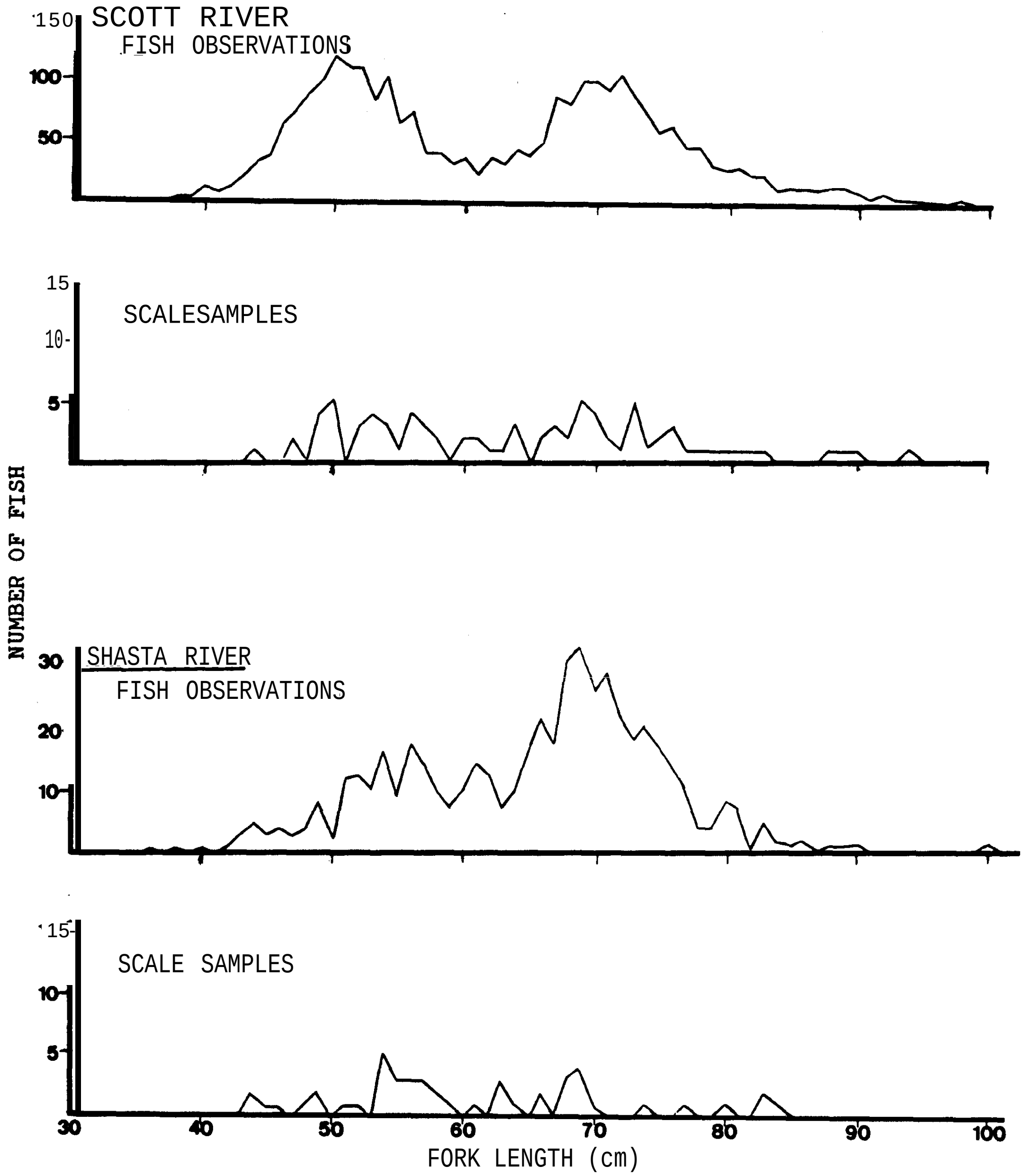

Figure 2. Length Frequencies of Fish Observations Compared to Lengths of Fish Included in the Scale Analysis for Each Weir Site Sampled During 1986. (continued)

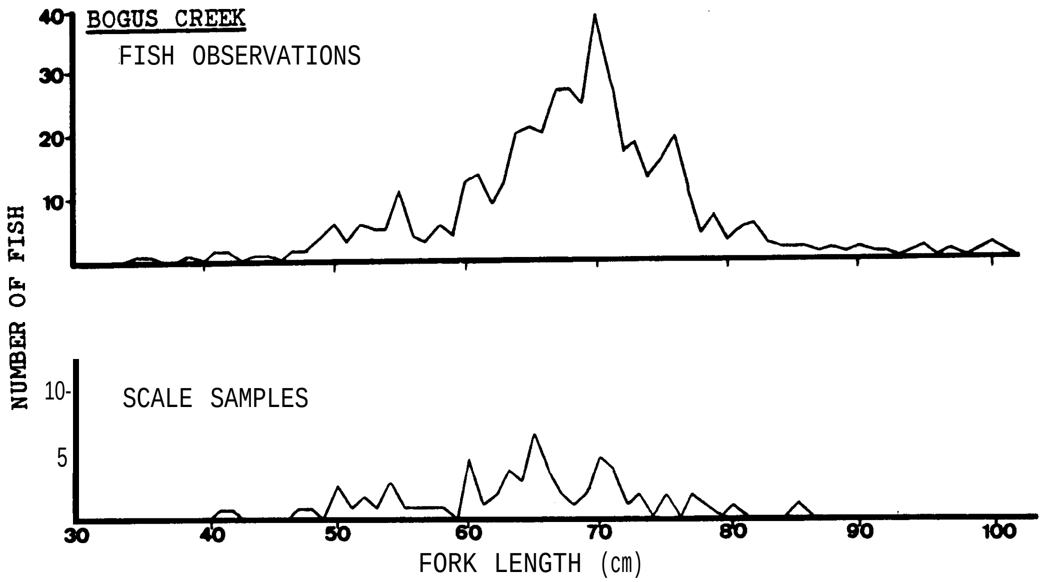

Figure 2. Length Frequencies of Fish Observations Compared to Lengths of Fish Included in the Scale Analysis for Each Weir Site Sampled During 1986. (continued)

all locations sampled, South Fork Trinity scale samples probably best represented the actual age composition of the run.

South Fork Trinitv River - 1984-1986 Return Years

Analysis of South Fork Trinity River samples showed that the 1984 and 1986 runs were similar in age composition (Table 2). Age 3 fish dominated these runs while age 4 spawners were poorly represented. The 1985 return year differed, having a high proportion of jacks, a weak age 3 component, and a significant number of age 4 spawners.

Juvenile Life Historv

Life History Types

Three major types of juvenile life histories were arbitrarily defined from the study of adult scales (Table 3). The primary characteristics used to distinguish the three juvenile life history types were: number of freshwater circuli, amount of freshwater growth, and the spatial relationship of the ocean entrance check to the first annulus. Type-I is characterized by having 9-22 freshwater circuli with the majority (>90 percent) having 11-18. This type reaches the ocean early enough to experience strong first year ocean growth (Figure 3). Type-II fish have more freshwater circuli (20-36) and exhibit much less first year ocean growth. They enter the ocean later in the year when ocean growth conditions are less optimal and typically form

Table 2. Age Composition of Fall Chinook Salmon Returning to the South Fork Trinity River in 1984-1986.

	Age at Return							
	2		3		4		5	
Return Year	%	n	%	n	%	n	%	n
1984	32	(12)	63	(24)	5	(2)	0	(0)
1985	74	(84)	10	(12)	15	(17)	1	(1)
1986	33	(69)	65	(137)	2	(5)	0	(1)

Table 3. Description of the Major Types of Juvenile Life Histories of Fall Chinook Salmon in the Klamath River, California.

Type	Description
I	Rear in freshwater for several months before migrating to the ocean during the summer months.
II	Rear in freshwater for an extended time period, migrating to the ocean in the autumn or as late as mid-winter. This type is assumed to include both juveniles that remain in the tributaries until autumn rains, and those that migrate to the main river in spring or early summer and rear either in the mainstem or estuary until ocean entry.
III	Rear in freshwater through the summer, autumn, and winter entering the ocean the following spring as yearlings.

Figure 3. Scale Characteristics of a Type-I, Age 3, 70cm Spawner Sampled From the Scott River Showing the Outside Edge of Freshwater Circuli at the Point of Ocean Entry (o.e.) and the First Annulus (1) Formed in the Ocean.

the first ocean annulus a shorter distance out from the ocean entry check (Figure 4). Type-III individuals do not have clearly distinguishable ocean entry and first annular checks, both occurring in roughly the same scale position (Figure 5). They enter the ocean at the time when types I and II are forming the last part of the ocean annulus which is assumed to form in the late winter or early spring (Fraser 1916; Snyder 1931).

It is the consistency of the scale patterns within each group which determined the level of confidence the author has in making inferences about early life history characteristics (timing of ocean entry, the location and duration of freshwater rearing, etc.) from the scale patterns observed. While type-1 group scales exhibited little difference among patterns within the group for most brood years, type-II group scales, by contrast, showed a much greater variety of scale patterns within the type-II group.

The typical type-1 group scale pattern was assumed to represent individuals that emigrate from spawning tributaries relatively soon after emergence, migrating to the ocean early enough to put on significant ocean growth during the first year. By contrast, the general scale characteristics of the type-II group scale patterns included greater freshwater growth and much less first year ocean growth which taken together indicate later ocean entrance timing and result in smaller size at the time of first

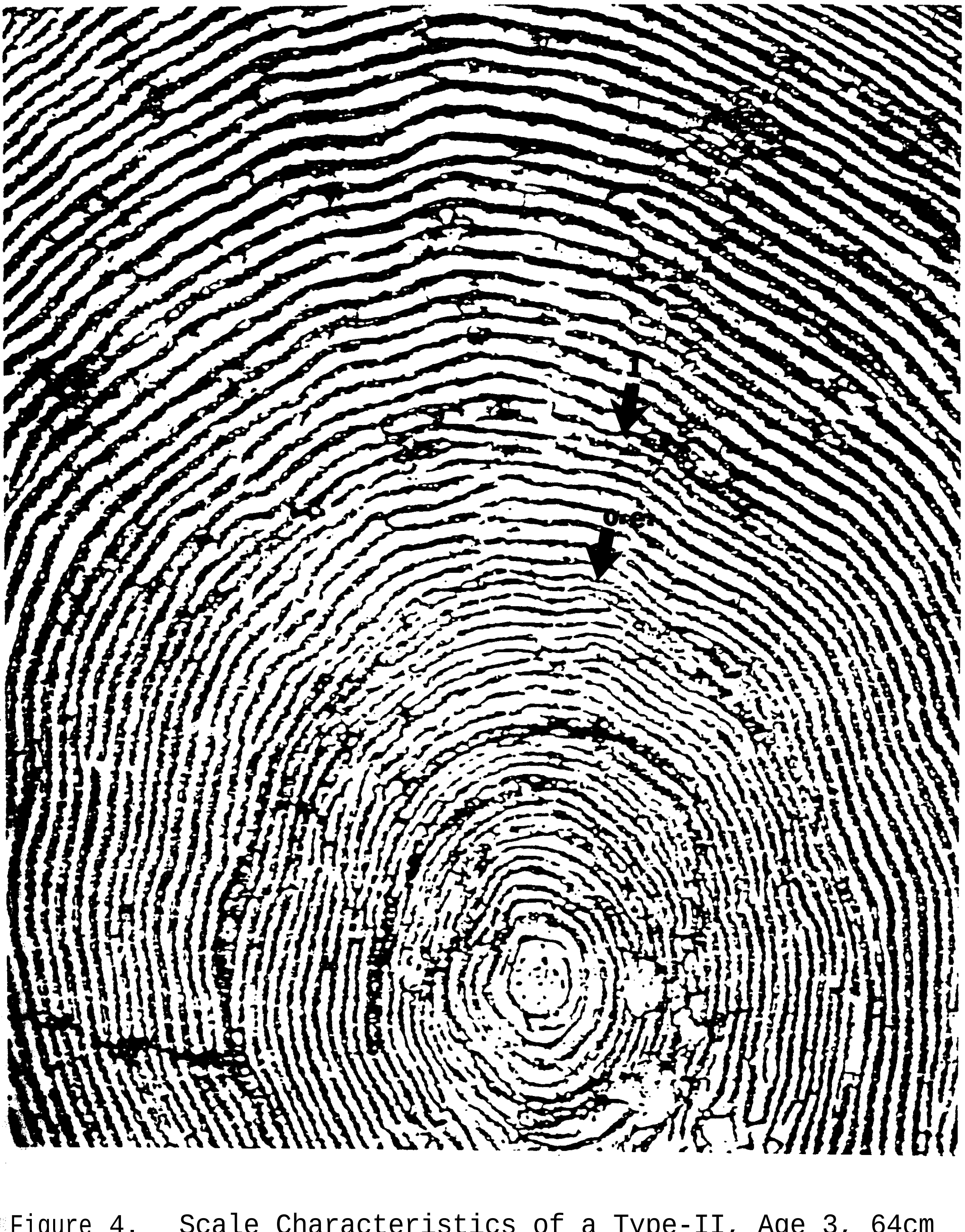

Figure 4. Scale Characteristics of a Type-II, Age 3, 64cm Spawner Sampled From the Scott River Showing the Point of Ocean Entry (o.e.) and the First Annulus (1) Formed in the Ocean. Note the Greater Number of Freshwater Circuli and Smaller Number of First-Year Ocean Circuli Than on the Type-I Spawner.

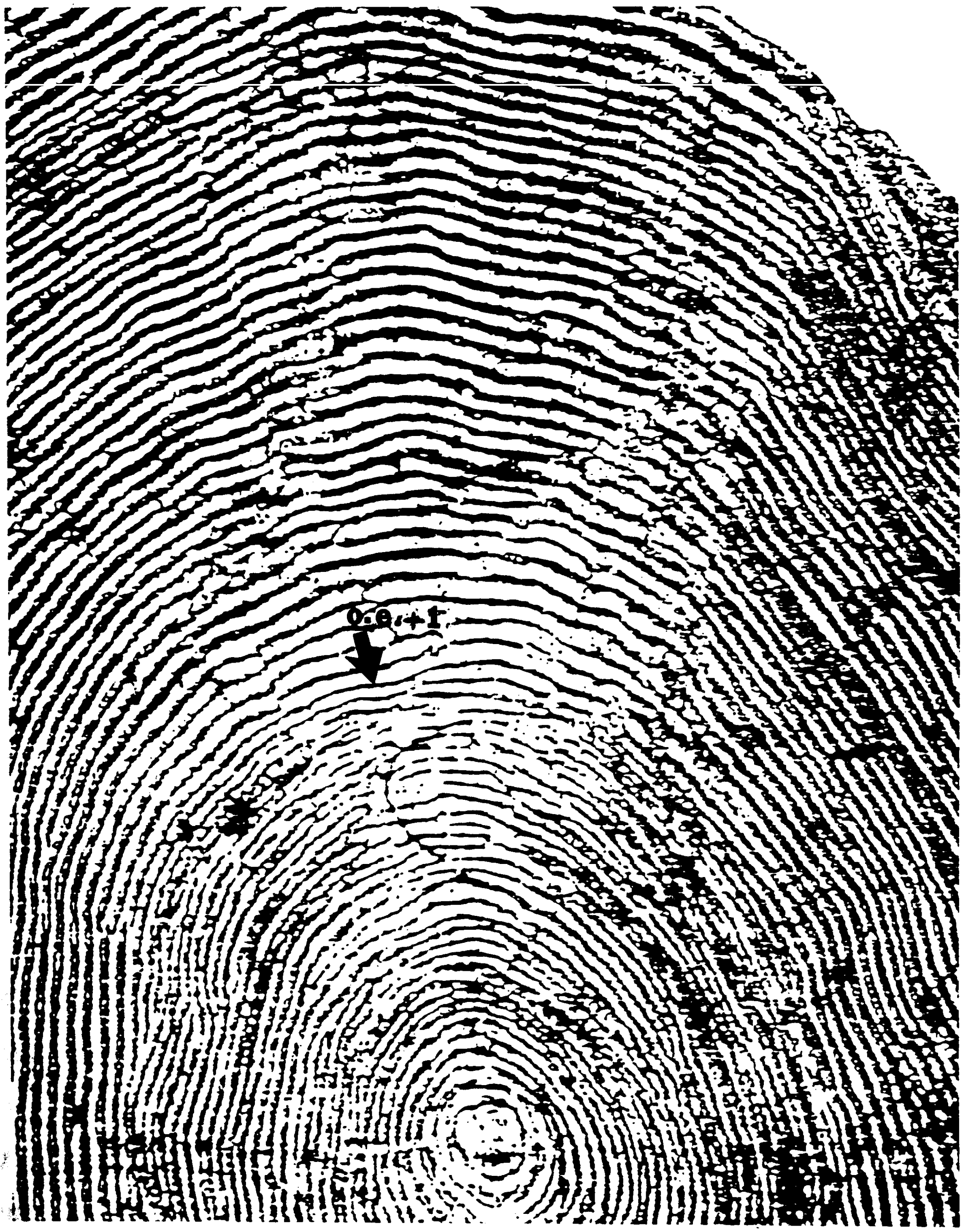

Figure 5. Scale Characteristics of a Type-III, Age 3, 58cm Spawner Sampled From the Scott River Showing the Point of Ocean Entry (o.e.) and the First Annulus (1) in Roughly the Same Scale Position.

annulus formation. Though all type-II individuals exhibited these basic scale characteristics that distinguished them from the type-1 group, much variation was observed for certain scale characteristics within the type-II group. This makes the inferences about possible life history scenarios within the type-II group more speculative and based on more assumptions. For example, the amount of first year ocean growth on type-11 scales could range from just a few first year ocean circuli up to 10-15 in number. Individuals with less first year ocean circuli usually had greater numbers of freshwater circuli. It was assumed that these observed differences in the number of first year ocean circuli represented a broad range in ocean entrance timing. While some type-11 individuals reached the ocean several months before first 10-15 formation and before the end of the ocean growth season, others entered the ocean just before annulus formation putting on very little growth in the ocean during the first year. In addition, freshwater circuli spacing for type-11 individuals could be very narrow or very broad, or a single type-11 individual could exhibit a combination of bands of narrow and widely spaced freshwater circuli prior to the ocean entrance check. This variation in freshwater circuli spacing among different type-II individuals was assumed to represent differences in freshwater growth rates that could be attributable at least in part to freshwater residence by some individuals in areas of the Klamath River basin which had favorable growth conditions versus residence by others in areas in the basin with much poorer growth conditions, or movement between these two.

The type-II group is therefore a catchall group that contains within it several life history sub-groups that could not be defined during this study from interpreting scale patterns. The description therefore of the type-11 group given in table 3 is more speculative and is based on several assumptions as previously stated.

Overview of Life History Results

The type-1 life history was the most abundant group among all age 2 and age 3 fish returning to all locations during 1986 (Table 4). Type-I fish dominated the age 2 groups while type-II fish were more prevalent among returning three year olds particularly for Salmon River, Scott River, and Bogus Creek spawners. Life history types of Bogus Creek spawners cannot be directly compared to other groups due to higher straying rates of unmarked hatchery fish (Ivan Paulsen, CDFG, pers. comm.). It is possible that the relatively high proportion of type-II to type-1 fish among Bogus Creek age 2 and age 3 spawners is partially the result of high straying rates of Iron Gate Hatchery fall releases.

Hatchery fall chinook straying rates based on adipose clip observations on other upper Klamath River tributaries are low (Hankin and Diamond 1984). Significant hatchery straying has occurred in past years on the

Table 4. Relative Proportions of Klamath Basin Fall Chinook Salmon Life History Types (I,II,III) For Each Age at Return by Location and Return Year, 1984-1986.

Return year	Location	Age at Return: 2			3			4		
		I % (n)	II % (n)	III % (n)	I % (n)	II % (n)	III % (n)	I % (n)	II % (n)	III % (n)
1986	Salmon River	80(4)	20(1)	0(0)	59(22)	41(15)	0(0)	21(3)	71(10)	7(1)
1986	Scott River	100(33)	0(0)	0(0)	76(28)	22(8)	3(1)	27(3)	73(8)	0(0)
1986	Shasta River	96(26)	4(1)	0(0)	94(15)	6(1)	0(0)	75(3)	25(1)	0(0)
1986	Bogus Creek	79(11)	21(3)	0(0)	52(28)	46(25)	2(1)	0(0)	100(1)	0(0)
1986	S. Fk. Trinity	91(63)	7(5)	1(1)	91(125)	5(7)	4(5)	60(3)	0(0)	40(2)
1985	S. Fk. Trinity	98(82)	2(2)	0(0)	25(3)	58(7)	17(2)	88(15)	6(1)	6(1)
1984	S. Fk. Trinity	67(8)	25(3)	8(1)	75(18)	17(4)	8(2)	100(2)	0(0)	0(0)

South Fork Trinity, but in 1986 straying was much lower due to reduced off-site hatchery releases of 1982-84 brood year fish (Terry Mills, CDFG, pers. comm). Shasta River and South Fork Trinity age-at-return groups were dominated by type-1 fish with very few spawners exhibiting extended freshwater rearing as juveniles. Type-III fish were rarely encountered among all samples and are assumed to be quite rare among returning wild Klamath River fall chinook salmon adults.

Low numbers of age 4 chinook returned to Klamath River spawning tributaries in 1986. Age 4 groups had high proportions of individuals with the type-II life history (Table 4). Juvenile life history patterns of age 4 fish returning in 1986 were more difficult to interpret than the patterns of age 2 and age 3 spawners. This held true for all 1982 brood year samples (1984 South Fork Trinity two year olds, 1985 South Fork Trinity three year olds, and 1986 four year old groups from all locations). Results of life history classificationsfor South Fork Trinity returns during 1984 and 1985 also show high proportions of type-11 individuals from 1982 brood year groups (Table 4). Because of the difficulty in distinguishing life history types for 1982 brood year samples, I tried to separate life history types using a method which would be more objective than visual interpretation. A radius measurement from the scale focus to the 30th circulus proved to be the best scale variable to distinguish between types I and II for combined age 3 returns (1983 brood year) (Figure 6). Life history types of combined age 4 returns (1982 brood) did not clearly separate using this method suggesting that first year growth was about the same for these two life history types. This was confirmed by measurements to the 30th circulus for age 4 hatchery returns. Coded wire tagged (CWT) age 4 hatchery spawners returning in 1986 were sampled from the Indian gill net fishery. Iron Gate Hatchery and Trinity River Hatchery age 4 fish were grouped by hatchery release type (Figure 6). Age 4 fingerling (June) releases show on the average poorer growth to the 30th circulus than do fall releases. In light of these results, life history classifications for the 1982 brood must be viewed more tentatively than results for other brood years.

Juvenile life history can affect the ultimate size of returning adults (Table 5). This becomes clear when comparing the size at return of type-1 age 3 spawners with size at return of type-II and type-111 age 3 spawners returning in 1986 (Figure 7). Juvenile life history type did not produce an obvious difference in size at return among age 4 spawners, however. Figure 7 presents Bogus Creek (high hatchery stray rate) size at return for age 3 spawners for comparison with grouped age 3 spawners from upper Klamath tributaries (low hatchery stray rates). Length frequency distributions of age 4 hatchery returns during 1986 (1982 brood) showed that June release hatchery

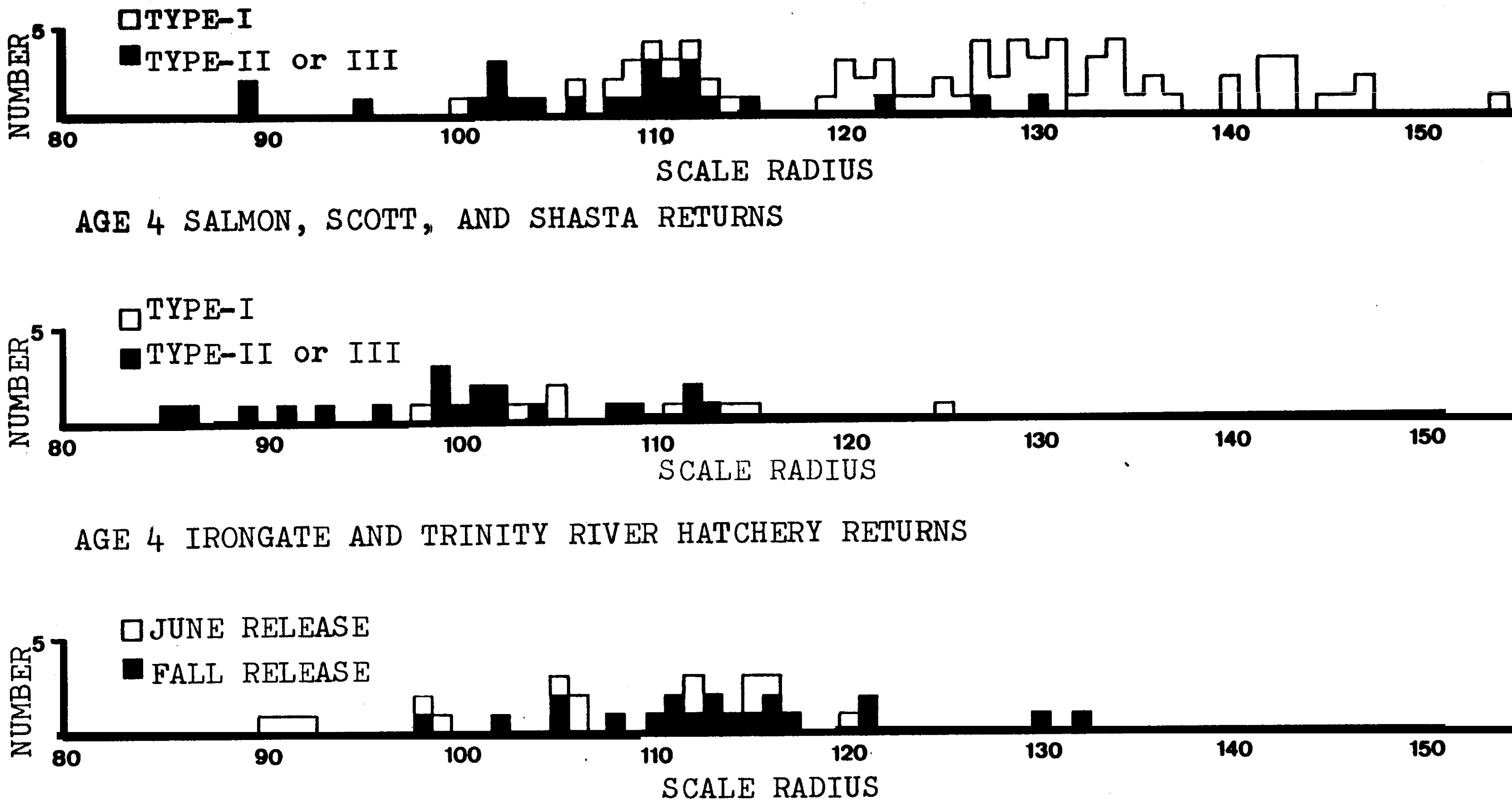

Figure 6. Scale Radius Measurements to Circulus 30 in mm (x140) for Age 3 and Age 4 Returns From the Salmon, Scott, and Shasta Rivers Grouped by Life History Type, and Age 4 Irongate and Trinity River Hatchery Returns Grouped by Release Type.

Table 5. Mean Length (cm) of Klamath River Adult Chinook Salmon by Life History Type (I,II,III), Age at Return, and Location for Samples from 1986 Return Year./a

	Age at Return								
	2			3			4		
Location	I	II	III	I	II	III	I	II	III
S. Fk. Trinity	48.8	46.0	46.0/b	69.1	63.1	58.6	83.3		80.0
Salmon River	54.5	48.0/b	-	75.2	67.0		88.7	89.0	96.0/b
Scott River	52.0			70.1	62.1	58.0/b	85.0	82.4	
Shasta River	53.1	57.0/b	-	68.0	66.0/b	-	82.0	84.0/b	-
Bogus Creek	53.1	43.3		68.9	63.4	65.0/b		85.0/b	-
Klamath River/c		46.6			66.9			83.9	

a/Group sample sizes are identical to those presented in table 4.

b Single value.

c/Mean Length at age of Klamath River fall chinook salmon entering the estuary during 1986 (USFWS 1987).

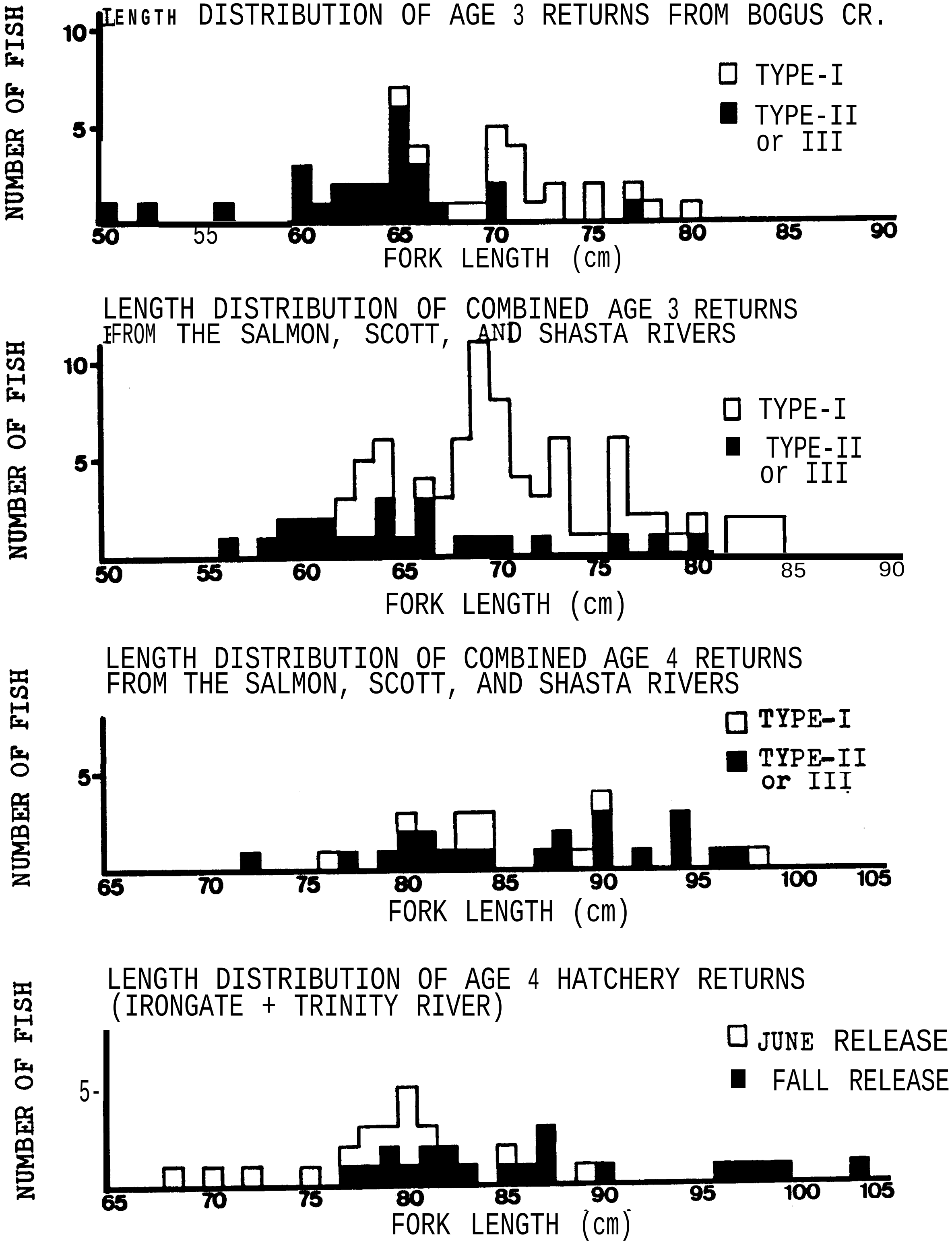

Figure 7. Comparisons of Size at Return by Life History Type for Various Spawner Age Groups Returning to Klamath River Tributaries and Hatcheries in 1986.

returns were **on the average smaller than returns from fall** releases.

Size at the Time of Ocean Entry

Mean **scale** measurements to point of ocean entry grouped by age-at-return and life history type were quite variable between the different tributaries studied (Table 6). Type-I age 2 and type-1 age 3 groups provided the largest sample sizes and the most meaningful comparisons of size at ocean entry (Figure 8). Mean scale radius to ocean entry was larger for type-1 age 2 groups than for type-1 age 3 groups at all locations sampled except Bogus Creek, although this difference was statistically significant ($p<0.05$) at only 3 of the 4 sampling sites (South Fork Trinity, Scott, and Shasta Rivers). Bogus Creek values for age 2 and age 3 type-1 groups were the highest of all locations sampled. Salmon, Scott, and Shasta River values all appear to be close in magnitude. South Fork Trinity River age 2 and age 3 type-1 groups had by far the lowest scale radius measurement to ocean entry values of any of the locations sampled. Size at ocean entrance for South Fork Trinity age 2 type-1 fish were significantly smaller ($p<0.05$) than Scott, Shasta, and Bogus Creek age 2 type-1 groups and the South Fork Trinity age 3 type-I group was significantly smaller ($p<0.001$) than Salmon, Scott, Shasta, and Bogus Creek age 3 type-1 groups. The relative small size at ocean entry of returning South Fork Trinity adults

Table 6. Mean Scale Radius Measurement (mm x 140) to the Point of Ocean Entry for Life History Type Groups (I,II,III) by Age at Return and Location for Fall Chinook Salmon Returning to Klamath River Tributaries in 1986.

	Age at Return								
	2			3			4		
Location	I	II	III	I	II	III	I	II	III
S. Fk. Trinity	59.3	94.8	110.0[a]	54.2	83.3	109.0	63.7	-	120.0
Salmon River	64.0	96.0[a]	-	61.7	106.1	-	65.7	106.3	150.0[a]
Scott River	67.3	-		62.9	91.1	136.0[a]	79.7	108.3	-
Shasta River	66.6	93.0[a]	-	58.6	102.0[a]	-	53.0	79.0[a]	-
Bogus Creek	67.4	107.0	-	69.5	105.9	125.0[a]	-	119.0[a]	-

[a]Single value.

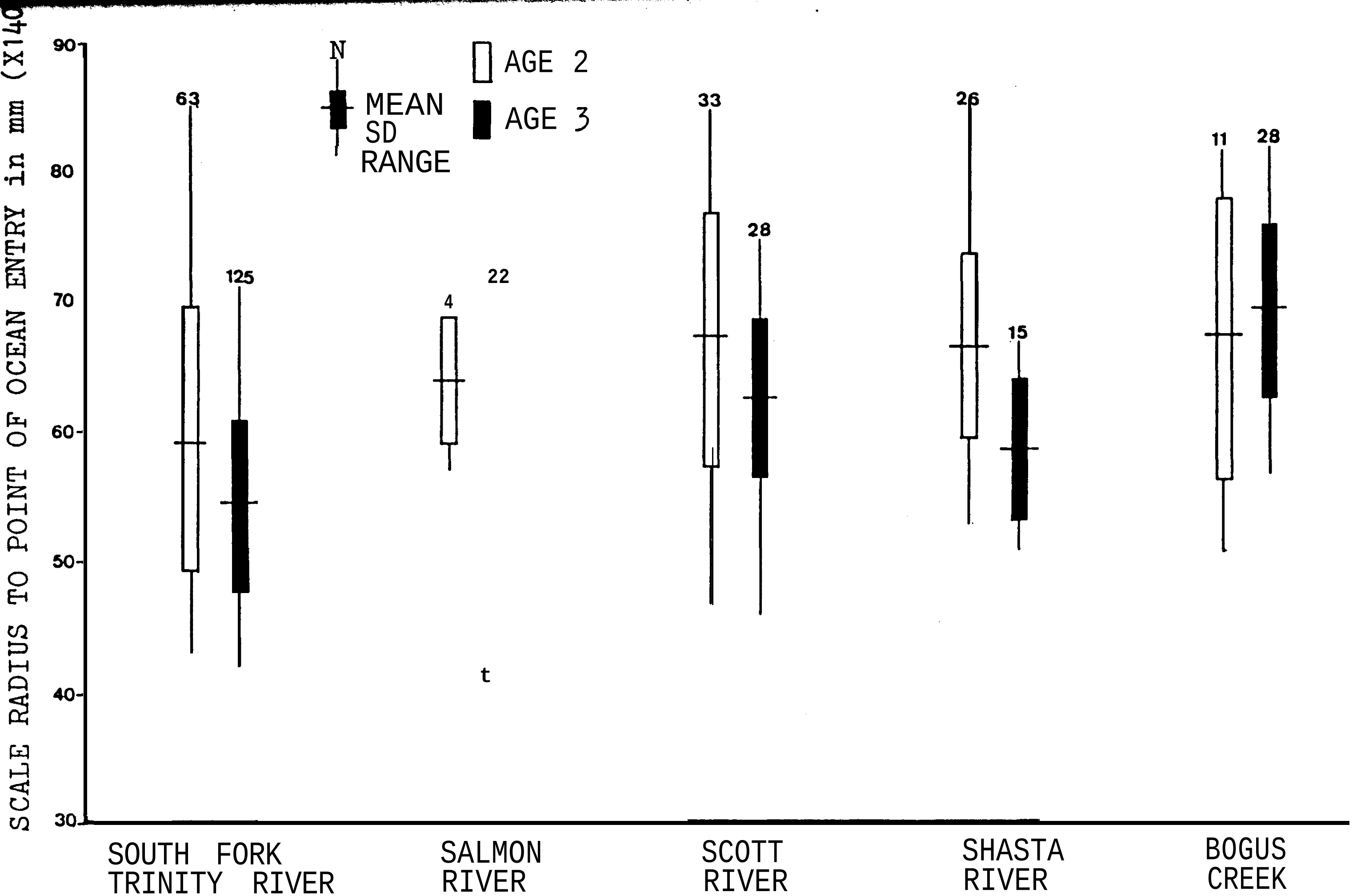

Figure 8. Scale Measurements to Point of Ocean Entry for Age 2 and Age 3 Type-I Fall Chinook Salmon Returning to Klamath River Tributaries in 1986.

is also confirmed by results for two year old type-l groups from 1984 and 1985 (Table 7).

Average back calculated lengths at ocean entry for age 2 and age 3 type-1 groups ranged from 92.2 mm to 117.4 mm (Table 8). Type-II groups ranged from 133.9 mm to 161.9mm indicating good freshwater growth for this type during the late summer and fall months before ocean entry.

Freshwater Growth

Early freshwater growth rates represented by scale radius measurements to circulus 10 were variable among the different sampling locations (Table 9). Age 2 and age 3 type-1 early growth rates (Figure 9) matched well with the size these groups attained at ocean entry (Figure 8), suggesting a strong positive correlation between early freshwater growth rates and size at ocean entry. South Fork Trinity type-1 two and three year olds showed the slowest freshwater growth rates and tested significantly lower than all other locations ($p<0.005$). Mean values for type-1 two year olds were larger than type-1 three year olds at all locations except at Bogus Creek although these differences were not statistically significant ($p>0.05$).

Size at the Time of First Annulus Formation

Size attained at the time of first annulus formation represented by scale radius measurements is presented in Figure 10. Major differences are apparent between the age groups of the 1986 returns. Age 2 fish on the average

Table 7. Mean Scale Radius Measurement (mm X 140) to the Point of Ocean Entry for Life History Type Groups (I,II,III) by Age at Return for Fall Chinook Salmon Returning to the South Fork Trinity River in 1984-1986.

Return year	Ase at Return								
	2			3			4		
	I	II	III	I	II	III	I	II	III
1984	61.6	105.0	112.0[a]	64.6	101.0	98.5	56.5	-	
1985	59.6	109.5	-	81.3	108.3	100.5	61.7	89.0[a]	115.0[a]
1986	59.3	94.8	110.0[a]	54.2	83.3	109.0	63.7	-	120.0

[a]Single value.

Table 8. Predicted Mean Length (mm) at the Time of Ocean Entry for Life History Type Groups (I,II,III) by Age at Return and Location for Fall Chinook Salmon Returning to Klamath River Tributaries in 1986.

	Age at Return								
	2			3			4		
Location	I	II	III	I	II	III	I	II	III
S. Fk. Trin.	105.3	147.6	165.7[a]	99.2	133.9	164.6	110.5	-	177.7
Salmon R.	110.9	149.0[a]	-	108.1	161.1	-	112.9	161.3	213.5[a]
Scott R.	114.8	-		109.5	143.2	196.8[a]	129.6	163.7	-
Shasta R.	114.0	145.5[a]	-	104.4	156.2[a]	-	97.7	128.8[a]	-
Bogus Cr.	114.9	162.2	-	117.4	160.9	183.6[a]		176.5[a]	-

[a]Single value.

Table 9. Mean Scale Radius Measurement (mm x 140) to Circulus 10 Grouped by Life History Type (I,II,III) and Age at Return for Fall Chinook Salmon Returning to Klamath River Tributaries during 1986.

Location	Age at Return								
	2			3			4		
	I	II	III	I	II	III	I	II	III
S. Fk. Trinity	32.2	33.2	27.0[a]	32.1	32.3	31.8	37.3	-	31.5
Salmon River	44.3	42.0[a]	-	37.9	37.4	-	33.0	33.9	37.0[a]
Scott River	39.7	-		38.6	34.3	36.0[a]	38.0	32.1	-
Shasta River	37.7	36.0[a]	-	35.5	41.0[a]	-	33.3	30.0[a]	-
Bogus Creek	40.1	38.3	-	40.2	38.0	42.0[a]	-	41.0[a]	-

[a]Single value.

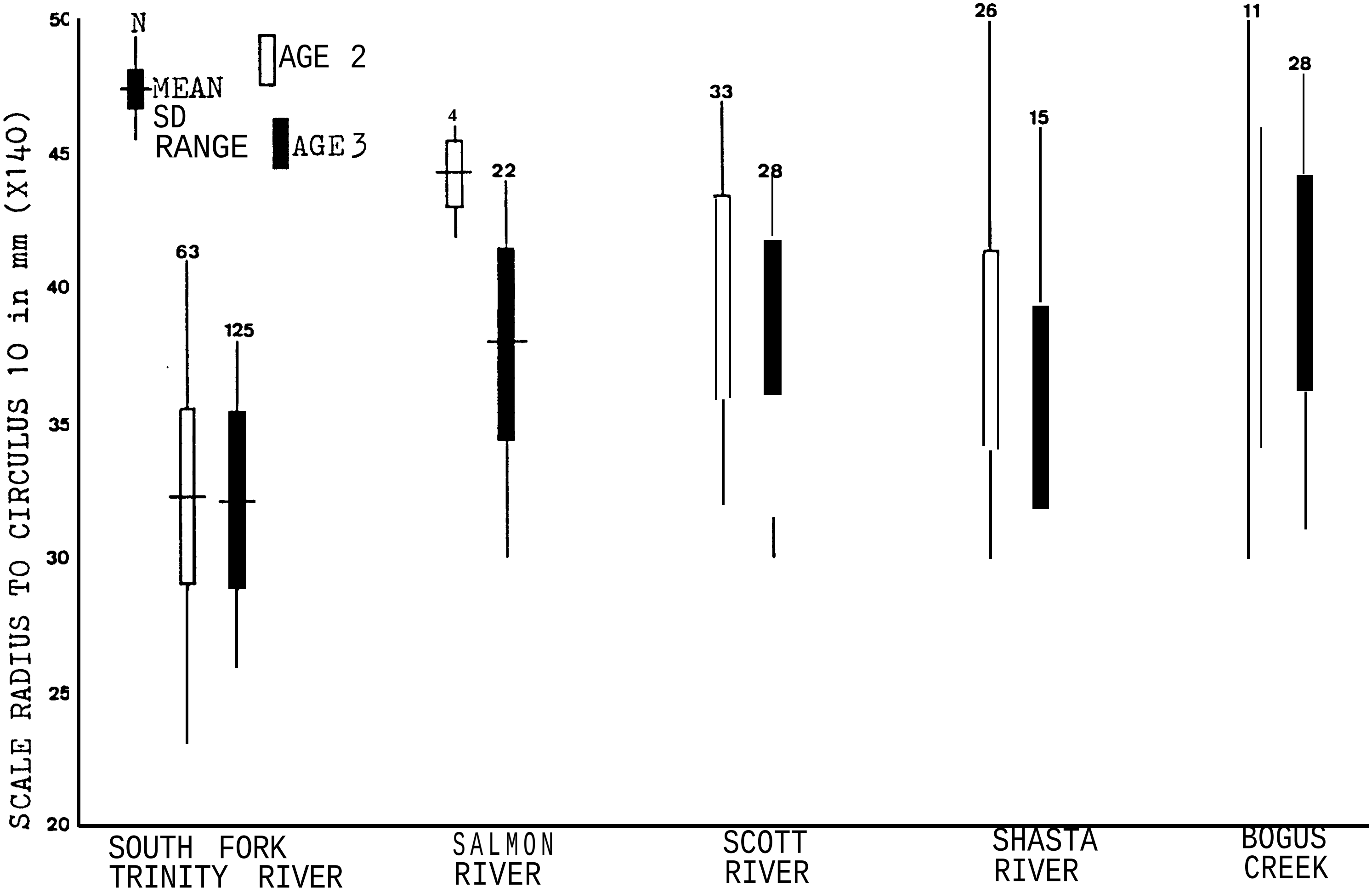

Figure 9. **Scale Radius Measurements to Circulus 10 for Age 2 and Age 3 Type-I Fall Chinook Salmon Returning to Klamath River Tributaries in 1986.**

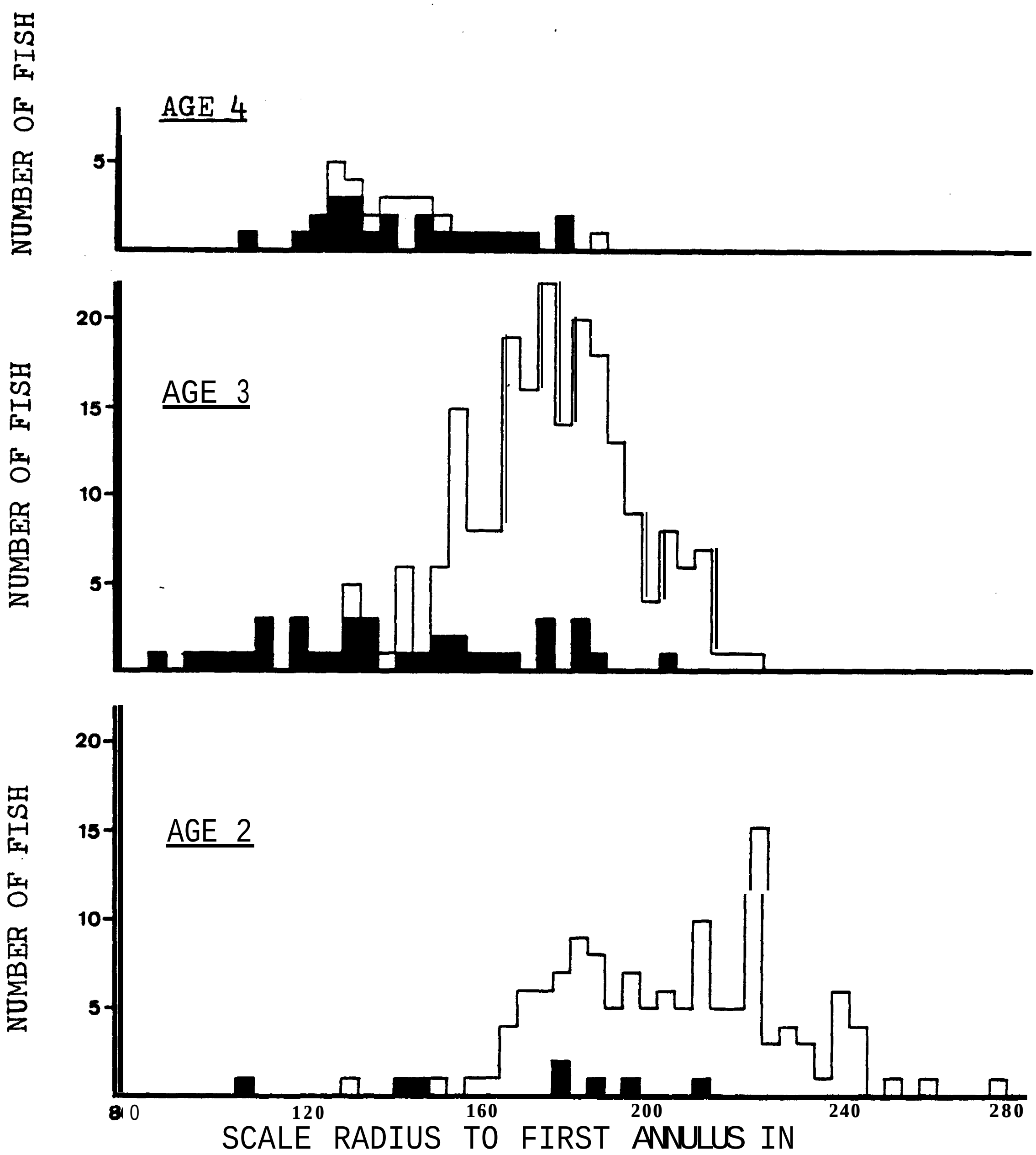

Figure 10. Scale Radius Measurements to the First Annulus for Combined 1986 Returns from the South Fork Trinity, Salmon, Scott, and Shasta Rivers. Open Areas Represent Fish with the Type-I Life History, Darkened Areas Represent the Type-II or Type-III Life History.

attained the largest size at the time of first annulus formation, age 4 returns were the smallest, and age 3 fish were of intermediate sizes. A trend of smaller sizes at first annulus formation for older age groups is apparent.

The relatively small sizes at first annulus formation for age 4 (1982 brood) fish returning in 1986 were also observed for the other age groups returning from the 1982 brood. Fish returning to the South Fork Trinity River at age 3 in 1985 and at age 2 in 1984 also show small relative sizes at the time of first annulus formation (Figure 11). This is most evident when comparing Figure 10 with Figure 11.

The 1921 Return Year

A length frequency distribution for 3,949 fall chinook captured in the estuary gillnet fishery during 1921 is presented in Figure 12. Substantial size selection in the gillnet fishery is evident. Age 2 jacks and smaller three year olds probably did not contribute to the harvest. Estimated age composition of the catch was 38.2 percent age 3, 42.8 percent age 4, 18.5 percent age 5 and 0.6 percent age 6. Juvenile life history proportions for the different age at return groups is presented in Table 10. An increased proportion of life history types II and III is observed for the older age at return groups.

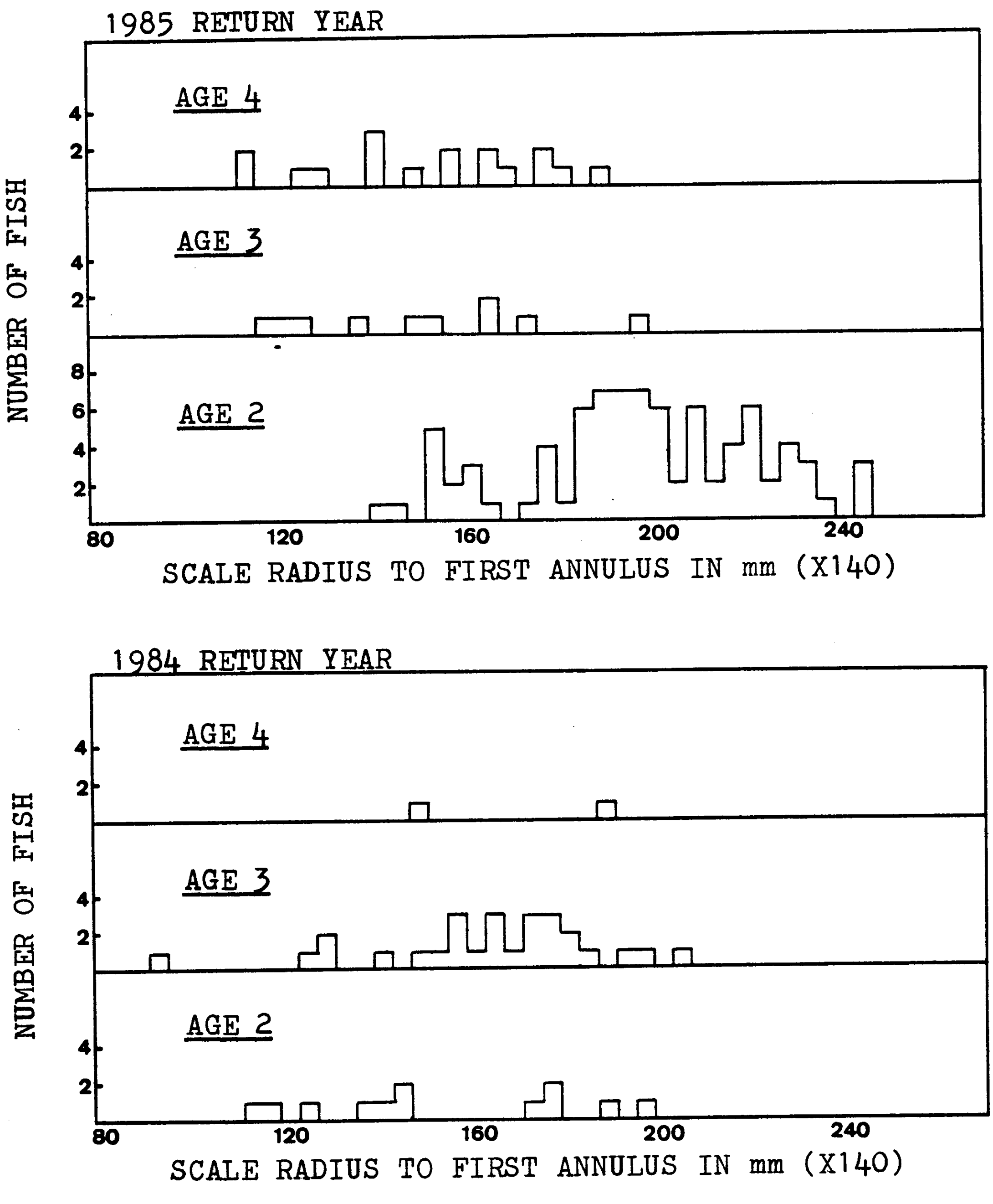

Figure 11. Scale Radius Measurements to the First Annulus for Samples Collected From the South Fork Trinity River During 1984 and 1985.

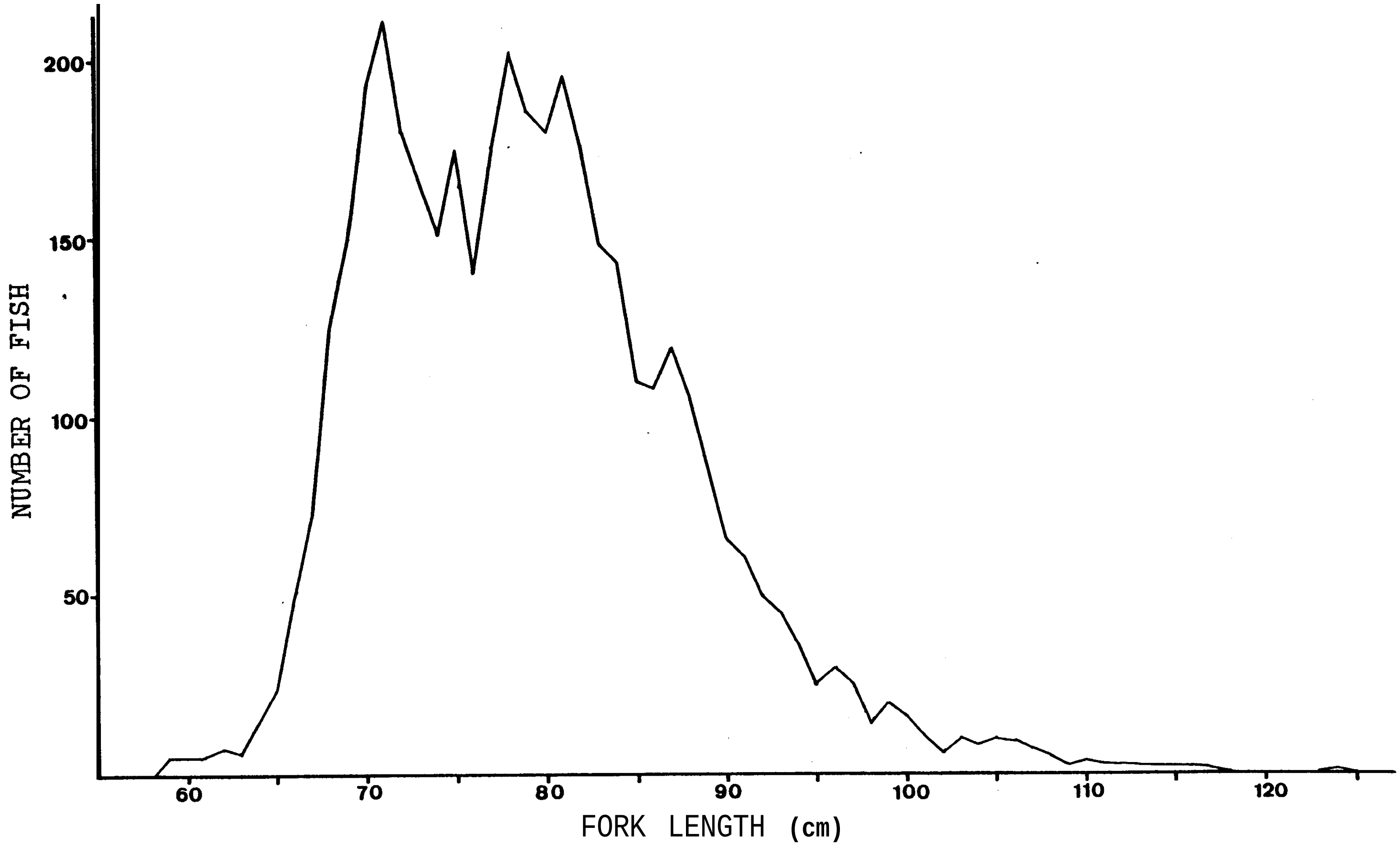

Figure 12. Length Frequency Distribution for 3949 Fall Chinook Salmon Captured in the Klamath Estuary Gillnet Fishery During 1921

Table 10. Relative Abundance of Klamath River Fall Chinook Life History Types (I,II,III) for Each Age at Return for Samples Collected from the 1921 Gillnet Fishery.

Life History Type	Ase at Return							
	3		4		5		6	
	%	n	%	n	%	n	%	n
I	100	66	94.6	70	78.1	25	0	0
II	0	0	4.1	3	18.8	6	0	0
III	0	0	1.4	1	3.1	1	100	1

DISCUSSION

Three juvenile life histories were identified from the scales of wild adult Klamath River fall chinook salmon. Life history type-1 (salmon which migrated during their first summer) dominated age 2 and age 3 groups from all locations sampled in 1986 contributing 79-100 percent among age 2 return groups and 52-94 percent among age 3 return groups. Type-II fish (migrate to the ocean in fall or early winter) were more prevalent among age 3 than age 2 groups. Though of limited value due to small sample sizes, age 4 groups from 1986 returns had high relative frequencies of the type-II life history. A trend of higher proportions of individuals with extended freshwater rearing (type II) among the older age at return groups is evident for 1986 returns. Similar relationships have been identified for historic Klamath River fall chinook salmon runs (Snyder, 1931) and for chinook salmon sampled from the Northern California troll fishery (Denega 1973). Reimers (1971), however, found no apparent relationship between juvenile life history type and the age of return spawners in his investigations on Sixes River, Oregon.

Age 4 spawners were poorly represented in spawning runs from all locations sampled except on the Salmon River (24 percent). A trend of larger, older spawners on the

Salmon River has been observed for some years (Jim Hopelain, CDFG, pers. comm.). Possible causes of poor age 4 returns in 1986 to major Klamath River spawning tributaries include: the selective targeting of the larger, older adults by the terminal Indian net fishery, higher commercial ocean troll fishery exploitation rates for age 4 fish, and the effects of the 1983 El Nino event on the 1982 brood.

The Effects of the 1983 El Nino on the 1982 Brood

Many of the first year scale patterns of age four fish returning in 1986 were difficult to interpret. This held true for all age groups returning from the 1982 brood. All early emigrating fish (type-I) from the 1982 brood exhibited first year ocean growth which was as poor or poorer than typical freshwater growth. Circuli spacing was very narrow in the first year scale ocean growth zone making the point of ocean entry difficult to identify. In addition, most type-1 fish from the 1982 brood showed two or three checks in ocean growth during the first year, the strongest occurring in the scale region where most type-II fish put down an ocean entry check thus making even juvenile life history classification uncertain in many cases. For these reasons it is possible some type-1 1982 brood year fish may have been misclassified as type-II.

The peak physical effects of the El Nino event appear to have occurred in the spring of 1983 (Norton et al. 1985) and produced decreased phytoplankton and zooplankton levels during the summer and fall (McGowan 1985). During the early summer, type-1 Klamath River juvenile chinook enter the ocean and start their first year ocean growth period. Therefore, the difficulty encountered in interpreting 1982 brood juvenile life histories may be largely due to poor ocean growth conditions off the Northern California coast produced by the 1983 El Nino event. Because of the confusing nature of the first year scale patterns of the 1982 brood, I compared my juvenile life history classifications with Oregon Department of Fish and Wildlife personnel (Lisa Borgerson, Corvallis Research Station, ODFW, pers. comm.). She concurred almost completely with my interpretations of 1982 brood Klamath River scale patterns.

It appears that the 1983 El Nino had at least two effects on 1982 brood year Klamath River chinook. First, ocean growth rates in the first year were reduced, as confirmed by narrow first year ocean Circuli spacing (Figure 6) and by small relative scale measurements to the first annulus (Figures 10 and 11). Second, a possible high mortality of type-1 juveniles was suggested by the relatively high proportions of type-II to type-1 fish among all age groups returning from the 1982 brood (Table 4).

Juvenile Life History Type Frequencies on the Tributaries

Differences in relative frequencies of life history types were also apparent between the different tributaries studied. The Scott and Salmon rivers appear to support fairly large proportions of returning age 3 and age 4 adults with the type-II life history. South Fork Trinity and Shasta River returning adults showed this type to a lesser degree.

Rearing conditions during the summer months on the tributaries studied may partially account for the observed differences in the incidence of extended juvenile rearing. Water temperatures on the Shasta and South Fork Trinity rivers rise to high levels early in summer, approaching 27°C by July, and usually remain at high levels through the summer months (USFWS 1985; Mark Zuspan, CDFG, pers. comm.). These summer temperatures exceed the lethal limit for chinook salmon juveniles (Brett 1952) and severely restrict the amount of summer juvenile rearing habitat available within each subbasin. Summer water temperatures in the Shasta subbasin have been reported as the most important constraint to anadromous fish production (USFWS 1985). Results of juvenile sampling on the Shasta River indicate that virtually all juveniles migrate out of this tributary by late June or early July (CDFG, unpublished data). In contrast, water temperatures on the Salmon and Scott Rivers are significantly lower during summer months (USFWS 1985), rarely rising above 23°C during August. Juvenile chinook salmon have been sampled on the lower reaches of these two systems during the late summer and fall months (CDFG, unpublished data) although the majority of juveniles migrate out of the Scott and Salmon rivers by early summer.

South Fork Trinity type-1 juveniles had slower early freshwater growth and were smaller at ocean entry than fish from any other system studied. This may be indicative of poor growth conditions in the South Fork Trinity River or could be a genetic attribute of this run. Sedimentation has been reported as the most important constraint to anadromous fish production on the South Fork Trinity River (USFWS 1985). Large sediment loads in the South Fork Trinity River and its tributaries have filled in juvenile rearing pools. Severely degraded juvenile rearing habitat caused by large sediment loads may be responsible for the observed reduced growth of type-1 South Fork Trinity fish. Shasta River type-1 three year olds had the next slowest growth and size at ocean entry although these values could be lower than true population values due to biased sampling of smaller sized (slower growing) adults.

Size at the Time of Ocean Entry

Mean back-calculated lengths at ocean entry for type-1 juveniles were similar to lengths observed during the summer months in the estuary (USFWS 1981; Klamath estuary investigation, CDFG, 1986, unpublished data). Type-I back-calculated lengths at ocean entrance are similar to back-calculated lengths at ocean entry reported for Rogue River fall chinook (McPherson and Cramer 1983) and spring chinook salmon (Schluchter and Lichatowich 1977) with similar ocean entrance timing.

Mean back-calculated lengths at ocean entry for type-II and type-III groups are comparable to reported juvenile sizes in the estuary during the fall and winter months (USFWS 1981; Klamath estuary investigation, CDFG, 1986, unpublished data). Mean back-calculated lengths at the time of ocean entry for type-II and type-III groups are much larger than those reported for juveniles with similar ocean entrance timing on the Rogue River (Schluchter and Lichatowich 1977) and Sixes River (Reimers 1973) in Oregon.

Many of the individuals that had the largest back-calculated sizes at ocean entry (150-190mm) among the type-II and type-III groups had first year scale patterns which looked very similar to observed scale patterns of hatchery chinook salmon released in the fall. Oregon Department of Fish and Wildlife personnel familiar with the scale patterns of similar releases on the Rogue River strongly concurred with these observations and identified many of the scale patterns of individuals from the type-II and type-III groups as obvious "hatchery patterns" (Appendix A). If this conclusion is correct it would help account for the large sizes at ocean entry for these groups when compared to wild juveniles with similar ocean entrance timing from other systems. Irongate and Trinity River hatcheries release fall chinook at average sizes of 140-170mm (CDFG 1984) and it is possible that fall release strays may partially account for the large average size at ocean entry among these life history groups. This explanation, however, is contradicted by the extremely low numbers of fin clipped hatchery fish observed at the tributary counting weirs for the last 10 years (Hankin and Diamond 1985: Ivan Paulsen, CDFG, 1986, pers. comm.).

Another possible source of the type-II and type-III fish with very large size at ocean entry are the chinook pond rearing programs operated on the upper Klamath River. Many juvenile chinook reared at Irongate Hatchery are trucked to pond sites along the Klamath River in June of each year. These fish are then reared at the ponds through the summer and released during the fall. Most of the fish identified as having the type-II life history in this investigation came from the Salmon and Scott rivers (Table 4). Many of the pond rearing programs are in fairly close proximity to these tributaries. Straying rates of pond-reared fish are difficult to evaluate because of an inconsistent marking program. Approximately one third of 218,000 pond-reared fish released during 1983 (1982 brood) were given left pectoral (LP) fin clips (CDFG 1985a). Very few fish with LP clips were observed at the Shasta, Scott, and Salmon River weirs in 1985 and 1986 when these fish returned at ages 3 and 4 (Jim Hopelain, CDFG, pers. comm; CDFG, unpublished data). However, none of the 388,000 pond-reared fish released in 1984 (1983 brood) were given an identifying mark of any kind (CDFG 1985b) and straying rates into major Klamath River tributaries by these fish when they returned at age 3 in 1986 are unknown.

Using Scale Analysis to Understand the Nature of Extended Freshwater Rearing

Much of the extended freshwater growth observed on many of the type-II and type-III first-year scale patterns does not appear to take place during tributary residency. Maximum juvenile lengths observed during juvenile sampling studies (CDFG, 1985, unpublished data) on the South Fork Trinity and Scott rivers ranged from 100-120mm during September. Average back-calculated sizes at ocean entry for these groups are much larger than this suggesting that much of the freshwater growth put on during the fall and winter months must occur during mainstem or estuary residency. Another possible explanation would be that the largest juveniles are more difficult to capture during tributary sampling studies because of greater agility and awareness or because larger juveniles hold in deeper water with higher current velocities.

At the present time there is not enough information available to determine the exact nature of the extended freshwater rearing of type-II and type-III wild Klamath River fall chinook. Type-II individuals include all fish which migrated to the ocean late in their first year. Snyder (1931) acknowledged that within his "ocean type" group were many individuals which had extended freshwater growth beyond what was normally observed for the typical ocean type pattern. Snyder assumed that after spring and summer downstream migration, a significant number of juveniles delayed ocean entrance and established residence in the estuary during the summer and early fall. It was thought that favorable estuarine growth conditions allowed these individuals to attain large sizes before ocean entrance in the fall. In my investigation, there is evidence from 1984-1986 adult scale patterns that my type-II group may itself consist of two types: (a) fish which reside in low productivity areas (possibly tributary streams) until autumn rains, then emigrate to the ocean, and (b) another group which exhibit strong freshwater growth (indicative of productive mainstem or estuary rearing). There is no clear distinction between these two types however, and I could not justify separation of the type-II group based on this speculation. Only if large numbers of juvenile scale samples were analyzed from the various spawning tributaries, mainstem, and estuary over several years would it be possible to answer this kind of question.

The importance of using wild juvenile scale analysis to correctly interpret the juvenile life history from adult spawner scales cannot be over-emphasized. Reimers (1973) carried out extensive juvenile scale sampling and analysis to establish a solid foundation of baseline information which he used to interpret the juvenile life histories of returning adults. This is difficult to do on the Klamath system because large numbers of hatchery release groups are present in the mainstem river and estuary throughout the summer, fall, and winter. Juvenile samples collected from these locations usually contain large proportions of hatchery releases which makes inferences about the location and duration of wild juvenile chinook rearing difficult. As a result, my conclusions about the locations of extended freshwater rearing and time of ocean entry particularly for type-11 and type-III groups must be considered speculative and general. The point of ocean entry and the first annular check were-usually easy to identify on most type-II individuals. The increased number of freshwater Circuli and the reduced amount of first year ocean growth evident on type-11 scales justify their distinction from type-1 fish. However, the wide variation of patterns in the type-II group (appendixes A and B) suggests that further separation into types based on a thorough analysis of wild juvenile scale samples may be possible.

Use of the Estuary for Rearinq

Scale analysis did not suggest extensive estuarine rearing by wild Klamath River fall chinook salmon juveniles. Reimers (1973) determined that chinook estuarine growth was intermediate between freshwater and ocean growth for Sixes River fall chinook salmon. Estuarine circuli were intermediate in spacing between those formed in freshwater and the ocean. Rich (1920) discovered many juveniles with intermediate Circuli spacing in samples he collected in the Columbia River estuary and concluded that this spacing represented growth in the estuary. Clearly distinctive intermediate Circuli spacing was not evident on Klamath River adult fall chinook scales. This observation does not necessarily lead to the conclusion that Klamath River chinook do not use the estuary for extended rearing, however. Estuary growth rates have been found to vary widely (Shepard 1981). When estuary growth rates are similar to mainstem growth rates, scale Circuli spacing is also similar (Healey 1980). Under these conditions the distinction between freshwater growth and estuary growth based on scale analysis may not be possible. Rich and Holmes (1929) found estuary scale growth very difficult to distinguish from stream growth and ocean growth for Columbia River chinook salmon. Snyder (1931) collected very large juveniles (160-180mm) in the Klamath River estuary during the fall and reasoned that these large sizes could only be attained after significant growth in the estuary. Recent investigations suggest that a limited number of wild chinook salmon juveniles may currently use the estuary for extended rearing in early fall (CDFG, unpublished data) but further investigations are needed to support this evidence.

The Relationshin of First Year Growth to Age of Maturation

In general, age 2 chinook had greater freshwater growth rates and were larger at ocean entry than age 3 fish.

Cramer and McPherson (1983) obtained similar results for Rogue River spring chinook salmon. They found a negative correlation between age-at-return and freshwater growth as represented by freshwater Circuli spacing. It has often been shown that early-maturing salmon grow more rapidly than late-maturing ones (Ricker 1964; Parker and Larkin 1959). Size at the time of first annulus formation represented by scale measurements to the first annulus was negatively correlated with age of maturation (Figure 10). Neilson and Green (1986) found a similar relationship between age of maturation and back-calculated size at formation of the first otolith annulus for male Sixes River chinook salmon.

Vulnerabilitv of Capture for Life Historv Types

It is of interest to note the average sizes at return of type-1 and type-II age 3 groups returning in 1986. Average size at return for type-11 groups ranged from 62.1 cm to 67.0 cm while type-1 age 3 groups ranged from 68.0 cm to 75.2 cm. Hankin (1985) showed that Klamath River hatchery release groups which produced larger fish at age 3 exhibited greater age 3 exploitation rates. With a commercial size limit of 66 cm, type-1 fish (faster growing, earlier maturing) are more vulnerable to capture at age 3 in the ocean troll fishery than are type-II or type-III fish at age 3. However, adults which reared for an extended period in freshwater are on the average slower growing throughout their life and are more likely to mature at older ages.

Therefore, the selective advantage of avoiding the troll and net fisheries for type-II and type-III age 3 returns (because of small size) is offset by the disadvantage of being vulnerable to capture in greater numbers at age 4.

The 1921 Return Year

The length frequency distribution presented in Figure 8 shows the narrow size selection by gillnets used to harvest fall chinook salmon in the Klamath estuary. This characteristic of the distribution was also observed by Snyder (1931) for the 1919, 1920, 1923, and 1930 gillnet harvests. Fish smaller than 65 cm were almost entirely excluded from the catch, thus excluding age 2 fish and the small age 3 fish. Age 4 and age 5 adults were more heavily' targeted because of the net mesh size used. These characteristics of the historic gillnet fishery are very similar to those of the current net fishery operating on the Klamath River today (USFWS 1986).

Type-I scale patterns from the 1921 samples were very similar to type-1 patterns observed from the 1986 samples, suggesting that freshwater growth rates and the size and timing of ocean entry for this dominant life history type has not changed much over time. In general, wild Klamath River fall chinook salmon returning to major spawning tributaries during 1986 exhibited greater proportions of extended freshwater life histories than did the 1921 samples collected from the estuary gillnet fishery.

Meaningful comparisons between the two populations are difficult to make however, because of the different sampling methods employed. Tributary populations were sampled randomly by length while the historic sample was biased towards larger fish. A good example of how this may affect life history proportions is the complete absence of type-11 and type-III life histories among age 3 fish from the 1921 sample (Table 10). Smaller sized age 3 returns (less than 65 cm) were excluded from the sample because of the size selectivity of the fishery. It is known from analysis of the 1986 returns that smaller sized age 3 fish were the most likely to have had extended freshwater residency as juveniles (Figure 7). In addition, the extreme effects of the 1983 El Nino make comparisons between age 4 fish difficult.

Juvenile life history type analyses for the different age-at-return groups from the 1921 return year show increased proportions of life history types with extended freshwater rearing among the older age-at-return groups. This trend was observed by Snyder (1931) for return years 1919, 1920, 1923, and 1930 and was also evident among 1986 returns to Klamath River tributaries (Table 4). This trend has also been reported by other workers using scale analysis to identify life history types of fall chinook salmon caught in ocean fisheries (Van Hyning 1951; Denega 1973).

Age composition results for the 1921 harvest (Figure 9) are similar in many ways to age compositions determined by Snyder (1931) for the 1919, 1920, and 1923 harvests. Age 4 fish dominated the catch in the early days of the gillnet fishery representing from 63-78 percent of the harvest for any given return year while age 3 (11-16 percent) and age 5 (10-20 percent) groups composed proportionately much less of the total catch. The major differences in the age composition of 1921 returns when compared to Snyder's results are a comparatively weak return of age 4 fish (43 percent) coupled with a comparatively strong return of age 3 fish (38 percent). Age 5 fish represented 19 percent of the catch which is within the range Snyder observed.

Changes in the Ase Structure of Wild Klamath River Fall Chinook Salmon

Comparisons of the age composition of the Klamath River fall chinook salmon population of the 1920's with the age composition of the current population are difficult to make but can be very useful in understanding how fishing pressures over the years may have affected the population. Inferences can be made about the age composition of the current gillnet catch using length frequency data (USFWS 1986). Age 5 fish do not appear to currently contribute as much to the catch. In addition, age 3 and age 4 fish now contribute about equally to the gillnet harvest but during the 1920's age 4 fish almost always dominated the catch.

The age composition of the entire population entering the Klamath estuary has been determined for return years 1979-1986 using scale analysis (USFWS 1986). Age 2 fish have contributed on the average 26.1 percent, age 3 41.6 percent, age 4 29.0 percent and age 5 only 3.3 percent over that span. In addition, very few wild age 4 and age 5 fish were observed on major Klamath River tributaries during 1986 (Table 1). This body of evidence suggests a decrease in the average age of returning Klamath River fall chinook salmon.

Ricker (1980) discussed the reduction in age at maturity of eastern Pacific chinook stocks at great length and gave eight possible causes. Ricker stated that in many areas the chinook troll fishery captures many fish that do not mature in the year of capture thereby reducing the average age of spawning fish. Snyder (1931) observed a dramatic reduction in the age structure of the 1930 net harvest when compared to the age structure of earlier years. He speculated that selective depletion of the older age groups by the net fishery left earlier maturing fish to propagate in undue proportions. Snyder felt that if the tendency to mature at a certain age was heritable then a selective advantage to mature at younger ages would exist under these conditions. Since the time of Snyder's work, it has been shown that age of maturation is partly heritable (Donaldson and Menasveta 1961) and can be modified by selection. Others have suggested that many North American chinook salmon populations are now exploited at levels which if not reduced will lead to stock collapse (Hankin and Healey, 1986). High rates of exploitation coupled with selective targeting of larger, older adults can cause severe loss of stock reproductive potential and genetic selection for small size and early age of maturation. My hope is that the wild Klamath River fall chinook salmon population can be managed in the future to offset these problems by allowing greater numbers of larger, later maturing adults to successfully reach their spawning grounds and reproduce and avoid the historical trend of decreasing stock size and the disturbing prospect of potential genetic selection for earlier age of maturation.

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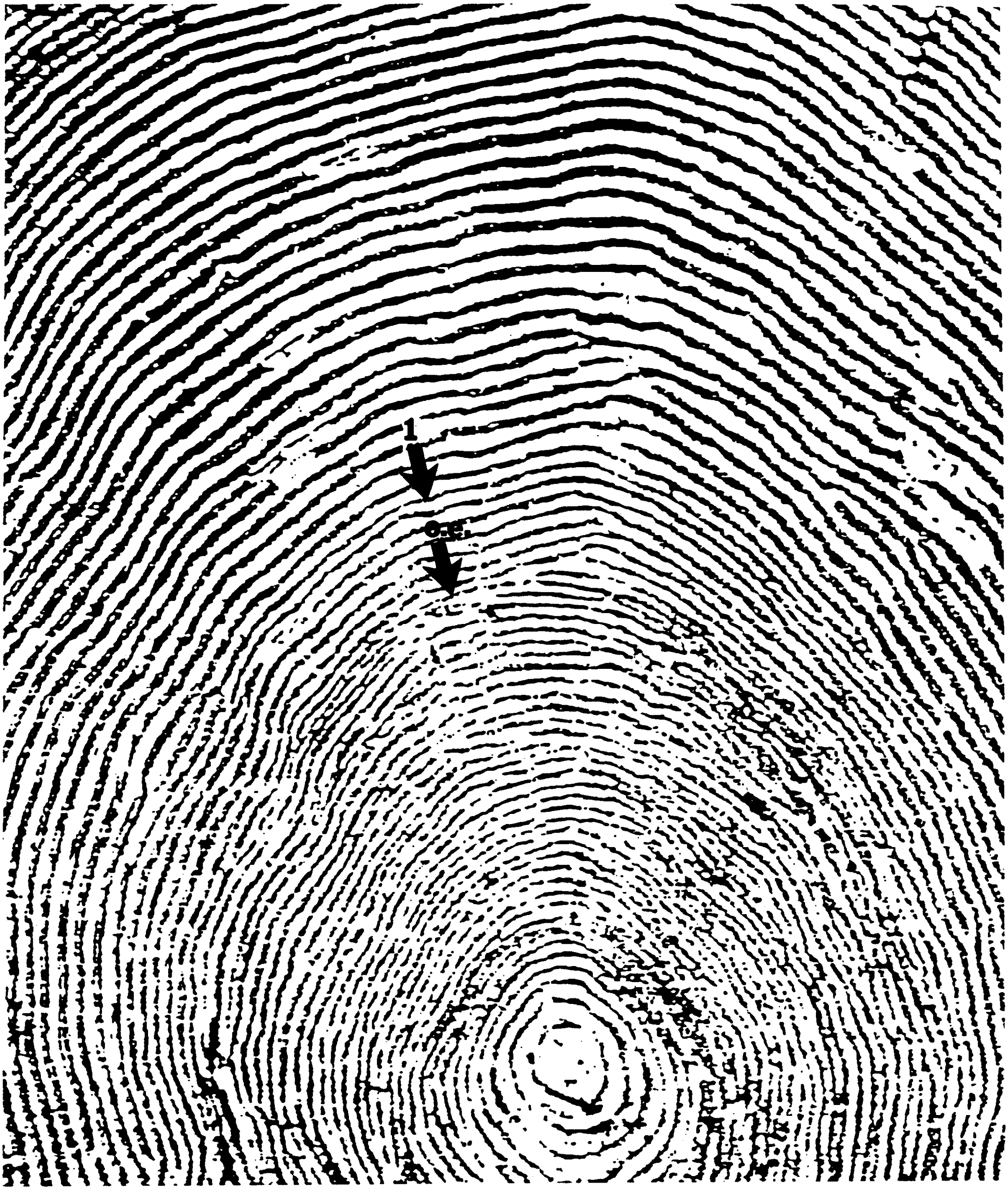

APPENDIX A. Scale Characteristics of a Type-II, Age 3, 68cm Spawner Sampled From the Salmon River in 1986 Showing Very Rapid Freshwater Growth, Attaining Large Size at the Time of Ocean Entry (o.e.) With a Small Amount of Ocean Growth Before Forming the First Annulus (1).

APPENDIX B. Scale Characteristics of a Type-II, Age 3, 59cm Spawner Sampled From the Salmon River in 1986 Showing Freshwater Growth to the Point of Ocean Entry (o.e.) and the First Annulus (1) Formed in the Ocean. Note the Reduced Amount of Freshwater Growth and Greater Amount of First-Year Ocean Growth on this Scale When Compared to Appendix A Showing the Diversity Within the Type-II Group.

APPENDIX C. Scale Characteristics of a Type-I, Age 3, 84cm Spawner Sampled from the Salmon River in 1986. This was the Most Abundant Life History Pattern Observed for Klamath River Wild Fall Chinook Showing a Limited Amount of Freshwater Growth Before Ocean Entry (o.e.) and a Large Amount of First-Year Ocean Growth to the First Annulus (1).