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AGE, GROWTH, AND LIFE HISTORY OF KLAMATH RIVER BASIN STEELHEAD TROUT (*Oncorhynchus mykiss irideus*) AS DETERMINED FROM SCALE ANALYSIS

by

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ABSTRACT

Adult steelhead (*Oncorhynchus mykiss irideus*) scales were analyzed from eight fall-run, two spring-run, and one winter-run stocks within the Klamath-Trinity River system, from 1981 through 1983, to provide basic age, growth, and life history data. The higher degree of half-pounder occurrence of upper Klamath River steelhead stocks (86.7 to 100%) compared to Trinity River steelhead stocks (32.0 to 80.0%) was the major life history difference noted in scale analysis. Early life history was similar for all areas sampled with most juveniles (86.4%) remaining in freshwater during the first two years of life before migrating to sea. Repeat spawning ranged from 17.6 to 47.9% for fall-run, 40.0 to 63.6% for spring-run, and 31.1% for winter-run steelhead. Mean length of adults at first spawning was inversely related to percent half-pounder occurrence in each stock. Ages of returning spawners, back calculated lengths at various life stages, and growth information are presented.

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PREFACE

This report represents the final form of a preliminary draft that was first completed in 1985. A subsequent draft, completed in 1987, was distributed widely and was cited as an unpublished document by many authors. The information contained in this final document is essentially the same as that contained in the earlier drafts, however, there are some minor revisions. The most substantial revision was standardizing the age notation to conform more closely with earlier published reports. It is hoped that the information in this report will provide current steelhead managers with background for initiating further investigations concerning steelhead stocks in the Klamath-Trinity River system.

INTRODUCTION

The Klamath-Trinity River basin, located in northern California and southern Oregon (Figure 1), is an important producer of anadromous salmonids and the number-one producer of steelhead trout (*Oncorhynchus mykiss irideus*) in California. The system supports spring and fall runs of chinook salmon (*O. tshawytscha*), coho salmon (*O. kisutch*), and three distinct runs of steelhead: i) a winter run, entering the river from November through March, ii) a spring run entering the river from March through June, and iii) a fall run, entering the river from July through October.

Very little information has been published concerning the winter-run steelhead in the Klamath-Trinity River system. It generally receives little attention by sports persons, primarily because of relatively poor winter angling conditions. The size of the winter steelhead run is unknown but, based on limited angler and Indian gill net harvest data, I believe the magnitude was about 5,000 to 25,000 adults during the years 1980-82. Annual counts (1980-82) of spring-run steelhead in holding areas throughout the system have ranged from 500 to 3,000 adult-size fish (Roeloffs 1983). The fall run is by far the largest of the three runs and supports the most popular steelhead sport fishery in California. Fall steelhead run size during the years 1980-82 was estimated to include 55,000 to 75,000 adults and 150,000 to 225,000 non-spawning fish called half-pounders (D.P. Lee, CDFG, pers. comm.). Half-pounders are immature steelhead, 25 to 41 centimeters (cm) fork length (FL), that return to fresh water 3 to 4 months after initial entry into salt water. This phenomenon is unique to streams located in extreme northern California and southern Oregon (Kesner and Barnhart, 1972; and Everest 1972).

Limited information regarding Klamath-Trinity River system steelhead life history, or age and growth based on scale analysis is available. Kesner and Barnhart (1972) provide life history and growth information in their description of angler-caught half-pounders from the lower Klamath River. Freese (1982) presented age and life history information of adult spring steelhead from North Fork Trinity and New rivers. Winter (1983) analyzed Wooley Creek and Elk Creek spring steelhead otolith and scale morphology in an attempt at racial separation. More recently, steelhead life history and age during freshwater and ocean periods have been described based on scale interpretations from steelhead in the South Fork Trinity River (Mills and Wilson 1991, Wilson and Mills 1992, and Collins and Wilson 1994).

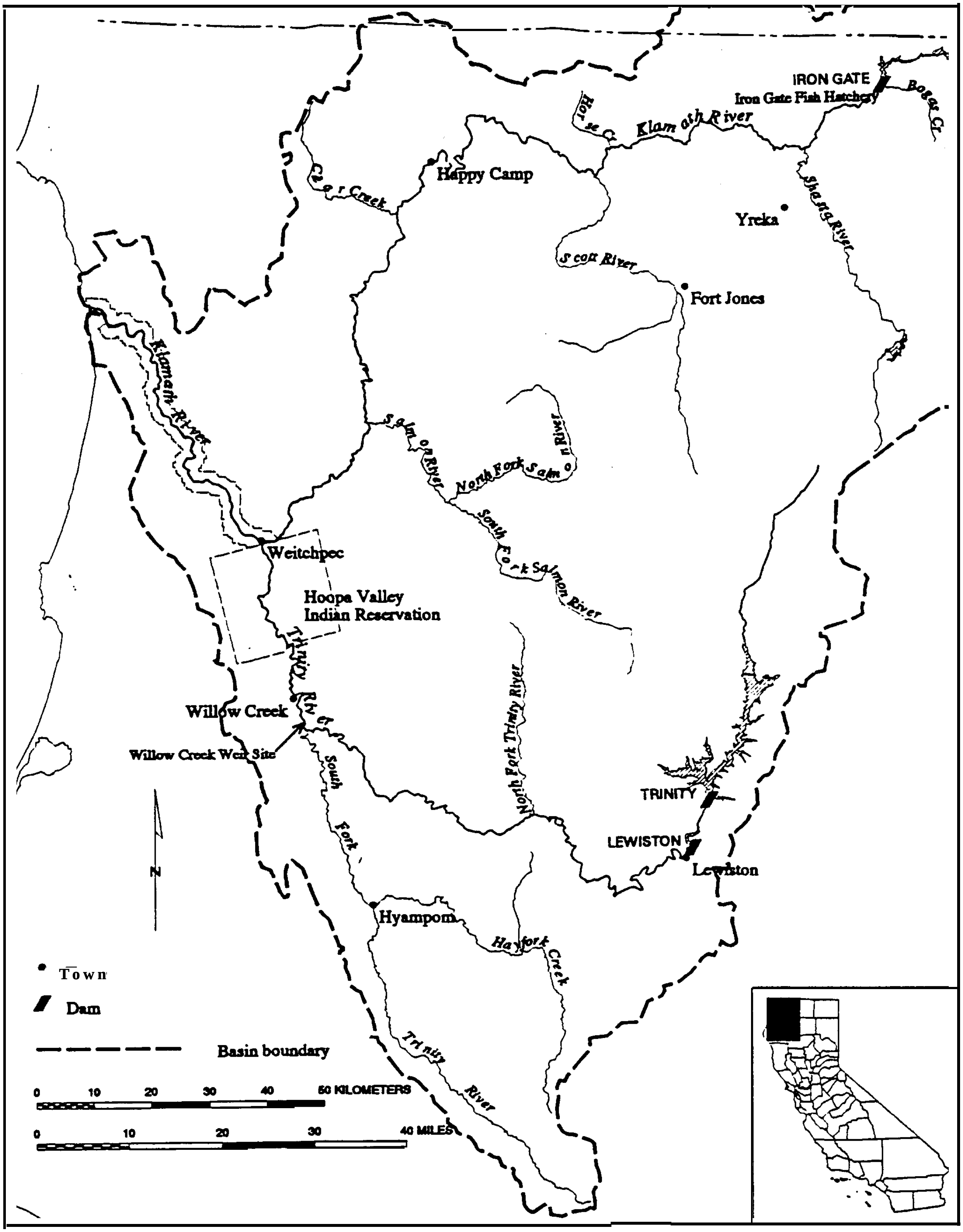

Figure **1. Klamath-Trinity** River System

Understanding basic life history characteristics of the individual steelhead runs and relationships between the runs is of fundamental importance for proper management of the Klamath-Trinity River basin steelhead resource. The purpose of this report is to provide additional information on steelhead life history in terms of age, occurrence of half-pounder phenomenon, spawning frequency, growth, and a general comparison of life history and growth characteristics among the three steelhead runs of the Klamath-Trinity River system.

METHODS

The sampling objective was to obtain scale samples from a minimum of 25 adult steelhead during each annual upstream spawning migration in major Klamath-Trinity River steelhead spawning tributaries and Iron Gate Hatchery (IGH). Electrofishing and angling were used to capture steelhead in most tributaries. All Shasta River, 1982 Bogus Creek, and IGH samples were obtained from California Department of Fish and Game (CDFG) trapping facilities. Hatchery samples include unmarked (assumed to be wild) steelhead only. Winter-run steelhead scales were collected by U.S. Fish and Wildlife Service (USFWS) biologists in 1980 from Indian gill-net-caught steelhead.

The race of each steelhead stock sampled was assumed based on river location and time of capture. For example, steelhead captured in the North Fork Trinity River in July and August were assumed to be spring run because it is unlikely that fall-run individuals would have entered freshwater and traveled over 140 miles in about a month. Similarly, steelhead captured in the lower Klamath River below Weitchpec in February and March were assumed to be winter run because of their close proximity to the river mouth and their bright appearance, suggesting they recently entered freshwater. In addition, race was assumed in specific tributaries based on CDFG file information. For example, CDFG file information indicates no known spring-run steelhead in the Scott or Shasta rivers, Bogus Creek or IGH, therefore, all steelhead in these areas were assumed to be fall run. Although the Salmon River system is known to contain spring-run steelhead, fish were captured in areas not in close proximity to known spring-run steelhead holding areas. I assumed steelhead captured in the Salmon River for this study were fall-run.

Scale samples were taken from an area below the posterior margin of the dorsal fin and two scale rows above the lateral line. Scale-sampled steelhead were measured to the nearest centimeter (cm) fork length (FL), and the gender, and location and date of capture noted.

Scales were mounted dry on a standard microscope slide and held in place with a cover slip and transparent tape. Scale images were projected using a Bell and Howell microfiche reader. Interpretation of scale patterns was performed by the author using standard techniques of annuli and spawning check identification (Lagler 1956). Measurements of scales to the nearest millimeter (mm) were taken along a line about 15 degrees on either side of the longitudinal axis. Annulus or check areas were measured from the scale center to the anterior or outer margin of the annulus or check.

Scales that were difficult to interpret were read and analyzed a second time approximately two weeks later. Scales that could not be interpreted with confidence at the second reading were read and analyzed by a another trained individual. If agreement could not be reached, the scale was discarded.

An important aspect of scale reading is the development of references that verify or support interpretations from circuli patterns on the scales. I developed a reference collection of scales from known steelhead life stages that ranged from Age 1 and 2 wild juveniles, hatchery smolts, smolts in the Klamath River estuary, upstream migrating half-pounders, and spawning adults. Circuli patterns at these various known life stages were used as training aids and as verification ("ground truthing") during interpretation of scale information from subsequently sampled adults.

Life history stages were categorized into six general periods: 1) freshwater years, 2) plus growth (growth after freshwater annulus formation and before ocean entry), 3) ocean entry, 4) ocean or salt water years, 5) half-pounder occurrence, and 6) spawning.

Age notation used in this report is similar to that used by Shapovalov and Taft (1954), except an additional character 'h' was included to represent half-pounder occurrence. The following is an example of notation:

2/h.1s

Where: freshwater years are left of slash
saltwater years are right of slash
h = half-pounder run occurred
s = number of spawning runs

In the above example, the fish spent two years in freshwater, returned from the ocean as a half-pounder during its first ocean year, and returned to spawn during its second ocean year. Total age is four years.

In another example: 2/1.1s represents an age four-year fish that spent two years in freshwater and two years in the ocean, returning during the second ocean winter to spawn.

Fish lengths at various life stages were back-calculated using the Lee method (Carlander 1981):

$$Li = \underline{c} + \frac{Si(L-\underline{c})}{S}$$

where: Li = fish length at point (i) in cm
Si = scale length at point (i) in mm
$\underline{c}$ = body scale constant = 3.0 cm
S = total scale radius in mm

L = fish length at capture (cm FL)

The body scale constant is the fish length at which scale formation first begins. A scale radius-body length regression of steelhead in my sample yielded an intercept of 3.0 cm (1.2 in.) for all three runs. This agrees with a C value of 3.01 cm (1.2 in.) for Klamath River fall-run steelhead determined by Kesner and Barnhart (1972)

Only scales exhibiting less than two spawning checks were used for back calculations. Scale margin erosion and regeneration of scale material from fish with two or more spawning checks was generally too severe for reliable back calculation results.

RESULTS

Shasta River

Scale samples were taken from 119 adult fall-run steelhead between December and March, 1981 through 1983. Mean length of fish sampled was 55.2 cm (21.7 in.) FL, and ranged from 43 to 70 cm (16.9 to 27.6 in.) FL. The most common age categories represented on the scales were 2/h.1s (47.9%), 2/h.2s (23.5%), and 2/h.3s (16.0%) (Table 1). Based on scale interpretation, during the juvenile rearing period 94.1 percent remained in freshwater for two years prior to emigrating to the ocean as smolts (Table 1), a half-pounder cycle occurred in 94.1 percent (Table 2), and repeat spawners comprised 47.9 percent of the sample (Table 3).

Scott River

Scale samples were taken from 78 adult fall-run steelhead between December and March, 1981 through 1983. Mean length of fish sampled was 52.1 cm (20.6 in.) FL, and ranged from 42 to 69 cm (16.5 to 27.2 in.) FL. The most common age categories represented on the scales were 2/h.1s (62.8%) and 2/h.2s (19.2%)(Table 1). Based on scale interpretation, during the juvenile rearing period 89.7 percent remained in freshwater for two years prior to emigrating to the ocean as smolts (Table 1), a half-pounder cycle occurred in 96.1 percent (Table 2), and repeat spawners comprised 26.9 percent of the sample (Table 3).

Salmon River

Scale samples were taken from 15 adult fall-run steelhead captured by angling between January and March, 1981 through 1983. Mean length of fish sampled was 51.1 cm (20.1 in.) FL, and ranged from 40 to 63 cm (15.7 to 22.4 in.) FL. The most common age category represented on the scales was 2/h.1s (66.7%)(Table 1). Based on scale interpretation, during the juvenile rearing period 93.3 percent remained in freshwater for two years prior to emigrating to the ocean as smolts (Table 1), a half-pounder cycle occurred in 86.7 percent (Table 2), and repeat spawners comprised 26.7 percent of the sample (Table 3).

Table 1. Steelhead age category summary as determined by scale analysis from adult steelhead from selected areas of the Klamath-Trinity River system.

Sample location	First-time spawners												
	2/1s[1]	3/1s	1/1.1s	2/1.1s	3/1.1s	1/h.1.1s	2/h.1.1s	2/2.1s	3/2.1s	1/h.1s	2/h.1s	3/h.1s	n
Shasta River				3							57	2	62
Scott River			1	1						3	49	3	57
Salmon River				1							10		11
Bogus Creek										10	44	2	56
Horse Creek											4		4
Clear Creek											4		4
Iron Gate Hatchery	1			2		1	1			9	56	1	71
Trinity River (Willow Cr. Weir)	1									3	27		31
N. Fork Trinity R.			1	9			1	1			2		14
S. Fork Trinity R.	4	1		7			1	3	1	1	5		23
Lower Klamath R.	1			18	2		3	5			1		30

1/ Age notation: numbers to left of slash represent years in freshwater, numbers to right of slash represent years in saltwater. "h" indicates half-pounder run, "s" indicates a spawning run. Example: 2/h.1s indicates a four-year old fish that spent two years in freshwater, and two ocean years with a half-pounder run and a spawning run.

2/ "n" represents number of fish sampled

Table 1 (continued). Steelhead age category summary as determined from scales taken from adult steelhead in selected areas of the Klamath-Trinity River system.

Sample location	Second-time spawners									
	1/2s[1]	2/2s	3/2s	1/h.2s	2/h.2s	3/h.2s	1/1.2s	2/1.2s	2/h.1.2s	n
Shasta River		1	1		28	1		2	2	35
Scott River		1		1	15					17
Salmon River			1		3					4
Bogus Creek	1	4	1		6					12
Horse Creek					2					2
Clear Creek					7					7
Iron Gate Hatchery				16	25	1		1		43
Trinity River (Willow Cr. Weir)		7		2	4			1		14
N. Fork Trinity R.		3		1	4			2		10
S. Fork Trinity R.				1	2			4		7
Lower Klamath R.		2	1		3		1	6	1	14

1/ Age notation: numbers to left of slash represent years in freshwater, numbers to right of slash represent years in saltwater. An "h" indicates half-pounder run, "s" indicates a spawning run. Example: 2/h.1s indicates a four-year old fish that spent two years in freshwater, and two ocean years with a half-pounder run and a spawning run. -- 2/"n" represents number of fish sampled

Table 1 (continued). Steelhead age category summary as determined from scales taken from adult steelhead in selected areas of the Klamath-Trinity River system.

Sample location	Third-time spawners							Fourth-time spawners		
	1/3s[1]	2/3s	3/3s	1/h.3s	2/h.3s	3/h.3s	n	2/h.4s		n
Shasta River				3	19		22			
Scott River					2		2	2		2
Salmon River										
Bogus Creek										
Horse Creek						1	1			
Clear Creek										
Iron Gate Hatchery			1	1	3		5			
Trinity River (Willow Cr. Weir)										
N. Fork Trinity R.		1					1			
S. Fork Trinity R.		1	1		2		4			
Lower Klamath R.		1					1			

1/ Age notation: numbers to left of slash represent years in freshwater, numbers to right of slash represent years in saltwater. "h" indicates half-pounder run, "s" indicates a spawning run. Example: 2/h.1s indicates a four-year old fish that spent two years in freshwater, and two ocean years with a half-pounder run and a spawning run. 2/ "n" represents number of fish sampled

Table 2. Comparison of half-pounder occurrence as determined from adult steelhead scales in the Klamath-Trinity River System.

Stream	Percent of sample with half-pounder check	Sample size
Shasta River	94.1	119
Scott River	96.1	78
Salmon River	86.7	15
Bogus Creek	91.2	68
Iron Gate Hatchery	95.8	119
Trinity River (Willow Creek weir)	80.0	45
N.F. Trinity River	32.0	25
S.F. Trinity River	35.3	34
Lower Klamath River (winter run)	17.8	45
Clear Creek	100.0	11
Horse Creek	100.0	7

Table 3. Comparison of adult steelhead spawning frequency in selected tributaries of the Klamath-Trinity River System as determined from scales.

Stream	Spawning migration: First	Second	Third	Fourth	Sample Size
	Percent of sample				
Shasta River	52.1	29.4	18.5		119
Scott River	73.1	21.8	2.6	2.6	78
Salmon River	73.3	26.7			15
Bogus Creek	82.3	17.6			68
Iron Gate Hatchery	59.7	36.1	4.2		119
Horse Creek	57.1	28.6	14.3		7
Clear Creek	36.4	63.6			11
Trinity River (Willow Cr. weir)	68.9	31.1			45
S.Fork Trinity River	67.6	20.6	11.8		34
N.Fork Trinity River	56.0	40.0	4.0		25
Lower Klamath River	66.7	31.1	2.2		45

Bogus Creek

In 1982 and 1983 adult fall-run steelhead were collected in Bogus Creek between January and March by electrofishing and trapping at the CDFG temporary weir. Scale samples were taken from 68 fish for analysis. Mean length of fish sampled was 50.2 cm (19.7 in.) FL, and ranged from 41 to 66 cm (16.1 to 26.0 in.) FL. The most common age categories represented on the scales were 2/h.1s (64.7%)(Table 1). Based on scale interpretation, during the juvenile rearing period 79.4 percent remained in freshwater for two years prior to emigrating to the ocean as smolts (Table 1), a half-pounder cycle occurred in 91.2 percent (Table 2), and repeat spawners comprised 17.6 percent of the sample (Table 3).

Horse Creek

Scale samples were taken from 7 adult fall-run steelhead captured by electrofishing during February 1981. Mean length of fish sampled was 56.9 cm (22.4 in.) FL, and ranged from 39 to 58 cm (15.4 to 22.8 in.) FL. The most common age category represented on the scales was 2/h.1s (57.1%)(Table 1). Based on scale interpretation, during the juvenile rearing period 85.7 percent remained in freshwater for two years prior to emigrating to the ocean as smolts (Table 1), a half-pounder cycle occurred in 100 percent (Table 2), and repeat spawners comprised 42.8 percent of the sample (Table 3).

Iron Gate Hatchery

Scale samples were taken from 119 adult fall-run steelhead captured during February and March, 1980 through 1983. Mean length of fish sampled was 51.2 cm (20.2 in.) FL, and ranged from 46 to 64 cm (18.1 to 25.2 in.) FL. The most common age categories represented on the scales were 2/h.1s (47.0%), 2/h.2s (21.0%), and 1/h.2s (13.4%) (Table 1). Based on scale interpretation, during the juvenile rearing period 74.8 percent remained in freshwater for two years prior to emigrating to the ocean as smolts (Table 1), a half-pounder cycle occurred in 95.8 percent (Table 2), and repeat spawners comprised 40.3 percent of the sample (Table 3).

Trinity River (between Willow Creek and Burnt Ranch)

Scale samples were taken from 45 adult fall-run steelhead captured between August and October 1982. Mean length of fish sampled was 54.7 cm (21.5 in.) FL, and ranged from 44 to 61 cm (17.2 to 24.0 in.) FL. The most common age categories represented on the scales were 2/h.1s (60.0%), and 2/2s (15.5%) (Table 1). Based on scale interpretation, during the juvenile rearing period 88.9 percent remained in freshwater for two years prior to emigrating to the ocean as smolts (Table 1), a half-pounder cycle occurred in 80 percent (Table 2), and repeat spawners comprised 31.1 percent of the sample (Table 3).

South Fork Trinity River

Scale samples were taken from 34 adult steelhead captured during November and December 1981, and during February and March 1982. Mean length of fish sampled was 61.0 cm (24.0 in.) FL, and ranged from 41 to 76 cm (16.1 to 29.9 in.) FL. The most common age categories represented on the scales were 2/1.1s (20.6%), 2/h.1s (14.7%), 2/1s (11.8%), and 2/1.2s (11.8%) (Table 1). Based on scale interpretation, during the juvenile rearing period 85.3 percent remained in freshwater for two years prior to emigrating to the ocean as smolts (Table 1), a half-pounder cycle occurred in 35.3 percent (Table 2), and repeat spawners comprised 32.3 percent of the sample (Table 3).

North Fork Trinity River

Scale samples were taken from 25 adult spring-run steelhead captured during July and August 1983. Mean length of fish sampled was 57.6 cm (22.7 in.) FL, and ranged from 50 to 66 cm (19.7 to 26.0 in.) FL. The most common age categories represented on the scales were 2/1.1s (36.0%), 2/h.2s (16.0%), and 2/2s (12.0%) (Table 1). Based on scale interpretation, during the juvenile rearing period 92.0 percent remained in freshwater for two years prior to emigrating to the ocean as smolts (Table 1), a half-pounder cycle occurred in 32.0 percent (Table 2), and repeat spawners comprised 44.0 percent of the sample (Table 3).

Clear Creek

Scale samples were taken from 11 adult spring-run steelhead captured during August 1980 and October 1981. Mean length of fish sampled was 48.6 cm (19.1 in.) FL, and ranged from 38 to 56 cm (15.0 to 22.0 in.) FL. Only two age categories were represented on the scales, 2/h.2s (63.6%) and 2/h.1s (36.4%) (Table 1). Based on scale interpretation, during the juvenile rearing period 100 percent remained in freshwater for two years prior to emigrating to the ocean as smolts (Table 1). A half-pounder run was observed in all fish sampled (Table 2). Repeat spawners comprised 63.6 percent of the sample (Table 3).

Lower Klamath River

Scale samples were taken from 45 adult winter-run steelhead captured in gill nets during February and March 1980. Mean length of fish sampled was 66.4 cm FL, and ranged from 55 to 83 cm FL. The most common age categories were 2/1.1s (40.0 %), and 2/1.2s (13.3%) (Table 1). Most juveniles, 91.1 percent, remained in freshwater for two years before emigrating to the ocean. A half-pounder cycle was observed in 17.8 percent of the fish sampled (Table 2). Repeat spawners comprised 33.3 percent of the sample (Table 3).

Growth

Steelhead juvenile mean growth in freshwater was similar for all tributaries and runs sampled. For all tributaries, back-calculated mean lengths at the end of the first freshwater annulus ranged from 8.6 to 10.3 cm (3.4 to 4.1 in.) (Table 4). Mean freshwater growth between the first and second annuli ranged 5.3 to 7.4 cm (2.1 to 2.9 in.) (Table 5). Mean plus growth, from the end of the last freshwater annulus to ocean entry, a period of 2 to 4 months, ranged from 4.8 to 8.0 cm (1.9 to 3.1 in.) (Table 5).

TABLE 4. Mean lengths (cm FL) of Klamath-Trinity River Steelhead at Various Life History Stages as Determined from Scale Calculations from First-time Spawners that Emigrated to the Ocean after Two Years in Freshwater.

Stream	Sample years	Sample size	Years in Freshwater 1	2	Ocean entry	First ocean check [1/]	First spawning
			--------------------Centimeters fork length------------------------				
Shasta River	81-83	62	9.3	14.8	22.6	36.2	50.1
Scott River	81-83	55	9.5	15.3	22.1	35.8	48.8
Bogus Creek	82-83	57	9.5	14.8	22.8	36.2	48.7
Salmon River	83	14	9.2	14.9	20.8	37.1	50.4
Iron Gate Hatchery	83	29	10.3	17.2	23.7	36.9	49.3
Trinity River (Willow Creek)	82	31	8.8	14.4	19.2	37.3	51.7
N.Fork Trinity River (spring run)	83	17	8.8	15.2	20.1	47.5	58.9
S.Fork Trinity River	82	24	9.6	17.0	22.0	43.7	58.2
Lower Klamath River (winter run)	80	30	9.9	16.7	21.6	48.7	64.8
Horse Creek	81	7	9.1	15.6	20.6	30.3	40.4
Clear Creek (spring run)	80	11	8.6	14.5	22.4	34.0	44.5

1/ The first ocean check is the half-pounder check for those individuals re-entering freshwater after a few months in the ocean.

Table 5. Growth of Klamath-Trinity River system steelhead between selected life history stages as determined from scale analysis.

	Intervals between life history stages			
Stream 2 FW	1 FW [1/] to Ocean entry	2 FW to 1 ocean [2/]	Ocean entry to 2 ocean [3/]	1 ocean to
	Mean lengths in centimeter fork length			
Fall Run				
Shasta River	5.5	7.8	13.6	13.9
Scott River	5.8	6.8	13.7	13.0
Salmon River	5.7	5.9	16.3	13.3
Bogus Creek	5.3	8.0	13.4	12.5
Iron Gate Hatchery	6.9	6.5	13.2	12.4
Horse Creek	6.5	5.0	9.7	10.1
Trinity River Willow Creek weir	5.6	4.8	18.1	14.4
S. Fork Trinity River	7.4	5.0	21.7	14.5
Spring Run				
N. Fork Trinity River	6.4	4.9	27.4	11.4
Clear Creek	5.9	7.9	11.6	10.5
Winter Run				
Lower Klamath River	6.8	4.9	27.1	16.1

1/ FW = Fresh water
2/ 1 Ocean = first ocean annulus or half-pounder check.
3/ 2 Ocean = second ocean annulus or first spawning check.

DISCUSSION

Fall Run

Areas known to have fall runs of steelhead that were sampled included IGH, Shasta, Scott, and Salmon rivers, and Bogus and Horse creeks. In general, steelhead from these areas exhibited the following characteristics: a) juveniles remained in freshwater for two years prior to emigrating to the ocean, b) mean lengths of smolts at ocean entry range from 21 to 23 cm FL, c) 86 to 100 percent return as half-pounders, d) most return to spawn for the first time the year following their half-pounder run, e) 15 to 30 percent return to spawn a second time, and f) up to 20 percent return to spawn a third time.

It is assumed steelhead captured from the Trinity River near Willow Creek, Burnt Ranch Falls and Greys Falls during the month of October were fall run. However, they differ significantly (Chi-square, $P<0.05$) from the other fall run listed above by showing a lower half-pounder rate of 64.4 percent. Other life history characteristics appear to be similar for fall-run steelhead from the Klamath and Trinity rivers.

Steelhead sampled from the South Fork Trinity River were thought to be fall run. However, the diversity of life history stages (unlike all other fall-run steelhead samples) raises the question of this sample being strictly fall run. Mean length of adults sampled from the South Fork Trinity River was significantly larger than fall-run steelhead sampled from all other areas (T-test, $P<0.05$). Interestingly, mean lengths of South Fork Trinity River adult steelhead (assumed to be fall-run) were comparable to mean lengths from North Fork Trinity River spring-run and lower Klamath River winter-run adult steelhead. The half-pounder rate of 41.2 percent for South Fork Trinity River fall-run steelhead is significantly lower (Chi-square, $P<0.5$) than any other fall-run samples. Either this run is unique or the sample contained mixed runs.

Winter Run

Steelhead sampled from the lower Klamath River were assumed to be winter run, based on the time and location of capture. Based on a bright silvery appearance, these fish appeared to have recently entered the river. This conclusion is supported by the fact they were captured at approximately river-mile 12 during February and March. Their spawning destination is unknown.

Lower Klamath River winter-run steelhead life history characteristics were more similar to North Fork Trinity River spring-run steelhead than upper Klamath River stocks. Lower Klamath River winter-run steelhead had the lowest incidence of half-pounder occurrence of all areas sampled, 17.8 percent. North Fork Trinity River spring-run steelhead half-pounder occurrence of 32.0 percent was also relatively low compared to upper Klamath River locations. Incidence of repeat spawning (33.3%), and length at various life stages were also more similar to Trinity River stocks than to upper Klamath River stocks (Table 4). Approximately 91 percent of Klamath River winter-run steelhead juveniles enter the ocean at age two, compared with 68 percent of age-two juveniles entering the ocean from Waddell Creek as reported by Shapovalov and Taft (1954). Repeat spawners also made up a greater proportion of the winter steelhead run in the Klamath River than representative smaller coastal streams like Waddell Creek, 33.3 and 17.1 percent, respectively. However, mean lengths of similar age adults (same number of freshwater and ocean years) were comparable in both Klamath River and Waddell Creek winter steelhead runs, 64.8 and 68.0 cm FL, respectively.

Spring Run

Clear Creek spring-run steelhead exhibited scale characteristics more similar to upper Klamath River fall-run steelhead than the other spring-run stock sampled from the North Fork Trinity River. Clear Creek spring-run half-pounder incidence of 100% differed significantly with North Fork Trinity River spring-run half-pounder rate of 32.0% (Chi-square, $P < 0.05$). Mean lengths at various juvenile life stages were comparable with North Fork Trinity River spring-run steelhead, however, mean lengths at first and second ocean annuli were significantly different for the two spring-run stocks (T-test, $P < 0.05$).

North Fork Trinity River spring-run steelhead differed significantly (Chi-square, $P < 0.05$) in many scale characteristics compared to fall-run steelhead, but were similar in many respects to winter-run steelhead. Half-pounder incidence was only 32.0 percent in North Fork Trinity River spring-run steelhead compared to 93.5 percent for upper Klamath River fall-run steelhead, but nearly twice that of lower Klamath River winter-run which had a half-pounder incidence of 17.8 percent. Freese (1982) reports a half-pounder incidence of 41.5 percent from North Fork Trinity River spring-run samples.

Fresh water growth of North Fork Trinity River spring-run steelhead was similar to all other sample locations (Table 5 and Figure 2). The majority (92%) of North Fork Trinity River spring-run steelhead remained in freshwater for two years prior to emigration. Freese (1982) found 95.1 percent of North Fork Trinity River spring-run steelhead exhibited two years of stream growth prior to emigration.

Klamath River winter-run and North Fork Trinity River spring-run steelhead had similar mean lengths at all life history stages (differences not statistically significant, $P > 0.05$) except the 2-Ocean stage.

Although freshwater characteristics of spring-run stocks are similar with all other fall-run and winter-run stocks, ocean life history is much more diverse compared to fall-run stocks. A similar broad spectrum of ocean age history occurred in lower Klamath River winter-run and South Fork Trinity River fall-run scale samples (Table 1).

This study was limited in scope, and some locations (Salmon River, Clear Creek and Horse Creek) were represented by relatively small samples. Conclusions of life history descriptions or growth rates of specific steelhead stocks should be viewed with caution because of the many variable environmental conditions (e.g. river and ocean temperature, stream flows, storms, and ocean upwelling) that were not identified or accounted for in this study. These data are intended to be viewed as trend or framework pieces that partly describe a complex Klamath-Trinity River system steelhead population.

It is generally accepted that the ocean environment produces better growth than the freshwater environments. First year ocean mean growth varies substantially among Klamath-Trinity River system steelhead stocks, depending upon the degree of half-pounder occurrence. In general, longer periods spent in the ocean produce greater absolute growth. There is a strong inverse

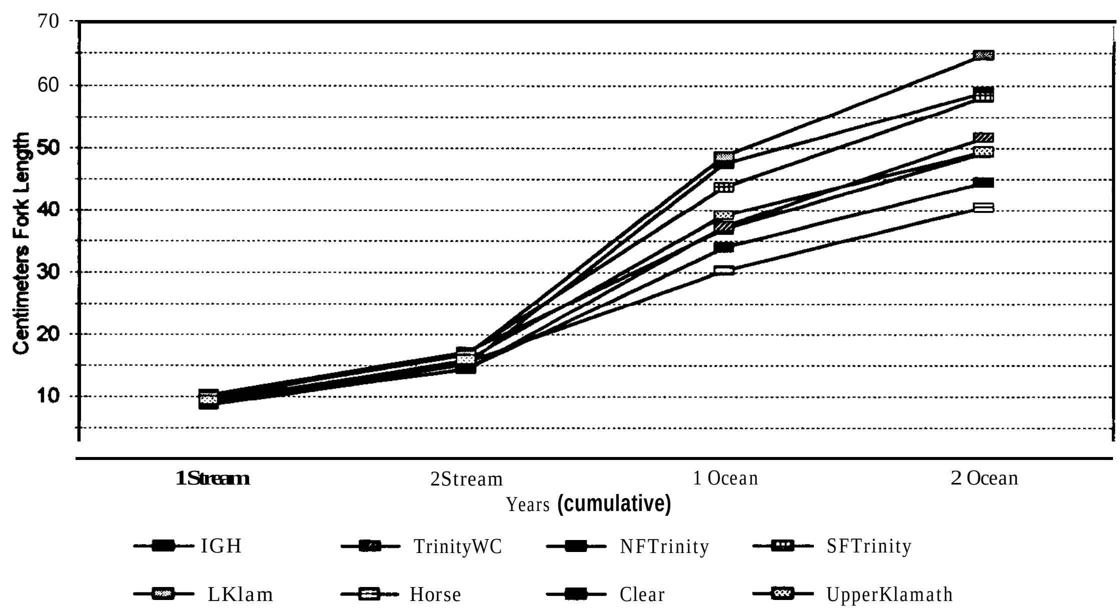

Figure 2. Mean lengths at four life history stages for selected Klamath-Trinity River system steelhead stocks.

linear relationship (r^2 = 0.87) between rate of occurrence of half-pounder migration and length at first-time spawning for individual stocks (Figure 3).

For steelhead stocks demonstrating a half-pounder phase, mean growth from ocean entry and return to freshwater as half-pounders (an average period of three months) is 10.2 cm (4.0 in.). Everest (1973) reported a similar growth of 11.9 cm (4.7 in.) during the same three-month period

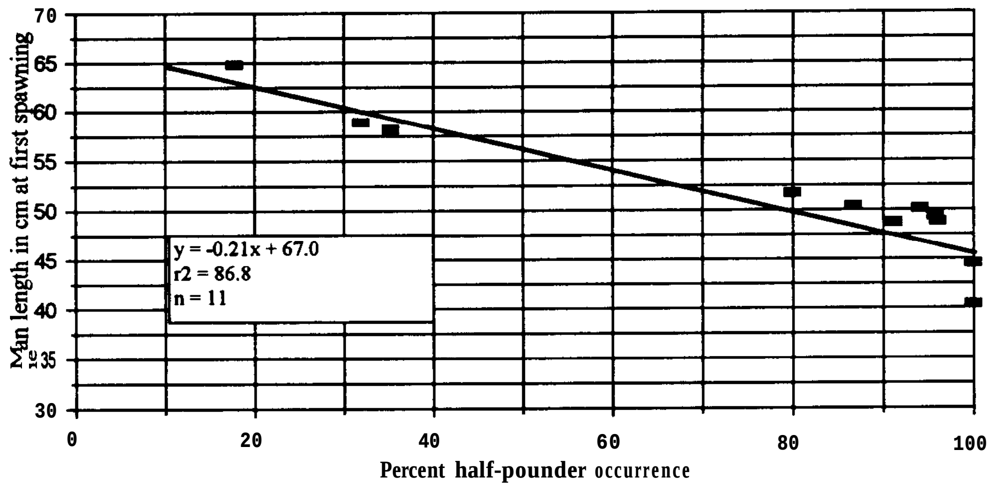

Figure 3. Relationship between percent half-pounder occurrence and mean length at maiden spawning for selected Klamath-Trinity River system steelhead stocks.

for Rogue River steelhead half-pounders. An additional average length of 2.4 cm (1 .O in.) is added during the half-pounder's stay in freshwater.

North Fork Trinity River spring-run and Klamath River winter-run steelhead stocks do not generally return as half-pounders and have first-year ocean growth ranging from 27.1 to 27.4 cm (10.7 to 10.8 in.). Stocks with intermediate degrees of half-pounder occurrence (Trinity River and South Fork Trinity River fall-runs) exhibit a corresponding intermediate growth of 18.1 to 21.7 cm (7.1 to 8.5 in.) during the first ocean growth period (Table 5).

Second year ocean growth is also directly related to amount of time spent in the ocean. Monthly growth rates are highest for spring-run fish and lowest for winter-run fish (Table 6). The amount of absolute growth, however, appears to be a function of ocean duration. Spring-run steelhead spend an estimated 2 to 4 months in the ocean after the end of the first ocean annulus and increase in length 10.5 to 11.4 cm (4.1 to 4.5 in.) before the first spawning.. Fall-run steelhead spend an estimated 4 to 7 months in the ocean after the half-pounder check and increase in length 12.4 to 14.5 cm (4.9 to 5.7 in.) before making the first spawning run. Everest (1973) reported Rogue River steelhead averaged 5.2 inches of growth between the half-pounder event and first spawning. Winter-run steelhead spend an estimated 9 to 12 months in the ocean after the first ocean annulus and exhibit an increase in mean length of 16.1 cm (6.3 in.) before the first spawning.

Mean lengths obtained from the various stocks examined at the end of the first and second growing seasons in the ocean may be related to genetic differences or to ocean productivity. Klamath River winter-run and Clear Creek spring-run steelhead samples represent similar brood years but significantly different mean lengths at adult life stages (t-test, $P<0.05$) Trinity River adult steelhead stocks are typically larger than Klamath River adult steelhead stocks for similar brood years. Comparison of mean lengths of first-time spawners revealed that upper Klamath River steelhead were significantly smaller than Trinity River steelhead (t-test, $P <0.05$) (Figure 2 and Table 4). The mean size differences of adult first-time spawners among the stocks sampled appears to be related directly to the percent of half-pounder occurrence within each stock (Figure 3). The simple explanation for this phenomenon is that increased time spent in the ocean produces greater length of adults.

RECOMMENDATIONS

This is the first known major compilation of life history, age, and growth information interpreted from scales for Klamath-Trinity River system steelhead. Some unique variation between various steelhead stocks has been identified. Additional studies are needed to more throughly define and understand the variation among steelhead stocks. Future studies should address the following:

1. Expand scale analysis throughout the Klamath-Trinity River system to provide a more complete description of life history and age structure. Emphasis should be placed on obtaining scales of similar brood years for comparison of year class characteristics between stocks.

2. Priority should be given to analyzing scales from spring-run and winter-run wild steelhead stocks and from both hatcheries.

3. Winter-run steelhead run timing, abundance, and spawning locations should be determined.

4. Information of juvenile productivity and time of smolt emigration in selected streams should be determined or refined.

5. Improve accuracy of steelhead run size estimates for all Klamath-Trinity River steelhead stocks.

Some of the above factors are beyond the scope of scale studies but are necessary pieces of information for understanding and managing the Klamath-Trinity River system steelhead resource.

With the passage of Senate Bill 2261 in 1988 that mandated the Department of Fish and Game to significantly increase the numbers of naturally spawning steelhead throughout the state, the need to better understand existing steelhead population levels, natural production potential, genetic uniqueness, and life history stages became vital to enable fishery managers to design sound programs to achieve this goal. More recently, wild steelhead stocks throughout California have become candidates for listing under the federal Endangered Species Act. Since the naturally spawning steelhead in the Klamath-Trinity River system are perceived to be in peril, it is even more important today to have a more thorough knowledge of their status, and the critical interactions within the ecosystem during various phases of their life cycle.

SUMMARY

Main stem Klamath River tributaries upstream of the confluence of the Trinity River have the highest incidence of half-pounder occurrence within the Klamath-Trinity River system. Fall-run steelhead sampled from five streams and IGH had a mean half-pounder incidence of 94.3 percent, ranging from 86.7 to 100 percent. Everest (1973) reported a 97 percent half-pounder incidence for fall-run steelhead (these fish are called summer-run in Oregon) in the Rogue River.

South Fork Trinity River fall-run steelhead and North Fork Trinity River spring-run steelhead had nearly identical rates of half-pounder occurrence, 35.3 and 32.0 percent, respectively. Both of these rates were significantly lower than half-pounder occurrence observed from steelhead sampled in the main stem Trinity River near Willow Creek (80.0 %) (Chi-square, $P < 0.05$).

Half-pounder occurrence from winter-run steelhead in the lower Klamath River was the lowest of all stocks sampled at 17.8 percent.

All Klamath-Trinity River system wild steelhead exhibit similar freshwater age and growth characteristics. Age at smolt emigration occurred at the following mean percentages: Age 1 at 9.9, Age 2 at 86.4, and Age 3 at 3.7.

Incidence of repeat spawning for the steelhead stocks sampled ranged from 17.6 to 47.9 percent for fall run, 40.0 to 63.6 percent for spring run, and 31.1 percent for winter run.

Mean length of upper Klamath River and Trinity River fall-run first-time spawners is 49.5 and 51.7 cm FL (19.5 and 20.3 in.), respectively. North Fork Trinity River spring-run first-time spawners averaged 58.9 cm FL (23.2 in.). Lower Klamath River winter-run first-time spawners averaged 64.8 cm FL (25.5 in.). All of these differences are statistically significant (T-test, $P<0.05$).

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