AN ABSTRACT OF THE THESIS OF

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Title: RACIAL IDENTIFICATION OF CHINOOK SALMON *(Oncorhynchus tshawytscha)* AND JUVENILE STEELHEAD TROUT *(Salmo gairdneri)*.

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Efforts to manage stocks of salmonids in Pacific Northwest stream systems are complicated by the occurrence of several runs of a species thought to represent races rearing sympatrically as juveniles. In order to collect the population statistics needed to properly manage these stocks, managers need a method of identifying juvenile salmonids by race. In an effort to determine if taxonomic or morphological differences exist between these races, wild juvenile summer and winter steelhead trout *(Salmo gairdneri)* and wild juvenile spring and fall chinook salmon *(Oncorhynchus tshawytscha)* from the Rogue River (Oregon) were studied. The goal of the study was to determine if differences in taxonomic characters would allow racial identification of individual fish with 90% accuracy.

The wild juvenile summer steelhead trout had significantly fewer vertebrae and larger nuclei, greater average intracircular spacing, and a larger length at first annulus formation of scales than winter steelhead trout. No differences between juvenile summer

and winter steelhead trout were found in otolith nuclear diameter, total lipids or fatty acid composition of the muscle tissue.

Wild juvenile spring chinook salmon exhibited significantly lower vertebral counts, larger otolith nuclear diameter, greater average intracircular spacing, larger scale nuclei, and a larger first and second band of five intracircular spaces than juvenile fall chinook salmon.

Mesentary fat deposition was highly variable between fish from the same streams and was not useful in separating juveniles by race.

Although significant differences between races were found for both species, none of these differences were sufficient to allow the racial identification of individual fish with 90% accuracy. It is not known if the differences found were caused by genetic or environmental effects or both. One experiment showed that summer and winter steelhead showed no difference in vertebrae or otolith dimensions when incubated under the same conditions, suggesting that differences found in wild steelhead trout were caused by environmental effects.

The lack of distinct phenotypic differences between individual fish of different races may be caused by extensive interbreeding between races of salmonids in the Rogue Basin due to large environmental variability during the spawning season for chinook salmon and steelhead trout. It is also possible that environmental variation in the early life history masked genetic differences between the races.

Racial Identification of Chinook Salmon *(Oncorhynchus tshawytscha)* and Juvenile Steelhead Trout *(Salmo gairdneri)*

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

RACIAL IDENTIFICATION OF CHINOOK SALMON *(Oncorhynchus tshawytscha)* AND JUVENILE STEELHEAD TROUT *(Salmo gairdneri)*

INTRODUCTION

Fishery management has been complicated by the occurrence of distinct populations or races which may be genetically segregated but exist sympatrically in streams. The manager needs to identify the various races or distinct populations within a basin, but this can be confounded by the lack of phenotypic differences, particularly in juveniles.

Stocks of chinook salmon and steelhead trout in the Rogue River in southern Oregon are separated into two major runs each. These runs are considered to be races isolated by spawning timing and area (Rivers 1963; Everest 1973; Lichatowich 1976). Management of these stocks has concentrated on adults because races can be separated by differences in size at return, migration timing, seasonal distribution, timing of spawning, spawning habitat, and scale characteristics (Rivers 1963; Everest 1973; Lichatowich 1976).

Knowledge of how juveniles of these races partition the freshwater environment in time and space has been incomplete because of the inability to identify juvenile salmonids by race in field collections. To understand how environmental alteration and changing management approaches will affect populations of salmonids in streams, managers need to determine changes in distribution, growth, survival, migration size and time, and parr-smolt transformation of juvenile salmonids. Changes in these characteristics have been shown to be related to adult return of salmonids.

Since effects may not be the same for juveniles of all races of a species, managers would gather separate population statistics if the juveniles of each race could be identified in field collections. The general purpose of this study was to determine characteristics by which juvenile chinook salmon and steelhead trout could be racially identified in field collections from the Rogue River.

The usefulness of differences between races in taxonomic characters to the fishery manager depends on two factors: 1) the magnitude of the differences, which determine how accurately individual fish can be identified by race, and 2) the genetic basis for these differences, which affect their stability in time and space. A reasonable goal for separation of juveniles by race for the collection of population statistics is separation of individual fish with 90% accuracy. To achieve this goal, a characteristic would have to differ between races such that the 90% confidence interval for individual observations (mean $\pm$ "t" standard deviations) do not overlap.

Although samples were selected from as widely divergent habitats as possible to maximize the environmental variability, it should be clear that this experiment was not designed to account for the genetic or environmental effects which may have caused these differences in characteristics. The specific goal of the study was to examine field collections of steelhead trout and chinook salmon from the Rogue Basin for differences in characteristics which would allow separation of individual fish by race with 90% accuracy.

Characteristics to be screened were selected from a review of the literature. I evaluated the differences between juvenile summer and winter steelhead trout and juvenile spring and fall chinook salmon in vertebrae number and mesentary fat (Smith 1969), otolith dimensions (McKern, Horton and Koski 1974; Rybock, Horton and Fessler 1975) and scale characteristics (Clutter and Whitesel 1956). I also evaluated total lipids and fatty acid composition (Saddler et al., 1965) for differences between races of steelhead trout.

MATERIALS AND METHODS

Juvenile salmonids of known race were collected from areas of the Rogue Basin where races of steelhead trout and chinook salmon are segregated in spawning habitat. I assumed that fish collected in areas where a single race spawns are progeny of that race. The racial segregation of spawning areas was determined by studies of adult salmonids in the Rogue Basin (Everest 1973; Lichatowich 1976). Fish were trapped, seined or electrofished from streams throughout the Rogue Basin (Figure 1). The wild juvenile spring and fall chinook salmon were collected and frozen in May through July 1977. The wild juvenile summer and winter steelhead were collected March through July 1977. Special samples of wild juvenile summer and winter steelhead trout were collected for the total lipids and fatty acid analysis in February 1978 (Table 1).

Samples of eggs from summer and winter steelhead were incubated and reared under identical conditions at Cole Rivers Hatchery, Oregon to test the importance of genetics in determining potential differences in vertebral number and otolith characteristics. Adult summer and winter steelhead were identified by scale characteristics and time of entry into the hatchery.

Vertebral Number

Vertebrae, including the last three upturned centra, were counted on X-Ray photographs taken of the specimens. A random sample of 25% of the fish were counted again to check the accuracy of the first count.

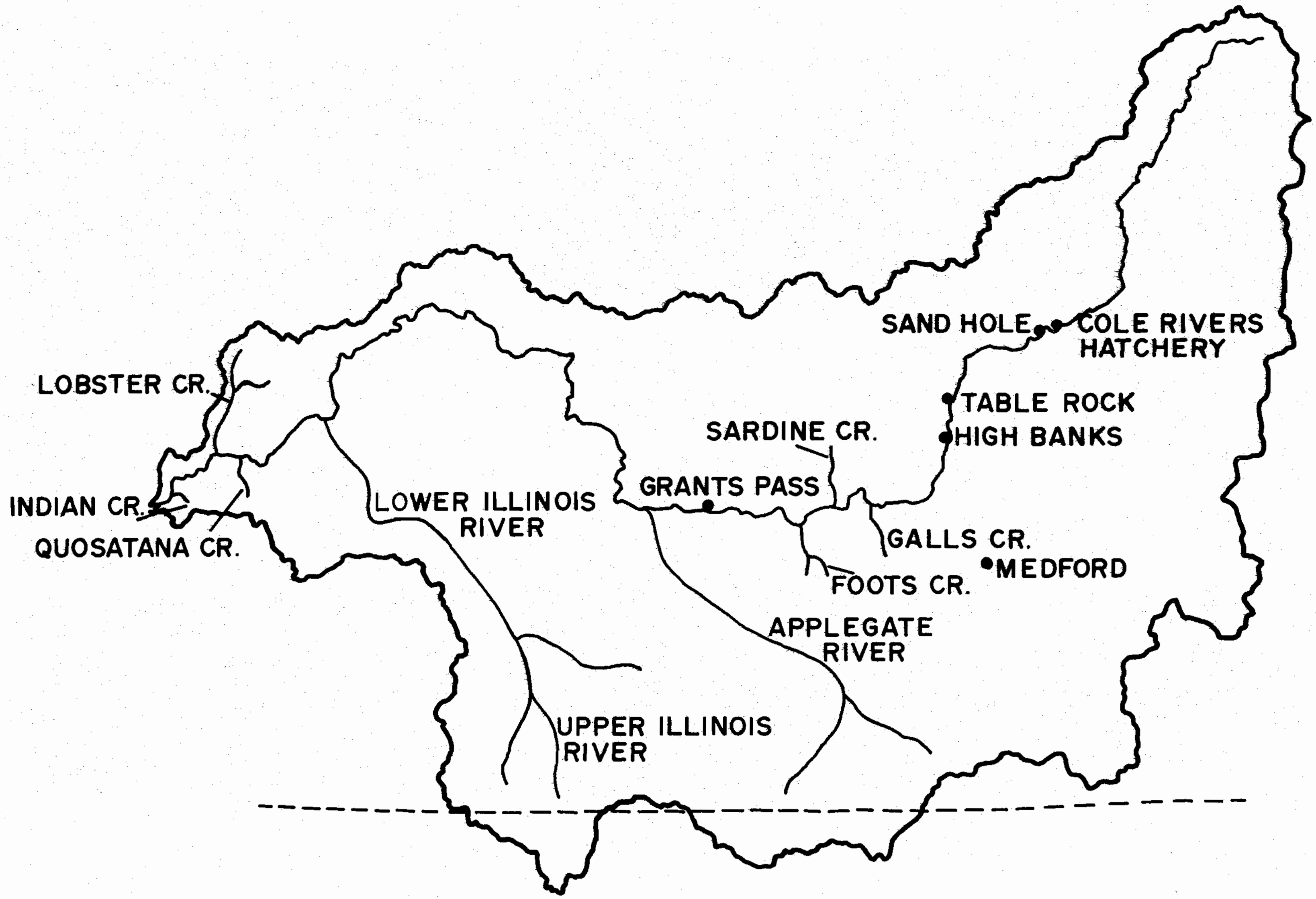

Figure 1. Sampling locations in the Rogue River basin.

Table 1. A summary of field collections sampled from the Rogue Basin.

Stock	Date	Collection Site	Method
Summer Steelhead	3/77	Galls Creek	Electrofished
	2/78	Galls Creek	Electrofished
	3/77	Sardine Creek	Electrofished
	3/77	Foots Creek	Electrofished
	2/78	Foots Creek	Electrofished
	4/78	Cole Rivers Hatchery	Seined
Winter Steelhead	7/77	Lower Illinois R.	Seined
	6/77	Lobster & Quosatana Cr.	Seined
	3/77	Upper Illinois R.	Electrofished
	2/78	Indian Creek	Electrofished
	4/78	Cole Rivers Hatchery	Seined
Spring Chinook	5/77	Sand Hole	Seined
	5/77	Table Rock	Trapped
	5/77	High Banks	Seined
Fall Chinook	5/77	Applegate R.	Seined
	6/77	Lobster Creek	Trapped
	7/77	Quosatana Creek	Seined

Mesentary Fat Deposition

Mesentary fat was dissected from the stomach and gut as described by Smith (1969) and then weighed.

Scale Characteristics

The largest unregenerated scales from each fish were mounted on a glass slide in a solution of 5% glycerine and 95% waterglass (sodium silicate). A cover slip was placed over the scales. All scales were read on a Bausch and Lomb scale projector which magnified the image 88 times. Measurements were taken in the anterior field at a 20° angle from the midline bissecting the length of the scale. Each scale was measured for nuclear radius, total scale radius, total circuli number, average intracircular spacing, and width of the first and second band of five circuli. The samples of steelhead trout included some older age classes of juveniles. Measurements of radius, circuli number and average spacing between annuli were made on scales from these fish. All scale characteristics were read on two scales from each fish and a mean was calculated.

The length at annulus formation was calculated for all 1+ or older steelhead using the Lee-Fraser method (Tesch 1971) given by

$$L_n = S_n/S\ (L-C) \quad +C$$

Where: L_n = fork length (cm) of fish at time n, L = fork length (cm) of fish when captured, S_n = scale radius at time n, S = total scale radius (mm) when captured, and C = length (cm) of fish when scale radius is equal to zero. The value of C is calculated from a least squares regression of scale radius on fork length.

Another technique used to back-calculate length at first annulus was to insert the measurement of scale radius to the first annulus into the scale radius vs. fork length regression generated for all the samples of a particular race.

Regressions of scale radius on length and circuli number on scale radius were compared between races using the full and reduced model comparisons described by Neder and Wasserman (1974).

Otolith Nuclear Radius

The otoliths collected from the juvenile salmonids were cleared and stored for approximately one week in a solution of 50% glycerine and 50% water prior to the first reading. Otoliths were read in a black porcelain watch glass under a microscope with a micrometer in the eyepiece. Light was reflected downward onto the otolith at a 45° angle (Kim and Koo 1963).

The metamorphic check of the nucleus was identified as a narrow black band near the center of the otolith, well within the first year's summer growth band (Figure 2). If two or more bands were present, the darkest was measured, and if both bands were equally dark, the narrowest band was measured. Both otoliths were read and a mean value was calculated for each fish. Approximately 25% of the samples were not clear enough to read. If the difference between readings of two otoliths from the same fish was greater than 25% of the mean value, the sample was considered not clear.

Total Lipids

Lipids were extracted with chloroform-methanol (2:1) as described

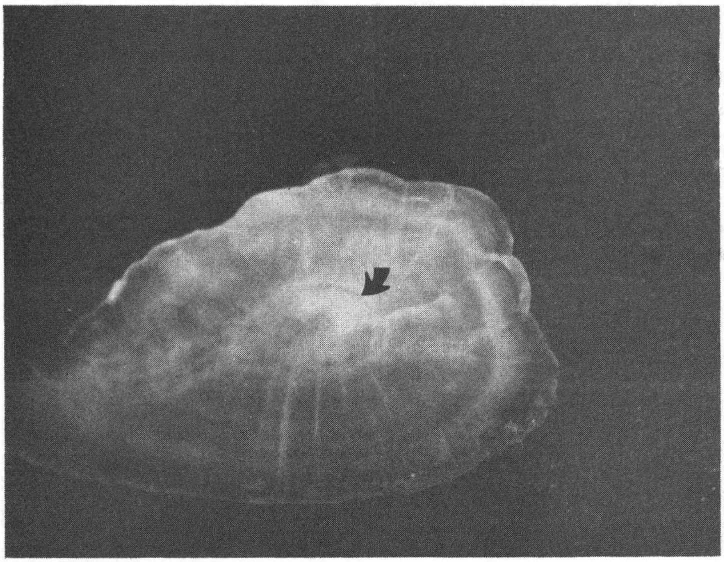

Figure 2. Steelhead trout otolith showing the metamorphic check enclosing the nuclear area (arrow).

by Bligh and Dyer (1959) from a 2 g sample of epaxial muscle from the anterior right side of eight juvenile summer steelhead and four juvenile winter steelhead trout. The total weight of the lipids was determined as the weight of the dried solvent phase.

Fatty Acid Composition

A portion of the lipid extract described above was methylated and a fraction of it injected into a Hewlett-Packard gas chromatograph using a hydrogen flame detector and a liquid phase of ethylene glycol succinate for analysis of the composition of fatty acids in the lipid sample from each fish. The oven temperature was 160 C and the helium carrier gas flow rate was 5 ml/min (Saddler et al. 1965, Lowry and Tinsely 1975).

Peaks on the chart paper represent different fatty acids and were compared using the retention time from the injection point as a standard reference for peak identification (Figure 3). The area under each peak is proportional to the amount of that particular fatty acid in the total sample. Since varying amounts of methylated lipid extract were injected for different fish, the peaks were analyzed as a relative percent of the total area for each fish. These relative percent values were pooled for all the summer steelhead and winter steelhead and the pooled samples were compared for differences.

Figure 3. Gas chromatogram of fatty acids from a steelhead trout.

RESULTS

Steelhead Trout

Vertebral Number

Wild juvenile summer steelhead trout had significantly ($p \leq .05$) fewer vertebrae than juvenile winter steelhead (Table 2). These differences were insufficient to allow separation of individual fish by race with 90% accuracy.

The juvenile summer and winter steelhead trout from Cole Rivers Hatchery that were incubated and reared under the same conditions showed no difference in vertebral number. The mean vertebral number was 63.2 and 63.3 for summer and winter steelhead trout, respectively.

Scale Characteristics

A regression analysis of the relationship of scale radius on fork length showed differences ($p \leq .001$) between juvenile summer and winter steelhead trout (Table 3). A similar analysis of the relationship between scale radius and circuli number showed differences ($p \leq .01$) between juvenile summer and winter steelhead trout (Table 4).

Juvenile summer steelhead trout also had a larger scale nucleus ($p \leq .01$) and a greater average intracircular spacing ($p \leq .001$) than juvenile winter steelhead trout (Table 2).

The size at first annulus formation, which was back-calculated using two different methods, showed that summer steelhead were significantly ($p \leq .001$) larger than juvenile winter steelhead (Table 5). None of the differences in scale characteristics was sufficient

Table 2. Selected taxonomic characteristics for juvenile summer and winter steelhead trout from the Rogue River.

Race	Collection site	Vertebrae Mean	Vertebrae Std. error	Vertebrae n	Total lipids (% of body weight) Mean	Total lipids Std. error	Total lipids n	Ratio of mesentary fat to body weight Mean	Ratio Std. error	Ratio n
Summer steelhead	Galls Creek	62.4	0.3	23						
	Sardine Creek	62.6	0.3	22						
	Foots Creek	63.4	0.1	22						
	Pooled[a]	62.8	0.2	67	1.67	0.27	8	0.027	0.008	69
Winter steelhead	Upper Illinois R.	63.2	0.2	22						
	Lower Illinois R.	63.5	0.2	21						
	Lobster and Quosatana Creek	63.0	0.2	22						
	Pooled[a]	63.2	0.1	65	2.06	0.43	3	0.149	0.363	69

[a] *Pooled samples represent all samples from a race pooled into a single comparison between races.*

Table 2 (continued)

Race	Collection site	Scale nucleus radius (mm x 88)			Scale radius to first annulus			Ave. spacing to first annulus		
		Mean	Std. error	n	Mean	Std. error	n	Mean	Std. error	n
Summer steelhead	Galls Creek	6.2	0.3	22	30.2	2.0	22	1.78	0.05	22
	Sardine Creek	6.2	0.3	22	33.1	1.5	22	1.74	0.04	22
	Foots Creek	5.9	0.3	22	34.7	1.7	22	1.71	0.03	22
	Pooled[a]	6.1	0.1	66	32.5	1.0	66	1.75	0.03	66
Winter steelhead	Upper Illinois R.	6.1	0.3	20	28.5	1.9	20	1.58	0.06	20
	Lower Illinois R.	5.6	0.2	23	32.8	2.0	23	1.69	0.04	23
	Lobster and Quosatana Creek	5.4	0.4	20	28.7	2.8	20	1.59	0.11	20
	Pooled[a]	5.7	0.2	63	30.0	1.2	63	1.63	0.03	63

[a]*Pooled samples represent all samples from a race pooled into a single comparison between races.*

Table 3. Regressions of scale radius (mm x 88) on fork length for juvenile summer and winter steelhead trout from the Rogue River.

Race	n	Regression equation	R^2	t	Significance level
Summer Steelhead	66	Length = 3.3683 + 0.1719 (radius)	0.836	18.041	$p \leq .001$
Winter Steelhead	62	Length = 1.1596 + 0.2053 (radius)	0.909	24.478	$p \leq .001$

Model	n	Error sums of squares	F	Significance level
Full[a]	128	157.998	9.108	$p \leq .001$
Reduced[a]	178	181.204		

[a]*The error sums of squares for the full model is the sum of the error sum of squares for both of the individual regressions. The error sum of squares, for the reduced model, is generated by pooling all data and calculating a pooled or "reduced" model.*

Table 4. Regressions of circuli number in scale radius (mm x 88) of juvenile summer and winter steelhead trout from the Rogue River.

Race	n	Regression equation	R^2	t	Significance level
Summer Steelhead	66	Circuli No.=3.0936 + 0.3929 (radius)	0.876	21.301	$p \leq .001$
Winter Steelhead	62	Circuli No.=0.5814 + 0.4714 (radius)	0.890	22.068	$p \leq .001$

Model	n	Error sums of squares	F	Significance level
Full[a]	128	802.344	6.454	$p \leq .001$
Reduced[a]	128	885.869		

[a]*The error sums of squares for the full model is the sum of the error sum of squares for both of the individual regressions. The error sum of squares, for the reduced model, is generated by pooling all data and calculating a pooled or "reduced" model.*

Table 5. Length of juvenile summer and winter steelhead trout at first annulus formation, back-calculated using the Lee-Fraser direct proportion method and a scale radius vs. fork length regression method (see text).

Race	n	Mean length (cm)	Standard error	t	Significance level
Lee-Fraser Method					
Summer Steelhead	65	8.95	0.19	6.52	$p \leq .001$
Winter Steelhead	39	7.50	0.22		
Regression Method					
Summer Steelhead	65	8.96	0.17	6.43	$p \leq .001$
Winter Steelhead	39	7.33	0.25		

to allow separation of individual fish by race with 90% accuracy.

Mesentary Fat Deposition

The amount of mesentary fat in juvenile steelhead was highly variable. Since the size of the steelhead varied widely due to the presence of older age class individuals, values for mesentary fat weight were expressed as milligrams of mesentary fat/gram of body weight. Winter steelhead had more fat on the average than did summer steelhead, but the variation was large (Table 2). Part of the high variation in values of mesentary fat was due to the difficulty in identifying and dissecting very small amounts of mesentary fat from small fish. In both summer and winter steelhead trout juveniles, the coefficient of variation was over 200% of the mean. The relationship of fat/body weight to condition factor showed a correlation coefficient of 0.14 and 0.12 for summer and winter steelhead trout, respectively (not significant at $p \leq .05$).

Otolith Nuclear Diameter

The diameter of the nucleus of the otoliths from juvenile summer and winter steelhead was measured three times because of inconsistency in identifying the metamorphic check enclosing the nucleus. Identification of the correct check became more difficult the longer the otoliths were allowed to clear in the glycerine-water solution. After the first reading, there appeared to be a clear difference ($p \leq .001$) between the juvenile summer and winter steelhead trout. In an effort to determine bias in interpretation, the collections were randomly subsampled and the otoliths were reread without knowledge of the race beforehand. The results were dramatically different from the first readings, so the subsample was read again by a different, experienced otolith reader without knowledge of race beforehand. In each of the "blind" readings, the difference between summer and winter steelhead trout was not statistically significant. This indicated a major problem in interpreting which check to call the metamorphic check and which one to measure. This problem increased as the otolith cleared with more time in the clearing solution.

Otoliths were measured from a sample of 25 summer and 25 winter steelhead trout juveniles incubated and reared under the same environmental conditions at Cole Rivers Hatchery. The mean diameter of the nucleus was 0.37 and 0.38 for summer and winter steelhead, respectively and did not differ significantly.

Total Lipids

No significant difference was observed in adjusted percent lipids in the muscle samples of the summer and winter steelhead trout juveniles (Table 6).

Fatty Acid Composition

There was no significant difference in mean relative percent of particular fatty acids between juvenile summer and winter steelhead trout (Table 7).

Table 6. Total muscle lipids from summer and winter steelhead trout from the Rogue River.

Race	Stream	km	n	Mean lipid composition (%)	Standard error	t
Summer						
Steelhead	Foots Cr.	182	4	1.65	0.28	
	Galls Cr.	190	4	1.69	0.27	
	(pooled)		8	1.67	0.18	
						0.90 (NS)
Winter						
Steelhead	Indian Cr.	1	3	2.06	0.43	

(NS) = not significant at $p \leq .05$.

Table 7. Relative amounts of 15 fatty acids in juvenile summer and winter steelhead trout from the Rogue River[a].

Peak No.	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
<u>Summer Steelhead</u>															
Mean relative percent	0.51	1.67	0.29	1.53	25.63	1.74	6.25	0.76	0.61	7.67	17.92	4.39	4.87	7.29	18.38
Standard error	0.19	0.24	0.06	0.31	1.37	0.35	1.37	0.08	0.09	0.37	1.94	0.43	0.58	0.93	2.06
n	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
<u>Winter Steelhead</u>															
Mean relative percent	0.85	1.87	0.20	1.45	24.20	1.56	6.51	0.56	0.71	7.73	21.82	5.78	5.61	6.42	14.92
Standard error	0.61	0.66	0.06	0.40	0.41	0.41	2.16	0.11	0.35	0.92	4.65	2.88	1.68	1.80	2.63
n	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4

[a]*All comparisons showed no significant differences at* $p \leq .05$ *between races.*

Chinook Salmon

Vertebral Number

Juvenile fall chinook salmon had significantly ($p \leq .01$) higher vertebral counts than spring chinook salmon juveniles (Table 8). These differences were not sufficient to allow separation of individual fish with 90% accuracy.

Scale Characteristics

The regression of scale radius on fork length for the chinook samples showed no significant difference between spring and fall chinook juveniles (Table 9). A similar comparison of regressions of scale radius on circuli number showed differences ($p \leq .001$) between the races of chinook salmon (Table 10).

There were also large differences in average intracircular spacing ($p \leq .01$) and the radius of the scale nucleus ($p \leq .05$) with spring chinook salmon larger in both respects than fall chinook salmon juveniles (Table 8). Juvenile spring chinook had significantly larger first and second bands of five intracircular spaces ($p \leq .001$ and $p \leq .05$ respectively) than juvenile fall chinook salmon (Table 8).

Mesentary Fat Deposition

The weights of mesentary fat dissected from the juvenile chinook salmon were highly variable (Table 8). The coefficient of variation for mean weight of mesentary fat ranged from approximately 150% to 300%. The fall chinook samples also included the Applegate River

Table 8. Selected taxonomic characteristics of juvenile spring and fall chinook salmon from the Rogue River.

Race	Collection site	Vertebrae Mean	Vertebrae Std. error	Vertebrae n	Otolith nuclear diameter Mean	Otolith nuclear diameter Std. error	Otolith nuclear diameter n	Mesentary fat (mg) Mean	Mesentary fat (mg) Std. error	Mesentary fat (mg) n
Spring Chinook	Sand Hole	68.3	0.2	22	0.62	0.01	16	0.52	0.42	23
	Table Rock	68.4	0.2	22	0.63	0.01	19	0.30	0.25	23
	High Banks	68.4	0.2	22	0.58	0.01	18	0.63	0.16	23
	Pooled[a]	68.4	0.1	66	0.61	0.01	53	0.48	0.17	69
Fall Chinook	Applegate R.	68.7	0.2	23	0.61	0.01	20	3.74	0.70	23
	Lobster Cr.	68.7	0.2	23	0.58	0.01	19	0.11	0.54	23
	Quosatana Cr.	69.0	0.2	23	0.59	0.01	19	0.24	0.10	23
	Pooled[a]	68.8	0.1	69	0.59	0.01	58	0.17	0.57	46[b]

[a]*Pooled samples represent all samples from a race pooled for a single comparison between races.*
[b]*Applegate sampled excluded (see text).*

Table 8. (continued)

Race	Collection site	Scale nuclear diameter			Ave. intr. spacing			1st band width			2nd band width		
		Mean	Std. error	n	Mean	Std. error	n	Mean	Std. error	n	Mean	Std. error	n
Spring chinook	Sand Hole	5.4	0.3	22	2.37	0.06	22	13.4	0.6	14	12.0	-	1
	Table Rock	6.5	0.3	22	2.42	0.10	22	13.1	0.5	22	10.6	0.4	15
	High Banks	6.3	0.2	22	2.53	0.05	22	14.3	0.4	23	11.1	0.5	12
	Pooled	6.2	0.2	66	2.44	0.05	66	13.6	0.3	59	10.8	0.3	28
Fall Chinook	Applegate R.	6.0	0.2	23	2.34	0.05	23	13.0	0.3	23	11.0	0.3	21
	Lobster Cr.	5.4	0.2	23	2.16	0.08	23	11.9	0.4	23	9.8	0.4	8
	Quosatana Cr.	5.9	0.2	23	2.03	0.06	23	11.3	0.3	23	9.6	0.5	23
	Pooled	5.8	0.1	69	2.17	0.04	69	12.0	0.2	69	10.2	0.2	52

[a] *Pooled samples represent all samples from a race pooled for a single comparison between races.*
[b] *Applegate sample excluded (see text).*

Table 9. Regressions of scale radius on fork length of juvenile spring and fall chinook salmon from the Rogue River.

Race	n	Regression equation	R^2	t	Significance level
Spring chinook salmon	63	Length (cm)=2.2262 + 0.18486 Scale radius(mm x 88)	0.7859	14.96	$p \leq .001$
Fall chinook salmon	69	Length (cm)= 2.9262 + 0.16094 Scale radius(mm x 88)	0.6117	10.27	$p \leq .001$

Model	n	Error sums of squares	F	Significance level
Full[a]	132	78.795	0.7448	NS = not significant at $p \leq .05$
Reduced[a]	132	79.712		

[a] *The error sums of squares for the full model is the sum of the error sums of squares for both of the individual regressions. The error sum of squares for the reduced model is generated by pooling all data and calculating a pooled or "reduced" model.*

Table 10. Regressions of scale radius on circuli number for juvenile spring and fall chinook from the Rogue River.

Race	n	Regression equation	R^2	t	Significance level
Spring chinook salmon	63	radius (mm x 88) = 5.0759 + 2.5648 (circuli number)	0.7651	14.096	$p \leq .001$
Fall chinook salmon	69	radius (mm x 88) = 9.8254 + 1.8206 (circuli number)	0.6688	11.633	$p \leq .001$

Model	n	Error sum of squares	F	Significance level
Full[a]	132	173.337	13.542	$p \leq .001$
Reduced[a]	132	210.012		

[a]*The error sum of squares for the full model is the sum of the error sum of squares for the two individual regressions. The error sum of squares for the reduced model is generated by pooling all data and calculating a pooled or "reduced" model.*

samples which were seined from the stream and reared for a short period at Cole Rivers Hatchery. The influence of the hatchery rearing caused the mesentary fat amounts to be 15 times larger than the next largest values for wild fall chinook salmon juveniles. This indicates that differences in food supply can quickly and drastically affect the mesentary fat amounts, regardless of race.

Mesentary fat was poorly correlated to condition factor, with a correlation coefficient of 0.14 and 0.05 for fall and spring chinook respectively.

Otolith Nuclear Diameter

The nucleus of the otoliths of chinook salmon juveniles was easily identified and measured. Unlike the steelhead trout samples, there was little problem with interpretation and measurements did not change with additional readings. The coefficient of variation was 6.7% and 7.1% for spring and fall chinook salmon juveniles, respectively. There were significant ($p \leq .05$) differences between spring and fall chinook juveniles, but these differences were insufficient to allow separation of individual fish by race with 90% accuracy (Table 8).

DISCUSSION

Wild juvenile summer steelhead trout had fewer vertebra, a larger scale nucleus, greater average intracircular spacing on scales, and a larger size at first annulus formation than juvenile winter steelhead trout. The differences in the number of vertebrae were not seen in juvenile summer and winter steelhead trout which were incubated and reared under the same conditions at Cole Rivers Hatchery, indicating that differences noted in the field samples were primarily due to environmental effects.

There were also differences between juvenile spring and fall chinook salmon from the Rogue Basin. Fall chinook exhibited higher vertebral number, smaller otolith nuclear diameter, lower average spacing on scales, smaller scale nuclei and smaller first and second band widths than juvenile spring chinook salmon.

The differences in most of the scale characteristics between the races of salmon and trout were probably due to differences in growth in the first year of life (Reimers 1973). Summer steelhead emerge from the gravel earlier than winter steelhead trout (Everest 1973). In addition, summer steelhead trout rear in the main stem of the Rogue and some of the low elevation tributaries, while winter steelhead trout rear for most of their first year in less productive headwater streams (Rivers 1963; Everest 1973).

Spring chinook salmon emerge earlier than fall chinook salmon and usually show superior growth during the early months of freshwater rearing (Cramer, unpublished data). Differences between races in growth are subject to environmental variability and are not considered to be extremely stable between years, indicating that scale characteristics would be less consistently useful to the manager in separating juvenile salmonids by race than other characteristics under less environmental control.

Mesentary fat was not a useful character for separating wild juvenile salmonids from the Rogue River Basin by race. Amounts of mesentary fat varied greatly between fish from the same stream. This is probably due to the variability in food availability and social position of the particular fish. Smith (1969) used this characteristic to separate juvenile summer and winter steelhead trout that had been reared together in a hatchery. The hatchery feeding situation probably allowed the accumulation of much greater amounts of mesentary fat than fish could accumulate in the wild. This is also indicated by the much greater amount of mesentary fat accumulated by the Applegate River chinook salmon juveniles during their short period of rearing at Cole Rivers Hatchery compared to the other wild chinook juveniles, regardless of race.

Differences in otolith nuclear diameter between races of salmon and steelhead in the Rogue Basin were minor or nonexistant. In no case could individual fish be separated with 90% accuracy using this character. Otolith nuclear diameter as described by McKern, Horton and Koski (1974) was distributed in a widely separated bimodal distribution which allowed them to separate adult summer and winter steelhead trout with 90% accuracy. They hypothesized that this differences was due to differences in egg size which was a genetic trait of the races throughout the Pacific Northwest, but these differences were not found in samples from the Rogue River basin. McKern and Horton make no mention of multiple checks in the nuclear area, causing problems with interpretation. Part of the discrepancy may be because they used otoliths from adult steelhead while all of my samples were from juveniles. Otoliths from juveniles clear much more rapidly, and as they cleared, additional checks began to appear in the nuclear area of the otolith. Another possibility is that Rogue steelhead are more variable in size than most stocks from the Pacific Northwest and may have a greater variability in egg size causing variability in otolith nuclear diameter. This possibility does not account for the multiple checks in the nuclear area.

As mentioned earlier, the usefulness of differences between races in taxonomic characters to the fishery manager depends on the magnitude of the differences, which determine how accurately individual fish can be identified by race, and the genetic basis for these differences.

The goal of separation of individual fish with 90% accuracy can be achieved if a characteristic differs between races such that the 90% confidence intervals for individual observations (mean $\pm$ "t" standard deviations) do not overlap. No characteristic or combination of characteristics studied were distributed in this manner in the chinook salmon or steelhead trout from the Rogue River basin.

Differences in taxonomic characters may indicate genetic isolation of races and may be a response to genetic drift or directional natural selection (Ricker 1969; Smith 1969). Races of salmonids in the Rogue basin seem to segregate in spawning areas and to some extent in rearing areas, thus differences could be caused by different environmental conditions in the early life history. This hypothesis was suggested by the lack of differences in vertebral number in the summer and winter steelhead trout juveniles incubated and reared together at Cole Rivers Hatchery. In a similar experiment, Smith (1969) showed differences between summer and winter steelhead trout from the Capilano River, British Columbia. He concluded that these differences indicated genetic isolation of the races of steelhead trout. Because my samples were collected from different segregated spawning areas of adult salmonids, I was not able to determine if the differences in characteristics were the effect of genetics, environment or both.

The genetic isolation of races of chinook salmon and steelhead trout in the Rogue basin may be a response to differences in spawning timing and habitat or area (Rivers 1963; Everest 1973; Lichatowich 1976). Isolating mechanisms break down and interbreeding between races occurs in years of environmental extremes. In 1977, for example, a draught caused summer steelhead trout to spawn in the main stem of the Rogue River and larger tributaries that are usually only used by winter steelhead trout. Warmer water temperatures in the fall of 1977 caused adult fall chinook salmon to migrate higher in the Rogue system than usual and it is probable that they interbred more with spring chinook salmon than usual.

The Rogue River is characteristically highly variable in flow and temperature during the spawning seasons of chinook salmon and steelhead trout, and it is likely that a considerable amount of interbreeding between races occurs in many years. This interbreeding may contribute to a large amount of diversity and variation, which may be why investigators have been unable to separate the races of steelhead trout or chinook salmon from the Rogue on the basis of isoenzyme patterns (Oregon Cooperative Fishery Research Unit, 1977). In a stream system like the Rogue, with the possibility of extensive racial interbreeding and highly variable environmental conditions, it is not surprising that morphological and life history characteristics of juvenile salmonids are highly variable and differences between races are not distinct.

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