AN ABSTRACT OF THE THESIS OF

DONALD EUGENE BENNETT for the MASTER OF SCIENCE
(Name) (Degree)

in FISHERIES presented on December 8, 1970
(Major) (Date)

Title: BIOLOGY OF THE REDTAIL SURFPERCH (Amphistichus rhodoterus)

Abstract approved: Redacted for Privacy
Dr. Raymond C. Simon

Data on the life history of the redtail surfperch (Amphistichus rhodoterus) from the central coast of Oregon were collected from April, 1967 to April, 1969. The scale method of age determination proved satisfactory for surfperch from age groups 0 to IX. Annulus formation occurred between February and June and was influenced by size and age of the fish. Smaller and younger fish had new growth on the scale margin earlier than larger and older fish. The largest surfperch captured measured 375 mm in total length, while the heaviest fish was 1, 125 g. Females older than those in age group II grew faster than males of similar age. Lee's phenomenon of apparent change in growth rate was not observed in redtail surfperch. Mating occurred during late December and early January, and spawning occurred during July through September. The reproductive cycles coincided for two consecutive years. Linear regressions were calculated that

describe the relationship between female size and fecundity. The growth of embryos was followed throughout the gestation period. Mean size of embryos was positively correlated with the size of the female. An embryonic mortality of 1.25 percent was estimated. Males first matured in age groups II and III while females first matured in age groups III and IV. Sex ratios appeared to be 1:1. The food items of redtail surfperch from the surf zone consisted of crustaceans, fish, molluscs, and polychaetes, in that order of importance. Crustaceans were the most important food item in both frequency of occurrence and total volume. Parasites of redtail surfperch were: immature nematodes (Anisakinae), the digenetic trematode, *Genitocotyle acirra*, the monogenetic trematode, *Diclidophora* sp., and copepods (*Caligus* sp., *Clavella* sp., and *Argulus catastomi*).

Biology of the Redtail Surfperch
(*Amphistichus rhodoterus*)

by

Donald Eugene Bennett

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

June 1971

APPROVED:

Redacted for Privacy

Professor of Fisheries
in charge of major

Redacted for Privacy

Acting Head of Department of Fisheries and Wildlife

Redacted for Privacy

Dean of Graduate School

Date thesis is presented December 8, 1970

Typed by Opal Grossnicklaus for Donald Eugene Bennett

ACKNOWLEDGEMENT

I wish to thank Dr. Richard S. Wydoski, who suggested the research problem, for his guidance during the study as well as his advice during the preparation of the thesis. The Oregon Cooperative Fishery Unit and the Tiburon Marine Laboratory of the Bureau of Sport Fisheries and Wildlife provided the financial support of the research. Cooperating agencies of the fishery unit include the Bureau of Sport Fisheries and Wildlife, the Oregon State Game Commission, the Fish Commission of Oregon, and the Department of Fisheries and Wildlife at Oregon State University. I would like to thank Dr. Raymond C. Simon, my major professor, who kindly gave his time. Mr. David V. Buchanan, Mr. A. Warren Hansen, Mr. William F. Hunter, and Mr. Dennis C. Wilson aided in the collection of specimens. Dr. Robert E. Olson helped identify food items and parasites; Dr. Raymond E. Millemann aided in identification of parasites.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

BIOLOGY OF THE REDTAIL SURFPERCH
(*Amphistichus rhodoterus*)

INTRODUCTION

This study of the redtail surfperch, *Amphistichus rhodoterus* (Agassiz), was undertaken with the aim of furnishing life history information which could assist conservation agencies in the formulation of sound management decisions with regard to this marine viviparous sport species. The main objectives were to determine age and growth by sex, length-weight relationships, relation between age and size to sexual maturity, fecundity, food habits, and parasites of the species.

Life history information concerning the redtail surfperch is sparse (Miller, 1960). The published literature on the redtail has been limited to taxonomy, distribution, description, formation of keys and encounters with individual specimens. Barnhart (1936), Eigenmann and Ulrey (1894), Roedel (1948), Schultz (1936), and Walford (1931) constructed keys that distinguish the redtail surfperch from other viviparous perches. Girard (1854) supplied information on reproduction of the species. He examined one redtail surfperch which had 16 young in her ovary. Several other authors (Jordan, 1885; Jordan and Evermann, 1896; and Jordan, Evermann and Clark, 1930) included the redtail perch in catalogues of fishes known to inhabit the waters of North America.

The redtail surfperch is one of the largest size surf dwelling members of the family Embiotocidae in the sport fishery along the coast of northern California, Oregon, and Washington. This species ranges from Monterey Bay, California, to Vancouver Island, British Columbia (Clemens and Wilby, 1961; Tarp, 1952). It is commonly caught by sport fishermen along rocky outcroppings, jetties, sandy beaches, and, during the period of April through September, in bays.

The field work was conducted between April 1967, and April 1969, at the Oregon State University Marine Science Center, located at Newport, Oregon.

This research was supported by the Oregon Cooperative Fishery Unit and the Tiburon Marine Laboratory, Bureau of Sport Fisheries and Wildlife, Belvedere-Tuburon, California. Cooperating agencies of the Unit include the Bureau of Sport Fisheries and Wildlife, the Oregon State Game Commission, the Fish Commission of Oregon, and the Department of Fisheries and Wildlife at Oregon State University.

METHODS

Description of Area Studied

The area in which this study was conducted included Alsea and Yaquina Bays and the connecting surf zone along approximately 14 miles of the central coast of Oregon in Lincoln County. This section of coastline consisted mostly of sandy beaches except for one large rocky outcropping at Seal Rock, which was approximately one-half the distance between the mouths of Alsea and Yaquina Bays (Figure 1). I divided the area into the estuary zone and the surf zone for convenience of comparison and discussion.

Collection of Specimens

Sampling Schedule

Initially, my plan was to sample redtail surfperch in the surf zone near Yaquina Bay bi-monthly with equal effort throughout a two year period. However stormy weather and rough surf conditions reduced the success of sampling during the fall and winter months and caused the frequency of sampling to vary from once a month to as many as six times a month.

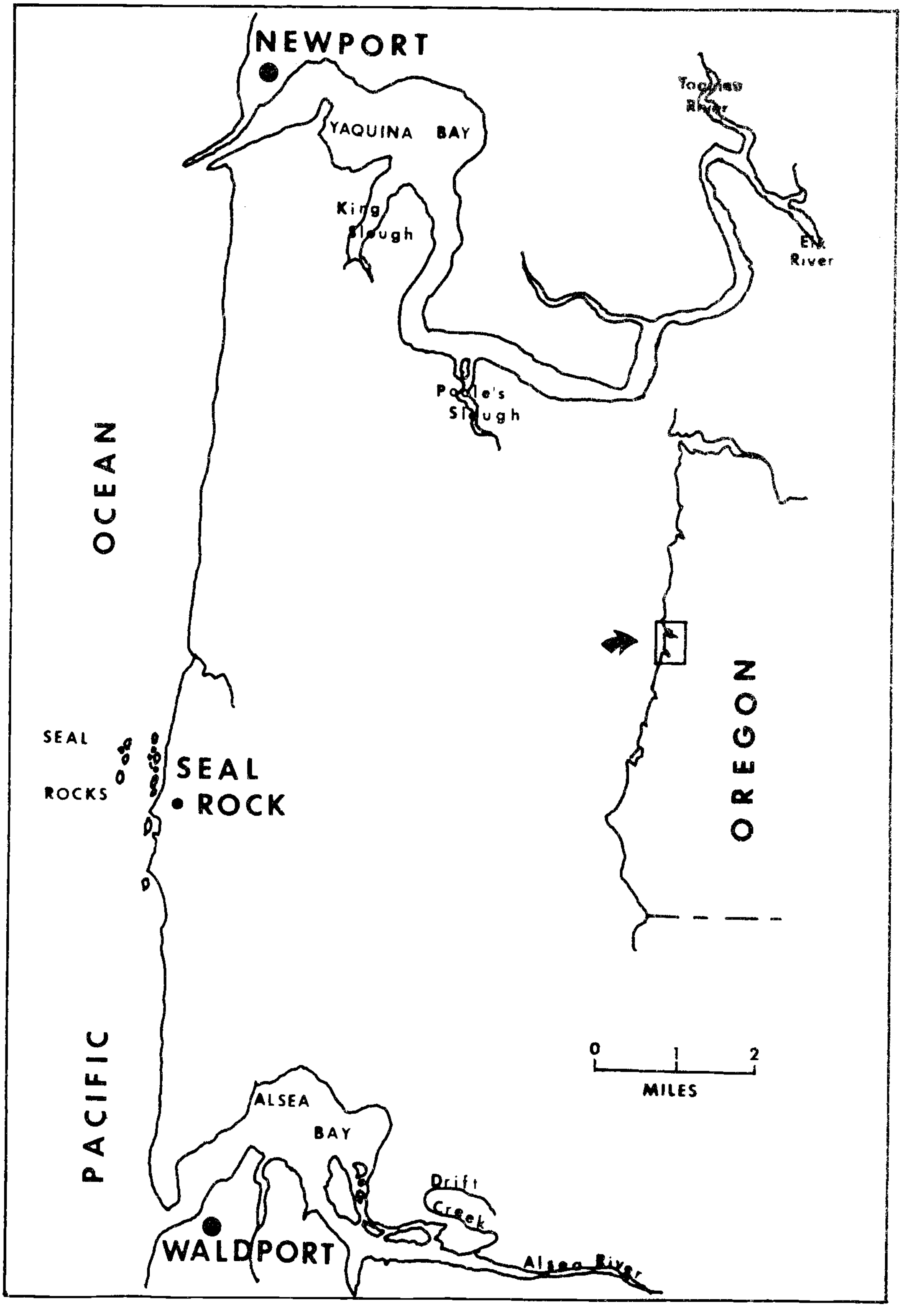

Figure 1. Map showing study area along the central Oregon Coast.

Sampling Gear

Fish were captured by gill net, otter trawl, and hook and line. The use of gill nets was restricted to the bay areas during summer months when perch were abundant. Two 100-foot monofilament nylon gill nets were used. Both nets were six feet deep and contained four panels with one having stretched mesh sizes of 2, 3, 4, 5 inches, and the other 1.5, 2.5, 3.5, 4.5. These nets were difficult to set in rough water, and often were clogged with debris during strong tidal currents. However the gill nets produced more fish per-unit-of-effort than any other method and caught all sizes. The monofilament gill nets were always fished on the bottom perpendicular to the shoreline in 6 to 40 feet of water. Because of damage to specimens caused by Dungeness crab (Cancer magister), the nets were fished only for 10 to 15 minute intervals.

The otter trawl was used mainly during the late summer and early fall months in an attempt to capture young-of-the-year. Known as a shrimp try-net, the trawl had a 16-foot headrope. It was towed at about 2 to 3 knots behind a 16-foot runabout powered by an 18 HP outboard motor. Although large numbers of other embiotocids were taken with this gear, only a few young-of-the-year redtails were captured.

Because of rough water, the only gear that worked well in the surf during the entire two year period was hook and line. This gear consisted of one to two dropper hooks above a 2 to 3-ounce sinker attached to monofilament line. The most successful bait used in the estuary was the ghost shrimp (Callianassa californiensis), while in the surf the orange mantle of the sea mussel (Mytilus californianus) caught the most fish. Both of these baits were fished on the bottom and proved to be a reliable method for catching perch of age group II and above. Female surfperch did not abort embryos when taken by hook and line unless they were near term or had begun to suffocate after removal from water. Individual females were placed in separate plastic sacks to assure keeping the embryos with each fish.

Data Collected from Specimens

All fish were examined within two hours after capture. Thus all measurements were taken from fresh fish. The following data were recorded for each specimen: location and date of capture; fork length and total length in mm; weight to the nearest gram; sex; stage of maturity; type of collecting gear used; and the collector's name. Later the following additional data were added: Standard length in mm; weight of the testes to a hundredth of a gram; whether or not the stomach and ovary or embryos were saved; and the number and species of parasites found on each fish. Also, otoliths were taken from fish of selected sizes to substantiate age determined from scale readings.

Age and Growth

Age Determinations

A scale sample from each fish was taken from an area about four scale rows below the lateral line on an oblique from the origin of the dorsal fin. Impressions of these scales were made on 3 x 5-inch acetate cards. These impressions were produced by a hydraulic scale press at a pressure of 6, 700 psi at 100 C for approximately five minutes. The scale impressions were then read and measured on the screen of an Eberbach scale projector. The scales were read three times, twice by the author and once by another reader. To aid in interpreting scale features, otoliths from 108 redtail surfperch were examined. Following the technique of Hile (1948), fish were placed in the next higher age group after January 1.

Back-Calculations of Lengths at Previous Ages

Back-calculations were made on a computer with a program described by Reed (1968). Since samples were taken every month, growth would vary in individual fish. Back-calculation analyses provides estimates of the fish size at the end of each season of growth.

Length-Weight Relationship

The length-weight relationship for redtail surfperch was calculated from total lengths in millimeters and body weights in grams in the form $W = aL^b$ where W = weight, L = length, a = constant, and b = constant.

Condition

The condition factor for 333 male and 450 female redtail surfperch was determined by a computer program (Reed, 1968). Ages were determined for all fish and the average "K" values were determined for each sex by month of the year. Comparisons were made between the age groups and the month of year collected. Mean condition factors were calculated by applying the equation $K = 100{,}000 \times W/L^3$, where L = total length in mm and W = weight in grams.

Reproduction

Sex Ratios

The sexes were determined externally by the differences in the anal fins in the two sexes and verified internally by dissection. The anterior lobe of the anal fin becomes modified into a bulbous genital organ in maturing males. The bilobed appearance is easily recognized in males larger than 160 mm total length. This characteristic, however, was not reliable for yearlings or young-of-the-year (less than 160 mm total length). This method was accurate in separating sexes throughout the entire year.

Sexual Maturity

Male surfperch mature in winter and females give birth during the summer. Macroscopic examination of the gonads at other times was not a reliable indicator of state of maturity. Therefore, collections made in April, May, June, July, and August were analyzed to determine the relationship of size and age to sexual maturity in female redtail surfperch, while collections made in October, November, December, January, and February were used to determine the relationship of size and age to sexual maturity in the males.

Maturity Index for Males

An increase in testes weight preceding the mating season occurs in maturing males; immature males do not undergo a substantial seasonal change in gonad size during this time. Larimore (1957) and Wares (1968) used a maturity index to follow the seasonal development of the testes. Because of their size and firmness, testes of redtail surfperch were easy to remove in their entirety. Testes were weighed to the nearest one hundredth of a gram. The maturity index or degree of development was determined by applying the following formula: Testes weight (g) × 100/fish weight (g).

Fecundity

Fecundity was analyzed by removal and dissection of the ovary. The horns were snipped with scissors and then by sliding the fingers under the body of the sac-like enlargement, it was simply pulled toward the vent until free. Embryos were separated from the ovarian folds as the ovary was placed in ten percent buffered formalin.

Fecundity was determined by direct count of embryos. A few females contained from one to several embryos that were much smaller than the majority. These were included with the malformed embryos because it was felt that their fate was death. The normal embryos were measured to the nearest millimeter of standard length (tip of snout to hypural plate). The hypural plate was easily located because a heavily pigmented spot marked its location. In very small transparent embryos, the hypural plate was easily seen using a dissecting microscope and the standard length was measured by use of an ocular micrometer. All embryos were weighed to the nearest hundredth of a gram after they were blotted dry with paper towels. The shape of embryo tails was recorded as round, square, or forked for individual females. Females containing embryos with forked tails were excluded from fecundity analysis because these embryos were nearing term and had a greater possibility of being aborted. Other females that contained less developed embryos appeared to retain their embryo complement rather well.

Standard regression analysis was used to determine the relationship of female size to number of embryos. The growth of embryos was followed throughout the gestation period.

Food Habits Study

Food habits of the redtail surfperch were studied in the two habitats, surf and estuary. Analyses were made volumetrically and by frequency of occurrence of each food item. Results were grouped by month of collection and by size of fish. The embiotocid digestive tract is not clearly divided into a stomach and intestine by a pyloric valve. The "stomach" in this study was defined as that portion of the alimentary canal between the opening of the esophagus and the apex of the first bend in the canal, following Gordon (1965) and Wares (1968).

Food samples were obtained by clamping the two ends of the stomach, excising it and injecting several ml of fixative into the stomach to stop enzymatic action. Stomachs were preserved in a fixative comprised of 40 ml of stock formalin per liter of 50 percent isopropyl alcohol (Gotshall et al., 1965). The stomachs remained in the fixative until examination. Due to the time it took for taking data from individual fish, stomachs were removed only from fish of selected sizes.

For examination, the stomach was slit and the contents were placed in a shallow dish. The food items and fragments were then sorted under a binocular microscope and identified as specifically as possible. However, identification to taxa differed for various food items because the extent of digestion varied in different samples. After each food item was identified, its volume was measured to the nearest 0.1 ml.

In addition to determining the volume of each food item, the frequency of occurrence of each item was determined. This value is reported as the percentage of the stomachs examined that contained a particular food item.

Comparisons of food items by month and size of fish were based on the percent of total volume and the percent of frequency of occurrence.

Parasite Study

Fish of all ages and of both sexes were examined for parasites shortly after they had been killed. The examination consisted of a routine dissection in which all of the organs, the cavities, the gills, and the digestive tract were closely inspected. This procedure was modified later in the study to include only the gills, gill arches, fins, skin, and intestine since these areas contained most of the parasites.

Parasites were killed, fixed, and prepared for identification by the methods of Millemann (1967) and those recommended by personal communication with Dr. Ivan Pratt, Department of Zoology at Oregon State University. I used the statistic "infestation rate" to define the number of parasites divided by the number of fish examined (Wares, 1968).

RESULTS

Age and Growth

Conversion of TL Measurements to SL and FL

Regression equations were computed using a linear regression analysis program (Table 1). These calculations were made from total lengths that were grouped into one centimeter intervals. The standard length equation was derived from data on 178 female and 154 male redtail surfperch ranging in size from 77 to 366 mm total length. The fork length equation was derived from data on 450 female and 333 male redtail surfperch ranging in size from 77 to 375 mm total length. The calculated equations allow conversions to any of the accepted measurements for reason of comparison.

Table 1. Regression equations to convert total length (TL) into standard length (SL) or forked length (FL) for redtail surfperch collected from the central coast of Oregon.

Conversion	Regression Equation	Correlation Coefficient	N
TL to SL	SL = 0.81 TL - 5.29	0.9993	25
TL to FL	FL = 0.95 TL - 5.09	0.9992	29

Adequacy of Scales for Age Determination

Consistency tests were conducted to determine the adequacy of scales for age determination. I (Reader I) studied the scale impressions from 776 redtail surfperch and assigned ages twice, while a second reader (Reader II) studied the same scale impressions once. My first reading agreed with Reader II 77.6 percent of the time or 602 out of 776 observations. However, my second reading agreed 85.9 percent or 667 out of 776 times with reader II (Table 2). I studied the scale impressions and made the final age determination where disagreement occurred between the two readings.

Comparison of Age Determination Between Scales and Otoliths

Otoliths were collected from 108 fish selected from age group zero to age group eight (77-339 mm TL).

Ages determined from scale impressions were compared with ages determined from otoliths (Table 3). The final age determinations from scales agreed 96 percent (102 of 108) of the time with age determinations from otoliths. Other age determinations from various readings of scales and from readings of otoliths resulted in agreements between 91 and 97 percent.

Table 2. Comparison of age determinations in redtail surfperch from the second reading by scale Reader I compared with the first reading by scale Reader II.

Ages from First Reading by Scale Reader II	Ages from Second Reading by Scale Reader I: 0	I	II	III	IV	V	VI	VII	VIII	IX
0	2									
I		72								
II		21	133	11						
III			12	181	14					
IV				14	115	8				
V					8	78	5			
VI						6	52	4		
VII						1	1	25	3	1
VIII									8	
IX										1

Table 3. Comparison of the final age determination from scales with ages from otoliths in redtail surfperch.

Final Age Determinations from Scales by Scale Reader I

Ages from Otoliths by Scale Reader I	0	I	II	III	IV	V	VI	VII	VIII	IX
0	1									
I		17								
II			24							
III			1	17	1					
IV					16	1				
V						17				
VI							5			
VII								4		
VIII									1	
IX									1	

Adequacy of Scales for Length Determination

Three primary conditions must be satisfied for accuracy in length determination by the scale method. These conditions are taken from a critique on the scale method by Van Oosten (1929). The three conditions are: (1) The number and identity of scales must remain constant throughout the life of the fish; (2) The increase in scale size must be proportional to the increase in body length; and (3) Yearly check marks or annuli are formed once at approximately the same time each year.

Scale Counts. To satisfy condition one of the scale method, three different counts of scales were made on young and adult red-tails. These three counts were: (1) Along the lateral line; (2) From the origin of the dorsal fin to the lateral line; and (3) From the origin of the anal fin to the lateral line. Also the focal areas of scales from young and adults were compared.

The counts of scales for all fish examined were essentially equal. The nuclear area or focus of scales from young fish were structurally identical with scales of adult fish. Also all regenerated scales had a characteristically disrupted center portion and were easily distinguishable from nonregenerated scales.

Body-Scale Relationship. Scale measurements were taken along the anterio-lateral radius because the annuli were clearly seen on this axis and more precise measurement was possible. Data for a body-scale relationship were taken from 773 surfperch collected from April, 1967 to April, 1969.

The regression equation obtained was $y = 0.44x - 12.42$ with a correlation coefficient of 0.952 (Figure 2). This relationship satisfies condition two of the scale method. The apparent fish length at the time of initiation of scale development is the x-intercept or 28 mm TL (17 mm SL). This value was used for the correction factor ("a value") for back-calculations in the program described by Reed (1968).

Time of Annulus Formation. The scale structure of the redtail surfperch is similar to that described for other embiotocids. The birthmark or "metamorphic annulus" described by Hubbs (1921) and reported by Carlisle *et al.* (1960), Gordon (1965), Swedberg (1965), Wares (1968), and Anderson and Bryan (1970) was present on the scales of both male and female redtails. This check was very clear in some fish and almost lacking in others.

The doubling of annuli or spawning checks also reported by the above authors were observed on the scales of female redtail surfperch. The first three spawning checks were clear, while subsequent spawning checks were not. Perhaps this phenomenon can be explained by the fact that spawning checks after the fifth year of life were incorporated with the true annuli. Alternately it is possible that spawning checks are not formed by older females. The spawning checks were quite similar in their appearance to true annuli, but were less distinct and

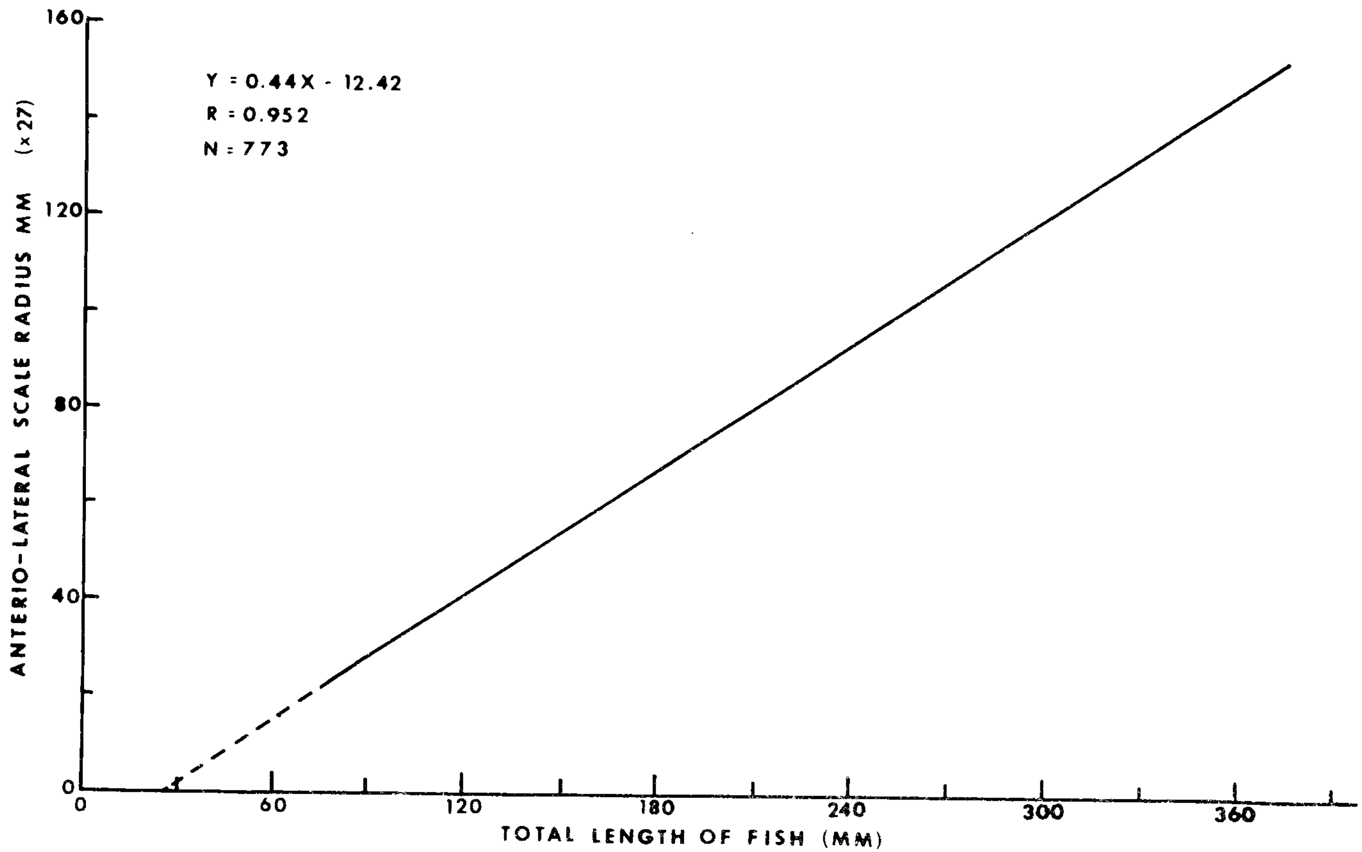

Figure 2. Body-Scale relationship calculated from 773 redtail surfperch captured along the Oregon coast from April, 1967 to April, 1969.

without the feature of "cutting over." Thus the physical features of each check were used to distinguish among various checks on the scales. Not all fish showed birth or spawning checks. Gordon (1965) reported these checks were absent in some specimens of Cymatogaster aggregata. When determining age, care was taken not to include the metamorphic annuli or the spawning checks as year marks. Some scales were difficult to interpret and required careful examination. Male surfperch did not show any checks that were associated with maturation because they matured during the winter when growth for that season had ceased.

Examination of scales collected during the entire year revealed the time of annulus formation was from February to June (Figure 3). The time of annulus formation was, however, influenced by size and age with the smallest and youngest fish forming annuli in February and the larger and older fish forming annuli later in May and June (Table 4). Mr. Robert Mausolf of Peninsula College (personal communication) has observed this relationship for redtail surfperch in the Port Angeles area of the state of Washington.

In determining the influence of size and age on new scale growth, only those samples taken during January through June were examined. All of age group I fish (110 to 179 mm TL) had new scale growth for the period. By the end of April all of age group II fish (170 to 219 mm TL) and age group V fish (240 to 319 mm TL) had new scale growth.

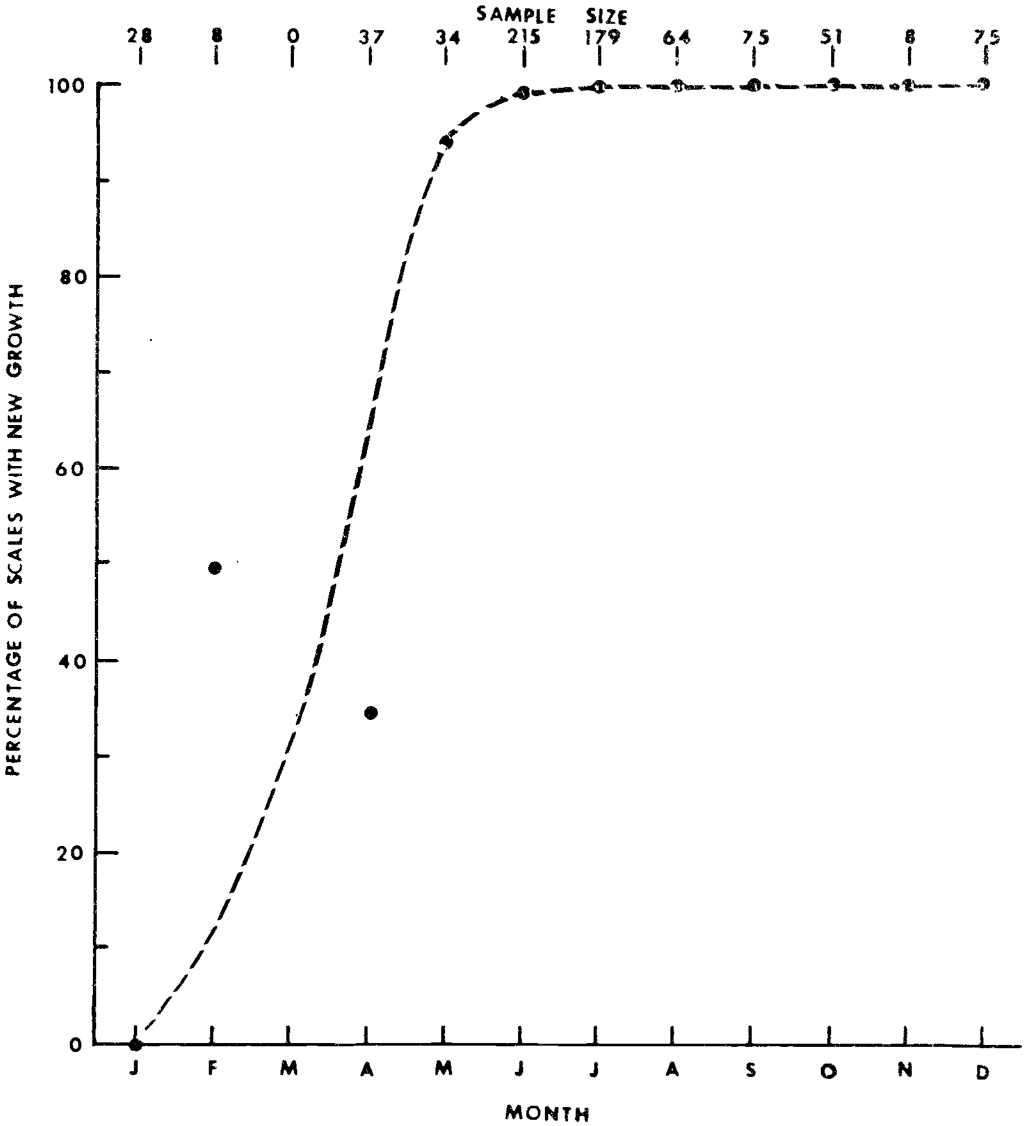

Figure 3. Percentage of redtail surfperch with new growth on scale margin by month. Data from all age groups are combined. Line from January to April drawn by inspection based on sample size.

Table 4. Percentage of redtail surfperch with new growth on the scale margin by month.

Age Group	Number of Fish						Percentage of Fish With Recognizable Annuli					
	Jan.	Feb.	Mar.	Apr.	May	June	Jan.	Feb.	Mar.	April	May	June
I	-	1	-	-	1	4	-	100.0	-	-	100.0	100.0
II	8	3	-	18	3	54	0.0	66.7	-	22.2	100.0	100.0
III	4	2	-	7	3	53	0.0	0.0	-	42.9	100.0	96.2
IV	3	1	-	9	13	48	0.0	0.0	-	44.4	92.3	100.0
V	2	-	-	2	9	25	0.0	-	-	100.0	100.0	100.0
VI	6	1	-	1	4	17	0.0	100.0	-	0.0	75.0	100.0
VII	4	-	-	-	1	14	0.0	-	-	-	100.0	100.0
VIII	1	-	-	-	-	-	0.0	-	-	-	-	-
Total	28	8	-	37	34	215	0.0	50.0	-	35.1	94.1	99.5

But it was not until after June that 100 percent of age group III (180 to 279 mm TL), age group IV (200 to 299 mm TL), age group VI (260 to 339 mm TL), age group VII (270 to 379 mm TL), and age group VIII (290 to 299 mm TL) had new scale growth. When broken down by percentage for each month, 35.1 percent of the fish had new growth by the end of April; 94.1 percent had new growth by the end of May; and 99.5 percent had new growth by the end of June (Table 4).

These data satisfy condition three of the scale method since annuli were formed only once and at approximately the same time each year. Further evidence to support this condition was the good correlation of the number of rings on otoliths to the checks on scales (Table 3).

Back-Calculation of Lengths at Various Ages

The mean back-calculated and empirical mean total lengths for males and females were similar up to age group II. However, the mean back-calculated total lengths for females of age III and older were greater than for males of corresponding ages. The means between the sexes increased with age (Table 5).

Lee's phenomenon (Ricker, 1958) of apparent change of growth rate was not observed in redtail surfperch (Table 5). This may be explained in part by the low fishing pressure. Intensive angling would no doubt bring about a greater exploitation of the redtails that are

Table 5. Calculated lengths at the end of each year of life for each age group of redtail surfperch from the Oregon coast.

Age Group	Number of Fish	Calculated Total Lengths at Each Annulus								
		I	II	III	IV	V	VI	VII	VIII	IX
					Females					
I	44	108.9								
II	92	101.6	168.9							
III	117	99.2	153.4	215.6						
IV	88	105.6	161.3	207.6	253.0					
V	46	102.9	153.6	201.3	246.2	275.8				
VI	34	106.1	166.5	215.0	257.8	285.7	307.3			
VII	21	100.7	157.7	212.7	260.3	294.3	314.5	332.2		
VIII	5	97.1	173.1	231.4	276.9	302.9	327.6	342.3	356.5	
Average		102.9	160.3	211.2	253.6	283.9	311.5	334.1	356.5	
Increment		102.9	57.4	50.9	42.4	30.3	27.6	22.6	22.4	
Number		447	403	311	194	106	60	26	5	
					Males					
I	29	112.7								
II	69	100.8	170.6							
III	99	102.0	154.8	209.6						
IV	54	107.1	161.0	208.7	242.3					
V	30	104.1	163.9	205.7	240.5	263.9				
VI	27	105.4	159.2	205.3	237.5	263.2	278.8			
VII	14	100.4	157.8	208.4	237.5	262.9	279.1	291.0		
VIII	4	103.9	159.4	206.7	236.8	262.3	280.5	294.2	307.3	
IX	1	94.6	173.3	227.4	261.8	288.8	301.1	313.4	328.2	333.1
Average		103.9	161.2	208.3	240.4	263.7	279.5	292.8	311.5	333.1
Increment		103.9	57.2	47.2	32.0	23.4	15.8	13.3	18.6	21.6
Number		327	298	229	130	76	46	19	5	1

active feeders and faster growing.

Age Frequencies

Age group III was dominant in the collections for both males and females (Figure 4). In the surf most males collected were in age group III while most females were in age group II. In the estuary, age group III formed the mode of the distributions for both males and females. The number of females captured exceeded males in all age groups except 0, and IX (Figure 4). In the estuary the numbers of females captured exceeded males in all age groups, while in the surf the numbers of males exceeded females in all age groups except I (Figure 4).

These age frequency distributions form a catch curve which reflects the collecting devices that were used and the habitats or areas that were sampled during this study.

Lengths and Weights of Captured Fish

Female redtail surfperch ranged from 82 mm to 375 mm TL, while males ranged from 77 mm to 338 mm TL. The average total length for males and females in age groups 0, I, and II were very similar. However, the average total length for females in all age groups older than II were greater than that of males of corresponding ages (Table 6).

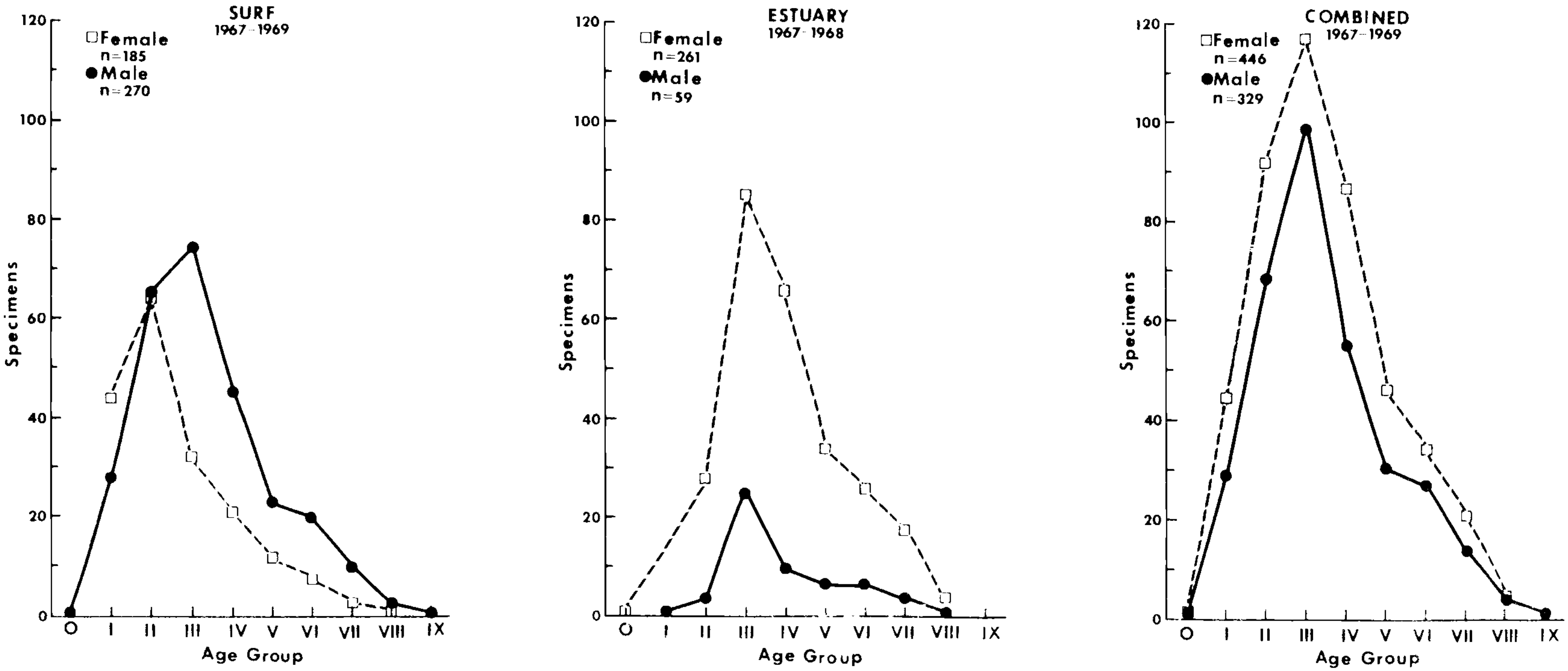

Figure 4. Age frequency distribution of redtail surfperch caught on the Oregon coast.

Table 6. Mean sizes of each age group in 446 female and 328 male redtail surfperch from the Oregon coast during 1967-1969.

Age Group	Number of Fish	Total Length (mm)			Weight (g)		
		Mean	Standard Deviation	Range	Mean	Standard Deviation	Range
				Females			
0	1	82.0	-	-	5.0	-	-
I	44	153.9	12.58	114-175	63.1	16.00	22-92
II	92	198.8	14.78	170-238	137.3	33.42	83-241
III	116	243.3	13.97	197-278	254.4	48.08	131-402
IV	87	271.9	17.53	207-304	360.4	75.01	163-520
V	46	289.4	15.37	245-326	430.2	71.13	246-585
VI	34	318.1	14.46	290-339	579.8	84.73	404-710
VII	21	342.9	18.47	312-375	754.4	142.86	543-1065
VIII	5	367.2	3.87	362-371	974.8	134.13	760-1125
				Males			
0	1	77.0	-	-	6.0	-	-
I	29	157.3	12.13	124-184	68.0	5.13	30-100
II	69	199.2	15.26	171-228	140.4	34.62	78-208
III	99	234.8	15.13	184-269	231.8	45.24	100-329
IV	54	257.0	13.36	223-283	300.0	46.71	203-398
V	30	276.2	10.79	259-301	376.4	44.88	292-473
VI	27	287.2	12.87	261-306	423.0	64.82	297-547
VII	14	296.4	12.38	273-317	459.0	64.49	362-575
VIII	4	312.5	8.79	298-320	565.0	67.55	450-620
IX	1	338.0	-	-	695.0	-	-

Female redtail surfperch ranged in weight from 5 to 1,125 g, while males range from 6 to 620 g. The mean weight for males and females in age groups, 0, I, and II were very similar. However, in age group III and older, the average weights of females exceeded those of males (Table 6).

Length-Weight Relationships

Regression of $\log_{10}$ of weight on $\log_{10}$ of length were computed separately by sex (Figure 5) and combined for males and females. The regression for males was $\log W = 3.08 \log L - 4.96$ with a correlation coefficient of 0.993. The regression for females was $\log W = 3.14 \log L - 5.09$ with a correlation coefficient of 0.994. The regression for the combined data of males and females was $\log W = 3.12 \log L - 5.04$ with a correlation coefficient of 0.993.

Condition

Male surfperch tended to have a slightly better condition factor than females (Figures 6 and 7). Females tended to drop in condition during August when they were giving birth but regained their condition within a month. The mean and range in condition became larger for females in June when the embryos were rapidly growing in size in gravid females (Table 7 and Figure 6). The low part of the range was due to immature females being included in the analysis. The low point

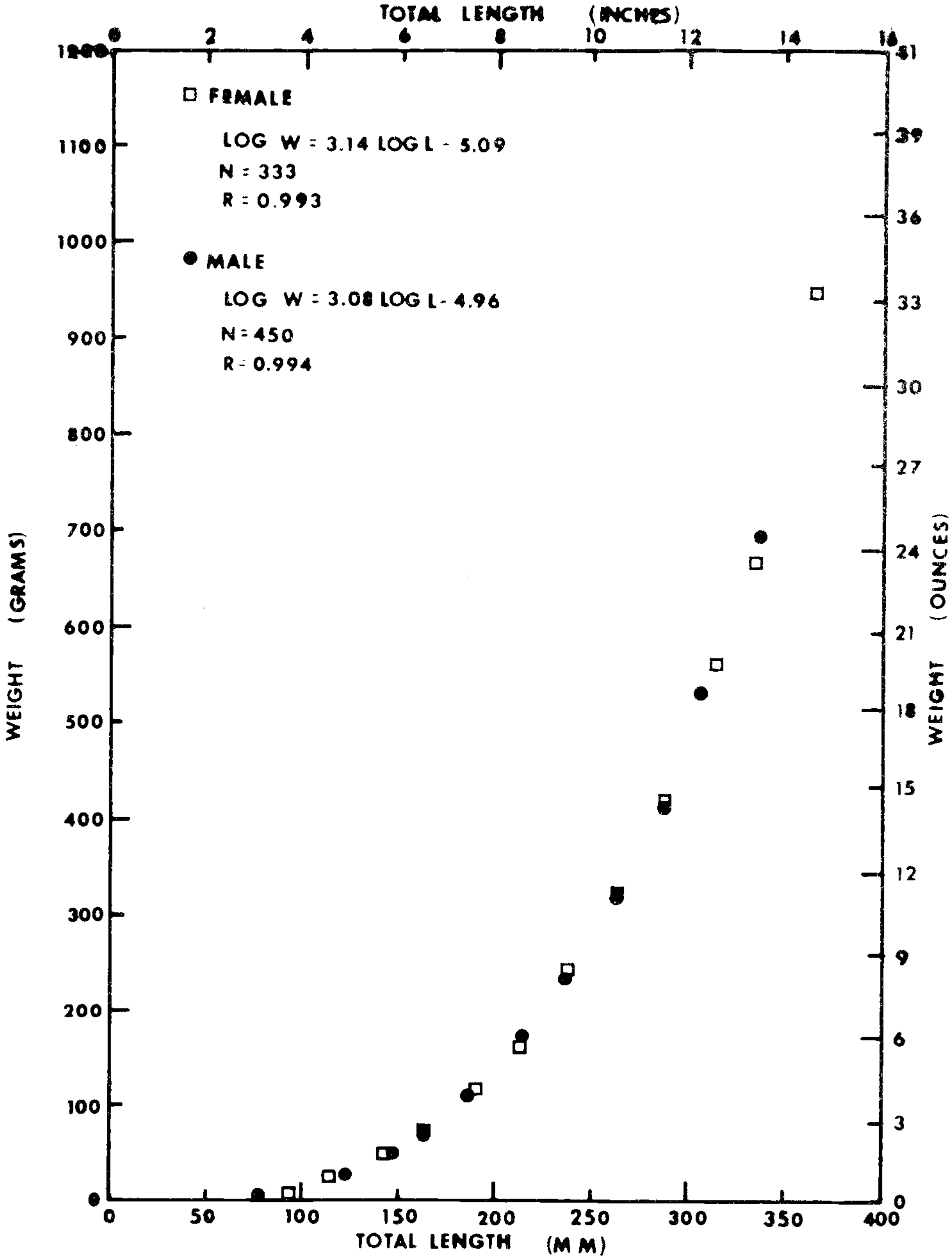

Figure 5. Length-weight relationship for male and female redtail surfperch collected from the Oregon coast during 1967-1969.

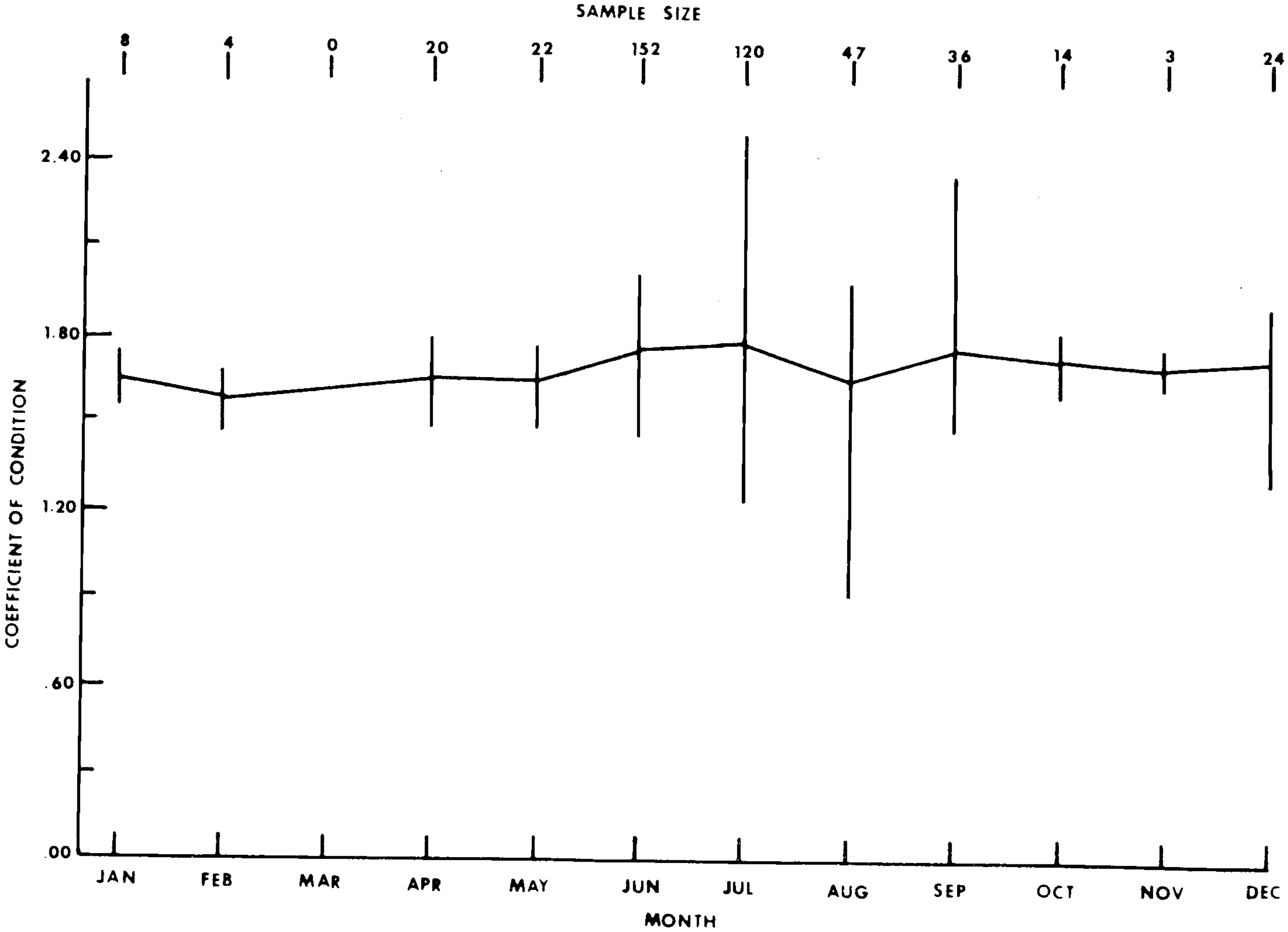

Figure 6. Mean coefficient of condition by month for 450 female redtail surfperch caught during 1967-1969. (Ranges are given as vertical lines)

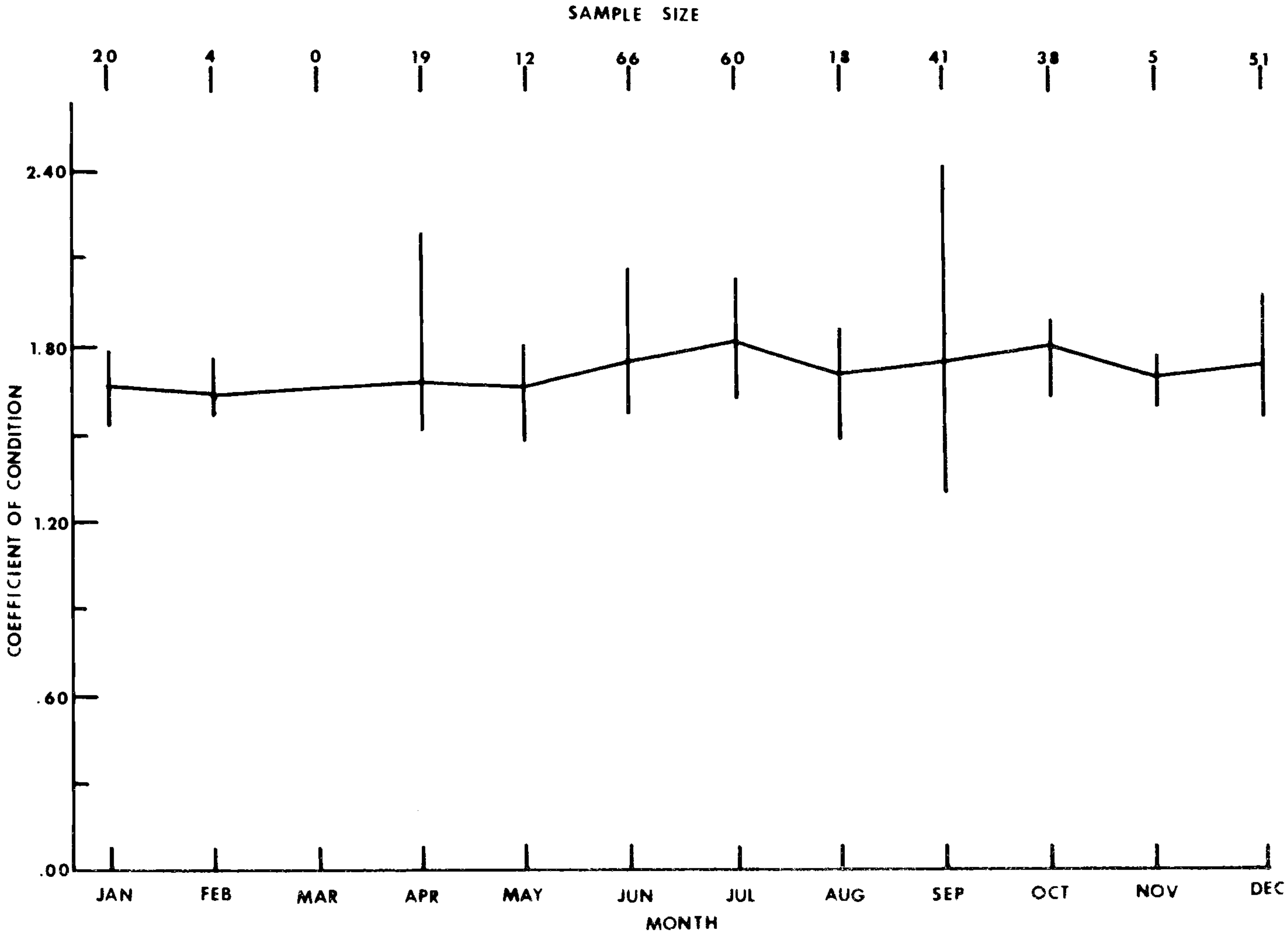

Figure 7. Mean coefficient of condition by month for 333 male redtail surfperch caught during 1967-1969. (Ranges are given as vertical lines)

Table 7. Mean condition factor calculated by age group for redtail surfperch from the Oregon coast during 1967-1969.

Age Group	Males			Females		
	Number of Fish	Mean Condition Factor	Range	Number of Fish	Mean Condition Factor	Range
0	1	1.31	-	1	.91	-
I	29	1.75	1.48-1.96	44	1.73	1.46-1.87
II	69	1.78	1.53-1.98	92	1.75	1.46-1.94
III	99	1.79	1.41-2.41	116	1.77	1.25-2.50
IV	54	1.77	1.48-2.19	87	1.79	1.55-2.14
V	30	1.79	1.98-1.53	46	1.77	1.51-2.37
VI	27	1.79	1.56-2.06	34	1.80	1.51-2.03
VII	14	1.76	1.58-1.99	21	1.87	1.61-2.07
VIII	4	1.85	1.70-1.91	5	1.97	1.59-2.22
IX	1	1.80	-	-	-	-

of the range in July indicated that females had begun to give birth. By August, most females had given birth and this was correlated with the low mean value and the extremely low point in the range of condition. The mean and range for September depicted the rapid recovery of spent females. The drop in condition for males during August was probably an artefact due to a small sample size. The condition of males decreased during January when they were ripe. The condition for both sexes was low from January through May and increased in June when all age groups showed new growth on their scale margins. Both sexes showed an increase in condition with age (Table 7). Since age had an effect on mean size (Table 6), the increase in condition with age also holds for an increase with size.

Reproduction

Sex Ratios

Although the combined samples from the estuary and the surf indicated a preponderance of females, confidence intervals calculated by the method of Simpson et al. (1960), overlap the 50 percent point except for age group IV (Table 8). The combined data, therefore, did not indicate a departure from the theoretical 1:1 sex ratio.

Samples from the estuary contained a preponderance of females while the samples from the surf indicated a greater percentage of

Table 8. Sex ratios of redtail surfperch from the Oregon coast given as the percentage of females. (95 percent confidence intervals (CI) are given in parentheses).

Age Group	Surf			Estuary			Combined		
	N	%F	CI	N	%F	CI	N	%F	CI
0	1	0.0	(-)	1	100.0	(-)	2	50.0	(0.0-100.0)
I	72	61.1	(49.9-72.3)	1	0.0	(-)	73	60.3	(49.1-71.5)
II	129	49.6	(41.0-58.2)	32	87.5	(76.1-98.9)	161	57.1	(49.5-64.7)
III	106	30.2	(21.4-39.0)	110	77.3	(69.5-85.1)	216	54.2	(47.5-60.9)
IV	66	31.8	(20.6-43.0)	76	86.8	(79.2-94.4)	142	61.3	(53.3-69.3)
V	35	34.3	(18.6-50.0)	41	82.9	(75.2-98.4)	76	60.5	(49.6-71.4)
VI	28	28.6	(11.2-46.0)	33	78.8	(64.9-92.7)	61	55.7	(43.4-68.0)
VII	13	23.1	(0.0-59.0)	22	81.8	(64.8-98.8)	35	60.0	(43.7-76.3)
VIII	4	25.0	(0.0-85.2)	5	80.0	(34.0-100.0)	9	55.6	(18.5-92.7)
IX	1	0.0	(-)	-	-	(-)	1	0.0	(-)

males (Table 8). The greater percentage of females taken in the estuary reflected a possibility that many females spawn in the estuary (see discussion section "Age and Growth"). However, other females that contained embryos near term were collected from the surf at low tide during the late summer of 1968. Since repeated 15-minute gill net sets demonstrated that redtail surfperch entered the estuary during incoming tide and returned to sea just as the tide turned, it is likely that gravid females in the surf at low tide may enter the estuary at high tide to bear their young. Miller and Gotshall (1965) stated "The best catches occur in the spring when they concentrate for spawning in harbors and estuaries of larger rivers as well as the surf line."

The greater percentages of males in the surf may have reflected the sampling location. Seal Rock was chosen as a sampling location for the surf because the rocks provided a refuge from the rough surf and, therefore, allowed routine sampling throughout the year. This location was approximately seven miles from the mouth of the estuary. Although numerous immature females were taken with males, few gravid females nearing parturition were taken at this location. It is possible that gravid females remained near the mouth of the estuary during low tide since a sport fishery in the Alsea estuary took many such fish during each high tide.

Sexual Maturity

Females. The percentage of mature females in each age group was determined by the presence of embryos or whether in a recently spent condition (Table 9). Spent ovaries that were enlarged and flaccid could easily be distinguished from small and firm immature ovaries. The data presented in Table 9 were taken from females captured during the period of gestation.

Although sexual maturity was attained by the majority of female redtails at the end of their fourth year of life, a small percentage matured as three year olds (Table 9). No females smaller than 240 mm were mature. Although the percentage of total mature females for each age group gives a gross idea of maturity, both size and age have a great influence on maturity. Thus, a greater percentage of females that were 240 mm or larger in age group IV were mature than in corresponding size groupings in age group III. These data followed the accepted concept that faster growing fish mature earlier (Woodhead, 1960) and gave further evidence that age has an influence on sexual maturity as related to the rate of growth.

Males. The percentage of mature males in each age group was determined by noting the enlarged testes between September and January. During the other months, size of the testes was not reliable in determining potential for reaching maturity during that year.

Table 9. Relationship of size and age to sexual maturity in female redtail surfperch from the central coast of Oregon.

Age Group	Total Length in mm	Total Number of Individuals	Number of Mature Individuals	Percent Mature
0	90-99	1	0	0.0
	Total:	1	0	0.0
I	120-129	1	0	0.0
	130-139	-	-	-
	140-149	5	0	0.0
	150-159	2	0	0.0
	160-169	1	0	0.0
	Total:	9	0	0.0
II	170-179	4	0	0.0
	180-189	11	0	0.0
	190-199	23	0	0.0
	200-209	6	0	0.0
	210-219	6	0	0.0
	Total:	50	0	0.0
III	200-209	1	0	0.0
	210-219	2	0	0.0
	220-229	10	0	0.0
	230-239	26	0	0.0
	240-249	32	5	15.6
	250-259	14	4	28.6
	260-269	7	3	42.9
	270-279	4	4	100.0
	Total:	96	16	16.7
IV	200-209	1	0	0.0
	210-219	-	-	-
	220-229	-	-	-
	230-239	3	0	0.0
	240-249	3	1	33.3
	250-259	10	8	80.0
	260-269	9	8	88.9
	270-279	15	15	100.0
	280-289	24	24	100.0
	290-299	7	7	100.0
	300-309	1	1	100.0
	Total:	73	64	87.7

Table 9. Continued.

Age Group	Total Length in mm	Total Number of Individuals	Number of Mature Individuals	Percent Mature
V	240-249	1	0	0.0
	250-259	-	-	-
	260-269	4	4	100.0
	270-279	4	4	100.0
	280-289	9	9	100.0
	290-299	12	12	100.0
	300-309	4	4	100.0
	310-319	2	2	100.0
	Total:	36	35	97.2
VI	290-299	5	5	100.0
	300-309	3	3	100.0
	310-319	5	5	100.0
	320-329	7	7	100.0
	330-339	8	8	100.0
	Total:	28	28	100.0
VII	310-319	3	3	100.0
	320-329	2	2	100.0
	330-339	3	3	100.0
	340-349	4	4	100.0
	350-359	2	2	100.0
	360-369	3	3	100.0
	370-379	2	2	100.0
	Total:	19	19	100.0
VIII	360-369	1	1	100.0
	370-379	3	3	100.0
	Total:	4	4	100.0

Sexual maturity was attained by the majority of male redtails at the end of their second year and all were mature by the third year (Table 10). No male under 200 mm was judged to be mature. Although the sample size for age group II was small, the influence of the rate of growth was demonstrated with a greater percentage of mature fish of larger size.

Maturity Index for Males

The annual development of the testes was measured by a mean maturity index calculated by month (Figure 8). This development was broken down further by calculating the mean monthly maturity index by age groups I, II, and III^+. Age group I contained no maturing fish and the maturity index indicated the relative size of immature testes. Because of the small sample and difficulty in judging maturity macroscopically (except at the peak of testes development), the maturity index for age group II was calculated separately. All fish of age group III^+ or older were judged to be mature during the peak of testes enlargement. The points indicated by age groups III^+ form the annual cycle of testes development. Mature males were ripe (i.e. milt readily emitted) in late December and early January. At the peak of enlargement, maturing testes amounted to about 4.4 percent of the body weight.

Table 10. Relationship of size and age to sexual maturity in male redtail surfperch from the central coast of Oregon.

Age Group	Total Length in mm	Total Number of Individuals	Number of Mature Individuals	Percent Mature
0	70-79	1	0	0.0
	Total:	1	0	0.0
I	150-159	6	0	0.0
	160-169	5	0	0.0
	170-179	3	0	0.0
	180-189	1	0	0.0
	Total:	15	0	0.0
II	170-179	1	0	0.0
	180-189	2	0	0.0
	190-199	1	0	0.0
	200-209	4	2	50.0
	210-219	11	10	90.9
	220-229	8	7	87.5
	Total:	27	19	70.4
III	210-219	2	2	100.0
	220-229	1	1	100.0
	230-239	13	13	100.0
	240-249	16	16	100.0
	250-259	12	12	100.0
	260-269	6	6	100.0
	Total:	50	50	100.0
IV	240-249	2	2	100.0
	250-259	6	6	100.0
	260-269	5	5	100.0
	270-279	4	4	100.0
	280-289	3	3	100.0
	Total:	20	20	100.0
V	260-269	3	3	100.0
	270-279	4	4	100.0
	280-289	6	6	100.0
	290-299	1	1	100.0
	300-309	1	1	100.0
	Total:	15	15	100.0
VI	260-269	3	3	100.0
	270-279	1	1	100.0
	280-289	3	3	100.0
	290-299	3	3	100.0
	300-309	4	4	100.0
	Total:	14	14	100.0

Table 10. Continued.

Age Group	Total Length in mm	Total Number of Individuals	Number of Mature Individuals	Percent Mature
VII	270-279	1	1	100.0
	280-289	3	3	100.0
	290-299	1	1	100.0
	300-309	2	2	100.0
	310-319	1	1	100.0
	Total:	8	8	100.0
VIII	290-299	1	1	100.0
	300-309	-	-	100.0
	310-319	1	1	100.0
	320-329	1	1	100.0
	Total:	3	3	100.0
IX	330-339	1	1	100.0
	Total:	1	1	100.0

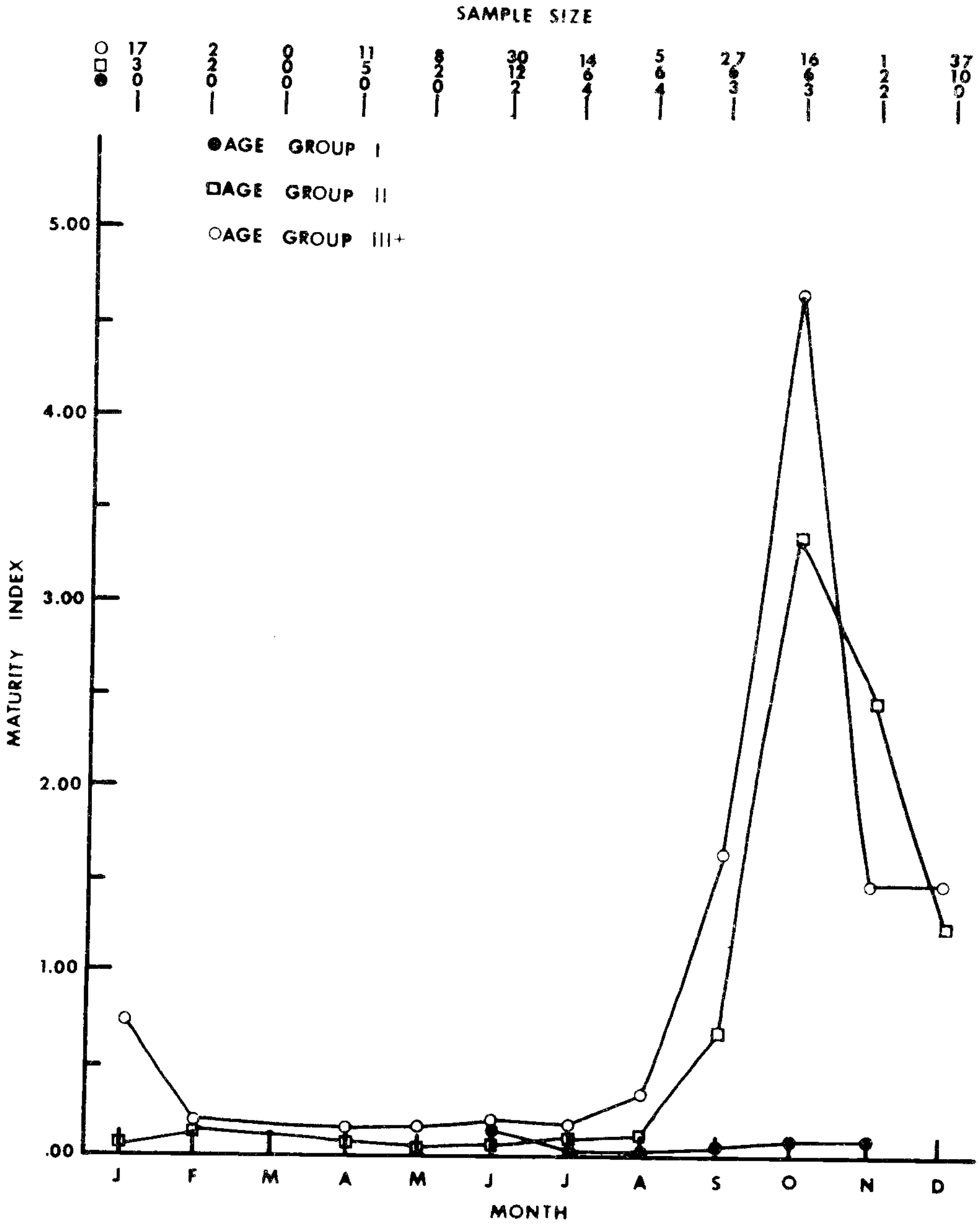

Figure 8. The annual reproductive cycle of male redtail surf-perch by age groups as indicated by the mean maturity index (gonad weight x 100 divided by the body weight) for each month.

Fecundity

During the study 168 gravid females which ranged in age from 3 to 8 years were collected. From these 168 females, a total of 2,239 embryos were taken (Appendix Table 1). The number of embryos per female ranged from 1 to 39 with a mean of 13.3. Age specific fecundity rates are given in Table 11. The mean number of embryos increased from 7.44 per female for age group III to 33.67 embryos per female for age group VIII. The mean number of embryos per female increased with mean size and age of the female. The correction or shrinkage factor (Appendix Table 2) was applied to all embryos used in fecundity analysis. Twelve of the 168 females contained a total of 28 malformed or diminutive embryos, with the number per female ranging from 1 to 9. If it can be assumed that these malformed embryos do not survive, then an embryonic mortality of 1.25 percent (28 of 2,2239) was indicated.

Growth of Embryos. During 1967 gravid females were collected from April through August; in 1968 gravid females were collected from April through September. All mature females collected in October were spent. The smallest embryo (7.9 mm SL) was collected in April of 1968, while the largest embryo (63.9 mm SL) was collected in September of 1968. The general growth of embryos for 1967 and 1968 is shown in Table 12. This summary gives the mean

Table 11. Age specific fecundity rates for redtail surfperch from the central coast of Oregon.

Age Group of Female	Number of Fish	Female Size		Mean Number of Embryos
		Mean Length (mm)	Mean Weight (g)	
III	16	257.8 ± 12.1	298.3 ± 53.5	7.44 ± 2.71
IV	60	275.9 ± 13.4	378.5* ± 59.9	8.68 ± 3.45
V	34	286.8 ± 14.6	415.4 ± 63.9	11.88 ± 4.09
VI	27	316.4 ± 14.8	583.3 ± 93.4	18.44 ± 4.64
VII	15	346.9 ± 19.9	796.3 ± 146.5	25.40 ± 8.72
VIII	3	367.3 ± 4.6	1005.0 ± 113.2	33.67 ± 6.66

± indicates one standard deviation

* Mean weight of 59 fish

Table 12. The growth of embryos in redtail surfperch from the central coast of Oregon.

Date	Number of Females	Female*		Embryos**	
		Mean TL (mm)	Standard Deviation	Mean SL (mm)***	Range
			1967		
4/26	2	309.5	-	10.9	10.4-11.3
5/4	1	331.0	-	16.6	-
5/11	1	266.0	-	15.7	-
6/13	4	282.8	5.12	25.0	21.8-28.6
6/24-6/28	43	289.5	31.65	29.5	17.5-40.8
7/6	35	307.3	35.11	34.1	24.2-47.4
7/12	13	290.5	31.10	35.1	26.2-41.9
8/14	8	276.4	16.03	48.5	36.9-57.8
8/15	8	309.3	23.56	53.2	44.7-58.5
			1968		
4/19-4/20	3	273.7	25.17	9.2	7.9-10.5
5/4-5/5	5	277.3	26.12	12.2	10.9-14.6
5/10	11	275.0	21.10	16.0	13.1-17.8
6/12	3	289.3	26.10	24.6	22.1-27.0
6/21	26	298.0	30.31	30.0	25.6-35.9
7/3-7/18	3	292.5	-	37.5	29.4-38.7
8/20-9/19	4	293.3	6.18	58.0	51.8-63.9

*Lengths from fresh fish

**Lengths from embryos preserved in 10 percent formalin corrected to fresh lengths by application of thefactor (X 1.09).

***Mean of embryo means for individual females.

size of embryos for females of all sizes and age groups. These data indicate that growth rates were about the same on comparable dates in either year. Gross examination of the data indicated that a relationship might exist between the size of female and the size of her embryos. The total length of individual females was plotted against the mean standard lengths of her embryos by month. Different symbols were used to show the age group of individual females. These graphs indicated that the mean lengths of the embryos were related more to the lengths than to the ages of females (Figure 9). Regression equations that describe this relationship were calculated for each month by the method of least squares (Table 13). The correlation coefficients were tested for significance following Alder and Roessler (1960) and were found to be significant at the five percent level for this relationship in all months except April and May. Lines determined by applying the regression equations were drawn through the individual points (Figure 9). These regression lines show that the relationship between female size and embryo size becomes more apparent as the gestation period progresses.

Number of Embryos versus Size of Females. There was a positive linear correlation between the number of embryos and total length of females (Figure 10) as well as the weight of females (Figure 11). Figures 10 and 11 represent only 1968 data because special care was taken at this time to avoid any possible loss of

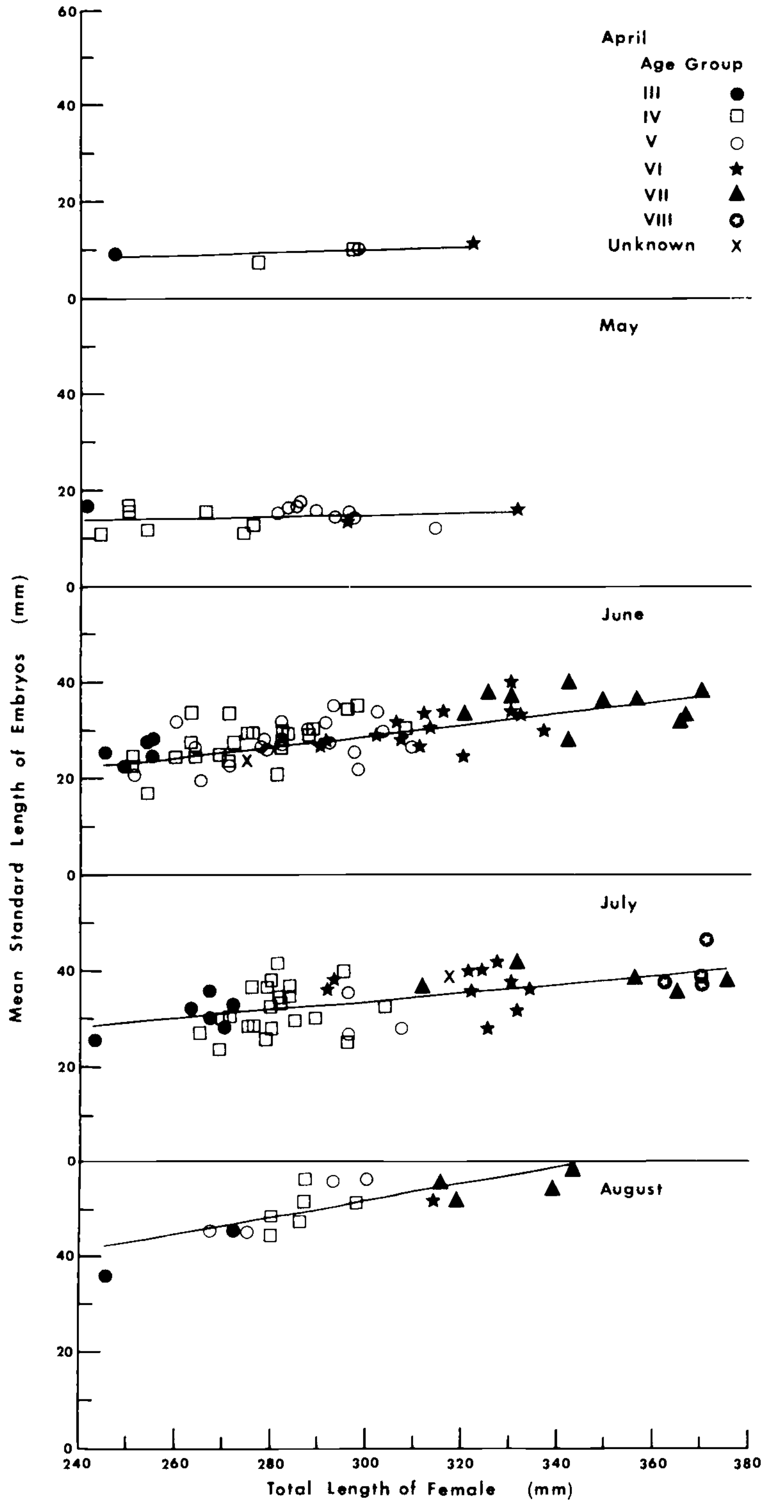

Figure 9. The variation in the mean size of embryos during the gestation period for redtail surfperch. Data are combined for 1967 and 1968. (See table 13 for regression equations)

Table 13. Regression equations for the relationship of embryo size related to female size during the gestation period. Data for 1967 and 1968 are combined.

Month	Number of Fish	Regression Equation	Correlation Coefficient	T-Test Value	D. F.
April	5	Y = 0.036x - 0.499	0.750	1.96	3
May	19	Y = 0.012x + 11.538	0.131	0.55	17
June	76	Y = 0.104x - 1.171	0.639*	7.18	74
July	51	Y = 0.087x + 8.072	0.567*	4.81	49
August	17	Y = 0.176x - 0.677	0.773*	4.71	15

*Significant at 5 percent level; t-test was made following Alder and Roessler (1960).

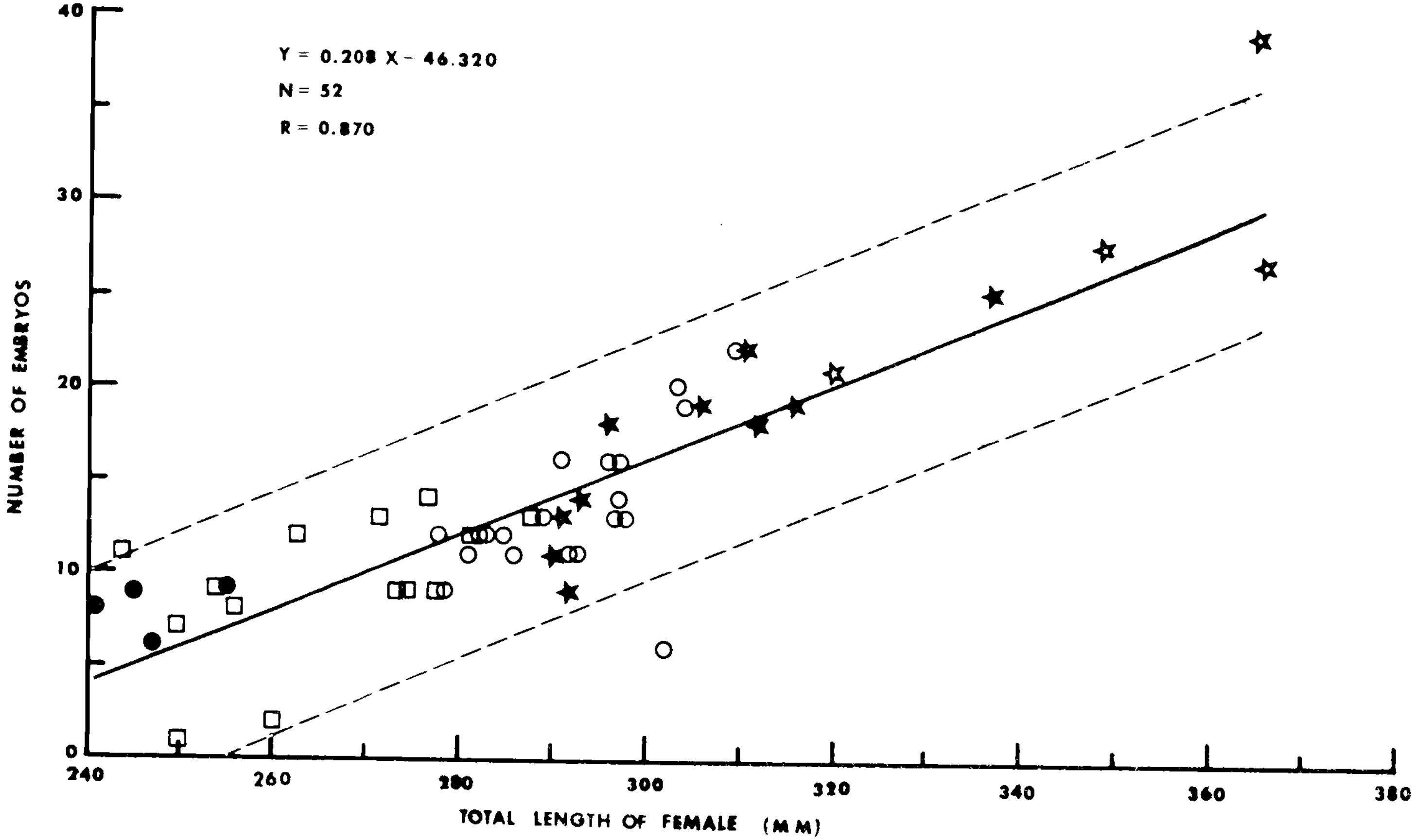

Figure 10. Regression of the number of embryos compared with total length of redtail surfperch from the central coast of Oregon in 1968. Dashed lines indicate the 95 percent confidence interval around the regression line. Symbols indicate age group: III - ● ; IV - □ ; V - ○ ; VI - ★ ; VII - ☆ .

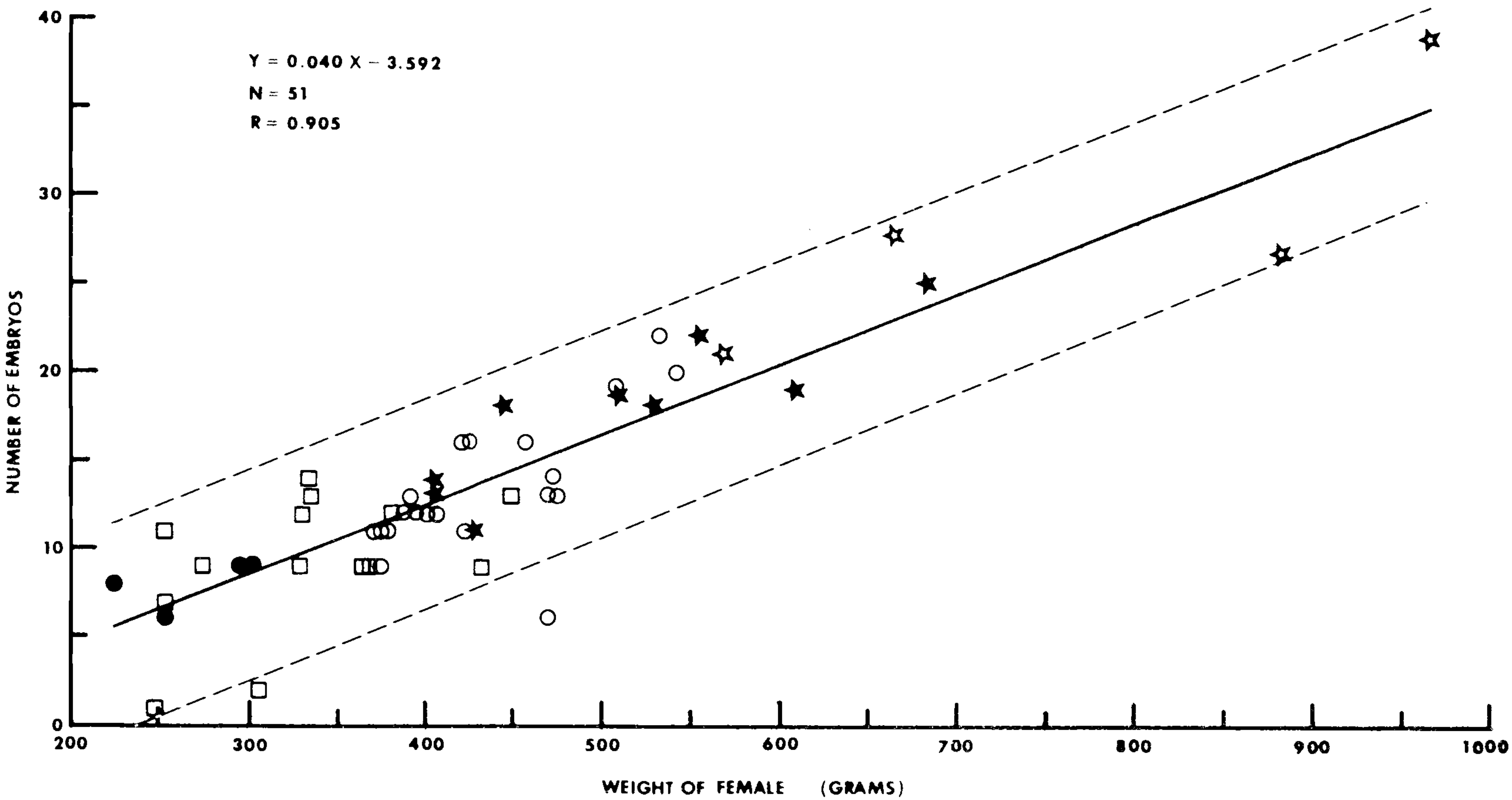

Figure 11. Regression of the number of embryos compared with weight of redtail surfperch for the central coast of Oregon in 1968. Dashed lines indicate the 95 percent confidence interval around the regression line. Symbols indicate age group: III - ● ; IV - □ ; V - ○ ; VI - ★ ; VII - ☆ .

embryos by abortion. Size appeared more important than age when compared with the number of embryos contained per female. Females of approximately the same size but of different ages produced approximately the same number of embryos (Figures 10 and 11). The smaller females of an age group tended to have fewer embryos than the larger females in that age group. These data support the concept that growth rate is important in determining the reproductive potential of fish (Woodhead, 1960).

Size of Embryos at Birth. To investigate the relationship of mean size of embryo to size of female, 14 females of varying sizes were captured and held in individual tanks in the laboratory. Four females of different sizes gave birth successfully under laboratory conditions. From a total of 37 embryos, the range in total length was from 66 to 83 mm with a mean of 75.8 mm, while the weight ranged from 2.9 to 8.9 g with a mean of 5.8 g (Appendix Table 3). Although the sample size was small, the mean size of young at birth was directly related to the size of the female. Not all young from an individual female were born in one day. Although the adaptive significance of the size of young at birth cannot be established from these data, one might speculate that larger young may have greater survival.

Only two young-of-the-year were collected during this study. A female was collected on August 22, 1967 that was 82 mm in total length and weighed 5 g. A male was collected on September 9, 1968 that was 77 mm in total length and weighed 6 g. Although the exact dates that these fish were born is not known, both fisn were collected during the spawning season and were approximately the same size as the young at birth from the females held in the laboratory.

Young redtails were born along the central coast of Oregon from late July through September. This period is based on the percentage of spent females captured during each month. Only two percent of the mature females captured in July were spent while 100 percent of those captured in October were spent. The majority of mature females (83 percent) in the September collections were spent which might indicate the peak of the spawning season was during late August and early September.

Food Habits

Stomachs from 335 redtail surfperch were collected from both the surf and estuary for food habit analysis. Of the total 335, 226 stomachs were taken from redtails captured in the surf, while the remaining 109 stomachs were taken from redtails captured in the estuary. Of those stomachs taken from the surf caught fish, 13.3 percent were empty and 1.3 percent contained only bait. Of those stomachs taken from estuary caught fish, 39.5 percent were empty and 11.9 percent contained only bait. Food items were identified as closely as possible to the specific taxonomic grouping. Difficulties were encountered because only pieces of organisms were found and because enzymatic breakdown caused losses of specific taxonomic criteria. A taxonomic list of all food items is summarized in Table 14. Eight major categories were taken from this list: Polychaeta, Mollusca, Cirripedia, Isopoda, Amphipoda, Decapoda, Fish, and Miscellaneous. The miscellaneous category is not listed in the taxonomic list and consisted of items such as sand grains, wood, pieces of old shells, algae, unidentified eggs and objects, and incidental items as hydroids, tube worms cases, peanut worms, and bryozoans.

Frequency of Occurrence and Total Volume

Surf. The diet of surf-caught redtails consisted of crustaceans, fish, molluscs, and polychaetes in decreasing order of importance (Figure 12). Crustaceans as a group were most important in both frequency of occurrence and total volume. Although the frequency of occurrence for fish was equal to polychaetes and less than for molluscs, fish were listed second in importance since this group formed a greater percentage of food by volume. Molluscs were listed third in importance because they were found in a larger percentage of redtail stomachs than polychaetes although the total volume was nearly equal. Decapoda, amphipods, isopods, and cirripeds respectively were the important and common groups of crustaceans.

Table 14. Taxonomic list[1] of all food organisms identified from the stomachs of 335 redtail surfperch collected along the Oregon coast between June, 1967 and October, 1968.

Phylum Porifera	Unidentified Porifera
Phylum Coelenterata	
Class Hydrozoa	Unidentified Hydrozoa
Class Anthozoa	Unidentified Anthozoa
Phylum Annelida	
Class Polychaeta	Unidentified Polychaeta
Phylum Mollusca	
Class Amphineura	Unidentified Amphineura
Class Gastropoda	Unidentified Gastropoda
Order Mesogastropoda	
Family Naticidae	Unidentified Naticidae
Class Pelecypoda	Unidentified Pelecypoda
Order Filibranchia	*Mytilus* sp.
Phylum Arthropoda	
Subphylum Mandibulata	
Class Crustacea	
Subclass Cirripedia	*Balanus* sp.
Subclass Malacostraca	
Order Isopoda	Unidentified Isopoda
	Idothea sp.
Order Amphipoda	Unidentified Amphipoda
Family Caprellidae	Unidentified Caprellidae
Family Gammaridae	Unidentified Gammaridae
Order Decapoda	
Suborder Natantia	Unidentified Natantia
	Crago sp.
Suborder Reptantia	Unidentified Reptantia
	Callianassa californiensis
	Cancer magister
	Cancer sp.
	Emerita sp.
	Petrolisthes sp.
	Pugettia sp.
Phylum Sipunculida	Unidentified Sipunculida
Phylum Ectopiocta	
Class Gymnolaemata	Unidentified Gymnolaemata
Order Ctenostomata	*Flustrella* sp.
Phylum Chordata	
Class Pisces	Unidentified Pisces
Order Percomorphi	
Suborder Percoidea	
Family Ammodytidae	*Ammodytes hexapterus*
Order Scleroparei	
Suborder Scorpoenoidea	
Family Cottidae	Unidentified Cottidae

[1]Taxa of invertebrates above the level of family are from Barnes (1963); families follow Light (1954).

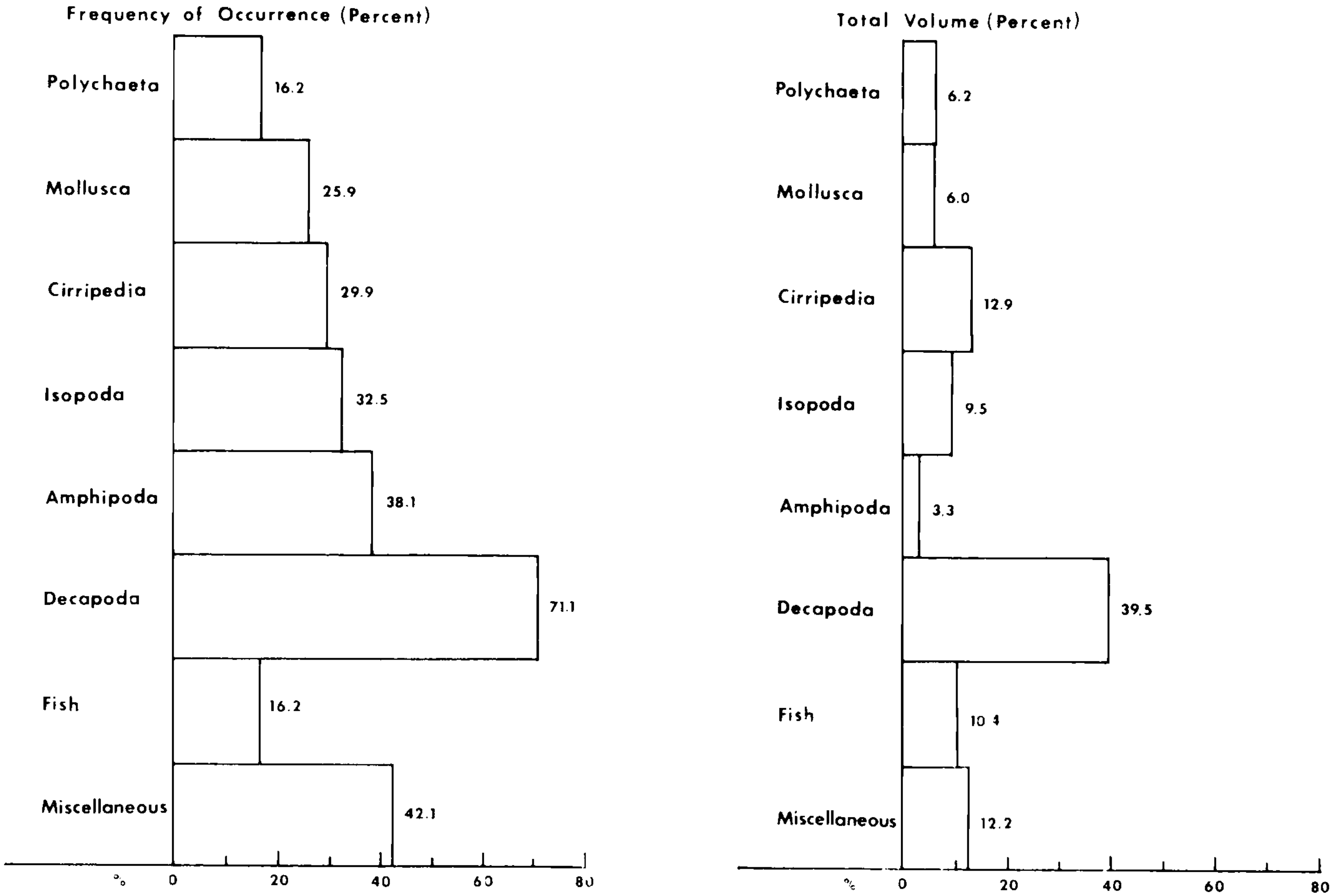

Figure 12. Food of 193 redtail surfperch collected from the Oregon surf during June 1967 to October 1968.

As a percentage of the total volume, the importance of cirripeds, isopods, and amphipods were reversed from the percentage of frequency of occurrence. Decapods made up the most important single food category in the stomachs; they were found in 71.1 percent of the stomachs containing food and comprised nearly 40 percent of the total volume of food.

Estuary. Stomachs from estuary caught redtails contained primarily decapods and fish; a small percentage of redtail contained amphipods and molluscs (Table 15). Although the sample size in the estuary was small, the order of importance of crustaceans and fish was the same as in the surf (Table 15).

Influence of Fish Size on Food Habits

Surf. Decapods were found in approximately two-thirds of the stomachs from all sizes of redtail surfperch (Figure 13). The percentage, however, dropped for fish larger than 300 mm TL. Fish of this large size appear to be opportunistic rather than selective in their food habits. The small sample size for fish under 100 mm did not allow for adequate comparison. As fishes increased in length, they ate fewer isopods and polychaetes. This was true of all size groups except one (Figure 13). A larger percentage of fish over 300 mm TL contained polychaetes. The percentage of fish containing amphipods decreased with increasing size of the fish. However,

Table 15. Food of 53 redtail surfperch collected from Alsea Bay, Oregon during June and July of 1967 and 1968.

Food Category	Frequency of Occurrence by Percent	Total Volume by Percent	Percent Frequency of Occurrence by Size Group — Total Length of Size Groups in mm: 151-200	201-250	251-300	301-350	351-400	Percent Frequency of Occurrence by Date of Collection: 6/12-21 1968	6/27 1967	7/3-11 1968	7/6-12 1967
Polychaeta	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mollusca	3.1	0.3	0.0	0.0	5.7	0.0	0.0	0.0	6.7	0.0	3.6
Cirripedia	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Isopoda	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Amphipoda	3.1	0.1	0.0	0.0	2.8	7.7	0.0	0.0	6.7	0.0	3.6
Decapoda	44.6	42.0	20.0	57.1	62.9	15.4	0.0	20.0	73.3	50.0	46.4
Fish	43.1	46.2	40.0	57.1	31.4	61.5	60.0	20.0	26.7	50.0	67.9
Miscellaneous	13.8	2.2	20.0	0.0	5.7	30.8	40.0	15.0	6.7	0.0	17.9

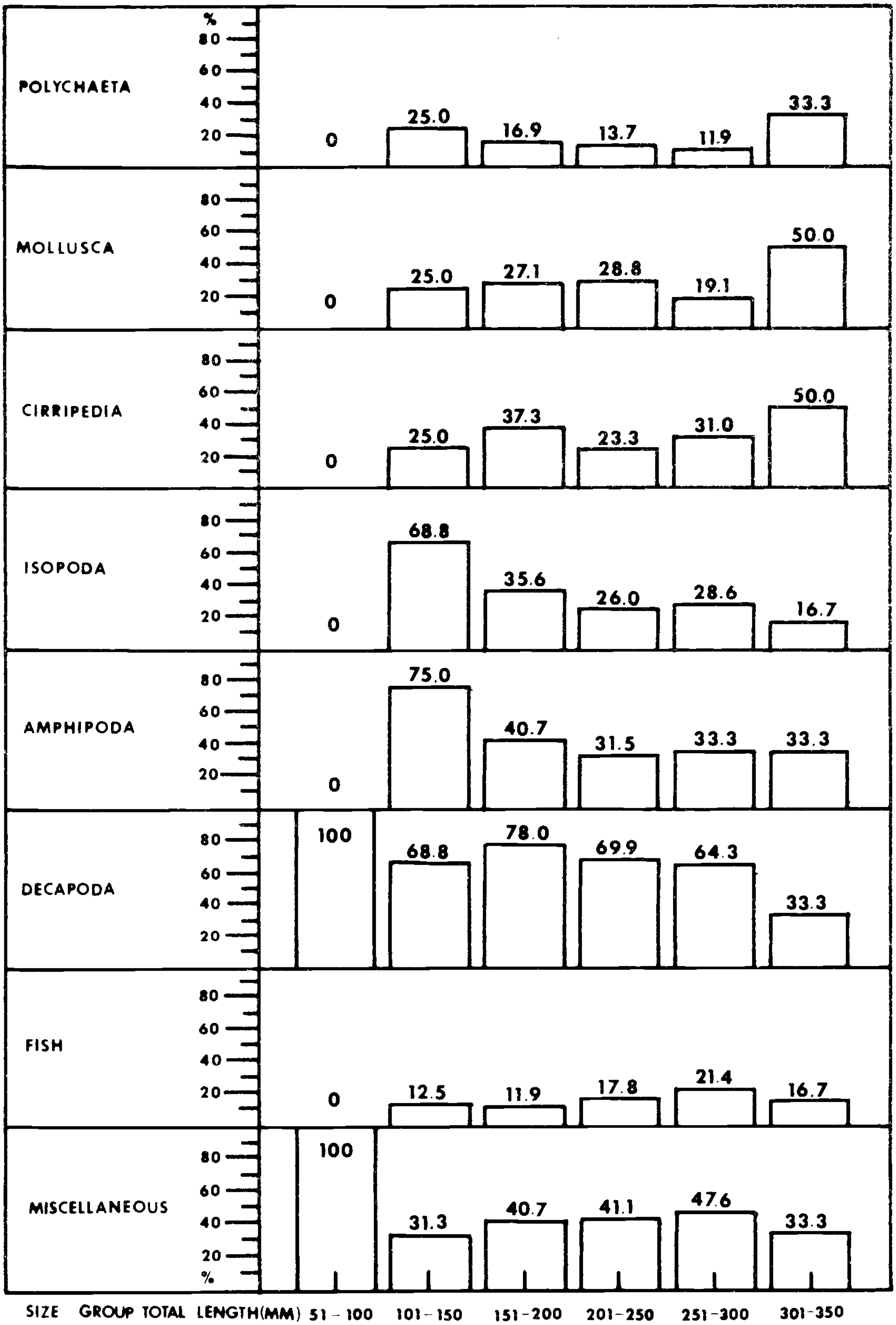

Figure 13. Percent frequency of occurrence of food items by different size groups of 193 redtail surfperch from the Oregon surf.

amphipods were found in about one-third of the fish larger than 200 mm. In general, large redtails captured more fishes. No trend was detected in the consumption of molluscs and cirripeds as fish size increased. Items from these two food groups occurred in approximately 25 percent of the stomachs.

Estuary. A higher percentage of decapods were found in redtail surfperch between 200 and 300 mm TL than in other sizes (Table 15). Fish appeared to be important for redtail surfperch of all sizes that were taken in the estuary. Because of the small sample size and high percentage of empty stomachs, this data may not be adequate to describe the food habits of redtail surfperch taken from the estuary.

Variation by Date of Collection

Surf. Redtails inhabiting the surf contained a high percentage of polychaetes in spring and fall while the percentage was low during the summer months (Figure 14). From May through October molluscs were found in approximately 25 percent of the stomachs. Although cirripeds were in a low percentage of the stomachs in the spring, this group was found in slightly over two-thirds of the fish examined during the summer and fall. In the spring a substantial increase occurred in the percentage of stomachs with amphipods with another slight increase occurring in both isopods and amphipods again in the late summer (Figure 14). In June a substantial increase

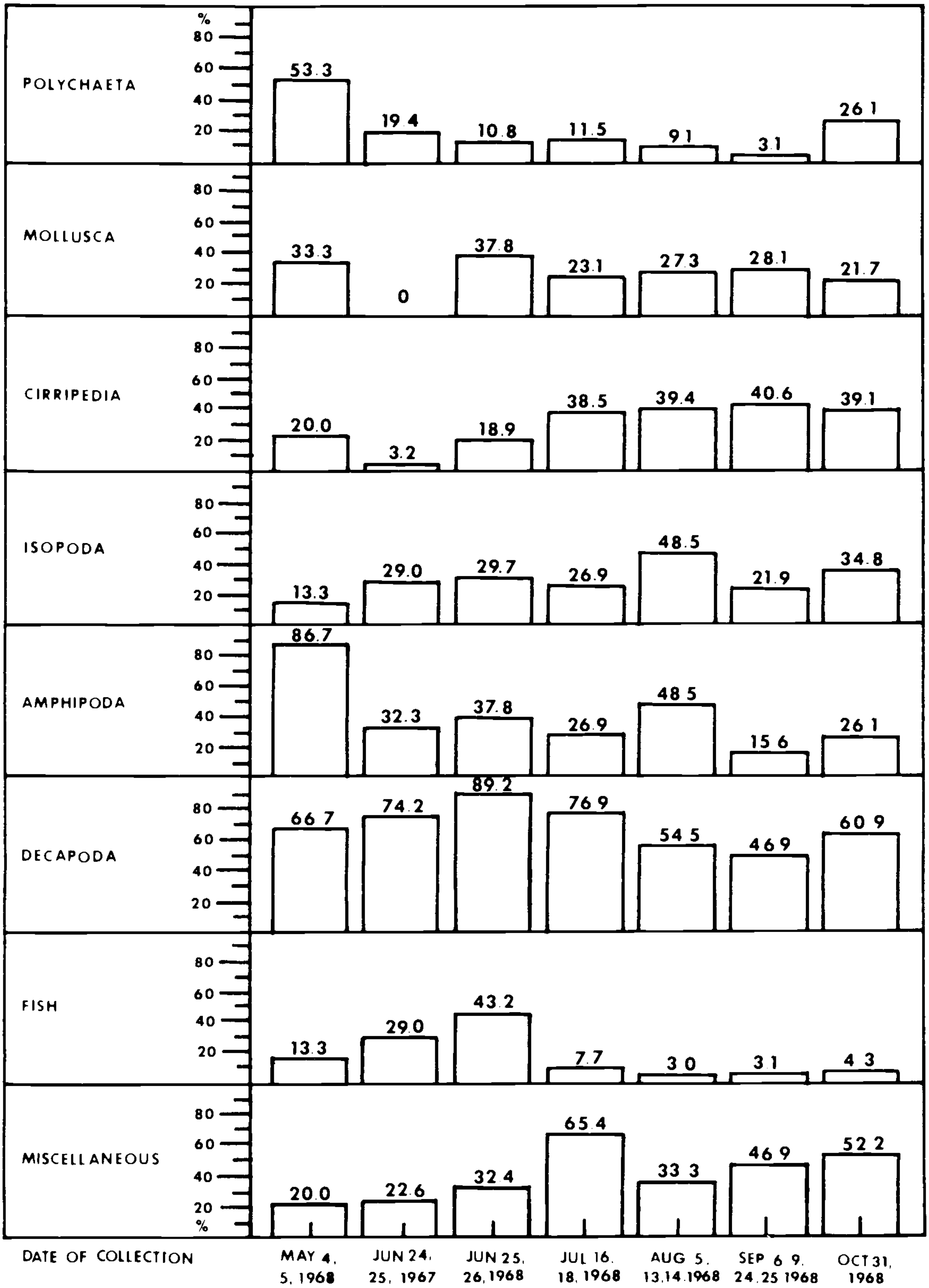

Figure 14. Percent frequency of occurrence of food items by different size groups of 193 redtail surfperch from the Oregon surf.

in decapods and fish occurred in redtail stomachs. The increased percentages in both the spring and fall might be explained by the fact that both these periods are times of active feeding.

Estuary. Collections of redtails in the estuary were made only in June and July of 1967 and 1968 primarily to collect data on the reproductive biology. The occurrence of food items by date for the estuary are given in Table 15.

Parasites

All of the 356 redtail perch that were examined were infected with one or more of the parasites listed in Table 16. These parasites belonged to three main groups: Trematoda, Nematoda, and Copepoda.

The digenetic trematode (*Genitocotyle acirra*) was found in the intestine of every fish (170) examined from 126 to 366 mm TL. The number of parasites varied from a few to several hundred, generally increasing with size of fish. Adult digenetic trematodes belonging to the family Bucephalidae are sometimes found in the intestine and occasionally bucephalid metacercariae are found in the gills (Dr. Robert E. Olson, personal communication).

A monogenetic trematode, *Dichlidophora* sp., was found on the gills of the redtail surfperch as well as the silver (*Hyperprosopon ellipticum* Gibbons) and walleye (*Hyperprosopon argenteum* Gibbons) surfperches. This monogenetic trematode was found on 132 of 356

Table 16. Taxonomic list of parasites identified from 356 redtail surfperch that were collected along the Oregon coast between April, 1968 and April, 1969.

Major Taxa	Specific Taxa	Location in/on fish
Phylum Platyhelminthes		
Class Trematoda		
Subclass Digenea		
Family Bucephalidae[1]	Unidentified Bucephalidae	Gills, intestine
Family Opecoelidae	Genitocotyle acirra	Intestine
Subclass Monogenea		
Family Diclidophoridae	Diclidophora sp.	Gills
Phylum Aschelminthes		
Class Nematoda		
Superfamily Ascaroidea		
Family Heterocheilidae		Liver, intestine
Subfamily Anisakinae	Unidentified Anisakinae	Musculature
Phylum Arthropoda		
Class Crustacea		
Subclass Copepoda		
Order Caligidea		
Family Caligidae	Caligus sp.	Body surface
Order Lerneopodidea		
Family Lerneopodidae	Clavella sp.	Gills, fins
Class Branchiura		
Family Argulidae	Argulus catostomi	Body surface

[1]From Dr. Robert E. Olson, personal communication.

fish; the most heavily parasitized fish had six worms. The mean infestation rate was .48 parasites per fish for all redtail surfperch. The summaries in Tables 17-19 apply to adult parasites; no data were collected on larval forms. In general, no seasonal trend could be detected in the infestation rate or percentage of fish that were infected with this monogenetic trematode (Table 17). However, as fish size increased so did the percent of fish infected and the infestation rate (Table 18). A strong relationship existed between the age of the surfperch and the incidence and infestation rate of this parasite (Table 19).

Nematoda was the rarest group of parasites found. Only 18 immature nematodes belonging to the subfamily Anisakinae were found in 13 of 276 fish. One nematode was found in the liver, the musculature, and the mesentery; the remaining 15 were found in the digestive tract.

Three different genera of the group Copepoda were the most common parasites found on the redtail (Table 16). The two copepods found on the body surface were *Caligus* sp. and *Argulus catostomi*. *Caligus* sp. was found in two different stages--attached to the skin and free on the body surface. The highest number of copepods on the body surface was eight with a mean infestation rate of 0.70 parasites per fish. The two parasites were considered together for analysis since combined records were kept for copepods on the body

Table 17. Monthly variation in infestation rate and percentage of redtail surfperch infected with several parasites.

Parasite	Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Diclidophora sp.												
Fish examined	28	7	0	31	31	75	42	44	50	25	9	10
Percentage infected	25	29	-	36	36	44	50	18	38	48	11	40
Infestation rate	.29	.29	-	.45	.45	.61	.55	.27	.60	.64	.11	.70
Caligus and Argulus												
Fish examined	0	0	0	2	22	76	42	43	50	25	0	0
Percentage infected	-	-	-	100	50	40	31	44	36	52	-	-
Infestation rate	-	-	-	1.00	.73	.74	1.05	.91	.64	.76	-	-
Clavella (fin)												
Fish examined	0	0	0	5	31	76	42	43	50	25	0	0
Percentage infected	-	-	-	100	55	62	67	54	52	68	-	-
Infestation rate	-	-	-	3.20	2.39	1.72	1.95	1.77	1.82	2.56	-	-
Clavella (gills)												
Fish examined	0	0	0	0	2	76	42	43	50	25	0	0
Percentage infected	-	-	-	-	100	8	2	7	6	8	-	-
Infestation rate	-	-	-	-	2.50	.30	.02	.16	.18	.08	-	-

Table 18. The relationship of size in redtail surfperch to the percentage of fish infected and infestation rate of several parasites.

Parasite	Length Group											
	76-100	101-125	126-150	151-175	176-200	201-225	226-250	251-275	276-300	301-325	326-350	351-375
Diclidophora sp.												
Fish examined	1	0	17	42	58	58	44	56	51	18	7	2
Percentage infected	0	-	12	2	29	33	45	52	55	56	14	0
Infestation rate	0	-	.12	.02	.34	.38	.68	.73	.82	.72	.14	0
Caligus and Argulus												
Fish examined	1	0	18	32	30	46	26	44	40	16	5	2
Percentage infected	0	-	33	28	20	26	39	55	50	81	80	100
Infestation rate	0	-	.39	.34	.37	.46	.81	1.09	.98	2.31	1.80	3.00
Clavella (fin)												
Fish examined	1	0	19	31	31	49	31	44	42	16	5	2
Percentage infected	0	-	53	65	77	80	55	57	36	63	40	50
Infestation rate	0	-	1.68	1.52	2.42	3.94	1.29	1.55	.74	2.25	.40	.50
Clavella (gills)												
Fish examined	1	0	18	32	28	47	21	38	32	13	6	2
Percentage infected	0	-	11	9	11	13	5	0	6	0	0	0
Infestation rate	0	-	.17	.09	.21	.64	.05	0	.13	0	0	0

Table 19. The percentage of fish infected and infestation rate of parasites by age of redtail surfperch.

Parasite	Age Group 0	I	II	III	IV	V	VI	VII	VIII	IX
Diclidophora sp.										
Fish examined	1	54	106	52	53	39	27	14	2	1
Percentage infected	0	6	31	44	57	46	48	36	100	100
Infestation rate	0	.06	.37	.60	.85	.64	.70	.50	1.50	1.00
Caligus and *Argulus*										
Fish examined	1	49	73	36	36	33	19	8	1	1
Percentage infected	0	29	25	42	64	42	74	75	0	100
Infestation rate	0	.35	.44	.97	1.25	1.03	1.68	1.50	0	2.00
Clavella (fin)										
Fish examined	1	50	74	38	40	35	20	8	1	1
Percentage infected	0	60	81	47	63	40	40	63	0	100
Infestation rate	0	1.58	3.46	1.63	1.43	1.20	.75	1.63	0	1.00
Clavella (gills)										
Fish examined	1	49	72	34	25	26	19	7	1	1
Percentage infected	0	10	11	3	0	4	5	0	0	0
Infestation rate	0	.12	.47	.03	0	.04	.16	0	0	0

surface of the fish. Infestation rate and percentage of fish infected did not show any seasonal trends (Table 17). An increase in both percentage of fish infected and infestation rate occurred with increasing size (Table 18) and age (Table 19) in redtails.

Clavella sp. was found attached to the gills and fins of the redtail surfperch. The heaviest infestation on the fins of one fish was 16 parasites with a mean of 1.76 parasites for all fish. The heaviest infestation on the gills of one fish was nine parasites with a mean of 0.17 parasites for all fish. Although the percentage of fish infected with Clavella on the fins did not vary by season, the infestation rate tended to be lower during the summer months (Table 17). No such trend could be detected for Clavella on the gills. No trends could be observed for either parasite location in the infestation rate or percentage of fish infected by size (Table 18) or age (Table 19) of the fish.

DISCUSSION

Age and Growth

Female redtail surfperch grew faster than males after age group II. This change in growth rate was correlated with age upon reaching sexual maturity. Other embiotocids have generally demonstrated similar growth that varies by species. Species that show this type of differential growth by sex include pile seaperch, Rhacochilus vacca (Wares, 1968), shiner perch, Cymatogaster aggregata, white seaperch, Phanerodon furcatus, and walleye surfperch (Anderson and Bryan, 1970). In one exception to this trend, male striped seaperch, Embiotoca lateralis, grew faster than females (Gnose, 1968).

Lee's phenomenon of an apparent change in growth rate was not found in the redtail surfperch. This phenomenon that is common for many fishes was not found in the pile seaperch (Wares, 1968), but was reported for the older females in shiner perch, white seaperch, and walleye surfperch (Anderson and Bryan, 1970). Anderson and Bryan suggest that the sportfishery in Humboldt Bay may select the faster growing young fishes and may be a partial explanation for this phenomenon.

The age frequencies in Figure 5 do not represent the age composition of the redtail surfperch from this area. The sampling devices used were selective in capturing fish in age group III and older. Behavior is an important factor for this selective sample. Sex, age, and maturity were factors that influenced behavior. Since most of the fish were collected during the summer when gravid females were giving birth, the dominance of females that were collected in the estuary poses some questions. The majority of females (159 of 262 or 61 percent) captured in the estuary were either gravid or spent, which indicated that females gave birth there. However, otter trawling that captured many young embiotocids of other species did not reveal any concentrations of young redtails. Either the young redtails were in areas that could not be sampled because of obstacles or they returned quickly to the surf. On one occasion, Dr. Richard S. Wydoski and I visually identified young redtail surfperch in the shallow surf at Beverly Beach, north of Newport. During the same time that gravid females were prevalent in the estuary, males were more prevalent in the surf several miles from the mouth of the estuary. Sampling the surf zone with nets no doubt would have produced fish from the younger age groups. This was not feasible because of prevalent rough surf conditions and lack of manpower. The lack of knowledge of fishes inhabiting the surf zone has been attributed to the difficulties in sampling this habitat (Schaefer, 1967).

Annulus Formation

The time of annulus formation varies considerably in the Embiotocidae. This timing is governed by the seasonal rate of growth that is influenced by factors such as water temperatures and available food. Table 20 shows a trend in annulus formation with latitude. Annulus formation as shown by new growth on the scale margin occurred earlier in the south and later in the north. The age of the fish should also be considered in the time of annulus formation because younger fish will begin to grow before older fish.

Reproduction

Mating in the redtail surfperch occurred from late December to early January. Milt was readily emitted from males collected in early January. Histological sections of testes that were collected on January 13, 1969 confirmed the stages of maturity from ripe to spent for different males as judged from macroscopic examination. Embryos between 7.3 and 10.5 mm in standard length were taken from females collected during the third week of April. Although previous investigators reported that spermatazoa may be stored in the female for a period of time before egg fertilization in other embiotocids (Eigenmann, 1892, Hubbs, 1921, and Wares, 1968) this phenomenon probably does not occur in the redtail surfperch, based on the sizes of the

Table 20. Comparison of the time of annulus formation in Embiotocidae by location on the Pacific Coast.

Species	Location	Time of Annulus formation	Reference
Amphigonopterus aurora and Micrometrus minimus	Southern California	December	Hubbs (1921)
Amphistichus argenteus	Southern California	September-April	Carlisle et al. (1960)
Cymatogaster aggregata and Phanerodon furcatus	Northern California	March or April	Anderson and Bryan (1970)
Amphistichus rhodoterus	Central Oregon	February-June	(this study)
Embiotoca lateralis	Central Oregon	March 15-June 12	Swedberg (1965)
Rhacochilus vacca	Central Oregon	May	Wares (1968)
Cymatogaster aggregata	Northern Washington	May	Suomela (1931) and Gordon (1965)
Taeniotoca lateralis	Northern Washington	December-May	Sivalingam (1953)

embryos during the fourth month after mating.

Size and age at first maturity varies for different embiotocids. Shiner perch males were reported to be sexually mature during their first year of life (Hubbs, 1921). Based on macroscopic examination and a maturity index, I concluded that 70 percent of the male redtail surfperch were mature in age group II and all were mature in age group III. Carlisle *et al.* (1960), reported that barred surfperch, *Amphistichus argenteus*, reach sexual maturity in their second year of life. Swedberg (1966) reported that 23 percent of age group II male striped seaperch were mature while Gnose (1968) reported that 31 percent were mature for the second age group in the male species. Based on relative gonad size, Wares (1968) reported that some males from age group II of pile perch were sexually mature.

This study has shown that the number and size of embryos increases with the size of female redtail surfperch. This positive correlation between fecundity and increasing size of the female has been reported for other species of Embiotocids (Eigenmann, 1892; Carlisle *et al.*, 1960; Gordon, 1965; Hubbs, 1921; Suomela, 1931; Swedberg, 1965; Wares (1968; and Wilson and Millemann, 1969). In addition, Carlisle *et al.* (1960) reported that larger females bear young earlier in the barred surfperch.

The spawning periods of the Embiotocidae appear to vary geographically (Table 21). The period is earlier for embiotocids in

Table 21. Comparison of spawning seasons in the Embiotocidae by location on the Pacific Coast.

Species	Location	Spawning season	Reference
Hyperprosopon argenteum	Southern California	March-May	Rechnitzer and Limbaugh (1952)
Amphistichus argenteus	Southern California	March-May	Carlisle *et al.* (1960)
Embiotoca lateralis	Central Oregon	May-Sept.	Swedberg (1965) and Gnose (1965)
Rhacochilus vacca	Central Oregon	May-Sept.	Wares (1968)
Amphistichus rhodoterus	Central Oregon	July-Sept.	(This study)
Cymatogaster aggregata	Northern Washington	July-August	Suomela (1931) and Gordon (1965)
Embiotoca lateralis	Northern Washington	June-July	Blanco (1938)
Cymatogaster aggregata	Southern British Columbia	June-July	Wiebe (1968)

southern waters and becomes later with embiotocids inhabiting northern waters.

Food Habits

Redtail surfperch are well adapted for feeding on benthic and drifting organisms. Their body form and quick swimming movements allow them to effectively capture food in the surging surf zone. No doubt these surfperch are opportunistic feeders, since they live in a habitat that is turbid from wave action. On one occasion a bright fluorescent red yarn fly caught surfperch more readily than mussel mantle from a highly turbid surf. This situation indicated that sight plays an important role in their feeding behavior. Their well formed jaw teeth enable them to feed on sessile food organisms while the well formed pharyngeal teeth permits crushing of hard food items. The diets of both small and large fish were similar. The main difference was that smaller fish feed on smaller organisms.

Parasites

Infestation by parasites did not appear to harm the surfperch that were examined. Except for rather large numbers of digenetic trematodes from the intestine of the surfperch, only small numbers of the other parasites were observed. Although the incidence and infestation rate of the various parasites were analyzed by month and by size and age of the surfperch, these analyses did not consider the biology of the parasites. Other workers at the Marine Science Center in Newport are investigating this subject.

Sport Fishery Potential

The redtail surfperch is the species that can offer the greatest recreational potential along the extensive sandy beaches of the Oregon coast. A sport fishery of fair magnitude exists on the species in Washington and northern California. Baxter (1960) stated that the redtail is the number one sport fish in the surf-angler's catch in northern California. Miller and Gotshall (1965) stated that the redtail surfperch is second to the barred surfperch in the catch for shore fishermen from Point Arguello, California to Oregon. Also since most of the Washington coast is composed of sandy beaches, the redtail is the main fish available for sport along the coast. On one occasion, R. S. Wydoski (personal communication) observed approximately 100 surfperch fishermen on about one mile of shoreline at Copalis Beach, Washington. Surfperch fishermen have indicated that fishing pressure has been increasing along these beaches.

While collecting specimens for this study, catch-per-angler-hour records were kept to determine the sport fishery potential for the redtail. The catch per angler hour varied from 0.08 to 1.85 for Alsea Bay and from 0.00 to 4.17 for the surf zone. This success was comparable with data collected in northern California. The catch of redtail surfperch near the outfall of an atomic steam-generation plant in Humboldt Bay, California, ranged from less than one to four fish per angler hour (Allen et al., 1970). This embiotocid provided the highest catch per angler hour among the different species taken in this study of Humboldt Bay.

SUMMARY

1. The redtail surfperch is perhaps the species offering the greatest recreational potential along the extensive sandy beaches from northern California to the Canadian border. Published literature on the biology of this species is sparse. This study summarizes the biology for this species.

2. The scale method of age determination was satisfied and a relationship between the total length of the fish and the anterio-lateral radius of the scale was calculated as SR = 0.44 TL - 12.42 where SR = scale radius and TL = total length. Consistency tests of age determination agreed 85.9 percent between two scale readers and 96 percent between scales and otoliths.

3. The time of annulus formation occurred between February and June. Smaller and younger fish had new growth on the scale margin earlier than larger and older fish.

4. Calculated mean total lengths in mm at the end of each season of growth were:

Age Group	Female	Male
I	103	104
II	160	161
III	211	208
IV	254	240
V	284	264
VI	312	280
VII	334	293
VIII	357	312
IX	-	333

Females grew faster than males after age group II.

5. Equations were calculated to convert total length (TL) to standard length (SL) or forked length (FL) as follows: SL = 0.81 TL - 5.29 and FL = 0.95 TL - 5.09.

6. The largest female that was collected measured 375 mm in total length and the largest female weighed 1,125 g. The largest male collected was 338 mm in total length, while the heaviest male weighed 620 g.

7. About one-fifth of the female surfperch were mature for the first time in age group III, nearly 88 percent were mature in age group IV, and almost all were mature in age group V. Seventy percent of the male surfperch were sexually mature in age group II and all were mature in age group III.

8. Mating occurred during late December and early January and spawning occurred during July through September.

9. Linear regressions were calculated that describe the positive relationship between female size and fecundity.

10. The mean size of embryos was positively correlated to the size of the female for the last three months of the gestation period. Newly born redtail surfperch were 66 to 83 mm in total length for females held under laboratory conditions.

11. Food of surfperch from the surf zone consisted mostly of crustaceans, fish, molluscs, and polychaetes. In both the frequency

of occurrence and total volume, crustaceans were the most important group. The diets of small and large fish were similar; the main difference was that small fish feed on smaller food organisms.

12. Parasites of the redtail surfperch were: immature nematodes (Anisakinae), the digenetic trematode, *Genitocotyle acirra*, the monogenetic trematode, *Diclidophora* sp., and copepods (*Caligus* sp., *Clavella* sp., and *Argulus catostomi*).

BIBLIOGRAPHY

Alder, H. L. and E. B. Roessler. 1960. Introduction to probability and statistics. San Francisco, W. H. Freeman and Co. 252 p.

Allen, G. H., L. B. Boydstun, and F. G. Garcia. 1970. Reaction of marine fishes around warmwater discharge from an atomic steam-generating plant. Progressive Fish-Culturist 32(1):9-16.

Anderson, R. D. and C. F. Bryan. 1970. Age and growth of three surfperches (Embiotocidae) from Humboldt Bay, California. Transactions of the American Fisheries Society 99(3):475-482.

Barnes, R. D. 1963. Invertebrate zoology. Philadelphia, Saunders. 632 p.

Barnhart, P. S. 1936. Marine fishes of Southern California. Berkeley, University of California Press. 209 p.

Baxter, J. L. 1960. Inshore fishes of California. Sacramento, California Department of Fish and Game. 80 p.

Blanco, G. J. 1938. Early life history of the viviparous perch, Taeniotoca lateralis Agassiz. Philippine Journal of Science 67(4):379-391.

Carlisle, J. G. Jr., J. W. Schott and N. J. Abramson. 1960. The barred surfperch (Amphistichus argenteus) in Southern California. California Department of Fish and Game, Fish Bulletin no. 109. 79 p.

Clemens, W. A. and G. V. Wilby. 1961. Fishes of the Pacific Coast of Canada. Second edition Fisheries Research Board of Canada. Bulletin no. 68. 443 p.

Eigenmann, C. H. 1892. Cymatogaster aggregata Gibbons; a contribution to the ontogeny of vivparous fishes. Bulletin of the United States Fisheries Commission 12:401-478.

Eigenmann, C. H. and A. B. Ulrey. 1894. A review of Embiotocidae. Bulletin of the United States Fisheries Commission 12:382-400.

Girard, C. F. 1854. Notice upon vivparous fishes inhabiting the Pacific coast of North America with an enumeration of the species observed. Proceedings of the Boston Society of Natural History 5:81-82.

Gnose, C. 1968. Ecology of the striped seaperch (Embiotica lateralis) in Yaquina Bay, Oregon. Master's thesis. Corvallis, Oregon State University. 53 numb. leaves.

Gordon, C. D. 1965. Aspects of the age and growth of Cymatogaster aggregata Gibbons. Master's thesis. Vancouver, University of British Columbia. 90 numb. leaves.

Gotshall, D. W., J. G. Smith and A. Holbert. 1965. Food of the blue rockfish Sebastodes mystinus. California Fish and Game 51(3):147-162.

Hile, R. 1948. Standardization of methods of expressing lengths and weights of fish. Transactions of the American Fisheries Society 75:157-164.

Hubbs, C. L. 1921. The ecology and life-history of Amphigonopterus aurora and of other vivparous perches of California. Biological Bulletin 40:181:209.

Jordon, D. S. 1885. A catalogue of the fishes known to inhabit the waters of North America, north of the Tropic of Cancer, with notes on the species discovered in 1883 and 1834. Report of the United States Commission of Fisheries, part 13. 185 p.

Jordon, D. S., B. W. Everman, and H. W. Clark. 1930. Check list of fishes and fishlike vertebrates of North and Middle America, north of the northern boundary of Venezuela and Columbia. Report of the United States Commission of Fisheries, part 2, 670 p.

Jordon, D. S., and B. W. Evermann. 1896. A check-list of the fishes and fish-like vertebrates of North and Middle America. Report of the United States Commission of Fisheries, part 21. 207-584.

Larimore, W. R. 1957. Ecological life history of the warmouth (Centrarchidae). Illinois Natural History Survey Bulletin 27(1) August, 1957.

Light, S. F. 1954. Intertidal invertebrates of the central California coast. Berkeley, University of California. 446 p.

Mausolf, R. 1970. Professor, Peninsula College, Department of Fisheries. Personal communication. Port Angeles, Washington.

Millemann, R. E. 1967. Laboratory manual for Fisheries 490-parasites and diseases of fish. Corvallis, Oregon State University. 153 p.

Miller, D. J. 1960. Redtail surfperch, p. 62-63. In California Ocean Fisheries Resources to the Year 1960. Sacramento, California Department of Fish and Game.

Miller, D. J. and D. W. Gotshall. 1965. Ocean sportfish catch and effort from Oregon to Point Arguello, California. California Department of Fish and Game, Fish Bulletin 130. 135 p.

Olson, R. E. 1969. Research Associate, Oregon State University, Marine Science Center, Department of Zoology. Personal communication. Newport, Oregon.

Rechnitzer, A. B. and C. Limbaugh. 1952. Breeding habits of *Hyperprosopon argenteum*, a viviparous fish of California. Copeia 1:41-42.

Reed, R. J. 1968. Back-calculation and condition factor computer programs. Massachusetts Cooperative Fishery Unit, Amherst, University of Massachusetts. 3 p. with enclosure (mimeographed).

Ricker, W. E. 1958. Handbook of computations for biological statistics for fish populations. Ottawa. 300 p. (Canada. Fisheries Research Board. Bulletin 119)

Roedel, P. M. 1948. Common marine fishes of California. California Department of Fish and Game, Fish Bulletin no. 68. 153 p.

Schaefer, R. H. 1967. Species composition, size and seasonal abundance of fish in the surf waters of Long Island. New York Fish and Game Journal 14(1):1-46.

Schultz, L. P. 1936. Keys of the fishes of Washington, Oregon, and closely adjoining regions. University of Washington Publication in Biology 2(4):103-228.

Simpson, G. G., A. Roe and R. C. Lewontin. 1960. Quantitative zoology. New York, Harcourt, Brace and Co. 440 p.

Sivalingam, S. 1953. Age and growth of Taeniotoca lateralis. Master's thesis. Seattle, University of Washington. 53 numb. leaves.

Suomela, A. J. 1931. The age and growth of Cymatogaster aggregata Gibbons, collected in Puget Sound, Washington. Master's thesis. Seattle, University of Washington. 43 numb. leaves.

Swedberg, S. E. 1965. Age fecundity relationships in the striped seaperch, Embiotoca lateralis, from Yaquina Bay, Oregon. Master's thesis. Corvallis, Oregon State University. 41 numb. leaves.

Tarp, F. H. 1952. A revision of the family Embiotocidae (the surfperches). California Department of Fish and Game, Fish Bulletin no. 88. 99 p.

Van Oosten, J. 1929. Life history of the lake herring (Leucichthyes artedi Le Seur) of Lake Huron as revealed by its scales, with a critique of the scale method. United States Bureau of Fisheries Bulletin 44:265-428.

Walford, L. A. 1931. Handbook of common commercial and game fishes of California. California Department of Fish and Game, Fish Bulletin no. 28. 181 p.

Wares, P. G. 1968. Biology of the pile perch (Rhacochilus vacca). Master's thesis. Corvallis, Oregon State University. 73 numb. leaves.

Wiebe, J. P. 1968. The effects of temperature and day length on the reproductive physiology of the viviparous seaperch, Cymatogaster aggregata Gibbons. Canadian Journal of Zoology 46: 1207-1219.

Wilson, D. C. and R. E. Millemann. 1969. Relationships of female age and size to embryo number and size in the shiner perch, Cymatogaster aggregata. Journal of the Fisheries Research Board of Canada 26:2339-2344.

Woodhead, A. D. 1960. Nutrition and reproductive capacity of fish. Proceedings of the Nutrition Society 19:23-28.

Wydoski, R. S. 1970. Assistant Leader of the Washington Cooperative Fishery Unit, University of Washington, Department of Fisheries. Personal communication. Seattle, Washington.

APPENDIX

Appendix Table 1. Summary of size and age of female redtail surfperch to mean embryo size by date.

Date	Female*				Embryos**				
	Serial Number	Total Length (mm)	Weight (g)	Age Group	No.	Mean SL (mm)	S.D.	Shape of tail***	Number of malformed Embryos
4/26/67	1	322	600	6	15	10.5	0.19	r	3
"	2	297	445	4	18	9.6	0.23	r	
5/4/67	4	331	630	6	22	15.4	0.40	r	
5/11/67	5	266	326	4	9	14.6	0.42	r	
6/13/67	7	278	402	3	13	20.2	0.75	r	
"	8	281	443	4	11	26.5	0.61	r	
"	9	282	430	4	12	23.1	0.57	r	
"	10	290	450	4	11	22.8	0.34	r	
6/24/67	11	254	321	4	7	16.2	0.81	r	
6/27/67	45	332	630	6	21	31.2	0.81	r-s	
"	49	307	546	6	15	23.6	1.10	r	
"	50	250	268	4	8	21.1	0.64	r	
"	52	251	276	5	8	19.4	0.74	r	
"	53	288	434	5	7	28.7	0.49	r-s	
"	57	265	302	5	12	18.3	0.62	r	
"	59	282	368	5	8	29.9	1.36	r-s	
"	60	282	388	5	5	27.0	0.00	r-s	
"	66	276	268	4	7	27.7	0.76	r-s	
"	67	293	454	4	9	33.0	1.00	s	1
"	68	330	670	5	26	31.7	0.84	s	
"	73	275	402	6	7	21.9	0.90	r	
"	74	255	285	3	9	23.0	1.22	r	
"	75	313	620	6	23	28.4	0.66	r-s	
"	76	356	770	7	25	33.2	0.73	r-s	
"	77	330	645	6	17	37.8	0.83	s	
"	79	302	530	6	13	27.6	0.65	r	
"	80	320	620	6	25	23.4	0.65	r	
"	82	325	675	7	27	35.4	0.80	s	
"	83	330	655	7	17	34.3	0.69	s	2
"	84	298	512	4	15	32.9	0.80	s	
"	85	288	387	4	1	28.0	-	r	
"	86	370	910	7	33	35.6	1.00	s	
"	87	296	440	4	8	32.1	0.64	s	
"	88	288	473	4	9	28.4	1.13	r-s	
"	89	342	750	7	3	25.7	0.58	r	
"	90	282	401	4	10	25.1	0.74	r-s	
"	91	342	720	7	34	37.3	0.68	s	
"	92	275	366	4	6	28.5	1.05	r-s	
"	94	250	259	3	2	21.0	1.41	r	
"	95	260	328	5	8	29.6	0.74	r-s	
"	96	271	356	4	6	31.8	0.75	s	1
"	101	281	416	4	4	19.8	0.50	r	

Appendix Table 1. Continued.

Date	Female*				Embryos**				
	Serial Number	Total Length (mm)	Weight (g)	Age Group	No.	Mean SL (mm)	S.D.	Shape of tail***	Number of malformed Embryos
6/27/67	102	254	308	3	5	25.8	0.48	r	
"	103	264	342	5	6	25.3	0.82	r-s	
"	104	263	334	4	7	32.0	0.82	s	
"	105	282	400	4	11	27.0	1.23	r	
"	106	269	344	4	7	23.4	0.53	r	
"	108	271	368	4	7	22.2	0.41	r	
"	109	271	371	5	11	21.6	0.67	r	
"	110	251	275	4	5	23.0	1.23	r	9
6/28/67	145	264	350	4	11	23.2	0.75	r	
7/6/67	146	365	965	7	29	33.1	0.65	r-s	
"	147	375	1065	7	28	35.9	1.03	s	
"	148	334	710	6	23	33.3	0.63	r-s	
"	149	331	700	6	19	29.4	0.93	r	
"	150	371	1099	8	29	43.9	0.83	f	
"	151	356	900	7	32	35.9	0.81	r-s	
"	152	370	900	8	26	35.1	0.61	r-s	
"	153	325	620	6	23	25.8	0.63	r	1
"	154	362	990	8	37	35.6	0.90	s	
"	155	327	685	6	16	39.1	0.76	s	
"	156	330	640	6	11	34.8	0.81	r-s	
"	157	331	750	7	19	39.0	0.86	s	1
"	158	321	670	6	20	37.3	0.77	s	
"	159	324	610	6	21	37.7	1.10	s	
"	160	296	452	5	9	33.6	0.70	r-s	
"	161	296	490	5	13	25.0	0.74	r	
"	162	322	620	6	20	33.2	0.71	r-s	
"	163	289	402	4	13	28.3	0.77	r	
"	164	270	330	4	7	27.9	0.45	r	
"	167	284	430	4	11	32.0	0.79	r-s	
"	169	279	410	4	8	34.8	0.75	r-s	
"	170	276	410	4	4	34.5	0.58	r-s	
"	171	280	392	4	7	26.4	0.45	r	
"	173	282	416	4	10	32.8	0.54	r-s	
"	174	296	450	4	9	23.7	0.51	r	
"	175	280	430	4	9	30.6	0.77	r	1
"	176	272	360	3	5	30.5	0.35	r	
"	177	279	432	4	12	24.5	0.69	r	
"	178	276	390	4	3	26.8	1.04	r	
"	179	269	358	4	5	22.4	1.14	r	
"	180	285	384	4	10	27.9	0.85	r	
"	182	307	500	5	19	26.6	0.50	r	
"	185	265	332	4	8	25.5	0.93	r	
"	193	263	228	3	7	30.0	1.15	r	
"	213	267	330	3	11	33.3	0.84	r	

Appendix Table 1. Continued.

Date	Female*				Embryos**				
	Serial Number	Total Length (mm)	Weight (g)	Age Group	No.	Mean SL (mm)	S.D.	Shape of tail***	Number of malformed Embryos
7/12/67	258	284	418	4	7	34.6	1.03	r-s	
"	259	317	615	-	21	36.2	0.71	s	
"	260	370	1125	8	38	36.3	0.83	s	
"	262	281	410	4	5	38.8	0.91	s-f	3
"	264	304	481	4	14	30.8	0.85	r	
7/12/67	265	295	472	4	12	36.8	1.05	r-s	
"	268	282	393	4	4	31.4	0.63	r-s	
"	269	280	394	4	9	35.5	1.03	r-s	
"	271	271	356	4	8	28.4	0.52	r	
"	272	270	360	3	9	26.7	0.67	r	
"	274	267	338	3	6	28.7	0.82	r	
"	276	312	595	7	19	34.1	0.89	r-s	
"	280	243	254	3	9	24.3	0.62	r	
8/14/67	284	298	471	4	11	48.5	0.84	f	
"	286	287	349	5	9	42.9	0.77	s-f	
"	287	272	337	3	6	42.8	0.52	s	
"	288	245	233	3	5	34.2	0.91	r-s	
"	290	275	377	5	11	42.5	1.40	s-f	
"	293	287	388	4	7	52.6	0.38	f	
"	294	280	355	4	6	46.1	0.38	s	
"	295	287	285	4	4	53.5	1.00	f	
8/15/67	297	280	398	4	10	41.4	0.79	s-f	
"	298	300	461	5	6	53.2	1.17	f	
"	299	293	449	5	10	52.3	0.98	f	
"	300	343	780	7	22	54.2	1.10	f	
"	301	314	590	6	18	48.6	0.88	s-f	
"	302	286	417	4	12	44.4	1.22	s-f	
"	303	319	543	7	13	48.7	1.65	f	
"	304	339	675	7	19	50.8	1.55	f	
4/19/68	420	247	252	3	6	8.4	0.18	r	
4/20/68	424	297	472	5	14	9.7	0.27	r	
"	425	277	336	4	14	7.3	0.43	r	
5/4/68	428	254	272	4	9	11.1	0.24	r	
"	432	281	378	5	11	10.7	0.20	r	
"	433	244	252	4	11	10.1	0.32	r	
"	436	274	367	4	9	10.9	0.17	r	
5/5/68	439	314	510	5	20	11.3	0.27	r	
"	442	297	425	5	16	13.5	0.32	r	
5/10/68	448	283	384	5	12	15.6	0.47	r	
"	449	293	381	5	11	13.5	0.17	r	
"	450	289	393	5	13	15.0	0.58	r	
"	451	286	372	5	11	16.5	0.31	r	
"	452	256	-	4	8	12.1	0.44	r	

Appendix Table 1. Continued.

Date	Female*				Embryos**				
	Serial Number	Total Length (mm)	Weight (g)	Age Group	No.	Mean SL (mm)	S. D. of	Shape of tail***	Number of malformed Embryos
5/10/68	453	296	446	6	18	13.4	0.35	r	
"	454	296	458	5	16	14.6	0.25	r	
"	455	250	248	4	1	14.6	-	r	
"	456	241	225	3	8	15.8	0.29	r	
"	457	285	394	5	12	16.2	0.30	r	
"	458	250	253	4	7	15.7	0.17	r	
6/12/68	460	260	306	4	2	23.0	0.00	r	
"	461	298	478	5	13	20.5	0.35	r	
"	462	310	534	5	22	25.0	0.67	r	
6/21/68	463	349	765	7	28	33.2	0.43	r	1
"	464	312	530	6	18	31.3	0.60	r	
"	465	279	375	5	9	25.3	0.62	r	1
"	466	365	970	7	39	31.9	1.68	s	
"	467	272	337	4	13	25.6	0.76	r	
"	468	303	543	5	20	28.1	0.53	r	
"	469	283	386	4	12	27.3	0.58	r	
"	470	306	509	6	19	29.8	0.62	r	
"	471	278	402	5	12	25.2	0.40	r	
"	472	310	555	6	22	25.3	0.45	r	
"	473	288	451	4	13	28.4	0.70	r	
"	474	337	685	6	25	28.4	1.46	r	
"	475	366	885	7	27	30.6	0.52	r	
"	476	316	610	6	19	31.3	0.51	r	
"	477	245	304	3	9	23.7	0.35	r	
"	479	297	271	5	13	28.9	0.84	r	
"	482	263	331	4	12	25.5	0.62	r	
"	484	282	406	5	12	25.5	0.54	r	
"	486	291	404	6	13	26.1	0.49	r	
"	487	290	426	6	11	25.5	0.69	r	
"	488	320	570	7	21	30.9	0.48	r	
"	489	255	297	3	9	26.9	0.74	r	
"	490	278	370	4	9	26.1	0.22	r	
"	491	292	423	5	11	26.2	0.41	r	
"	492	302	469	5	6	31.9	0.74	r	4
"	493	291	426	5	16	29.9	0.70	r	
7/3/68	536	275	330	4	9	27.2	0.35	r	
7/6/68	550	292	434	6	9	33.6	0.77	s	
7/18/68	577	293	405	6	14	35.8	0.99	s	
8/5/68	594	315	590	7	18	51.8	1.55	f	

* Lengths and weights taken from fresh fish; malformed embryos excluded from analysis.

** Lengths taken from embryos preserved in 10% formalin.

*** r-round; s-square; f-forked.

Appendix Table 2. Shrinkage of redtail surfperch embryos preserved in 10 percent formalin.

Condition	Dates Measured	Mean Standard Length (mm)*	Mean Correction Factor**
Fresh	5/11/68-7/3/68	26.17***	-
Preserved	9/15/69-11/7/69	24.25	1.089
Preserved	4/6/70-4/10/70	24.16	1.093

* Mean of embryo means for individual females

** $C.F. = \frac{S.L.\ Fresh}{S.L.\ Preserved}$

*** Mean standard lengths for fresh embryos from 13.7 to 34.7 mm

Appendix Table 3. The size of embryos at birth for redtail surfperch held in the laboratory. Females arranged by increasing lengths.

	Size of Female			Size of Embryo		
Date of Birth	Total Length in mm	Weight in g	Age Group	Standard Length in mm	Total Length in mm	Weight in g
8/20/68	281	505	6			
				50	67	3.15
				49	66	2.94
				52	69	3.58
8/26/68				54	70	3.50
				53	69	3.55
				53	70	3.62
			Mean Size	51.8	68.5	3.39
			Standard Deviation	1.94	1.64	0.278
8/20/68	286	500	4			
				56	73	4.72
				58	75	5.18
				58	74	4.80
				57	76	4.89
				59	77	5.37
				56	74	4.73
				60	77	5.59
			Mean Size	57.7	74.9	5.04
			Standard Deviation	1.50	1.57	0.344
8/26/68	292	520	4			
				58	75	5.20
				58	76	5.78
				58	75	5.42
				58	74	5.30
				58	76	5.70
8/28/68				60	77	5.83
				59	76	5.82
				60	77	5.90
				59	76	5.72
8/29/68				58	76	5.50
				59	76	5.60
				58	75	5.50
				59	78	6.20
				58	75	5.50
			Mean Size	58.6	75.9	5.64
			Standard Deviation	0.75	1.03	0.266

Appendix Table 3. Continued.

Date of Birth	Size of Female Total Length in mm	Weight in g	Age Group	Size of Embryo Standard Length in mm	Total Length in mm	Weight in g
	294	419	5			
9/6/68				64	83	8.00
				64	81	7.62
				64	81	8.03
				63	79	7.30
				64	80	7.53
				67	82	7.90
				64	81	7.58
9/17/68				62	79	7.15
9/19/68				61	78	8.17
				66	83	8.90
			Mean Size	63.9	80.7	7.82
			Standard Deviation	1.728	1.70	0.502