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Title: BIOLOGY OF THE PILE PERCH (Rhacochilus vacca)

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Data were gathered on the life history of the pile perch (Rhacochilus vacca) from Yaquina Bay, Oregon, between April, 1966, and July, 1967. Pile perch feed on the bottom and consume mostly molluscs, barnacles and decapod crustaceans. Food habits varied among seasons and locations within the bay, whereas the diet of young-of-the-year perch differed only slightly from the diet of older fish. Mating occurred from October to January and the young were born from mid-July to mid-August. Timing of the reproductive cycles coincided in the two years observed. The gestation period is approximately six months. Fecundity was positively correlated with lengths of fish. An intraovarian mortality rate of 4.8 percent was estimated. Instantaneous daily growth rates in weight of 0.0606 for embryos and 0.0093 for newborn fish were estimated. About one-third of the females were mature at age III and nearly all were mature at age IV. Longevity exceeded ten years and maximum attainable lengths (l_∞) of 432 and 490 mm (TL) were estimated for males and females, respectively. Females grew slightly faster than males. Few perch of age classes I and II were captured. Females generally occurred higher (upstream) in the bay than males. Pile perch were commonly host to the copepods, Clavella and Lepeoptheirus; the nematode, Cucullanus;and metacercariae of bucephalid trematodes. The rate of copepod infestations varied seasonally.

Biology of the Pile Perch
(*Rhacochilus vacca*)

by

Paul Gordon Wares

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Typed by Velda D. Mullins for Paul Gordon Wares

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The studies described herein were conducted to obtain basic information on the life history of the pile perch (Rhacochilus vacca). The specific objectives of the study were to investigate age and growth, reproduction, food habits and parasites of the species. My broad objective was to develop knowledge of the general biology of the pile perch which could assist conservation agencies in the formulation of sound management decisions.

The pile perch, also called dusky seaperch or porgy by local fishermen, is one of the larger members of the family Embiotocidae, a family distinguished by its extraordinary viviparity. This species ranges from southeastern Alaska to southern California and is commonly caught along rocky shores, in bays, and especially around wharf pilings from which it probably gets its common name. Parrish (1966) found that the pile perch was the third most important food fish, by weight,in the creel of sportfishermen in Yaquina Bay. Morgan (1961) reported the species as the most abundant embiotocid in Siletz Bay, Oregon. Pile perch were listed as "... a moderately important commercial species..." by Tarp (1952).

Yaquina Bay was selected for the field work of this study because of the convenience of the facilities of Oregon State University's Marine Science Laboratory located on the bay. There is also a rapidly increasing knowledge of the physical and biological characteristics of this bay to which the findings of this research can ultimately be related. The field work was conducted between April, 1966, and July, 1967, in cooperation with a study of the movement and migration of pile perch and three other important food fish: the striped seaperch (Embiotoca lateralis), the white seaperch (Phanerodon furcatus) and the starry flounder (Platichthys stellatus). The effort and equipment for collecting specimens were shared between the two studies.

There is little published information on the biology of the pile perch. Wales (1929) observed a large school of pile perch mating in water about 15 feet deep at the fish wharf in Monterey Bay, California, on December 20, 1928. Rechnitzer and Limbaugh (1952) noted that they begin giving birth about the middle of April in the ocean near La Jolla, California. Morgan (1961) found in the upper part of Siletz Bay, Oregon, that the pile perch was the most abundant viviparous species; the population was at its peak from June to July, when it was comprised mostly of gravid females; and very few unspawned females were found by late August. Additional references to literature pertinent to my study are cited in the text.

This research was supported principally by a grant from the Sport Fishing Institute and the Oregon Agricultural Experiment Station through the Department of Fisheries and Wildlife.

METHODS

Description of Study Area

Yaquina Bay is the estuary of the Yaquina River located on the central Oregon coast. The river empties into the Pacific Ocean between mile-long jetties at the town of Newport in Lincoln County. A map of that portion of the estuary in which pile perch were found during this study is shown in Figure 1.

I have divided the bay into three zones, lower, middle and upper, for convenience of discussion. These zones coincide with the three realms of sediment deposition: marine, marine-fluviatile and fluviatile (Kulm 1965). Other distinctive environmental aspects of these zones are: the lower zone characterized by deep water, strong tidal currents, scoured sandy bottom, a nearly oceanic temperature, salinity and biota; the middle zone characterized by shallow depths, moderate currents, soft silty bottom, intermediate temperature, salinity and biota (here the eel grass, Zostera, is a dominating element); the upper zone characterized by moderate depth, hard mud-gravel bottom, fairly strong currents, highly fluctuating temperature and salinity and an increasing fresh water biota. Burt and McAlister (1959) have described the estuary as partly mixed (fresh and salt water) from February to May and well mixed from August to January.

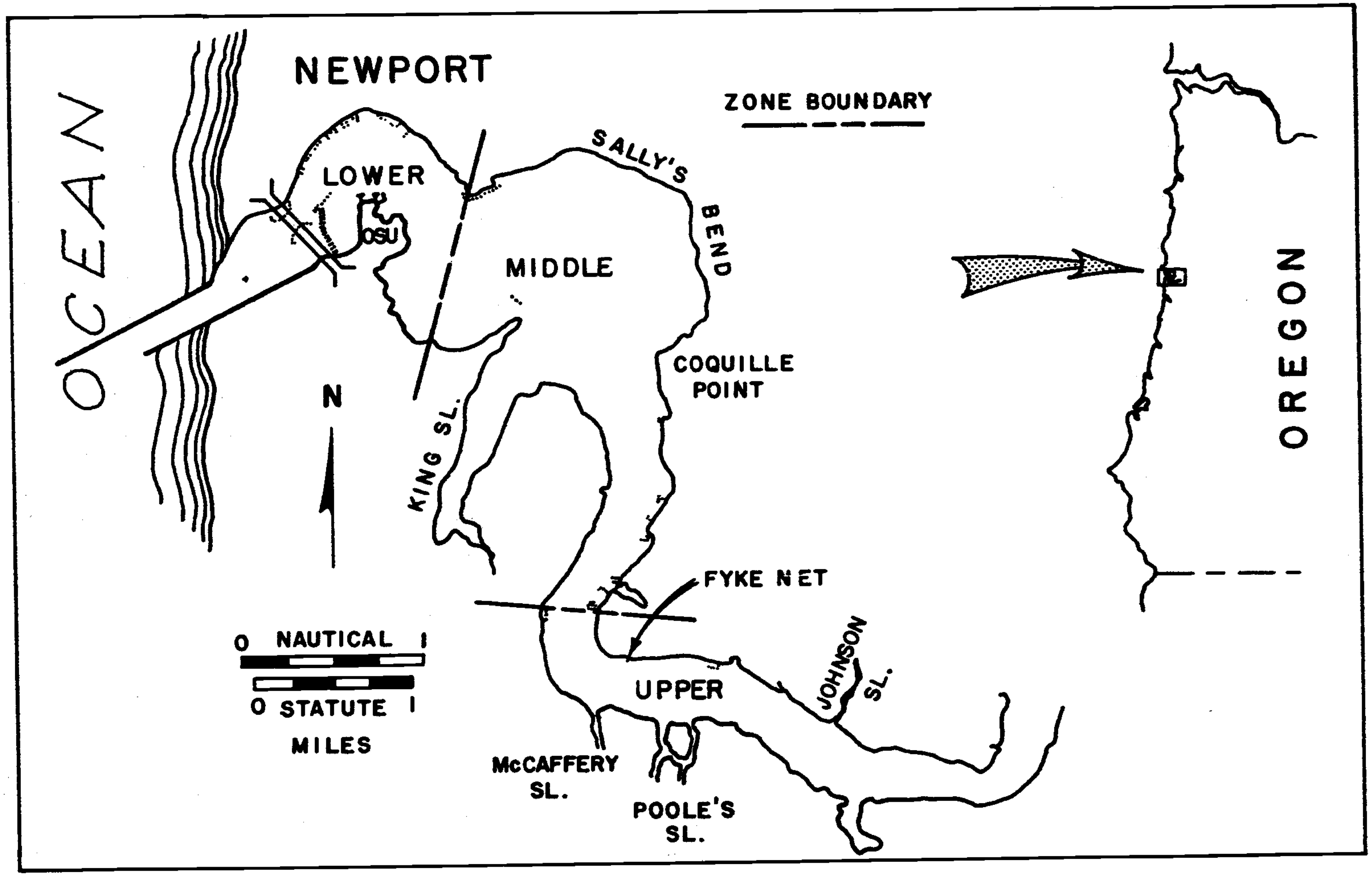


Figure 1. Map of Yaquina Bay, Oregon, showing that portion of the Yaquina River estuary in which pile perch occur.

Sampling Schedule

My plan was to sample pile perch in Yaquina Bay with equal effort throughout the year. However, emigration of fish from the study area and rigorous weather reduced the frequency and success of sampling during the fall and winter months. As a result, the number of specimens obtained from October through March was small in comparison to the number collected from April through September.

Sampling Gear

The diversity of gear used to sample pile perch made it possible to collect specimens of all age classes comprising the population. Fish were captured with gill nets, a beach seine, an otter trawl, a fyke net, and on hook and line. The seine, otter trawl, and hook and line were used throughout the year. Use of the gill nets was restricted to the period December, 1966, to July, 1967. High water levels, strong tidal currents and drifting debris made it impractical to use the fyke net during the winter months.

Two monofilament and one multifilament, nylon gill nets were used. The two monofilament nets were 100 ft. long by 5 ft. deep and contained four panels having stretched mesh sizes of 2, 3, 3-1/2 and 4-1/2 inches, respectively. These nets were cumbersome to use, were difficult to set in rough weather, and became clogged with debris in strong tidal currents. Despite these drawbacks, they produced more of the specimens used in this study and were the least selective of all the apparatus used. The monofilament gill nets usually were fished nearly perpendicular to the current, but on occasion were set parallel to the current in the lower bay near the laboratory dock. Most gill net sets in the upper bay were in water from 6 to 12 ft. deep. Many sets in the lower bay were made in water nearly 30 ft. deep. These nets were always fished on the bottom and never intentionally drifted.

The multifilament gill net was 300 ft. long by 12 ft. deep and had a stretched mesh of 5 inches. This large mesh gill net was used occasionally to secure larger specimens. The net was set in a semi-circle in shallow water (less than 10 ft.) at slack tide, and then the water within the arc was slapped with a long pole for about 10 minutes. Immediately the net was retrieved and the fish removed.

The beach seine was 200 ft. long by 8 ft. deep and had a bag of 1/2-inch square mesh. Use of the seine was limited to areas near shore having suitable slope and freedom from obstruction. Although used infrequently, the beach seine did provide some of the fish used in my study. Since both large and small perch were captured in the seine, it did not appear to be a selective method of sampling.

The semi-balloon otter trawl was a small shrimp try-net with a 16 ft. opening. It was towed behind a 17 ft. skiff powered by an 18 hp. outboard motor at speeds of about 2 to 3 knots. This convenient piece of gear was used almost exclusively for sampling young-of-the-year perch. Unfortunately, the trawl was not efficient in capturing pile perch older than two years.

Fyke nets are essentially a series of funnels which lead fish to an area of capture. The one used in my study had steel frames 10 ft. in diameter and the over-all net was 18 ft. long (Figure 2). The net was usually set at high tide and retrieved at low tide. Many times the net was fished for a full tidal cycle, and occasionally for two full cycles when difficulty was encountered either in setting or retrieving the device. The fyke net was located on the north bank of the estuary about 4.5 nautical miles above the mouth of the bay (Figure 1). Setting the net was accomplished by rolling it into the water with its long axis parallel to the shore. The open end faced upstream and to it was attached a bridle, swivel, and about 50 ft. of 1/4-inch steel rope which served to anchor the net to a large rock at water's edge. Another steel rope was fastened in the middle and looped over the cylinder so that it wound around the net as it was rolled into the water. This cable passed through a block attached to a drift log on shore and was used to hold the net at the desired fishing depth and to retrieve the net with the aid of a truck. The

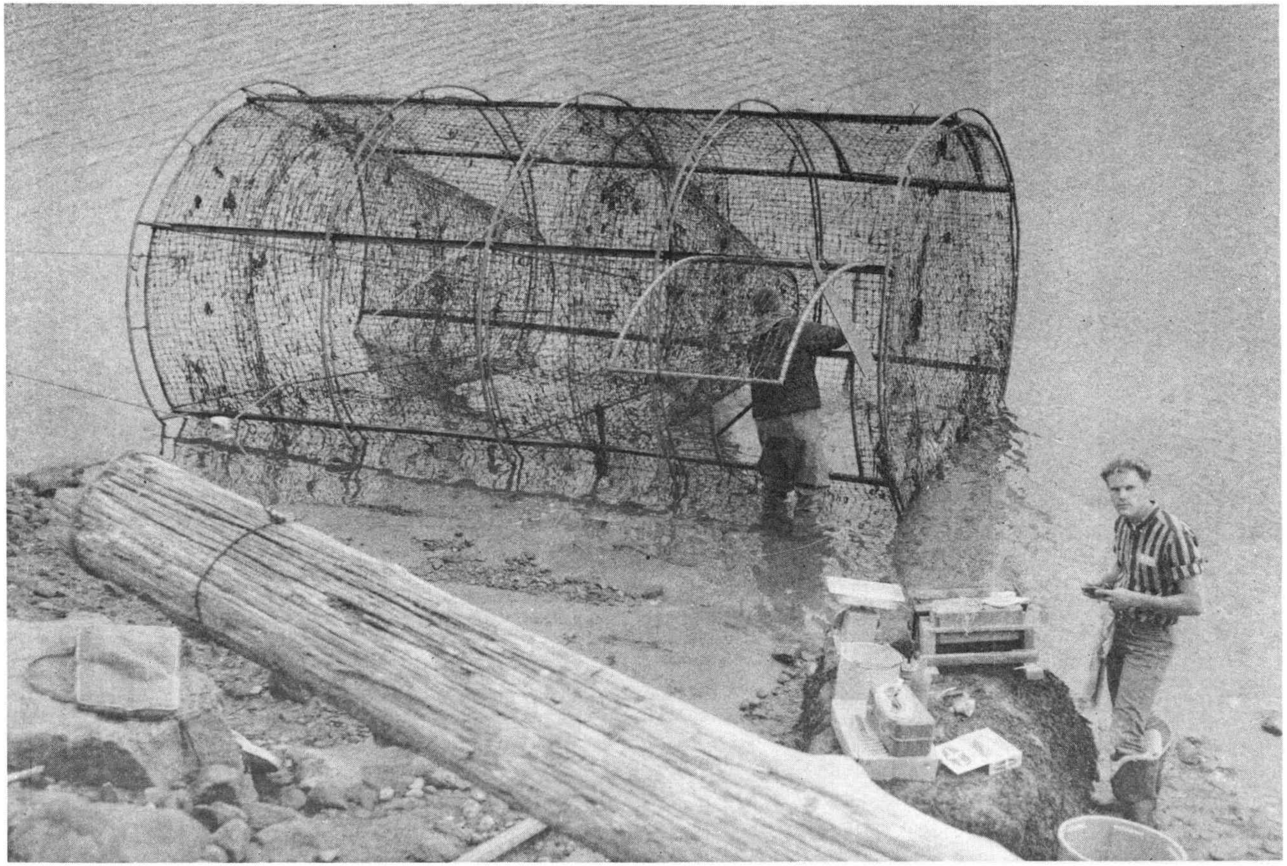


Figure 2. The steel fyke net used to capture pile perch in Yaquina Bay during 1966 and 1967.

value of the fyke net for food habits studies was limited because the captured fish were confined within the trap for varying periods and usually had empty stomachs when examined.

Pile perch were often captured using hook and line gear. In the upper part of the bay, one or two hooks baited with mud shrimp (Upogebia) or ghost shrimp (Callianassa) and fished on the bottom provided a reliable method of catching perch above age class II. In the lower bay, pile perch were caught most easily on hooks baited with barnacles (Balanus) or mussels (Mytilus edulus) drifted on an unweighted line among pilings at high tide. Often data were gathered from the creels of bank anglers about 1/4-mile above the location of the fyke net. Anglers at this location caught all species of Embiotocidae commonly occurring in Yaquina Bay, with pile perch being one of the most abundant species in the catch.

Data Collected From Specimens

Almost all of my measurements were made on freshly sacrificed specimens. Occasionally I held fish alive in sea water for later measurement at the laboratory. One sample of six fish was held frozen for a week prior to examination. Small fish (age class O) were preserved in 10 percent buffered sea water formalin immediately after capture and examined several days later. Data obtained for each specimen included: Collection number; species; location of capture; date; total body length in mm; weight to the nearest 0.1 oz. (converted later to g); length and width of one testis, or number of the collecting jar in which the ovary was preserved; number of the jar in which the stomach was preserved, or a note if the stomach was empty; kind of collecting gear used; and the collector's name.

To achieve the uniformity necessary to confirm the relationship between scale growth and body length, a "key scale" located five scales below the lateral line in the scale column originating below the third dorsal spine was selected from each fish. This scale was chosen because of its large and uniform size. A scale was removed from each side of the fish. In the event one (or both) of the key scales was found to be regenerated, the scale immediately anterior or posterior to the key scale was removed and stored in a scale envelope.

Parasite Study

Fish of both sexes and all ages were posted shortly after they had been killed. This work was performed in the laboratory. Routinely, the digestive tract, liver, spleen, kidney, heart and gills were examined under a binocular microscope. Each gill arch was also examined, and the digestive tract was slit lengthwise to remove the contents for examination. The internal surface of the tract was examined under a stream of tap water issued from a squeeze bottle. When excessive amounts of slime adhered to the mucosa, the tissue was shaken vigorously in a pint jar filled two-thirds with tap water and then re-examined. Any parasites in the wash water were recovered by settling and decanting. Parasites were killed, fixed and prepared for identification by the methods recommended by Millemann (1967). The parasite data were analysed using a statistic which I shall call "infestation rate" and define as: the number of parasites divided by the number of fish examined.

Food Habits Study

For convenience and usefulness in analysis of food habits data, collections were grouped by seasons of the year and three "zones" of Yaquina Bay. The seasons are defined as: spring (March-May); summer (June-August); fall (September-November) and winter (December-February). The lower, middle and upper zones are defined in Figure 1. The combination of both groupings results in 12 sampling units (lower-spring, middle-summer, etc.).

Food habits were studied by analysing the gut contents volumetrically. The volumetric analysis required that a constant proportion of the alimentary canal be sampled from each fish. This presented a problem in that the Embiotocid digestive tract is not differentiated clearly into stomach and intestine, nor is it marked by the presence of pyloric caecae. Consequently, for the purposes of this study the "stomach" was defined as that portion of the alimentary canal between the pharyngeal mill and the apex of the first bend in the canal.

The stomach was removed by first tying off its posterior end with nylon string, clamping its anterior end with surgical forceps, pulling it free and cutting the canal below the tied string. The stomach was slit after removal and dropped in an eight ounce jar containing 10 percent buffered formalin. Some stomach samples were stored four months prior to examination.

For examination, the contents of each stomach were rinsed in tap water, drained and placed in a shallow dish. Food fragments were identified as specifically as possible and sorted under a dissecting microscope. The volume of each food item was measured to the nearest 0.1 ml. The sum of the volumes of all food items in a stomach was defined as "actual stomach volume." These volumes were considered minimal, however, as a certain amount of unidentifiable slime was lost during washing and was therefore not included in the total volumes.

The volumetric analysis was patterned after the method outlined by Reimers (1964). This method essentially reduces food volumes to per unit weight of fish and allows for an objective estimation of the fullness of each stomach. This is accomplished indirectly by assuming that stomach capacity ("potential volume") of each individual fish is a function of its weight. A graph from which the potential volume of the stomach of each fish can be read is similar to a weight-length curve except that the units of the ordinate were adjusted to give potential volume (Figure 3).

The relationship of potential volume to length was determined by removing two empty stomachs in the manner described above and filling them with water from a squeeze bottle. The averages of three separate fillings of each are plotted with a (+) in Figure 3. The curve in the figure was derived by transposing the weight-length relationship for male pile perch (discussed later) so that it intercepted the volume plot of the larger water-filled stomach. This curve was used to determine "potential stomach volume" for each fish. Actual volumes of food items were then expressed as percent of the assumed potential capacity of the stomach. "Percent of potential" volume for a given food item within a sampling unit (season-locality) was determined by the average (i.e., the sum of the percent of potential volume that the item filled for each fish, divided by the number of fish sampled). Summing the average percentage values of all food items within each sampling unit gave the average fullness of the stomachs sampled. Dividing values for individual food items by this value gave the values termed

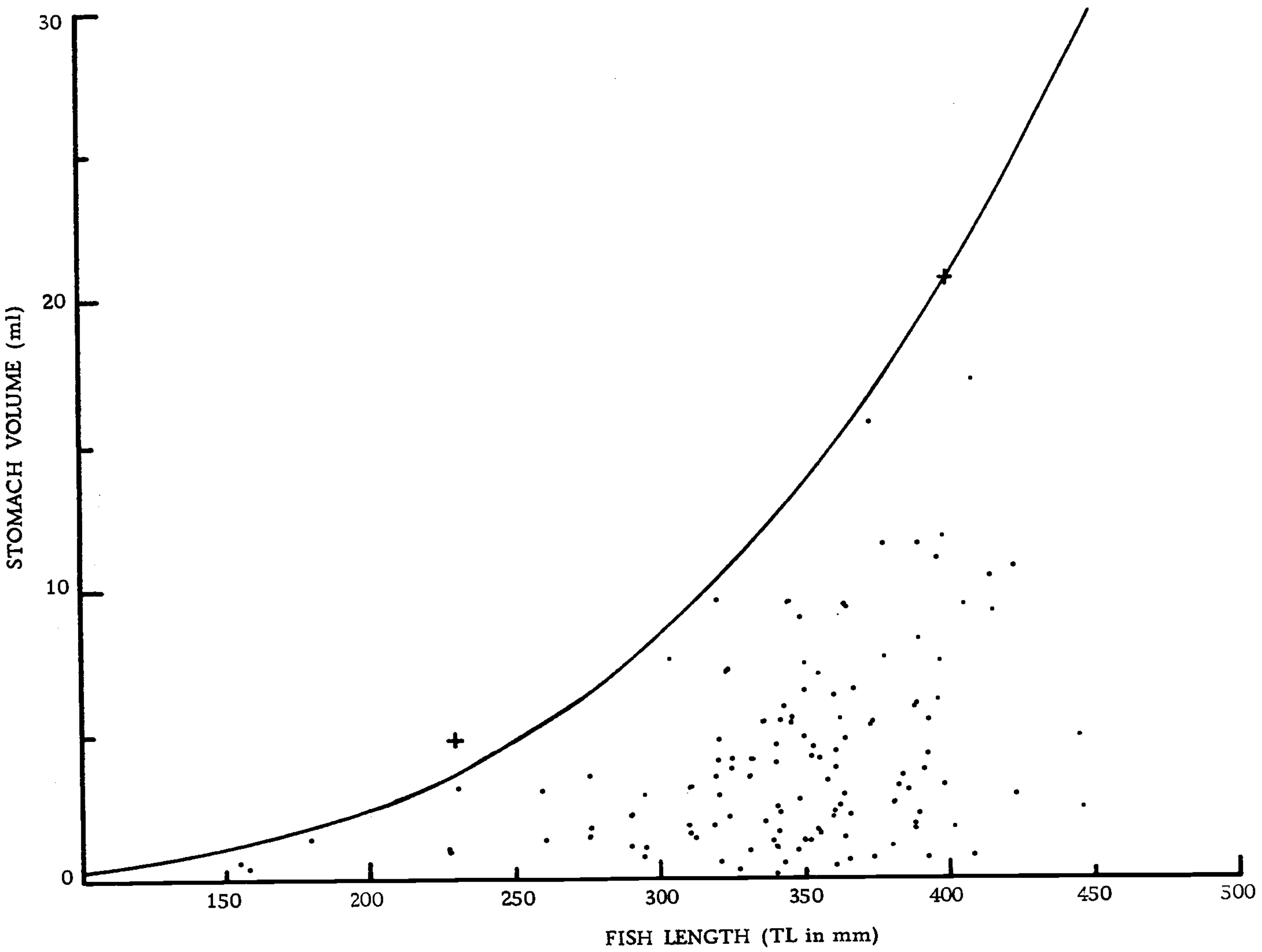


Figure 3. Curve used to establish "potential stomach volume" of pile perch. Plotted points are actual stomach content volumes. The curve was derived by transposing the weight-length curve for pile perch.

"percent of food volume" used in most of the figures. Volumes initially recorded as a "trace" (less than 0.1 ml) were given the value of 0.5 percent of the potential volume of the stomach in which they occurred. This was done under the rationale that two trace values equaled approximately 0.1 ml which is roughly 0.5 percent of the potential volume of an average size pile perch (350 mm TL).

Frequency of occurrence of each food item was calculated. This value is simply the percentage of the stomachs examined in which the particular food item was found.

In some samples considerable amounts of nondigestible material (in addition to the shells and skeletons of the food organisms themselves) were found. These included rock (sandstone), sand, pieces of old clam shell, fragments of eel grass (Zostera) and algae. These items were included in the analysis under the category "rock, etc.".

The methods outlined above were for fish one year old or older. Young-of-the-year perch were sampled as outlined below due to the small size of their stomachs. The entire digestive tract was removed and preserved either individually or with others collected at the same time and place. Frequency of occurrence of each food item was calculated on the basis of samples instead of individual fish. Likewise, volume of each food item was expressed as a percent of the total volume of food in the sample. These percentages were then multiplied by the number of tracts in the sample and summed with other such calculated values in the sampling unit. The total was then divided by the number of fish sampled within the sampling unit to give average percent of volume.

Index of Maturity For Males

I reasoned that size of testes relative to size of fish could be used to indicate both the age at first maturity and the annual cycle of maturity of male pile perch. An increase in testis size should precede the mating season, and only mature males should undergo seasonal changes in gonad size. The testes of pile perch are firm and it is convenient to obtain measurements of their dimensions in the field. The following formula was used to index the degree of development: Testis length (mm) x testis width (mm)/ fish weight (g).

Examination of Ovary Samples

Ovary samples were preserved in 10 percent formalin for at least a week before the embryos were separated from the ovarian tissue and placed in 40 percent isopropyl alcohol for storage. Since there is normally little difference in size among the embryos from a given ovary, the average weights and lengths were obtained by the following procedure: The sample was poured into a sieve, drained for several seconds, tamped vigorously on paper towels until it would no longer wet the towels, and weighed.

After blotting on a paper towel, each embryo was placed on a sheet of ruled notebook paper. The tip of the snout was placed over the red margin line, and the body was laid parallel to the rulings. While the embryo was in this position, a hole was punched with a pin through the hypural plate and the underlying paper. The hypural plate was easily seen in the small transparent embryos; in larger specimens, a heavily pigmented spot indicated its location. Twenty to 50 embryos could be measured in this manner on each sheet of paper. A millimeter rule was mounted on a T-square and run down the aligned sheet of notebook paper to facilitate rapid measurements. The smallest embryos, however, were measured with an ocular micrometer mounted on a dissecting scope. Except for a few samples measured in their entirety, 10 embryos were selected at random from each ovary for standard length measurement. All malformed or degenerating embryos were recorded, but never included in average weight or length measurements.

This procedure was modified slightly in 1967, in order to recover dead eggs. The last 70 ovaries collected were washed carefully, the wash water decanted and the sediments searched under a dissecting microscope for eggs. All eggs thus recovered from each ovary were recorded and preserved in alcohol for later study.

Age Determinations

Age data were derived from analysis of scale impressions made on 3x5-inch acetate cards with an hydraulic scale press. The settings found to give the best impressions were 6, 700 psi of pressure at 100 C for five minutes. Scales were viewed and measured on an Eberbach scale projector. Otoliths from 47 pile perch were examined as an aid to interpreting scale features. Relationship between scale size and fish length was determined by regression analysis using a Control Data 3300 computer. Computer programs were used also to calculate the weight-length relationships of both adults and embryos.

An arbitrary birth date of January 1 was used in assigning age for all fish. For example, a perch captured in February which had not completed the current annulus was placed in age class V if its scales bore four annuli.

Selection of Length-Frequency Data

Length-frequency data must represent a compromise between the advantages of large sample size and those of short sampling period. However, since shortness of sampling period is less critical for faster growing young fish, and since most of the young pile perch were collected in the summer, the length-frequency data used in this study were gathered in the following manner: All pile perch under 300 mm TL in my collection were included, while the sample of larger fish was derived from the July, 1966, data of this study combined with those of Beardsley (unpublished) for the same month.

Back-Calculations of Lengths at Previous Ages

Back-calculations were performed by a computer program employing a formula given by Rounsefell and Everhart (1953):

$$L^1 = C + S^1/_S\ (L-C)$$

where

L = fish length at time of capture.

L^1 = fish length when annulus x was formed.

S = total scale radius.

S^1 = scale radius to annulus x.

C = correction factor (length of fish at time of scale formation).

The program treated each sex separately and provided as output the mean lengths at each annulus for each age class, mean length for combined age classes (grand means), and the sample sizes and standard errors associated with each mean.

RESULTS

Age and Growth

Conversion of TL Measurements to SL

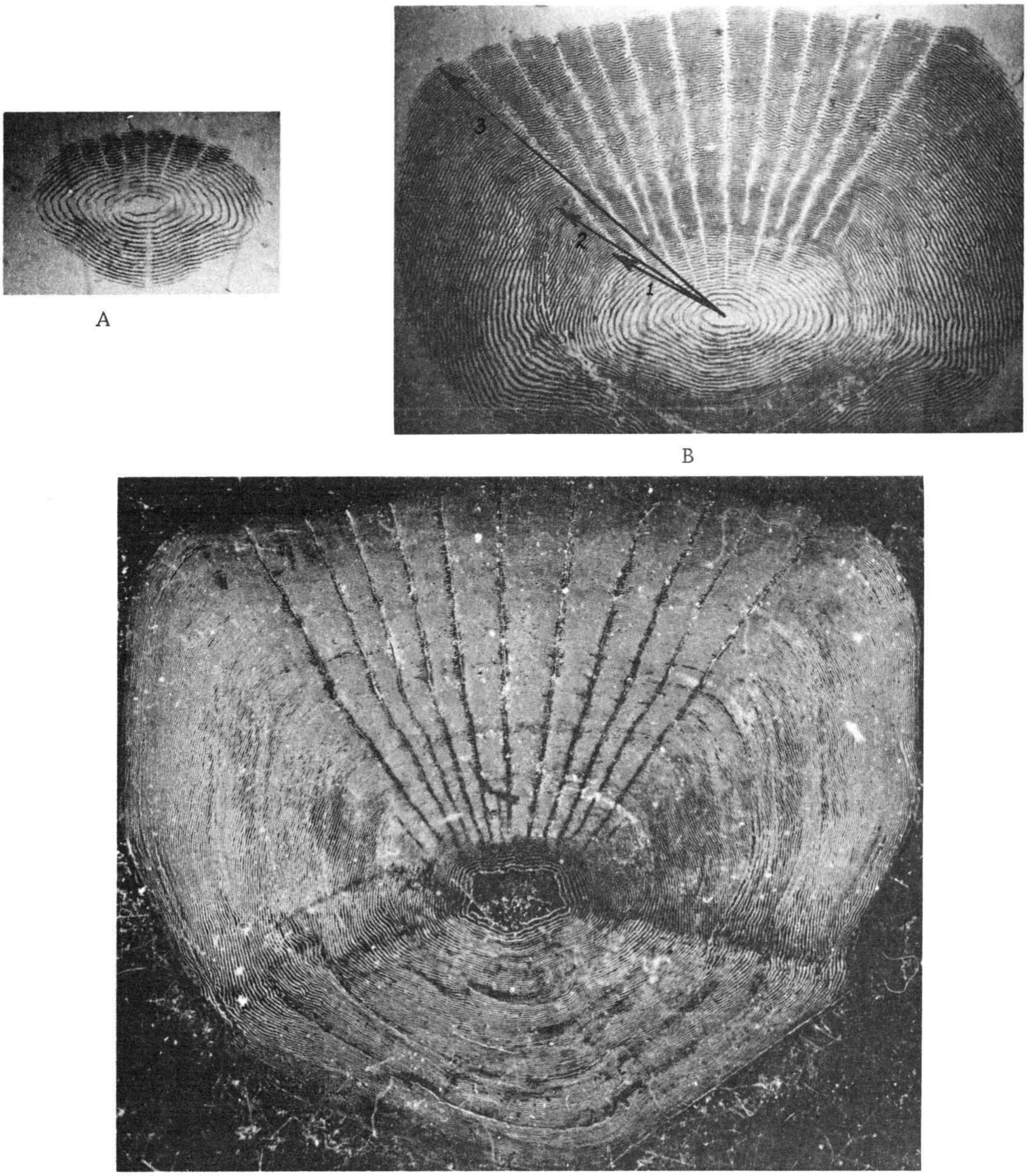
The equation SL = .75TL - 1.51 was derived graphically from data on 12 male and 8 female pile perch ranging in size from 76 to 398 mm TL. This linear equation fits the data closely over the range of lengths included in the sample. The equation enabled me to calculate hypothetical total lengths of embryos (for which no measurable total lengths exist) whenever I wanted to compare characteristics of embryos to adults.

Adequacy of Scales For Age and Length Determination

Rounsefell and Everhart (1953) list three conditions under which the determination of size from scale measurements is possible: "(1) The scales must remain constant in number and identity throughout the life of the fish... (2) Growth of the scale must be proportional to the growth of the fish... (3) The annulus must be formed yearly and at the same approximate time each year."

Condition one was tested for pile perch by counting the scales in the lateral line and in the circumference of embryos, young-of-the year, and adults; and by comparing the focal areas of the scales of young and adult fish. The counts of scales were essentially equal for all fish examined, and the focal areas of scales from young and old fish were structurally identical (Figure 4). Also regenerated scales were distinguishable from nonregenerated scales (Figure 4C). After birth, growth of the key scale is directly proportional to growth in length of pile perch. Regression of key scale radius on fish length for 218 pile perch was analysed by computer program. The regression equation obtained was $y = .67\,x - 20.75$ with a coefficient of determination (R^2) of .965 (Figure 5), thus satisfying condition two. The x- intercept of 31 mm TL (22 mm SL) is the apparent fish length at time of initiation of scale development. This value was used for the correction factor "C" in the formula for back-calculation even though key scales could not be detected on alizarin stained embryos shorter than 28 mm SL (38 mm TL).

Check marks (annuli) distinguishable from the metamorphic annulus (birth check) and from "spawning" checks were formed only once a year, primarily during the month of May. My conclusion that these check marks are "annuli" and satisfy condition three above is supported by the close correlation of length-frequency peaks with lengths of fish aged by these annuli (Figure 6). Rings on otoliths also corresponded in number to the age of fish inferred from scale annuli (Figure 7).



A

B

C

Figure 4. Scales of pile perch: (A) embryo 59 mm SL; (B) age II perch captured just prior to annulus formation showing measurement of 1. metamorphic annulus, 2. annulus I, and 3. total scale radius; (C) age IV female showing regenerated focus. [(A) and (B) are of the same magnification, (C) is less.]

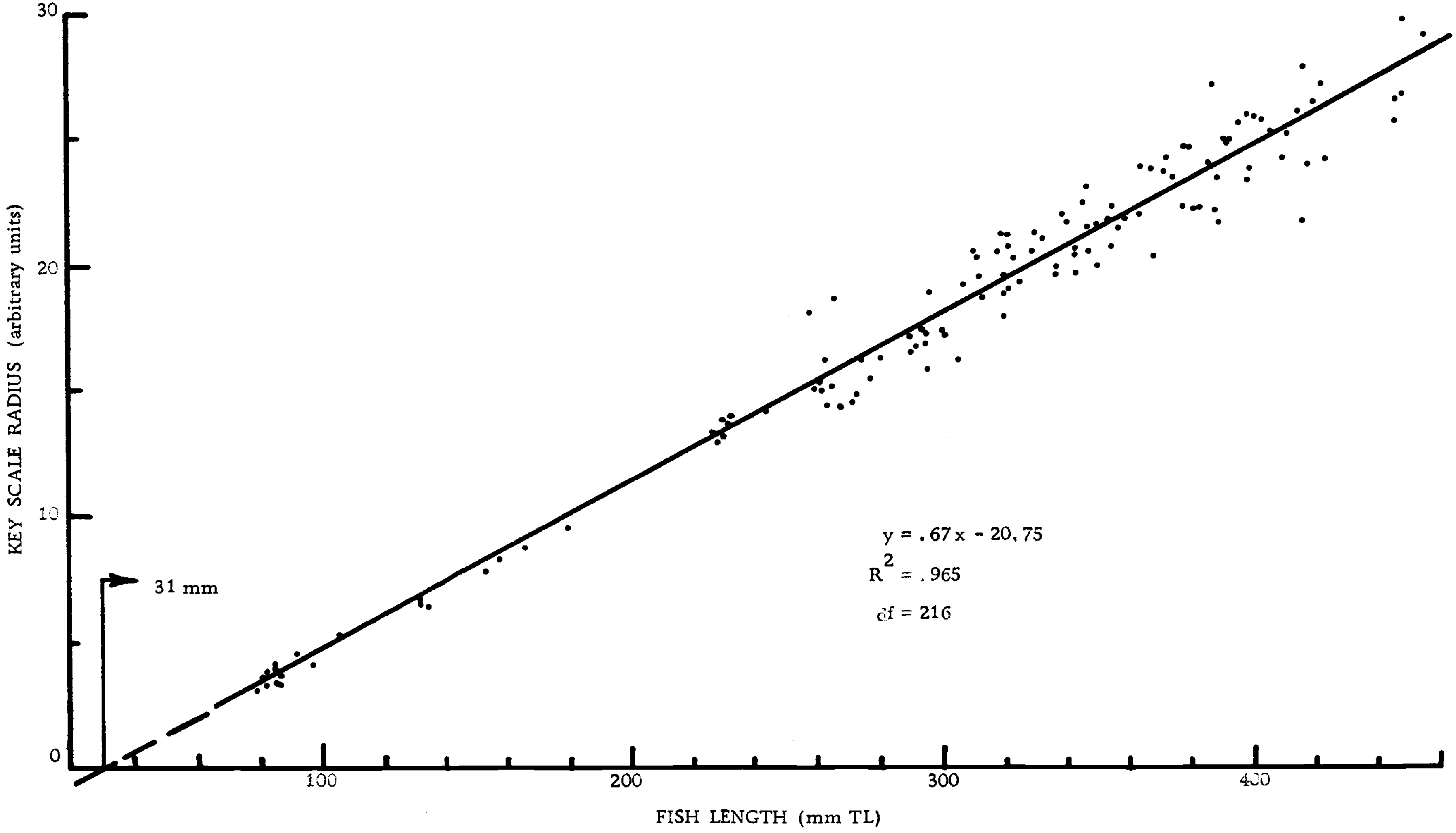


Figure 5. Regression of key scale radius on body length calculated from 218 pile perch captured in Yaquina Bay during 1966 and 1967.

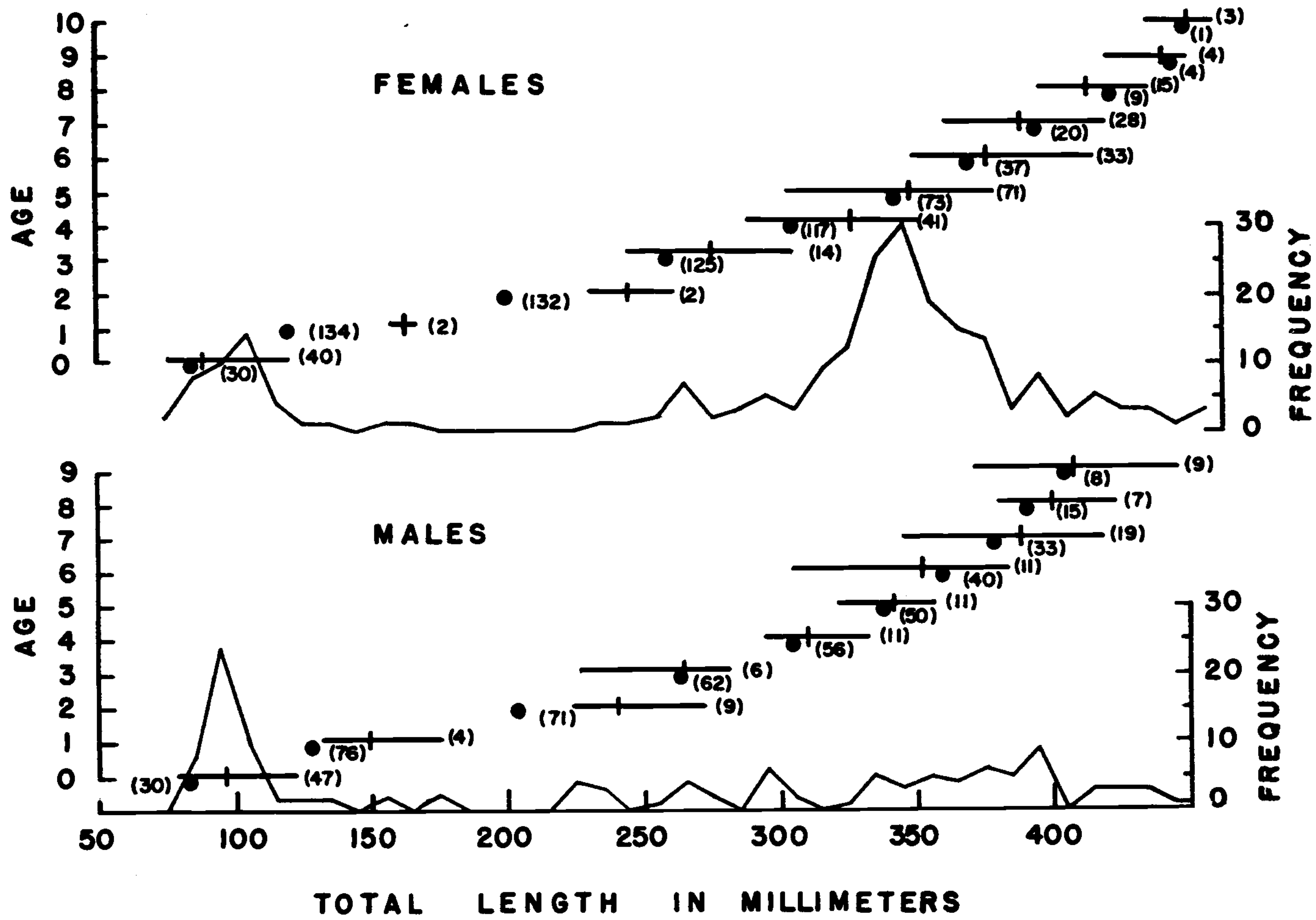
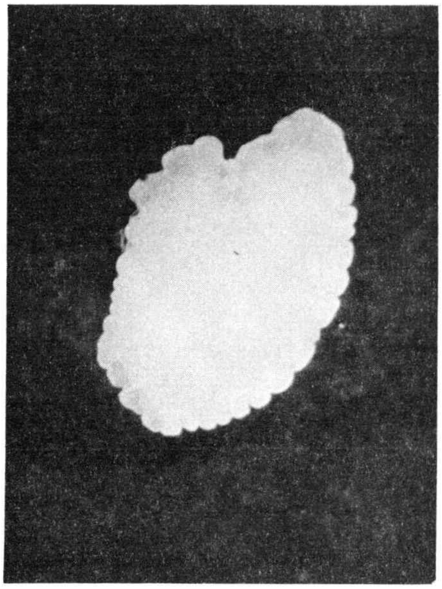


Figure 6. Mean back-calculated lengths (dots); range and mean of observed lengths (bars) and length frequencies (line) of pile perch captured in Yaquina Bay during 1966 and 1967 (sample sizes in parentheses).



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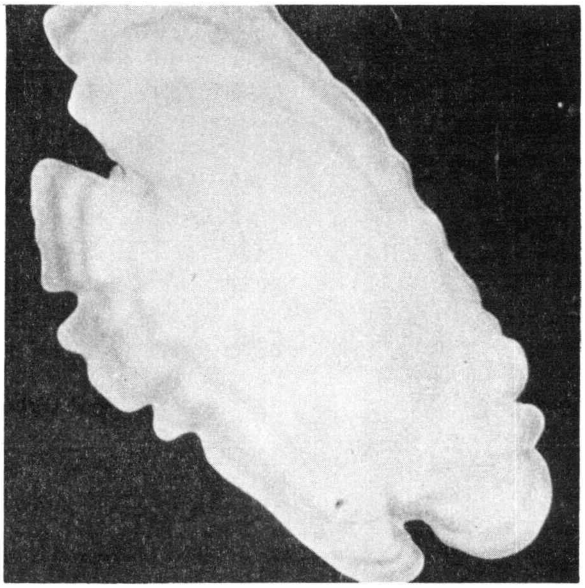

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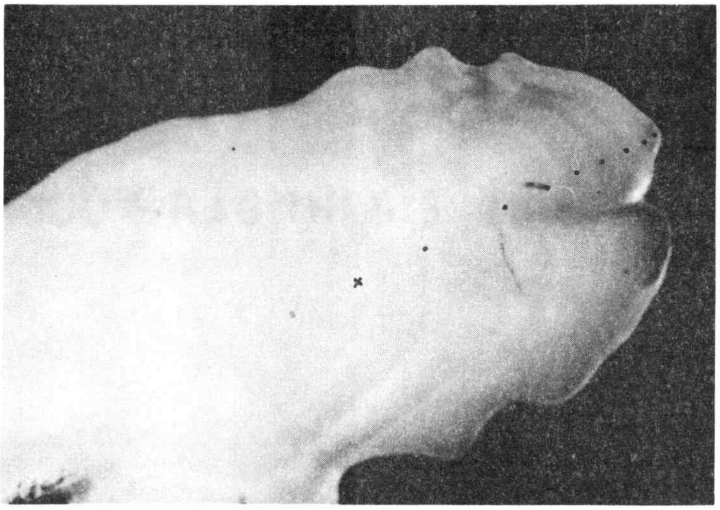

C

Figure 7. Otoliths from pile perch captured in Yaquina Bay in 1966 and 1967. (A) Young-of-the-year, 102 mm TL, captured August 24. (B) Age III male, 253 mm TL, captured August 9. (C) Age VIII female, 420 mm TL, captured July 12. (x - indicates metamorphic annulus, dots indicate annuli.) Magnification approximately 20 x.

Lengths of Age Classes and Absence of Lee's Phenomenon

Data on the lengths of pile perch during each year of life presented in Figure 6 were derived from two sources. One source was the observed lengths of all perch in each age class, while the other was the grand mean of the back-calculated lengths at each annulus.

"Rosa Lee's phenomenon" as defined in Ricker (1958) was not observed. That is, mean back-calculated lengths at formation of annulus I did not show a decreasing trend with increasing age of the fish sampled (Table 1).

Table 1. Mean body lengths at age I back-calculated from pile perch of each age class. Sample sizes are in parentheses.

Age of fish	Calculated lengths at annulus I	
	Male	Female
I	131 (5)	116 (2)
II	128 (9)	123 (7)
III	129 (6)	126 (8)
IV	124 (6)	117 (44)
V	122 (10)	118 (36)
VI	131 (7)	117 (17)
VII	129 (18)	121 (11)
VIII	127 (7)	123 (5)
IX	129 (7)	122 (3)
X		132 (1)

Age Frequencies

The age classes most frequently caught during my research, other than age class zero, were age class V for females and VII for males. Numbers of females captured exceeded males in all age groups except 0, I, II and IX (Figure 8).

Maximum Size of Pile Perch

Walford lines (Figure 9) indicated maximum attainable total lengths (TL_∞) of 432 mm for male and 490 mm for female pile perch. Weights corresponding to these lengths (calculated from the relationships of weight to length established below) are 1, 119 g and 2, 001 g, respectively. One fish was captured which exceeded the maximum predicted size, a male 448 mm TL and 1, 148 g.

Weight-Length Relationships

Computed regressions of $\log_{10}$ of weight on $\log_{10}$ of length are shown for males and females in Figure 10. In Figure 11 the relationship of weight to length is illustrated on a linear scale for each sex. Only those females without embryos or those with embryos less than 30 mm SL were included.

The regression equation for embryos was computed to be $\log_{10} W = 3.56 \log_{10} SL - 5.51$ with a coefficient of determination

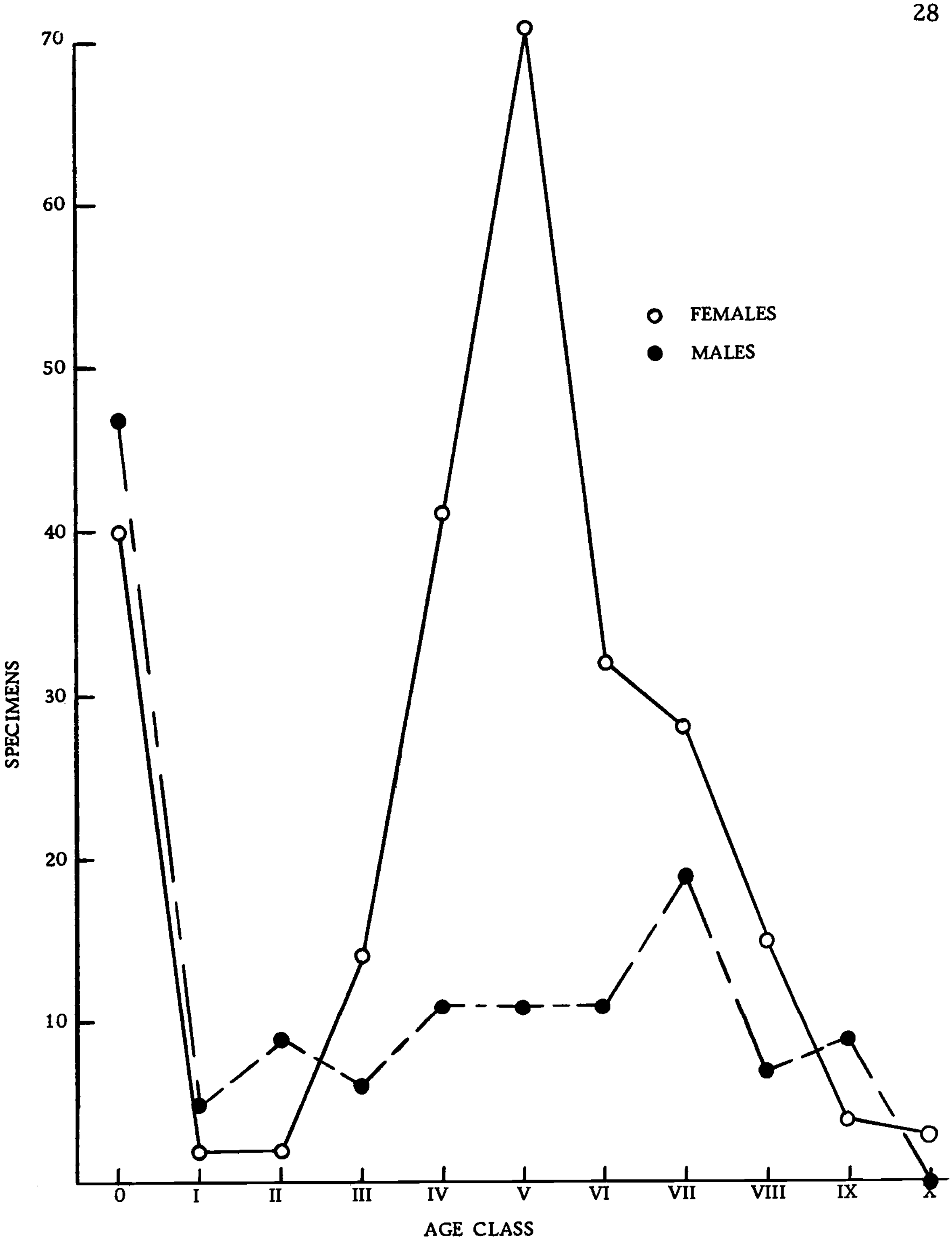

Figure 8. Age frequency distribution by sex of all pile perch examined from Yaquina Bay during 1966 and 1967.

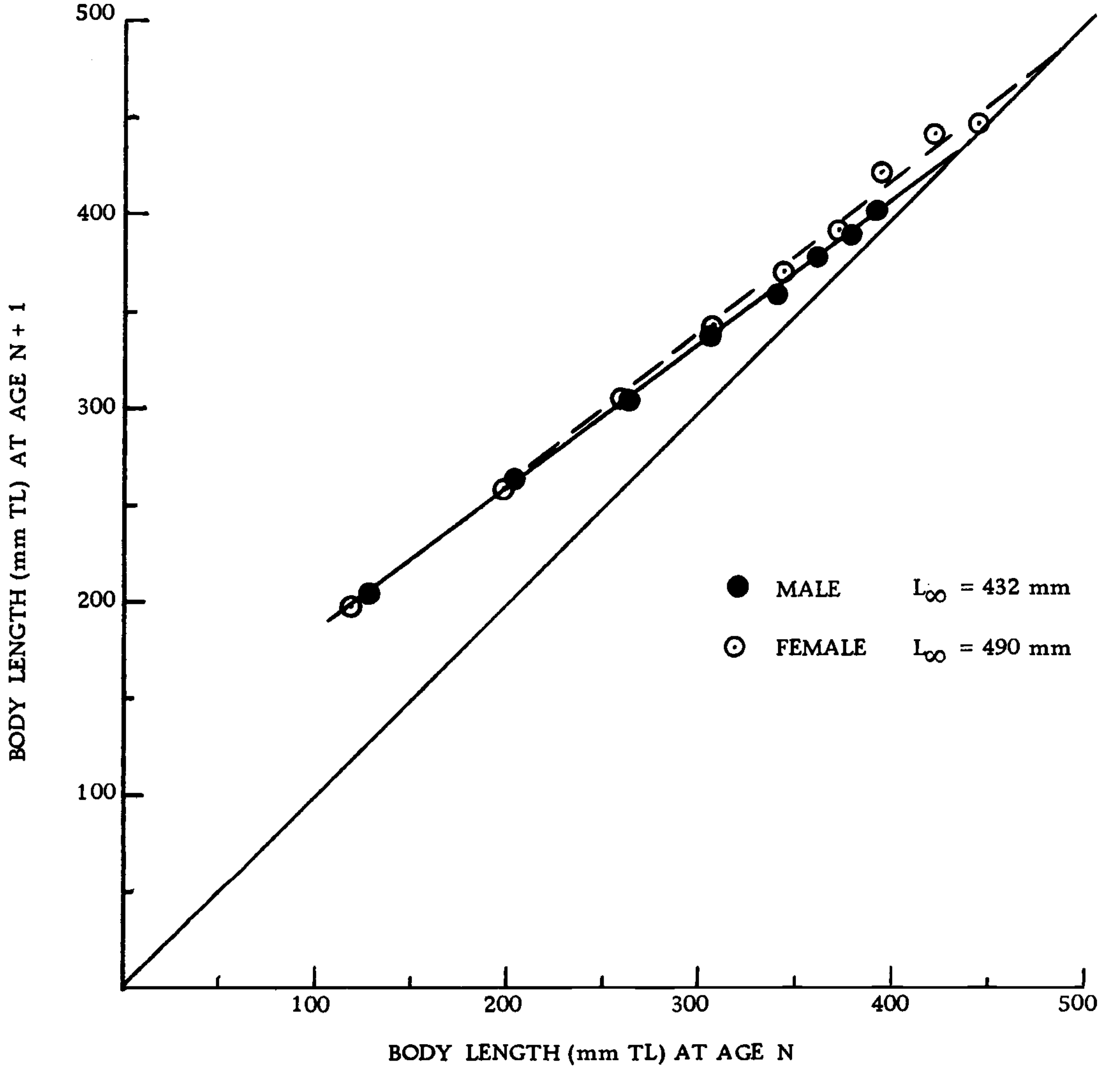

Figure 9. Walford lines based on 97 male and 229 female pile perch collected in Yaquina Bay, Oregon, during 1966 and 1967.

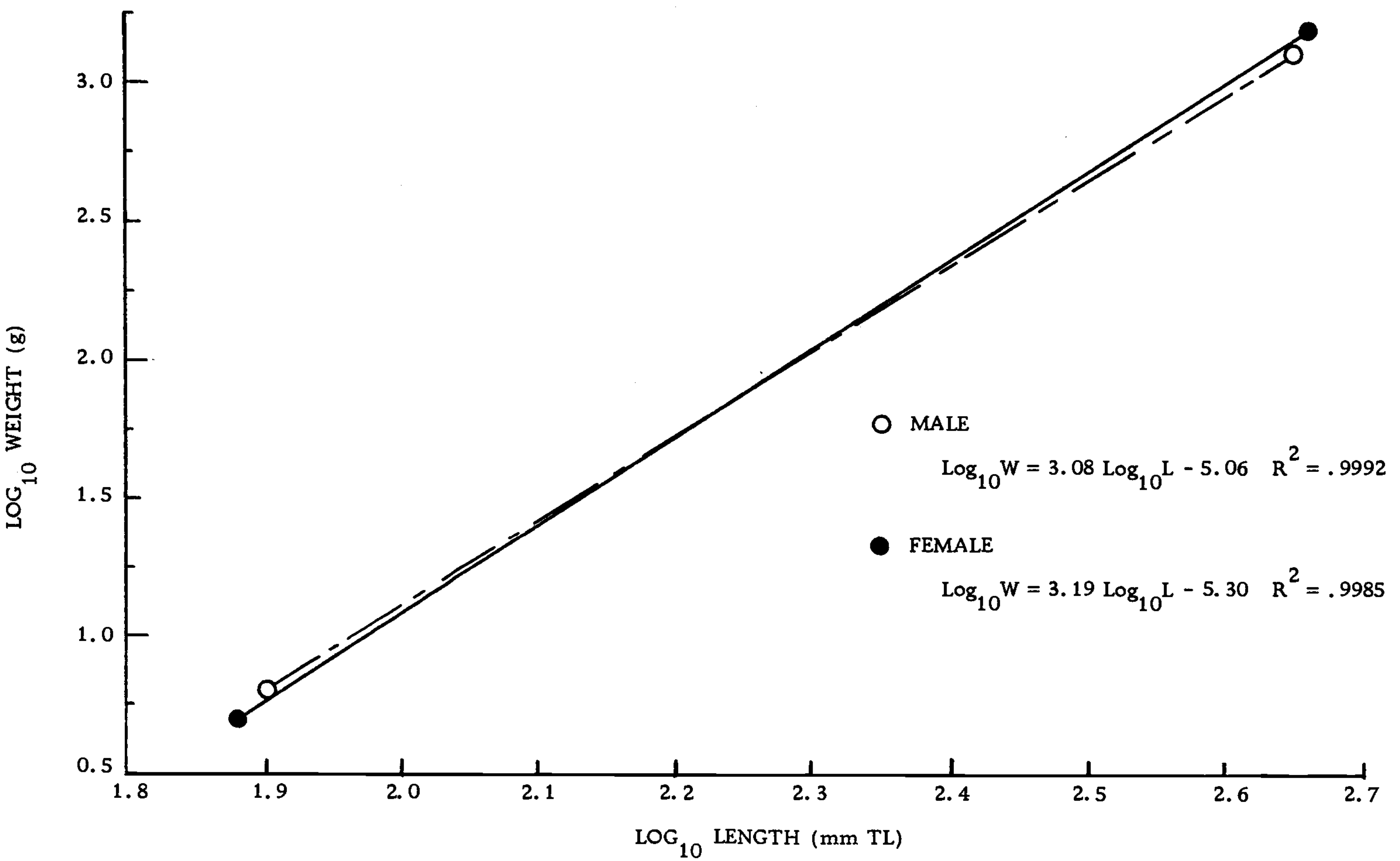

Figure 10. Weight-length relationships for 97 male and 229 female pile perch collected in Yaquina Bay, Oregon, in 1966 and 1967.

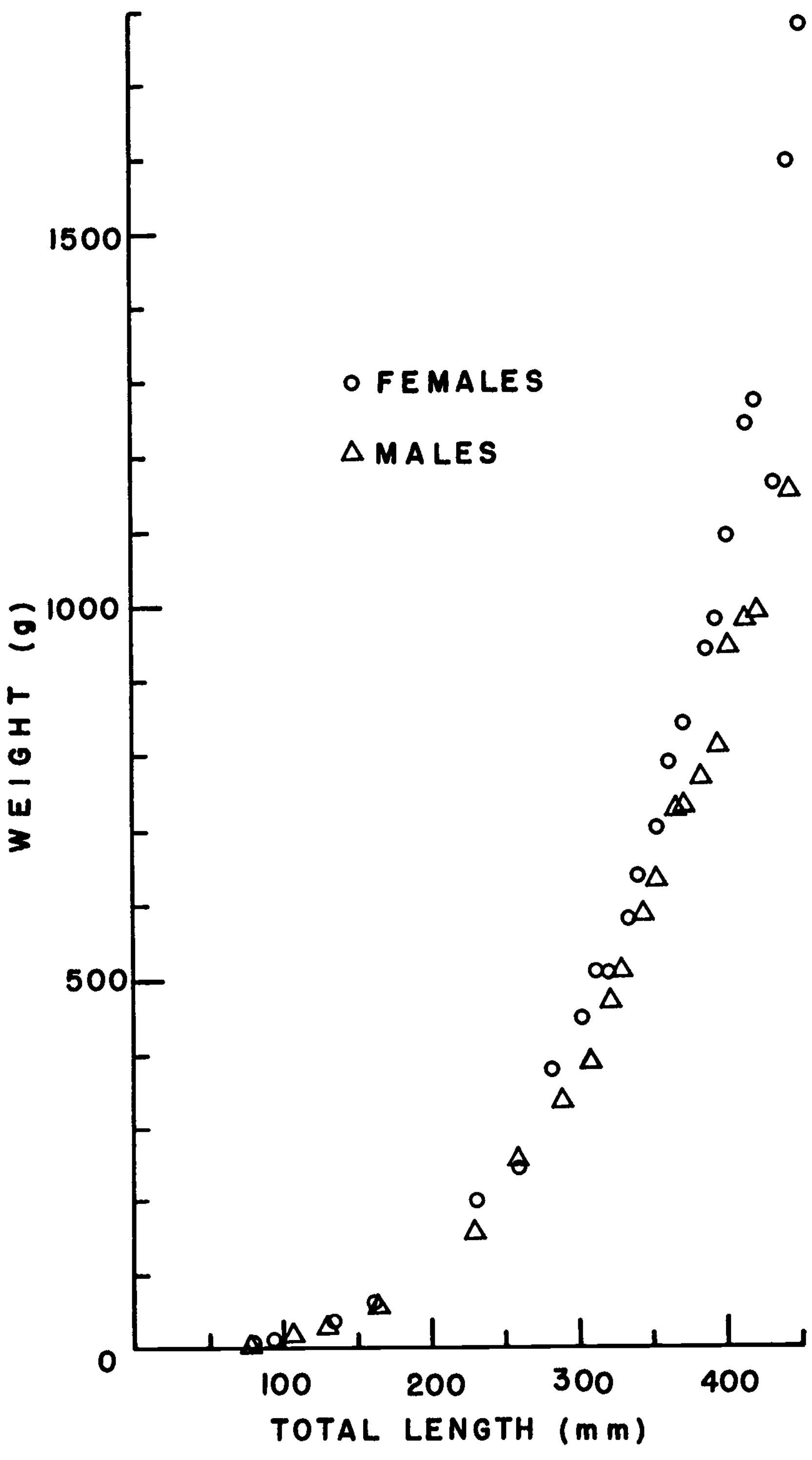

Figure 11. Mean weights compared to mean lengths at various length intervals for male and female pile perch collected in Yaquina Bay, Oregon, in 1966 and 1967.

(R^2) of .996. For comparison to the adult relationship, the regression line was transformed by application of the SL-TL regression and graphed in Figure 12.

Size at Birth

Based on the smallest new-born and largest unborn pile perch observed, the range in size at birth was 76.0 to 85.7 mm TL and 4.5 to 8.9 g. Back-calculated lengths at the time of formation of the metamorphic annulus ranged from 73 to 94 mm and averaged 82.7 mm TL for 30 males and 30 females. There was no significant difference between these lengths with respect to sex.

There was no indication that size at birth was dependent upon size or age of parent. Two age IV females carried embryos nearly the size of the largest observed. The data are presented in Figure 13 on page 35.

Size of Eggs

Most of the ovaries obtained from December 17 to February 22 contained fertilized eggs free in the ovarian cavity. Seven such ova were weighed together on an analytical balance and found to average .00016 g each. These same eggs measured 792µ in diameter. Using half this value as egg radius (R) in the formula, $V = 4/3\,\pi R^3$, the volume of an egg was computed to be .00026 cm^3.

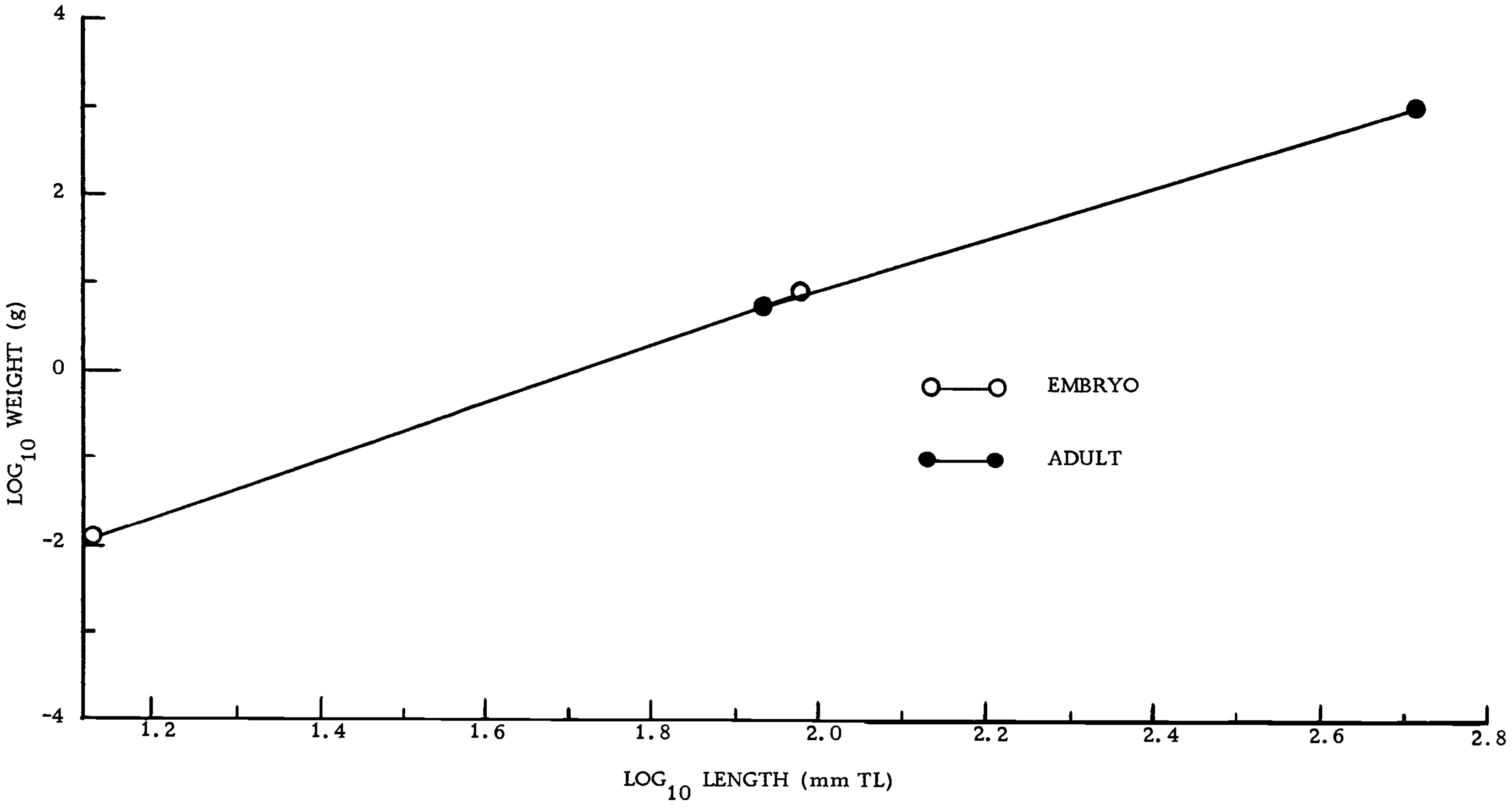

Figure 12. Weight-length relationships of pile perch embryos and adults from Yaquina Bay, Oregon, 1966 and 1967.

This volume indicates an average weight of .00029 g if a specific gravity of 1.1 is assumed. Since the two weight estimates above differ by only a factor of two, and since preserved eggs are probably slightly larger and heavier than those in nature, the lower estimate was chosen for purposes of discussion in the following section.

Growth of Embryos

In order to estimate the growth rate of embryos, the probable dates of fertilization and birth, and the relationships of these parameters to age of the female parent, the pertinent data were assembled in Figure 13. In this figure, the weights of eggs, embryos and new-born pile perch are plotted against dates of observation on a logarithmic scale. Egg and embryo weights were plotted with symbols indicating the age of the female parent from which the data were collected. Each plot of embryo weight is the mean wet-weight of the embryos of a single ovary, while each plot of young-of-the-year fish represents an individual. Weight of each fertilized egg was assumed to be 0.00016 g.

Unfortunately, there is little data on embryos smaller than 0.01g. Nevertheless, I infer that growth rate of embryos between hatching and birth is nearly constant (line A in Figure 13). This

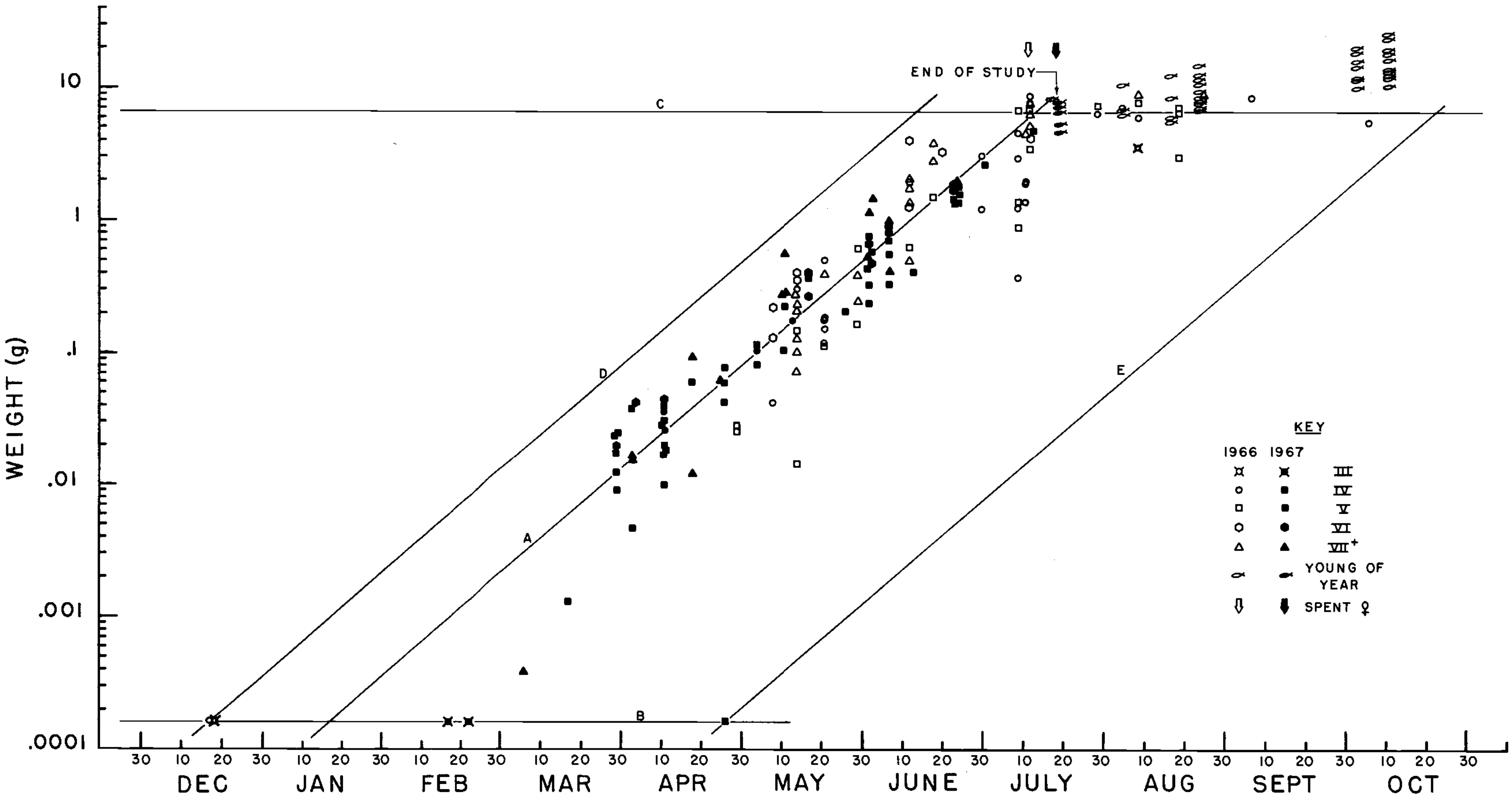

Figure 13. Mean weights of eggs, embryos and newborn pile perch by date of collection. Symbols indicate age of female parent from which eggs or embryos were obtained. Line A represents trend of embryo growth; line B egg weight; line C average birth weight; lines D and E growth curves of extreme data.

line represents an instantaneous daily growth rate by weight (g_w) of 0.0606, calculated by the formula $\log_e W_T - \log_e W_t / T - t$. It may be argued from the same data that the growth rate of embryos larger than two grams appears to decline somewhat. A dramatic decline takes place after birth. An instantaneous daily growth rate of 0.0093 was estimated for the first two months after birth.

Neglecting the slight decline in growth rate above 2 g, line A of Figure 13 can be regarded as the growth curve over the entire span from hatching to birth; and a line constructed parallel to it and passing through any plotted embryo weight represents a projected growth history of that embryo (or brood of embryos). Such a line provides by its intersections with line B (weight of fertilized eggs) and line C (mean weight at birth) rough estimates of dates of fertilization and birth, respectively, for the brood involved. The growth history lines D and E were erected from the earliest and latest fertilized eggs observed and encompass all such lines which could be constructed from the data and therefore define the range of projected fertilization and birth dates as December 17 to April 15 and June 14 to October 22, respectively. Eighty-five percent of the projected dates, however, are included in the periods of December 30 to February 7 and June 27 to August 4, respectively. Gestation is nearly six months (179 days).

Actual fertilization dates may be considerably earlier than those predicted because I have no estimate of incubation period for the eggs. Two females (age II and VI) taken November 14 contained no eggs but showed maturing follicles. An age IV female caught December 15 contained only maturing follicles while two females (age III, IV) on December 17 contained fertilized eggs. The next females obtained were caught on February 17. Both were age III and the smaller (265 mm) contained maturing follicles while the larger (273 mm) contained fertilized eggs. All ovaries obtained after this date contained either fertilized eggs or embryos.

There is a tendency for older females to bear their young earlier, though, as inspection of Figure 13 will readily confirm, there are exceptions to this.

Reproduction

Maturity of Females

Since age at first maturity is an important factor in the reproductive potential of a species, the percentage of mature females in each age class was estimated from the samples (Table 2). Females were considered mature during the year they would have given birth. For example, an age III perch captured in December and found to contain fertilized eggs would be considered as mature at age IV. Females captured too late in a season to show evidence of having just given birth and too early to possess fertilized eggs were excluded from the sample.

Table 2. Percent of mature female pile perch in each age class.

Age class	Number of females examined	Percent mature
0	40	0
I	2	0
II	2	0
III	15	33
IV	35	89
V	72	97
VI+	82	98

Maturity of Males

The index of relative testis size was plotted against the date of collection by a numeral indicating the age of the fish in Figure 14. Asterisks (*) indicate the individual males from which semen could be expressed at the time of capture.

Though small sample sizes during the critical season (October-April) make inferences difficult, it appears that at least a portion of the male pile perch population matures during their second year of life. Mature males are in spawning condition at least from late October to late January and the peak in index values suggests they may be ripe as early as late September.

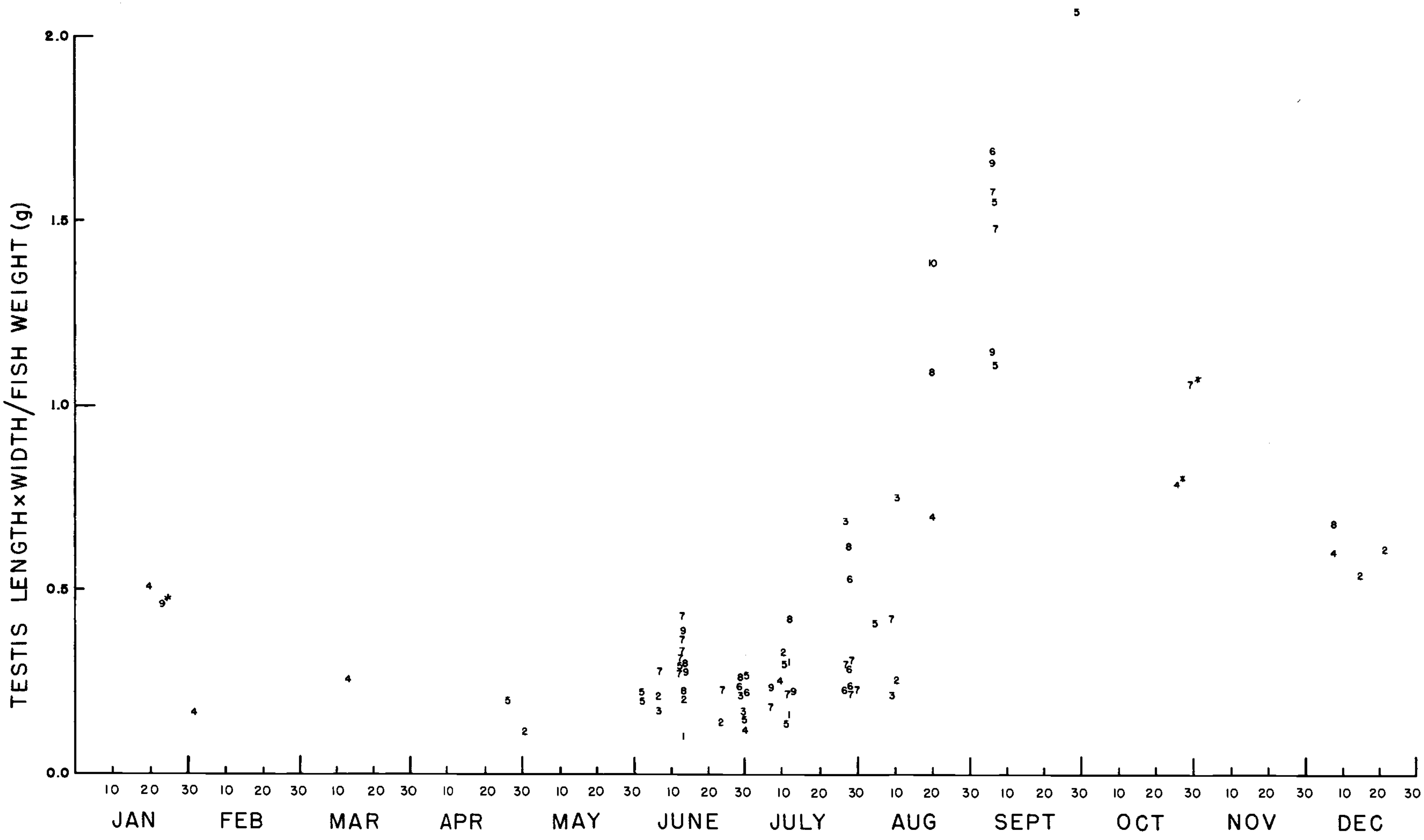

Figure 14. Index of testis size by age class related to date. The index value calculated for each perch is plotted against the date of capture by a number indicating the age of the fish. Asterisks indicate males which readily emitted sperm.

Fecundity

There was a positive correlation of fecundity with size of females (Figure 15). As near term embryos were often aborted and lost during capture or handling of parents, females that contained embryos longer than 30 mm SL were excluded from measurements of fecundity.

Fecundity seemed to be determined prior to fertilization (embryonic mortality is discussed in the next section). At any time during the year, hundreds of oöcytes of varying sizes were visible on the ovarian sheets. In late fall and early winter, several oöcytes in random locations became swollen and supplied with blood vessels. The number of these maturing follicles in two fish captured on November 14 was consistent with the number of embryos to be expected from fish their size.

Prenatal Mortality

Mortality of both eggs and embryos was observed. Since dead eggs in various stages of development were recovered from ovaries containing embryos as large as 43 mm SL, it appeared that dead eggs were not resorbed in the ovary or digested by the embryos. I calculated mortality rates of eggs in 65 ovaries examined in 1967 by counting both dead and live ova and embryos. Twenty-three (or

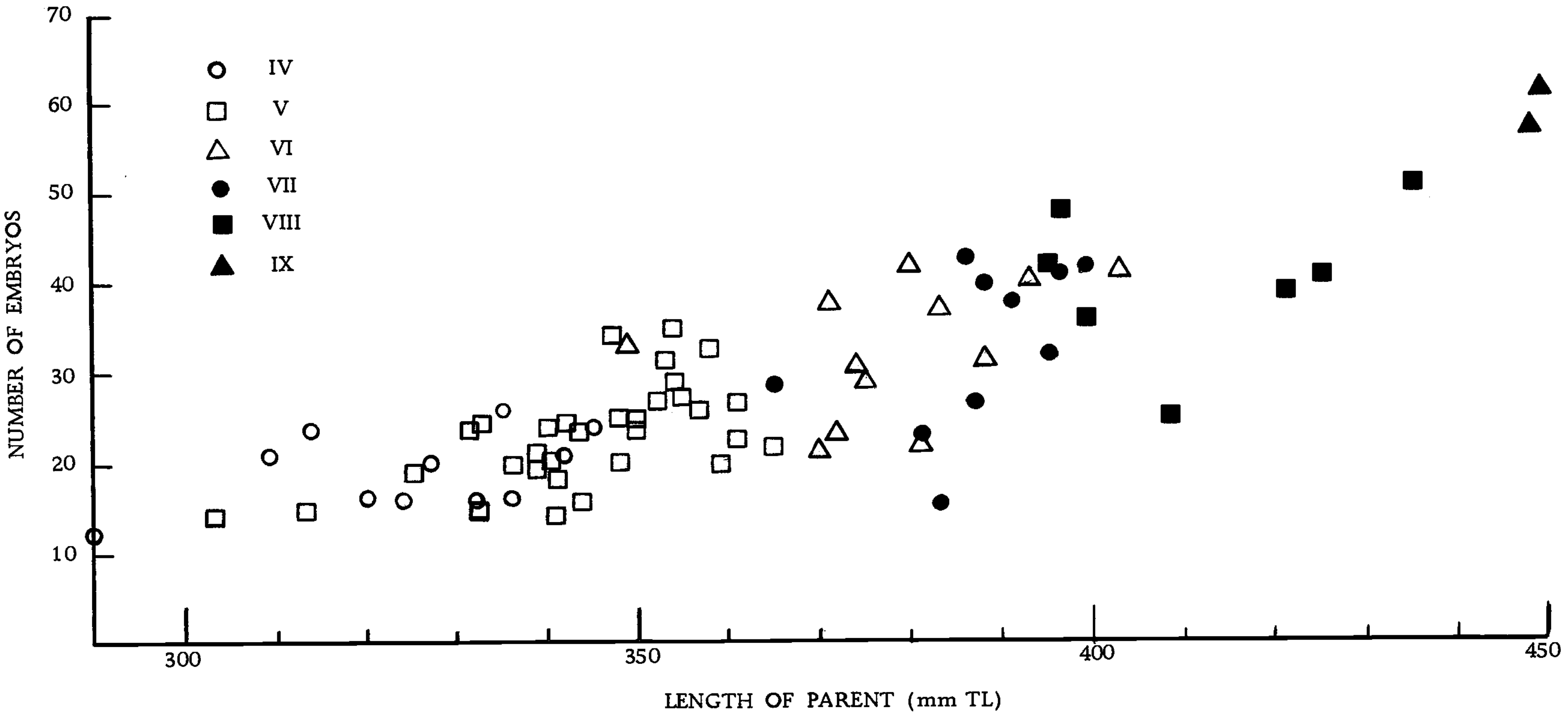

Figure 15. Length, age and fecundity relationships of 74 pile perch from Yaquina Bay, Oregon in 1966 and 1967 (based on females whose embryos were less than 32 mm SL).

34 percent) of the ovaries examined contained a total of 67 dead eggs. The ovaries contained 1, 759 live embryos; hence, 3. 7 percent of the eggs ovulated apparently died before hatching.

Malformed embryos (also called dwarf or diminutive embryos) have been reported from the ovaries of other embiotocids (Swedberg, 1966 and Eigenmann, 1892). Several types of malformations are shown with one normal individual in Figure 16. These malformed individuals and several others are shown in Figure 17 after clearing in KOH and staining in alizarin. Cleared and stained normal embryos are shown for comparison in Figure 18.

Of the 149 ovaries examined, 15 (10 percent) contained at least one dwarf embryo. Only three contained more than one. In one of these, 19 of 20 embryos were malformed and were about half the size of the normal individual (41 mm SL). All of the malformed embryos in this brood were nearly identical in size and exhibited nearly identical malformations characterized by a tight S-shaped curve in the anterior portion of the vertebral column. For another ovary containing more than one dwarf, 11 of 16 embryos were malformed (Figure 19). The third sample contained three dwarfs and 29 normal embryos.

If death can be presumed to be the fate of malformed embryos, then an embryonic mortality of 1. 1 percent (44 of 3, 875) is indicated from these data. This percentage should be regarded as

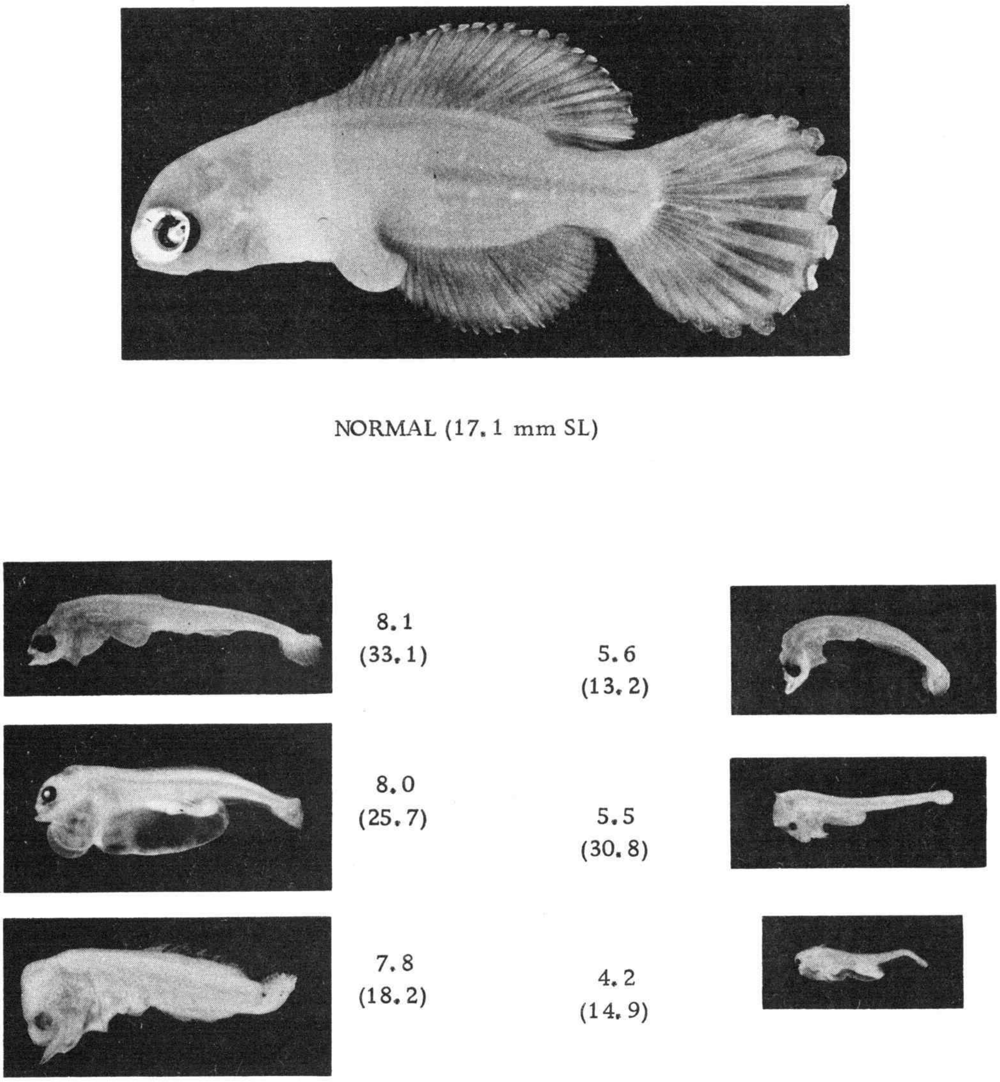

Figure 16. A normal embryo and six malformed embryos. Standard lengths (mm) of malformed embryos are given, with the standard lengths of normal embryos from the same ovary shown in parentheses. (Magnification approximately 4x).

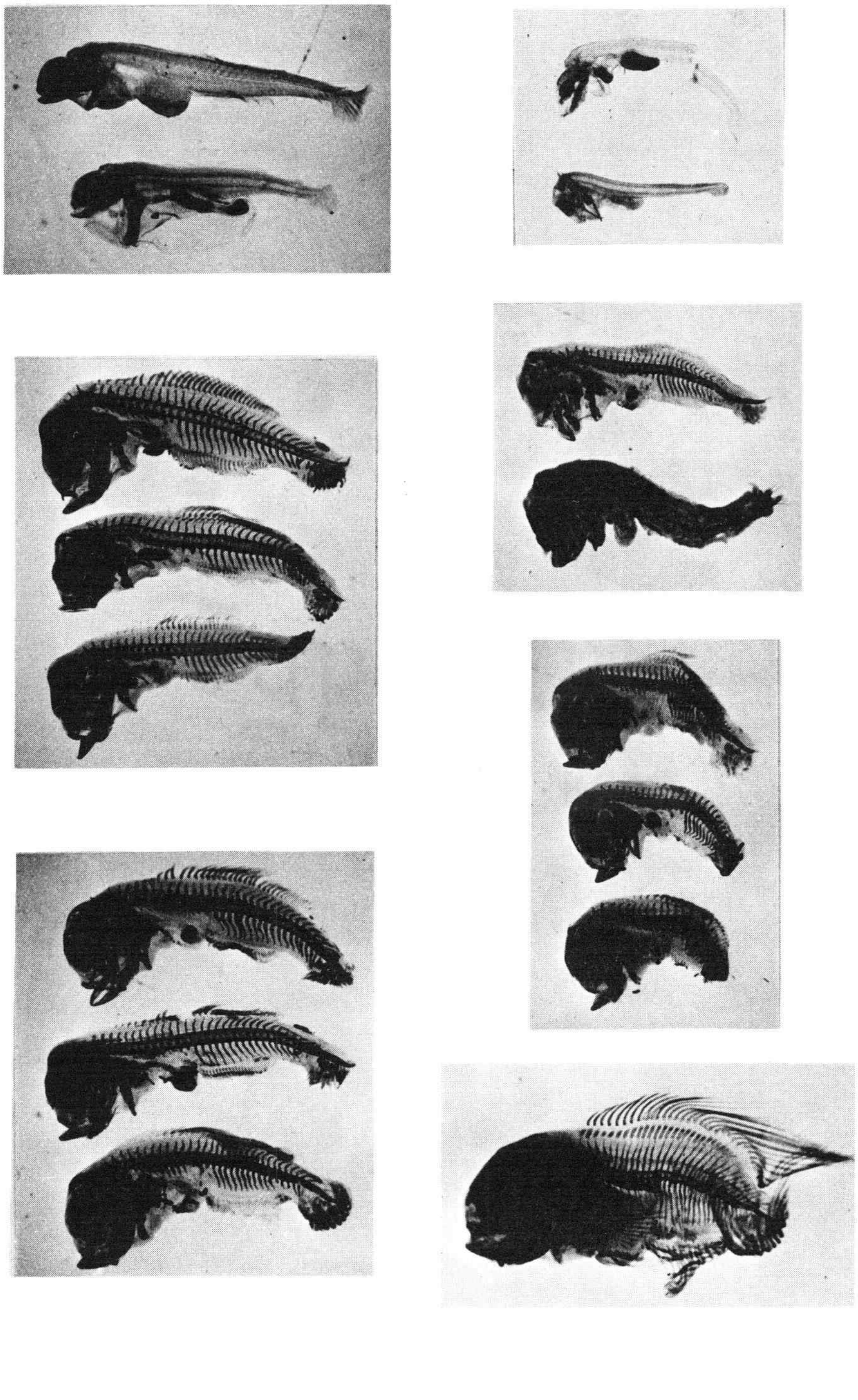

Figure 17. Malformed embryos after clearing in KOH and staining in alizarin. (Magnification approximately 4 x.)

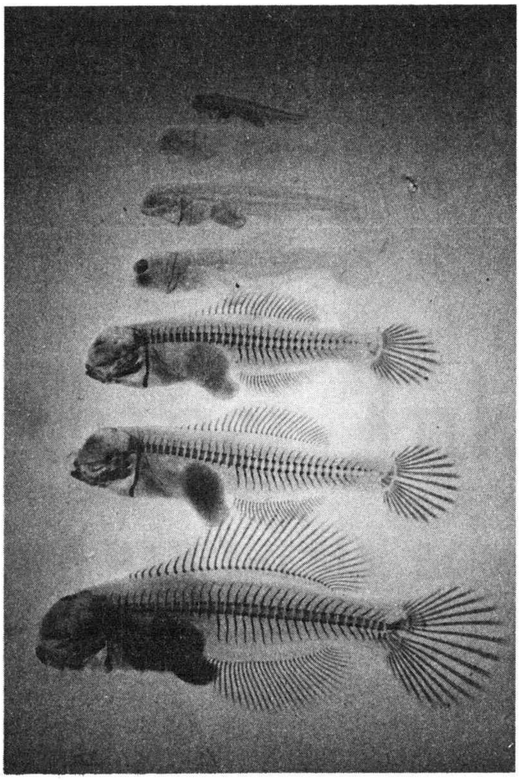

Figure 18. Normal embryos cleared in KOH and stained in alizarin ranging in size from 6.8 mm to 20.6 mm SL. (Magnification approximately 2.35 x.)

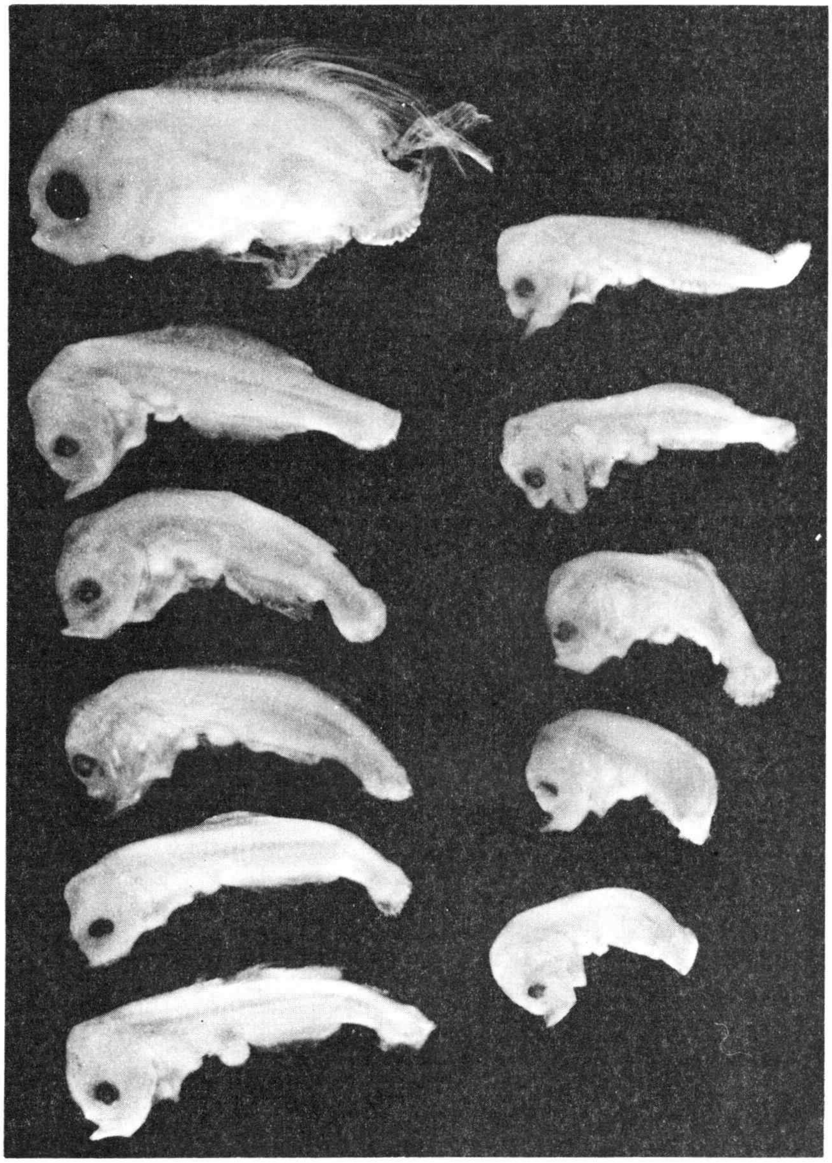

Figure 19. Eleven malformed embryos ranging from 6.0 to 11.0 mm SL from a single ovary which contained only five normal embryos which averaged 25.7 mm SL. (Magnification approximately 4.5 x.)

minimum because some dwarfs may have been completely resorbed or otherwise overlooked.

The combined effect of a 3.7 percent mortality of eggs and a 1.1 percent mortality of embryos results in a total prenatal mortality of about 4.8 percent of all eggs ovulated.

Food Habits

A taxonomic list of all organisms identified from the stomachs of pile perch is presented in Table 3. Analysis of food habits for each sampling unit was performed separately for young-of-the-year and "adults" (all fish older than young-of-the-year). Samples were grouped this way for three reasons. First, food habits of all older perch are similar. Second, there are distinct differences between the food habits of age zero fish and older pile perch. Third, there were few samples of age classes I and II. Young-of-the-year fish were captured in Yaquina Bay only during the summer and fall seasons, and were captured only in the middle and upper zones.

Virtually all of the items found in the stomachs of pile perch can be grouped under one of the following 11 categories: Foraminifera; worms (polychaetes); mussels; clams; barnacles; amphipods; shrimp (including burrowing shrimp); crabs (set); crab megalops; snails and "rock, etc." (which includes all items such as sand grains, pieces of sandstone, wood, or old clam shell, and algae). The importance

Table 3. Taxonomic list[1] of all food organisms identified from the stomachs of 190 pile perch (Rhacochilus vacca) collected in Yaquina Bay, Oregon, between April, 1966, and July, 1967.

Phylum Protozoa	
Class Sarcodina	
Order Foraminiferida	Unidentified Foraminiferida
Phylum Annelida	
Class Polychaeta	Unidentified Polychaeta
Phylum Mollusca	
Class Gastropoda	Unidentified Gastropoda
Order Archaeogastropoda	Acamaea sp.
Order Mesogastropoda	
Family Calyptraeidae	Crepidula sp.
Family Naticidae	Unidentified Naticidae
Order Neogastropoda	
Family Epitoniidae	Unidentified Epitoniidae
Family Cerithiidae	Unidentified Cerithiidae
Family Olividae	Olivella biplicata
Family Muricidae	Thais canaliculata
	T. lamellosa
Order Nudibranchia	Unidentified dorid nudibranch
Class Pelecypoda	
Order Filibranchia	Mytilus edulis
	Ostrea lurida
Order Eulamellibranchia	Unidentified Eulamellibranchia
Family Tellinidae	Macoma nasuta
	M. secta
Family Cardiidae	Clinocardium nuttallii
Family Veneridae	Protothaca sp.
	Saxidomus nuttalli
	Transennella tantilla
Family Myidae	Mya arenaria
	Cryptomya californica
Family Hiatellidae	Hiatella sp.
Family Pholadidae	Unidentified Pholadidae
Phylum Arthropoda	
Class Crustacea	
Subclass Cirripedia	Balanus sp.

Continued

Table 3. Taxonomic list[1] of all food organisms identified from the stomachs of 190 pile perch (Rhacochilus vacca) collected in Yaquina Bay, Oregon, between April, 1966, and July, 1967--Continued.

Subclass Malacostraca	
Order Isopoda	Idothea sp.
Order Amphipoda	Corophium sp.
	Unidentified Amphipoda
Order Decapoda	
Suborder Natantia	Unidentified Natantia
Suborder Reptantia	Callianassa californiensis
	Upogebia pugettensis
	Pagurus sp.
	Cancer magister
	C. productus
	C. oregonensis
	Hemigrapsus nudus
	H. oregonensis
	Pugettia sp.
	Pinnixa sp.
Phylum Echinodermata	
Class Ophiuroidea	Unidentified Ophiuroidea
Phylum Chordata	
Class Osteichthyes	
Order Clupeiformes	
Family Clupeidae	Clupea harengus pallasi (eggs)

1 Taxa of invertebrates above the level of family are from Barnes (1963); families are ordered after Light et al. (1964).

of each of these items in the food habits of pile perch within each sampling unit is presented on the bases of both percent frequency of occurrence and percent of total food volume in Figure 20 for adults and Figure 21 for age class zero.

Detailed volumetric data are presented in Table 4 for adults and Table 5 for young-of-the-year perch.

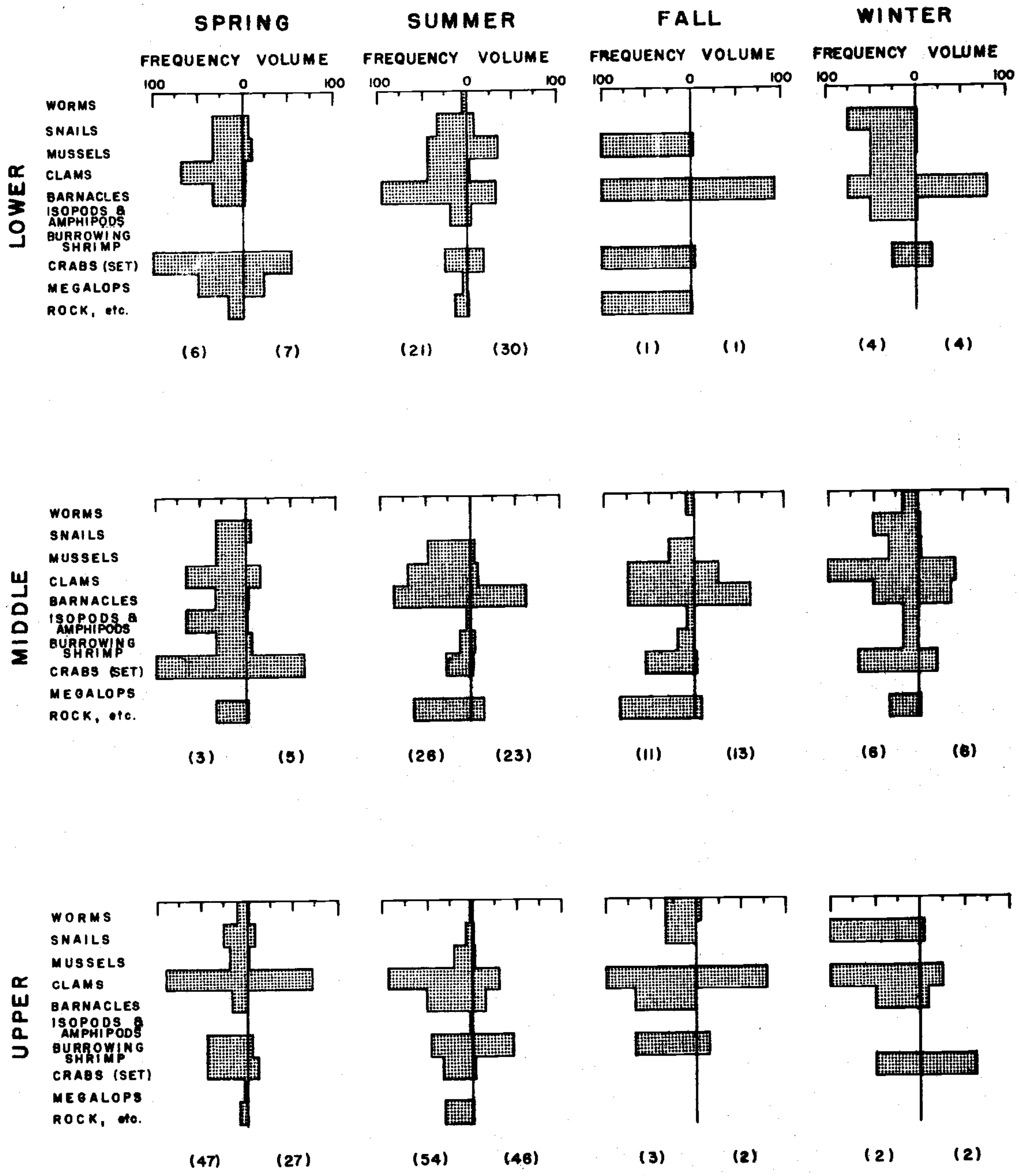

Figure 20. Percent frequency of occurrence and percent of total food volume of each food group by sampling unit for adult pile perch from Yaquina Bay, Oregon, in 1966 and 1967. (Sample sizes in parentheses.)

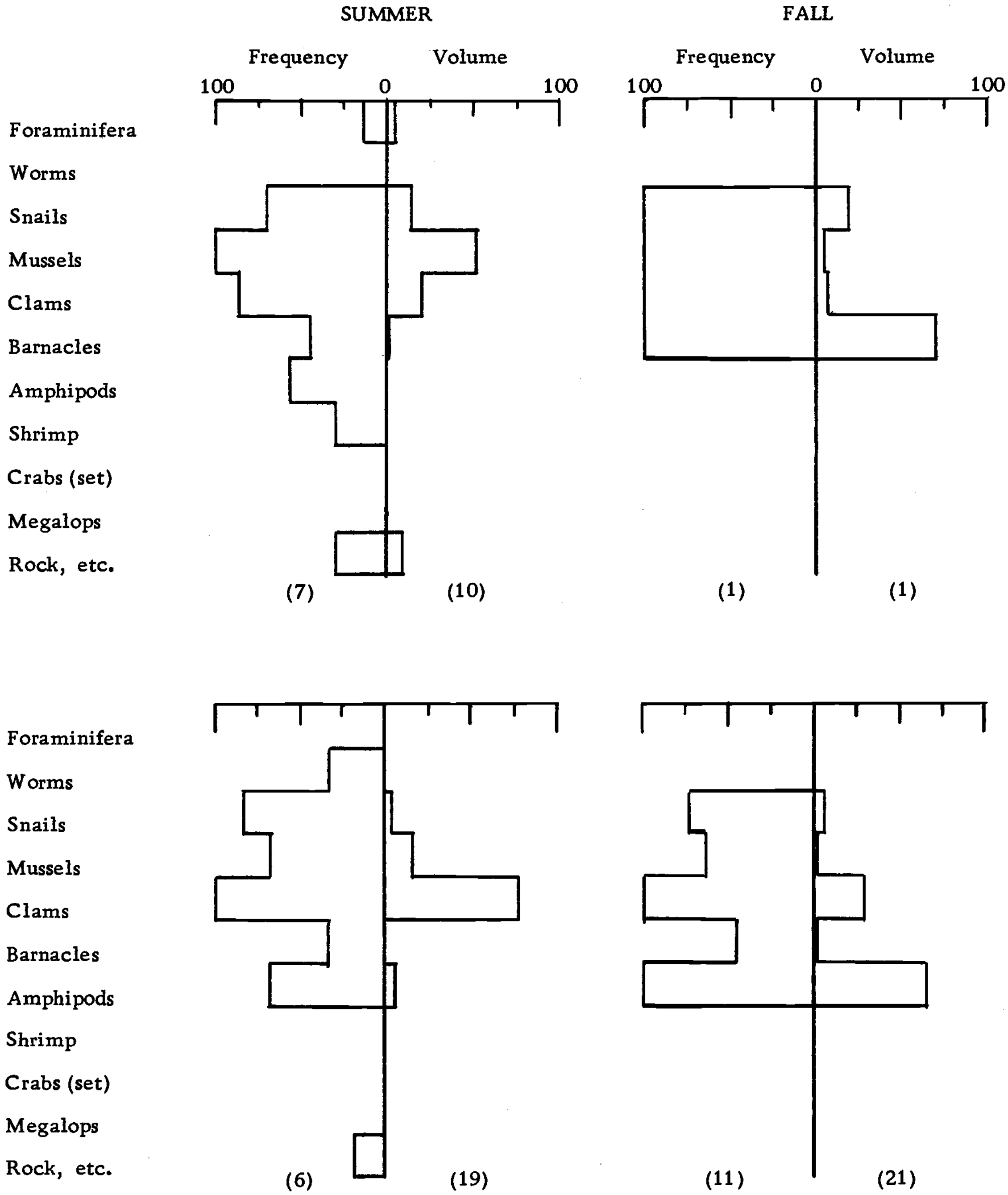

Figure 21. Percent frequency of occurrence and percent of total volume of each food group for young-of-the-year pile perch from Yaquina Bay in 1966 and 1967. (Sample sizes in parentheses.)

Table 4. Average percent of potential stomach volume for each food item found in the stomachs of 166 adult pile perch collected in Yaquina Bay, Oregon, from June, 1966 through July, 1967.

SAMPLING UNITS	FOOD ITEMS:	Polychaeta	*T. canaliculata*	*T. lamellosa*	Naticidae	*Olivella*	Epitoniidae	Cerithiidae	Unidentified Snails	Nudibranchia	*Mytilus edulis*	*Ostrea*	*Clinocardium*	*Mya*
LOWER	Spring		.07			.45		1.24			2.96		.72	
LOWER	Summer	.02		.02	.35	1.35	.03		..05		9.11		.02	.44
LOWER	Fall										.50			
LOWER	Winter					.18					.23			
LOWER	Year	.02	.07	.02	.35	1.99	.03	1.24	.05		12.80		.74	.44
MIDDLE	Spring										.10		.52	1.16
MIDDLE	Summer							1.20			.83		.06	.42
MIDDLE	Fall										.06		4.29	1.59
MIDDLE	Winter	.08				.08			.08		.48		6.20	.08
MIDDLE	Year	.08				.08		1.20	.08		1.47		11.07	3.25
UPPER	Spring	.14	.04	.12					1.03	.63	.11		3.31	.52
UPPER	Summer	.01							.02		.40	.07	.48	.62
UPPER	Fall	3.30											3.55	41.10
UPPER	Winter		1.15										3.60	.25
UPPER	Year	3.45	1.19	.12					1.05	.63	.51	.07	10.94	42.49

SAMPLING UNITS	FOOD ITEMS:	*Cryptomya*	*Protothaca*	*M. nasuta*	*M. secta*	*Saxidomus*	*Transennella*	*Hiatella*	Unidentified Clams	*Balanus*	Isopods	Amphipods	Unidentified Shrimp	*Callianassa*	*Upogebia*	*Pagurus*	*C. magister* (set)	*C. magister* (megalops)	*C. productus*	*C. oregonensis*
LOWER	Spring				.07					.63						.11	13.46	6.01	.86	
LOWER	Summer		.14		.14		.05	.03	.02	8.73		.66				.04	1.65	.02		3.14
LOWER	Fall									26.00							1.00			
LOWER	Winter									16.13	.12	.12							3.75	
LOWER	Year		.14		.21		.05	.03	.02	51.49	.12	.78				.15	16.11	6.03	4.61	3.14
MIDDLE	Spring	.10	1.02	.52						.56	.10	.10			1.40	.10	13.94			
MIDDLE	Summer		1.07						.02	10.64		.02			.75	.02	.54			
MIDDLE	Fall									13.83		.04			.04		.49			.21
MIDDLE	Winter			2.53						8.07							.47		2.07	.55
MIDDLE	Year	.10	2.09	3.05					.02	33.10	.10	.16			2.19	.12	15.43		2.07	.76
UPPER	Spring	1.17	9.87		.04	.21				.05	.01		.01	.11	1.03	.21	1.93	.04		
UPPER	Summer	4.84	.96		.15		.01			3.62					10.22		.28			.30
UPPER	Fall									.25					8.35					
UPPER	Winter		.75			1.30				2.05						.45	2.80			11.55
UPPER	Year	6.01	11.58		.19	1.51	.01			5.97	.01		.01	.11	19.60	.66	5.01	.04		11.85

SAMPLING UNITS	FOOD ITEMS:	*H. nudus*	*H. oregonensis*	Pinnotheridae	Unidentified Crab	Ophiuroidea	Herring eggs	Algae	*Zostera*	Rock	Σ = Percent Fullness of Average Stomach	No. of Stomachs
LOWER	Spring					.02					26.6	7
LOWER	Summer									.24	26.3	30
LOWER	Fall							.50			28.0	1
LOWER	Winter						.13				20.7	4
LOWER	Year					.02	.13	.50		.24		42
MIDDLE	Spring								.34		21.2	5
MIDDLE	Summer							.04		2.73	17.1	23
MIDDLE	Fall								.04	1.73	22.3	13.
MIDDLE	Winter		1.38					.08		.10	22.2	6
MIDDLE	Year		1.38					.12	.38	4.56		47
UPPER	Spring		.21	.03	.03					.02	20.6	27
UPPER	Summer	.06		.08	.01			.01	.02	.26	22.7	46
UPPER	Fall										56.5	2
UPPER	Winter										23.9	2
UPPER	Year	.06	.21	.11	.04			.01	.02	.28		77

Table 5. Average percent of volume of digestive tract contents for each food item eaten by young-of-the-year pile perch collected in Yaquina Bay, Oregon, between July, 1966, and July, 1967.

Sampling units		Food items														
		Foraminifera	Polychaetes	Naticidae	Unid. snails	*Mytilus edulis*	*Macoma*, *Mya*, *Cryptomya*	*Clinocardium*	*Protothaca*	*Transennella*	Unid. clams	*Balanus*	*Corophium*	Unid. Amphipods	Rock	Samples
MIDDLE	Summer	4		3	11	51	14	1	1	5		1		T*	9	10
	Fall			T	18	5	5	T	2			10				1
UPPER	Summer		1	1	2	13	45	34		T		1	3	T	T	23
	Fall			5	T	1	24	1	2		1	1	65	T		21

* T = trace.

Only a few food items are of great importance in the pile perch diet of young or adults within any given sampling unit. In all but two sampling units, the most important food item volumetrically was at least twice as important as any other item. Table 6 for adults and Table 7 for young-of-the-year list the most important food items in decreasing order which make up 80 percent or more of the weighted food volume for each sampling unit.

Table 6. Food organisms, listed in decreasing order of importance, which made up 80 percent or more of the total weighted food volume of adult pile perch in each sampling unit (sample sizes in parentheses).

	Spring		Summer		Fall		Winter	
	Food	Percent	Food	Percent	Food	Percent	Food	Percent
LOWER	C. magister (set)	51	Mytilus	35	Balanus	93	Balanus	78
	C. magister (megalops)	23	Balanus	33			C. productus	18
	Mytilus	11	C. oregonensis	12				
		85		80				96
	(6)		(22)		(1)		(3)	
MIDDLE	C. magister (set)	66	Balanus	62	Balanus	62	Balanus	36
	Upogebia	7	Protothaca	6	Clinocardium	19	Clinocardium	28
	Certhidae	6	Mytilus	5			M. nasuta	11
	Mya	6	Upogebia	4			C. prod-ductus	9
			C. magister (set)	3				
		85		80		81		84
	(3)		(14)		(9)		(5)	
UPPER	Protothaca	48	Upogebia	45	Mya	73	C. oregonsis	48
	Clinocardium	16	Cryptomya	21	Upobegia	15	Clinocardium	15
	C. magister (set)	9	Balanus	16			C. magister (set)	12
	Cryptomya	6					Balanus	9
	Upogebia	5						
		84		82		88		84
	(23)		(37)		(2)		(2)	

Table 7. Food organisms listed in decreasing order of importance which made up 80 percent or more of the total food volumes of age zero pile perch in each sampling unit (sample sizes in parentheses)

	Summer		Fall	
	Food	Percent	Food	Percent
MIDDLE	*Mytilus*	51	*Balanus*	70
	Mya, *Cryptomya*, *Macoma*	14	Unidentified snail	18
	Unidentified snail	11		
	Transennella	5		
		81		88
		(10)		(1)
UPPER	*Mya*, *Cryptomya*, *Macoma*	53	*Corophium*	64
	Clinocardium	24	*Mya*, *Cryptomya*, *Macoma*	25
	Mytilus	15		
		92		89
		(19)		(21)

Parasites

Six of seven young-of-the-year fish and 59 of 62 adult fish were infected with one or more of the parasites listed in Table 8. Adult pile perch were examined during every month of the year and from each zone of the bay, whereas all young-of-the-year pile perch were collected during November in the upper zone.

The only parasite infecting young-of-the-year fish was Clavella, probably C. insolita (Edward R. Long, personal communication) which was attached to the ends of the gill filaments. The average infestation was 2.4 parasites per fish. The most heavily infected fish had seven parasites.

Fifteen of 47 adult pile perch were infected with myxosporidian cysts on the gills. The most heavily parasitized fish carried 99 cysts, while the average infection was 15 cysts. Seventeen of 47 perch were infected with encysted metacercariae of bucephalid trematodes belonging to the genera Prosorhynchus, Rhipidocotyle and Bucephalopsis. These minute, whitish-appearing parasites were found in the heart, liver and kidney. Three adult trematodes of the genus Derogenoides were found in the liver. One adult specimen of Telolecithus pugetensis and Genitocotyle sp. were found in the digestive tract. Four immature spiruroid nematodes were found in the liver. Ten adult nematodes (Cucullanus sp.) were

Table 8. Taxonomic list of parasites identified from the gills, heart, liver, kidney and digestive tracts of 62 pile perch from Yaquina Bay, Oregon, between June, 1966, and July, 1967.

Phylum Protozoa	
Subphylum Cnidosporidea	Unidentified myxosporidian cysts
Phylum Platyhelminthes	
Class Trematoda	
Subclass Digenea	
Family Bucephalidae	*Prosorhynchus* sp.
	Rhipidocotyle sp.
	Bucephalopsis sp.
Family Hemiuridae	*Derogenoides* sp.
Family Monochiidae	*Telolecithus pugetensis*
Family Opecoelidae	*Genitocotyle* sp.
Phylum Aschelminthes	
Class Nematoda	
Superfamily Spiruroidea	Unidentified Spiruroids
Family Cucullanidae	*Cucullanus* sp.
Phylum Arthropoda	
Class Crustacea	
Subclass Copepoda	
Order Caligidea	
Family Caligidae	*Lepeoptheirus* sp.
Order Lerneopodidea	
Family Lerneopodidae	*Clavella* sp.

found in the digestive tract.

Infestation rate of copepods on the gills was related to season (Figure 22). The numbers of other parasites, as demonstrated for metacercariae in Figure 23, were not related to season. Occurrence of metacercariae in pile perch increased with size of fish (Figure 24).

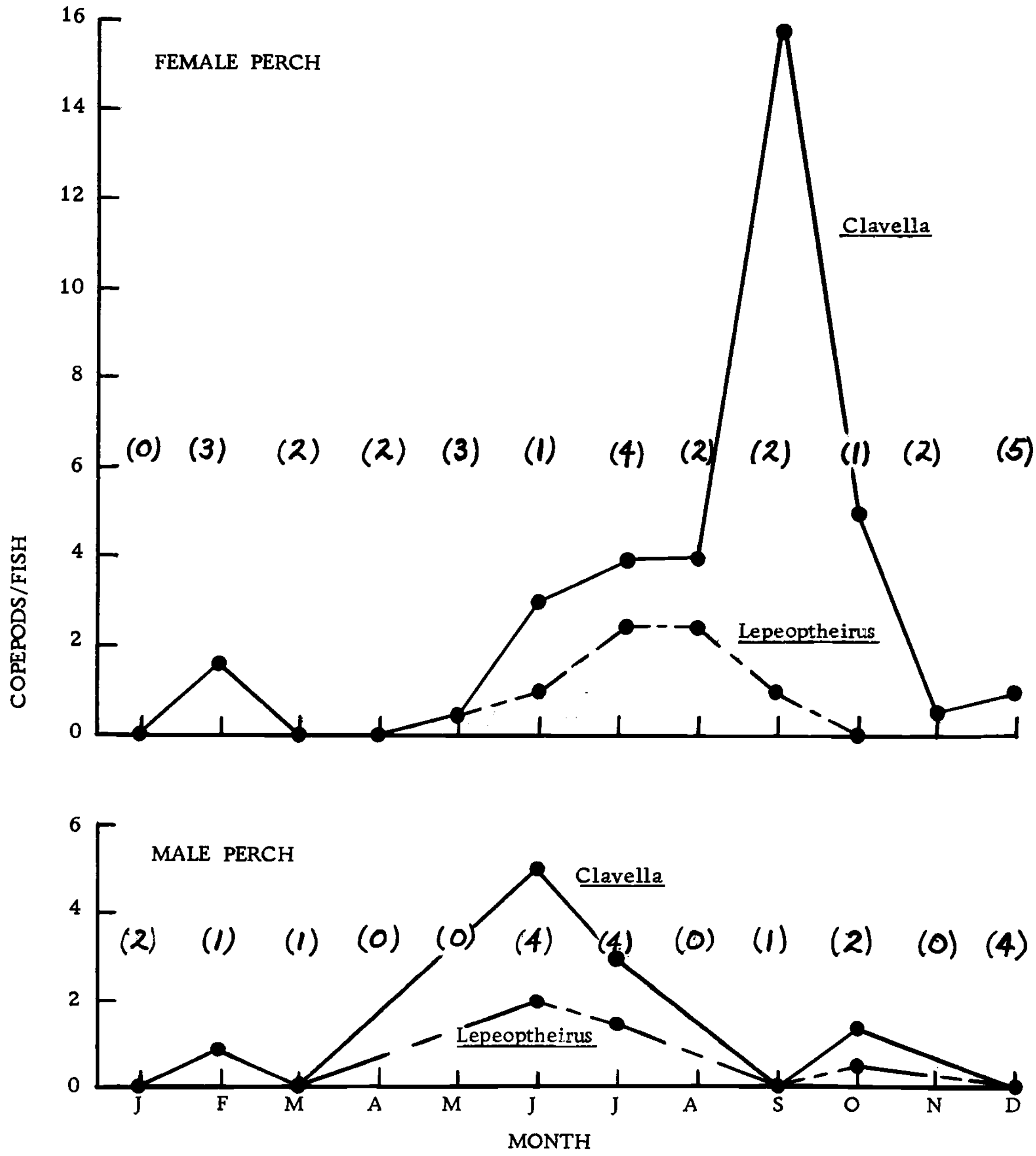

Figure 22. Infestation rate of gill copepods by month for each sex of host pile perch. (Sample sizes in parentheses.)

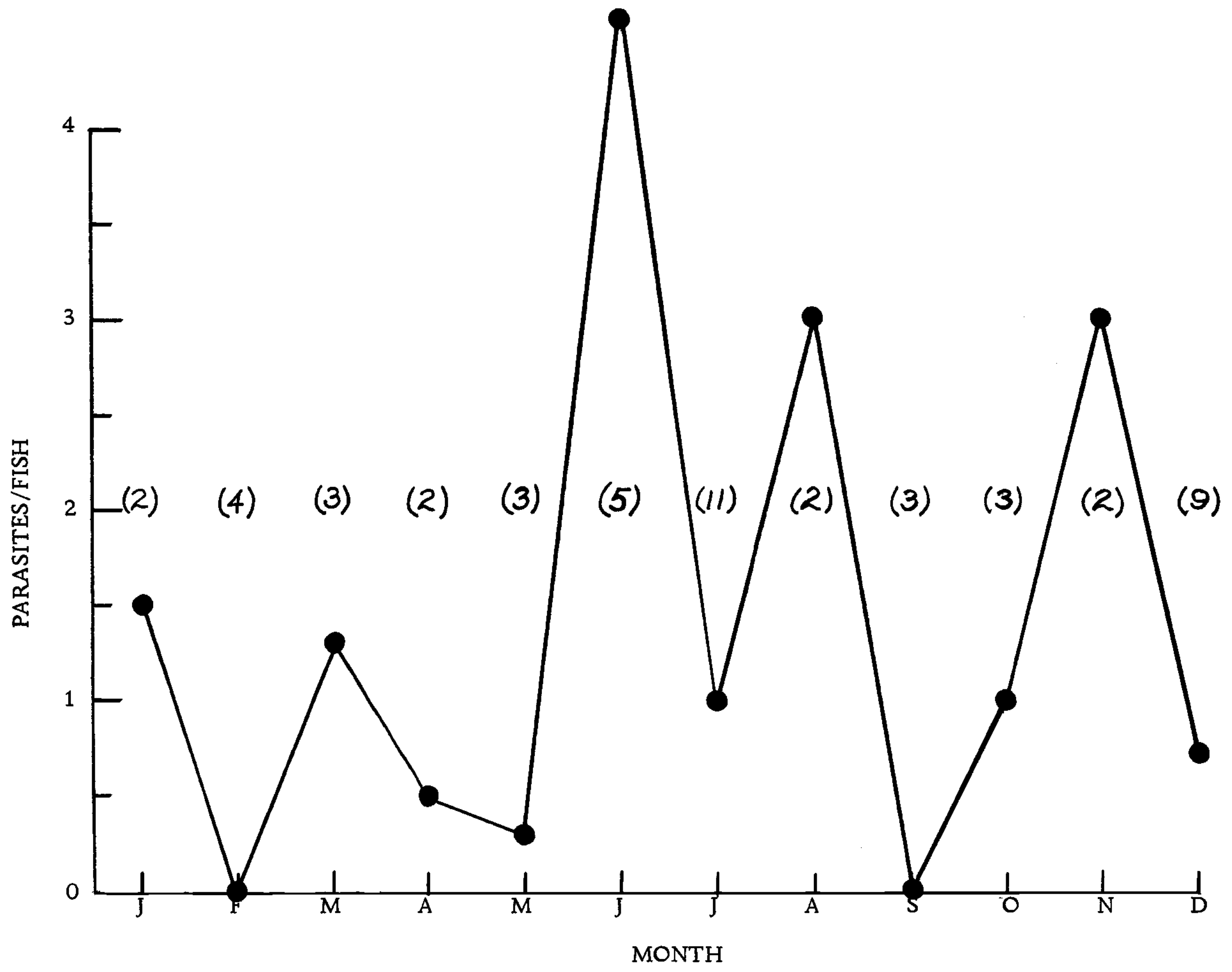

Figure 23. Monthly infestation rate of bucephalid metacercariae in the heart, liver and kidney of 49 pile perch captured in Yaquina Bay, Oregon, during 1966 and 1967. (Sample size in parentheses.)

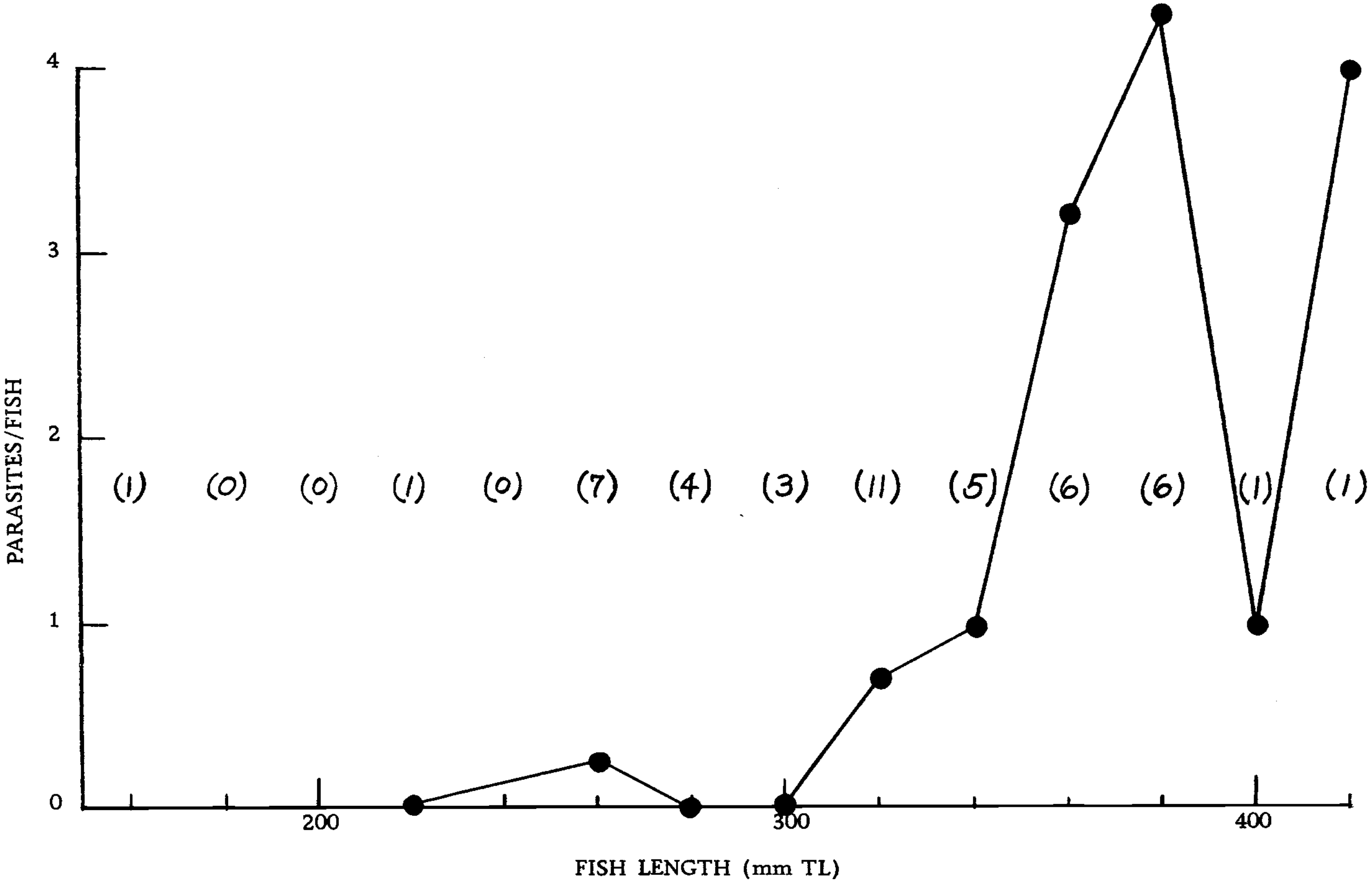

Figure 24. Infestation rate of bucephalid metacercariae in the heart, liver and kidney as a function of fish length. Numbers of pile perch sampled in each 20 mm length group is given in parentheses.

DISCUSSION

Age and Growth

Several points on age and growth deserve additional comment. The variation in the form of growth between the sexes of pile perch was the reverse of that reported for the striped seaperch (Embiotoca lateralis) by Gnose (1968). For both species, the weight-length regression lines for the two sexes cross; however, the line for females is the steeper in pile perch, whereas the line for males is the steeper in the striped seaperch.

The absence of Lee's Phenomenon is an indication that a mortality factor selective for faster growing fish is not operating to a significant degree on the pile perch of Yaquina Bay. The angling in Yaquina Bay is definitely selective, there being virtually no representatives of age classes 0, I and II in the catch. It may be, then, that this mortality is not significant to the population or that this mortality compensates a natural mortality selective for smaller fish acting on the first three age classes.

Since back-calculated lengths are estimates of fish length at the beginning of each growing season, one would normally expect observed lengths (collected throughout the year) to average longer than calculated lengths. My data in Figure 6 thus appears to be anomalous for females of age classes VII, VIII, IX, and for males of age class VI. I believe the cause for these questionable data is a combination of early (before annulus formation) average date of capture and differing sample size. The sample size for back-calculated lengths is larger than that for observed lengths in all but the oldest age class since calculated lengths for an age class include all fish in that age class plus all fish older.

The age frequencies presented in Figure 8 should not be considered indicative of the actual age structure of the pile perch population because of selective sampling. I do not think the unstable age structure indicated is entirely due to gear selectivity, however, since the trawl, seine and experimental gill nets were used frequently to minimize the chance of obtaining a highly selective sample. I offer the hypothesis, therefore, that the younger age classes behave differently than the older fish and have a different spatial distribution. I found that the sexes of older pile perch are segregated during the summer months when gravid females are generally found in the bay at distances farther from the ocean than the males. Perhaps the general behavior pattern is centered around the adaptive values of placing gravid females in the estuary where predators are fewer, temperature and salinity may be more favorable, or food is more abundant for both the females and their offspring. I suspect that the younger perch behave as males in this respect and were distributed in the lower estuary (or the ocean) where they were less vulnerable to my sampling efforts.

Food Habits

Both adult and juvenile pile perch are benthic feeders, with the young being adapted to a diet very similar to that of adults. Except for the absence of decapods, little reliance on barnacles and significant use of Corophium, the young-of-the-year fish feed on the smaller individuals of the same food species as the adults. These foods are probably the offspring of the current season and are at their peak abundance when the young perch are born. Young perch are well adapted for utilizing small molluscs, since their pharyngeal teeth are calcified before birth. Their mouths and bodies are small which probably renders them ill-adapted for utilizing the most abundant food organisms of the lower bay (barnacles and crabs).

Reproduction

From the data on male gonad development and the data on embryonic growth (Figure 25), there appears to be an interval of approximately two and one-half months between mating and fertilization of eggs. This conclusion is tentative because I have few observations of ovaries during October, November and

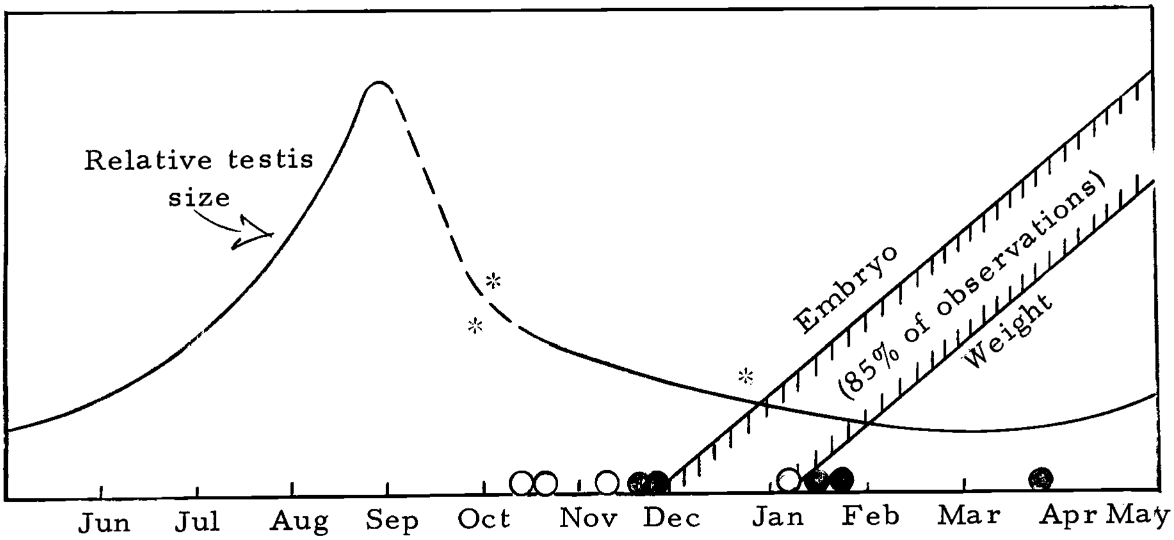

Figure 25. Summary of data on annual reproductive cycle from Figures 13 and 14. Asterisks indicate testes which readily emitted sperm; open circles indicate maturing follicles; closed circles indicate fertilized eggs.

December. Perhaps fertilization takes place soon after mating and early development is considerably slower than I have concluded. Conversely, it is possible that females store spermatozoa for an extended period before fertilization of the eggs. Eigenmann (1892) demonstrated for the shiner perch (Cymatogaster aggregata) that fertilization occurred about six months after mating and Hubbs (1921) gave evidence which suggested that Amphigonopterus aurora females also store spermatozoa for a considerable period.

Unfortunately, my techniques did not enable me to observe spermatozoa in the reproductive tracts of females (or even males that were definitely ripe). Further study to answer this important question will require more samples between early October and late January.

It appears that the reproductive cycle is timed later in the year with increasing latitude within the range of the pile perch as Rechnitzer and Limbaugh (1952) report the species giving birth in the vicinity of La Jolla, California, in April.

My conclusion that some age II males may be sexually mature is based on observations of relative gonad size. The major premise of my argument is that gonads of mature males will increase in size relative to body size during the mating season. Swedberg (1966) and Gnose (1968) found that 23 percent and 31 percent, respectively, of male striped seaperch were mature at age II. The striped seaperch is also found in Yaquina Bay where its size and longevity are similar to the pile perch.

Parasites

None of the parasite infections appeared to be of significance to the health of the fish. Damage to gill filaments from copepods was noted, but it never appeared to impair respiration significantly.

The seasonal occurrence of copepods appears to be related to the cyclic abundance of infective copepods rather than to the distribution of pile perch. Male fish which tended to remain in the lower portion of the estuary showed a similar infestation as female fish which tended to move farther into brackish water.

SUMMARY

1. Standard length measurements of pile perch can be calculated from known total lengths (or *vice versa*) by the equation $SL = .75\ TL - 1.51$.

2. Mean lengths of male and female pile perch (mm TL) in May of each year of life are as follows:

	Male	Female
I	128	119
II	204	199
III	264	258
IV	305	306
V	338	343
VI	360	371
VII	378	394
VIII	391	422
IX	404	444
X	---	449

3. Rosa Lee's phenomenon is absent in the population of pile perch in Yaquina Bay.

4. Maximum lengths were predicted from Walford Lines to be 432 mm for males and 490 mm TL for females.

5. The relationship of weight to length was $\log_{10} W = 3.08 \log_{10} L - 5.06$ for males, $\log_{10} W = 3.19 \log_{10} L - 5.30$ for females, and $\log_{10} W = 3.56 \log_{10} L - 5.51$ for embryos.

6. A minimum range in the size of newly born pile perch was 76 to 86 mm TL.

7. Average size of preserved pile perch eggs (after fertilization) was 792μ.

8. Average instantaneous daily growth rate in weight (g_w) was estimated to be 0.0606 for embryos between .01 and 2.0 g and to be 0.0093 for the first two months after birth.

9. Growth rate of embryos over 2.0 g decreases significantly.

10. Eighty-five percent of the population of gravid pile perch in Yaquina Bay were estimated to have given birth between June 27 and August 4.

11. Calendar dates of growth histories of embryos coincided in 1966 and 1967.

12. One-third of the female pile perch matured in their third year of life and nearly 90 percent were mature in their fourth year.

13. Some males may mature in their second year of life.

14. Mature males were in spawning condition from at least mid-October to late January.

15. Fecundity is related to size of females, and ranges from about 12 young for the smallest breeding females to over 50 for the largest.

16. Intraovarian mortality of eggs and embryos was estimated to be 4.8 percent of reproductive potential.

17. Gestation period was estimated as 179 days.

18. Food habits varied seasonally and between zones in Yaquina Bay. The most important food organisms were barnacles, clams, mussels, crabs, mud shrimp and Corophium.

19. The major differences in the diets of young-of-the-year and adult pile perch were the inclusion of Corophium and virtual exclusion of decapods in the food items consumed by young perch.

20. Parasites identified from pile perch were the metacercariae of Prosorhynchus, Rhipidocotyle and Bucephalopsis; and adults of Derogenoides, Telolecithus pugetensis, Genitocotyle, Cucullanus, Lepeoptheirus and Clavella.

21. Infection of copepods was seasonal, whereas infection of metacercariae was not related to season but increased with fish length.

BIBLIOGRAPHY

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

Beardsley, Alan J. 1967. Unpublished research on embiotocids in Yaquina Bay. Corvallis, Oregon State University, Department of Fisheries and Wildlife.

Burt, Wayne V. and W. Bruce McAlister. 1959. Recent studies in the hydrography of Oregon estuaries. Fish Commission of Oregon Research Briefs 7:14-27.

Eigenmann, Carl H. 1892. On the viviparous fishes of the Pacific Coast of North America. Bulletin of the U. S. Fish Commission 12:381-478.

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

Hubbs, Carl L. 1921. The ecology and life-history of Amphigonopterus aurora and of other viviparous perches of California. Biological Bulletin 40:181-206.

Kulm, Laverne Duane. 1965. Sediments of Yaquina Bay, Oregon. Ph. D. thesis. Corvallis, Oregon State University. 184 numb. leaves.

Light, S. F. et al. 1964. Intertidal invertebrates of the central California coast. Berkeley, University of California. 446 p.

Long, Edward R. 1966. Graduate Research Assistant, Oregon State University, Dept. of Zoology. Personal communication. Corvallis, Oregon.

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

Morgan, Alfred R. 1961. Siletz Bay surf perch tagging. Fish Commission of Oregon Research Briefs 8:5-13.

Parrish, Loys P. 1966. The predicted influence of kraft mill effluent on the distribution of some sport fishes in Yaquina Bay, Oregon. Master's thesis. Corvallis, Oregon State University. 88 numb. leaves.

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

Reimers, Paul E. 1964. A modified method of analyzing stomach contents with notes on food habits of coho salmon in the coastal waters of Oregon and southern Washington. Fish Commission of Oregon Research Briefs 10:46-56.

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

Rounsefell, George A. and W. Harry Everhart. 1953. Fishery science, its methods and applications. New York, John Wiley. 444 p.

Swedberg, Stephen Ernferd. 1966. Age fecundity relationships in the striped seaperch (Embiotoca lateralis) from Yaquina Bay, Oregon. Master's thesis. Corvallis, Oregon State University. 41 numb. leaves.

Tarp, Harold Fred. 1952. A revision of the family Embiotocidae (the surfperches). Sacramento. (California Dept. of Fish and Game. Fisheries Bulletin no. 88)

Wales, Joseph Howe. 1929. A note on the breeding habits of the viviparous perch Damalichthyes. Copeia 172:57-58.