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BIOLOGY OF THE PILE PERCH, Rhacochilus vacca, IN YAQUINA BAY, OREGON

By Paul G. Wares, Fishery Biologist
Tiburon Marine Laboratory, Tiburon, California

ABSTRACT.--Growth, reproduction, food habits, and parasites of pile perch, Rhacochilus vacca (Girard), were investigated in Yaquina Bay, Oreg., between April 1966 and July 1967. The research disclosed that pile perch live at least 10 years. Males and females of given ages are close to the same size up to age IV, after which females are increasingly larger than males. Males and females respectively approach average ultimate sizes of 1,120 g at 430 mm and 2,000 g at 490 mm total length. Some females mature in their second year; 90 percent mature at age III. Some males also mature in their second year. Mating occurs in the fall; there is a delay of about 3 months before fertilization. The gestation period is about $6\frac{1}{2}$ months; most young are born between late June and early August. Fecundity increases with size and age of fish (observed range 7 to 61 embryos). Dead eggs and malformed embryos are occasionally found among healthy embryos, the occurrence of malformed embryos being inversely related to age of parent, the occurrence of dead eggs being independent of age of parent. Pile perch are carnivorous feeders, obtaining food from the bottom or protruding surfaces in the littoral zone. The diet varies between seasons and localities. Principal foods are barnacles, mussels, the bay clams, crabs, mud shrimp, and a tube dwelling amphipod. None of the pile perch examined was heavily parasitized. Infestations of gill copepods vary seasonally.

The pile perch (Rhacochilus vacca), a member of the surfperch family (Embiotocidae), ranges from southeastern Alaska to northern Baja California (Tarp, 1952). It can be recognized by its high anterior dorsal fin rays which form a prominent peak in the contour of the fin and by its silvery color variably overlain with sooty tones which usually include a single dark verticle bar slightly posterior to the middle of the body. Its preference for near-shore areas, bays, and docks makes it easily accessible to fishermen. This coupled with its size and palatability, makes it a valuable recreational resource. An angler survey by Parrish (1966) showed that the pile perch was the third most important fish by weight caught by sport fishermen in Yaquina Bay, Oreg. Morgan (1961) reported it as the most abundant embiotocid in Siletz Bay, Oreg. and Tarp (1952) listed it as a moderately important commercial species.

Most published information on the biology of the pile perch concerns reproduction and population movements. Wales (1929) observed a large school of pile perch mating in water

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about 15 feet deep at the fish wharf in Monterey, Calif., on December 20, 1928. Rechnitzer and Limbaugh (1952) noted that pile perch began giving birth about the middle of April in the ocean near La Jolla, Calif. Morgan (1961) found that the pile perch population in Siletz Bay, Oreg. is migratory and that the population size is at its peak in the upper part of the Bay from June to July, when it consists mostly of gravid females. He also found that most females had produced young by late August.

The present study was conducted in Yaquina Bay, estuary of the Yaquina River, which communicates with the Pacific Ocean between mile-long jetties at the town of Newport on the central Oregon coast. The estuary is divided into a lower, a middle, and an upper zone, each with a distinct aquatic environment (fig. 1). The lower zone is characterized by strong tidal currents, scoured sandy bottom, and nearly constant ocean salinity. The middle zone is characterized by extensive mud flats with eel grass (Zostera) beds, moderate currents, soft silty bottom, and moderately fluctuating salinity. The upper zone is characterized by firm mud-gravel bottom, fairly strong currents, and highly fluctuating salinity (both tidally and seasonally). These zones coincide with the three realms of sediment deposition defined by Kulm and Byrne (1966): marine, marine-fluviatile, and fluviatile. Precipitation in the area is seasonal, with 80 to 90 percent of the annual average of 65 inches falling between September and May, primarily in the form of rain (Kulm and Byrne, 1966).

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AGE AND GROWTH

Method of age determination

Length-frequency data from this study were of no value in distinguishing age classes of

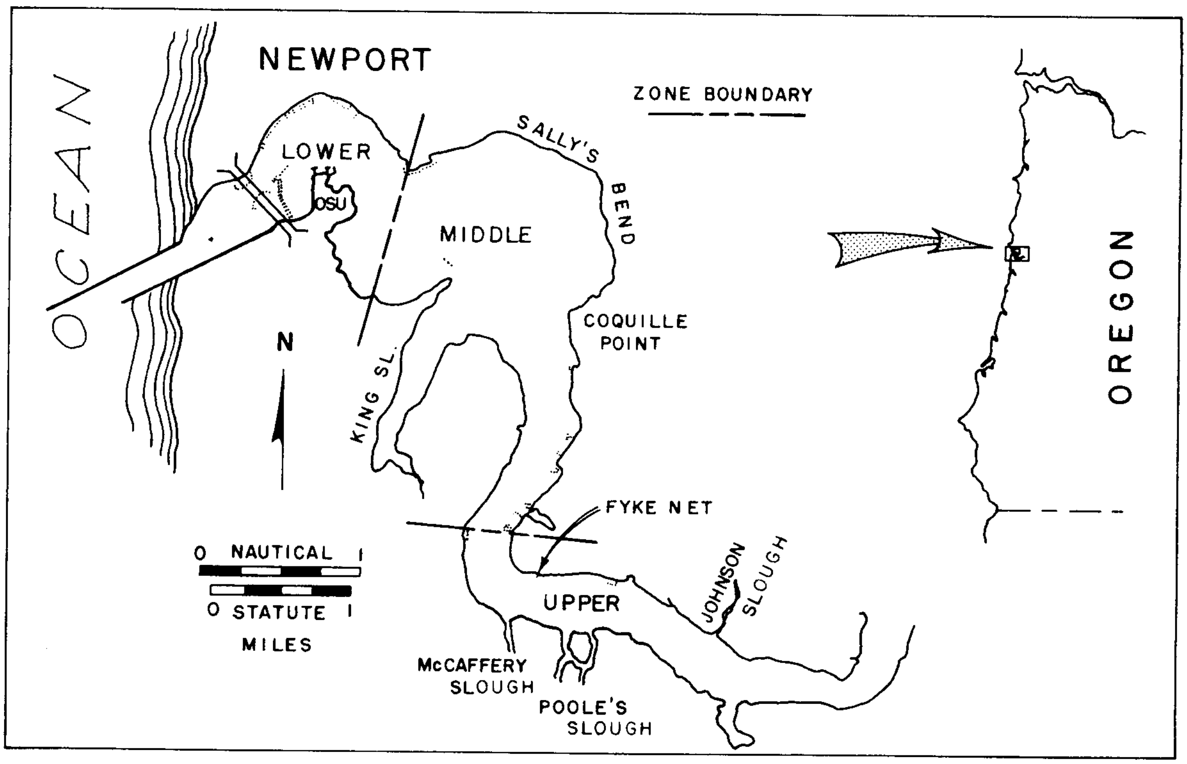

Figure 1.--Yaguina Bay, Oregon, showing that portion of the estuary in which pile perch occur.

pile perch above age I, partly because of the lack of a large sample obtained over a short time. The scale method of age determination, used successfully in aging other embiotocids (Carlisle, Schott, and Abramson, 1960; Sivalingam, 1956; Hubbs, 1921), was employed. An attempt was made to collect fish throughout the year, but success was poor in winter. Gill nets, a seine, an otter trawl, a fyke net, and hook and line gear were all used at various times during the study, making it possible to collect specimens of all age classes in the population. All lengths and weights were obtained in the field from freshly killed specimens, except for young-of-the-year fish which were first preserved in 10 percent formalin.

To achieve uniformity, a specific scale located five rows below the lateral line in the scale column originating below the third dorsal spine was taken from each side of the body. When one of these "key scales" was found to be regenerated, an adjacent (anterior or posterior) scale was used. Scale features were studied and measurements were made from acetate impressions projected with an Eberbach projector. Typical scales of pile perch and the method of measuring annuli and scale radius are shown in figure 2. The metamorphic "annulus" is a recognizable check formed approximately at the time of birth.

Because fish were collected during all months of the year, a "birthday" was needed for assigning ages, and January 1 was chosen. Thus, because annuli were formed from March through June, fish caught in January and February were assigned ages greater by 1 than their number of annuli. Assignment of ages for fish caught from March through June required in each case judgement whether the current year's annulus had been formed. These judgements were made on the basis of scale growth beyond the last annulus. Total lengths (TL) at previous ages were calculated by the direct-proportion formula with correction factor (Rounsefell and Everhart, 1953). The calculations were performed by computer.

Growth rates

Regression analysis of key scale radius on total length for 218 pile perch yielded the equation $Y = 0.67X - 20.75$ with a correlation coefficient (r) of 0.9835. The apparent total length of pile perch at the time of scale formation (x-intercept) was 31 mm. This was used as the correction factor in the back-calculation formula.

Males and females grew at about the same rate for the first 3 or 4 years, after which the growth rate of males declined more rapidly than that of females (fig. 3). The apparent increase in growth rates for females during the eighth and ninth years is probably not real. Two factors tend to diminish the reliability of average back-calculated lengths as age increases: increasing proportion of erroneous age determinations and decreasing size of sample. Back-calculations were based on the following numbers of males and females, respectively, in each age-class: I, 4 and 2; II, 9 and 2; III, 6 and 14; IV, 11 and 41; V, 11 and 71; VI, 11 and 33; VII, 19 and 28; VIII, 7 and 15; IX, 9 and 4; X, 0 and 3.

Total lengths (in millimeters) may be converted to standard lengths (SL) (in millimeters) by the formula $SL = 0.75TL - 1.51$. This equation was derived graphically from data on 12 male and 8 female pile perch ranging in size from 76 mm to 398 mm TL.

Growth transformations (Walford, 1946) indicated maximum attainable total lengths (TL_∞) of 432 mm for male and 490 mm for female pile perch (fig. 4).

Rosa Lee's phenomenon as presented by Ricker (1958) appeared to be absent. Growth rates of young fish did not appear to be slower (or faster) when calculated from scales of older fish than when calculated from scales of younger fish. This is as would be expected, since the sport fishery for pile perch is not selective for the faster (or slower) growing individuals.

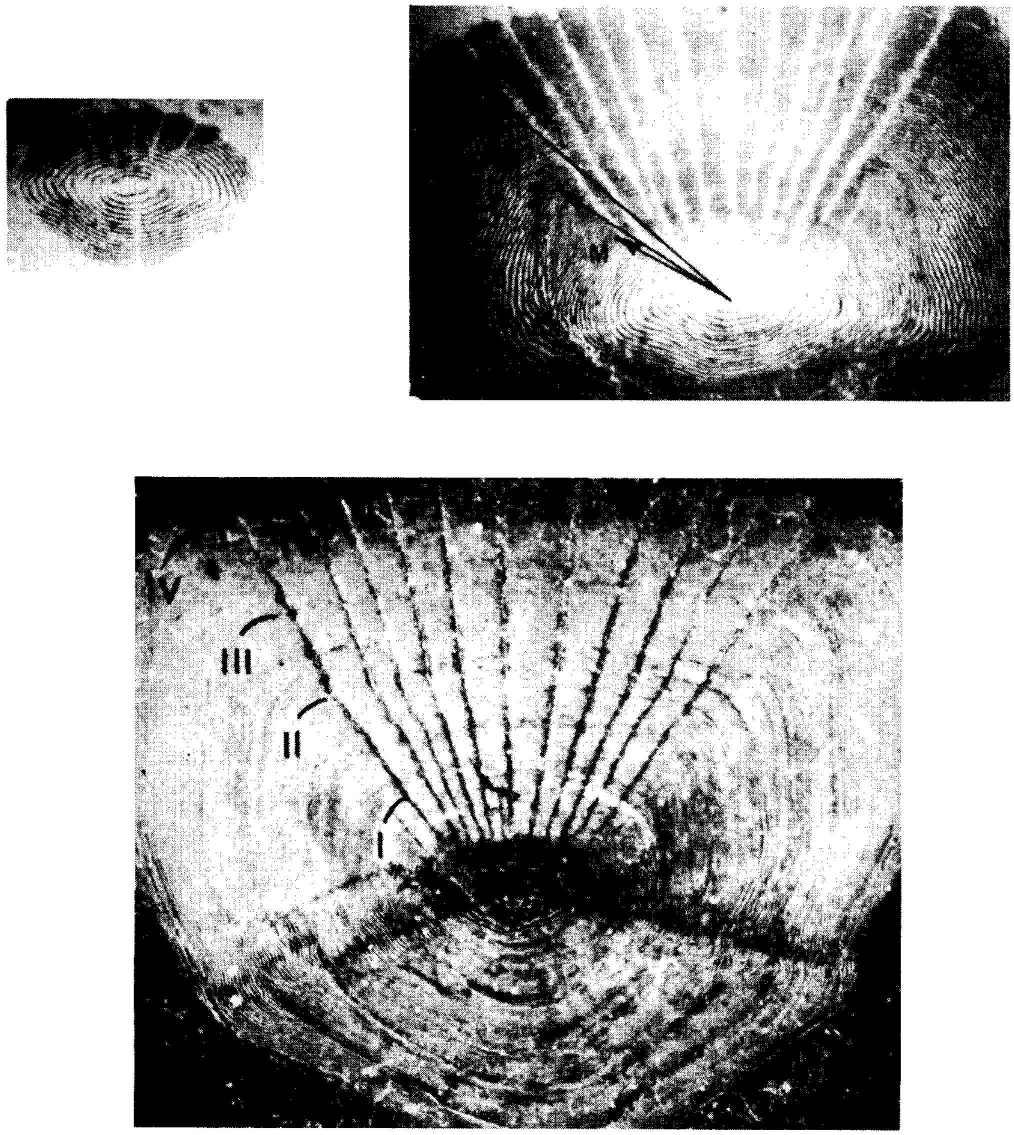

Figure 2.--Scales of pile perch. a, Near-term embryo 59 mm standard length, b, Age II perch captured just before annulus formation showing measurement of metamorphic "annulus" M, annulus I, and total scale radius R, c, Age IV female showing regenerated focus. (a and b are of the same magnification, c is less magnified.)

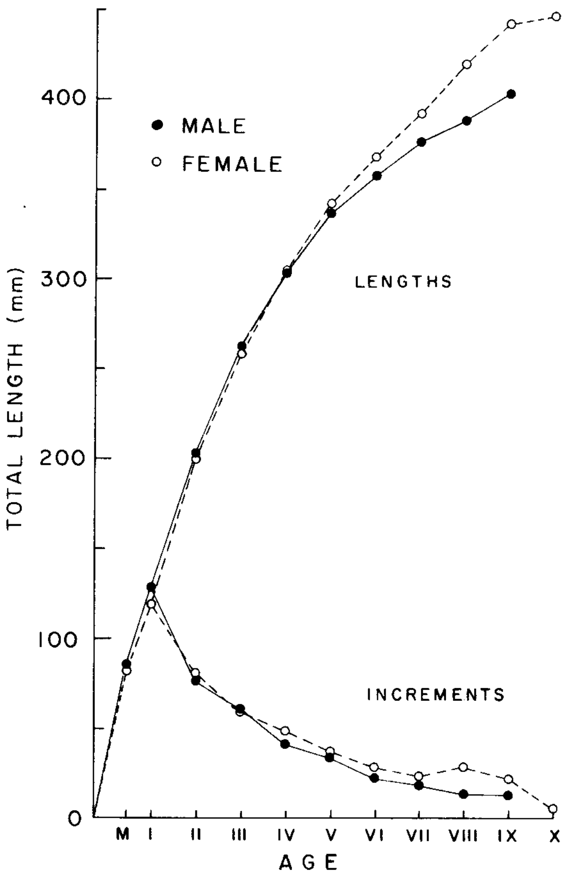

Figure 3.--Mean back-calculated lengths at each annulus and annual increments in length for 87 male and 231 female pile perch. Age M refers to length at formation of the metamorphic annulus, or the approximate length at birth.

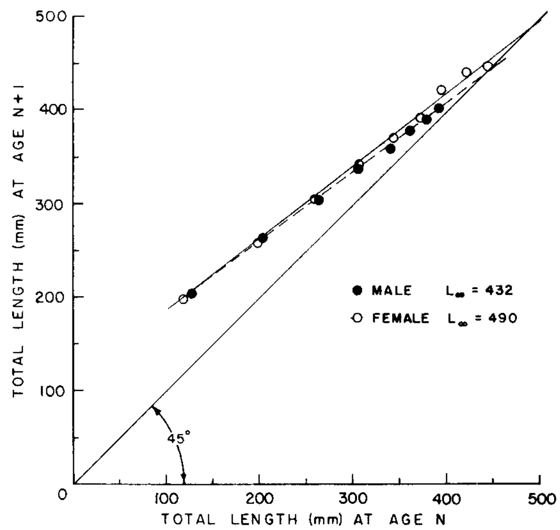

Figure 4.--Eye-fitted growth transformations based on mean back-calculated lengths of 87 male and 231 female pile perch.

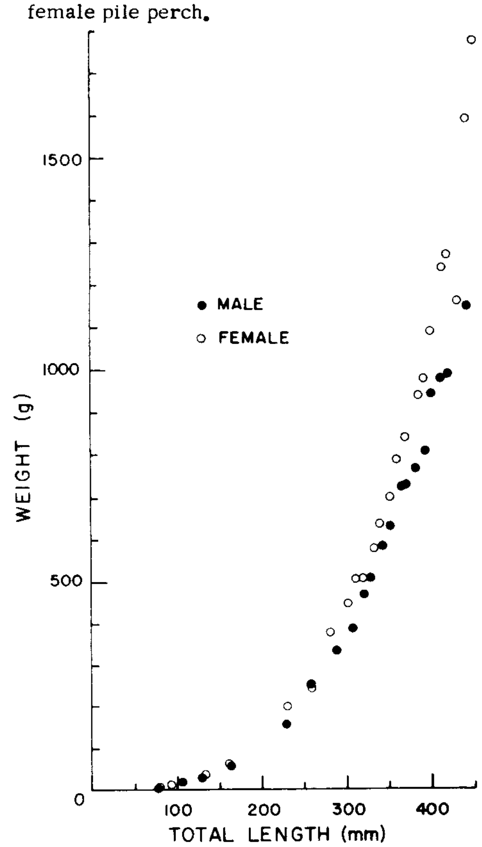

Figure 5.--Mean weights compared to mean lengths at various length intervals for male and female pile perch. Females with embryos larger than 30 mm SL were excluded.

Weight-length relations

In figure 5 the relation of weight to length is illustrated on a linear scale for each sex. For females, only those without embryos or those with embryos less than 33 mm SL were included in analysis of the weight-length relation. The general exponential relation of weight to length $W = cL^n$ was assumed. Regression lines fitted by least squares to the logarithms of lengths and weights had the following equations:

$$\mathrm{Log}_{10}W = 3.08\ \mathrm{Log}_{10}L - 5.06 \text{ (males) and}$$

$$\mathrm{Log}_{10}W = 3.19\ \mathrm{Log}_{10}L - 5.29 \text{ (females)}$$

where W = body weight in grams and L = total length in millimeters. Correlation coefficients (r) of data in these equations are 0.9996 and 0.9993 respectively. Growth in weight and annual increments in weight are shown in figure 6. Average weights at each annulus were calculated by inserting mean back-calculated lengths in the regression equations for weight on length.

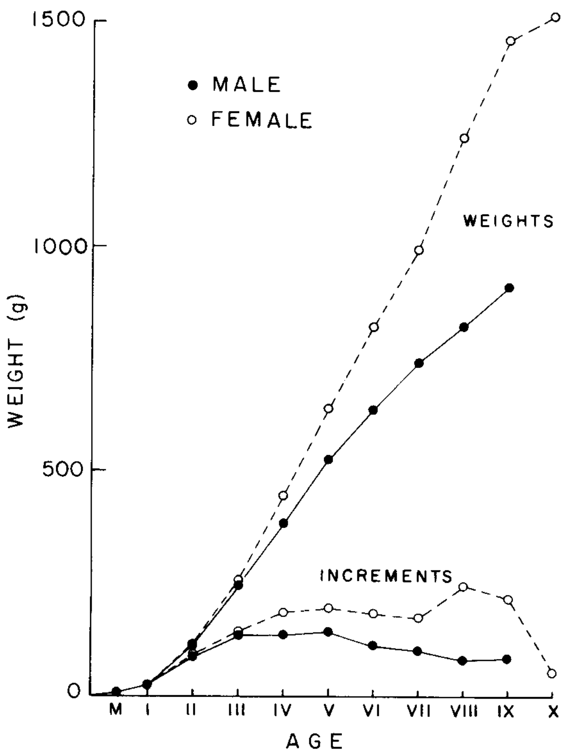

Figure 6.--Calculated mean weights at each annulus and annual increments in weight for male and female pile perch.

Distribution within the bay by sex and age

Pile perch appeared to enter the estuary in spring and to leave it in the fall, as catch per effort was very low in late fall and winter and high in spring and summer. Morgan (1961) found a similar migratory pattern for pile perch in Siletz Bay, Oreg. During the spring and summer the sexes were partially segregated in Yaquina Bay, the catches dominated by males in the lower zone, by females in the upper zone, and mixed in the middle zone.

It became apparent during the study that age classes I, II, and III were captured less frequently than expected, though young-of-the-year pile perch and other small fish were captured with the seine, otter trawl, and experimental gill nets. A catch curve (fig. 7) for pile perch caught with these types of gear confirms the low abundance for these early age classes. Apparently these young fish tend to remain out of the estuary after leaving during their first winter; it seems unlikely that these age classes were present in the Bay but concentrated in areas separate from the older fish, as many areas were sampled and nowhere were more than one or two individuals of these ages captured at one time.

REPRODUCTION

In embiotocids the male gonads are separate, except for the ducts which unite and exit through the urinogenital opening. In females the gonads are fused into a single bilobed organ which is internally divided lengthwise by several membranes called ovarian septa. The eggs are produced on the septa and expelled from the follicles into the chambers between the septa either just before or just after fertilization. The septa also provide surface area for gas exchange between maternal and embryonic blood supplies. The vertical fins of the embryos are well vascularized and greatly enlarged for this purpose. The embryos remain free within the ovary until birth and receive nourishment by ingesting ovarian secretions. The yolk is small and provides nourishment for only a small fraction of intraovarian development (Triplett, 1960; Engen, 1968). The term "embryo" is used in this paper in reference to the young in all stages prior to birth.

Methods of study

Data on reproduction were gathered by examination of reproductive tracts of pile perch obtained throughout the study. Maturity of male reproductive organs was assessed by an index calculated as follows:

$$\frac{\text{testis length (mm) x testis width (mm)}}{\text{fish weight (g)}}$$

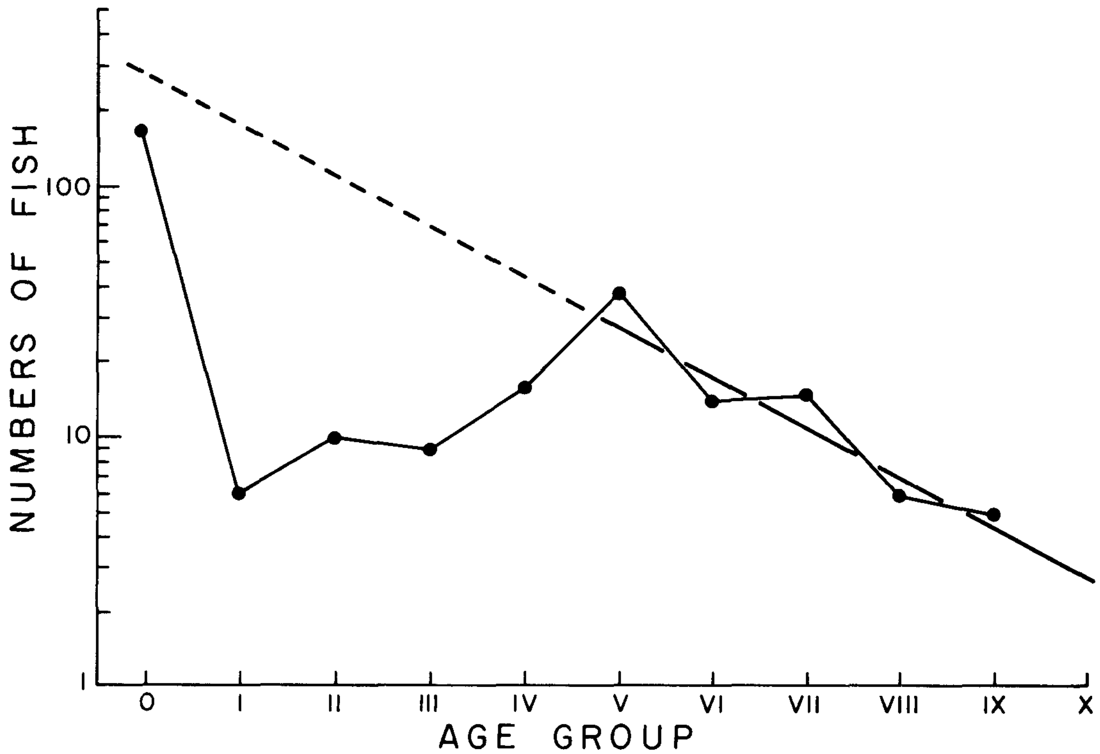

Figure 7.--Catch curve for pile perch captured with otter trawl, seine, and multimeshed gill nets. The trend (heavy line) based on age groups V through IX indicates (dashed portion) expected catches much higher than actually made for age groups I, II, and III.

Testis measurements were made in the field on the unpreserved tissue, the larger of the two gonads being selected for measurement in each case.

Ovaries were fixed in 10 percent formalin and preserved in 40 percent isopropyl alcohol for later examination. Since there was little variation in sizes of normal embryos of a given ovary, average weights were used to describe development of embryos. Average weights were obtained by weighing several embryos together and dividing by the number of embryos weighed. Before weighing, embryo samples were drained in a sieve and the sieve tamped on paper towels to absorb excess moisture. All malformed embryos were recorded but never included in the average weight determinations. These are discussed in detail in the section titled Prenatal Mortality.

To determine egg mortality, 65 ovaries containing embryos were carefully opened and washed out, the wash water decanted, and the sediments searched for eggs under a dissecting microscope. All eggs recovered from these ovaries were recorded and preserved for later study.

Maturity and fecundity

Data from 76 males (fig. 8) indicate that the peak testis index occurred sometime during September and October. The highest index value was observed on September 29 and was about 10 times as large as midsummer values. The gonad index was not applied to age 0 males, but the gonads appeared obviously immature. No conclusions could be made regarding maturity of age I males because none were observed during the mating season.

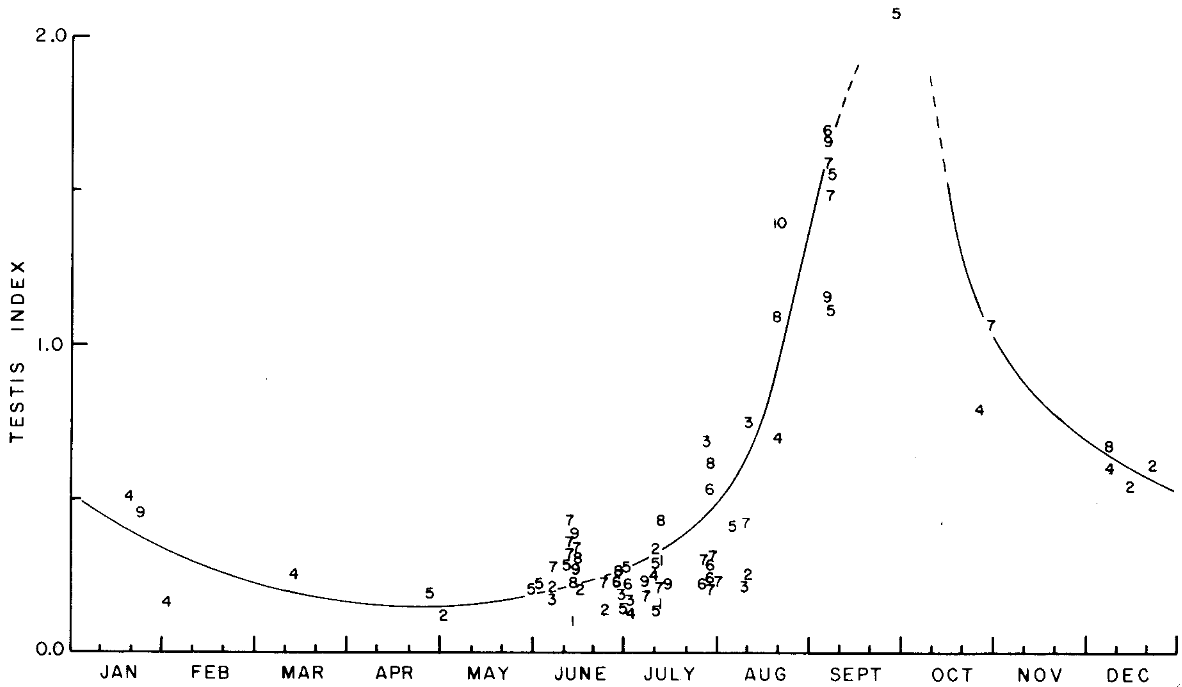

Figure 8.--Seasonal variation in testis index. The index value calculated for each male pile perch is plotted against the date of capture by a number indicating the age of the fish. Trend line fitted by eye.

Index values of two age II males captured in December were three times as great as summertime values, indicating that some may be mature at this age.

In determining age at first maturity, females were considered mature during the year they mated rather than during the year they gave birth. Because data on males indicated fall mating, it was assumed that all gravid females observed in spring or summer months had mated the previous fall. On this basis the earliest maturity was age II, in which 33 percent of 15 specimens were mature. The percentage of females that were mature in each age class is presented in table 1. Caution should be used in applying these percentages to the population in general. There are significant differences in distribution between young and older pile perch, as pointed out in the previous section, and these may be related to sexual maturity. For this reason the sample may be composed of a disproportionately high percentage of mature individuals, and the actual percentage of the population that matures at ages II and III may be considerably less that that indicated.

Table 1.--Maturity of female pile perch
[See text for basis of assigning age of maturity]

Age class	Number of females examined	Percent mature
0........	42	0
I........	2	0
II	15	33
III.......	35	89
IV.......	72	97
V or older. .	82	98

Fecundity was positively correlated with size and age of females (fig. 9). The most fecund individual was an age IX female 449 mm TL that contained 61 embryos.

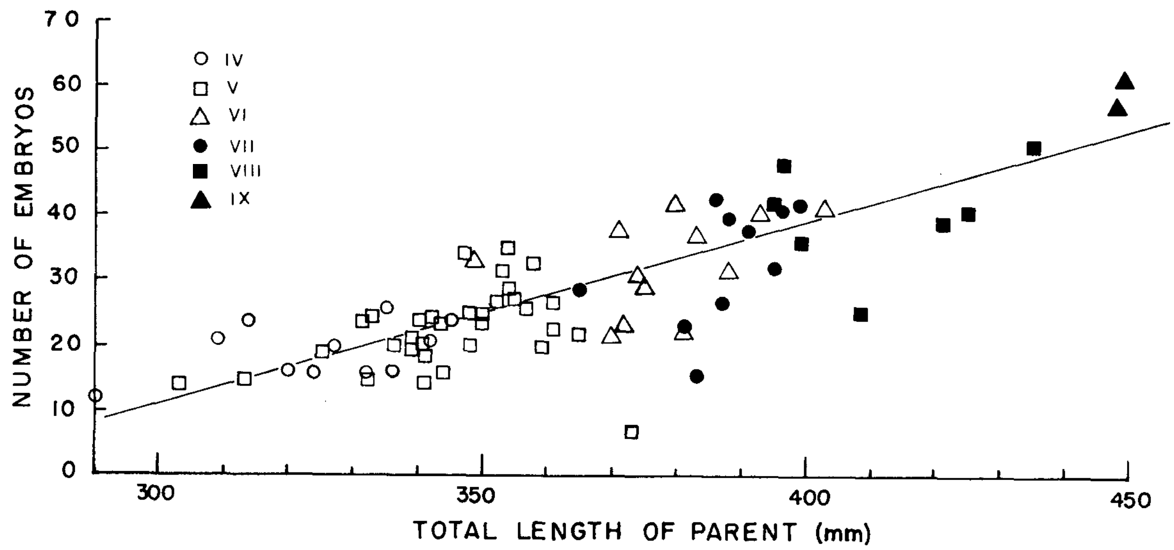

Figure 9.--Length, age, and fecundity relations of 74 pile perch from Yaquina Bay, Oreg., in 1966 and 1967. Trend line fitted by eye. (Only data for which embryos were less than 32 mm SL were included because larger embryos tended to be aborted during capture).

Prenatal mortality

Two sources of prenatal mortality were found: egg deaths and deaths from malformations. Dead eggs were found in ovaries which contained embryos. Many of these eggs were shriveled and opaque, but those in a more normal condition were recognized as fertilized eggs in various stages of development. Since in some cases the embryos occurring with the dead eggs were nearly of terminal size, it appeared that eggs which die before hatching are not resorbed. Therefore, the counts of these eggs may provide valid estimates of mortality between fertilization and hatching. Sixty-five ovaries contained a total of 1,734 embryos and a total of 69 dead eggs, an apparent mortality of 3.8 percent of all eggs fertilized.

Malformed embryos (fig. 10) were considered mortalities because all of the malformations appeared severe enough to be ultimately lethal. It is not known whether any were living at the time of capture, but many obviously were dead and some were partially resorbed. Of 3,699 embryos examined during the study, 44 (1.2 percent) were malformed. Only three ovaries contained more than one malformed individual. In one of these, 19 of 20 embryos were malformed and were about half the size of the normal individual, which was 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 (scoliosis) in the anterior portion of the vertebral column. Of 16 embryos in the second ovary, 11 were all less than half the length of the normal embryos but ranged greatly in length (from 6 mm to 11 mm SL). These embryos again were similar to one another in type of malformation, which was characterizeby an enlarged head and protruding lower jaw. The third overy contained three malformed embryos and 29 normal embryos.

Although egg mortality appeared unrelated to age of parent female, occurrence of malformed embryos was markedly associated with younger females (table 2). Females age V or younger carried only 48 percent of all embryos examined but carried 95 percent of all the malformed embryos.

Embryonic growth

Preliminary observations indicated that embryonic growth was essentially exponential. To verify this and to provide a means of

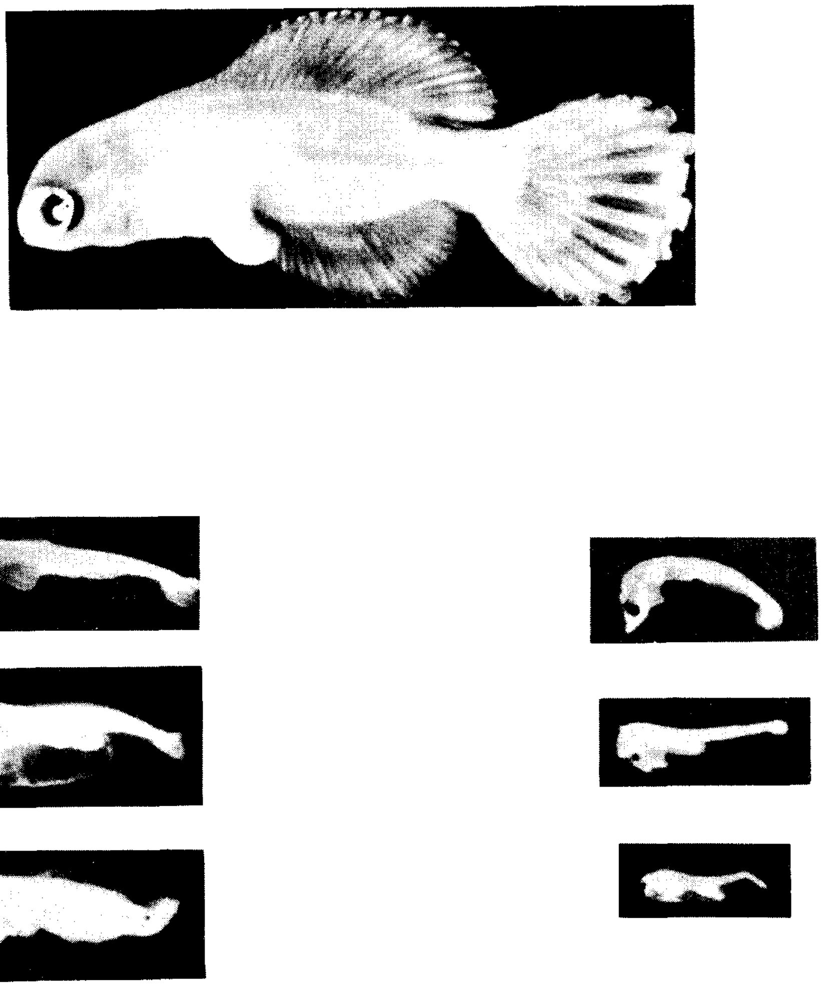

Figure 10.--Normal and malformed pile perch embryos. Standard lengths (mm) of malformed embryos are given, with the average standard lengths of normal embryos from the same ovary shown in parentheses.

extrapolating dates of fertilization and birth, embryo weights were plotted on logarithmic scale against dates of capture (fig. 11). Weight of young at birth and weight of eggs are indicated in the figure by reference lines. Actual average birth weight can be obtained only by holding females in confinement until parturition. In lieu of these data the midpoint, 6.7 g, of the observed range from the smallest newborn (4.5 g) to the largest unborn young observed (8.9 g) was used.

The regression line (A) fitted by least squares to the pooled data for both years had a correlation coefficient (r) of 0.993. The intersections of the regression line with egg weight and birth weight lines indicate that mean fertilization date was January 8 and mean birth date was July 24. This represents a mean gestation period of 196 days. Using the slope of the regression line to project fertilization and birth dates for all the data, it was found that fertilization dates ranged from December 5 to April 25 and birth dates from June 21 to November 12. Ninety percent of the projected fertilization and birth dates were included in the periods December 16 to February 2 and July 1 to August 17 respectively.

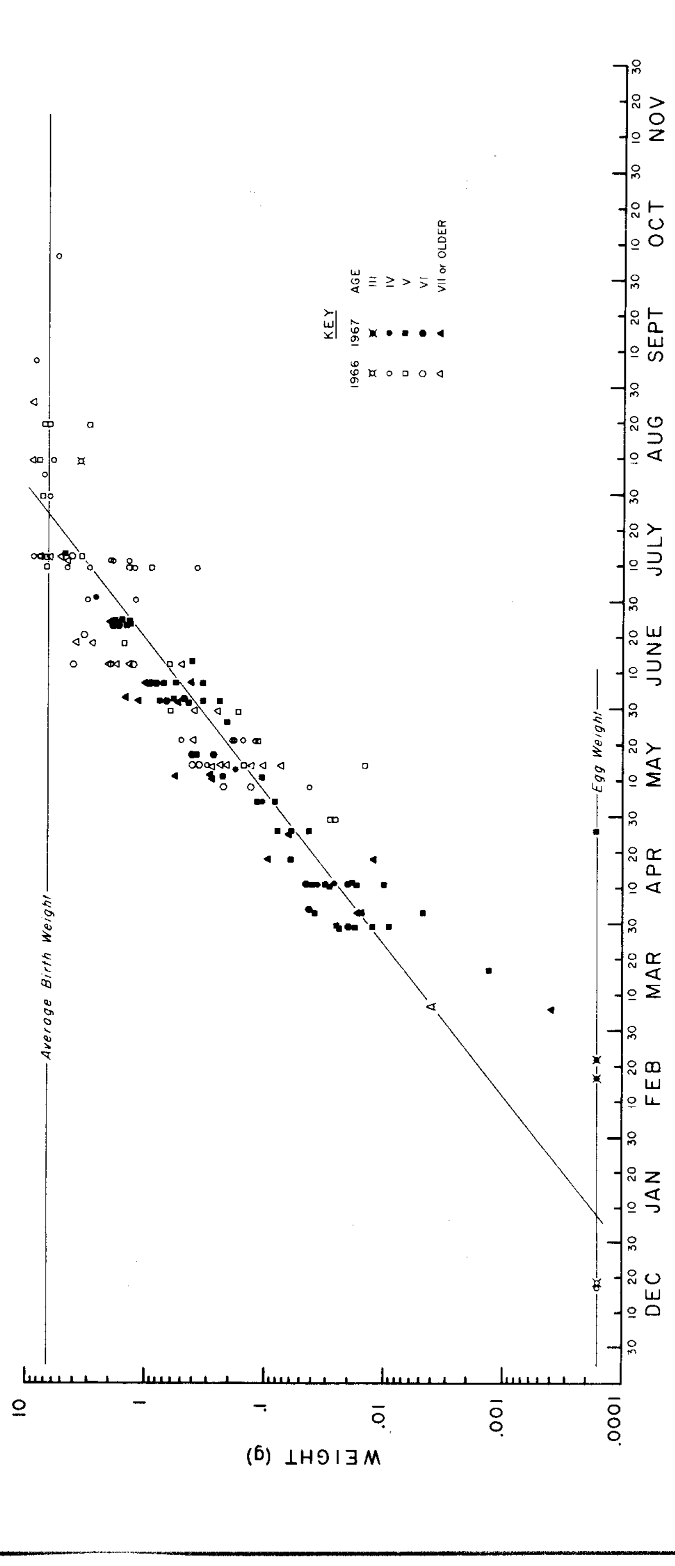

Figure 11.--Weights of fertilized eggs and embryos of pile perch plotted by date of capture and regression line. Symbols indicate age of parent females and year of capture.

Table 2.--Distribution of malformed embryos and dead eggs by age of parent

	For parents in age class--								
	III	IV	V	VI	VII	VIII	IX	X	Total
Embryos:									
Number of ovaries examined.....	1	27	58	23	18	11	4	1	143
Total number of embryos	24	452	1294	660	569	438	210	52	3699
Number of malformed embryos ...	0	34	8	1	1	0	0	0	44
Percent malformed	0	7.5	0.6	0.2	0.2	0.0	0.0	0.0	--
Percent of ovaries affected......	0	22.2	10.3	4.3	5.5	0.0	0.0	0.0	--
Eggs:									
Number of ovaries examined.....	0	6	36	10	6	4	3	0	65
Number of embryos plus eggs	--	87	825	361	202	166	162	--	1803
Number of dead eggs	--	2	52	5	3	5	2	--	69
Percent of dead eggs	--	2.3	6.7	1.4	1.5	3.1	1.3	--	--
Percent of ovaries affected......	--	33.3	38.9	30.0	33.3	25.0	66.7	--	--

The reproductive cycle may be timed later with increasing latitude because pile perch in southern California are reported to give birth in April (Rechnitzer and Limbaugh, 1952).

Other authors have reported a tendency in some embiotocids for older females to ovulate or to bear young earlier in the season than younger females (Hubbs, 1921; Carlisle, Schott, and Abramson, 1960; Triplett, 1960). Projected birth dates (fig. 12) derived from figure 11 indicate that this generalization would be applicable to pile perch if it could be assumed that size at birth is independent of age (or size) of parent. But the findings of Wilson and Millemann (1969) cast doubt on this assumption. These authors have shown for the shiner perch (Cymatogaster aggregata) that size at birth is directly related to size of parent females--over the range of females they observed, embryo weights ranged from 39 percent below to about 43 percent above the overall average. A similar relation for pile perch would cause an extreme difference in estimated birth dates of about 15 days, which is approximately the difference shown in figure 12.

Delayed fertilization

Eigenmann (1892) demonstrated for the shiner perch (Cymatogaster aggregata) that fertilization occurs about 6 months after mating, and Hubbs (1921) gave evidence which suggests that the reef perch (Amphigonopterus aurora) females also store spermatozoa for a considerable period after mating before the eggs are fertilized. It appears that pile perch females may store sperm for about 3 months before fertilization, since data on males (fig. 8) indicate that mating is centered in late September and data on females (fig. 11) indicate that fertilization is centered in early January.

FOOD HABITS

Methods of analysis

Food habits data were grouped by seasons and by the three zones of Yaquina Bay, giving a combination of 12 "sampling units." The seasons are defined as spring (March-May), summer (June-August), fall (September-November), and winter (December-February).

Table 3.--Taxonomic list of all food organisms identified from the stomachs of 190 pile perch collected in Yaquina Bay, Oreg., between April 1966 and July 1967

Phylum Protozoa:	
Class Sarcodina:	
Order Foraminifera	Unidentified Foraminifera
Phylum Annelida:	
Class Polychaeta	Unidentified Polychaeta
Phylum Mollusca:	
Class Gastropoda	Unidentified Gastropoda
Order Archaeogastropoda	*Acmaea* 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*
Do	*T. lamellosa*
Order Nudibranchia	Unidentified dorid nubibranch
Class Pelecypoda:	
Order Filibranchia	*Mytilus edulis*
Do	*Ostrea lurida*
Order Eulamellibranchia	Unidentified Eulamellibranchia
Family Tellinidae	*Macoma nasuta*
Do	*M. secta*
Family Cardiidae	*Clinocardium nuttallii*
Family Veneridae	*Protothaca staminea*
Do	*Saxidomus nuttalli*
Do	*Transennella tantilla*
Family Myidae	*Mya arenaria*
Do	*Cryptomya californica*
Family Hiatellidae	*Hiatella* sp.
Family Pholadidae	Unidentified Pholadidae
Phylum Arthropoda:	
Class Crustacea:	
Subclass Cirripedia	*Balanus* sp.
Subclass Malacostraca:	
Order Isopoda	*Idothea* sp.
Order Amphipoda	*Corophium* sp.
Do	Unidentified Amphipoda
Order Decapoda:	
Suborder Natantia	Unidentified Natantia
Suborder Reptantia	*Callianassa californiensis*
Do	*Upogebia pugettensis*
Do	*Pagurus* sp.
Do	*Cancer magister*
Do	*C. productus*
Do	*C. oregonensis*
Do	*Hemigrapsus nudus*
Do	*H. oregonensis*
Do	*Pugettia* sp.
Do	*Pinnixa* sp.
Phylum Echinodermata:	
Class Ophiuroidea	Unidentified Ophiuroidea
Phylum Chordata:	
Class Osteichthyes:	
Order Clupeiformes:	
Family Clupeidae	*Clupea harengus pallasi* (eggs)

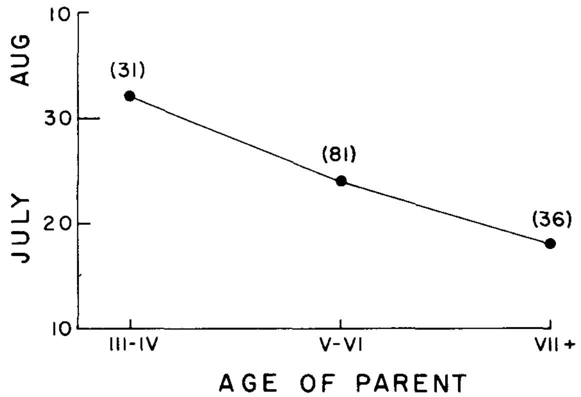

Figure 12.--Mean projected birth dates of embryos by age of parent. Sample sizes in parentheses.

Food habits of young-of-the-year and older fish were treated separately. Both frequency of occurrence and volumetric methods of analysis were used. Frequency of occurrence for each food group is expressed as percent of stomachs containing some food.

The volumetric analysis used for all fish except young-of-the-year was patterned after the method outlined by Reimers (1964), which eliminates bias from differing fish sizes on the assumption that a full stomach is just as important to a small fish as it is to a large one. Stomach capacity was assumed to be proportional to weight of fish, and an adjusted weight-length curve was used to determine potential stomach capacity for each fish. All food volumes were converted to percent of stomach capacity. Since the embiotocid digestive tract is not differentiated into stomach and intestine, the "stomach" was arbitrarily considered as that portion between the pharyngeal teeth and the first bend of the S-shaped digestive tract. Food volumes were measured by water displacement.

Food habits of young-of-the-year perch were analyzed by a different method because of the small size of their stomachs. Separate sample vials were used to preserve the contents from individual digestive tracts or from an aggregate of the digestive tracts collected at the same time and place. The volumetric analysis was based on estimated food fractions of measured total food volumes of samples. In computing frequency of occurrence, each sample was treated as a unit whether it was an aggregate sample or an individual sample.

Young-of-the-year occur only in the summer and fall seasons and were not captured in the lower zone during this study.

Results and discussion

Examinations of 217 stomachs revealed that the fish studied were entirely carnivorous. The traces of plant material occasionally found were usually attached to barnacles or mussels and were probably ingested incidentally. Food was derived from six phyla, but mollusks and arthropods provided 99 percent of the volume in the diet. The food organisms found during the study are listed systematically in table 3. With the exception of crab megalops, all of these animals are typically benthic or sessile. However, crab megalops settle to the bottom just before metamorphosis and are probably captured there rather than in the water column. The bulk of the Cancer magister eaten were small, newly metamorphosed individuals.

Frequency of occurrence and volumetric importance of the major stomach contents are presented in figures 13 and 14 grouped as follows: worms (polychaetes), snails (gastropods), mussels (Mytilus edulis), clams (all other bivalves), barnacles (Balanus sp.), amphipods, mud shrimp (Upogebia pugettensis), crabs (true crabs and hermit crabs), megalops (crab megalops larvae), rock, etc. (rock and sand particles).

For a given sampling unit, for both adults and young-of-the-year fish, only a few food species were of importance volumetrically. In all cases the two most important food species made up over 60 percent of the food volume, and with only two exceptions the most important species was at least twice as important volumetrically as any other species (tables 4 and 5). There was a tendency for dominance of diet to shift from encrusting organisms (Balanus and Mytilus) in the lower zones to mud dwelling organisms (Protochaca, Mya, and Upogebia) in the upper zone.

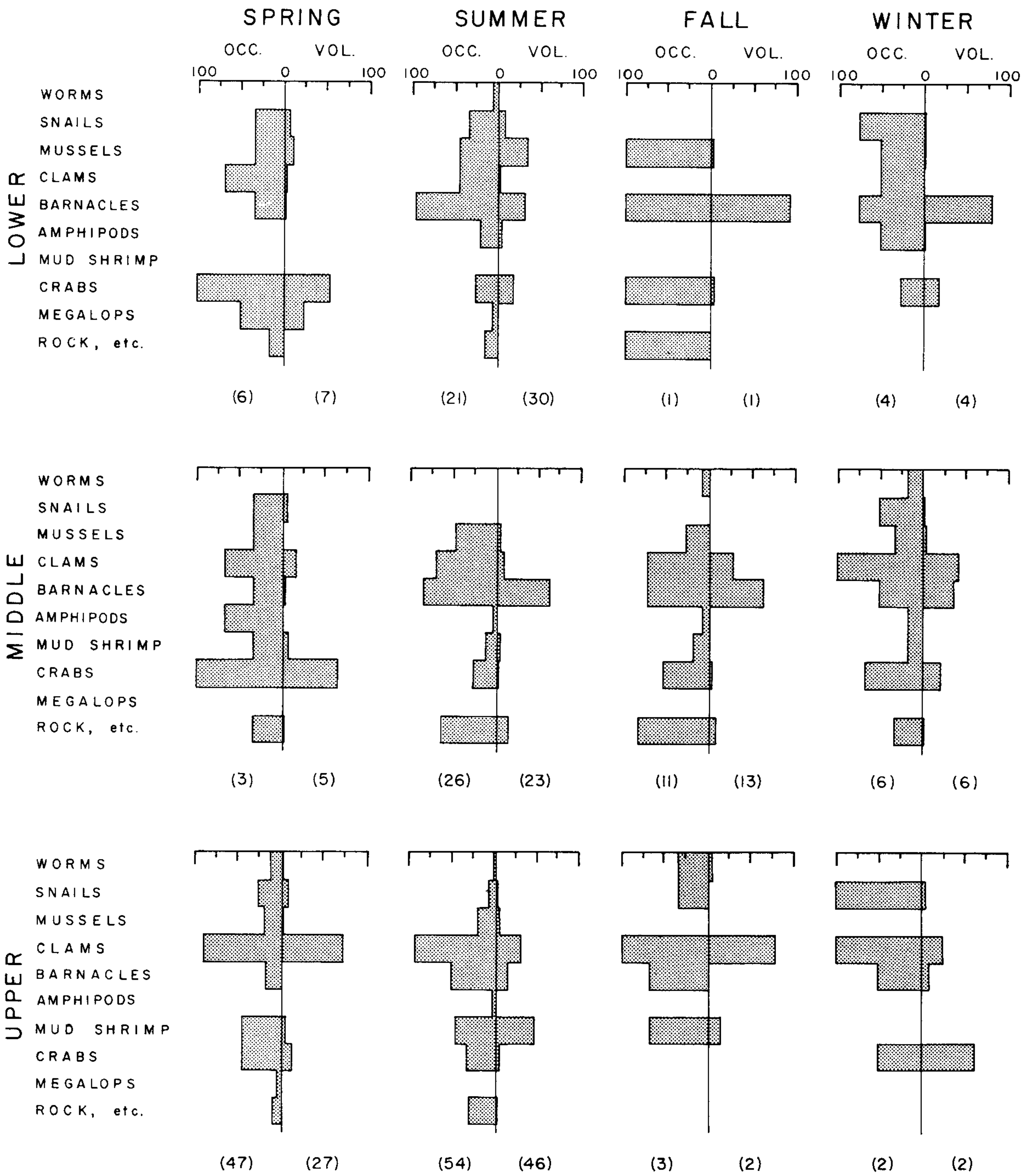

Figure 13.—Seasonal and regional variations in food habits of adult pile perch in Yaquina Bay as percent frequency of occurrence and percent of food volume for major groups of stomach contents. Sample sizes are in parentheses.

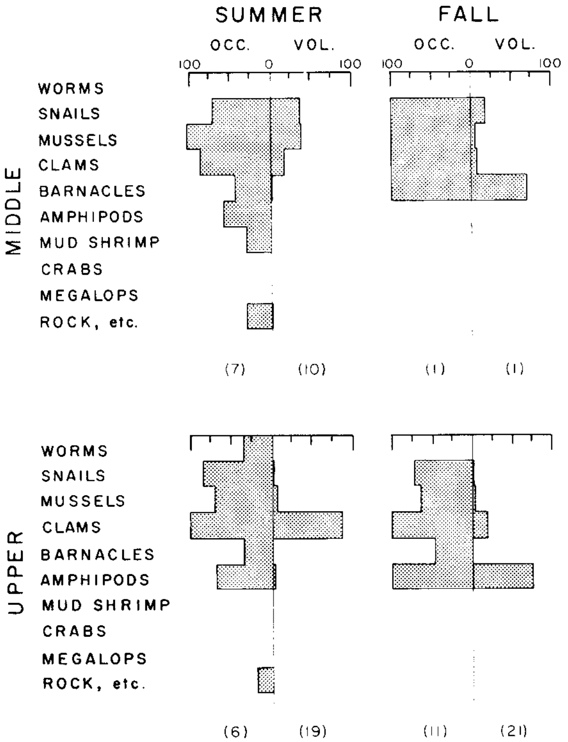

Figure 14.--Seasonal and regional variations in food habits of young-of-the-year pile perch in Yaquina Bay as percent frequency of occurrence and percent of total food volume for major groups of stomach contents. Sample sizes in parentheses refer to numbers of aggregate samples and numbers of fish under occurrence and volume respectively.

The food habits of young-of-the-year differed from those of the older fish by an absence of decapods, little reliance on barnacles, and a significant use of the amphipod Corophium, which was not used by adults. They fed on very small individuals (possibly the offspring of the current season) of the same mollusk species as the adults utilized.

Pile perch appear well adapted for the utilization of the hard-shelled animals of the benthos. The strong pharyngeal mill is paved with hard grinding teeth which are calcified even before birth. The undifferentiated tubular shape of the digestive tract and absence of a pylorus may facilitate passage of the great bulk of sharp, angular shell fragments that occur with most of the food organisms. The rectal portion of the digestive tract, which is a darker color than the anterior portion, was prolapsed in many of the specimens captured. Perhaps an ability of the rectum to evert easily is an adaptive mechanism for excretion of abrasive shell fragments.

PARASITES

Methods of study

During the study, 69 pile perch were examined in the laboratory for the presence of

Table 4.--Food organisms, listed in order of importance, which made up 80 percent or more of the food volume of adult pile perch in each sampling unit
[Sample sizes in parentheses]

Zone	Spring		Summer		Fall		Winter	
	Food	Per-cent	Food	Per-cent	Food	Per-cent	Food	Per-cent
Lower	C. magister	51	M. edulis	35	Balanus sp.	93	Balanus sp.	78
	Megalops	23	Balanus sp.	33			C. productus	18
	M. edulis	11	C. oregonensis	12				
	(7)		(30)		(1)		(4)	
Middle	C. magister	66	Balanus sp.	62	Balanus sp.	62	Balanus sp.	36
	U. pugettensis	7	P. staminea	6	C. nuttallii	19	C. nuttallii	28
	Cerithidae	6	M. edulis	5			M. nasuta	11
	M. arenaria	6	U. pugettensis	4			C. productus	9
			C. magister	3				
	(5)		(23)		(13)		(6)	
Upper	P. staminea	48	U. pugettensis	45	M. arenaria	73	C. oregonensis	48
	C. nuttallii	16	C. californica	21	U. pugettensis	15	C. nuttallii	15
	C. magister	9	Balanus sp.	16			C. magister	12
	C. californica	6					Balanus sp.	9
	U. pugettensis	5						
	(27)		(46)		(2)		(2)	

Table 6.--Taxonomic list of parasites identified from the gills, heart, liver, kidney, and digestive tracts of 62 pile perch from Yaquina Bay, Oreg., between June 1966 and July 1967.

Phylum Protozoa:	
Subphylum Cnidosporidea	Unidentified myxosporidian cysts
Phylum Platyhelminthes:	
Class Trematoda:	
Subclass Digenea:	
Family Bucephalidae	Prosorphynchus sp.
Do	Rhipidocotyle sp.
Do	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.

internal parasites. Seven of these were young-of-the-year perch taken in November. At least one adult fish was autopsied each month. The digestive tract, heart, liver, spleen, kidney, and gills were checked.

A stereoscopic (X7 to X30 variable power) microscope was used to search for parasites. The digestive tract was slip open and examined while a stream of water from a squeeze bottle was played over its internal surface. When excessive amounts of slime adhering to the mucosa prevented this method, the tissue was shaken vigorously in a jar of tap water and reexamined. Any parasites in the wash water were recovered by settling and decanting. Each gill arch was examined for external parasites; the other organs were teased apart carefully to find parasites imbedded in the tissues as well as those on the surface. Infestation rates were calculated by dividing the number of parasites found by the number of fish examined.

Results and discussion

The parasites found infecting pile perch are listed systematically in table 6.

The only parasite infecting young-of-the-year fish was the copepod Clavella sp., attached to the ends of the gill filaments. The average infestation in these young fish was 2.4 parasites per fish; the most heavily infected fish had seven parasites.

Adult fish had more parasites than young-of-the-year fish. Of 45 adult pile perch, 13 were infected with myxosporidian cysts on the gills. These had an average of 17 cysts per fish, and the most heavily infected fish carried 99 cysts. Three adult trematodes of the genus Derogenoides and four immature spiruroid nematodes were found in the livers. One adult specimen each of the trematodes Telolecithus pugetensis and Genitocotyle sp.

and 10 adult nematodes (Cucullanus sp.) were found in the digestive tracts.

Of the two species of copepods found in the gills, Clavella sp. was more abundant than Lepeoptheirus sp. For both species, infestation rates were markedly greater during summer and fall than winter and spring (fig. 15). This seasonal trend held for perch sampled in each zone of the Bay, although there was also a tendency for infestations of Clavella sp. to be higher in the upper zone during each season. Extent of copepod infections was clearly not related to size of fish.

Of 47 perch, 17 were infected with encysted metacercariae of bucephalid trematodes belonging to the genera Prosorhychus, Rhipidocotyle, and Bucephalopsis. The minute cysts of these parasites were found in the heart, liver, and kidney, with infestation rate directly related to fish size (fig. 16), suggesting that these cysts are accumulated over the years.

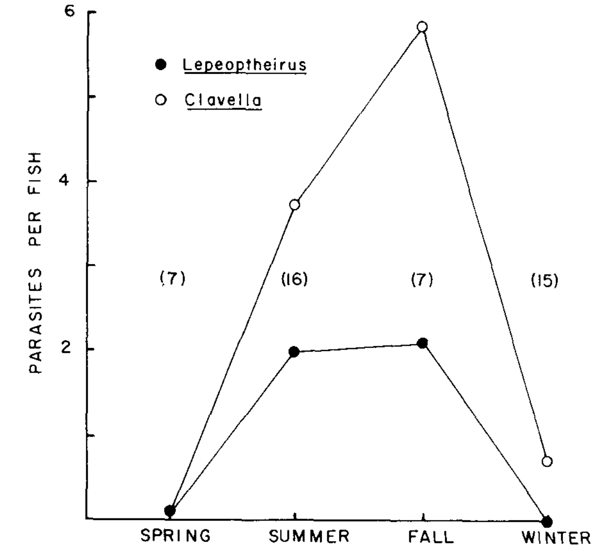

Figure 15.--Infestation rates of gill copepods by seasons. Number of pile perch sampled in each season is given in parentheses.

None of the parasite infections appeared to have been significant to the health of the host pile perch, though slight mechanical damage to gill filaments from copepods was noted.

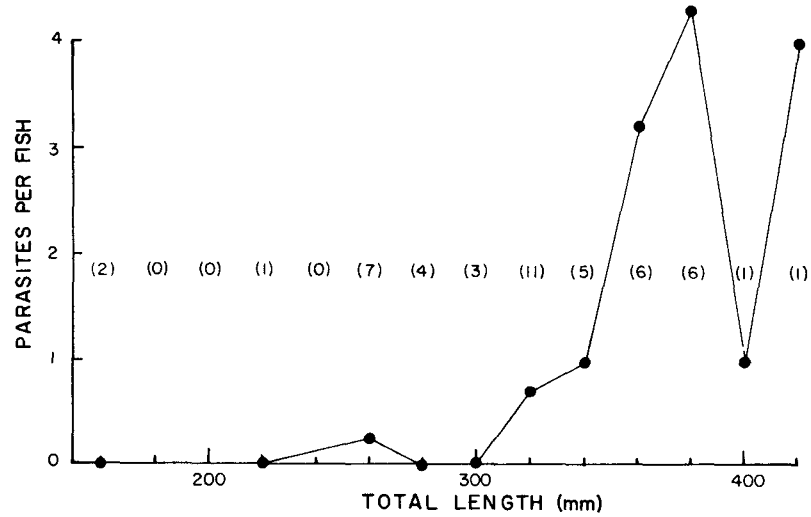

Figure 16.--Infestation rate of bucephalid metacercariae in the heart, liver, and kidney as a function of fish length. Numbers of pile perch sampled in each 20 mm length group are given in parentheses.

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