AN ABSTRACT OF THE THESIS OF

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Title: LIFE HISTORY OF THE SNAKE PRICKLEBACK *LUMPENUS SAGITTA* WILIMOVSKY, 1956

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Dr. Howard F. Horton

Data are presented on the life history of snake pricklebacks, *Lumpenus sagitta*, collected in Yaquina Bay, Oregon, from June 1977 to October 1978. Specimens were collected primarily by beach seine from four sampling sites in the bay. Snake pricklebacks feed on algae (mainly genus *Enteromorpha*), on polychaeta (mainly genus *Neoamphitrite*), on crustacea (mainly harpacticoida), and other bottom-dwelling organisms. They were non-selective in feeding. Based on gonado-somatic indices and egg diameter, I found that snake pricklebacks probably spawn near the end of fall and during winter. Fecundity was positively correlated with standard length of the fish and had a correlation coefficient of 0.85. The number of eggs per fish varied from 2,277 to 6,100 with a mean fecundity of 4,089 eggs. Otoliths are more useful than scales for determining the age of the snake pricklebacks. There is agreement between ages as established by the length-frequency method and those

established by the otolith method only until age two. The length-weight relationship was described by the model $\ln W = \ln a + b \ln L$. The value of the constant "b" was lower than 3.0 for both males and females and varied from 2.33 to 2.78. Females showed a larger constant "b" than males during both years of sampling. Length and weight was correlated for males and females and for sexes combined with "r" values ranging from 0.94 to 0.98. In static bioassays, low salinities (<1.0 ppt) and high temperatures (>20.0 C) deleteriously affected the survival of snake pricklebacks.

Life History of the Snake Prickleback *Lumpenus sagitta* Wilimovsky, 1956

by

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LIFE HISTORY OF THE SNAKE PRICKLEBACK
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INTRODUCTION

This thesis contains results of a study of the life history of the snake prickleback, *Lumpenus sagitta* Wilimovsky, 1956, in Yaquina Bay, Oregon. The study was conducted from June 1977 to October 1978 on specimens collected by beach seine in four principal sampling sites in the bay. The purpose of the study was to accumulate knowledge of the life history of the snake prickleback to help understand the role of the species in the ecosystem and to provide a broader basis for making management decisions.

The snake prickleback belongs to the family Stichaeidae and is distributed from Humboldt Bay, California to the Bering Sea and the Sea of Japan (Miller and Lea, 1972). In Oregon it has been found in the Columbia River estuary (Reimers, 1964; Haertel and Osterberg, 1967), Tillamook Bay (Forsberg, et al., 1977), Netarts Bay (Amandi, et al., 1976), Sixes River (Reimers and Baxter, 1976), and Yaquina Bay (Pearcy and Myers, 1974; Bayer, 1978).

Most information on the biology of the snake prickleback is related to its taxonomy, distribution, abundance, and food habits. Schultz and DeLacy (1936) described the distribution of *Lumpenus anguillaris* Pallas, which is a synonym of Lumpenus sagitta, as being from Alaska to San Francisco and indicated that is a common marine species with no commercial value. Wilimovsky (1956, 1963) proposed Lumpenus sagitta as a new name for Lumpenus gracilis Ayres and indicated the presence of snake pricklebacks within the fish fauna of the Aleutian Archipelago.

Barraclough (1967a, 1967b), Barraclough, et al. (1968), Barraclough and Fulton (1968), and Robinson, et al. (1968) reported the number, size, and weight of young snake pricklebacks caught with trawls and other gear in the surface waters of the Strait of Georgia and Saanich Inlet, British Columbia, and indicated that copepods were the most common food of larvae and juveniles.

Haertel and Osterberg (1967), using an otter trawl as the major sampling device, caught Lumpenus sagitta in the Columbia River estuary in waters with salinity >0.5 ppt. They indicated that the snake prickleback is a plankton feeder, eats large quantities of copepods, and also shows no major changes in food habits with increasing age or size.

Hart (1973) described the species and indicated that young snake pricklebacks (5-52 mm long) occurred abundantly near the surface in April and May of the outlet of the Fraser River. He also reported that the species is common from northern California to the Bering Sea, and in a variety of locations throughout British Columbia at depths to 113 fathoms. Hart (ibid.) listed the main food for young snake pricklebacks as almost entirely copepods.

Pearcy and Myers (1974) described the relative abundance, seasonal and annual occurrence, and distribution of larval snake pricklebacks in Yaquina Bay estuary, based on a survey of 393 plankton samples collected from January 1960 to December 1970. The species was found in eight samples with a total of 29 individuals and only in the first three stations up the estuary (Hwy. 101 bridge, and buoys 15 and 21) and never outside the bay in the open ocean. The months of occurrence were January and February.

Amandi, et al. (1976) collected over 10,000 specimens of fishes from June to September 1975 in Netarts Bay and its drainage. They reported snake pricklebacks ranging in size from 90-140 mm and 25 in total number which represented 0.24% of the total catch. They also reported that 20% of snake pricklebacks were found in association with sand and 80% were in association with sand-rocks. The range of temperature was 12-16 C and the salinity was 31-34 ppt at the time of collection.

Somerton and Murray (1976) reported that snake pricklebacks were common and most often observed on sandy bottoms in Puget Sound, Washington, especially at night, and frequently were completely exposed.

Forsberg, et al. (1977) reported that snake pricklebacks comprised 0.04% of a total 126,389 fish representing 56 species captured from May 1974 to May 1976 in Tillamook Bay, Oregon. Bayer (1978) reported collections of snake pricklebacks in Yaquina Bay, Oregon, during the months of August and September 1975, and June and July 1976. Of 42,096 fish captured from August 1975 through July 1976, snake pricklebacks numbered 342 with total lengths between 86-395 mm. Ninety four percent of this number were found in eelgrass (*Zostera marina*) and the rest in the upper intertidal zone.

The objectives of my study were to determine the food habits of snake pricklebacks and their possible variations, to calculate the fecundity of the species, to determine if scales and otoliths are useful for aging snake pricklebacks, to describe the relationship between length and weight of the species, and to determine the salinity tolerances at 5, 10, 15 and 20 C for snake pricklebacks captured in Yaquina Bay.

MATERIALS AND METHODS

Collection of Specimens

Specimens of snake pricklebacks were captured at biweekly or more frequent intervals from June 1977 to October 1978. The fish were captured with a 100- x 3-m variable mesh beach seine, identical in construction to that described by Sims and Johnsen (1974), except that the anchor wing, bunt, and inner wing sections were all constructed with 0.95-cm stretched mesh, knotless, nylon seine netting.

The four sites in Yaquina Bay where samples of snake pricklebacks were captured are shown in Figure 1. The first site was a beach on the south side of the estuary, approximately 0.7 km up-bay from the U.S. Highway 101 bridge, and adjacent to the Oregon Aqua Foods' release channel; the second was a beach on the south side of the estuary, approximately 0.7 km up-bay from site 1, and adjacent to the Marine Science Center small boat dock; the third was a beach on the north side of the estuary, approximately 1.3 km up-bay from site 2, and located directly below the liquid natural gas storage plant; and the fourth was a beach on the north side of the estuary across from channel marker 38, approximately 11 km up-bay from site 3.

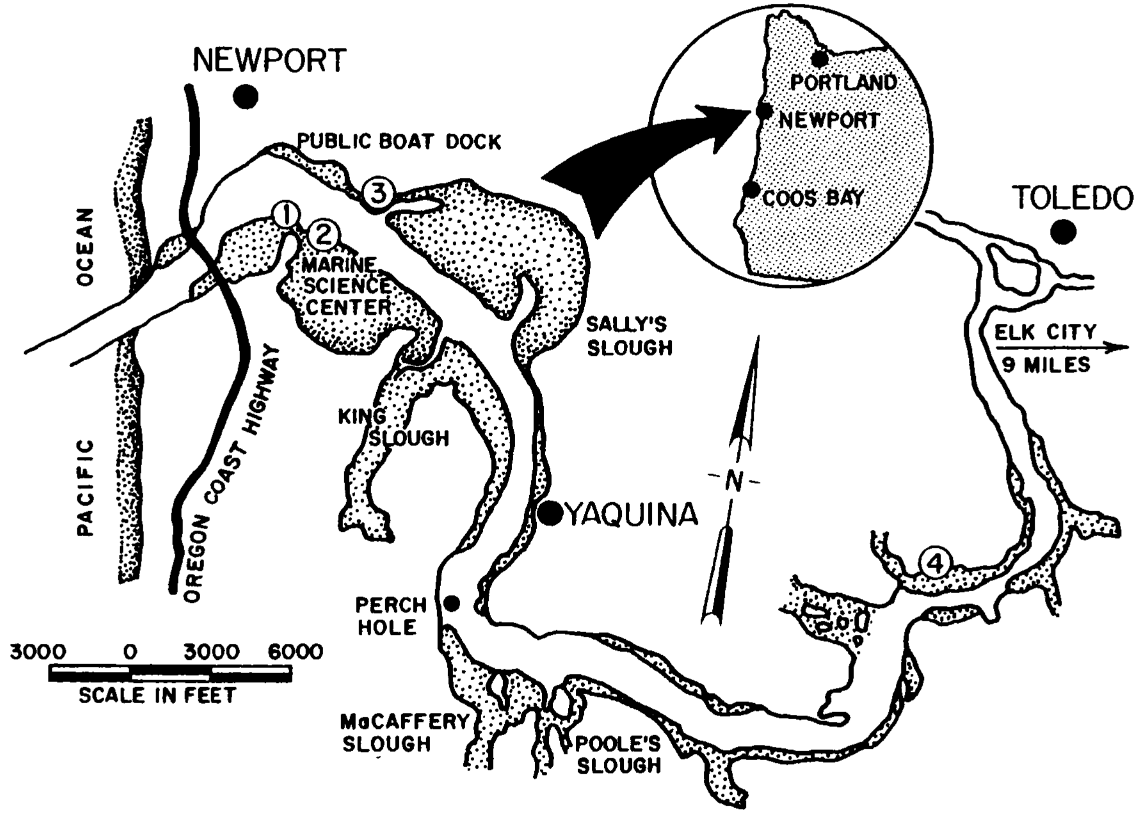

Figure 1. Map of Yaquina Bay, Oregon showing the location of the four sampling sites where snake pricklebacks were captured.

On one occasion, a small otter trawl was used to sample specimens in the main channel of the estuary from site 2 to the Perch Hole (Fig. 1).

Food Habits

For each specimen collected the total and standard length to the nearest mm and the total weight to the nearest g were measured. The stomach was then removed and weighed to the nearest 0.001 g with and without contents using an electronic balance. The difference in weight between the stomach with contents and the stomach alone was the weight of the contents.

The contents were preserved in 45% isopropyl alcohol and analyzed with respect to types of organisms, frequency of occurrence of organisms, and total weight of each major taxonomic group. The weight of the organisms belonging to each major taxonomic group per fish stomach was obtained using an electronic balance to the nearest 0.001 g. The frequency of occurrence and weight of each major taxonomic group was expressed as a percent of the total number of stomachs analyzed and the total weight of the food contents as recommended by Lagler (1956) and Windell (1968).

Reproductive Biology

The sex for each specimen and the maturity stage of the gonads were determined using the generalized classification of maturity stages of Kesteven (1960). The total weight of the gonads to the nearest 0.001 g and the total length of the organs to the nearest mm were measured.

Diameter of ova in each ovary was determined by use of an ocular micrometer in a dissecting microscope. The ripe ovaries were also used to determine fecundity by the gravimetric method (Lagler, 1956; Bagenal and Braum, 1968). The fecundity determinations were performed as follows:

1. Small samples from each anterior, middle, and posterior portions of each ovary were removed and weighed to the nearest 0.001 g.
2. The number of eggs per sample was determined under a dissecting microscope.
3. The average weight and number of eggs per sample was calculated.
4. The total number of eggs per both ovaries was determined according to the following equation:

$$\text{Total eggs} = \frac{\text{total weight of both ovaries}}{\text{average weight per sample}} \times \begin{array}{l}\text{average number}\\ \text{eggs per sample}\end{array}$$

From the data of total eggs and standard length, a regression equation was calculated by the method of least squares.

A gonado-somatic index (G.S.I.) for males and females for each month of sampling was calculated using the equation:

$$G.S.I. = \frac{\text{gonad weight in g}}{\text{body weight without viscera in g}} \times 100$$

Age Determination

One hundred specimens of snake pricklebacks captured in August 1978 were analyzed to determine if scales and otoliths were useful for age determination. Scales were collected from the side of the body just above the lateral line and below the origin of the dorsal fin, and from under the pectoral fin as recommended by Chugunova (1959).

Scales were collected after the fish was weighed and its length measured. To remove the mucus and small scales of other fish adhering to the surface of the body and to reduce subsequent labor required for cleaning, the blunt side of a scalpel was passed over the side of the fish from head to the caudal fin. The scales were removed with the same scalpel.

For whole mounts of fish scales, I used slides, cover slides, and tape. The scales were labeled and examined under a microscope for the presence of annuli formation following the recommendation of Lagler (1956) and Everhart, et al. (1975). Histograms of length frequency distributions were made for each age group based on scale interpretations.

Measurements of scale radii were made on photomicrographs taken at 150X. From the data of standard length and scale radii, a regression equation was calculated by the method of least squares. The scales of specimens of snake pricklebacks collected in 1978 were used to determine the time of annulus formation.

Sagittae were collected following the recommendation of Chugunova (1959). The gills of the fish were detached from the isthmus and the lower part of the cranium exposed. After removing the musculature both otic capsules were exposed. A scalpel was used to make a cut through the posterior third of the otic capsules; then the sagittae were removed with a pair of fine forceps. The sagittae were cleaned with water and stored in jars with a 50:50 alcohol-glycerin solution.

Examination of the sagittae was done under a dissecting microscope over a black background using reflected light (Williams and Bedford, 1974). In order to improve light transmission through the otoliths, they were examined while immersed in the alcohol-glycerin solution. Against the dark background the opaque zones appeared as white rings and the hyaline zones as dark rings. Length frequency distributions were constructed for each age group according to the otolith age interpretations.

The otolith radii were determined using an ocular micrometer in a dissecting microscope with a magnification of 30X. From the data of standard length and total otolith radius a regression equation was calculated by the method of least squares. The time of annulus formation was determined from analysis of the otoliths of snake pricklebacks collected in 1978.

Length-Weight Relationship

The data on standard length, total weight, and sex were used for studies of length-weight relationships. A correction factor of K_l = +3.25% for standard length and K_w = +3.20% for total weight was used to compensate the loss in length and weight caused by preservation of specimens in Formalin. The correction factors were obtained by placing fresh fish in jars containing the Formalin solution; then the length and weight of each fish (50 specimens) was obtained daily until the values remained constant. Differences between the initial and final values for length and weight were used to compute the K factors.

The relationship between length and weight was determined for all specimens as well as for males and females for each year as recommended by LeCren (1951), Lagler (1956), and Ricker (1975). The model of regression was chosen according to the scatter plot of each data. The value of regression coefficient and intercept for each case was calculated by computer. "F" tests were applied at the 0.001 level of significance.

Salinity Tolerances

The experiment for testing salinity and temperature tolerances was conducted at the Marine Science Center during July and August 1978. Once a week approximately 40 to 45 specimens of snake prickleback averaging 150 mm standard length were collected and stored in concrete tanks provided with flowing sea water. Fish were fed with Oregon Moist Pellets. After one week the fishes were acclimated at 13 C in 32 ppt salinity for one week prior to use. The acclimation was in two 160-l fiberglass tanks provided with water recirculated through charcoal filters.

To assess the salinity tolerances at 5, 10, 15 and 20 C, the specimens were placed in plastic aquaria of 40 l provided with water recirculated through charcoal filters. Acclimation tanks and aquaria were held in a cold room and heated by opposition with Versa-Therm electronic temperature controllers sensitive to 0.005 C. The desired salinity of water (0.0, 1.0, 3.2, 10.0, 32.0 and 42.0 ppt) for each test was obtained by dilution of sea water with distilled water or addition of Instant Ocean synthetic sea salt (Doudoroff, 1951; Barton, 1978).

For each test run (one salinity and four temperatures), 40 fishes were tested -- 10 fishes for each combination of temperature and salinity. The fishes were observed at intervals of 0.25, 0.50, 1.0, 2.0, 4.0, 8.0, 16.0, 24.0, 32.0, 40.0, 48.0, 72.0 and 96.0 hours. The criteria for death was the cessation of opercular movements and failure to respond to prodding (Doudoroff, 1951; Barton, 1978).

Percent survival at the end of each observation interval was plotted vs time on semilogarithm paper with percent survival converted to probits. Histograms were plotted arithmetically from the data.

RESULTS

Food Habits

Of 283 stomachs of snake pricklebacks examined, 264 (93.3%) contained food and 19 (6.7%) were empty. Food was classified into seven categories which, in order of importance were: Algae, Polychaeta, Crustacea, Fishes, Bivalvia, Gastropoda, and Miscellaneous. This last category consisted of parts of animals (Polychaeta, Crustacea, Mollusca, scales of fishes), vegetable matter (Algae), and grains of sand.

Algae were most important in both total weight (42.71%) and frequency of occurrence (79.17%)(Tables 1 and 2, and Fig. 2). The genus Enteromorpha was the most frequent alga in all the samples and during all the time of sampling with the exception of June 1977 and October 1978 when the genus Porphyra was the most frequent.

Polychaeta was the second most important group, because it was the second in total weight (15.82%)(Table 1 and Fig. 2) and it was present in a considerable number of samples (18.94%)(Table 2 and Fig. 2). The family Terebellidae was the most frequent among the Polychaeta, except in May and October 1978.

Crustacea was ranked as the third most important item, although it did not represent a large percentage of total

Table 1. Percent of total weight of the various food items found in the stomachs of 264 snake pricklebacks captured in Yaquina Bay, Oregon.

GROUP	MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		TOTAL
	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978	
Algae		0.37	3.24	6.01	7.98	7.22	6.13	7.93	2.33	0.77	0.02	0.72	42.71
Polychaeta		0.002	1.11	4.49	7.78	1.23	1.07	0.001	0.03	0.08	0.02	0.004	15.82
Crustacea		0.40	0.31	0.20	0.27	0.24	0.81	0.21	0.89	0.02	0.10	0.10	3.55
Fishes			1.69					7.69					9.38
Bivalvia			0.08	0.04	0.02	0.50	0.24	0.08	0.28	0.004		0.004	1.25
Gastropoda						0.01	0.03	0.002	0.007			0.01	0.06
Miscellaneous		0.28	2.09	13.00	3.81	2.19	1.57	1.85	1.49	0.65	0.12	0.17	27.22

Table 2. Percent frequency of occurrence of various food items found in the stomachs of 264 snake pricklebacks captured in Yaquina Bay, Oregon.

CLASSIFICATION	MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		TOTAL
	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978	
ALGAE		1.52	5.68	15.15	12.87	12.50	13.26	7.58	6.44	1.89	0.38	1.89	79.17
Div. Chlorophyta													
Class Chlorophyceae													
Order Ulvales													
Family Ulvaceae													
Genus *Enteromorpha*		0.38											
E. intestinalis v. *intestinalis*			1.52	3.79	4.55		4.92	0.76				0.38	
E. intestinalis v. *clavata*		1.34		10.61	3.79	9.47		6.44	4.92	1.89			
E. compressa					7.56		4.17						
E. prolifera			1.52	0.38		1.14	1.16	0.38	0.38	0.38		0.38	
Order Clodophorales													
Family Clodophoraceae													
Genus *Rhizoclonium*													
R. riparium				0.38			0.76			0.38			
Div. Rhodophyta													
Class Bangiophyceae													
Order Bangiales													
Family Bangiaceae													
Genus *Porphyra*													
P. miniata			3.78	2.65	9.47	3.03	9.47	0.38	3.40		0.38	1.89	
P. spp.		0.76						0.38	1.14				
Div. Chrysophyta													
Class Bacillariophyceae													
Order Naviculales													
Diatom				0.38			0.76					0.38	

Table 2 (continued)

CLASSIFICATION	MAY 1977	MAY 1978	JUNE 1977	JUNE 1978	JULY 1977	JULY 1978	AUGUST 1977	AUGUST 1978	SEPTEMBER 1977	SEPTEMBER 1978	OCTOBER 1977	OCTOBER 1978	TOTAL
POLYCHAETA		0.38	1.14	6.06	4.17	1.52	1.89	0.38	1.52	0.76	0.38	0.76	18.94
Family Phyllodocidae Genus *Eteone*													
E. spp.		0.38		0.38									
Family Goniadidae Genus *Glycinde*													
G. picta				0.38					1.14			0.76	
G. armigera								0.38					
G. spp.				0.38									
Family Nephthyidae Genus *Nephthys*													
N. spp.				0.38									
Family Terebellidae Genus *Neoamphitrite*													
N. robusta			1.14	4.92	3.79	1.52	1.89		0.38	0.38			
Family Opheliidae Genus *Armandia*													
A. bioculata										0.38			
Family Orbiniidae Genus *Orbinia*													
O. spp.												0.38	
Family Polynoidae Genus *Tenonia*													
T. kitsapelsis					0.76								

Table 2 (continued)

CLASSIFICATION	MAY 1977	MAY 1978	JUNE 1977	JUNE 1978	JULY 1977	JULY 1978	AUGUST 1977	AUGUST 1978	SEPTEMBER 1977	SEPTEMBER 1978	OCTOBER 1977	OCTOBER 1978	TOTAL
Family Spionidae Genus *Boccardia*													
B. spp.											0.38		
CRUSTACEA		2.65	4.55	9.47	11.74	8.71	14.02	8.33	10.61	2.65	0.76	2.27	75.76
Amphipoda			1.52	3.79	2.65	3.03	6.82	2.65	2.27	1.89		2.27	
Cumacea		1.14	1.52	2.65	3.41	2.65	3.03	1.52	3.03	0.38		1.52	
Tanaidacea			0.76	0.76	3.03	1.52	3.03	1.14	1.89			1.14	
Decapoda			3.03	0.76	0.38	2.27	3.03	1.14	0.76				
Calanoida		1.14	1.14	1.52	2.27		1.14	1.52	0.38				
Harpacticoida		2.65	4.17	4.92	9.85	4.55	13.26	6.06	9.47	1.89	0.76	0.76	
FISHES			0.38					2.27					2.65
Family Atherinidae Genus *Atherinops*													
A. affinis								0.38					
Family Engraulidae Genus *Engraulis*													
E. mordax								0.76					
Family Osmeridae Genus *Hypomesus*													
H. pretiosus			0.38					2.27					

Table 2 (continued)

CLASSIFICATION	MAY		JUNE		JULY		AUGUST		SEPTEMBER		OCTOBER		TOTAL
	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978	1977	1978	
BIVALVIA			0.76	0.76	1.52	5.30	3.03	3.03	4.53	0.38		0.76	20.08
Family Mytilidae							1.14		0.38				
Family Tellinidae			0.76	0.76	1.52	4.55	2.27	2.65	4.17	0.38		0.76	
Family Cardiidae					0.76	1.14	0.76	0.38	2.27	0.38		0.38	
Family Garidae					0.38	0.76	0.38	0.38	0.38				
GASTROPODA						2.27	0.38	0.38	0.38			0.38	3.79
Family Olividae						1.52	0.38	0.38	0.38				
Family Nassariidae						0.38							
Family Naticidae						0.38			0.38				
Family Rissoidae												0.38	

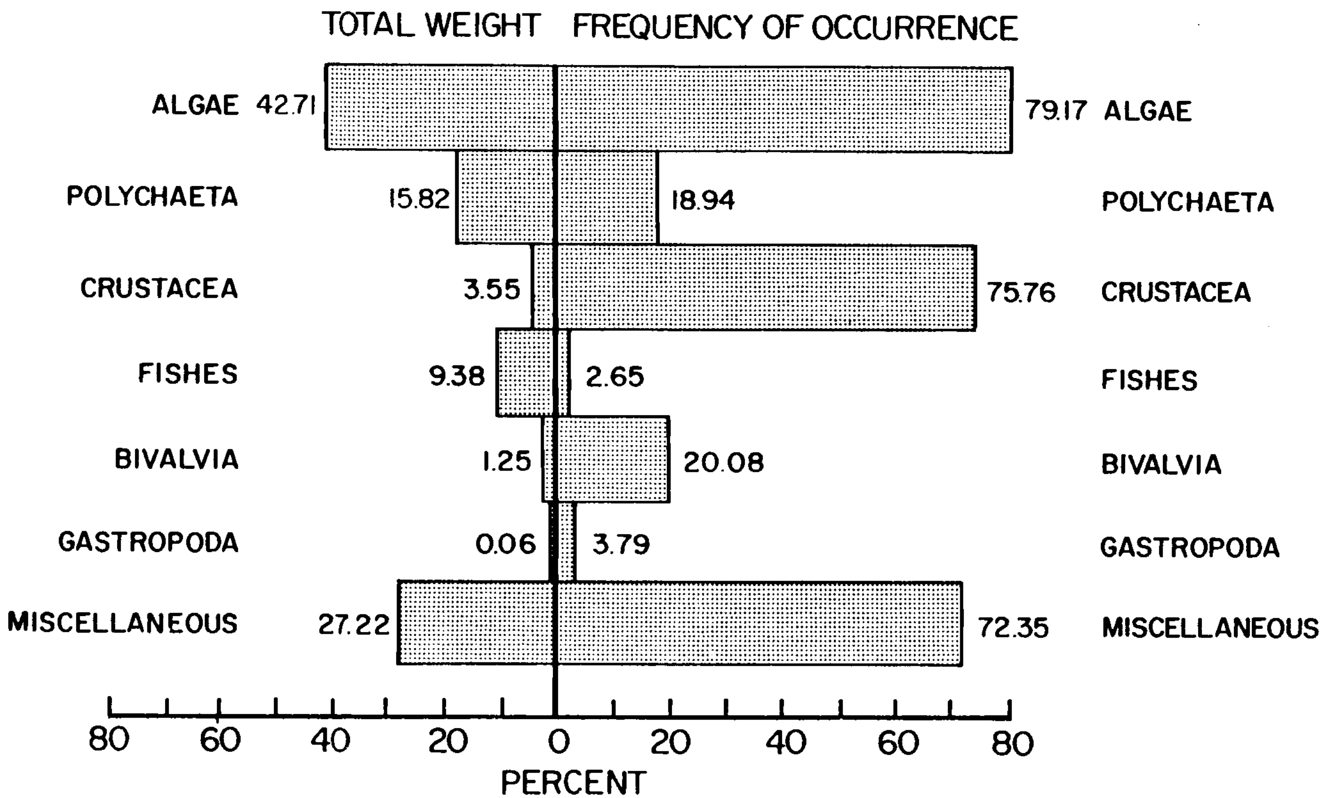

Figure 2. Percent of weight and percent frequency of occurrence of food groups identified in the stomachs of 264 snake pricklebacks sampled during 1977 and 1978 in Yaquina Bay, Oregon.

weight (3.55) (Table 1 and Fig. 2) it was found in almost all the samples examined (75.76%) (Table 2 and Fig. 2). Harpacticoida was the group most frequently present within Crustacea in most of the samples with the exception of October 1978 when Amphipoda became the most important organism in this group.

Fishes were ranked in fourth place because they represented more weight (9.36%) than Bivalvia (1.25%) and Gastropoda (0.06%), although they were found only during the months of June 1977 and August 1978. The family Osmeridae was the most important among the fishes (Tables 1 and 2, and Fig. 2).

Bivalvia were ranked in fifth place because they made up a low percentage of total weight (1.25%), but they were present in a considerable number of samples (20.08%). The family Tellinidae was the most important group in Bivalvia (Tables 1 and 2, and Fig. 2).

Gastropoda was ranked as the last group because it was found in the lowest percent of weight (0.06%) and almost the lowest percent of frequency of occurrence (3.79%). The family Olividae was the most important group in Gastropoda (Tables 1 and 2, and Fig. 2).

Reproductive Biology

I found gonads of snake pricklebacks close to the mature stage only in September and October of 1977 and 1978.

At this time the ovaries were yellow and occupied almost all of the internal cavity. The right ovary was slightly larger than the left ovary. The difference in size of ovaries was most pronounced during the immature stage when these gonads were a transparent grey color.

The male gonads were transparent with slightly brown spots during the immature stage. These spots disappeared as the gonads matured and became milky in color. The paired gonads for males were equal in size.

The gonado-somatic index for males and females increased from July to October during both 1977 and 1978 (Fig. 3). For females, the increase in G.S.I. coincided with the increase in egg diameter (Fig. 4). Mean diameter of eggs ranged from 196 μm in June to 775 μm in October of 1977, and 185 μm in June to 887 μm in October of 1978.

Fecundity

The number of eggs per fish (Table 3) varied from 2,277 (standard length 248 mm) to 6,100 (standard length 313 mm) with a mean fecundity of 4,089 eggs.

The number of eggs was positively correlated with the standard length of the snake pricklebacks. The correlation coefficient (r) between these two parameters was 0.85 (Fig. 5).

The regression equation which related the number of eggs to standard length at maturity was:

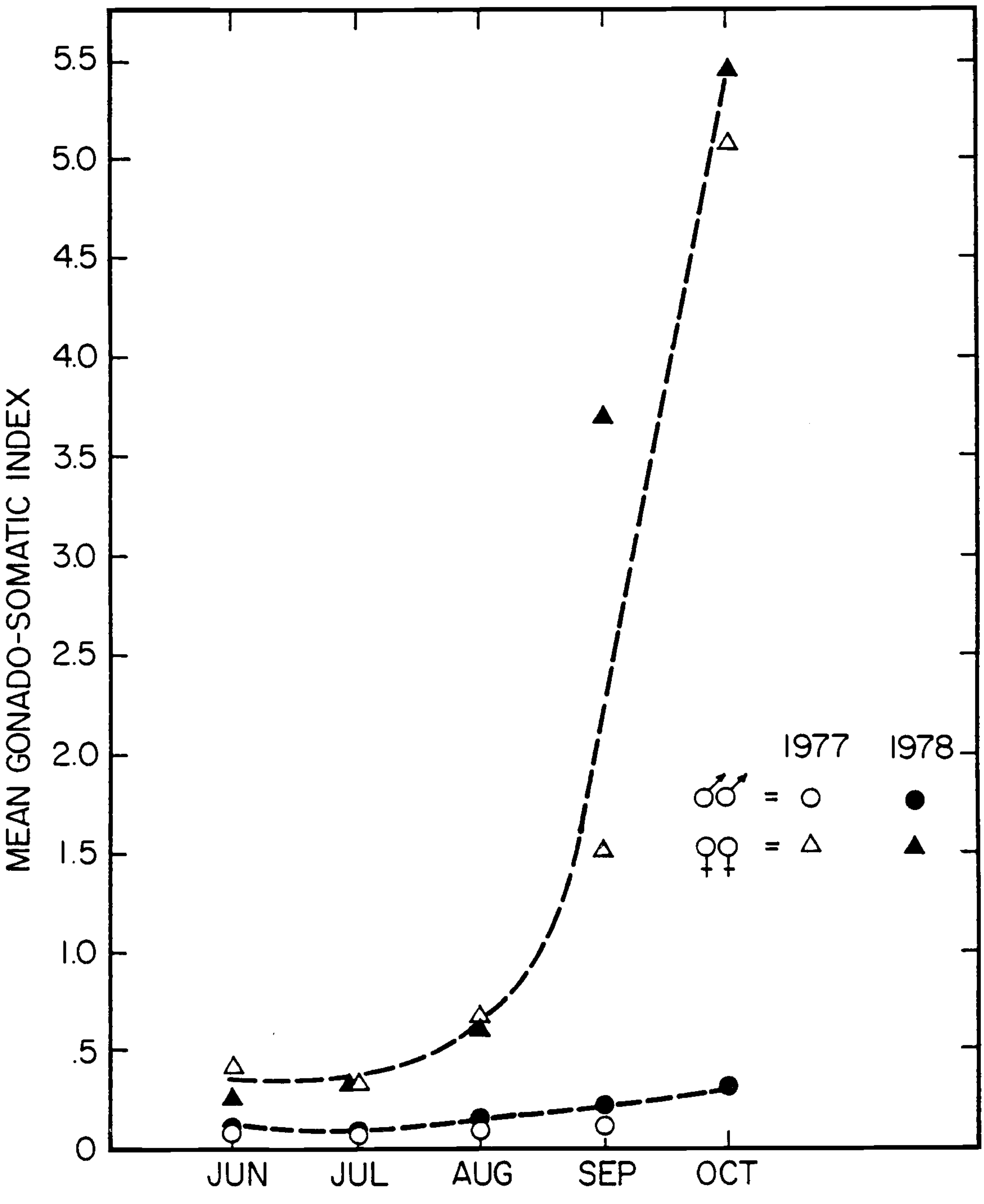

Figure 3. Monthly variation in the mean gonado-somatic index of male and female snake pricklebacks in Yaquina Bay, Oregon.

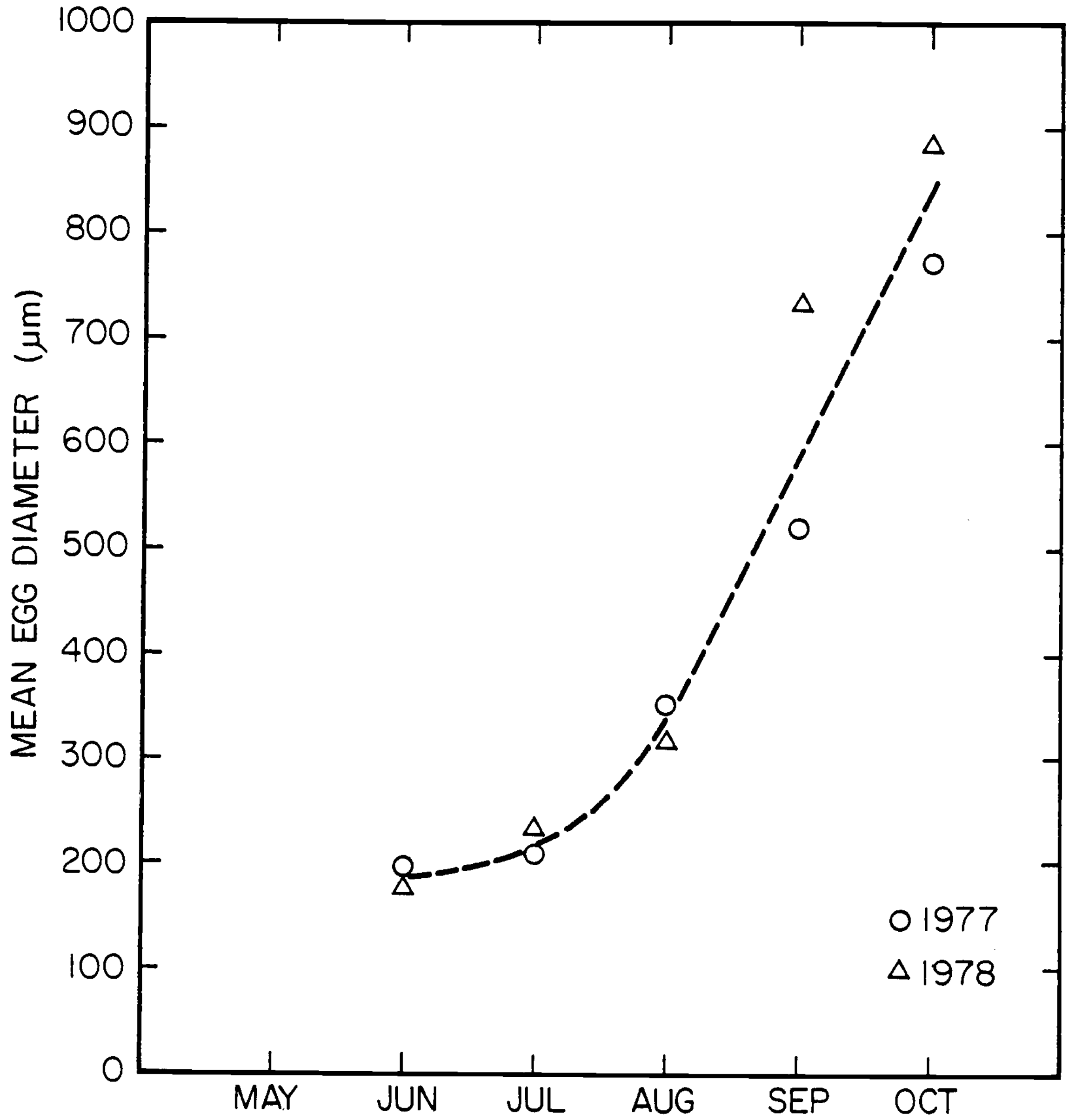

Figure 4. Monthly variation in mean egg diameter for snake pricklebacks in Yaquina Bay, Oregon

Table 3. Standard length (mm) and fecundity of eleven *Lumpenus sagitta* collected in Yaquina Bay, Oregon.

Date	Standard length (mm)	Fecundity
September 1977	296	6,089
" "	236	3,717
October 1977	243	2,418
September 1978	278	5,179
" "	278	3,733
" "	260	2,656
October 1978	299	5,856
" "	313	6,100
" "	280	3,788
" "	267	3,166
" "	248	2,277
Mean	273	4,089

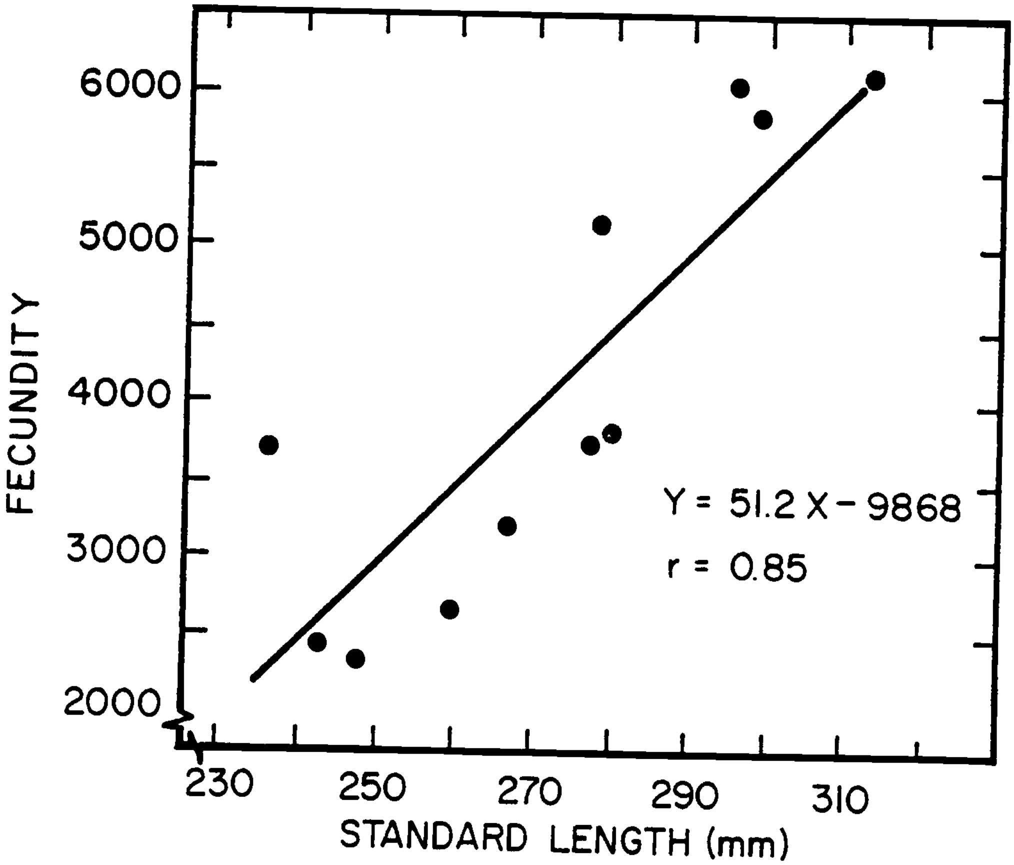

Figure 5. Fecundity as a function of standard length (mm) for snake pricklebacks captured in Yaquina Bay, Oregon during 1977-78.

$$Y = 51.2X - 9,868$$

where: Y = Number of eggs

X = Standard length in mm at maturity.

Age Determination Methods

Figure 6 is a length frequency distribution of the snake pricklebacks from which scales and otoliths were collected. In this figure, four modes can be discerned. The first is at 140 mm, the second at 200 mm, the third at 260 mm, and the fourth at 320 mm in length. These modes were considered to be age groups 0+, 1+, 2+, and 3+. The most frequent age group is 2+.

The scales of snake pricklebacks clearly show areas where "cutting over" of circuli occurs (Fig. 7). This cutting over characteristic was the criterion used to identify annuli or year marks. The annuli appear to be well formed by September (Fig. 8).

The length frequency distribution based on scale interpretation (Fig. 9) shows very good agreement with the length frequency distribution of Figure 6, except for age group 3+.

The relationship between scale radius and standard length is linear (Fig. 10) and the equation that relates these two parameters is:

$$L = 4.18X - 38.92$$

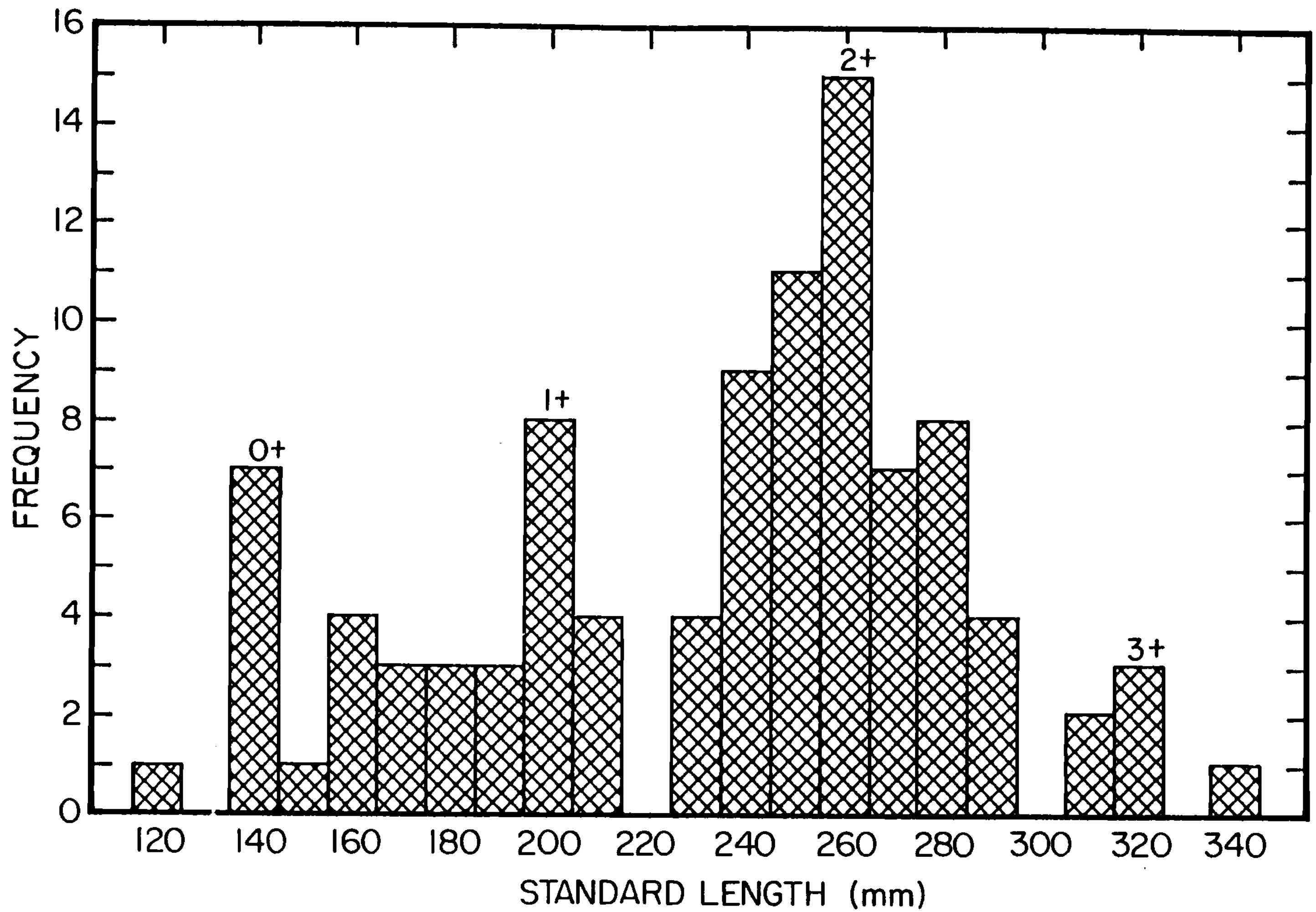

Figure 6. Standard length frequency distribution for snake pricklebacks collected in Yaquina Bay, Oregon on August 24, 1978.

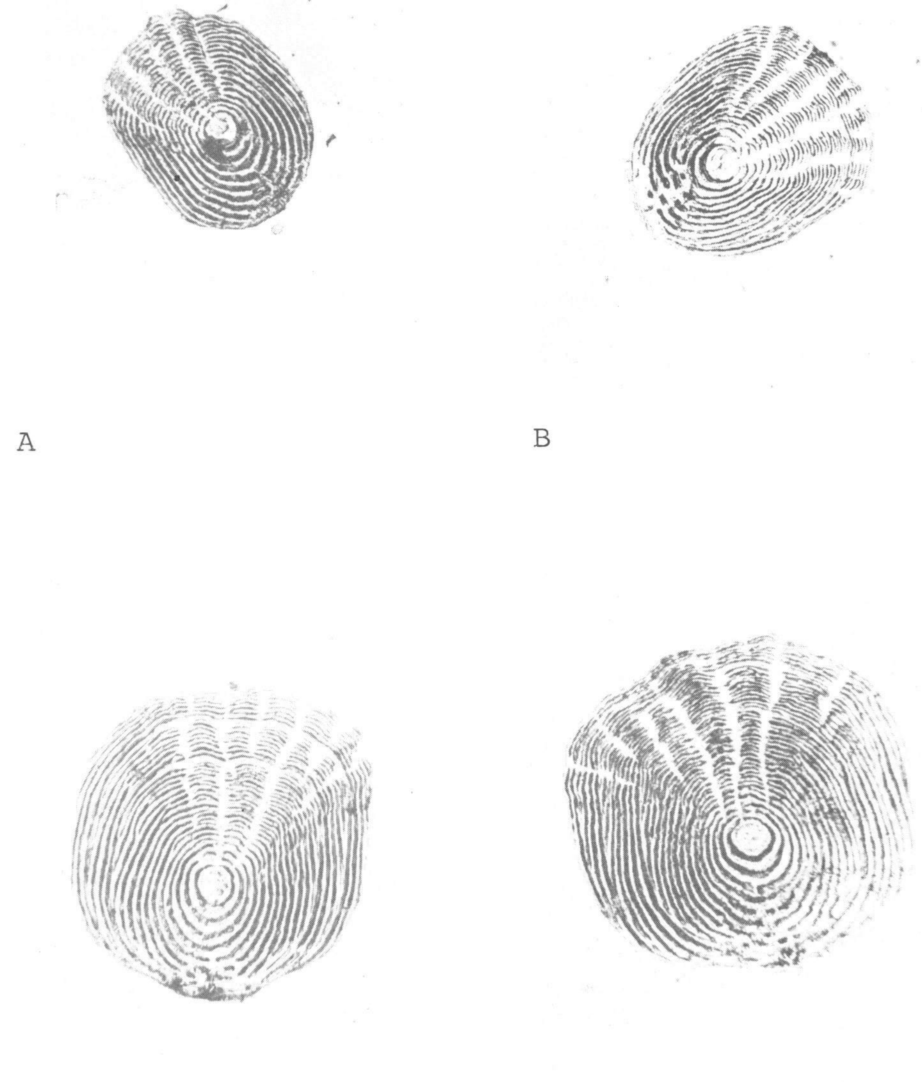

Figure 7. Scales of snake pricklebacks where (A) indicates its first year of life (0+), (B) its second year of life (1+) where one check is visible, (C) its third year of life (2+) where two checks are visible, and (D) its fourth year of life (3+) where three checks are visible.

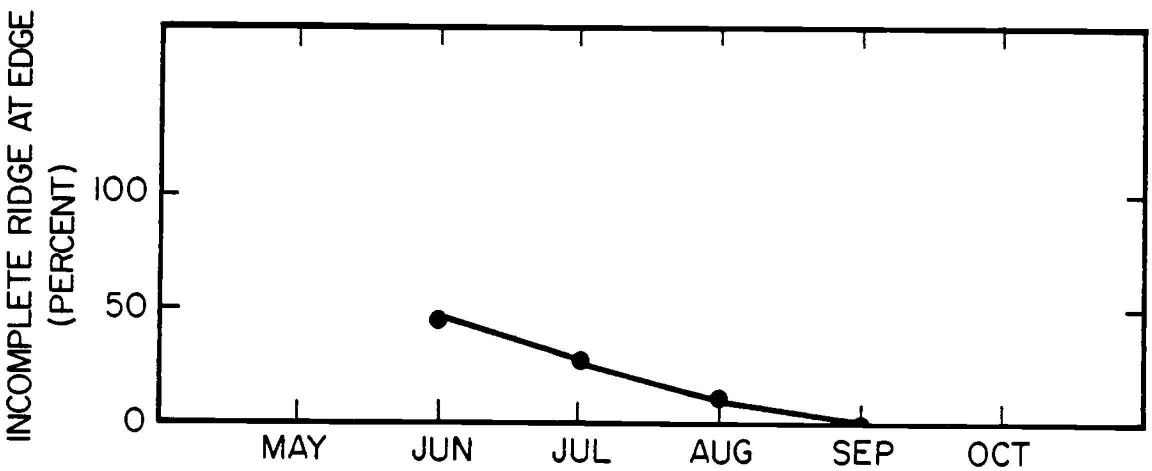

Figure 8. Percent distribution of scales with an incomplete ridge on their edge obtained from snake pricklebacks captured in Yaquina Bay, Oregon between May and October 1978.

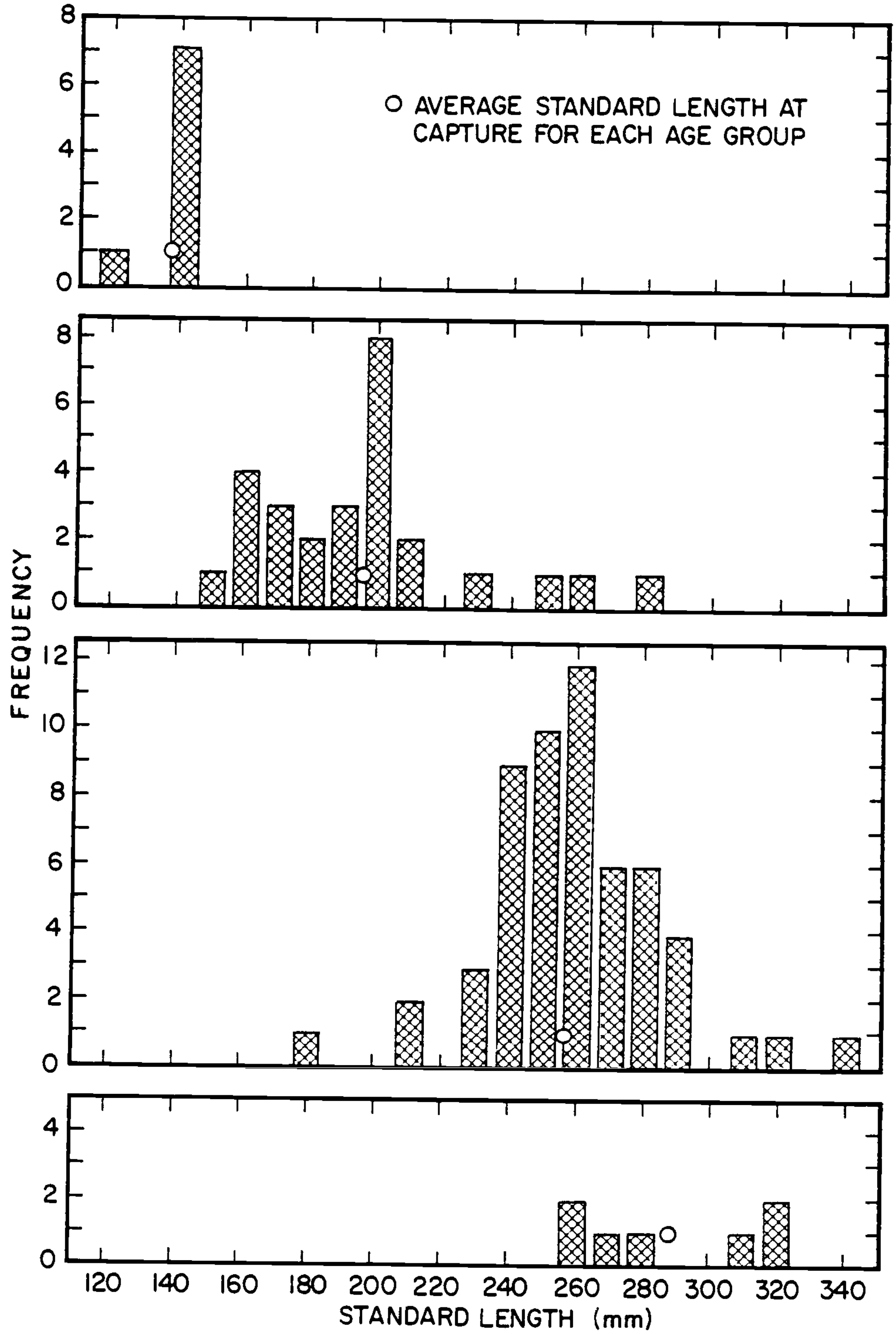

Figure 9. Standard length frequency distribution by age group at the time of capture determined from scale characteristics of snake pricklebacks captured in Yaquina Bay, Oregon on August 24, 1978.

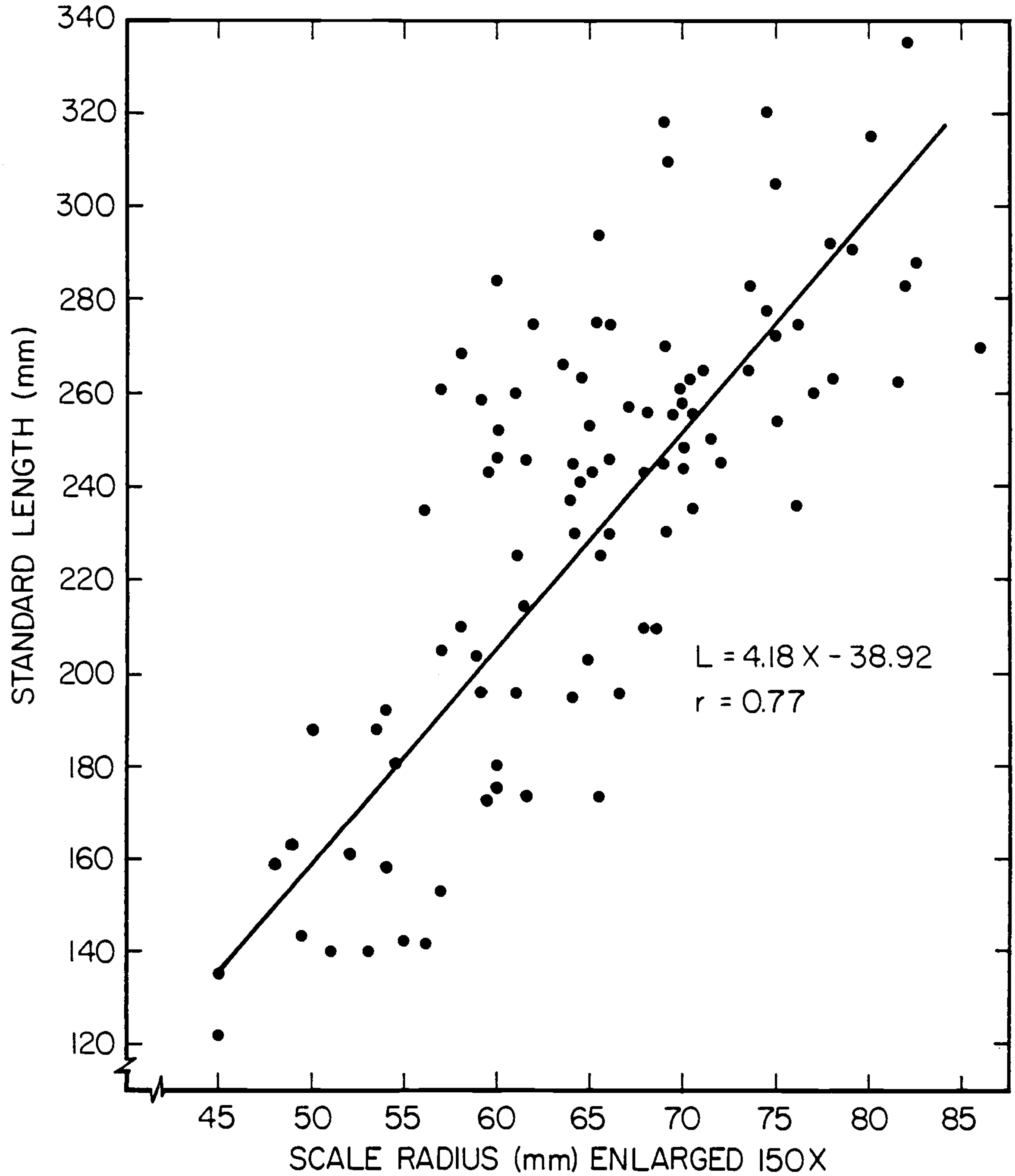

Figure 10. Relationship between scale radius and standard length of snake pricklebacks captured in Yaquina Bay, Oregon on August 24, 1978.

where: L = Standard length of the fish at the time the scale was obtained

X = Total scale radius.

The correlation coefficient for these two parameters is 0.77.

The otoliths of snake pricklebacks are very thin, with the focus always bordered by an opaque zone (Fig. 11). The criteria for annulus designation was one opaque and one hyaline zone. The annuli appear well formed mostly during September (Fig. 12).

The length frequency distribution (Fig. 13) based on otolith annuli parallels the one in Figure 6, although age group 3+ in Figure 11 appears to overlap with age group 2+ in Figure 6.

The relationship between otolith radius of snake pricklebacks and standard length is curvilinear (Fig. 14) and the equation which relates these parameters is:

$$\log L = 1.30 + 1.14 \log X$$

or

$$L = 1.30\ X^{1.14}$$

where: L = Standard length of the fish at the time the otolith was obtained

X = Total otolith radius

The correlation coefficient for these two parameters is 0.92.

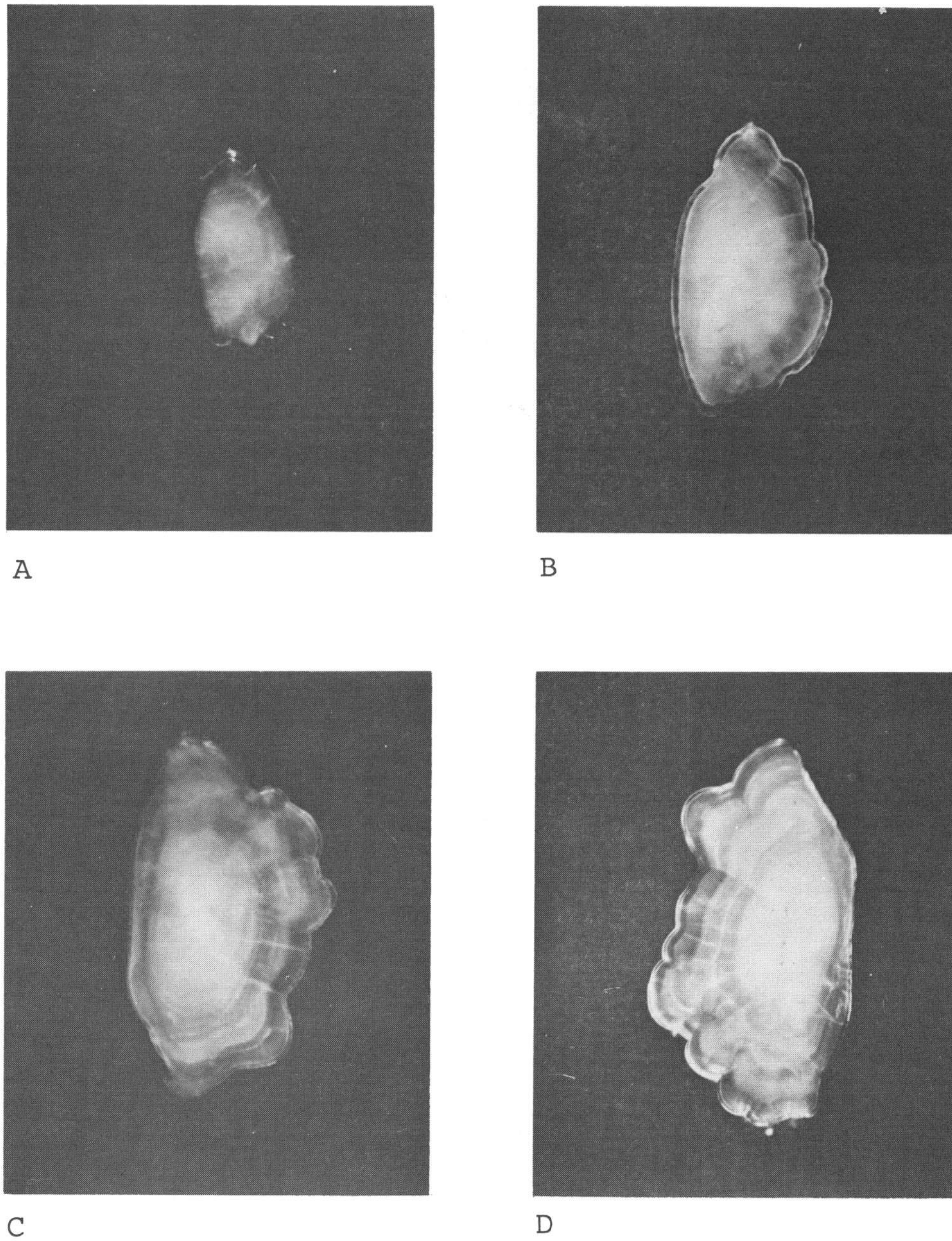

Figure 11. Otoliths of snake pricklebacks where (A) indicates its first year of life (0+), (B) its second year of life (1+) where one opaque and one hyaline zone are visible, (C) its third year of life (2+) where two opaque and two hyaline zones are visible, and (D) its fourth year of life (3+) where three hyaline and three opaque zones are visible.

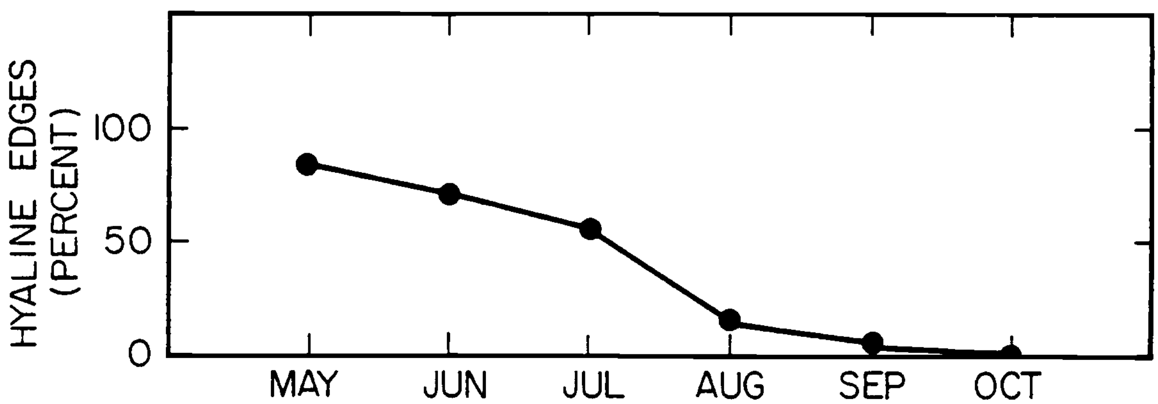

Figure 12. Percent distribution of otoliths with a hyaline edge obtained from snake pricklebacks captured in Yaquina Bay, Oregon between May and October 1978.

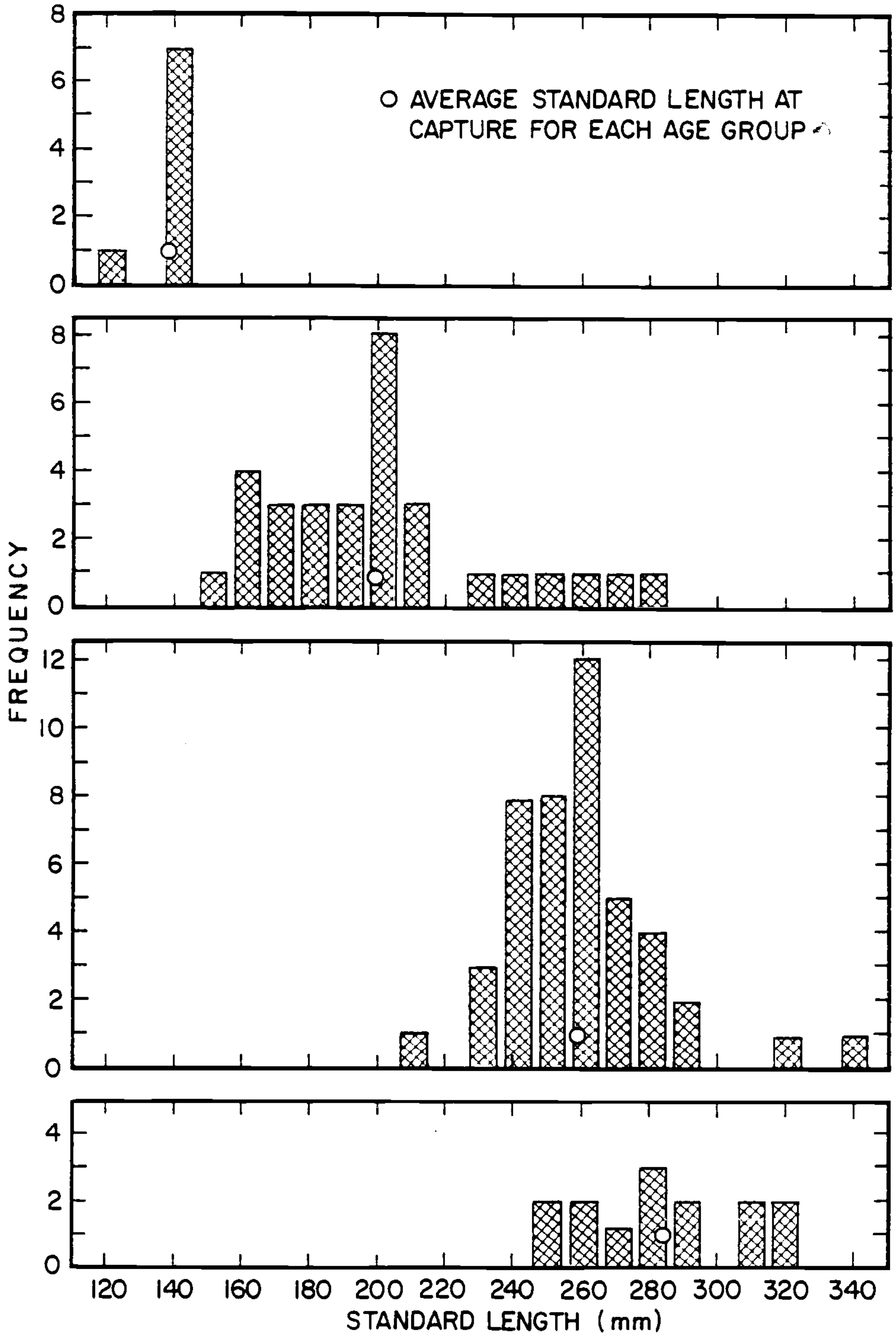

Figure 13. Standard length frequency distribution by age group at the time of capture determined from otolith characteristics of snake pricklebacks captured in Yaquina Bay, Oregon on August 24, 1978.

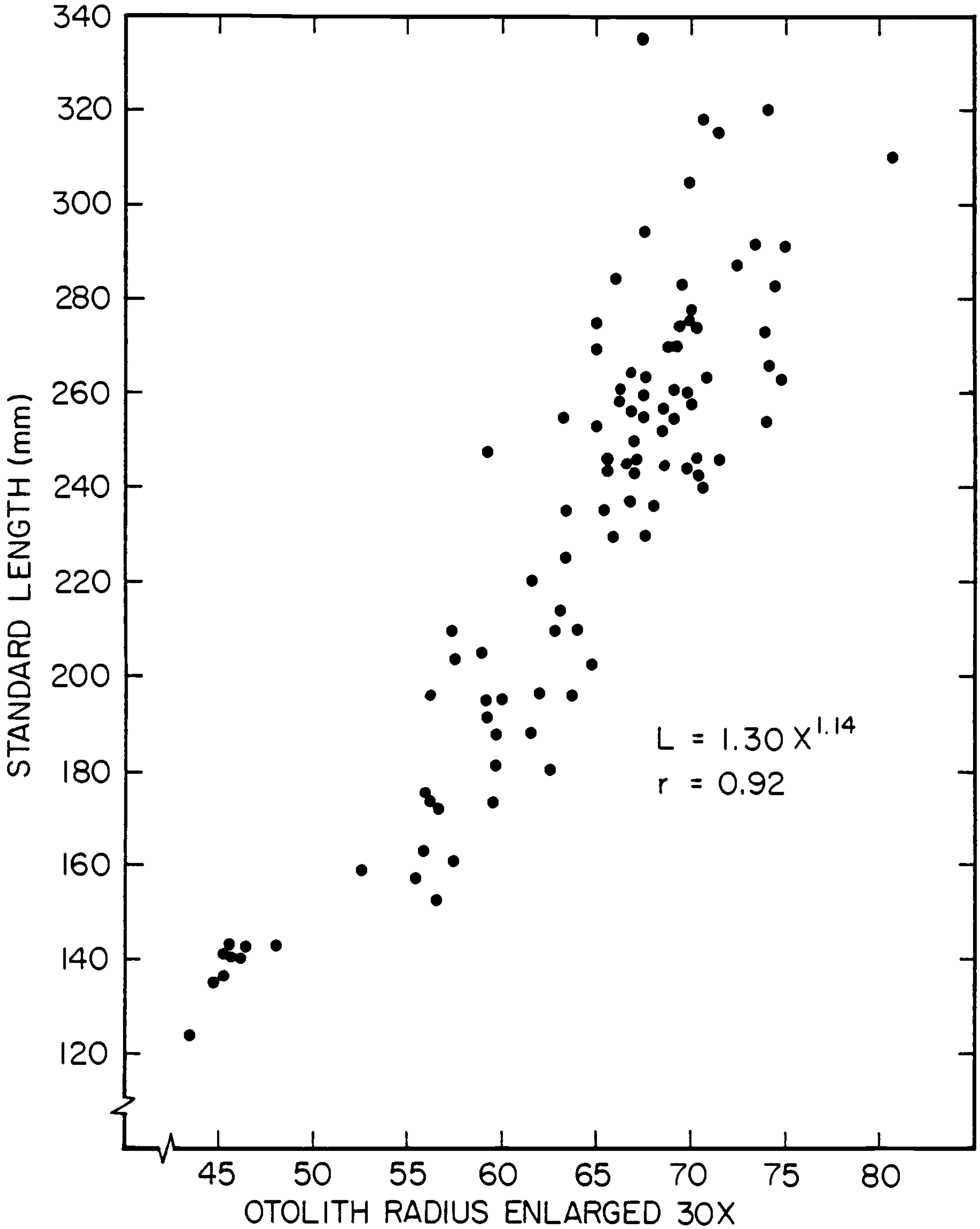

Figure 14. Relationship between otolith radius and standard length of snake pricklebacks captured in Yaquina Bay, Oregon on August 24, 1978.

Length-Weight Relationship

Measurements of 72 male and 59 female snake pricklebacks were used in this analysis for 1977 and 127 male and 90 female snake pricklebacks for 1978. The length-weight relationship for snake pricklebacks was described by the model Ln W = Ln a + b Ln L (Royce, 1972). The relationship between length and weight for sexes combined and for males and females separately for each year are illustrated in Figures 15, 16, 17, and 18.

The regression estimators are presented in Appendix Table 1. The values of the exponent "b" for 1977 are larger than for 1978. Also, the values of "b" for females are larger than for males in both years. However, females in both years show a larger value for the exponent "b" only after 155 mm of standard length (Fig. 16, 18). Thus, with the same length increment females put on more weight than males after both have reached 155 mm in length.

Salinity and Temperature Effects

In static bioassays, there was a low percent survival of snake pricklebacks at low salinities (0 and 1 ppt) for all the temperatures tested (5-20 C)(Fig. 19). Generally, the mortality at low salinity increased as the temperature increased, although this relationship did not appear to hold at 0.0 ppt salinity and 5 C temperature. Salinities in the

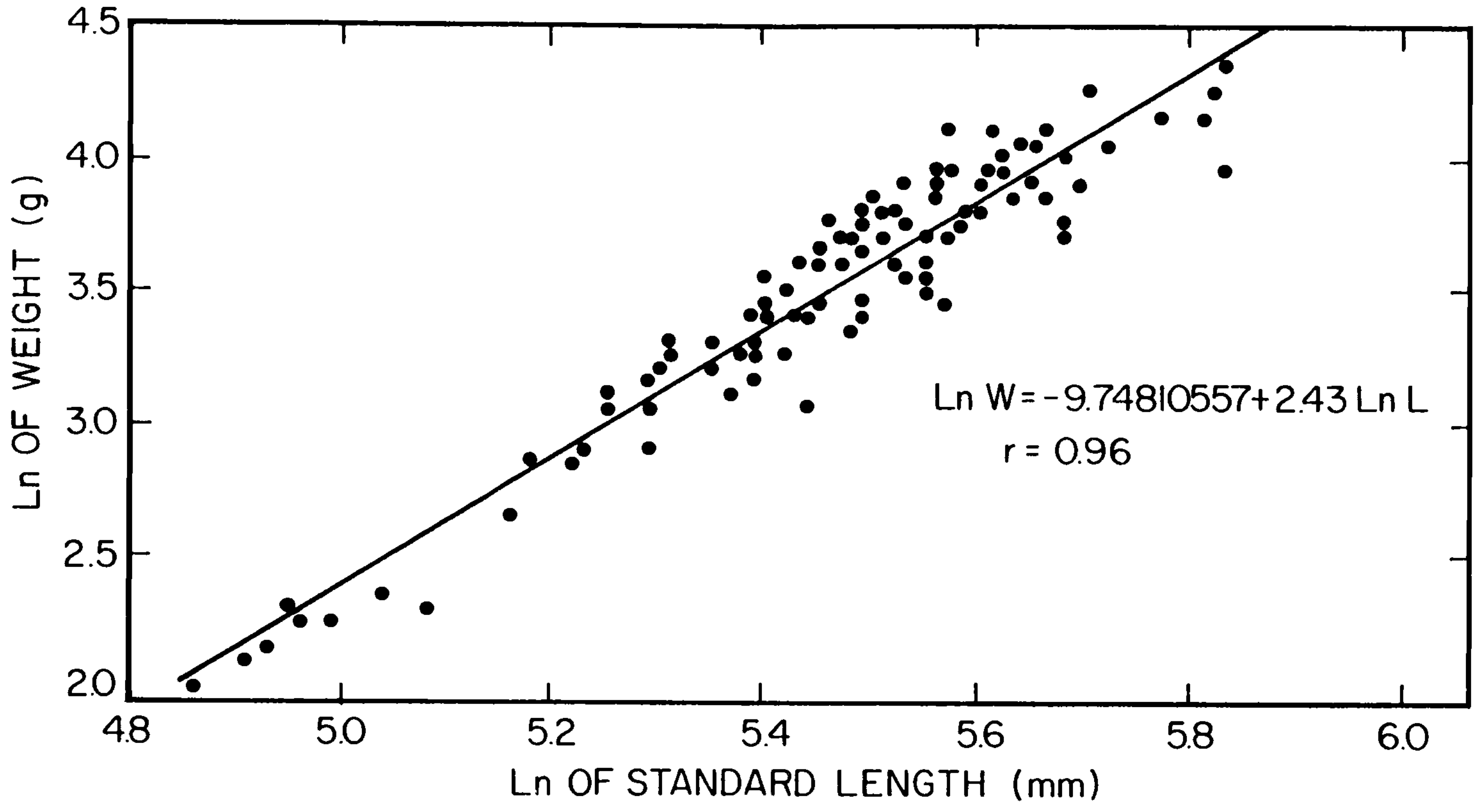

Figure 15. Relationship between length and weight for sexes combined for snake pricklebacks captured in 1977 in Yaquina Bay, Oregon.

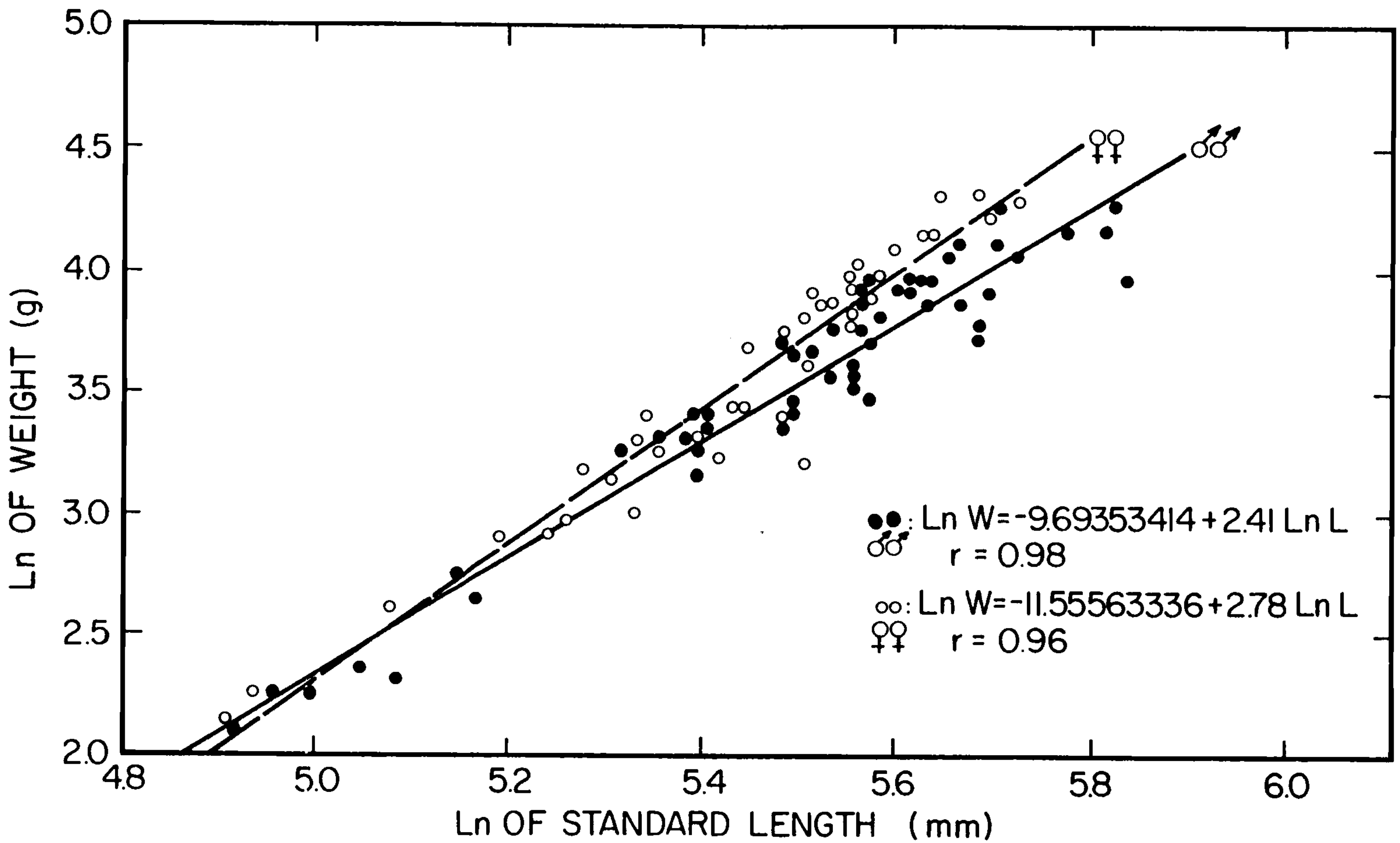

Figure 16. Relationship between length and weight for male and female snake pricklebacks captured in 1977 in Yaquina Bay, Oregon.

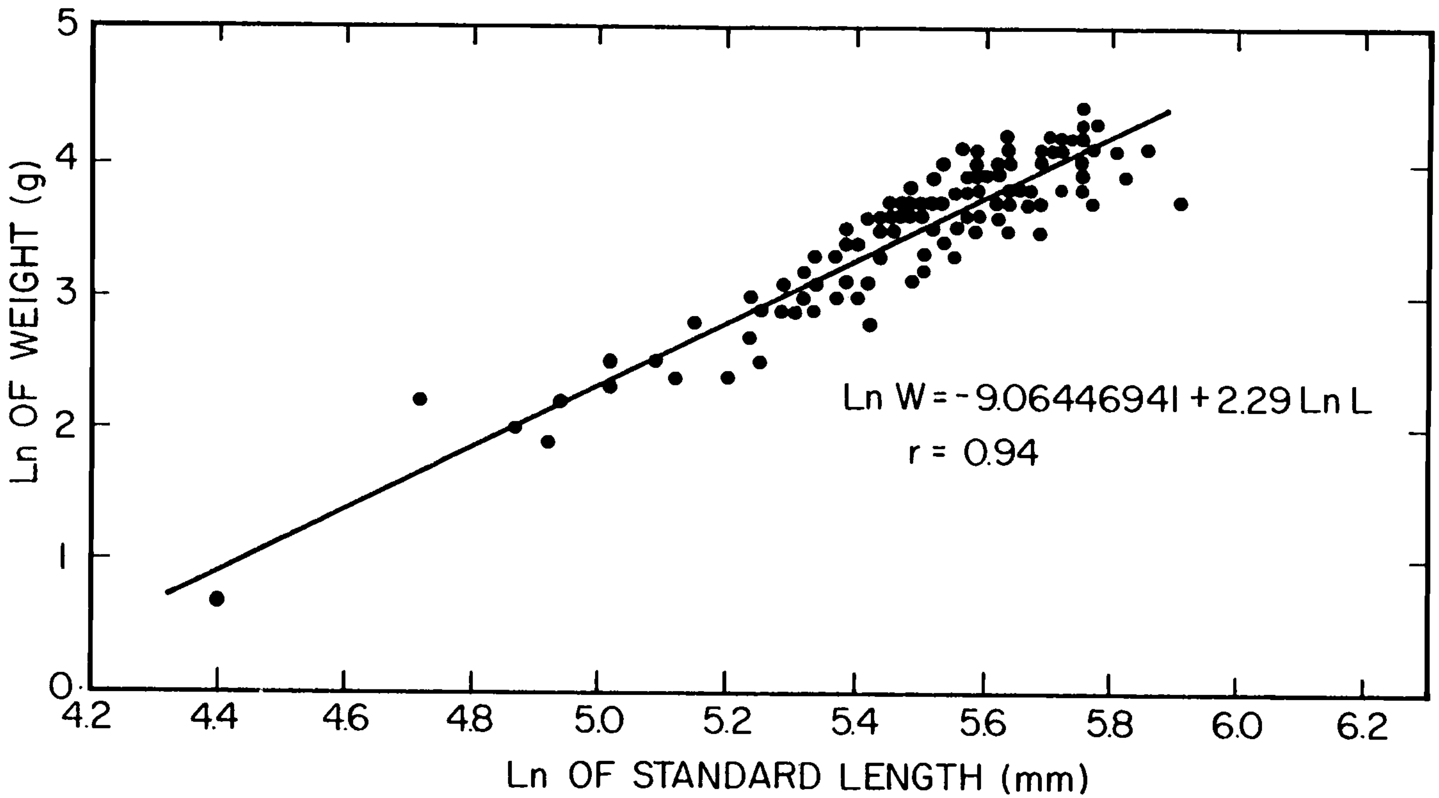

Figure 17. Relationship between length and weight for sexes combined for snake pricklebacks captured in 1978 in Yaquina Bay, Oregon.

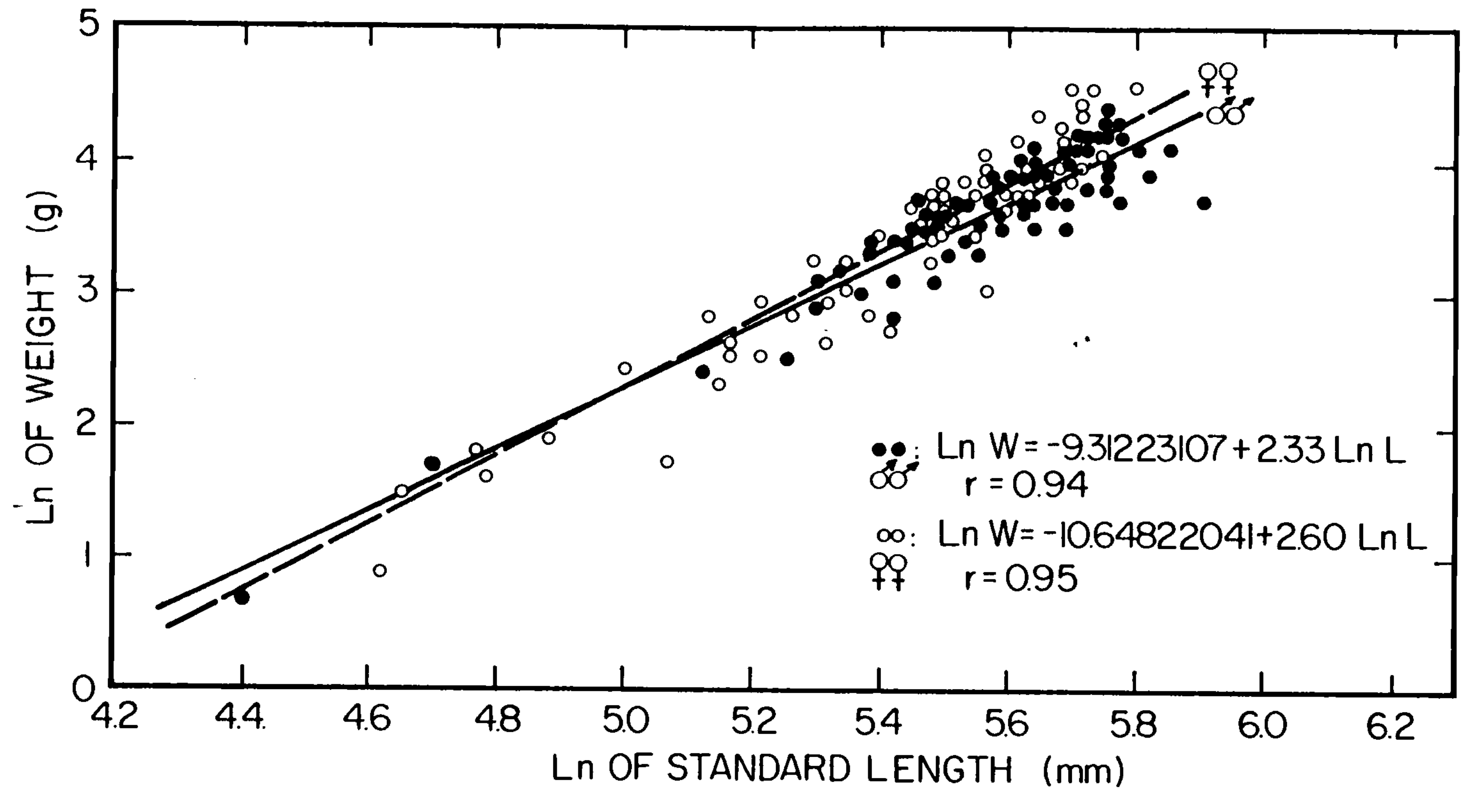

Figure 18. Relationship between length and weight for male and female snake pricklebacks captured in 1978 in Yaquina Bay, Oregon

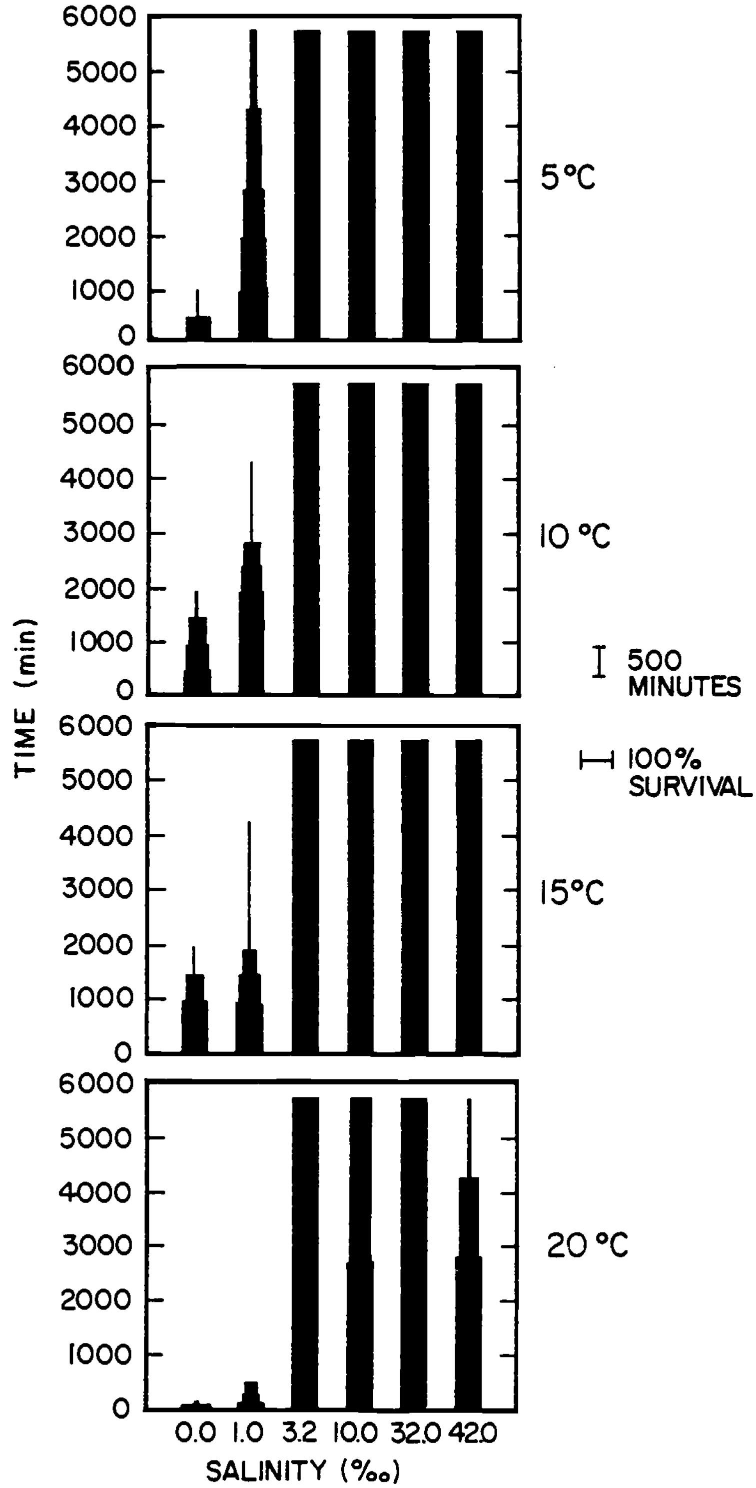

Figure 19. Effects of salinity concentration, exposure time, and temperature on the percent survival of snake pricklebacks from Yaquina Bay, Oregon in August 1978.

range of 3.2 to 42.0 ppt and temperatures of 5 to 15 C had no marked effect on percent survival.

Median survival time was low at low salinity and high temperature (Fig. 19 and 20). At salinities of 3.2 to 42.0 ppt, median survival was nearly 100% except at 42.0 ppt and 20 C where appreciable mortality occurred after 72 hours exposure time.

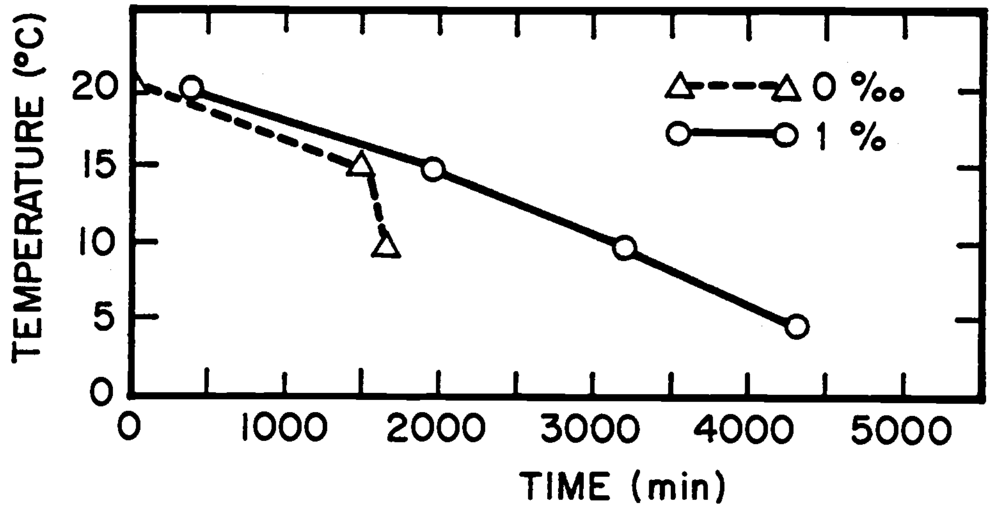

Figure 20. Median survival time vs temperature at 0 and 1 ppt salinity for snake pricklebacks from Yaquina Bay, Oregon in August, 1978.

DISCUSSION

Food Habits

Most of the species eaten by snake pricklebacks were algae, polychaeta, crustacea, and bottom-dwelling organisms. The variation in the different items consumed appears to be based on the availability of the different foods. Kjeldsen (1967) reported that the largest number of estuarine macroalgae in Yaquina Bay occurs during the spring and summer. Crandell (1967) reported that the populations of harpacticoids during fall and winter were reduced. All these occurrences appear to reflect in a general way on the variations in the main foods of snake pricklebacks. Russell (1964), however, indicated that the availability of food may not be the only criteria for determining food habits of herring (Clupea harengus pallasi). Size, relative ease of capture, and whether or not food organisms are in patches are probably additional criteria. The size of the food organisms injested by snake pricklebacks appears to be important, because I found that fishes <150 mm standard length fed on small crustacea, small polychaeta and small gastropoda. Also Barraclough (1967a, 1967b), Barraclough, et al. (1968), Barraclough and Fulton (1968), Robinson, et al. (1968), and Hart (1973) reported that copepods constituted the most common food of young snake pricklebacks.

Gibson (1970) reported that the main food for *Gobius cobitis* was the alga *Enteromorpha*, and the second most important food was amphipoda. He also found a considerable difference in the diets of different size groups. Young fish up to 8 or 9 cm in length fed mainly on smaller food items such as copepods, ostracods and amphipods. As the fish grew longer their diet changed to include larger organisms such as large amphipods, polychaetes, and increased amounts of green algae.

The wide variety of species occurring in the stomach of snake pricklebacks indicates that they are non-selective in feeding and this species appears capable of utilizing many sources of protein as food.

Analysis of stomach contents of snake pricklebacks revealed the presence of fish in only a few instances. The fact that these fishes were largely undigested and were present in the beach seine seems to indicate that they were eaten during the catching process. This reinforces the notion that snake pricklebacks are non-selective in their feeding habits.

In conclusion, I believe that snake pricklebacks are non-selective, omnivorous, bottom feeders, having algae, polychaeta, and crustacea as the main components of their diets.

Reproductive Biology

Gupta (1974) stated that the gonado-somatic index is one measure which can be used to assess the degree of ripeness of gonads. This appears true for snake pricklebacks which show an increase in G.S.I. from July to October (Fig. 3). This increase agrees well with the increase in egg diameter (Fig. 4). The increase in G.S.I. in females is much more marked than in males.

The absence of data from November to May prevents observing the full seasonal gonadal cycle, but based on the trend in the G.S.I., I assume that snake pricklebacks probably spawn near the end of fall and during winter. Wingert (1975) indicated that *Xiphister atropurpureus*, which belongs to the family Stichaeidae and was caught near San Simeon, California, spawns from February to April with the major portion of the population spawning in March. In an 11-year study in Yaquina Bay, Pearcy and Myers (1974) found larvae of snake pricklebacks commencing during January and February.

The mean fecundity (4,089 eggs) reported in this research is larger than the mean fecundity shown for other species of Stichaeids. Breeder and Rosen (1966) reported 3,000 ripe ova for *Anoplarchus purpurescens*, and Wingert (1975) observed a mean fecundity of 1,825 eggs in *Xiphister atropurpureus*.

The number of eggs in snake pricklebacks is positively correlated ($r = 0.85$) with the increasing body length (Fig. 5). Wingert (1975) reported the same relationship for *X. atropurpureus* with a correlation coefficient of 0.83.

Age Determination Methods

Van Oosten (1929) and Everhart, et al. (1975) indicated that there are three primary conditions that scales must meet in order to be accepted as a device for accurate determination of age of a fish:

1. The scales must remain constant in number and identity throughout the life of the fish.
2. The growth of the scales must be proportional to the growth of the fish.
3. The annulus must be formed yearly and at the same approximate time each year.

Part of the first condition was reached through the examination of the focus of the different ages of fish. In Figure 7 the focus of the young snake prickleback looks structurally identical to the focus of older fish. Also, regenerated scales were distinguishable from non-regenerated scales.

The linear relationship between scales and standard length (Fig. 10) helps meet the second condition. This relationship shows that the growth of scales is proportional to the growth of the body length after birth. This linear relationship can also be used as an indirect indicator that the number of scales remains constant. Van Oosten (1929) indicated that if the number of scales increases with age, they cannot grow in proportion to the body's growth.

The third condition was satisfied by assuming that annulus formation on scales happens mostly in September (Fig. 8), and that the "cutting over" shown on scales of snake pricklebacks is a useful criteria for annulus identification such as Beckman (1942), Lagler (1956), and Everhart, et al. (1975) considered. This assumption is further supported by the agreement between modes in the length frequency distribution (Fig. 6) with the modal lengths of corresponding age groups based on scale interpretation mainly for age groups 0+, 1+, and 2+ (Fig. 9).

Williams and Bedford (1974) indicated that if the otoliths of any species of fish are used for age determination it is necessary to establish that:

1. A recognizable pattern can be seen in the otolith either by viewing it directly by ordinary light or after some method of preparation.
2. A regular time scale can be allocated to the visible pattern; this time scale is not necessarily annual although it is usually so, particularly in cold and temperate areas.

The otoliths of snake pricklebacks show very clear opaque and hyaline zones (Fig. 11) when examined under light reflected from a black background. Also I assumed that the deposition of the alternate opaque and hyaline zones is a regular annual occurrence which coincides with the physical condition of the water at the sites of sampling (Appendix Fig. 2). In this way an annulus is formed by one opaque and one hyaline zone. This appears to be true because agreement was found between the modes of length frequency distributions and the modes of the length frequency distributions based on otolith interpretations (Fig. 6 and 13). Also, the annulus appears to be formed each year during September (Fig. 12).

Carlander (1974) stated that length frequency analysis often gives a method of verifying scale or otolith readings and of clearing up some difficulties in interpretation. In the case of snake pricklebacks this appears to be true only until two years of age, after which the lengths of older fish appear to overlap with age.

Good agreement was found between scale and otolith age interpretations until the age of two, thereafter large disagreements were observed. There are some difficulties in visualizing the "cutting over" on scales as the fish gets older and this may be the reason for the low estimate of age group 3+.

I believe the otolith method gives a better estimate of age of snake pricklebacks than the scale method, especially for the older age groups.

Length-Weight Relationship

The length-weight relationship for snake pricklebacks reflects a general increase in weight with increasing length, but at a rate somewhat lower than the cube of the length (Appendix Table 1). Carlander (1969) stated that the value of the constant "b" will usually be near 3.0 since the weight of a fish will vary as the cube of its length if shape and specific gravity remain the same. This does not happen with snake pricklebacks, because the constants "b" are all lower than 3.0.

Snake pricklebacks have a shape that is basically anguilliform. The regression coefficient "b" of other species which have similar shapes show different values. Sawyer (1967) reported that the constant "b" for *Pholis gunnellus* is equal to 3.0 in females and larger than this in males (3.1).

Female snake pricklebacks >155 mm of length, had slopes larger than males in 1977 and 1978 (Fig. 16 and 18). I think these differences are due to a larger relative increase in gonad weight in females than in males.

Salinity and Temperature Effects

The salinity at collecting site four (the site furthest up-bay) was always lower than the other three sites, and on one occasion (Dec. 1977) dropped to 0 ppt (Appendix Fig. 1-4).

The temperature at site four during summer was always higher than at the other three sites and at times exceeded 20 C; coincidentally the catch of snake pricklebacks at site four was almost zero for the whole period of study.

From results of the bioassay experiments, I concluded that low salinities and high temperatures deleteriously affected the survival of snake pricklebacks (Fig. 20). Although in most cases I found no salinities below 6 ppt in the field, I believe that salinity becomes a limiting factor during the rainy season (winter), but during summer temperature becomes the limiting factor.

Kinne (1964) indicated that temperature can modify the effects of salinity and enlarge, narrow, or shift the salinity range of an individual; and salinity can modify the effect of temperature accordingly. These combined effects may be the reason why I did not catch many snake pricklebacks at site 4.

Ferguson (1958) reported that temperature, if acting alone, can determine the distribution of fish in experimental apparatuses. Strawn and Dunn (1967) indicated for salt-marsh fishes that as temperature decreased optimum salinities for survival increased. Blaber (1973) concluded from experiments with temperature and salinity tolerances in juvenile *Rhabdosargus holubi* that the distribution of this species is related to temperature and that there is little interaction between temperature and salinity.

Whitfield and Blaber (1976), however, reported that evidences of their experiments suggest that the distribution of Tilapia rendalli is governed by both temperature and salinity.

From the field data (Appendix Fig. 1-4) and from the results of the bioassays (Fig. 19), it appears that snake pricklebacks found suitable conditions at sites one, two, and three from June to October 1977 and May to October 1978; however, this species was not caught during late fall and winter.

During the analysis of gonads, I observed that the gonads mature from July to October. This suggests that snake pricklebacks migrate to sea during fall and winter to find environmental conditions needed for completion of maturation of their gonads and for spawning.

The report of Pearcy and Myers (1974) supports this idea because they found snake prickleback larvae during January and February at buoy 21 (midway between sites 3 and 4). They considered Yaquina Bay estuary as an important nursery for several species of marine fishes, among which is the snake prickleback.

Nikolsky (1963) indicated that fishes migrate to the places where they find the conditions they require at that particular phase of their life history and that the cycle of migration usually consists of spawning migrations, feeding migrations, and wintering migrations.

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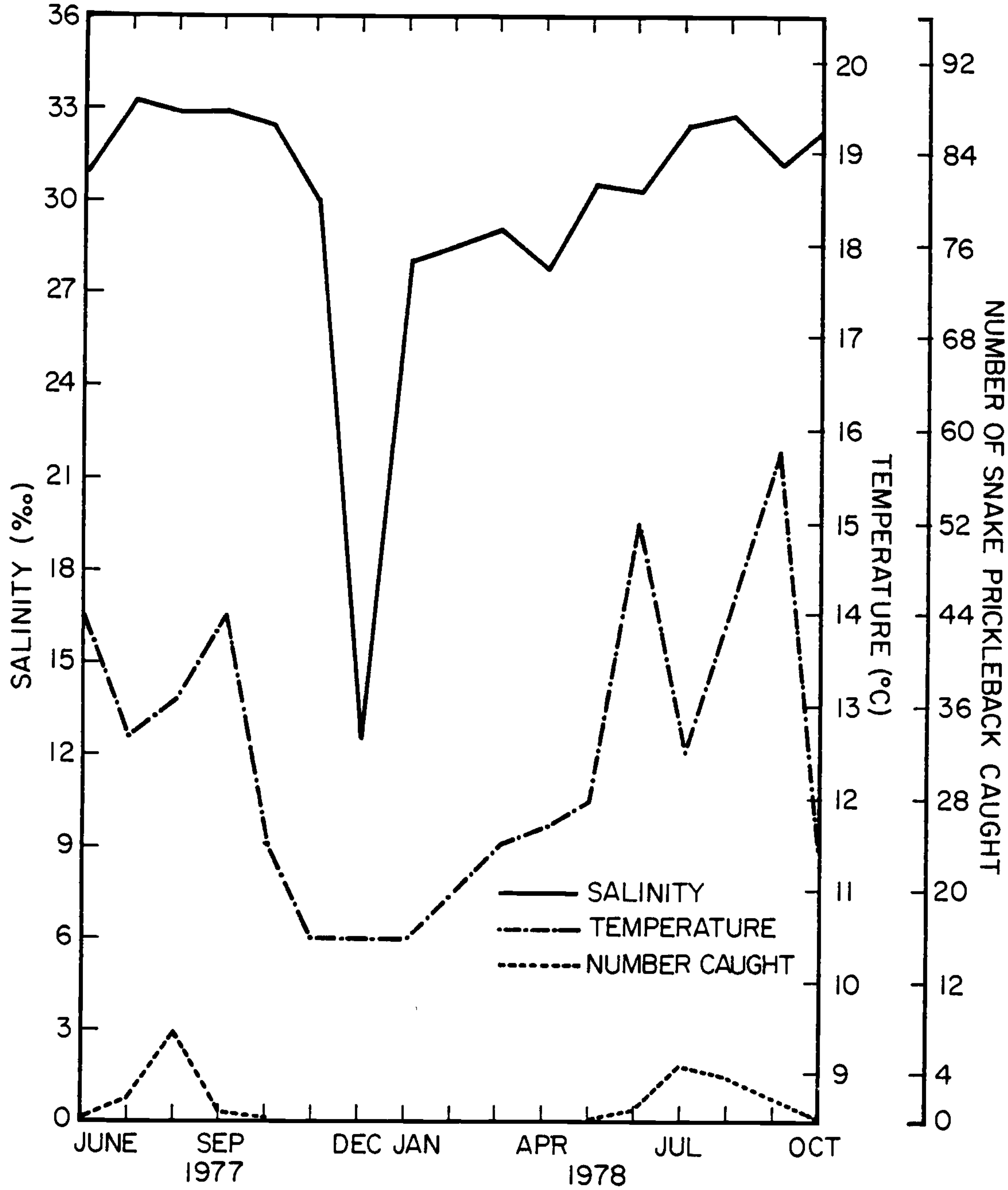
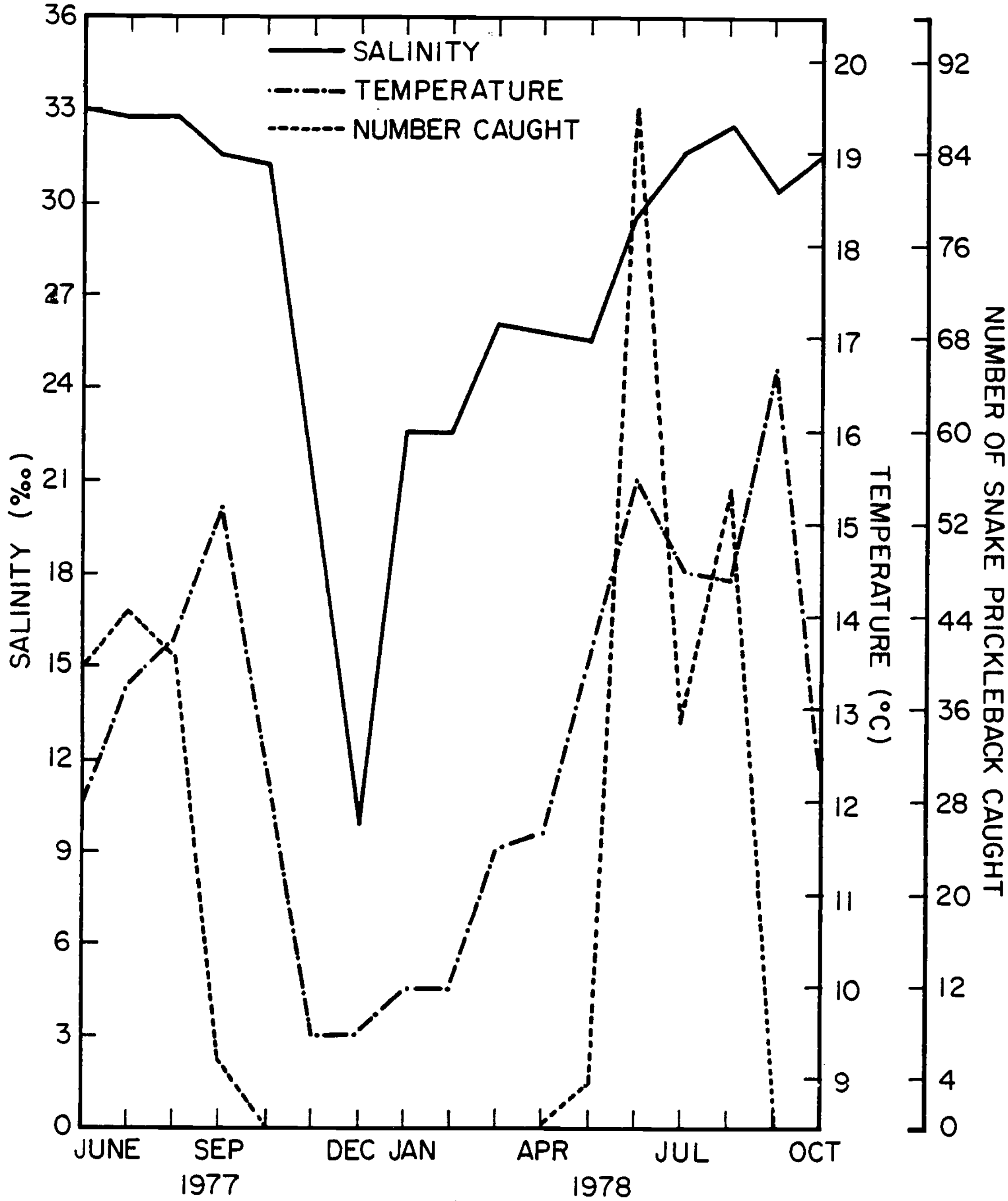
APPENDIX

Appendix Table 1. The regression estimators and coefficient of correlation for snake pricklebacks sampled in 1977 and 1978 in Yaquina Bay, Oregon.

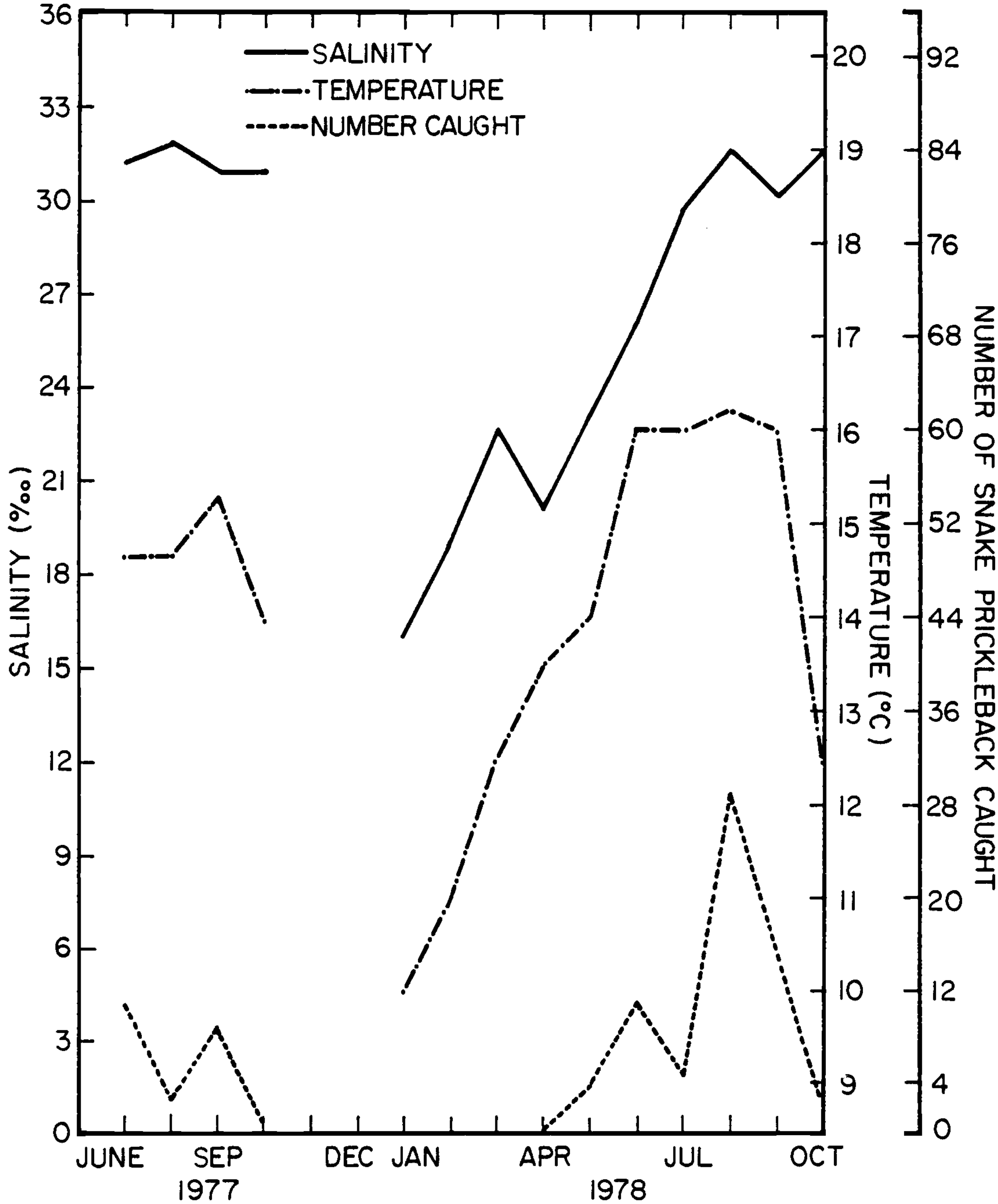
Sex	No. sampled	a	b	r
	1977			
Male and female	131	0.0000584	2.43	+0.964
Male	72	0.0000617	2.41	+0.979
Female	59	0.0000096	2.78	+0.964
		1978		
Male and female	217	0.0001157	2.29	+0.935
Male	127	0.0000617	2.33	+0.940
Female	90	0.0000237	2.60	+0.946



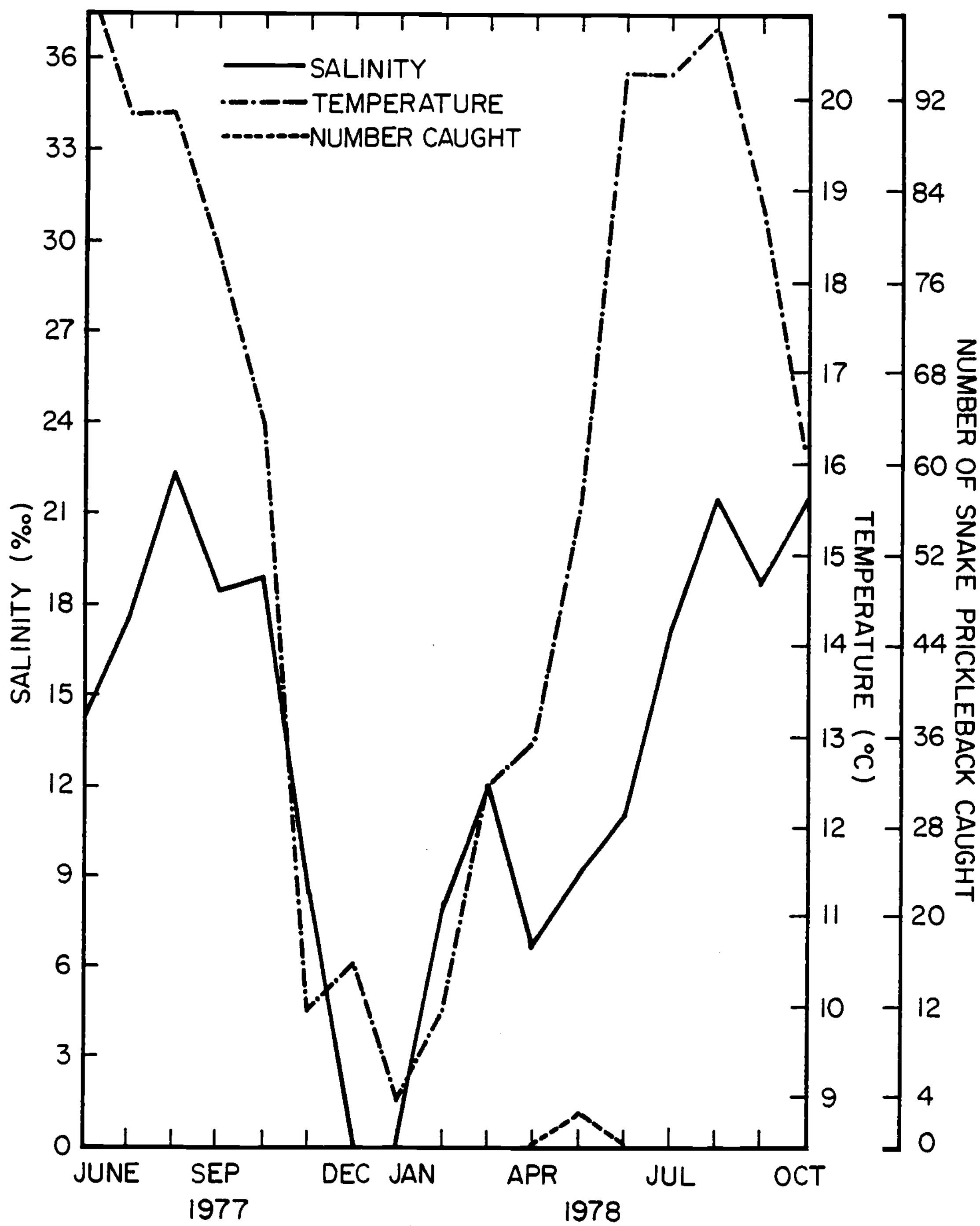
Appendix Figure 1. Average salinity, temperature and number of snake pricklebacks caught for each month of sampling at site 1 in Yaquina Bay, Oregon.



Appendix Figure 2. Average salinity, temperature and number of snake pricklebacks caught for each month of sampling at site 2 in Yaquina Bay, Oregon.



Appendix Figure 3. Average salinity, temperature and number of snake pricklebacks caught for each month of sampling at site 3 in Yaquina Bay, Oregon.



Appendix Figure 4. Average salinity, temperature and number of snake pricklebacks caught for each month of sampling at site 4 in Yaquina Bay, Oregon.