LENGTH-WEIGHT RELATIONSHIP, FOOD HABITS, PARASITES, AND SEX AND AGE DETERMINATION OF THE RATFISH, *HYDROLAGUS COLLIEI* (LAY AND BENNETT)[1]

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ABSTRACT

In the fall and winter of 1965-1967, 292 ratfish (*Hydrolagus colliei*) were collected from four locations off the Pacific coast of Oregon. Specimens were examined for length-weight relationships, food habits, parasites, and a method of sex and age determination. Equations describing the body weight-body length (snout to vent) relationships were log weight = log −4.3217 + 3.0546 log length for males, and log weight = log −4.1692 + 2.9720 log length for females. The food organisms most important to ratfish were shrimp (*Pandalus* and *Crago*), mollusks (*Musculus* and *Amphissa*), and echinoderms (*Brisaster*). Two occurrences of cannibalism were found in ratfish collected off Cape Arago, Oreg. Infestations by *Gyrocotyle* ranged from 29 to 66% among samples from the four locations. The copepod, *Acanthochondria* sp., was attached to the claspers of seven males from Cape Arago. Eye-lens weights (wet and dry), vertebral radii, basal sections of the dorsal spine and left pectoral fin, and body-length frequencies were studied, but no accurate method of age determination was found. Tritors on the posterior side of the vomerine dental plate may be indicative of age, but the precise relationship was not determined.

The ratfish, *Hydrolagus colliei* (Lay and Bennett), is a member of the class Chondrichthyes, order Chamaeriformes, and family Chimaeridae (Bailey, 1970). Distributed from western Alaska to northern Baja California (Koratha, 1960), this cartilaginous fish is the only chimaeroid found on the Pacific coast of Canada and the United States. Ratfish are of little economic value, but their liver oil is an excellent lubricant and could be used commercially (Clemens and Wilby, 1961). Ratfish are an important source of food for such commercial fishes as soupfin sharks, *Galeorhinus zyopterus* (Nakatsu, 1957), spiny dogfish, *Squalus acanthias* (Alverson and Stansby, 1963), and Pacific halibut, *Hippoglossus stenolepis* (Thompson, 1915). Conversely, ratfish are commonly caught in the trawls of commercial fishermen who consider them a nuisance. Our study was conducted to help fill the need for more information on the general biology of this primitive fish (Bigelow and Schroeder, 1953; Crescitelli, 1969).

Little information has been published on the food habits of *H. colliei*. Dean (1906) reported that *Chimaera* (*Hydrolagus*) *colliei* fed on small isospondylous fishes, opisthobranchs, annelids, crustaceans, mollusks, squids, and nudibranchs. Olsson (1896) and Legendre (1944) reported that *Chimaera monstrosa* fed on mollusks, decopods, annelids, amphipods, echinoderms, and coelenterates.

Several studies have been conducted on the parasites of *H. colliei*. Wardle (1932) reported that most ratfish contained a pair of *Gyrocotyle urna* in the anterior region (spiral valve) of the intestine. Lynch (1945) concluded that *G. urna* should be divided into *G. urna* and *G. fimbriata*. Koratha (1960) examined two *H. colliei* from

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Baja California and found two digenea (*Otodistomum* sp.) and one cestode from the intestine, one hirudinean (*Branchellion* sp.) from the skin surface, and three copepods (*Chondracanthus epacthes*) and one monogenea from the gills. A monogenea reported from the gills of ratfish from Washington waters was *Octobathrium leptogaster* (Bonham, 1950). Wilson (1935) reported the copepods *Acanthochondria clavata* and *A. epachthes* from the claspers and gills, respectively, of *H. colliei* from California waters. Kabata (1968) could not accept Wilson's (1935) identification of *A. clavata*, because the species had never been found outside the North Sea, and described *A. holocephalarum* from the claspers of ratfish captured off British Columbia.

Most morphometric studies of ratfish have been descriptive or histological in nature. Sanford, Clegg, and Bonham (1945) studied the liver oil and vitamin A content of 35 ratfish captured off Tatoosh Island, Wash. These factors were related later to size and sex of ratfish by Pidlaoan (1950). Halstead and Bunker (1952) described the venom apparatus and anatomy of the dorsal spine of ratfish. They concluded that the venom of *H. colliei* was not capable of inflicting fatal injuries to man. A histological study of the digestive tract and of the pituitary of *H. colliei* was conducted by Clothier (1957) and Sathyanesan (1965), respectively.

Stanley (1961) performed a morphometric study of the genital systems of *H. colliei* and found that summer was the peak reproductive period although one-third of the females and all of the males evidenced reproductive activity throughout the year. Sexual maturity was attained at 24-25 cm (S-V)[4] for females and 18.5-20 cm (S-V) for males.

METHODS

Four collections totaling 292 ratfish were made by otter trawl off the coast of Oregon at depths ranging from 50 to 120 fm from 1965 to 1967. The collection from off Newport ($N = 189$) was frozen while specimens collected off Cape Blanco ($N = 44$), Cape Arago ($N = 35$), and Astoria ($N = 24$) were preserved in 10% Formalin.

All ratfish were examined as follows: Sex was determined by inspection of the gonads; snout to vent length was measured in millimeters, and total weight was measured in grams; all specimens were examined for internal and external parasites; alimentary canals were examined along their entire length for food items; and dental plates, dorsal spines, left pectoral fins, and a piece of the vertebral column were decalcified, sectioned frozen, treated with Delafield's hematoxylin stain, and examined for growth structures indicative of age. Both eye lenses were removed from specimens in the Newport and Astoria collections. The wet and dry weight of each lens was determined to the nearest ten thousandth of a gram. For wet-weight determinations, lenses were stored in 10% Formalin for 1 month, removed and blotted, and immediately weighed. For dry weight determinations, the lenses were then desiccated at 80°C for 82 hr and reweighed. The 82-hr drying period was determined from a curve of weights of 10 lenses dried at 80°C and weighed at progressive time intervals. The 82-hr period assured evaporation to a stable weight.

Most statistical analyses of body length-body weight and body length-eye-lens weight relationships were performed on a CDC 3300 computer[5] utilizing program FISH 6669 in the Department at Oregon State University.

RESULTS AND DISCUSSION

There was a highly significant correlation ($P = 0.01$) of body length to body weight for male and female ratfish in the large Newport collection and for the aggregate of each sex collected (Table 1). Based on the coefficient of determination (r^2) (Croxton, 1953), more than 87% of the variation in weight in males and more than 96% in females was attributable to the variation in length of the ratfish. The length-

[4] Body length measured from the tip of the snout to the anterior edge of the vent.

[5] Reference to trade names in this publication does not imply endorsement of commercial products by the National Marine Fisheries Service.

TABLE 1.—Data to describe length-weight relationship (log weight = log a + b log length) for male and female ratfish collected off Oregon during 1965-67.

Location	Sex	Sample size	Constant log a	Constant b	r	Sign. Level of r (P = 0.01)*	r^{2}**
Newport	Male	128	—2.0168	2.0447	0.9352	0.234	0.8746
Newport	Female	56	—3.1384	2.5336	.9824	.361	.9651
Total†	Male	175	—4.3217	3.0546	.9917	.210	.9835
Total†	Female	112	—9.1692	2.9720	.9943	.257	.9886

* From Table X in Quenouille (1952).
** Coefficient of determination (Croxton, 1953).
† Composite of collections from Newport, Astoria, Cape Arago, and Cape Blanco.

weight relationship for male and female ratfish collected off Newport is defined and illustrated in Figure 1.

A taxonomic list of all food organisms identified from the alimentary canals of 283 ratfish is presented in Table 2. The table also contains lists of the relative importance of food items by the frequency of occurrence and numerical methods (Lagler, 1956) and gives the locations of the collections in which the food items were found.

Based on these data, ratfish appear to be opportunistic feeders. The most important food items (>10% occurrence) were shrimp (*Pandalus* and *Crago*), mollusks (*Musculus* and *Amphissa*), and echinoderms (*Brisaster*). In general, young and adult ratfish ate the same foods. Dean (1906) found seaweed in the alimentary canals of ratfish, but we did not find any plant materials in the specimens we examined.

In the Cape Arago collection, ratfish were eaten by ratfish. One egg capsule and a caudal fin were eaten by two large females (280 mm). We are not aware of any previous record of cannibalism in ratfish. Of the teleostomi, flatfish appeared to be taken most frequently by ratfish. The two flatfish found were *Hippoglossoides elassodon* and *Esopsetta jordani*.

In the food habits study, we did not use a volumetric method of examination because in many alimentary canals only shells and fragments remained. Also, materials such as carapaces of shrimp have a large surface to volume relationship which causes them to displace little water or to float. Ratfish often void ingested matter between capture and landing, making volumetric measurements inaccurate. Dean (1906) commented on this habit, and we noticed it in ratfish captured by hook and line. In addition, we found *Gyrocotyle* in the mouths of some trawl-caught ratfish, indicating that the contents of the alimentary canals recently had been voided. According to Lynch (1945), *Gyrocotyle* would normally be restricted to the anterior section of the intestine (spiral valve).

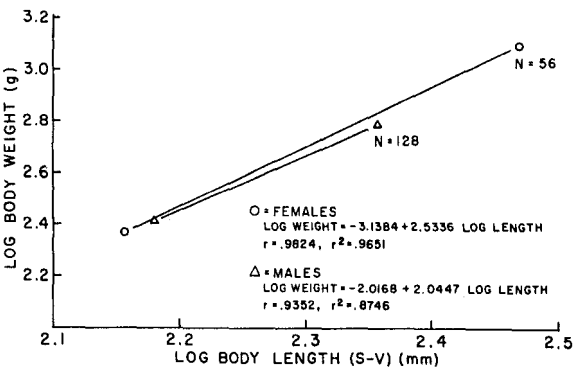

FIGURE 1.—Length-weight relationship of male and female ratfish collected off Newport, Oreg., 1965.

The parasites found on or in the ratfish were *Gyrocotyle urna*, *G. fimbriata*, and the copepod, *Acanthochondria* sp. Table 3 lists the frequency of *Gyrocotyle* occurring in the four collections of ratfish. Both *G. fimbriata* and *G. urna* appeared in about equal numbers in the Newport collection, but only *G. fimbriata* occurred in the Astoria and Cape Arago collections. The frequency of infestation by *Gyrocotyle* in young fish from the Cape Blanco collection was 30%. We did not find evidence of mass infestation by *Gyrocotyle*, as suggested by Wardle (1932). The young fish (<50 mm) contained from zero to two *Gyrocotyle* each. The voiding of canal contents by the ratfish interfered with obtaining an accurate estimation of the degree of infestation.

TABLE 2.—Taxonomic list[1] and relative importance of food organisms identified from the alimentary canals of 283 ratfish (*Hydrolagus colliei*)[2] collected off Oregon during 1965-1967.

Organisms	Frequency of occurrence (%)	Numerical method[3]		Location[4]			
		Organisms	%	A	N	CA	CB
Phylum Annelida							
Class Polychaeta							
Aphrodita	4.4	10	1.0	×	×		×
Unidentified	2.2	10	1.0		×		×
Phylum Mollusca							
Class Gastropoda							
Amphissa	33.4	1,016	74.5	×	×	×	×
Amygdalum	2.2	9	1.0				×
Yoldia	2.6	6	0.0+		×		
Musculus	24.6	66	4.9	×	×	×	×
Leptopecten	0.9	2	0.0+		×		
Pecten	1.8	7	0.0+			×	
Cardiomya	6.1	27	2.0				×
Calliostoma	0.4	1	0.0+				×
Searlesia	0.4	1	0.0+	×			
Class Scaphopoda							
Dentalium	3.1	7	0.0+		×		×
Phylum Arthropoda							
Class Crustacea							
Livoneca	4.8	26	2.0		×	×	×
Crago	12.3	32	2.3		×		
Pandalus	20.2	81	5.9	×		×	×
Cancer	0.9	2	0.0+	×	×		
Chionectes	0.4	1	0.0+				×
Unidentified	3.5	13	1.0		×		
Phylum Echinodermata							
Class Echinoidea							
Brisaster	11.0	25	1.8	×	×	×	
Strongylocentrotus	0.9	2	0.0+	×		×	
Phylum Chordata							
Class Chondrichthes							
Hydrolagus	0.9	2	0.0+			×	
Class Osteichthyes							
Pleuronectidae	0.7	2	0.0+		×	×	
Unidentified	5.5	13	1.0	×	×	×	
Unknown	0.4	1	0.0+		×		
Total		1,362	98.4+				

[1] After Smith et al. (1954), Barnes (1963), and Bailey (1970).
[2] Of the 283 ratfish, 224 contained food organisms.
[3] Fragments (less than one-half an animal) were recorded as one individual.
[4] Locations were: A = Astoria, N = Newport, CA = Cape Arago, and CB = Cape Blanco.

Gyrocotyle were found lodged in the folds of the spiral valve and were not embedded in the intestinal wall, thus making expulsion by violent intestinal movements possible.

In the Cape Arago collection, 7 of the 21 adult male ratfish had from two to eight *Acanthochondria* sp. attached to the free ends of their claspers. The immature males and the females did not carry this copepod. The species is similar to, but not the same as, *A. compacta*.[6]

An unidentified fungus, which occurred on the intestine of 29% of the Newport collection, was not necessarily a parasite as it may have developed in the interval between capture and preservation. No visible lesions or other damage were noticed on the body or alimentary canal surfaces of the ratfish in which the fungus occurred. The fungus appeared to be of nonseptate, white, filamentous type.

Sex and relative age of ratfish can be determined by examination of the secondary sex characteristics. Males possess a frontal tenaculum, prepelvic tenacula, and claspers, whereas fe-

[6] Personal communication, Dr. Satyu Yamaguti, Beltsville, Md., June 13, 1967.

TABLE 3.—*Gyrocotyle* found in 283 ratfish (*Hydrolagus colliei*) collected off the coast of Oregon, 1965-1967.

Location	Total number of *Gyrocotyle*[1]			Number of ratfish examined	Percent infested[2]
	G. fimbriata	*G. urna*	Unidentified		
Newport	50(34)	62(39)	38(25)	184	53.2(60.0)
Astoria	8(7)	-- --	-- --	24	29.2(31.8)
Cape Arago	40(23)	-- --	-- --	35	65.8(79.4)
Cape Blanco	18(11)	4(2)	-- --	40	30.0(35.4)

[1] Number in parenthesis is the number of ratfish infested.
[2] Number in parenthesis is the percent infestation when alimentary canals that contained neither food nor parasites were excluded.

males do not possess these structures but develop paired oviducal openings not possessed by males. Development of these structures can be used to separate ratfish into young, immature, and adult age groups. Young males have a frontal tenaculum streak and diminutive claspers (Figure 2); immature males have a small frontal tenaculum and claspers which are not perforated at their free ends (Figure 3); and mature males have a well-developed frontal tenaculum and well-developed claspers which are perforated at their free ends (Figure 4). Young females have no oviducal openings (Figure 2); the oviducts of immature females have small openings (Figure 3); and mature females have oviductal openings which are large, elongated, and swollen

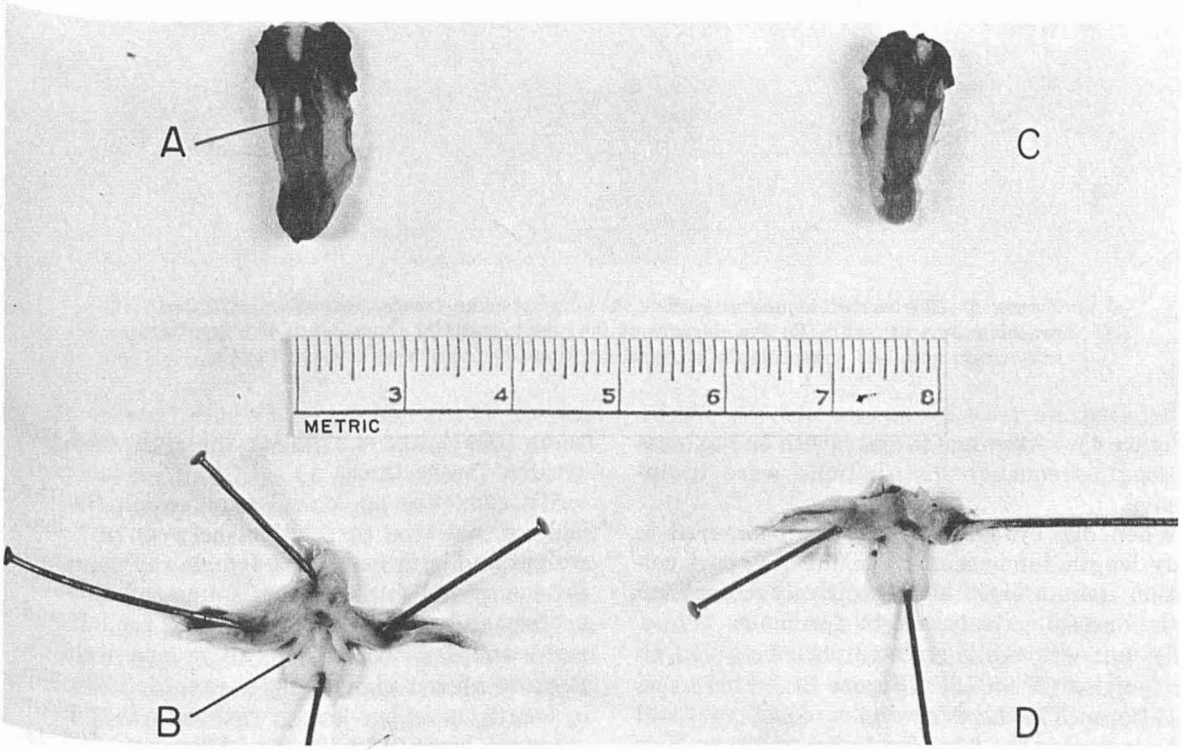

FIGURE 2.—Regions of young ratfish showing (A) the frontal tenaculum streak, and (B) the small claspers of the male; and (C) the absence of a frontal tenaculum streak, and (D) the absence of oviductal openings in the female.

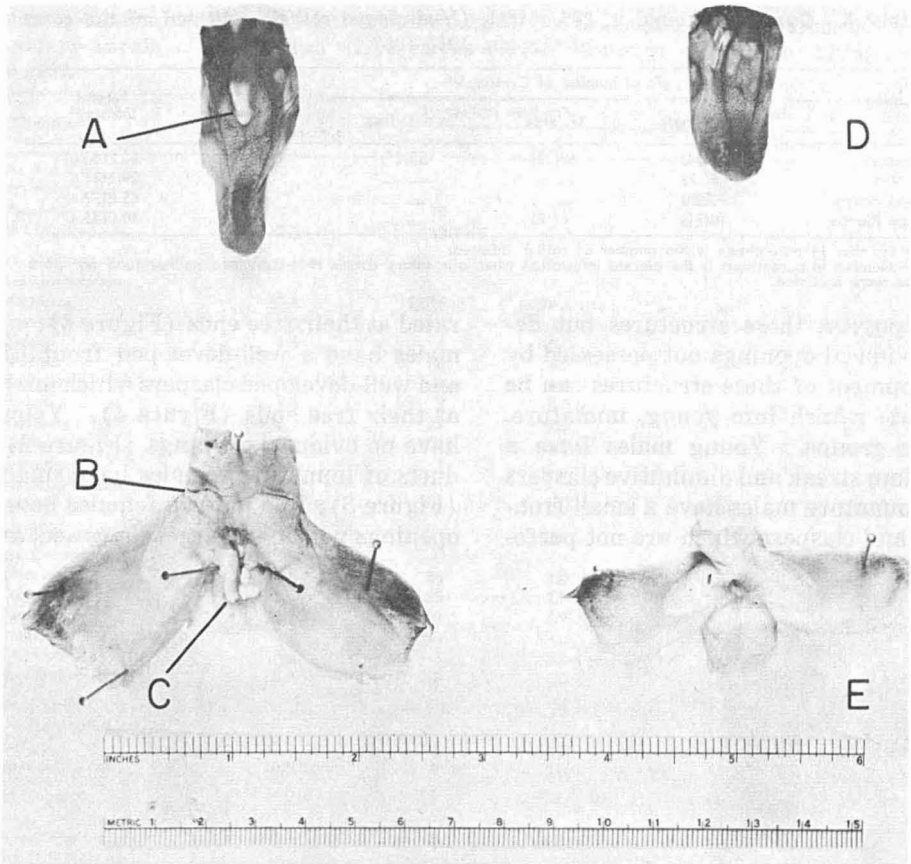

FIGURE 3.—Regions of immature ratfish showing (A) the frontal tenaculum, (B) the prepelvic tenacula, and (C) the claspers of the male; and (D) the absence of a frontal tenaculum, and (E) the presence of small openings to the oviducts of the female.

(Figure 4). Attempts to age ratfish on the basis of length-frequency distributions were inconclusive.

When dry eye-lens weight was compared to body length for specimens in the Newport collection, lens weight was positively correlated with increasing body length for males (N = 128), but was not correlated with body length for females (N = 56) (Figure 5). There was no difference in the dry weights of the right and left eye lens at the 95% level of confidence. Wet eye-lens weights were similarly related to body lengths with the coefficient of determination (r^2) for males being 0.8788 and 0.9292 for the right and left eye lens respectively, and for females being 0.0017 and 0.0133 for the right and left eye lens respectively.

We can offer no logical explanation for the lack of positive correlation between eye-lens weight and body length for female ratfish. Data for males and females were processed simultaneously and were consistent, by sex, for left and right and for wet and dry eye-lens weights. Because all but eight females exceeded 230 mm in length, most eye-lens growth may take place between birth (30-40 mm [Stanley, 1961]) and maturity (240-250 mm [Stanley, 1961]). The possibility of decreasing density of the lens with size (and maturity) should be investigated.

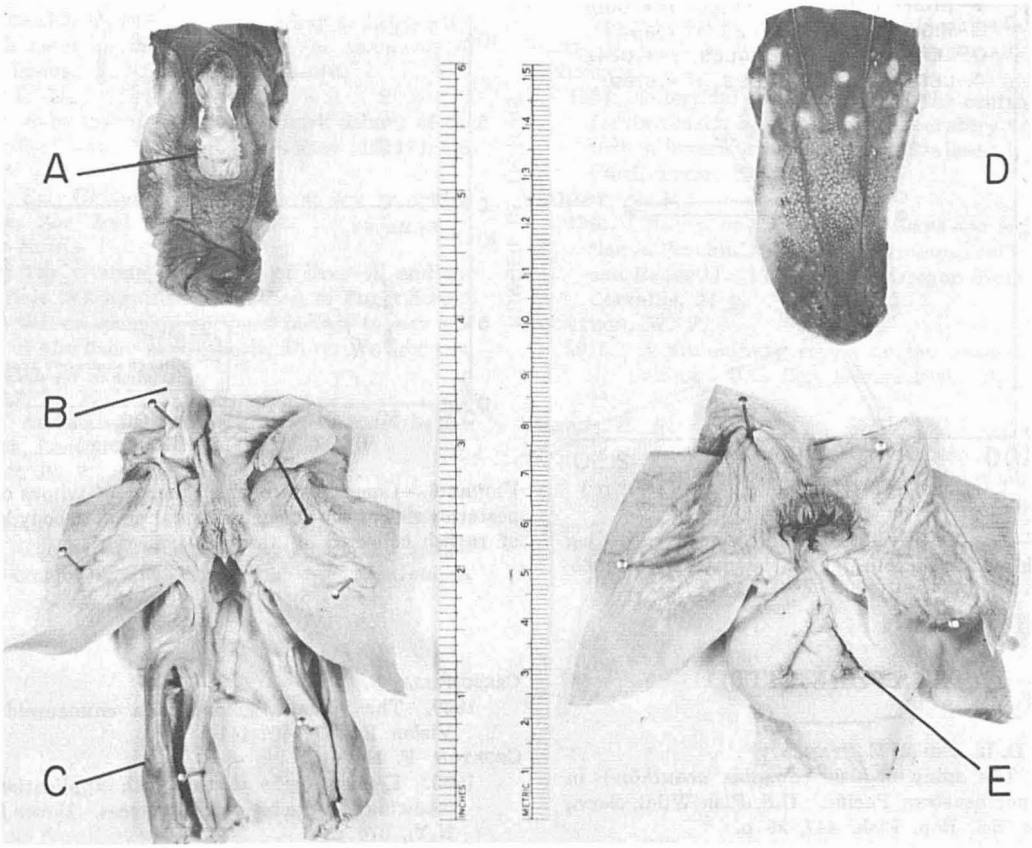

FIGURE 4.—Regions of mature ratfish showing (A) the frontal tenaculum, (B) the prepelvic tenacula, and (C) the claspers of the male; and (D) the absence of a frontal tenaculum, and (E) the presence of well-developed openings to the oviducts of the female.

In general, there was an increase in the size of other body parts (teeth, vertebrae, base of left pectoral fin, and base of dorsal spine) with increasing body length. We did not find any layering or structures in these body parts which were sufficiently correlated with body length to provide a possible means of age determination.

The number of tritors (horizontal ridges) on the posterior side of the left vomerine dental plate was compared to the respective body length of male and female ratfish in the Cape Blanco and Newport collections. In general, the number of tritors increased with increasing body length (Figure 6). Two problems arose in using this structure as a basis for age determination: (1) No comparison to known-aged fish was possible. (2) The amount of wear on these ridges per unit of time was not known.

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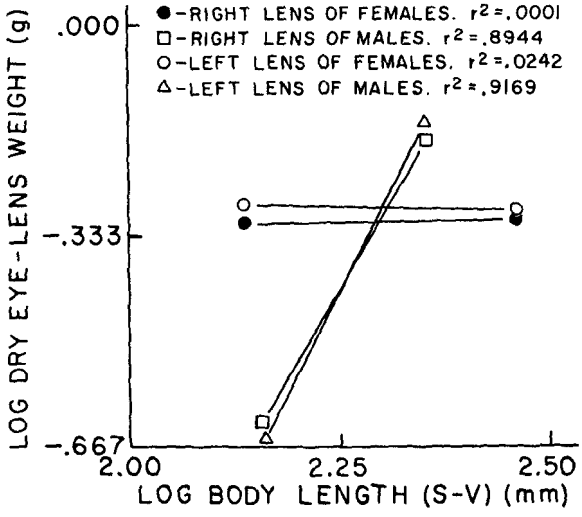

FIGURE 5.—Log dry eye-lens weight compared to log body length for ratfish collected off Newport, Oreg., 1965.

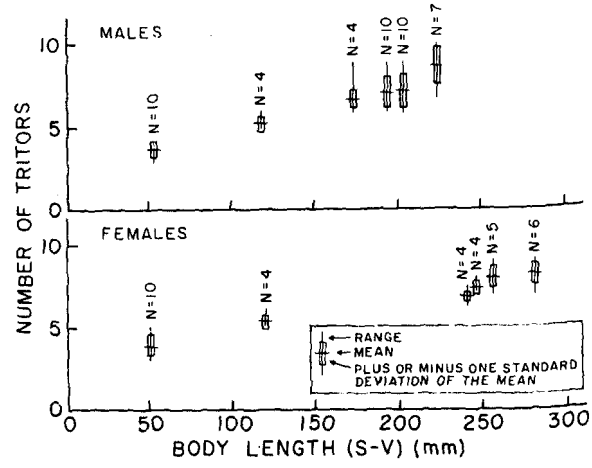

FIGURE 6.—Comparison of the number of tritors on the posterior side of the vomerine dental plate to body length of ratfish collected off Oregon, 1965-1967.

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