SOME METAZOAN PARASITES OF THE EASTERN PACIFIC SAURY, *COLOLABIS SAIRA*

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ABSTRACT

Parasite composition of the eastern Pacific saury, *Cololabis saira*, and severity of infections were investigated to determine their possible effects on potential food fish markets and to assist in determining population structure of the stock. Infection data from two copepods and one acanthocephalan are presented and examined for host dependent factors, temporal and spacial variation, and variation between saury with different scale features (hypothesized spring- and autumn-born fish). The acanthocephalan infecting saury was also identified in the steelhead trout, *Salmo gairdneri*, which is reported as a second definitive host. It is concluded that because of parasites, only 30 to 60% of marketable-sized saury occurring off the Washington-Oregon coast would be acceptable as fresh-food fish sold in the round although most would be acceptable as canned products. The parasite data do not indicate that fish with the two different patterns of growth on the scales are independent subpopulations.

The eastern Pacific saury, *Cololabis saira*, is a pelagic teleost occurring in offshore waters along the Pacific coast of North America. Although previously recognized mainly as a food source for albacore, *Thunnus alalunga*, the saury resource in the eastern Pacific attracted the interest of foreign and domestic fishermen during the late 1960's. Potential domestic markets included fresh, frozen, and canned products for human consumption. Studies to determine the parasite composition and severity of infections, believed an important consideration in assessing the potential value of saury as a food fish, were undertaken by the National Marine Fisheries Service at the Northwest Fisheries Center. Parasite data were also examined for their possible use in determining the population structure of saury in the sampled area. Preliminary growth and scale studies (Hughes, in press; Mosher[2]) suggested two spawning groups of saury, spring- and autumn-born.

Initial samples collected off California in 1969 and limited information from two previous reports (Eberhardt, 1954; Sokolovskii, 1969) indicated that the eastern Pacific saury were primarily parasitized by two species of copepods and one acanthocephalan. Results of a detailed study by Baeva (1970) indicated the eastern Pacific saury are infected by at least 10 species of parasites. Eberhardt reported the copepod *Pennella* sp. parasitized more than 20% of 250 saury captured off California in 1950-52. Although several *Pennella* species infecting marine fish have been described and partial life histories determined, detailed work on the saury parasite appears lacking. My preliminary studies and a recent Soviet study by Sokolovskii indicated that up to 90% of the eastern Pacific saury were infested by the copepod *Caligus macarovi* Gussev. This copepod also infects the western Pacific saury, but Sokolovskii and Baeva reported that *Pennella* sp. is peculiar to the eastern Pacific stock. The acanthocephalan detected in the preliminary studies was described by Laurs and McCauley (1964) as a new species, *Rhadinorhynchus cololabis*. Further reports on this species also appear lacking.

This report presents data on the numbers and incidence of infestation for *Pennella* sp., *Caligus*

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[2] Mosher, K. H. Age determination procedures for saury (*Cololabis saira*) from the northeastern Pacific Ocean, using scales. Manuscr. in preparation. Northwest Fish. Cent., Natl. Mar. Fish. Serv., NOAA, Seattle, Wash.

Manuscript accepted February 1973.
FISHERY BULLETIN: VOL. 71, NO. 4, 1973

macarovi, and *Rhadinorhynchus cololabis* infections found on and in Pacific saury captured off the Oregon, Washington, and British Columbia coasts during August-September 1970-71. Incidence of infestation and numbers of scars resulting from previous copepod infestations are presented by geographical areas and correlated to size, age, and possible racial composition of the host species. Sex ratio and length data are included for *R. cololabis* recovered from saury; a second definitive host infected by this acanthocephalan is reported.

MATERIALS AND METHODS

A total of 4,396 saury sampled from 13 individual fish schools captured in offshore waters along the Pacific coast of North America between lat. 44°01'N and lat. 49°16'N were involved in this study. Fish were captured with a modified purse seine-artificial light attraction system (Ellis and Hughes, 1971). Random samples were collected and frozen for processing at shoreside facilities. In the laboratory, fish samples were examined for copepod parasites and scars from previous copepod infestations. Simultaneously, host length, weight, sex, maturity, and age indicators were collected. Digestive tracts from 20 saury randomly subsampled from 12 of the 13 samples were placed in 10% Formalin[3] and later examined for metazoan parasites with the aid of a dissecting microscope (7× – 50×). Each *R. cololabis* was measured (trunk length) to the nearest 0.5 mm, and its sex determined by dissection and examination of the posterior portion. Females were generally swollen with bipolar eggs, and the uterus was easily distinguished from cement glands in the males. Host age was determined from scales. Patterns of growth displayed on the scales were used to identify the two hypothesized spawning groups, spring- and autumn-born fish.

Specimens were photographed in a circumilluminated lightbox, using standard techniques and materials.

[3] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

RESULTS

Two copepods, *Pennella* sp. and *Caligus macarovi*, and the acanthocephalan *Rhadinorhynchus cololabis* made up the major macroparasitic fauna of the eastern Pacific saury. Other than an occasional nematode located in the body cavity, additional metazoan parasites were not detected.

Incidence and intensity of infection of parasites recovered on and in saury throughout the study are presented by sample in Table 1.

Pennela sp.

An adult fish heavily parasitized by this large copepod is shown in Figure 1. In addition to three mature females (one with broken egg strings), two juveniles are shown — one posterior to the pectoral fin and the other posterior to the pelvic fin and above the anal finlets. Figure 2 shows an entire mature female (A), with a juvenile (B), after removal from the host. The external portion of this parasite usually protruded from the host at some point below the darkly colored dorsal surface but above the lateral line; and the head was usually lodged in or adjacent to the host's heart or major blood vessels. The tissue invading portion ends where the trunk diameter increases notably. Infected hosts weighed as much as 17% less than uninfected hosts of equal length, and extensive destruction of host tissue occurred during degeneration of the parasite.

Pennella sp. was frequently encountered in each of the six samples collected in 1970 but was detected in only one of seven samples collected in 1971. Incidence of infection for schools sampled in 1970 ranged from 17.0 to 21.6% (mean 18.4%) off Oregon and 11.5 to 18.4% (mean 14.5%) off Washington. Multiple infections were common. Only 2.1% of one school was infected in 1971 and no multiple infections were detected.

The 1970 data showed a trend toward increasing incidence of infection with increasing host size. To determine whether this noted increase was a function of increasing host age, length, or both, Washington and Oregon *Pennella* sp. data were analyzed by host age groups, length

TABLE 1.—Parasites recovered from Pacific saury, *Cololabis saira*, captured off the Oregon and Washington coasts in 1970 and the Oregon and Washington-southern British Columbia coasts in 1971.

Year and coastal area	Location		No. of fish examined	*Pennella* sp.				*Caligus macarovi*				*Rhadinorhynchus cololabis*			
				Total no.	No. per infected fish		Incidence of infection (%)	Total no.	No. per infected fish		Incidence of infection (%)	Total no.	No. per infected fish		Incidence of infection (%)
	Lat. N.	Long. W			Range	Mean			Range	Mean			Range	Mean	
1970:															
Oregon	45°03′	125°50′	300	93	1-6	1.82	17.0	21	1-2	1.10	6.3	—	—	—	—
			20	—	—	—	—	—	—	—	—	98	1-14	7.0	70.0
	44°33′	125°11′	300	96	1-5	1.48	21.6	57	1-2	1.19	16.0	—	—	—	—
			20	—	—	—	—	—	—	—	—	74	1-20	4.1	90.0
	44°30′	125°08′	300	94	1-4	1.74	18.0	61	1-4	1.15	17.7	—	—	—	—
			19	—	—	—	—	—	—	—	—	47	1-13	3.4	73.9
Washington	47°43′	126°02′	284	47	1-5	1.20	13.7	158	1-5	1.44	38.7	—	—	—	—
			20	—	—	—	—	—	—	—	—	16	1-4	2.0	40.0
	47°41′	125°58′	191	25	1-4	1.14	11.5	81	1-4	1.36	42.4	—	—	—	—
			20	—	—	—	—	—	—	—	—	20	1-4	1.8	55.0
	47°39′	126°00′	192	44	1-3	1.26	18.4	62	1-5	1.35	24.0	—	—	—	—
			20	—	—	—	—	—	—	—	—	27	1-9	2.7	50.0
1971:															
Oregon	44°01′	125°01′	419	0	—	0	0	20	1-2	1.11	4.3	—	—	—	—
			20	—	—	—	—	—	—	—	—	1	1	1.0	5.0
	43°55′	124°59′	508	0	—	0	0	34	1	1.00	6.7	—	—	—	—
			20	—	—	—	—	—	—	—	—	0	—	0	0
	43°54′	125°00′	508	0	—	0	0	37	1	1.00	7.3	—	—	—	—
			20	—	—	—	—	—	—	—	—	2	1	1.0	10.0
	44°02′	125°02′	268	0	—	0	0	18	1-2	1.06	6.3	—	—	—	—
			20	—	—	—	—	—	—	—	—	4	1-2	1.3	15.0
	43°58′	125°04′	507	0	—	0	0	14	1	1.00	2.8	—	—	—	—
Washington-British Columbia	48°21′	126°04′	513	11	1	1.00	2.1	41	1-2	1.03	7.8	—	—	—	—
			19	—	—	—	—	—	—	—	—	109	1-13	6.4	89.5
	49°16′	127°06′	106	0	—	0	0	24	1-3	1.26	17.9	—	—	—	—
			20	—	—	—	—	—	—	—	—	21	1-5	2.3	45.0
Total			4,396	410				628				419			

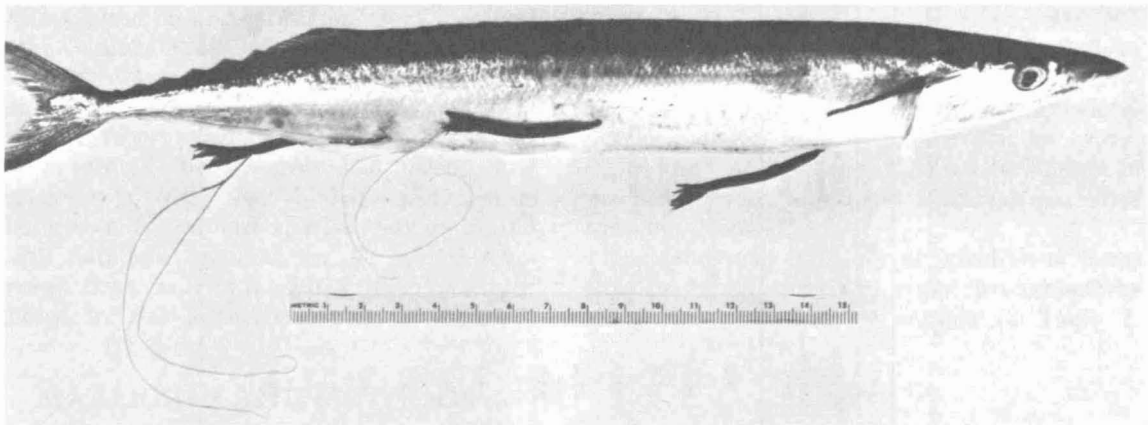

FIGURE 1.—Pacific saury with three adult female and two juvenile copepods, *Pennella* sp. Oken.

groups, and length groups within age. The increasing incidence of infection was found to be a function of age (Table 2) but not length. A chi-square test was employed to test the null hypothesis that the occurrence of infected II-, III-, and IV-year-old-fish was the same in potential harvest areas off Washington and Oregon (0.05 level). This hypothesis was rejected (0.025 level) for II-year-olds and accepted for III- and IV-year-olds.

Caligus macarovi

Incidence of infection by *C. macarovi* (Figure 3) showed both annual and geographic variability (Table 1). The proportion of infected saury in 1970 samples ranged between 6.3 and 17.7% (mean 12.8%) off Oregon and between 24.0 and 42.4% (mean 35.0%) off Washington. Infections were less common in 1971 samples, 2.8 to 7.3% (mean 5.5%) off Oregon and 7.8 to 17.9% (mean 12.9%) off Washington. These percentages, however, are certainly minimum estimates of the rate of infection of the sampled population because some *C. macarovi* dropped off captured fish.

Both 1970 and 1971 Washington and Oregon data were separately examined for changes in infection rate with increasing host size and age. No trends of change related to those factors

TABLE 2.—Numbers and percent incidence of *Pennella*-infected saury in different host age groups in samples taken in September 1970 from off the Washington and Oregon coasts.

Fishing area and type of data	Host age (years)					
	I	II	III	IV	V	VI
Washington coast:						
No. fish examined	9	326	244	22	4	1
No. fish infected by *Pennella* sp.	0	55	98	7	2	1
Incidence of infection (%)	0	16.87	40.16	31.81	50.00	100
Oregon coast:						
No. fish examined	314	322	70	10	—	—
No. fish infected by *Pennella* sp.	26	80	32	5	—	—
Incidence of infection (%)	8.26	24.84	45.71	50.00	—	—

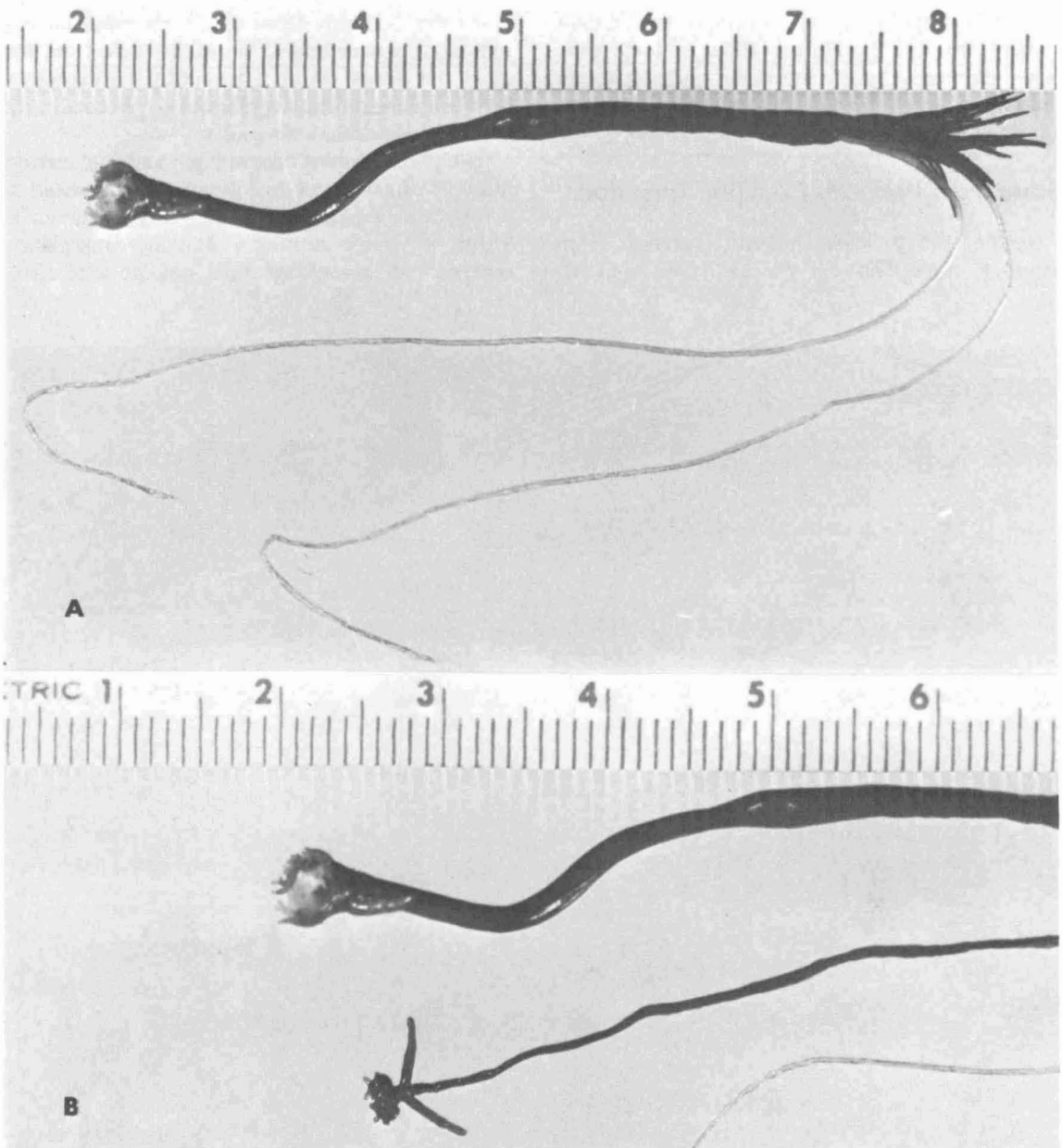

FIGURE 2.—Mature female *Pennella* sp. (A), with a juvenile (B), after removal from the host.

were detected. Accordingly, fish from individual schools captured in each area and year were combined and tested by chi-square analysis between areas. In both 1970 and 1971, numbers of fish infected with *C. macarovi* were significantly higher (0.05 level) off Washington than off Oregon.

This ectoparasitic copepod usually occurred more frequently than *Pennella* sp., but was considered less burdensome due to small size,

method of infection, and minimal host-tissue damage (Figure 3). Hotta (1962) reports that tissue damaged by *C. macarovi* infestation is limited to the epidermis and mucosa while the muscle is not penetrated.

Scars from Previous Copepod Infections

Pacific saury were heavily scarred from previous infections by *Pennella* sp. and *C. macarovi*. In many cases the scar's shape clearly indicated a previous *C. macarovi* infection, but most old scars could not readily be discerned between specific causes (Figure 4). Accordingly, all scars were treated equally.

The percentage of scarred fish and the average number of scars per fish generally increased as a function of increasing age. This is shown in Table 3 where numbers and percentages of scarred fish are categorized by age into three

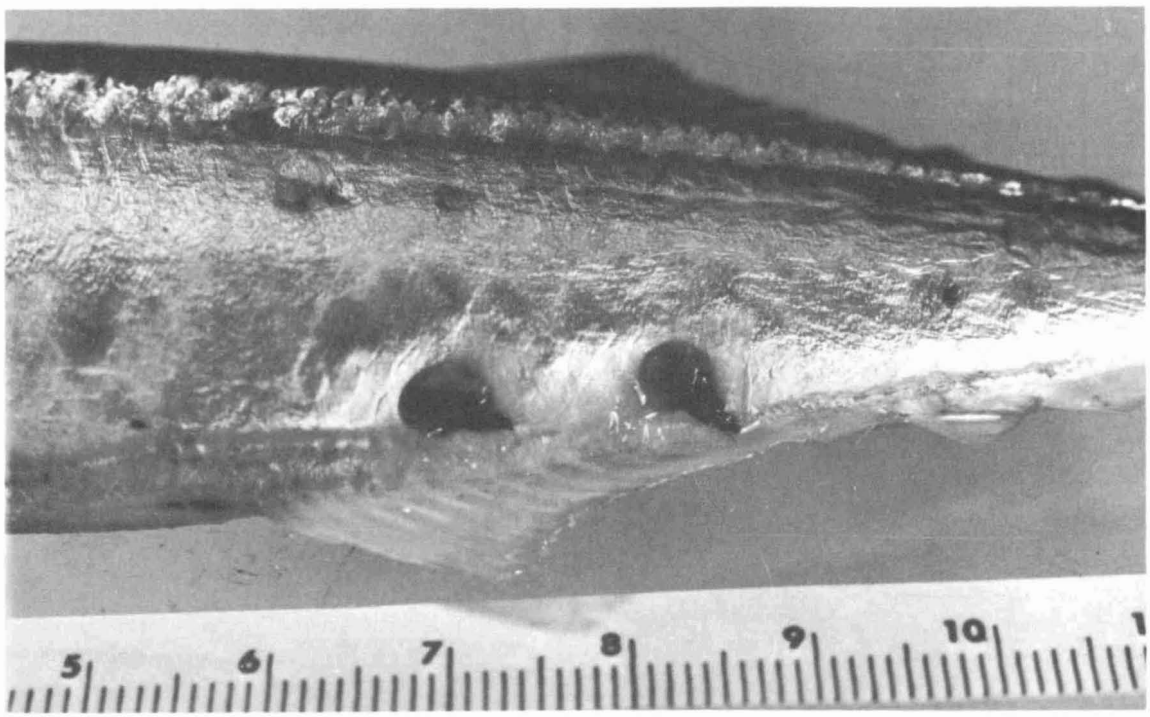

FIGURE 3.—Pacific saury infected by the copepod, *Caligus macarovi* Gussev.

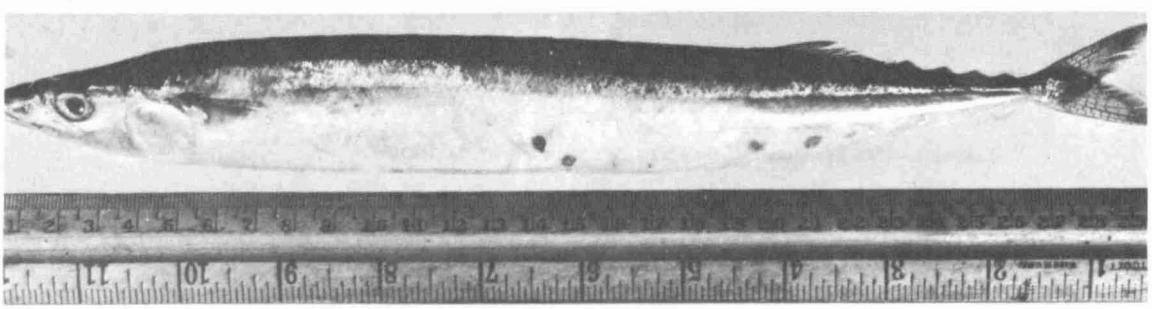

FIGURE 4.—Examples of scars resulting from previous infections by copepods on Pacific saury.

TABLE 3.—Pacific saury scarred from infections with the copepods *Pennella* sp. and *Caligus macarovi* as sampled off the Pacific coast of North America during August-September 1970-71.

Year and coastal area	Fish age (years)	No. fish examined	Fish with 1-3 scars		Fish with >3 scars		Total scarred fish	
			No.	%	No.	%	No.	%
1970:								
Oregon	I	314	224	71.3	20	6.4	244	77.7
	II	320	232	72.5	40	12.5	272	85.0
	III	70	47	67.1	15	21.4	62	88.5
	IV	10	5	50.0	5	50.0	10	100
Washington	I	9	5	55.6	4	44.4	9	100
	II	326	150	46.0	163	50.0	313	96.0
	III	244	68	27.9	196	80.3	237	97.2
	IV	22	5	22.7	17	77.2	22	100
1971:								
Oregon	I	576	172	29.9	1	0.2	173	30.1
	II	729	356	48.8	7	1.0	363	49.8
	III	137	79	57.7	3	2.2	82	59.9
Washington-southern British Columbia	II	26	13	50.0	2	7.7	15	57.7
	III	104	62	59.6	8	7.7	70	67.3
	IV	277	157	56.7	26	9.4	183	66.1
	V	97	54	55.7	7	7.2	61	62.9

groups—those fish with one to three scars, those with more than three scars, and total number of scarred fish. In 1970 when scarred fish were more prevalent (77.7-100%), the percentage of fish with one to three scars decreased with increasing age whereas those with more than three scars increased. The fact that 1971 fish were less severely scarred than 1970 fish is puzzling.

Rhadinorhynchus cololabis

This acanthocephalan was associated primarily with the lower digestive tract although worms were also found attached in the mid-stomach area (Figure 5). Tissue damage around the point of attachment appeared minimal, and the worm's proboscis rarely protruded through the wall of the digestive tract. Female *R. colo-*

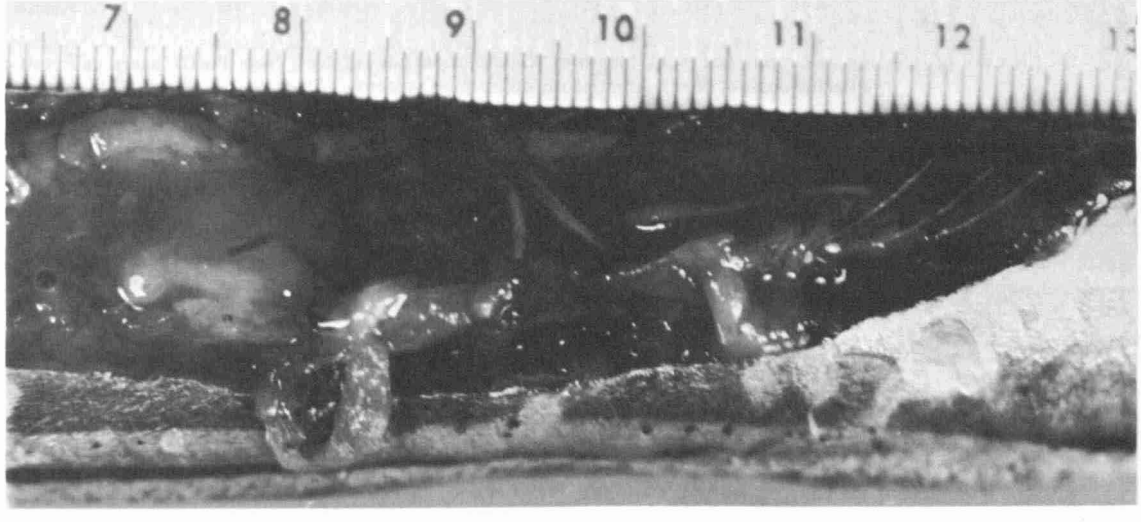

FIGURE 5.—Lower digestive tract of a Pacific saury typically infected by the acanthocephalan, *Rhadinorhynchus cololabis* Laurs and McCauley.

labis were much larger than males and occurred less frequently (Table 4). The range of trunk lengths for both males and females is increased from the original reporting—females 18.0 to 26.7 mm, now 13.5 to 35.0 mm, and males 9.20 to 12.16 mm, now 7.5 to 14.0 mm. All females with trunk lengths exceeding 15.0 mm were swollen with bipolar eggs.

Occurrence of this parasite as presented in Tables 1 and 4 was minimal since worms were often squeezed from the host's anus as fish were brailed aboard the ship. Occurrence of *R. cololabis* showed inconsistent geographic and annual variability precluding further meaningful analysis. Proportions of infected saury in 1970 samples ranged between 70.0 and 90.0% (mean 78.0%) off Oregon and between 40.0 and 55.0% (mean 48.3%) off Washington. Like the parasitic copepods, incidence of infection was generally lower in 1971, ranging between 0 and 15.0% (mean 7.5%) off Oregon and between 45.0 and 89.5% (mean 67.2%) off Washington. Rates of infection were found to be independent of host size and age.

R. cololabis in Steelhead Trout

The steelhead trout was found bearing the adult form of the same acanthocephalan identified in Pacific saury. Steelhead trout had previously been reported with an acanthocephalan identified as *Rhadinorhynchus* sp., Shaw (1947); however, more recent or specific reports have not been located.

C. M. Senger, Professor of Biology, Western Washington State College, Bellingham, Wash., recovered two Acanthocephala from steelhead trout captured in Skagit County, Wash., in 1967-68. He later compared these with specimens I supplied from Pacific saury and concluded both hosts carried *R. cololabis*. Additional steelhead trout from Skagit County (1969-72) and from high-seas areas of the northwestern Gulf of Alaska (August 1970) were subsequently examined. Nine of 28 steelhead trout from Skagit County and 4 of 22 steelhead trout from the northwestern Gulf of Alaska were infected with *R. cololabis*. Multiple but not severe infections were noted from hosts collected in both areas. The heavy egg load carried by female *R. cololabis* indicated the steelhead trout to be a second definitive host.

Copepod Infections in Two Possible Subpopulations of Saury

Chi-square analysis was applied to test the null hypothesis that no significant differences (0.05 level) in numbers of infected fish existed between the two possible subpopulations (spring- and autumn-born saury) that were classified by means of scale features. The two indicators

TABLE 4.—Intensity of infection, sex ratio, and trunk length of *Rhadinorhynchus cololabis* from Pacific saury captured off the Pacific coast of North America during August-September 1970-71.

Year and coastal area	Location		No. fish examined	Incidence of infection (%)	Sex ratio (%)		Trunk length (mm)			
							Males		Females	
	Lat. N	Long. W			M	F	Range	Mean	Range	Mean
1970:										
Oregon:	45°03′	125°50′	20	70.0	64.3	35.7	8.0-13.0	10.1	16.0-27.0	21.0
	44°33′	125°11′	20	90.0	77.0	23.0	7.5-12.0	9.4	16.0-32.0	23.0
	44°30′	125°08′	19	73.9	66.0	34.0	8.5-13.0	10.4	17.5-28.0	21.5
Washington	47°43′	126°02′	20	40.0	81.2	18.8	8.5-12.0	10.1	22.0-23.0	22.5
	47°41′	125°58′	20	55.0	55.0	45.0	9.5-12.0	10.6	13.5-27.5	22.8
	47°39′	126°00′	20	50.0	63.3	36.7	8.5-12.5	10.5	15.0-33.0	22.8
1971:										
Oregon	44°01′	125°01′	20	5.0	100.0	—	12.0-	12.0	—	—
	43°55′	124°59′	20	0	—	—	—	—	—	—
	43°54′	125°00′	20	10.0	50.0	50.0	10.0-	10.0	17.0-	17.0
	44°02′	125°02′	20	15.0	75.0	25.0	10.0-14.0	12.0	21.0-	21.0
Washington-southern British Columbia	48°21′	126°04′	19	89.5	69.3	29.7	10.0-13.0	11.0	15.0-35.0	23.8
	49°16′	127°06′	20	45.0	81.0	19.0	10.0-14.0	11.5	16.0-26.0	20.3

were *Pennella* sp. and *C. macarovi* since insufficient data excluded use of the acanthocephalan.

As previously shown, infections by *Pennella* sp. increased with increasing host age, and *C. macarovi* infections were found to be independent of host age or length. Accordingly, chi-square tests of *Pennella* sp. infections were conducted for spring-born versus autumn-born fish by individual age groups for each area during 1970. *C. macarovi* infections were compared after combining all host age groups within each area for 1970 and 1971.

Results of chi-square tests are summarized in Table 5. The only significant difference in numbers of saury infected by *Pennella* sp. occurred between spring- and autumn-born II-year-olds captured off Oregon in 1970. No significant differences between numbers of spring- and autumn-born saury infected by *C. macarovi* existed in either area during 1970 and 1971.

CONCLUSIONS AND SUMMARY

The eastern Pacific saury was found to be infected with two species of copepods and one acanthocephalan, in addition to being scarred from previous copepod infections. Mean incidence of *Pennella* sp. infections was 18.4% off the Oregon coast and 14.5% off the Washington coast in 1970, but this parasite was rarely found

TABLE 5.—Numbers and percentage incidence of copepods (*Pennella* sp. and *Caligus macarovi*) in two possible subpopulations of eastern Pacific saury. Chi-square values are presented testing the null hypothesis that no significant difference in numbers of infections exists (0.05 level) between the hypothesized spring- and autumn-born fish. Fish ages are in parentheses.

Year and area	Pacific saury examined for *Pennella* sp.	Number of saury			Incidence of infection (%)	χ^2	Null hypothesis	
		Noninfected	Infected	Total			Accept	Reject
1970:								
Washington	Spring born (II)	221	47	268	17.5	1.03	X	—
	Autumn born (II)	51	7	58	12.7			
	Spring born (III)	103	45	148	30.4	0.42	X	—
	Autumn born (III)	63	33	96	34.4			
Oregon	Spring born (II)	154	64	218	29.4	6.93	—	0.01
	Autumn born (II)	86	16	102	15.7			
	Spring born (III)	23	13	36	36.1	2.70	X	—
	Autumn born (III)	15	19	34	55.8			

Year and area	Pacific saury examined for *Caligus macarovi*	Number of saury			Incidence of infection (%)	χ^2	Null hypothesis	
		Noninfected	Infected	Total			Accept	Reject
1970:								
Washington	Spring born	329	114	443	25.7	0.58	X	—
	Autumn born	126	37	163	22.7			
Oregon	Spring born	503	71	574	12.4	1.11	X	—
	Autumn born	118	22	140	15.7			
1971:								
Washington	Spring born	368	32	400	8.0	3.16	X	—
	Autumn born	96	15	111	13.5			
Oregon	Spring born	1,211	83	1,294	6.4	2.42	X	—
	Autumn born	150	16	166	9.6			

in 1971. Incidence of infection increased with host age. Mean incidence of *C. macarovi* infections was 12.8% off Oregon and 35.0% off Washington in 1970 and also decreased in 1971 to 5.5% off Oregon and 12.9% off Washington. Infection rates were independent of host size and age. The incidence of scars resulting from previous copepod infections was very high. Mean incidence of *R. cololabis* in 1970 was 78.0% off Oregon and 48.3% off Washington and decreased substantially during 1971. Infection rates were independent of host size and age. Trunk length measurements increased the known length range for both male and female worms.

R. cololabis was also identified in steelhead trout, which is reported as a second definitive host. It seems most likely that both hosts are infected through a common food organism carrying the acanthor stage although steelhead trout are known to feed on saury in ocean waters.

For aesthetic reasons, presence of copepod parasites or scars, and to a lesser extent the acanthocephalan, would undoubtedly limit usage of saury in the round as a fresh fish product for human consumption. Saury infected by the obnoxious appearing *Pennella* sp. and those with multiple infections of *C. macarovi* or numerous scars, would undoubtedly be rejected by consumers. Although western Pacific saury are not infested by *Pennella* sp., Nishimura (1964) reports that saury heavily blemished by *C. macarovi* have a lower commercial value than nonblemished fish. The acanthocephala are not as unsightly as either copepod, although the bright orange worms are often clearly visible protruding from the anus.

Considering apparent annual and age dependent changes in incidence of infection, only 30 to 60% of the market-sized saury occurring in Washington-Oregon coastal waters appear to be acceptable as a fresh-food fish sold in the round. Although some geographical variations of infection rates and occurrence of scars have been noted, the percentage of fish usable as a fresh product appears nearly equal off Washington and Oregon.

Test packs prepared by the Pacific Fishery Products Technology Center, National Marine Fisheries Service, Seattle, have indicated that these parasites have practically no effect on canned saury products. Acanthocephala are removed with the vicsera, and *C. macarovi* can be scraped free with resulting wounds and old scars presenting no qualitative or aesthetic problems. Uninfected portions of saury with pennellids can also be used.

Pennella sp. and *C. macarovi* were also employed as racial indicators by comparing their occurrence between fish displaying spring- and autumn-born growth patterns on their scales. Seven of eight chi-square tests showed no significant differences (0.05 level), between fish of the two scale features; thus, evidence from the parasite data does not indicate the existence of separate populations. Although use of parasites as biological indicators is not a strong test of population structure, particularly without knowledge of the parasites' life history, biochemical and growth studies likewise do not indicate existence of two genetically isolated populations (Hughes, see footnote 2).

ACKNOWLEDGMENTS

I thank Paul L. Illg, Professor of Zoology, University of Washington, for confirming identification of the copepods, and Clyde M. Senger, Professor of Biology, Western Washington State College, for his cooperative work on the acanthocephalan and review of this manuscript.

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