Taxonomy and Host Associations of Some Parasitic Copepods (Crustacea) from Pelagic Teleost Fishes[1]

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DURING THE SPRING OF 1963 the senior author was fortunate enough to participate in the second cruise of the United States Research Vessel "Anton Bruun" during the International Indian Ocean Expedition. This paper is an analysis made of the copepod parasites collected from pelagic teleost fishes, other than istiophorids, during this cruise. The copepods collected from both elasmobranch fishes and istiophorid teleosts were given to Dr. Roger Cressey of the Smithsonian Institution.

The taxonomy of copepod parasites of pelagic fishes of the Indian Ocean has been fairly well studied, as indicated by the titles in the publication "A Partial Bibliography of the Indian Ocean" (Ryther, 1962). Additional publications (e.g., Shiino, 1958; Kirtisinghe, 1964) have added to the taxonomic knowledge of these organisms. In almost all cases, however, the identifications have been dependent upon a few specimens from a limited geographic area. The collection made during cruise 2 of the R/V "Anton Bruun" contained enough specimens of several species to give an indication of size variation and host preference as well as, in one case, an indication of competition between two species of copepods.

The senior author is indebted to the officers and crew of the "Anton Bruun" for the assistance given to him during the cruise. The technical assistance given by Miss Margaret McKenzie in measuring the copepods and by Mrs. Margaret Jensen in the preparation of the text figures is deeply appreciated. The study was supported by a grant (GB-3932) from the National Science Foundation.

MATERIALS AND METHODS

Cruise 2 of the "Anton Bruun" extended along the 70° meridian from Bombay to a latitude of 37°12′S and then north, along the 80° meridian, to Colombo, Ceylon (see Table 1 for station list). Fishes examined for parasitic copepods were collected by Japanese longline, or by rod and reel or handline. The external surface, gill cavities, buccal cavity, and nasal cavities of the fishes were examined for copepods (see Table 2 for list of fishes examined). Collected copepods were killed and preserved in 95 percent ethyl alcohol.

TABLE 1
LOCATION OF R/V "ANTON BRUUN" CRUISE 2 STATIONS LISTED IN THIS REPORT

STATION NUMBER	LATITUDE	LONGITUDE
108	13°50′N	70°07′E
109	11°59′N	69°55′E
110	09°46′N	70°06′E
111	08°09′N	70°02′E
112	05°48′N	70°03′E
113	03°33′N	69°54′E
114	01°30′N	70°01′E
115	01°07′S	71°00′E
116	02°23′S	70°24′E
118A	06°37′S	70°09′E
118B	06°48′S	70°07′E
119	08°35′S	69°55′E
121	13°15′S	69°51′E
122	15°25′S	69°58′E
123	17°18′S	70°05′E
124	19°30′S	69°51′E
tr-1*	19°32′S	65°46′E
tr-2*	19°23′S	61°35′E
125	21°40′S	67°06′E
126	23°47′S	69°05′E
127	26°34′S	70°12′E
128	28°33′S	69°58′E
129	30°34′S	69°55′E
130	32°52′S	69°52′E
131	35°09′S	69°59′E
132	37°12′S	70°10′E
133	30°11′S	79°42′E
135	20°02′S	79°50′E
137	14°44′S	79°44′E
139	08°37′S	79°34′E
142	00°33′S	80°08′E
143	01°54′N	79°52′E
144	04°18′N	80°08′E

* Trolling station.

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TABLE 2

PELAGIC TELEOST FISHES, OTHER THAN ISTIOPHORIDS EXAMINED ON CRUISE 2 OF THE R/V "ANTON BRUUN"
(Fish names are those used either by Gosline and Brock, 1960, or by Shomura, 1967)

STATION NUMBER	FISH NAME	FORK LENGTH (cm)
108	*Coryphaena equisetis*	25.0*, 24.0*, 28.0*
109	*Alepisaurus* spp.	111.1, 110.3
110	*C. equisetis*	26.0*, 27.5*, 26.9*
	Parathunnus sibi	149.7, 143.0
111	*Katsuwonus pelamis*	57.9, 27.0*, 62.3*, 33.5*, 28.8*
	Alepisaurus sp.	146.2
	Neothunnus macropterus	34.3*, 31.7*
112	*N. macropterus*	82.6, 85.6
	K. pelamis	60.3
	P. sibi	123.8
	Alepisaurus sp.	86.0
	C. equisetis	31.9*, 31.3*, 28.8*, 26.7*
113	*Sphyraena* sp.	76.0, 88.1*
	Gempylus serpens	83.9
	N. macropterus	49.1*
114	*N. macropterus*	97.6, 114.4, 99.5, 124.0, 91.8, 102.1, 104.9
115	*N. macropterus*	103.8, 127.1, 122.9, 128.1
116	*N. macropterus*	109.7, 105.0, 132.3, 120.1, 136.8
	P. sibi	101.0
118A	*Elagatis bipinnulatus*	66.9*
118B	*N. macropterus*	140.1
	P. sibi	149.0
119	*Alepisaurus* spp.	138.6, 64.4, 148.7, 90.8
	P. sibi	not measured
121	*Alepisaurus* spp.	124.0, 58.0, 77.3, 63.2, 150.1, 54.7
	P. sibi	104.0
	N. macropterus	130.7
	K. pelamis	46.0*
	Sphyraena sp.	68.2
122	*Alepisaurus* spp.	85.0, 80.9, 148.0
	Thunnus alalunga	101.8
123	*T. alalunga*	106.5, 107.1, 102.9, 108.1
	Alepisaurus spp.	86.1, 90.6
	Acanthocybium solandri	127.1
	P. sibi	145.8, 149.0, 167.3
124	*T. alalunga*	112.0, 100.0, 105.4, 100.9, 106.2, 101.8
124 (*Cont.*)	*N. macropterus*	126.7
	P. sibi	143.0
tr-1	*Coryphaena hippurus*	not measured*
tr-2	*N. macropterus*	96.9*, 65.9*
125	*T. alalunga*	106.4, 107.1, 106.0, 103.7
	N. macropterus	133.4, 138.4
	Alepisaurus sp.	93.4
126	*T. alalunga*	100.2, 100.5, 105.5
127	*T. alalunga*	104.3, 104.7, 103.0, 105.2, 107.0, 103.2
	N. macropterus	147.8
	Alepisaurus sp.	104.5
128	*N. macropterus*	132.0, 105.0
	T. alalunga	96.1, 88.4
	K. pelamis	67.0
129	*Alepisaurus* spp.	104.6, 73.4, 91.4
	T. alalunga	104.8
130	*T. alalunga*	87.0, 88.0, 78.0
	P. sibi	118.1, 140.6, 129.9, 114.6
	Lampris regius	88.5
131	*T. alalunga*	111.5, 100.2, 79.5
	Alepisaurus spp.	120.4, 111.5
132	*T. alalunga*	87.7, 96.5
133	*N. macropterus*	130.0
	K. pelamis	61.6
	T. alalunga	91.9, 90.9
	Alepisaurus sp.	112.5
135	*A. solandri*	150.0
	N. macropterus	137.9
	K. pelamis	75.8, 79.2, 80.2
	T. alalunga	100.9, 98.3
137	*Alepisaurus* spp.	71.8, 96.8
	T. alalunga	107.1, 105.7
	N. macropterus	149.9, 134.9
139	*N. macropterus*	139.9, 134.2, 135.9, 145.3
	Alepisaurus sp.	63.7
	P. sibi	138.5
142	*N. macropterus*	129.8, 129.9, 135.9, 140.3, 132.7
	Alepisaurus spp.	68.5, 81.9
	C. hippurus	85.6*, 95.0*
143	*N. macropterus*	131.8, 130.1, 123.0, 129.1, 135.1, 129.3
144	*Alepisaurus* sp.	112.9
	K. pelamis	62.6

* Captured by rod and reel or hand line.

Only sexually mature copepods were measured, although the number of immature specimens was recorded and this information was used, in part, in the discussion of host-parasite associations. The determination of sexual maturity or immaturity was based on the state of development and condition of the genital segment, the development of eggs or spermatophores within the segment, the presence of recently placed spermatophores, or indication of previous placement, on the female genital segment, as well as the state of development of certain appendages (e.g., the antennae).

Specimens to be measured were placed in 85 percent lactic acid containing chlorazol black E until they were sufficiently stained to allow visual distinction of the various body parts. They were then placed in clear 85 percent lactic acid in a depression slide and covered with a cover slip supported so that the shape of the organism was not distorted. Measurements were made by using a Bausch and Lomb Tri-Simplex Micro-Projector and projecting the image of the specimen vertically onto a piece of white matteboard where it was measured with a millimeter rule. The magnification of the specimens was determined by projecting the image of a stage micrometer in the same manner. Periodic checks were made of the measurements by remeasuring a series of specimens with an ocular micrometer in a Wild M-5 dissecting microscope. To reduce the possibility of an error due to individual interpretation of the limits of the body parts measured, several series of specimens were rechecked by another individual.

The measurements of each copepod were converted into millimeters and the data recorded for analysis. The analysis was carried out on an IBM 7044 to determine the following values for each measurement for each sex of each species: (1) mean of all specimens, (2) mean of all specimens from each station, (3) mean of all specimens from each host type, (4) mean of all specimens from each host type from each station, and (5) confidence limits (.01) for all means (individual measurements are given instead of confidence limits if the number of specimens was small).

The measurements used include: (1) overall length, excluding terminal setae and processes, (2) length and width of the cephalothorax (or prosome), (3) length and width of the genital segment (or trunk, or urosome), (4) length of the abdomen if present, and (5) length of the egg strings on ovigerous females (strings were measured only if they were complete).

TERMINOLOGY

The term cephalothorax is used to indicate the part of the body consisting of the cephalon fused with one or more thoracic segments. The maxilliped-bearing segment is considered as the first thoracic segment. The term pedigerous segment is used to indicate a leg-bearing thoracic segment, while the terms free thoracic segments and free pedigerous segments are used to designate those thoracic segments not fused with the cephalon. The term genital segment is used, with some reservation, to designate the fused sixth and seventh thoracic segments (= fifth and sixth pedigerous segments) in the Caligidea (= Caligoidea of Yamaguti, 1963). The term ovigerous is used to indicate a female with egg strings, the term nonovigerous to indicate a female without egg strings even though the genital segment may contain eggs.

The terminology applied to the appendages and processes, with the exception of the maxillae and the postoral process, is the same as that used in Lewis, 1968. The pair of appendages immediately adjacent to the mouth cone and posterior to the mandibles in caligids are the maxillules (postoral processes or "POP" in Lewis, 1968), while the pair immediately adjacent to the maxillary glands are the maxillae (Lewis, 1969).

The term length, as used in Figures 1–9, is meant to imply total length. These figures are the length-frequency distributions of the various species for which the collection included sufficient specimens.

SPECIES IDENTIFICATION AND MEASUREMENTS

Family EURYPHORIDAE

Euryphorus nordmanni Milne-Edwards
Fig. 1

Euryphorus nordmanni Milne-Edwards, 1840, p. 462, pl. 39, fig. 1. Lewis, 1967, p. 32, figs. 12–15.

DISTRIBUTION AND HOSTS: See Lewis (1967).

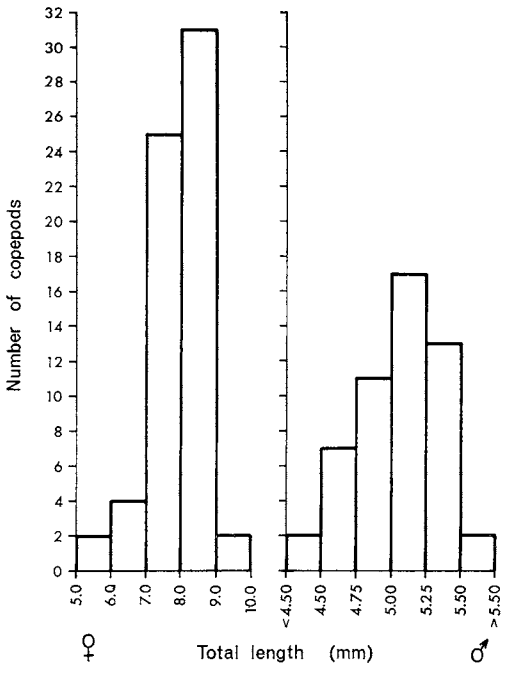


FIG. 1. Length frequency distribution of *Euryphorus nordmanni*. *Left graph,* female; *right graph,* male.

MATERIAL: 63 female and 52 male specimens from the gill cavities of *Coryphaena hippurus* and *C. equisetis*. Distribution of specimens is given in Table 3.

MEASUREMENTS: See Table 4.

REMARKS: The small number of specimens and the small number of parasitized hosts that were examined (4 specimens of *C. hippurus*, 6 of *C. equisetis*) make most generalizations questionable. One suggested tendency, however, is for a heavier infestation on the larger of the two hosts (21.5 copepods per specimen of *C. hippurus*, 4.8 per specimen of *C. equisetis*). A second tendency is for the copepods on the larger of the two hosts to be themselves generally larger. Whether or not these two tendencies are a direct, or an indirect, result of host size (presumably surface area) or some other factor cannot be determined from the existing data. See Table 19 for a comparison of the total lengths with those of specimens from other geographic areas.

TABLE 3
DISTRIBUTION OF SPECIMENS OF *Euryphorus nordmanni*
(F = female, M = male)

STATION	*C. hippurus* F/M	*C. equisetis* F/M
108		0/6
110		5/2
112		8/8
141	18/12	
142	32/24	
Sum	50/36	13/16

Elytrophora brachyptera Gerstaecker
Figs. 2, 3*a–c*

Elytrophora brachyptera Gerstaecker, 1853, p. 60, pl.3, fig. 12. Lewis, 1967, p. 42, figs. 16–21.

DISTRIBUTION AND HOSTS: See Lewis (1967).

MATERIAL: 979 female and 762 male specimens from *Neothunnus macropterus, Parathun-*

TABLE 4
MEANS (C.L.$_{.01}$) OF MEASUREMENTS (IN MILLIMETERS) OF *Euryphorus nordmanni*

ITEM MEASURED	FEMALES (63 SPECIMENS) ALL SPECIMENS	*C. hippurus*	*C. equisetis*	MALES (52 SPECIMENS) ALL SPECIMENS	*C. hippurus*	*C. equisetis*
Total length	7.93(.11)	8.10(.12)	7.26(.13)	5.08(.04)	5.22(.03)	4.76(.05)
Cephalothorax length	2.20(.02)	2.26(.01)	1.96(.02)	2.05(.02)	2.12(.01)	1.89(.01)
Genital segment length	1.67(.03)	1.68(.03)	1.65(.04)	1.12(.01)	1.15(.01)	1.07(.01)
Abdomen length	3.31(.07)	3.38(.09)	3.04(.09)	1.27(.02)	1.31(.02)	1.17(.03)
Cephalothorax width	2.19(.02)	2.26(.01)	1.93(.02)	1.94(.02)	2.01(.02)	1.80(.02)
Genital segment width	1.90(.03)	1.90(.04)	1.94(.08)	0.90(.01)	0.94(.01)	0.80(.01)
Egg string length	7.48(.20)	7.48(.24)	7.45(.24)			
(No. of strings)	(77)	(64)	(13)			

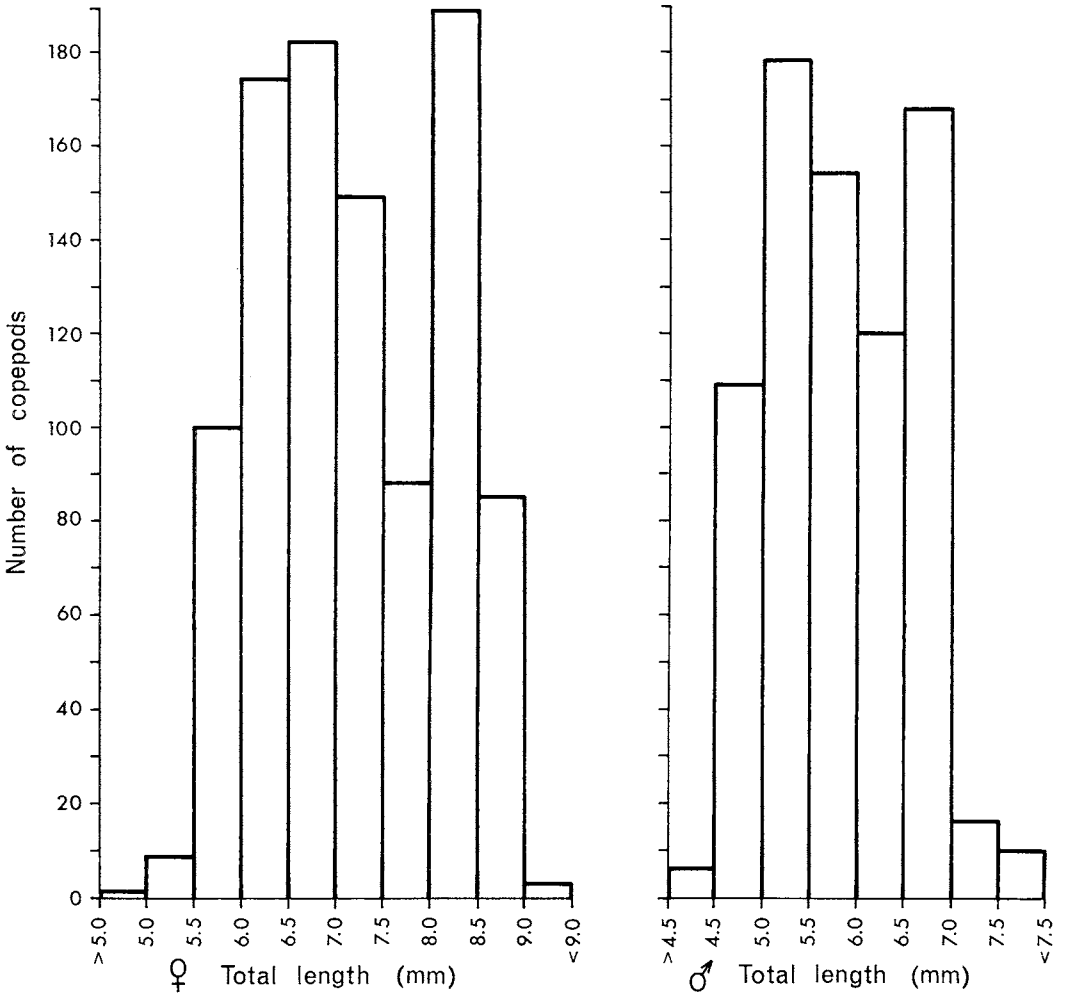


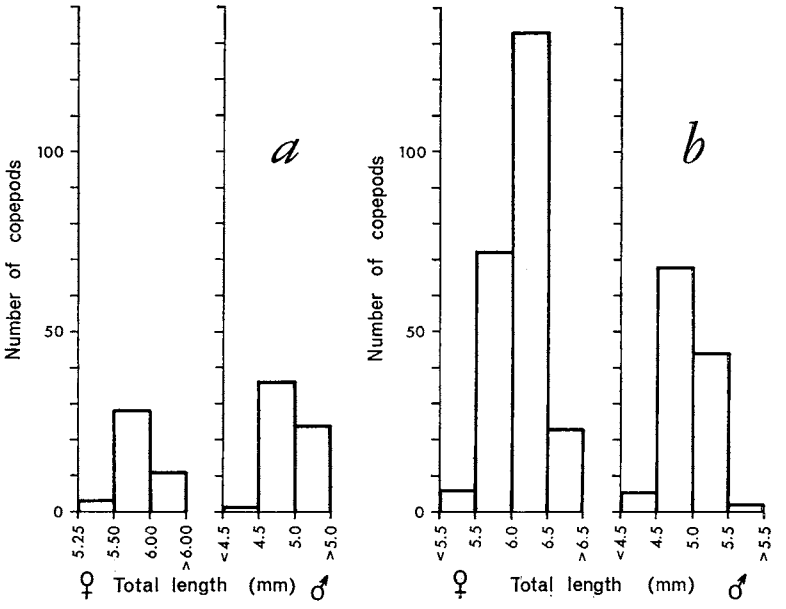
FIG. 2. Length frequency distribution of all specimens of *Elytrophora brachyptera*. *Left graph*, female; *right graph*, male.

nus sibi, and *Thunnus alalunga*. Distribution of specimens is given in Table 5.

MEASUREMENTS: See Table 6.

REMARKS: *Elytrophora brachyptera* exhibits some characteristics that can be directly or indirectly attributed to the effect of the host. Most of the host-associated characteristics are given in the discussion, but one characteristic that is also associated with the state of sexual maturity bears mentioning here. Most of the immature specimens live on the external surface of the host while sexually mature specimens live primarily in the gill cavity. One aspect of this that may indicate some response to the host type is the location of the immature specimens on *Thunnus alalunga*. The immature specimens on this host are most frequently found either in

FIG. 3. Length frequency distribution of *Elytrophora brachyptera* on each of the three host species. *Left graph*, female; *right graph*, male. *a*, Distribution on *Neothunnus macropterus*; *b*, distribution on *Thunnus alalunga*; *c*, distribution on *Parathunnus sibi*.


a
b
Number of copepods
100
50
0
5.25
5.50
6.00
>6.00
<4.5
4.5
5.0
>5.0
♀ Total length (mm) ♂
<5.5
5.5
6.0
6.5
>6.5
<4.5
4.5
5.0
5.5
>5.5
♀ Total length (mm) ♂

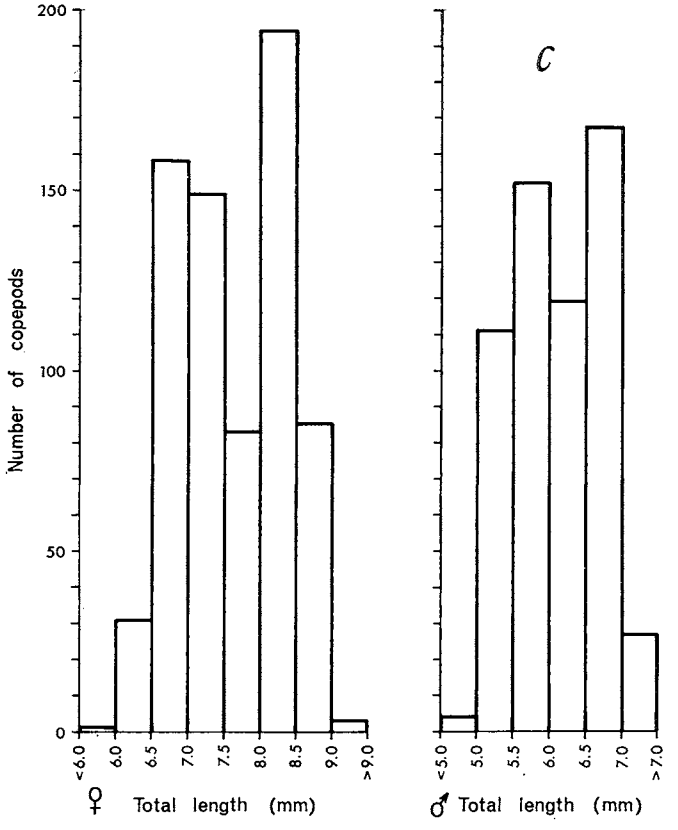

c
Number of copepods
200
150
100
50
0
<6.0
6.0
6.5
7.0
7.5
8.0
8.5
9.0
>9.0
♀ Total length (mm)
<5.0
5.0
5.5
6.0
6.5
7.0
>7.0
♂ Total length (mm)

TABLE 5
DISTRIBUTION OF SPECIMENS OF *Elytrophora brachyptera*
(F = female, M = male, E = external surface, G = gill cavity, B = buccal cavity)

STATION	*N. macropterus* F/M	*P. sibi* F/M	*T. alalunga* F/M
110		44G/35G, 1E	
112		25G/30G	
114		0/1G	
115	2G/0		
116	1G/1G	21G/10G	
118A	1G/0	40G/70G	
119		36G/24G	
121	2G/2G	29G/21G	
122			3G/2G
123		156G/124G	60G/37G
124	4G/6G	67G/56G	16G, 1E/13G, 1E
125			19G/7G
126			27G/19G
127			6G/3G
128	3G/3G		
129			5G/1G
130		150G/102G	1G/1G
131			17G/6G
132			12G/0
133			5G/0
135	0/2G		11G/5G
137	16G/26G		51G/24G
139	2E/1G, 1E	66G/51G, 1E	
141	2G/1G	70G/57G	
142	7G/1B, 11G, 2E		
143	1G/3G		
Sum	41/60	704/583	234/119

TABLE 6
MEANS (C.L.$_{.01}$) OF MEASUREMENTS (IN MILLIMETERS) OF *Elytrophora brachptera*

ITEM MEASURED	FEMALES (979 SPECIMENS)			
	ALL SPECIMENS	*N. macropterus*	*P. sibi*	*T. alalunga*
Total length	7.18(.03)	5.84(.04)	7.62(.03)	6.12(.02)
Cephalothorax length	3.46(.01)	2.94(.02)	3.65(.01)	2.98(.01)
Genital segment length	1.87(.01)	1.42(.02)	2.00(.01)	1.58(.01)
Abdomen length	1.14(.01)	0.92(.01)	1.22(.01)	0.94(.004)
Cephalothorax width	3.73(.01)	3.20(.02)	3.93(.01)	3.25(.01)
Genital segment width	1.45(.01)	1.28(.02)	1.49(.01)	1.36(.01)
Egg string length	9.23(.09)	5.46(.16)	10.55(.10)	6.99(.08)
(No. of strings)	(915)	(51)	(597)	(267)
	MALES (762 SPECIMENS)			
	ALL SPECIMENS	*N. macropterus*	*P. sibi*	*T. alalunga*
Total length	5.83(.03)	4.95(.02)	6.10(.03)	4.93(.02)
Cephalothorax length	2.87(.01)	2.51(.01)	2.98(.01)	2.50(.01)
Genital segment length	1.34(.01)	1.16(.01)	1.40(.01)	1.17(.01)
Abdomen length	0.99(.01)	0.76(.01)	1.05(.01)	0.77(.01)
Cephalothorax width	2.77(.01)	2.51(.01)	2.86(.01)	2.43(.02)
Genital segment width	1.09(.004)	0.99(.01)	1.12(.004)	0.98(.01)

the immediate vicinity of the anal opening or on the body surface under the long pectoral fins. In this latter case they are associated with, or are the cause of, a lightly colored oval area on the surface of the very heavy layer of scales found in this region. The association of the immature specimens with a particular region on the external surface does not appear to be as evident on the other two hosts (*Parathunnus sibi, Neothunnus macropterus*). See Table 19 for a comparison of the total lengths with those of specimens from other geographic areas.

Gloiopotes hygomianus Steenstrup and Lütken

Gloiopotes hygomianus Steenstrup and Lütken, 1861, p. 363, pl. 5, fig. 9. Lewis, 1967, p. 66, figs. 25–27.

DISTRIBUTION AND HOSTS: See Lewis (1967).

MATERIAL: One nonovigerous female and one male from the external surface of a specimen of *Acanthocybium solandri* captured at station 123. One ovigerous female and 2 males from the external surface of a specimen of *A. solandri* captured at station 135.

MEASUREMENTS: See Table 7.

TABLE 7
MEASUREMENTS (IN MILLIMETERS) OF *Gloiopotes hygomianus*

ITEM MEASURED	FEMALES (2)	MALES (3)
Total length	13.46, 12.86	8.78, 9.53, 9.00
Cephalothorax length	6.39, 6.19	4.09, 4.28, 4.16
Length of genital segment including posterior projections but not fifth legs	5.14, 5.03	1.54, 1.58, 1.58
Length of fifth legs	1.39, 1.39; 1.39, 1.39	1.20, 1.13; 1.28, 1.24; 1.24, broken
Length of alae on fourth pedigerous somite	2.34, 3.49; 2.93, damaged	1.35, 1.35; 1.24, 1.24; 1.24, 1.31
Abdomen length	3.00, 2.81	1.46, 1.65, 1.50
Cephalothorax width	5.10, 4.88	3.00, 3.08, 3.08
Genital segment width	2.81, 2.63	1.35, 1.50, 1.35
Length of egg strings	11.63, 12.30	

REMARKS: See Table 19 for a comparison of the total lengths with those of specimens from other geographic areas.

Family CALIGIDAE

Lepeophtheirus crassus (Wilson and Bere)

Gloiopotes crassus Wilson and Bere, *in* Bere, 1936, p. 590, pl. 5, figs. 109–111; pl. 6, figs. 125–155.

Lepeophtheirus crassus (Wilson and Bere) Shiino, 1960, p. 546, figs. 3–4. Lewis, 1967, p. 76, figs. 28–30.

DISTRIBUTION AND HOSTS: See Lewis (1967).

MATERIAL: 2 ovigerous females from the external surface of a specimen of *Remora remora* removed from a specimen of *Istiophorus gladius* taken at station 113.

MEASUREMENTS (in millimeters) of the 2 females:

Total length	5.18,5.06
Cephalothorax length	2.89,2.85
Length of genital segment excluding fifth legs	1.43,1.39
Length of fifth legs	0.60,0.56; 0.56,0.71
Abdomen length	0.64,0.60
Cephalothorax width	2.59,2.63
Genital segment width	1.43,1.50
Length of egg strings	3.11,3.11; 3.26,3.30

REMARKS: See Table 19 for a comparison of the total lengths with those of specimens from other geographic areas.

Midias lobodes Wilson
Fig. 4

Midias lobodes Wilson, 1911, p. 626, pl. 65. Lewis, 1967, p. 94, figs. 34–36.

DISTRIBUTION AND HOSTS: See Lewis (1967).

MATERIAL: 9 females and one male from the external surface of two specimens of *Sphyraena* sp. captured at station 113; 2 females and 3 males from the external surface of a specimen of *Sphyraena* sp. captured at station 121.

MEASUREMENTS: See Table 8.

REMARKS: See Table 19 for a comparison of the total lengths with those of specimens from other geographic areas.

Caligus coryphaenae Steenstrup and Lütken
Fig. 5

Caligus coryphaenae Steenstrup and Lütken, 1861, p. 360, pl. 4, fig. 7. Lewis, 1967, p. 101, figs. 37–39.

DISTRIBUTION AND HOSTS: See Lewis (1967).

MATERIAL: 36 female and 23 male specimens from the external surface of *Neothunnus macropterus, Parathunnus sibi, Katsuwonus pelamis, Coryphaena hippurus*, and *Elagatis bipinnulatus*. Distribution of specimens is given in Table 9.

MEASUREMENTS: See Table 10.

REMARKS: The small number of specimens suggests that *C. coryphaenae* is a relatively un-

TABLE 8
MEANS (C.L.$_{.01}$) OF MEASUREMENTS (IN MILLIMETERS) OF *Midias lobodes*

ITEM MEASURED	FEMALES (11)	MALES (4)
Total length	8.74(.20)	5.84(.18)
Cephalothorax length	3.62(.06)	3.11(.18)
Genital segment length	2.32(.08)	1.31(.07)
Abdomen length	2.46(.07)	1.15(.09)
Cephalothorax width	3.35(.08)	2.75(.12)
Genital segment width	2.32(.08)	1.47(.04)
Abdomen width	2.35(.08)	0.92(.05)

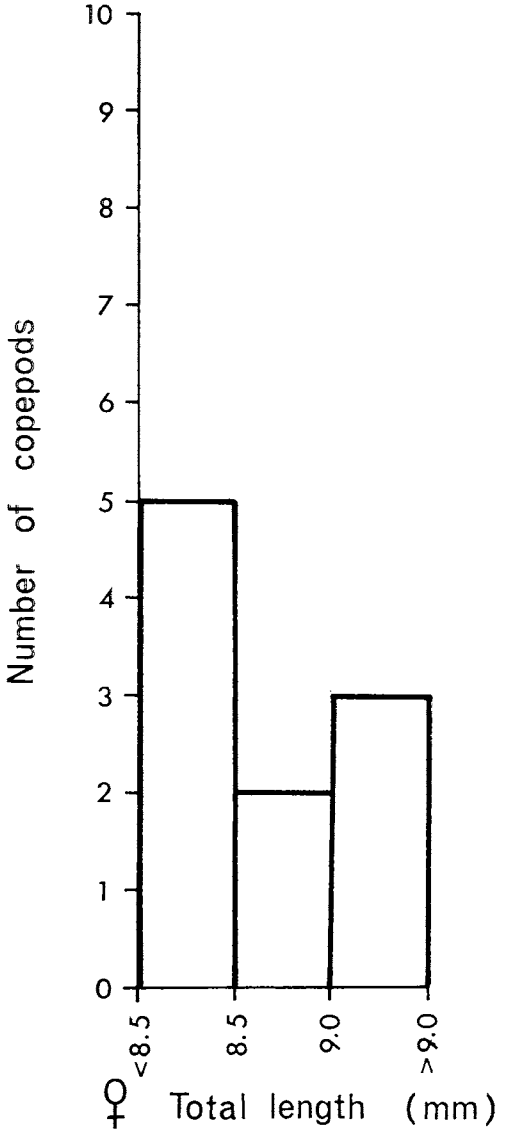


FIG. 4. Length frequency distribution of the female of *Midias lobodes*.

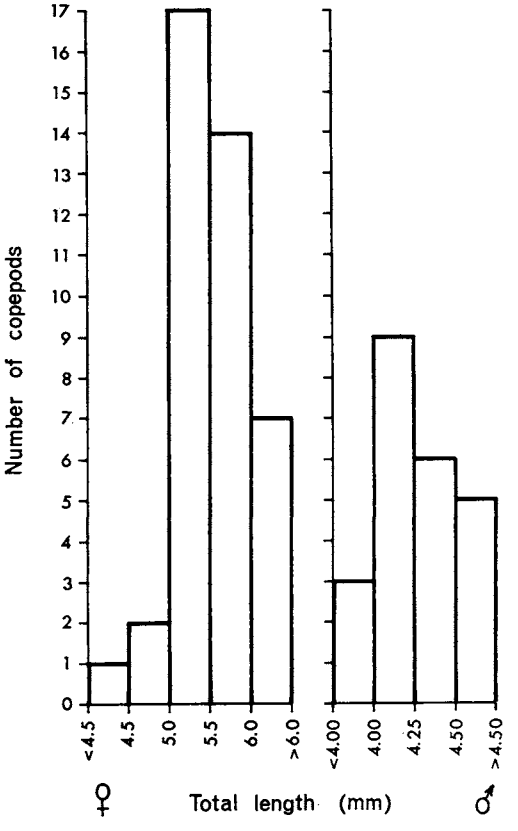


FIG. 5. Length frequency distribution of *Caligus coryphaenae*. *Left graph*, female; *right graph*, male.

TABLE 9
Distribution of Specimens of *Caligus coryphaenae*
(F = female, M = male)

Station	*N. macropterus* F/M	*P. sibi* F/M	*K. pelamis* F/M	*C. hippurus* F/M	*E. bipinnulatus* F/M
110		1/0			
111			3/1		
112			2/2		
114	3/1				
115	2/1				
119					0/1
121	1/0		0/2		
tr-1				0/1	
tr-2	0/1				
128			1/2		
130		4/0			
135			3/3		
137	1/0				
139		2/0			
141		1/0		5/5	
142	3/1			2/0	
143	2/1				
144			0/1		
Sum	12/5	8/0	9/11	7/6	0/1

TABLE 10
Means (C.L.$_{.01}$) of Measurements (in Millimeters) of *Caligus coryphaenae*

Item measured	Females (36 specimens) All specimens	*N. macropterus*	*P. sibi*	*K. pelamis*	*C. hippurus*
Total length	5.57(.08)	5.65(.10)	5.80(.24)	5.49(.16)	5.25(.07)
Cephalothorax length	2.62(.02)	2.61(.04)	2.69(.03)	2.60(.04)	2.57(.06)
Genital segment length	1.43(.03)	1.40(.03)	1.53(.12)	1.42(.06)	1.35(.04)
Abdomen length	1.37(.03)	1.37(.04)	1.46(.12)	1.34(.07)	1.31(.05)
Cephalothorax width	2.19(.02)	2.21(.05)	2.22(.02)	2.21(.03)	2.11(.03)
Genital segment width	1.29(.03)	1.26(.04)	1.34(.09)	1.32(.05)	1.25(.03)
Egg string length	6.19(.32)	7.17(.58)	8.16(.64)	5.36(.47)	4.52(.47)
(No. of strings)	(53)	(16)	(9)	(16)	(12)

	Males (23 specimens) All specimens	*N. macropterus*	*K. pelamis*	*C. hippurus*	*E. bipinnulatus*
Total length	4.23(.05)	4.35(.10)	4.30(.10)	4.04(.09)	4.01
Cephalothorax length	2.68(.03)	2.73(.06)	2.70(.04)	2.59(.07)	2.63
Genital segment length	0.77(.02)	0.84(.04)	0.78(.01)	0.73(.04)	0.71
Abdomen length	0.71(.02)	0.76(.02)	0.75(.02)	0.60(.02)	0.64
Cephalothorax width	2.17(.03)	2.24(.07)	2.21(.03)	2.05(.05)	2.06
Genital segment width	1.00(.02)	1.02(.04)	0.99(.01)	1.01(.09)	0.94

common form on the three most common hosts (*Neothunnus macropterus, Parathunnus sibi, Thunnus alalunga*). See Table 19 for a comparison of the total lengths of members of the present collection with those of specimens from other geographic areas.

Caligus quadratus Shiino
Fig. 6

Caligus quadratus Shiino, 1954*b*, p. 26, fig. 1. Lewis, 1967, p. 109, figs. 40–42.

DISTRIBUTION AND HOSTS: See Lewis (1967).

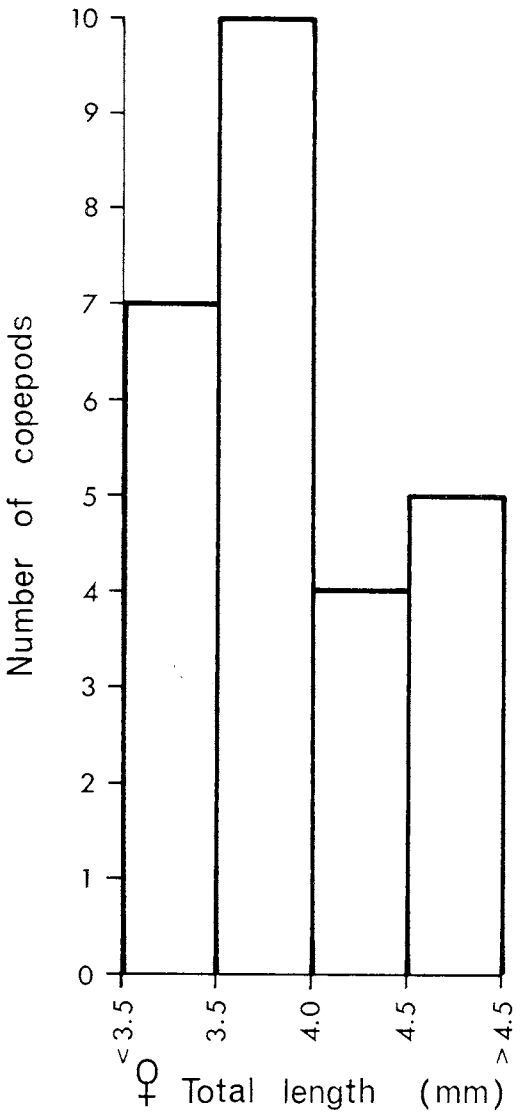


FIG. 6. Length frequency distribution of the female of *Caligus quadratus*.

MATERIAL: 29 females and 2 males from *Coryphaena hippurus* and *C. equisetis*. Distribution of specimens is given in Table 11.

MEASUREMENTS: See Table 12.

REMARKS: The tendencies indicated by the small sample are for the number and size of the specimens on the larger of the two hosts (*C. hippurus*) to be greater than those on the smaller, a characteristic noted for another species found on the same hosts (*Euryphorus nordmanni*). See Table 19 for a comparison of the total lengths with those of specimens from other geographic areas.

TABLE 11
DISTRIBUTION OF SPECIMENS OF *Caligus quadratus*
(F = female, M = male)

STATION	*C. hippurus* F/M	*C. equisetis* F/M
108		1E, 2G/0
110		1G/0
112		2G/0
tr-1	1E, 2G/0	
141	1E, 7G/0	
142	1E, 11G/2E	
Sum	23/2	6/0

Caligus productus Dana
Fig. 7

Caligus productus Dana, 1853, p. 1354, pl. 94, fig. 4. Lewis, 1967, p. 116, figs. 43–45.

DISTRIBUTION AND HOSTS: See Lewis (1967).

MATERIAL: 904 female and 246 male specimens from *Neothunnus macropterus, Parathunnus sibi, Thunnus alalunga, Katsuwonus pelamis, Acanthocybium solandri, Coryphaena hippurus, Coryphaena equisetis, Naucrates ductor, Elagatis bipinnulatus*. Specimens distributed as follows (F = female, M = male, E = external surface, G = gill cavity, B = buccal cavity):

STATION	FISH HOST AND NUMBER OF COPEPODS
108	*Naucrates ductor*, 1G (F)
119	*Elagatis bipinnulatus*, 1G (M)
123	*Acanthocybium solandri*, 10G (F)
tr-1	*Coryphaena hippurus*, 1G (M)
142	*Coryphaena hippurus*, 2G (F)

For remaining distributions, see Table 13.

MEASUREMENTS: See Table 14.

REMARKS: *Caligus productus* and *Elytrophora brachyptera* are both found in large numbers on three species of hosts. The relationships between these two species of copepods and their hosts, as indicated by the present data, are given in the discussion. See Table 19 for a comparison of

TABLE 12
MEASUREMENTS (IN MILLIMETERS) OF *Caligus quadratus*

ITEM MEASURED	FEMALES (29 SPECIMENS), MEANS (C.L.$_{.01}$)			MALES (2 SPECIMENS)
	ALL SPECIMENS	*C. hippurus*	*C. equisetis*	*C. hippurus*
Total length	4.05(.22)	4.16(.27)	3.60(.13)	2.21, 2.18
Cephalothorax length	1.38(.07)	1.42(.08)	1.22(.07)	1.13, 1.16
Genital segment length	1.20(.06)	1.23(.07)	1.10(.04)	0.45, 0.38
Abdomen length	1.24(.09)	1.29(.11)	1.08(.05)	0.38, 0.38
Cephalothorax width	1.26(.07)	1.30(.08)	1.09(.07)	1.05, 1.05
Genital segment width	1.01(.05)	1.05(.05)	0.85(.08)	0.34, 0.30
Egg string length	2.86(.03)	3.15(.36)	2.20(.19)	
(No. of strings)	(23)	(16)	(7)	

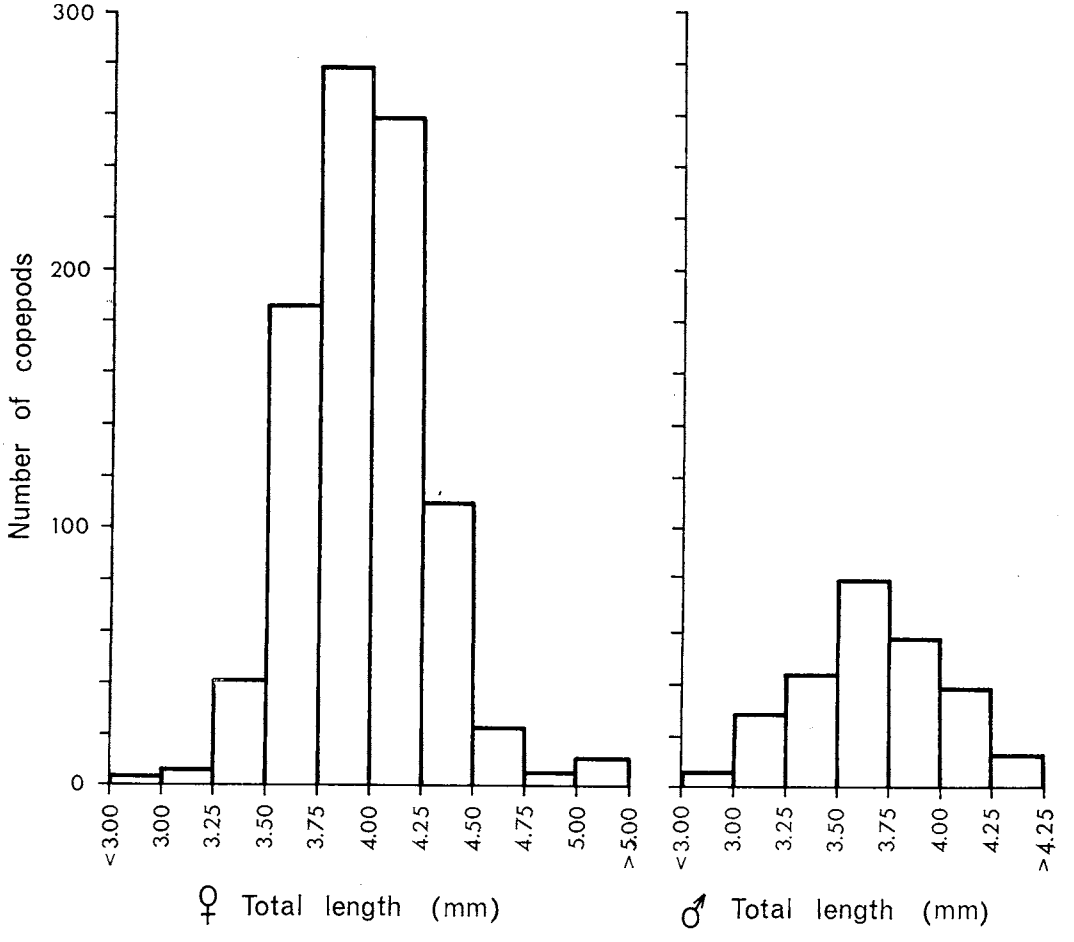


FIG. 7. Length frequency distribution of *Caligus productus*. *Left graph*, female; *right graph*, male.

TABLE 13
DISTRIBUTION OF SPECIMENS OF *Caligus productus* (*continued*)
(F = female, M = male, E = external surface, G = gill cavity, B = buccal cavity)

STATION	*N. macropterus* F/M	*P. sibi* F/M	*T. alalunga* F/M	*K. pelamis* F/M	*C. equisetis* F/M
110		13B/2B			0/1G
111	8B/1B			31B/10B	
	0/1G			33G/11G	
				1E/0	
112	108B/27B	11B/2B		13B/7B	2B/0
	5G/1G			3G/0	2G/0
	4E/1E			6E/0	4E/2E
113	22B/6B				
	1G/1G				
114	214B/44B				
	4G/0				
115	26B/6B				
116	14B/4B				
	1G/1G				
	0/1E				
118A	4B/0				
121	11B/4B			2B/0	
	1G/0			0/1E	
124	3B/2B				
tr-2	1B/0				
125	26B/14B		41B/13B		
126			0/2B		
			0/1E		
127	10B/4B				
128	0/1B			2B/0	
				0/2G	
135	5B/0		0/1E	5B/0	
				30G/6G	
137	2B/1B				
139	52B/9B				
	2G/0				
141	20B/6B				
142	37B/8B				
	19G/2G				
143	74B/22B				
144				6B/3B	
				10G/4G	
				2E/9E	
Sum	674/167	24/4	41/17	144/53	8/3

the total lengths of specimens of *C. productus* from various geographic areas.

Caligus confusus? Pillai

Caligus confusus Pillai, 1961, p. 104, fig. 10.

Caligus confusus? Pillai. Lewis, 1968, p. 53, figs. 22–23.

DISTRIBUTION AND HOSTS: See Lewis, 1968.

MATERIAL: 2 females from the gill cavity of a specimen of *Elagatis bipinnulatus* captured at station 119.

MEASUREMENTS (in millimeters) of the 2 females:

Total length	3.49,3.30
Cephalothorax length	1.50,1.43
Genital segment length	1.35,1.28
Abdomen length	0.53,0.38
Cephalothorax width	1.46,1.46
Genital segment width	0.86,0.75
Egg string length	2.81,2.74

REMARKS: See Table 19 for a comparison of the total lengths with those of specimens from other geographic areas.

TABLE 14
MEANS (C.L.$_{.01}$) OF MEASUREMENTS (IN MILLIMETERS) OF *Caligus productus*
(904 females and 246 males)

	FEMALES						
ITEM MEASURED	ALL SPECIMENS	*N. macropterus*	*P. sibi*	*T. alalunga*	*K. pelamis*	*A. solandri*	*C. equisetis*
Total length	3.96(.01)	3.95(.01)	3.89(.05)	4.21(.03)	3.92(.03)	4.35(.07)	3.59(.11)
Cephalothorax length	1.68(.01)	1.67(.01)	1.62(.02)	1.79(.02)	1.66(.01)	1.78(.03)	1.56(.05)
Genital segment length	1.22(.01)	1.22(.01)	1.20(.01)	1.30(.01)	1.22(.01)	1.42(.03)	1.03(.04)
Abdomen length	0.98(.01)	0.98(.01)	0.93(.02)	1.07(.01)	0.98(.01)	1.15(.03)	0.84(.03)
Cephalothorax width	1.48(.01)	1.47(.01)	1.42(.03)	1.59(.01)	1.47(.01)	1.58(.03)	1.36(.04)
Genital segment width	0.84(.01)	0.84(.01)	0.83(.02)	0.88(.01)	0.83(.01)	0.93(.02)	0.72(.04)
Egg string length	2.35(.02)	2.33(.02)	2.18(.10)	2.54(.07)	2.43(.05)	2.13(.17)	2.08(.10)
(No. of strings)	(1168)	(867)	(33)	(49)	(193)	(19)	(4)

	MALES				
	ALL SPECIMENS	*N. macropterus*	*P. sibi*	*T. alalunga*	*K. pelamis*
Total length	3.68(.02)	3.70(.02)	3.32(.21)	3.94(.07)	3.61(.04)
Cephalothorax length	1.79(.01)	1.80(.01)	1.61(.10)	1.94(.04)	1.76(.02)
Genital segment length	0.82(.01)	0.83(.01)	0.72(.06)	0.83(.02)	0.81(.01)
Abdomen length	0.77(.01)	0.78(.01)	0.68(.04)	0.83(.02)	0.75(.01)
Cephalothorax width	1.51(.01)	1.52(.01)	1.32(.05)	1.66(.03)	1.49(.02)
Genital segment width	0.57(.01)	0.57(.01)	0.50(.01)	0.63(.01)	0.58(.02)

	C. hippurus		*E. bipinnulatus*	*N. ductor*
	FEMALE	MALE	MALE	FEMALE
Total length	4.24, 3.60, 3.53	2.96	2.93	3.98
Cephalothorax length	1.73, 1.58, 1.61	1.46	1.43	1.65
Genital segment length	1.31, 1.01, 0.83	0.71	0.68	1.28
Abdomen length	1.13, 0.90, 0.83	0.60	0.68	0.98
Cephalothorax width	1.58, 1.39, 1.46	1.13	1.31	1.46
Genital segment width	0.94, 0.64, 0.56	0.41	0.41	0.90
Egg string length	3.94, –			

Family PSEUDOCYCNIDAE

Pseudocycnus appendiculatus Heller
Fig. 8

Pseudocycnus appendiculatus Heller, 1865, p. 218, fig. 7. Shiino, 1959*b*, p. 325, figs. 24–25.

For synonymy see Shiino, 1959*b*.

DISTRIBUTION AND HOSTS: See Shiino (1959*b*).

MATERIAL: 38 female specimens and one male specimen from *Neothunnus macropterus, Parathunnus sibi,* and *Thunnus alalunga.* Distribution of specimens is given in Table 15.

MEASUREMENTS: See Table 16.

REMARKS: The only tendency indicated by the present collection is the more common occurrence on *Neothunnus macropterus.* The small number of specimens reduces the value of a discussion of parasite-host and parasite-parasite relationships. See Table 19 for a comparison of the total lengths with those of specimens from other geographic areas.

Family LERNAEOPODIDAE

Brachiella thynni Cuvier
Fig. 9

Brachiella thynni Cuvier, 1829, p. 257, pl. 15, fig. 5. Lewis, 1967, p. 174, figs. 66–67.

DISTRIBUTION AND HOSTS: See Lewis (1967).

MATERIAL: 40 females and 14 males from the external surface of *Neothunnus macropterus,*

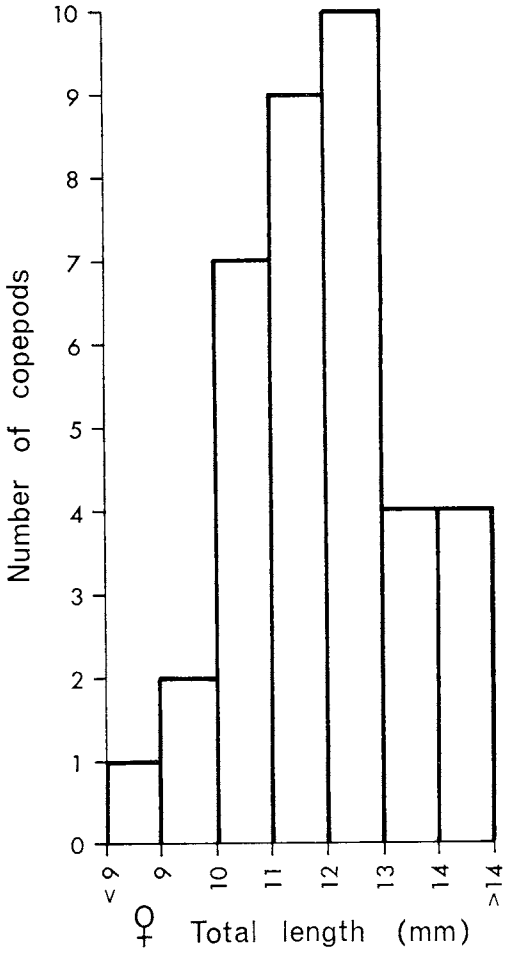


FIG. 8. Length frequency distribution of the female of *Pseudocycnus appendiculatus*.

Parathunnus sibi, Thunnus alalunga, and *Acanthocybium solandri.* Distribution of specimens is given in Table 17.

MEASUREMENTS: See Table 18.

REMARKS: The only tendency indicated by the collection is for the sexually mature female to occur more commonly on *Parathunnus sibi.* As with *Pseudocycnus appendiculatus*, the small number of specimens limits a discussion of parasite-host and parasite-parasite relationships. See Table 19 for a comparison of the lengths of these specimens with those of specimens from other geographic areas.

TABLE 15
DISTRIBUTION OF SPECIMENS OF *Pseudocycnus appendiculatus*
(F = female, M = male, E = external surface, G = gill cavity)

STATION	*N. macropterus* F/M	*P. sibi* F	*T. alalunga* F
112	1G/0		
113	1G/0		
114	3G/0		
115	1G/0		
116	1G/0		
118A	6G/0	1G	
121		1G	
124	1G/0		
tr-2	2G/1G		
126			1G
130			1G
131			5G
139	1G, 1E/0		
141	7G/0		
142	3G/0		
143	1G/0		
Sum	29/1	2	7

TABLE 16
MEASUREMENTS (IN MILLIMETERS) OF *Pseudocycnus appendiculatus*

ITEM MEASURED	FEMALES (38 SPECIMENS), MEANS (C.L.$_{.01}$)				MALE (1 SPECIMEN)
	ALL SPECIMENS	*N. macropterus*	*P. sibi*	*T. alalunga*	*N. macropterus*
Total length	11.83(.22)	11.63(.43)	14.44, 14.25	11.99(.36)	2.81
Cephalothorax length	1.17(.02)	1.15(.03)	1.50, 1.16	1.18(.02)	0.64
Trunk length	7.46(.14)	7.36(.26)	9.45, 8.44	7.50(.26)	1.50
Abdomen length	0.49(.01)	0.49(.03)	0.56, 0.64	0.47(.02)	0.23
Cephalothorax width	0.94(.02)	0.92(.03)	1.16, 1.13	0.94(.02)	0.71
Trunk width	0.88(.02)	0.88(.03)	1.09, 1.13	0.94(.02)	0.56
Egg string length	15.73(.82)	16.11(1.57)	26.33;	11.65(.17)	
(No. of strings)	(41)	(33)	14.44, 14.36	(5)	

DISCUSSION

The copepods in the RVAB#2 collection (that is, from cruise number 2 of the International Indian Ocean Expedition R/V "Anton Bruun") are found primarily on pelagic fishes. As such they are believed to have a potentially greater range of distribution than copepods restricted to inshore fishes. Because of this the discussion is concerned with differences in size between the present collection and other records and, as well, with the host associations indicated by the data from the RVAB#2 collection.

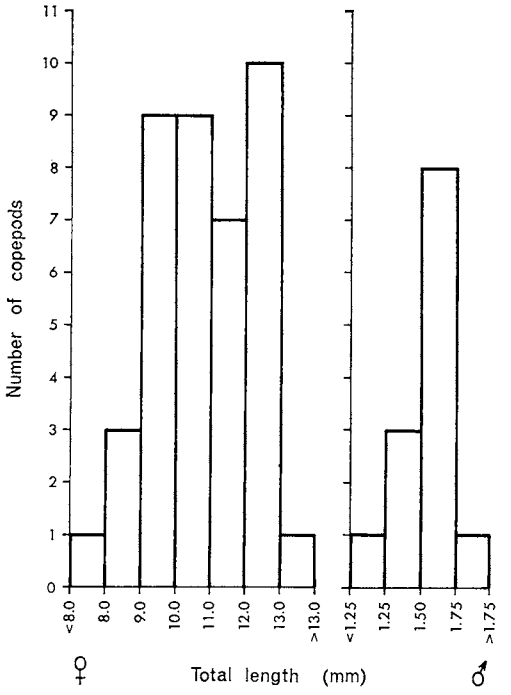


FIG. 9. Length frequency distribution of *Brachiella thynni*. *Left graph*, female; *right graph*, male.

Due to the problems of sample size in the present as well as previously described collections, there is only limited value in the comparison of the average total lengths of the RVAB#2 copepods with those of copepods from other areas (Table 19). Even in those examples where variation is obvious (e.g., *Euryphorus nordmanni*) it is difficult to evaluate the difference because the references do not always indicate what structures were included in the measurement. In addition, some of the differences (e.g., the male of *Brachiella thynni*) suggest that different techniques may have been used in measuring the specimens. About the only tendency indicated in Table 19 is that the specimens in the present collection are slightly smaller than those from most other areas.

Most of the hosts listed for each species of copepod have been recorded previously. Some of the host names not previously listed are felt to be synonyms of recorded names. The remaining hosts are believed to be new records and include the following: *Remora remora* (parasitized by *Lepeophtheirus crassus*); *Elagatis bipinnulatus* (by *Caligus coryphaenae*); *Coryphaena equisetis* (by *Caligus quadratus*); and *Acanthocybium solandri, Coryphaena equisetis,* and *Elagatis bipinnulatus* (by *Caligus productus*).

TABLE 17
DISTRIBUTION OF SPECIMENS OF *Brachiella thynni*
(F = female, M = male)

STATION	*N. macropterus* F/M	*P. sibi* F/M	*T. alalunga* F/M	*A. solandri* F/M
121	1/1	1/0		
123		9/6	3/1	2/1
124		6/0		
125			1/1	
127	3/1			
130		8/0	1/1	
131			1/1	
132			1/0	
135	1/0			
141	2/1			
Sum	7/3	24/6	7/4	2/1

TABLE 18
MEANS (C.L.$_{.01}$) OF MEASUREMENTS (IN MILLIMETERS) OF *Brachiella thynni*

ITEM MEASURED	FEMALES (40 SPECIMENS) ALL SPECIMENS	*N. macropterus*	*P. sibi*	*T. alalunga*	*A. solandri*
Total length	10.75(.24)	10.59(.64)	10.89(.25)	10.61(.52)	13.76, 6.68
Cephalothorax length (including neck)	5.45(.17)	5.54(.39)	5.34(.17)	5.43(.34)	9.19, 3.83
Trunk length	5.32(.12)	5.00(.25)	5.59(.13)	5.19(.22)	4.58, 2.81
Cephalothorax width (anterior region)	0.88(.02)	0.74(.04)	0.92(.02)	0.92(.02)	0.71, 0.56
Cephalothorax width (posterior region)	0.90(.02)	0.82(.06)	0.94(.02)	0.86(.02)	1.09, 0.79
Trunk width	2.86(.07)	2.56(.19)	3.05(.07)	2.60(.20)	3.15, 2.14
Egg string length (No. of strings)	8.86(.32) (55)	7.28(.13) (5)	8.96(.35) (41)	8.30(.38) (6)	14.59, 14.25; 4.76
ITEM MEASURED	MALES (14 SPECIMENS) ALL SPECIMENS	*N. macropterus*	*P. sibi*	*T. alalunga*	*A. solandri*
Total length	1.53(.05)	1.55(.17)	1.58(.03)	1.54(.04)	1.13
Prosome length	0.65(.02)	0.66(.04)	0.62(.03)	0.71(.03)	0.56
Urosome length	0.84(.03)	0.84(.13)	0.91(.03)	0.77(.03)	0.79
Width of constriction between prosome and urosome	0.20(.01)	0.20(.01)	0.21(.01)	0.19(all)	0.15
Prosome width	0.34(.01)	0.33(.03)	0.34(.02)	0.37(.03)	0.26
Urosome width	0.47(.01)	0.42(.01)	0.49(.02)	0.46(.01)	0.49
Caudal rami length (No. of rami) (28)	0.12(.01) (6)	0.10(.01) (12)	0.12(.01) (8)	0.13(.01)	0.11, 0.11

Within the RVAB#2 collection there are sufficient numbers of two species of copepods (*Elytrophora brachyptera* and *Caligus productus*) to compare the measurements of specimens taken at various stations along the cruise track. The comparison of these measurements, as well as measurements of specimens taken at opposite ends of the sampled portion of the latitudinal range, did not indicate any trend. As indicated by inspection, there was no apparent difference between stations.

The host associations and host preferences indicated by the RVAB#2 collection deal with two species of copepods (*Elytrophora brachyptera* and *Caligus productus*) and three species of large pelagic tunas (the yellowfin, *Neothunnus macropterus*, the bigeye, *Parathunnus sibi*, and the albacore, *Thunnus alalunga*). The evaluation is based on the percentage of hosts parasitized, the percentage of parasitized fish infested by each species, the length frequency distribution of the copepods on each host species, and the percentage of the adult copepod population comprised of sexually immature specimens on each host species.

A comparison of the list of hosts for both species of copepods (Lewis, 1967, pp. 43, 116) indicates that *E. brachyptera* is found on fewer species than is *C. productus*. This is also shown by the RVAB#2 collection, and it suggests that *E. brachyptera* exhibits a narrower host tolerance than does *C. productus* (assuming that an adequate number of potential hosts has been examined). The difference in tolerance may provide an indication of host preference as well as parasite competition on the hosts parasitized by both species of copepods.

Host preference can be indicated by the incidence of parasitism (Table 20), which shows a high incidence of parasitization by *E. brachyptera* and, with the exception of *N. macropterus*, a low incidence by *C. productus*. It further suggests that the order of host preference for *E. brachpytera* is *P. sibi, T. alalunga,* and *N. ma-*

TABLE 19
AVERAGE LENGTH RECORDS FOR COPEPODS; FROM SELECTED REFERENCES

(Length = average total length (mm) without processes unless otherwise indicated. RVAB#2 = cruise number 2 of the R/V "Anton Bruun." * = no record of number of specimens measured. † = approximate value; absolute value not given.)

	LENGTH	REFERENCE
Euryphorus nordmanni Milne-Edwards		
Indian Ocean	7.93 (63 females) 5.08 (52 males)	RVAB#2
Ceylon	12 (female*)[1] 5.7 (male*)	Kirtisinghe, 1964
Japan	13.5 (female*)[1] 5.2 (male*)	Shiino, 1954*a*
Central Pacific	9.65 (5 females) 5.84 (5 males)	Lewis, 1967
Tropical Atlantic	11–12 (female*)[1] 6–7 (male*)	Steenstrup and Lütken, 1861
Elytrophora brachyptera Gerstaecker		
Indian Ocean	7.18 (979 females) 5.83 (762 males)	RVAB#2
Japan	8.3 (female*) 6.0 (male*)	Shiino, 1954[2]
New Zealand	8.8 (1 female) 6.2 (1 male)	Hewitt, 1968
Central Pacific	8.37 (10 females) 6.33 (10 males)	Lewis, 1967
"European Seas"	11.5† (female*) 9† (male*)	Scott and Scott, 1913
Gloiopotes hygomianus Steenstrup and Lütken		
Indian Ocean	13.46, 12.86 (2 females) 8.78, 9.53, 9.00 (3 males)	RVAB#2
Central Pacific	14.33 (6 females) 9.92 (4 males)	Lewis, 1967
Cocos Island	13.66 (1–2 females) 8.27 (1 male)	Shiino, 1960*a*
Atlantic	14 (1 female)	Steenstrup and Lütken, 1861
Lepeophtheirus crassus (Wilson and Bere)		
Indian Ocean	5.18, 5.06 (2 females)	RVAB#2
Bay of Bengal	4.56–6.00 (21 females) 4.66 (male*)	Shiino, 1960*b*
Central Pacific	6.36 (7 females) 4.80 (1 male)	Lewis, 1967
Eastern Pacific	6.00–7.54 (17 females) 3.77–5.00 (3 males)	Shiino, 1963
Western Atlantic	7.25 (female*) 5 (male*)	Wilson and Bere (*in* Bere, 1936)

[1] No record of body parts included in measurement. (Because of the similarity of the measurements of the males from the listed areas it is believed that the egg strings of the females were included in some of the measurements.)
[2] Shiino later (1958) called these specimens *Elytrophora hemiptera* although Hewitt (1968) indicates that *E. hemiptera* is a synonym of *E. brachyptera*.

TABLE 19 (*continued*)

	LENGTH	REFERENCE
Midias lobodes Wilson		
Indian Ocean	8.74 (11 females) 5.84 (4 males)	RVAB#2
	10.04 (female*) 7.12 (male*)	Shiino, 1958
Central Pacific	12.00 (1 female) 6.30–7.13 (3 males)	Lewis, 1967
Gulf of Mexico	10–14 (female*) 7.25 (male*)	Wilson, 1911
Caligus coryphaenae Steenstrup and Lütken		
Indian Ocean	5.57 (36 females) 4.23 (23 males)	RVAB#2
Japan	6.60, 6.39 (2 females)	Shiino, 1959*a*
Central Pacific	6.61 (13 females) 5.52 (10 males)	Lewis, 1967
Gulf of Mexico	7.60 (1 female)	Wilson, 1935
Subtropical Atlantic	8 (female*) 7 (male*)	Steenstrup and Lütken, 1861
Caligus quadratus Shiino		
Indian Ocean	4.05 (29 females) 2.21, 2.18 (2 males)	RVAB#2
Western Pacific	4.45–5.96 (female*) 3.07 (1 male)	Shiino, 1959*b*
Hawaii	5.02 (11 females) 2.85–3.50 (3 males)	Lewis, 1967
Atlantic	6 (female*) 4.5 (male*)	Wilson, 1905
Caligus productus Dana		
Indian Ocean	3.96 (904 females) 3.68 (246 males)	RVAB#2
Pacific	4.18 (female*) 3.75 (male*)	Shiino, 1959*b*
Hawaii	4.80 (32 females) 4.58 (22 males)	Lewis, 1967
Subtropical Atlantic	4–5 (female*)	Steenstrup and Lütken, 1861
Caligus confusus? Pillai		
Indian Ocean	3.49, 3.30 (2 females)	RVAB#2
	4.5 (female*) 2.3 (male*)	Kirtisinghe, 1964[3]
	2.9 (female*)	Pillai, 1961
Eniwetok Atoll	3.22 (16 females) 2.14 (1 immature male)	Lewis, 1968
Panama (west coast)	5 (female*)	Wilson, 1937[3]
Costa Rica (west coast)	3.75 (1 female)	Shiino, 1959*c*[3]

[3] See discussion in Lewis (1968:59).

TABLE 19 (*continued*)

	LENGTH	REFERENCE
Pseudocycnus appendiculatus Heller		
Indian Ocean	11.83 (38 females) 2.81 (1 male)	RVAB#2
	11 (female*) 3.5 (male*)	Kirtisinghe, 1964
Mexico (west coast)	13.31 (female*)	Shiino, 1959*c*
Western North Atlantic	16 (female*) 4 (1 male)	Wilson, 1922
Brachiella thynni Cuvier		
Indian Ocean	10.75 (40 females) 1.53 (14 males)	RVAB#2
	up to 30 (female*)[4] 4.6 (male*)	Kirtisinghe, 1964
Japan	42.00 (1 female)[5] 4.60 (male*)[6]	Shiino, 1956
Central Pacific	9.30–16.13 (3 females) 1.85 (1 male)	Lewis, 1967
North Atlantic	6 (female*)[7] 2.25 (male*)	Wilson, 1915

[4] Including posterior processes.
[5] "Total length."
[6] Excluding caudal rami.
[7] Probably a misprint.

TABLE 20
INCIDENCE OF PARASITIZATION BY *E. brachyptera* AND *C. productus*

	PERCENTAGE OF FISH PARASITIZED AND AVERAGE NUMBER OF COPEPODS PER PARASITIZED FISH					
	N. macropterus		*P. sibi*		*T. alalunga*	
COPEPOD	%	NO. PER FISH	%	NO. PER FISH	%	NO. PER FISH
E. brachyptera	46	4.29	94	75.65	76	11.39
C. productus	76	22.24	12	9.33	15	9.67

cropterus and that for *C. productus* it is just the reverse. The environment, both on and adjacent to the host, as well as possible competition between the two copepods may affect the order of preference. The evidence of competition will be discussed later; the effect of the environment adjacent to the host is indicated by the parasitization of *T. alalunga* by *C. productus*. The copepod was found on this host only in areas where *N. macropterus* was found. The range of *T. alalunga* extends further south than does that of *N. macropterus*, and the effect of the environment may be a limiting factor at some stage in the life cycle of *C. productus*.

The term preference, as used with regard to the association of a copepod with several host species, is not an exact and clear term but rather implies the effect of a variety of factors. One of the concepts that must be brought into a discussion of host preference is that the effect of the host is exerted not only on the sexually mature copepod but also on all of the stages in the life cycle which infect the host. The host may, for example, be limiting at only one stage in the development or, in contrast, may provide a continuously limiting effect that allows development with only a relatively low percentage of survival. Because of these possibilities it was

felt best to use only the sexually mature adult for the analysis of host preference. However, it was deemed possible to obtain an estimate of the effect of the host on the survival of the copepod by determining the percentage of the total adult population comprised of sexually immature specimens. For this purpose, all host species on which sexually immature specimens of *E. brachyptera* and *C. productus* were found are included in Table 21.

There is an assumption made in the use of these data that could be misleading. It is that the fallout of the infecting stage, from the plankton, is random, which would provide equal numbers of specimens (per unit of host surface) on all species of pelagic fishes inhabiting the area in which the planktonic infecting stages of the life history are found. This implies that the host factors are operative after infection and that the parasite is not selective. It further implies that movement to a new host, after infection of an unsatisfactory host, is not possible. The latter, at least, is believed to be untrue because of the capture of "young" specimens in the plankton (Heegaard, 1955).

Even with the qualification of host transfer, a trend is suggested by the data in Table 21. This is for the percentage of immature *C. productus* specimens to be low on most fishes, suggesting that either the specimens die before they reach the immature adult stage or the requirements of the stages are sufficiently generalized to allow comparatively high survival. This last statement is made with the consideration that a high percentage of sexually immature specimens indicates that fewer specimens are surviving to maturity. With *E. brachyptera*, on the other hand, there is a suggestion that conditions associated with certain hosts (*Coryphaena hippurus, Alepisaurus* spp.) prevent or severely limit survival during maturation or cause abandonment of the host. Further, the relatively high percentage of immature specimens on both *N. macropterus* and *T. alalunga*, along with the lower percentage on *P. sibi* (comparable to the percentages of immature *C. productus* on the listed hosts), indicates that the conditions on and adjacent to *P. sibi* are more beneficial to the maturing *E. brachyptera* than are the conditions on any of the other hosts this copepod frequents.

TABLE 21
PERCENTAGE OF ADULT POPULATION COMPRISED OF SEXUALLY IMMATURE SPECIMENS
(Number of sexually immature specimens in parentheses)

HOST	*E. brachyptera*	*C. productus*
Neothunnus macropterus	36.0% (58)	4.3% (38)
Parathunnus sibi	7.9% (110)	3.4% (1)
Thunnus alalunga	27.81% (136)	6.45% (4)
Katsuwonus pelamis	–	4.6% (10)
Acanthocybium solandri	–	9.0% (1)
Coryphaena hippurus	100% (10)	25.0% (1)
Alepisaurus spp.	100% (25)	–

The nature of the host factors that cause a preference to be exhibited by the copepod is beyond the scope of this paper. The physical expression of these factors on the copepod can, however, be indicated not only by the exhibited preference but also by the size distribution plots for the total length of one of the copepod species, *E. brachyptera*. The overall distribution plot (Fig. 2) is bimodal. When the plot of each host species (Fig. 3) is examined, however, it is apparent that the smaller size mode is composed of specimens from all three hosts while the larger size mode is composed of specimens from *P. sibi*. There is thus evidence that conditions on and adjacent to this host allow growth to a larger size. Based on the assumption that the copepods reproduce throughout the year under the conditions existing where the RVAB#2 collection was made, the bimodal distribution on *P. sibi* suggests that reproduction, or survival of the life history stages, is reduced at some time.

The bimodal distribution in *E. brachyptera* is also apparent in the central Pacific (Lewis, 1967) and, at one time, was thought by the senior author to indicate two different species. (A similar case, but of two nominal species, *Gloiopotes huttoni* and *G. watsoni*, is discussed in Cressey, 1967). The variation exhibited by specimens of *E. brachyptera* from a single host specimen, the presence of specimens in both size modes on the same area of the same host specimen, and the morphological continuity of specimens from both size modes suggests that this variation is due to age with, in contrast to Lewis (1967, p. 54), an influence by the host. The question of subspecies in *E. brachyptera*, as discussed by Hewitt (1968), can not be an-

swered here because of the absence of sufficient specimens.

In addition to the relationship between the copepod and its host, it would be of interest to know if there is any evidence of competition between *E. brachyptera* and *C. productus*, since both occur on the same hosts. With the present collection it was felt that this could best be indicated if there was a reduction, from an assumed "average" level, in the number of specimens of one species from a region on the host. This was with the assumption that the reduction is not due to the effect of the host. The analysis is derived from the percentage of the total population of sexually mature specimens found in each of the three areas of infestation (external surface, gill cavity, and buccal cavity) on each of the three host species, as well as a host parasitized by *C. productus* but not by *E. brachyptera* (Table 22).

One further assumption must be made in order to establish some idea of what an average level, or percentage distribution, is in regard to the distribution of *C. productus* on each of the three areas on a host. This assumption is that the distribution of *C. productus* on *Katsuwonus pelamis* represents the average level, an assumption made because *E. brachyptera* is not present and the numbers of specimens of other copepod species is low. Further, although the competition with other types of parasites is unknown, it is assumed to be slight enough to cause little if any effect on the distribution of *C. productus* on *Katsuwonus pelamis*.

The data suggest that *E. brachyptera* is most frequently found in the gill cavity of the three host species while *C. productus* is most commonly found in the buccal cavity. The distribution of *C. productus* on *Katsuwonus pelamis* however, suggests that the distribution of the other three host species should be more nearly equal and that some factor is limiting. The infestation of *E. brachyptera* on three of the host species but not on *Katsuwonus pelamis* suggests that the factor may be competition.

TABLE 22
PERCENTAGE OF SEXUALLY MATURE ADULT POPULATIONS OF TWO COPEPODS INFESTING DIFFERENT HOST REGIONS
(E = external surface, G = gill cavity, B = buccal cavity)

Elytrophora brachyptera			
HOST	E	G	B
Neothunnus macropterus	4.85	94.18	0.97
Parathunnus sibi	0.16	99.84	0.00
Thunnus alalunga	0.57	99.43	0.00
Caligus productus			
HOST	E	G	B
Neothunnus macropterus	1.18	4.50	94.32
Parathunnus sibi	0.00	0.00	100.00
Thunnus alalunga	3.45	0.00	96.55
*Katsuwonus pelamis**	14.01	48.79	37.20

* A species of tuna which is heavily infested by *C. productus* but not infested (RVAB#2 collection only) by *E. brachyptera*. Other species of copepods are represented on this host but only in small numbers.

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