

Pelagic Copepods of the
Family Oithonidae (Cyclopoida)
from the East Coasts of
Central and South America

FRANK D. FERRARI
and
THOMAS E. BOWMAN

SERIES PUBLICATIONS OF THE SMITHSONIAN INSTITUTION

Emphasis upon publication as a means of “diffusing knowledge” was expressed by the first Secretary of the Smithsonian. In his formal plan for the Institution, Joseph Henry outlined a program that included the following statement: “It is proposed to publish a series of reports, giving an account of the new discoveries in science, and of the changes made from year to year in all branches of knowledge.” This theme of basic research has been adhered to through the years by thousands of titles issued in series publications under the Smithsonian imprint, commencing with *Smithsonian Contributions to Knowledge* in 1848 and continuing with the following active series:

Smithsonian Contributions to Anthropology
Smithsonian Contributions to Astrophysics
Smithsonian Contributions to Botany
Smithsonian Contributions to the Earth Sciences
Smithsonian Contributions to Paleobiology
Smithsonian Contributions to Zoology
Smithsonian Studies in Air and Space
Smithsonian Studies in History and Technology

In these series, the Institution publishes small papers and full-scale monographs that report the research and collections of its various museums and bureaux or of professional colleagues in the world of science and scholarship. The publications are distributed by mailing lists to libraries, universities, and similar institutions throughout the world.

Papers or monographs submitted for series publication are received by the Smithsonian Institution Press, subject to its own review for format and style, only through departments of the various Smithsonian museums or bureaux, where the manuscripts are given substantive review. Press requirements for manuscript and art preparation are outlined on the inside back cover.

S. Dillon Ripley
Secretary
Smithsonian Institution

Pelagic Copepods of the
Family Oithonidae (Cyclopoida)
from the East Coasts of
Central and South America

Frank D. Ferrari
and Thomas E. Bowman



SMITHSONIAN INSTITUTION PRESS

City of Washington

1980

ABSTRACT

Ferrari, Frank D., and Thomas E. Bowman. Pelagic Copepods of the Family Oithonidae (Cyclopoida) from the East Coasts of Central and South America. *Smithsonian Contributions to Zoology*, number 312, 27 pages, 15 figures, 1 table, 1980.—Twelve species of cyclopoid copepods of the family Oithonidae are described from eastern coastal waters of Central and South America from Belém, Brazil, to Belize City, Belize. Three are new species: *Oithona bjornbergae*, *O. fonsecae*, and *Paroithona flemingeri*. Sexes of *O. plumifera* are very similar in the copepod V stage; the male characters (lack of rostrum, flap on cephalosome and pore signature, and extra outer setae on swimming leg exopods) are acquired during the final molt. Several morphological characters besides the traditional ones are used to separate species: the pattern of male integumental organs (pore signature), the armature of the female genital segment, and the modified endopod setae of the female fourth swimming leg. Spermatophores were found ventrally on urosome segments of *O. oculata* and *O. plumifera*. It is suggested that during mating the male grasps the female fourth legs with his geniculate first antennae as in *Cyclops*, and tactile recognition of the male pore signature is accomplished by the modified endopod setae of the female fourth leg.

OFFICIAL PUBLICATION DATE is handstamped in a limited number of initial copies and is recorded in the Institution's annual report, *Smithsonian Year*. SERIES COVER DESIGN: The coral *Montastrea cavernosa* Linnaeus).

Library of Congress Cataloging in Publication Data

Ferrari, Frank D.

Pelagic copepods of the family Oithonidae (Cyclopoida) from the east coasts of Central and South America

(Smithsonian contributions to zoology ; no. 312)

Bibliography: p.

Supt. of Docs. no.: SI 1.27:312

1. Oithona—Classification. 2. Paroithona—Classification. 3. Crustacea—Classification. 4. Crustacea—South America—Classification. 5. Crustacea—Central America—Classification. 6. Crustacea—Atlantic Ocean—Classification. I. Bowman, Thomas E., joint author. II. Title. III. Series: Smithsonian Institution. Smithsonian contributions to zoology; no. 312. QL1.S54 no. 312 [QL444.C73] 591'.08s [595'.34] 79-607098

Contents

	<i>Page</i>
Introduction	1
Methods	1
Characters	3
Genus <i>Oithona</i> Baird, 1843	4
Subgenus <i>Dioithona</i> (Kiefer), 1935	4
<i>Oithona oculata</i> Farran, 1913	4
Subgenus <i>Oithona</i> Baird, 1843	5
<i>Oithona amazonica</i> Burckhardt, 1912	5
<i>Oithona bjornbergae</i> , new species	9
<i>Oithona decipiens</i> Farran, 1913	10
<i>Oithona fonsecae</i> , new species	11
<i>Oithona hebes</i> Giesbrecht, 1891	13
<i>Oithona nana</i> Giesbrecht, 1892	14
<i>Oithona neotropica</i> Herbst, 1967	15
<i>Oithona plumifera</i> Baird, 1843	17
<i>Oithona setigera</i> Dana, 1853	19
<i>Oithona simplex</i> Farran, 1913	19
<i>Oithona</i> sp. 1	20
<i>Oithona</i> sp. 2	20
Genus <i>Paroithona</i> Farran, 1913	22
<i>Paroithona flemingeri</i> , new species	22
Commentary	22
Literature Cited	26

Pelagic Copepods of the Family Oithonidae (Cyclopoida) from the East Coasts of Central and South America

*Frank D. Ferrari
and Thomas E. Bowman*

Introduction

From 11 June to 18 July 1977, one of us (FDF) accompanied the Scripps Institution of Oceanography RV *Alpha Helix* on a cruise from Belém, Brazil, in the mouth of the Amazon River, along the east coast of Central America to Belize City, Belize. Numerous samples were taken for the Smithsonian Oceanographic Sorting Center (SOSC) in nearshore waters from the *Alpha Helix* or small skiffs working closer to shore. Most zooplankton samples analyzed in this study were taken by hand-towing an open conical net from a small skiff through shallow, subtidal waters. Net velocity was kept low to minimize loss of appendages, spines, and setae of delicate oithonids. In addition to SOSC samples, specimens were studied from *Alpha Helix* Station 5.5 (belonging to Scripps Institution of Oceanography Plankton collection) and NMNH-STRI Stations 55 and 126 (from the Panama Survey conducted by the National Museum of Natural History and the

Smithsonian Tropical Research Institute). Two unusual oithonid males were sorted from RV *Melville* Stations 353 and 359 in the eastern Pacific Ocean. Although collected beyond the strict geographical limits of this study, these specimens are used to illustrate the variation in integumental organ patterns. A list of stations with locality data and general notes is given in Table 1.

We wish to thank Dr. Abraham Fleminger, chief scientist of the cruise, for the opportunity to collect biological samples. We are also especially appreciative of the efforts of Dr. William Overall, Department of Invertebrates of the Museo Goeldii in Belém, without whose help the very valuable samples from the mouth of the Amazon River would not have been collected, and Drs. Meredith Jones, Department of Invertebrate Zoology, National Museum of Natural History, and David Judkins, Brookhaven National Laboratories, for contributing samples and specimens that have added much to our basic knowledge of oithonids. Our special thanks are also extended to Mr. Richard Hammer for reviewing the manuscript.

METHODS.—Plankton samples were fixed initially in 4% formaldehyde buffered with sodium tetraborate. Prior to examination in the labora-

Frank D. Ferrari, Smithsonian Oceanographic Sorting Center, Smithsonian Institution, Washington, D.C., 20560. Thomas E. Bowman, Department of Invertebrate Zoology, National Museum of Natural History, Smithsonian Institution, Washington, D.C., 20560.

TABLE 1.—Station information for all samples studied

STATION	LATITUDE	LONGITUDE	DATE	TIME	DEPTH OF TOW	BOTTOM DEPTH	NOTES
PN-1-260	01° 27.8'S	48° 29.2'W	VI/11/77	17:-19:00	surface	3m	mouth of northern channel of Rio Guama, south of Belem, Brazil
PN-2-260	"	"	"	"	0-8m	8m	same
PN-3-260	"	"	"	"	0-4m	4m	same
PN-5-260	"	"	VI/14/77	08:-11:00	0-4m	4m	mouth of Rio Acara Granda
PN-6-260	"	"	"	"	surface	5m	same
PN-7-260	"	"	"	"	0-15m	15m	same
PN-8-260	"	"	"	"	surface	1m	same
PN-9-260	"	"	"	"	surface	1m	same
PN-11-60	06° 09.2'N	54° 21.5'W	VI/19/77	22:30	0-12m	25m	1km from shore (Surinam)
PN-13-60	10° 41.2'N	63° 14.8'W	VI/22/77	15:-17:00	surface	10m	800m from jetty at harbor of Carupano, Venezuela
PN-14-60	12° 10.2'N	68° 18.2'W	VI/25/77	10:-11:00	0-100m	300m	southern end of Bonaire
ALPHA HELIX St 5.5	"	"	"	"	13:-14:00	surface	?
PN-16-60	12° 30.3'N	70° 02.7'W	VI/26/77	09:-11:00	0-12m	30m	500m south of Oranjestad, Aruba
PN-18-60	"	"	"	"	13:-15:00	surface	?
PN-19-60	08° 54.7'N	77° 41.0'W	VI/29/77	09:-15:00	0-12m	35m	800m east of Isle de Oro in Sasardi Island Group, Bahia Caladonio, Panama
PN-20-60	"	"	"	"	surface	4m	70m south of Isle de Oro; inside tidal front
PN-21-60	"	"	"	"	0-3m	?	large lagoon northwest of Isle de Oro
PN-22-60	"	"	"	"	surface	?	small lagoon west of Isla de Oro
PN-23-60	09° 34.6'N	78° 43.2'W	VI/30/77	09:-11:00	0-4m	4m	small lagoon of Caobos Cay in Hollandes Cays Group between Mayflower Channel and Caribbean Sea, Panama
PN-24-60	09° 32.8'N	78° 59.5'W	VI/30/77	13:-16:00	surface	7m	in freshwater runoff through mangrove in cove opposite San Blas Peninsula, Panama
PN-25-60	"	"	"	"	0-4m	10m	middle of same cove
PN-26-60	"	"	"	"	0-5m	50m	100m north of same cove
PN-27-60	09° 22.4'N	79° 53.4'W	VII/5/77	21:-22:00	surface	?	Cristobal Harbor, Canal Zone, Panama
NMNH-STRI St 126	"	"	XI/15/72	22:00	surface	?	same
PN-29-200	09° 12.8'N	82° 02.7'N	VII/6/77	13:-17:00	surface	18m	between Crawl Cay and Canal del Tigre, outside Laguna Chiriqui, Panama
PN-30-200	"	"	"	"	0-8m	?	in Laguna Chiriqui
PN-32-200	"	"	"	"	0-3m	?	in Crawl Cay Channel
PN-33-200	10° 16.5'N	83° 16.5'W	VII/9/77	19:-19:30	surface	?	1000m south of jetty at Limon, Costa Rica
PN-34-200	11° 59.5'N	83° 40.6'W	VII/10/77	11:-11:30	surface	?	2000m from shore, off Bluefields Nicaragua
PN-35-200	12° 10.0'N	83° 04.1'W	VII/10/77	15:-17:00	surface	4m	60m from northeastern shore of Isla Grande del Maiz
PN-36-200	"	"	"	"	surface	7m	30m from southeastern shore of same island
PN-37-200	14° 29.6'N	83° 12.8'W	VII/11/77	11:-11:30	surface	?	400m from Nicaraguan coast
PN-38-200	14° 34.2'N	82° 58.0'W	"	14:-22:00	0-3m	10m	25m south of Mid Ham Cay, Hamkera
PN-42-200	15° 43.2'N	83° 21.6'W	VII/12/77	08:-11:30	surface	5m	embayment off north bank of channel, Laguna de Caratasca, Honduras
PN-43-200	"	"	"	"	surface	?	75m from sandy beach north of channel mouth
PN-44-200	"	"	"	"	surface	?	400m from sandy beach
PN-45-200	"	"	"	"	surface	?	1000m from sandy beach
PN-46-200	16° 00.0'N	84° 55.0'W	VII/12/77	19:00	surface	?	1500m from eastern shore of Cape Cameroun, Honduras
PN-49-200	16° 04.5'N	87° 59.2'W	VII/14/77	07:-11:00	0-4m	?	150m of southwestern shore of the island of Utila, Honduras
PN-50-200	"	"	"	"	surface	2m	mouth of creek on southwestern shore of Utila
PN-51-200	16° 43.8'N	87° 52.0'W	VII/15/77	08:-11:00	0-8m	15m	100m outside reef crest, southeastern end of Glover's Reef
PN-52-200	"	"	"	"	0-5m	10m	lagoon of Glover's Reef, south of Southwest Cay
PN-55-200	17° 10.0'N	87° 56.1'W	VII/15/77	14:-19:00	0-8m	12m	Turneffe Reef, weather side of southeast corner of reef crest
PN-56-200	"	"	"	"	0-2m	2m	southern end of lagoon, Turneffe Reef
PN-57-200	"	"	"	"	surface	2m	" " " " " "
PN-58-200	"	"	"	"	0-5m	8m	leeward side of Cay Bokel, Turneffe Reef
PN-59-200	"	"	"	"	surface	8m	" " " " " "
PN-62-200	17° 15.0'N	88° 03.0'W	VII/16/77	14:-15:30	surface	?	25m west of Rendezvous Cay, inside Barrier Reef
PN-63-200	"	"	"	"	surface	?	100m east of " " " " " "
PN-64-200	17° 13.2'N	88° 15.5'W	VII/17/77	10:-12:00	0-6m	6m	800m into channel of Southern Lagoon, Belize
PN-65-200	"	"	"	"	0-3m	3m	mouth of channel of Southern Lagoon
PN-66-200	"	"	"	"	surface	3m	" " " " " "
PN-67-200	"	"	"	"	0-5m	?	1000m from mouth of channel
PN-70-200	17° 13.2'N	88° 16.5'W	VII/18/77	09:-10:00	surface	?	500m from mouth of Sibun River, Belize Harbor, Belize
NMNH-STRI St 55	08° 55.2'N	79° 32.3'W	XI/4/71	15:30	surface	?	Naos Pilot Float, Panama Bay, Panama
MELVILLE St 353	15° 51.5'S	76° 25.0'W	IV/23/77	00:22	65m	3100m	
MELVILLE St 359	"	"	"	04:42	20m	3100m	

tory, oithonids were transferred to distilled water and then 70% ethanol, the final preservative. Specimens to be studied with a light microscope were first cleared in lactic acid and then stained with a solution consisting of approximately 1% by weight chlorazol black E dissolved in 70% ethanol (as described in Fleminger, 1973) added to lactic acid. The amount of stain added and time of exposure (15–60 minutes) varied depending upon the species and condition after preservation. All staining was carefully monitored. When prepared in this manner, many details of oithonid external morphology could be examined and compared prior to dissection. Drawings were made with the aid of a camera lucida; for most appendages an oil immersion lens was used. Type material is deposited in the National Museum of Natural History (NMNH) under the collection numbers of the former United States National Museum (USNM).

Females and males of some abundant species were studied with a scanning electron microscope (SEM) to better understand several characters used in differentiating various species. Specimens in 70% ethanol/30% water were brought through baths of 80%/20% and 90%/10% to 100% ethanol. From this solution they were transferred through two dilutions, 66% ethanol/33% amyl acetate and 33%/66% to 100% amyl acetate, the transition fluid for critical point drying. Standard critical point drying techniques were used to prepare specimens for gold coating prior to SEM examination.

Results of preparation by this procedure were not particularly encouraging. The thin cuticle of species of Oithonidae was easily wrinkled during this preparation, giving a distorted perspective when studied with the SEM. Thus we were never sure how much information was lost during preparation, which made interpretation of detail more difficult. Nevertheless some of the better micrographs are presented. As would be expected examination of the cuticle of oithonids with the SEM reveals a whole series of new morphological structures. Generally we confine our comments to those structures that can be observed with the

light microscope and of whose systematic value we have some appreciation.

The following abbreviations are used in the text and illustrations:

Pr	prosome
Cph	cephalosome
Pg	pediger
Ur	urosome
CR	caudal ramus
A1	first antenna
A2	second antenna
Md	mandible
Mx1	first maxilla
Mx2	second maxilla
Mxp	maxilliped
P	swimming leg
B	basipod
Re	exopod
Ri	endopod
Se	external seta or spine
Si	internal seta or spine
St	terminal seta or spine

CHARACTERS.—The important characters traditionally used to differentiate species within the family Oithonidae are armature and development of the Md and Mx1, shape of the rostrum and CR, and number of Se and ReP1–4. Definitive description of a species has been based on the anatomy of the female. Males have presented difficulties due to the sexual dimorphism in the above-mentioned characters, particularly the rostrum, shape of CR, Se on ReP1–4, and in some cases the armature of B2Md. Among small oithonid species sexual dimorphism in size is not pronounced; males and females are often collected in plankton nets with small mesh widths. As species increase in size, sexual dimorphism in size becomes more pronounced (Giesbrecht, 1892). Thus large females are often collected with standard plankton nets, while the conspecific smaller males are lost through the larger mesh widths of these nets. Matching males with females has often depended solely on cooccurrences in samples (Rosendorn, 1917); this method is especially unreliable when sexual dimorphism in size is pronounced.

In addition to the above-mentioned characters we will emphasize several others that have been

found particularly useful in previous studies. The RiP4 of the female may possess one to three setae modified from the usual plumose condition. The number and extent of the modification have been used in a few species descriptions (Giesbrecht, 1892; González and Bowman, 1965; Wellershaus, 1969; Bowman, 1975; Ferrari, 1977; and Fonseca & Björnberg, 1977). These modified setae seem less fragile than plumose setae and are often present when tips of the others have been broken. The modifications involve the thickness, curvature, and presence of a distal flange. The specific differences, pronounced in many species, are often obscure in those that exhibit a great degree of overall morphological similarity. The armature of the knob on the genital segment near the female genital opening has also proven to be of taxonomic value; hence, illustrations of the female urosome are presented in lateral view. Ornamentation of other urosome segments, although not developed in all species, is also useful. The pattern of tiny hairs on B1 and 2 of P4 often shows distinct differences between species. However, because these hairs are easily broken off or lost in preparation and the patterns difficult to see even in the best stained specimens, we have not emphasized their usefulness in our descriptions.

Male animals continue to present problems. The presence and shape of the lateral flap of the Cph and the accompanying pattern and number of integumental organs are useful in differentiating males (Ferrari, 1977). The flap appears as a thin, almost transparent, extension of the Cph. It may extend over Pg1 or Pg1 and 2. The articulations of the Pg's can be seen beneath the flap although these articulations are not shown in our drawings of the organ patterns. The flap is apparently not attached to the Pg's. A general impression of the integumental organ pattern (hereafter referred to as the "pore signature" of Mauchline and Nemoto, 1977; "pore signature pattern" of Fleminger, 1977, seems redundant) can be observed in lateral view of a carefully stained male. Dissection of the Cph and flap allows a more exact mapping of position and number of organs. Separation of males of other-

wise morphologically similar species is still difficult; we have not had enough material to do a thorough analysis of variation within any one species or between two similar species. The armature of the mouthparts, especially Ri and Re of Md and Mx1, are difficult to study because they are easily broken or missed during dissection and examination but remain important in matching males with females.

We initially felt the structure of the geniculate A1 would also be useful in differentiating males; however, studies with the light microscope and SEM have not proved useful. Telescoping of segments at the proximal geniculation prevents a clear interpretation of the number, size, or armature of the segments. In addition, the segments are seldom fixed in a consistent alignment, permitting accurate comparison between them.

Genus *Oithona* Baird, 1843

Subgenus *Dioithona* (Kiefer), 1935

***Oithona oculata* Farran, 1913**

FIGURES 1, 15a

Oithona oculata Farran, 1913:188-189, pl. 30: figs. 8-10; pl. 31: figs. 2, 3.—González and Bowman, 1965:273-274, fig. 20*h*, *i*.—Nishida et al., 1977:139-140, fig. 13.

MATERIAL.—Numerous ♀♀ and ♂♂ from PN-13-60, PN-18-60, PN-32-200, PN-35-200, PN-50-200, PN-55-200, PN-58-200, and PN-59-200.

FEMALES.—Length range (30 specimens) 0.61-0.80 mm; Pr/Ur-1.6. Ri2P4 (Figure 1*a*) with both setae modified, slightly curved toward their tips; proximal seta with serrate flange on distal 1/3 of medial edge; distal seta with serrate flange on distal 1/4. Ri3P4 proximal seta similarly modified with serrate flange on distal 1/6. Knob near genital opening (Figure 1*b*) armed with anterodorsally curved spine, bearing tiny distinct teeth on posterior margin; below this spine a small point.

MALES.—Length range (30 specimens) 0.59-0.70 mm; Pr/Ur-1.5. Cph in lateral view (Figure 1*d*) produced into a small triangular extension near posterior ventral edge. Extension not homologous to flap previously described for *O. dissimilis* and *O. hebes* (Ferrari, 1977) or those of

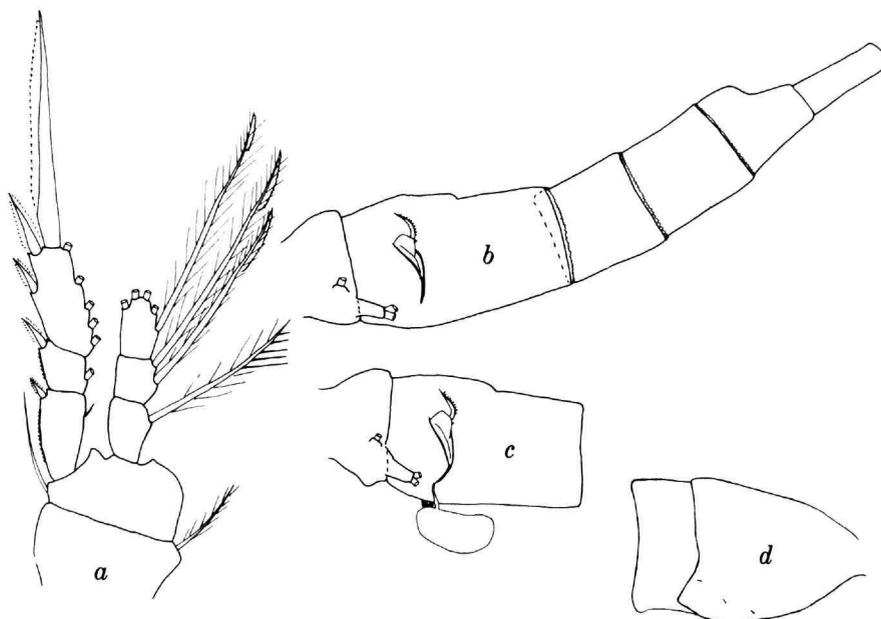


FIGURE 1.—*Oithona oculata*, ♀: *a*, P4; *b*, Ur, lateral; *c*, Ur1 and 2, lateral, with spermatophore. ♂: *d*, Cph, lateral.

other oithonids in this paper; in these species posterior edge of Cph visible beneath translucent flap. Cph with a few integumental organs scattered over the lateral surface but not placed in a distinctive pattern. Organs (Figure 15*a*) with form of shallow pore without thickened peripheral ridge; small hair arises from the center of pore. Cph pitted with slight circular depressions, smaller in diameter than pore.

REMARKS.—Specimens of *O. oculata* agree with recent description by González and Bowman (1965). The dorsal ridge, which they describe on the female genital segment, is depicted in lateral view as a simple notch along the dorsal edge of the segment. Two kidney-shaped spermatophores were attached to several females and have helped in understanding features of the genital segment. As in females of the family Cyclopidae, the spermatophores are attached ventrally on the genital segment with an adhesive substance on the anterodorsal edge of the spermatophore (Figure 1*d*). A small tubule passes dorsally from the spermatophore. We have not yet identified the genital opening in any oithonid. It may be located near

the termination of the spermatophore tube, but it appears that the tubule empties instead into a sulcus or groove formed by two ridges of the integument. The ridges, depicted by heavy lines in Figure 1*b, c*, extend dorsally on each side of the armed knob of the genital segment. The position of the ridges, one to the other, appears to vary slightly and these changes can occasionally produce various stress lines on the cuticle. We attempted to study this area under SEM but the integument folded and buckled during preparation.

Subgenus *Oithona* Baird, 1843

Oithona amazonica Burckhardt, 1912

FIGURE 2

Oithona amazonica Burckhardt, 1912:726; 1913:422, p1. 15p: figs. 6-22; p1. 15q: figs. 2, 3; p1. 16r: figs. 2-4, 7-9, 11, 12; p1. 16s: figs. 1, 3-8, 17.

Oithona amazonica continentalis Lindberg, 1954:193-195, fig. 1.

MATERIAL.—3 ♀♀ and 3 ♂♂ from PN-8-260.

FEMALE.—Lengths 0.61, 0.60, 0.60 mm; Pr/Ur-1.3, 1.3, 1.4. ReP1 (Figure 2*e*) with 1-1-3 Se.

St Re3P1 seta-like (see "Remarks"); Se ReP2 1-1-3, ReP3 1-1-1, and ReP4 0-0-1; St Re3P2-4 well developed. Ri2P4 with both setae unmodified; Ri3P4 proximal seta straight, slightly thickened, with serrate flange on distal $\frac{2}{3}$ of medial edge (Figure 2*h*). Knob near genital opening armed with a minute, slender spine (Figure 2*b*).

MALE.—Length of specimens 0.57, 0.56, 0.55 mm; Pr/Ur-1.7, 1.5, 1.6. Se ReP1 1-1-3 (Figure 2*k*); Se ReP2-4: 1-1-3, 1-1-1, 0-0-1; St Re3P1-4 well developed; Ri3P4 proximal seta not modified. Cph and flap (Figure 2*j*) not dissected from specimens. Pore signature similar to *hebes/fonsecae* pattern (described under *O. fonsecae*) but with distinct hiatus between dorsal horizontal row and 2 anterior columns of organs making up anterodorsal cluster. In *O. hebes* and *O. fonsecae* longitudinal row proceeds into and is continuous with anterodorsal cluster.

REMARKS.—A fundamental difficulty with the female of this species is the armature of ReP1. Generally species of *Oithona* bear either a seta, often reduced, or a series of hairs on the inner margin of Re1; Re2 bears a well-developed plumose seta; Re3 usually bears four internal plumose setae, the distalmost in juxtaposition to the terminal spine. Se on these segments are not as stiff as those on the other swimming legs. Each Se is ornamented on both sides with a hyaline membrane, often reduced, whose outer edge is serrate. Distally it continues as a flexible whiplike extension, unique to P1. St of Re3 is a distinctively thickened, rigid structure with a well-developed, serrate, hyaline membrane on its lateral edge. The medial edge may be naked or plumose along most or all of its length. By convention, St is omitted from counts of the external spines although in some earlier accounts it was included.

Our specimens agree in most respects (e.g., length range, armature of Md and P2-4) with *O. amazonica*, first described by Burckhardt in 1912 and described and illustrated by him in 1913. However, St of Re3P1 looks like the other four Si; the lateral membrane is absent and both margins are plumose. The distal Se is longer than the two proximal Se. Burckhardt's (1913) draw-

ing shows two Se on Re3P1, which he records, and distally a longer spine in a more terminal position, which he obviously considered the St. He states that the proximal of the three Se of Re3 is absent. However, Burckhardt makes no particular note of the number of Si on Re3; these are not illustrated. If there were five, then his St would correspond to the third and distal, Se, the true St, as in our specimens, being replaced by a seta. If there were only four Si, his interpretation of the armature would be fundamentally correct and the morphological differences would warrant a new name for our specimens. We have also noted, incidentally, that Burckhardt's (1913) identification of his illustrations corresponds to the citations in the text, but the letters and numerals on the illustrations themselves are discordant; figures 13 J, K, and L should read as 13 K, L, and M; 14 M and N as 14 N and O; 15 O and P as 15 P and Q; 16 Q and R as 16 R and S; 17 S and T as 17 U and V.

Lindberg (1954) based his subspecies, *O. amazonica continentalis*, from Rio Negro near Manaus, on the replacement of all Se on ReP1 by setae. If such major differences occur in the armature of this appendage, his subspecies should be recognized as a new species. Lindberg's illustration of P1, like Burckhardt's, is difficult to interpret. The Se are drawn as setae. However, these structures, with their whiplike extensions and often reduced hyaline membranes, might have been mistaken for setae by Lindberg.

Without a more thorough survey of the lower Amazon River basin, it is difficult to determine if the above-discussed specimens belong to three distinct species or to the same species originally described by Burckhardt. Certainly the diversity and complexity of oithonid species in the mouths of large tropical rivers may be much greater than has been realized to date. With the discovery of the new species described below, there are at least three species in the east coast drainages of South America, *O. gessneri* Kiefer, 1954 (described twice by Kiefer, 1954, 1956), from the Orinoco River and *O. amazonica* and *O. bjornbergae* from the Amazon River.

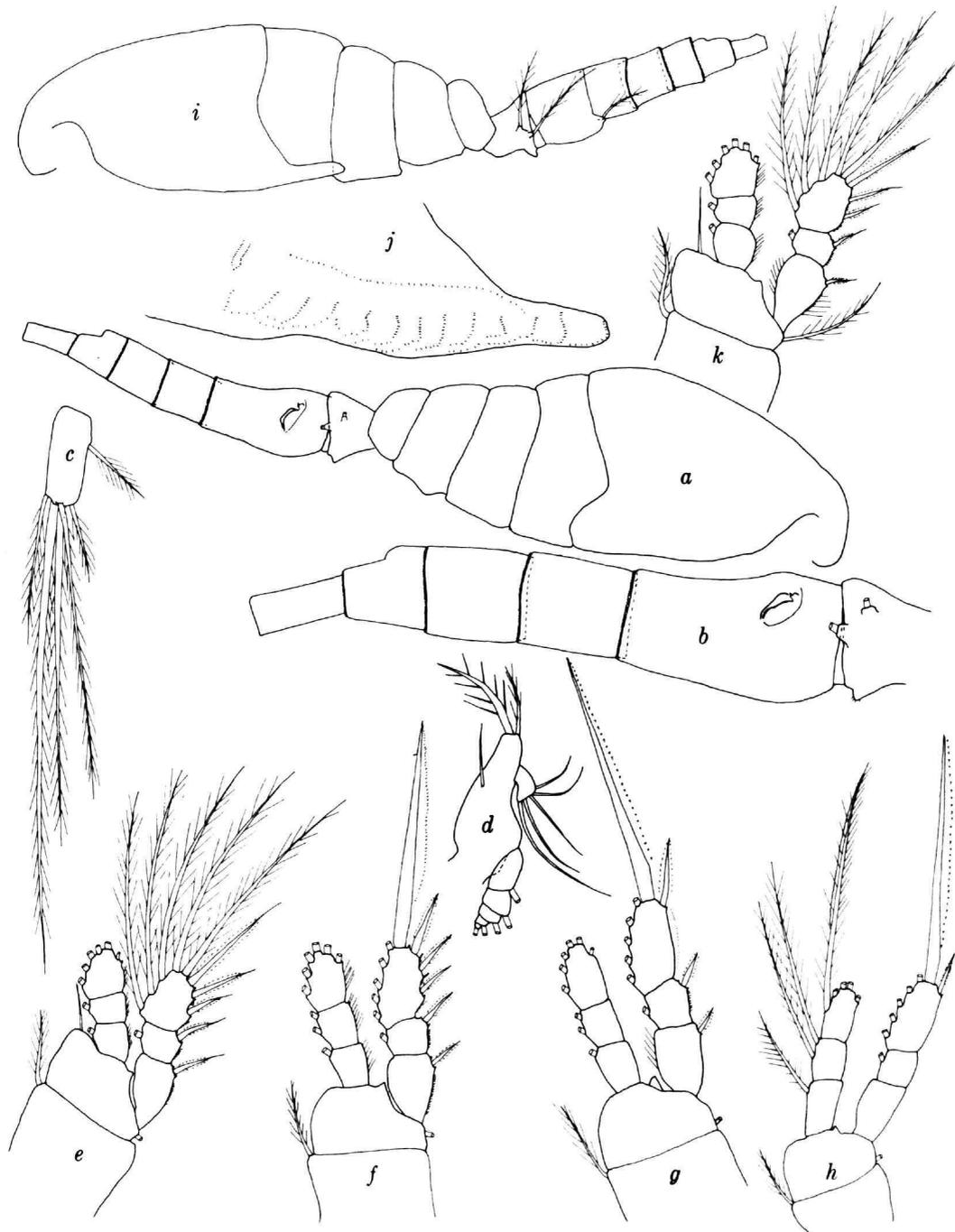


FIGURE 2.—*Oithona amazonica*, ♀: *a*, habitus, lateral; *b*, Ur, lateral; *c*, CR, dorsal; *d*, Md; *e*, P1; *f*, P2; *g*, P3; *h*, P4. ♂: *i*, habitus, lateral; *j*, Cph and flap; *k*, Pl.



FIGURE 3.—*Oithona bjornbergae*, ♀: *a*, habitus, lateral; *b*, anterior part of head, dorsal; *c*, Ur, lateral; *d*, Ur2-4, ventral; *e*, CR, dorsal; *f*, A1; *g*, A2; *h*, Md; *i*, Mx1; *j*, Mx2; *k*, Mxp; *l*, P1; *m*, P2; *n*, P3; *o*, P4.

Oithona bjornbergae, new species

FIGURES 3, 4

Material.—Numerous ♀♀ and ♂♂ from PN-1-60, PN-5-60, PN-6-60, PN-7-60, and PN-8-60.

FEMALE.—Length range (30 specimens) 0.44–0.51 mm; Pr/Ur–1.4. Head rounded in dorsal view; rostrum absent (Figure 3a). Ur2–4 fringed on posterolateral margin; Ur2 and 3 with 1 transverse row of minute hairs on ventral surface near posterior margin (Figure 3d); Ur4 with 2 rows. CR length 2 times width; apical seta 2 and 3 thickened, with shorter, more dense plumes than other setae, (Figure 3e). A1 and 2 similar to other species of *Oithona*. B2Md (Figure 3h) with 2 thick, curved spines of equal length, bearing fine spinules; Ri with 4 plumose setae; Re 4-segmented with 4 setae. B2Mx1 (Figure 3i) with 2 thin spines bearing thick spinules; Ri absent; Re with 3 setae. Mx2 and Mxp as in Figure 3j, k; Se ReP1–4: 1–1–2, 1–1–2, 0–1–1, 0–0–1; Si Re1P1 absent. Both

setae on Ri2P4 and proximal seta on Ri3P4 modified; all straight; proximal seta of Ri2 with small serrate flange on distal $\frac{1}{6}$; flange well developed on distal $\frac{1}{3}$ of distal seta of Ri; proximal seta of Ri3 slightly thicker than others with flange on distal $\frac{1}{3}$. Knob near genital opening armed with a small spine (Figure 3c).

MALE.—Length range (30 specimens) 0.41–0.48 mm; Pr/Ur–1.4. Head rounded dorsally, laterally slightly more acuminate than female (Figure 4a). As in *O. oculata*, Cph with triangular extension posteriorly toward ventral margin. Articulation along dorsal part of triangle poorly developed as shown by broken line in Figure 4a and thinner line in Figure 4b. Cph with few unorganized sensory hairs and pores, which differ in structure from those of pore signature in most oithonids. Ur3–6 fringed on posterior edge; Ur3 and 4 with 1 transverse row of minute hairs on ventral surface near posterior margin; Ur5 with 2 rows (Figure 4d). All apical spines and dorsal

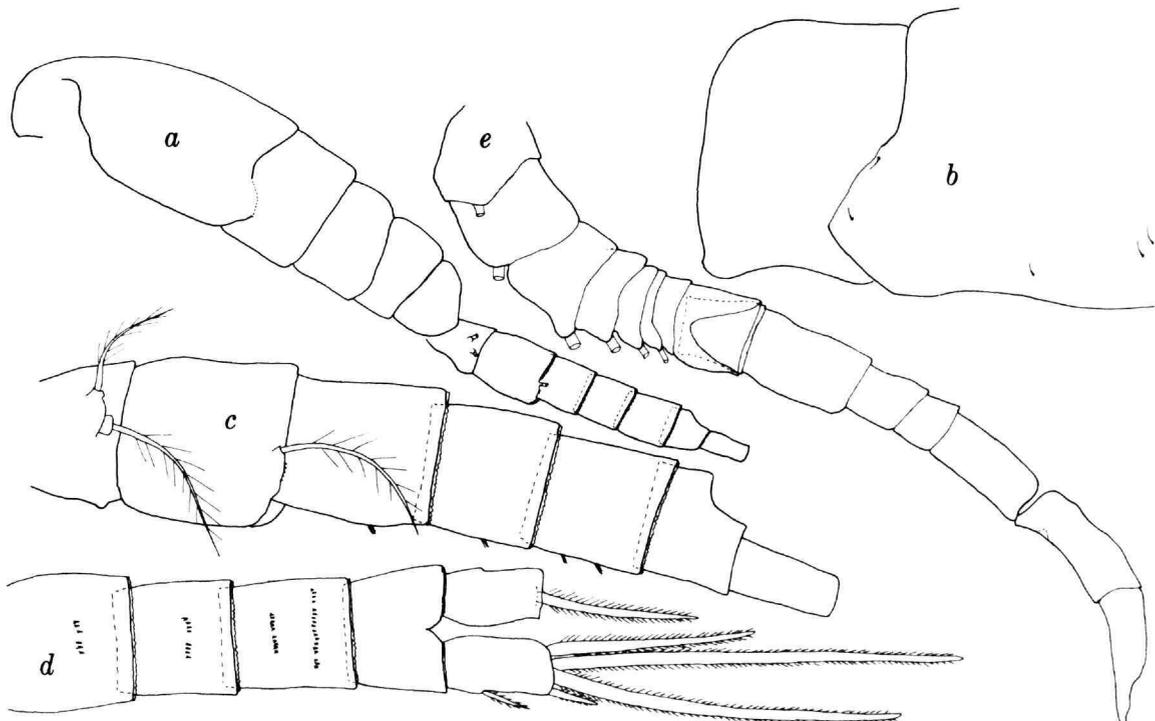


FIGURE 4.—*Oithona bjornbergae*, ♂: a, habitus, lateral; b, Cph, lateral; c, Ur, lateral; d, Ur3–6 and CR, ventral; e, A1.

spine of CR thickened. Genital flap with 1 large seta; below it several tiny toothlike spines. A1 as in Figure 4e; remaining appendages similar to female except Ri2 and 3P4, which lack modified setae.

REMARKS.—The spine count of ReP1–4 of *O. bjornbergae* is identical to that of only one other oithonid, *O. gessneri* Kiefer, 1954. Kiefer twice described this as a new species (1954, 1956) from female specimens. In neither publication were the mouthparts or modified setae on Ri2 and 3P4 described. Although the size (0.5 mm) of the single specimen of *O. gessneri* reported in 1954 is comparable to that of *O. bjornbergae*, the latter females can be readily separated by the middle two thickened apical setae on the CR and the transverse rows of tiny hairs ventrally on Ur2–4. Kiefer reports (1954) and illustrates (1956) tiny hairs ventrally on the posterior margin of Ur3–5. In Kiefer (1956), at the bottom of page 262, exopod 1 is identified as exopod 2.

Oithona gessneri was collected in a lagoon of the Orinoco River near Barrancas, Venezuela; *O. bjornbergae* was found in the flowing waters of the Rio Guama and Rio Acara Granda of the Amazon River drainage. Without further survey it is impossible to determine whether these species are isolated in separate drainages, separated simply

by habitat (flowing or standing waters), or cooccur.

ETYMOLOGY.—This species is named for Dr. Tagea K. S. Björnberg, Brazilian carcinologist, who has contributed to our understanding of many copepods, including the oithonids.

TYPE MATERIAL.—Female holotype (USNM 172183), 37 ♀ and 28 ♂ paratypes (USNM 172184, 172185) from PN-7-260, 01°27.8'S, 48°29.2'W, mouth of Rio Araca Granda, Para, Brazil; 11 Jun 1977.

Oithona decipiens Farran, 1913

FIGURE 5

Oithona decipiens Farran, 1913:184–185, pl. 28: figs. 4–11.—Kiefer, 1929:7.—Mori, 1937:111, pl. 61: figs. 9–14.—Chen et al., 1974:32, pl. 2: figs. 1–5.—Nishida et al., 1977:183–184, fig. 7.

MATERIAL.—34 ♀♀ from PN-13-60.

FEMALE.—Length range 0.60–0.72 mm. Knob near genital opening armed with a single, thick, curved spine, toothed on posterior edge (Figure 5a). Ri2P4 both setae modified (Figure 5b), slightly curved; distal thicker than proximal, with more well-developed flange on distal $\frac{1}{3}$; proximal with flange on distal $\frac{1}{4}$. Ri3P4 proximal setae thickened with flange on distal $\frac{1}{3}$.

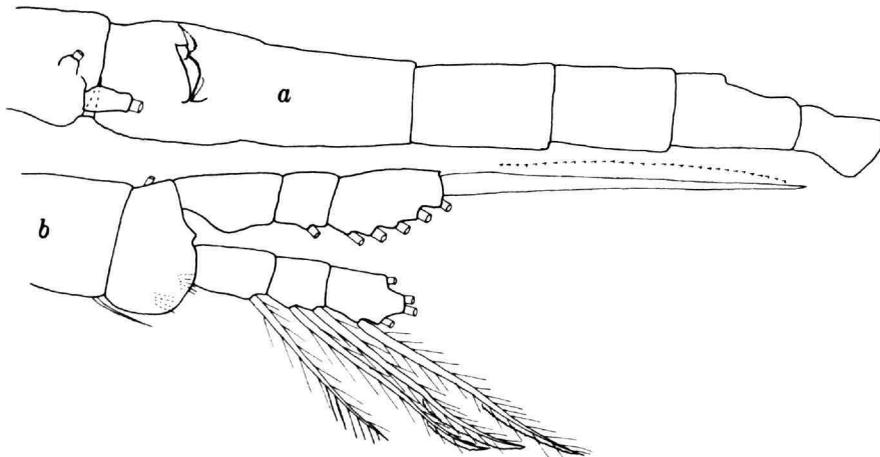


FIGURE 5.—*Oithona decipiens*, ♀: a, Ur, lateral; b, P4.

REMARKS.—Our specimens agree with those described and illustrated by Farran (1913). Nishida et al. (1977) report some specimens with 0–0–1 Se on ReP4. For reasons that will be presented in the discussion section, we agree with Kiefer (1956) that variation in spine number is important in separating species. A more extensive survey of the area around Sagami Bay should be made in order to resolve the reported variation.

Oithona fONSECAE, new species

FIGURE 6

Material.—5 ♀♀ from PN-11-60, 31 ♀♀ and 37 ♂♂ from PN-23-60, 1 ♀ from PN-43-200, and 8 ♀♀ from PN-70-200.

FEMALE.—Length range 0.49–0.60 mm; Pr/Ur–1.4. Head rounded in dorsal and lateral views (Figure 6a, b). Pg4 with tiny hairs along postero-lateral border. Ur1 (Figure 6d) dorsal surface with 2 long central hairs followed by a long transverse row of smaller hairs, roughly U-shaped; posterior and lateral to this row, 2 rows separated by a gap at midwidth. CR length 3 times width. B2Md (Figure 6f) with 2 thick, slightly curved spines bearing small spinules; Re 5-segmented with 5 setae; Ri with 5 setae, lateralmost plumose; 1 small setae arising near base of Ri. RiMx1 (Figure 6g) with 3 setae, 1 arising near base; B2Mx1 with 3 spines, 2 with long marginal spinules. Se ReP1–4: 1–1–3, 1–1–3, 1–1–3, 1–1–2; Re1P1 with 1 Si. Ri2P4 proximal seta slender, without flange; distal seta much thicker, slightly curved with well-developed flange on distal $\frac{1}{3}$; Ri3P4 proximal seta longer and thinner than distal setae of Ri2, curvature less pronounced, flange on distal $\frac{1}{4}$. P5 with small seta near base. Knob near genital opening with spine curved dorsally, ventral to this a second smaller spine (Figure 6c).

MALE.—Length range 0.49–0.51 mm; Pr/Ur–1.5. Head slightly more truncate than female in dorsal view, laterally rounded; rostrum absent. Flap of Cph tongue-shaped, reaching slightly beyond Pg1. Pore signature (Figure 6k) similar to

that of *O. hebes*; anterodorsal cluster of 2 oblique columns; followed posteriorly by long horizontal row; ventral to horizontal row, 11 columns, the last on Cph flap. Ventrally each column continues anteriorly as a horizontal series of organs; the first 2 columns appear continuous through a horizontal series. In addition to 11th (last) column, Cph flap has several peripheral organs and 2 smaller oblique rows extending from dorsal edge of flap. CR length 2 times width. B2Md (Figure 6n) with 2 spines; much thinner than on female, 1 naked, other ornamented with thicker, longer spinules than in female. Remaining aspects of Md and Mx1 similar to female, although slightly reduced. Armature of P1–4 as in female except Si Ri2 and 3P4 not modified. P5 with reduced seta at base. Genital flap with 1 long plumose seta and reduced seta ventral to it.

REMARKS.—Several small species of *Oithona*, which inhabit the eastern tropical coastal waters of South America, have been described with the same number of Se on ReP1–4: *O. hebes* Giesbrecht, 1891; *O. ovalis* Herbst, 1955; *O. neotropica* Herbst, 1967; *O. oligohalina* Fonseca and Björnberg, 1977; and this new species. Females of all except *O. ovalis* and *O. oligohalina* were collected during this study; males of only *O. fONSECAE* and *O. hebes* were collected. Characters helpful in separating females of *O. fONSECAE* are the rounded shape of head in lateral view; five setae on RiMd and the reduced seta at the base of RiMd; slight differences in modified setae of Ri2 and 3P4; hairs on posterior edge of Pg4 and Ur1; armature of knob near genital opening; length/wide ratio of CR. Males of *O. fONSECAE* can be separated from *O. hebes* by the five setae on RiMd and the reduced seta at its base.

ETYMOLOGY.—This species is named for Dr. Vera Lucia Fonseca, Brazilian carcinologist, in recognition of her work on habitat partition by closely related species of *Oithona*.

TYPE MATERIAL.—Female holotype (USNM 172186), 27 ♀ and 31 ♂ paratypes (USNM 172187, 172188) from PN-23-60, 09° 34.6'N, 78° 59.5'W, in small lagoon of Caobos Cay in Hollandes Cay Group, between Mayflower Channel and Caribbean Sea, Panama, 30 Jun 1977.

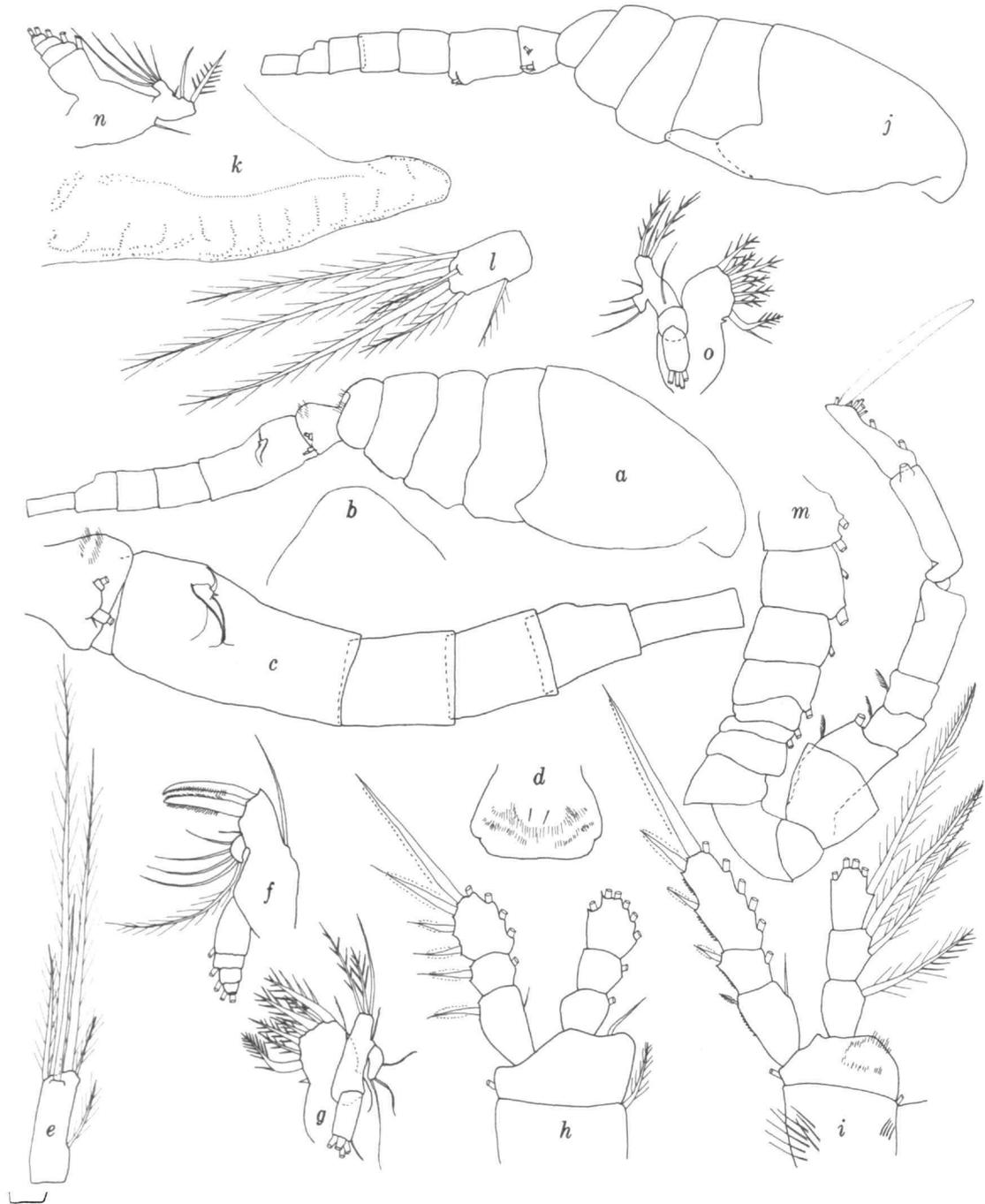


FIGURE 6.—*Oithona fonsecae*, ♀: *a*, habitus, lateral; *b*, anterior part of head, dorsal; *c*, Ur, lateral; *d*, Ur1, dorsal; *e*, CR, dorsal; *f*, Md; *g*, Mx1; *h*, P1; *i*, P4. ♂: *j*, habitus, lateral; *k*, Cph and flap; *l*, CR, dorsal; *m*, A1; *n*, Md; *o*, Mx1.

Oithona hebes Giesbrecht, 1891

FIGURES 7, 15

Oithona hebes Giesbrecht, 1891:475.—Ferrari, 1977:406–407, figs. 3C–D, 4, 5.

MATERIAL.—♀♀ and ♂♂ from PN-11-60, PN-13-60, PN-19-60, PN-21-60, PN-27-60, PN-32-200, PN-33-200, PN-43-200, PN-46-200, PN-65-200, PN-65-200, PN-67-200, PN-70-200, NMNH-STRI Sta 55, and NMNH-STRI Sta 126.

REMARKS.—*Oithona hebes* has been redescribed from specimens from the type-locality, the Gulf of Guayaquil (Ferrari, 1977). We present here several points not mentioned in that study, but which agree with specimens reexamined from Guayaquil, the Pacific coast of Panama, as well as those from the east coast of Central America. Head of female distinctly quadrate in lateral view (Figure 7a). Distal seta of Ri2P4 (Figure 7c) thicker than proximal seta of Ri3P4 but not so great a difference as shown in Figure 3D of Ferrari (1977). P5 with reduced seta at base (Figure 7b). Knob near genital opening with a single well-developed spine, not a small point. Male P5 with reduced seta at its base. A more complete illustration of the pore signature from the dissected Cph

and flap is shown here (Figure 7d). Previous illustrations (Ferrari, 1977) were made from the entire animal. The major features of the pore signature (anterodorsal cluster, horizontal row, 11 vertical columns ventrally, each extended anteriorly by a horizontal series, peripheral organs, and two oblique rows on cephalosomal flap) agree very closely with *O. fonsecae* males.

Figure 15b–e shows SEM micrographs of parts of *O. hebes* pore signature. In Figure 15b (left side) the anterodorsal cluster is shown in the center of the field. The integument has cracked along the dorsal horizontal row (to the left) although the first few organs of that row can be seen. Ventrally the integument has curled and only the top organs of the columns can be seen.

Figure 15c is a view of the anterodorsal cluster. Each integumental organ consists of a pore, guarded on one side by a thin ridge. The relief of this ridge appears variable for those organs in the cluster. It is this ridge that is visible under the light microscope. Short hairs can be seen associated with most ridges under the light microscope, although they are absent in the micrograph. Figure 15d, badly distorted due to buckling, is the

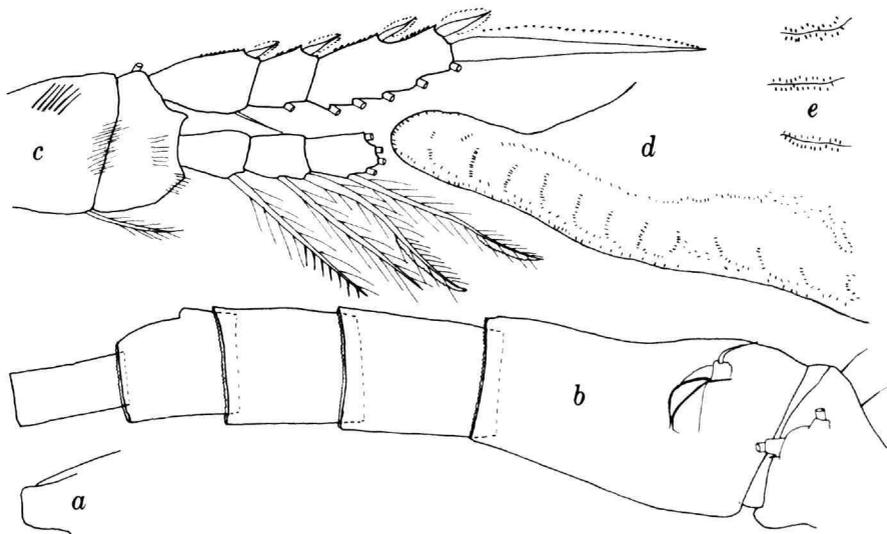


FIGURE 7.—*Oithona hebes*, ♀: a, anterior part of head, lateral; b, Ur, lateral; c, P4. ♂: d, Cph and flap; e, anterodorsal pore signature clusters from left sides of 3 other specimens.

right side of another male. Organs of the anterodorsal cluster are visible in the top right corner; the dorsal horizontal row passes obliquely toward the lower left corner. These pores also seem to have distinct ridges associated with them. In the center are several columns that extend into horizontal series. Figure 15*e* is another view of the conjunction of column to horizontal series. Distinct ridges also appear to be associated with the pores of columns. In contrast, the pores of horizontal series are surrounded by slightly thickened integument.

Variation in the pore signature can be noted in specimens examined with the light microscope. We have not had enough specimens, however, to study differences between inter- and intraspecific variation. For this reason we have not been able to find consistent differences between the pore signature of *O. fonsecae* and *O. hebes*. Figure 7*e* shows the anterodorsal cluster from the left side of three specimens of *O. hebes* from PN-27-60. A line has been drawn to separate the two oblique rows composing each cluster. Not only do the positions of the organs shift, relative to one another, but in the third cluster there are 10 organs in the upper row and 12 in the lower; these counts on the other two specimens are 11/12. Besides *O. hebes*, *O. nana* and *O. simplex* were the only other species collected at this station. Because their pore signatures are distinctly different, we have not confused several species in this case. Before males of *O. hebes* and *O. fonsecae* can be separated, information from series of specimens of both species throughout their ranges must be obtained and a thorough study of intraspecific variation undertaken.

Oithona nana Giesbrecht, 1892

FIGURE 8

Oithona nana Giesbrecht, 1892:538-546, pl. 34: figs. 10-11, 20, 24, 26, 34, 35, 42; pl. 44: figs. 2, 4, 6.—González and Bowman 1965:272, fig. 20*c-g*.—Nishida et al., 1977:138-139, figs. 11, 12.

MATERIAL.—♀ and ♂ from PN-11-60, PN-13-60, PN-18-60, PN-20-60, PN-21-60, PN-23-60, PN-25-60, PN-26-60,

PN-27-60, PN-29-200, PN-30-200, PN-32-200, PN-33-200, PN-34-200, PN-35-200, PN-36-200, PN-37-200, PN-38-200, PN-43-200, PN-44-200, PN-45-200, PN-46-200, PN-49-200, PN-55-200, PN-56-200, PN-57-200, PN-58-200, PN-59-200, PN-62-200, PN-64-200, PN-65-200, PN-67-200, PN-70-200, *Alpha Helix* Sta 5.5, and NMNH-STRI Sta 126.

FEMALES.—Length range (30 specimens) 0.58–0.72 mm; Pr/Ur-1.1. Ri1P4 (Figure 8*c*) with a distinct row of 4 long spines; *O. nana* is the only species encountered with surface armature on RiP1-4. Ri2P4 (Figure 8*c*) with both setae modified; neither seta strongly curved, both with flange on distal $\frac{3}{5}$; Ri3P4 proximal seta similar, with flange on distal $\frac{3}{5}$. P5 elongate, with several long hairs dorsal to it on posterior margin of Ur1. Knob near genital opening armed with short, thick spine and longer seta.

MALE.—Length range (30 specimens) 0.47–0.53 mm; Pr/Ur-1.3. Flap of Cph (Figure 8*e*) relatively broader and shorter than in *O. hebes* and *O. fonsecae*; it reaches middle of Pg1. Pore signature significantly different; anterodorsal cluster roughly circular; posterior to this a poorly defined horizontal group of organs usually followed by 5 distinct columns. Ventral organs of columns also appear as continuation of horizontal group. Cph flap with less distinct series of columns much more closely spaced. Below horizontal group an area devoid of organs and ventral to this, a group of poorly organized organs along ventral part of Cph and flap.

Intraspecific variation in the pore signature has been observed in this species. In another specimen, on the right side, organs in the horizontal group anterior to the 5 distinct columns appear organized into a smaller 6th column (Figure 8*f, g*). This new column simply may have resulted from shifting in position of the organs; such shifting has been noted in *O. hebes*. On the right side of a 3rd specimen, a distinct gap behind a horizontal group was followed by only 4 columns; on left side gap was absent and 6 columns were present (Figure 8*h, i*).

REMARKS.—*Oithona nana* has been described numerous times; recent useful accounts are González and Bowman (1965) and Nishida et al. (1977).

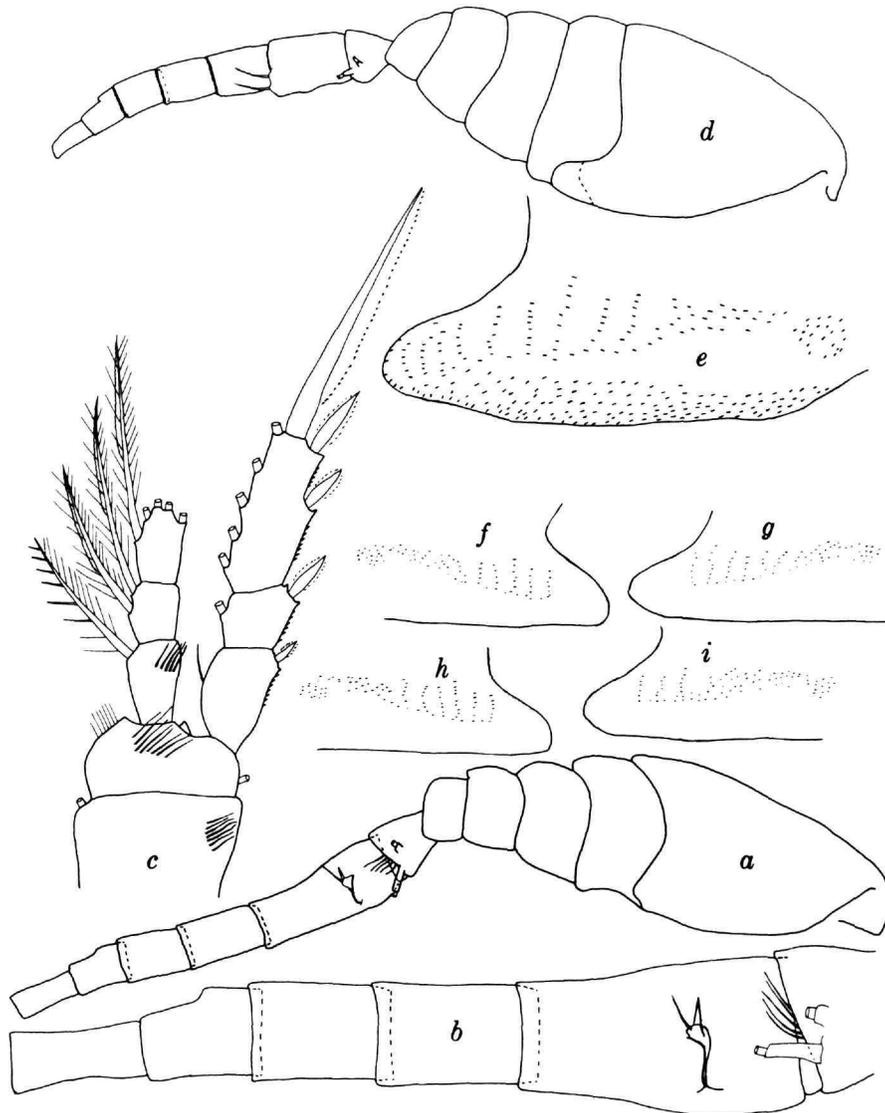


FIGURE 8.—*Oithona nana*, ♀: a, habitus, lateral; b, Ur, lateral; c, P4. ♂: d, habitus, lateral; e, Cph and flap; f-g, left and right pore signatures of second ♂; h-i, same of third ♂.

***Oithona neotropica* Herbst, 1967**

FIGURE 9

Oithona neotropica Herbst, 1967:96-101, figs. 1-12.
 [?] *Oithona oligohalina* Fonseca and Björnberg, 1977:127-131,
 figs. 1-4.

MATERIAL.—6 ♀♀ from PN-13-60 and 2 ♀♀ from PN-43-200.

FEMALE.—Length range 0.56-0.64 mm; Pr/Ur-1.3. Head broadly pointed dorsally, laterally distinctly quadrate; rostrum absent (Figure 9a, b). Pg4 with hairs on posterior border. CR length 3 times width. B2Md (Figure 9d) with 2 slightly curved, robust spines bearing tiny spinules; Ri with 5 setae. Ri3P4 distal seta thickened, slightly curved, with flange on distal ½; Ri3P4 proximal

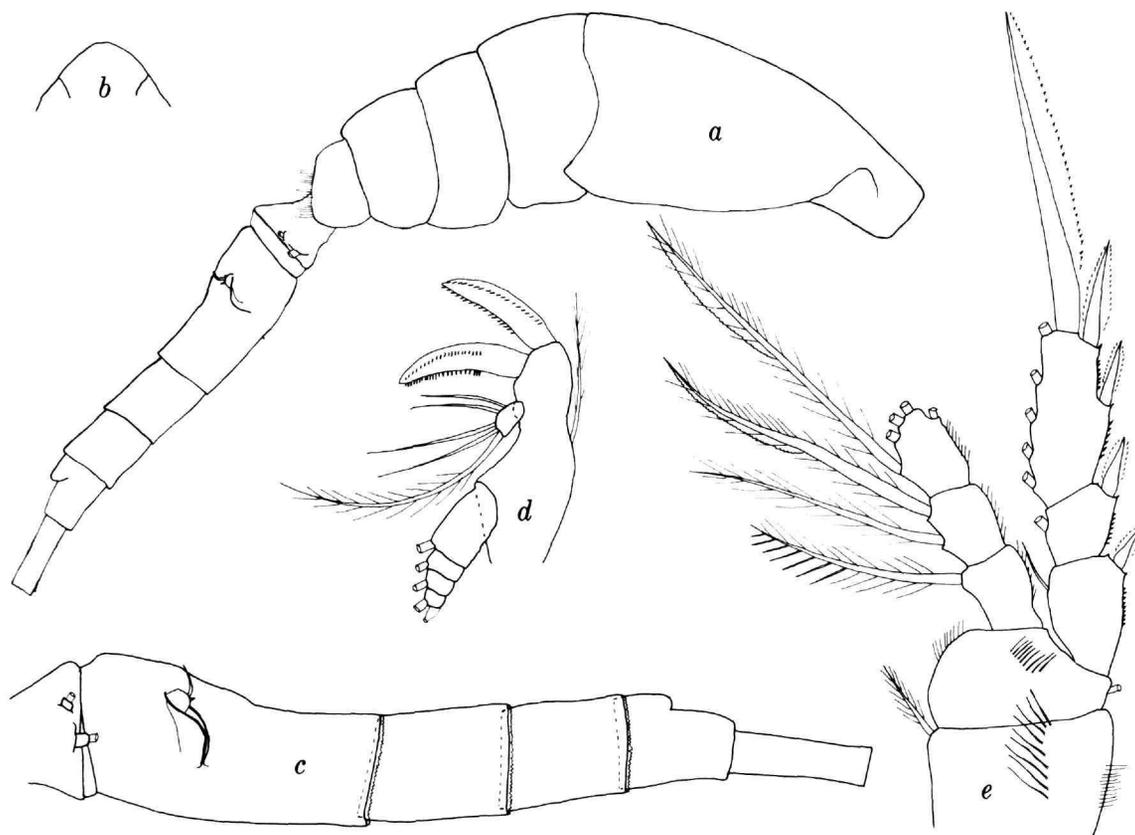


FIGURE 9.—*Oithona neotropica*, ♀: *a*, habitus, lateral; *b*, anterior part of head, dorsal; *c*, Ur, lateral; *d*, Md; *e*, P4.

seta straight with flange on distal $\frac{1}{2}$ (Figure 9*e*). Knob near genital opening with a curved spine and below it a smaller straight spine (Figure 9*c*).

REMARKS.—In our opinion the type-locality and only locality reported for *O. neotropica*, Laguna Mucubaji, Venezuela, is erroneous. Collections in Laguna Mucubaji were made by Fritz Gessner during German expeditions to Venezuela in 1952 (Gessner, 1956) and 1963 (Gessner and Hammer, 1967). Copepods from the 1952 expedition were reported on by Kiefer (1956); the only copepod from Laguna Mucubaji was a new subspecies, *Metacyclops leptopus mucubajiensis* Kiefer. Copepods from the 1963 expedition were given to Herbst (1967), who found two species from Laguna Mucubaji, *Acartia tonsa* Dana and *Oithona neotropica*. Other crustaceans from Laguna Mu-

cubaji were typical freshwater Cladocera (Brehm, 1956).

Acartia tonsa and *Oithona* spp. are marine and estuarine species, and it is surprising that Herbst did not comment on their anomalous occurrence in Laguna Mucubaji. *Acartia tonsa* tolerates reduced salinities better than most other marine calanoids (Lance, 1963, 1964) but it does not survive in freshwater. In Delaware Bay Cronin et al. (1962) found a few specimens at salinities below 1 ‰ but the usual lower limit was about 5 ‰. Laguna Mucubaji is located in the Venezuelan Andes at 8°39'N, 70°49'W at an elevation of 3560 m, more than 50 km SE of Lake Maracaibo. Dissolved minerals are very low; Gessner and Hammer (1967) report the following: μ S 11, alkalinity 0.1, pH 6.7.

The location, elevation, and low mineral content of Laguna Mucubaji and the presence of freshwater crustaceans exclude the possibility that *Acartia tonsa* and *Oithona neotropica* could survive there. Perhaps there was a mixup of labels in Gessner's collections. The true type-locality of *O. neotropica* is unknown, but it seems likely that the sample supposedly taken in Laguna Mucubaji actually came from coastal waters of Venezuela.

Herbst describes and figures *O. neotropica* with four setae on RiMd. The setae on this appendage are easy to miss; the quadrate head, CR (3 times as long as wide), and Se ReP1-4 (1-1-3, 1-1-3, 1-1-3, 1-1-2) would seem to distinguish females of this species. Fonseca and Björnberg (1977) described *O. oligohalina* from low salinity waters of a coastal lagoon near Cananeia, Brazil, in the state of São Paulo. There seems little difference between *O. oligohalina* and *O. neotropica* except habitat preference and number of setae on RiMd, which we have already commented upon. The possible separation needs further investigation.

Oithona plumifera Baird, 1843

FIGURES 10, 15f

Oithona plumifera Baird, 1843:59.—Kiefer, 1929:4.—Mori, 1937:109, pl. 60: figs. 3-15.—Sewell, 1947:255.—Nishida et al., 1977:140-142, figs. 14, 15.

MATERIAL.—♀♀ and ♂♂ from PN-13-60, PN-14-60, PN-18-60, PN-19-60, PN-20-60, PN-21-60, PN-23-60, PN-25-60, PN-26-60, PN-29-200, PN-32-200, PN-33-200, PN-35-200, PN-58-200, PN-59-200, PN-62-200, PN-63-200, and *Alpha Helix* Sta 5.5.

FEMALE.—Length range (30 specimens) 1.06-1.28 mm; Pr/Ur-1.1. Ur2 (Figure 10a) with tuft of hairs on anteroventral surface and small row of spinules posterior to knob near genital opening; knob with small, thin spine and spinule ventral to it. As Crisafi (1958) has noted, Ur4 with 2 rows of 4 thick hairs on anteroventral margin; lengths of hairs increase laterally (Figure 10b); Ur5 with lateral and dorsal rows of hairs (Figure 10c). CR also with hairs on posteromedial edge. A1 with tiny hairs, without associated pores, on 1-10 free segments (Figure 15f); Ri2P4 both setae modi-

fied; thick, curved with flange over distal 1/3; curvature of distal seta more pronounced; Ri3P4 with proximal seta modified; thick, slightly curved toward tip, with flange on distal 1/3. Re3P4 St plumose on distal 1/3 of medial edge. P5 with hairs on medial edge.

MALE.—Length range (30 specimens) 0.59-0.68 mm; Pr/Ur-1.5. Cph flap (Figure 10h) much thinner than *O. hebes*; digitiform; attenuate end reaching beyond posterior edge of Pg1. Pore signature similar to *O. hebes*. Anterodorsal cluster not organized into columns; posterior to this, horizontal row curves ventrally onto Cph flap and converges with 11th column. Ventral to horizontal row 10 distinct columns on Cph; 11th on flap. Ventrally, columns continue anteriorly as horizontal series. Posterior to 11th column, flap with 2 chevrons and peripheral organs along posterior edge.

REMARKS.—Males of this species agree in Se ReP1-4 with Nishida et al. (1977), not with Wellershaus (1970), who apparently mistakenly cited Giesbrecht (1892). Giesbrecht's descriptions and illustrations (table 44, figs. 12-15) clearly show *O. plumifera* males with 1-1-2, 1-1-3, 1-1-3, 1-1-2 Se on ReP1-4.

Spermatophore placement similar to *O. oculata* (Figure 10d). Spermatophore placed ventral to tuft of hairs on genital segment but is attached to Ur1, not to genital segment as in *O. oculata*. Tubule connecting spermatophore to sulcus much thicker and appears as central duct with surrounding sleeve.

Sexual dimorphism in *O. plumifera* may not be confined to structures directly involved in copulatory behavior (which generally appear only in copepodid VI, the adult stage) but is manifested in other external structures, such as the rostrum (present in females; absent in males) and number of Se ReP1-4 (1-1-2, 1-0-2, 1-0-1, 0-0-1 in females; 1-1-2, 1-1-3, 1-1-3, 1-1-2 in males). For this reason we initially felt females and males could be distinguished at copepodid V. We decided to separate copepodid V specimens to determine if immature males possessed a flap on the Cph and accompanying pore signature. The sample from *Alpha Helix* Sta 5.5, from a small lagoon

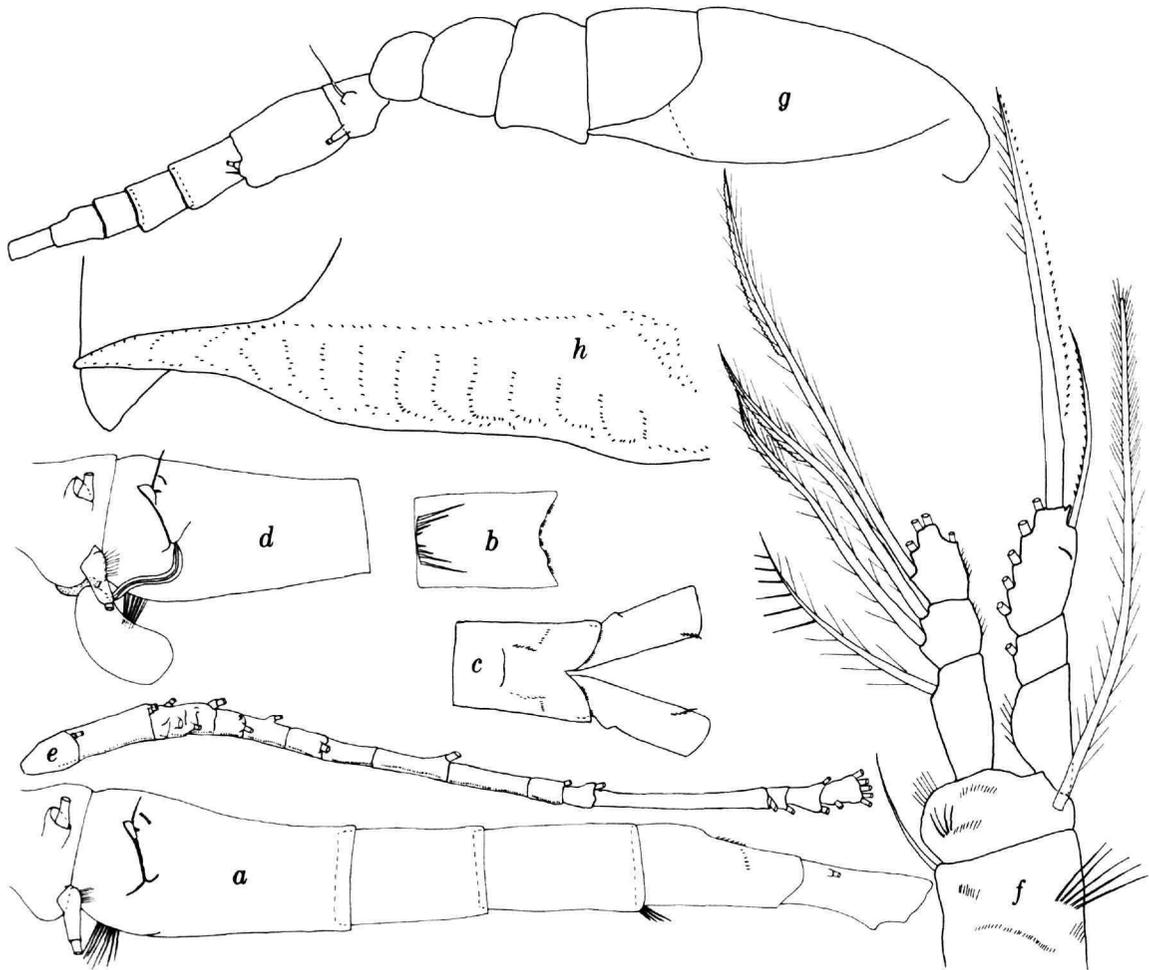


FIGURE 10.—*Oithona plumifera*, ♀: a, Ur, lateral; b, Ur4, ventral; c, Ur5 and CR, dorsal; d, Ur1 and 2 with attached spermatophore, lateral; e, A1; f, P4. ♂: g, habitus, lateral; h, Cph and flap.

on Klein Bonaire, was chosen for study since it contained numerous adults and copepodids of only two oithonids, *O. nana* and *O. plumifera*. Both females and males of *O. nana* have 1-1-3, 1-1-3, 1-1-3, 1-1-2 Se ReP1-4. Smaller copepodids with those Se numbers were considered immature *O. nana*. All large copepodids possessed a rostrum and 1-2-2, 1-0-2, 1-0-1, 0-0-1 Se ReP1-4; they appeared to be immature females of *O. plumifera*. Upon closer examination, however, one specimen was found to be a mature male within the im-

mature exoskeleton described above. The animal was captured during its final molt and possessed male attributes, no rostrum, flap on Cph with pore signature, and 1-1-2, 1-1-3, 1-1-3, 1-1-2 Se. Apparently male and female copepodid V's are morphologically similar and resemble the female in those dimorphic characters present. The male copepodid V then undergoes significant morphological reorganization. During the final molt of ontogenetic development, the male acquires a number of Se on ReP1-4. It is interesting

to note that Burckhardt (1913) assumed that the phylogenetic trend in females has been toward a reduction in the number of these spines from the basic 1-1-3, 1-1-3, 1-1-3, 1-1-3 numbers exhibited by *O. simplex*.

Oithona setigera Dana, 1853

FIGURE 11

Oithona setigera Dana, 1853:1101-1102, pl. 76: fig. 6a-f.—Kiefer, 1929:6.—Mori, 1937:110, pl. 60: figs 1, 2.—Sewell, 1947:257.—Nishida et al., 1977:147-149, figs. 19-20.

MATERIAL.—2 ♀♀ from PN-14-60 and 1 ♀ from PN-25-60.

FEMALE.—Length of females 1.62, 1.69, and 1.57 mm; Pr/Ur-0.9, 0.9, and 0.9. Knob near genital opening with short, straight, thick spine, denticulate on posterior edge and small spine

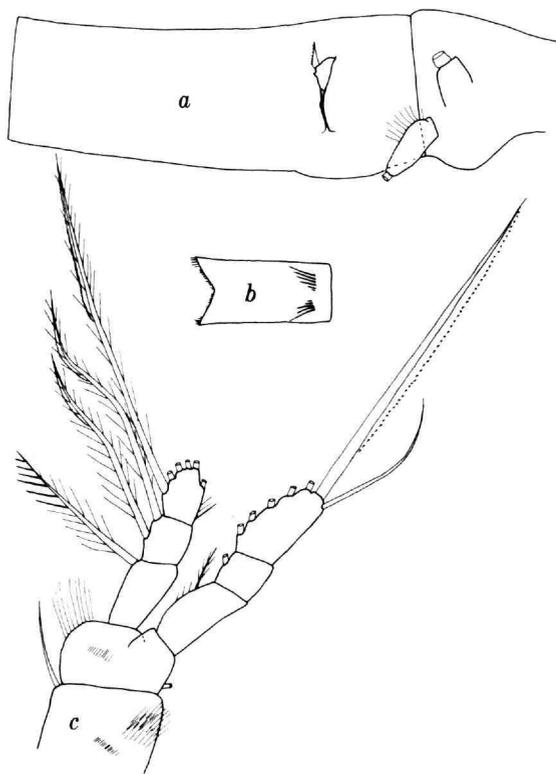


FIGURE 11.—*Oithona setigera*, ♀: a, Ur1 and 2, lateral; b, Ur4, ventral; c, P4.

ventral to it (Figure 11a). Ur4 ventrally with 2 rows of 5 or 6 hairs, increasing in length laterally (Figure 11b). Ri2P4 (Figure 11e) both setae modified, thick, curved, with flange on distal $\frac{1}{3}$; proximal seta on Ri3P4 virtually straight, but thicker, with flange on distal $\frac{1}{2}$. P5 with hairs on medial edge.

REMARKS.—Nishida et al. (1977) have noted variation in this species. Our three specimens were in such poor condition that we cannot comment on intraspecific variation. *Oithona setigera*, like many oithonids, is in need of a thorough zoogeographic analysis.

Oithona simplex Farran, 1913

FIGURES 12, 15g, h

Oithona simplex Farran, 1913:187-188, pl. 29: figs. 10-14; pl. 30: figs 1, 2.—González and Bowman, 1965:274, fig. 21f-i.—Chen et al., 1974:74, pl. 3: figs. 1-3.—Nishida et al., 1977:151-152, fig. 23.

MATERIAL.—Numerous ♀♀ and ♂♂ from PN-11-60, PN-19-60, PN-19-60, PN-20-60, PN-21-60, PN-23-60, PN-25-60, PN-26-60, PN-27-60, PN-32-200, PN-32-200, PN-33-200, PN-44-200, PN-45-200, PN-46-200, PN-65-200, PN-66-200, PN-67-200, PN-70-200, and NMNH-STRI Sta 126.

FEMALE.—Length range (30 specimens) 0.37-0.41 mm; Pr/Ur-1.6. Ri2 and 3P4 Si without curvature or flange, simple and plumose yet shorter and thinner than remaining Si (Figure 12c). Knob near genital opening with small, thin spine medially, a smaller spine ventrally, and a tiny spine dorsally (Figure 12b).

MALES.—Length range (30 specimens) 0.41-0.50 mm; Pr/Ur-1.5. Cph similar to female, without flap. Pore signature a series of columns with some connection ventrally between columns, suggesting horizontal series; without anterodorsal cluster (Figures 12d, g, 15g). Individual pores without well-developed ridges; integument slightly thickened anteriorly and posteriorly (Figure 15h).

REMARKS.—*Oithona simplex* has recently been discussed and illustrated by González and Bowman (1965) and Nishida et al. (1977).

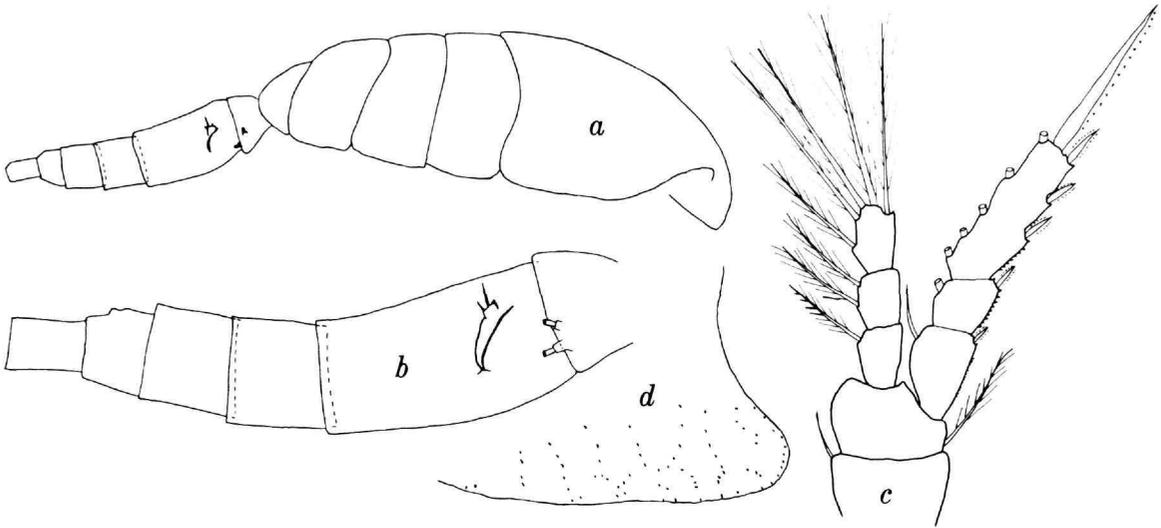


FIGURE 12.—*Oithona simplex*, ♀: *a*, habitus, lateral; *b*, Ur, lateral; *c*, P4. ♂: *d*, Cph.

Oithona sp. 1

FIGURE 13*a-c*

MATERIAL.—1 ♀ from PN-13-60.

FEMALE.—Length 0.74 mm; Pr/Ur-1.1. Anterior end of head swollen, terminating in small pointed rostrum laterally (Figure 13*a*). B2Md elongate, with 2 large spines bearing spinules; Ri with 4 setae, 1st and 4th longer and plumose. ReP1-4, Se 1-1-3, 1-1-3, 1-1-2 (distal Se of Re3 missing), 1-1-2. Ri1P4 Si missing (Figure 13*c*); Ri2P4 proximal Si missing; distal thick, straight with flange on distal ½; Ri3P4 proximal Si missing. Knob near genital opening (Figure 13*b*) with long flexible seta, shorter, stiff spine ventrally, and reduced spine dorsally.

REMARKS.—This specimen is in very poor condition; one exopod each of P3 and P4 and many spines and setae missing. It is similar to *O. vivida* of Nishida et al. (1977) and Chen et al. (1974) in these features: lateral profile of head, number and shape of Se ReP1-4, and elongate seta on knob near genital opening. The number of setae on RiMd differs, but these are easily broken or missed.

We agree with Nishida et al. (1977), as well as Rosendorn (1917), that Farran (1913) probably

reversed figures 7 and 8 of plate 27 (pp. 2, 3). Although Farran did not illustrate P4, he states that “exopodite appears to have 1-1-3 or 1-0-3 slender minute outer edge spines.” These spines on our specimen and that of Nishida et al. (1977), although slender, are not minute and there are only two on Re3P4. Farran shows a smooth tapering rostrum in lateral view, not swollen and then tapering to a point. Rosendorn (1917), who apparently had several specimens of *O. vivida*, describes them with 1-1-3 Se on ReP4, although her specimens differ from Farran’s in the armature of B2Md, RiMd, and ReMx1. We must concur with Kiefer (1956) concerning the importance of number and shape of Se on ReP4. Specimens described by Nishida et al. (1977) appear to belong to a new species to which ours could be assigned, but we choose not to erect a new species on the basis of a single specimen.

Oithona sp. 2

FIGURE 13*d,e*

MATERIAL.—1 ♂ from PN-13-60.

MALE.—Length 0.57 mm; Pr/Ur-1.5. Rostrum absent; head rounded in lateral view. Cph flap a

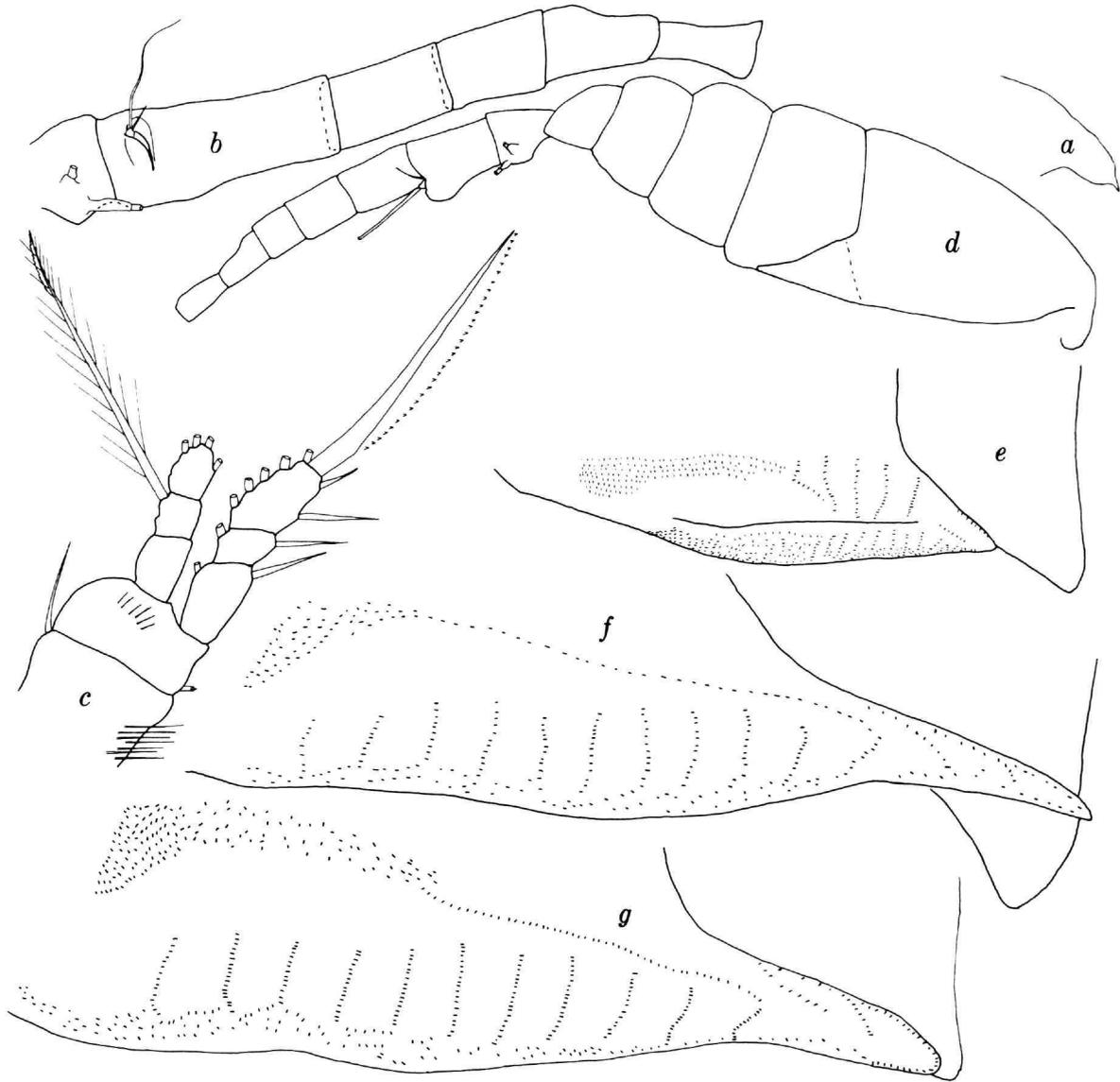


FIGURE 13.—*Oithona* sp. 1, ♀: *a*, anterior part of head, lateral; *b*, Ur, lateral; *c*, P4. *Oithona* sp. 2, ♂: *d*, habitus, lateral; *e*, Cph and flap. *Oithona* sp. 3, ♂: *f*, Cph and flap. *Oithona* sp. 4, ♂: *g*, Cph and flap.

right triangle, reaching middle Pg1 (Figure 13*e*); ridge parallel to ventral edge of cephalosome divides pore signature. Anterodorsal cluster well developed with 7 or 8 rows of organs; dorsal 4 rows continue posteriorly as horizontal row; behind this a chevron-shaped column followed by

4 columns. Ventral to ridge a large number of organs, organized anteriorly in horizontal patterns, posteriorly as vertical or oblique rows. ReP1-4 Se 1-1-3, 1-1-3, 1-1-3, 1-1-2; P5 with single seta; genital flap with small bump armed with thick (probably elongate) seta (broken in

this specimen) and a smaller seta dorsally (Figure 13*d*).

REMARKS.—This specimen differs from any previously described male. Females of *O. decipiens*, *Oithona* sp. 1, and *Paroithona flemingeri*, new species, from PN-13-60 have not had males attributed to them. Assuming this male belongs to one of these species, only *P. flemingeri* can be eliminated on the basis of size and number of endopodal segments of the swimming legs. Since only one specimen is available, we have not dissected the appendages and thus confined our descriptive account to those characters that could be observed on the whole animal.

Genus *Paroithona* Farran, 1913

Paroithona flemingeri, new species

FIGURE 14

MATERIAL.—38 ♀♀ from PN-13-60.

FEMALE.—Length range 0.40–0.45 mm; Pr/Ur–1.2. Head rounded in lateral view, rostrum absent (Figure 14*a*). CR (Figure 14*d*) slightly longer than wide; dorsal and 1 apical seta thick and elongate, bearing lateral hyaline membrane similar to StP1–4 of most oithonids; 2 apical setae absent; lateral seta reduced. A1 (Figure 14*e*) with 9 free segments. A2 with 1st segment elongate (Figure 14*f*). B2Md (Figure 14*g*) with 1 large, thick, slightly curved spine, bearing spinules and 1 small, thin seta in inferior position; ReMd 4 segments, terminal seta reduced; RiMd a bump with 4 setae. RiMx1 (Figure 14*h*) naked. Mx2 and Mxp as illustrated (Figure 14*i, j*). ReP1 2-segmented, Re2 and 3 fused; ReP2–4 3-segmented; RiP1–4 2-segmented. ReP1–4 Se 1–3, 1–1–2, 1–0–2, 1–0–1; ReP1–4 Si 0–4, 0–1–5, 0–1–5, 0–0–5; RiP1–4 Se 0–1, 0–1, 0–1, 0–1; RiP1–4 Si 1–6, 0–3, 0–3, 1–3. All Si RiP4 unmodified. P5 with 1 seta. Knob near genital opening with 1 spine pointing posterodorsally and below this 1 thinner spine (Figure 14*b*).

REMARKS.—*Paroithona flemingeri* is most easily separated from the two other species of the genus by number of Se ReP1–4; *P. parvula*: 1–3, 1–1–2,

1–1–2, 1–1–1; *P. pulla*: 1–3, 1–1–2, 1–0–1, 0–0–1 (not 1–1–2 for ReP3 as listed in Wellershaus, (1970) table).

ETYMOLOGY.—The species is named for Dr. Abraham Fleminger, who has contributed so much to our understanding of the systematics of free-swimming marine copepods.

TYPE MATERIAL.—Female holotype (USNM 172189), 34 ♀ paratypes (USNM 172190) from PN-13-60, 10°41.2'N 63°14.8'W, 800 m from jetty at Carupano, Venezuela; 22 Jun 1977.

Commentary

About 60 species have been placed in the family Oithonidae since Baird's (1843) initial description of *Oithona plumifera*. Despite the amount of information that has accumulated about oithonids over the past century, there are still difficulties in assigning values to characters studied in standard systematic accounts. Aside from denoting characters that have intrinsic value in classification, simply because they do vary, knowledge of the biology of oithonids is of such a poor state that there has been no attempt to order these characters in a system reflecting the evolutionary trends of the animals. Over 50 years have passed since the only attempt was made to relate several species within the genus *Oithona* (Burckhardt, 1913).

As an example of the lack of basic biological information, we know of no direct observations of oithonid mating behavior. However, this behavior in other gnathostome cyclopoids of the family Cyclopidae has received attention from a number of authors, e.g., Hill and Coker (1930) and Rylov (1948). These observations indicate that males use their digeniculate first antenna to grasp the ReP4 of the female. Their ventral surfaces are facing. There is some question as to whether this is the initial contact position or whether the male moves to this position from a previous one, grasping the Pr/Ur articulation of the female dorsally (Hill and Coker, 1930). Nonetheless the male must reach the A1/P4 position in order to attach the spermatophores ventrally on the female genital segment over the ventrally placed female genital openings. Spermatophore

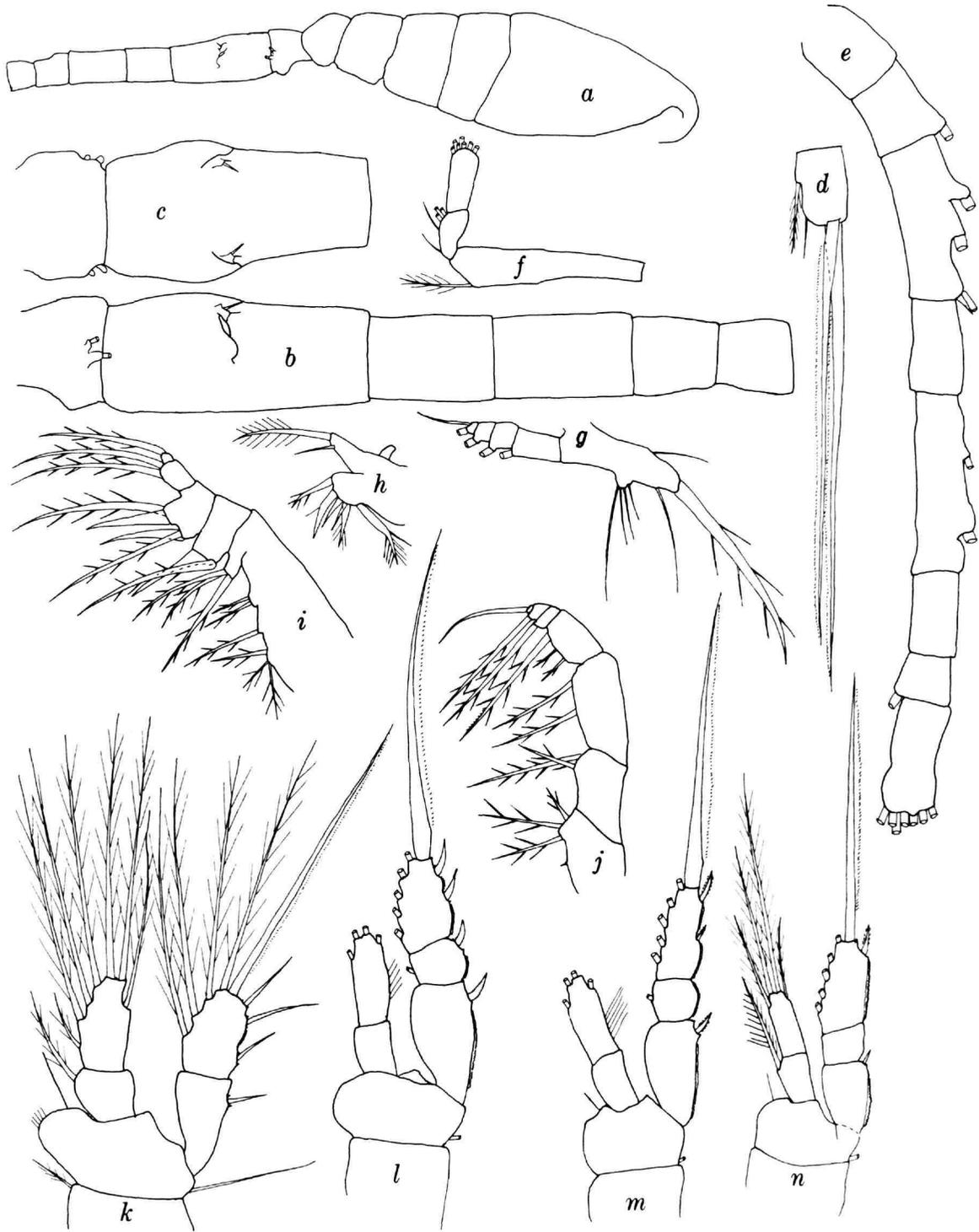


FIGURE 14.—*Paroithona flemingeri*, ♀: a, habitus, lateral; b, Ur, lateral; c, Ur1 and 2, dorsal; d, CR, dorsal; e, A1; f, A2; g, Md; h, Mx1; i, Mx2; j, Mxp; k, P1; l, P2; m, P3; n, P4.

transfer is affected with the tips of the male swimming legs. Thus spermatophores can be transferred by use of virtually unspecialized swimming legs; specialized appendages or seta need not have evolved for this purpose as Ferrari (1977) has suggested.

Although no observations have been published on mating behavior of oithonids, certain observations suggest a similar pattern of events. Female genital openings in the Oithonidae are dorsal or dorsolateral in position but spermatophores are attached to females of *O. plumifera* and *O. oculata* ventrally as in the Cyclopidae. It is not known whether the male grasps the female as in *Cyclops*, at the ReP4. Assuming that he does, however, one might expect to find a tactile recognition system during this positioning and the system may be reflected in the morphology of the appendages involved. No study of the complex male digeniculate A1 has been undertaken to enumerate differences between species. However, distinct differences in numbers and shapes of spines on ReP4 have been used quite commonly in separating species of oithonids, and the taxonomic value of these structures has been emphasized by Kiefer (1956).

If the position of male/female at the time of spermatophore transfer is similar to the final mating position of, e.g., *Cyclops americanus*, as illustrated by Hill and Coker (1930, fig. 2), the female could use the specialized setae of RiP4 for tactile interrogation of the male pore signature prior to spermatophore transfer. All females of the genus *Oithona* have modified setae on RiP4, although in *O. simplex* these setae are reduced rather than bearing a flange. Not all males possess a well organized pore signature, however. *Oithona oculata* and *O. bjornbergae* lack this pore signature, although in SEM micrographs, the lateral surface of Cph of *O. oculata* is densely pitted.

Observations of living oithonids will eventually elucidate the functions of modified setae on RiP4 of females and pore signature of males. Because of their value in systematic studies, we feel it would be beneficial to know the role these structures play in the biology of oithonids. If it is shown that these integumental organs function in

some interrogating system during reproduction, this would suggest their importance in a speciation process emphasizing the development of prezygotic isolating mechanisms. Further, an effort

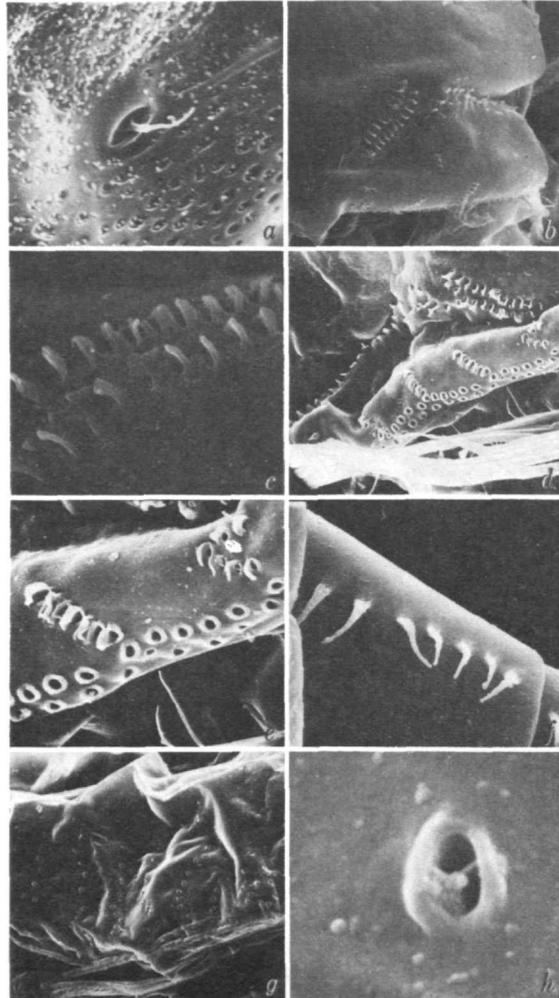


FIGURE 15.—*Oithona oculata*, ♂: a, integumental organ of cephalosome, $\times 10,000$. *Oithona hebes*, ♂: b, anterodorsal cluster, anterior part of horizontal row, and several vertical columns with their horizontal continuations, $\times 2000$; c, anterodorsal cluster, $\times 7500$; d, 2nd ♂, right side, anterodorsal cluster, part of horizontal row, and several vertical columns with their horizontal continuations, $\times 2000$; e, 1st 2 vertical columns and horizontal continuations, $\times 5000$. *Oithona plumifera*, ♀: f, hairs on A1. *Oithona simplex*, ♂, right side: g, pore signature, $\times 1800$; h, single pore. (Micrographs reduced to 44%.)

should be made to collect males of closely related species over their entire zoogeographic range, so that the general organization and intraspecific variation of the pore signature can be characterized and compared to the variation between species. Once the extent of intraspecific variation is understood, more difficult problems can be addressed, such as characterization of populations, definition of population boundaries, and extent of interpopulation movements.

Regardless of their denouement in the evolution of the genus *Oithona*, several types of pore signatures can be recognized in species studied. All species possess vertical columns of organs, which are interconnected ventrally. This pattern is present even in *O. simplex*, which possesses the fewest number of organs and no Cph flap. Except for *O. simplex*, all species possess a distinct anterodorsal cluster of organs. Two males (Figure 13f, g) from Melville Stations 359 and 353, respectively, although geographically beyond the scope of this study, serve to emphasize the importance of this anterodorsal cluster. *Oithona* sp. 3 (male) is 0.80 mm long with the same spine count as *Oithona plumifera* (1-1-2, 1-1-3, 1-1-3, 1-1-2). The pore signature and flap development (Figure 13f) is similar to *O. plumifera*. However, the anterodorsal cluster has more organs than *O. plumifera* and these seem more densely spaced. In *O. plumifera* (Figure 10h) there is a rather abrupt transition between the anterodorsal cluster and horizontal row. On *Oithona* sp. 3 the transition is immediate but the horizontal row begins as a jumbled group of organs before resolving into the single row.

Oithona sp. 4 (male) is 0.76 mm long; the spine count on ReP1-4 is 1-1-3, 1-1-3, 1-1-3, 1-1-2.

The pore signature is also similar to *O. plumifera*. The anterodorsal cluster (Figure 13g) is composed of more organs than *O. plumifera* or the previous male. It merges rather indistinctly, again via a jumble of organs, into the horizontal row, which eventually resolves into a single row of organs.

The anterodorsal cluster can be considered the anterior end of the horizontal row of organs, the third general feature of the pore signature. This row is either set dorsally to the columns, in effect confining them, e.g., *O. amazonica*, *O. hebes*, *O. plumifera*, or appears less distinctly as a forward extension of the ventral organs in the columns as in *O. nana* and *Oithona* sp. 2. These latter two males also possess numerous scattered organs ventral to the columns and horizontal row. The organs are separated from columns and row in the former species by an area devoid of organs and in the latter by a ridge of the integument.

All females show modifications of one or more internal setae on the RiP4. These modifications may simply be a reduction in the size of the setae compared to other internal plumose ones as in *O. simplex* but more often involves development of a medial flange on the tip of a thick seta. One, (*O. amazonica*), two (*O. fonsecae* and *O. hebes*), or three (*O. plumifera*, *O. decipiens*, *O. oculata*, and *O. bjornbergae*) setae may be modified with varying degrees of curvature; the flange length also varies in relation to the length of seta. These female characters may contain as much taxonomic information as the pore signature. The latter are more easily studied because slight variations in the setae may be reflected in the degree of curvature and length of flange. These are more difficult to analyze than the discrete male organs.

Literature Cited

- Baird, W.
1843. Note on the Luminous Appearance of the Sea, with Descriptions of Some of the Entomostracous Insects by Which It Is Occasioned. *The Zoologist*, 1:55–61.
- Bowman, T.
1975. *Oithona colcarva*, n. sp., an American Copepod Incorrectly Known as *O. brevicornis* (Cyclopoida: Oithonidae). *Chesapeake Science*, 16(1):134–137.
- Brehm, V.
1956. Cladocera aus Venezuela. *Ergebnisse der Deutschen Limnologischen Venezuela-Expedition*, 1:217–232.
- Burckhardt, G.
1912. Ein zweites Cyclopidengenuss in süßen Wasser. *Zoologischen Anzeiger*, 39(25/26):725–727.
1913. Wissenschaftliche Ergebnisse einer Reise um der Erde von M. Pernod und C. Schröter, III: Zooplankton aus ost-und südasiatischen Binnengewässern. *Zoologische Jahrbücher, Systematik*, 34:341–472.
- Chen, Q., S. Zhang, and C. Zhu
1974. On Planktonic Copepods of the Yellow Sea and the East China Sea, II: Cyclopoida and Harpacticoida. *Studia Marina Sinica*, 9:27–76. [In Chinese with English summary.]
- Crisafi, P.
1958. Su una popolazione di *Oithona plumifera* Baird (Copepoda, Cyclopoida) dello stretto de Messina. *Archivio Zoologico Italiano*, 43:179–201.
- Cronin, L., J. Daiber, and E. Hulbert
1962. Quantitative Seasonal Aspects of Zooplankton in the Delaware River Estuary. *Chesapeake Science*, 3(2):63–93.
- Dana, J.
1853. Crustacea. In *United States Exploring Expedition during the Years 1838, 1839, 1840, 1841, 1842 under the Command of Charles Wilkes*, 14(2):693–1618.
- Farran, G.
1913. Plankton from Christmas Island, Indian Ocean, II: On Copepoda of the Genera *Oithona* and *Paroithona*. *Proceedings of the Zoological Society of London*, 1913:181–193.
- Ferrari, F.
1977. A Redescription of *Oithona dissimilis* Lindberg, 1940, with a Comparison to *Oithona hebes* Giesbrecht, 1891 (Crustacea, Copepoda, Cyclopoida). *Proceedings of the Biological Society of Washington*, 90(2):400–411.
- Fleminger, A.
1973. Pattern, Number, Variability, and Taxonomic Significance of Integumental Organs (Sensilla and Glandular Pores) in the Genus *Eucalanus* (Copepoda, Calanoida). *Fishery Bulletin*, 71(4):965–1010.
1977. Geographical Range and Taxonomic Divergence in North Atlantic *Calanus* (*C. helgolandicus*, *C. finmarchicus*, and *C. glacialis*). *Marine Biology*, 40:233–248.
- Fonseca, V., and T. Björnberg
1977. *Oithona oligohalina*, sp. n., de Cananéia (est. de São Paulo) e considerações sobre *Oithona ovalis* Herbst (Copepoda, Cyclopoida). *Anais de Academia Brasileira de Ciências*, 47:127–131.
- Gessner, F.
1956. Der Verlauf der Venezuela-Expedition 1952. *Ergebnisse der Deutschen Limnologischen Venezuela-Expedition*, 1:1–22.
- Gessner, F., and L. Hammer
1967. Limnologische Untersuchungen an Seen der Venezolanischen Hochanden. *Internationale Revue der Gesamten Hydrobiologie*, 52(3):301–320.
- Giesbrecht, W.
1891. Elenco dei Copepodi pelagici raccolti dal tenente di Vascello Gaetano Chierchia durante il viaggio della R. Corvetta “Vettor Pisani” negli anni 1882–1885, e dal tenente di vascello Francesco Orsini nel Mar Rosso, nel 1884. *Rendiconti della Rome Accademia del Lincei*, series 4, 7(1):474–481.
1892. Systematik und Faunistik der pelagischen Copepoden des Golfes von Neapel und der angrenzenden Meersabschnitte. *Fauna and Flora des Golfes von Neapel* (monograph), 19:831 pages, 541 plates.
- González, J., and T. Bowman
1965. Planktonic Copepods from Bahía Fosforescente, Puerto Rico, and Adjacent Waters. *Proceedings of the United States National Museum*, 117(3513):241–304.
- Herbst, H.
1955. Cyclopoida Gnathostoma (Crustacea Copepoda) von der brasilianischen Atlantikküste. *Kieler Meeresforschungen*, 11(2):214–229.
1967. Copepoda und Cladocera (Crustacea) aus Südamerika. *Gewässer und Abwässer*, 44/45:96–108.

Hill, L., and R. Coker

1930. Observations on Mating Habits in *Cyclops*. *Journal of the Elisha Mitchell Scientific Society*, 45(2):206-220.

Kiefer, F.

1929. Copepoda 2: Cyclopoida Gnathostoma. *Das Tierreich*, 53:102 pages.
1935. Zur Kenntnis der Oithonidae (Crustacea Copepoda Cyclopoida). *Zoologischer Anzeiger*, 112(11/12):322-327.
1954. Drei neue Ruderfusskrebse (Crust. Cop.) aus Venezuela. *Zoologischer Anzeiger*, 153(7/8):170-174.
1956. Freilebende Ruderfusskrebse (Crustacea Copepoda), I: Calanoida und Cyclopoida. *Ergebnisse der Deutschen Limnologischen Venezuela-Expedition, 1952*, 1:233-268.

Lance, J.

1963. The Salinity Tolerance of Some Estuarine Planktonic Copepods. *Limnology and Oceanography*, 8(4):440-449.
1964. The Salinity Tolerances of Some Estuarine Planktonic Crustaceans. *Biological Bulletin*, 127(1):108-118.

Lindberg, K.

1954. Cyclopoïdes (Crustacés Copépodes) de l'Amérique du Sud. *Arkiv för Zoologi*, series 2, 7(11):193-222.

Mauchline, J., and T. Nemoto

1977. The Occurrence of Integumental Organs in Copepodid Stages of Calanoid Copepods. *Bulletin of the Plankton Society of Japan*, 24(2):108-114.

Mori, T.

1937. *The Pelagic Copepoda from the Neighbouring Waters of Japan*. 140 pages, 80 plates. Tokyo.

Nishida, S., O. Tanaka, and M. Omori

1977. Cyclopoid Copepods of the Family Oithonidae in Suruga Bay and Adjacent Waters. *Bulletin of the Plankton Society of Japan*, 24(2):119-158.

Rosendorn, I.

1917. Die Gattung *Oithona*. *Wissenschaftliche Ergebnisse der auf dem Dampfer "Valdivia," 1898-1899*, 23:1-58.

Rylov, V.

1948. *Freshwater Cyclopoida, Fauna of U.S.S.R.* Volume 3, number 3, 314 pages. [In Russian; English translation by Israel Program for Scientific Translations Ltd., 1963.]

Sewell, R.

1947. The Free-swimming Planktonic Copepoda: Systematic Account. *Scientific Reports of the John Murray Expedition, 1933-1934*, 8(1):1-303.

Wellershaus, S.

1969. On the Taxonomy of Planktonic Copepoda in the Cochin Backwater (a South Indian Estuary). *Veröffentlichungen des Instituts für Meeresforschung in Bremerhaven*, 11:245-286.
1970. On the Taxonomy of Some Copepoda in Cochin Backwater (a South Indian Estuary). *Veröffentlichungen des Instituts für Meeresforschung in Bremerhaven*, 12:463-490.

REQUIREMENTS FOR SMITHSONIAN SERIES PUBLICATION

Manuscripts intended for series publication receive substantive review within their originating Smithsonian museums or offices and are submitted to the Smithsonian Institution Press with approval of the appropriate museum authority on Form SI-36. Requests for special treatment—use of color, foldouts, casebound covers, etc.—require, on the same form, the added approval of designated committees or museum directors.

Review of manuscripts and art by the Press for requirements of series format and style, completeness and clarity of copy, and arrangement of all material, as outlined below, will govern, within the judgment of the Press, acceptance or rejection of the manuscripts and art.

Copy must be typewritten, double-spaced, on one side of standard white bond paper, with 1 $\frac{1}{4}$ " margins, submitted as ribbon copy (not carbon or xerox), in loose sheets (not stapled or bound), and accompanied by original art. Minimum acceptable length is 30 pages.

Front matter (preceding the text) should include: **title page** with only title and author and no other information, **abstract page** with author/title/series/etc., following the established format, **table of contents** with indents reflecting the heads and structure of the paper.

First page of text should carry the title and author at the top of the page and an unnumbered footnote at the bottom consisting of author's name and professional mailing address.

Center heads of whatever level should be typed with initial caps of major words, with extra space above and below the head, but with no other preparation (such as all caps or underline). Run-in paragraph heads should use period/dashes or colons as necessary.

Tabulations within text (lists of data, often in parallel columns) can be typed on the text page where they occur, but they should not contain rules or formal, numbered table heads.

Formal tables (numbered, with table heads, boxheads, stubs, rules) should be submitted as camera copy, but the author must contact the series section of the Press for editorial attention and preparation assistance before final typing of this matter.

Taxonomic keys in natural history papers should use the aligned-couplet form in the zoology and paleobiology series and the multi-level indent form in the botany series. If cross-referencing is required between key and text, do not include page references within the key, but number the keyed-out taxa with their corresponding heads in the text.

Synonymy in the zoology and paleobiology series must use the short form (taxon, author, year:page), with a full reference at the end of the paper under "Literature Cited." For the botany series, the long form (taxon, author, abbreviated journal or book title, volume, page, year, with no reference in the "Literature Cited") is optional.

Footnotes, when few in number, whether annotative or bibliographic, should be typed at the bottom of the text page on which the reference occurs. Extensive notes must appear at the end of the text in a notes section. If bibliographic footnotes are required, use the short form (author/brief title/page) with the full reference in the bibliography.

Text-reference system (author/year/page within the text, with the full reference in a "Literature Cited" at the end of the text) must be used in place of bibliographic footnotes in all scientific series and is strongly recommended in the history and technology series: "(Jones, 1910:122)" or ". . . Jones (1910:122)."

Bibliography, depending upon use, is termed "References," "Selected References," or "Literature Cited." Spell out book, journal, and article titles, using initial caps in all major words. For capitalization of titles in foreign languages, follow the national practice of each language. Underline (for italics) book and journal titles. Use the colon-parentheses system for volume/number/page citations: "10(2):5-9." For alinement and arrangement of elements, follow the format of the series for which the manuscript is intended.

Legends for illustrations must not be attached to the art nor included within the text but must be submitted at the end of the manuscript—with as many legends typed, double-spaced, to a page as convenient.

Illustrations must not be included within the manuscript but must be submitted separately as original art (not copies). All illustrations (photographs, line drawings, maps, etc.) can be intermixed throughout the printed text. They should be termed **Figures** and should be numbered consecutively. If several "figures" are treated as components of a single larger figure, they should be designated by lowercase italic letters (underlined in copy) on the illustration, in the legend, and in text references: "Figure 9b." If illustrations are intended to be printed separately on coated stock following the text, they should be termed **Plates** and any components should be lettered as in figures: "Plate 9b." Keys to any symbols within an illustration should appear on the art and not in the legend.

A few points of style: (1) Do not use periods after such abbreviations as "mm, ft, yds, USNM, NNE, AM, BC." (2) Use hyphens in spelled-out fractions: "two-thirds." (3) Spell out numbers "one" through "nine" in expository text, but use numerals in all other cases if possible. (4) Use the metric system of measurement, where possible, instead of the English system. (5) Use the decimal system, where possible, in place of fractions. (6) Use day/month/year sequence for dates: "9 April 1976." (7) For months in tabular listings or data sections, use three-letter abbreviations with no periods: "Jan, Mar, Jun," etc.

Arrange and paginate sequentially EVERY sheet of manuscript—including ALL front matter and ALL legends, etc., at the back of the text—in the following order: (1) title page, (2) abstract, (3) table of contents, (4) foreword and/or preface, (5) text, (6) appendixes, (7) notes, (8) glossary, (9) bibliography, (10) index, (11) legends.

