

Seven *Lubbockia* Species  
(Copepoda: Cyclopoida) from the  
Plankton of the Northeast Pacific,  
with a Review of the Genus

GAYLE A. HERON  
and  
DAVID M. DAMKAER

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Seven *Lubbockia* Species  
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*Gayle A. Heron*  
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## ABSTRACT

Heron, Gayle A., and David M. Damkaer. Seven *Lubbockia* Species (Copepoda: Cyclopoida) from the Plankton of the Northeast Pacific, with a Review of the Genus. *Smithsonian Contributions to Zoology*, number 267, 36 pages, 22 figures, 2 tables, 1978.—Among the marine plankton cyclopoids, the oncaeids represent a great number and wide variety of relatively little studied species. The family Oncaeidae is defined in this report, and a key is given for its five genera. Of these, the genus *Lubbockia* is defined in detail, and a key (Figure 2) is given for its 11 species. Relationships within the genus, as well as to other oncaeids, are discussed. The bulk of the report is based on seven *Lubbockia* species collected from the plankton of the northeast Pacific Ocean; most of these species are also widely distributed elsewhere. Descriptions, illustrations, and notes on distributions are provided for these seven species, four of which are new. Descriptive notes and illustrations are also given for two other *Lubbockia* species known from tropical and subtropical areas of the Pacific.

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# Seven *Lubbockia* Species (Copepoda: Cyclopoida) from the Plankton of the Northeast Pacific, with a Review of the Genus

Gayle A. Heron  
and David M. Damkaer

## Introduction

Among the Poecilostoma (Copepoda: Cyclopoida), most attention has been given to the numerous families associated with benthic invertebrates (see, for example, Gooding, 1963; Humes and Stock, 1973). The marine plankton poecilostomes, except perhaps for the Corycaidae, have by comparison been little studied. The "planktonic" poecilostomes (Corycaidae, Sapphirinidae, and Oncaidae) are possibly not truly planktonic, but may be associated, at least at times, with larger plankton organisms (Sars, 1918). *Sapphirina* species, especially, are known to associate as parasites and predators on salps (A. C. Heron, 1973). *Oncaea* species have been seen to graze on appendicularian houses (Alldredge, 1976). There is no doubt that *Lubbockia* species would be mechanically able to hold other organisms with their well developed maxillipeds, but their actual food sources are not definitely known. The broad specific differences in maxilliped construction suggest that food sources vary among *Lubbockia* species.

At present, 11 named species can be assigned to

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the genus *Lubbockia* and are included in our key. Notes on a North Atlantic species, *L. extenuata*, were provided by G. Boxshall (personal communication), but the published report (Boxshall, 1977) was not available before the present paper went to press. Neither *L. extenuata* nor *L. brevis*, originally described from off Ireland, were found in the northeast Pacific, and they are not described in this report. A description of both sexes of *L. brevis*, and also of *L. glacialis*, is included in a report of Arctic Oncaidae to be published soon (Heron and English, in prep.). *Lubbockia squillimana* and *L. aculeata*, from tropical and subtropical areas, also were not found in our northeast Pacific samples, but descriptive notes are given here for these species as well as for the seven species (including four which are new) that are known for the northeast Pacific. Only the male of *L. forcipula* remains unknown.

Most *Lubbockia* species have a wide distribution, and of those species found in the northeast Pacific, we have also studied specimens from other areas: the Antarctic (*L. carinata*, *L. flemingi*, *L. forcipula*, and *L. wilsonae*; Tables 1, 2), the Atlantic (*L. minuta*; Tables 1, 2), and the Arctic oceans (*L. glacialis*; Heron and English, in prep.). *Lubbockia petersoni* has been found only in the northeast Pacific.

MATERIAL AND METHODS.—Sources of the speci-

mens examined during this study are listed in Table 1 and the species are itemized in Table 2. Those specimens that were studied in detail are enumerated under "Material Studied" in each species presentation.

Type specimens or reference specimens of all species described in this report have been deposited in the National Museum of Natural History, Smithsonian Institution, Washington, D. C., where they bear the catalog numbers of the former United States National Museum (USNM).

The samples from NOAA *Surveyor* were collected using a 60 cm diameter closing ringnet of 211  $\mu\text{m}$  mesh, hauled vertically through discrete layers. The *Brown Bear* and *Thompson* samples from Mr. Willis K. Peterson were collected with a specially designed plankton net, mesh aperture 110  $\mu\text{m}$ , which accompanied a deep water-bottle cast. Two Clarke-Bumpus nets were sewed together with the open cod end of the shorter one reduced to about 5 cm diameter and extended into the mouth of the other; a small collecting bucket was attached to the end of the outer net. A steel ring was sewed into the mouth of the common opening, and fastened by a short bridle to the hydrographic wire. Another short bridle extended from the bucket, and this bridle was fastened to the wire beneath the net. Thus the sampler was held parallel to the hydrographic wire and it sampled only as it was retrieved. The net was attached beneath the deepest water-bottle on a hydrographic cast (1800 m or more). The maximum depth of the net sample was estimated from the deepest thermometric depth. The constricted cod end of the inner net and the relatively great length of the entire device limited the escape of plankton when an ascending haul was stopped to remove water bottles.

The other *Thompson* samples were collected using a multiple net trawl described by Frost and McCrone (1974).

Figures were drawn with the aid of a Wild M20 drawing tube. In the figure legends, the capital letter following the explanation of each figure component refers to the particular scale to which the component was drawn. These scales are illustrated in Figure 1. Some *Lubbockia* species have a large number of spinules, sensilla, and gland vents (Fahrenbach, 1962), the latter associated with internal tubules. Only such external features that are conspicuous have been illustrated. Swimming legs

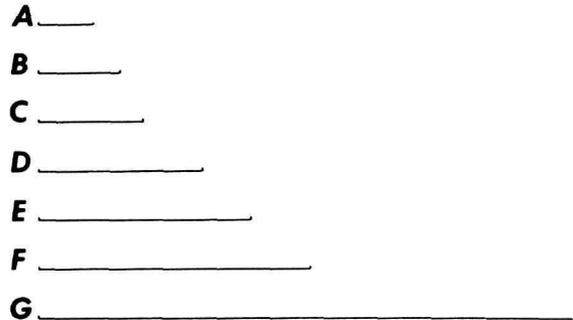


FIGURE 1.—Scales used in drawing figure components (each scale = 0.1 mm).

are illustrated in anterior view.

Terminology used in describing the armature of swimming legs is as follows: setae are represented by arabic numerals, spines by roman numerals; Si = inner border of segments, Se = outer border, St = terminal border. In describing the armature of antenna 1, arabic numerals used alone represent the number of setae. For use of "uropod" and "pediger," see Bowman (1971, 1976).

ACKNOWLEDGMENTS.—We are indebted to and thank the following persons for loans of specimens or samples: Dr. Thomas E. Bowman, National Museum of Natural History (NMNH), Smithsonian Institution, Washington, D. C., the depository of specimens bearing catalog numbers of the former United States National Museum (USNM); Dr. Frank D. Ferrari, Smithsonian Oceanographic Sorting Center (SOSC), Washington, D. C.; and Dr. Bruce W. Frost, Mr. Willis K. Peterson, and Mr. David S. Thoreson, Department of Oceanography, University of Washington (UW), Seattle, Washington.

We are grateful to Dr. Takasi Tokioka, Seto Marine Biological Laboratory, for providing the rare Marukawa (1927) publication, and also to Dr. Shigeo Ooishi, Faculty of Fisheries, Mie University, for translating the relevant text.

We also appreciate the information kindly given by Drs. T. Björnberg, Universidade de Sao Paulo, Brasil, and G. Boxshall, British Museum (Natural History), concerning *Lubbockia* species studied by them.

This study was supported in part by the Alaska Outer Continental Shelf Environmental Assessment Program, sponsored by the National Oceanic and

Atmospheric Administration (NOAA) and the U.S. Department of Interior, Bureau of Land Management (BLM). This publication is Contribution Number 950, Department of Oceanography, University of Washington WB-10, Seattle, Washington.

#### Family ONCAEIDAE Giesbrecht, 1892

Prosome and urosome divisions well defined, the latter generally slender. Prosome, and urosome of female, 5-segmented; urosome of male 6-segmented. Prosome elongate to elongate-oval, or cyclopidiform. Antenna 1 short, with reduced number of segments. Antenna 2 3-segmented, subprehensile to prehensile. Labrum medially incised. Mandible complex, with 3-5 subterminal elements. Maxilla 1 small, bilobed. Maxilliped a well developed claw in both sexes. Legs 1-4, exopods and endopods essentially 3-segmented. Leg 5 a single free segment or represented by 1-3 setae.

Sars revised the family Oncaeiidae and questioned the inclusion of the genus *Pachos* (Claus, 1863). On the basis of a female and a male specimen in the genus *Pachos* that occurred in sample TA 45 (Table 1), it is apparent that the antenna 1 and the oral

appendages of this genus differ from any of the other genera Sars included in the family Oncaeiidae: *Conaea*, *Lubbockia*, *Oncaea*, and *Pseudolubbockia*. As a result of having examined specimens from each of these genera and from the genus *Epicalymma*, recently described as an addition to the Oncaeiidae (G. A. Heron, 1977), we affirm Sars' supposition and exclude *Pachos* from the Oncaeiidae.

Humes and Stock (1973) stated that Oncaeiidae are rather closely related to the sabelliphilid and lichomolgid poecilostomes, but that several important features establish their distinctions. It is likely that Humes and Stock considered only the genus *Oncaea* when they included among these principal differing features a nonprehensile antenna 2 and the form of the mandible. In our opinion, antenna 2 of Oncaeiidae is at least subprehensile, grading through *Oncaea* species toward a prehensile type, found also in *Epicalymma* and *Conaea* species, while in *Pseudolubbockia* and *Lubbockia* species, especially in females, it is definitely prehensile. The form of the mandible in *Lubbockia* species also approaches the lichomolgoide type. We believe, therefore, that Oncaeiidae are even more closely related to the Lichomolgoidea than has previously been suggested.

#### Key to the Genera of the Family Oncaeiidae

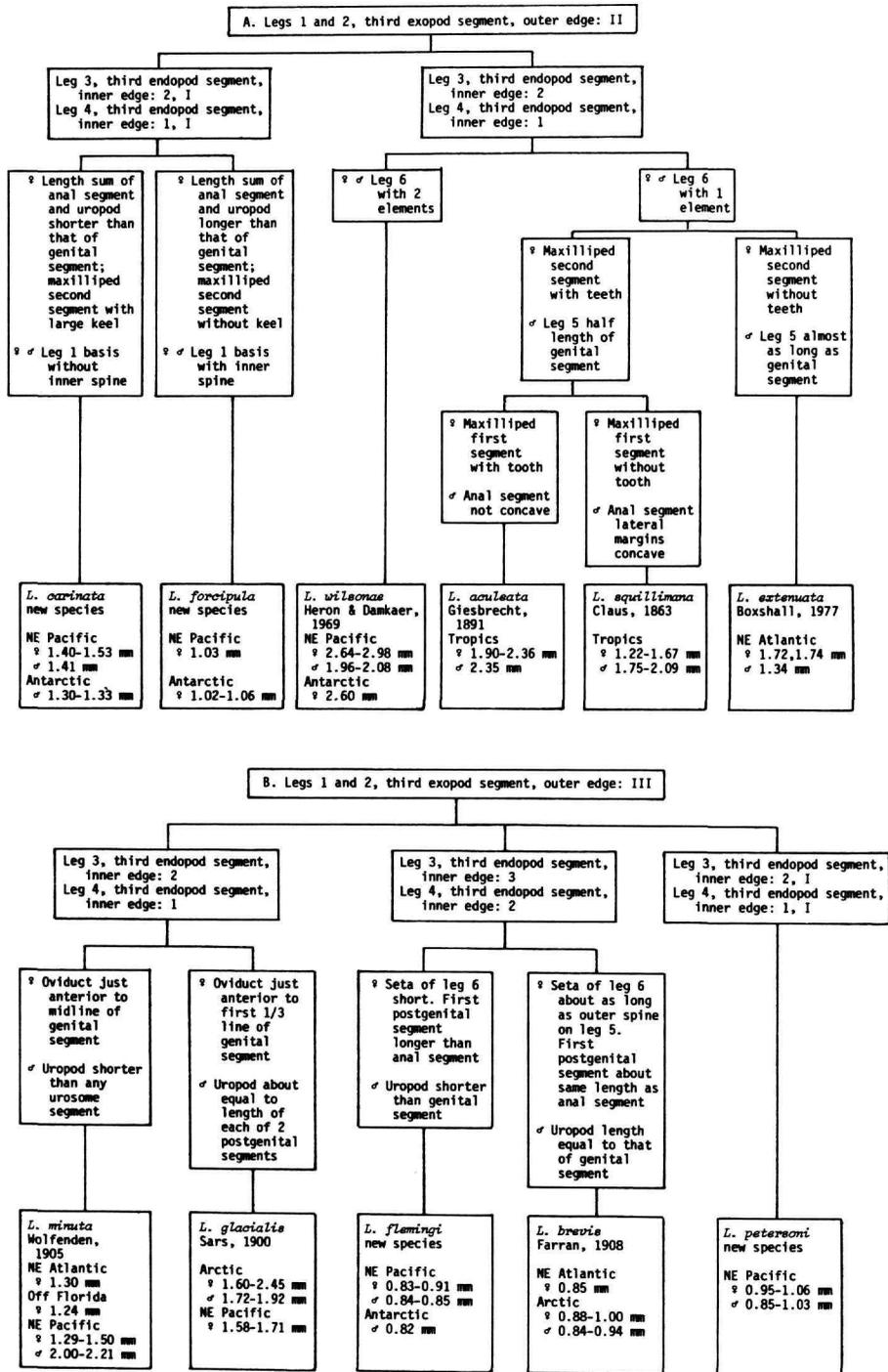
1. Legs 1-4 with inner coxal seta ..... 2  
    Legs 1-4 without inner coxal seta ..... 3
2. Mandible with narrow serrate tip; leg 5 a free segment armed with 4 elements .....  
    ..... *Pseudolubbockia* Sars, 1909  
    Mandible terminating in a lash or lashed element; leg 5 absent (1 species) or a free segment  
    armed with 2 elements ..... *Lubbockia* Claus, 1863
3. Uropod with conspicuous expansion on dorsal surface, surrounding insertion of dorsal seta .... 4  
    Uropod without expansion on dorsal surface ..... *Oncaea* Philippi, 1843
4. Legs 1-3 third exopod segment with II, III, III outer spines ..... *Epicalymma* G. A. Heron, 1977  
    Legs 1-3 third exopod segment with III, II, II outer spines ..... *Conaea* Giesbrecht, 1891

#### Genus *Lubbockia* Claus, 1863

Prosome elongate to elongate-oval; urosome slender. Antenna 1 7-segmented, with 1 or more incomplete sutures on female, the third segment with 2 spines; at least the 3 terminal segments always fused on male. Antenna 2 with elongate third segment; female armature formula: 0, 1, 3 (sub-apical) + 3 (terminal) + 3 or 4 terminal claws. Mandible blade with scalelike denticles on median edge and terminating in a lash; 1 inner and 2

dorsal elements. Maxilla 1 a bilobed appendage, lobes with 2, 3 or 3, 3 elements. Maxilla 2 with a short setule and 3 (1 bifurcate) or 4 ornamented elements. Oral appendages of male degenerate in some species, maxilliped usually dimorphic.

Variable armature characteristics, as noted under species descriptions, are: (1) inner edge of leg 1 basis, (2) outer edge of third exopod segment in legs 1 and 2, and (3) inner edge of third endopod segment in legs 3 and 4. Such characteristics appear to reflect natural groups in the *Oncaea-Epicalym-*

FIGURE 2.—Diagrammatic key to the species of the genus *Lubbockia*.

*ma-Conaea* complex but probably no such groups exist within *Lubbockia* species. The characteristics enumerated above are among those used to prepare a diagrammatic key to the species of *Lubbockia* (Figure 2). The generic pattern of armature is as follows, with a numeral representing a constant value and an asterisk indicating a variable count.

Leg	Coxa		Basis		Endopod				Exopod						
	Si		Si	Se	1	2	3	St	Se	1	2	3	Si	St	Se
1	1		*	1	1	1	4	I	I	I	1	I	4	I	*
2	1		0	1	1	2	3	II	I	I	1	I	5	I	*
3	1		0	1	1	2	*	II	I	I	1	I	5	I	II
4	1		0	1	1	2	*	II	I	I	1	I	5	I	II

present even when the projection is lacking. Often a vent is also on the inner distal corner of the basis of all swimming legs.

Leg 5 a free segment bearing 2 terminal elements, or leg 5 absent and represented by 1 lateral seta.

*Lubbockia* is an interesting and complex genus, far more variable than many other polytypic poecilostome genera. Specific differences include slight variations in body shape, but major differences in maxilliped and leg 5 structure, and armature and relative length of endopods and exopods of legs 1-4. The individual *Lubbockia* species show various relationships to other oncaeid genera, depending on the morphological features compared. The relationship of *Lubbockia* to *Pseudolubbockia* is seen to be close when the comparison is based on *L. carinata*, *L. forcipula*, and *L. petersoni*.

With considerable foresight, Claus (1863) named *Lubbockia* "for the deserving English investigator" John Lubbock, afterward Sir John Lubbock, Lord Avebury (1834-1913). It is difficult to select a single area of endeavor to characterize Lubbock, for he became preeminent in many fields and was the author of a great number of scientific and popular books. His earliest published papers dealt with Copepoda (1853-1863), including specimens collected by Darwin on H.M.S. *Beagle*. Although much of Lubbock's efforts were in taxonomy, he felt strongly that these investigations were not ends in themselves, but only instruments for the understanding of animal behavior. Lubbock was the first to experiment on color vision in insects, and he did extensive research on social-insect be-

All species, except *Lubbockia flemingi*, with hyaline papilla partially covering vent on outer edge of leg 1 coxa. *Lubbockia*, as well as *Oncaea*, species usually have small or conspicuous conical projections between 2 terminal spines on the endopods of legs 2 and 3, and sometimes leg 4. These terminal projections appear to support a vent, which is

havior. By profession a banker, Lubbock instigated major alterations in English banking practices. He was a Member of Parliament, where he introduced far sighted legislation having a present day cast. Among these proposals were: Open Spaces Act, Ancient Monuments Acts, and Wild Birds Protection Act. Lubbock was the first to correctly attribute Stonehenge to the Bronze Age; his archeology texts, in which he coined the terms "paleolithic" and "neolithic," were standard for a generation. Lubbock's father, Sir John Lubbock, was a physical astronomer, dealing especially with tidal theory; both men were vice-presidents of the Royal Society. Young Lubbock was a friend, neighbor, and finally pallbearer of Charles Darwin, who said that he relied on the opinions of three men only—Hooker, Huxley, and Lubbock. Lubbock's name is also perpetuated in some genera of insects, and in some copepod species. There are several biographies of Lubbock, including a recent one by Pumphrey (1959).

### *Lubbockia carinata*, new species

#### FIGURES 3-6

MATERIAL STUDIED (Tables 1, 2).—NE PACIFIC: 4 females, 1.40-1.53 mm, NP 4 et al. (including: holotype, 1.44 mm, NP 4, USNM 168487; 1 paratype, 1.41 mm, NP 12, USNM 168489); 1 male, allotype, 1.41 mm, NP 7, USNM 168488; 1 juvenile, stage IV, 1.16 mm, NP 32. ANTARCTIC OCEAN: 2 males, 1.30-1.33 mm, AA 41, 42.

FEMALE.—Average length 1.47 mm. Prosome

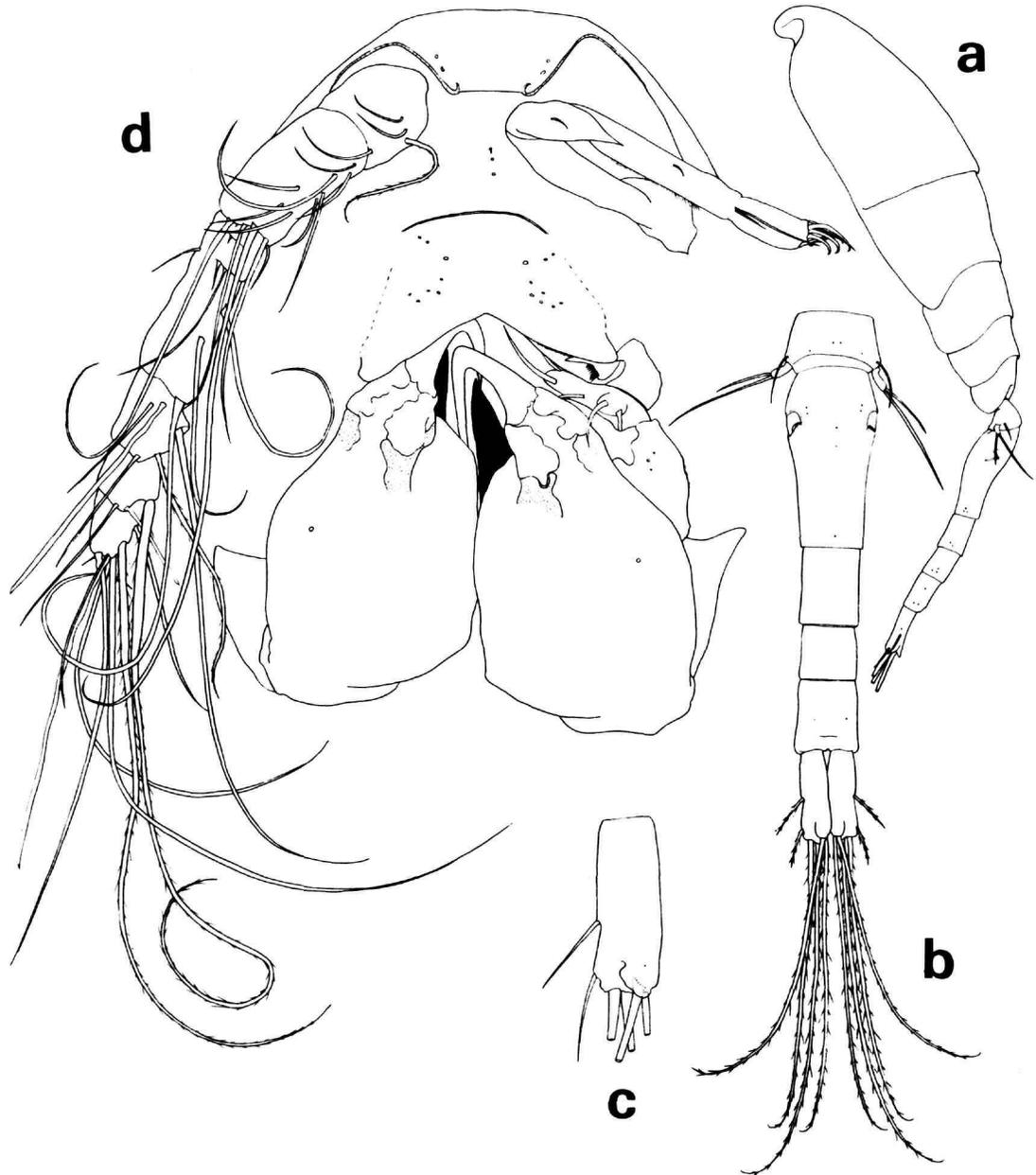


FIGURE 3.—*Lubbockia carinata*, new species, female: a, lateral (A); b, urosome, dorsal (C); c, uropod, dorsal (E); d, cephalosome, ventral (maxilliped keel darkened) (E).

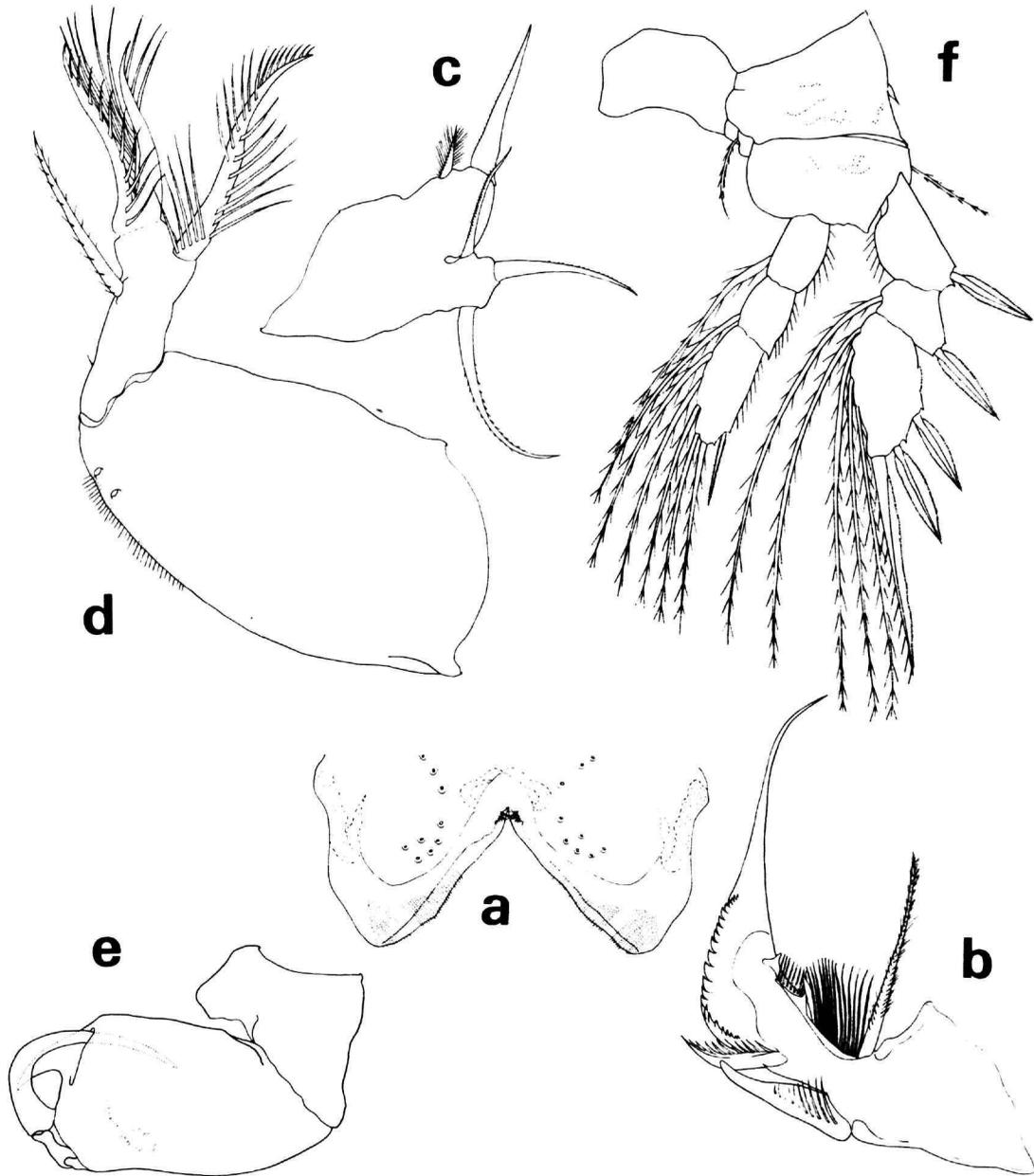


FIGURE 4.—*Lubbockia carinata*, new species, female: *a*, labrum, ventral (F); *b*, mandible, right (G); *c*, maxilla 1, left (G); *d*, maxilla 2, right (G); *e*, maxilliped, right (E); *f*, leg 1 (E).

(Figure 3a) about 1.6 times length of urosome, with rounded posterior corners.

Pediger 5 (Figure 3b) with faint transverse ridge dorsoposteriorly. Genital segment with areas of external genital apparatus on anteriolateral third of segment, each area with 3 setules; genital segment and each postgenital segment with delicate spinules on posteroventral margin. Uropod approximately half the length of genital segment, with short spinules on ventral surface; dorsal, innermost, and outer long terminal setae nearly as long as inner long terminal seta; rounded laminal flap (Figure 3c) extending over base of dorsal seta.

Rostrum (Figure 3d) with thickened posteroventral margin, truncate as shown in ventral view.

Antenna 1 (Figure 3d) 7-segmented, with rudimentary articulation between segments 3-4 and 5-6. Armature formula: 4, 13 + 1 spinule, 1 + 2 spines, 4, 4 + 1 esthete, 2 + 1 esthete, 7 + 1 esthete.

Antenna 2 (Figure 3d) 3-segmented, with incomplete suture at distal third of terminal segment. Second segment with 1 seta. Third segment with inner setules and 3 subapical setae; armed terminally with 3 setae and 4 claws, all short.

Labrum (Figure 4a) with free margin divided into 2 deltoid posteroventral lobes; a number of conspicuous gland vents on outer surface and rows of setules inserted on under surface.

Mandible (Figure 4b) with 2 outer elements ornamented with rows of setules; mandible blade with row of graduated, scalelike denticles on the median edge; apical lash slender and long; concave edge of base with a hirsute element and rows of long setules supported by 2 riblike processes.

Maxilla 1 (Figure 4c) flat, bilobed; 3 barbed elements on outer lobe and 1 barbed and 1 setose element on inner lobe.

Maxilla 2 (Figure 4d) 2-segmented. First segment with expanded base and outer row of setules. Second segment outer margin with a hyaline setule and setose, stout seta; terminally bearing 2 setulose elements; a constriction and sclerotization suggesting segmentation near the anterior base but posterior base fused; curved setulose element on inner margin.

Maxilliped (Figure 4e) apparently 4-segmented; complicated sclerotized pattern in area of segment 3. Second segment with a remarkable anterior keel-like process, curving posteriorly beside an inner pocket which serves as a sheath for the terminal

claw; segment 2 with short outer spinules.

Leg 1 (Figure 4f) without inner spine on basis, third exopod segment with 2 short outer spines. Leg 2 (Figure 5a) third exopod segment with 2 short outer spines. Leg 3 (Figure 5b) inner edge of third endopod segment with 2 setae and 1 spine. Leg 4 (Figure 5c) inner edge of third endopod segment with 1 seta and 1 spine. Legs 2-4 endopods terminate with a small vented conical projection between spines.

Leg 5 (Figure 3b) with short free segment; 2 terminal elements, the longer tapering in a way which suggests there is a fine serrate, hyaline flange; length less than twice that of the outer. Seta on body near leg.

Leg 6 probably represented by 3 short, hyaline setules in area of external genital apparatus.

MALE.—Average length 1.35 mm. Prosome (Figure 6a) about 1.7 times the length of urosome.

Urosome (Figure 6b) with the 4 postgenital segments bearing spinules on posteroventral margins. Uropodal setae with relative lengths as in female.

Rostral area and mouthparts, except antenna 1 and maxilliped, as in female.

Antenna 1 with segments corresponding to terminal 3 of female, fused in male; armature similar to corresponding segments of female.

Maxilliped (Figure 6c) with segment 2 and claw elongate compared to female; 2 short segments proximal to claw.

Swimming legs and leg 5 resemble those of female.

Leg 6 (Figure 6b) probably represented by posteroventral pointed flap on genital segment.

STAGE IV.—Length 1.16 mm, with 4 segments and uropod in urosome; leg 5 small and segmented (Figure 6d). Maxilliped with keel-like process well developed.

ETYMOLOGY.—The specific name *carinata*, from the Latin *carinatus* (keeled) refers to the keel-like process on the maxilliped of the female.

REMARKS.—*Lubbockia carinata* superficially resembles *L. forcipula*, but differs from it by the relatively shorter uropods, distinctively keeled female maxilliped and by the lack of an inner spine on leg 1 basis. *Lubbockia carinata*, *L. glacialis*, and *L. minutus* are the only *Lubbockia* species without a spine on leg 1 basis.

*Lubbockia carinata* also resembles *L. forcipula*

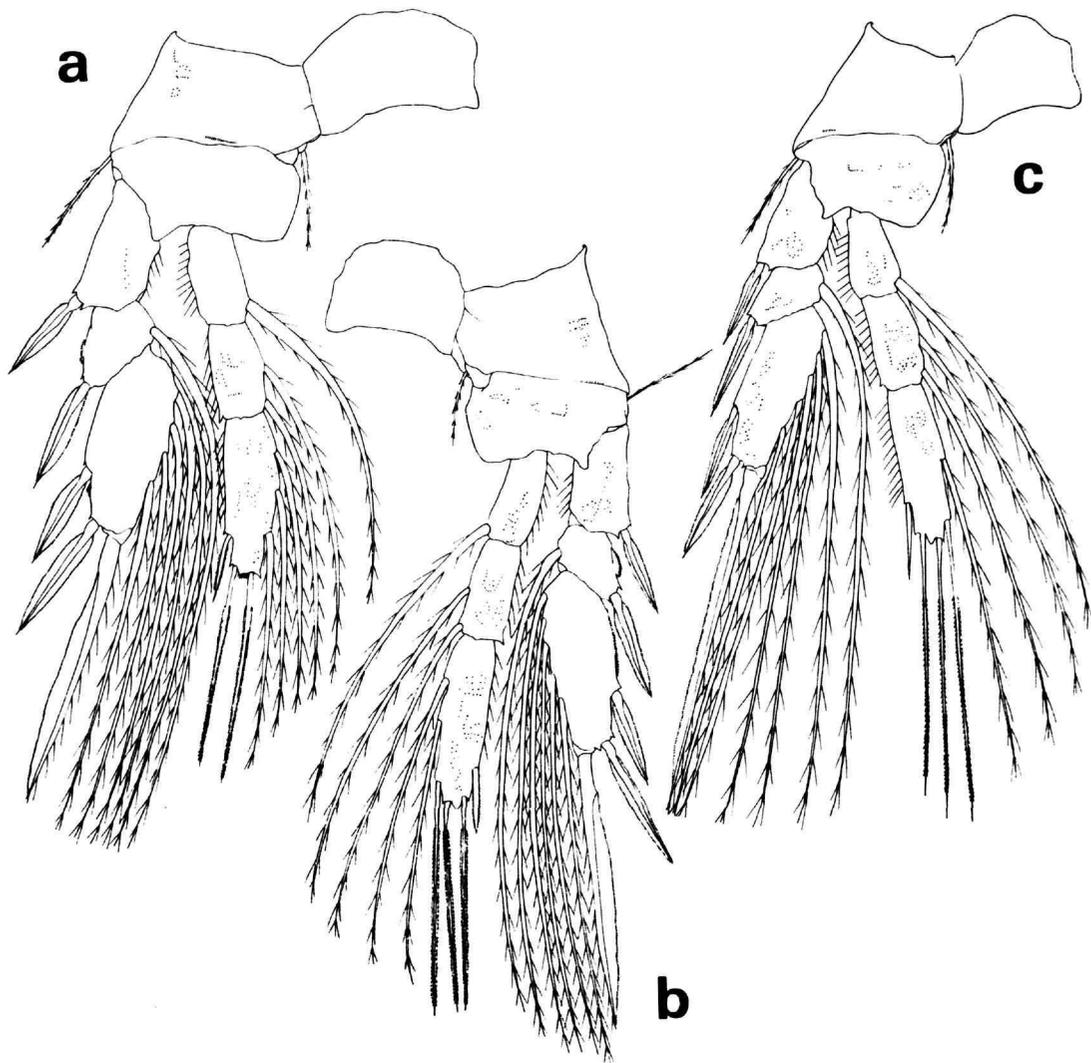


FIGURE 5.—*Lubbockia carinata*, new species, female: a, leg 2 (E); b, leg 3 (E); c, leg 4 (E).

in having a seta on body near leg 5. *Lubbockia petersoni* has such a seta but lacks leg 5. These are the only known *Lubbockia* species with this seta, which is probably a remnant of leg 5 basis. A similarly placed seta is characteristic of the other genera of Oncaeidae: *Pseudolubbockia*, *Oncaea*, *Epicalymma*, and *Conaea*.

*Lubbockia carinata* and *L. forcipula* have armature of female antenna 1 resembling that of *Pseudo-*

*lubbockia dilatata* Sars, 1909, except for having 2 additional setae and 1 spinule on segment 2. These 3 Oncaeidae species also differ from all other *Lubbockia* females by having an additional seta on segments 3 and 5, and 7 setae and 1 esthete on the terminal segment instead of the usual 5 setae and 2 esthetes.

We have restudied *Pseudolubbockia dilatata* for comparison with *Lubbockia* species and have modi-

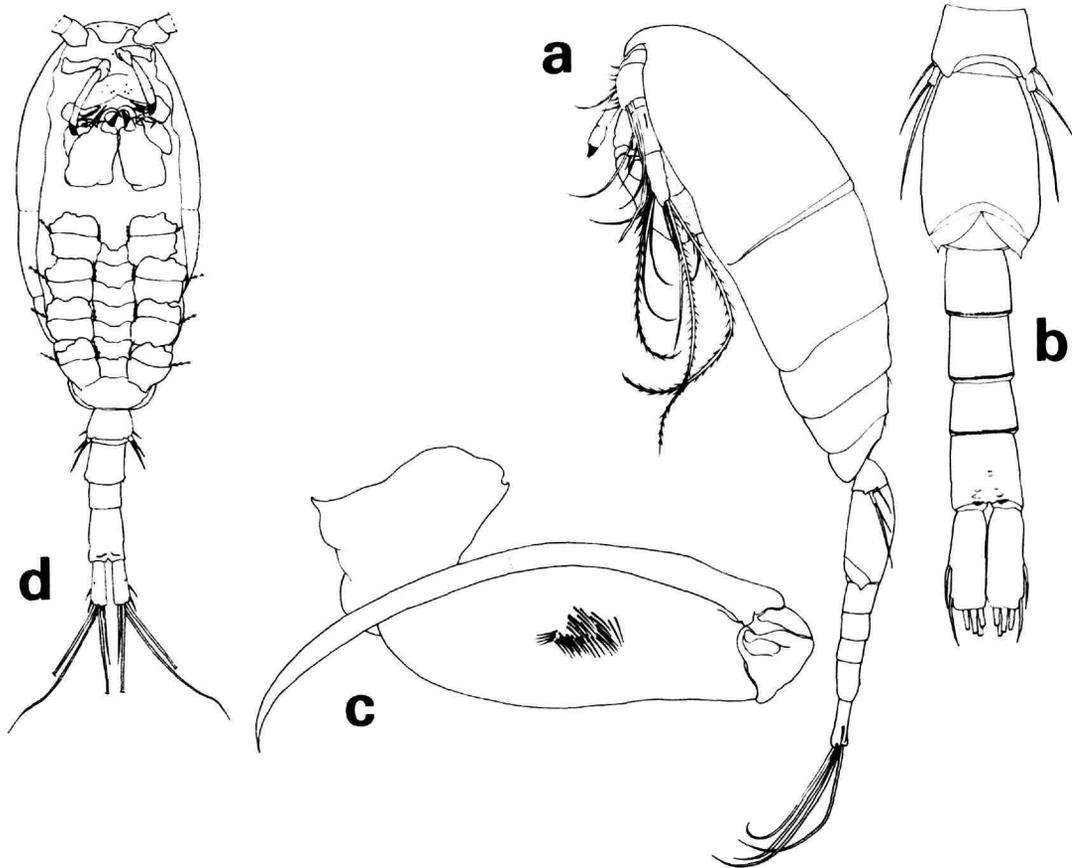


FIGURE 6.—*Lubbockia carinata*, new species, male: a, lateral (A); b, urosome, ventral (C); c, maxilliped, left (E). Stage IV: d, ventral (maxilliped keel darkened; antenna 1, except basal segment, and swimming leg rami omitted) (A).

fed our diagnosis concerning details of *P. dilatata* antenna 1. Antenna 1, 7-segmented, with an incomplete suture on inner surface between 5–6. Armature formula: 4, 11, 1 + 2 spines, 4, 4 + 1 esthete, 2 + 1 esthete, 7 + 1 esthete. The esthetes are relatively short, narrow, and each is associated with a short seta, on proximal third of segment 5 and distal margins of segments 6 and 7. The short seta on the posterior margin of segment 5 is an error in figure 2, Heron and Damkaer, 1969.

The maxillipeds of several species of caligoid copepods have been described with a prominent second segment keel or similar process associated with the tip of the terminal claw, as in *L. carinata*:

*Dysgamus atlanticus* Steenstrup and Lütken, 1861 (pl. 4: fig. 8), *Dysgamus pacificus* Wilson, 1950 (pl. 6: fig. 55), and Lewis (1968, fig. 8d) for *Dissonus heronensis* Kabata, 1966. Lewis (pers. comm.) has stated that the legends for his figure 8d,e were inadvertently transposed and that figure 8d is the maxilliped of female *D. heronensis*.

The long, resilient uropodal setae of *L. carinata* and *L. forcipula* resemble the uropodal setae in *Conaea* and *Epicalymma* species, but differ from those of *Oncaea*, *Pseudolubbockia*, and the other *Lubbockia* species.

DISTRIBUTION.—Northeast Pacific and Antarctic Ocean (Tables 1, 2).

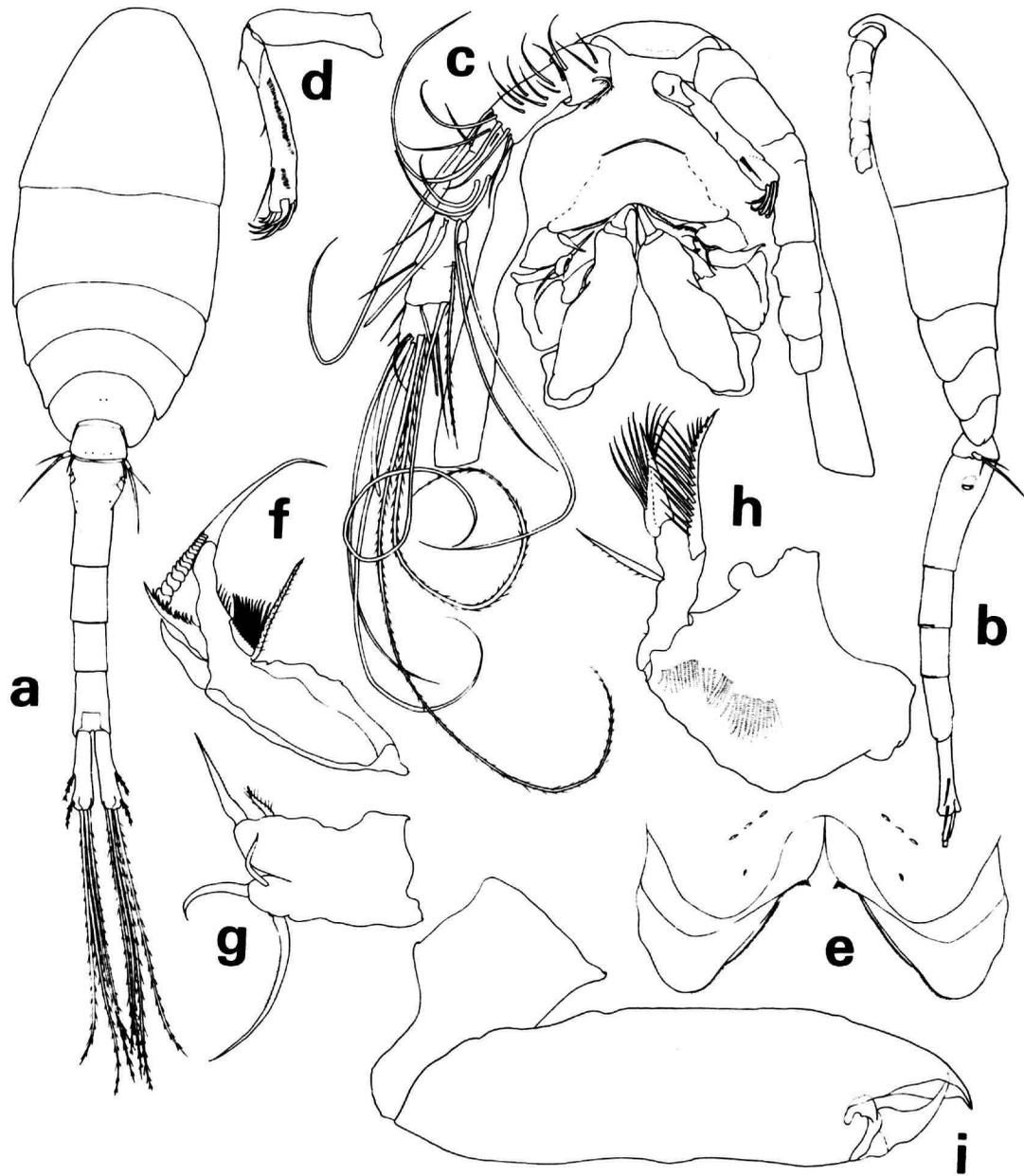


FIGURE 7.—*Lubbockia forcipula*, new species, female: a, dorsal (C); b, lateral (C); c, cephalosome, ventral (E); d, antenna 2, right (E); e, labrum, ventral (G); f, mandible, left (G); g, maxilla 1, right (G); h, maxilla 2, right (G); i, maxilliped, right (G).

*Lubbockia forcipula*, new species

FIGURES 7-8

MATERIAL STUDIED (Tables 1, 2).—NE PACIFIC: 1 female, holotype, 1.03 mm, NP 11, USNM 168492. ANTARCTIC OCEAN: 2 females, 1.08, 1.12 mm, AA 42.

FEMALE.—Length about 1.08 mm. Prosome (Figure 7a,b) 1.2 times the length of urosome.

Pediger 5 with transverse sclerotized ridge dorso-

posteriorly. Genital segment with areas of external genital apparatus on anteriolateral third of segment; each area with a setule. Genital segment and each postgenital segment with delicate minute spinules on posteroventral margin. Uropod about  $\frac{2}{3}$  length of genital segment, posteriorly dilated over base of dorsal seta; dorsal, innermost, and outer long terminal setae nearly as long as inner long terminal seta.

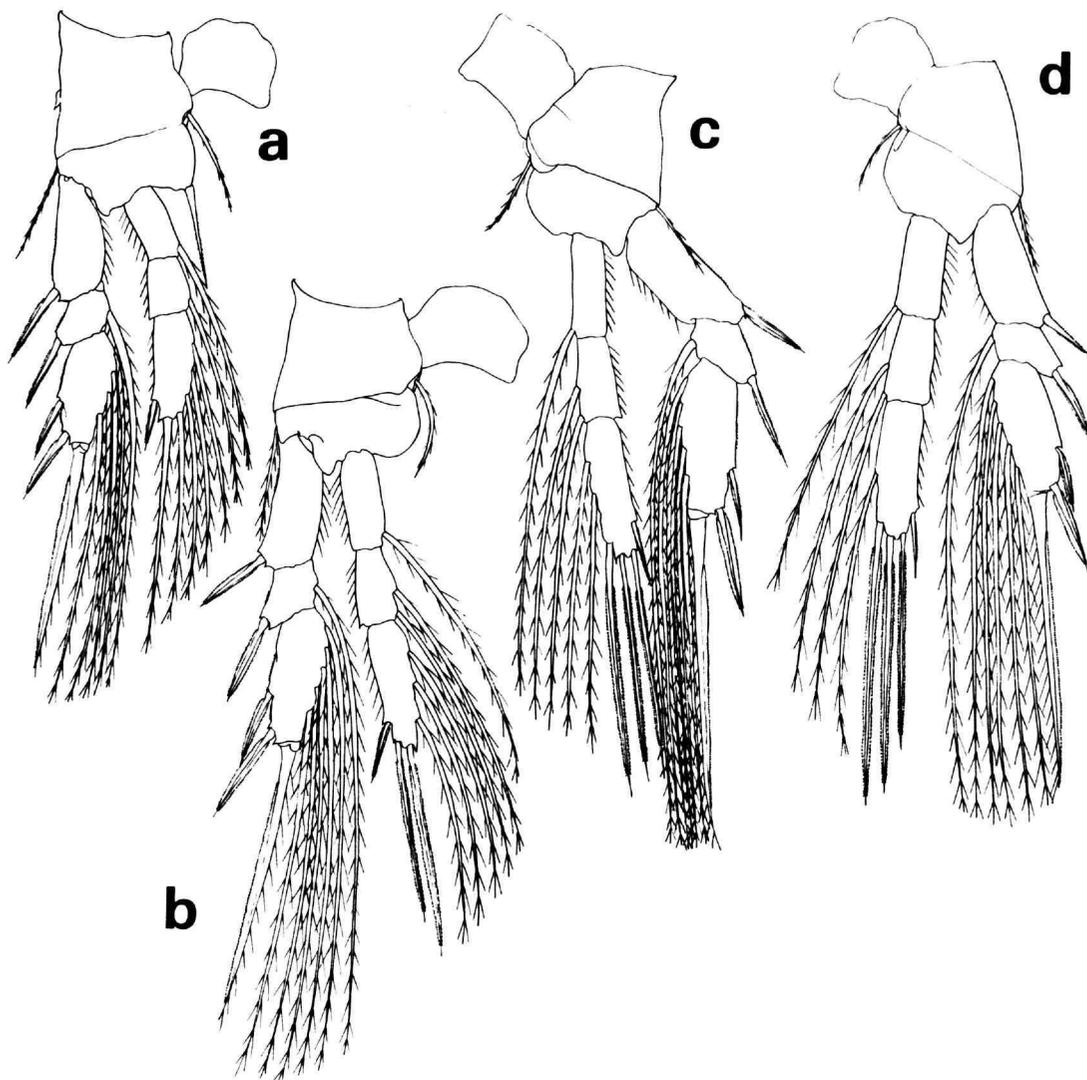


FIGURE 8.—*Lubbockia forcipula*, new species, female: a, leg 1 (E); b, leg 2 (E); c, leg 3 (E); d, leg 4 (E).

Rostrum with thickened posteroventral margin slightly depressed and indented as shown in ventral view of cephalosome (Figure 7c).

Antenna 1 (Figure 7c) and antenna 2 (Figure 7c,d) with armature similar in number to that of *L. carinata*.

Labrum (Figure 7e) with free margin divided into 2 posteroventral lobes, each with a subapical cluster of setules; complex pattern of layers of tissues with hyaline setules inserted on under surfaces.

Mandible (Figure 7f), maxilla 1 (Figure 7g), and maxilla 2 (Figure 7h) with armature similar in number to that of *L. carinata*.

Maxilliped (Figure 7i) 4-segmented, cheliform. Second segment beaklike, projecting beyond and somewhat enclosing the tip of short terminal claw, the complex forming a short, strong pincer.

Legs 1-4 (Figure 8a-d) with armature similar in number to that of *L. carinata* except for the addition of an inner spine on leg 1 basis.

Leg 5 (Figure 7a) similar in general form to that of *L. carinata*, including seta on body near leg.

Leg 6 probably represented by short, hyaline setule in area of external genital apparatus.

MALE.—Unknown.

ETYMOLOGY.—The specific name, from the Latin *forcipula* (nippers, tongs), refers to the appearance of the maxilliped in the female.

REMARKS.—The truncate shape of the *L. forcipula* rostrum resembles *L. carinata*, but the depressed and indented posterior margin is similar to that of *Pseudolubbockia dilatata*.

Of the known species of *Lubbockia*, only *L. forcipula*, *L. carinata*, and *L. petersoni* have an inner spine on legs 3 and 4 third endopod segment; *L. carinata* and *L. forcipula* differ from *L. petersoni* by having 2 (rather than 3) outer spines on legs 1 and 2 third exopod segment. *Lubbockia forcipula* and *L. carinata* also differ from other *Lubbockia* species by having 13 setae (rather than 7) on antenna 1 second segment.

The unusual maxilliped of *L. forcipula*, having a short, hooded terminal claw, separates it from *L. carinata*, which it otherwise resembles. The maxilliped of *L. forcipula* resembles that of *Phyllotherus cornutus* (Milne-Edwards, 1840), a caligoid copepod parasitic on sharks (see Cressey, 1967, fig. 130).

DISTRIBUTION.—Northeast Pacific and Antarctic Ocean (Tables 1, 2).

### *Lubbockia wilsonae* Heron and Damkaer, 1969

FIGURE 9

*Lubbockia aculeata*.—Vervoort, 1951:151; 1957:148. [Not *L. aculeata* Giesbrecht, 1891.]

*Lubbockia wilsonae* Heron and Damkaer, 1969:9-15, figs. 11-19.

The original description of *Lubbockia wilsonae* was based on 2 females (2.70, 2.75 mm) from the Gulf of Alaska. Additional specimens of both sexes from the northeast Pacific have made it possible to describe the male and amend the original description of the female.

MATERIAL STUDIED (Tables 1, 2).—NE PACIFIC; Prince William Sound, Alaska: 3 females, 2.80-2.98 mm, NP 1. Near the Canadian weathership sta P: 6 females, 2.64-2.88 mm, NP 38, 39; 3 males, 1.96-2.08 mm, NP 38, USNM 168503, 168504; 8 juveniles, stage V, NP 38, 39; 2 juveniles, stage IV, both 1.48 mm, NP 39; 2 juveniles, stage III, 0.97, 1.06 mm, NP 7, 4 (frequency of sex and stage categories by depth for samples NP 38, 39 shown in accompanying tabulation). ANTARCTIC OCEAN: 3 males, 2.42-2.44 mm, AA 42.

m	6 Aug			7 Aug		
	♀	♂	V	♀	V	IV
165-110		1				
220-165	1		1			
275-220				2	1	1
330-275			3		2	1
385-330	1	2	1			
440-385	1			1		

FEMALE.—Rostrum (Figure 9a) rounded posteriorly. Antenna 1 in all *Lubbockia* species appears to be fundamentally 7-segmented; segment 3 often with incomplete or no suture separating 4. Female *Lubbockia* specimens have been described as having from 4 or 5 to 7 segments in antenna 1; some sutures are incomplete on inner surface, while articulation is usually more distinct on outer surface. *Lubbockia wilsonae* female antenna 1 is 7-segmented (rather than 6) with segments 3-4 partially or completely fused. Armature should be corrected from original description to 4, 6 + 1 esthete + 1 spinule, 2 spines, 4, 3 + 1 esthete, 2 + 1 esthete, 5 + 2 esthetes (1 seta, about equal to combined length of segments 5-7, in place of 2 short setae shown on figure 14 of Heron and Damkaer, 1969).

Maxilla 1 (Figure 9b) bilobed; inner lobe with 2 elements and short hyaline setules; 3 elements on larger lobe.

MALE.—Length about 2.01 mm (NE Pacific) to

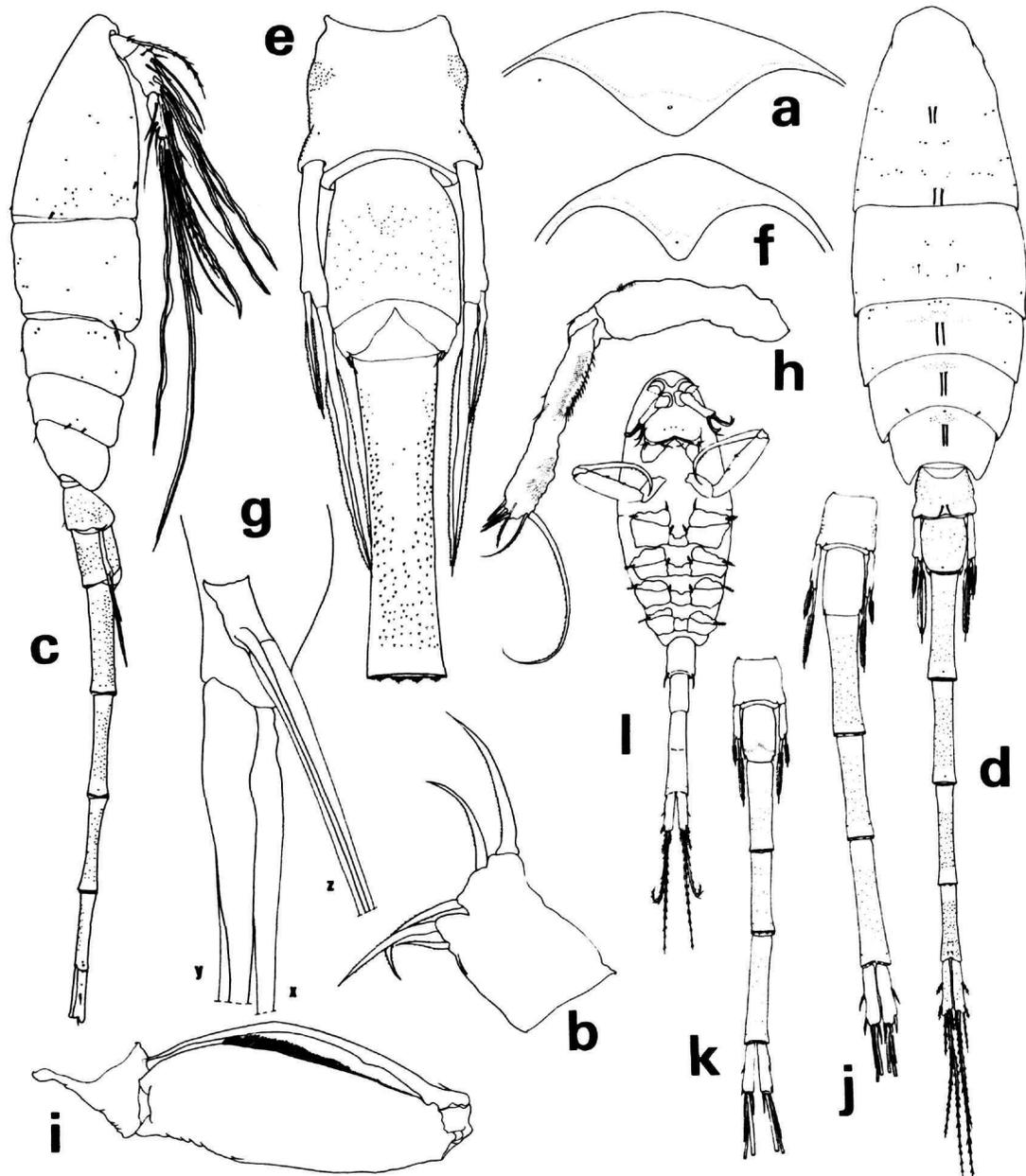


FIGURE 9.—*Lubbockia wilsonae* Heron and Damkaer, female: *a*, rostrum, ventral (E); *b*, maxilla 1, right (F). Male: *c*, lateral (A); *d*, dorsal (A); *e*, first 3 urosomal segments, ventral (D); *f*, rostrum, ventral (E); *g*, antenna 1 distal esthete bases *x*, *y*, and *z* (G); *h*, antenna 2, left (E); *i*, maxilliped, right (E). Stage V, female: *j*, urosome, ventral (A). Stage V, male: *k*, urosome, ventral (A). Stage III: *l*, ventral (antenna 1, except basal segment, and swimming leg rami omitted) (A).

2.43 mm (Antarctic). Body (Figure 9c,d) slender, with prosome to urosome ratio and relative lengths of urosomal segments similar to female. Prosome with conspicuous sensilla, gland vents, and minute spinules. Urosomal segments covered with minute spinules, somewhat larger on most ventral surfaces; posteroventral margins with spinule patterns similar to those of female. Genital segment (Figure 9e) with conspicuous spinules on ventral surface. Relative lengths of uropodal setae as in female.

Rostrum (Figure 9f) more tapered posteroventrally than in female.

Antenna 1 distinctly segmented only between segments 4 and 5 and outer surface of 1 and 2. Armature similar in number to that of female except for additions of esthete on segment 2 and 2 esthetes on segment 4. All esthetes, except 1 each on segments corresponding to segments 2 and 7 (labeled "x" in Figure 9g) longer and of a different structure than those of female. Terminal esthete (labeled "y" in Figure 9g) with broad base and wide setalike rib supporting entire length; nearly reaches urosome segment 3. The 5 other esthetes extend from a short base (labeled "z" in Figure 9g) and also have a supporting rib.

Antenna 2 (Figure 9h) third segment sexually dimorphic; 3 terminal claws of female modified to 3 short setae, and 1 seta modified to long lash; 2 clusters of long setules on inner surface.

Labrum with hood extending to cover vertex between the 2 posteroventral lobes.

Mandible, maxilla 1, and maxilla 2 degenerate, variable between specimens and right and left.

Maxilliped (Figure 9i) with outer surfaces of segments 1 and 2 rugose; second segment with inner row of setules; cluster of long, delicate setules on inner distal surface; terminal claw undulant.

Swimming legs and leg 5 as in female.

Leg 6 probably represented by posteroventral flap on genital segment, bearing 2 elements.

STAGE V.—Female (Figure 9j) 1.98 mm, male (Figure 9k) 1.75 mm, with 5 segments and uropod in urosome; leg 5 well developed. Male with a faint sclerotized ventral line on genital segment in area of adult anterior margin of posteroventral flap.

STAGE IV.—Length 1.48 mm, with 4 segments and uropods in urosome; leg 5 small with 2 spines; inner spine reaching beyond posterior edge of next segment.

STAGE III.—Two specimens, 0.97, 1.06 mm, with

5 segments in the prosome and 3 segments and uropods in urosome (Figure 9l); leg 5 represented by 1 spine. Antenna 2 with 6 elements similar to that in adult female. Maxilliped with relative size similar to that in adult female, 2 small triangular spines on second segment and small hyaline spinules on terminal claw.

REMARKS.—The 3 *L. wilsonae* males from the Antarctic differ from the northeast Pacific specimens by their larger size and greater number of spinules on the urosome. All other morphological characters appear to be similar.

Among the *Lubbockia* species with 2 outer spines on legs 1 and 2 third exopod segment, only *L. wilsonae* has 2 elements representing leg 6.

DISTRIBUTION.—Northeast Pacific and Antarctic Ocean (Tables 1, 2; Heron and Damkaer, 1969).

### *Lubbockia aculeata* Giesbrecht, 1891

#### FIGURES 10-11

*Lubbockia aculeata* Giesbrecht, 1891:477; 1892:606-611, pl. 48: figs. 3, 9, 11, 13, 16, 20.

Giesbrecht described *Lubbockia aculeata* from specimens collected in the tropical eastern Pacific Ocean (female, 2.30 mm; male, 2.35 mm).

Our specimens agree with the characters which Giesbrecht outlined for the species. Additional species in the genus now require more detailed comparisons, so we include figures of several features not emphasized by Giesbrecht.

MATERIAL STUDIED (Tables 1, 2).—ATLANTIC OCEAN, off Bahamas: 2 females, 1.90, 2.13 mm, TA 44. Near Florida: 2 females, 2.10, 2.36 mm, TA 45. PACIFIC OCEAN, near Philippine Islands: 1 female, 2.05 mm, TP 43.

FEMALE.—Average length about 2.09 mm. Body and all appendages with unusually thick exoskeleton. Rostrum with complex pattern of sclerotization and pointed posteroventral margin as shown in ventral view of cephalosome (Figure 10a).

Antenna 1 as in *L. wilsonae*.

Antenna 2 (Figure 10b) and mandible (Figure 10c) with armature similar in number to that of *L. carinata*.

Maxilliped similar to *L. squillimana* and *L. wilsonae*, with large dentiform processes on second segment, but *L. aculeata* with 1 large dentiform process on first segment (Figure 11a). First segment

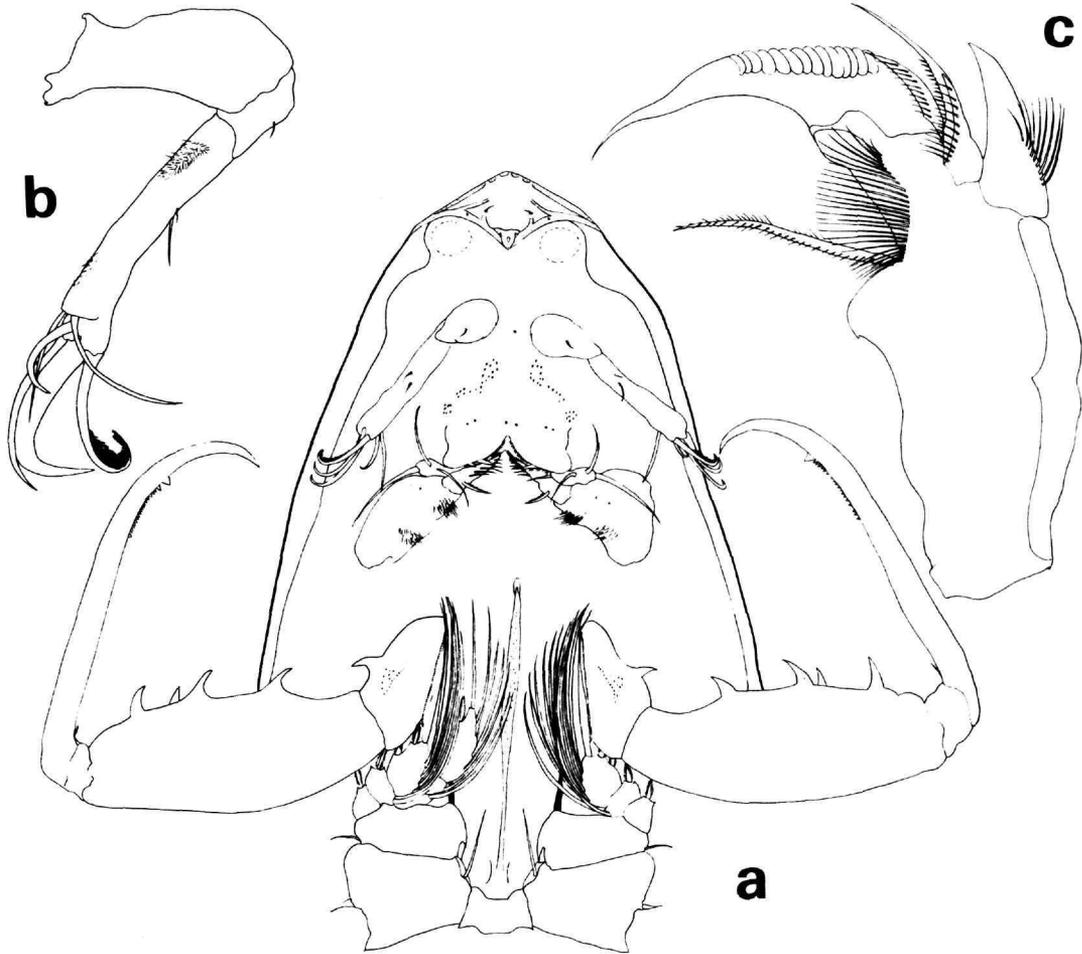


FIGURE 10.—*Lubbockia aculeata* Giesbrecht, female: a, cephalosome and somite of leg 1, ventral (C); b, antenna 2, left (E); c, mandible, left (G).

may have small spinules in addition to dentiform process (Figure 10a).

Leg 1 (Figure 11b) with inner spine on basis, third exopod segment with 2 short outer spines. Leg 2 (Figure 11c) third exopod segment with 2 short outer spines. Leg 3 (Figure 11d) inner edge of third endopod segment with 2 setae. Leg 4 (Figure 11e) inner edge of third endopod segment with 1 seta. Legs 2-4 endopods terminate with a vent between spines.

REMARKS.—Fryer (1957:14) stated that the swimming legs of certain freshwater cyclopoids are always directed forward while feeding, but that the

legs play no part in the actual feeding mechanism. When legs are directed either posteriorly or anteriorly, the usual cases in preserved specimens, the direction of the inner spine on the basis is not clearly apparent (see spine darkened on Figure 10a). However, legs of some specimens were preserved in intermediate positions, and the direction of this spine was obvious (see spine darkened on Figure 11a); it appears that this spine would be useful in holding food. Three of the 11 named *Lubbockia* species (4 of 12 including stages IV and V of "*Lubbockia* species") lack this spine: *L. carinata*, *L. glacialis*, and *L. minuta*.

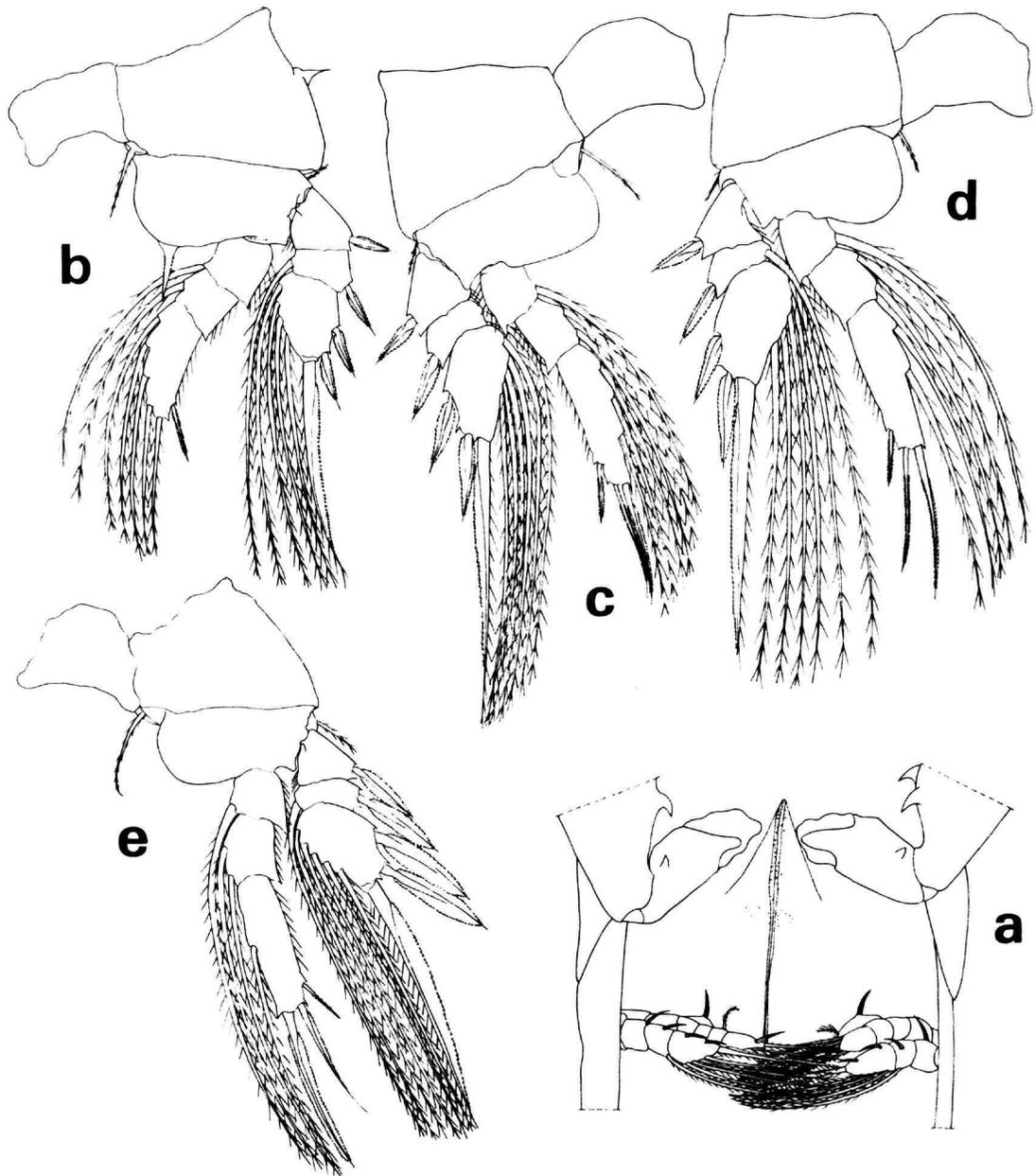


FIGURE 11.—*Lubbockia aculeata* Giesbrecht, female: *a*, maxilliped basal segment and leg 1, ventral (C); *b*, leg 1 (D); *c*, leg 2 (D); *d*, leg 3 (D); *e*, leg 4 (D).

**DISTRIBUTION.**—*Lubbockia aculeata* has a definite tropical distribution, although a few specimens have been collected just outside tropical waters. Records and summaries are from the Pacific Ocean (Tables 1, 2; Giesbrecht, 1891; Farran, 1936; Björnberg, 1973); Indian Ocean and Indo-Pacific (Sewell, 1947); Atlantic Ocean (Tables 1, 2; Cleve, 1904; Farran, 1926; Owre and Foyo, 1967; Vives, 1972); and the Mediterranean Sea (Razouls, 1974).

***Lubbockia squillimana* Claus, 1863**

Figure 12

*Lubbockia squillimana* Claus, 1863:164, 165, pl. 25: figs. 1–5.—

Giesbrecht, 1892:606–611, pl. 4: fig. 6, pl. 48: figs. 1, 2, 4–8 17–19, 21.

*Lubbockia minuta*.—Marukawa, 1927:1237, fig. 2384. [Not *L. minuta* Wolfenden, 1905.]

*Lubbockia marukawai* Mori, 1937:122, 123, pl. 67: figs. 10–13.

Specimens that we studied from different areas varied as little as did ones from within the same sample, and all specimens agreed with Giesbrecht's (1892) excellent description. We have supplemented this description of *L. squillimana*, because of the additional *Lubbockia* species that have been added since Giesbrecht's study.

**MATERIAL STUDIED** (Tables 1, 2).—MEDITERRANEAN SEA, Gulf of Naples: 20 females, 1.29–1.67 mm, M 47, USNM

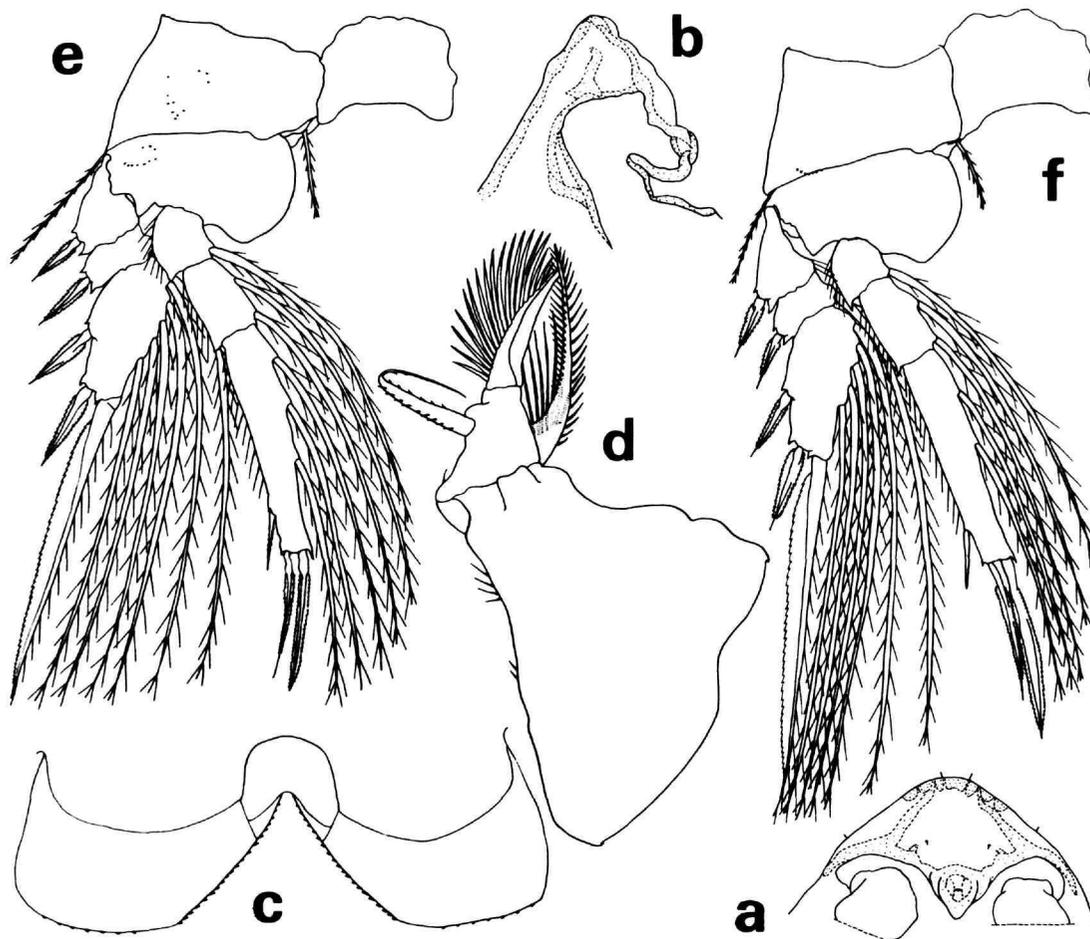


FIGURE 12.—*Lubbockia squillimana* Claus, female: a, rostrum, ventral (E); b, rostrum, lateral (E); c, labrum, ventral (G); d, maxilla 2, right (G); e, leg 2 (E); f, leg 3 (E).

168505; 3 males, 1.98–2.09 mm, M 47, USNM 168505. Western Mediterranean: 3 females, 1.33–1.48 mm, M 46. ATLANTIC OCEAN, near Florida: 82 females, 1.22–1.44 mm, TA 45; 3 males, 1.75–1.86 mm, TA 45, USNM 168506. Off Bahamas: 1 damaged male, TA 44.

**FEMALE.**—Body and all appendages with unusually thick exoskeleton, with complex sclerotized pattern in some areas (Figure 12a,b).

Antenna 1 as in *L. wilsonae*.

Labrum (Figure 12c) with free margin divided into 2 posteroventral lobes, each margin with a row of processes on under surface; short medial hood over apex.

Maxilla 2 (Figure 12d) with armature similar in number to that of *L. carinata*.

Legs 1–4 armature similar to that of *L. aculeata*; legs 2 and 3 (Figure 12e,f) and leg 4 endopods terminate with a vent between spines.

**DISTRIBUTION.**—*Lubbockia squillimana*, like *L. aculeata*, has a definite tropical distribution, although a few specimens have been collected just outside tropical waters. Principal records and summaries are from the Pacific Ocean (Giesbrecht, 1891; Farran, 1936; Mori, 1937, 1942; Wilson, 1950); Indian Ocean and Indo-Pacific (Scott, 1909; Krishna-swamy, 1953); Atlantic Ocean (Giesbrecht, 1892; Marques, 1958; Owre and Foyo, 1967; Vives, 1972); and the Mediterranean Sea (Razouls, 1974).

### *Lubbockia minuta* Wolfenden, 1905

FIGURES 13–15

*Lubbockia minuta* Wolfenden, 1905:15, 16.

*Lubbockia glacialis*.—Heron and Damkaer, 1969:16–18, figs. 20, 21.—Boxshall, 1977:118, fig. 8.—Deevey and Brooks, 1977:287. [Not *L. glacialis* Sars, 1900.]

Wolfenden collected 1 female (1.30 mm) off the west coast of Ireland, which he described without illustrations. The copepod collection of Richard Norris Wolfenden, M.D. (1856–1923) was recently made available to the authors by his heirs. While a number of copepod type specimens have been found in this collection, we have unfortunately not located the *Lubbockia minuta*. Some *L. squillimana* were found (see above), and also an empty slide labeled "*Lubbockia*." The Wolfenden Collection will be cataloged and deposited in NMNH.

**MATERIAL STUDIED** (Tables 1, 2).—NE PACIFIC: 32 females, 1.29–1.50 mm, NP 2 et al., USNM 168508–168512; 2 males, 2.00, 2.03 mm, NP 9, 14, USNM 168507; 5 juveniles, stage V,

1.03–1.10 mm, NP 9 et al.; 8 juveniles, stage IV, 0.89–0.97 mm, NP 9 et al. ATLANTIC OCEAN, near Florida: 1 female, 1.24 mm, TA 45.

**FEMALE.**—Average length about 1.41 mm. Prosoma of equal or slightly greater length than urosome (Figure 13a). Urosome (Figure 13b,c) with delicate hyaline spinules on posteroventral margin of postgenital segments. Genital segment length twice that of uropod; area of external genital apparatus located just anterior to midlength of segment, each area with a setule. Second postgenital segment usually about  $\frac{3}{4}$  length of genital segment, occasionally as long as genital segment.

Rostrum rounded posteriorly as shown in ventral view of cephalosome (Figure 13d).

Antenna 1 (Figure 13a,d) 7-segmented with variable rudimentary articulations between segments 3–4 and 5–6. Armature formula: 4, 7 + 1 spinule, 2 spines, 4, 3 + 1 esthete, 2 + 1 esthete, 5 + 2 esthetes; esthetes elongate.

Antenna 2 (Figure 13d) with 1 seta on second segment. Third segment with inner setules and 3 subapical setae; armed terminally with 4 short claws and 3 short setae, 1 nude, 1 setose, and 1 lashlike.

Labrum (Figure 13e) with free margin divided into 2 rounded posteroventral lobes, each margin with a row of short setules on under surface.

Mandible (Figure 13f) with stout, setulose outer element; mandible blade with row of size-graduated scalelike denticles and lashlike element adjacent to blade; concave inner edge of mandible base with a setulose element and row of long setules.

Maxilla 1 (Figure 13g) flat, bilobed; 3 elements on each lobe.

Maxilla 2 (Figure 13h) with expanded first segment. Second segment outer margin with a hyaline setule and stout setulose element; terminates in element adjacent to setulose seta; curved setulose element on inner margin.

Maxilliped (Figure 13i) 4-segmented. Second segment with inner cluster of short, delicate hyaline setules. Terminal segment a sharply pointed claw.

Leg 1 (Figure 14a) without inner spine on basis, third exopod segment with 3 short outer spines. Leg 2 (Figure 14b) third exopod segment with 3 short outer spines. Leg 3 (Figure 14c) inner edge of third endopod segment with 2 setae. Leg 4 (Figure 15a) inner edge of third endopod segment with 1 seta. Legs 2–4 endopods terminate with a small vented projection between spines.

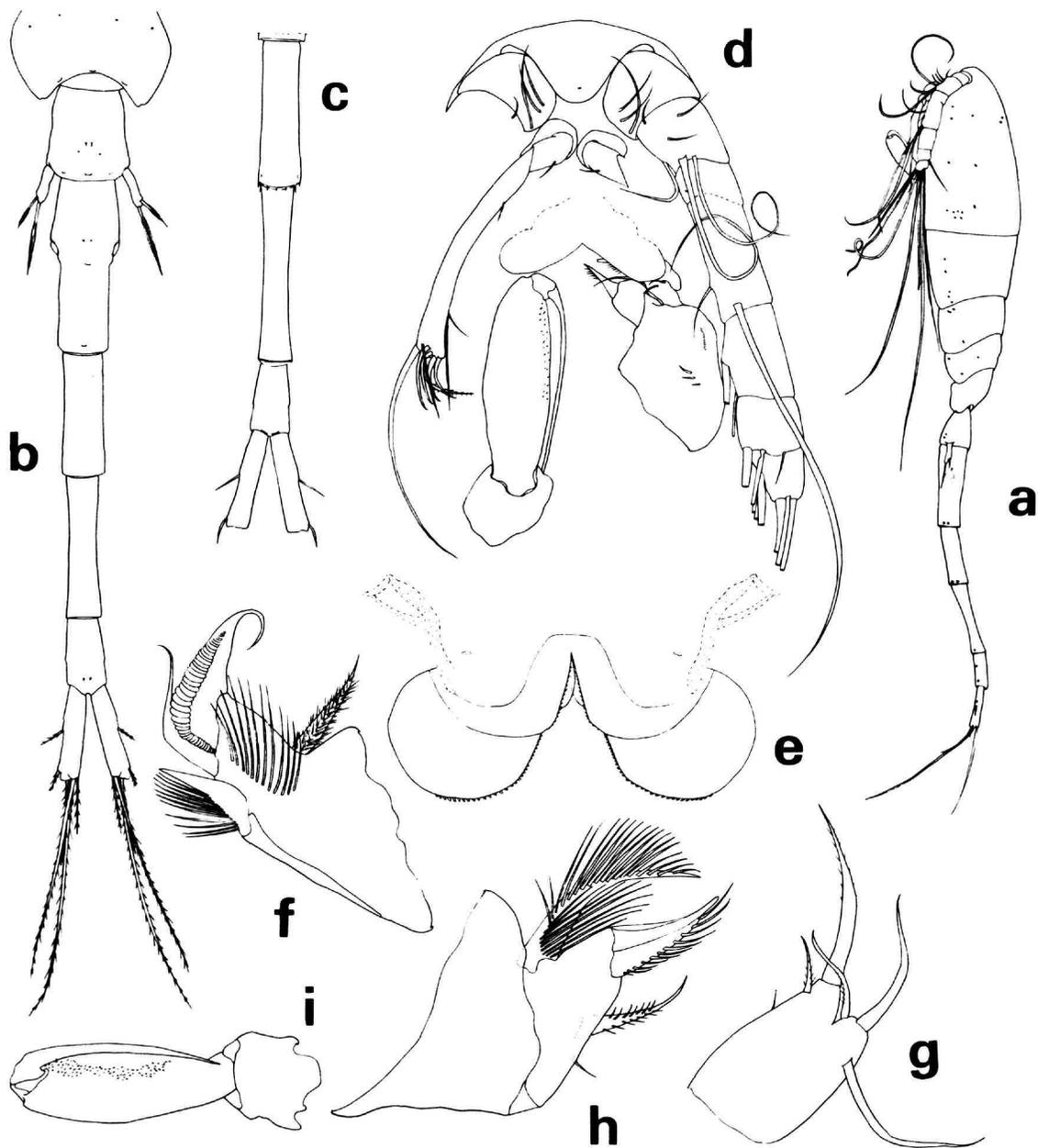


FIGURE 13.—*Lubbockia minuta* Wolfenden, female: *a*, lateral (A); *b*, urosome, dorsal (C); *c*, postgenital segments and uropods, ventral (C); *d*, cephalosome, ventral (E); *e*, labrum, ventral (C); *f*, mandible, right (G); *g*, maxilla 1, left (G); *h*, maxilla 2, left (G); *i*, maxilliped, right (E).

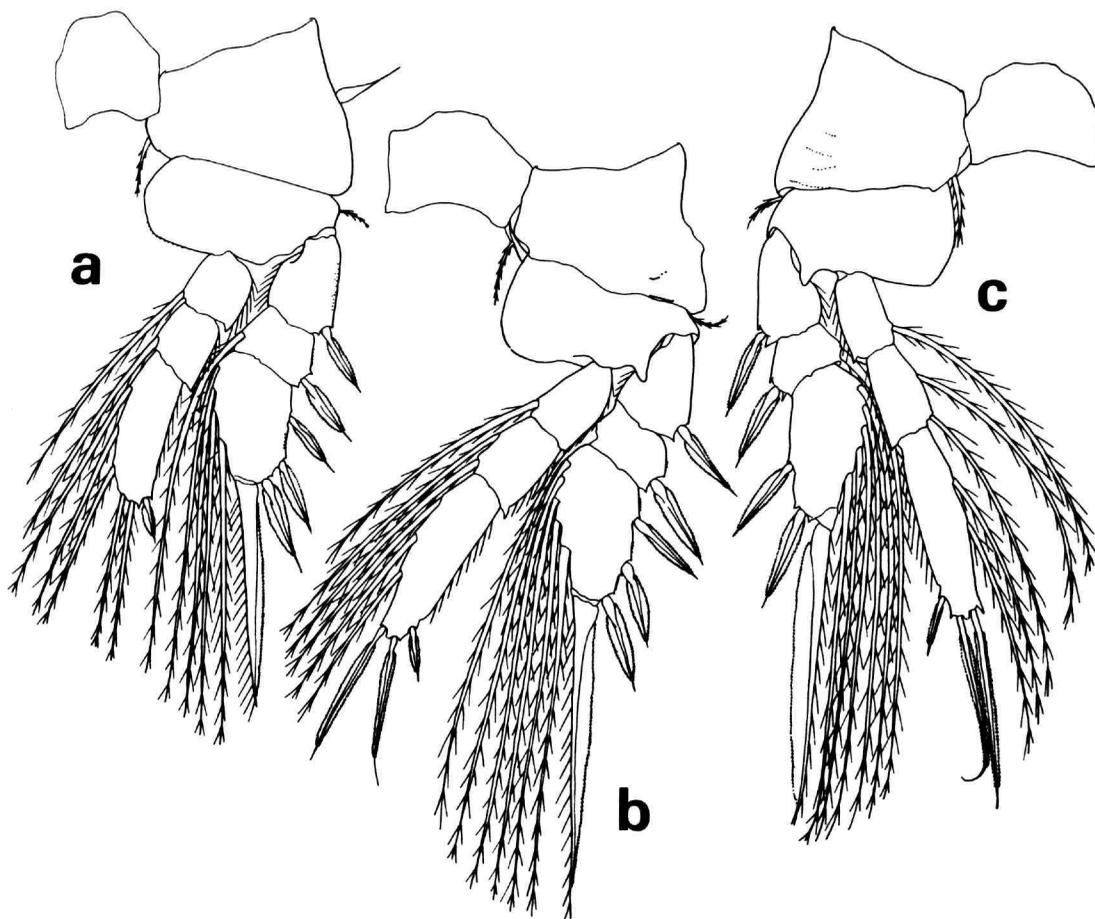


FIGURE 14.—*Lubbockia minuta* Wolfenden, female: a, leg 1 (E); b, leg 2 (E); c, leg 3 (E).

Leg 5 (Figure 15b) with slender free segment not extending to area of external genital apparatus; 2 terminal spines with narrow, delicate hyaline flange.

Leg 6 probably represented by small, hyaline setule in area of external genital apparatus.

MALE.—Urosome about 1.3 times length of prosome (Figure 15c). Solophenyl blue 2RL stain (English and Heron, 1976) revealed minute hyaline setules on ventral posterior margins of 3 postgenital segments. Third postgenital segment shows sexual dimorphism in being  $\frac{1}{3}$  longer than preceding segment rather than only slightly longer as in female.

Rostrum as in female.

Antenna 1 with a single distinct articulation between segments 2, 3 of female; a partial line sepa-

rates segments 1, 2; armature similar to corresponding segments of female, except for addition of 1 esthete on segment 2 and 2 esthetes on segment 4. These additional esthetes and esthete on segment 6 elongate, supported by setalike rib; a terminal esthete reaches fifth urosomal segment.

Antenna 2 third segment with the 4 terminal claws of the female modified into 4 setae.

Mandible, maxilla 1, and maxilla 2 degenerate.

Maxilliped 3-segmented, without short segment proximal to claw of female.

Swimming legs as in female.

Leg 5 with relative length of spines differing slightly from female.

Leg 6 probably represented by posteroventral flap

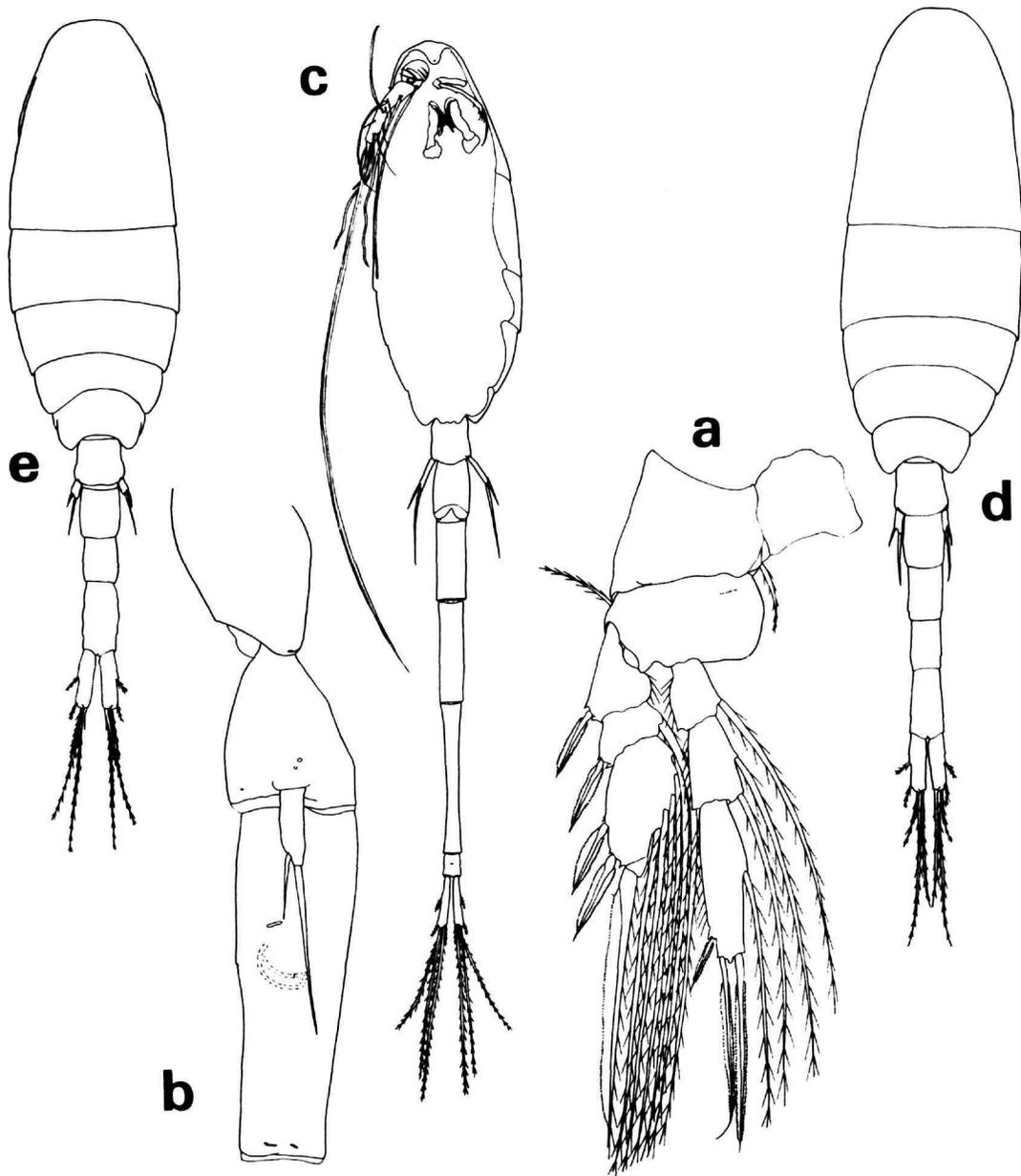


FIGURE 15.—*Lubbockia minuta* Wolfenden, female: *a*, leg 4 (E); *b*, last prosomal segment and first 2 urosomal segments, lateral (E). Male: *c*, ventral (A). Stage V: *d*, dorsal (B). Stage IV: *e*, dorsal (B).

on genital segment, bearing a small pointed posterior process.

STAGE V.—Average length of 5 specimens 1.06 mm (1.03–1.10 mm). These specimens resemble *L. glacialis*, but are slightly smaller and more slender, and have shorter uropods in relation to the preceding (anal) segment and urosome (Figure 15*d*).

STAGE IV.—Average length of 8 specimens 0.95 mm (0.89–0.97 mm). The same criteria used to separate stage V were used to distinguish this stage (Figure 15*e*).

REMARKS.—A single damaged male of *Lubbockia minuta* was reported earlier as *L. glacialis* from the Gulf of Alaska (Heron and Damkaer, 1969); the size and swimming legs of that male resembled those of female *L. glacialis* (male unknown at that time). Since the females of *L. minuta* have now been recognized with males in northeast Pacific samples, it is believed that these males are sexually dimorphic males of *L. minuta*. *Lubbockia minuta* closely resembles *L. glacialis*, including the sexually dimorphic characters. A forthcoming study of Arctic Ocean Oncaeidae includes the description of the male *L. glacialis*, 1.72–1.92 mm  $\bar{x}$  = 1.82 mm).

*Lubbockia minuta* has a shorter leg 5 and more distal female genital operculum than *L. glacialis*. The inner spine of *L. glacialis* male leg 5 reaches the middle of the second postgenital segment.

The female specimen of *L. minuta* found near Florida is slightly smaller (1.24 mm) than the smallest northeast Pacific female (1.29 mm), but appears to be similar except for more distinct segmentation between segments 3, 4 on antenna 1.

DISTRIBUTION.—NE Atlantic (Wolfenden, 1905) and tropical Atlantic Ocean (Tables 1, 2); NE Pacific Ocean (Tables 1, 2).

### *Lubbockia glacialis* Sars, 1900

FIGURE 16

*Lubbockia glacialis* Sars, 1900:114–118, pl. 33: figs. 1–15.

MATERIAL STUDIED (Tables 1, 2).—NE PACIFIC: 6 females, 1.58–1.71 mm ( $\bar{x}$  = 1.63 mm), NP 6 et al., USNM 168513–168515; 1 juvenile, stage V, 1.20 mm, NP 4; 1 juvenile, stage IV, 1.03 mm, NP 27.

REMARKS.—The specimens from the northeast Pacific enumerated above were so much smaller than those which Sars described (2.45 mm) from the Norwegian North Polar Expedition that it took a

considerable amount of study to conclude that these are the same species. Seventy-five *L. glacialis* females from the Arctic Ocean (which are not listed in Tables 1, 2 but are to be discussed in a forthcoming report, Heron and English, in prep.), measured 1.60–1.92 mm ( $\bar{x}$  = 1.72 mm).

The relative lengths of the 2 postgenital segments of *L. glacialis* females are slightly variable. The second postgenital segment of the northeast Pacific specimens is slightly longer than the first postgenital segment, while these 2 segments are about the same length in Arctic specimens. The prosome appeared larger in relation to the urosome on Arctic specimens, but this could be an effect of their diet. The intestinal structures of all the Arctic females and juveniles appear to be bulging with a material which is conspicuously darker than the exoskeleton, even in unstained specimens. The expanded prosome, variable in extent and occasionally asymmetrical, may be an effect of the gut content. The Pacific specimens resemble the Arctic specimens in all other characters.

*Lubbockia glacialis* females resemble *L. minuta* in many characters, but differ in having the external genital apparatus on the anterior third of the genital segment, and in having a longer uropod in relation to the anal segment (Figure 16*a,b*).

STAGE V.—One specimen, 1.20 mm, NP 4, differed from the very similar *L. minuta* by the slightly larger size and longer uropodal length relative to the preceding segment (Figure 16*c*).

STAGE IV.—One specimen, 1.03 mm, NP 27, was separated from the similar specimens of *L. minuta* on the same criteria as those used for stage V (Figure 16*d*).

DISTRIBUTION.—Arctic Ocean (Sars, 1900; Grice, 1962; Johnson, 1963; Minoda, 1967; Heron and English, in prep.) and the North Pacific Ocean (Tables 1, 2; Minoda, 1971). Hardy and Gunther (1935) reported *L. glacialis* from the Antarctic, but with some doubt.

### *Lubbockia* species

FIGURE 17

STAGE V.—Seven specimens, 1.37–1.44 mm ( $\bar{x}$  = 1.40 mm) from the northeast Pacific (Tables 1, 2). Body proportions (Figure 17*a*) and appendages are similar to those in *L. minuta* and *L. glacialis*. Areas

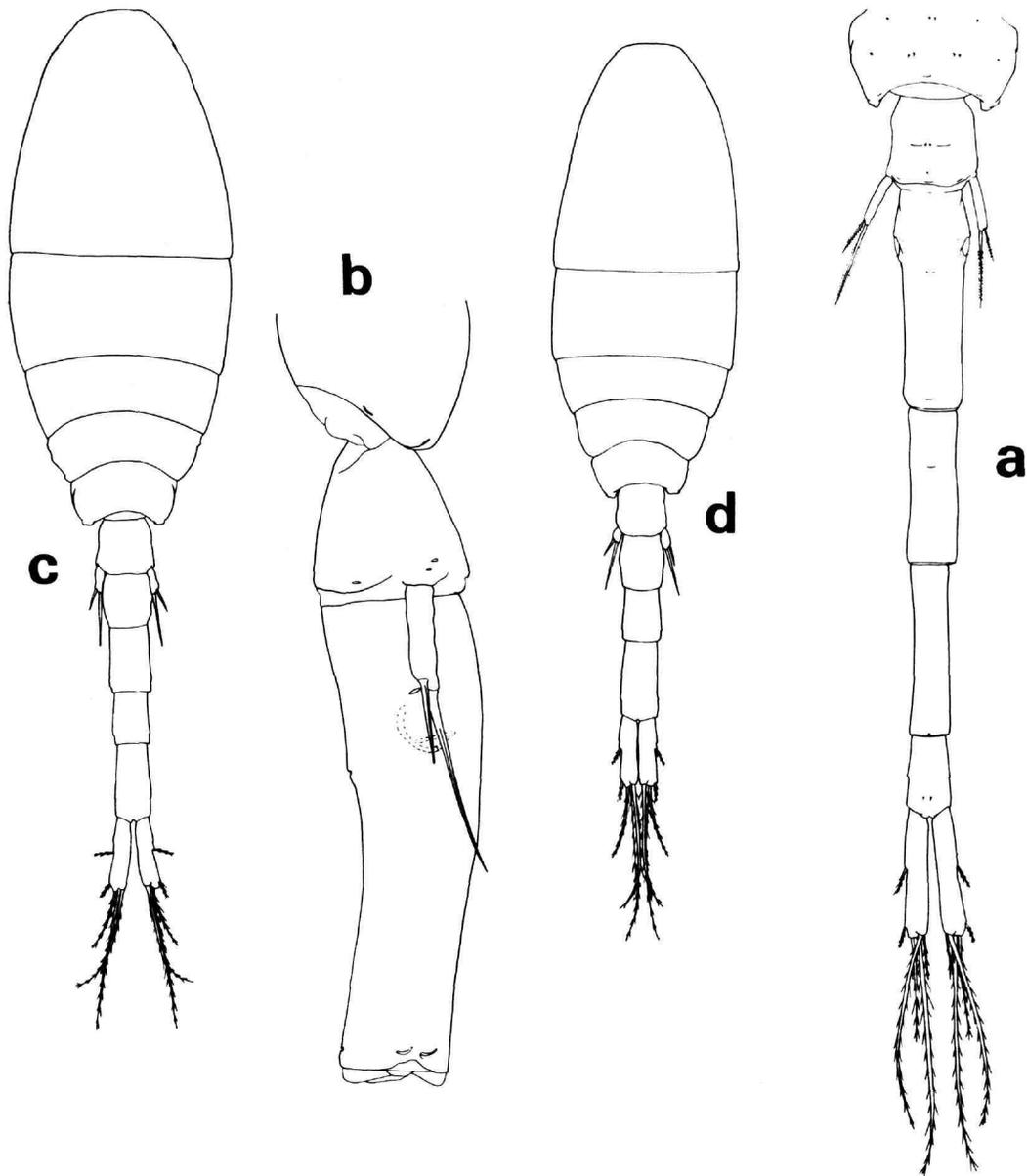


FIGURE 16.—*Lubbockia glacialis* Sars, female: a, urosome, dorsal (C); b, last prosomal segment and first 2 urosomal segments, lateral (E). Stage V: c, dorsal (B). Stage IV: d, dorsal (B).

of dense refractile points on fourth and fifth urosomal segments separate this species from the others. These specimens were larger than the juveniles of *L. minuta* and *L. glacialis* from the northeast Paci-

fic, but were approximately the same size as *L. glacialis* juveniles from the Arctic Ocean (Heron and English, in prep.).

STAGE IV.—A specimen (1.14 mm) (Table 2) was

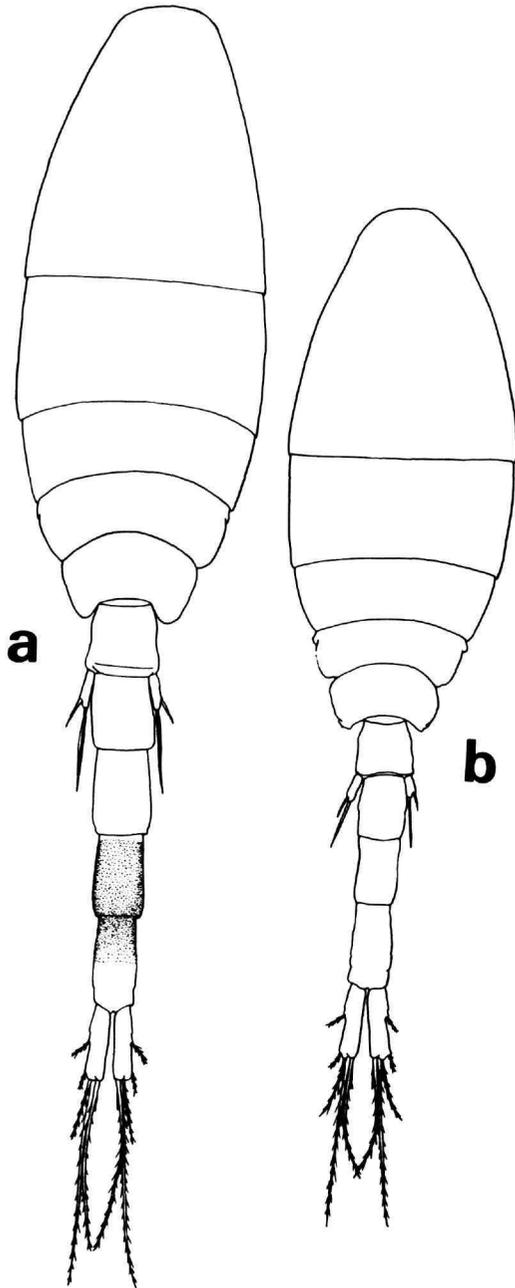


FIGURE 17.—*Lubbockia* species, stage V: a, dorsal (B). Stage IV: b, dorsal (B).

compared with similar size specimens of Arctic *L. glacialis*, and each urosomal segment of this undescribed species appeared more robust and wider in relation to the length (Figure 17b).

### *Lubbockia flemingi*, new species

FIGURES 18–20

**MATERIAL STUDIED** (Tables 1, 2).—NE PACIFIC: 6 females, 0.83–0.91 mm, NP 7 et al., (including: holotype, 0.83 mm, NP 7, USNM 168493; 2 paratypes, 0.84 mm, NP 13, 17, USNM 168495, 168496); 2 males, 0.84, 0.85 mm, NP 16, 26 (including: allotype, 0.84 mm, NP 16, USNM 168494). ANTARCTIC OCEAN: 1 male, 0.82 mm, AA 42.

**FEMALE**.—Average length about 0.85 mm. Prosome (Figure 18a,b) about 1.7 times length of urosome. Pediger 5 with slight transverse dorsoposterior sclerotized ridge. Genital segment with areas of external genital apparatus on anterior third of dorsolateral surface, each area with a setule. Genital segment and each postgenital segment with fine spinules on posteroventral margins. Uropod about 3 times as long as wide; outermost proximal seta about midsegment.

Rostrum with thickened posteroventral margin, deltoid in ventral view as shown in figure of orientation of oral appendages (Figure 18c).

Antenna 1 with armature and segmentation similar in number to that of *L. minuta*.

Antenna 2 (Figure 18c) with 1 seta on second segment. Third segment with inner setules and 3 subapical setae; armed terminally with 4 short claws and 3 setae.

Labrum (Figure 18d) with free margin divided into 2 rounded posteroventral lobes, each margin with row of hyaline setules and small dentiform processes on under surface; complex pattern of layers of tissue over- and underlying sclerotized areas.

Mandible (Figure 18e) with 2 outer elements, both with rows of setules; mandible blade with row of size-graduated scalelike denticles on median edge, and apical lash; concave edge of mandible base with a setulose element and rows of long setules.

Maxilla 1 (Figure 18f) flat, bilobed; 3 elements on each lobe.

Maxilla 2 (Figure 19a) first segment expanded. Second segment with a hyaline setule and stout setulose element; terminal bifurcate, setulose element; curved setulose element on inner margin.

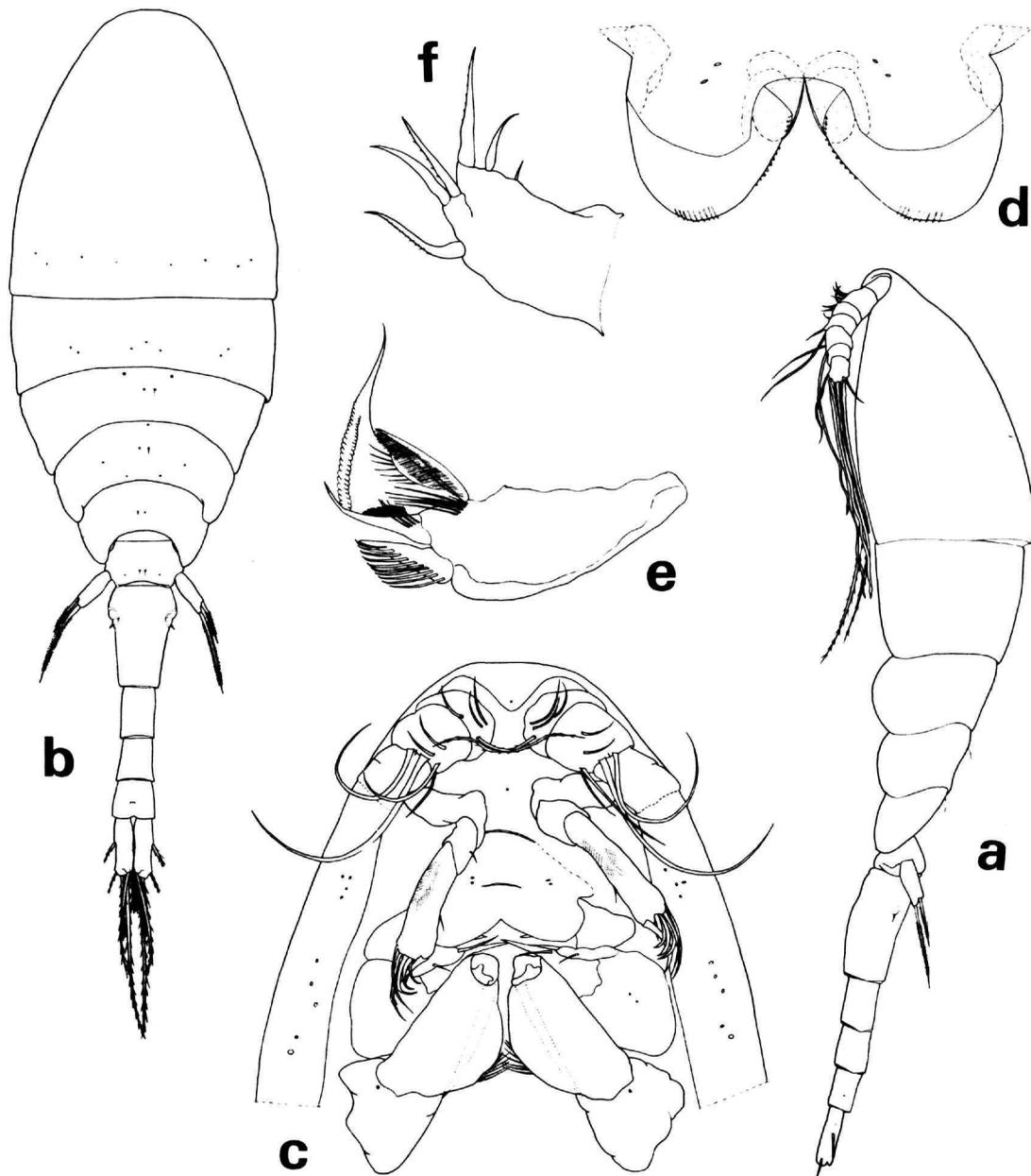


FIGURE 18.—*Lubbockia flemingi*, new species, female: *a*, lateral (C); *b*, dorsal (C); *c*, cephalosome, ventral (E); *d*, labrum, ventral (G); *e*, mandible, right (G); *f*, maxilla 1, right (G).

Maxilliped (Figure 19*b*) 4-segmented. Second segment with a row and cluster of setules on inner surface (Figure 18*c*). Terminal segment a long claw.

Leg 1 (Figure 19*c*) with inner spine on basis, third

exopod segment with 3 short outer spines. Leg 2 (Figure 19*d*) third exopod segment with 3 short outer spines. Leg 3 (Figure 19*e*) inner edge of third endopod segment with 3 setae. Leg 4 (Figure 19*f*)

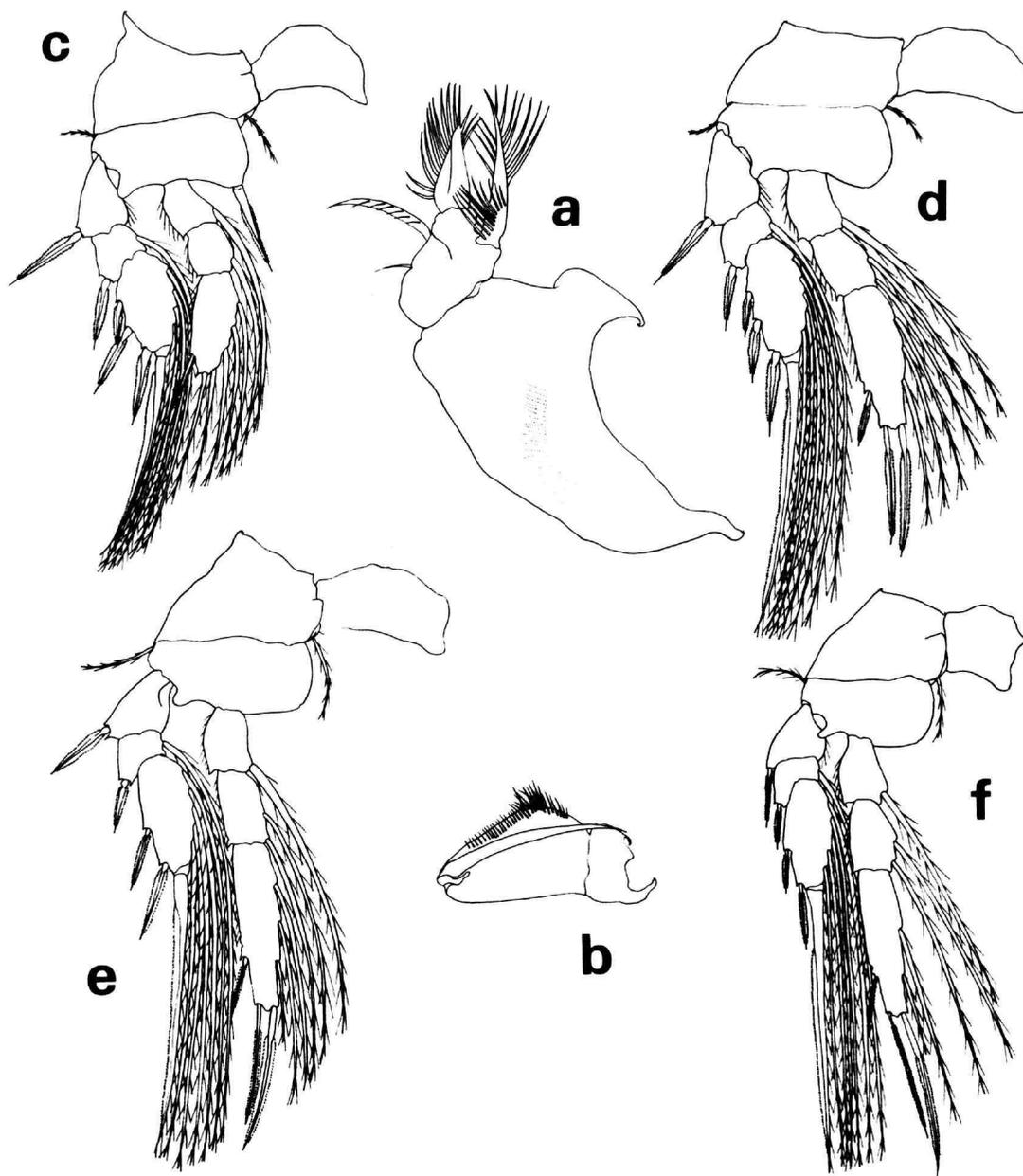


FIGURE 19.—*Lubbockia flemingi*, new species, female: a, maxilla 2, right (C); b, maxilliped, left (E); c, leg 1 (E); d, leg 2 (E); e, leg 3 (E); f, leg 4 (E).

inner edge of third endopod segment with 2 setae. Legs 2-4 endopods with a small vented projection between terminal spines. Leg 1 coxa lacks an outer papilla, but a vent is present.

Leg 5 (Figure 18b) with free segment about  $\frac{1}{3}$  length of genital segment; 2 terminal spines with serrate, hyaline flange; outer spine slightly more than  $\frac{1}{2}$  length of inner, which reaches beyond pos-

terior margin of genital segment.

Leg 6 probably represented by hyaline setule in area of external genital apparatus.

MALE.—Prosoma (Figure 20a) about 1.7 times as long as urosome. Urosome (Figure 20b) with the 4 postgenital segments and uropods bearing spinules on ventral margin. Uropodal setae with relative lengths as in female.

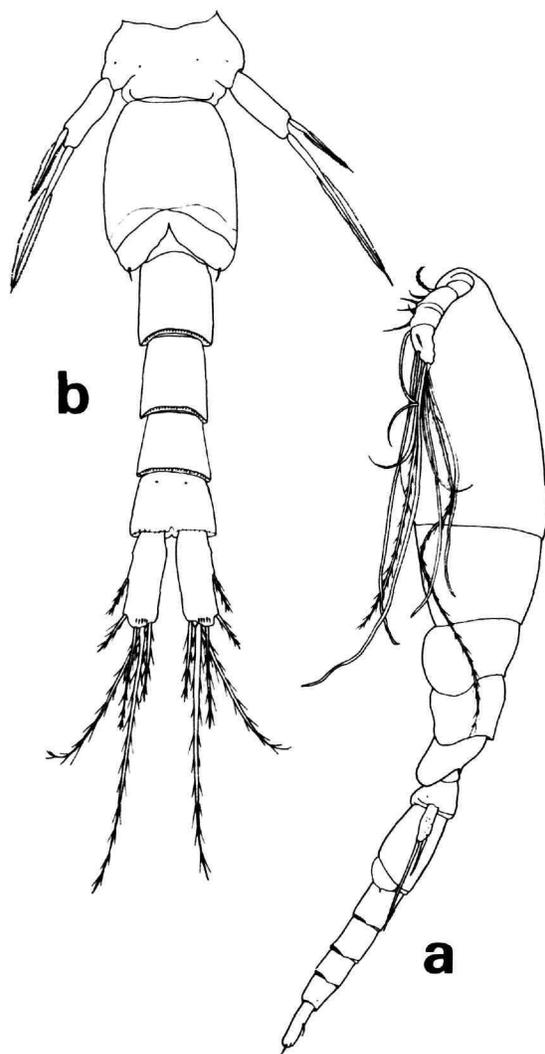


FIGURE 20.—*Lubbockia flemingi*, new species, male: a, lateral (C); b, urosome, ventral (E).

Rostrum and mouthparts, except antenna 1, as in female.

Antenna 1 with segments corresponding to terminal 3 of female fused in male; armature similar to corresponding segments of female, except for addition of 1 esthete on segment 2 and 2 esthetes on segment 4; additional esthetes and 1 esthete on each of segments 6 and 7 somewhat longer than on female.

Swimming legs and leg 5 as in female with additions of clusters of short spinules on legs 1–4, most numerous on anterior surfaces of legs 1–3 and outer coxa and basis of leg 4.

ETYMOLOGY.—With the name *Lubbockia flemingi*, we wish to express our sincere appreciation to Professor Richard H. Fleming, Department of Oceanography, University of Washington, for our memorable introduction to oceanography.

REMARKS.—*Lubbockia flemingi* resembles *L. brevis* Farran, 1908, described from a deep sample off the coast of Ireland. Additional descriptions of both female and male *L. brevis* from the Arctic Ocean will be published in a report on Arctic Oncaeidae (Heron and English, in prep.). In *L. brevis* the length of the spiniform setule of female leg 6 is about  $\frac{1}{3}$  the length of the genital segment. *Lubbockia brevis* uropod is 4 to 5 times as long as wide on the female and about the same length as the genital segment of the male. *Lubbockia flemingi* and *L. brevis* differ from all other known *Lubbockia* species by having 3 inner setae on leg 3 third endopod segment and 2 inner setae on leg 4 third endopod segment. In addition, they are the only *Lubbockia* species without a sexually dimorphic maxilliped.

The vents associated with the terminal projections on the swimming leg endopods occasionally have an exuding material, most apparent on stained specimens.

Dr. T. Björnberg informed us that the single female reported as *L. brevis* from the Marchile I Expedition (Björnberg, 1973:364) measured 1.25 mm. She kindly sent us illustrations of the urosome which showed that the uropod and the seta representing leg 6 resemble those of *L. flemingi* more closely than those of *L. brevis*.

DISTRIBUTION.—Northeast Pacific and Antarctic Oceans (Tables 1, 2); Southeast Pacific Ocean (Björnberg, 1973).

*Lubbockia petersoni*, new species

FIGURES 21-22

MATERIAL STUDIED (Tables 1, 2).—NE PACIFIC: 26 females, 0.95–1.06 mm, NP 10 et al. (including: holotype, 0.99 mm, NP 24, USNM 168497; 9 paratypes, 0.95–1.05 mm, NP 10, 24, 33, USNM 168499–168501); 12 males, 0.85–1.03 mm, NP 10 et al. (including: allotype, 0.99 mm, NP 24, USNM 168498; 4 paratypes, 0.91–0.95 mm, NP 10, 24, 33, USNM 168499–168501).

FEMALE.—Average length about 1.00 mm. Prosome about 1.8 times the length of the slender urosome, posterior corners rounded (Figure 21a,b).

Urosome first segment with slight transverse, sclerotized dorsoposterior ridge. Genital segment with areas of external genital apparatus posterior to midpoint on dorsal surface of segment, each area with 2 setules. Genital segment and each postgenital segment with fine spinules on posterior margins. Uropod with hyaline flap extending over base of dorsal seta.

Rostrum with sclerotized pattern accentuating a thickened rhomboidal ventral surface as shown in ventral view of cephalosome (Figure 21c). Protruding sclerotized process posterior to rostrum (Figure 21d), with vent near apex of process.

Antenna 1 with armature similar in number to that of *L. minuta*; variable rudimentary articulation between all segments, except distinct articulation between segments 4, 5.

Antenna 2 with armature similar to that of *L. minuta*, third segment with 4 terminal claws, 1 long seta, and 2 short setae (Figure 21c).

Labrum (Figure 21e) with free margin divided into 2 rounded posteroventral lobes, separated by a triangular vertex, from which arises a short hyaline hood.

Mandible (Figure 21f) with 2 adjacent, setulose outer elements; mandible blade with row of scale-like denticles on median edge; concave edge of base with a setulose element, spinules, and row of long setules.

Maxilla 1 (Figure 21g) and maxilla 2 (Figure 21h) with armature similar in number to that of *L. minuta*; ornamentation differs as shown in figures.

Maxilliped (Figure 21i) first segment with posterior protuberant process (Figure 21a,c). Second segment and terminal claw relatively reduced in length; incomplete suture separating terminal claw.

Leg 1 (Figure 21j) with inner spine on basis, third exopod segment with 3 short outer spines, proximal spine reduced. Leg 2 (Figure 22a) third exopod segment with 3 short outer spines, proximal spine reduced. Leg 3 (Figure 22b) inner edge of third endopod segment with 2 setae and 1 spine. Leg 4 (Figure 22c) inner edge of third endopod segment with 1 seta and 1 spine. Legs 2, 3 endopods terminate with a small vented projection; leg 4 endopod terminates with a vent between 2 most distal spines.

Leg 5 represented only by 1 seta on midlateral surface of first urosomal segment (Figure 21a,b).

Leg 6 probably represented by 2 hyaline setules in area of external genital apparatus.

MALE.—Average length about 0.93 mm. Prosome about 1.8 times length of slender urosome (Figure 22d,e).

Urosome with the 4 postgenital segments bearing fine spinules on posterior margins.

Rostral area and mouthparts, except antenna 1 and maxilliped, as in female; sclerotized process posterior to rostrum.

Antenna 1 with segmentation similar to that of female; armature similar to female except for addition of long esthete on segment 2 and 2 esthetes on segment 4; all esthetes elongate.

Maxilliped (Figure 22f) with small segment between second segment and slender, elongate claw.

Swimming legs and uropod segment 1 (Figure 22g) as in female, except narrower flange on swimming leg spines.

Leg 6 probably represented by posteroventral pointed flap on genital segment.

ETYMOLOGY.—It is a pleasure to name this species for Willis K. Peterson, Department of Oceanography, University of Washington, who designed and built the net for collecting deep plankton samples during hydrographic casts off the Washington coastal shelf. Mr. Peterson has generously made these samples available to us.

REMARKS.—*Lubbockia petersoni* differs from all other species of *Lubbockia* by the absence of leg 5. The complex pattern of sclerotization in the rostral area of *L. petersoni* resembles that in *L. squillimana* and *L. aculeata*. The stocky antenna 2 resembles that in *L. flemingi* except for having a longer lash-like seta. Maxilla 2 resembles that in *L. flemingi*. Among *Lubbockia* species, only *L. petersoni*, *L. carinata*, and *L. forcipula* have an anterolateral seta

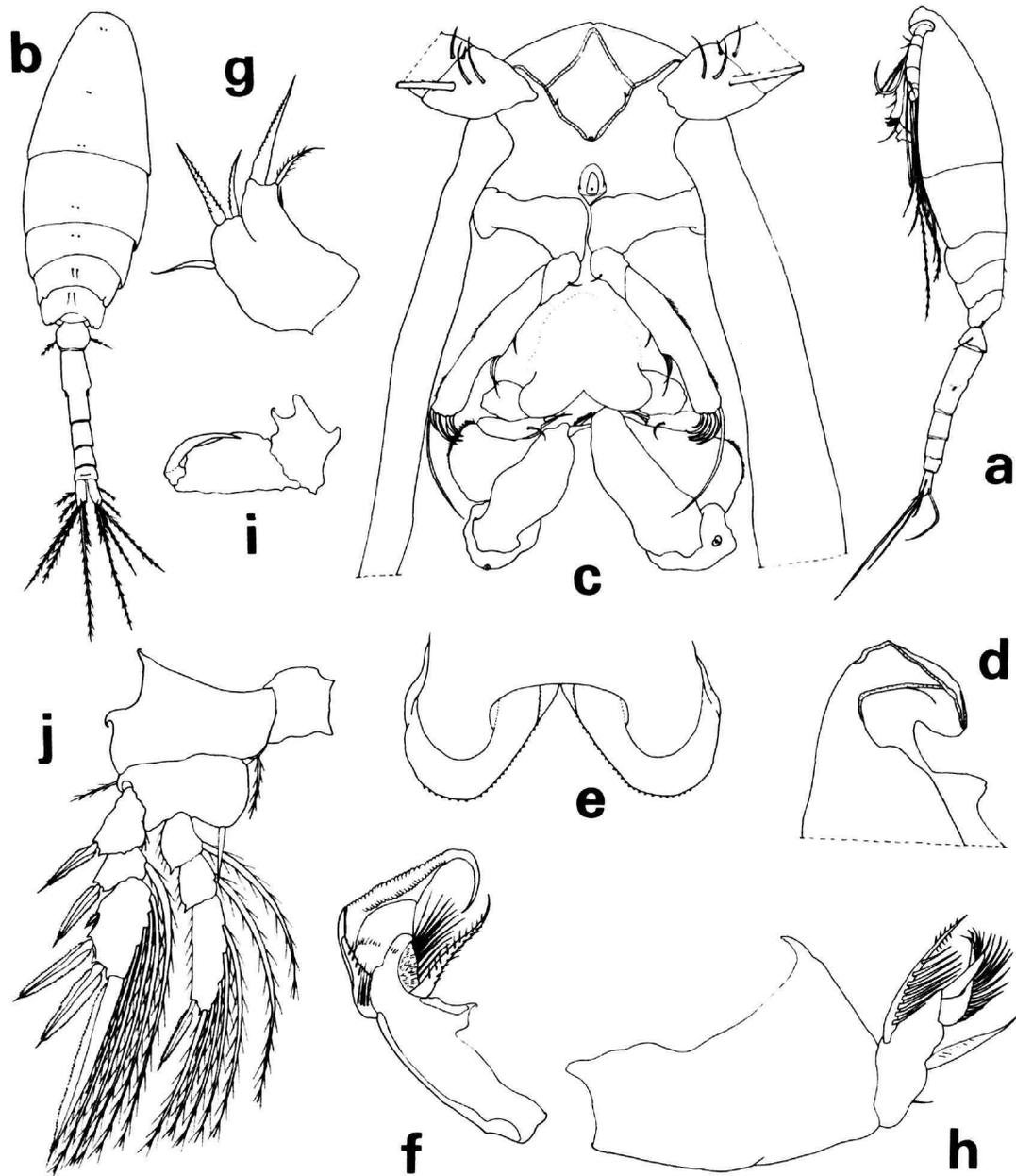


FIGURE 21.—*Lubbockia petersoni*, new species, female: *a*, lateral (A); *b*, dorsal (A); *c*, cephalosome, ventral (E); *d*, rostrum and ventral process, lateral (antenna 1 and antenna 2 omitted) (E); *e*, labrum, ventral (G); *f*, mandible, right (G); *g*, maxilla 1, left (G); *h*, maxilla 2, left (G); *i*, maxilliped, right (E); *j*, leg 1 (E).

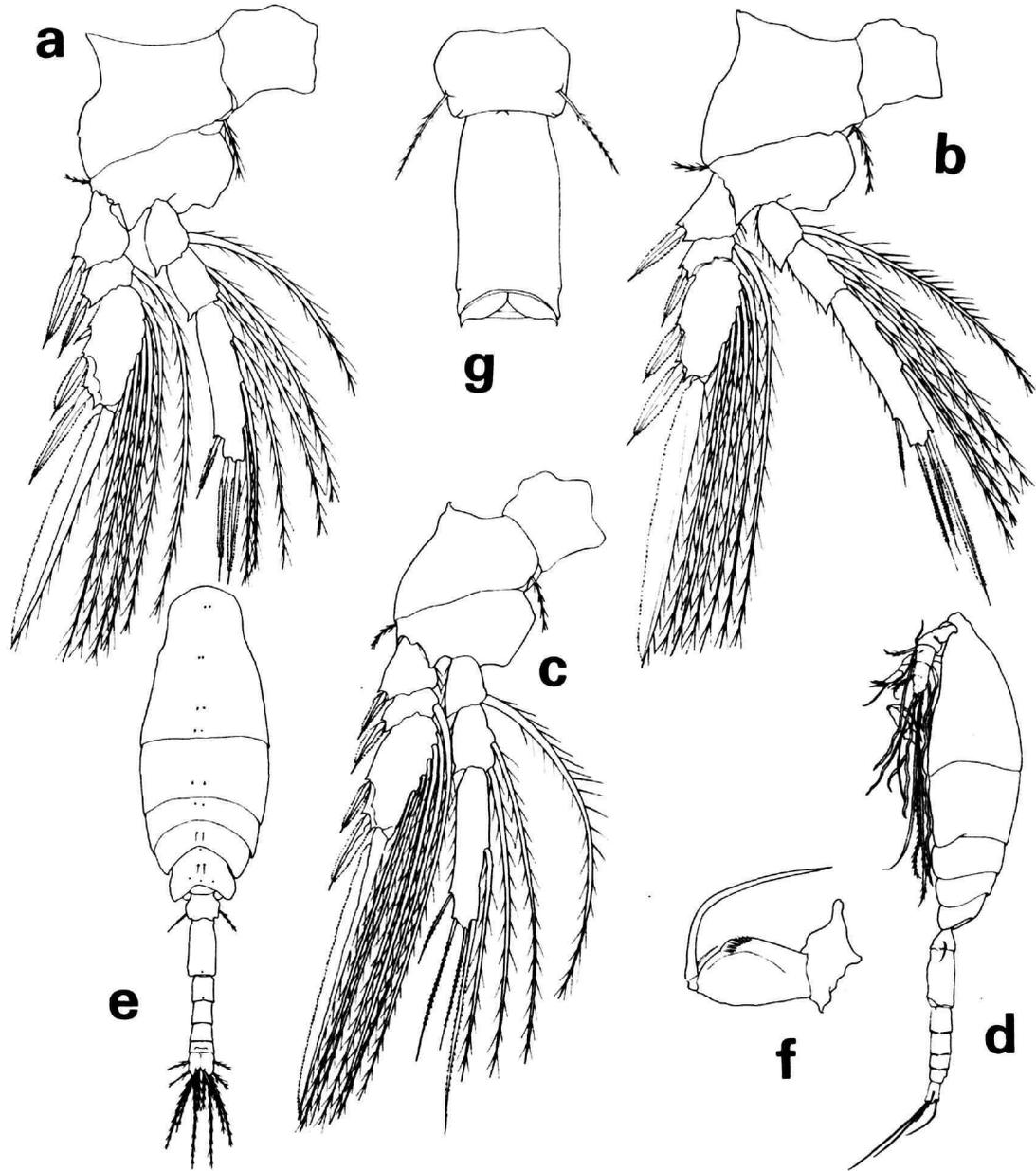


FIGURE 22.—*Lubbockia petersoni*, new species, female: *a*, leg 2 (E); *b*, leg 3 (E); *c*, leg 4 (E). Male: *d*, lateral (A); *e*, dorsal (A); *f*, maxilliped, right (E); *g*, first 2 urosomal segments, ventral (E).

on pediger 5, which is common to all other Oncaei-  
dae species.

The sclerotized process posterior to the rostrum  
resembles a structure illustrated for the cyclopoid  
copepods *Nasomolgus cristatus* Sewell, 1949 (fig.  
35B) (Lichomolgidae)\* and *Hippomolgus latipes*  
Humes and Ho, 1967 (fig. 44) (Clausidiidae).

Sample NP 24 (Tables 1, 2) also contained a  
number of the pelagic tunicate *Doliolum* species.  
Two *L. petersoni* specimens were inside of 1 doli-  
lid and 1 in another; this might not reflect a natural  
association.

DISTRIBUTION.—Northeast Pacific Ocean (Tables  
1, 2).

# Appendix

## Tables

Table 1.—Sources of specimens (AA = Antarctic Ocean, M = Mediterranean Sea, NP = northeast Pacific Ocean, TA = tropical west Atlantic Ocean, TP = tropical Pacific Ocean; for institutional abbreviations see “Acknowledgments”)

Sample	Cruise	Station	Date	Location	Depth (m)	Collection
NP 1	NOAA <i>Surveyor 75D</i>	1,2	4 Oct 75	60°40.7'N, 147°41.1'W	99–50	Heron and Damkaer
NP 2		8	5 Oct 75	60°40.7'N, 147°43.1'W	212–70	
NP 3	<i>Brown Bear 332</i>	AF6	26 Aug 63	45°20.0'N, 130°00.0'W	453–0	U.W. (Peterson)
NP 4	344	4	19 May 64	47°33.5'N, 126°48.5'W	1800–0	
NP 5		5	20 May 64	47°33.8'N, 128°22.7'W	2128–0	
NP 6		11	23 May 64	47°44.8'N, 134°55.8'W	2536–0	
NP 7		19	27 May 64	49°56.0'N, 144°54.0'W	4014–0	
NP 8		21	28 May 64	47°49.2'N, 144°57.7'W	4306–0	
NP 9		25	30 May 64	45°17.0'N, 141°48.0'W	4500–0	
NP 10		26	31 May 64	45°15.7'N, 132°44.0'W	2000–0	
NP 11		31	2 Jun 64	45°15.7'N, 132°44.0'W	3183–0	
NP 12		35	4 Jun 64	45°29.3'N, 126°58.0'W	2750–0	
NP 13	349	25	24 Aug 64	45°19.5'N, 132°26.0'W	1800–0	
NP 14	352	16	22 Jan 65	45°13.0'N, 136°04.0'W	3500–0	
NP 15		16	22 Jan 65	45°13.0'N, 136°04.0'W	4150–0	
NP 16		20	25 Jan 65	45°22.0'N, 128°10.0'W	2000–0	
NP 17		21	26 Jan 65	45°27.0'N, 126°33.0'W	2750–0	
NP 18	357	19	20 Apr 65	45°17.5'N, 138°34.0'W	4000–0	
NP 19		19	20 Apr 65	45°17.5'N, 138°34.0'W	4150–0	
NP 20		22	22 Apr 65	47°59.5'N, 139°58.0'W	4000–0	
NP 21	368	20	10 Aug 65	45°22.0'N, 128°36.0'W	2700–0	
NP 22		23	12 Aug 65	45°20.0'N, 132°28.0'W	2000–0	
NP 23		25	13 Aug 65	45°20.6'N, 134°56.5'W	2000–0	
NP 24		28	14 Aug 65	45°17.5'N, 139°09.6'W	4250–0	
NP 25		30	15 Aug 65	46°20.8'N, 139°50.5'W	4200–0	
NP 26		31	16 Aug 65	47°05.8'N, 139°51.0'W	2000–0	
NP 27		32	16 Aug 65	47°58.5'N, 139°44.4'W	4000–0	
NP 28		33	17 Aug 65	47°58.5'N, 139°44.4'W	4000–0	
NP 29		36	18 Aug 65	47°47.6'N, 135°34.7'W	3700–0	
NP 30		37	18 Aug 65	47°43.1'N, 134°17.0'W	2000–0	
NP 31		38	19 Aug 64	47°33.3'N, 132°32.0'W	3000–0	
NP 32		40	20 Aug 65	47°55.3'N, 129°09.5'W	1967–0	
NP 33	380	13	10 Nov 65	45°32.0'N, 139°48.0'W	4650–0	
NP 34	<i>Oshawa 6</i>	12	22 Oct 64	45°20.0'N, 139°06.0'W	2250–0	
NP 35		12	22 Oct 64	45°20.0'N, 139°06.0'W	4200–0	
NP 36	<i>Thompson TT002</i>	32	10 Aug 67	44°37.0'N, 128°00.0'W	147–0	
NP 37	TT030	65	23 Jul 68	47°66.0'N, 128°50.0'W	75–0	
NP 38	TT082	P	6 Aug 73	49°56.0'N, 144°54.0'W	440–110	UW (Frost)
NP 39		P	7 Aug 73	49°56.0'N, 144°54.0'W	440–220	
NP 40		P	8 Aug 73	49°56.0'N, 144°54.0'W	3000–0	UW (Thoreson)
AA 41	<i>Eltanin 27</i>	1811	7 Jan 67	62°59.0'S, 177°40.0'E	2000–1000	SOSC
AA 42		1817	9 Jan 67	65°59.0'S, 176°23.0'E	2000–1000	
TP 43	<i>Albatross</i>	5185	30 Mar 08	10°05.8'N, 124°18.5'E	1167	USNM 73654
TA 44	<i>Bache</i>	10209	22 Mar 14	off Bahamas	100–0	USNM 79578
TA 45	<i>Gosnold 74</i>	2348	21 Aug 65	29°44.9'N, 76°50.8'W	0–200–0	SOSC
M 46	<i>Silver Belle</i>	44	22 Aug 04	35°45.0'N, 3°41.0'W	183	R. N. Wolfenden
M 47			1 Feb 67	Gulf of Naples	100–0	USNM 168505



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