

Adult and Larval Stomatopod Crustaceans Occurring in Hawaiian Waters¹

SIDNEY JOSEPH TOWNSLEY²

INTRODUCTION

THE STOMATOPODA constitute the only order belonging to the division Hoplocarida of the malacostracan Crustacea. All living forms are included in a single family, the Squillidae, whose characteristics are the same as those of the order. The order, according to Bigelow (1894), may be defined as Crustacea which have these characteristics: the stalked eyes and antennules are borne upon distinct movable segments; the adult rostrum is separated from the carapace by a movable joint; the carapace is small and does not cover the last four thoracic somites; the first five pairs of thoracic appendages are not biramous and serve as accessory mouth parts, with the second pair strongly developed into large raptorial limbs; the last three pairs of thoracic appendages are adapted for walking, are biramous and bear a lateral segment upon the penultimate segment; the abdomen is well developed; filamentous gills are carried upon the exopod of the first five abdominal appendages; the sixth abdominal appendages, the uropods, with the telson, act as a powerful tail fan.

At the present time the six recognized genera have a world-wide distribution, being found in the tropical, subtropical, and temperate waters of the Atlantic, Pacific, and Indian oceans. All six genera are represented in the Hawaiian fauna. Edmondson (1921), reporting upon the stomatopods in the collec-

tion of the Bernice P. Bishop Museum, found six genera and eight species from Hawaii: *Squilla oratoria*, *S. alba*, *Pseudosquilla ciliata*, *P. oculata*, *Coronida sinuosa*, *Lysiosquilla maculata*, *Odontodactylus hanseni*, and *Gonodactylus guerini*. Since that time no extensive studies have been made on specimens from Hawaii, but occasional reports of previously recorded species from this region have found their way into the literature. In addition to these eight species which have been again collected during the progress of this study, I have found two species which have not been recorded from this region previously, namely, *Squilla boöps* and an undescribed species of *Squilla*.

Stomatopods are usually found in very shallow water, but some species occur at greater depths. I have collected *Gonodactylus guerini* in Hawaii only at depths over 100 meters, and Kemp (1913) reports that *Squilla leptosquilla* was dredged by the "Investigator" at a depth of 370-419 fathoms. The adults are bottom dwellers where they may burrow into the substrate or inhabit crevices in coral. They are seclusive in their habits and during the day are usually found either in their burrows or but a short distance away. At times they wander some distance from their burrows, as is shown by the fact that they are occasionally captured in crab nets and at submersible lights used for collecting at night. Inasmuch as the burrows are quite deep (a foot or more below the surface), and because the animals retire to the bottom of them at the least alarm, stomatopods are quite difficult to collect; consequently, the group has been studied very little, the most notable works being those

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² Graduate assistant, Osborn Zoological Laboratory, Yale University.

of Miers (1880), Brooks (1886), Bigelow (1894), and Kemp (1913). Of these works, the most useful for the identification of the Hawaiian species has been Kemp's monograph on the Indo-Pacific species.

Stomatopods are carnivorous and readily seize any flesh held in front of their burrows. This behavior has provided the most satisfactory means for capturing them, as they can be lured from their burrows by suspending fish flesh a short distance away and captured when they attack the flesh. Considerable dexterity is necessary, however, as they withdraw rapidly into their burrows. It has been impossible to keep more than one specimen at a time in small aquaria as they are highly cannibalistic.

It is doubtful whether the adults often serve as food for other animals, although they may occasionally be found in the stomach contents of fish; but the planktonic larval stages which compose a substantial proportion of the neritic plankton form a considerable part of the diet of pelagic fishes.

Instead of carrying their incubating eggs attached to the abdominal appendages, as do most Malacostraca, the stomatopods deposit them at the bottom of the burrows where they are aerated by currents of water produced by the abdominal appendages of the parent. These appendages are paddle shaped and conform to the cylindrical shape of the hole. The eggs perish when they are deprived of this constant current of water, and, as the female will not remain with the eggs when placed in an aquarium, no larvae have been reared from the egg in captivity.

The young do not hatch as nauplius larvae. All known forms hatch in an advanced stage which bears many adult characteristics, but it is difficult to assign the early larvae properly because the diagnostic characters do not appear until later.

The larvae are delicate, transparent organisms which lead a planktonic existence. The larval life is long, and they pass through many molts before reaching the adult stage. Not-

withstanding their great abundance, only two or three early larval forms have been traced to their adult counterpart. Their long planktonic existence easily accounts for the worldwide distribution of the genera and the presence of species such as *Pseudosquilla ciliata* in the Pacific Ocean, Indian Ocean, Red Sea, and Atlantic Ocean. At present there appear to be only two species which are endemic in Hawaii, namely, *Coronida sinuosa* and *Squilla calumnia* n. sp.

Attempts were made to rear larval specimens, collected in plankton tows, in the laboratory, but this proved to be impossible as their period of survival in captivity was very short, and none of the larvae ever molted while in an aquarium. Because rearing of the larvae was unsuccessful, it was necessary to study specimens collected in plankton tows and at night light stations and material from the stomach contents of pelagic fishes.

The earlier authors such as Miers (1880), in their work on larval stomatopods, were content with bestowing separate generic and trivial names upon the larvae. If the adult genus to which the larval specimens belonged was known, they added the suffix *-erichthus* to the first syllable of the adult genus plus a trivial designation (except in the case of alima of *Squilla*). Thus *Pseuderichthus communis* Hansen, according to this system of classification, represented the larval form of a species of *Pseudosquilla*. Because no keys to these individual larval species were included, future authors found it difficult to identify specimens in their possession with those which had been previously described, and new larval species were erected to compensate for this. Claus (1872) and Brooks (1886) have done the most notable works on the larval forms. Giesbrecht (1910), Foxon (1932), and Gurney (1942) have reviewed the works of Claus and Brooks and expanded their results to include other unidentified larvae. However, I have found that the material has not been adequately simplified below the level of the genus, because in many cases they have retained the

previously assigned generic and trivial names of the larvae, thus making it difficult to ascertain the relationship of these species to those collected in Hawaii. Most of the larvae belonging to a particular genus resemble one another so closely that it is virtually impossible to place them in their proper specific category without rearing them to maturity. Because of these difficulties, I have not tried to relate the Hawaiian larval forms with those of the previously described species, but where it has been possible I have attempted to correlate them with their proper adult species. The specific identification of the larvae was made in the manner used by Claus (1872) and Brooks (1886) in which three methods were employed: (1) a comparison of larval stages with postlarval forms which show characteristics of both the larvae and adults, in this manner working from the adult back through the larval series to the earliest identifiable stage; this is by far the most accurate means of identification, except, of course, where rearing of the larvae to the adult has been accomplished; (2) a comparison of the distribution of larval forms and known adults in which it is possible to make specific diagnoses with some accuracy in those cases where only one or two adult species are known to occur, but cases may arise in which the adult specimen is unknown; (3) the relative abundance of larval and adult species, although this is the least accurate method used, has proved to be useful when one species is known to be more numerous than others and it is assumed that the larval forms also retain the same relative numerical relationship.

Almost all authors who have worked with larval stomatopods have noted that invariably there are forms present which in no respects bear any resemblance to the adults recorded for the region. This is also true of the material at hand from Hawaii. This would seem to indicate that there are numerous species throughout the world, probably from greater depths, which are known only in their larval stages.

The present study was undertaken because recent investigations on the feeding habits of pelagic fishes have shown that the larval stages of the Stomatopoda rank second in importance as food for certain species of tuna in the Hawaiian area, and that they are significant in the diet of several other pelagic fishes. Inasmuch as the adult stages of the pelagic larvae involved are found on the reefs and shores of the Islands, it is apparent that the general economy of the neritic waters in the vicinity is influenced to some extent by the productivity of the reef and shore fauna. These two points suggest a third, namely, that pelagic fishes may be influenced to venture close to shore because of the increased food supply there.

In order to assess objectively the importance of these larval stages in the general economy of the neritic realm, it is necessary to be able to identify the species involved, so that a rapid qualitative and quantitative analysis of both the plankton and the stomach contents of pelagic fishes may be made. The present problem was designed to accomplish these ends for the Stomatopoda, and it is hoped that the results obtained will prove of use to workers in other fields.

Acknowledgments

I wish to express my thanks to Dr. C. H. Edmondson for permitting me to examine the specimens in the Bernice P. Bishop Museum, to Mr. Vernon Brock for making available specimens collected by the Territorial Division of Fish and Game, and to the staff of the Pacific Oceanic Fishery Investigations for providing specimens collected by them. I am indebted to Dr. A. H. Banner for his constant help and criticism on the collection of material and preparation of the manuscript, and to Dr. R. W. Hiatt for suggesting the problem and for criticism of the manuscript. In addition I would like to extend my thanks to Mr. Kenji Ego, Mr. Daniel Yamashita, and Miss Winifred Tseu for their help in collecting specimens.

ADULT HAWAIIAN SQUILLIDAE

The genera of *Squillidae* easily fall into two groups which are distinguished by differences in the ischio-meral articulation of the raptorial claw (second maxilliped). In one group the articulation between the merus and ischium is terminal, whereas in the other the ischium articulates at a point anterior to the proximal end of the merus. This character is the basis for the primary division of the family, with *Squilla*, *Pseudosquilla*, *Lysiosquilla*, and *Coronida* comprising the first group, and with *Gonodactylus* and *Odontodactylus* comprising the latter group. Although the phylogenetic significance of the ischio-meral articulation of the raptorial claw is not clearly understood,

the species of each natural group resemble each other far more closely than they do those of the other group.

Squilla is separated from the other members of the first group in that its species all possess longitudinal carinae on the body segments. *Pseudosquilla*, *Lysiosquilla*, and *Coronida* are separated from one another by the shape of the body, the carapace, and the telson, as is indicated in the following key and descriptions. *Odontodactylus* and *Gonodactylus* are readily distinguished because species of *Odontodactylus* possess teeth on the inner margin of the dactylus of the raptorial claw, whereas species of *Gonodactylus* lack such teeth.

To avoid confusion in terminology, Figure 1 presents characteristics used in the key and

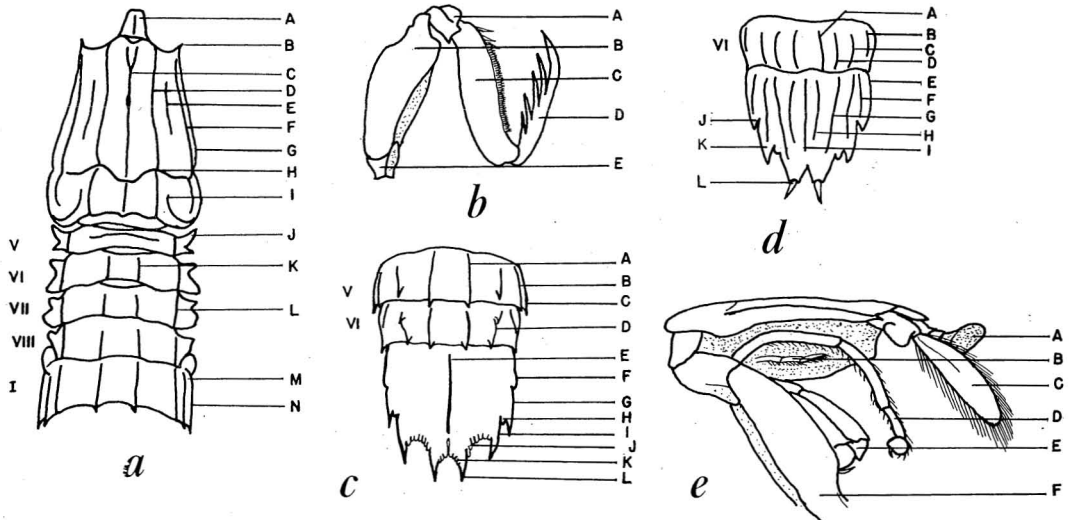


FIG. 1. Diagrams illustrating morphological details and terminology of stomatopods.

- a, Rostrum, carapace, exposed thoracic somites, and first abdominal somite of *Squilla*. A-I, Structures of carapace. A, Rostrum; B, anterolateral spine; C, median carina; D, gastric groove; E, intermediate carina; F, lateral carina; G, marginal carina; H, cervical groove; I, posteriorly reflexed marginal carina. J-N, Structures of thoracic and abdominal somites. J, Anterolateral spine of fifth thoracic somite; K, submedian carina; L, intermediate carina; M, lateral carina; N, marginal carina. V-VIII, Fifth to eighth thoracic somites. I, First abdominal somite.
- b, Second thoracic appendage (raptorial claw). A, Carpus; B, merus; C, propodus; D, dactylus; E, ischium.
- c, Telson and last two abdominal somites of *Squilla*. A-E, Structures of abdominal somites. A, Submedian carina; B, lateral carina; C, marginal carina; D, intermediate carina; E, median carina. F-L, Structures of telson. F, Pre-lateral denticle; G, lateral tooth; H, lateral denticle; I, intermediate tooth; J, intermediate denticles; K, submedian denticles; L, submedian tooth. V-VI, Fifth and sixth abdominal somites.
- d, Last abdominal somite and telson of *Odontodactylus*. A-D, Structures of sixth abdominal somite (VI). A, Submedian carina; B, lateral carina; C, second intermediate carina; D, first intermediate carina. E-L, Structures of telson. E, Marginal carina; F, second lateral carina; G, intermediate carina; H, submedian carina; I, median carina; J, lateral tooth; K, intermediate tooth; L, submedian tooth.
- e, Lateral aspect of head and carapace of *Squilla*. A, Cornea of eye; B, mandibular palp; C, antennal scale; D, first thoracic appendage; E, third thoracic appendage; F, second thoracic appendage (raptorial claw).

in the descriptions of the species. These have been partially adapted from Kemp (1913), whose terminology has been employed throughout this work.

Key to Adult Hawaiian Squillidae

- A. Raptorial claw with articulation of merus and ischium terminal (Fig. 3g), merus grooved ventrally for reception of propodus throughout its length, propodus finely pectinate or with a series of fixed spines along the upper margin, dactylus not inflated at base **B**
- AA. Raptorial claw with ischio-meral articulation at a point anterior to the proximal end of the merus (Fig. 21c), ventral surface of merus grooved for reception of propodus for not more than 0.75 of its length, propodus may or may not be finely pectinate along the upper margin, dactylus inflated at base (**Odontodactylus** and **Gonodactylus**) **I**
- B. Carapace with well-marked carinae, cervical groove defined across the dorsal surface; first 5 abdominal somites with longitudinal carinae (**Squilla**) **C**
- BB. Carapace without well-marked carinae, cervical groove not extending over dorsal surface; first 5 abdominal somites without longitudinal carinae **F**
- C. Anterolateral angles of carapace armed with short, acute spines; cornea of eyes set obliquely on stalk (Fig. 3a), nearly 1.5 times as wide as greatest breadth of stalk, distinctly bilobed **D**
- CC. Anterolateral angles of carapace rounded, without short acute spines (occasionally with spines in *S. alba*); cornea of eyes set transversely on eyestalk (Fig. 6), slightly wider than the greatest breadth of stalk, very slightly bilobed **E**
- D. Dactylus of raptorial claw with 6 teeth;³ body usually more than 100 mm. in

- length from tip of rostrum to tip of submedian spines of telson **Squilla oratoria**
- DD. Dactylus of raptorial claw with 5 teeth; body not reaching over 90 mm. in length from tip of rostrum to tip of submedian spines of telson **Squilla boops**
- E. Submedian teeth on posterior margin of telson with movable tips; 5 or 6 movable spines along outer margin of exopod of uropod; 2 rounded lobes between inner and outer spine of basal prolongation of uropod; body opaque white throughout **Squilla alba**
- EE. Submedian teeth on posterior margin of telson without movable tips; 8 or 9 movable spines along outer margin of exopod of uropod; 1 rounded lobe near base of inner spine of basal prolongation of uropod; body with definite brown pigment marking carinae and margins **Squilla calumnia** n. sp.
- F. Lateral margins of exposed thoracic somites and abdominal somites parallel throughout, not increasing in breadth posteriorly; telson with sharp median carina and with lateral carinae (**Pseudosquilla**) **G**
- FF. Lateral margins of exposed thoracic and abdominal somites not parallel throughout, abdominal somites increasing in breadth posteriorly; telson with median carina low and rounded, and without lateral carinae (**Lysiosquilla** and **Coronida**) **H**
- G. Inner spine of basal prolongation of uropod longer than outer spine; eyes small and cylindrical; 6 carinae besides median carina on telson **Pseudosquilla ciliata**
- GG. Inner spine of basal prolongation of uropod shorter than outer spine; eyes flattened, club-shaped; 8 carinae besides median carina on telson **Pseudosquilla oculata**
- H. Alternating bands of light and dark pig-

³ The number given for the teeth on the raptorial dactylus throughout this study includes the terminal tooth in all species, except *Odontodactylus hanseni*.

ment throughout length of body; raptorial dactylus with 9 or 10 teeth on inner margin; telson with low, rounded, median carina. . . . **Lysiosquilla maculata**

HH. No alternating bands of light and dark pigment throughout length of body; raptorial dactylus with 4 teeth on inner margin; telson closely studded with large tubercles in definite patterns. . . .

. **Coronida sinuosa**

I. Dactylus of raptorial claw with 9 teeth on inner margin; telson with ordinary longitudinal carinae; rostrum with evenly convex anterior border and evenly rounded angles; eyes large, breadth of cornea about equal to 0.5 the length of the carapace; preserved specimens yellowish white or pink.

. **Odontodactylus hanseni**

II. Dactylus of raptorial claw without teeth on inner margin; telson with concentric rings of flesh-tipped spines; rostrum trispinous; eyes small, breadth of cornea about equal to 0.125 the length of the carapace; preserved specimens mottled red or reddish brown.

. **Gonodactylus guerini**

***Squilla oratoria* de Haan**

Figs. 2, 3a-k

Squilla oratoria de Haan, 1844: pl. 51, fig. 2 [figures only]; 1849: 223 [description].

Squilla affinis Berthold, 1845: 26, pl. 3, figs. 1-2.

Squilla nepa Miers, 1880: 25.

Chloridella affinis de Man, 1907: 439.

DESCRIPTION: Carapace considerably narrower anteriorly than posteriorly; nearly twice as long (including rostrum) as greatest breadth anteriorly; conspicuous gastric and cervical grooves, the latter continuous across mid-dorsal region; seven distinct, longitudinal carinae, median bifurcated anteriorly for about 0.25 the distance to cervical groove, intermediate extending nearly entire length of carapace, marginal produced anteriorly into sharp spine and posteriorly rounded and reflexed

toward gastric grooves. Rostrum longer than wide, subquadrate, with small median spine, lateral margins convergent anteriorly, not covering ophthalmic somite. Eyes large; cornea bilobed, set transversely on stalk; anterior margin of ophthalmic somite slightly truncate between base of eyestalks (Fig. 3a). Merus of raptorial claw articulating terminally with ischium, ventral surface longitudinally grooved throughout its length for reception of propodus; propodus finely pectinate along upper margin and with four sharp movable spines; dactylus not inflated at base, with six long, sharp teeth on inner margin. Propodus of first, third, and fourth thoracic appendages nearly circular, that of fifth subcircular, being slightly longer than wide (Fig. 3f, b, i). Mandibular palp of three segments (Fig. 3b, c). Free thoracic and abdominal somites dorsoventrally flattened, all possessing longitudinal carinae (first five abdominal somites

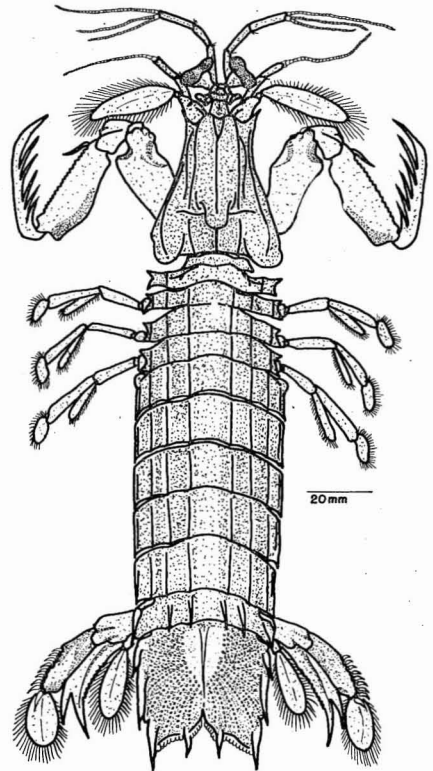


FIG. 2. *Squilla oratoria* de Haan (male).

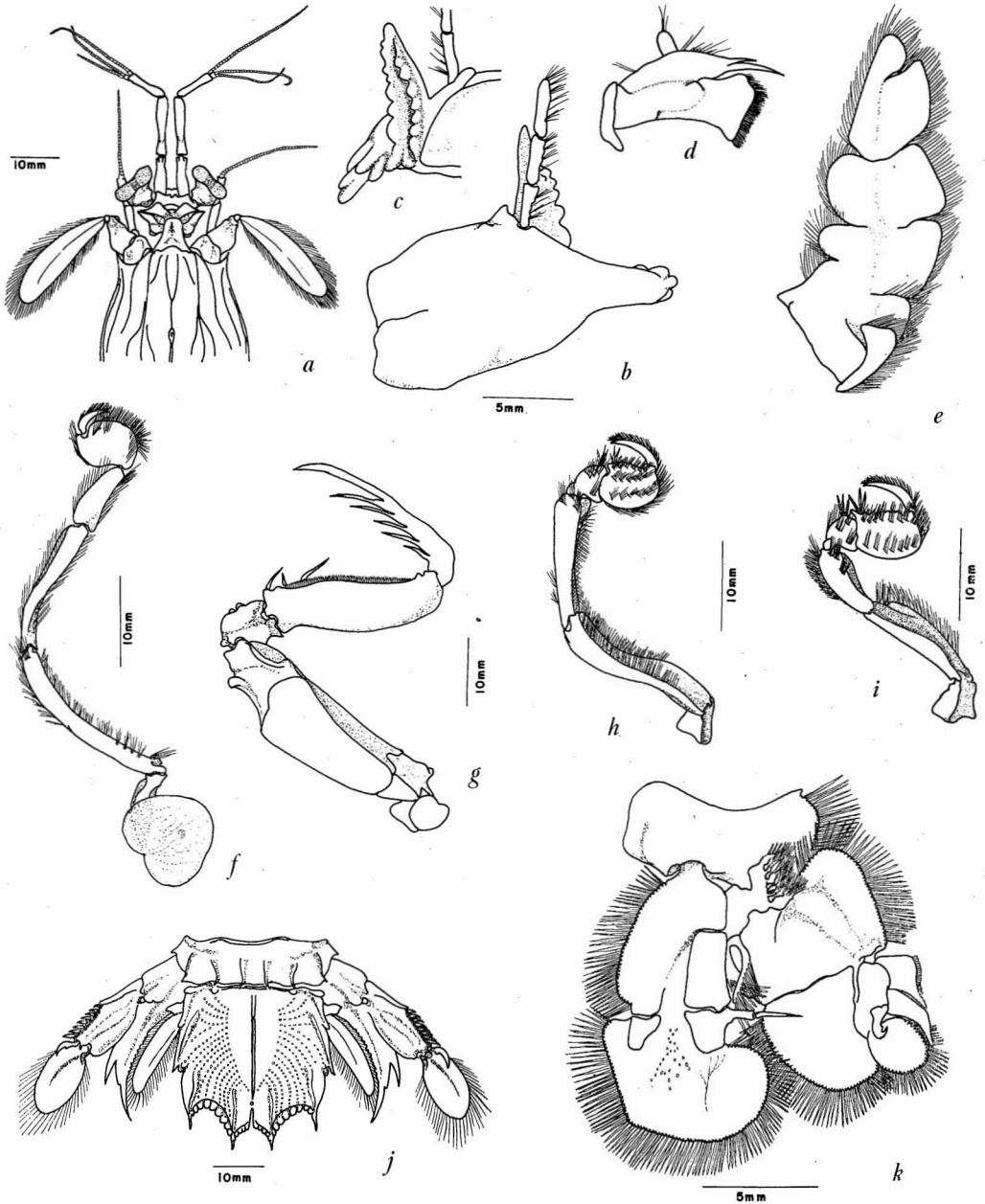


FIG. 3. *Squilla oratoria* de Haan. *a*, Anterior segments of adult; *b*, right pars molaris of mandible and mandibular palp (ventral aspect); *c*, right pars molaris of mandible (dorsal aspect); *d*, right pars incisiva of mandible; *e*, right maxilla; *f, g*, right first and second thoracic appendages; *h*, right third and fourth thoracic appendages; *i*, right fifth thoracic appendage; *j*, telson and uropods; *k*, right first abdominal appendage of male.

each with eight carinae); fourth through eighth thoracic somites exposed; intermediate carinae and lateral carinae of abdominal somites 1-5 end in short, sharp spines; sixth ab-

dominal somite with six spines, two submedian, two intermediate, two lateral. Telson with a single median crest, with radiating series of pits on each side; distal margin armed

with three pairs of large immovable teeth, submedian, intermediate, and lateral; three to five submedian denticles, seven to nine intermediate denticles, and a single lateral denticle, also a pair of prelateral denticles. Exopod of uropods with nine movable spines on outer margin. Basal portion of uropod elongated into two spines, inner longer than outer, a small lobe near the outer edge of the inner spine (Fig. 3j). Accessory reproductive organ of male shown in Figure 3k. The dorsal surface of the specimens is somewhat pitted and a dull mottled tan in color, the ventral surface is highly polished and somewhat lighter in color. Specimens vary from 145 to 200 mm. in length from the anterior end of the rostrum to the extremity of the submedian spines of the telson.

DISCUSSION: Several varieties of this species are recognized, but the Hawaiian specimens seem to fit the characteristics given by Kemp (1913) for those specimens which he had examined from this region. He found that specimens from Hawaii did not seem to fit any of the described varieties and did not attempt to place them in any definite variety.

Three males and three females collected at Oahu were examined. All were collected in regions with a muddy bottom suitable for burrowing. The Bishop Museum has eight specimens, two females collected at Guam, and two males and four females bought at a Honolulu market. All were very similar in appearance, except for small variations in color and size; characteristics which do not seem to be of systematic importance. There seems to be no apparent sexual dimorphism. The only positive means found for distinguishing males from females was the penis at the base of the eighth thoracic appendage, and the accessory reproductive organ of the male found on the first abdominal appendage (Fig. 3k).

This species is commonly taken in crab nets by fishermen at the Ala Wai Canal, Honolulu. Occasionally they appear in the Honolulu fish markets, their large size making them desirable for food.

DISTRIBUTION: This species appears to be somewhat more restricted in distribution than are other stomatopods, being reported only from the Hawaiian Islands, Guam, Philippine Islands, inland waters of Japan, and the China Sea.

Squilla boops Kemp

Figs. 4, 5a-f

Squilla boops Kemp, 1911 [May]: 97.

Squilla quadraicauda Fukuda, 1911 [August]: 287, pl. 11, figs. 3-5.

DESCRIPTION: Carapace broad anteriorly, breadth behind anterolateral spines exceeds 0.5 the total length including the rostrum; conspicuous gastric and cervical grooves, the latter continuous across the middorsal region; seven distinct longitudinal carinae, median discontinuous anterior to cervical groove, ending in a small pit, marginal produced anteriorly into a short spine and posteriorly rounded and reflexed toward gastric grooves. Rostrum broader than long, lateral margins upturned, rounded and slightly convergent anteriorly, a small median carina. Ophthalmic somite exposed, anterior margin truncate between eyestalks. Eyes large; cornea distinctly bilobed, set obliquely on stalks, considerably more than 0.3 length of carapace; prominent lobe on external aspect of eyestalk. Ischiomeral articulation of raptorial claw terminal; ventral surface of merus longitudinally grooved throughout its length for reception of propodus; carpus with three carinae; propodus finely pectinate along upper margin and with two movable spines proximally; dactylus not inflated at base, with a small ventral tubercle, five teeth on inner margin (Fig. 5b). Propodus of third and fourth thoracic appendages rounded posteriorly, those of first and fifth nearly straight and parallel to anterior margin (Fig. 5a, c-e). Mandibular palp composed of three segments, similar to that of *S. oratoria* (Fig. 3b). Free thoracic and abdominal somites dorsoventrally depressed, increasing in breadth posteriorly; all possess-

ing longitudinal carinae; fourth through eighth thoracic somites exposed, lateral margin of fifth produced into an anteriorly directed spine and a rounded posterior lobe, lateral margin of sixth of two rounded lobes, seventh and eight rectangular; first five abdominal somites with eight carinae, the marginal and lateral ending in a short acute spine, all intermediates except that of the first somite ending in spines, submedian of fifth ending in spines; sixth abdominal somite with six carinae, submedian, intermediate, and lateral all ending in spines. Telson with a single median crest terminating in a short spine; radiating series of pits on each side of median crest; distal margin armed with three pairs of immovable teeth, submedian, intermediate, and lateral; three to five submedian denticles, seven to nine intermediate denticles, one lateral denticle, also a pair of prelateral denticles. Exopod of uropods with seven movable spines along outer margin. Basal portion of uropods elongated into two spines, inner longer than

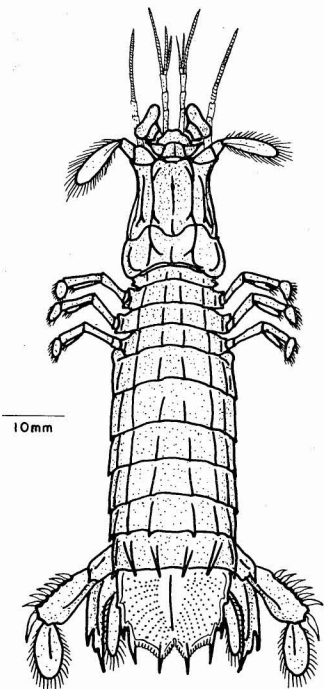


FIG. 4. *Squilla boops* Kemp (male).

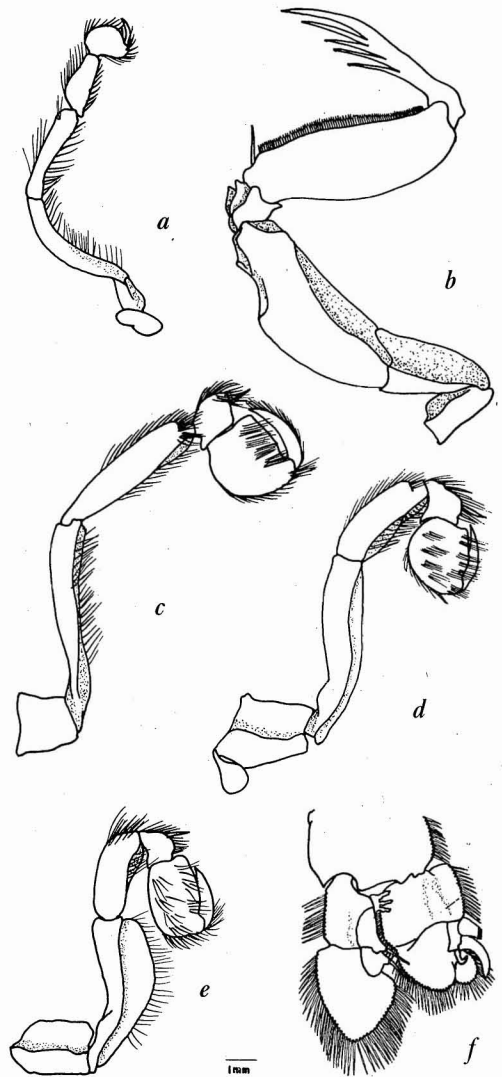


FIG. 5. *Squilla boops* Kemp. *a,b,c,d,e*, Right first, second, third, fourth, fifth thoracic appendages; *f*, right first abdominal appendage of male.

outer, a small rounded lobe between the two (Fig. 4). Accessory reproductive organ of male shown in Figure 5*f*. Kemp mentions that the type had the median portion of the carapace, abdomen, and telson covered with small, gray chromatophores. These were not sufficiently abundant to detract from the general coloration, which was yellowish in his type specimen but faintly pink in the specimens at hand. The posterior half of the fifth

abdominal somite between the lateral and marginal carinae and the outer angles of the sixth somite are black in all three of these specimens, as well as in Kemp's type specimen. No mention of the color of Fukuda's specimen was made. The three local specimens vary from 68 to 75 mm.; Kemp's was 89 mm., and Fukuda's 40 mm.

DISCUSSION: One male and two female specimens of this species have been examined. They were taken from the stomach contents of black skipjack, *Euthynnus yaito* Kishinouye, caught off Moku Manu [Island] off the northeast coast of Oahu. One specimen, a male, was but slightly digested, so the characteristics given by Kemp for this species could be easily recognized.

S. boops can be readily distinguished from *S. oratoria* by its smaller size and by the presence of only five teeth on the raptorial dactylus and only seven spines on the outer margin of the uropod. Early in this study it was thought that these were small specimens of *S. oratoria*, but the differences noted above have shown them to be the adults of Kemp's *Squilla boops*.

Kemp and Fukuda's specimens were both females; thus previously no description has been made of the modified accessory reproductive organ of the male found on the first abdominal appendage. However, Kemp's (1913) figures of the female have been useful in identifying the present specimens, which I consider conspecific.

DISTRIBUTION: The type specimen, a female, was taken by the "Investigator" in the Gulf of Martaban, Burma, at a depth of 67 fathoms. Another female was collected at Matsuwa, Sagami Province, Japan. One male and two females have been obtained from the stomach contents of a black skipjack (*Euthynnus yaito*) caught off Moku Manu (Bird Island), Oahu.

Squilla alba Bigelow

Figs. 6, 7a-f

Squilla alba Bigelow, 1893: 103; 1894: 539-541, pl. 22. [Complete description and figures.]

DESCRIPTION: Carapace longer than greatest breadth, slightly narrower anteriorly than posteriorly, with distinct gastric and cervical grooves, with five longitudinal carinae, anterolateral angles rounded and usually armed with short acute spines, posterolateral angles broadly rounded. Rostrum longer than broad, truncate or triangular. Ophthalmic somite partially exposed, anterior margin straight between base of eyestalks, with small rounded process at base of each eye dorsally. Eyes large; cornea set transversely on stalks, only slightly broader than greatest breadth of stalk, about 0.3 total length of carapace, including rostrum. Antennular peduncle about same length as carapace, including rostrum. Ischiomeral articulation of raptorial claw terminal; ventral surface of merus grooved longitudinally throughout its length for reception of propodus; carpus with a blunt median carina; outer margin of propodus finely pectinate, three movable spines near proximal end (only one shown in Fig. 7b, other two not visible in this view); dactylus not inflated at base, notched inferiorly, outer margin straight or slightly concave, inner margin armed with six teeth. Anterior and posterior margins of third and fourth thoracic appendages rounded, first and fifth straight and nearly parallel (Fig. 7a, c-e). No mandibular palp. Fifth through eighth thoracic somites exposed; lateral margin of fifth seen in dorsal view composed of two distinct processes, a long, anteriorly directed spine and a rounded posterior lobe; sixth, seventh, and eighth not bilobed, but rounded. Longitudinal carinae on all exposed somites, eight on first five abdominal somites, none ending in spines; posterolateral margins acute and rounded; sixth abdominal somite with six carinae ending in spines, two submedian, two intermediate, two lateral. Telson with indistinct median carina but a small median spine posteriorly; radiating series of pits on dorsal surface; armed with six marginal teeth, two submedian with movable tips, two intermediate, two lateral; five or six minute submedian spinules, 11 or 12 intermediate,

one lateral. Exopod of uropods with five or six movable spines along their outer margin. Basal portion of uropods elongated into two spines, inner longer than outer, with a distinct, rounded lobe near base of each spine (Fig. 6). First abdominal appendage shown in Figure 7*f*. Body of specimens an opaque white, eyestalks yellow with a very black cornea. Abdominal and thoracic somites and carapace with large, white pigment cells distributed at random over their surface. Telson, seen from above, nearly transparent so that tissue projecting into it can be easily seen and produces the pattern shown in Figure 6. Specimens range in size from 20 to 47 mm. in length.

DISCUSSION: A small female specimen, 20 mm. long, was collected by Mr. Kenji Ego

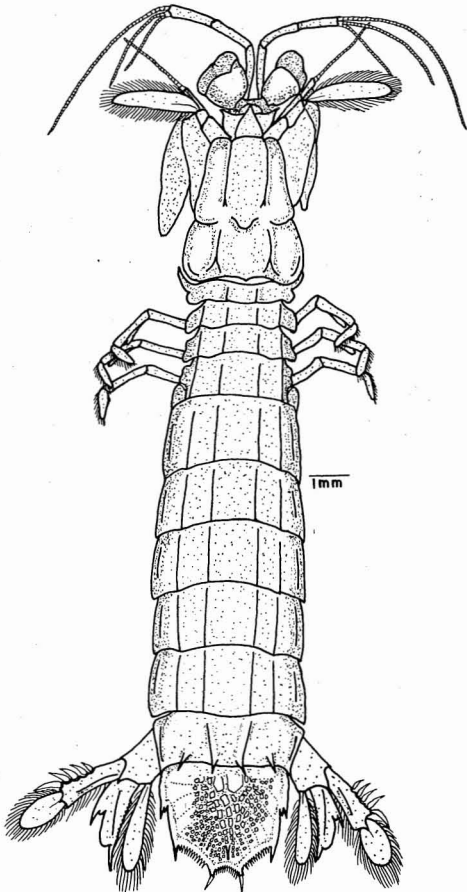


FIG. 6. *Squilla alba* Bigelow (female).

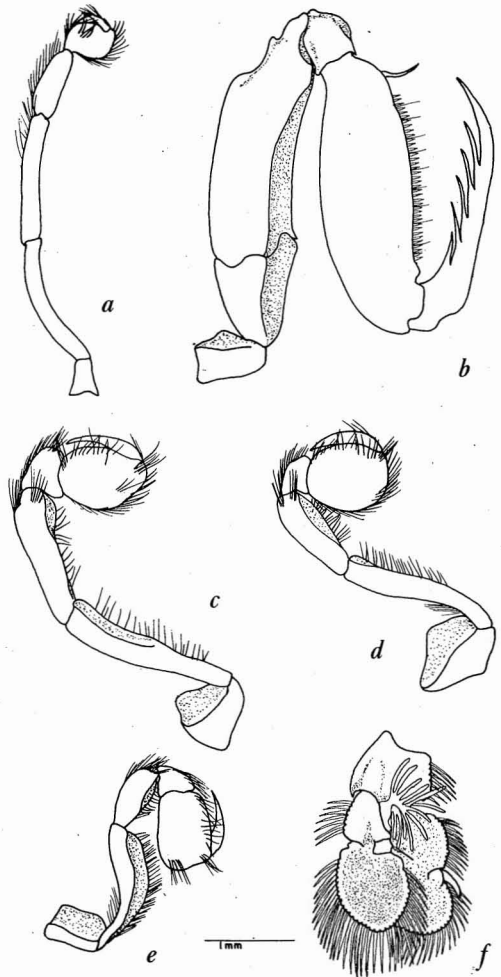


FIG. 7. *Squilla alba* Bigelow. *a, b, c, d, e*, Right first, second, third, fourth, fifth thoracic appendages; *f*, right first abdominal appendage of female.

at Kawaihae, Hawaii, in a night light station. This is a very striking species, as the color of the specimens immediately attracts attention. Its shape is also somewhat peculiar, the carapace and exposed portion of the thorax being equal in length and together making up nearly 0.44 of the total length of the body. The entire surface of the body is smooth and polished, interrupted occasionally by distinct carinae. The lateral margins of the fifth thoracic somite with their long, anteriorly directed spines and rounded posterior lobes are also characteristic of this species.

The type specimen was collected by Bigelow at Bimini Harbor, Bahamas. Edmondson (1921) reported that a female specimen was taken on Waikiki Reef, Oahu. Unfortunately, I have not been able to locate this specimen in the Bishop Museum for comparison with the specimen taken at Kawaihae. Edmondson states that the specimen which he collected agreed with Bigelow's previous description for the species. The Kawaihae specimen agrees with Bigelow's description in color, shape of the eyes, general body proportions, shape of the lateral margin of the fifth thoracic somite, shape of the telson, and the presence of two lobes between the inner and outer spines of the uropods. However, there are certain characteristics in which the specimens differ considerably. Bigelow's type possesses definite longitudinal carinae on the carapace, the rostrum is truncate, the anterolateral angles of the carapace are rounded and armed with a short spine, and the outer margin of the uropods is armed with six movable spines. The Kawaihae specimen, on the other hand, does not have any carinae on the carapace, the rostrum is distinctly triangular, the anterolateral angles of the carapace are rounded and unarmed, and the outer margin of the uropods is armed with only five movable spines. I believe that these differences are due to the relatively immature condition of the Kawaihae specimen, and that it is probably the last postlarval stage of this species. It is possible that the subsequent molt would reconcile the differences between this and the Bimini specimen.

Bigelow makes little note of the submedian spines on the posterior margin of the telson. His figure (1894: pl. 22) is indistinct, but there appears to be a line indicating that they possess movable tips. In the Kawaihae specimen the tips of these spines are unquestionably movable.

No male specimens have been reported. The largest of Bigelow's specimens was 41 mm., Edmondson's was 47 mm., and the Ka-

waihae specimen is considerably smaller, being only 20 mm. in length.

DISTRIBUTION: The type specimen was collected in calcareous sand at Bimini Harbor, Bahamas. In the Hawaiian Islands one specimen was taken from dead coral on Waikiki Reef, Oahu, and another at Kawaihae, Hawaii, at a night light. These are the only records known for this species.

Squilla calumnia n. sp.

Figs. 8, 9a-f

DESCRIPTION: Carapace, excluding rostrum, about as long as greatest breadth; slightly narrower anteriorly than posteriorly; distinct gastric grooves and cervical groove; median, intermediate, lateral, and marginal longitudinal carinae present, median discontinuous and bifurcated anterior to cervical groove, lateral posteriorly reflexed toward gastric groove; anterolateral and posterolateral angles unarmed and rounded. Rostrum broader than long, truncate, small median carina, lateral margins upturned and rounded anteriorly. Ophthalmic somite exposed, anterior margin concave between base of eyestalks. Eyes large; cornea set transversely on stalks, only slightly broader than greatest breadth of stalk, about 0.25 total length of carapace, including rostrum. Antennular peduncle about same length as carapace, excluding rostrum. Ischio-meral articulation of raptorial claw terminal; ventral surface of merus longitudinally grooved throughout its length for reception of propodus; carpus with median and lateral carinae; propodus finely pectinate along outer surface, three movable spines near proximal end; dactylus not inflated at base, outer margin slightly concave, armed with six teeth. Anterior margin of propodus of third, fourth, and fifth thoracic appendages straight (Fig. 9c-e), posterior margins rounded; propodus of first thoracic appendage nearly circular (Fig. 9a). Mandibular palp composed of two segments. Fifth through eighth thoracic somites exposed, with longitudinal carinae; lateral mar-

gin of fifth, seen in dorsal view, composed of two distinct processes, anteriorly directed spine and nearly straight posterior spine; lateral margin of sixth nearly straight, angular; seventh rounded posteriorly. Eight longitudinal carinae on first five abdominal somites, submedian, intermediate, lateral, marginal; all marginal carinae terminating in a short acute spine; sixth abdominal somite with six carinae, all ending in spines, two submedian, two intermediate, two lateral. Telson with median carina, ending in a small median spine posteriorly; radiating series of pits on each side

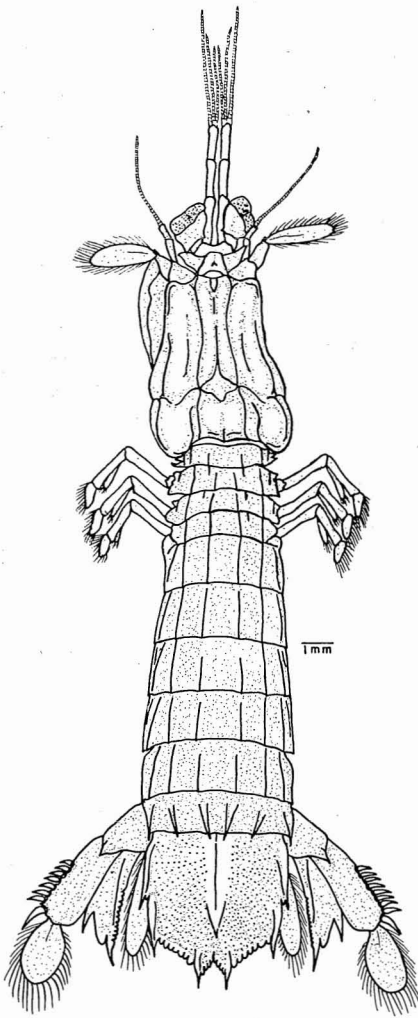


FIG. 8. *Squilla calumnia* n. sp. (female).

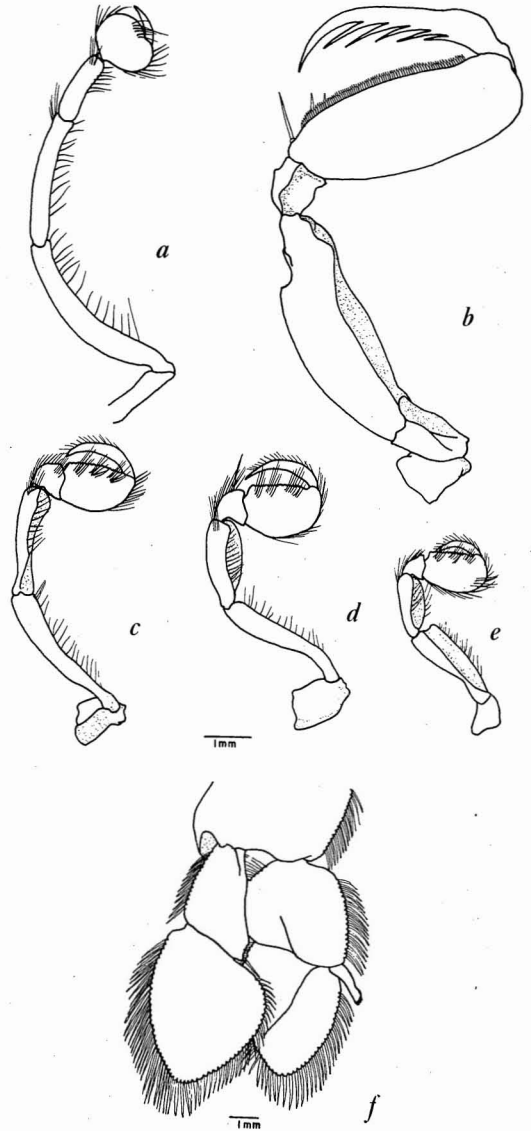


FIG. 9. *Squilla calumnia* n. sp. a, b, c, d, e, Right first, second, third, fourth, fifth thoracic appendages; f, right first abdominal appendage of female.

of median carina; armed with six teeth, two submedian, two intermediate, two lateral; four submedian denticles, seven intermediate denticles, one lateral denticle. Outer margin of exopod of uropods with eight movable spines on one side, nine on the other. Basal portion of uropods elongated into two spines, inner longer than outer, distinct rounded

lobe near base of inner. First abdominal appendage shown in Figure 9f. The coloration of the specimen is sufficient to distinguish it from others which I have examined. The ground color is an opaque white, which is partially obscured by dark-brown chromatophores along the posterior border of the thoracic and abdominal somites and which also clearly mark all the longitudinal carinae of the body. The cornea of the eyes is a deep black, the eyestalks retaining the opaque white of the body. Specimen 26 mm. long.

TYPE LOCALITY: A single male specimen 26 mm. long was collected by the Territorial Division of Fish and Game at a night light station at Hilo Dock, Hilo, Hawaii.

DISCUSSION: Although the penis which is located at the base of the eighth thoracic appendage is present, the specimen is apparently immature, as the accessory reproductive organ on the endopod of the first abdominal appendage is undeveloped. In spite of this condition I feel that the other characteristics are sufficiently distinct for the separation of this specimen from the other species in this genus.

At first glance this species and *Squilla alba* appear to be very similar; but the immovable submedian spines along the outer margin of the telson, the more numerous spines along the outer margin of the uropods, the shape of the lateral margin of the fifth thoracic somite, and the single lobe at the base of the inner spine of the uropod will serve to distinguish this species from *S. alba*. The rounded anterolateral angles of the carapace, the large globular eyes, and the six teeth on the raptorial dactylus are shared by both these species and will serve to separate them from the other members of this genus.

The fifth thoracic somite in this specimen appears to be composed of two distinct processes when seen from above, but it is different from others showing this same condition. In others, e.g., *S. laevis* Hess (1865), *S. hieroglyphica* Kemp (1911), and *S. alba* Bigelow (1893), there is a spine directed anteriorly and a

rounded posterior lobe. Here both processes are distinctly angular, the anterior spine curved forward, the posterior one projecting laterally. The shape of the sixth thoracic somite is distinctive in this species as well, in that the others have rounded lateral margins or are distinctly bilobed.

TYPE SPECIMEN: U.S.N.M. 93097.

Pseudosquilla ciliata (Fabricius)

Figs. 10, 11a-m

Squilla ciliata Fabricius, 1787: 333.

Cancer ciliatus Linnaeus, 1790: 2990.

Cancer (mantis) [sic] *ciliatus* Herbst, 1796: 102.

Squilla stylifera Lamarck, 1818: 189.

Squilla quadrispinosa Eydoux and Souleyet, 1841: 262, pl. 5, fig. 1.

Pseudosquilla stylifera Dana, 1852: 622, pl. 12, figs. 4a-e.

DESCRIPTION: Carapace longer than greatest breadth, slightly narrower anteriorly than posteriorly with conspicuous gastric grooves, cervical groove wholly absent, lacking carinae, anterolateral and posterolateral angles unarmed and rounded. Rostrum rounded anteriorly, about as wide as long, covering the ophthalmic somite. Eyes tubular, cornea following long axis of stalk (Fig. 11a). Merus of raptorial claw articulating terminally with ischium, ventral surface grooved throughout its length for reception of propodus; propodus with fine pectinations along outer margin and with four movable spines near proximal end; dactylus with three (sometimes four) long, sharp teeth. Propodus of fifth thoracic appendage subcircular, slightly longer than wide (Fig. 11i). Mandibular palp of three segments. Free thoracic and abdominal somites compressed, all lacking longitudinal carinae; sixth, seventh, and eighth thoracic somites exposed; posterolateral angles of abdominal somites with small, sharp spines; sixth abdominal somite with four spines, two submedian, two intermediate. Telson with seven carinae, one median, two submedian, two

intermediate, two lateral; armed with six spines, two submedian with movable tips, two intermediate, two lateral; no submedian denticles, two intermediate denticles, single lateral denticle. Exopod of uropods with nine (sometimes ten) movable spines on outer margin. Basal portion of uropod elongated into two spines, inner longer than outer. Accessory reproductive organ of male shown in Figure 11/. Specimens vary from 35 to 85 mm. in length.

DISCUSSION: Fifty-eight specimens of this well-known species were examined, of which 23 were males and 35 were females. All were collected from the reefs around Oahu in water not over 2 fathoms deep. This species represents the dominant form of the Hawaiian Islands. It has been collected from both Kauai and Hawaii where it seems to be as abundant as it is at Oahu. The species appears to prefer the rough substrate of the large exposed reef flats such as those found in Kaneohe Bay, Oahu. It has not been found in those regions having a substrate of coarse shifting sand or strong wave action.

There appears to be no clearly defined sexual dimorphism, and the only definite means that I have found for distinguishing males from females lies in the penis found at the base of the eighth thoracic leg (Fig. 11/) and the accessory reproductive organ of the male found on the first abdominal appendage (Fig. 11/). Specimens exhibit all degrees of coloring from an olive drab through yellow to a light tan with bright red, blue, and yellow chromatophores. The dactyli of the thoracic appendages are, in most cases, light rose.

According to Brooks (1886) the Atlantic specimens of this species differ in certain small details from those which are found in the Indo-Pacific region. Borradaile (1899) named the Atlantic specimens' var. *occidentalis*, but later workers such as Tattersall (1906) and Kemp (1913) have shown that the characters used by Borradaile are to be found in the Indo-Pacific specimens as well. The specimens from the Hawaiian Islands also appear

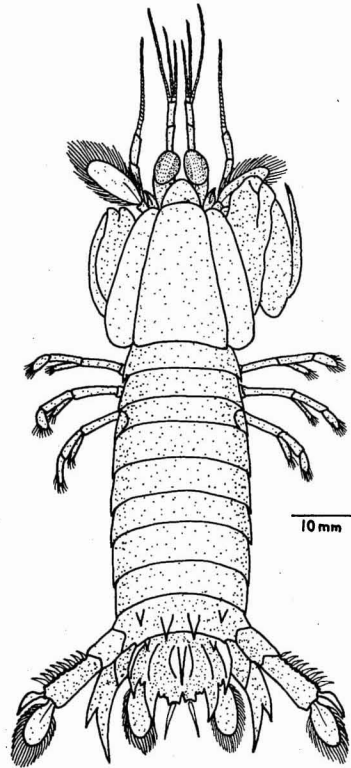


FIG. 10. *Pseudosquilla ciliata* (Fabricius) (male).

to be quite variable, but this variability is not sufficient to warrant their being placed in any other group. I have examined three specimens from Kaneohe Bay, Oahu, in which there were ten spines rather than nine on the exopod of the uropod; and one specimen in which there were nine spines on one side and ten on the other. Two specimens in the collection have the outer spine of the basal prolongation of the uropod longer than the inner. This is a character which has been considered to be specific for *P. oculata* (Brullé), but all other characters of this specimen are those of *P. ciliata*.

Specimens vary in length from 38 to 85 mm. Generally this species is somewhat larger than its congener, *P. oculata*, and in the field they can usually be distinguished in this way.

DISTRIBUTION: There are 12 species of *Pseudosquilla*, nine of which are found in the Indo-Pacific region. *P. ciliata* and its Hawaiian

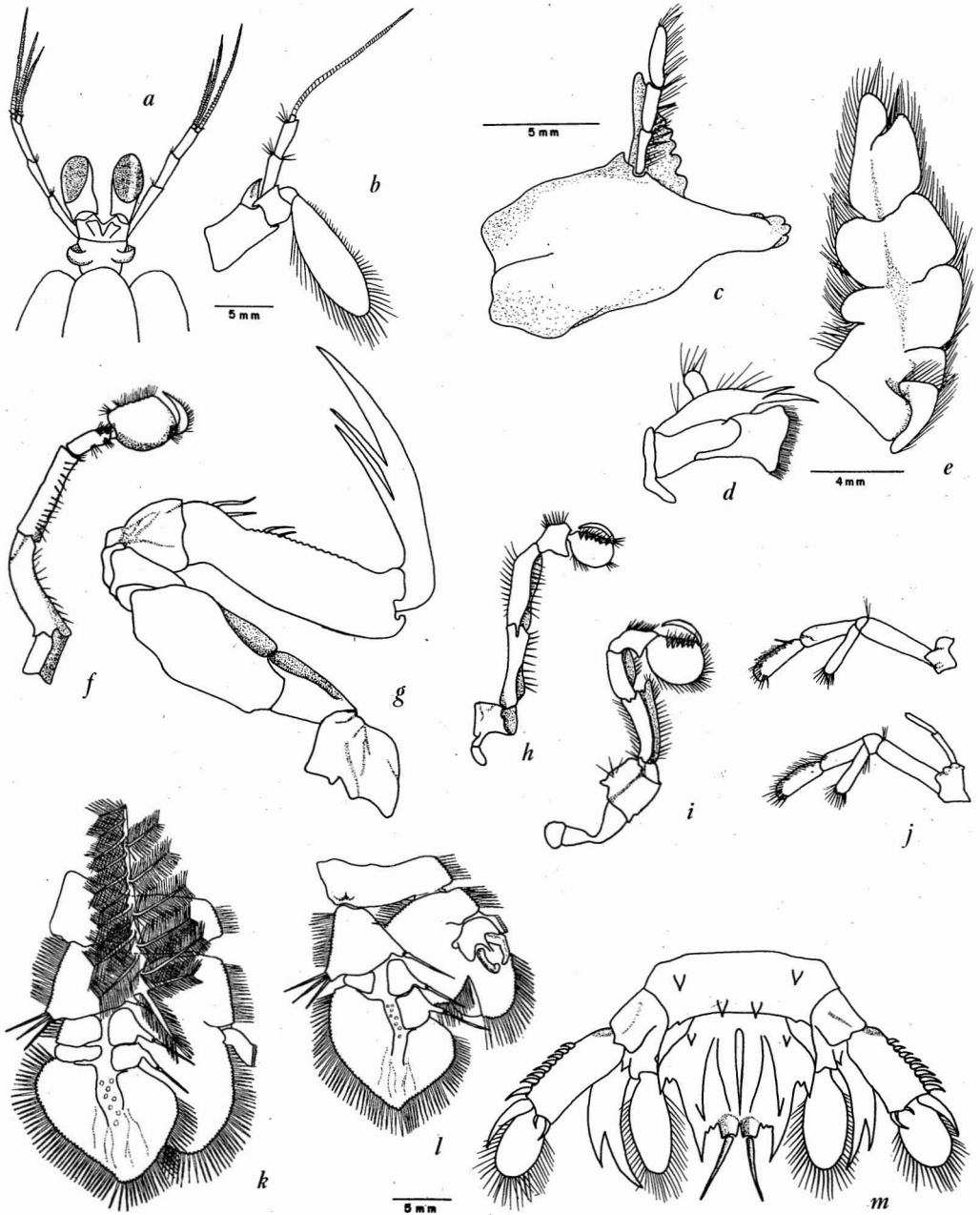


FIG. 11. *Pseudosquilla ciliata* (Fabricius). *a*, Anterior segments with rostrum removed; *b*, right antenna with scale; *c*, right pars molaris of mandible and mandibular palp; *d*, right pars incisiva of mandible; *e*, right maxilla; *f, g*, right first and second thoracic appendages; *h*, right third and fourth thoracic appendages; *i*, right fifth thoracic appendage; *j*, eighth thoracic appendage of female (top) and male showing penis (bottom); *k, l*, right first abdominal appendages of female and male; *m*, telson and uropods.

relative, *P. oculata*, are both known from the Pacific, Indian, and Atlantic oceans. Ordinarily they are found in the intertidal area in these regions, but Bigelow (1891) reports that *P. ciliata* was collected at a depth of 20–23 fathoms. *P. ciliata* has been reported from the Hawaiian Islands, Fiji Islands, Solomon Islands, Loyalty Islands, Japan, New Britain, New Guinea, Red Sea, Madagascar, Bermuda, Florida Keys, Puerto Rico, and St. Thomas.

***Pseudosquilla oculata* (Brullé)**

Figs. 12, 13

Squilla oculata Brullé, 1836: 18, fig. 3.

Squilla monodactyla A. Milne-Edwards, 1878: 232.

Pseudosquilla oculata Miers, 1880: 110, pl. 3, figs. 3, 4.

Pseudosquilla monodactyla Miers, 1880: 110, pl. 3, figs. 1, 2.

DESCRIPTION: Carapace longer than greatest breadth, slightly narrower anteriorly than posteriorly, with conspicuous gastric grooves, cervical groove wholly absent, lacking carinae, anterolateral and posterolateral angles unarmed and rounded. Rostrum with small median spine, about as wide as long, covering ophthalmic somite. Eyes flattened, appearing somewhat club-shaped rather than tubular (compare Figs. 11*a* and 12), cornea set transversely on stalk. Merus of raptorial claw articulating terminally with ischium, ventral surface grooved longitudinally throughout its length for reception of propodus; propodus with fine pectinations along upper surface and with four movable spines near proximal end; dactylus with three long, sharp teeth. Propodus of fifth thoracic appendage subcircular, slightly longer than wide. Mandibular palp of three segments. Free thoracic and abdominal somites compressed, all lacking longitudinal carinae; fifth, sixth, seventh, and eighth thoracic somites exposed; posterolateral angles of abdominal somites with small, sharp spines; fifth abdominal somite

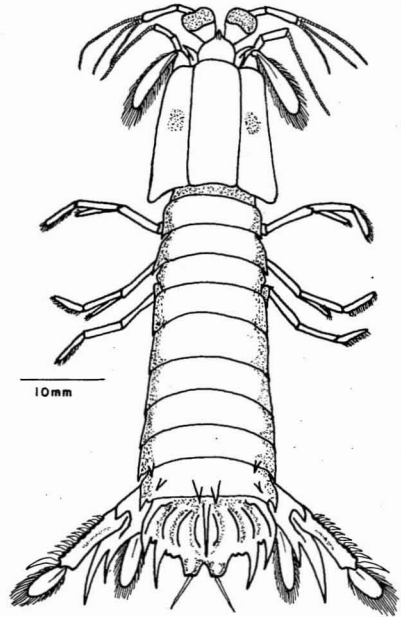


FIG. 12. *Pseudosquilla oculata* (Brullé) (male).

with two sublateral spines; sixth abdominal somite with two submedian and two sublateral spines. Telson with nine carinae, one median, two submedian, two intermediate, two sublateral, two lateral; armed with six spines, two submedian with movable tips, two intermediate, two lateral; no submedian denticles, two intermediate denticles, single lateral denticle. Exopod of uropods with ten (sometimes 11) movable spines along outer margin. Elongated basal portion of uropod with outer spine longer than inner (Fig. 12). Accessory reproductive organ of male shown in Figure 13. All specimens were a mottled tan and all possessed a dark spot on the lateral edges of the carapace, as noted by Kemp (1913). The dactyli are tipped with rose. Specimens vary from 35 to 70 mm. in length.

DISCUSSION: This species superficially resembles the more common *P. ciliata*. In Hawaiian waters the two species are commonly found in the same habitat, and, except through close scrutiny, *P. oculata* may often be mistaken for *P. ciliata*. The eyes of this species are very characteristic in shape and contrast

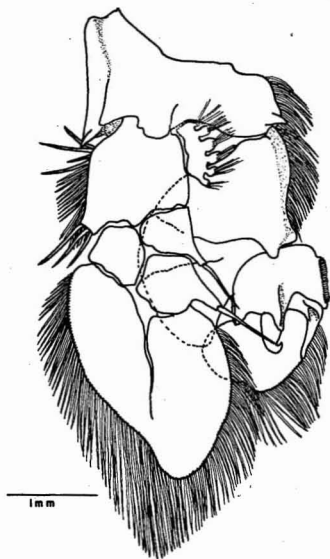


FIG. 13. *Pseudosquilla oculata* (Brullé), right first abdominal appendage of male.

well with those of *P. ciliata* (cf. Figs. 11a and 12). The spine-tipped rostrum, the extra pair of carinae on the telson, and the longer outer spine of the uropod will all serve to place specimens in this species.

This species is common in Hawaii: the Bishop Museum collection has five males and six females, and in addition I have examined one male and four females. The largest specimen was a male 70 mm. long, and the smallest was 35 mm. long. All specimens were collected at Oahu in shallow water together with specimens of *P. ciliata*.

Variability in color and form does not seem to be pronounced in this species. One specimen has 11 spines on the outer margin of the exopod of one uropod and 10 on the other. This variation parallels the condition found in *P. ciliata* and indicates that this characteristic is quite variable.

There is no clear sexual dimorphism. The accessory reproductive organ on the first abdominal appendage of the male is shown in Figure 13. If it is compared with Figure 11l, it can be seen that both *P. oculata* and *P. ciliata* are very similar with respect to this structure. Possibly this indicates strong affinities.

DISTRIBUTION: This species and *P. ciliata* are the only members of this genus which have been found in the Hawaiian Islands. As mentioned previously, *P. oculata* is found in the same environment as *P. ciliata*. Specimens are recorded from Samoa and Hawaii in the Pacific, from the Macclesfield Bank in the South China Sea, from Mauritius in the Indian Ocean, and from the Cape Verde Islands and Madeira in the Atlantic.

Lysiosquilla maculata (Fabricius)

Figs. 14, 15a-g

Squilla arenaria terrestris or *locusta* Rumphius, 1705: 4, pl. 3, fig. E.

Squilla maculata Fabricius, 1793: 511.

Cancer (mantis) [sic] *arenarius* Herbst, 1796: 96, pl. 33, fig. 2.

Squilla arenaria Randall, 1839: 146.

DESCRIPTION: Carapace nearly as broad as long, anterior breadth equal to posterior breadth, smooth, strongly convex from side to side, gastric grooves distinct, cervical groove obsolete or wholly absent, no longitudinal carinae, anterolateral and posterolateral angles broadly rounded. Rostrum broader than long, smooth, lateral margins convergent anteriorly to an acute but blunt apex, small longitudinal carina on anterior one third. Ophthalmic somite anteriorly exposed, dorsally produced into a pair of lobes terminating acutely on each side of rostral apex. Eyes large; cornea set obliquely on stalk, breadth about equal to greatest length of cornea and stalk combined. Antennular peduncle with small acute dorsal spine, less than one-half length of carapace, excluding rostrum. Ischio-meral articulation of raptorial claw terminal; merus grooved ventrally throughout its length for reception of propodus; carpus with blunt dorsal carina terminating in a sharp spine which overhangs anterior margin; propodus finely pectinate on upper margin, four movable spines near proximal end; dactylus slender, 9 to 11 teeth (usually 10), outer margin straight or slightly

concave (Fig. 15*d*). Propodus of third and fourth thoracic appendages orbicular with two weak spines at proximal end, those of first and fifth nearly rectangular and lacking spines (Fig. 15*c, f*). Fourth through eighth thoracic somites exposed, lateral margins rounded, lacking longitudinal carinae. Abdominal somites depressed; first through fifth lacking longitudinal carinae, increasing in breadth posteriorly; sixth narrower than preceding somites, with distinct grooves on each side of mid-line. Telson broader than long, convex dorsally, concave ventrally, both sides marked by a feeble median triangular elevation limited by a pair of posteriorly convergent

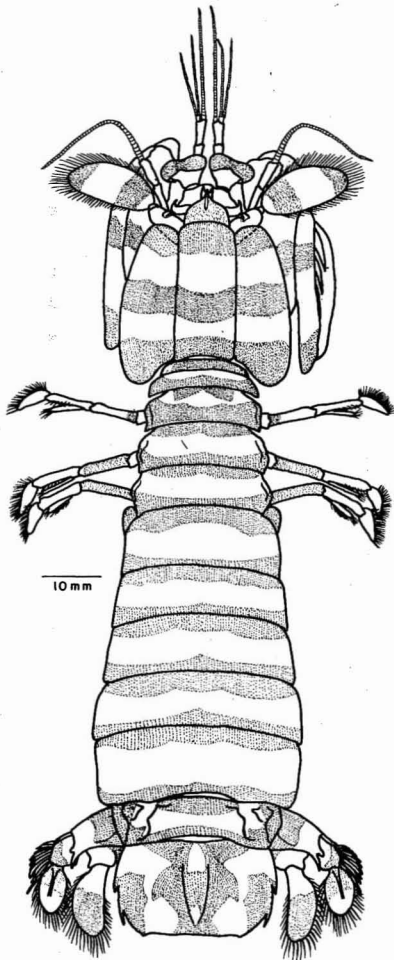


FIG. 14. *Lysiosquilla maculata* (Fabricius) (female).

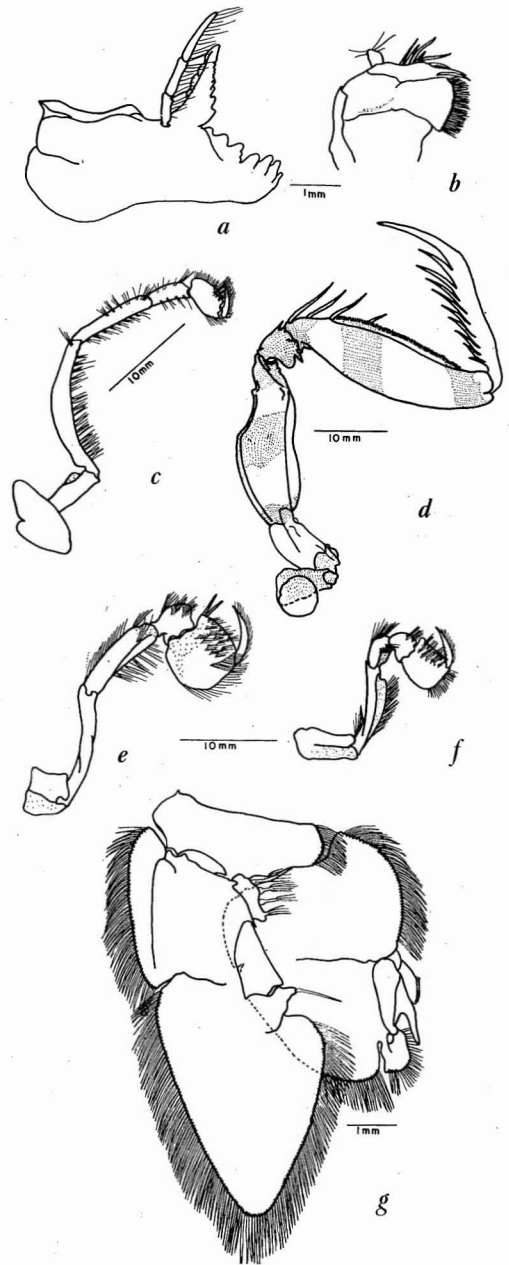


FIG. 15. *Lysiosquilla maculata* (Fabricius). *a*, Right pars molaris of mandible and mandibular palp; *b*, right pars incisiva of mandible; *c, d*, right first and second thoracic appendages; *e*, right third and fourth thoracic appendages; *f*, right fifth thoracic appendage; *g*, right first abdominal appendage of male.

grooves; sometimes marked by patches of pits rather regularly disposed near lateral margins; posterior margin indistinctly notched in mid-line with three pairs of blunt lobes, the two outermost generally sharper and more conspicuous than the inner. Inner dorsal edge of peduncular segment of uropods ending in short spine; exopod of uropods with eight or nine movable spines; basal portion of uropod elongated into two long spines, inner nearly twice length of outer, but obscured dorsally. Modified first abdominal appendage of male shown in Figure 15g. Animals are marked by alternating series of light and dark bands throughout the length of the body. Specimens vary in length from 69 to 283 mm.

DISCUSSION: This species is very readily identified. All specimens which have been hitherto reported, as well as those which I have examined, have possessed the characteristic dark transverse bands shown in Figure 14. In large female specimens this appears to be a secondary sexual characteristic, inasmuch as the carapace, free thoracic somites, and sixth abdominal somite are almost entirely blue-black. Nearly always in males there are alternating dark and light bands with the telson having a pattern which may vary from that shown in the figure but which usually has dark central and lateral areas. Preserved specimens retain the coloration, but the dark pigment becomes a brownish black.

There appear to be other characteristics showing a sexual dimorphism in this species. Miers (1880) and Kemp (1913) record several large females in which the carpus and the basal part of the raptorial propodus bear tufts of long hairs, and the latter with only two movable spines at its proximal end instead of four. The raptorial dactylus in these cases is also reported by them to have only a series of eight or nine denticles rather than the long teeth usually found there; however, none of the specimens which I have examined has shown these modifications. Evidently this is due to the relatively small size of the female specimens which I have examined compared

with those which they report as having these modifications.

This species and *Squilla oratoria* are the two largest stomatopods found in the Hawaiian Islands. I have examined six males and three females ranging from 70 to 185 mm. from the tip of the rostral spine to the posterior border of the telson. Other authors have reported specimens ranging from 69 to 283 mm.

Lysiosquilla maculata seems to occur in shallow water with a sandy or muddy substrate where it may burrow easily. All those specimens which I have examined had been collected in the fine silt on the reefs at Oahu and Hawaii. Mr. Kenji Ego (personal communication) reports that they occur in abundance in the mud flats at Kawaihae, Hawaii.

DISTRIBUTION: This species is widely distributed throughout the Indo-Pacific. In the Pacific it has been reported from the Hawaiian Islands, Marquesas Islands, Samoa, Fiji, Philippine Islands, and the Dutch East Indies.

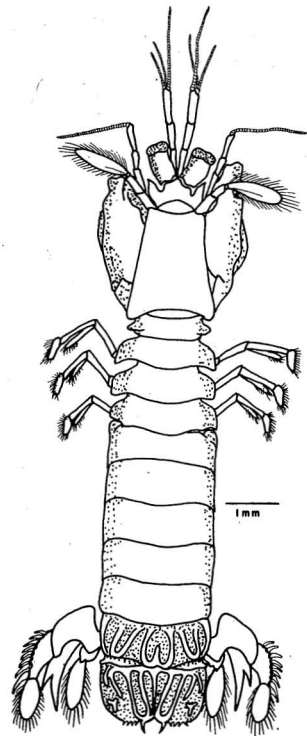


FIG. 16 *Coronida sinuosa* Edmondson (female).

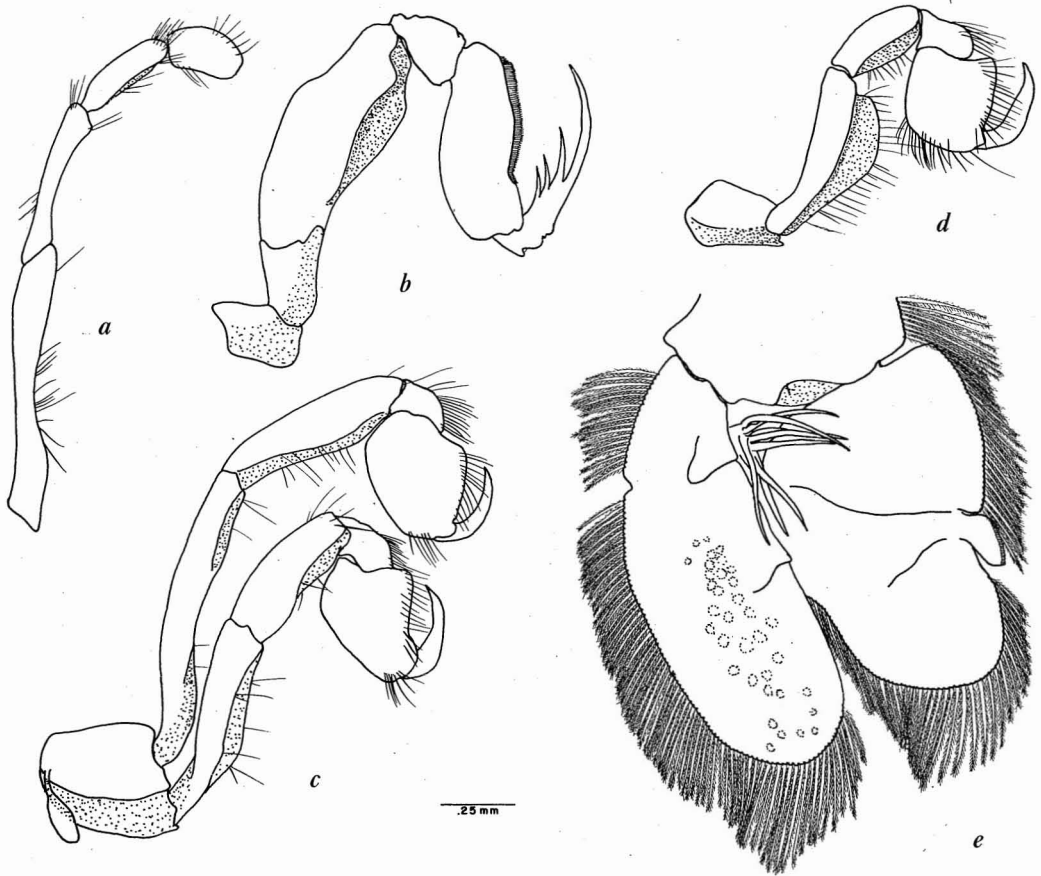


FIG. 17. *Coronida sinuosa* Edmondson. *a, b*, Right first and second thoracic appendages; *c*, right third and fourth thoracic appendages; *d*, right fifth thoracic appendage; *e*, right first abdominal appendage of female.

In the Indian Ocean it has been reported from Penung, Tuticorin, Madras, Mysore, and Durban. In the Atlantic Ocean adult specimens have been collected at Antigua, Dutch West Indies, and larvae from near the Cape of Good Hope.

***Coronida sinuosa* Edmondson**

Figs. 16, 17*a-e*

Coronida sinuosa Edmondson, 1921: 295, fig. 2.

DESCRIPTION: Carapace very slightly narrower anteriorly than posteriorly, nearly twice as long (including rostrum) as breadth at anterior border, lacking distinct carinae, cervical and gastric grooves wholly absent, anterolateral and posterolateral angles slightly round-

ed. Rostrum small, rounded anteriorly, breadth greater than length, not covering ophthalmic somite. Cornea of eyes set transversely on eyestalks, slightly bilobed; eyestalks narrow, elongated, flattened. Merus of raptorial claw articulating terminally with ischium (Fig. 17*b*), ventral surface longitudinally grooved throughout its length for reception of propodus; propodus finely pectinate along upper margin; dactylus notched and slightly inflated at base, with four sharp teeth on inner margin. First, third, fourth, and fifth thoracic appendages shown in Figure 17*a, c, d*. Mandibular palp absent. Free thoracic and abdominal somites dorsoventrally depressed, all lacking longitudinal carinae; fifth through eighth thoracic somites exposed, lateral margins of fifth with

an acute, anteriorly directed process, sixth, seventh, and eighth narrowed but evenly rounded (Fig. 16); dorsal surface of sixth abdominal somite ornamented with a scroll-like series of tubercles (carinae?), nearly symmetrical in arrangement. Telson with a series of similar tubercles which may be unsymmetrical except in the median region (Fig. 16); posterior border medially notched giving the appearance of two rounded lobes, with a pair of submedian spines and four to six marginal spines lateral to each submedian. Exopod of uropods with 8 to 11 movable spines on outer margin; elongated basal portion of uropods with two spines, inner longer than outer. First abdominal appendage of female shown in Figure 17e. Living animals are transparent white, preserved specimens opaque white throughout. Specimens range from 9.5 to 17.0 mm. in length.

DISCUSSION: Three female specimens of this small species have been examined, including the type specimen in the Bishop Museum. All had been collected from among dead coral on Waikiki Reef, Oahu.

The species is apparently closely allied to *Coronida multituberculata* (Borradaile) (1898), but differs considerably in the shape of the rostrum and in the ornamentation of the sixth abdominal somite and telson.

Specimens may be easily recognized by the ornamentation of the last two body segments. The tubercles (or carinae as they are called by Edmondson) of the sixth abdominal somite form a definite pattern which is nearly symmetrical on each side of the median line, suggesting a single median carina, paired submedian carinae, paired intermediate carinae, paired lateral carinae, and paired marginal carinae. The telson is similarly ornamented, but is not usually as symmetrical as shown in Figure 16. Here there is also a suggestion of a median carina, paired submedian carinae, and paired intermediate carinae; but all are somewhat joined to one another forming a scroll-like pattern. There appears to be considerable variation in the number of spines

found on the posterior margin of the telson, and I am inclined to believe that there is but a single pair of submedian spines, the rest being small, marginal denticles, although Edmondson (1921) recognized two other pairs.

The slightly inflated base of the dactylus suggests affinities to *Gonodactylus* and *Odontodactylus*, but the articulation of the ischium and merus of the raptorial claw indicates a close relationship to *Squilla*, *Pseudosquilla*, and *Lysiosquilla*.

Because of their very small size it can be seen why this species has not been collected more often. The three specimens which I have examined ranged from 9.5 to 17.0 mm. from the tip of the rostrum to the distal end of the submedian spines of the telson. Living adults are also very transparent and difficult to see,

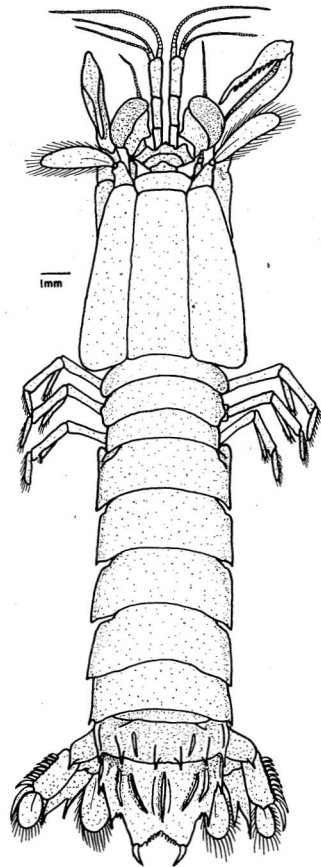


FIG. 18. *Odontodactylus hanseni* (Pocock) (male).

especially so in their native habitat on the reefs. Preserved specimens become opaque white or slightly yellowish, with the cornea of the eyes remaining very dark.

It is difficult to say whether or not the specimens are mature and whether there is a distinct sexual dimorphism, because all specimens are females and none were ever collected with egg masses. The absence of the gastric grooves and the very elongated antennal somites suggests that possibly they are in an immature stage. Edmondson (1921) states that the specimen in the Bishop Museum was kept alive for a month, during which time it molted with no apparent increase in size or change in structure.

DISTRIBUTION: All specimens collected have come from dead coral heads on Waikiki Reef, Oahu.

Odontodactylus hanseni (Pocock)

Figs. 18, 19*a-f*

Gonodactylus hanseni Pocock, 1893: 477, pl. 20, figs. 3, 36.

Odontodactylus latirostris Borradaile, 1907: 212, pl. 22, figs. 3, 3a.

DESCRIPTION: Carapace longer than greatest breadth, slightly narrower anteriorly than posteriorly, with distinct gastric grooves, cervical groove wholly absent, longitudinal carinae lacking, anterolateral and posterolateral angles unarmed and rounded. Anterior margin of rostrum evenly rounded, twice as broad as long. Ophthalmic somite exposed, dorsal process deeply excavate anteriorly. Eyes large, globular, corneal diameter 0.25 to 0.5 the length of carapace, excluding rostrum (Fig. 18). Ischio-meral articulation of raptorial claw situated at a point in advance of proximal end of merus (Fig. 19*b*); ventral surface of merus grooved longitudinally for not more than 0.6 its length for reception of propodus; upper surface of propodus not pectinate; dactylus inflated at base, armed with 9–11 teeth on its inner margin. Propodus of third, fourth, and

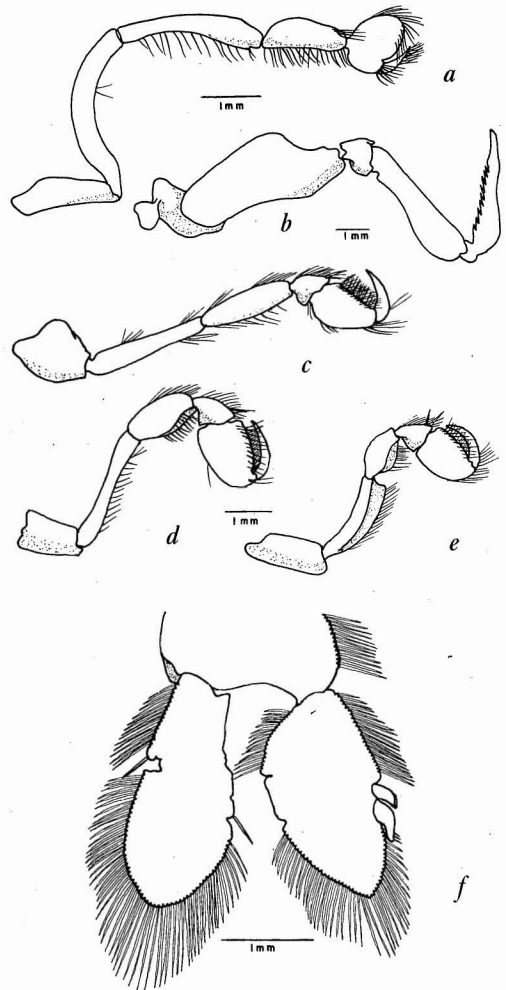


FIG. 19. *Odontodactylus hanseni* (Pocock). *a, b, c, d, e*, Right first, second, third, fourth, fifth thoracic appendages; *f*, right first abdominal appendage of male.

fifth thoracic appendages somewhat shield-shaped (Fig. 19*c-e*). Mandibular palp of three segments. Free thoracic and abdominal somites laterally compressed, distinct longitudinal carinae present only on sixth abdominal somite; sixth, seventh, and eighth thoracic somites exposed, lateral borders rounded; posterolateral angles of fourth and fifth abdominal somites ending in a short acute spine; sixth abdominal somite with four pairs of longitudinal carinae, one submedian pair ending in spines, one intermediate pair without spines, one second lateral pair ending in spines, one

marginal pair ending in spines. Telson with high median carina ending in a short terminal spine, submedian, intermediate, second lateral, and marginal carinae; armed with three pairs of strong marginal teeth, submedian (with movable tips), intermediate, and lateral; no submedian denticles but a series of minute spinules, two intermediate denticles, and a single lateral denticle. Exopod of uropods with 10 or 11 movable spines on outer margin. Basal portion of uropods elongated into two spines, inner shorter than outer. First abdominal appendage of male shown in Figure 19f. Color of the specimens is a uniform light yellowish pink above with the exposed thoracic and first four abdominal somites having a light pink posterior margin. The large globular eyes are dark brown and the flagella of the antennae are pink. The animals are quite small with the reported range in length from 27 to 80 mm.

DISCUSSION: In dorsal aspect this species very closely resembles small specimens of *Pseudosquilla*, but the ischio-meral articulation of the raptorial claw and the large globular eyes are suitable for distinguishing members of this genus from those of *Pseudosquilla*. The inflated dactylus and the ischio-meral articulation of the raptorial claw are features which members of this genus have in common with *Gonodactylus*, but the numerous carinae on the telson, the nonpectinate upper margin of the raptorial propodus, and the series of teeth on the inner margin of the raptorial dactylus will serve to separate this group from the latter. As stated by Bigelow (1894) this genus seems to occupy an intermediate position between *Gonodactylus* and *Pseudosquilla*.

Five female and three male specimens of this species have been examined, all of which were taken from stomachs of the skipjack, *Katsuwonus pelamis*, and of the yellowfin tuna, *Neothunnus macropterus*. The Bishop Museum has one male and two females which were dredged off Waikiki, Oahu, at a depth ranging from 30 to 50 fathoms. Pocock's (1893) type specimen was a single female from the Mac-

clesfield Bank, South China Sea, at a depth of 35 fathoms. Bigelow (1931) reported four males, one female, and two juveniles taken in Hawaiian waters by the "Albatross" in 1902 at depths ranging from 24 to 83 fathoms. The specimens which I have examined are in agreement with those previously reported. Some characteristics were relatively difficult to distinguish, but I attribute this to the fact that the animals were considerably disfigured from having been in the stomach. Edmondson (1921) has illustrated the telson of this species more clearly than is shown in Figure 18.

There appears to be no distinct sexual dimorphism. The first abdominal appendage of the male shown in Figure 19f is incomplete because the fixed limb in all three specimens was indistinguishable.

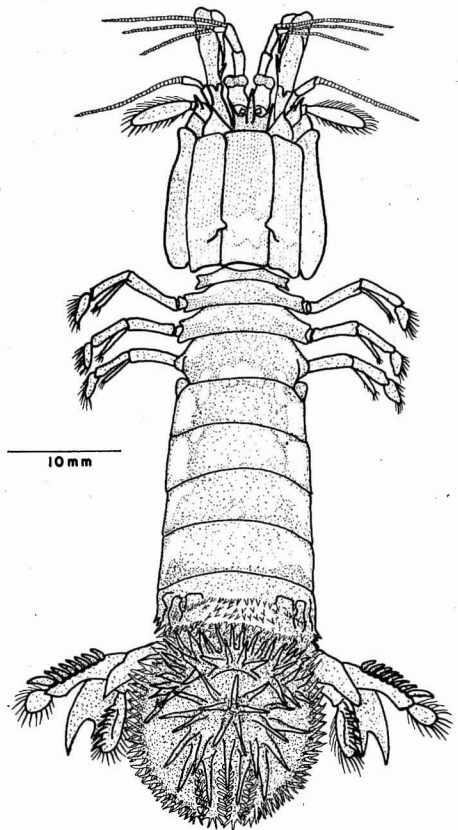


FIG. 20. *Gonodactylus guerini* White (female).

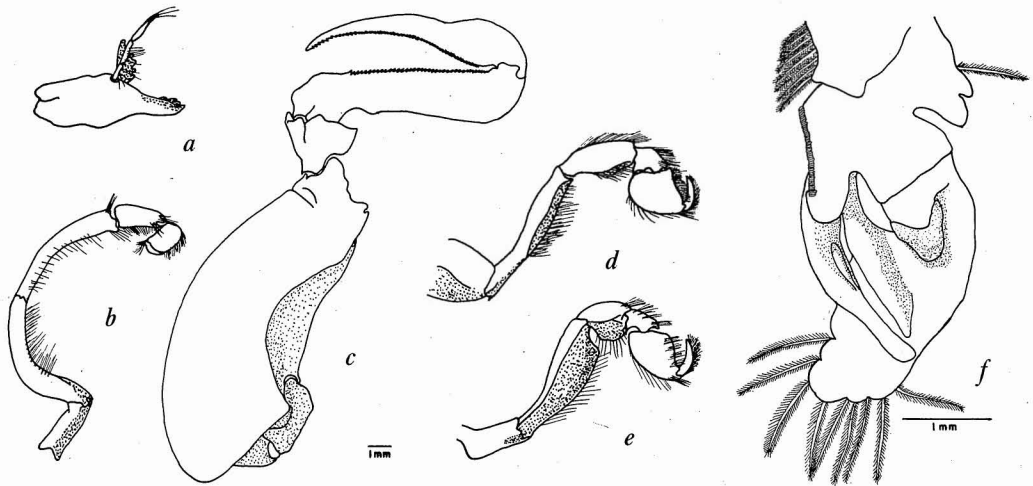


FIG. 21. *Gonodactylus guerini* White. *a*, Right pars molaris of mandible and mandibular palp; *b*, *c*, right first and second thoracic appendages; *d*, right third and fourth thoracic appendages; *e*, right fifth thoracic appendage; *f*, left first abdominal appendage of male (endopod only).

Evidently this species is quite common in deeper water because all other specimens have been taken at considerable depths. Apparently this species forms a considerable part of the diet of the tunas, inasmuch as the adults and larvae are often found in stomach contents. This indicates that this species is probably semiplanktonic, because the tunas feed in mid-water or at the surface. These stomatopods certainly spend some time on the bottom because other specimens have been dredged from a rough substrate.

DISTRIBUTION: Specimens have been reported from the Hawaiian Islands, the South China Sea, the East Indian Archipelago, and the Indian Ocean.

Gonodactylus guerini White

Figs. 20, 21a-f

Gonodactylus guerini White, 1861a: 43, pl. 7; 1861b: 480.

Protosquilla guerini Brooks, 1886: 75, pl. 16, figs. 1, 6.

DESCRIPTION: Carapace rectangular, nearly as wide as long, slightly narrower anteriorly, anterolateral and posterolateral angles broadly

rounded, lacking distinct carinae, gastric grooves well defined, cervical almost obsolete. Rostrum quadrate, trispinous, covering ophthalmic somite. Eyes small, tubular; cornea bilobed, set transversely on stalk. Ischiomeral articulation of raptorial claw situated at a point in advance of proximal end of merus so that merus extends backward beyond the joint (Fig. 21c); ventral surface of merus longitudinally grooved for not more than 0.75 its entire length for reception of propodus; upper margin of propodus with a series of fine acute teeth; dactylus inflated at base, elongated into a single acute tooth, inner margin of dactylus serrated. First, third, fourth, and fifth thoracic appendages shown in Figure 21b, d, e. Mandibular palp present, three segments (Fig. 21a). Free thoracic and abdominal somites laterally compressed, all lacking longitudinal carinae (indication of slight marginal carinae on first five abdominal somites); fifth through eighth thoracic somites exposed, slightly narrower than posterior width of carapace; posterior portion of fifth abdominal somite bears several rows of short spines, separated from smooth anterior part by a curved transverse line; sixth abdominal

somite armed with numerous long spines, each ending in a blunt, rounded tip from which protrudes a soft fleshy process. Articulation between telson and preceding segment barely discernible dorsally. Telson covered with series of 22 regularly arranged spines similar to those of preceding segment; distal margin composed of four spine-like processes bearing secondary spines on outer edges, two submedian with single row of secondary spines, two intermediate with single inner row of secondary spines and double row of secondary spines along outer border (Fig. 20). Exopod of uropods with eight movable spines on outer margin; endopod with five spines on dorsal surface; elongated basal portion of uropods with two spines, outer longer than the inner. Endopod of first abdominal appendage of male shown in Figure 21*f*. Specimens, when alive, are a brilliant red or orange. Specimens preserved in alcohol immediately turn a mottled yellow or tan, but those preserved in formaldehyde have retained their red color after several months. Specimens range in size from 28.5 to nearly 70 mm. from the tip of the rostrum to the distal margin of the telson.

DISCUSSION: This is the only species of this world-wide genus which has been reported from the Hawaiian Islands. The type specimen was taken by H.M.S. "Herald" at Fiji Islands. Miers (1880) reported this to be a female, but Kemp (1913) stated that it was a male; apparently Kemp was the one who made the error in identification. Another female was taken at Honolulu by H.M.S. "Challenger," but Brooks (1886) put it in the genus *Protosquilla*. The only other record of the species is a single male specimen in the Bishop Museum which was taken off Waikiki, Oahu. In the spring of 1949 two males and four females were dredged off Waianae, Oahu, in water 50-120 fathoms deep. This appears to be the greatest number of specimens collected at any one time.

This species is easily recognized by the radiating series of spines found on the telson

and the last two abdominal somites. The rectangular carapace with its trispinous rostrum is found in several species of this genus.

Gonodactylus and its related genus, *Odontodactylus*, are very similar with regard to the ischiomerical articulation and the inflated base of the raptorial dactylus (Fig. 21*c*); however, *Gonodactylus* is distinguished by the absence of spines on the raptorial dactylus, which may be entirely smooth or serrated on its inner margin (Fig. 21*c*). *Odontodactylus*, on the other hand, has several spines on the inner margin of the raptorial dactylus.

Brooks (1886) placed this and several allied species in a new genus, *Protosquilla*, because the telson and sixth abdominal somite, although separate, were nearly fused. He also stated that the small size of the antennary scales and uropods and the trispinous rostrum were sufficiently distinct to warrant the removal of these species from the genus *Gonodactylus*. Kemp (1913) and Edmondson (1921), however, did not consider these differences of a generic nature and retained the original name applied to the species by White (1861).

Two specimens were kept alive for observation in an aquarium. Both were females, one of which was collected with a mass of fertilized eggs; the other laid a mass of eggs in captivity. Both specimens survived very well even though they were both dredged from a depth of over 100 fathoms. The fertilized eggs developed until the time of hatching but then began to degenerate. Several eggs from the mass were removed at intervals and preserved in 7 per cent formalin solution with the hope that eventually they might be used to describe the embryology of this species. One female molted once while in captivity and remained a mottled yellow afterward. Little has been written about the function of the elaborate spines on the telson; however, my observations have shown that the animals either burrow into the substrate or select holes in dead coral which are just large enough for them to crawl into. Ordinarily they are found partially emerged from their burrows but when

disturbed they turn around and close the opening with their telson, which thus serves as an effective protective mechanism.

DISTRIBUTION: This species has been reported from Fiji and Honolulu, from relatively deep water, the only record being 50–120 fathoms.

LARVAL HAWAIIAN SQUILLIDAE

Larval stomatopods form a considerable part of the neritic plankton throughout the warmer waters of the world. They are transparent organisms which, at hatching, have many adult characteristics; however, the diagnostic features of the adult do not appear until late in development, thus making it difficult to associate the larval forms with the proper adults. The first attempt to draw up a key to the larvae was made by Bigelow (1894); however, he based his key on the general appearance of the forms, a characteristic which is often very deceptive. Hansen (1895) made a careful study of the larvae and divided them into two major groups, the alima-type larvae of *Squilla* and the erichthus-type larvae of *Lysiosquilla*, *Coronida*, *Odontodactylus*, *Gonodactylus*, and *Pseudosquilla*, on the basis of the shape of the propodus of the third, fourth, and fifth thoracic appendages. This division was thought by Hansen to emphasize the relationship of the various genera to one another, but Kemp (1913) and Foxon (1932) do not believe that this is of phylogenetic importance, because none of the larval types possesses characteristics which can be considered as an ancestral condition from which the rest of the genera developed.

Giesbrecht (1910) has noted that in the Stomatopoda two types of larvae occur at hatching, but the differences between them gradually disappear through a succession of later stages. These two early larval types have been designated pseudozoea and antizoea. The antizoea is characterized at the time of hatching by biramous appendages on the first five thoracic somites, an abdomen which is usually unsegmented and lacking pleopods,

and by later development into an erichthus type of larva. The pseudozoea hatches with only the first and second thoracic appendages, the second being in the form of a raptorial claw as in the adult, a fully segmented abdomen bearing four pairs of functional pleopods; later these develop into either an erichthus- or an alima-type of larva. Species of *Lysiosquilla* and *Coronida* hatch as antizoea, later developing into erichthus larvae; species of *Gonodactylus*, *Odontodactylus*, and *Pseudosquilla* all hatch as pseudozoea and later develop as erichthus larvae. Species of *Squilla* hatch as pseudozoea but later develop an alima-type of larva.

Foxon (1932), following the work begun by Hansen, attempted to bring the classification of the larvae into agreement with the divisions of the adults as presented by Kemp (1913). In doing this he has set down the morphological features which serve to identify the larvae from their earliest stages until the time they take on the characters observed in the adults. Brooks (1886), Giesbrecht (1910), Hansen (1926), and Foxon (1932) have all noted that the only constant difference between alima and erichthus larvae is the number of intermediate denticles between the submedian and the two lateral denticles of the telson. In the former there are always more than four of these denticles, whereas in the latter there are less than four. If one uses these denticles as a diagnostic character, it is then possible to divide the larval forms into the same major groups as the adults. In using this system of classification the larval groups are the same as those of the adults, the likeness becoming greater at each successive molt.

This method of classification is unquestionably suitable for distinguishing the genera to which the larvae belong, but it is a much more difficult task to assign them to their proper species. In no species has an individual in an early larval stage been reared to the adult form. Individuals in later stages have been reared to the postlarval condition, but they are so delicate that laboratory con-

ditions must be ideal, requiring water which is well aerated and free of sediment. In consequence, I have found it necessary to assign the larval species on the basis of the adult characteristics. If one has identified all adult species occurring in a particular region, then, by studying the postlarval forms which show both adult and larval characteristics, it is possible to correlate the larval forms occurring in the same region by working back from the adult species to the earliest recognizable larvae of those species. Using this method, I have been able to identify larval stages of *Pseudosquilla* as those belonging to adult *P. ciliata*. Larvae of *Lysiosquilla* and *Squilla* are likewise assigned to their respective species, but this identification is not positive. At this time larvae of *Coronida* and *Odontodactylus* cannot be referred to any definite species. Larval forms of *Gonodactylus* have not been found in these waters.

The following key is designed to facilitate the identification of the larvae with their respective genera, and is intended to be used for larvae in all stages of development. There is no reference to species, but where the adult species is known it will be mentioned in the description given for each genus.

Key to the Genera of Larval
Hawaiian Stomatopoda

- A. Larvae hatch without raptorial claw (antizoea with biramous appendages on first 5 thoracic somites) or with raptorial claw (pseudozoea with only first and second thoracic appendages) and with the propodus finely pectinate along its upper margin; ischio-meral articulation of raptorial claw always terminal in later stages (Figs. 22a, 25b).....B
- AA. Larvae always hatch with raptorial claw (pseudozoea) and the propodus never pectinate along its upper margin; ischio-meral articulation of raptorial claw at a point in advance of the proximal end of the merus in later stages (Fig. 28a)..E
- B. Larvae hatch with raptorial claw (Fig. 22a); propodus of fourth thoracic appendage rectangular, generally longer than broad, and only slightly broader than that of fifth (Fig. 23f).....C
- BB. Larvae hatch with biramous thoracic appendages (Fig. 25a) which undergo transformation into typical subchelate form; propodus of fourth thoracic appendage rounded, broader than long, more than twice as large as that of fifth (Fig. 27b).....D
- C. Telson with 4 or more intermediate denticles between submedian and lateral denticles (Fig. 22b).....*Squilla* (alima larva)
- CC. Telson with 3 or fewer intermediate denticles between submedian and lateral denticles (Fig. 23e).....*Pseudosquilla* (pseuderichthus larva)
- D. Propodus of raptorial claw broad, dactylus slightly inflated at base (Fig. 26e).....*Coronida* (coroniderichthus larva)
- DD. Propodus of raptorial claw long and slender, dactylus not inflated at base (Fig. 25b).....*Lysiosquilla* (lysioerichthus larva)
- E. Spines of telson greatly elongated (Fig. 28a).....*Odontodactylus* (odonterichthus larva)
- EE. Spines of telson not greatly elongated.....*Gonodactylus* (gonerichthus larva)

Squilla sp?, probably *S. oratoria*

Fig. 22a-d

STAGE 1 (Fig. 22a): This is the earliest stage of the alima-type larva which has been found. Larvae bear completely developed first and second thoracic appendages, the second being in the form of a raptorial claw; propodus of this claw with two small spines near its proximal end, upper margin finely pectinate; dactylus nearly straight, no teeth along inner margin; eyes borne on long stalks, this condition being retained throughout successive stages; antennules fully formed; antennal

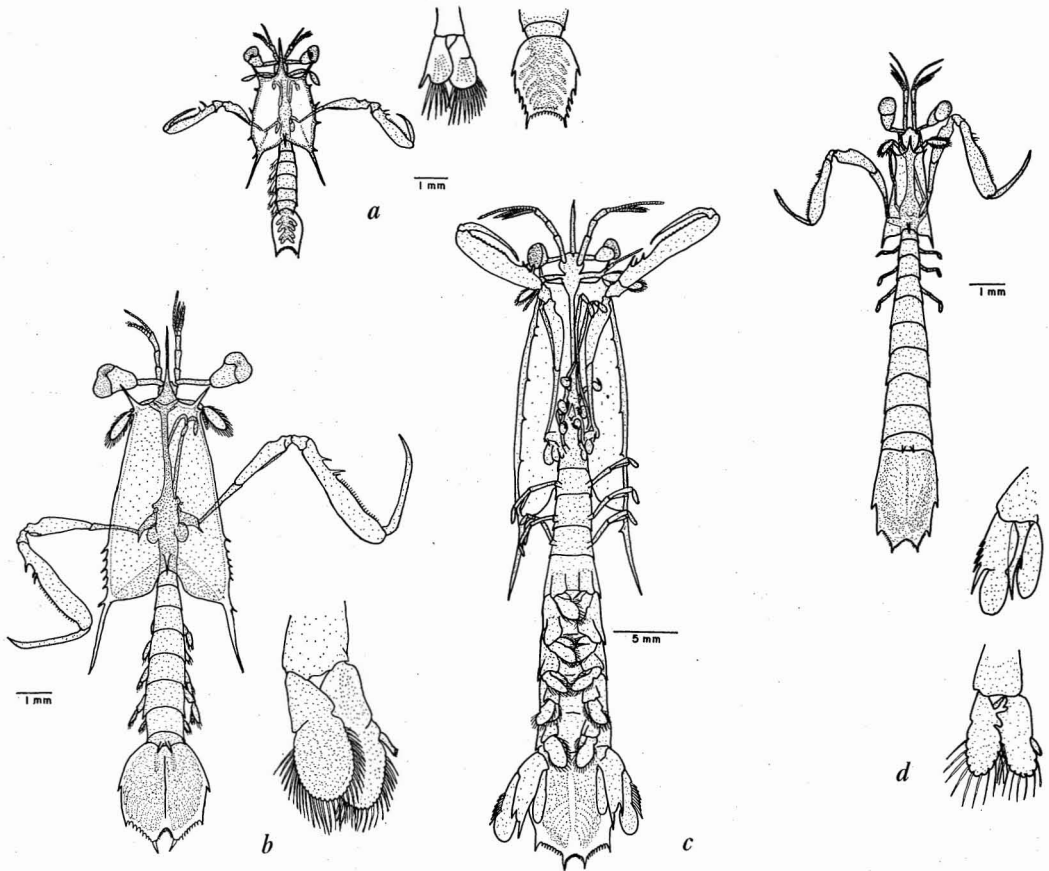


FIG. 22. Larval forms of *Squilla*. *a*, Dorsal view of pseudozoaea, first abdominal appendage and telson (probably *S. oratoria*); *b*, dorsal aspect of alima larva and first abdominal appendage (probably *S. oratoria*); *c*, ventral aspect of alima larva (probably *S. oratoria*); *d*, dorsal aspect of alima larva, first abdominal appendage and uropod (*Squilla* sp.).

scale present but flagella absent; carapace very clear, covering nearly 0.5 the entire body, this relationship remaining the same throughout successive stages; anterior margin of carapace trispinous, posterior margin with two posterolateral spines and small zoeal spine between them; lateral margins of carapace usually armed with three laterally directed and two ventrally directed denticles, small denticle at base of posterolateral spines; abdomen completely segmented, sixth abdominal somite indistinct; four pairs of biramous pleopods without gills, fifth pair represented by small buds; no uropods; telson longer than wide with 11 or 12 denticles between submedian

denticles and four between lateral and submedian denticles.

The specimens range in size from 5.5 to 8.0 mm. from the tip of the rostral spine to the posterior margin of the telson. This stage has been taken in plankton tows in the waters around Oahu throughout the year, most abundantly during the summer months.

STAGE 2 (Fig. 22*b*): This larval form is similar to the preceding stage except for a conspicuous change in size, the animals now measuring 15 to 20 mm. Body proportions remain the same, carapace still covering nearly 0.5 total length of body; antennal flagella present; third, fourth, and fifth thoracic ap-

pendages present; sixth, seventh, and eighth thoracic appendages represented by small buds; abdominal appendages all present, with small gills attached to exopods; uropods beginning to form; sixth abdominal somite with two small submedian spines; telson well developed, beginning to assume adult condition with two well-developed spines on distal margin and distinct submedian and intermediate denticles.

As with the first stage, all the specimens have been collected from regions where *S. oratoria* is either known or thought to be present. Innumerable specimens have been taken in plankton tows in the waters around Oahu throughout the year. They may frequently be found in the stomach contents of the yellowfin tuna, *Neothunnus macropterus*.

STAGE 3 (Fig. 22c): By the time the larvae have reached this stage, they have gained further adult characteristics. Sixth, seventh, and eighth thoracic appendages fully developed; uropods with adult characteristics, basal portion elongated into two spines and small rounded lobe between them, exopods with eight spines, as yet immovable, along their outer margin; telson more adult-like in appearance; no longitudinal carinae on body; carapace still very transparent, no indication of facies of adult carapace showing through chitin.

At this time the specimens measure 45 to 60 mm. in length. This stage forms a conspicuous part of the plankton and has been taken in plankton tows from the surface down to a depth of 200 meters.

There are no specimens beyond this stage in the collections. It is rather unusual that no postlarval forms have been found in which the adult characteristics such as the body carinae, the adult carapace, and the teeth on the raptorial dactylus are present. I assume from this that the larvae become bottom dwellers immediately after they lose the larval carapace.

Squilla sp?

Fig. 22d

Approximately 200 specimens of this alima larval stage were taken in night light stations at Honolulu Yacht Harbor, Oahu. They closely resemble the preceding larval types, but, as only one stage was collected, it is impossible to assign the specimens to an adult species. Carapace covers less than 0.3 total length of body, very narrow; all appendages fully developed, gills represented by small buds on exopod of pleopods; telson very large compared with other body segments, composing about 0.25 total length of body; fully developed uropods, bearing five spines along outer margin of exopod, with basal portion elongated into two spines, inner shorter than outer.

Pseudosquilla ciliata

Figs. 23a-f, 24a-c

STAGE 1 (Fig. 23a): Brooks (1886) has illustrated a pseudozoea larva similar to this stage. This represents the earliest larval stage of members of the genus *Pseudosquilla*. By observing the relative changes in the other stages, I have come to the conclusion that these are the young of *P. ciliata*. Typical erichthus larva with only first and second thoracic appendages present; abdomen with four pairs of biramous pleopods, without gills; telson nearly rectangular, with eight small denticles between submedian denticles; eyes not borne on long stalks as in alima of *Squilla* as articulation is close to ophthalmic somite; antennules present; antennae appear as small buds; merus and ischium of raptorial claw with terminal articulation, propodus finely pectinate along upper margin, dactylus composed of single spine; carapace trispinous anteriorly, posteriorly bearing two long spines reaching second abdominal somite; may or may not have small zoal spine between two posterior spines; carapace longer than broad, its lateral margins depressed.

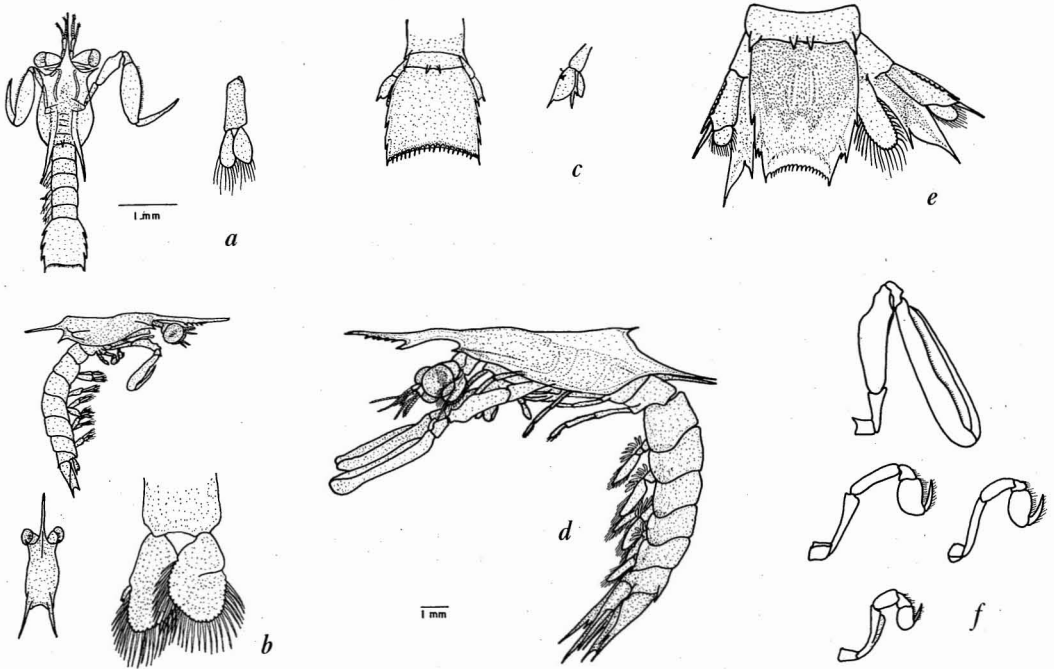


FIG. 23. Larval forms of *Pseudosquilla ciliata* (Fabricius). *a*, Dorsal aspect of pseudozoëa and first abdominal appendage; *b*, lateral aspect of pseuderichthus larva, dorsal aspect of carapace and first abdominal appendage; *c*, dorsal aspect of last abdominal somite, telson, and uropods of larva shown in *b*; *d*, *e*, lateral aspect of larger pseuderichthus larva and dorsal aspect of last abdominal somite, telson, and uropods; *f*, second, third, fourth, and fifth thoracic appendages of larva *d*.

Larval specimens in this stage of development have been taken in great numbers in plankton tows throughout the year at Kaneohe Bay, Oahu. Since adults of *P. ciliata* and *oculata* occur in abundance on the reefs in the bay, these specimens are believed to be the first larval stage of a *Pseudosquilla*. Unfortunately, I find no way to differentiate the early larvae of species in this genus. The specimens vary from 3.5 to 5.0 mm. from the tip of the rostral spine to the posterior margin of the telson.

STAGE 2 (Fig. 23*b, c*): At this stage in development the larvae show characteristics of both the preceding stage and the fourth stage. Entire body and larval carapace have increased in size but retain same relative proportions to one another; carapace may or may not bear small zoeal spine; first through fifth thoracic appendages present; propodus of fourth and fifth thoracic appendages rectangular in shape

and nearly equal in size (not well shown in Fig. 23*b*); no appendages on sixth through eighth thoracic somites; eyes globular, protruding from anterior margin of carapace; antennae present; pleopods resemble those of following stage, but have no gills; sixth abdominal somite distinct, bearing two submedian spines; uropods composed of short exopod and endopod, with basal portion elongated into two spines, inner shorter than outer; telson retains same general appearance of preceding stage, but somewhat larger.

Specimens measure 9.5 to 12.5 mm. in length. Approximately 200 individuals in this stage of development have been examined. Most of the specimens were taken in plankton tows from Kaneohe Bay, Oahu, but they have also been found in the tows from the Molokai Channel made by the Territorial Division of Fish and Game.

STAGE 3: This stage has not been found, but examination of the preceding stage and that of the next indicates what specimens in this stage of development should look like. By this time, all appendages should be present, gills should appear on the exopod of the pleopods, and the telson and uropods should be similar to the following stage. They should range from 15 to 20 mm. in length.

STAGE 4 (Fig. 23*d-f*): Thoracic appendages all present, showing adult characteristics, except raptorial claw; raptorial claw still very long and slender, propodus much longer than ischium and merus combined, dactylus composed of a single long spine with no indication of teeth along inner margin; facies of postlarval carapace and rostrum show through chitin of larval carapace; uropods greatly enlarged with two immovable spines on outer margin of exopod, definite pits for others show through chitin, outer spine of basal prolongation of uropods longer than inner; telson armed with two submedian, two intermediate, and two lateral spines, with 15 to 20 denticles between submedian and intermediate spine; facies of postlarval telson showing through chitin, with characteristic shape of adult, being nearly as broad as long.

Specimens of this stage measure 20 to 22.5 mm. in length. Very few of these larvae have been collected in regions where the previous stages were most numerous. Occasionally they are taken in the protected inshore waters, but they are more often found in the offshore waters such as the Molokai Channel. This seems to indicate that these larvae seek less sheltered waters and return to the shallow inshore waters only when they lose the larval carapace.

STAGE 5: There are no great changes from the preceding stage at this time. Slight increase in size; carapace very loosely attached to body; mandibular palp present, composed of three segments; nine or ten immovable spines along outer margin of exopod of uropod.

STAGE 6 (Fig. 24*a, b*): This is the first postlarval form of *P. ciliata*. No larval carapace, but animals remain planktonic; eyes resemble adult, nearly tubular in shape, cornea following long axis of stalk; rostrum triangular; carapace distinctly adult in shape, with distinct gastric grooves, covering only anterior 0.25 of body; all appendages, except second thoracic appendage, resemble those of adult; second thoracic appendage, raptorial claw, with shortened propodus and dactylus so that they fit into grooved merus and ischium when flexed, dactylus still lacks teeth on inner

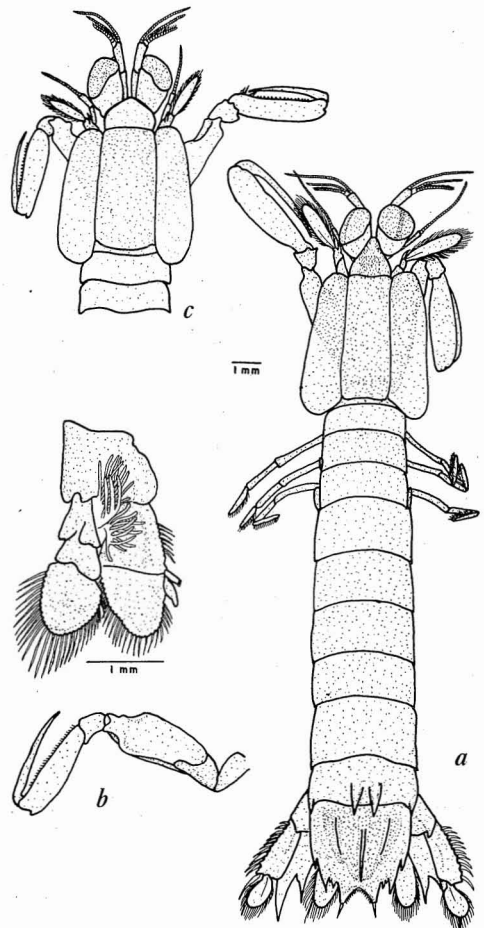


FIG. 24. Larval forms of *Pseudosquilla ciliata* (Fabricius). *a, b*, Dorsal aspect, second thoracic appendage, and first abdominal appendage of first postlarval stage; *c*, dorsal aspect of anterior segments of last postlarval stage.

margin; abdominal somites and appendages distinctly adult in structure, gills on pleopods nearly fully developed, sixth abdominal somite with two well-developed submedian and two lateral spines; uropods with nine or ten movable spines along outer margin of exopod, spines of elongated basal portion changing relationship to one another so that in some specimens these two spines are nearly equal in length; telson with three distinct longitudinal carinae, median and two submedians, posterior margin with pair of movable submedian spines bearing series of denticles between them, pair of immovable intermediate spines with two denticles between them and submedian spines, pair of immovable lateral spines.

The specimens now reach a maximum length of 20 to 25 mm. This developmental stage is very common in the plankton during the spring and summer months and occurs in both the inshore and offshore waters of Hawaii. They may occasionally be found in the stomach contents of the yellowfin tuna, *Neothunnus macropterus*, and the skipjack, *Katsuwonus pelamis*.

STAGE 7 (Fig. 24c): There is little change in this form from the preceding stage. Rostrum nearly adult in form, broader than long; eyes more tubular in shape; raptorial dactylus composed of single tooth, facies of other teeth on inner margin can be seen through chitin in some specimens.

Individuals in this developmental stage have been taken in the plankton from Kaneohe Bay, Oahu, and at Honolulu Yacht Harbor, Oahu. This indicates that the larvae are returning to the shallower, more protected waters and are preparing to settle down on the bottom to complete their life cycle.

Lysiosquilla sp?

Fig. 25a

Brooks (1886) has illustrated this antizoeal form and states that numerous specimens were taken by the "Challenger" at Honolulu. Both

Brooks's specimens and those at hand agree with those described by Claus (1872) from Messina. These very small larvae occur in great numbers in the plankton throughout the year. Due to their relatively small size (2.5 to 3.5 mm.) they are very often overlooked or cast aside as some unknown form. Although they lack the characteristic subchelate appendages, the eyes and telson have distinct stomatopod characteristics. These larvae represent the first larval stage of *Lysiosquilla* or *Coronida*, and because of their great abundance I am inclined to believe that they belong to *Lysiosquilla* which is apparently more abundant in Hawaiian waters than *Coronida*. There is no diagnostic character sufficiently developed to indicate conclusively the species to which these specimens belong, and none have ever been reared in captivity to the following stage. The carapace completely covers the animal from head to abdomen leaving only the eyes and telson exposed. There are five pairs of biramous thoracic appendages present, the abdomen is only faintly segmented, and the pleopods are absent. This larval form gives rise to an erichthus in later stages.

Lysiosquilla sp?

Figs. 25b, c

Nine specimens of this lysioerichthus stage were collected in a plankton tow in the Molo-kai Channel. In all respects this larval form represents the typical lysioerichthus. No spines between submedian and lateral spines on telson (Fig. 25c); raptorial propodus finely pectinate along upper margin, dactylus composed of single acute spine, not inflated at base, ischio-meral articulation terminal; all thoracic appendages present, propodus of third and fourth rounded and broader than long, fourth nearly twice as large as that of fifth; abdomen increasing in breadth posteriorly; pleopods all present, gills absent; uropods partially developed, exopod and endopod both present, with basal portion elongated into two spines,

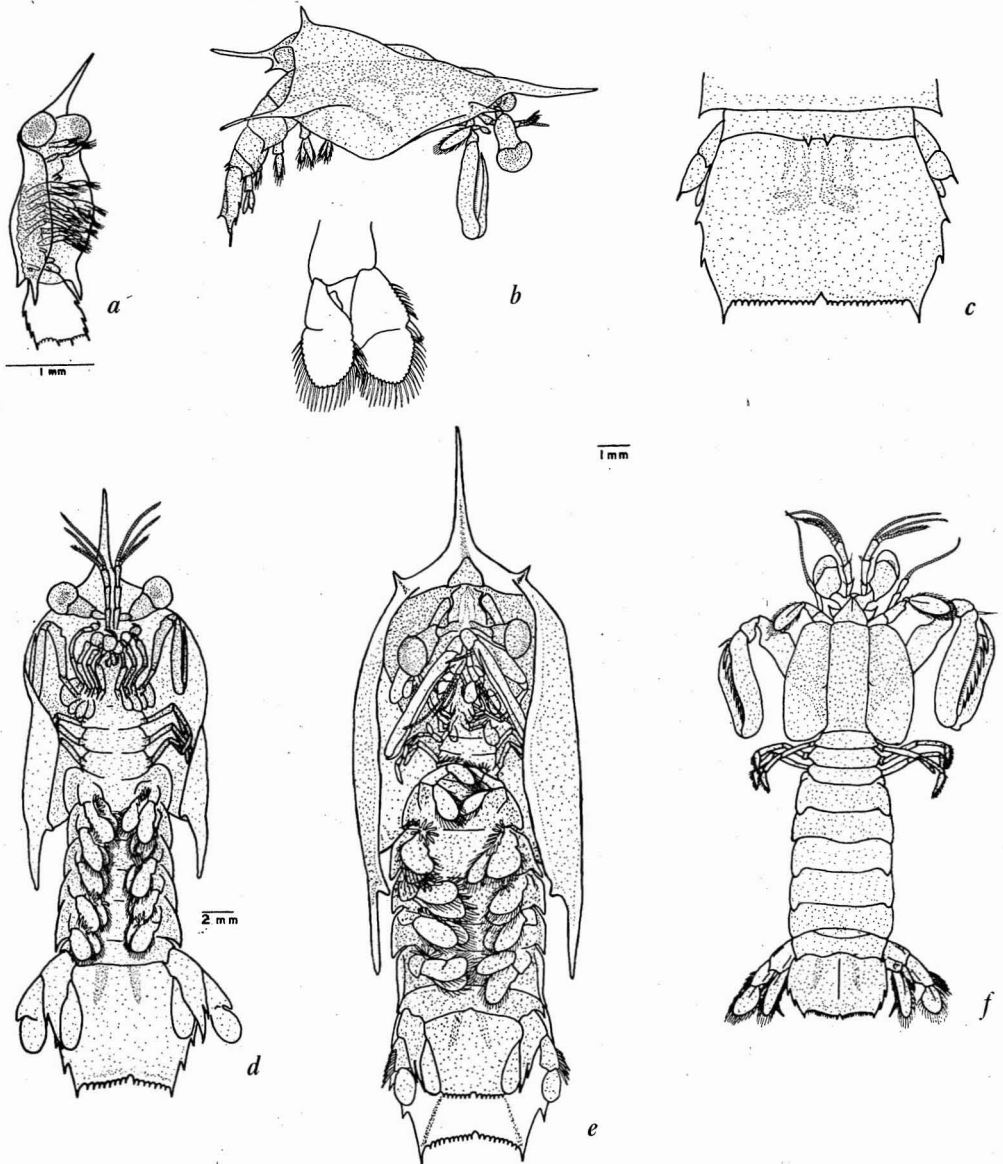


FIG. 25. Larval forms of *Lysiosquilla*. *a*, Antizoea; *b*, lateral aspect of lysioerichthus larva and first abdominal appendage; *c*, dorsal aspect of last abdominal somite, telson, and uropods of same; *d*, ventral aspect of lysioerichthus larva; *e*, ventral aspect of last larval stage of *L. maculata*; *f*, dorsal aspect of first postlarval stage of *L. maculata*.

inner longer than outer; carapace nearly as broad as long from base of anterolateral spines to base of posterolateral spines; lateral margins turned downward and toward median line; most preserved specimens with abdomen and telson reflexed anteriorly so that ventral

opening of carapace is completely closed.

Specimens measure 14.5 to 28.5 mm. in length. The 28.5 mm. specimen shows the facies of ten spines along the inner margin of the raptorial dactylus much the same as those seen in the adults of *L. maculata*.

Lysiosquilla sp?

Fig. 25*d*

This lysioerichthus larval form is represented by a single specimen taken in a plankton tow in the Molokai Channel. Its very large size (45 mm.) immediately draws attention. All structures are the same as for the previously described larvae of this genus. It was temporarily believed to belong to *L. maculata*, but its size and relative immaturity (cf. Fig. 25*e*, which is only 15 mm. long) seem to indicate that it may be the larval stage of a species of *Lysiosquilla* which has not been found in the adult form in Hawaii.

Lysiosquilla maculata

Fig. 25*e, f*

Figure 25*e* represents one of seven lysioerichthus larvae, three of which were collected in plankton tows at Truk Island and four from Kawaihae, Hawaii. These are fully developed larvae, which I believe to be the last larval stage of *L. maculata*. This conclusion is based on an examination of postlarval forms and the adults of this species. Appendages, except raptorial claw, telson, and uropods, resemble those of adult *L. maculata*; facies of postlarval telson show through chitin, very closely resembling telson of postlarval forms shown in Figure 25*f*. It is very probable from these facts that the next molt would produce the postlarval stage of *L. maculata*. Specimens range from 15 to 16 mm. from the tip of the rostral spine to the posterior margin of the telson.

The postlarval form (Fig. 25*f*) undoubtedly belongs to *L. maculata*. All anterior appendages are the same as those of the adult, and the raptorial dactylus bears nine teeth on its inner margin similar to the condition found in some of the adults of this species. The telson and uropods have the same general appearance of the adult as well. These specimens and the adults have eight spines along the outer margin of the exopod of the uro-

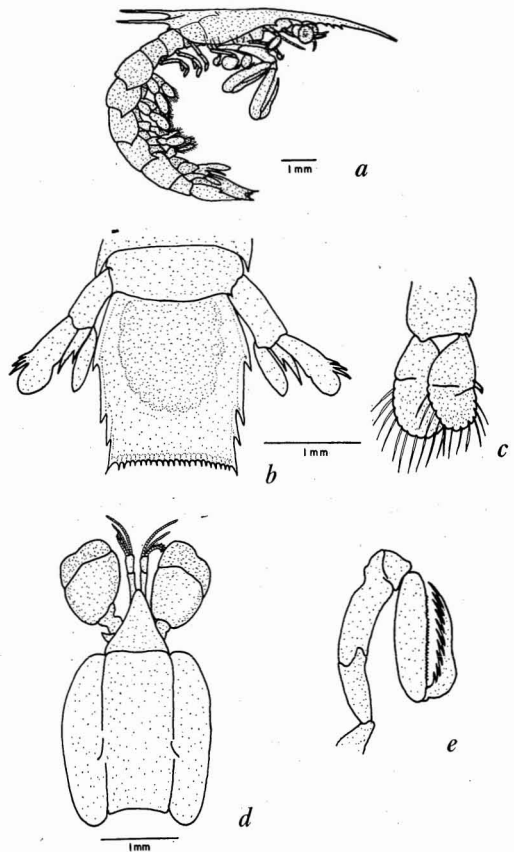


FIG. 26. Larval forms of *Coronida* sp. *a*, Lateral aspect of last larval stage of coroniderichthus larva; *b*, dorsal aspect of last abdominal somite, telson, and uropods of same; *c*, first abdominal appendage of same; *d*, dorsal aspect of anterior segments of first postlarval stage; *e*, second thoracic appendage of same.

Pods. A single specimen measuring 16.5 mm. in length was collected at Kawaihae, Hawaii, at a night light station, which further substantiates the identification because the adult species is very common in that region.

Coronida sp?

Fig. 26*a-e*

In Figure 26*a* there is represented the last larval stage (coroniderichthus) of some unknown species of *Coronida*. This form is found in the Ala Wai Canal, Oahu, and at Kawaihae, Hawaii, in moderate numbers dur-

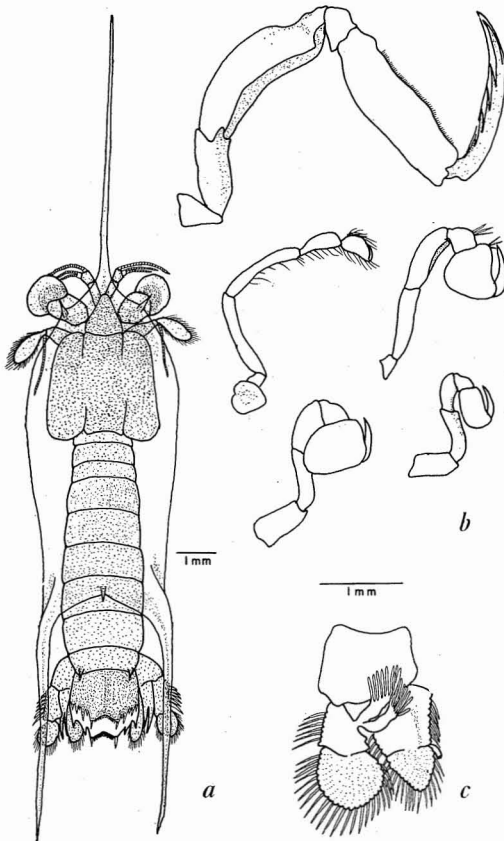


FIG. 27. Larval form of *Coronida* sp. a, Dorsal aspect of coroniderichthus larva; b, second, first, third, fourth, and fifth thoracic appendages; c, first abdominal appendage.

ing the summer. Larvae resemble lysioerichthus in shape of thoracic appendages, but with raptorial dactylus slightly inflated at its base; propodus of fourth thoracic appendage rounded, nearly twice as large as that of fifth which is rectangular; all abdominal appendages present; no gills; telson rectangular as in most larval forms, bearing two denticles between submedian and lateral denticles; uropods present, outer margin of exopod armed with three spines, basal portion elongated into two spines, outer longer than inner.

Specimens measure 10.0 to 14.5 mm. from the tip of the rostral spine to the posterior margin of the telson.

Figures 26*d, e* represent the first postlarval stage of this species which is found in nearly

equal numbers with the previous stage. Only the carapace and anterior segments and the raptorial claw have been illustrated as all other structures are the same as those seen in the preceding stage. The inner margin of the dactylus is armed with ten teeth. There is no distinct increase in size over that of the last larval stage. These forms may be larval stages of *C. sinuosa*, but the larval structures bear no resemblance to diagnostic characteristics of this species. Apparently the species to which these larvae belong is quite common, although it has not been found as yet.

Coronida sp?

Fig. 27*a-c*

Five coroniderichthus larvae measuring 18 to 20 mm. from the tip of the rostral spine to the posterior margin of the telson were collected at Kawaihae, Hawaii. The appendages indicate that they belong to some species of *Coronida*, but no adult specimens have been found which have the same characteristics as those possessed by this larval stage. I believe that the first postlarval stage would appear at the next molt because the facies of the adult carapace, telson, and raptorial dactylus show through the very clear chitin. These specimens are unique in that the larval carapace covers all but the last two abdominal somites and the telson, and the median anterior spine and posterolateral spines are greatly elongated. This condition is not found in any other larval form, hence it should serve as a diagnostic character for the separation of this larval form from others belonging to this genus.

Odontodactylus sp?

Fig. 28*a-e*

Eight odonterichthus larvae, ranging in length from 18 to 35 mm., were taken in a plankton tow in the Molokai Channel. They resemble pseuderichthus larvae very much, and it is possible to distinguish the two only

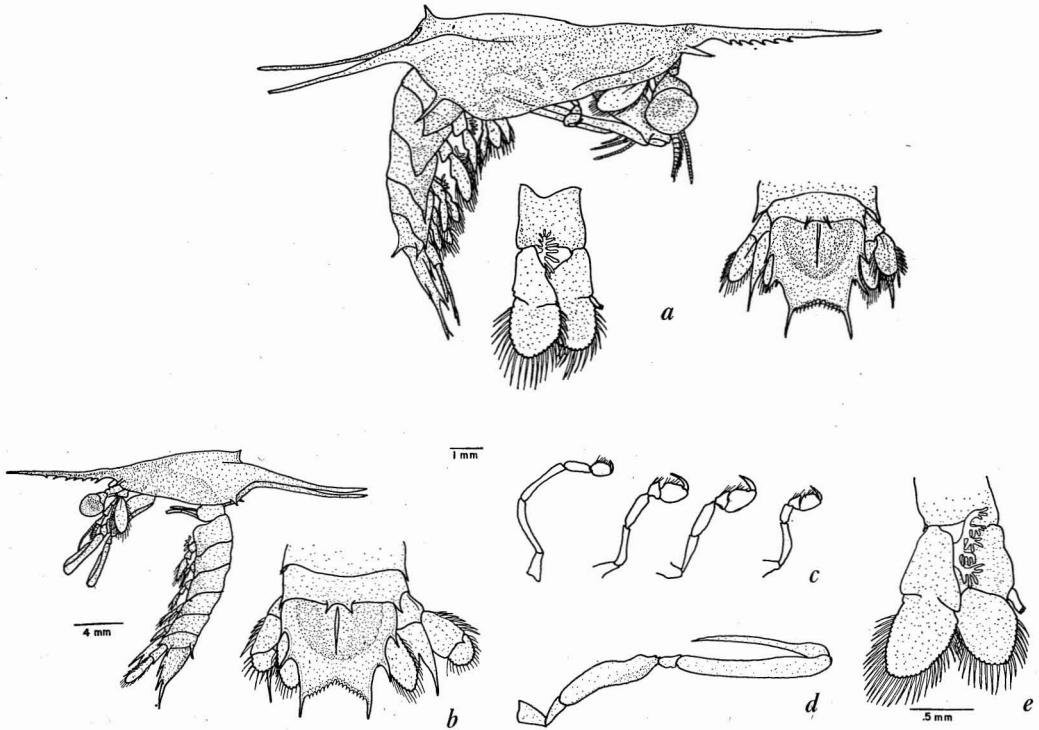


FIG. 28. Larval forms of *Odontodactylus*. *a*, Lateral aspect of odonterichthus larva, first abdominal appendage, and dorsal aspect of last abdominal somite, telson, and uropods; *b*, lateral aspect of odonterichthus larva and dorsal aspect of last abdominal somite, telson, and uropods; *c*, first, third, fourth, and fifth thoracic appendages of same; *d*, second thoracic appendage of same; *e*, first abdominal appendage of same.

by comparing the raptorial claws. In pseudorichthys larvae this appendage is finely pectinate along the upper margin of the propodus, and the dactylus is not inflated at the base. In odonterichthus, however, the raptorial propodus is not pectinate along its upper margin, and the dactylus is inflated at its base. In later stages the ischio-meral articulation of the raptorial appendage would be a useful diagnostic character, but none of the specimens has attained this condition, which is present in the adult. This genus is undoubtedly closely related to *Gonodactylus*, but it has been impossible to compare the larvae of the two genera because no specimens of the latter have been collected in Hawaiian waters. Claus (1872) and Brooks (1886) have both illustrated gonerichthus larvae which were collected from other regions, and com-

parisons with their figures show that the Molokai Channel specimens definitely belong to the odonterichthus type. Foxon (1932) uses the character of the long spines found on the telson of *Odontodactylus* larvae for separating them from *Gonodactylus*, although he does not present any figures to illustrate his statements. Since no *Gonodactylus* larvae have been collected in the Hawaiian waters, I cannot say whether or not this is a valid character for the separation of the larvae of the two genera, but comparisons with Claus's and Brooks's figures of gonerichthus larvae show that the spines on the telson of their specimens are considerably shorter than those found in the present specimens. With this in mind I have placed the character in the key with the hope that some future worker who may find the gonerichthus larvae will be saved some effort in

trying to place them in their correct genus.

REFERENCES

- BERTHOLD, A. A. 1845. Über verschiedene neue oder seltene Reptilien aus Neu-Granada und Crustaceen aus China. *Gess. Wiss. Göttingen, Abhandl.* 3: 26-32.
- BIGELOW, R. P. 1893. The Stomatopoda of Bimini. *Johns Hopkins Univ., Cir.* 106: 102-103.
- 1894. Report on the Crustacea of the order Stomatopoda collected by the steamer "Albatross" between 1885 and 1891, and other specimens in the U. S. National Museum. *U. S. Natl. Mus., Proc.* 17: 489-550.
- 1931. Stomatopoda of the southern and eastern Pacific Ocean and the Hawaiian Islands. *Harvard Univ., Mus. Comp. Zool., Bul.* 72 (4): 105-191.
- BORRADAILE, L. A. 1898. On some crustaceans from the South Pacific. *Zool. Soc. London., Proc.* 3(1): 32-38.
- 1899. On the Stomatopoda and Macrura brought by Dr. Willey from the South Seas. In: *Zoological results based on material from New Britain, New Guinea, Loyalty Islands and elsewhere collected during the years 1895-1897*. Part 4: 395-427, pls. 36-39. University Press, Cambridge.
- 1907. Stomatopoda from the western Indian Ocean. *Linn. Soc. London, Trans., Zool.* II, 12: 204-216.
- BROOKS, W. K. 1886. *Report on the Stomatopoda collected by the H.M.S. "Challenger" during the years 1873-1876*. Vol. 16, part 65, 116 pp., 16 pls. Eyre and Spothswoode, London.
- BRULLÉ, M. 1836. In: *Histoire naturelle des Îles Canaries, Zool.* Vol. 2, part 2 (Crust.) [ed. Barker-Webb and S. Berthelot], 152 pp., 7 pls. Mellier, Paris.
- CLAUS, C. 1872. Die Metamorphose der Squilliden. *Gess. Wiss. Göttingen, Abhandl.* 16: 111-163, 8 pls.
- DANA, J. D. 1852. Crustacea. In: *United States Exploring Expedition during the years 1838-1842 under the command of Charles Wilkes, U.S.N.* Vol. 13, part 1, viii+ 685 pp., 96 pls. C. Sherman, Philadelphia.
- DE HAAN, W. 1850. Crustacea. In: *Fauna Japonica* [ed. F. Siebold]. Vol. 1, xxxi+244 pp., 70 pls. J. G. La Lau, Lugundi-Batavorum.
- DE MAN, J. G. 1907. On a collection of Crustacea, Decapoda and Stomatopoda, chiefly from the Inland Sea of Japan; with descriptions of new species. *Linn. Soc. London, Trans., Zool.* II, 7: 439-440.
- EDMONDSON, C. H. 1921. Stomatopoda in the Bernice P. Bishop Museum. *Bernice P. Bishop Mus., Occas. Papers* 7(13): 281-302.
- EYDOUX, F., and L. SOULEYET. 1841. *Voyage autour du monde exécuté pendant les années 1836 et 1837 sur la corvette la Bonite, commandée par M. Vaillant, Zoologie*. Vol. 1, xxxvii+334 pp. A. Bertrand, Paris.
- FABRICIUS, J. C. 1787. *Mantissa insectorum*. Vol. 1. xx+330 pp. C. G. Proft, Hafniae.
- 1793. *Entomologia systematica emendata et aucta*. Vol. 2. viii+519 pp. C. G. Proft, Hafniae.
- FOXON, G. E. H. 1932. Report on stomatopod larvae, Cumacea and Cladocera. *Great Barrier Reef Expedition 1928-29, Scientific Reports* [Brit. Mus. (Nat. Hist.)] 4(11): 375-398.
- FUKUDA, T. 1911. Further report on Japanese Stomatopoda with descriptions of two new species. *Annot. Zool., Jap.* 7: 285-289.
- GIESBRECHT, W. 1910. Stomatopoden. In: *Fauna und Flora des Golfes von Neapel und der Angrenzenden Meeresabschnitte*. Monog. 33(1), 239 pp., 11 pls. R. Friedländer und Sohn, Berlin.
- GURNEY, R. 1942. *Larvae of decapod Crustacea*. vi+306 pp. Ray Society, London.
- HANSEN, H. J. 1895. Isopoden, Cumaceen und Stomatopoden der Plankton Expedition. *Ergebnisse der Plankton Expedition der Humboldt Stiftung* 2: 1-105, 8 pls., 1 chart. Lipsius und Tischer, Kiel und Leipzig.
- 1926. The Stomatopoda of the Siboga Expedition. *Siboga Expeditie 1899-1900, Monog.* 18, 48 pp., 2 pls. E. J. Brill, Leiden.

- HERBST, J. F. W. 1796. *Versuch einer Naturgeschichte der Krabben und Krebse*. Vol. 2, vii+225 pp., 25 pls. G. A. Lange, Berlin und Stralsund.
- HESS, W. 1865. Beiträge zur Kenntniss der Decapoden-Krebse Ost Australien. *Arch. f. Naturgesch.* XXXI, 1: 168-170.
- KEMP, S. 1911. Preliminary descriptions of new species and varieties of Crustacea Stomatopoda in the Indian Museum. *Indian Mus., Rec.* 6: 93-100.
- 1913. An account of the Crustacea Stomatopoda of the Indo-Pacific region. *Indian Mus., Mem.* 4(1): 1-217.
- LAMARCK, J. B. 1818. *Histoire naturelle des animaux sans vertèbres*. Vol. 5, 612 pp. Lanoe, Paris.
- LINNAEUS, C. A. 1788. *Systema Naturae*, Ed. 13. Vol. 1, 4,120 pp. Gmelin, Leipzig.
- MIERS, E. J. 1880*a*. On the Squillidae. *Ann. and Mag. Nat. Hist.* V, 5: 1-30.
- 1880*b*. On the Squillidae. *Ann. and Mag. Nat. Hist.* V, 5: 108-127.
- MILNE-EDWARDS, A. 1878. Description des quelques espèces nouvelles des crustacés provenant du voyage aux îles du Cap-Vert de MM. Bouvier et de Cessac. *Soc. Philomath., Bul.* VII, 2(4): 225-232.
- POCOCK, R. I. 1893. Report upon the stomatopod crustaceans obtained by P. W. Basset Smith, Esq., Surgeon, R.N., during the cruise in the Australian and China Seas of H.M.S. "Penguin," Commander W. U. Moore. *Ann. and Mag. Nat. Hist.* VII, 11: 473-479.
- RANDALL, J. W. 1839. Catalogue of Crustacea brought by T. Nuttall and J. K. Townsend from the west coast of North America and the Sandwich Islands, with descriptions of such species as are apparently new, among which are included several species of different localities previously existing in the collection of the academy. *Acad. Nat. Sci. Phila., Jour.* I, 8: 106-147.
- RUMPHIUS, G. E. 1705. *D' Amboinsche Rariteitkamer*. xliii+340 pp., 60 pls. Halma, Amsterdam.
- TATTERSALL, W. M. 1906. Report on the Lepidostrotraca, Schizopoda, and Stomatopoda, collected by Professor Herdman at Ceylon in 1902. In: Herdman, *Report to the govt. of Ceylon on the pearl oyster fisheries of the Gulf of Manaar*. Part 5, pp. 158-188, 3 pls. Royal Society, London.
- WHITE, A. 1861*a*. Descriptions of two species of Crustacea belonging to the families Callianassidae and Squillidae. *Zool. Soc. London, Proc.* 1861: 42-44.
- 1861*b*. Descriptions of two species of Crustacea belonging to the families Callianassidae and Squillidae. *Ann. and Mag. Nat. Hist.* III, 7: 479-481.